WORKING GROUP ON WIDELY DISTRIBUTED STOCKS (WGWIDE)

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Andrew Campbell

Authors

Thomas Brunel • Andrew Campbell • Neil Campbell • Pablo Carrera • Rui Catarino • Anatoly Chetyrkin • Gersom Costas • Laurent Dubroca • Roxanne Duncan • Sólva Eliasen • Patricia Goncalves • Åge Højnes • Sondre Hølleland • Eydna í Homrum • Jan Arge Jacobsen • Teunis Jansen • Alexander Krysov • Bernhard Kühn • Gwladys Lambert • Lisa Anne Libungan • David Miller • Richard Nash • Leif Nøttestad • Anna H. Olafsdottir • Alessandro Orio • Martin Pastoors • Are Salthaug • Sonia Sanchez • Aril Slotte • Claus Sparrevohn • Erling Kåre Stenevik • Nikolay Timoshenko • Jens Ulleweit • Sindre Vatnehol • Morten Vinther

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Contents

i Executive summary

As a consequence of the impact of the COVID pandemic on international travel which prevented the traditional meeting from taking place, the Working Group on Widely Distributed Stocks (WGWIDE) met online via WebEx hosted by ICES. Prior to the 2020 meeting, the generic ToRs for species and regional working groups were re-prioritised by ACOM to allow the WG to focus primarily on those ToRs most applicable to the provision of advice. WGWIDE reports on the status and considerations for management of Northeast Atlantic mackerel, blue whiting, Western and North Sea horse mackerel, Northeast Atlantic boarfish, Norwegian spring-spawning herring, striped red mullet (Subareas 6, 8 and Divisions 7.a-c, e-k and 9.a), and red gurnard (Subareas 3, 4, 5, 6, 7, and 8) stocks.

Northeast Atlantic (NEA) Mackerel. This stock is highly migratory and widely distributed throughout the Northeast Atlantic with significant fisheries is most ICES subareas. A diverse range of fleets from smaller artisanal, handline vessels to large (100m+) factory freezer vessels and modern RSW trawlers and purse seiners take part in what is one of the most valuable European fisheries. The assessment conducted in 2020 is an update assessment, based on the configuration agreed during the most recent inter-benchmark exercise in 2019 and incorporates the most recent data available from sampling of the commercial catch in 2019, the final 2019 egg survey SSB estimate, an updated recruitment index and tagging time series along with 2020 survey data from the IESSNS swept area survey. Advice is given based on stock reference points which were updated during a management strategy evaluation carried out in 2020. Following a strong increase from 2007 to 2014, SSB has been declining although it remains well above MSY $B_{trigger}$. Fishing mortality has been below F_{MSY} since 2016. There have been a number of large year classes since 2001 with above average recruitment over much of the most recent decade.

Blue Whiting. This pelagic gadoid is widely distributed in the eastern part of the North Atlantic. The 2020 update assessment followed the protocol from the most recent inter-benchmark in 2016 and used preliminary catch data from 2020. Due to the cancellation of the 2020 acoustic survey, this data was not available. The effect on the assessment was minimal and limited to increases in uncertainty of the terminal year estimates. The SSB continues to decrease from the most recent maximum in 2017 mainly due to below average recruitment since 2017, although it remains above MSY $B_{trigger}$. Fishing mortality has been above F_{MSY} since 2014.

Norwegian Spring Spawning Herring. This is one of the largest herring stocks in the world. It is highly migratory, spawning along the Norwegian coast and feeding throughout much of the Norwegian Sea. The 2020 assessment is based on an implementation of the XSAM assessment model introduced at the benchmark in 2016. This years' assessment indicates that the stock is continuing to decline from the peak in 2008 of 7Mt to just above MSY $B_{trigger}$ due to successive years of average or below average recruitment. Catch advice for 2021 is given on the basis of the agreed management plan and represents a substantial increase over the 2020 advice due to an upward revision in the estimate of the 2016 year-class which is considered to be the most significant year-class since 2004.

Western Horse Mackerel. Horse mackerel is distributed throughout ICES areas 4,6,7,8 and 9 with the Western stock is found mainly in the Northern North Sea, west of Britain and Ireland and in the Bay of Biscay. Following a benchmark in 2017, the stock is assessed using the Stock Synthesis integrated assessment model. Stock reference points were revised in 2019. Following a period of declining SSB, above average recruitments from 2014-2018 have contributed to a recent rise in SSB, albeit from a low level in 2017 such that current SSB is just above $B_{lim.}$ Following a decline associated with reduced catches, fishing mortality has been increasing since 2017 and

is now above FMSY. As in previous years the assessment output, while indicating the same trend as previous assessments rescales the absolute levels of SSB and F in the most recent 15 years.

North Sea Horse Mackerel. 2021 advice for this stock was issued in 2019. However, the WG considered an update assessment which is based on a combined survey index from groundfish surveys in the North Sea and the Channel following the benchmark in 2017. The most recent index value suggests that the stock remains at a low level following a decline in 2017. The ratio of F/F_{MSY}, estimated using length information from sampled catch remains slightly above 1 although with a declining trend.

Northeast Atlantic Boarfish. Boarfish is a small, pelagic, planktivorous, shoaling species, found at depths of 0 to 600 m and is distributed widely from Norway to Senegal. The directed fishery occurs primarily in the Celtic Sea and developed during the early 2000s, initially unregulated before the introduction of a TAC in 2011 and catches have reduced since 2012 to the current level. Advice is provided using the data limited category 3 approach based on output from an exploratory Bayesian surplus production assessment model with catch and survey data from groundfish surveys and an acoustic survey. The current assessment indicates that biomass peaked in 2012 before declining sharply. The most recent estimate is the highest for several years and is primarily due to an increased acoustic estimate in 2020 which contains a significant juvenile pro**portion.**

Striped Red Mullet in North Sea, Bay of Biscay, Southern Celtic Seas, Atlantic Iberian Waters. This stock has been considered by WGWIDE since 2016 with advice given triennially on the basis of the precautionary approach. There is no currently assessment and limited information on abundance and exploitation level such that a further precautionary reduction in landings is advised for 2021–23.

Northeast-Atlantic Red Gurnard. This stock was first considered by WGWIDE in 2016 with advice issued biennially, most recently in 2019. This is a category 6 stock, with large uncertainties in landings data due to poor resolution at the species level. Landings have fluctuated without trend throughout much of the time series and discarding levels are significant. An index based on survey observations will be considered during a future benchmark.

ii Expert group information

Expert group name	Working Group on Widely Distributed Stocks (WGWIDE)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chair(s)	Andrew Campbell, Ireland
Meeting venue(s) and dates	26 August- 1 September 2020, by correspondence (41 participants)

1 Introduction

1.1 Terms of References (ToRs)

The Working Group on Widely Distributed Stocks (WGWIDE), chaired by Andrew Campbell, Ireland, met virtually from 26 August – 1 September 2020. A virtual meeting replaced the planned physical meeting at ICES Headquarters due to restrictions resulting from the COVID-19 emergency. The terms of reference for the meeting consisted of re-prioritised generic Regional and Species Working Group ToRs:

High Priority

c) Conduct an assessment on the stock(s) to be addressed in 2020 using the method (analytical, forecast or trends indicators) as described in the stock annex and produce a brief report of the work carried out regarding the stock, summarising where the item is relevant. **Check the list of the stocks to be done in detail and those to roll over**.

   i) Input data and examination of data quality;

   ii) Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;

   iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area) estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2019.

   v) The developments in spawning stock biomass, total stock biomass, fishing mortality, catches (wanted and unwanted landings and discards) using the method described in the stock annex;

   vi) The state of the stocks against relevant reference points;

   vii) Catch scenarios for next year(s) for the stocks for which ICES has been requested to provide advice on fishing opportunities;

   viii) Historical and analytical performance of the assessment and catch options with a succinct description of quality issues with these. For the analytical performance of category 1 and 2 age-structured assessments, report the mean Mohn's rho (assessment retrospective (bias) analysis) values for R, SSB and F. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

d) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines. Check list to confirm whether the stock requires a concise advice sheet or a traditional advice sheet.

f) Prepare the data calls for the next year update assessment and for planned data evaluation workshops;

j) Audit all data and methods used to produce stock assessments and projections.

Medium Priority

a) Consider and comment on Ecosystem and Fisheries overviews where available;

b) For the aim of providing input for the Fisheries Overviews, consider and comment for the fisheries relevant to the working group on:

i) descriptions of ecosystem impacts of fisheries
ii) descriptions of developments and recent changes to the fisheries
iii) mixed fisheries considerations, and
iv) emerging issues of relevance for the management of the fisheries;
e) Review progress on benchmark processes of relevance to the Expert Group; High for application;

Low Priority

c iv) Estimate MSY proxy reference points for the category 3 and 4 stocks

g) Identify research needs of relevance for the work of the Expert Group.

h) Review and update information regarding operational issues and research priorities and the Fisheries Resources Steering Group SharePoint site.

i) Take 15 minutes, and fill a line in the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity'; for stocks with less information that do not fit into this approach (e.g. higher categories >3) briefly note in the report where and how productivity, species interactions, habitat and distributional changes, including those related to climate-change, have been considered in the advice. ACOM would encourage expert groups to carry out this term of reference later in the year through a WebEx.

1.1.1 The WG work 2020 in relation to the ToRs

The WG considered update assessments for all eight stocks within its remit. Based upon these assessments and associated short term forecasts, the group produced full draft advice sheets for Northeast Atlantic mackerel and blue whiting and abbreviated advice sheets for Norwegian spring spawning herring, western horse mackerel and striped red mullet. 2021 catch advice for the remaining three stocks (North Sea horse mackerel, boarfish and red gurnard) was issued previously and therefore not required this year although update assessments were presented to the group. All draft advice sheets were agreed in plenary. Advice sheets, report sections and assessments were audited with 3 working group members assigned to each stock. In addition, five stock annexes were updated and the productivity audit was completed for each stock.

1.2 Participants at the meeting

WGWIDE 2020 was attended by 39 delegates from the Netherlands, Ireland, Spain, Norway, Germany, Portugal, Iceland, UK (England and Scotland), Faroe Islands, France, Denmark, Greenland, Russia and Sweden. The full list of participants, all of whom are authors of this report is given in Annex 1.

All the participants were made aware of ICES Code of Conduct, which all abided by and none had Conflicts of Interest that prevent them from acting with scientific independence, integrity, and impartiality.

1.3 Overview of stocks within the WG

Eight stocks are assessed by WGWIDE. In 2020, the group drafted 2021 advice sheets for 5 stocks. Full advice sheets were drafted for Northeast Atlantic Mackerel and Blue Whiting with abbreviated sheets for Norwegian Spring Spawning Herring, Western Horse Mackerel and Striped Red Mullet. 2021 advice for the remaining stocks was issued previously although the relevant data series and stock assessments were updated and considered at WGWIDE 2020. A summary of the WGWIDE stocks, current data category and assessment method and advice frequency is given in the table below:

Stock	ICES code	Data Category	Assessment method	Assessment Frequency	Last Assessment	2021 Advice Sheet
Boarfish	boc.27.6-8	3.2	Bayesian Schafer surplus production model	2	2019	NA
Red gurnard	gur.27.3-8	6.2	No assessment	2	2019	NA
Norwegian spring-sp. herring	her.27.1-24a514a	1	XSAM	1	2019	Abbreviated
Western horse mackerel	hom.27.2a4a5b6a7a-ce-k8	1	Stock Synthesis	1	2019	Abbreviated
North Sea horse mackerel	hom.27.3a4bc7d	3.2	Survey trends based	2	2019	NA
NE-Atlantic mackerel	mac.27.nea	1	SAM	1	2019	Full
Striped red mullet	mur.27.67a-ce-k89a	5	No assessment	3	2017	Abbreviated
Blue whiting	whb.27.1-91214	1	SAM	1	2019	Full

1.4 Quality and Adequacy of fishery and sampling data

1.4.1 Sampling Data from Commercial Fishery

The working group again carried out a review of the sampling data and the level of sampling on the commercial fisheries. Details are given in the relevant stock-specific sections of this report.

Generally, the amount and quality of available data to the WG has been unchanged in the most recent years. The WG identified issues associated with the formatting and availability of data from commercial catch sampling programmes such as the requirement for length frequency and age-length key data for the assessment of Western horse mackerel and the availability of data arising from the sampling of catches of North Sea horse mackerel from foreign flagged vessels. The issues have been included on the individual stock issue lists and the ICES data call has been updated such that future data submissions should provide data in the appropriate format.

1.4.2 Catch Data

The WG has on number of occasions discussed the accuracy of the catch statistics and the possibility of large scale under reporting or species and area misreporting. The working group considers that the best estimates of catch it can produce are likely to be underestimates.

In the case of red gurnard catch data, the available information is limited. Prior to 1977, red gurnard catches were not reported. Since this time, landings of gurnards have often been reported as mixed gurnards. With the exception of Portugal, there is no detail provided to the WG on the methodology used to estimate the proportion of red gurnards.

1.4.3 Discards

In 2015, the European Union introduced a landing obligation for fisheries directed on small pelagic fish including mackerel, horse mackerel, blue whiting and herring. The obligation was expanded over the following years in a stepwise fashion such that discarding of small pelagic species could still legally occur in other fisheries. From 2019 onwards the landing obligation is generally effective. A general discard ban is already in place for Norwegian, Faroese and Icelandic fisheries.

Historically, discarding in pelagic fisheries is more sporadic than in demersal fisheries. This is because the nature of pelagic fishing is to pursue schooling fish, creating hauls with low diversity of species and sizes. Consequently, discard rates typically show extreme fluctuation (100% or zero discards). High discard rates occurred especially during ´slippage´ events, when the entire catch is released. The main reasons for ´slipping´ are daily or total quota limitations, illegal size and mixture with unmarketable bycatch. Quantifying such discards at a population level is extremely difficult as they vary considerably between years, seasons, species targeted and geographical region.

Discard estimates of pelagic species from pelagic and demersal fisheries have been published by several authors. Discard percentages of pelagic species from demersal fisheries were estimated between 3% to 7% (Borges *et al.*, 2005) of the total catch in weight, while from pelagic fisheries were estimated between 1% to 17% (Pierce *et al.* 2002; Hofstede and Dickey-Collas 2006, Dickey-Collas and van Helmond 2007, Ulleweit and Panten 2007, Borges *et al.* 2008, van Helmond *et al.* 2009, 2010, van Overzee *et al.* 2011, 2013, Ulleweit *et al.* 2016, van Overzee *et al.* 2020). Slipping estimates have been published for the Dutch freezer trawler fleet only, with values at around 10% by number (Borges *et al.* 2008) and around 2% in weight (van Helmond *et al.* 2009, 2010 and 2011) over the period 2003—2010. Nevertheless, the majority of these estimates were associated with very large variances and composition estimates of ´slippages´ are liable to strong biases and are therefore open to criticism.

Because of the potential importance of significant discarding levels on pelagic species assessments, the Working Group again recommends that observers should be placed on board vessels in those areas in which discarding occurs, and existing observer programmes should be continued. Furthermore, agreement should be made on sampling methods and raising procedures to allow comparisons and merging of dataset for assessment purposes. The newest update on discards for the different stocks assessed by the WG is provided in the sections for each of the stocks.

1.4.4 Age-reading

Reliable age data are an important prerequisite in the stock assessment process. The accuracy and precision of these data, for the various species, is kept under constant review by the Working Group. The newest updates on this aspect for the different stocks are addressed below.

1.4.4.1 Mackerel

The most recent workshop on age reading of Atlantic mackerel otoliths (WKARMAC2) took place in October 2018 and was attended by 23 participants from 14 separate laboratories (ICES 2019c).

Through on-screen discussion, the workshop identified a number of issues leading to differences in age determination between readers for difficult and/or old otoliths and calibration. This resulted in revisions to ageing guidelines with modifications agreed and adopted by the workshop participants. As a result, the workshop indicates an improvement in the agreement between readers (66.8% agreement, 31.4% CV), and particularly for expert readers (73.2% agreement, 16.4% CV). However, the agreement between readers for otoliths with older ages (from age 6) continues to be very low (40-58% for all readers; 53-71% for expert readers). This increasing reduction in agreement for older ages was also confirmed by an exercise with quasi age validated Norwegian otoliths from tag-recaptured experiments.

An image collection of agreed age otoliths was assembled on the WKARMAC2 SharePoint and the Age Forum site. This otolith collection includes the otoliths with > 80% agreement between expert readers from the WKARMAC2 calibration exercise. In addition, the images of the otoliths from the exchange with Norwegian otoliths from the tag-recapture experiments will also be included in the reference otolith collection.

A further, small scale exchange on NE A mackerel otoliths is scheduled for the 4th quarter 2020.

At the NEA mackerel Inter-benchmark in 2019, concerns related to the quality of age reading of commercial catch were discussed. WGWIDE concludes that additional investigation on the impact of ageing error on stock assessment outputs are required. This includes the development of standardized sensitivity analyses for this purpose, which would be applicable to the different stocks.

1.4.4.2 Horse mackerel

The most recent workshop on the age reading of *Trachurus trachurus (*also *T. mediterraneus* and *T. picturatus)* was carried out in November 2018 and involved 15 age readers from 9 countries.

The objectives of this workshop were to review the current methods of ageing *Trachurus* species, to evaluate the new precision of ageing data of *Trachurus* species and to update guidelines, common ageing criteria and reference collections of otoliths. The exchange results showed a low value of percentage of agreement from 45.1% to 59.1% for the three *Trachurus* species. The Coefficient of Variation was lower for *T. trachurus* (17.3–32.2) than for the other *Trachurus* species (60.1-73.4) because the sampled specimens were older for this species than for the two other species. With feedback from the readers present at the exchange and the discussion during the WKARHOM3 meeting, the main cause of age determination error for *T. trachurus* was identified as otolith preparation techniques (whole/slice).

However, for the three *Trachurus* species, there are several difficulties in age determination: identification of the first growth annulus, presence of many false rings (mainly in the first and second annuli) and the interpretation and identification of the edge characteristics (opaque/ translucent). The second reading was performed during the workshop with 50 images per each species. Each reader read only the images of the species that is read in their laboratory. The percentage of agreement between readers increased to 70.6% with a CV of 18.4 for *T. trachurus* and to 67.8% with a CV of 31.7 for *T. mediterraneus*. Finally, the group reached an agreement on defining an ageing guideline and a reference collection presented in this report and the aim is to employ these tools for all laboratories.

1.4.4.3 Norwegian Spring-spawning Herring

For some years, there have been issues with age reading of herring. These issues were raised around 2010, and since then two scale/otolith exchanges and a workshop have been held; and a final workshop was planned after the second exchange. There were, however, concerns with the second scale/otolith exchange and the final workshop was postponed indefinitely. It is therefore recommended to organise a new scale/otolith exchange and a follow up workshop.

There are several topics to cover in the recommended work.

Firstly, age-error matrices are needed as input to the stock-assessment, to evaluate sensitivity to ageing errors, and such age-error matrices are an output of age-reading inter-calibrations.

Secondly, stock mixing is an issue. There are several herring stocks surrounding the distribution area of Norwegian spring spawning (NSS) herring, *e.g.* North Sea herring, Icelandic summer spawning herring, local autumn-spawning herring in the Norwegian fjords, and Faroese autumn spawning herring. Mixing with these other stocks in the fringe areas of the NSS herring distribution area leads to confounding effects on the survey indices of NSS herring in the ecosystem surveys and potentially also in the catch data. Methods to separate the NSS herring stock from the other herring stocks are needed – both with regards to obtain more accurate age-readings as well as to reduce confounding effects on the survey indices.

Finally, the experience from earlier exchanges is that age of older fish is more prone to be underestimated when aged is read from otoliths as compared to being read from scales. Some of the institutes mainly sample and read scales, whereas other institutes use the otoliths.

1.4.4.4 Blue Whiting

The most recent workshop on age reading of blue whiting (WKARBLUE2) took place in June 2017 (ICES, 2017a). The workshop was preceded by an otolith exchange, which was undertaken using WebGR in the year prior to the workshop. The otoliths were also sent around to all participants. The exchanged collection included 245 otoliths from the entire stock distribution area. The overall agreement of the pre-workshop exercise was 64.1% considering all readers and 70% for the assessment readers. During the workshop 129 otoliths with annotations were discussed in plenary and 85% agreement was achieved. There were no clear signs of seasonal misinterpretations, but the Mediterranean and most northern areas (ICES area 27.14.b and NAFO 1C) proved to be quite difficult to interpret.

Different methods to help age readers on classifications were discussed during the workshop. The burning of otoliths showed some potential in interpreting the inner ring, but not to be used as a routine. The sliced technique is time consuming, does not show advantages on ring interpretation, and in turn can also introduces more misinterpretation on ageing. During the workshop some of the otoliths from the exercise were polished, to help readers in the cases were the age rings were not so evident, completely absent, or showing a growth pattern different from the expected. The polishing results revealed to be useful on the ring interpretation and to help during the plenary discussion, although it is not recommended that this technique is routinely used, as it is very time consuming. The OtoRing plug-in for ImageJ , which can detect variation in opacity in the otolith surface and be used as a tool on age rings identification was presented (Gonçalves *et al.* 2017a). Furthermore, a criteria table with possible otolith ring diameters from an IPMA study was tested during the workshop (Gonçalves and Dores, 2017). The table showed potential, but a larger dataset is required before it can be implemented as a guideline. The dataset will consider samples by area and sex to achieve criteria's classification which take into account those differences in growth patterns, due to the sexual dimorphism in blue whiting (Gonçalves *et al.* 2017b).

A study on the otoliths from the Portuguese coast showed differences between the first ring length in this area and the average length described in the literature (8.33 and 9.33 mm). Rings measurements of the first annulus, taken during the workshop, revealed also differences between ICES areas (27.2.a – 27.9.a), 27.14.b and Mediterranean.

Recurrent issues among age readers were the identification of the position of the first annual growth ring, false rings and interpretation of the edge. In order to overcome those problems, age validation studies on blue whiting otoliths were further recommended and should be conducted until the next age reading workshop. An age reading inter-calibration exchange commenced in May 2020 and will conclude by November 2020. A further age validation study on this species is being conducted together with the preparation of the 2021 age reading workshop planned to be carried out in June 2021.

1.4.4.5 Boarfish

Sampling of the commercial catch of boarfish has been included within the EU data collection framework since 2017. An age length key was produced in 2012 following increased sampling of a developing fishery. The age reading was conducted by DTU Aqua on samples from the three main fishery participants: Ireland, Denmark and UK (Scotland). No ageing has been carried out since 2012 although otoliths continue to be collected from the Irish fishery during routine catch sampling.

1.4.4.6 Striped red mullet

In 2011, an otolith exchange was carried out, the second such exercise for the striped red mullet. For details see section 12.7.

1.4.4.7 Red gurnard

Age data are available for red gurnard from the EVHOE and IGFS groundfish surveys. Improvements in the understanding of the age structure of this stock would be improved by reading otoliths from other surveys in the assessment area (*e.g.* NS-IBTS, SCO-WCS, CGFS) which also contribute information on stock status in term of their CPUE series.

1.5 Quality Control and Data Archiving

1.5.1 Current methods of compiling fisheries assessment data

Information on official, area misreported, unallocated, discarded and sampled catches have again this year been recorded by the national laboratories on the WG-data exchange sheet (MS Excel; for definitions see text table below) and sent to the stock co-ordinators and uploaded through the InterCatch hosted application. Co-ordinators collate data using the either the sallocl (Patterson, 1998) application which produces a standard output file (Sam.out) or the InterCatch hosted application.

There are at present no specified criteria on the selection of samples for allocation to unsampled catches. The following general process is implemented by the species co-ordinators. A search is made for appropriate samples by gear (fleet), area, and quarter. If an exact match is not available the search will extend to adjacent areas, should the fishery extend to this area in the same quarter. Should multiple samples be available, more than one sample may be allocated to the unsampled catch. A straight mean or weighted mean (by number of samples, aged or measured fish) of the observations may be used. If there are no samples available the search will move to the closest non-adjacent area by gear (fleet) and quarter, but not in all cases.

It is not possible to formulate a generic method for the allocation of samples to unsampled catches for all stocks considered by WGWIDE. However full documentation of any allocations made are stored each year in the data archives (see below). It should be noted that when samples are allocated the quality of the samples may not be examined (i.e. numbers aged) and that allocations may be made notwithstanding this. The Working Group again encourages national data submitters to provide an indication of what data could be used as representative of their unsampled catches.

Following the introduction of the landings obligations for EU fisheries new catch categories had to be introduced from 2015 onwards. The catch categories used by the WGWIDE are detailed below:

Official Catch	Catches as reported by the official statistics to ICES
Unallocated Catch	Adjustments (positive or negative) to the official catches made for any special knowledge about the fishery, such as under- or over-reporting for which there is firm external evidence.
Area misreported Catch	To be used only to adjust official catches which have been reported from the wrong area (can be negative). For any country the sum of all the area misreported catches should be zero.
BMS landing	Landings of fish below minimum landing size according to landing obligation
Logbook registered discards	Discards which are registered in the logbooks according to landing obligation
Discarded Catch	Catch which is discarded
WG Catch	The sum of the 6 categories above
Sampled Catch	The catch corresponding to the age distribution

1.5.2 Quality of the Input data

Primary responsibility for the accuracy of national biological data lies with the national laboratories that submit such data. Each stock co-ordinator is responsible for combining, collating, and interpolating the national data where necessary to produce the input data for the assessments. A number of validation checks are already incorporated in the data submission spreadsheet currently in use, and these are checked by the co-ordinators who in the first instance report anomalies to the laboratory which provided the data.

Overall, data quality has improved and sampling deficiencies have been reduced compared to earlier years, partly due to the implementation of the EU sampling regulation for commercial catch data. However, some nations have still not or inadequately aged samples. Occasionally, no data are submitted such that only catch data from EuroStat is available, which are not aggregated quarterly but are yearly catch data per area.

The Working Group documents sampling coverage of the catches in two ways. National sampling effort is tabulated against official catches of the corresponding country (see stock specific sections). Furthermore, tables showing total catch in relation to numbers of aged and measured fish by area give a picture of the quality of the overall sampling programme in relation to where the fisheries are taking place. These tables are contained in the species sections of this report.

The national data on the amount and the structure of catches and effort are archived in the ICES InterCatch database. The data are provided directly by the individual countries and are highly aggregated for the use of stock assessments.

There exist gaps in some data series, in particular for historical periods. The WG has requested members to provide any national data reported to previous working groups (official catches, working group catches, catch-at-age and biological sampling data) not currently available to the WG. Furthermore, the WG recommends that national institutes increase national efforts to collate historic data.

Stock data problems relevant to data collection A number of stock data problems relevant to data collections have been brought forward to the contact person in preceding years. Those that still apply are listed in table below for the information of ICES-Working Groups and RCMs as specified.

Stock	Data Problem	How to be addressed in	By who
Northeast Atlantic Mackerel	Submission of data	Data submissions must include all the data outlined in the data call and be submitted by the deadline. Data should include length distributions split by area and quarter. Should the data submitter be unavailable after the data has been submitted (e.g. vacation) an alternative contact should be available who can be contacted in the event of any queries.	National laboratories
Northeast Atlantic Mackerel	Discard and slippage information	Discard and slippage information is incomplete. All fleets, including demersal fleets should be monitored and sampled for discards and slipping. Data should be supplied to the coordinator by the submission deadline, accompanied by documentation describing the sampling protocol.	National laboratories, RCG NA, RCG NS&EA
Northeast Atlantic Mackerel	Sampling deficiencies– general	All countries involved should provide sampling information. Increased cooperation between countries would help reduce redundancy and increase coverage.	National laboratories, RCG NA, RCG NS&EA
Northeast Atlantic Mackerel	Sampling of foreign vessels	Any information available from the sampling of foreign vessels should be forwarded to the appropriate person in the national laboratory in order that they may use this information when compiling the data submission.	National laboratories; RCG NA, RCG NS&EA
Horse Mackerel – Western Stock	Missing sampling data for some parts of the distribution area (27.2a, 7e)	Fishing nations to Sample age and length Distributions from commercial fleets	National Institutes
Horse Mackerel – North Sea Stock	Incomplete report of discards by non-pelagic fleet.	Reporting of discards by national institutes.	National Institutes
Horse Mackerel – North Sea Stock	Lack of maturity ogive both by age or length	Collection of information about maturity stage during regular biological sampling (otoliths) in commercial and survey fleets	National institutes
Horse Mackerel – North Sea Stock	Lack of length distributions in the discarded component	Sampling of length distribution of discarded individuals	National institutes
Horse Mackerel – North Sea Stock	Low contribution of countries to the estimation of	To ensure the sampling of age and length information from all catch fractions and all areas and within all quarters from all commercial	National institutes

Stock	Data Problem	How to be addressed in	By who
	the age and length distribution of catches	fleets with a distribution of sampling effort over the year and areas in the North Sea	
Norwegian Spring-spawning Herring	Low sampling effort on some nations	Sampling effort should be increased by nations with little or no samples.	National laboratories; RCG NS&EA
Red gurnard	Discard and slippage information	Discard rates for this species can be very high (up to 100% of catch at a trip level). Alternative data sources and methods for estimation (e.g. CCTV systems) should be investigated.	National laboratories
Red gurnard	Stock area	Red gurnard is found all along the Iberian continental shelf. There are no records of catches of red gurnards in SA5, and this area could be removed from the data call.	
Northeast Atlantic Blue whiting	Submission of data	Data submissions must include all the data outlined in the data call and be submitted by the deadline. Should the data submitter be unavailable after the data has been submitted (e.g. vacation) an alternative contact should be available who can be contacted in the event of any queries.	National laboratories

1.5.3 Quality control of data and assessments, auditing

As a quality control of the data and the assessment, three WG participants were appointed as auditors for each stock. The primary aim of the auditing process is to check that the assessment and forecast has been conducted as detailed in the relevant stock annex. Auditors conducted checks of the assessment input data, assessment code (time permitting), draft WG report and draft advice sheet. Auditors completed an audit report upon completion (annex 5). Issues identified in the audit reports were followed up by the appropriate stock coordinator/assessor with updates made where appropriate.

1.5.4 Information from stakeholders

The procedure for the submission of inputs from stakeholders into the scientific advice has changed in 2020. Instead of contributing information directly into the Advice Drafting Groups, the procedure is now that the information from stakeholders should be submitted to the expert groups who will then consider the information for inclusion into the advice, if applicable.

For WGWIDE stocks there are several instances of strong cooperation between research institutes and fishing industries in the collection of data that is used in the assessments, *e.g.* the acoustic survey for Norwegian Spring Spawning herring, the extension of the IESSNS survey into the North Sea and several cases where industry vessels are collecting samples for catch monitoring. In these cases, the research institutes are coordinating the activities and bringing the results directly to the expert group(s).

A recent development that started around 2014 involves fishing industry organizations taking initiatives on their own, to collect additional information that is contributed to the expert groups. In many cases these research activities are undertaken in close cooperation with research institutes. In WGWIDE 2020, the following contributions from fishing industry research activities have been reported to the working group:

1. PFA self-sampling report 2015-2020
2. Gonad sampling for mackerel and horse mackerel 2019-2020
3. Inventory of industry acoustic data for blue whiting
4. Evaluation of a potential rebuilding plan for Western horse mackerel
5. Genetic stock identification of horse mackerel

1.5.4.1 PFA self-sampling report 2015-2020 (WD01)

The Pelagic Freezer-trawler Association (PFA) initiated a self-sampling programme in 2015, aimed at expanding and standardizing ongoing fish monitoring programmes by the vessel quality managers on board of the vessels. An overview of the self-sampling in widely distributed pelagic fisheries is presented in the text table below (number of vessels, trips, days, hauls, catch (tonnes), catch per day (tonnes), %non-target catch and number of fish measured. * denotes incomplete year).

Year	Vessels	Trips	Days	Hauls	Catch	Catch/Day	Non-target	Lengths
2015	4	26	390	869	65 899	168	1.10%	69 680
2016	9	47	647	1 456	126 997	196	0.50%	78 708
2017	12	64	887	1 886	184 460	207	0.20%	95 190
2018	16	88	1 330	2 901	272 416	204	0.20%	176 455
2019	16	101	1 423	3 109	252 973	177	0.30%	150 806
2020*	13	65	908	2 092	215 627	237	0.40%	178 114
ALL		391	5 585	12 313	1 118 372			748 953

***incomplete**

The Mackerel fishery takes place from October through to March of the subsequent year. Minor bycatches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2015 – 2020 (up to August) covered 323 fishing trips with 4,725 hauls, a total catch of 286,957 tonnes and 91,000 individual length measurements. The main fishing areas are ICES division 27.4.a (between 27% and 54% of the catch) and division 27.6.a (between 25% and 44% of the catch). Compared to the previous years, mackerel in the catch have been relatively large in 2020 with median length of 36.4 cm compared to 32.4-35.4 in the preceding years. Also, the median weight has been somewhat higher with median weight of 417 gram compared to 379-400 gram the preceding years. Average annual fat content ranges from 17 to 21% with individual measurements reaching up to 30%

The horse mackerel fishery takes place from October through to March of the subsequent year. Overall, the self-sampling activities for the horse mackerel fisheries during the years 2015 – 2020 (up to August) covered 457 fishing trips with 3,454 hauls, a total catch of 140,633 tonnes and 125,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 21% and 40% of the catch), division 27.7.b (7%-22%) and division 27.7.d (19%-34%, note that this is considered as the North Sea horse mackerel stock). Horse mackerel have a wide range in the length distributions in the catch. Median lengths have fluctuated between 22.8 cm and 30.0 cm. In 2019 and 2020 there are some indications of a stronger year class being available to the fishery, with a narrower length distribution. For example, in 27.6.a, the mode was 26.6 cm in 2019 and 27.5 cm in 2020. Average annual fat content ranges from 5 to 7.5% with individual measurements reaching up to 15%.

The blue whiting fishery takes place from February through to May although some minor fisheries for blue whiting may remain over the other months. Overall, the self-sampling activities for the blue whiting fisheries during the years 2015 – 2020 (up to August) covered 365 fishing trips with 5,836 hauls, a total catch of 561,888 tonnes and 128,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 41% and 65% of the catch), division 27.7.c (6%-36%) and division 27.7.k (2%-32%). Blue whiting have a wide range in the length distributions in the catch. Median lengths have fluctuated between 23 cm (2016) and 30 cm (2015). During the period 2016 - 2020, the median length is consistently increasing (from 23 cm to 28 cm), indicating that the fishery is probably concentrating on a strong year class going without new year classes coming in. Fat content for blue whiting is generally low (on average less than 1%).

The fishery for Atlanto-Scandian herring (ASH) is a relatively small fishery for the PFA and takes place mostly in October. Overall, the self-sampling activities for the ASH fisheries during the years 2015 – 2020 (up to August) covered 27 fishing trips with 406 hauls, a total catch of 30,234 tonnes and 8,918 individual length measurements. Only the herring fishery in ICES division 27.2.a is considered for ASH. Note that there are herring catches in other divisions within the selected trips. These are trips where North Sea herring has been fished with some bycatches of mackerel for example. Atlanto-Scandian herring have a narrow range in the length distributions in the catch. Median lengths have fluctuated between 32 and 36 cm. Average annual fat content for ASH has been between 17 and 20% with individual measurements going up to 25%).

1.5.4.2 Gonad sampling for mackerel and horse mackerel 2019-2020 (WD08)

Working Document 08 summarizes the status of the industry-science collaboration aimed at improving the knowledge on gonad development of mackerel and horse mackerel. The work is based on samples taken by the fishing industry (PFA vessels) on both targeted and by-catches of mackerel and/or horse mackerel. The overall aim of the Year of the Mackerel project is to gain insight in the gonad development of female and male mackerel throughout the year in order to gain improved understanding of the spawning strategy. For horse mackerel, the aim is to investigate the period during which spawning occurred in 2020 for the Western horse mackerel. To date, 1365 individual mackerel and 197 horse mackerel have been sampled (horse mackerel sampling only started in 2020). Preliminary results of the analysis on mackerel are presented in the working document. Final results for mackerel are expected in October 2020 and for horse mackerel in the first half of 2021.

1.5.4.3 Inventory of industry acoustic data for blue whiting (WD07)

Since 2012 the Dutch pelagic industry (PFA) has been engaged in the collection of acoustic data at a large scale. Working document 07 presents an overview of the acoustic data with a focus on blue whiting. Further work will be carried out to (automatically) analyse the acoustic data and couple those results with the PFA self-sampling data. The ambition is to explore the development of an index of abundance from commercial acoustic data that could aid the blue whiting acoustic survey in case of missing surveys or bad weather conditions.

1.5.4.4 Evaluation of a potential rebuilding plan for Western horse mackerel (WD02)

Working document 02 summarises a number of analyses conducted in an attempt to develop a potential rebuilding plan for the Western horse mackerel. Even though western horse mackerel was not classified by ICES as in need of rebuilding in their latest advice (ICES, 2019a), the general perception within the fishing industries has been that the stock has been in a poor state recently although there are some positive signals in recent recruitment. Ensuring that these recent recruitments can lead to improvements in stock status requires a careful management approach. The Pelagic Advisory Council (PELAC) has been a proponent of developing management plans for all stocks in their remit. In the case of Western horse mackerel, the PELAC has adopted a rebuilding plan approach because of the current stock status of the stock. The working document summarizes the progress on horse mackerel stock ID (Farrell et al., 2020), issues around the length compositions in the catch, spawner per recruit analysis, the development of an alternative assessment (SAM) and associated reference points.

A key point in the context of WGWIDE is the evaluation of potential harvest control rules (HCRs) for Western horse mackerel. The HCR analyses represent two different assessment methods (SS3 and SAM) and two different HCR evaluation tools (EqSim and SAM HCR). Both HCR evaluation tools are of the type 'short-cut' with appropriate conditioning of the uncertainties in the assessment based on historical CV and autocorrelation in line with the recommendations from WKMSYREF3 and WKMSYREF4. The evaluations followed the guidelines from WKGMSE2 (ICES, 2019c) and WKREBUILD (ICES, 2020b).

Three different types of harvest control rules were evaluated:

- Constant F strategy: fixed F_{target} independent of biomass level
- ICES Advice Rule: breakpoint at $B_{trigger}$ and linear reduction in F to zero when below $B_{trigger}$.
- Double Breakpoint rule: a breakpoint at $B_{trigger}$ and linear reduction in F to 20% of F_{target} at B_{lim}. Below B_{lim} continued fishing at F = 0.2 * F_{target}.

For each of the HCRs, a number of different F_{target} values were explored (0.0, 0.05, 0.075, 0.1, 0.125, 0.15). No evaluation of different $B_{trigger}$ values was carried out, so that all evaluations used MSY $B_{trigger}$ as the trigger point. All HCRs where evaluated with three variants:

- Without any additional constraints
- With a minimum TAC of 50 kt
- With a maximum 20% inter-annual variation (IAV) in TAC, but only when the stock is above $B_{trigger}$)

Two simulation tools were used: the EqSim simulator and the SAM HCR forecast. The EqSim simulator is a modified version of the SimpSIM approach that was used for the blue whiting MSE in 2016 (ICES, 2016). The code was further developed by Andrew Campbell and Martin Pastoors to improve standardization, documentation and visualization of results. EqSim makes use of an Operating Model (OM) and a Management Procedure (MP). The SAM HCR forecast is a simple stochastic forecast with HCR to evaluate management for fish stocks that need rebuilding in the short-term. The stochastic forecasts start from the currently perceived stock, *i.e.* the assessment estimates currently used for tactical management advice, but incorporating consideration of the uncertainty in these estimates. Rebuilding is evaluated by forward projection for a specified number of years and for different target fishing mortality values.

The EqSim with SS3 results indicate that the constant F strategy is the least cautious rule and the double breakpoint rule is the most cautious rule. Under the F strategy rule with a Ftarget of 0.075, rebuilding to B_{pa} is only just being achieved (probability just above 50%) by 2025, while in the double breakpoint rule this is expected to be achieved in 2024 with substantially higher probabilities of remaining above B_{pa}. The first year of rebuilding to B_{pa} in the double breakpoint rule with target fishing mortalities up to 0.1 is the same as the first year of rebuilding under the zero fishing scenarios.

Similar results have been obtained with the EqSim with SAM evaluations although the levels of SSB are slightly higher and risk to B_{lim} is slightly lower. According to these evaluations, rebuilding to Bpa could be obtained by 2022 in all scenarios.

Given that the EqSim with SS3 evaluation is closest methodologically to the ICES advisory practice, this was used as the basis for the preferred rebuilding plan by the PELAC. The PELAC preferred options are:

- Target fishing mortality at F_{MSY} = 0.074 (approximated by 0.075 in the simulations)
- B_{lim} at ICES B_{lim} (834 480 t)
- $B_{trigger}$ at ICES MSY $B_{trigger}$ (1 168 272 t)
- Double breakpoint rule with 20% constraint on IAV above $B_{trigger}$
- Minimum F when stock is below B_{lim} at 20% of F_{MSY} = 0.015

The selected rebuilding plan has a 50% probability of rebuilding to B_{lim} by 2021 (similar to zero catch option) and a 50% probability of rebuilding to B_{pa} /MSY $B_{trigger}$ by 2024 (similar to the zero-catch option). Furthermore, the probability of being below B_{lim} remains well below 5% for the duration of the simulation. This has formed the basis of the rebuilding plan proposed by PELAC to the EC, with a request to have the evaluation reviewed by ICES.

1.5.4.5 Genetic stock identification of horse mackerel (WD11)

Atlantic horse mackerel is currently assessed and managed as three distinct stocks: the Western, the North Sea and the Southern. Despite the commercial importance of the horse mackerel, the accuracy of alignment of these stock divisions with biological units is remains uncertain. The aims of this study were to identify informative genetic markers for the stock identification of horse mackerel and to estimate the extent of genetic differentiation among populations distributed across the distribution range of the species. For this we used modern sequencing techniques that allowed us to assess genetic variants in the entire genome. We discovered that while the populations differ in a small fraction of their DNA (< 1.5%), such genetic differences are significant as they likely represent natural selection and might be involved in local adaptation. We validated a small fraction of these highly differentiated genetic variants by a SNP assay and demonstrated that they can be used as informative molecular markers for the genetic identification of the main stock divisions of the Atlantic horse mackerel.

The results, based on the analysed samples, indicated that the North Sea horse mackerel are a separate and distinct population. The samples from the Western stock, west of Ireland and the northern Spanish shelf, and the northern part of the Southern stock, northern Portugal, appear to form a genetically close group. There was significant genetic differentiation between the northern Portuguese samples and those collected in Southern Portuguese waters, with those in the south representing a separate population. The North African and Alboran Sea samples were distinct from each other and from all other samples.

These results indicate that a further large-scale analysis of samples, with a greater temporal and spatial coverage, with the newly identified molecular markers is required to test and reassess the current stock delineations.

1.6 Comment on update and benchmark assessments

Updates were presented to the WG for all the eight stocks in the group.

Western and North Sea horse mackerel were assessed on basis of benchmark that took place in January 2017 (ICES 2017a) and NEA mackerel on an inter-benchmark that took place in 2019 (ICES 2019b).

Norwegian spring spawning herring was assessed using the XSAM implementation benchmarked in 2016. A minor update to the historic acoustic survey time series following development of the StoX software was implemented. Data from a juvenile survey in the Barents Sea was unavailable this year (2020) due to technical difficulties with the vessel.

The Blue whiting assessment also used an updated acoustic survey StoX time series. In addition, due to disruption to the survey programme as a result of the COVID-19 emergency, no 2020 survey was conducted. As in 2019, the stock weights in the assessment year were determined from preliminary catch data rather than using the average of the most recent three years.

The remaining three stocks addressed by the WG (boarfish, red gurnard and striped red mullet) have not been benchmarked recently but were still assessed by the WG.

1.7 Planning future benchmarks

Two of the WGWIDE stocks are yet to be benchmarked; Boarfish for which an exploratory surplus production model is used and Striped red mullet for which there is no assessment in place. The WG considers that both stocks should be benchmarked in 2022 with considerable scope for development of these assessments.

The current implementation of the Stock Synthesis model for the assessment of Western horse mackerel has been used since the benchmark in 2017. The working group considers that there are sufficient issues in relation to the input data and model configuration and proposes a new benchmark in 2022. In particular, the length frequency information from the commercial catch should be reviewed and expanded to include information from the discarded component (unavailable in 2017). The assessment configuration with respect to the dynamics of the fishery should be reviewed to investigate the inclusion of time varying selectivity and spatial dynamics (multi-fleet). The relative weight of the various data sources should also be reviewed, in particular with regard the use of both ALKs and age composition data. The re-weighting scheme employed should also be explored following model stability issues in 2020. The fishery independent data, in particular the utility of a number of acoustic surveys and the egg survey should be evaluated. Advances with regard to data collected by industry, the development of an alternative assessment model (SAM) and the SS model itself since 2017 should also be considered.

The assessment of Norwegian spring spawning herring makes use of an acoustic survey time series conducted on the spawning grounds in February and March. This survey was not conducted between 2006 and 2014 and, when included in the assessment following the 2016 benchmark exercise, was treated as a single time series despite changes in the survey design on its resumption in 2015. There are now 6 data points the recent time series (2015-2020) and WGWIDE proposes that an inter-benchmark be conducted to investigate the splitting of this survey time series within the assessment. It is also proposed that the inter-benchmark explore the implementation of the assessment within the SAM model (which has been updated and now supports the XSAM model), review and (if necessary) update the MSY and PA reference points and update the stock annex.

The current status of the WGWIDE stock with respect to benchmarking is summarised below:

Stock	Benchmark History	WGWIDE 2020 Proposal
Boarfish	Never benchmarked	Full benchmark
Red gurnard	Full benchmark scheduled 2021 (WKWEST)	
Norwegian Spring Spawning herring	Full benchmark 2016	Inter-benchmark
Western horse mackerel	Full benchmark 2017 Reference point inter-benchmark 2019	Full benchmark
North Sea horse mackerel	Full benchmark 2017	
Northeast Atlantic mackerel	Full benchmark 2014 Full benchmark 2017 Inter-benchmark 2019	
Striped red mullet	Never benchmarked	Full benchmark
Blue whiting	Benchmarked 2012 Inter-benchmark 2016	

1.8 Special Requests to ICES regarding stocks within WGWIDE

During 2020 a request to evaluate long-term management strategies for Northeast Atlantic mackerel using a full feedback approach was considered by ICES (WKMSEMAC, (ICES, 2020c)) with advice released on August 3rd 2020 (https://doi.org/10.17895/ices.advice.7446). The advice identified combinations of F_{target} and $B_{trigger}$ that maximize median annual yield in the long term and simultaneously minimise the risk of falling below B_{lim}. At the time of WGWIDE 2020, the requesting parties had yet to on a candidate set of HCR parameter values and it was therefore not possible to include the corresponding catch option in the draft advice sheet.

1.8.1 Request to ICES from EU, Norway and the Faroe Islands on the long-term management strategies for Northeast Atlantic mackerel (full feedback approach).

The European Union, Norway and the Faroe Islands jointly request ICES to advise on the longterm management strategies on Northeast Atlantic Mackerel. A request is provided below.

ICES is requested to identify appropriate precautionary combinations in the Tables given in its response to the EU, Norway and the Faroe Islands request to ICES to evaluate a multi-annual management strategy for mackerel in the North East Atlantic (ICES 2017), using:

- *A range of Btrigger from two to five million tonnes with an appropriate range of target Fs*
- *A harvest control rule with a fishing mortality equal to the target F when SSB is at or above* $B_{trigger}$

- *In the case that the SSB is forecast to be less than $B_{trigger}$ at spawning time in the year for which the TAC is to be set, the TAC shall be fixed consistently with a fishing mortality that is given by: $F = F_{target}*SSB/B_{trigger}$*

All alternatives should be evaluated with and without a constraint on the inter-annual variation of TAC. When the rules would lead to a TAC, which deviates by more than 20% below or 25% above the TAC of the preceding year, the Parties shall fix a TAC that is respectively no more than 20% less or 25% more than the TAC of the preceding year. The TAC constraint shall not apply if the SSB at spawning time in the year for which the TAC is to be set is less or equal to Btrigger.

The constraint mechanism shall be tested separately from and in combination with 10% banking and borrowing mechanism.

Evaluation and performance criteria

Each alternative shall be assessed in relation to how it performs in the short term (5 years), medium term (next 10 years) and long term (next 25 years) in relation to:

- *Average SSB*
- *Average yield*
- *Indicator for year to year variability in SSB and yield*
- *Risk of SSB falling below B_{lim}*

The approach should follow the same full feedback methodology that has been recently used to evaluate stocks in the North Sea (ICES, 2019). The evaluation should be conducted to identify options that are robust to alternative operating models including but not limited to:

A. Investigating alternative plausible recruitment dynamics and scenarios,

B. Alternative natural mortality assumptions,

C. The potential impact of density dependent growth.

Following initial consideration of the request by ICES, the requesting parties confirmed that the strategy should also be evaluated with a banking and borrowing scheme representative of recent behaviour. The requesters furthermore confirmed that banking and borrowing should be suspended when SSB is below $B_{trigger}$, and that implications of any future catch scenario that exceeds the advised catch should not be evaluated.

References:

ICES, 2017. EU, Norway, and the Faroe Islands request concerning long-term management strategy for mackerel in the Northeast Atlantic. ICES Special Request Advice. https://10.17895/ices.pub.3031

ICES, 2019. EU and Norway request concerning the long-term management strategy of cod, saithe, and whiting, and of North Sea autumn-spawning herring. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.06, https://doi.org/10.17895/ices.advice.4895

1.9 General stock trends for widely distributed and migratory pelagic fish species

This working group has carried out the stock assessments of the following widely distributed and migratory pelagic species: boarfish, red gurnard, Norwegian spring spawning herring, Western horse mackerel, North Sea horse mackerel, Northeast Atlantic mackerel, Striped red mullet and Blue whiting.

Analytical (category 1) type of assessments are available for the four species that make up the bulk of the biomass of pelagic species in the Northeast Atlantic:

- Northeast Atlantic mackerel
- Norwegian spring spawning herring
- Blue whiting
- Western horse mackerel.

The time series of the combined catch of these four stocks since 1988 are shown in Figure 1.9.1.

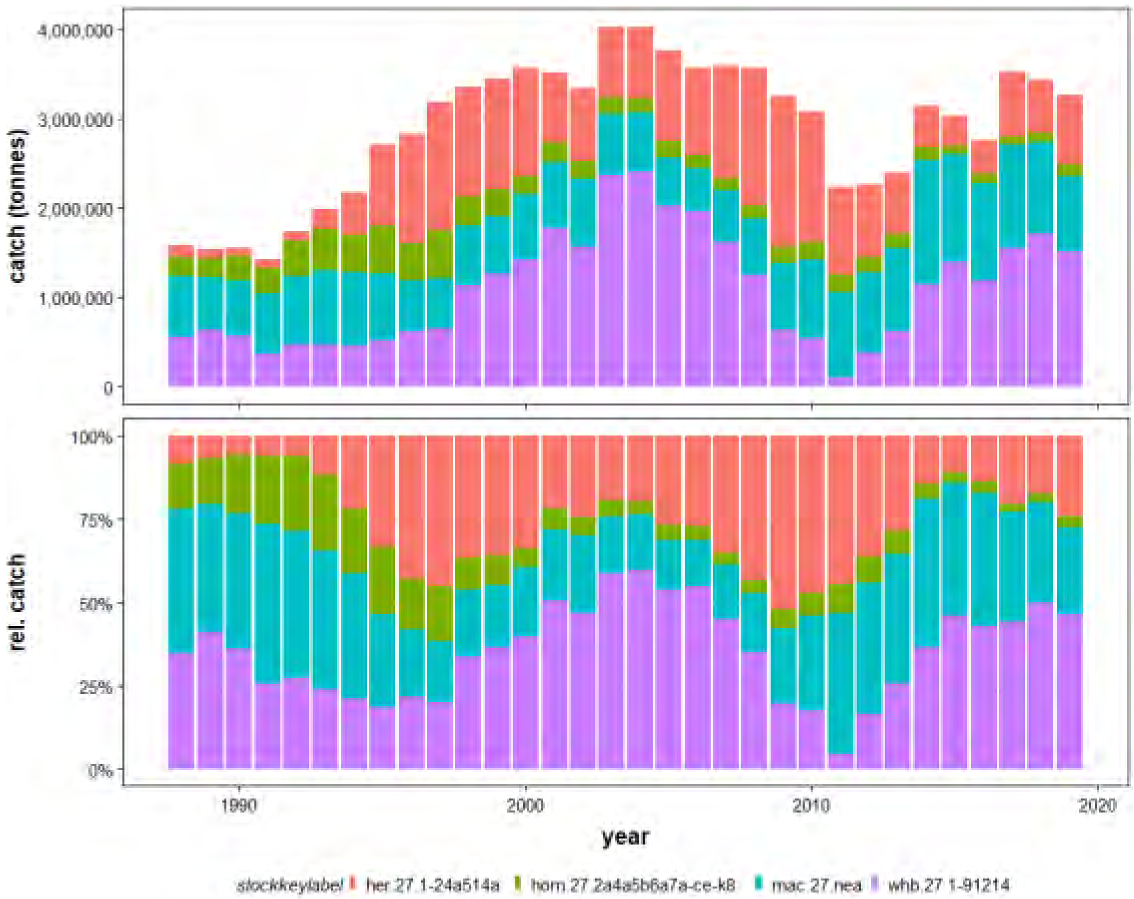

Figure 1.9.1: Catch of mackerel, western horse mackerel, blue whiting and Norwegian spring spawning herring

The trends in SSB of the four stocks are shown in Figure 1.9.2, first in historical perspective (assessments 2017-2020) with the uncertainty estimates from the most recent assessment, then for the current assessment (2020) in absolute biomass (tonnes) and in relative proportions. At the maximum, the total pelagic biomass of these species has been just above 15 million tonnes. In 2019, the pelagic biomass is estimated to be around 13.5 million tonnes. The relative contributions of Norwegian Spring-spawning herring and Western horse mackerel has decreased in recent years while blue whiting and Northeast Atlantic mackerel have increased.

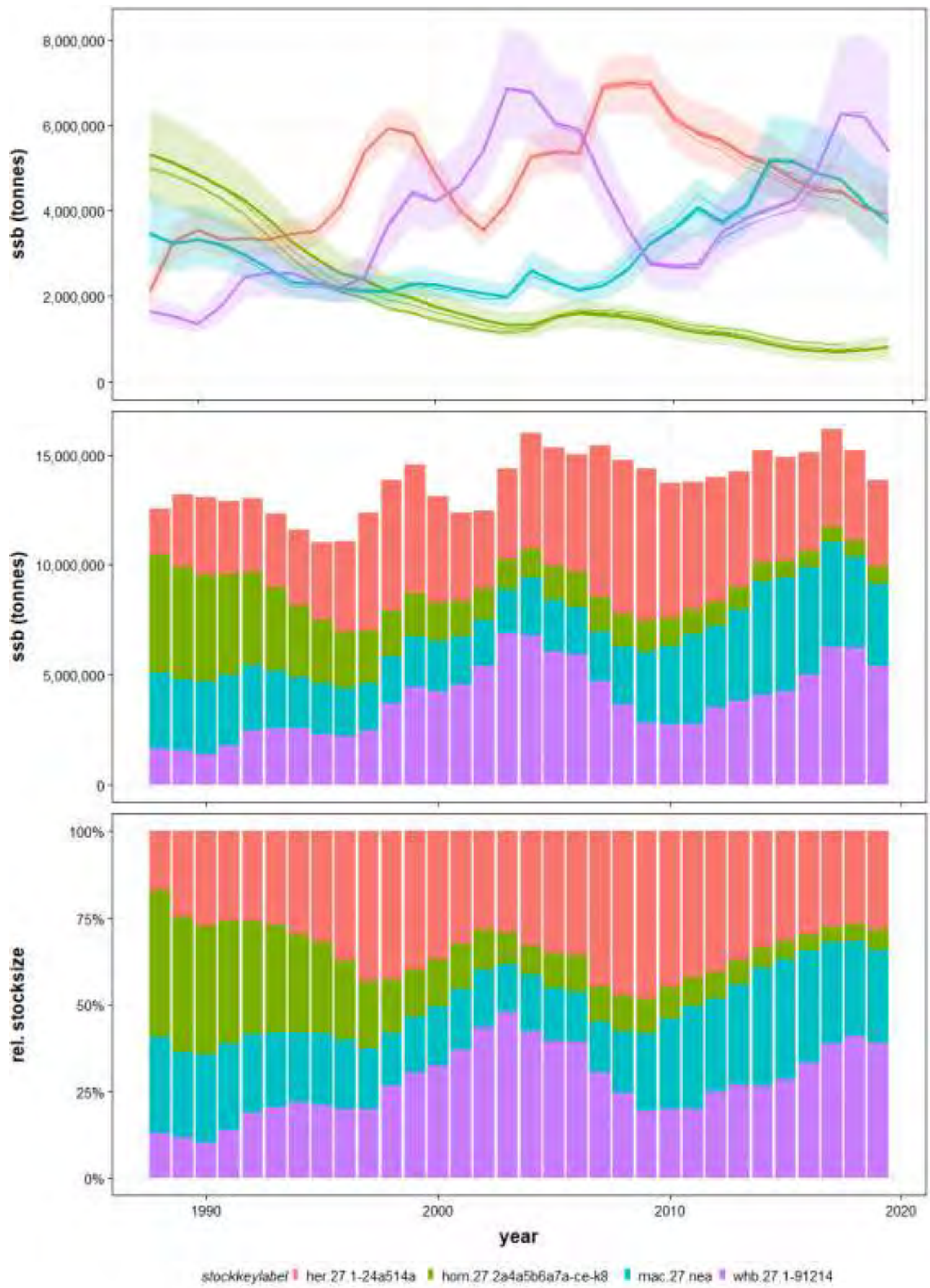

Figure 1.9.2: SSB of mackerel, western horse mackerel, blue whiting and Norwegian spring spawning herring. The top figure has the most recent assessment in bold and with confidence intervals and the two previous estimates. The bottom two graphs refer only to the most recent assessment.

An overview of the key variables for each of the stocks (stock size, fishing mortality and recruitment), in historical perspective (assessments 2017-2020) with the uncertainty estimates from the most recent assessment, is shown in Figure 1.9.3. From these comparisons it can be concluded that the fishing mortality of mackerel and blue whiting has generally been higher than the fishing mortality of horse mackerel and herring. Recruitment levels of blue whiting and herring are on a comparable scale and substantially higher than horse mackerel (except for the 1982 year-class) and mackerel. Biomass trends of the different stocks are somewhat on the same level but show very different tendencies.

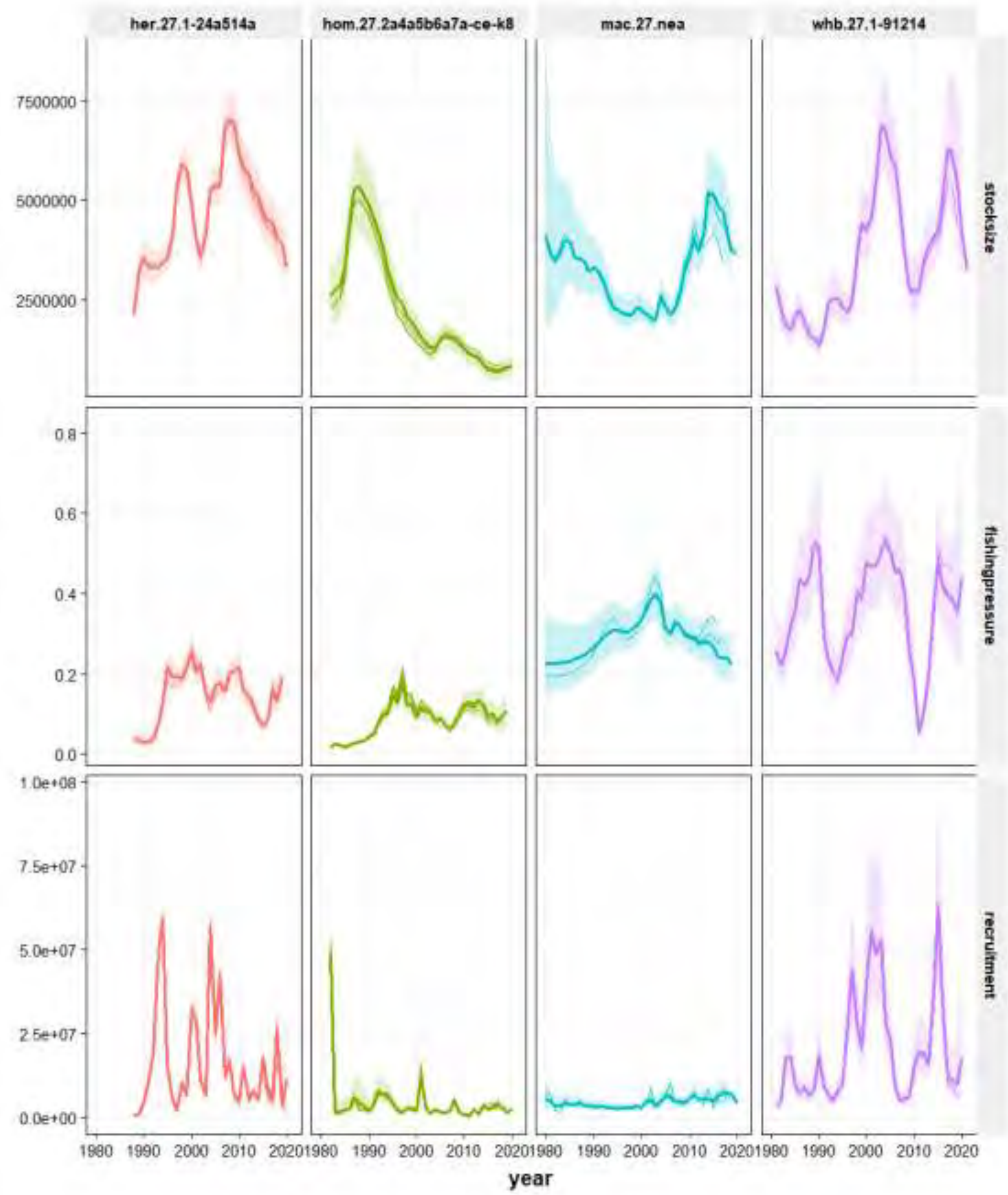

Figure 1.9.3: SSB of mackerel, western horse mackerel, blue whiting and Norwegian spring spawning herring

An overview of stock weight at age for mackerel and blue whiting is shown in figures 1.9.4 and 1.9.5. For mackerel, a decline in weight at age started around 2005 for most ages. In more recent years, this has ceased with increases for younger fish noted since 2012. Weight at age of blue whiting shows substantial fluctuations over time. For most ages, a decline in weight at age has been observed from 2010 although this appears to have ceased and, for some ages reversed in the most recent years.

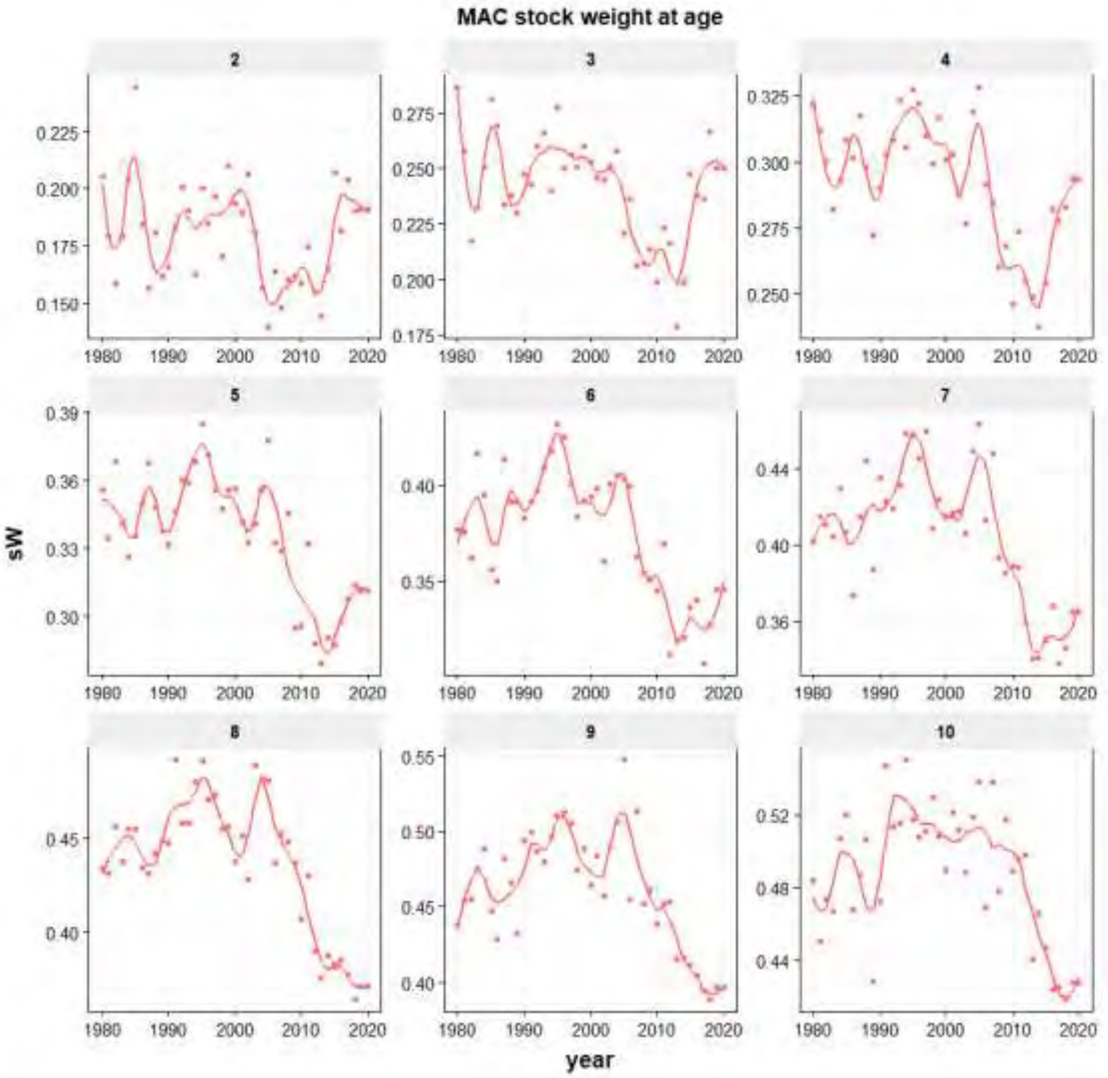

Figure 1.9.4: Stock weight at age of NEA mackerel

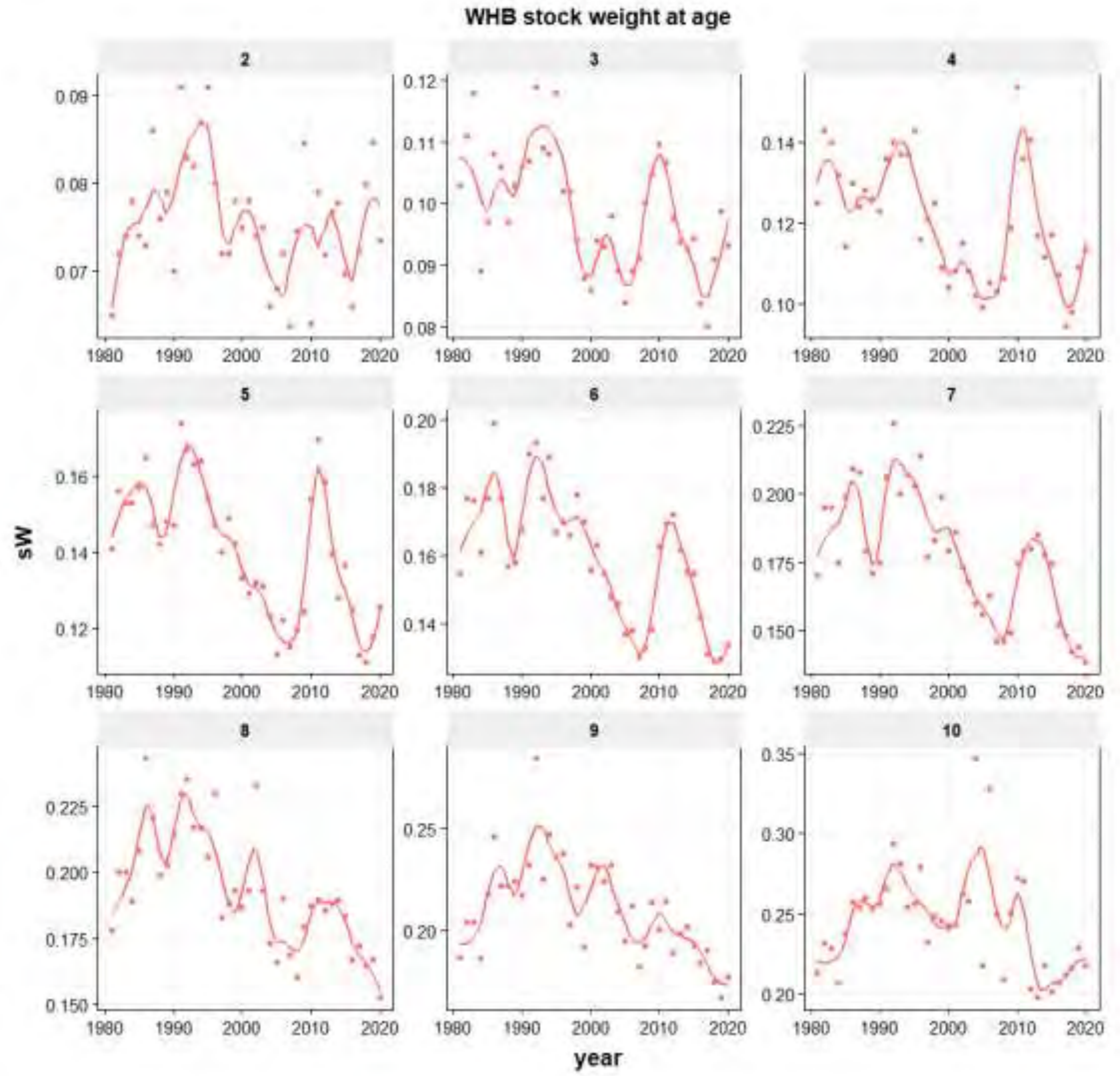

Figure 1.9.5: Stock weight at age of blue whiting

WGWIDE and its precursors WGMHSA and WGNPBW have been publishing catch per statistical rectangle plots in their reports for many years. Catch by rectangle has been compiled by WG members and generally provide a WG estimate of total catch per rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches. In the individual stock report sections, the catch by rectangle is been presented by quarter for the most recent year. For this overview, WGWIDE has collated all the catch by rectangle data that is available for herring, blue whiting, mackerel and horse mackerel. For horse mackerel and mackerel, a long time series is available, starting in 2001 (HOM) and 1998 (MAC). The time series for herring and blue whiting are shorter (starting in 2011) although additional information could still be derived from earlier WG reports.

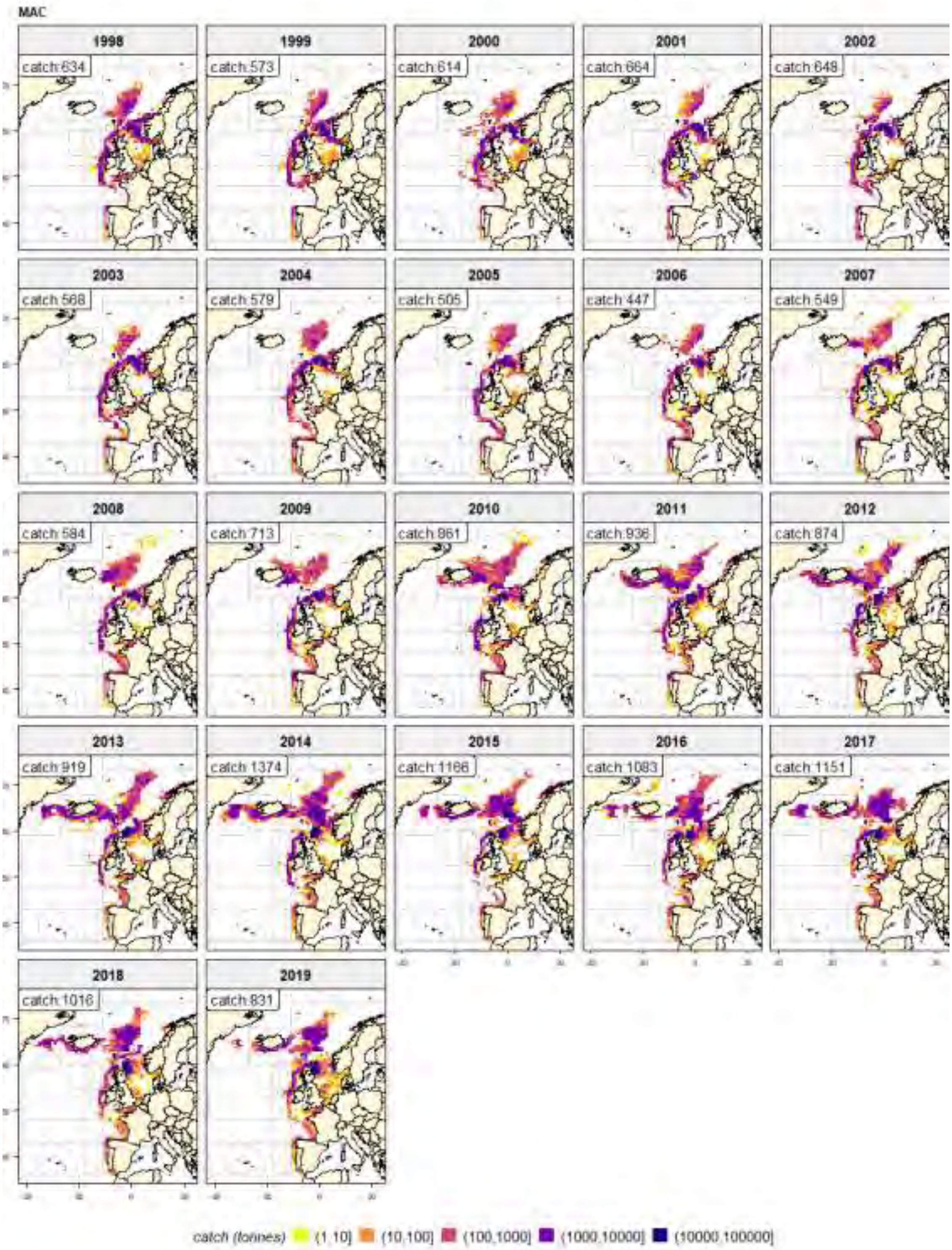

Figure 1.9.6: Catch of mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

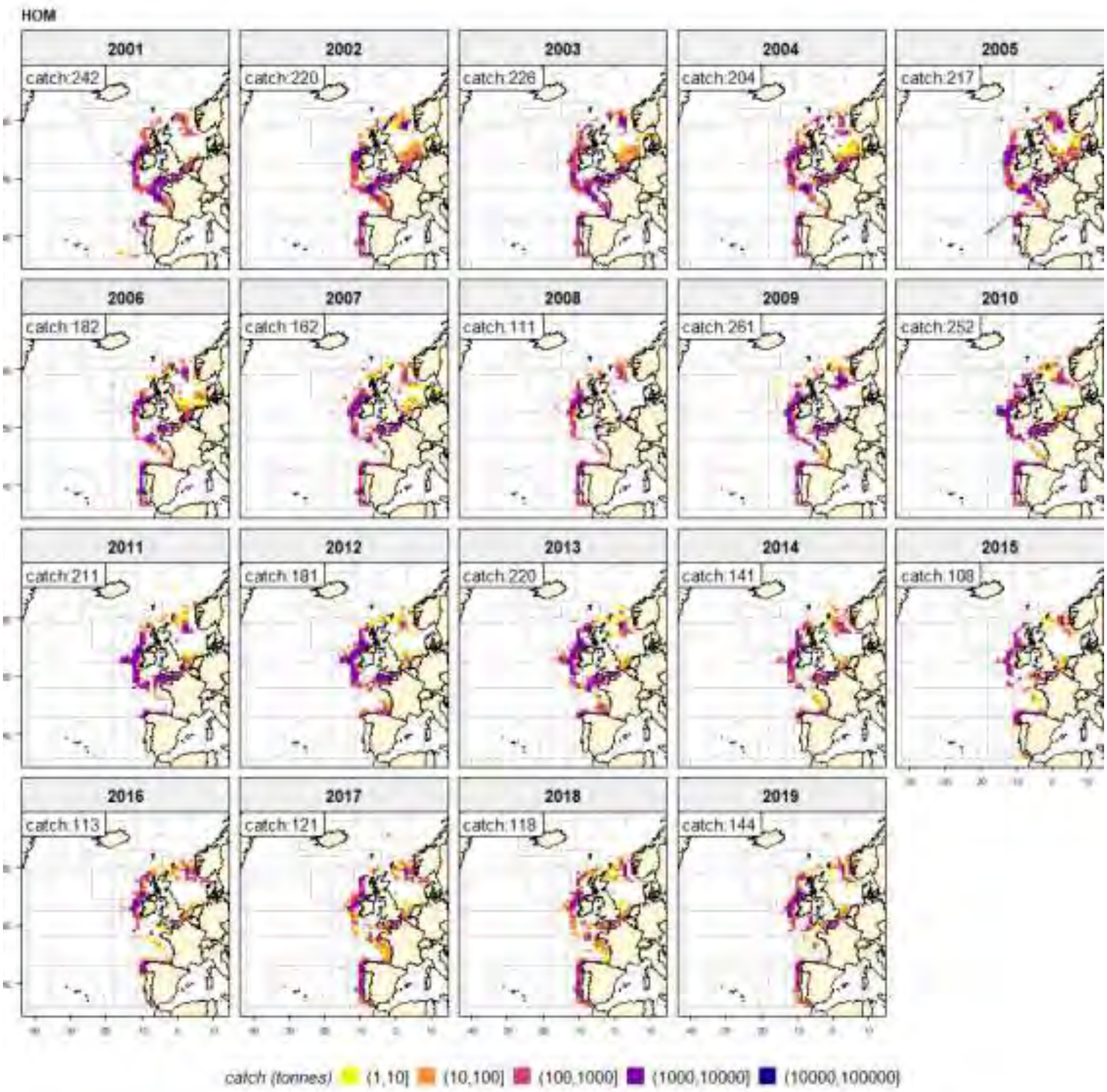

Figure 1.9.7: Catch of horse mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

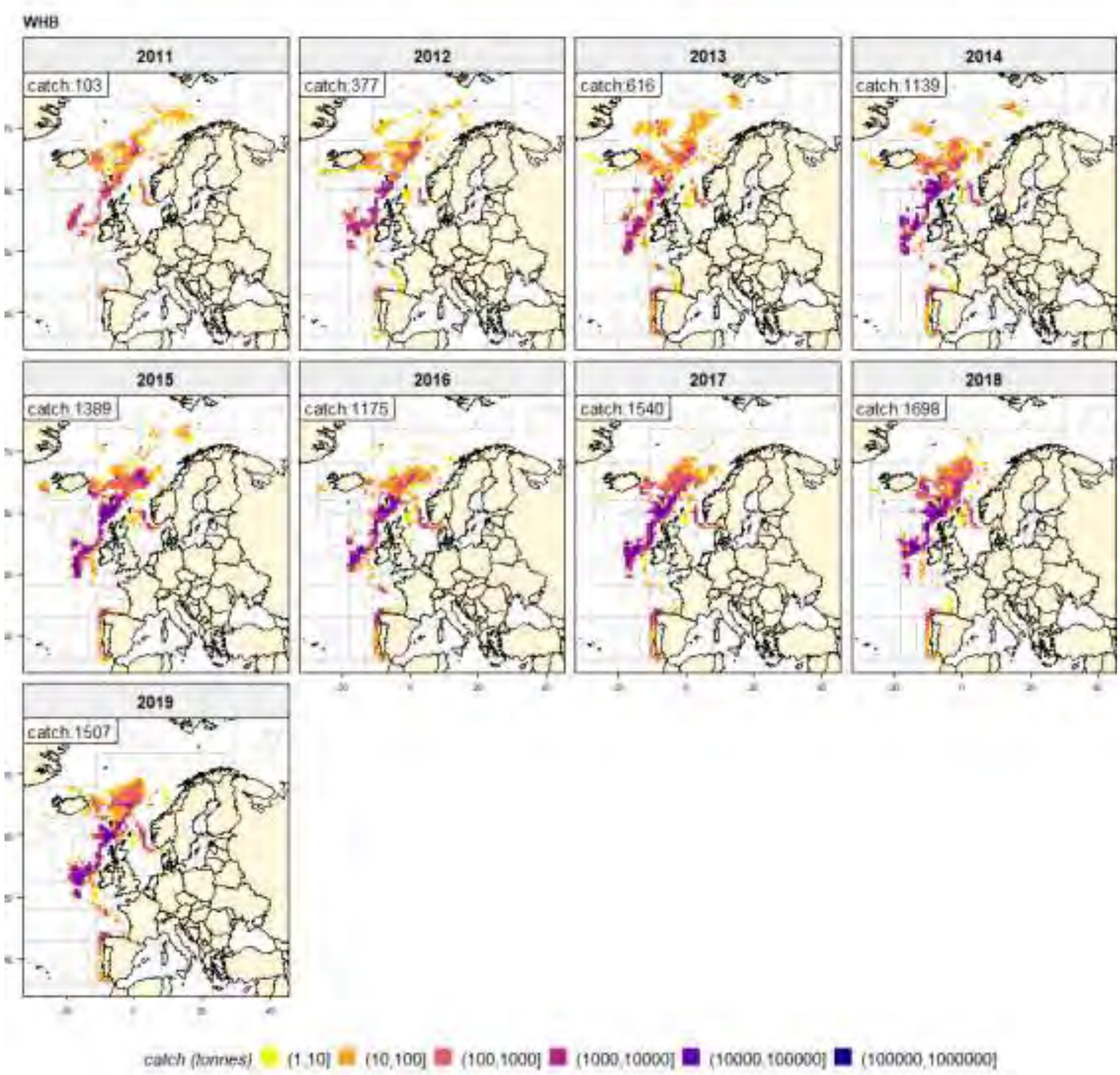

Figure 1.9.8: Catch of blue whiting (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

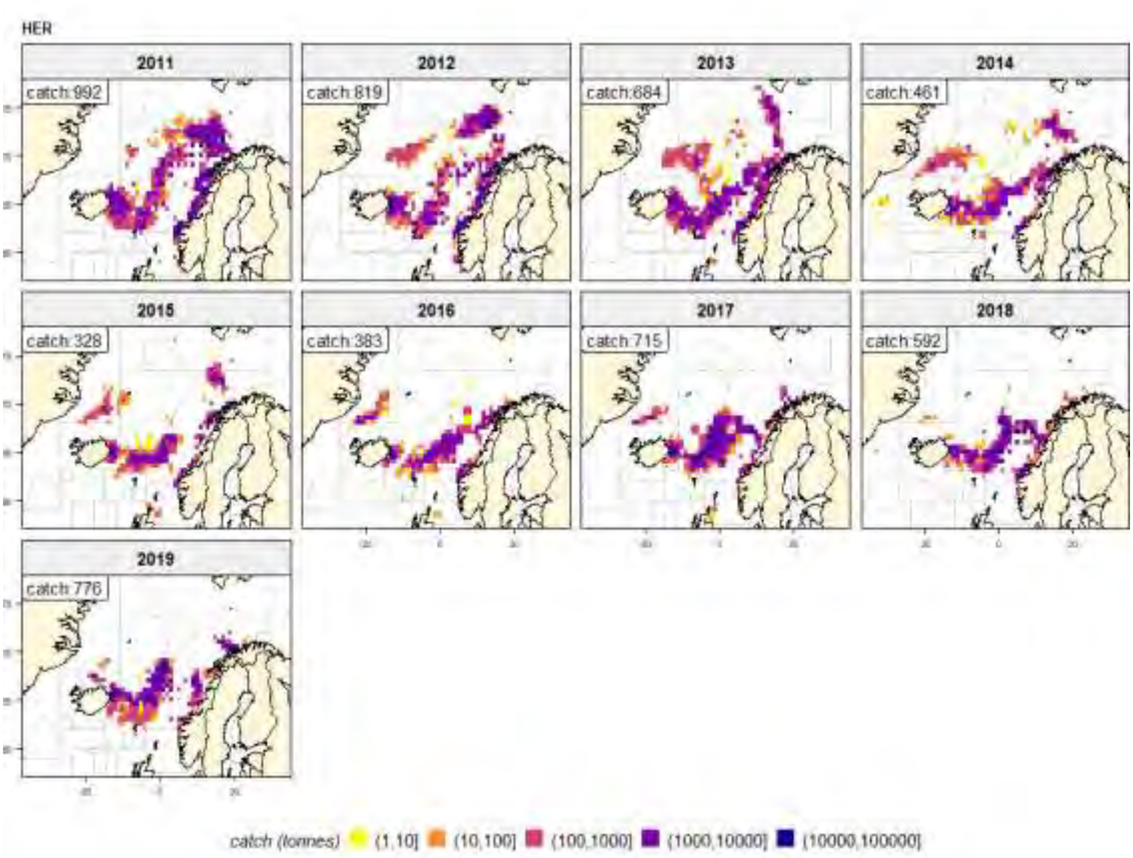

Figure 1.9.9: Catch of Norwegian spring-spawning (Atlanto-scandian) herring (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

1.10 Ecosystem considerations for widely distributed and migratory pelagic fish species

A number of studies demonstrate that environmental conditions (physical, chemical and biological) can significantly influence stock productivity by changing the level of recruitment, growth rates, survival rates, or inducing variations in their geographical distribution (*e.g.* Skjoldal *et al.*, 2004, Sherman and Skjoldal 2002). It has been acknowledged that future lines of work in stock assessment should take ecosystem considerations into account in order to reduce the levels of uncertainty regarding the present and future status of commercial stocks. Hence, WGWIDE encourages further work to be carried out on ecosystem considerations linked to widely distributed fish stocks including NEA mackerel, Norwegian spring-spawning herring, blue whiting and horse mackerel. A close collaboration with the Working Group on Integrated Assessment of Norwegian Sea (WGINOR; ICES 2018a), and hopefully other relevant Integrated Assessment groups within ICES in the near future, will help in operationalizing ecosystem approach for the widely distributed pelagic stocks assessed by WGWIDE. The text below was largely provided by WGINOR (ICES 2016e; 2018a; 2019a).

1.10.1 Climate variability and climate change

The North Atlantic Oscillation (NAO) corresponds with the alternating periods of strong and weak differences between Azores high and Icelandic low pressure centres. Variations in the

NAO influence winter weather over the North Atlantic and have a strong impact on oceanic conditions (sea temperature and salinity, Gulf Stream intensity, and wave height). The 2015 winter NAO index was high, and simultaneously cold/freshwaters on the Canadian site of the Atlantic that winter and spring because of increase advection resulted in relative low temperatures in the Sub Polar Gyre (SPG) and low temperatures at all depths in 2015 in the large part of the Northeast Atlantic in comparison to the 20-year long-term mean (ICES, 2015). The NAO index has been positive throughout the period 2014-2018. Such an extended period without the NAO index changing sign is very unusual. The last comparable period during which the NAO index was consistently positive was in the period 1992–1995.

The classical measure of global warming is the northern hemisphere Temperature anomaly (NHT) (Jones and Moberg, 2003) which is computed as the anomaly in the annual mean of seawater and land air surface temperature over the northern hemisphere. During the last three decades, NHT anomalies have exhibited a strong warming trend. Pelagic planktivorous species such as Northeast Atlantic mackerel (Astthorsson *et al.*, 2012; ICES, 2013; Nøttestad *et al.* 2016), Norwegian spring-spawning herring and blue whiting may and have taken advantage of warming oceans by extending their possible feeding opportunities further north, e.g. in Arctic waters. If such changes are, however, directly or indirectly driven by the warming are not fully understood (Olafsdóttir *et al.* 2018; Nikolioudakis *et al.*2018).

Acidification of the oceans is another event related to accumulation of anthropogenic greenhouse gases in the atmosphere. During the last 30 years, pH has decreased significantly in most water layers in Lofoten and the Norwegian basins. Different components like CO_2, aragonite and number of other factors such as temperature, salinity, and alkalinity may affect pH and carbon systems in the ocean. The impacts of the acidification on the ecosystem remains to be explored.

1.10.2 Circulation pattern

The circulation of the North Atlantic Ocean is characterized by two large gyres: the Subpolar Gyre (SPG) and subtropical gyre (Rossby, 1999). When the SPG is strong it extends far eastwards bringing cold and fresh Subarctic water masses to the NE Atlantic, while a stronger SPG allows warmer and more saline subtropical water to penetrate further northwards and westwards over the Rockall plateau area. Changes in the oceanic environment in the Porcupine/Rockall/Hatton areas have been shown to be linked to the strength of the Subpolar Gyre (Hátún *et al.*, 2005). The large oceanographic anomalies in the Rockall region spread directly into the Nordic Seas, regulating the living conditions there as well as further south. Such changes are likely to have an impact on the spatial distribution of spawning and feeding grounds and on migration patterns of widely distributed pelagic fish species.

1.10.3 Recent trends in oceanography and zooplankton in Norwegian Sea

The time-series of ocean heat content in the Atlantic Water of the Norwegian Sea starting in 1951 show that the recent warm period continues (Figure 1.11.1). However, during the last two years, 2017 and 2018 the basic covariance between cold/fresh and warm/salt condition are lost (Figure 1.11.1). Instead, the situation is now that the temperature is still relative warm, but that the salinity has a marked decrease. For example, the salinity in 2018 in the Svinøy section, was the lowest value since "The Great Salinity Anomaly" of the late 1970s (ICES 2019a).

The changes in the Norwegian Sea in 2017 and 2018 with relative warm but with low salinity are unusual. This affects the vertical stability of the water column, of importance both for biological production and as well as for the conversion to denser water that contribute to the large-scale thermohaline circulation. Observations upstream in the North Atlantic Current, in the Icelandic Basin, in 2016 and 2017 show a prominent freshwater anomaly (about -0.1 in salinity). Under the assumption that circulation patterns do not change, this situation with anonymously fresh Atlantic water in the Norwegian Sea is expected to continue and even increase in the coming years. Although the temperature upstream in the Atlantic is also relatively low in the period 2013-2017, this has been compensated by reduced heat loss inside the Norwegian Sea, linked to a coincidence with the positive NAO index. If, on the other hand, we get a winter with a negative NAO index, we can expect a decrease in the temperature in the Norwegian Sea. However, this is not very predictable because the atmosphere is largely stochastic on time scales beyond about 5-10 days (ICES 2019a).

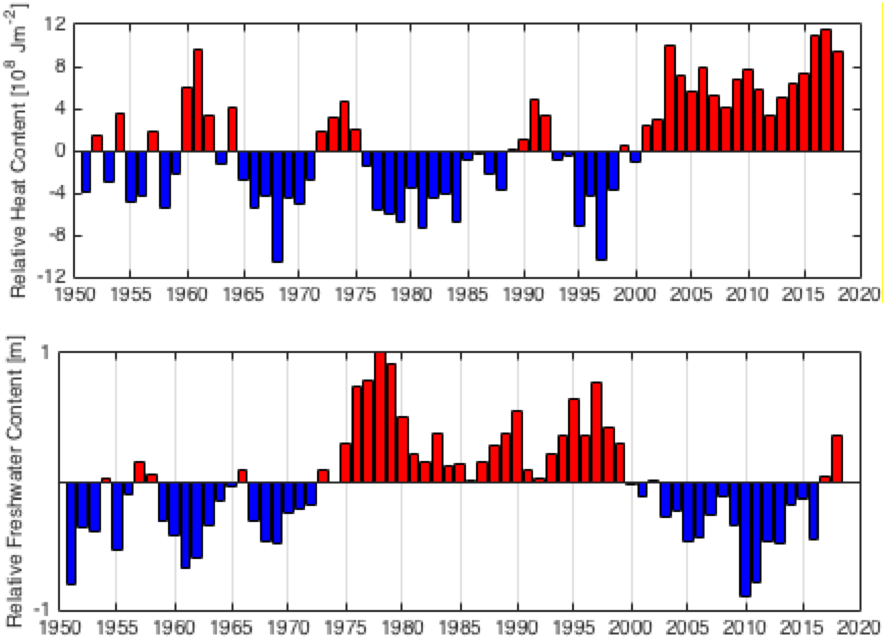

Figure 1.11.1. Time-series of anomalies of heat content (upper panel) and salinity (lower panel) of and the Atlantic waters in Norwegian Sea for the years 1951–2018(ICES 2019a).

The zooplankton plays an important role in the epipelagic ecosystem of the Norwegian Sea by transferring energy from the phytoplankton to higher trophic levels. The time-series of meso-zooplankton biomass in the Norwegian Sea from the International Ecosystem Survey in Norwegian Sea (IESNS) in May shows strong long-term variability (Figure 1.11.2). Following a period with high biomass from mid-1990s to early 2000s, the biomass declined to minimum in 2006. From 2010 the downward trend reversed, and the biomass may have increased after that. Interestingly, all areas show the same long-term trend, however the area east of Iceland had a longer high-biomass period and the decreasing trend started a few years later than the other areas. The biomass has been at about the same level for all the sub-areas the last three years (between 6 and 12 gm^{-2})

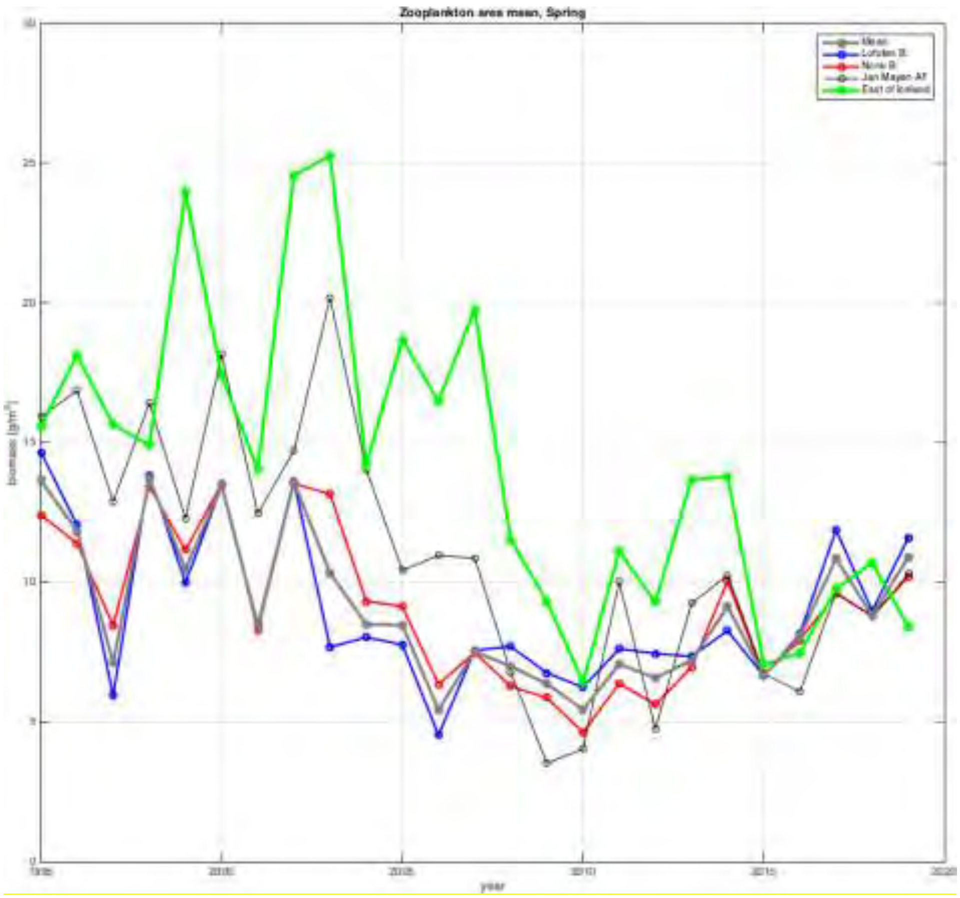

Figure 1.11.2. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in different areas in and near Norwegian Sea from 1995 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (ICES 2019b; see details on methods and areas in ICES 2016a).

1.10.4 Species interactions

The fish stocks addressed by WGWIDE show a seasonal and annual variation in spatial distribution and can overlap to a varying degree. Where overlapping, density-dependent competition for food and predation can be expected. All the species are potential predators on eggs and larvae and the larger species (mackerel and horse mackerel) are also potential predators of the juveniles. Consequently, cannibalism and interspecific predation is likely to play an important role in the dynamics of these pelagic stocks. As examples, density-dependent growth has been observed both for mackerel (Olafsdottir*et al.* 2015) and Norwegian spring-spawning herring (Hömrum *et al.* 2016). Furthermore, several studies on diet composition have shown a high overlap (see overview in ICES 2016a) and even intraguild predation between species, *e.g.* NEA mackerel predation on NSS herring larvae on the Norwegian shelf area (Skaret *et al.* 2015) and sardine predation on anchovy eggs in the Bay of Biscay (Bachiller *et al*. 2015).

The Norwegian Sea and adjacent waters are the main summer feeding grounds for the three main small pelagic fish stocks (NSS herring, blue whiting and NEA mackerel; Skjoldal *et al*., 2004; Langøy *et al.* 2012; ICES 2018b). The three stocks are able to adapt their feeding strategy to different conditions, including herring preying in cold water masses, where they show significantly higher feeding incidence and stomach fullness (Bachiller *et al*. 2016). In the later years the geographical distribution overlap between mackerel and herring has been most pronounced in the south-western part of the Norwegian Sea. In 2018 there was very little overlap between mackerel and NSS herring in the central Norwegian Sea (ICES 2019a).

Stomach analyses indicate that NEA mackerel and NSS herring have similar diet, which represents mainly calanoid copepods, especially *C. finmarchicus*. Blue whiting shows lower diet overlap with these two species, broader diet composition and dominance of larger prey like euphausiids and amphipods (Langøy*et al*. 2012, Bachiller *et al*. 2016). Recent estimates based on bioenergetics show that these three species consume on average 135 million tonnes of zooplankton per year (2005-2010; Bachiller *et al*. 2018), which are higher than previous estimates (e.g. Utne *et al*., 2012; Skjoldal *et al*., 2004). NEA mackerel consumed 23%-38%, NSS herring 38%–51% and blue whiting 14%–39% of the total zooplankton eaten by pelagic fish during the feeding season. This means that, in terms of consumption/biomass ratios, NEA mackerel feeding rates can be as high as that of the NSS herring during some years. Together, these three stocks were estimated to have consumed annually 53–81 million tonnes of copepods, 26–39 million tonnes of euphausiids and amphipods, 8–42 million tonnes appendicularians and 0.2–1 million tonnes of fish.

Sardine, mackerel, horse mackerel, blue whiting and herring have all been found in the diet of several cetacean and seabird species and are also part of the diet of other fish species (*e.g.* hake, tuna found with sardine and anchovy) (Anker-Nilssen and Lorentzen, 2004; Nøttestad *et al*. 2014). Comparison of population estimates of pelagic fish with those of top predators (*e.g*. minke whale, fin whale, killer whales) suggests that predation on pelagic fish by other pelagic fish has a much bigger potential for impact in regulating populations than that the predation by marine mammals and seabirds in the North Sea (Furness, 2002). Nevertheless, top predators could play a bigger role in pelagic fish dynamics at regional or local scales particularly when fish biomass is low (Nøttestad *et al*., 2004). Aspects of interaction between the pelagic fish stocks are discussed in the stock specific sections of this report.

1.11 Future Research and Development Priorities

As part of the planning towards future benchmark assessments, the working group maintains, for each stock, a list of research and development priorities on topics including proposed research projects, improved sampling and data collection and development of stock assessment techniques. In addition to these individual stock issues, increased consideration should be given to integrated ecosystem assessments for the stocks within WGWIDE. A number of WGWIDE members are also participants in the work of the Working Group on Integrated Assessment for Norwegian Sea (WGINOR). Improving linkages with other regional Integrated Ecosystem Assessment groups within ICES would be beneficial and should be considered in future.

1.11.1 NEA Mackerel

In 2019, the ICES Workshop on a Research Roadmap for Mackerel (WKRRMAC, (ICES, 2019f)) met to discuss the research needs for the provision of advice for the management of NEA Mackerel. The workshop involved a diverse range of stakeholders including industry representatives, managers and scientists and identified a number of priorities which are summarised below (see report of WGWIDE 2019 (ICES, 2019) for additional discussion).

1. Identification of funding mechanisms to improve research capability
2. Investment in and improved co-ordination of available fisheries science expertise, in particular with respect to stock assessment modelling via improvements in collaboration, documentation, training and upskilling.
3. Evaluate management and advisory mechanisms that result in robust, quality assured advice. The rollout of the Transparent Assessment Framework by ICES is an important step in improving quality assurance. A number of WG members have attended ICES

TAF workshops and a number of the stocks assessed by WGWIDE have been trialled in TAF in preparation for full implementation. In addition, WGWIDE recommends the collection of appropriate data and the development of a framework to explore the impacts of uncertainties in assessment inputs (sampling, ageing) and improved documentation for sampling and survey procedures.

4. Explore which surveys contribute the strongest signal into the stock assessment, and reconcile survey information. The SAM assessment currently uses information from 4 separate fishery independent indices (swept area survey, egg survey, tag returns and a recruitment index). The model parameter values and diagnostic leave one out analysis indicates that the relative contribution and influence of each survey on the assessment in recent years has varied due to a number of potential factors including the length of the individual time series the number of data points within each data series and the survey estimates. Additional research is required to investigate the relative weighting of each survey series by the assessment model, to improve process knowledge and investigate contradictory survey indices.
5. Explore the expansion of existing surveys to seasons and areas currently not covered. At its 2020 meeting WGIPS (ICES, 2020a) considered a recommendation from WGWIDE 2019 to consider the feasibility of a southern expansion of the IESSNS. They concluded the existing surveys (HERAS and WESPAS) conducted in July do not currently have the operational capacity to include surface trawling effort alongside the current (acoustic) programme such that additional vessel capacity would be required. July surveys have been conducted in the area in question for several years. Experience indicates that the appropriateness of estimating mackerel abundance on the basis of a surface trawl requires further investigation as mackerel has been encountered at a range of depths over the survey area. Existing acoustic, haul, camera and hydrographic data series from these surveys should be explored (*e.g.* using the most recent developments in acoustic algorithms) to further investigate both the feasibility of the swept area method in this area and the potential of the acoustic data. With regard to the other surveys, the expansion of tagging and scanning into areas not currently covered should also be explored.
6. Further extend the winter acoustic survey time series.
7. Build mechanisms to incorporate industry sampling of biological information into the formal stock assessment process. The contribution of industry data to the WG has continued this year although the mechanisms for incorporation of the this in a quantitate manner in the stock assessment requires further development.
8. Develop approaches to formalise the flow of information of industry perceptions of the state of the stock and the fishery into the assessment process. The process for the submission of information from industry has changed this year with stakeholders requested to submit information in advance of the working group.
9. Develop methods for industry surveys that maintain credible methods and scientific rigour.

WGWIDE discussed and proposed the establishment of a workshop to review information on the stock structure of NEA Mackerel and subsequent implications for the current (component based) regional management measures (minimum landing size, area and seasonal closures). The current basis, whereby the stock is considered to consist of 3 separate components (North Sea, Western and Southern) derives from research conducted several decades ago. Since this time, there have been advances in several stock identification methods (*e.g.* genetics, simulation approaches). The workshop will review available information from appropriate methods to infer the stock structure of NEA Mackerel. The draft ToRs for the workshop are detailed in annex 2.

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1.11.2 Blue Whiting

Numerous scientific studies have suggested that blue whiting in the North Atlantic consists of multiple stock units. The ICES Stock Identification Methods Working Group (SIMWG) reviewed this evidence in 2014 (ICES, 2014) and concluded that the perception of blue whiting in the NE Atlantic as a single-stock unit is not supported by the best available science. SIMWG further recommended that blue whiting be considered as two units. There is currently no information available that can be used as the basis for generating advice on the status of the individual stocks. However, there are some studies going on and more data being collected to allow clarify the stock definition for this species. In the future, the newly collected information on stock composition should be evaluated on the behalf of a benchmark of this stock.

1.11.3 NSS Herring

The Norwegian spawning ground survey was reintroduced in 2015 as part of the tuning series (fleet 1). However, changes were made to the survey compared to the older part of the series. At the 2016 assessment benchmark, the inclusion of the surveys from 2015 was accepted as an extension to the tuning series. It is now considered appropriate to investigate the splitting of this survey series, particularly since 2020 has provided the sixth estimate from the survey since it was reintroduced. and the time series is now long enough to do this exercise. An inter-benchmark exercise to explore this was proposed during WGWIDE 2020.

There are a number of other issues (not proposed for the inter-benchmark) that should be considered in future

The relevance of inclusion of a new tuning series (IESSNS) in the assessment

Consider the inclusion of a new tuning series (tagging data based on RFID) in the assessment.

Request and incorporate within the assessment information on the uncertainty in catches from all countries submitting catch data (currently only available from Norway).

1.11.4 Western Horse Mackerel

Considering the potential of mixing between Western and North Sea horse mackerel occurring in Division 7.d and 7.e, improved insight into the origin of catches from that area will be a major benefit for improvement of the quality of future scientific advice and thus management of the North Sea and Western horse mackerel stocks. A project addressing stock structure and boundaries of horse mackerel was initiated by the Northern Pelagic Working Group in collaboration with University College Dublin and Wageningen Marine Research. In 2018, the results of the genetic analysis have been published (Farrell *et al* 2018) which concluded that the spawners of North Sea and Western horse mackerel can be genetically identified as two distinct stocks. However, at present it is not yet possible to separate the two stocks when they occur in mixed samples. Therefore, a follow-up project has been initiated to carry out a full genome sequencing of horse mackerel which will allow for future analysis of mixed samples. Results are expected in 2020.

Further analysis on the mixing between the Western stock and the Southern stock in area 8c should be carried out: the fishery in the area targets mainly juveniles, would be therefore be very important to understand the impact of this fishery on each of the two stocks.

1.11.5 North Sea horse mackerel

Firstly, studies on stock identity and the degree of connection and migrations between the North Sea and the Western Stock are considered particularly relevant. On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated. Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015- 2017. The results indicated that the western horse mackerel stock is clearly genetically different from the North Sea stock (Farrell and Carlsson, 2019; Fuentes-Pardo *et al*., 2020). Markers were identified that will be able to reveal the stock identity of individual horse mackerel caught in potential mixing areas. Horse mackerel samples from Division 7.d and 7.e will be collected by the PFA on board of commercial vessels in the Autumn of 2020, while horse mackerel from Division 4.a will be collected during the NS-IBTS in Q3. With the genetic markers developed, the stock identity of the individual horse mackerel caught can be identified, which will shed light on mixing in the sampled areas during Q3.

Efforts are required to upload historic age and length data to the InterCatch database. The current stock assessment method is based on length data and, with only data from 2016 onwards currently available in InterCatch, it is impossible to compare the F/F_{MSY} proxy and the length-based indicators that the proxy is based on with information from earlier years. Furthermore, length data are only submitted by accessions to stock coordinators directly, and not through InterCatch. This makes the process of combining the data from different countries prone to error and lack transparency. Since 2020, national data submitters were requested to submit data both via the accessions as well as through InterCatch. A comparative analysis has to be carried out to evaluate the feasibility of using length data from InterCatch only in the future. Moreover, several hundred age readings have not been uploaded to InterCatch since 2012/2013. This information should be uploaded in order to increase (the currently low) confidence in the estimates of catch-at-age.

Future work on the exploitable biomass index will focus on including a spatial component when modelling the joint CGFS and NS-IBTS survey index. Additionally, application of the SPiCT model to the stock will be evaluated.

1.11.6 Boarfish

From 2017, this stock has been included on the list of stocks sampled under the data collection framework (DCMAP). This permitted sampling of commercial catch for both length and age. However, age reading is difficult and expertise is limited. An increase in the number of age readers would help develop a time-series of commercial catch-at-age which would in turn enable the development of an age-based assessment methodology. The current ALK is static and is based on a limited number of age readings.

Improvements in the survey data can be realized through a change in sampling protocol on groundfish surveys to ensure boarfish are measured to the 0.5cm. The acoustic time-series should continue to be developed. The current survey does not contain the stock. The use of information from other acoustic surveys should also be explored.

At WGWIDE 2018, an issue list was prepared for the stock and it still applies for potential benchmark in 2022.

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2 Blue whiting (*Micromesistius poutassou*) in subareas 27.1–9, 12, and 14 (Northeast Atlantic)

Blue whiting (*Micromesistius poutassou*) is a small pelagic gadoid that is widely distributed in the eastern part of the North Atlantic. The highest concentrations are found along the edge of the continental shelf in areas west of the British Isles and on the Rockall Bank plateau, where it occurs in large schools at depths ranging between 300 and 600 meters, and is also present in almost all other management areas between the Barents Sea and the Strait of Gibraltar and west to the Irminger Sea. Blue whiting reaches maturity at 2–7 years of age. Adults undertake long annual migrations from the feeding grounds to the spawning grounds. Most of the spawning takes place between March and April, along the shelf edge and banks west of the British Isles. Juveniles are abundant in many areas, with the main nursery area believed to be the Norwegian Sea. See the Stock Annex for further details on stock biology.

2.1 ICES advice in 2019

ICES notes that fishing mortality (F) has decreased since 2015 but is estimated to be above F_{MSY} in 2019. Spawning-stock biomass (SSB) has decreased since 2018 but it is estimated to remain well above MSY $B_{trigger}$. Recruitment (R) in 2017 to 2019 is estimated to be low, following a period of high recruitment. ICES advised that when the long-term management strategy agreed by the European Union, the Faroe Islands, Iceland, and Norway is applied, catches in 2020 should be no more than 1 161 615 tonnes.

2.2 The fishery in 2019

The total catch in 2019 was 1.52 million tonnes. The main fisheries on blue whiting were targeting spawning and post-spawning fish (Figures 2.2.1 and 2.2.2). Most of the catches (89%) were taken in the first two quarters of the year and the largest part of this was taken along the slopes of the Western European shelf, in the Rockall Trough and in the deep trenches around the Faroes. Smaller quantities were taken in the Norwegian Trench and along the coast of Spain and Portugal.

The fishery in the latter half of the year was mainly east of the Faroes and in the central Norwegian Sea, with smaller amounts in the Norwegian Trench, along the slopes of the Western European shelf and along the coast of Portugal and Spain.

The multinational fleet targeting blue whiting in 2019 consisted of several types of vessels from 17 countries. The bulk of the catch is caught with large pelagic trawlers, some with capacity to process or freeze on board. The remainder is caught by RSW vessels.

2.3 Input to the assessment

At the Inter-Benchmark Protocol on Blue Whiting, IBPBLW (ICES, 2016a), it was decided to use preliminary within year, quarter 1 and quarter 2, catch-at-age data in the assessment to get additional information to the within year IBWSS result. In most recent years around 90% of the annual catches of the age 3+ fish are taken in the first half year, which makes it reasonable to estimate the total annual catch-at-age from reported first semester (Q1 & Q2) data. The catch data sections in this report give first a comprehensive description of the 2019 data as reported to ICES and then a section including a brief description of the 2020 preliminary catch data.

2.3.1 Officially reported catch data

Official catches in 2019 were estimated as 1 515 527 tonnes based on data provided by WGWIDE members (Table 2.3.1.1). Data provided as catch by rectangle represented more than 99% of the total WG catch in 2019.

In 2019, the majority of catches were caught at the spawning grounds with largest contribution from ICES area 27.7.c, 27.5.b, 27.6.a, and 27.7.k respectively (Figure 2.3.1.1; Table 2.3.1.2, 2.3.1.3), and caught respectively in quarter 1 and quarter 2 (Figure 2.3.1.6). In the first two quarters, catches are taken over a broad area, with the highest catches respectively in 27.7.c, 27.5.b, and 27.6.a, while later in the year catches are mainly taken further north in area 27.2.a and in the North Sea (27.4.a) (Figure 2.3.1.6 and 2.3.1.7 and Table 2.3.1.3).The spatial and temporal distribution of catches in 2019 are similar to previous years (Figures 2.3.1.2, 2.3.1.3, 2.3.1.4; Table 2.3.1.4). Majority of blue whiting were caught by four nations, Norway, Faroe Islands, Iceland, and Russia, respectively (Figure 2.3.1.5).

Discards of blue whiting are small. Most of the blue whiting caught in directed fisheries are used for reduction to fish meal and fish oil. However, some discarding occurs in the fisheries for human consumption and as bycatch in fisheries directed towards other species.

Reports on discarding from fisheries which catch blue whiting were available from the Netherlands for the years 2002—2007 and 2012—2014. A study carried out to examine discarding in the Dutch fleet found that blue whiting made a minor contribution to the total pelagic discards when compared with the main species mackerel, horse mackerel and herring.

The blue whiting discards data provided by Portuguese vessels operating with bottom otter trawl within the Portuguese portions of ICES Division 27.9.a are available since 2004. The discards data are from two fisheries: the crustacean fishery and the demersal fishery. The blue whiting estimates of discards in the crustacean fishery for the period of 2004–2011 ranged between 23% and 40% (in weight). For the same period the frequency of occurrence in the demersal fishery was around zero for the most of the years, in the years where it was significant (2004, 2006, 2010) ranged between 43% and 38% (in weight). In 2019, discards were 24% of the total catches for blue whiting along the Portuguese coast (Table 2.3.1.5). The total catch from Portugal is less than a half percentage of the total international catches.

Information on discards was available for Spanish fleets since 2006. Blue whiting is a bycatch in several bottom-trawl mixed fisheries. The estimates of discards in these mixed fisheries in 2006 ranged between 23% and 99% (in weight) as most of the catch is discarded and only the catch of the last day may be retained for marketing fresh. The catch rates of blue whiting in these fisheries are however low. In the directed fishery for blue whiting for human consumption with pair trawls, discards were estimated to be 5% (in weight) in 2019 (Table 2.3.1.5). Spanish catches are around 2% of the international catches.

In general, discards are assumed to be small in the blue whiting directed fishery. Discard data are provided by Denmark, France, Ireland, Portugal, Spain, Sweden, UK (England and Wales) and UK (Scotland), to the working group. The discards constituted 0.17% of the total catches, 2570 tonnes. BMS landings were reported by UK (England and Wales), although no minimum conservation reference size is defined on blue whiting, those landings are related to fish that have not been sold at market but was landed, for example damaged fish, and it correspond to 34 tonnes in 2019.

The total estimated catches (tonnes) inside and outside the NEAFC regulatory area by country were reported on Table 2.3.1.6. The catches inside the NEAFC RA represent 22% of the total catches of blue whiting in 2019.

2.3.1.1 Sampling intensity

In 2019, 84% of catches were covered by the sampling program. In 2019, 1537 length samples, 1253 age samples, were collected from the fisheries , and 136604 fish were measured and 17869 were aged. Sampling intensity for blue whiting with detailed information on catch, proportion of catch covered by sampling program, the number of samples, number of fish measured, and number of fish aged per year from 2000 to 2019 is given in Table 2.3.1.1.1. Sampling intensity per country, quarter and ICES division for 2019 is listed in Tables 2.3.1.1.2, 2.3.1.1.3 and 2.3.1.1.4. The most intensive sampling, considering the age samples and the number of aged fish, took place in areas 27.2.a, 27.5.b, 27.6.b, 27.7.b, 27.7.c, 27.7.k, 27.8.c and 27.9.a. No sampling was carried out by Greenland, Poland, Sweden and the UK (England, Wales, Northern Ireland) which combined represent 4% of the total catches. The sampled and estimated catch-at-age data are shown on Figure 2.3.1.1.1.

Sampling intensity for age and weight of blue whiting are made in proportion to landings according to CR 1639/2001 and apply to EU member states. The Fisheries Regulation 1639/2001, requires EU Member States to take a minimum of one sample for every 1000 tonnes landed in their country. Various national sampling programs are in force.

2.3.1.2 Age compositions

As an example of an age-length key from sampled catches in 2019, data from ICES area 27.6.a is presented by quarter and country (Figure 2.3.1.2.1). The mean length (mm) by ages reveals that age classifications do present some differences between countries. The difference in mean length-at-age increases in older ages, higher than age 6.

The ICES InterCatch program was used to calculate the total international catch-at-age, and to document how it was done.

2.3.2 Preliminary 2020 catch data (Quarters 1 and 2)

The preliminary catches for 2020 as reported by the WGWIDE members are presented in Table 2.3.2.1.

The spatial distribution of these 2020 preliminary catches is similar to the distribution in 2019 with majority of catches taken in division 27.7.c, 27.6.a, 27.5.b, and 27.7.k , respectively (Figure 2.3.2.1 and Table 2.3.2.2).

Sampling intensity for blue whiting from the preliminary catches by area with detailed information on the number of samples, number of fish measured, and number of fish aged is presented in Table 2.3.2.2.

WGWIDE estimated the expected total catch for 2020 from the sum of declared national quotas, corrected for expected national uptake and transfer of these quotas (Table 2.3.2.3).

For the period 2016 to 2019, preliminary and final catch estimates are similar with maximum deviation in 2019 when the final catch was 4.7 % higher than the preliminary catch (Table 2.3.2.4). Age composition is also similar between preliminary and final catch data, with a few exceptions between 2016 and 2018, however some deviations were observed for the ages 1 and 2 in 2019 (Figure 2.3.2.2).

The estimation of catch at age and mean weight at age followed the method described in the (2019 updated) Stock Annex.

2.3.3 Catch-at-age

Catch-at-age numbers from 1981 to 2020 are presented in Table 2.3.3.1 and catch proportions at age shown in Figure 2.3.3.1. Strong year classes that dominated the catches can be clearly seen in the early 1980s, 1990 and the late 1990s. In 2020, the age compositions are dominated by the ages 4-6

Catch curves for the international catch-at-age dataset (Figure 2.3.3.2), indicate a consistent decline in catch number by cohort in years with rather high landings (and probably similar high effort). The catch curves for year classes 2010-2011 show a consistent decline in the stock numbers with an estimated total mortality (Z=F+M) around 0.6-0.7 for the ages fully recruited to the fisheries. With an estimated historical F around 0.4-0.5, this indicates that the used natural mortality (0.2) is a reasonable choice for the fully selected year classes.

2.3.4 Weight at age

Table 2.3.4.1 and Figure 2.3.4.1 show the mean weight-at-age for the total catch during 1981-2020 used in the stock assessment. Mean weight at ages 3-9 has generally decreased in the most recent 10 years, even though some increase can be observed for the most recent years for ages 4-6.

The weight-at-age for the stock is assumed the same as the weight-at-age for the catch.

2.3.5 Maturity and natural mortality

Blue whiting natural mortality and proportion of maturation-at-age are shown in Table 2.3.5.1. See the Stock Annex for further details.

2.3.6 Information from the fishing industry

No new information available.

2.3.7 Fisheries independent data

Data from the International Blue Whiting spawning stock survey are used by the stock assessment model (last updated in 2019), while recruitment indices from several other surveys are used to qualitatively adjust the most recent recruitment estimate by the assessment model and to guide the recruitments used in the forecast.

2.3.7.1 International Blue Whiting spawning stock survey

The Stock annex gives an overview of the surveys available for the blue whiting. The International Blue Whiting Spawning Stock Survey (IBWSS) is the only survey used as input to the assessment model. The survey was not carried out in 2020 due to the COVID-19 situation.

The full time series of IBWSS was recalculated in summer 2020, using the same software (StoX) and method as previously applied. The recalculated values are presented in Table 2.3.7.1.1. and Figure 2.3.7.1.1.a. Differences between the old values and the recalculated values are displayed in Table 2.3.7.1.2. The indices are identical for 7 years. The indices deviate with maximum of 1 (probably a rounding issue) for 3 years and with a deviation > 1 occurs in 6 years with the largest deviation in relative terms for 2017 with deviations up to 4%. WGWIDE decided to use the recalculated values as these can be reproduced, are practically identical and as assessment results are the same for old and recalculated index.

The survey time-series (2004-2019, not updated in 2020) show variable internal consistency (Figure 2.3.7.1.1B) for the main age groups.

The distribution of acoustic backscattering densities for blue whiting for the period 2016-2019 is shown in Figure 2.3.7.1.2. The abundance estimate of blue whiting for IBWSS are presented in Table 2.3.7.1.1.

Length and age distributions for the period 2015 to 2019 are given in Figure 2.3.7.1.3.

Survey indices, (ages 1-8 years 2004-2019) as applied in the stock assessment are shown in Table 2.3.7.1.1.

2.3.7.2 Other surveys

The Stock Annex provides information and time-series from surveys covering parts of the stock area. A brief survey description and survey results are provided below.

The International ecosystem survey in the Nordic Seas (IESNS) in May which is aimed at observing the pelagic ecosystem with particular focus on Norwegian spring-spawning herring and blue whiting (mainly immature fish) in the Norwegian Sea (Table 2.3.7.2.1).

Norwegian bottom-trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March where blue whiting are regularly caught as a bycatch species. This survey gives the first reliable indication of year class strength of blue whiting. The 1-group in this survey is defined as less than 19 cm (Table 2.3.7.2.2).

Icelandic bottom-trawl surveys on the shelf and slope area around Iceland. Blue whiting is caught as bycatch species and 1-group is defined as less than 22 cm in March (Table 2.3.7.2.3).

Faroese bottom-trawl survey on the Faroe plateau in spring where blue whiting is caught as bycatch species. The 1-group in this survey is defined as less than 23 cm in March (Table 2.3.7.2.4).

The International Survey in Nordic Seas and adjacent waters in July-August (IESSNS). Blue whiting are from 2016 included as a main target species in this survey and methods are changed to sample blue whiting. This was a recommendation from WGWIDE 2015 to try to have one more time-series for blue whiting. Data for the survey are not used yet, due to the short time series.

2.4 Stock assessment

The IBWSS survey is the only survey used by the SAM assessment, but this survey was cancelled in 2020 due to the COVID-19 pandemic.

Apart from the missing 2020 IBWSS data, the presented assessment in this report follows the recommendations from the Inter-Benchmark Protocol of Blue (ICES, 2016a) to use the SAM model.

2.4.1 Analysis of the effects of missing survey data for the terminal year.

The use of preliminary catch at age data was introduced in 2016, to have additional data for evaluation of potential bias in the survey results from the same year. Without a survey in the terminal year (the case this year) the benefit of using preliminary catch data will depend on the quality of the preliminary catch data. There is a high consistency between the preliminary and final catches (Figure 2.3.2.2). However, for a better understanding of the importance of preliminary catch data in a situation like this year, with no survey data for the terminal year, scenarios were investigated with 2017 and 2018 as final survey year, and with use of both preliminary and "final" data for the terminal year.

As an example of that analysis, the results for a scenario with 2018 as the last IBWSS year, and 1) no preliminary data for 2019, 2) preliminary data for 2019 and 3) final catch data for 2019 are shown in Figure 2.4.1.1. If run 3) with the use of final catch data for 2019 is seen as the most "correct" assessment results (as it contains the longest time series with final data), it is seen that the use of preliminary catch data gives an assessment result for SSB and F closer to the "correct" assessment than the assessment with no preliminary catch data. Based on the log likelihood from the models, the use of final data gave a slightly better fit than the use of preliminary data (as expected). The best fit was however obtained for the run without catch data for the year after the last survey year, probably due to the fewer observations in that run. There was no clear conclusion on the "best" use of data from the parameter estimates from the three configurations.

The scenarios also showed that the inclusion of preliminary catch data did not change the historical estimates of SS, SSB and recruitment much.

The analysis was only conducted for two analyses using 2017 and 2018 as the last year with survey data. Both sets of runs showed a small improvement in assessment result using the preliminary catches. In addition, with use of preliminary catch data, the benchmark recommended method for calculating F in the "intermediate year" (use assessment F from the terminal year, i.e. from preliminary catches) could also be applied. Based on these reasons, the assessment this year used also preliminary data for 2020.

2.4.2 2020 stock assessment

For a model as SAM, Berg and Nielsen (2016) pointed out that the so-called "One Step Ahead" (OSA) residuals should be used for diagnostic purposes. The OSA residuals (Figure 2.4.2.1) show a quite random distribution of residuals. There might be an indication of "years effect" (too low index) for the IBWSS 2015 observations which has also be seen in previous assessment.

The estimated parameters from the SAM model from this year's assessment and from previous years (retrospective analysis) are shown in Table 2.4.2.1. There are only a very few abrupt changes in the estimated parameters over the time-series presented. Observation noises for the IBWSS increase in 2019 and 2020 (with no new observations) are practically the same, indicating a similar model weighting of data for the two years. The lowest observation noise has in all years been from catches ages 3-8.

The process error residuals ("Joint sample residuals") (Figure 2.4.2.2) are reasonable randomly distributed. Process noise SAM is implemented as a "process mortality, Z"; these deviations in mortalities are shown in Figure 2.4.2.3. The deviations in mortality (plus or minus mortality) seems fairly randomly distributed without very pronounced clusters.

The correlation matrix between ages for the catches and survey indices (Figure 2.4.2.4) show a modest observation correlation for the younger ages and a stronger correlation for the older ages. This difference is more distinct for catches, probably because it includes older ages (1-10+) than the survey data (ages 1-8).

Figure 2.4.2.5 presents exploitation pattern for the whole time-series. There are no abrupt changes in the exploitation pattern from 2010 to 2020, even though the landings in 2011 were just 19% of the landings in 2010, which might have given a different fishing practice. The plateau in selection at age 6 and older seen for the last 15 years seems more realistic than the more linear selection estimated for previous years. The estimated rather stable exploitation pattern might be influenced by the use of correlated random walks for F at age with a high estimated correlation coefficient (rho = 0.94, Table 2.4.2.1).

The retrospective analysis (Figure 2.4.2.6) shows a quite stable assessment for the last 5 years, previous years within 95% CI for the current assessment. Mohn's rho by year and as the average value over the last five years are presented in (Table 2.4.2.2). Even though the annual values might be high (reflecting large changes from one year to the next) the average Mohn's rho is rather low indicating no serious bias.

Stock summary results with added 95% confidence limits (Figure 2.4.2.7 and Table 2.4.2.5) show a decrease in fishing mortality in the period 2004—2011, followed by a steep increase in F up to 2015 after which F has fluctuated around 0.4. Recruitment increased from low recruitments in 2006–2009 to a historically high recruitment in 2015. This is followed by a lower recruitment in 2016 and a much lower recruitments in 2017-2020. SSB has increased in the period 2010-2018, followed by a large reduction.

2.4.3 Alternative model runs

The assessment models TISVPA and XSA were run for a better screening of potential errors in input and for comparison with the SAM results. All three models gave a similar result with respect F and SSB dynamics (Figure 2.4.3.1), even though the absolute values differ between models.

SAM and TISVPA show a low recruitment in the most recent years, while XSA estimates recruitment higher. Without survey data from 2020, XSA cannot estimate recruits in the terminal year and recruitment was estimated in an alternative way, which might explain the higher XSA estimate of recruitment in the last two years.

2.5 Final assessment

Following the recommendations from Inter-Benchmark Protocol on Blue Whiting (ICES, 2016a) the SAM model is used for the final assessment. The model settings can be found in the Stock annex. Alternative model runs give similar results.

Input data are catch numbers-at-age (Table 2.3.3.1), mean weight-at-age in the stock and in the catch (Table 2.3.4.1) and natural mortality and proportion mature in Table 2.3.5.1. Applied survey data are presented in Table 2.3.7.1.1.

The model was run for the period 1981—2020, with catch data up to 2019 and preliminary catch data for the first semester (Q1 and Q2) of 2020 raised to expected annual catches, and survey data from March-April, 2004–2019 (no new survey in 2020). SSB 1st January in 2020 is estimated from survivors and estimated recruits (for 2021 estimated outside the model, see short-term forecast section). 11% of age group 1 is assumed mature, thus recruitment influences the size of SSB. The key results are presented in Tables 2.4.2.3–2.4.2.4 and summarized in Table 2.4.2.5 and Figure 2.4.2.7. Residuals of the model fit are shown in Figures 2.4.2.1 and 2.4.2.2.

2.6 State of the Stock

F has increased from a historic low at 0.051 in 2011 to around 0.4 since 2014. F has been above F_{MSY} (0.32) since 2014. SSB increased from 2010 (2.73 million tonnes) to 2017 (6.27 million tonnes), followed by a decline to 2021 (3.25 million tonnes). SSB has been above B_{pa} (2.25 million tonnes) since 1997.

Recruitment (age 1 fish) was high in 2014-2016 followed by recruitments in the low end of the historical recruitments. The lower recruitment in combination with a high F in recent years have resulted in a decline in SSB.

2.7 Biological reference points

In spring of 2016, the Inter-Benchmark Protocol on Blue Whiting (IBPBLW) (ICES, 2016a) delegated the task of re-evaluating biological reference points of the stock to the ICES Workshop on Blue Whiting Long Term Management Strategy Evaluation (WKBWMSE) (ICES 2016b). During the WGWIDE meeting 2017, WKBWMSE concluded to keep B_{lim} and B_{pa} unchanged but revised F_{lim}, F_{pa}, and F_{MSY}. The table below summarises the currently used reference points.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	2.25 million t	B_{pa}	ICES (2013a, 2013b, 2016b)
	F_{MSY}	0.32	Stochastic simulations with segmented regression stock–recruitment relationship	ICES (2016b)
Precautionary approach	B_{lim}	1.50 million t	Approximately B_{loss}	ICES (2013a, 2013b, 2016b)
	B_{pa}	2.25 million t	B_{lim} exp(1.645 × σ), with σ = 0.246	ICES (2013a, 2013b, 2016b)
	F_{lim}	0.88	Equilibrium scenarios with stochastic recruitment: F value corresponding to 50% probability of (SSB< B_{lim})	ICES (2016b)
	F_{pa}	0.53	Based on F_{lim} and assessment uncertainties. F_{lim} exp(−1.645 × σ), with σ = 0.299	ICES (2016b)

2.8 Short-term forecast

2.8.1 Recruitment estimates

The benchmark WKPELA in February 2012 concluded that the available survey indices should be used in a qualitative way to estimate recruitment, rather than using them in a strict quantitative model framework. The WGWIDE has followed this recommendation and investigated several survey time-series indices with the potential to give quantitative or semi-quantitative information of blue whiting recruitment. The investigated survey series were standardized by dividing with their mean and are shown in Figure 2.8.1.1.

The International Ecosystem Survey in the Nordic Seas (IESNS) only partially covers the known distribution of recruitment from this stock. The 1–group (2019 year class) and the 2–group (2018 year class) indices from the survey in 2020 were approximately at the median and below the median of the historical range, respectively.

The International Blue Whiting Spawning Stock Survey (IBWSS) was not updated in 2020.

The Norwegian bottom-trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March 2020, showed that 1-group blue whiting was above the median in the time series(Table 2.3.7.2.2). However, the index in 2020 is low compared to the strong year classes observed earlier. This index should be used as a presence/absence index, in the way that when blue whiting is present in the Barents Sea, this is usually a sign of a strong year class, as all known strong year classes have been strong also in the Barents Sea.

The 1-group estimate in 2020 (2019 year class) from the Icelandic bottom-trawl survey showed an increase compared to 2019 and was above the median in the time-series.

The 1-group estimate in 2020 (2019 year class) from the Faroese Plateau spring bottom-trawl survey was the lowest observed in the time-series.

In conclusion, the indices from available survey time-series indicate that the 2018 year class is in the low end and it corresponds to the SAM assessment results. The 2019 year classes estimated from surveys are also in the low end, which also is the result of the SAM assessment where it is in the lower end. It was therefore decided not to change the SAM estimate of the 2018 and 2019 year classes.

No information is available for the 2020 and 2021 year classes and the geometric mean of the full time-series (1981—2019) was used for these year classes (14.75 billion at age 1 in 2021) (Table 2.8.1.1).

2.8.2 Short-term forecast

As decided at WGWIDE 2014, a deterministic version of the SAM forecast was applied. Details about specific implementation can be found in the Stock Annex.

2.8.2.1 Input

Table 2.8.2.1.1 lists the input data for the short-term predictions. Mean weight at age in the stock and mean weight in the catch are the same, and are calculated as three year averages (2018—2020) in accordance with the 2019 updated Stock Annex. Selection (exploitation pattern) is based on F in the most recent year. The proportion mature for this stock is assumed constant over the years and values are copied from the assessment input.

Recruitment (age 1) in 2019 and 2020 are assumed as estimated by the SAM model, as additional survey information was not conflicting this result. Recruitment in 2021 and 2022 are assumed at the long-term average (geometric mean for the full time-series, minus the last year (1981-2019).

As the assessment uses preliminary catches for 2020 an estimate of stock size exist for the 1st of January 2021. The normal use of an "intermediate year" calculation is not relevant in this case. F in the "intermediate year" (2020) is as calculated by the assessment model. Catches in 2020 is the (model input) preliminary catches (1478358 tonnes). Intermediate year assumptions are summarised in Table 2.8.2.1.2.

2.8.2.2 Output

A range of predicted catch and SSB options from the deterministic short-term forecast used for advice are presented in Table 2.8.2.2.1.

Following the ICES MSY framework or the target F from the LTMS implies fishing mortality to be at F_{MSY} = 0.32 which will give a TAC in 2021 at 841717 tonnes. This corresponds to a 27.5 % reduction compared to the ICES advice last year, and 43.1% reduction compared to the preliminary estimate of catches in 2020.

The LTMS specifies a TAC constraint at +25 / -20 %. With at maximum decrease at 20% in catches in relation to the ICES advice last year (LTMS advice), catches in 2021 is calculated to be at 929292 tonnes. SSB in 2022 is predicted to decrease 6.2 % to 3046216 tonnes, if the advised catches are taken.

2.9 Comparison with previous assessment and forecast

Comparison of the final assessment results from the last 5 years is presented in Figure 2.9.1. The last two assessments are very similar for the historical results for SSB and F, but differs more for recruitment, probably an effect of the missing 2020 survey results. For the five years period, result from the 2018 assessment differs most.

2.10 Quality considerations

Based on the confidence interval produced by the assessment model SAM there is a moderate to high uncertainty of the absolute estimate of F and SSB and the recruiting year classes (Figure 2.4.2.7). The retrospective analysis (Figure 2.4.2.6), the comparison of SSB and F estimated by three different assessment programs TISVPA, XSA and SAM (Figure 2.4.3.1) and the comparison of the 2016-2020 assessments (Figure 2.9.1) suggest a consistent assessment.

There are several sources of uncertainty: age reading, stock identity, and survey indices. As there is only one survey (IBWSS) that covers the spawning stock, the quality of the survey influences the assessment result considerably. The Inter-Benchmark Protocol on Blue Whiting (IBPBLW 2016) introduced a configuration of the SAM model that includes the use of estimated correlation for catch and survey observations. This handles the "year effects" in the survey observation in a better way than assuming an uncorrelated variance structure as usually applied in assessment models. However, a biased survey indices will still give a biased stock estimate with the new SAM configuration. The estimated correlation for catch at age observations might correspond to the age reading discrepancy estimated from inter-calibration exercise .

Utilization of preliminary catch data provides the assessment with information for the most recent year in addition to the survey information. This should give a less biased assessment, as potential biased survey data in the final year are supplemented by additional catch data.

The effect of the missing survey data for 2020 have provided slightly more uncertain assessment results for SSB and F compared to last year, and a more uncertain estimate of recruitment in 2020. The missing data seems not to have influenced the historical estimate of SSB, F and recruitment much. This year's assessment results for the historical part the time series are very close to the result estimated last year. However, additional data years, including survey data, are necessary to fully realise the effect of the missing 2020 survey data.

2.11 Management considerations

The assessment estimates low 2016-2019 year classes, which is confirmed by a series of surveys not used in the assessment model. This low recruitment will result in a decrease in stock size, and a reduction in fishing opportunities.

2.12 Ecosystem considerations

Blue whiting is one of the most abundant pelagic and mesopelagic fish stocks in the Northeast Atlantic, SSB estimated from 1.4 - 6.9 million ton during the period from 1981 to 2020 (ICES, 2020). The stock is widely distributed and highly migratory. It´s distribution range is approximately from latitude 30 °N to 80 °N and from the coast of Europe to Greenland, into Barents Sea and the Mediterranean Sea (Trenkel *et al.*, 2014). Spawning is in the spring and mostly occurs on the shelf and banks west of Ireland and Scotland and major summer feeding area is in the Norwegian Sea. Blue whiting is most frequently observed at 100-600 m depth (Heino and Godo, 2002). Their most important prey is respectively euphausiids, amphipods and copepods (Pinnegar *et al*., 2015, Bachiller *et al*., 2016) and they are prey for piscivorous fish (Dolgov *et al*., 2010) and cetaceans (Hátún *et al*., 2009a). Large stock size suggests blue whiting is an important species in the pelagic and mesopelagic ecosystem of the NE Atlantic and it´s best documented ecosystem interactions are listed below:

(a) Stock productivity - recruitment: blue whiting population dynamic is driven by large annual variability in recruitment (at age 1 in the assessment model) which is not linked to spawning stock size (ICES, 2020). Changes in recruitment have been correlated to changes in the North Atlantic subpolar gyre between strong and weak states (Hátún *et al*., 2009a,b). Two hypotheses have been suggested to explain a mechanical relationship between low gyre index and high recruitment (Payne *et al*., 2012). One suggests changes in marine climate where weak gyre results in increased flow of warm subtropical waters and increased abundance of important prey for juvenile blue whiting on their nursing grounds west of Ireland and Scotland. The other suggests increasing predation of mackerel on blue whiting larvae during years of weak index, but neither has been proven right (Payne *et al*., 2012). Future benchmarks should explore options to include the subpolar gyre index in the assessment model forecast for recruitment.

(b) Changes in distribution: blue whiting spawning distribution varies between years. It has been linked to the North Atlantic subpolar gyre as a strong gyre, cold and fresh water masses on the Rockall Plateau, shrinks the spawning area compared to a weak gyre, increasing saline and warm waters at Rockall, which expands the spawning area northward and westward into Rockall Plateau (Hátún *et al.,* 2009a,b; Miesner and Payne, 2018). Salinity appears specifically to impact spawning location of blue whiting (Miesner and Payne, 2018). Future benchmarks should explore options to include information on spawning ground salinity in the assessment model forecast for recruitment.

(c) It is disputed if there are one or two blue whiting populations in the Northeast Atlantic (Keating *et al*., 2014; Pointin and Payne, 2014; ICES, 2016c; Mahé *et al*., 2016). Currently blue whiting is considered a single population for management purpose. Future benchmarks should explore the impact of single population assessment versus an assessment for two populations.

(d) Trophic interactions in the Norwegian Sea: it appears to be limited prey competition between blue whiting and the two other abundant pelagic species, Norwegian spring-spawning herring and Atlantic mackerel, as studies show limited dietary overlap between blue whiting and the two other species (Bachiller *et al*., 2016; Pinnegar *et al*., 2014). Limited prey competitions between blue whiting and mackerel can be explained by limited geographical overlap, mackerel mostly feed in the surface layer and blue whiting deeper in the water column (Utne *et al*., 2012). Whereas distribution of blue whiting and herring overlap (Utne *et al*., 2012) they appear to feed on different species (Bachiller *et al.,* 2016; Pinnegar et al., 2014). Given the current knowledge, future benchmarks do not need to prey competition between blue whiting and herring/mackerel, future benchmarks do not need to consider adding mackerel and NSS herring stock size to the blue whiting stock assessment model.

An extensive overview of ecosystem considerations relevant for blue whiting can be found in the stock annex.

2.13 Regulations and their effects

There is an agreed long-term management strategy agreed by the European Union, the Faroe Islands, Iceland and Norway. However there is no agreement between the Coastal States, i.e. EU, Norway, Iceland and the Faroe Island on the share of the blue whiting TAC. An overview of the scientific advice, the TACs (or sum of unilateral quota) and the catches is shown in Figure 2.13.1.

While from 2010 until 2013, TACs were set in line with the scientific advice, from 2014 onwards the sum of unilateral quota and catches have been 20-50% in access of the scientific advice.

WGWIDE members estimate the total expected catch to be 1,478,358 tonnes in 2020, whereas ICES advised that when the long-term management strategy agreed by the European Union, the Faroe Islands, Iceland, and Norway is applied, catches in 2020 should be no more than 1,161,615 tonnes.

2.13.1 Management plans and evaluations

A response to NEAFC request to ICES to evaluate a long-term management strategy for the fisheries on the blue whiting ICES WKBWMSE was established in the fall of 2015. The ICES Advice September 2016, "NEAFC request to ICES to evaluate a long-term management strategy for the fisheries on the blue whiting (*Micromesistius poutassou*) stock" concluded that:

- That the harvest control rule (HCR) proposed for the Long-Term Management Strategy (LTMS) for blue whiting, as described in the request, is precautionary given the ICES estimates of Blim (1.5 million t), Bpa (2.25 million t), and F_{MSY} (0.32).
- The HCR was found to be precautionary both with and without the 20% TAC change limits above Bpa. However, the 20% TAC change limits can lead to the TAC being lowered significantly if the stock is estimated to be below Bpa, while also limiting how quickly the TAC can increase once the stock is estimated to have recovered above Bpa.
- The evaluation found that including a 10% interannual quota flexibility ('banking and borrowing') in the LTMS had an insignificant effect on the performance of the HCR.

2.14 Recommendations

The WGWIDE expert group analysed the mean length at age by area and by quarter of the data submitted from the different institutes/member states and differences have been identified in the data from the northern and southern areas. Due to the impact that biased age classifications could have on the blue whiting stock assessment, an inter-calibration exercise and a workshop is needed to review the age criteria used on this species. An age reading inter-calibration exercise is currently going on, which involves the readers providing data for stock assessment, and with samples covering this species distribution, the main quarters and the length composition of catches. A workshop on age reading is also planned for June 2021, in which the results and the age classifications from the exchange will be reviewed and discussed. The age-error matrix resulting from the inter-calibration exercise and the workshop, will be used to correct the catch-at-age and survey data used for assessment. The impact of these uncertainties on age reading on the stock assessment results will be further investigated.

2.15 Deviations from stock annex caused by missing information from Covid-19 disruption.

The one and only survey used for the SAM assessment, The International Blue Whiting Spawning Stock Survey (IBWSS) was not conducted in 2020. The method used this year follows the method outlined in the Stock Annex, but setting the survey observations for 2020 to "missing". The data situation and approach are described in more details below, using the ICES template.

1. Stock: Blue whiting (*Micromesistius poutassou*) in subareas 27.1–9, 12, and 14 (Northeast Atlantic)

2. Missing or deteriorated survey data:
   The assessment uses preliminary catch at age data and survey data for the assessment year (2020). The International Blue Whiting Spawning Stock Survey (IBWSS) is the only survey used in the quantitative assessment and this survey was cancelled in 2020 due to the COVID-19 pandemic. Other surveys used for a qualitative estimate of recruitment were conducted in 2020.

3. Missing or deteriorated catch data: No

4. Missing or deteriorated commercial *LPUE*/*CPUE* data: No

5. Missing or deteriorated biological data: No

6. Brief description of methods explored to remedy the challenge:
   The use of preliminary catch at age data was introduced in 2016, to have additional data for evaluation of potential bias in the survey results from the same year. Without a survey in the terminal year (the case this year) the benefit of using preliminary catch data will depend on the quality of the preliminary catch data. There is a high consistency between the preliminary and final catches (Figure 2.3.2.2). However, for a better understanding of the importance of preliminary catch data in a situation like this year, with no survey data for the terminal year, scenarios were investigated with 2017 and 2018 as final survey year, and with use of both preliminary and "final" data for the terminal year.

   As an example of that analysis, the results for a scenario with 2018 as the last IBWSS year, and 1) no preliminary data for 2019, 2) preliminary data for 2019 and 3) final catch data for 2019 are shown in Figure 2.4.1.1. If run 3) with the use of final catch data for 2019 is seen as the most "correct" assessment results (as it contains the longest time series with final data), it is seen that the use of preliminary catch data gives an assessment result for SSB and F closer to the "correct" assessment than the assessment with no preliminary catch data. Based on the log likelihood from the models, the use of final data gave a slightly better fit than the use of preliminary data (as expected). The best fit was however obtained for the run without catch data for the year after the last survey year, probably due to the fewer observations in that run. There was no clear conclusion on the "best" use of data from the parameter estimates from the three configurations.

   The scenarios also showed that the inclusion of preliminary catch data did not change the historical estimates of F, SSB and recruitment much.

   The analysis was only conducted for two cases using 2017 and 2018 as the last year with survey data. Both sets of runs showed a small improvement in assessment result using the preliminary catches. In addition, with use of preliminary catch data, the benchmark recommended method for calculating F in the "intermediate year" (use assessment F from the terminal year, i.e. from preliminary catches) could also be applied. Based on these reasons, the assessment this year used also preliminary data for 2020.

7. Suggested solution to the challenge, including reason for this selecting this solution: See above.

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out?
   The effect of the missing survey data for 2020 have provided slightly more uncertain assessment results for SSB and F compared to last year, and a more uncertain estimate of recruitment in 2020. The missing data seems not to have influenced the historical estimate of SSB,

F and recruitment much. This year's assessment results for the historical part the time series are very close to the result estimated last year. However, additional data years, including survey data, are necessary to fully realise the effect of the missing 2020 survey data.

2.16 References

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2.17 Tables

Table 2.3.1.1. Blue whiting. ICES estimated catches (tonnes) by country for the period 1988–2019.

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2003
Denmark	18 941	26 630	27 052	15 538	34 356	41 053	20 456	12 439	52 101	26 270	61 523	82 935
Estonia					6 156	1 033	4 342	7 754	10 982	5 678	6 320	
Faroes	79 831	75 083	48 686	10 563	13 436	16 506	24 342	26 009	24 671	28 546	71 218	329 895
France		2 191				1 195		720	6 442	12 446	7 984	14 149
Germany	5 546	5 417	1 699	349	1 332	100	2	6 313	6 876	4 724	17 969	22 803
Iceland		4 977						369	302	10 464	68 681	501 493
Ireland	4 646	2 014			781		3	222	1 709	25 785	45 635	22 580
Japan					918	1 742	2 574					
Latvia					10 742	10 626	2 582					
Lithuania						2 046						
Netherlands	800	2 078	7 750	17 369	11 036	18 482	21 076	26 775	17 669	24 469	27 957	48 303
Norway	233 314	301 342	310 938	137 610	181 622	211 489	229 643	339 837	394 950	347 311	560 568	834 540
Poland	10											
Portugal	5 979	3 557	2 864	2 813	4 928	1 236	1 350	2 285	3 561	2 439	1 900	2 651
Spain	24 847	30 108	29 490	29 180	23 794	31 020	28 118	25 379	21 538	27 683	27 490	13 825
Sweden **	1 229	3 062	1 503	1 000	2 058	2 867	3 675	13 000	4 000	4 568	9 299	65 532
UK (England + Wales)***												
UK (Northern Ireland)												
UK (Scotland)	5 183	8 056	6 019	3 876	6 867	2 284	4 470	10 583	14 326	33 398	92 383	27 382
USSR / Russia *	177 521	162 932	125 609	151 226	177 000	139 000	116 781	107 220	86 855	118 656	130 042	355 319
Greenland**												
Unallocated												
TOTAL	557 847	627 447	561 610	369 524	475 026	480 679	459 414	578 905	645 982	672 437	1 128 969	2 321 406

* From 1992 only Russia.

** Estimates from Sweden and Greenland: are not included in the Catch at Age Number.

*** From 2012.

Table 2.3.1.1. (continued). Blue whiting. ICES estimated catches (tonnes) by country for the period 1988–2019.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Denmark	89500	41450	54663	48659	18134	248	140	165	340	2167	35256	45178	39395	60868	87348	68716
Estonia	*															0
Faroes	322322	266799	321013	317859	225003	58354	49979	16405	43290	85768	224700	282502	282416	356501	349838	336569
France		8046	18009	16638	11723	8831	7839	4337	9799	8978	10410	9659	10345	13369	16784	16095
Germany	15293	22823	36437	34404	25259	5044	9108	278	6239	11418	24487	24107	20025	45555	47708	38244
Iceland	379643	265516	309508	236538	159307	120202	87942	5887	63056	104918	182879	214870	186914	228934	292944	268356
Ireland	75393	73488	54910	31132	22852	8776	8324	1195	7557	13205	21466	24785	27657	43238	49903	38836
Lithuania			4635	9812	5338						4717		1129	5300		
Netherlands	95311	147783	102711	79875	78684	35686	33762	4595	26526	51635	38524	56397	58148	81156	121864	75020
Norway	957684	738490	642451	539587	418289	225995	194317	20539	118832	196246	399520	489439	310412	399363	438426	351429
Poland														15889	12152	27185
Portugal	3937	5190	5323	3897	4220	2043	1482	603	1955	2056	2150	2547	2586	2046	2497	3481
Spain	15612	17643	15173	13557	14342	20637	12891	2416	6726	15274	32065	29206	31952	28920	24718	22782
Sweden	19083	2960	101	464	4	3	50	1	4	199	2	32	42	90	16**	54
UK (England + Wales)	2593	7356	10035	12926	14147	6176	2475	27	1590	4100	11	131	1374+	3447	1864	4062
UK (Northern Ireland)										1232	2205	1119			4508	2899
UK (Scotland)	57028	104539	72106	43540	38150	173	5496	1331	6305	8166	24630	30508	37173	64724	66682	54040
Russia	346762	332226	329100	236369	225163	149650	112553	45841	88303	120674	152256	185763	173655	188449	170892	188006
Greenland										2133				20212	23333	19753
Unallocated									3499							
TOTAL	2380161	2034309	1976176	1625255	1260615	641818	526357	103620	384021	628169	1155279	1396244	1183224	1558061	1711477	1515527

*** Reported to the EU but not to the ICES WGNPBW. (Landings of 19,467 tonnes).**

**** only landings (2018).**

+ data updated in 2018.

Table 2.3.1.2. Blue whiting. ICES estimated catches (tonnes) by country and ICES division for 2019.

ICES Division	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	UK (England + Wales)	UK (Northern Ireland)	UK (Scotland)	Total
27.2.a	271	24250		579	4009	14694	9	604	1293	96		21349						**67154**
27.3.a	77													54				**131**
27.4																	129	**129**
27.4.a	70	3764	59	1173	2130	14116	3	1012	21347			894						**44569**
27.4.b	4								25						0		0	**28**
27.5.a		1039				400												**1439**
27.5.b	1066	169397	1397	195	10215	121714			2452	1217		75507			174			**383334**
27.6.a	18413	56688	7141	25671	3399	22587	23990	53076	97762	16444		20342	619		3848	12	14360	**364351**
27.6.b	2618	9394	396	177		7515	5824	369	20047	213		7562	46				12550	**66711**
27.7.b	1730		214	408			15	529					2		6			**2905**
27.7.c	40184	58171	5545	9220		77127	6541	15616	154805	6711		54557	257		1	2887	22908	**454531**
27.7.d															0			**0**
27.7.e			2												0			**2**
27.7.f								0							0			**0**
27.7.g			0				0						2		0			**2**
27.7.h			0				21	17					4					**42**
27.7.j			894	89			11	330		474			75		31			**1905**
27.7.k	4284	13866	0			10203	2414	3076	53698			7744	1				4093	**99378**
27.8.a			132	733			8			1568			1					**2443**
27.8.b			3					392					136					**531**
27.8.c			0								1204		16130					**17334**
27.8.d			311							462			1					**774**
27.9.a											2277		5507					**7784**
27.12												51						**51**
Total	**68716**	**336569**	**16095**	**38244**	**19753**	**268356**	**38836**	**75020**	**351429**	**27185**	**3481**	**188006**	**22782**	**54**	**4062**	**2899**	**54040**	**1515527**

Table 2.3.1.3. Blue whiting. ICES estimated catches (tonnes) by quarter and ICES division for 2019.

ICES Division	Quarter 1	Quarter 2	Quarter 3	Quarter 4	2019*	Total
27.2.a	448	14048	19160	33499		67154
27.3.a	2	23	29	76		131
27.4					129	129
27.4.a	233	8550	10229	25556		44569
27.4.b	0	15	12	0		28
27.5.a	12	7	1373	48		1439
27.5.b	46485	305785	107	30957		383334
27.6.a	84374	253281	7	26686	4	364351
27.6.b	65618	1014	2		77	66711
27.7.b	818	2037	46	4		2905
27.7.c	441654	12843	33			454531
27.7.d	0					0
27.7.e	0	0	2	0		2
27.7.f	0			0		0
27.7.g	2	0	0	0		2
27.7.h	2	17	23			42
27.7.j	36	61	385	1422		1905
27.7.k	99267		111			99378
27.8.a	741	1	0	1700		2443
27.8.b	30	74	10	417		531
27.8.c	4856	5145	4035	3299		17334
27.8.d	1	0	0	773		774
27.9.a	996	2469	2262	2058		7784
27.12	51					51
Total	**745625**	**605370**	**37826**	**126497**	**209**	**1515527**

***Discards data from UK(Scotland) were provided by year, due to sampling intensity.**

Table 2.3.1.4. Blue whiting. ICES estimated catches (tonnes) from the main fisheries 1988–2019 by area.

Year	Norwegian Sea fishery (SAs1+2;Divs .5.a,14a-b)	Fishery in the spawning area (SA 12.; Divs. 5.b, 6.a-b, 7.a-c)	Directed- and mixed fisheries in the North Sea (SA4; Div.3.a)	Total northern areas	Total southern areas (SAs8+9;Div s.7.d-k)	Grand total
1988	55829	426037	45143	**527009**	30838	**557847**
1989	42615	475179	75958	**593752**	33695	**627447**
1990	2106	463495	63192	**528793**	32817	**561610**
1991	78703	218946	39872	**337521**	32003	**369524**
1992	62312	318018	65974	**446367**	28722	**475026**
1993	43240	347101	58082	**448423**	32256	**480679**
1994	22674	378704	28563	**429941**	29473	**459414**
1995	23733	423504	104004	**551241**	27664	**578905**
1996	23447	478077	119359	**620883**	25099	**645982**
1997	62570	514654	65091	**642315**	30122	**672437**
1998	177494	827194	94881	**1099569**	29400	**1128969**
1999	179639	943578	106609	**1229826**	26402	**1256228**
2000	284666	989131	114477	**1388274**	24654	**1412928**
2001	591583	1045100	118523	**1755206**	24964	**1780170**
2002	541467	846602	145652	**1533721**	23071	**1556792**
2003	931508	1211621	158180	**2301309**	20097	**2321406**
2004	921349	1232534	138593	**2292476**	85093	**2377569**
2005	405577	1465735	128033	**1999345**	27608	**2026953**
2006	404362	1428208	105239	**1937809**	28331	**1966140**
2007	172709	1360882	61105	**1594695**	17634	**1612330**
2008	68352	1111292	36061	**1215704**	30761	**1246465**
2009	46629	533996	22387	**603012**	32627	**635639**
2010	36214	441521	17545	**495280**	28552	**523832**
2011	20599	72279	7524	**100401**	3191	**103592**
2012	24391	324545	5678	**354614**	29402	**384016***
2013	31759	481356	8749	**521864**	103973	**625837****
2014	45580	885483	28596	**959659**	195620	**1155279**
2015	150828	895684	44661	**1091173**	305071	**1396244**
2016	59744	905087	55774	**1020604**	162583	**1183187*****
2017	136565	1284105	45474	**1466144**	91917	**1558061**
2018	143204	1445957	43484	**1632646**	78831	**1711477**
2019	**68593**	**1271883**	**44856**	**1385333**	**130194**	**1515527**

*** Official catches by area from Sweden are not included (2012).**

**** Official catches by area from Sweden and Greenland are not included (2013).**

***** Grand total includes only 1336 tonnes from UK(England+Wales)
(2016 total catch from UK(England+Wales) = 1374 ton).**

Table 2.3.1.5. Blue whiting. ICES estimates (tonnes) of catches, landings and discards by country for 2019.

Country	Catches	BMS landings	Landings	Discards	% discards
Denmark	68716	0	68634	82	0.12
Faroe Islands	336569		336569	0	0.00
France	16095		16095	0	0.00
Germany	38244		38244	0	0.00
Greenland	19753		19753	0	0.00
Iceland	268356		268356	0	0.00
Ireland	38836		38569	267	0.69
Netherlands	75020		75020	0	0.00
Norway	351429		351429	0	0.00
Poland	27185		27184	0	0.00
Portugal	3481		2659	822	23.62
Russia	188006		188006	0	0.00
Spain	22782		21603	1179	5.17
Sweden	54	0	43	11	19.65
UK (England+Wales)	4062	34	4027	0	0.01
UK(Northern Ireland)	2899		2899	0	0.00
UK(Scotland)	54040		53831	209	0.39
Total	**1515527**	**34**	**1512922**	**2570**	**0.17**

Table 2.3.1.6. Blue whiting. ICES estimated catches (tonnes) inside and outside NEAFC regulatory area for 2019 by coun-try.

	Catches inside NEAFC RA	Catches outside NEAFC RA	Total catches
Denmark	655	68061	68716
Faroe Islands	70321	266248	336569
France	74	16022	16095
Germany	550	37694	38244
Greenland	19555	198	19753
Iceland	97022	171333	268356
Ireland	9	38827	38836
Netherlands*	557	74464	75020
Norway*	59690	291739	351429
Poland	1313	25872	27185
Portugal	0	3481	3481
Russia	90316	97690	188006
Spain	0	22782	22782
Sweden	0	54	54
UK (England + Wales)	0	4062	4062
UK(Northern Ireland)	0	2899	2899
UK(Scotland)	0	54040	54040
Total in 2019	**340062**	1175465	**1515527**

*** the values of catches inside/outside NEAFC RA are based on the ICES Preliminary Catch Statistics.**

Table 2.3.1.1.1. Blue whiting. ICES estimated catches (tonnes), the percentage of catch covered by the sampling programme, No. of age samples, No. of fish measured and No. of fish aged for 2000-2019.

Year	Catch (tonnes)	% catch covered by sampling programme	No. Age samples	No. Measured	No. Aged
2000	1412928	*	1136	125162	13685
2001	1780170	*	985	173553	17995
2002	1556792	*	1037	116895	19202
2003	2321406	*	1596	188770	26207
2004	2377569	*	1774	181235	27835
2005	2026953	*	1833	217937	32184
2006	1966140	*	1715	190533	27014
2007	1610090	87	1399	167652	23495
2008	1246465	90	927	113749	21844
2009	635639	88	705	79500	18142
2010	524751	87	584	82851	16323
2011	103591	85	697	84651	12614
2012	373937	80	1143	173206	15745
2013	625837	96	915	111079	14633
2014	1155279	89	912	111316	39738
2015	1396244	94	1570	102367	29821
2016	1183187	89	1092	120329	13793
2017	1558061	91	1779	147297	15828
2018	1711477	87	1565	131779	16426
2019	**1515527**	**84**	**1253**	**136604**	**17869**

Table 2.3.1.1.2. Blue whiting. ICES estimated catches (tonnes), the percentage of catch covered by the sampling programme (catch-at-age numbers), No. of length samples, No. of age samples, No. of fish measured, No. of fish aged, No. of fish aged by 1000 tonnes and No. of fish measured by 1000 tonnes by country for 2019.

Country	Catch (ton)	% catch covered by sampling programme	No. Length samples	No. Age samples	No. Measured	No. Aged	No Aged/ 1000 tonnes	No Measured/ 1000 tonnes
Denmark	68716	92	34	34	2359	1911	28	34
Faroe Islands	336569	91	17	17	1656	1636	5	5
France	16095	0	55	0	3659	0	0	227
Germany	38244	19	64	64	10792	730	19	282
Greenland	19753	0	0	0	0	0	0	0
Iceland	268356	100	98	98	7910	2341	9	29
Ireland	38836	61	90	15	8506	1504	39	219
Netherlands	75020	76	75	75	16080	1836	24	214
Norway	351429	93	32	32	838	838	2	2
Poland	27185	0	0	0	0	0	0	0
Portugal	3481	65	44	44	2611	986	283	750
Russia	188006	82	164	164	48980	3137	17	261
Spain	22782	96	853	699	30788	2463	108	1351
Sweden	54	0	0	0	0	0	0	0
UK (England + Wales)	4061.56	0	0	0	0	0	0	0
UK(Northern Ireland)	2899	0	0	0	0	0	0	0
UK(Scotland)	54040	73	11	11	2425	487	9	45
Total	**1515527**	**84**	**1537**	**1253**	**136604**	**17869**	**12**	**90**

Table 2.3.1.1.3. Blue whiting. ICES estimated catches (tonnes), No. of Age samples, No. of fish measured and No. of fish aged by country and quarter for 2019.

	Catch (tonnes)	No. Age samples	No. Length Measured	No. Age Samples
Denmark				
1	46543	21	1201	1201
2	21771	13	1158	710
3	46	0	0	0
4	355	0	0	0
Total	**68716**	**34**	**2359**	**1911**
Faroe Islands				
1	144389	9	890	888
2	162359	6	608	598
3	4165	0	0	0
4	25656	2	158	150
Total	**336569**	**17**	**1656**	**1636**
France				
1	4766	0	2460	0
2	8466	0	0	0
3	10	0	0	0
4	2854	0	1199	0
Total	**16095**	**0**	**3659**	**0**
Germany				
1	14854	3	141	137
2	20992	4	975	153
3	554	0	0	0
4	1844	57	9676	440
Total	**38244**	**64**	**10792**	**730**
Greenland				
1	1646	0	0	0
2	10590	0	0	0
3	65	0	0	0
4	7452	0	0	0
Total	**19753**	**0**	**0**	**0**
Iceland				
1	94857	37	3030	848
2	130017	48	3740	1168
3	5030	4	369	100
4	38452	9	771	225
Total	**268356**	**98**	**7910**	**2341**
Ireland				
1	23840	15	6101	1504
2	14794	0	0	0
3	140	0	2405	0
4	63	0	0	0
Total	**38836**	**15**	**8506**	**1504**
Netherlands				
1	12028	35	6872	866
2	52940	40	9208	970
3	250	0	0	0
4	9803	0	0	0
Total	**75020**	**75**	**16080**	**1836**

Table 2.3.1.1.3. (continued) Blue whiting. ICES estimated catches (tonnes), No. of Age samples, No. of fish measured and No. of fish aged by country and quarter for 2019.

	Catch (tonnes)	No. Age samples	No. Length Measured	No. Age Samples
Norway				
1	258073	24	617	617
2	77277	8	221	221
3	10201	0	0	0
4	5878	0	0	0
Total	**351429**	**32**	**838**	**838**
Poland				
1	11304	0	0	0
4	15881	0	0	0
Total	**27185**	**0**	**0**	**0**
Portugal				
1	1051	13	320	131
2	659	11	652	254
3	875	7	663	329
4	896	13	976	272
Total	**3481**	**44**	**2611**	**986**
Russia				
1	78279	103	30682	2615
2	86774	12	3550	140
3	10950	36	10833	353
4	12003	13	3915	29
Total	**188006**	**164**	**48980**	**3137**
Spain				
1	5103	197	9787	409
2	7692	294	8773	843
3	5486	93	5703	784
4	4501	115	6525	427
Total	**22782**	**699**	**30788**	**2463**
Sweden				
1	1	0	0	0
2	1	0	0	0
3	24	0	0	0
4	28	0	0	0
Total	**54**	**0**	**0**	**0**
UK (England + Wales)				
1	1	0	0	0
2	3199	0	0	0
3	31	0	0	0
4	830	0	0	0
Total	**4062**	**0**	**0**	**0**
UK (Northern Ireland)				
1	2899	0	0	0
Total	**2899**	**0**	**0**	**0**
UK (Scotland)				
1	45992	11	2425	487
2	7838	0	0	0
2019*	209	0	0	0
Total	**54040**	**11**	**2425**	**487**
Total Geral	**1515527**	**1253**	**136604**	**17869**

*** Discards data from UK (Scotland) were provided by year, due to sampling intensity.**

Table 2.3.1.1.4. Blue whiting. ICES estimated catches (tonnes), the percentage of catch covered by the sampling programme, No. of length samples, No. of age samples, No. of fish measured, No. of fish aged, No. of fish aged by 1000 tonnes and No. of fish measured by 1000 tonnes by ICES division for 2019.

ICES Division	Catch (ton)	No. Length samples	No. Age samples	No. Measured	No. Aged	No Aged/ 1000 tonnes	No Measured/ 1000 tonnes
27.2.a	67154	95	95	16705	770	11	249
27.3.a	131	0	0	0	0	0	0
27.4	129	0	0	0	0	0	0
27.4.a	44569	6	6	1103	208	5	25
27.4.b	28	0	0	0	0	0	0
27.5.a	1439	1	1	100	25	17	69
27.5.b	383334	76	76	11402	2125	6	30
27.6.a	364351	127	112	21574	3859	11	59
27.6.b	66711	36	36	7934	1500	22	119
27.7.b	2905	6	2	677	48	17	233
27.7.c	454531	191	153	33140	4391	10	73
27.7.d	0	0	0	0	0	0	0
27.7.e	2	0	0	0	0	0	0
27.7.f	0	0	0	0	0	0	0
27.7.g	2	15	0	0	0	0	0
27.7.h	42	6	0	1134	0	0	27098
27.7.j	1905	173	0	1731	0	0	909
27.7.k	99378	58	29	8443	1494	15	85
27.8.a	2443	0	0	0	0	0	0
27.8.b	531	132	132	1257	0	0	2368
27.8.c	17334	327	327	19870	1233	71	1146
27.8.d	774	4	0	299	0	0	386
27.9.a	7784	284	284	11235	2216	285	1443
27.12	51	0	0	0	0	0	0
TOTAL	**1515527**	**1537**	**1253**	**136604**	**17869**	**12**	**90**

Table 2.3.2.1. Blue whiting. ICES estimated preliminary catches (tonnes) in 2020 by quarter and ICES division. Data submitted to InterCatch.

ICES Division	Quarter 1	Quarter 2	Quarter 3	Total
27.2.a	526	24963		**25489**
27.3.a			**18**	**18**
27.4.a	511	29663		**30173**
27.5.a	3			**3**
27.5.b	26210	247998		**274208**
27.6.a	30748	249794		**280542**
27.6.b	18535	7138		**25673**
27.7.b	279	505		**784**
27.7.c	241076	46198		**287274**
27.7.j	0	22		**22**
27.7.k	241713			**241713**
27.8.a	0			**0**
27.8.b		20		**20**
27.8.d	365	68		**434**
27.9.a	366	336		**702**
Total	**560332**	**606706**	**18**	**1167057**

Table 2.3.2.2. Blue whiting. ICES estimated preliminary catches (tonnes), the percentage of catch covered by the sampling programme, No. of samples, No. of fish measured, No. of fish aged, No. of fish aged by 1000 tonnes and No. of fish measured by 1000 tonnes by ICES division for 2020 preliminary data (quarters 1 and 2). Data submitted to InterCatch.

ICES Division	Catch (ton)	No. samples	No. Measured	No. Aged
27.2.a	25489	2	300	300
27.3.a*	18	0	0	0
27.4.a	30173	2	225	275
27.5.a	3	0	0	0
27.5.b	274208	57	14982	940
27.6.a	280542	17	2563	1415
27.6.b	25673	21	4143	297
27.7.b	784	0	0	0
27.7.c	287274	45	3314	1970
27.7.j	22	0	0	0
27.7.k	241713	83	12616	2199
27.8.a	0	0	0	0
27.8.b	20	0	0	0
27.8.d	434	0	0	0
27.9.a	702	5	388	175
Total	**1167057**	**232**	**38531**	**7571**

*from Quarter 3 landings.

Table 2.3.2.3. Blue whiting. ICES estimates of catches (tonnes) in 2020, based on (initial) declared quotas and expected uptake estimated by WGWIDE.

Country	Prelim Q1-Q2 catch	Expected remaining catch or total year catch	Total catch
Denmark	58,604	0	58,604
Faroe Islands	273,153	51,543	324,696
Germany	38,497	6,500	44,997
Greenland	0	19,773	19,773
France	5,069	0	5,069
Iceland	185,477	61,423	246,900
Ireland	39,169	0	39,169
The Netherlands	57,304	16,000	73,304
Norway	329,584	30,000	359,584
Poland	35,508	0	35,508
Portugal	702	2,000	2,702
Russia	149,059	46,113	195,172
United Kingdom	51,371	0	51,371
Spain	11,972	9,467	21,439
Sweden	0	70	70
Total	1,235,469	242,889	1,478,358
EU	298,196	34,037	332,233
Non-EU	937,273	208,852	1,146,125
	Best estimate of catches in 2020		**1,478,358**

Table 2.3.2.4. Blue whiting. Comparison of preliminary and final catches (tonnes).

Year	Preliminary	Final	Deviation %*
2016	1147000	1183224	3.1
2017	1559437	1558061	-0.1
2018	1712874	1711477	-0.1
2019	1444301	1515527	4.7

*** (final-preliminary)/final*100**

Table 2.3.3.1. Blue whiting. Catch-at-age numbers (thousands) by year. Discards included since 2014. Values for 2020 are preliminary.

Year Age	1	2	3	4	5	6	7	8	9	10+
1981	258000	348000	681000	334000	548000	559000	466000	634000	578000	1460000
1982	148000	274000	326000	548000	264000	276000	266000	272000	284000	673000
1983	2283000	567000	270000	286000	299000	304000	287000	286000	225000	334000
1984	2291000	2331000	455000	260000	285000	445000	262000	193000	154000	255000
1985	1305000	2044000	1933000	303000	188000	321000	257000	174000	93000	259000
1986	650000	816000	1862000	1717000	393000	187000	201000	198000	174000	398000
1987	838000	578000	728000	1897000	726000	137000	105000	123000	103000	195000
1988	425000	721000	614000	683000	1303000	618000	84000	53000	33000	50000
1989	865000	718000	1340000	791000	837000	708000	139000	50000	25000	38000
1990	1611000	703000	672000	753000	520000	577000	299000	78000	27000	95000
1991	266686	1024468	513959	301627	363204	258038	159153	49431	5060	9570
1992	407730	653838	1641714	569094	217386	154044	109580	79663	31987	11706
1993	263184	305180	621085	1571236	411367	191241	107005	64769	38118	17476
1994	306951	107935	367962	389264	1221919	281120	174256	90429	79014	30614
1995	296100	353949	421560	465358	615994	800201	253818	159797	59670	41811
1996	1893453	534221	632361	537280	323324	497458	663133	232420	98415	82521
1997	2131494	1519327	904074	577676	295671	251642	282056	406910	104320	169235
1998	1656926	4181175	3541231	1044897	383658	322777	303058	264105	212452	85513
1999	788200	1549100	5820800	3460600	412800	207200	151200	153100	68800	140500
2000	1814851	1192657	3465739	5014862	1550063	513663	213057	151429	58277	139791
2001	4363690	4486315	2962163	3806520	2592933	585666	170020	97032	76624	66410

Year Age	1	2	3	4	5	6	7	8	9	10+
2002	1821053	3232244	3291844	2242722	1824047	1647122	344403	168848	102576	142743
2003	3742841	4073497	8378955	4824590	2035096	1117179	400022	121280	19701	27493
2004	2156261	4426323	6723748	6697923	3044943	1276412	649885	249097	75415	36805
2005	1427277	1518938	5083550	5871414	4450171	1419089	518304	249443	100374	55226
2006	412961	939865	4206005	6150696	3833536	1718775	506198	181181	67573	36688
2007	167027	306898	1795021	4210891	3867367	2353478	935541	320529	130202	88573
2008	408790	179211	545429	2917190	3262956	1919264	736051	315671	113086	126637
2009	61125	156156	231958	594624	1596095	1156999	592090	251529	88615	48908
2010	349637	222975	160101	208279	646380	992214	702569	256604	70487	43693
2011	162997	101810	63954	53863	69717	116396	120359	55470	25943	12542
2012	239667	351845	663155	141854	106883	203419	363779	356785	212492	157947
2013	228175	508122	848597	896966	462714	224066	321310	397536	344285	383601
2014	588717	584084	2312953	2019373	1272862	416523	386396	462339	526141	662747
2015	2944849	2852384	2427329	2465286	1518235	707533	329882	258743	239164	450046
2016	1239331	3518677	2933271	1874011	1367844	756824	339851	185368	131039	288635
2017	401947	1999011	7864694	4063916	1509651	777185	263007	110351	63945	149369
2018	418781	541041	3572357	7340084	2983975	1022883	424206	150753	90387	163289
2019	249923	433573	1288871	3778379	5037323	1645999	431925	145916	50622	81357
2020	870600	518121	1164363	2011963	3136797	3128045	1137272	338127	72711	93956

Table 2.3.4.1. Blue whiting. Individual mean weight (kg) at age in the catch. Preliminary values for 2020.

Year Age	1	2	3	4	5	6	7	8	9	10+
1981	0.052	0.065	0.103	0.125	0.141	0.155	0.170	0.178	0.187	0.213
1982	0.045	0.072	0.111	0.143	0.156	0.177	0.195	0.200	0.204	0.231
1983	0.046	0.074	0.118	0.140	0.153	0.176	0.195	0.200	0.204	0.228
1984	0.035	0.078	0.089	0.132	0.153	0.161	0.175	0.189	0.186	0.206
1985	0.038	0.074	0.097	0.114	0.157	0.177	0.199	0.208	0.218	0.237
1986	0.040	0.073	0.108	0.130	0.165	0.199	0.209	0.243	0.246	0.257
1987	0.048	0.086	0.106	0.124	0.147	0.177	0.208	0.221	0.222	0.254
1988	0.053	0.076	0.097	0.128	0.142	0.157	0.179	0.199	0.222	0.260

Year Age	1	2	3	4	5	6	7	8	9	10+
1989	0.059	0.079	0.103	0.126	0.148	0.158	0.171	0.203	0.224	0.253
1990	0.045	0.070	0.106	0.123	0.147	0.168	0.175	0.214	0.217	0.256
1991	0.055	0.091	0.107	0.136	0.174	0.190	0.206	0.230	0.232	0.266
1992	0.057	0.083	0.119	0.140	0.167	0.193	0.226	0.235	0.284	0.294
1993	0.066	0.082	0.109	0.137	0.163	0.177	0.200	0.217	0.225	0.281
1994	0.061	0.087	0.108	0.137	0.164	0.189	0.207	0.217	0.247	0.254
1995	0.064	0.091	0.118	0.143	0.154	0.167	0.203	0.206	0.236	0.256
1996	0.041	0.080	0.102	0.116	0.147	0.170	0.214	0.230	0.238	0.279
1997	0.047	0.072	0.102	0.121	0.140	0.166	0.177	0.183	0.203	0.232
1998	0.048	0.072	0.094	0.125	0.149	0.178	0.183	0.188	0.221	0.248
1999	0.063	0.078	0.088	0.109	0.142	0.170	0.199	0.193	0.192	0.245
2000	0.057	0.075	0.086	0.104	0.133	0.156	0.179	0.187	0.232	0.241
2001	0.050	0.078	0.094	0.108	0.129	0.163	0.186	0.193	0.231	0.243
2002	0.054	0.074	0.093	0.115	0.132	0.155	0.173	0.233	0.224	0.262
2003	0.049	0.075	0.098	0.108	0.131	0.148	0.168	0.193	0.232	0.258
2004	0.042	0.066	0.089	0.102	0.123	0.146	0.160	0.173	0.209	0.347
2005	0.039	0.068	0.084	0.099	0.113	0.137	0.156	0.166	0.195	0.217
2006	0.049	0.072	0.089	0.105	0.122	0.138	0.163	0.190	0.212	0.328
2007	0.050	0.064	0.091	0.103	0.115	0.130	0.146	0.169	0.182	0.249
2008	0.055	0.075	0.100	0.106	0.120	0.133	0.146	0.160	0.193	0.209
2009	0.056	0.085	0.105	0.119	0.124	0.138	0.149	0.179	0.214	0.251
2010	0.052	0.064	0.110	0.154	0.154	0.163	0.175	0.187	0.200	0.272
2011	0.055	0.079	0.107	0.136	0.169	0.169	0.179	0.189	0.214	0.270
2012	0.041	0.072	0.098	0.140	0.158	0.172	0.180	0.185	0.189	0.203
2013	0.051	0.077	0.094	0.117	0.139	0.162	0.185	0.188	0.198	0.197
2014	0.049	0.078	0.093	0.112	0.128	0.155	0.178	0.190	0.202	0.217
2015	0.039	0.070	0.094	0.117	0.137	0.155	0.174	0.183	0.193	0.201
2016	0.047	0.066	0.084	0.107	0.125	0.142	0.152	0.167	0.184	0.206
2017	0.056	0.072	0.080	0.094	0.113	0.131	0.148	0.172	0.190	0.212

Year Age	1	2	3	4	5	6	7	8	9	10+
2018	0.055	0.080	0.091	0.098	0.111	0.129	0.142	0.165	0.175	0.216
2019	0.068	0.085	0.099	0.109	0.118	0.130	0.144	0.167	0.167	0.228
2020	0.057	0.073	0.093	0.113	0.125	0.134	0.139	0.152	0.177	0.218

Table 2.3.5.1. Blue whiting. Natural mortality and proportion mature.

AGE	0	1	2	3	4	5	6	7–10+
Proportion mature	0.00	0.11	0.40	0.82	0.86	0.91	0.94	1.00
Natural mortality	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Table 2.3.7.1.1. Blue whiting. Time-series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS. Total biomass in last column (1000 t). Shaded values (ages 1-8; years 2004-2019) are used as input to the assessment

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB
2004	1097	5538	13062	15134	5119	1086	994	593	164	0	3505
2005	2129	1413	5601	7780	8500	2925	632	280	129	23	2513
2006	2512	2224	10881	11695	4717	2719	923	352	198	39	3517
2007	468	706	5241	11244	8437	3155	1110	456	123	65	3274
2008	337	524	1455	6661	6747	3882	1719	1029	269	296	2647
2009	275	329	360	1292	3739	3458	1636	587	250	194	1599
2010*											
2011	312	1361	1135	930	1043	1713	2171	2423	1298	272	1827
2012	1140	1816	6454	1021	595	1415	2220	1777	1249	1085	2347
2013	582	1337	6175	7211	2938	1282	1308	1398	929	1807	3110
2014	4183	1491	5239	8420	10202	2754	772	577	899	2251	3761
2015	3255	4570	1891	3641	1797	466	174	108	206	365	1405
2016	2745	7893	10164	6274	4687	1539	413	133	235	361	2873
2017	262	2248	15682	10176	3762	1793	921	76	84	173	3135
2018	836	628	6615	21490	7692	2187	755	188	72	138	4035
2019	1129	1169	3468	9590	16979	3434	484	513	99	43	4198

*Survey discarded.

Table 2.3.7.1.2. Blue whiting. Difference between the old StoX abundance estimates of blue whiting (millions) and the re-calculated StoX abundance estimates.

Year/Age	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
2004	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0
2006	0	-2	-23	-18	-4	-2	0	0
2007	0	0	0	0	0	0	0	0
2008	0	-1	-4	-19	-25	-13	-4	-1
2009	0	0	0	0	0	-1	0	0
2010	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	-1	-1	-1
2012	1	2	10	1	1	5	11	8
2013	4	9	8	-14	-5	-2	-2	-2
2014	0	0	0	0	0	0	0	0
2015	0	-5	-3	-11	-5	-1	-1	0
2016	0	0	0	0	0	0	0	0
2017	13	-68	257	20	-141	-82	-21	-1
2018	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0

Table 2.3.7.2.1. Blue whiting. Estimated abundance of 1 and 2 year old blue whiting from the International Norwegian Sea ecosystem survey, 2003–2020.

Year\Age	Age 1	Age 2
2003*	16127	9317
2004*	17792	11020
2005*	19933	7908
2006*	2512	5504
2007*	592	213
2008	25	17
2009	7	8
2010	0	280
2011	1613	0

Year\Age	Age 1	Age 2
2012	9476	3265
2013	454	6544
2014	3893	2048
2015	8563	2796
2016	4223	8089
2017	1236	2087
2018	441	1491
2019	3157	215
2020	2 822	481

***Using the old TS-value. To compare the results all values were divided by approximately 3.1.**

Table 2.3.7.2.2. Blue whiting. 1-group indices of blue whiting from the Norwegian winter survey (late January-early March) in the Barents Sea. (Blue whiting < 19 cm in total body length which most likely belong to 1-group.)

Catch Rate		
Year	**All**	**< 19 cm**
1981	0.13	0
1982	0.17	0.01
1983	4.46	0.46
1984	6.97	2.47
1985	32.51	0.77
1986	17.51	0.89
1987	8.32	0.02
1988	6.38	0.97
1989	1.65	0.18
1990	17.81	16.37
1991	48.87	2.11
1992	30.05	0.06
1993	5.80	0.01
1994	3.02	0
1995	1.65	0.10
1996	9.88	5.81

Catch Rate		
Year	All	< 19 cm
1997	187.24	175.26
1998	7.14	0.21
1999	5.98	0.71
2000	129.23	120.90
2001	329.04	233.76
2002	102.63	9.69
2003	75.25	15.15
2004	124.01	36.74
2005	206.18	90.23
2006	269.2	3.52
2007	80.38	0.16
2008	17.97	0.04
2009	4.50	0.01
2010	3.30	0.08
2011	1.48	0.01
2012	127.71	125.93
2013	39.54	2.33
2014	31.48	24.97
2015	148.4	128.34
2016	86.99	11.31
2017	167.16	0.71
2018	9.19	0.03
2019	22.56	11.79
2020	20.96	16.20

Table 2.3.7.2.3. Blue whiting. 1-group indices of blue whiting from the Icelandic bottom-trawl surveys, 1-group (< 22 cm in March).

Catch Rate	
Year	**< 22 cm**
1996	6.5
1997	3.4
1998	1.1
1999	6.3
2000	9
2001	5.2
2002	14.2
2003	15.4
2004	8.9
2005	8.3
2006	30.4
2007	3.9
2008	0.1
2009	1.6
2010	0.2
2011	10.8
2012	29.9
2013	11.7
2014	66.3
2015	43.8
2016	6.3
2017	1.8
2018	0.4
2019	0.1
2020	9.8

Table 2.3.7.2.4. Blue whiting. 1-group indices of blue whiting from Faroese bottom-trawl surveys, 1-group (< 23 cm in March).

Catch Rate	
Year	< 23 cm
1994	1382
1995	1105
1996	4442
1997	1764
1998	360
1999	1330
2000	782
2001	3357
2002	3885
2003	929
2004	15163
2005	23750
2006	13364
2007	11509
2008	840
2009	3754
2010	824
2011	11406
2012	5345
2013	8855
2014	51313
2015	14444
2016	22485
2017	5286
2018	1948
2019	285
2020	140

Table 2.4.2.1. Blue whiting. Parameter estimates, from final assessment (2020) and retrospective analysis (2016-2019).

Parameter Year	2016	2017	2018	2019	2020
Random walk variance					
-F Age 1-10	0.39	0.38	0.38	0.37	0.37
Process error					
-log(N) Age 1	0.58	0.62	0.62	0.61	0.61
--- Age 2-10	0.17	0.18	0.18	0.18	0.18
Observation variance					
-Catch Age 1	0.45	0.44	0.44	0.43	0.43
--- Age 2	0.29	0.28	0.28	0.28	0.27
--- Age 3-8	0.20	0.20	0.19	0.19	0.19
--- Age 9-10	0.40	0.40	0.40	0.39	0.38
-IBWSS Age 1	0.75	0.78	0.74	0.75	0.75
--- Age 2	0.31	0.32	0.31	0.33	0.34
--- Age 3	0.46	0.44	0.42	0.41	0.41
--- Age 4-6	0.45	0.40	0.39	0.37	0.37
--- Age 7-8	0.41	0.48	0.50	0.54	0.55
Survey catchability					
-IBWSS Age 1	0.07	0.06	0.07	0.07	0.06
--- Age 2	0.12	0.12	0.12	0.11	0.11
--- Age 3	0.36	0.38	0.37	0.37	0.36
--- Age 4	0.66	0.70	0.69	0.68	0.67
--- Age 5-8	0.86	0.89	0.87	0.87	0.86
Rho					
--	0.92	0.93	0.93	0.93	0.94

Table 2.4.2.2. Blue whiting. Mohn's rho by year and average over the last five years (n=5).

Year	R(age 1)	SSB	Fbar(3-7)
2015	-0.336	-0.149	0.289
2016	0.233	0.033	-0.057
2017	-0.075	-0.117	0.212
2018	-0.121	-0.118	0.163
2019	0.000	-0.020	0.042
rho.mean	-0.060	-0.074	0.130

Table 2.4.2.3. Blue whiting. Estimated fishing mortalities. Catch data for 2020 are preliminary.

Year Age	1	2	3	4	5	6	7	8	9	10+
1981	0.078	0.118	0.172	0.212	0.245	0.318	0.346	0.443	0.484	0.484
1982	0.067	0.102	0.148	0.183	0.208	0.270	0.293	0.371	0.403	0.403
1983	0.078	0.118	0.171	0.211	0.241	0.315	0.338	0.420	0.446	0.446
1984	0.096	0.143	0.212	0.266	0.306	0.398	0.419	0.510	0.531	0.531
1985	0.101	0.150	0.230	0.295	0.346	0.448	0.466	0.562	0.576	0.576
1986	0.113	0.168	0.268	0.358	0.431	0.552	0.573	0.692	0.704	0.704
1987	0.100	0.150	0.247	0.337	0.414	0.536	0.559	0.673	0.674	0.674
1988	0.098	0.148	0.253	0.349	0.438	0.574	0.588	0.694	0.677	0.677
1989	0.114	0.171	0.304	0.420	0.526	0.686	0.712	0.842	0.806	0.806
1990	0.105	0.159	0.292	0.408	0.511	0.664	0.712	0.849	0.816	0.816
1991	0.059	0.089	0.167	0.235	0.290	0.367	0.395	0.465	0.450	0.450
1992	0.049	0.073	0.140	0.196	0.234	0.286	0.311	0.370	0.363	0.363
1993	0.042	0.063	0.125	0.176	0.206	0.246	0.268	0.319	0.314	0.314
1994	0.036	0.054	0.112	0.159	0.185	0.219	0.241	0.291	0.285	0.285
1995	0.046	0.070	0.149	0.215	0.243	0.284	0.313	0.383	0.368	0.368
1996	0.056	0.085	0.185	0.271	0.297	0.348	0.383	0.473	0.451	0.451
1997	0.054	0.084	0.187	0.279	0.300	0.349	0.381	0.474	0.452	0.452
1998	0.070	0.110	0.251	0.381	0.408	0.474	0.510	0.630	0.593	0.593
1999	0.064	0.101	0.236	0.368	0.396	0.457	0.482	0.592	0.557	0.557
2000	0.074	0.117	0.278	0.445	0.497	0.575	0.589	0.705	0.665	0.665

Year Age	1	2	3	4	5	6	7	8	9	10+
2001	0.070	0.111	0.265	0.429	0.493	0.572	0.574	0.679	0.644	0.644
2002	0.065	0.103	0.250	0.416	0.500	0.592	0.595	0.699	0.664	0.664
2003	0.067	0.107	0.261	0.439	0.542	0.633	0.628	0.709	0.668	0.668
2004	0.069	0.109	0.269	0.460	0.588	0.688	0.686	0.752	0.708	0.708
2005	0.060	0.094	0.238	0.418	0.552	0.646	0.653	0.701	0.663	0.663
2006	0.051	0.082	0.208	0.371	0.504	0.592	0.603	0.637	0.602	0.602
2007	0.048	0.077	0.196	0.355	0.499	0.597	0.623	0.656	0.623	0.623
2008	0.042	0.067	0.170	0.306	0.437	0.522	0.556	0.584	0.561	0.561
2009	0.027	0.044	0.111	0.195	0.281	0.334	0.363	0.379	0.366	0.366
2010	0.019	0.032	0.080	0.137	0.196	0.232	0.254	0.261	0.252	0.252
2011	0.006	0.010	0.024	0.040	0.056	0.065	0.072	0.074	0.073	0.073
2012	0.012	0.020	0.052	0.085	0.119	0.138	0.156	0.164	0.162	0.162
2013	0.020	0.035	0.090	0.149	0.209	0.239	0.273	0.290	0.287	0.287
2014	0.037	0.066	0.176	0.292	0.403	0.459	0.524	0.562	0.553	0.553
2015	0.049	0.086	0.232	0.385	0.525	0.602	0.675	0.724	0.707	0.707
2016	0.042	0.074	0.198	0.333	0.453	0.525	0.585	0.627	0.610	0.610
2017	0.040	0.070	0.189	0.317	0.425	0.489	0.535	0.570	0.555	0.555
2018	0.039	0.069	0.188	0.316	0.421	0.483	0.529	0.563	0.548	0.548
2019	0.036	0.063	0.173	0.293	0.386	0.440	0.481	0.512	0.497	0.497
2020	0.045	0.078	0.215	0.365	0.479	0.545	0.599	0.640	0.618	0.618

Table 2.4.2.4. Blue whiting. Estimated stock numbers-at-age (thousands). Preliminary catch data for 2020 have been used.

Year Age	1	2	3	4	5	6	7	8	9	10+
1981	3957322	3489739	4854972	2065979	2614542	2139251	1643260	1743521	1225865	2975946
1982	4693398	2970934	2521470	3288892	1583580	1495334	1292773	1013457	890323	1941761
1983	18181946	3802399	1878891	1820333	1900567	1217877	1014672	855134	629325	1255912
1984	18057318	14506280	2445488	1233494	1261705	1396380	814834	549303	481906	923880
1985	9628473	13540999	9778114	1451846	749201	912758	745912	457685	264904	721686
1986	7242024	6401799	9413565	5551032	946025	451780	468785	375549	230722	498164
1987	9098048	5046259	4084300	6875450	2567269	394106	253680	237951	156379	293043
1988	6425056	6861058	3518414	2876446	3727398	1275068	199370	125554	99164	170230
1989	8511756	4628225	4992481	2426867	2131107	1686808	351034	103098	60814	115198
1990	18623678	5974494	3095519	2729757	1481267	1186503	560262	120893	33108	85596
1991	9002675	15566858	4258772	1787099	1490726	875378	563265	188301	32202	45478
1992	6723250	7441617	12474420	3306435	1258816	788954	486282	287705	101643	39141
1993	4998200	5137324	5294784	9722312	2261671	976954	517123	281785	157072	74264
1994	8148170	3399914	4077789	3396923	6939360	1438649	766045	328605	207238	115840
1995	9362066	5890028	3138122	2569503	2857808	3743702	1041845	545548	221316	184826
1996	28034940	7123125	4080490	2396115	1548699	1862607	2239666	646440	307312	249541
1997	44725598	21321139	5504031	2569826	1417099	1065693	1060692	1213227	288353	337022

Year Age	1	2	3	4	5	6	7	8	9	10+
1998	26724248	37873149	16434306	3499188	1373239	926111	783070	605224	617371	292586
1999	20359418	20546053	27680822	10579753	1707285	771721	519136	411176	236370	427894
2000	39255183	15303295	16598018	15821130	4342781	1111494	472900	323815	153448	313917
2001	55761819	31726262	12089094	10750048	7456817	1694176	489109	227465	163697	178113
2002	48895382	45307964	20438307	8318248	5458100	3394178	688059	256080	103005	154666
2003	52993568	39136408	35061195	13611508	5092905	2979654	1204953	345798	89080	107092
2004	28800650	42387475	30065499	20885180	7293341	2476605	1317926	502039	151737	80498
2005	22282661	21838601	28601857	18173003	10818542	3245612	1114934	515230	192201	98879
2006	9064943	15531344	22303629	19373722	9552994	4494242	1364758	485012	219098	120453
2007	4960888	6038015	13158471	15990860	10397135	4744134	1851627	613760	230388	164103
2008	5944464	3516588	4369307	11132684	9268106	4972044	1876451	761492	237644	202566
2009	5794358	4099827	2451029	3747407	7050758	4785985	2227533	868557	329440	191942
2010	15473168	5119277	2388694	1881875	3432417	4429064	2899397	1218840	421069	271434
2011	19647386	13564563	3362966	1679379	1646744	2664011	2747473	1368043	829001	399538
2012	19399347	15718811	12712845	2314738	1206670	1645367	2380410	2148962	1096107	914883
2013	16169499	16243351	11772431	7468821	2270594	1112147	1402439	1657863	1367804	1404005
2014	37230666	12842914	14022794	8127627	4452286	1367506	953262	1017784	1037089	1515358
2015	63695809	33279395	10954651	8616338	4291560	1772309	752903	530008	496325	1081099

Year Age	1	2	3	4	5	6	7	8	9	10+
2016	34888644	57860038	21711361	7837557	4453808	1864582	730271	362627	229704	615299
2017	11735400	28692060	46393085	15585864	4756946	2262907	775206	296291	170341	398032
2018	11679974	9113899	22773093	30644893	9392707	2672828	1017678	336146	155752	292155
2019	10145773	8756999	8619260	15408297	17672969	5250964	1314734	437472	159319	231967
2020	17925568	7615374	6543115	6708796	9143821	8679178	2824765	777733	189829	210776
2021		14036236	5764845	4320417	3812664	4636311	4121523	1270686	335703	176806

Table 2.4.2.5. Blue whiting. Estimated recruitment (R) in thousands, spawning-stock biomass (SSB) in tonnes, average fishing mortality for ages 3 to 7 (Fbar 3-7) and total-stock biomass (TBS) in tonnes. Preliminary catch data for 2020 are included.

Year	R(age 1)	Low	High	SSB	Low	High	Fbar(3-7)	Low	High	TSB	Low	High
1981	3957322	2540278	6164834	2845488	2232351	3627027	0.259	0.188	0.356	3343972	2673066	4183266
1982	4693398	2978221	7396359	2301321	1826705	2899252	0.220	0.163	0.298	2771973	2239181	3431536
1983	18181946	11793619	28030678	1855241	1505755	2285843	0.255	0.191	0.340	2883054	2342066	3549003
1984	18057318	11824046	27576577	1753978	1447345	2125575	0.320	0.244	0.421	3088192	2486524	3835446
1985	9628473	6333315	14638069	2092477	1722997	2541189	0.357	0.274	0.464	3233510	2633915	3969599
1986	7242024	4795267	10937224	2273644	1876035	2755523	0.436	0.337	0.565	3115330	2576333	3767092
1987	9098048	6010796	13770967	1933331	1597602	2339612	0.419	0.322	0.544	2817823	2333505	3402661
1988	6425056	4242157	9731218	1639304	1366293	1966867	0.440	0.339	0.571	2427862	2019034	2919474
1989	8511756	5599097	12939585	1547399	1293881	1850590	0.530	0.410	0.684	2393477	1981004	2891832
1990	18623678	12067196	28742500	1355825	1123181	1636656	0.517	0.394	0.680	2490258	1986610	3121590
1991	9002675	5764336	14060276	1775078	1421100	2217227	0.291	0.214	0.395	3215083	2511180	4116296
1992	6723250	4360685	10365822	2456884	1940172	3111208	0.233	0.172	0.318	3528611	2789388	4463737
1993	4998200	3203687	7797893	2542322	2016565	3205155	0.204	0.151	0.277	3422585	2733756	4284979
1994	8148170	5271609	12594387	2536056	2033675	3162541	0.183	0.135	0.250	3419060	2767399	4224173
1995	9362066	6120492	14320463	2311551	1896673	2817180	0.241	0.181	0.321	3361626	2759155	4095649
1996	28034940	18370286	42784193	2210252	1831448	2667406	0.297	0.225	0.392	3728476	3026212	4593707
1997	44725598	29370182	68109184	2466370	2039600	2982438	0.299	0.227	0.394	5431372	4259792	6925174

Year	R(age 1)	Low	High	SSB	Low	High	Fbar(3-7)	Low	High	TSB	Low	High
1998	26724248	17662958	40434076	3682009	3002195	4515758	0.405	0.311	0.527	6827399	5443897	8562501
1999	20359418	13389190	30958253	4448140	3612411	5477216	0.388	0.298	0.506	7180850	5822775	8855676
2000	39255183	25751761	59839380	4235816	3510177	5111462	0.477	0.369	0.615	7465559	6072934	9177537
2001	55761819	36892189	84282894	4577749	3809022	5501620	0.467	0.361	0.603	9014170	7254280	11201010
2002	48895382	32317499	73977208	5405309	4490236	6506867	0.471	0.363	0.610	10339364	8349834	12802943
2003	52993568	35480553	79150916	6880604	5696134	8311376	0.501	0.392	0.640	11863582	9699850	14509974
2004	28800650	19202255	43196876	6791916	5684725	8114751	0.538	0.424	0.684	10429351	8678702	12533136
2005	22282661	14889744	33346241	6055782	5073301	7228528	0.501	0.391	0.642	8541270	7137338	10221358
2006	9064943	5992001	13713814	5917460	4935259	7095137	0.455	0.353	0.588	7767939	6480256	9311494
2007	4960888	3266725	7533665	4703578	3909457	5659008	0.454	0.348	0.593	5747215	4786524	6900724
2008	5944464	3862982	9147506	3630450	2973117	4433114	0.398	0.296	0.535	4460271	3668178	5423404
2009	5794358	3642868	9216523	2795836	2229162	3506565	0.257	0.186	0.355	3521752	2827534	4386416
2010	15473168	9994421	23955257	2733239	2136290	3496996	0.180	0.127	0.254	3819177	3013063	4840958
2011	19647386	12798884	30160426	2753922	2166841	3500066	0.051	0.035	0.075	4514423	3553617	5735008
2012	19399347	12844864	29298453	3498827	2825110	4333209	0.110	0.082	0.148	5196215	4189355	6445060
2013	16169499	10733154	24359353	3821120	3147113	4639476	0.192	0.145	0.254	5661435	4639119	6909037
2014	37230666	24445788	56701895	4063545	3384144	4879342	0.371	0.283	0.486	6710317	5473437	8226706
2015	63695809	41772298	97125518	4251496	3521915	5132213	0.484	0.373	0.627	8267418	6572122	10400022

Year	R(age 1)	Low	High	SSB	Low	High	Fbar(3-7)	Low	High	TSB	Low	High
2016	34888644	22485578	54133253	5014269	4038626	6225606	0.419	0.318	0.552	9269532	7258837	11837187
2017	11735400	7189336	19156097	6266824	4913563	7992792	0.391	0.290	0.528	9034929	7018865	11630077
2018	11679974	6724704	20286662	6206072	4706773	8182958	0.387	0.271	0.553	8124813	6110876	10802476
2019	10145773	4949635	20796831	5387150	3790692	7655961	0.355	0.224	0.562	7057799	4888659	10189405
2020	17925568	6568567	48918733	4214250	2585528	6868966	0.441	0.236	0.824	5846514	3455778	9891181
2021				3248023*						4859014*		

***assuming long term GM(1981-2019) recruitment (14751018) in 2021 and weight at age as used for 2020 (preliminary catch data)**

Table 2.4.6. Blue whiting. Model estimate of total catch weight (in tonnes) and Sum of Product of catch number and mean weight at age for ages 1-10+ (Observed catch). Preliminary catch data for 2020 are included.

Year	Estimate	Low	High	Observed
1981	787308	563337	1100326	922980
1982	543109	412244	715517	550643
1983	512368	395589	663619	553344
1984	563653	434824	730652	615569
1985	639188	501565	814573	678214
1986	760632	597287	968648	847145
1987	637579	500965	811448	654718
1988	569521	448173	723725	552264
1989	619780	491071	782222	630316
1990	552813	435187	702233	558128
1991	406830	316193	523448	364008
1992	438679	345491	557004	474592
1993	440589	345323	562136	475198
1994	424106	330543	544153	457696
1995	508525	402970	641730	505176
1996	598340	474249	754901	621104
1997	639214	502628	812916	639681
1998	1080286	844264	1382291	1131955
1999	1245122	968306	1601075	1261033
2000	1502155	1177051	1917053	1412449
2001	1560956	1222689	1992809	1771805
2002	1707715	1338263	2179163	1556955
2003	2204215	1735617	2799328	2365319
2004	2321682	1835652	2936400	2400795
2005	2000723	1583907	2527227	2018344
2006	1856156	1469251	2344946	1956239
2007	1558008	1231223	1971527	1612269
2008	1168430	916486	1489634	1251851

Year	Estimate	Low	High	Observed
2009	655131	512725	837089	634978
2010	479696	369590	622604	539539
2011	135746	100184	183931	103771
2012	327167	258846	413522	375692
2013	591402	467158	748689	613863
2014	1110886	871693	1415713	1147650
2015	1354241	1072365	1710209	1390656
2016	1246768	984179	1579419	1180786
2017	1480424	1167180	1877736	1555069
2018	1688827	1325517	2151716	1709856
2019	1524159	1195250	1943578	1512026
2020	1489070	1164489	1904122	1478358

Table 2.8.2.1.1. Blue whiting. Input to short-term projection (median values for exploitation pattern and stock numbers).

Age	Mean weight in the stock and catch (kg) in 2020	Mean weight in the stock and catch (kg) in 2021+	Proportion mature	Natural mortality	Exploitation pattern	Stock numbers (2021) (thousands)
Age 1	0.057	0.060	0.11	0.20	0.101	14751018
Age 2	0.073	0.079	0.40	0.20	0.178	14036236
Age 3	0.093	0.094	0.82	0.20	0.488	5764845
Age 4	0.113	0.107	0.86	0.20	0.829	4320417
Age 5	0.125	0.118	0.91	0.20	1.088	3812664
Age 6	0.134	0.131	0.94	0.20	1.236	4636311
Age 7	0.139	0.142	1.00	0.20	1.359	4121523
Age 8	0.152	0.161	1.00	0.20	1.453	1270686
Age 9	0.177	0.173	1.00	0.20	1.403	335703
Age 10	0.218	0.221	1.00	0.20	1.403	176806

Table 2.8.2.1.2. Blue whiting. Deterministic forecast, intermediate year assumptions and recruitments.

Variable	Value	Notes
$F_{ages\ 3–7}$ (2020)	0.441	From the assessment (preliminary 2020 catches)
SSB (2021)	3248023	From forecast; in tonnes
Rage 1 (2020)	17925568	From the assessment; in thousands
Rage 1 (2021-2022)	14751018	GM (1981–2019); in thousands
Total catch (2020)	1478358	Preliminary 2020 catches as estimated by ICES, based on declared quotas and expected uptake; in tonnes.

Table 2.8.2.2.1. Blue whiting. Deterministic forecast (weights in tonnes).

Basis	Catch (2021)	F (2021)	SSB (2022)	% SSB change*	% Catch change**	% Advice change***
Long-term management strategy						
Catch (2021) = Advice (2020) -20 %	929292	0.360	3046216	-6.2	-37.1	-20.0
MSY approach: FMSY	841717	0.320	3127644	-3.7	-43.1	-27.5
F = 0	0	0.000	3921194	20.7	-100.0	-100.0
Fpa	1265493	0.530	2735932	-15.8	-14.4	8.9
Flim	1810385	0.880	2243305	-30.9	22.5	55.9
SSB (2022) = Blim	2677773	1.814	1500000	-53.8	81.1	130.5
SSB (2022 = Bpa	1802838	0.874	2250000	-30.7	21.9	55.2
SSB (2022) = MSY Btrigger	1802838	0.874	2250000	-30.7	21.9	55.2
F = F (2020)	1095465	0.441	2892329	-11.0	-25.9	-5.7
SSB (2022) = SSB (2021)	712737	0.264	3248040	0.0	-51.8	-38.6
Catch (2021) = Catch (2020)	1478380	0.654	2541771	-21.7	0.0	27.3
Catch (2021) = Catch (2020) -20 %	1182686	0.485	2811956	-13.4	-20.0	1.8
Catch (2021) = Catch (2020) +25%	1847948	0.909	2209901	-32.0	25.0	59.1
Catch (2021) = Advice (2020) -20 %	929292	0.360	3046216	-6.2	-37.1	-20.0

*) SSB 2022 relative to SSB 2021.

**) Catch 2021 relative to expected catch in 2020 (1478358 tonnes).

***) Catch 2020 relative to advice for 2020 (1161615 tonnes).

2.18 Figures

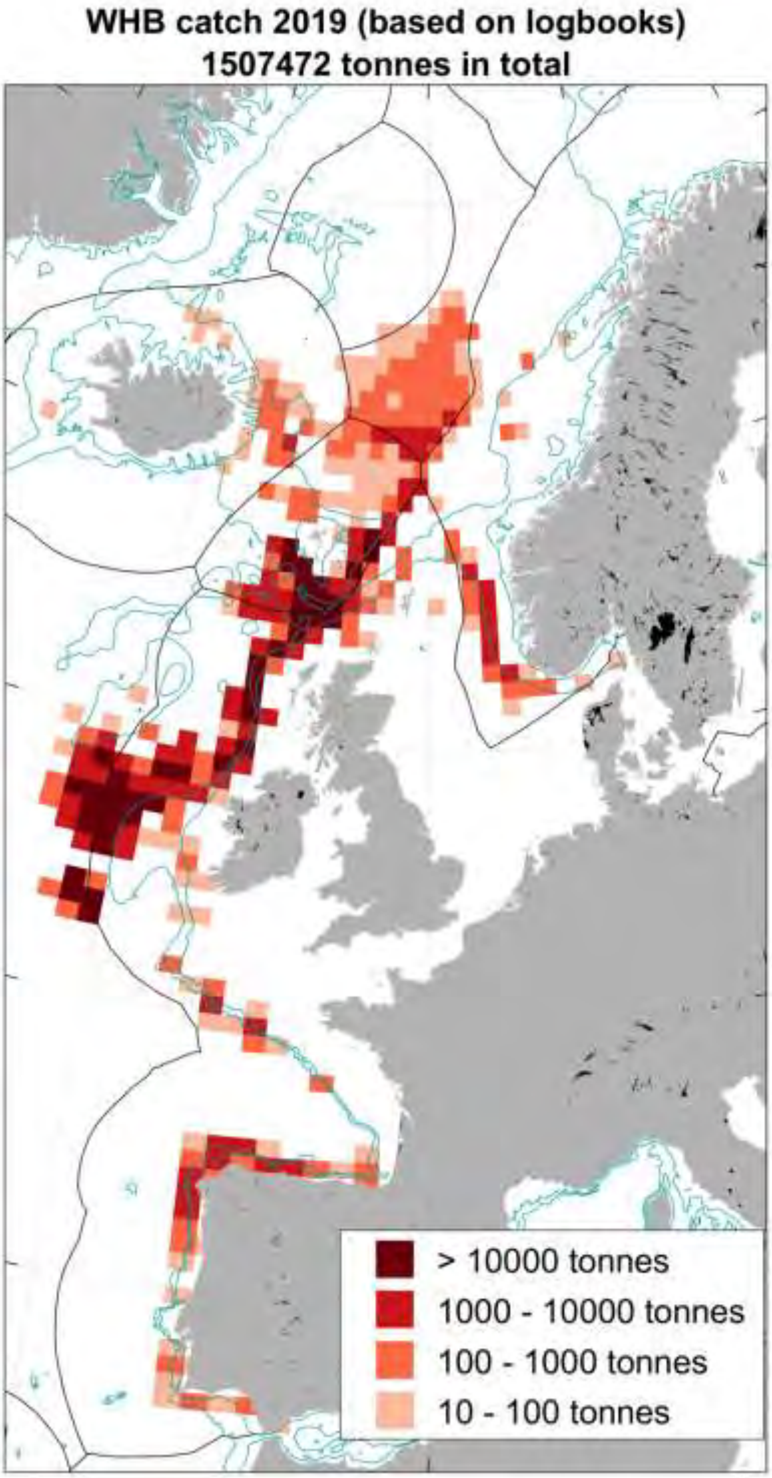


Figure 2.2.1. Blue whiting landings in 2019, based on logbook data. The catches on the map constitute 99.5 % of the ICES estimated catches. The 200 m and 1000 m depth contours are indicated in blue.

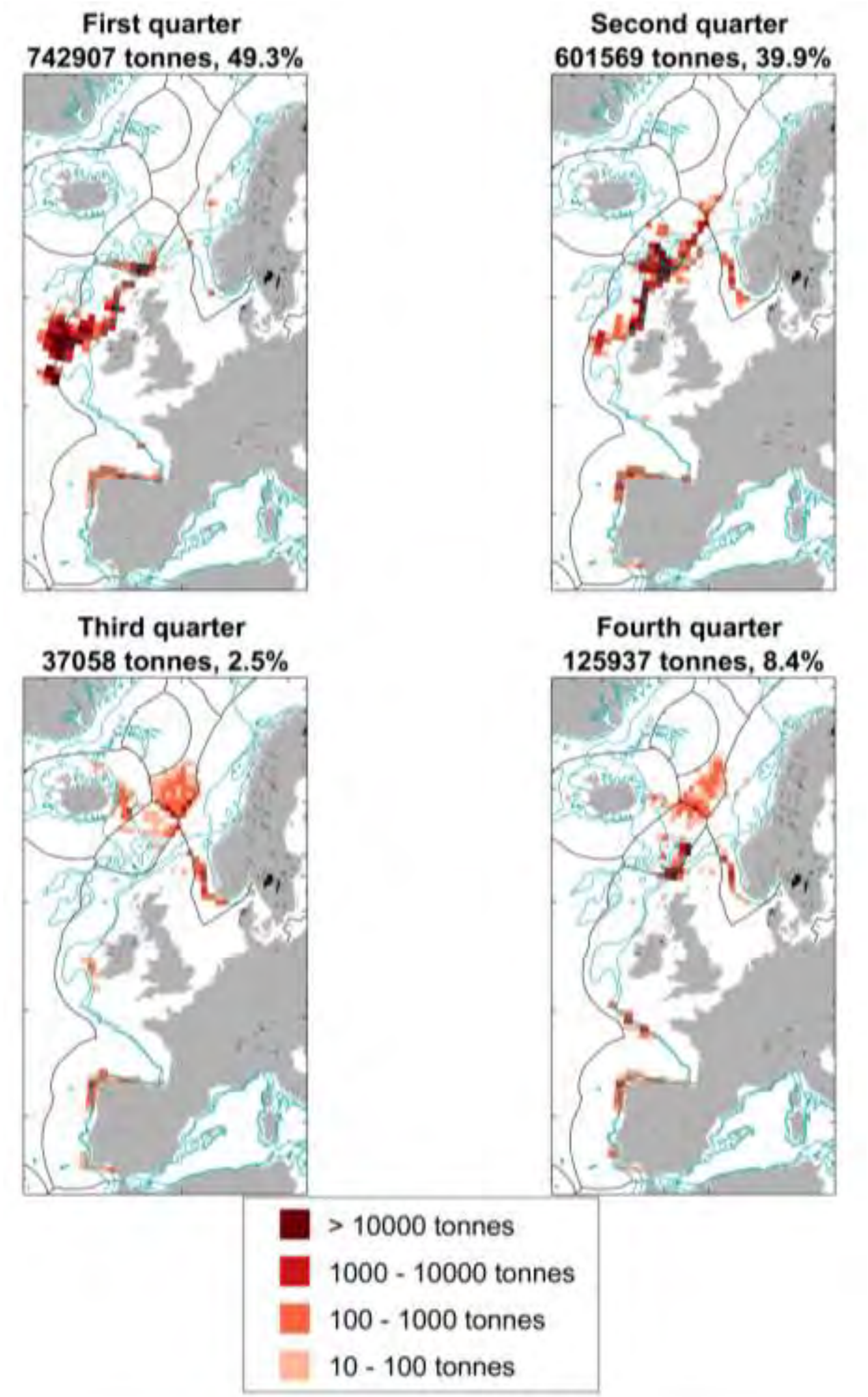


Figure 2.2.2. Blue whiting catches per quarter 2019. The catches on the map are based on logbook data and constitute 99.5 % of the ICES estimated catches. The total catches and percentages shown on each panel are also based on logbook data, and therefore deviate slightly from the ICES estimated catches pr. quarter. The 200 m and 1000 m depth contours are indicated in blue.

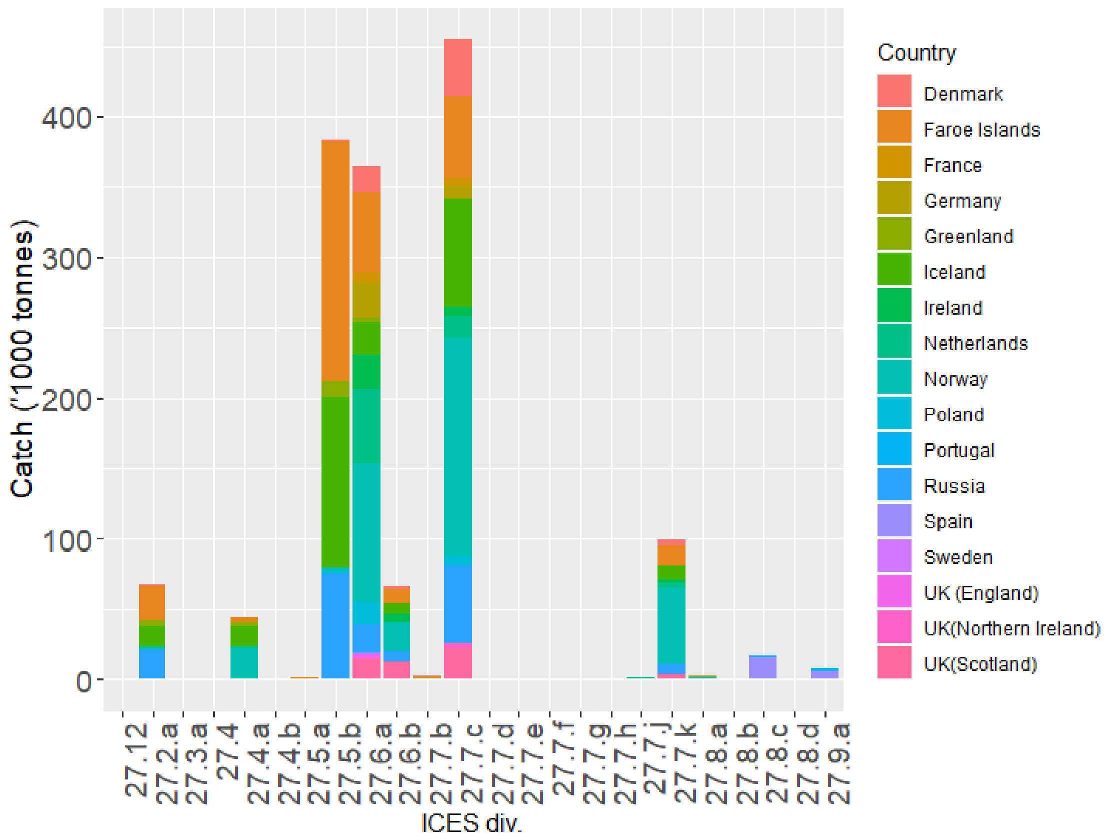
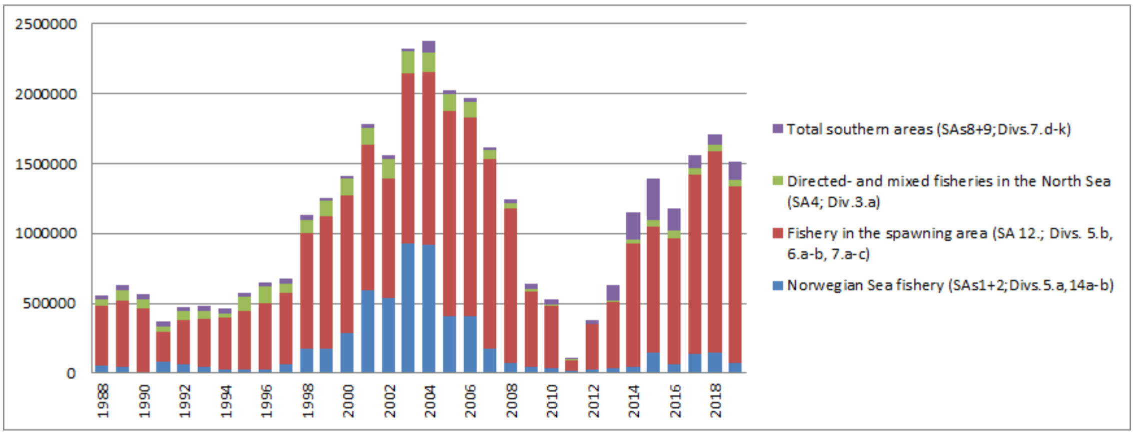


Figure 2.3.1.1. Blue whiting. ICES estimated catches ('1000 tonnes) in 2019 by ICES division and country.

A



B

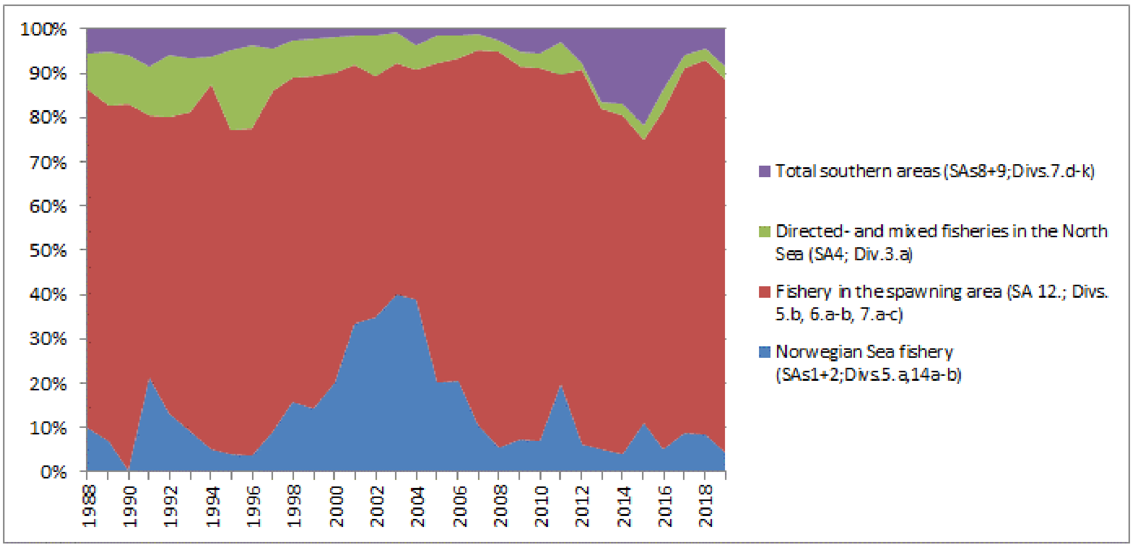


Figure 2.3.1.2. Blue whiting.(A) ICES estimated catches (tonnes) of blue whiting by fishery subareas from 1988-2019 and (B) the percentage contribution to the overall catch by fishery subarea over the same period.

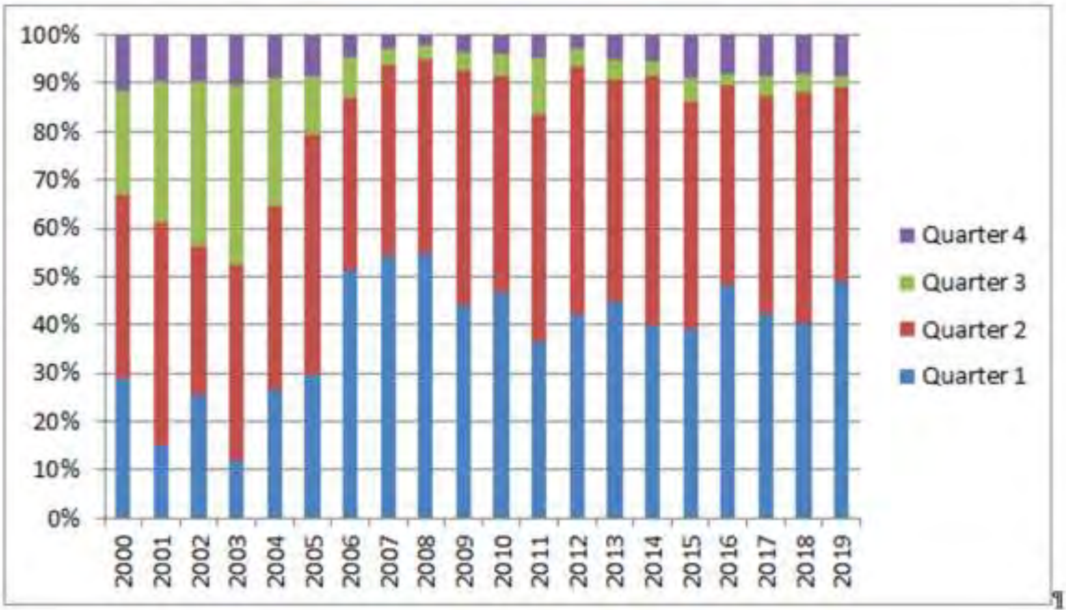


Figure 2.3.1.3. Blue whiting. Distribution of 2019 ICES estimated catches (in percentage) by ICES division area.

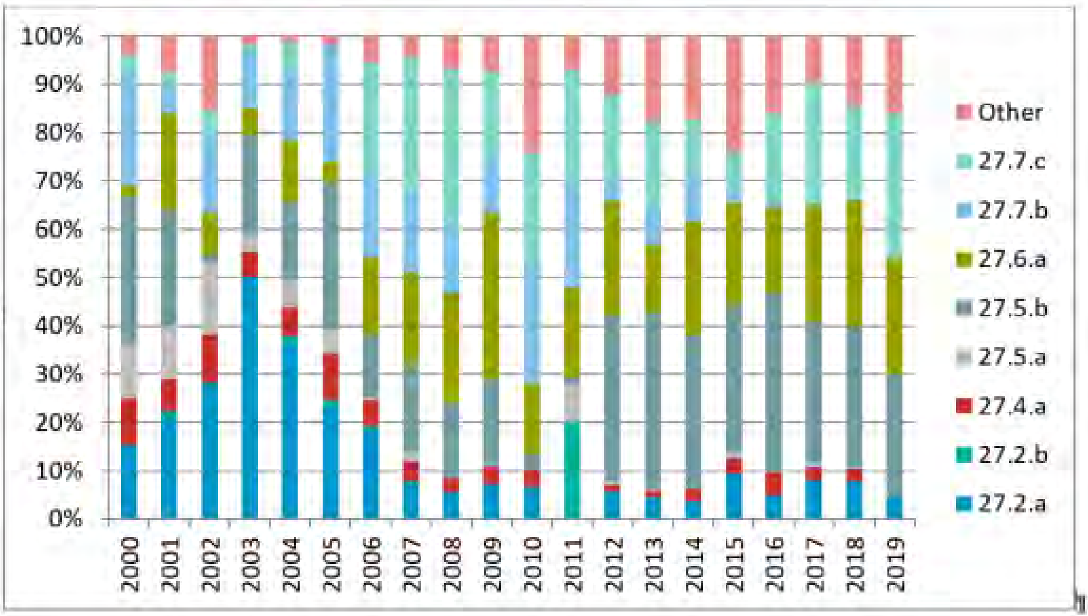


Figure 2.3.1.4. Blue whiting. Distribution of 2019 ICES estimated catches (in percentage) by quarter.

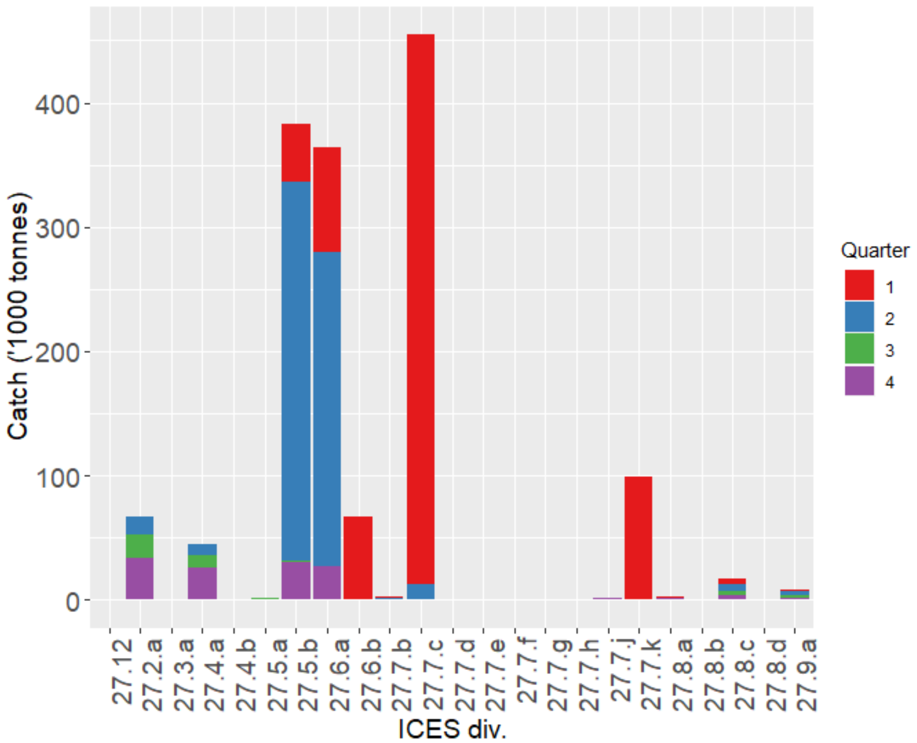


Figure 2.3.1.6. Blue whiting. Distribution of 2019 ICES estimated catches ('1000 tonnes) by ICES division and by quarter.

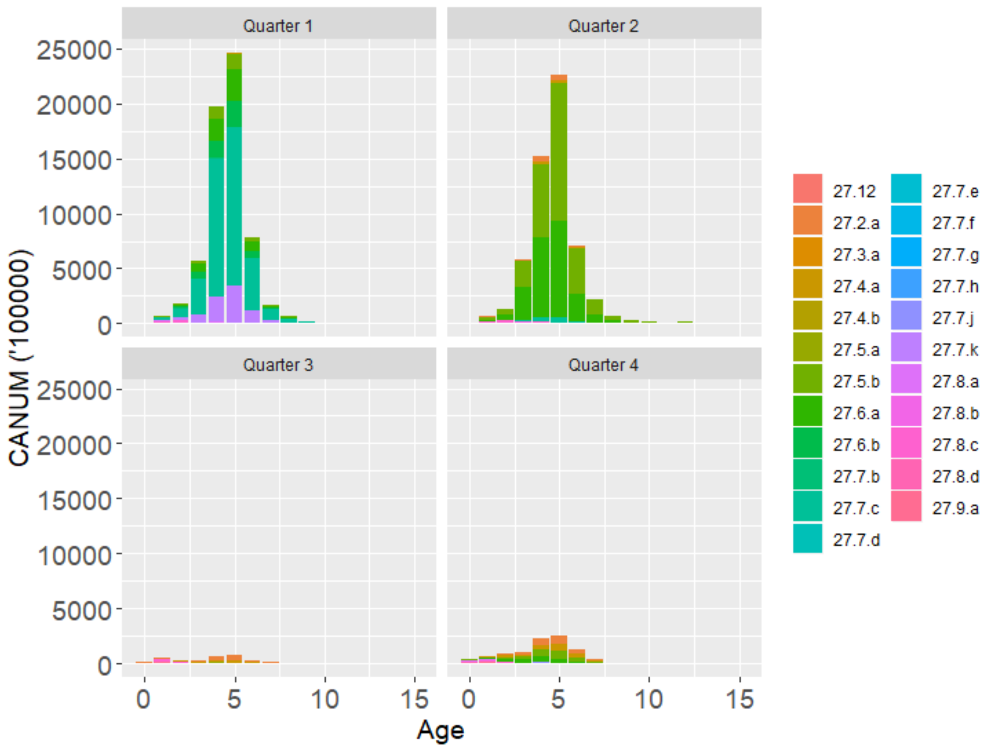


Figure 2.3.1.7. Blue whiting. Catch-at-age numbers (CANUM) distribution by quarter and ICES division for 2019.

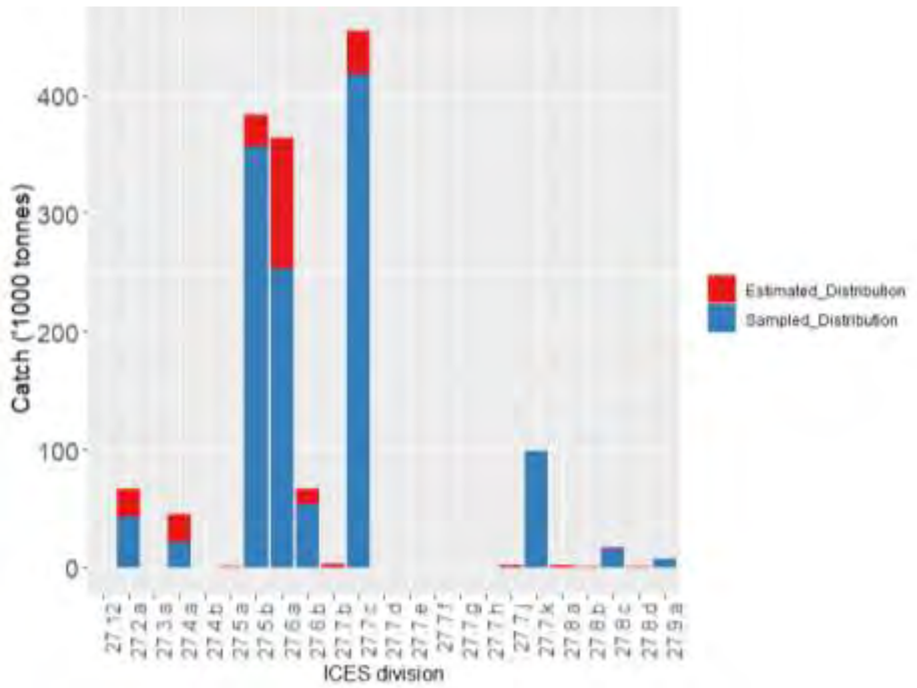


Figure 2.3.1.1.1. Blue whiting. 2019 ICES catches ('1000 tonnes) based on sampled or estimated distribution by ICES division.

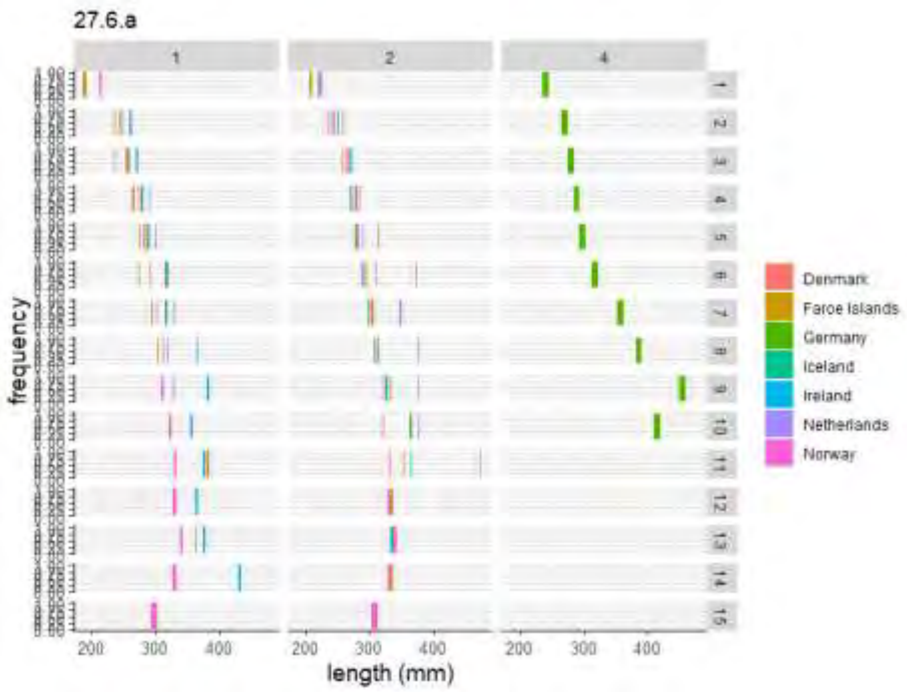


Figure 2.3.1.2.1. Blue whiting. Mean length (mm) by age (0-15 year), by quarter (1,2,4), by country for ICES division area 27.6.a. These data only comprises the 2019 ICES catch-at-age sampled estimates for ICES division 27.6.a.

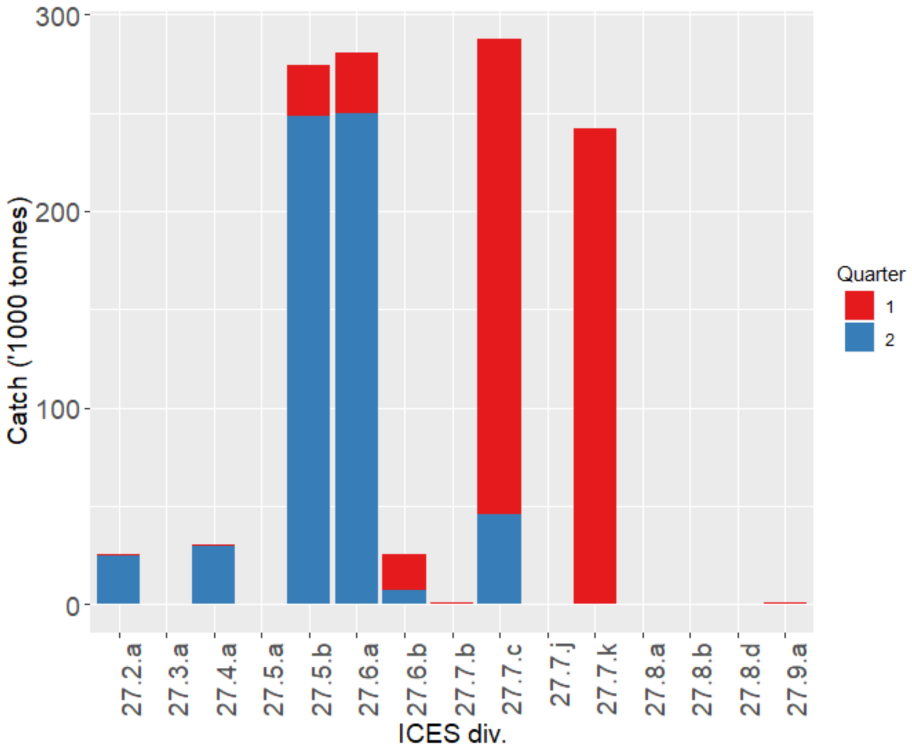


Figure 2.3.2.1. Blue whiting. Distribution of 2020 ICES preliminary estimated catches (tonnes) (1st semester) by ICES division and quarter.

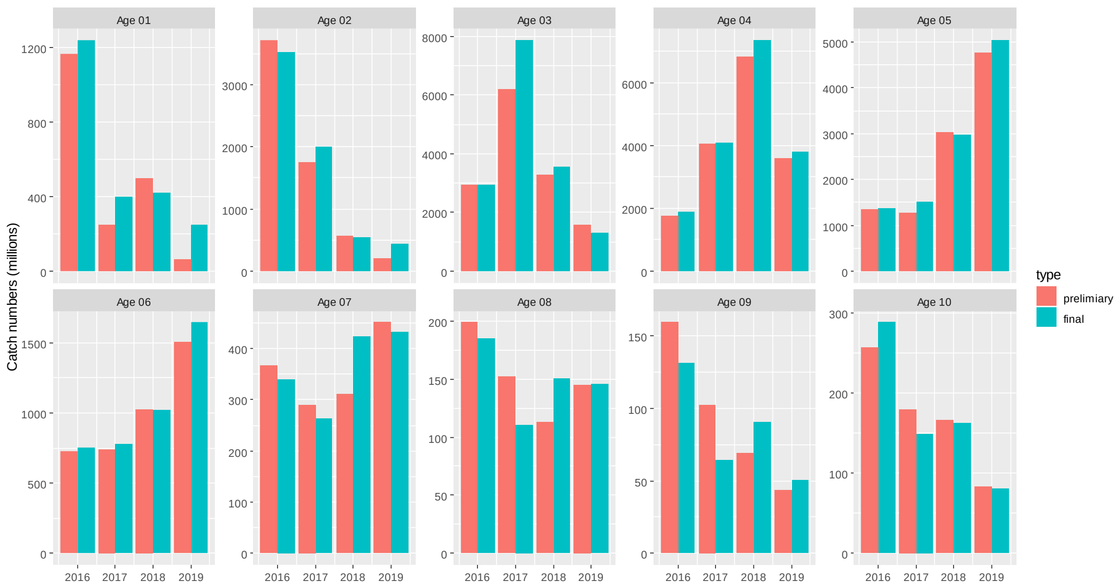


Figure 2.3.2.2 Preliminary and final estimates of catch at age number by age and year.

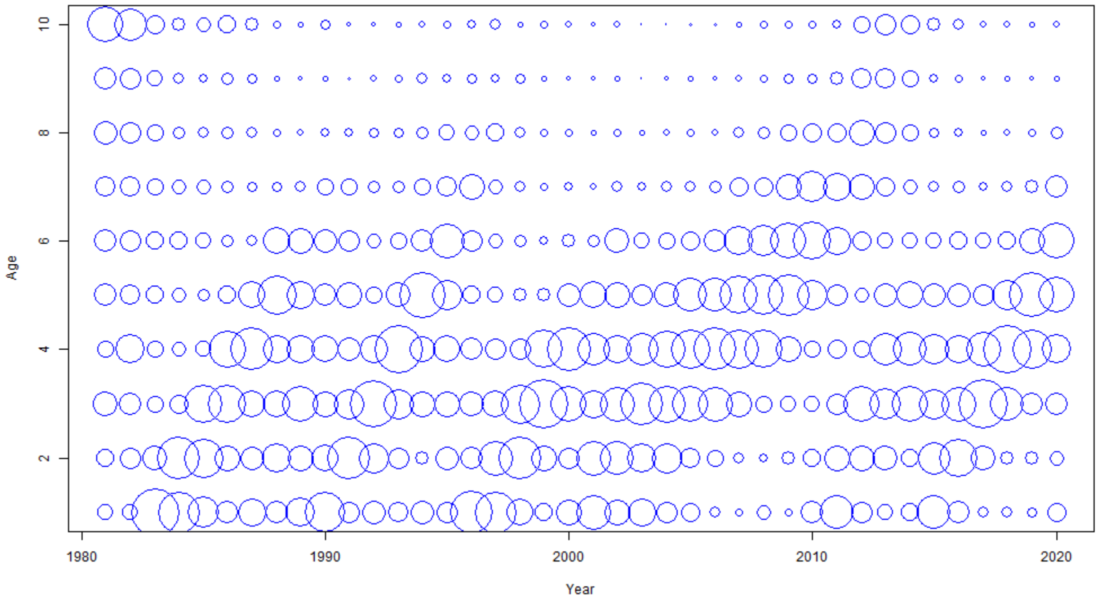


Figure 2.3.3.1. Blue whiting. Catch proportion at age, 1981-2020. Preliminary values for 2020 have been used.

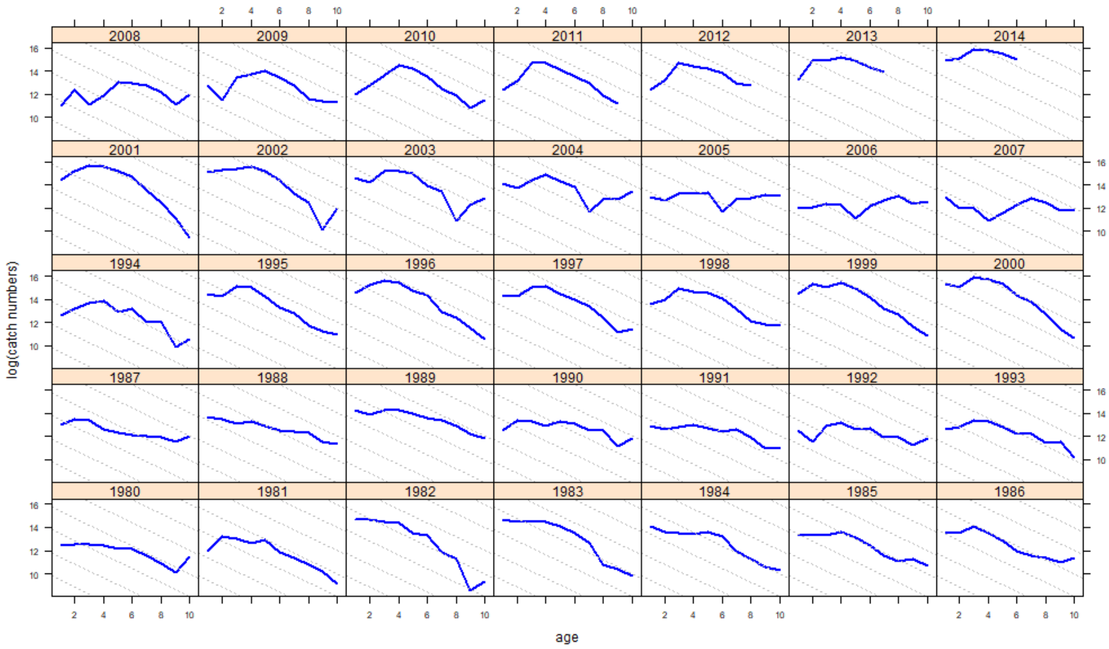


Figure 2.3.3.2. Blue whiting. Age disaggregated catch (numbers) plotted on log scale. The labels for each panel indicate year classes. The grey dotted lines correspond to *Z*=0.6. Preliminary catch-at-age data for 2020 have been used.

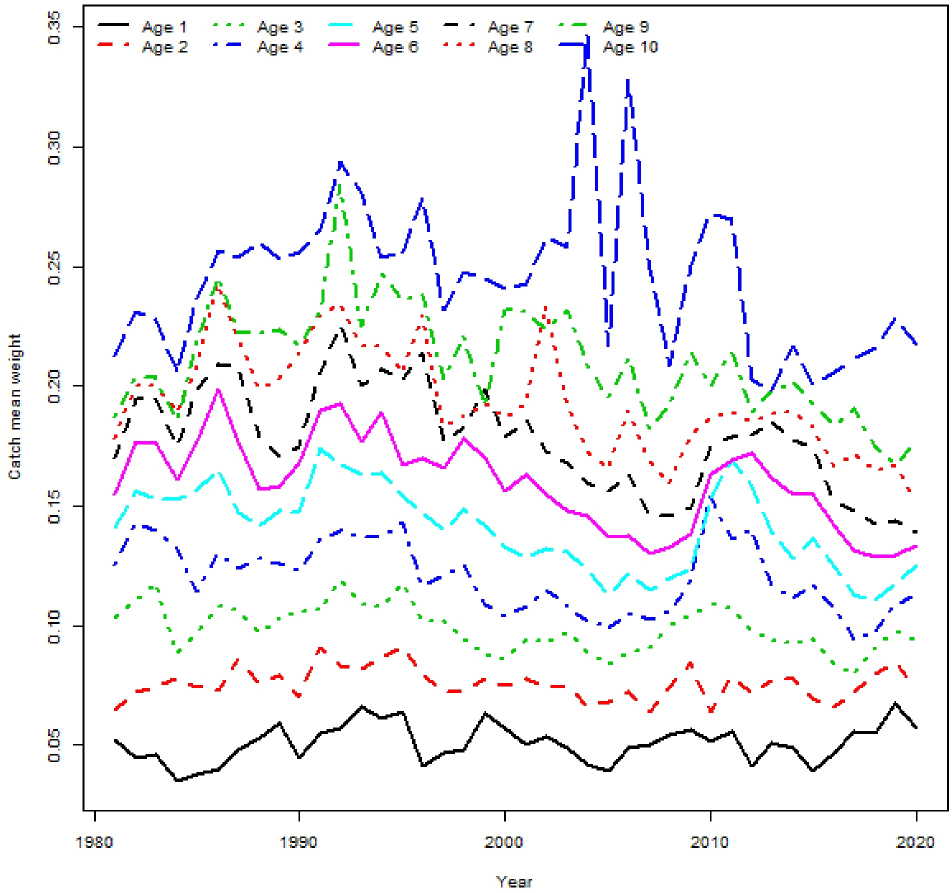


Figure 2.3.4.1. Blue whiting. Mean catch (and stock) weight (kg) at age by year. Preliminary values for 2020 have been used

A **B**

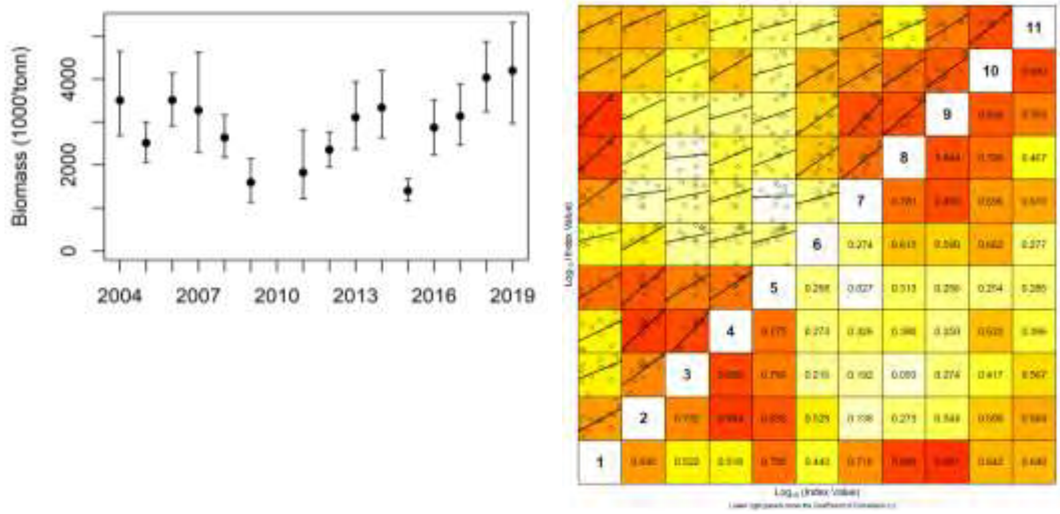
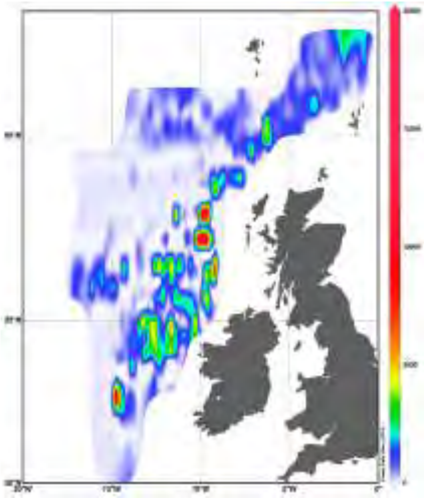
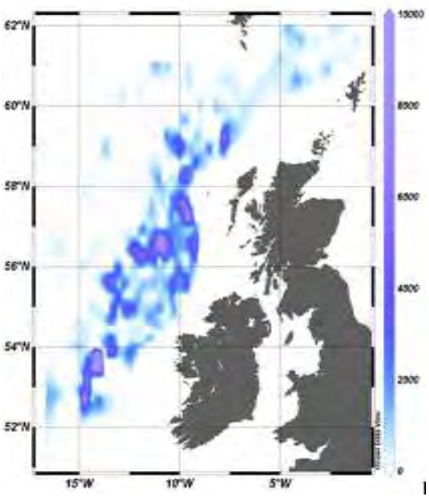


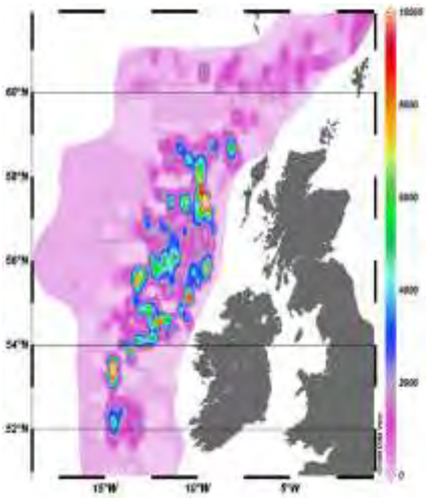
Figure 2.3.7.1.1. Blue whiting – Not updated in 2020. (A) Estimate of total biomass from the International blue whiting spawning stock survey. The black dots and error bands are StoX estimates with 90 % confidence intervals. (B) Internal consistency within the International blue whiting spawning stock survey. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.



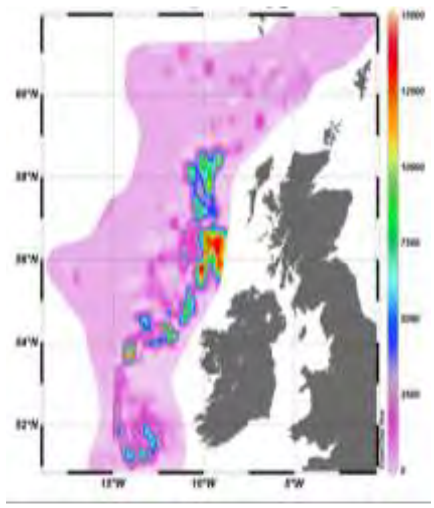
2016



2017



2018



2019

Figure 2.3.7.1.2. Map of blue whiting acoustic density (sA, m2/nm2) found during the spawning survey in spring 2016—2019. – Not updated in 2020.

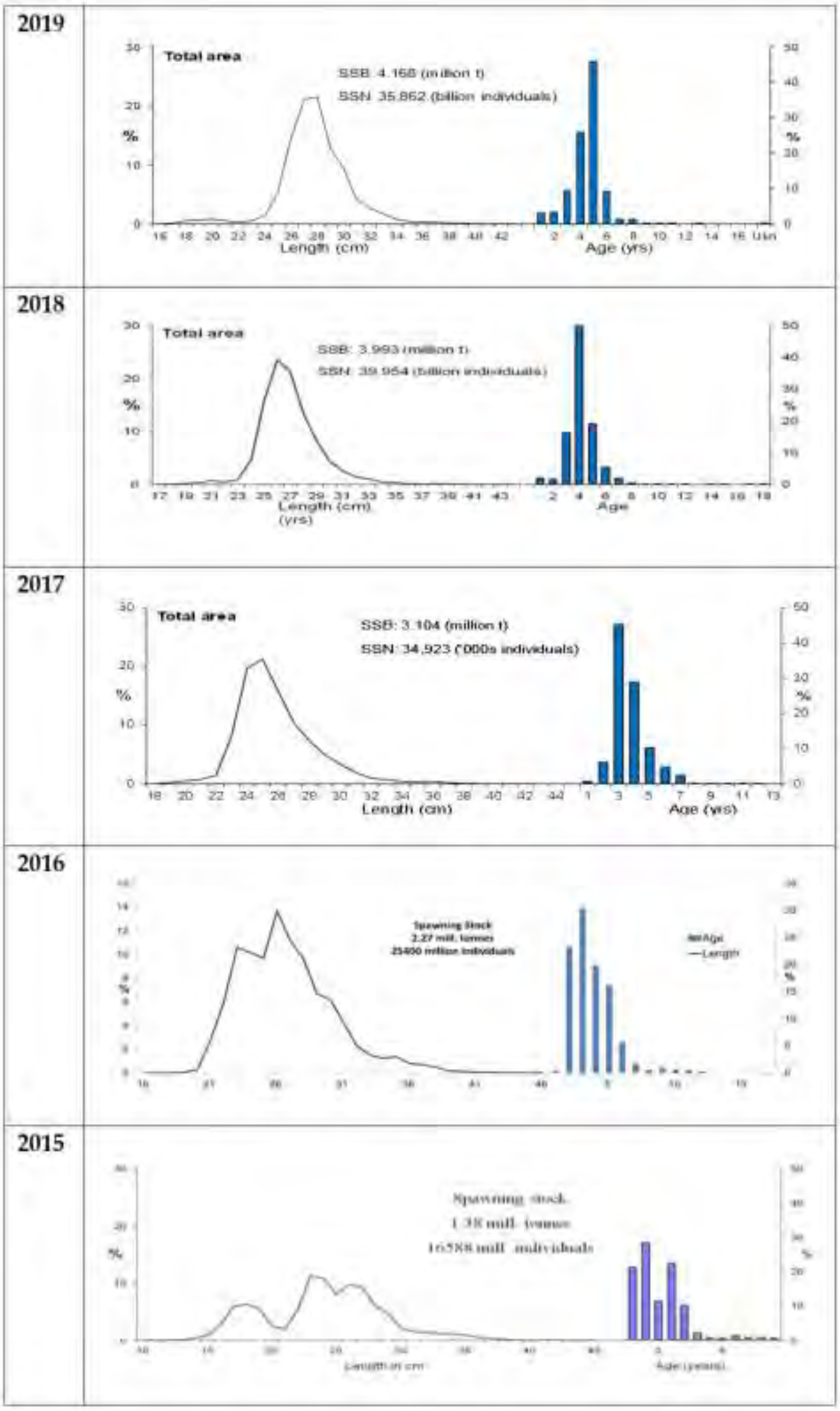


Figure 2.3.7.1.3. Blue whiting – Not updated in 2020. Length (line) and age (bars) distribution of the blue whiting stock in the area to the west of the British Isles, spring 2015 (lower panel) to 2019 (upper panel).Spawning-stock biomass and numbers are given.

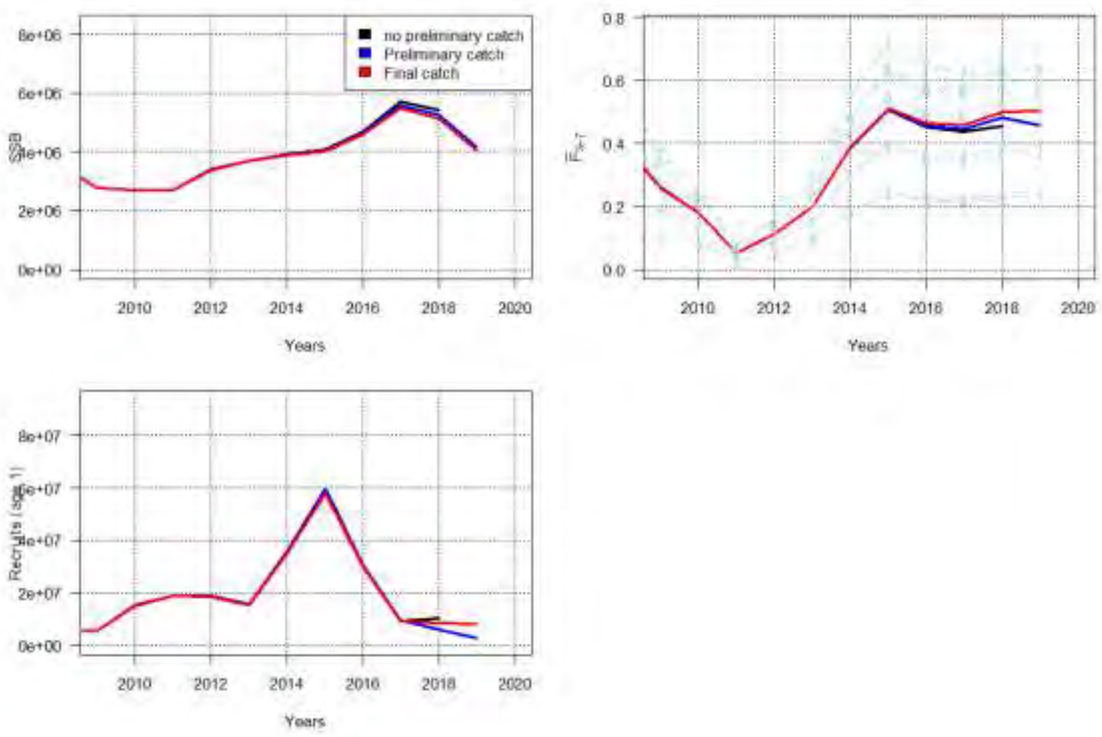


Figure 2.4.1.1. Blue whiting. Scenario results with 2018 as the last survey year, and 1) no preliminary catch at age data for 2019, 2) preliminary catch at data for 2019 and 3) final catch at age data for 2019.

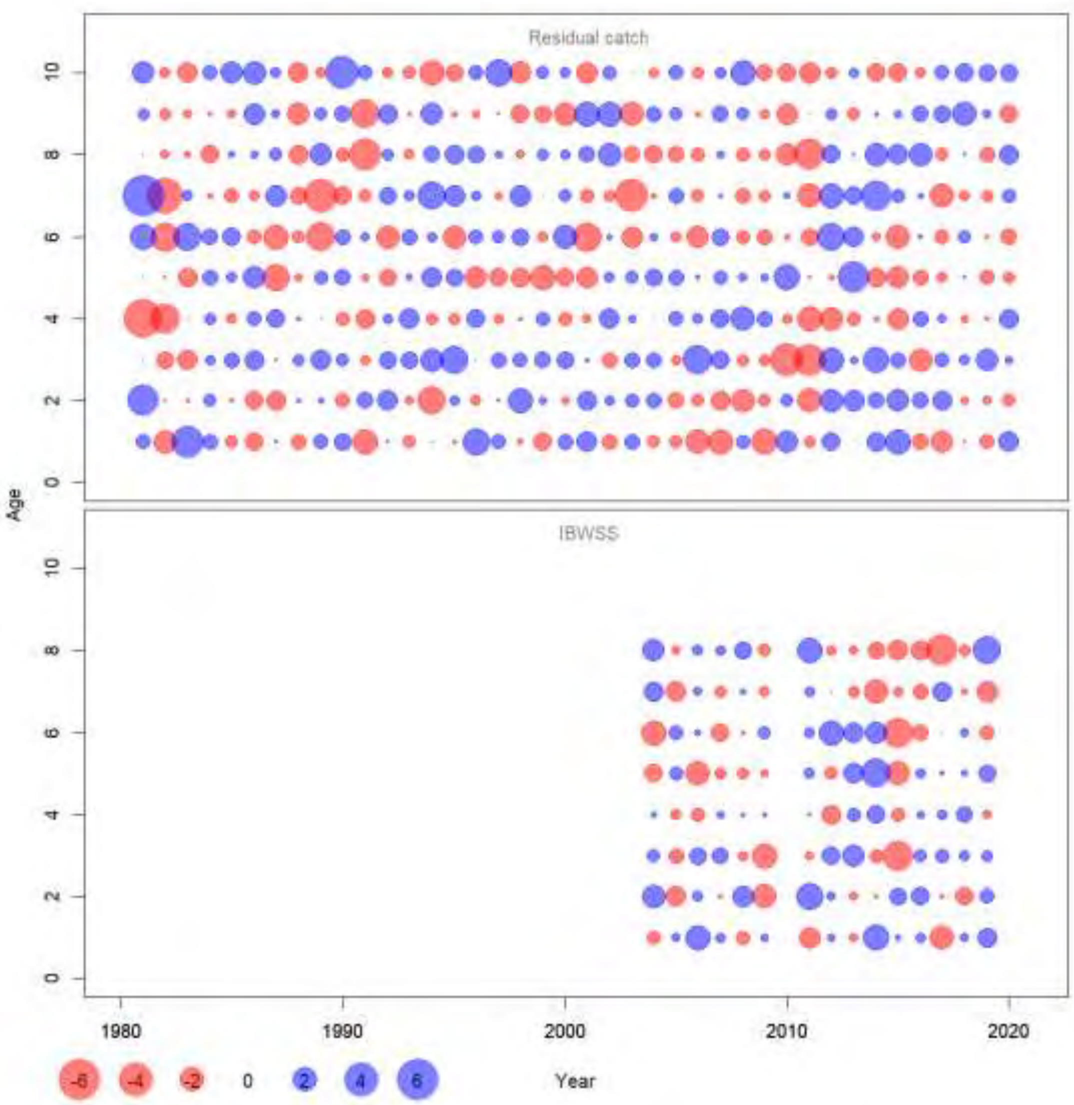


Figure 2.4.2.1. Blue Whiting. OSA (One Step Ahead) residuals (see Berg and Nielsen, 2016) from catch-at-age and the IBWSS survey 2004-2019 (no survey in 2020). Red (lighter) bubbles show that the observed value is less than the expected value. Preliminary catch data for 2020 have been used.

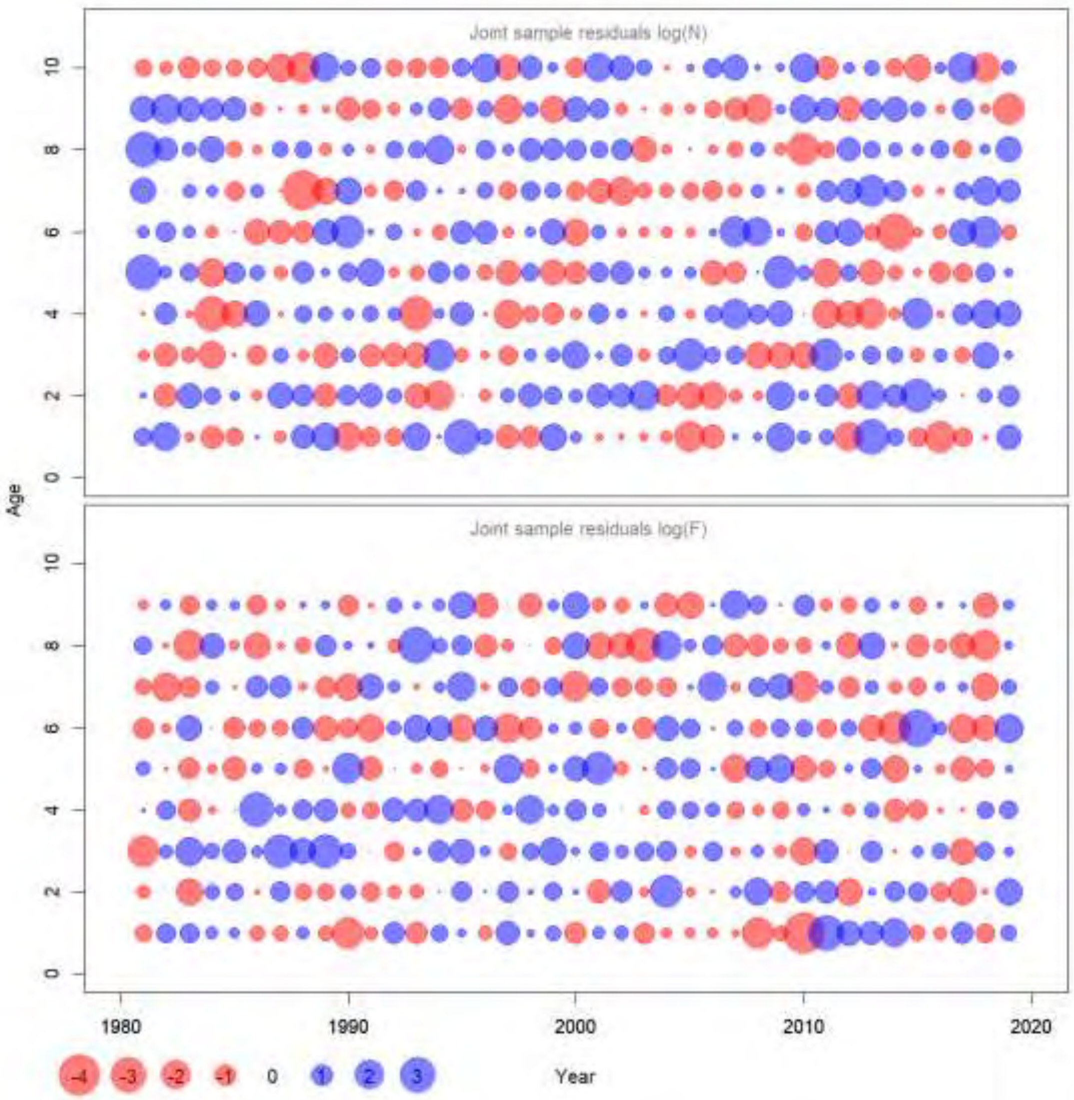


Figure 2.4.2.2 Blue whiting. Joint sample residuals (Process errors) for stock number and F at age. Red (lighter) bubbles show that the observed value is less than the expected value. Preliminary catch data for 2020 have been used.

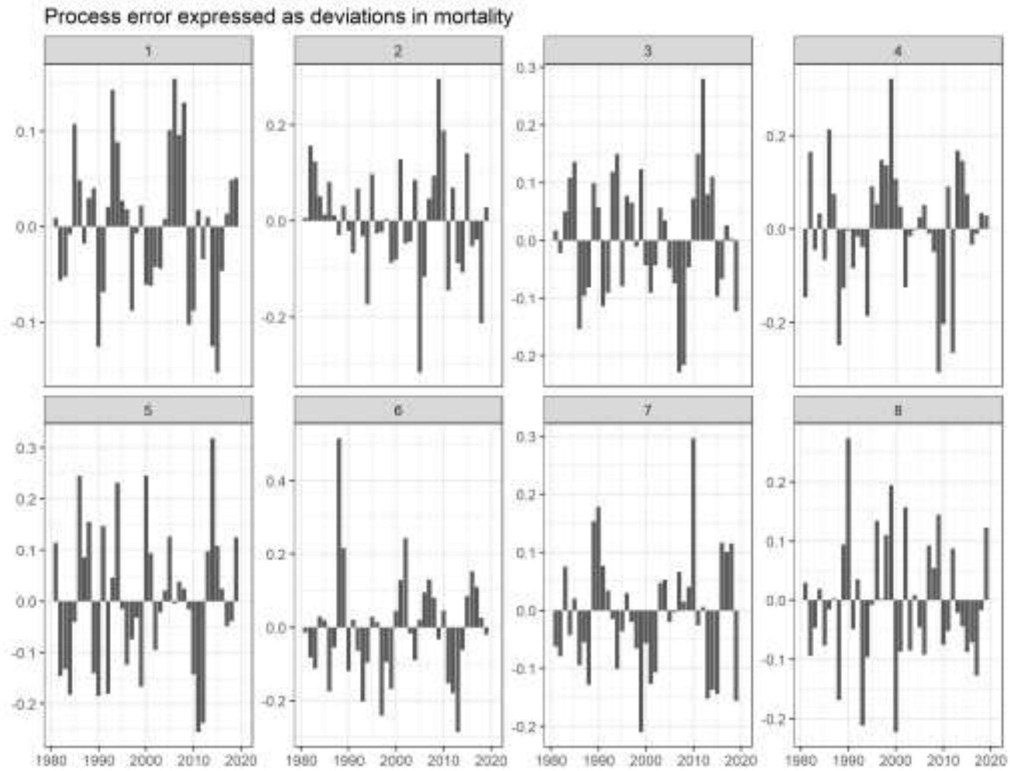
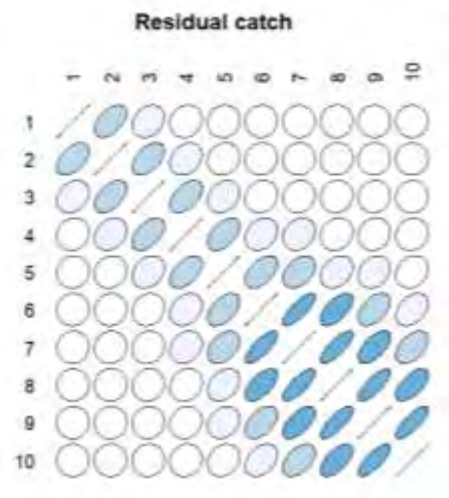


Figure 2.4.2.3. Blue whiting. Process errors expressed as deviation in instantaneous mortality at age by age and year.



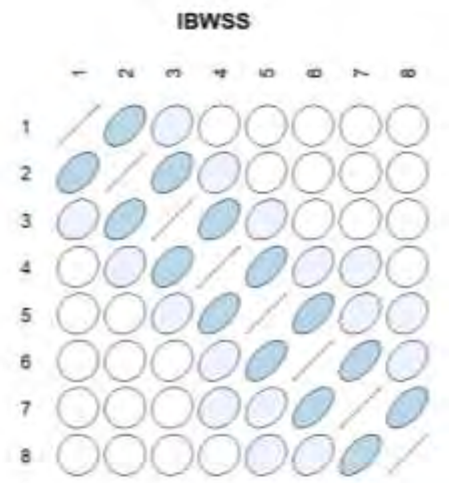


Figure 2.4.2.4. Blue whiting. The correlation matrix between ages for the catches and survey indices. Each ellipse represents the level curve of a bivariate normal distribution with the corresponding correlation. Hence, the sign of a correlation corresponds to the sign of the slope of the major ellipse axis. Increasingly darker shading is used for increasingly larger absolute correlations, while uncorrelated pairs of ages are depicted as circles with no shading.

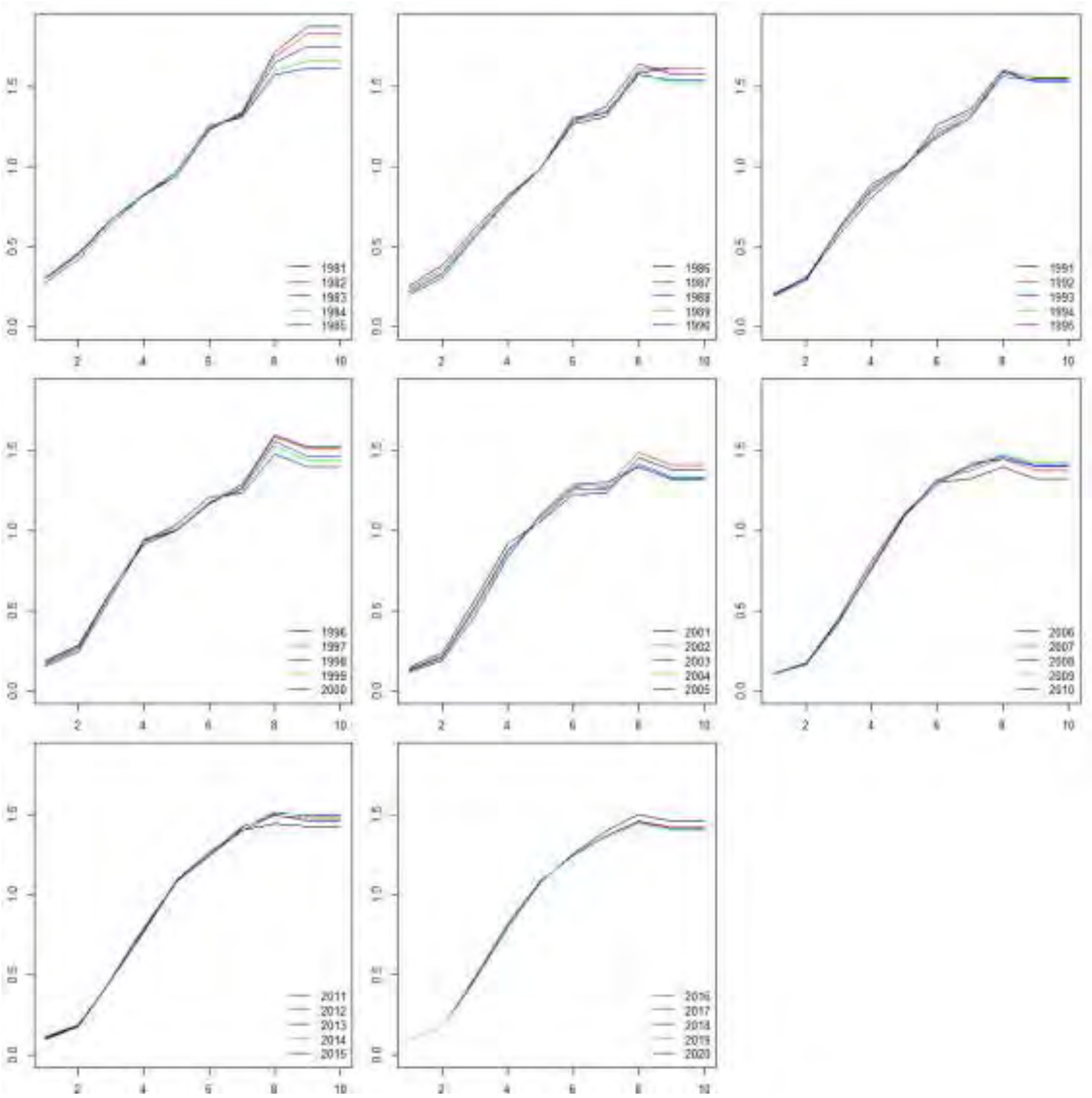


Figure 2.4.2.5. Blue whiting. Exploitation pattern by 5-years' time blocks. Values for 2020 are preliminary.

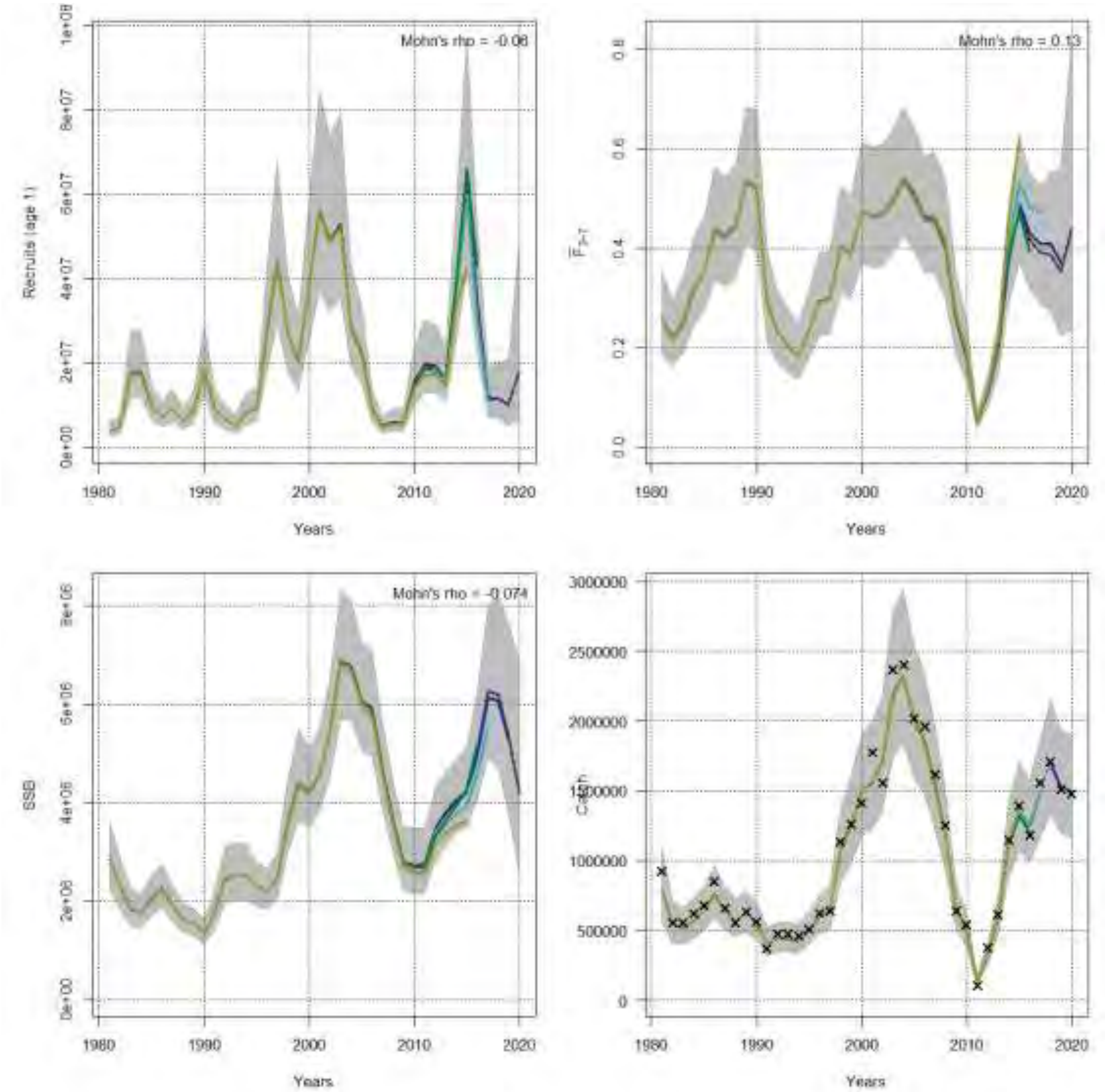


Figure 2.4.2.6. Blue whiting. Retrospective analysis of recruitment (age 1), SSB (tonnes), F and total catch using the SAM model. The 95% confidence interval is shown for the most recent assessment.

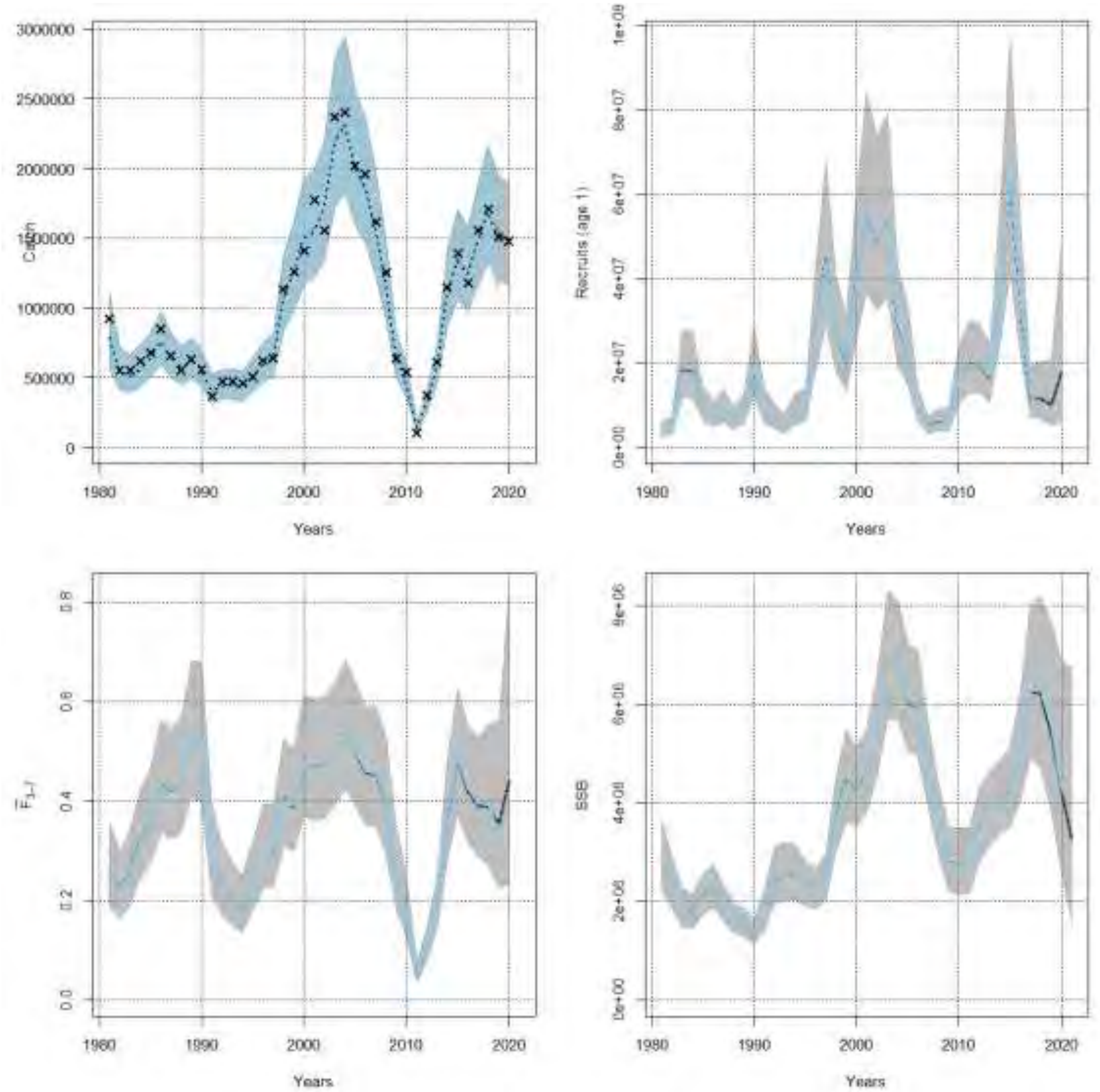


Figure 2.4.2.7. Blue whiting. SAM final run: Stock summary, total catches (tonnes), recruitment (age 1), F and SSB (tonnes). The graphs show the median value and the 95% confidence interval. The catch plot does also include the observed catches (x). The assessment results from 2020 assessment are shown by the black line, the assessment results from 2019 by the blue line. Catches for 2020 are preliminary.

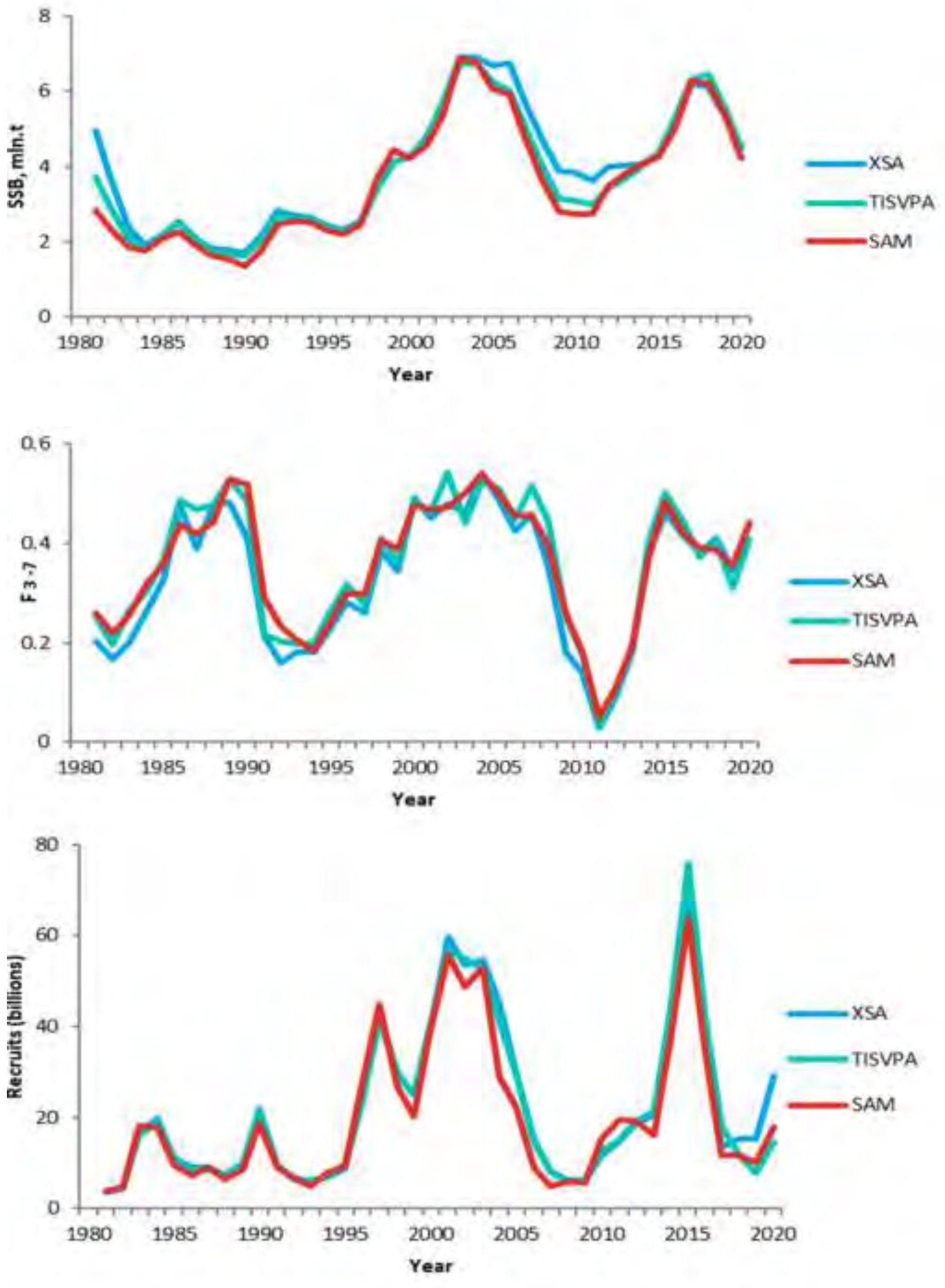


Figure 2.4.3.1. Blue whiting. Comparison of SSB, F and recruitment estimated by the assessment programs XSA, TISVPA and SAM. Catch values for 2020 are preliminary.

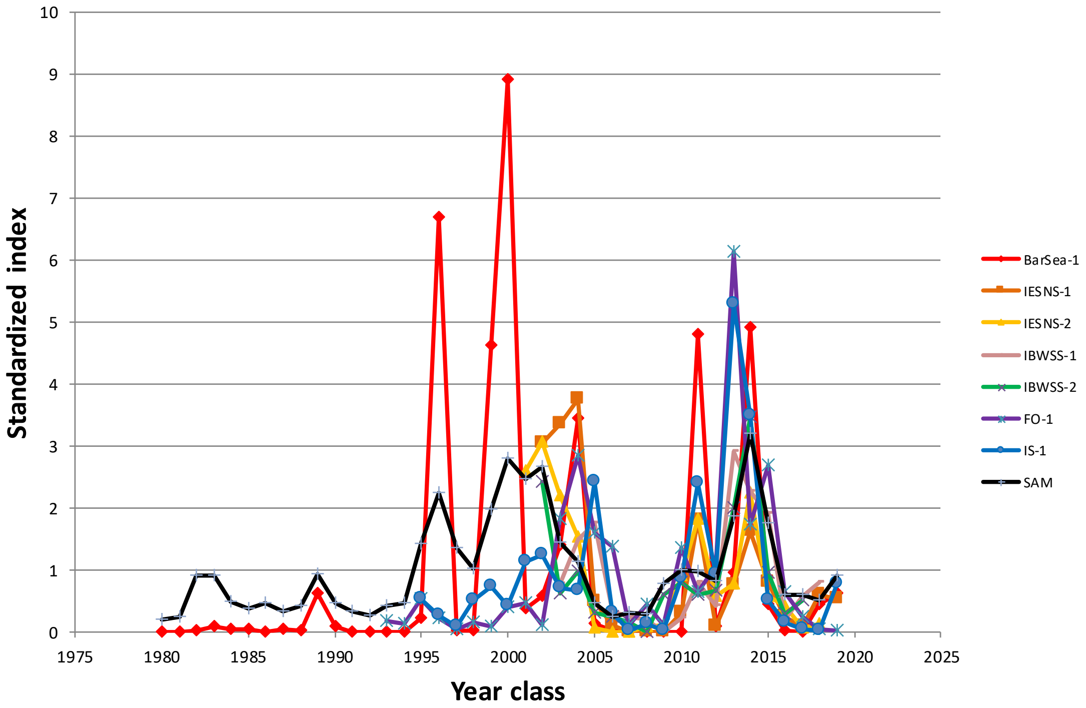


Figure 2.8.1.1. Blue whiting young fish indices from five different surveys and recruitment index from the assessment, standardized by dividing each series by their mean. BarSea - Norwegian bottom-trawl survey in the Barents Sea, IESNS: International Ecosystem Survey in the Nordic Seas in May (1 and 2 is the age groups), IBWSS (Not updated in 2020): International Blue Whiting Spawning Stock survey (1 and 2 is the age groups), FO: the Faroese bottom-trawl surveys in spring, IS: the Icelandic bottom-trawl survey in spring, SAM: recruits from the assessment.

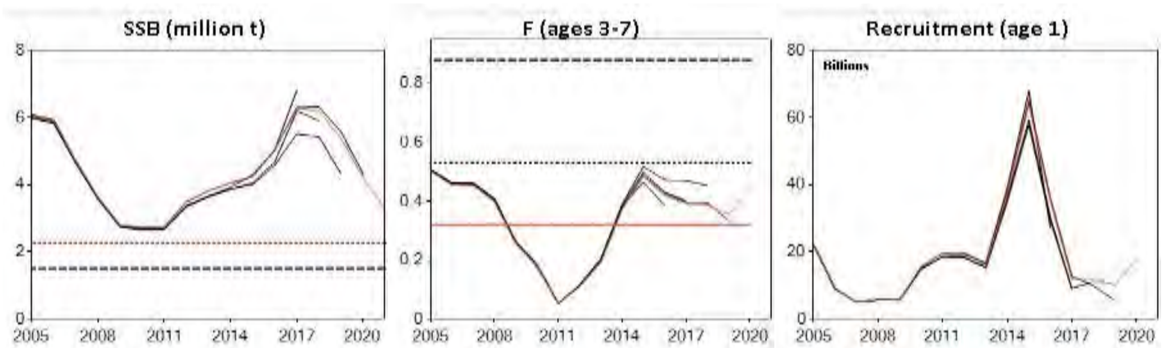


Figure 2.9.1. Blue whiting. Comparison of the 2016 - 2020 assessments.

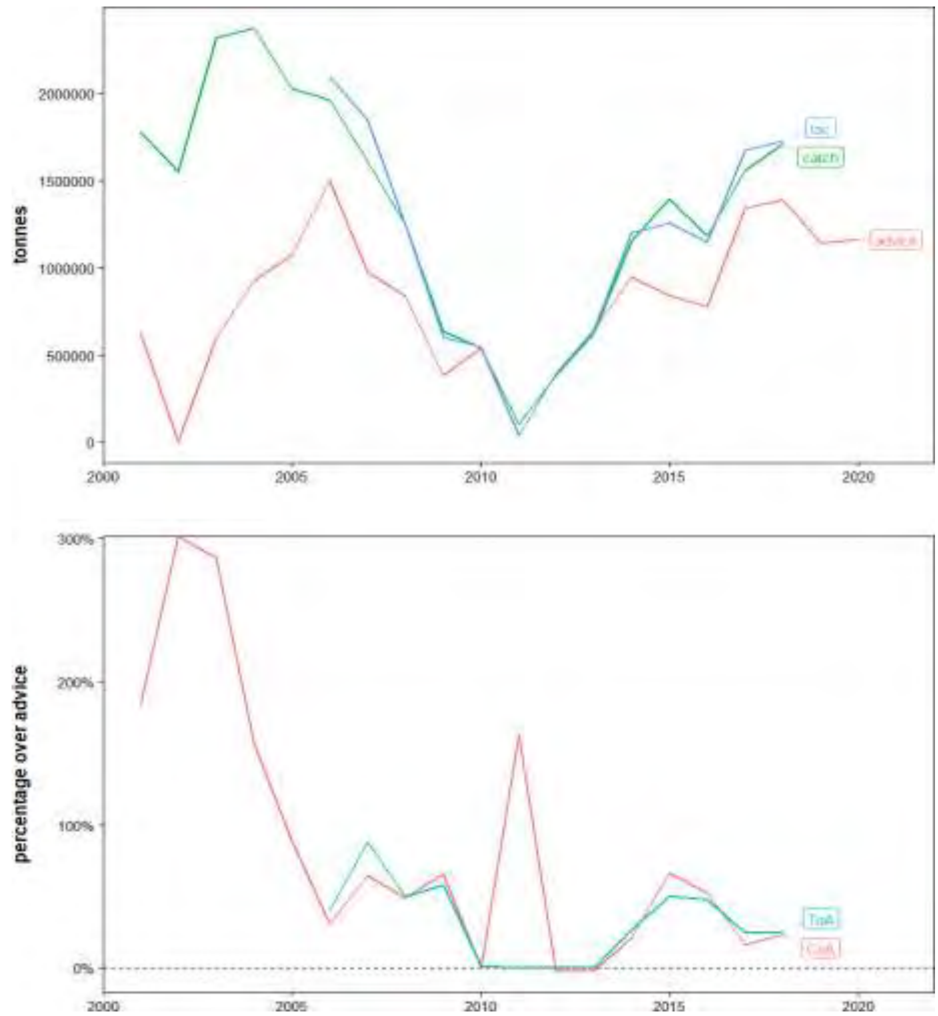


Figure 2.13.1. Blue whiting. Top: comparison of (max) scientific advice, TAC (or sum of unilateral quota) and Total Catch. Bottom: percentage deviation from ICES advice, CoA is Catch over Advice, ToA is TAC over Advice.

3 Northeast Atlantic boarfish (*Capros aper*)

The boarfish (*Capros aper*, Linnaeus) is a deep bodied, laterally compressed, pelagic shoaling species distributed from Norway to Senegal, including the Mediterranean, Azores, Canaries, Madeira and Great Meteor Seamount (Blanchard & Vandermeirsch 2005).

Boarfish is targeted in a pelagic trawl fishery for fish meal, to the southwest of Ireland. The boarfish fishery is conducted primarily in shelf waters and the first landings were reported in 2001. Landings were at very low levels from 2001-2005. The main expansion period of the fishery was 2006-2010 when unrestricted landings increased from 2 772 t to 137 503 t. A restrictive TAC of 33 000 t was implemented in 2011. In 2011, ICES was asked by the European Commission to provide advice for 2012.

An analysis of bottom trawl survey data suggests a continuity of distribution spanning ICES Subareas 27.4, 6, 7, 8 and 9 (Figure 3.1). Isolated occurrences appear in the North Sea (ICES Subarea 27.4) in some years indicating spill-over into this region. A hiatus in distribution was suggested between ICES Divisions 27.8.c and 9.a as boarfish were considered very rare in northern Portuguese waters but abundant further south (Cardador & Chaves 2010). Results from a dedicated genetic study on the stock structure of boarfish within the Northeast Atlantic and Mediterranean Sea suggests that this hiatus represents a true stock separation (Farrell *et al.* (2016); see section 3.12). Based on these data, a single stock is considered to exist in ICES Subareas 27.4, 6, 7, 8 and the northern part of 9.a. This distribution is slightly broader than the current EC TAC area (27.6, 7 and 8) and for the purposes of assessment in 2020 only data from these areas were utilized.

3.1 The fishery

3.1.1 Advice and management applicable from 2011 to 2019

In 2011 a TAC was set for this species for the first time, covering ICES Subareas 6, 7 and 8. This TAC was set at 33 000 t. Before 2010, the fishery was unregulated. In October 2010, the European Commission notified national authorities that under the terms of Annex 1 of Regulation 850/1998, industrial fisheries for this species should not proceed with mesh sizes of less than 100 mm. In 2011, the European Parliament voted to change Regulation 850/1998 to allow fishing using mesh sizes ranging from 32 to 54 mm.

For 2012, ICES advised that catches of boarfish should not increase, based on precautionary considerations. As supporting information, ICES noted that it would be cautious that landings did not increase above 82 000 t, the average over the period 2008-2010, during which the stock did not appear to be overexploited. In 2012 the TAC was set at 82 000 t by the Council of the European Union.

For 2013, ICES advised that catches of boarfish should not be more than 82 000 t. This was based on applying a harvest ratio of 12.2% (F0.1, as an F_{MSY} proxy). For 2013, the TAC was set at 82 000 t by the Council of the European Union.

For 2014, ICES advised that, based on F_{MSY} (0.23), catches of boarfish should not be more than 133 957 t, or 127 509 t when the average discard rate of the previous ten years (6 448 t) is taken into account. For 2014 the TAC was set at 133 957 t by the Council of the European Union. This advice was based on a Schaefer state space surplus production model (see section 3.6.3 for further details).

In 2014 there was concern about the use of the production model (see stock annex). ICES considered that the model was no longer suitable for providing category 1 advice and further model development was required. The model is still considered suitable for category 3 advice. The advised catch for 2015 of 53 296 t was based on the data limited stock HCR and an index calculated (method 3.1; ICES, 2012) using the total stock biomass trends from the model. Further work has been undertaken in 2015 to address the issues with the surplus production model and this work has been continued since.

For 2016, ICES advised based on the precautionary approach that catches should be no more than 42 637 t.

For 2017, ICES advised based on the precautionary approach that catches should be no more than 27 288 t. For the first time, the precautionary buffer has been applied resulting in a 36% reduction compared to the year before. The acoustic survey suggested that the stock abundance was at an historic low.

In 2017, the Advice Drafting Group decided the advice of 21 830 proposed (20% reduction) would stand for 2 years. The update assessments in 2018 and 2019 confirms that the biomass is rather stable and at a low level.

In 2019, advice of 19 152 t was issued for each of 2020 and 2021 on the basis of the precautionary approach.

Since 2011, there has been a provision for bycatch of boarfish (also whiting, haddock and mackerel) to be taken from the Western and North Sea horse mackerel EC quotas. These provisions are shown in the text table below. The effect of this is that a quantity not exceeding the value indicated of these 4 species combined may be landed legally and subtracted from quotas for horse mackerel.

Year	North Sea (t)	Western (t)
2011	2 031	7 779
2012	2 148	7 829
2013	1 702	7 799
2014	1 392	5 736
2015	583	4 202
2016	760	5 443
2017	912	4191
2018	759	5053
2019	912	4191

In 2010, an interim management plan was proposed by Ireland, which included a number of measures to mitigate potential bycatch of other TAC species in the boarfish fishery. A closed season from the 15th March to 31st August was proposed, as anecdotal evidence suggests that mackerel and boarfish are caught in mixed aggregations during this period. A closed season was proposed in ICES Division 7.g from 1st September to 31st October, in order to prevent catches of Celtic Sea herring, which is known to form feeding aggregations in this region at these times. Finally, if catches of a species covered by a TAC, other than boarfish, amount to more than 5%

of the total catch by day by ICES statistical rectangle, then fishing must cease in that rectangle for 5 days.

In August 2012 the Pelagic RAC proposed a long term management plan for boarfish (see section 3.15). The management plan was not fully evaluated by ICES. However, in 2013, ICES advised that Tier 1 of the plan can be considered precautionary if a Category 1 assessment is available.

A revised draft management strategy was proposed by the Pelagic AC in July 2015. This management strategy aims to achieve exploitation of boarfish in line with the precautionary approach to fisheries management, FAO guidelines for new and developing fisheries, and the ICES form of advice. ICES evaluated the plan and considered it to be precautionary, in that that it follows the rationale for TAC setting enshrined in the ICES advice, but with additional caution.

The closed season, in the interim and revised management plans, has been enacted in legislation in Ireland, but not in other countries.

3.1.2 The fishery in recent years

The first landings of boarfish were reported in 2001. Landings fluctuated between 100 and 700 t per year up to 2005 (Tables 3.1.2.1 & 3.1.2.2). In 2006 the landings began to increase considerably as a target fishery developed. Cumulative landings since 2001 exceed 500 000 t. The fishery targets dense shoals of boarfish from September to March. Catches are generally free from bycatch from September to February. From March onward a bycatch of mackerel can be found in the catches and the fishery generally ceases at this time. Information on the bycatch of other species in the boarfish fishery is sparse, though thought to be minimal. The fishery uses pelagic pair trawl nets with mesh sizes ranging from 32 to 54 mm. Preliminary information suggests that only the smallest boarfish escape this gear.

From 2001 to 2006 only Ireland reported landings of boarfish. In 2007 UK (Scotland) reported landings of 772 t. Scottish landings peaked at 9 241 t in 2010 and have declined since with no fishery since 2015. Denmark joined the fishery in 2008 and landed 3 098 t. Danish landings increased to 39 805 t in 2010 but have declined considerably to only 29 t in 2015. The fishery has been slowly increasing in recent years with 757 t landed in 2019. The vast majority of catches have come from ICES Division 27.7.j and 27.7.h (Figure 3.1.2.1 and Table 3.1.2.1). Since 2011 landings have been regulated by a TAC.

In 2014 and subsequent years, the full TAC has not been caught. This is thought to be partly due to lesser availability of fishable aggregations, and partly due to economic and administrative reasons. According to the industry, fishable aggregations were not always available during the fishery season which coincides with the mackerel and horse mackerel fisheries. Also, the Irish quota was allocated to individual boats, with non-specialist vessels receiving allocations that were not used. In 2015, Q3 and Q4 individual boat quotas were removed in Ireland, in an attempt to allow the specialist 6-7 vessels target the stock without (what the industry considers to be unnecessary) constraints. The same year, the Netherlands (375 t), UK England (104 t) and Germany (4 t) reported boarfish landings for the first time. These landings were mainly bycatch from freezer trawlers.

In 2016 a total of 19 315 t of boarfish were caught (Table 3.1.2.1). Ireland continued to be the main participant taking 17 496 t but is below its 29 464 t quota. Denmark took only 337 t, significantly under its national quota of 10 463 t. Scotland reported no boarfish landings. Table 3.1.2.2 shows that two thirds of the Irish landings were taken in ICES divisions 7.h and 8.a. Thirty-two Irish registered fishing vessels reported catches with the majority made in Q1 (7 143 t) and Q4 (8 711 t).

Previous to the development of the target fishery, boarfish was a discarded bycatch in pelagic fisheries for mackerel in ICES Subareas 7 and 8. A study by Borges *et al.* (2008) found that boarfish may have accounted for as much as 5% of the total catch of Dutch pelagic freezer trawlers. Boarfish are also discarded in whitefish fisheries, particularly by Spanish demersal trawlers (Table 3.1.2.3).

In 2017 a total of 17 388 t of boarfish were caught Table 3.1.2.1). Ireland continued to be the main participant landing 15 484 t but is almost 20% below its 18 858 quota. Denmark landed only 548 t, not even 10% of its national quota of 6 696 t. UK reported almost null boarfish landings. Discards accounted for 1 173 tonnes overall. About 90% of the Irish landings were taken in ICES divisions 7.h and 8.a. Thirty-five Irish registered fishing vessels reported catches with almost the entirety made in Q1 (8 570 t) and Q4 (6 270 t).

In 2018 a total of 11 286 t of boarfish were caught (Table 3.1.2.1). This represents 55% of the 2018 quota of 20 380 t. Ireland continued to be the main participant landing 9 513 t (68% of its national quota). The Irish catch represents 85% of the total boarfish catch in 2018. Other countries reporting boarfish in 2018 were Denmark (94 t), The Netherlands (172 t), Spain (148t), UK England (0.085 t) and UK Scotland (0.229 t). Discards accounted for 1 359 t overall. Table 3.1.2.2 shows that about 82% of the Irish landings were taken in ICES divisions 7.h and 8.a.

3.1.3 The fishery in 2019

A total of 11 312 t of boarfish was caught in 2019 (Table 3.1.2.1). This represents 52% of the 2019 quota of 21 830 t. The main participant in the fishery, Ireland, landed 9 910 t (75% of its national quota). The Irish catch represents 88% of the total boarfish catch in 2019. Other countries reporting boarfish catches in 2019 were Denmark (757 t), the Netherlands (317 t), England (19 t) and Spain (2.5 t). Discards accounted for 306 t overall. Table 3.1.2.2 shows that about 87% of Irish landings were taken in ICES divisions 7.h and 8.a.

3.1.4 Regulations and their effects

In 2010, the fishery finished early when the European Commission notified member states that mesh sizes of less than 100 mm were illegal. However, in 2011, the European Parliament voted to change Regulation 850/1998 to allow fishing for boarfish using mesh sizes ranging from 32 to 54 mm. The TAC (33 000 t) that was introduced in 2011 significantly reduced landings.

3.1.5 Changes in fishing technology and fishing patterns

The expansion of the fishery in the mid-2000s was associated with developments in the pumping and processing technology for boarfish catches. These changes made it easier to pump boarfish ashore. Efforts are underway to develop a human consumption market and fishery for boarfish. To date the majority of boarfish landings by Danish, Irish and Scottish vessels have been made into Skagen, Denmark and Fuglafjorour, Faroe Islands to be processed into fishmeal. A small number of Irish vessels have landed into Killybegs and Castletownbere, Ireland. These landings into Irish ports were expected to increase in the future with the development of a human consumption fishery but this development now seems unlikely. This is due to the species' small size and difficulty being processed on conventional equipment.

3.1.6 Discards

Since 2003, the major sources of discard estimates are the Dutch pelagic freezer trawlers and both the Irish and Spanish demersal fleets. More sporadic discards are observed in German pelagic freezer trawlers and the UK demersal fleet. In 2016, Lithuania declared discards for the first time. Discard estimates are not obtained from French freezer trawlers, though discard patterns in these fleets are likely to be similar to the Dutch fleet. Discard data from the Portuguese bottom otter trawl fleet in ICES Division 9.a are also available but are not included in the assessment as they are outside the TAC area. Table 3.1.2.3 shows available discard estimates.

It is to be expected that discarding occurred before 2003, particularly in demersal fisheries, however it is difficult to predict what the levels may have been.

Discard data were included in the calculation of catch numbers at age. All discards were raised as a single metier using the same age length keys and sampling information as for the landed catches. In the absence of better sampling information on discards, this was considered the best approach. This placed the stock in Category A2 for the ICES Advice in October 2013: Discards 'topped up' onto landings calculations. With the introduction of the discard ban in 2015 this stock was placed in A4: Discards known, with discard ban in place in year +1. As such the advice will be given for catch in ICES Advice October 2014 and onwards.

3.2 Biological composition of the catch

3.2.1 Catches in numbers-at-age

Catch number-at-age were prepared for Irish, Danish, Dutch, German and English landings using the ALK in Table 3.2.1.1 together with available samples from the fishery (Table 3.2.1.2). This general ALK was constructed based on 814 aged fish from Irish, Danish and Scottish caught samples from 2012 (see the stock annex for a description of ALKs prior to 2012). In 2019, allocations to unsampled metiers were made according to Table 3.2.1.3. In total, 18 samples with the appropriate 0.5 cm length bin measurements were collected in 2019 (Table 3.2.1.4). These samples covered the most heavily fished areas (Table 3.2.1.5) and equated to one sample per 629 t landed. The samples comprised 371 fish measured for length frequency.

The results of the application of the ALK to commercial length-frequency data available for the years 2007-2019 to produce a proxy catch numbers-at-age are available in Table 3.2.1.6. There have been no strong year classes with poor cohort tracking in the catch numbers. A high number of 2 year olds are present in the 2015 data but this does not echo in the number of 3-year-old fish in 2016. The modal age from 2007-2011 was 6 and in 2012-2018 it was 7. It should be noted that in WGWIDE 2011 and 2012 the plus group for boarfish was 20+. This was reduced to 15+ in WGWIDE 2013 due to potential inaccuracy of the age readings of older fish. Ageing was based on the method that has been validated for ages 0-7 by Hüssy *et al*. (2012a; b). The age range is similar to the published growth information presented by White *et al*. (2011).

3.2.2 Quality of catch and biological data

Table 3.2.1.3 shows allocations that were made to unsampled métiers in 2018. Length-frequencies of the international commercial landings by year are presented in Table 3.2.2.1.

Sampling in the early years of the fishery (2006-2009) was sparse as there was no dedicated sampling programme in place. The sampling programme was initiated in 2010 and good coverage of the landings has been achieved since then. Full details of the sampling programme in the earlier years are presented in the stock annex. Until 2017, boarfish was not included on the DCF list of species for sampling. Irish sampling comprises only samples from Irish registered vessels. Samples are collected on-board directly from the fish pump during fishing operations and are frozen until the vessel returns to port, which ensures high quality samples. Each sample consists of approximately 6 kg of boarfish. This equates to approximately 150 fish which, given the limited size range of boarfish, is sufficient for determining a representative length frequency. The established sampling target is one sample per 1 000 t of landings per ICES Division, which is also standard in other pelagic fisheries such as mackerel. Since 2017, all fish in each sample should be measured to the 0.5 cm below for length frequency. Following standard protocols 5 fish per 0.5 cm length class should be randomly selected from each sample for biological data collection *i.e.* otolith extraction, measurement to the 1mm below and sex and maturity determination.

There is no sampling programme in place for Scottish catches.

The current surplus production model used to assess boarfish is considered an interim measure prior to the development of an aged-based assessment. In 2017, boarfish was included in the list of species to be sampled by the Data Collection Multi Annual Programme (DCMAP) which should provide estimates of catch at age and facilitate the future development of an age-based stock assessment method.

3.3 Fishery Independent Information

3.3.1 Acoustic Surveys

The Boarfish Acoustic Survey (BFAS) was first conducted in July 2011 and is now in its tenth year. The 2020 survey was carried out on-board the RV *Celtic Explorer* and run in conjunction the Malin Shelf herring survey as the WESPAS survey (Western European Shelf Pelagic Acoustic Survey). The survey was carried out over a 42-day period beginning on the 3 June in the south (47°30N) and working northwards to 59°30N ending on 10 July.

Change in abundance calculation method

The StoX software package and ICES acoustic database have been fully adopted as the processing and repository for acoustic survey data (Johnsen *et al.*, 2019). Survey design and execution of the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (IPS) (ICES, 2015).

Survey results 2020

The estimate of boarfish biomass is presented in Table 3.3.1.1 and the spatial distribution of the echotraces attributed to boarfish in 2020 are presented in Figure 3.3.1.1. Overall, the WESPAS survey provided continuous synoptic coverage from south to north over 42 days covering relating to an area coverage of almost 56,686 nmi^2 (boarfish strata) and transect mileage of over 5,531 nmi. In total, 35 trawl stations were undertaken with 15 hauls containing boarfish providing 3,091 individual lengths, 1,204 length and weight measurements and 651 otoliths for use during the analysis.

The 2020 estimate of total stock biomass was over double that observed in 2019 (179,000 t in 2019, and 399,000 t in 2020). Over 65.6% of the biomass was observed in the Celtic Sea followed by 22% along the Irish west coast. The southern Celtic Sea/Northern Biscay area was found to contain a high abundance of immature boarfish as observed to a lesser extent in 2019. Immature boarfish represented 41.4% of the total abundance observed across the combined survey area.

The age composition of in 2020 was dominated by oldest age classes (15+), in terms of biomass, followed by the 8 and 9-year-old fish occurring as a second obvious cohort grouping. In terms of abundance, the older fish (15+) dominated (17%) followed by the influence pre-recruit immature fish (0-3-year-old fish), which combined contribute over 41% of the total abundance. The last two years of the survey have observed higher than average numbers of immature fish some of which will recruit to the spawning stock in the next 1 to 3 years. This pulse of recruitment is similar to that observed in the now 7-9-year-old fish (2011-2013 year classes).

During the 2020 survey access to French waters (southernmost transects) was hampered by naval operations which prevented trawling. This was problematic given this area contains variable proportions of immature and mature fish. Trawl samples from further north were applied during the analysis. The use of a static age-length-key to estimate the age composition remains an issue for this survey. Aging of survey derived samples would likely improve the ability to track cohorts more effectively within the survey index and reduce this potential source of error.

3.3.2 International bottom trawl survey (IBTS) Indices Investigation

The western IBTS data and CEFAS English Celtic Sea Groundfish Survey were investigated for their use as abundance indices for boarfish for the first time in 2012. An index of abundance was constructed from the following surveys:

- EVHOE, French Celtic Sea and Biscay Survey, (Q4) 1997 to 2011
- IGFS, Irish Groundfish Survey, (Q4) 2003 to 2011
- WCSGFS, West of Scotland, (Q1 and Q4) 1986 to 2009 (survey design changed in 2010)
- SPPGFS, Spanish Porcupine Bank Survey, (Q3) 2001 to 2011
- SPNGFS, Spanish North Coast Survey, (Q3/Q4) 1991 to 2011
- ECSGFS, CEFAS English Celtic Sea Groundfish Survey, (Q4) 1982 to 2003

From the IBTS data, CPUE was computed as the number of boarfish per 30 min haul. The abundance of boarfish per year per ICES statistical rectangle (used for visualisation only) was then calculated by summing the boarfish in a given rectangle and dividing by the total number of hauls in that rectangle. Length frequencies are presented in Table 3.3.2.1 for each survey. These surveys cover the majority of the observed range of boarfish in the ICES Area (Figure 3.1). Figure 3.3.2.1 also includes the spatial range of the Portuguese Groundfish Survey (1990-2011), however this survey is outside the current EC TAC area and has never been used in the assessment.

A detailed analysis of the IBTS data was carried out in 2012 to investigate the main areas of abundance of boarfish in these surveys. This analysis included GAM modelling based on the probability of occurrence of boarfish. The full details of this work are presented in the stock annex. The IBTS appears to give a relative index of abundance, with good resolution between periods of high and low abundance. The main centres of abundance in the survey Figure 3.3.2.2 correspond to the main fishing grounds (Figure 3.1.2.1). Figure 3.3.2.3 shows the signal in abundance, increasing in the 1990s, declining again in the early 2000s, before increasing again.

For subsequent surplus production modelling (see Section 3.6.3), biomass indices were extracted from each of the IBTS surveys using a delta-lognormal model (Stefánsson 1996). Many of the surveys exhibited a large proportion of zero tows with occasionally very large tows, hence the decision to explicitly model the probability of a non-zero tow and the mean of the positive tows. A delta-lognormal fit comprises fitting two generalized linear models (GLMs). The first model (binomial GLM) is used to obtain the proportion of non-zero tows and is fit to the data coded as 1 or 0 if the tow contained a positive or zero CPUE, respectively. The second model is fit to the positive only CPUE data using a lognormal GLM. Both GLMs were fit using ICES statistical rectangle and year as explanatory factor variables. Where the number of tows per rectangle was less than 5 over the entire series, they are grouped into an "others" rectangle. An index per rectangle and year is constructed, according to Stefánsson (1996), by the product of the estimated probability of a positive tow times the mean of the positive tows. The station indices are aggregated by taking estimated average across all rectangles within a year. To propagate the uncertainty, all survey index analyses were conducted in a Bayesian framework using Markov chain Monte

Carlo (MCMC) sampling (Kery 2010). As WinBugs is no longer updated, the analyses were migrated from WinBUGS to JAGS in 2017. Indeed, JAGS has an almost identical language to WinBUGS and its outputs have been proven equivalent to the previous software (Plummer 2003; Spiegelhalter *et al.* 2003). In 2018, the assessment was reverted back to WinBUGS as it MCMC sampler appeared more efficient than that of JAGS. The outputs derived from both software implementations are similar.

3.4 Mean weights- at-age, maturity-at-age and natural mortality

Mean weight-at-age was obtained from the ageing studies of Hüssy *et al.* (2012b). These mean weights are presented in the text table below. The variation in weight-at-age is due to small sample size and seasonal variation in weight and maturity stage.

Age	0	1	2	3	4	5	6	7	8	9
Mean Weight (g)	0.84	6.65	14.6	19.5	23.7	26.8	33.3	37.7	40	47.1

Age	10	11	12	13	14	15	16	17	18	19
Mean Weight (g)	50.2	51.2	62.8	56.4	62.2	68.9	50.5	86.7	77.9	64.6

Age	20	21	22	23	24	25	26	27	28	29
Mean Weight (g)	63.5	75	86	71	77	84.4	79.4	-	67.6	52.8

Maturity-at-age was obtained from the ageing studies of Hüssy *et al.* (2012a; b) and the reproductive study by Farrell *et al.* (2012).

Age	0	1	2	3	4	5	6+
Prop mature	0	0	0.07	0.25	0.81	0.97	1

Natural mortality (M) was estimated over the life span of the stock using the method described by King (1995). This method assumes that M is the mortality that will reduce a population to 1% of its initial size over the lifespan of the stock. Based on a maximum age of 31, M is calculated as follows

$$M = -ln(0.01)/31$$

Following this procedure, $M = 0.16$ year^{-1}. $M = 0.16$ is considered a good estimate of natural mortality over the life span of this boarfish stock, as it is similar to the total mortality estimate from 2007, ($Z = 0.18$, see Section 3.6.5). Given that catches in 2007 were relatively low, this estimate of total mortality is considered a good estimate of natural mortality, assuming negligible fishing mortality in previous years.

Similarly, total mortality was estimated from age-structured IBTS data from 2003 to 2006 (years from which data was available for all areas). The total mortality is considered a good estimate of natural mortality as fishing mortality was assumed to be negligible during this period. Total mortality ranged from 0.09–0.2 with a mean of 0.16.

The special review in 2012, questioned the validity of a single estimate of M across the entire age range. If an age based assessment is possible in the future, age specific estimates of natural mortality are required. However, the current estimate of M, which covers the whole age range, is considered appropriate in the context of the current situation where age data are used as an indicator approach, rather than as a full assessment method. Given that Z and F are also calculated over the entire (fully selected) range (Section 3.6.5) a single value of M is considered appropriate.

3.5 Recruitment

The IBTS data were explored as indices of abundance of 1-year-old, and 1-5 years old as a composite recruitment index (Figures 3.5.1 & 3.5.2). The EVHOE and SPNGFS surveys provide the best indices of recruitment as this is where the juveniles appear to be most abundant (Table 3.3.2.1). It appears that recruitment was high in the late 1990s but declined to a low in 2003. However, this apparent dip in recruitment was not observed in the commercial catch-at-age data. The recruitment signal for ages 1-5 combined has been stable since 2004 with a small increase evident in 2015. The recruitment signal for 1-year-old shows a more variable pattern with an increase in 2015 also evident (Figure 3.2.1.1). In 2016, almost all values for age 1 and combined ages 1-5 decreased compared to 2015. The decreases were rather important in the SPNGFS survey and led to historical lows for this survey.

3.6 Exploratory assessment

In 2012, a new stock assessment method for Boarfish was tested. In 2013 this Bayesian state space surplus production model (BSP; Meyer & Millar (1999)) was further developed following reviewers' recommendations in 2012. Different applications of a Bayesian biomass dynamic model were run in 2013 incorporating combinations of catch data, abundance data from the groundfish surveys, and estimates of biomass (and associated uncertainty) from the acoustic surveys (see stock annex for more details of the sensitivity runs). The model and settings from the final accepted run in 2013 were used as the basis of ICES category 1 advice for catch in 2014. However, in 2014 there was concern about the use of the production model for a number of reasons and ICES considered this model as no longer suitable for providing category 1 advice. Since 2014, the assessment model has been used as a basis for trends for providing DLS advice (ICES category 3). ICES considers the current basis for the advice on this stock to be an interim measure prior to development of an age-based assessment.

3.6.1 IBTS data

The common ALK (Table 3.2.1.1) was applied to the IBTS number-at-length data. The length-frequency is presented in Table 3.3.2.1 and the age-structured index in Table 3.6.1.1 and Figure 3.6.1.1. A cohort effect can be seen with those cohorts from the early 2000s appearing weak. This coincides with a decline in overall abundance in the early 2000s. From the mid-2000s onwards recruitment improved as observed in the abundance of 1-5 year olds in the EVHOE and Spanish northern shelf surveys (Figures 3.5.1 & 3.5.2). It should be noted however that the IBTS data is measured to the 1.0cm not the 0.5cm until 2015. Therefore, application of the common ALK to this data must be viewed with caution.

Some of the IBTS CPUE indices displayed marked variability with a large proportion of zero tows and occasionally very large tows (*e.g.* West of Scotland survey, Figure B.4.7 stock annex).

More southern surveys displayed a consistently higher proportion of positive tows. The variability of the data is reflected in the estimated mean CPUE indices (Figure 3.6.1.2). The West of Scotland survey index had been increasing between 2000 and 2009 but is uncertain, whereas the estimated indices from the other series are typically less variable (Figure 3.6.1.2). In 2014 four of the five current bottom trawl surveys experienced a sharp decline in CPUE, particularly the West of Scotland, the Spanish North Coast, the Spanish Porcupine and Irish Groundfish surveys. Both Spanish surveys remained low in 2015 whereas the latest IGFS and EVHOE surveys indicate an increase. In 2016, values were similar to those of the previous year for all surveys. In 2017, surveys suggest that the stock abundance increased compared to the year before. The only exception is the EVHOE survey but its coverage was only partial year due its research vessel breakdown. The CEFAS English Celtic Sea Groundfish Survey displays a steady increase from the mid-1980s to 2002 with a large but somewhat uncertain estimate in 2003 (Figures 3.6.1.2 & 3.6.1.3). The spatial extent of each survey is shown in Figure 3.3.2.1.

Diagnostics from the positive component of the delta-lognormal fits indicate relatively good agreement with a normal distribution on the natural logarithmic scale (Figure 3.6.1.4). There is an indication of longer tails in some of the surveys (*e.g.* WCSGFS, SPPGFS).

Pair-wise correlation between the annual mean survey indices varied. The IGFS, EVHOE and SPNGFS displayed positive correlation (Figure 3.6.1.5). The WCSGFS also displayed a negative correlation with the 2 Spanish surveys (SPPGFS and SPNGFS). The SPPGFS also displayed a negative correlation with EVHOE (Figure 3.6.1.5). Weighting the correlations by the sum of the pair-wise variances resulted in a largely similar correlation structure, though the WCSGFS and SPPGFS were more strongly correlated with the ECSGFS (Figure 3.6.1.6). Note that though some surveys displayed weak or no correlation, no surveys were excluded a-priori from the assessment. Sensitivity tests were conducted in 2013, which led to the exclusion of the surveys mentioned previously (see the stock annex).

3.6.2 Biomass estimates from acoustic surveys

The Boarfish Acoustic Survey (BFAS) series was initiated in July 2011 and is now in its 10th year. The initial survey in 2011 collected data over 24 hours. Since 2012, acoustic data has been collected between the hours of 04:00 and 00:00. The 2011 data was reworked in 2015 to exclude the data between 00:00 and 04:00. A TS model of -66.2dB was developed in 2013 (Fässler *et al.* (2013)) and is applied to all surveys in the time series (Figure 3.3.1.1). Over the time series of the survey total biomass has been estimated in the range 863 kt (in 2012) to 70 kt (2016). The precision on the estimates has been good, with coefficients of variation in the range 11 to 21. An overall downward trend is evident in the first years while estimates have been more stable since 2014. No strong evidence exists for removing any of the survey points from the time series although 2016 may look like an outlier (Table 3.3.1.1).

It should be noted that two acoustic surveys are conducted annually to the south of the southern limit of the dedicated Boarfish survey. In 2016 the PELACUS recorded an increase in biomass from 2015 although not of the order of the decrease seen further north. The Spanish PELGAS surveys recorded low levels of biomass, similar to that in 2015. Both these surveys take place 2-3 months prior to the boarfish survey. Neither survey was conducted in 2020 due to the COVID emergency.

3.6.3 Biomass dynamic model

In 2012 an exploratory biomass dynamic model was developed. This was a Bayesian state space surplus production model (Meyer & Millar 1999), incorporating the catch data, IBTS data, and acoustic biomass data. The assessment was peer-reviewed by two independent experts on behalf of ICES. In 2013 a new assessment was provided, which was based on the previous year's work and the reviewers' comments and formed the basis of a category 1 assessment. Details of the review and the associated changes can be found in the stock annex.

In 2014 the Bayesian state space surplus production model was fit using the catch data, delta-lognormal estimated IBTS survey indices, and the acoustic survey estimates. However, the inclusion of the low 2014 acoustic biomass estimate changed the perception on the stock, which raised concerns over the sensitivity and process error of the model and the stock assessment was moved from ICES category 1 to category 3 with the results of the surplus production model being used to calculate an index for the data limited stock approach.

Since 2014, the procedure used to run the model did not change with only the length of the time series used increasing annually. Details of this exploratory run used to calculate the DLS index are described below.

In the Bayesian state space surplus production model the biomass dynamics are given by a difference form of a Schaefer biomass dynamic model:

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

where B_t is the biomass at time t, r is the intrinsic rate of population growth, K is the carrying capacity, and C_t is the catch, assumed known exactly. To assist estimation, the biomass is scaled by the carrying capacity, denoting the scaled biomass $P_t = B_t / K$. A lognormal error structure is assumed giving the scaled biomass dynamics (process) model:

$$P_t = (P_{t-1} + rP_{t-1}(1 - P_{t-1}) + \frac{C_{t-1}}{K})e^{\mu_t}$$

where the logarithm of process deviations are assumed normal $u_t = N(0, \sigma_2^{\mu})$ with σ_2^{μ} the process error variance.

The starting year biomass is given by aK, where a is the proportion of the carrying capacity in the first year. The biomass dynamics process is related to the observations on the indices through the measurement error equation:

$$I_{j,t} = q_j P_t K e^{\varepsilon j,t}$$

where $I_{j,t}$ is the value of abundance index j in year t, q_j is survey-specific catchability, $B_t = P_t K$, and the measurement errors are assumed log-normally distributed with $u_t = N(0, \varepsilon_{e,j,t}^2)$ where $\varepsilon_{e,j,t}^2$ is the index-specific measurement error variance. $Var(I_{j,t})$ is obtained from the delta-lognormal survey fits. That is, the variance of the mean annual estimate per survey is inputted directly from the delta-lognormal fits (Figure 3.6.1.2) as opposed to estimating a measurement error within the assessment. The measurement error is obtained from:

$$\sigma_{e,j,t}^2 = ln(1 + \frac{Var(I_{j,t})}{(I_{j,t})^2})$$

For the acoustic survey, the CV of the survey was transformed into a lognormal variance via

$$\sigma_{\varepsilon,acoustic,t}^2 = ln(CV_{acoustic,t}^2 + 1)$$

Prior assumptions on the parameter distributions were:

- Intrinsic rate of population growth: $r \sim U(0.001, 2)$
- Natural logarithm of the carrying capacity: $ln(K) \sim U(ln(max(C), ln(10.sum(C)) = U(ln(144047), ln(4450407))$
- Proportion of carrying capacity in first year of assessment: $a \sim U[0.001, 1.0]$
- Natural logarithm of the survey-specific catchabilities $ln(q_i) \sim U(-16, 0)$ (for IBTS only). The acoustic survey prior is discussed below.

- Process error precision $\frac{1}{\sigma_u^2} \sim gamma\,(0.001{,}0.001)$

Specification

During the 2013 WGWIDE meeting a number of different iterations of the model were run to discern the best parameters for the assessment. After four initial runs and four sensitivity runs the settings for the final run (run 2.2) were chosen. These settings are shown below and were used for the assessment model since 2014. (More details of the trial runs in 2013 can be found in the stock annex).

The specifications for the final boarfish assessment model runs are:

Acoustic survey

Years: 2011–2020

Index value ($I_{acoustic,y}$): 'total' in tonnes (i.e. Definitely Boarfish + Probably Boarfish + Boarfish in a Mix)

Catchability ($q_{acoustic}$): A free, but strong prior (i.e. the acoustic survey is treated as a relative index but is strongly informed, this allows the survey to cover <100% of the stock).

IBTS surveys

6 delta log normal indices (WCSGFS, SPPGFS, IGFS, ECSGFS, SPNGFS, EVHOE)

First 5 and last 7 (since 2017, because of change in survey design) years omitted from WCSGFS

First 9 years omitted from ECSGFS

Following plenary discussion of the sensitivity runs in 2013, it was decided that the final run be based on a run that includes all surveys with the omission of the first 5 years of the WCSGFS and first 9 years of the ECSGFS. The reasons for this decision were: * it is unclear whether boarfish were consistently recorded in the early part of the ECSGFS, * the WCSGFS is thought to be at the northern extreme of the distribution and may not be an appropriate index for the whole stock, * the SPNGFS commences in 1991 such that running the assessment from 1991 onwards includes at least three surveys without relying, solely on the ECSGFS and WCSGFS, * surveys are internally weighted such that highly uncertain values receive lower weight.

Catches

2003–2020 time series

Priors

The final run assumes a strong prior $ln(q_{acoustic}) \sim N\ (1,\ 1/4)$ (mean 1, standard deviation 0.25), which has 95% of the density between 0.5 and 2. Given the short acoustic series (6 years) it is not possible to estimate this parameter freely (*i.e.* using an uninformative prior). The prescription of a strong prior removes the assumption of an absolute index from the acoustic survey. This assumption will be continually updated as additional data accrue.

Run convergence

Parameters for the 2020 model run converged with good mixing of the chains and Rhat values lower than 1.1 indicating convergence (Figures 3.6.3.1 & 3.6.3.2). MCMC chain autocorrelation was rather high but was compensated by long MCMC chains providing representative samples of the parameter posteriors (Figure 3.6.3.3).

Diagnostic plots are provided in Figure 3.6.3.4 showing residuals about the model fit. A fairly balanced residual pattern is evident. In some cases, outliers are apparent, for instance in the English survey in the final year (2003). However, these points are down weighted according to the inverse of their variance and hence do not contribute much to the model fit. The west of Scotland IBTS survey, located at the northern extreme of the stock distribution underestimates the stock in the early period (years) and overestimates it in the recent period from all fits. This could be indicative of stock expansion into this area at higher stock sizes and suggests that this index is not representative of the whole stock. Figure 3.6.3.5 shows the prior and posterior distributions of the parameters of the biomass dynamic model. The estimate of q is less than 1.0, leading to a higher estimate of final stock biomass than the acoustic survey.

Results

Trajectories of observed and expected indices are shown in Figure 3.6.3.6, along with the stock size over time and a harvest ratio (total catch divided by estimated biomass). Parameter estimates from the model run are summarized in Table 3.6.3.1. Biomass in 2020 is estimated to be 435 kt, continuing the relatively stable but low trend since 2014. The extremely low biomass estimate from the 2016 acoustic survey appears considered as an outlier by the model. Retrospective plots of TSB and F, presented in Figure 3.6.3.7, show that the perception of the stock is stable through time with the exception of 2013 prior to the inclusion of the lower biomass estimates of the acoustic surveys since 2014.

3.6.4 Pseudo-cohort analysis

Pseudo-cohort analysis is a procedure where mortality is calculated by means of catch curves derived from catch-at-age from a single year. This is in contrast to cohort analysis, which is the basis of VPA-type assessments. In cohort analysis, mortality is calculated across the ages of a year class, not within a single year. Because only seven years of sampling data were available and owing to the large age range currently in the catches a cohort analysis would only yield information for a very limited age and year range. Therefore, pseudo-cohort analysis was performed to supplement the Bayesian state space model.

Pseudo-cohort Z estimates increased with the rapid expansion of the fishery but decreased in 2011 due to the introduction of the first boarfish TAC (Table 3.6.4.1). By subtracting M (= 0.16), an estimate of F was obtained for each year (ages 7-14). This series was revised to represent ages 7-14, rather than 6-14 as in previous years, because in 2013 age 6 boarfish were not fully selected, *i.e.* age 7 had higher abundance at age.

It can be seen from the text table below that $Z = M$ in 2007, the initial year of the expanded fishery, while F is negligible. F increased to a high of 0.29 in 2012 and has gradually reduced down to 0.15 in 2015 and 2016. In 2017, it increased up to 0.17. There was a weak correlation between catches and pseudo-cohort F ($r^2 = 0.48$). Recent F estimated this way is close to F_{MSY} (0.149) and above $F_{0.1}$ (0.13).

Year	Z (7-14)	F (Z-M)	Catch (t)
2007	0.17	0.01	21 576
2008	0.33	0.17	34 751

2009	0.36	0.20	90 370
2010	0.33	0.17	144 047
2011	0.29	0.13	37 096
2012	0.45	0.29	87 355
2013	0.36	0.20	75 409
2014	0.37	0.21	45 231
2015	0.31	0.15	17 766
2016	0.31	0.15	19 315
2017	0.33	0.17	17 388
2018	0.36	0.20	11 286
2019	0.37	0.21	11 312

3.6.5 State of the stock

The most recent year assessment indicates that total stock biomass increased from a low to average level from the early to mid-1990s (Figure 3.6.3.6). The stock fluctuated around this level until 2009, before increasing until 2012. A sharp decline is seen between 2013 and 2014. Since 2014, the abundance has remained low but stable. There was concern in 2014 that this decline was exaggerated by an unusually low acoustic biomass estimate that led to a downward revision in stock trajectory. However, the 2014 survey is considered satisfactory in terms of containment. The comparably low 2014 biomass estimate was supported by results of the 2015 survey. The 2016 biomass estimate, the lowest of the time series is considered an outlier and has little influence on stock abundance estimates. The 95% uncertainty bounds are large and increasing with subsequent assessments. This reflects the uncertainty in the survey indices, and short exploitation history of the stock and the treatment of the acoustic survey as a relative biomass index. As more data accumulates from this survey, it is expected that the prior will become increasingly updated, and potentially less variable.

Catch data are available from 2001, the first year of commercial landings, and reasonably comprehensive discard data are available from 2003. Peak catches were recorded in 2010, when over 140 000 t were taken. Elevated fishing mortality was observed, associated with the highest recorded catch in 2010. Fishing mortality, expressed as a harvest ratio (catch divided by total biomass), was first recorded in 2003. Before that time, it is to be expected that some discarding took place, and there were some commercial landings. Fishing mortality increased measurably from 2006, reaching a peak in 2009-2010. F declined in 2011 as catches became regulated by the precautionary TAC but increased year on year until 2015 when reduced catches resulted in a reduction. The considerable catches in recent years do not appear to have significantly truncated the size or age structure of the stock and 15+ group fish are still abundant (Figure 3.2.1.1).

MSY reference points can be estimated from the assessment parameter values. In 2019, F_{MSY} and MSY $B_{trigger}$ are estimated as respectively equal to 0.168 (parameter r / 2) and 137 kt (parameter K / 4). Throughout the history of the fishery, estimates of stock biomass have remained above MSY $B_{trigger}$. Fishing mortality (F) was greater than F_{MSY} in 2009, 2010 and 2014, but has decreased since. In 2019, the stock is in the green area of the Kobe plot (Figure 3.6.6.1).

Estimates of recruitment are not available from the stock assessment. However, an independent index of recruitment is available from groundfish surveys (Section 3.5). Observations from the survey recruitment of 1 year olds show a slight upward trend for 2019 in the Spanish and Irish surveys while the French survey continues to show an upward trend (Figure 3.5.1).

3.7 Short Term Projections

As the assessment is exploratory, no short term projections were conducted.

3.8 Long term simulations

No long term simulations were conducted.

3.9 Candidate precautionary and yield based reference points

3.9.1 Yield per Recruit

A yield per recruit analysis was conducted in 2011 (Minto *et al.* 2011) and *F0.1* was estimated to be 0.13 whilst F_{MAX} was estimated in the range 0.23 to 0.33 (Figure 3.9.1.1). *F0.1* was considered to be well estimated (Figure 3.9.1.2). No new yield per recruit analyses were performed in subsequent years.

3.9.2 Precautionary reference points

It does not appear that boarfish is an important prey species in the NE Atlantic (Section 3.13). ICES considered that precautionary *F* targets (*Fpa*) should be consistent with F<M for prey species, and F=M for non-prey species. B_{lim} may be defined from the stock size estimates available from the stock assessment and set at *0.2*K* (0.2 * 528400 = 105 680 t), based on the exploratory assessment in 2019).

3.9.3 Other yield based reference points

Yield per recruit analysis, following the method of Beverton & Holt (1957), found *F0.1* to be robustly estimated at 0.13 (ICES 2011; Minto *et al.* 2011).

3.10 Quality of the assessment

ICES considers the current basis for the advice on this stock to be an interim measure prior to development of an age-based assessment. The acoustic survey has undergone several developments to improve its suitability with updates to methodology in 2012, a change in direction in 2017 and extension of transects at the boundaries to improve containment. The assessment was downgraded from Category 1 to Category 3 in 2014, and it has remained in this category since. The model is still considered suitable for category 3 advice, because it provides the best means of combining the available survey series. The assessment is sensitive to the acoustic series. In addition, a substantial part of the year to year variations in the stock abundance is linked to the process error. The use of some priors (like ratio to virgin biomass in the first year of the assessment) and survey (WCSGFS for instance) may require revision. Additional work to improve the surplus production model were undertaken in since 2015 and will continue next year.

The bottom trawl survey data are considered to be a good index of abundance given that boarfish aggregate near the bottom at this time of year. The trawl surveys record high abundances of the species, but with many zero hauls. The delta-lognormal error structure used in the analyses is considered to be an appropriate means of dealing with such data. The biomass dynamic model used in the stock assessment is based on the recent benchmarked assessment of megrim in Subdivisions 4 and 6. The model was further developed by including acoustic survey biomass estimates. One drawback of the model is that it does not provide estimates of recruitment. However, an estimate of recruitment strength is available from the Spanish and French trawl surveys.

3.11 Management considerations

As this stock is now placed in category 3, the ICES advice is based on harvest control rules for data limited stocks (ICES 2017). Since the biomass estimate from the Bayesian model is considered reliable for trend based assessment, an index can be calculated according to Method 3.1 of ICES (2012). The advice is based on a comparison of the average of the two most recent index values with the average of the three preceding values multiplied by the most recent catch. Table 3.6.5.1 shows the biomass estimates from the model from which the index was calculated.

Although no longer accepted as the basis for an analytic assessment, the surplus production model still provides the best unified view of this stock (Figure 3.6.3.6).

3.12 Stock structure

A dedicated study on the stock structure of boarfish within the Northeast Atlantic and Mediterranean Sea commenced in October 2013 in order to resolve outstanding questions regarding the stock structure of boarfish and the suitability of assessment data. Results (Farrell *et al.* 2016) indicated strong population structure across the distribution range of boarfish with 7-8 genetic populations identified (Figure 3.12.1).

The eastern Mediterranean (*MED*) samples comprised a single population and were distinct from all other samples. Similarly, the Azorean (*AZA*), Western Saharan (*MOR*) and Alboran (*ALM*) samples were distinct from all others. Of particular relevance to the assessment and management of the boarfish fishery is the identification and delineation of the population structure between southern Portuguese waters (*PTN2B-PTS*) and waters to the geographic north. A distinct and temporally stable mixing zone was evident in the waters around Cabo da Roca. The *PTN2A* sample appeared to be significantly different from all other samples however this sample was relatively small and was considered to represent a mixed sample rather than a true population.

No significant spatial or temporal population structure was found within the samples comprising the NEA population (Figure 3.12.1). A statistically significant but comparatively low level of genetic differentiation was found between this population and the northern Spanish shelf/northern Portuguese samples (NSA-PTN1). However, a high level of migration was revealed between these two populations and no barriers to gene flow were detected between them. Therefore, for the purposes of assessment and management these areas can be considered as one unit.

Analyses indicated a lack of significant immigration into this northeast Atlantic boarfish stock from populations to the south or from insular elements and the strong genetic differentiation among these regions indicate that the purported increases in abundance in the northeast Atlantic area are not the result of a recent influx from other regions. The increase in abundance is most likely the result of demographic processes within the northeast Atlantic stock (Blanchard & Vandermeirsch 2005; Coad *et al.* 2014).

Whilst the current assessment and management area constitutes the majority of the most northern population it should be extended into Northern Portuguese waters and repeated genetic monitoring of the stock in this region should be conducted to ensure the validity of this delineation. Based on analyses of IBTS data the biomass in this area is suspected to be small relative to the overall biomass in the TAC area.

3.13 Ecosystem considerations

The ecological role and significance of boarfish in the NE Atlantic is largely unknown. However, in the southeast North Atlantic, in Portuguese waters, they are considered to have an important position in the marine food web (Lopes *et al.* 2006). The diet has been investigated in the eastern Mediterranean, Portuguese waters and at Great Meteor Seamount and consists primarily of copepods, specifically *Calanus helgolandicus*, with some mysid shrimp and euphausiids (Macpherson 1979; Fock *et al.* 2002; Lopes *et al.* 2006). This contrasted with the morphologically similar species, the slender snipefish, *Macroramphosus gracilis* and the longspine snipefish, *M. scolopax*, whose diet comprised *Temora spp.*, copepods and mysid shrimps, respectively (Lopes *et al.* 2006). Despite the obvious potential for these species to feed on fish eggs and larvae, there was no evidence to support this conclusion in Portuguese waters and they were not considered predators of commercial fishes and thus their increase in abundance was unlikely to affect recruitment of commercial fish species. If the NE Atlantic population of boarfish is sufficiently large then there exists the possibility of competition for food with other widely distributed planktivorous species.

Both seasonal and diurnal variations were observed in the diet of boarfish in all three regions. In the eastern Mediterranean and Portuguese waters, mysids become an important component of the diet in autumn, which correlates with their increased abundance in these regions at this time (Macpherson 1979; Lopes *et al.* 2006). Fock *et al.* (2002) found that boarfish at Great Meteor Seamount fed mainly on copepods and euphausiids diurnally and on decapods nocturnally, indicating habitat dependent resource utilization.

Boarfish appear an unlikely target of predation given their array of strong dorsal and anal fin spines and covering of ctenoid scales. However, there is evidence to suggest that they may be an important component of some species' diets. Most studies have focused in the Azores and few have mentioned the NE Atlantic, probably due to the relatively low abundance in the region until recent years. In the Azores, boarfish was found to be one of the most important prey items for tope (*Galeorhinus galeus*), thornback ray (*Raja clavata*), conger eel (*Conger conger*), forkbeard (*Phycis phycis*), bigeye tuna (*Thunnus obesus*), yellowmouth barracuda (*Sphyraena viridensis*), swordfish (*Xiphias gladius*), blackspot seabream (*Pagellus bogaraveo*), axillary seabream (*Pagellus acarne*) and blacktail comber (*Serranus atricauda*) (Clarke *et al.* 1995; Morato *et al.* 1999, 2000, 2001, 2003; Arrizabalaga *et al.* 2008). Many of these species also occur in the NE Atlantic shelf waters although it is unknown whether boarfish represent a significant component of the diet in this region.

In the NE Atlantic boarfish have not previously been recorded in the diets of tope or thornback ray (Holden & Tucker 1974; Ellis *et al.* 1996). However, this does not prove that they are currently not a prey item. A study of conger eel diet in Irish waters from 1998-1999 failed to find boarfish in the diet (O'Sullivan *et al.* 2004). However, in Portuguese waters a recent study has found boarfish to be the most numerous species in the diet of conger eels (Xavier *et al.* 2010). It has been suggested that boarfish are an important component of the diet of hake (*Merluccius merluccius*), as they are sometimes caught together. However, a recent study of the diet of hake in the Celtic Sea and Bay of Biscay did not report any boarfish in the stomachs of hake caught during the 2001 EVHOE survey (Mahe *et al.* 2007).

The conspicuous presence of boarfish in the diet of so many fish species in the Azores is perhaps more related to the lack of other available food sources than to the palatability of boarfish themselves. Given the large abundance in NE Atlantic shelf waters it is likely that they would have been recorded more frequently if they were a significant and important prey item.

Boarfish are also an important component of the diet a number of sea birds in the Azores, most notably the common tern (*Sterna hirundo*) (Granadeiro *et al.* 2002) and Cory's shearwater (*Calonectris diomedea*) (Granadeiro *et al.* 1998). This is surprising given that in the Mediterranean discarded boarfish were rejected by seabirds whereas in the Azores they were actively preyed on (Oro & Ruiz 1997). Cory's shearwaters are capable of diving up to 15 m whilst the common tern is a plunge-diver and may only reach 2-3 m. It is therefore surprising that boarfish are such a significant component of their diet given that it is generally considered a deeper water fish. In the Azores boarfish shoals are sometimes driven to the surface by horse mackerel and barracuda where they are also attacked by diving sea birds (J. Hart, CW Azores, pers. comm.). Anecdotal reports from the Irish fishery indicate that boarfish are rarely found in waters shallower than 40 m. This may suggest that they are outside the range of shearwaters and gannets, the latter having a mean diving depth of 19.7±7.5 m (Brierley & Fernandes 2001). However, the upper depth range of boarfish is within maximum diving depth recorded for auks (50 m) as recorded by Barrett & Furness (1990). Given their frequency in the diets of marine and bird life in the Azores, boarfish appear to be an important component of the marine ecosystem in that region. There is currently insufficient evidence to draw similar conclusions in the NE Atlantic.

The length-frequency distribution of boarfish may be important to consider. IBTS data shows an increase in mean total length with latitude Table 3.3.2.1 and perhaps the smaller boarfish in the southern regions are more easily preyed upon. Length data of boarfish from stomach contents studies of both fish and sea birds in the Azores indicate that the boarfish found are generally < 10 cm (Granadeiro *et al.* 1998, 2002).

3.14 Proposed management plan

In 2015 the Pelagic Advisory Council submitted a revised draft management strategy for Northeast Atlantic boarfish. The EU has requested ICES to evaluate the following management plan:

This management strategy aims to achieve sustainable exploitation of boarfish in line with the precautionary approach to fisheries management, FAO guidelines for new and developing fisheries, and the ICES form of advice.

1) The TAC shall be set in accordance with the following procedure, depending on the ICES advice
   a) If category 1 advice (stocks with quantitative assessments) is given based on a benchmarked assessment, the TAC shall be set following that advice.
   b) If category 1 or 2 (qualitative assessments and forecasts) advice is given based on a non-benchmarked assessment the TAC shall be set following this advice.
   c) Categories 3-6 are described below as follows:
      i) Category 3: stocks for which survey-based assessments indicate trends. This category includes stocks with quantitative assessments and forecasts which for a variety of reasons are considered indicative of trends in fishing mortality, recruitment, and biomass.
      ii) Category 4: stocks for which only reliable catch data are available. This category included stocks for which a time series of catch can be used to approximate MSY.

iii) Category 5: landings only stocks. This category includes stocks for which only landings data are available.

iv) Category 6: negligible landings stocks and stocks caught in minor amounts as bycatch.

2) Notwithstanding paragraph 1, if, in the opinion of ICES, the stock is at risk of recruitment impairment, a TAC may be set a lower level.

3) If the stock, estimated in either of the 2 years before the TAC is to be set, is at or below B_{lim} or any suitable proxy thereof, the TAC shall be set at 0 t.

4) The TAC shall not exceed 75,000 t in any year.

5) The TAC shall not be allowed to increase by more than 25% per year. However, there shall be no limit on the decrease in TAC.

6) Closed seasons, closed areas, and moving on procedures shall apply to all directed boarfish fisheries as follows:

i) A closed season shall operate from 31st March to 31st August. This is because it is known that herring and mackerel are present in these areas and may be caught with boarfish.

ii) A closed area shall be implemented inside the Irish 12-miles limit south of 52°30 from 12th February to 31st October, in order to prevent catches of Celtic Sea herring, known to form aggregations at these times.

iii) If catches of other species covered by a TAC amount to more than 5% of the total catch by day by ICES statistical rectangle, then all fishing must cease in that rectangle for 5 consecutive days.

3.15 References

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3.16 Tables

Table 3.1.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Landings, discards and TAC by country by year (t), 2001–2019. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes

	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Unalloc	Discards	Total	TAC
2001			120							120	
2002			91							91	
2003			458						10929	11387	
2004			675						4476	5151	
2005			165						5795	5959	
2006			2772						4365	7137	
2007			17615			772			3189	21576	
2008	3098		21585			0.45			10068	34751	
2009	15059		68629						6682	90370	
2010	39805		88457			9241			6544	144047	
2011	7797		20685			2813			5802	37096	33000
2012	19888		55949			4884			6634	87355	82000
2013	13182		52250			4380			5598	75409	82000
2014	8758		34622			38			1813	45231	133957
2015	29	4	16325	375	104				929	17766	53296
2016	337	7	17496	171	21				1283	19315	47637
2017	548		15485	182	0.13				1173	17388	27288
2018	94		9513	172	0.08	0.23	148		1359	11286	21830
2019	757		9910	318	19		2.5		306	11312	21830

Table 3.1.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Landings by year (t), 2001–2019 (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
2001	ALL			120					120
2002	ALL			91					91
2003	ALL			458					458
2003	6.a			65					65
2003	7.b			214					214
2003	7.j			179					179
2004	ALL			675					675
2004	6.a			292					292
2004	7.b			224					224
2004	8.d			38					38
2004	7.j			122					122
2005	ALL			165					165
2005	6.a			10					10
2005	7.b			105					105
2005	8.a			38					38
2005	7.j			12					12
2006	ALL			2772					2772
2006	6.a			21					21
2006	7.b			15					15
2006	7.g			375					375
2006	8.a			1					1
2006	7.j			2360					2360
2007	ALL			17615			772		18386
2007	5.b2			6					6
2007	6.a			93					93
2007	7.b			1259					1259
2007	7.g			120					120

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
2007	8.a			5					5
2007	7.j			16131			772		16903
2008	ALL	3098		21584					24682
2008	6.a			28					28
2008	7.b			3					3
2008	7.g			184					184
2008	7.j			21370					21370
2009	ALL	15059		68629					83688
2009	6.a			45					45
2009	7.b			73					73
2009	7.c			1					1
2009	7.g			4912					4912
2009	7.h			18225					18225
2009	7.j			45372					45372
2010	ALL	39805		88457			9241		137503
2010	6.a			1349			10		1359
2010	6.aS			7					7
2010	7.b			2258					2258
2010	7.c			35			4		39
2010	7.e	2							2
2010	7.g	672		3649					4321
2010	7.h	1465		8453			1712		11629
2010	7.j	37667		72707			7515		117889
2011	ALL	7797		20685			2813		31295
2011	6.a			26					26
2011	7.b			274					274
2011	7.c			9					9
2011	7.g			811					811
2011	7.h	4155		8540			2813		15508

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
2011	8.a	18							18
2011	7.j	3624		11025					14648
2012	ALL	19888		55949			4884		80720
2012	6.a			125					125
2012	7.b	80		4501			838		5419
2012	7.c			108			907		1015
2012	7.g			616					616
2012	7.h	5837		10579			3139		19554
2012	8.a	1604		93					1697
2012	7.j	12366		39928					52294
2013	ALL	13182		52250			4380		69811
2013	6.a			538			15		553
2013	7.b			10405			100		10505
2013	7.e						883		883
2013	7.g			1808					1808
2013	7.h	955		11355			1728		14038
2013	8.a	1354		870					2224
2013	8.d			270					270
2013	7.j	10873		27003			1653		39529
2014	ALL	8758		34622			38		43418
2014	6.a			182			30		212
2014	7.b	12		3262					3274
2014	7.g			135					135
2014	7.h	4808		18389					23196
2014	8.a			119					119
2014	7.j	3886		12536			8		16429
2014	7.k	53							53
2015	ALL	29	5	16325	375	104			16837
2015	6.a	10		116		9			134

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
2015	7.b	8	4	2609		85			2706
2015	7.c			220					220
2015	7.g			547					547
2015	7.h	5		8506					8510
2015	8.a	6	1	682					688
2015	7.j			3646		10			3655
2015	6				128				128
2015	7				33				33
2015	8				214				214
2016	ALL	337	7	17496	171	21			18031
2016	6.a			377	45				422
2016	7.b		5	1198	35	0.66			1239
2016	7.c				0.08				0.08
2016	7.e				0.02				0.02
2016	7.h	330		6771					7101
2016	7.j			1852	90	16			1959
2016	8.a	2	1	6173		5			6181
2016	8.b					0.11			0.11
2016	8.d	5		1124					1129
2017	ALL	548		15485	182	0.13			16215
2017	4.a				0.03				0.03
2017	6.a	37		907	34				979
2017	7.b			124	118				242
2017	7.c				20				20
2017	7.d	1							1
2017	7.e				0.08				0.08
2017	7.f					0.02			0.02
2017	7.g			1		0.02			1
2017	7.h	239		2961		0.09			3200

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
2017	7.j			33	9				43
2017	8.a	271		10543					10814
2017	8.d			915					915
2018	ALL	94		9513	172	0.08	0.23	148	9928
2018	6.a	67		269	78				414
2018	7.b	19		163	9				191
2018	7.c	2			0.51				3
2018	7.f				3				3
2018	7.h	6		2582	46	0.08			2634
2018	7.j			1163	22		0.23		1185
2018	8.a			5182					5182
2018	8.b				14				14
2018	8.c							54	54
2018	8.d			154					154
2018	9.a							94	94
2019	ALL	757		9910	318	19		2	11005
2019	6.a	172		568	79	9			829
2019	7.b			238	150	0.36			388
2019	7.c			3	0.29				3
2019	7.d	1							1
2019	7.e				1	6			7
2019	7.f				6				6
2019	7.g			2	0.24				2
2019	7.h	268		6197	0.19	0.21			6466
2019	7.j			25	80	3		0.03	108
2019	8.a	315		2805					3121
2019	8.b				0.17				0.17
2019	8.c							2	2
2019	8.d			71					71

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
ALL	ALL	91195	12	432801	1218	144	22128	150	547644

Table 3.1.2.3. Boarfish in ICES Subareas 27.6, 7, 8. Discards of boarfish in demersal and non-target pelagic fisheries by year (t), 2003–2019. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Germany	Ireland	Netherlands	Spain	UK	Denmark	Lithuania	Total
2003		119	1998	8812				10929
2004		60	837	3579				4476
2005		55	733	5007				5795
2006		22	411	3933				4366
2007		549	23	2617				3189
2008		920	738	8410				10068
2009		377	1258	5047				6682
2010		85	512	5947				6544
2011	49	107	185	5461				5802
2012		181	88	6365				6634
2013	22	47	11	5518				5598
2014	117	50	477	1119	50			1813
2015		7		921	1			929
2016	869	20	41	348	4		1	1283
2017		640	146			386	1	1173
2018		525	89			744	0.55	1359
2019		57		240	8			306

Table 3.2.1.1. Boarfish in ICES Subareas 27.6, 7, 8. General boarfish age length key produced from 2012 commercial samples. Figures highlighted in grey are estimated.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
7.25	1	1													
7.75	1	1													
8.25		1													
8.75		1	1												
9.25		1	1												
9.75			1												
10.25			1												
10.75			2	10	3										
11.25			1	29	14	2	2								
11.75				9	21	21	18	2	2	1					
12.25				4	17	22	38	12	8						1
12.75					5	9	42	37	14	6	2		1	1	1
13.25					2	4	31	28	24	12	6	2	3	1	5
13.75					1	3	25	22	21	14	6	5	4	2	11
14.25							6	8	18	22	8	3	7	1	20
14.75						1	1	2	3	8	1	6	6	6	30
15.25							1	1		2	2	2	5	2	19
15.75										2				2	19
16.25															8
16.75															1
17.25															1
17.75															1
18.25															1
18.75															1

Table 3.2.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Number of samples collected from the catch per year.

Year	landings	% landings covered by sampling programme	no. samples	no. measured	no. aged
2001	120	0	0	0	0
2002	91	0	0	0	0
2003	458	0	0	0	0
2004	675	0	0	0	0
2005	165	0	0	0	0
2006	2772	0	0	0	0
2007	18387	NA	3	217	0
2008	24683	NA	1	152	0
2009	83688	NA	9	1475	0
2010	137503	NA	95	10675	403*
2011	31295	NA	27	4066	704
2012	80720	NA	80 (68)***	9656 (8565)***	814**
2013	69812	NA	76	9392	0****
2014	43418	NA	54	7008	0****
2015	16837	NA	32	3356	0****
2016	18031	NA	27	3861	0****
2017	16215	NA	18	1140	0****
2018	9927	NA	12	556	0****
2019	11006	NA	18	371	0****

* A common ALK was developed from fish collected from both commercial and survey samples. This comprehensive ALK was used to produce catch numbers at age data for pseudo-cohort analyses.

** A common ALK was developed from fish collected from samples from Danish, Irish and Scottish commercial landings. This comprehensive ALK was used for all metiers to produce catch numbers-at-age for pseudo-cohort analysis. Only aged fish measured to 0.5cm were included in the ALK.

*** Only Irish collected samples were used for length frequency, see stock annex.

****2012 ALK used

Table 3.2.1.3. Boarfish in ICES Subareas 5, 27.6, 7, 8. The allocation of Age length keys to unsampled metiers in 2019

Country	Area	Quarter	landed	ALK
DK	7.d	1	1	IE_8.a_Q1
DK	7.h	1	268	IE_8.a_Q1
DK	8.a	1	315	IE_8.a_Q1
ES	7.j	1	0.03	IE_8.a_Q1
ES	8.c	2	0.25	IE_8.a_Q1
ES	8.c	3	2	IE_8.a_Q4
IE	7.b	1	148	IE_7.h_Q4
IE	7.b	4	15	IE_7.h_Q4
IE	7.g	1	0.86	IE_8.a_Q1
IE	7.g	2	0.51	IE_7.h_Q4
IE	7.g	3	0.33	IE_7.h_Q4
IE	7.g	4	0.36	IE_7.h_Q4
IE	7.h	1	435	IE_8.a_Q1
IE	7.h	4	5762	IE_7.h_Q4
IE	7.j	1	22	IE_8.a_Q1
IE	7.j	2	2	IE_7.h_Q4
IE	7.j	3	0.76	IE_7.h_Q4
IE	7.j	4	0.79	IE_7.h_Q4
IE	8.a	1	1862	IE_8.a_Q1
IE	8.a	3	56	IE_8.a_Q4
IE	8.a	4	888	IE_8.a_Q4
IE	8.d	1	5	IE_8.a_Q1
IE	8.d	4	66	IE_8.a_Q4 IE_7.h_Q4
NL	7.b	3	6	IE_7.h_Q4
NL	7.b	4	2	IE_7.h_Q4
NL	7.c	3	0.29	IE_7.h_Q4
NL	7.e	1	1	IE_8.a_Q1
NL	7.f	2	5	IE_7.h_Q4

NL	7.f	4	1	IE_7.h_Q4
NL	7.g	4	0.24	IE_7.h_Q4
NL	7.h	1	0.19	IE_8.a_Q1
NL	7.j	1	9	IE_8.a_Q1
NL	7.j	2	0.94	IE_7.h_Q4
NL	7.j	3	70	IE_7.h_Q4
NL	7.j	4	0.47	IE_7.h_Q4
NL	8.b	4	0.17	IE_8.a_Q4
UKE	7.e	1	6	IE_8.a_Q1
UKE	7.h	1	0.21	IE_8.a_Q1
UKE	7.j	1	2	IE_8.a_Q1
UKE	7.j	2	0.01	IE_7.h_Q4
UKE	7.j	3	0.86	IE_7.h_Q4

Table 3.2.1.4. Boarfish in ICES Subareas 27.6, 7, 8. Catch per country and corresponding number of samples collected in 2019.

Country	Official Catch	Num Samples	Num Measured	Num Aged
DK	757			
ES	243			
IE	9967	18	371	
NL	318			
UKE	37			
UKS	1			

Table 3.2.1.5. Boarfish in ICES Subareas 27.6, 7, 8. Catch per area and corresponding number of samples collected in 2019

Area	Official Catch	Num Samples	Num Measured	Num Measured per 1000t
27.6.a	830			
27.6.b	42			
27.7.b	390			
27.7.c	13			
27.7.d	1			
27.7.e	14			

Area	Official Catch	Num Samples	Num Measured	Num Measured per 1000t
27.7.f	8			
27.7.g	7			
27.7.h	6529	6	66	10
27.8.a	3121	12	305	98
27.8.b	12			
27.8.c	137			
27.8.d	71			
27.7.j	189			
27.7.k	0.04			

Table 3.2.1.6. Boarfish in ICES Subareas 27.6, 7, 8. Proxy catch numbers-at-age of the international catches (raised numbers in '000s) for the years 2007-2019

Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1			1575	2415		28	301		5556	218	1862	314	17427
2	352	5488	15043	11229	2894	893	7148	695	116135	2385	4387	1736	37620
3	2114	21140	65744	72709	41913	5467	156680	49503	32248	10737	8830	2628	9737
4	40851	105575	338931	294382	28148	41278	58522	127520	16588	25114	34448	13610	9944
5	48915	141300	475619	567689	30116	110272	59797	93705	24564	20263	27266	15570	12682
6	62713	195339	543707	878363	175696	146582	68949	67275	26566	18025	21103	14731	12716
7	26132	104031	307333	522703	143967	492078	302967	193061	74115	61229	55189	38686	29513
8	29766	66570	172783	293719	107126	365840	250341	139124	52052	47573	38229	26821	18819
9	56075	53159	155477	276672	77861	271916	212318	121042	44615	42478	32258	23670	15875
10	44875	46893	130148	232122	60022	173486	160137	94225	34264	35150	25716	19395	11359
11	14019	15289	42521	78588	46079	69396	63025	36078	12999	13297	9560	7148	4272
12	32359	21178	61350	114600	40468	40968	41490	24895	9114	9132	7564	5846	2937
13	4848	11854	39609	59932	24352	58888	59380	36309	13362	13774	10922	8183	4256
14	16837	13570	31569	59060	19724	30277	30355	19064	7152	6682	5924	4554	2156
15+	109481	112947	196967	349320	157707	217260	239366	150688	59139	49589	40797	32130	14864

Table 3.2.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Length-frequency distributions of the international catches (raised numbers in '000s) for the years 2007-2019.

Length	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
0									14					14
1									878					878
2									515					515
3				156					810		765		15868	17599
4				439					14		4607	203	70362	75625
5				1090	522	56	52		513	417	5250	405	80160	88465
6			1354	1574			551		10598	1684	12616	2635	85420	116432
7			677	375	1345	185	1419		80716	8685	11473	4703	115154	224732
8				1082		555	3592	1064	49508	6412	10115	3559	67471	143358
9			677	5382	851	555	7263	327	10219	7104	3874	6554	16504	59310
10		7473	17367	7883	7012	641	47509	4916	213	23065	14047	6196	3147	139469
11	9609	11209	54130	29410	33243	2791	94702	31649	1211	46010	32346	5559	9173	361042
12		52308	174796	130889	15848	6132	59833	71344	3865	39071	36242	4450	10144	604922
13	84555	63517	343283	361774	70615	24571	18359	108261	12226	14181	32445	17658	5796	1157241
14		59781	321637	655875	93487	81928	20938	82470	28142	18249	31589	22826	22722	1439644
15	44199	119561	297737	739025	189434	264888	98564	84288	41613	30975	33618	24070	22353	1990325
16		70990	207739	564347	114904	398772	204868	112826	42461	51110	41650	24514	17521	1851702
17	82633	52308	147965	353484	133539	419060	315063	172416	59990	57000	46495	30665	28815	1899433

Length	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
18		29890	149314	246146	51235	307533	285688	153742	52625	58696	43121	38698	16688	1433376
19	117224	22418	105782	224611	50857	176710	210137	138549	50139	76872	45353	34080	20053	1272785
20		14945	71273	127711	25309	89726	105571	74059	28771	37755	39524	29908	13809	658361
21	65338	33627	47816	125463	25569	52791	62175	43347	16087	23137	21854	15561	5710	538475
22		11209	13082	81386	5473	25065	31122	22629	8572	7841	4932	5778	1513	218602
23	13452	11209	19397	24256	4181	13149	14990	7672	4331	625	1020	1948	143	116373
24		3736	4061	6209	2280	2738	4918	2134	2081	128		54	143	28482
25		3736	677	1913	456	827	1109	1361	289					10368
26							407		23					430
27				283			296							579
28									592					592

Table 3.3.1.1. Boarfish in ICES Subareas 27.6. 7, 8. Acoustic survey abundance and biomass estimates from 2011-2020

Age	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	-	-	-	-	-	-	-	-	-	1083.9
1	5	21.5	-	-	198.5	4.6	110.9	76.7	782.3	896.5
2	11.6	10.8	78	-	319.2	35.7	126.7	31.2	389.1	1156.7
3	57.8	174.1	1842.9	15	16.6	45.5	344.6	115	96.8	966.7
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3	93.1	112.6
5	436.7	95	381.6	102.3	80	6	156	106.7	88.2	157.3
6	1165.9	736.1	253.8	104.9	112	10	209	165.9	105.9	183.3
7	1184.2	973.8	1056.6	414.6	437.4	169	493.1	320.7	445.7	912.9
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7	182.6	884.5
9	1094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4	288.	720.7
10	1031.5	955.9	703.8	332.3	360	96.6	285.8	624.7	290.1	330.9
11	332.9	650.9	263.7	129.9	131.7	17	120.9	339.2	49.6	80.6
12	653.3	1099.7	202.9	104.9	113	32	82.1	264.1	192.2	194.9
13	336	857.2	296.6	166.4	174	48.7	74.4	198.4	79.1	298.7
14	385	655.8	169.8	88.5	108	18.3	220.4	116.5	57.2	266.7
15+	3519	6353.7	1464.3	855.1	1195	400.1	931	302.4	758.9	1641.0
TSN ('000)	11104	14257	9091	3098	3996	1157	4387	3221	3899	9888
TSB (t)	670176	863446	439890	187779	232634	69690	230062	186252	179156	399872
SSB (t)	669392	861544	423158	187654	226659	69103	218810	184624	169213	357871
CV	21.2	10.6	17.5	15.1	17	19	21.9	19. 9	25.4	34.8

Table 3.3.2.1. Boarfish in ICES Subareas 27.6, 7, 8. IBTS length-frequency data

EVHOE

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1997		5	11	7	17	197	2659	5020	3719	3598	4429	12065	16651	7198	3455	501	18	1		
1998		1	4	26	76	2093	18283	8631	6125	5966	7095	11730	14078	9260	5076	934	8			1
1999			13	52	33	245	11177	26610	23947	6684	2899	4709	7868	6160	1353	267	7			
2000		17	79	120	8	1504	26894	17674	9836	21967	16382	29585	36853	16522	5397	989	75			
2001		1	45	687	489	913	21297	37171	13276	28355	31514	18309	12232	6471	3186	1270	81	4		
2002		2	18	23	11	547	9631	29874	17777	13290	9470	9697	9751	6268	2484	641	37	1	1	
2003			17	47	17	57	426	1655	7142	20018	24842	20989	21263	14494	7086	1550	36			
2004			33	512	378	123	1248	1419	1307	1083	3102	7308	7224	6353	7866	3630	241	5		
2005		2	93	975	1285	146	1100	2326	1229	1553	3183	13398	15758	9834	6010	1658	117	70		
2006	1	26	112	79	75	15510	37566	10750	3622	2127	1521	1955	4131	3955	2535	921	94	2	12	
2007		8	187	467	234	1503	22689	126065	64536	6341	6731	5431	6004	5911	4238	1409	118	11		
2008		3	434	2807	827	5341	53189	247296	165392	163200	69382	38434	18390	17258	9178	3490	745	6	1	
2009		6	128	194	72	1496	19769	35819	5264	3913	9556	12269	9402	10831	6720	775	38	1		
2010		21	529	116	154	5755	46438	74986	27175	11952	37420	58313	34737	33774	14626	1561	249	8	1	
2011		60	95	215	5	541	2247	8368	15256	33221	30237	50384	56559	36673	11867	3082	573	159	47	
2012		9	145	584	137	2922	28865	26816	6124	11739	13606	22369	37135	44082	19963	4893	127	1		

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2013		3	48	91	10	306	2185	2165	2542	13649	9932	14987	37755	40524	20107	6918	666		2	
2014		2	693	1386	508	84	1440	885	3074	8732	28586	39397	74122	69736	26871	3908	59	433		
2015		5	183	5898	4143	607	19075	179269	119004	15765	18014	61575	62024	59904	21525	5487	541	429	8	
2016	5	31	379	846	115	733	10284	14280	17251	42132	25304	68583	130633	131220	48538	11611	1358	26		
2017		2	103	129	3	27	269	198	5											
2018		7	1846	64840	57946	102	5424	38028	23510	13486	18312	35122	54264	63350	21702	6292	275	9		
2019	2	997	6467	589	10688	531908	561517	329850	59733	4505	3418	8451	32547	61582	30031	7468	962	204		

IGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2003		1	32	22	7	22	129	172	879	2942	2322	1326	3822	4628	2898	896	163	38		
2004		23	63	34	8	96	532	1431	369	344	410	2253	4320	4698	3966	1017	87	2	1	
2005		8	59	52	20	203	1024	585	288	636	341	3463	11457	11348	7955	1744	382	2	1	
2006	5	60	68	48	35	212	969	621	2046	4190	8044	7946	24208	42119	32168	12296	2454	532		
2007	1	6	44	18	31	501	923	1251	1638	1166	2510	3581	8275	10740	7093	1934	92			
2008			26	18	23	127	672	531	2095	13780	17664	19268	16980	19484	15953	8789	1747	76	1	
2009		3	80	76	25	94	228	486	1000	1139	9081	7749	5138	6921	5592	1084	68	1		
2010		6	42	3	18	199	272	463	920	393	7914	34236	28611	16063	8161	1974	433			
2011		6	14	5	4	189	772	586	555	670	2578	20171	22082	10829	5298	2207	266	9	6	

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2012		7	36	20	10	131	271	378	702	2144	1183	11105	34010	22742	10906	3903	525	4		
2013	1	3	9	9	20	127	352	340	1320	2833	3971	15572	51637	52868	20485	6560	492	20		
2014		10	68	54	4	18	13	25	60	130	1127	3251	19125	23016	10355	2988	284	18		
2015		3	11	16	24	193	1008	3708	848	105	713	6314	29727	48221	33024	17350	1885	531		
2016	4	31	121	63	7	67	186	1515	4057	2891	1349	4110	32753	57753	40907	15527	3670	86		
2017		6	53	10169	689915	6406	1751	715	11818	21886	10164	11841	25588	42311	35049	17110	3299	369		
2018	4	51	247	140	32	45	286	585	1195	6107	17006	15167	48895	61832	36519	10722	2030	63		
2019	4	19	117	47	53	266	583	173	106	487	2677	4967	6864	12080	10480	5125	772	71	4	2

SPNGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1991		1			31	690	1311	313	49	9	6	7	7	4				6		
1992		57	38	9	178	3290	2743	282	48	10	8	69	162	390	779	246	95			
1993		57	1206	488	97	3730	3753	421	105	54	7	4	8	3	2					
1994	1	40	33		342	4789	10162	8920	3195	53	106	20	9	12	1					
1995		84	108	4	342	3063	2157	220	84	65	58	105	105	90	20	4				
1996		218	537	143	245	4457	4449	267	820	722	82	145	126	219	96	39	2			
1997	2	102	809	441	235	3458	6824	2189	1923	534	156	353	161	88	3					
1998	3	2	7	4	49	1920	4685	1815	337	153	125	88	147	135	86	13	2	3		

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1999		6	59	13	134	2736	3010	193	106	83	109	143	390	645	402	69				
2000		7	3729	2046	17	554	1947	489	277	486	756	1252	999	1021	199	34	13			
2001		68	4	1	153	3241	5085	659	225	206	205	236	692	407	120	22	9			
2002		4	20		133	2333	2013	284	50	58	54	60	231	314	72	9				
2003		4	950	567	4	77	221	57	39	28	16	22	17	23	16	5	1			
2004		6	22	4	43	2289	3808	443	110	83	58	219	931	776	303	2	1			
2005		16	451	25	9	754	1007	207	85	102	30	54	257	218	90	44	2			
2006		14	156	160	50	2238	8913	4507	175	94	9	36	229	419	169	9	2			
2007		49	40	1	111	3025	6620	1099	129	260	81	7	93	215	89	21	3			
2008	7	4	92	247	1	936	1561	1326	234	1483	304	537	11	833	201	186	11			
2009	1	17	53	125	9	2582	3816	4105	119	250	45	142	59	819	120	17	1	1		
2010		55	102	5	232	13090	22032	3169	1160	1056	89	82	179	1007	1981	518	9			
2011		29	260	105	46	2805	5511	1278	148	340	145	100	144	591	724	134	3	1		
2012		29	132	35	556	7550	7844	1364	88	53	59	170	1051	2394	1553	432	21			
2013			2	11	126	2163	4664	854	302	609	251	61	110	123	140	64	7			
2014		75	117	6	12	263	465	79	1083	1175	1174	1266	998	2444	3623	817	31	1		
2015		13	67	3	58	1889	4248	534	75	465	750	970	695	1173	1473	453	70	1		
2016		0.16	0.85	0.04	0.39	9	24	4	9	7	3	6	5	6	2	0.25	0.03			

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2017	0.01	0.2	0.18	0.01	0.14	6	18	7	1	2	3	4	6	10	9	2	0.11	0.03		
2018			0.02		0.43	7	15	2	0.61	0.91	2	4	9	20	26	6	0.04	0.02		0.02
2019		0.1			2	33	38	4	0.2	0.8	2	2	4	23	46	13	1			

SPPGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2001		2		2	2	4		88	10	104	266	323	1334	2259	460	81				
2002									1	4	90	212	791	843	313	60				
2003						1		3	15	22	21	62	268	426	249	51	2	1		
2004		1				5	2		4	5	18	100	312	483	319	43	1			
2005		1		1	6	1	18	10	9	14	7	101	530	935	705	226	18			
2006			1	1	6	91	89	21	34	75	27	45	335	670	555	197	10	1		
2007					3	4	9	15	12	9	27	25	72	151	144	26	4			
2008		1				1	13	7	16	13	55	106	237	457	302	78	5			
2009		6	5		2	7	8	1		1	154	318	924	1201	1172	324	7			
2010	1			1	5	14	3	1	5	2	31	284	521	717	459	123	10			
2011								3	16	18	5	147	671	792	429	122	13		2	
2012				1	1			2	2	1	8	70	369	468	218	66	3			
2013				1		7	22	6	9		1	42	435	889	480	141	12	1		

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2014		10	9		1		3	17	62	11	6	85	2453	6703	3168	2115	162	82		
2015				2	1			1	1			32	300	471	316	151	43			
2016			0.04				0.02		0.16	0.06		0.1	2	4	3	1	0.25			
2017		1	0.35				0.2			0.02	0.35	0.52	3	10	10	5	0.33			
2018		0.04	0.02	0.02								0.68	21	66	45	21	3			
2019	0.09	0.69	0.08						0.06	0.08		0.29	8	19	16	4	0.29			

WCSGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1986								0.5												
1987								0.5	0.5	2	0.5									
1988				0.5																
1989							0.5													
1990				1		0.5	1	2	24	54	50	43	12	1						
1991						1	0.5	8	38	183	266	316	48	16						
1992						1		10	38	468	1145	4001	1626	486						
1993							4		2	9	60	155	72	16		0.5				
1994									0.5	0.5	0.5			0.5						
1995									8	36	194	294	398	199	22					

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1996				2		4	3				1	55	610	1574	304					
1997			4			0.5	6	9	4	6	25	108	203	157	40	4				
1998				1		1	5	2		1	2		3							
1999			1			2	5	1	1		1	2	1							
2000							2	2	39	110	216	288	182	92	46	6				
2001		1						1	4	15	28	59	134	240	103	10	4			
2002						1	8	2	1	82	742	3211	5601	5772	1497	167	1			
2003			1				3	52		53	281	1473	3066	4895	3083	309	28			
2004				1			2	2	43	82	743	4569	8600	9514	5692	948	84			
2005		2					24	3	23	25	110	435	1085	1708	792	130	6			
2006		1	2	1		1	4		10	218	232	452	1396	2852	2051	434	72			
2007			2	2		2	1	3	21	159	780	2923	5194	6888	5283	1523	116			
2008		1	1			16	37	36	187	468	1395	3213	9893	22758	18399	6288	575	71		
2009			1			1		4	52	2442	2093	440	331	287	246	129	10			
2010											530	1443	1384	1357	828	149	29			
2011		1	4	1		1	5	254	1015	2034	7613	18918	14478	6445	2006	236	23			
2012			1			1	2		103	9	1267	6545	26337	29361	27333	15857	1505	496		
2013				1			1			1	143	3201	15282	11288	3934	858	6	1		

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2014		48	457	386	48	3	7	63	21	98	876	11668	30267	39236	10933	1363	111	1		
2015			4	18	14	115	102	18	5			30	262	345	220	86	10	1		1
2016				1	2	49	1413	2439	2065	342	436	4088	24632	33254	14568	3484	508	102		
2017																				
2018																				
2019																				

Table 3.6.1.1. Boarfish in ICES Subareas 27.6, 7, 8. IBTS length-frequency data converted to age-structured index by application of the 2010 common ALK rounded down to 1cm length classes.

EVHOE (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1997	23	1877	6003	3741	3911	3938	7066	5867	4218	4832	4259	1461	2428	1699	1214	623
1998	31	12978	15997	6247	6247	5591	7435	5732	3777	4806	4386	1463	2843	1635	1619	676
1999	65	7577	31224	19915	8732	3499	3308	2715	1905	2720	2357	744	1540	975	893	285
2000	216	17676	27730	12586	17986	15525	18740	14297	9737	11041	9490	3208	5160	3797	2556	1266
2001	733	14389	41313	20357	25467	21921	16211	9247	4525	4543	3951	1332	2057	1322	1099	578
2002	43	6720	31728	18455	12784	8389	7115	4767	2851	3429	3018	994	1806	1123	1009	421
2003	64	509	3993	7348	18371	17276	16113	10798	6270	7620	6852	2267	4294	2501	2456	1009
2004	545	1265	1975	1261	1722	2227	4124	3228	2061	2871	3058	1066	2426	939	1509	901

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2005	1070	2101	2603	1497	2099	3015	7160	5992	4177	5301	4873	1642	3144	1796	1776	833
2006	217	35834	26593	4803	2199	1386	1489	1332	947	1521	1484	485	1170	557	725	311
2007	662	16817	122140	65369	16986	4919	4316	2967	1715	2452	2392	788	1802	820	1124	484
2008	3244	41612	258758	168378	134062	77106	37738	18750	8277	9132	8183	2660	4868	2458	2992	1226
2009	328	13338	36829	12194	5626	5982	7788	5443	3054	4443	4230	1364	3079	1382	1965	618
2010	666	33602	83903	35048	21677	23503	34210	23037	12643	16303	14519	4647	9008	4716	5551	1689
2011	370	2212	12471	14982	28729	26114	31844	23915	15535	19473	16964	5542	10176	6534	5663	2262
2012	738	20090	34348	11535	11098	10795	14979	13308	9004	15662	14714	4598	11467	5540	7325	2325
2013	142	1647	3695	3805	10388	9207	11385	11271	8299	14485	13797	4374	10961	5364	6893	2550
2014	2081	1524	2365	3805	12988	17314	27692	24954	17460	27410	25016	7911	18267	9918	11160	3465
2015	6086	19233	175572	108367	35891	17618	33197	26770	17433	25562	22840	7208	15396	8396	9445	3078
2016	1256	7360	21027	18355	32937	28679	43627	41581	30274	49797	45444	14238	33654	17999	20815	6633
2017	234	187	263	50	0.92											
2018	66693	61905	37678	23753	16636	14374	22348	19805	13380	22885	20805	6396	15571	8029	9892	2972
2019	8053	799246	572542	111704	14384	3449	6655	9040	6614	17118	16938	5089	15345	6290	10428	2925

EVHOE (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1997	1215	159	659	623	848	768	214	325	543	100	158	51	314	416

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1998	1224	232	904	676	965	1042	327	476	752	187	231	93	461	353
1999	647	62	474	285	477	509	91	246	317	53	62	27	123	197
2000	2604	253	1384	1266	1782	1538	374	714	1022	198	245	99	491	921
2001	959	153	684	578	780	710	304	456	508	254	147	129	290	306
2002	796	117	572	421	617	625	192	324	429	128	113	65	227	244
2003	1838	326	1387	1009	1462	1557	491	763	1104	310	322	155	644	532
2004	917	382	1142	901	1100	1160	817	925	962	726	360	366	715	181
2005	1368	285	1065	833	1140	1184	486	639	877	332	308	201	546	394
2006	445	125	464	311	434	496	245	308	373	184	116	93	242	103
2007	678	204	715	484	668	778	381	467	594	282	198	146	385	150
2008	1876	492	1919	1226	1765	2062	1064	1237	1523	698	420	352	835	460
2009	1114	309	1064	618	956	1295	398	493	957	155	306	78	611	235
2010	3457	690	2957	1689	2745	3490	921	1368	2435	312	669	160	1331	868
2011	4513	597	3197	2262	3408	3485	1077	1762	2339	616	619	388	1126	1414
2012	4142	920	4165	2325	3703	4595	1448	2356	3218	979	908	490	1815	928
2013	4068	981	4205	2550	3816	4494	1872	2650	3227	1384	914	692	1830	944
2014	7107	1227	5977	3465	5645	6813	1636	2961	4634	782	1438	607	2443	1853
2015	5952	1033	5325	3078	4950	5809	1744	2969	3937	1097	1193	763	1965	1551

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2016	12839	2342	11704	6633	10734	12885	3911	6423	8785	2322	2219	1174	4413	3266
2017														
2018	5679	1014	5603	2972	4952	5987	1726	3238	4008	1258	991	634	1973	1357
2019	4917	1461	6057	2925	4850	6771	2496	3418	4847	1494	1467	849	2730	814

IGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2003	55	126	517	929	2306	1859	1433	1244	842	1549	1546	495	1309	576	842	317
2004	120	418	1422	594	396	484	1303	1341	993	1713	1773	589	1491	618	948	390
2005	119	814	982	379	542	665	2302	2884	2364	4129	4140	1360	3431	1569	2142	822
2006	176	850	1572	1988	4719	5051	6885	7522	5179	12177	13018	4151	12178	4448	8189	3297
2007	68	1052	1866	1385	1605	1648	2625	2628	1855	3547	3577	1145	3059	1292	1987	723
2008	44	589	1710	3445	12363	12597	13266	9219	5227	7773	7797	2576	6069	2491	3886	2029
2009	159	268	776	1076	3174	4543	5513	3620	1839	2701	2706	886	2101	818	1373	491
2010	51	374	746	902	3021	6591	17251	13258	8630	10098	8924	3002	5053	3150	2750	1284
2011	25	642	951	598	1500	3223	10092	8432	5965	6989	6169	2095	3519	2333	1835	1014
2012	63	302	673	754	1773	2197	7201	8422	7104	10272	9476	3134	6741	3972	3834	1736
2013	21	373	862	1243	3026	3903	10918	13284	10691	18929	17531	5483	13636	7177	8471	2878
2014	132	29	47	90	423	794	2958	4429	3697	7450	7127	2213	5965	2873	3818	1248

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2015	30	814	3473	1377	516	943	4845	7454	5858	14016	14639	4623	13524	5243	9030	3979
2016	215	282	2400	2888	2682	1761	4458	7773	6173	16077	17088	5386	16240	6066	10938	4231
2017	10228	696697	6080	9322	16417	11347	9585	8818	5853	12738	13721	4436	12670	4564	8475	3944
2018	438	273	1086	2052	7920	9719	13658	14344	10383	20166	20022	6346	17086	7532	11049	3955
2019	183	631	450	243	1035	1656	3072	2785	1752	3700	4002	1298	3660	1270	2463	1160

IGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2003	467	148	527	317	462	585	287	324	441	179	151	109	263	96
2004	543	189	584	390	537	672	317	350	525	203	181	103	362	108
2005	1289	400	1283	822	1177	1509	689	703	1154	349	363	175	724	286
2006	3989	1708	5570	3297	4613	6048	3673	3775	4731	2459	1728	1496	2924	605
2007	1072	332	1196	723	1058	1334	553	722	999	387	322	193	645	207
2008	2183	900	2996	2029	2637	3017	2303	2367	2409	1758	763	917	1451	424
2009	727	261	802	491	707	955	390	433	738	217	255	109	508	128
2010	2303	414	1616	1284	1786	1832	742	897	1330	395	371	197	742	715
2011	1683	267	1165	1014	1352	1212	568	780	873	441	245	225	488	552
2012	2907	548	2360	1736	2447	2518	1096	1491	1807	781	498	392	991	850
2013	5165	980	4941	2878	4530	5265	1784	2964	3613	1312	941	666	1862	1291

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2014	2146	499	2236	1248	1967	2437	883	1317	1717	598	480	308	941	478
2015	4494	1690	6438	3979	5486	6393	3990	4977	4886	3470	1767	2000	3002	743
2016	5302	2226	7389	4231	6036	8062	4880	4910	6258	3105	1902	1596	3719	819
2017	4195	1923	6278	3944	5266	6491	4624	4744	5168	3422	1778	1896	3186	640
2018	6037	1863	6800	3955	5887	7590	3544	4077	5658	2144	1691	1104	3320	1222
2019	1197	554	1821	1160	1538	1862	1298	1402	1485	1025	512	548	956	174

SPNGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	1	1403	881	103	15	6	5	3	2	2	2	0.62	0.98	0.78	0.5	0.18
1992	104	4609	1830	95	17	13	41	53	36	103	156	57	175	37	120	64
1993	1751	5508	2424	164	50	19	6	3	2	2	2	0.67	1	0.79	0.56	0.29
1994	73	10576	12411	3844	643	57	35	17	5	5	4	1	2	1	2	0.27
1995	196	4230	1525	107	66	51	64	48	30	41	35	11	22	14	13	4
1996	898	6707	2908	584	554	254	109	66	38	72	68	20	54	23	36	11
1997	1352	7306	5446	1609	680	249	203	121	67	69	56	18	22	18	11	4
1998	13	4493	3640	638	175	100	79	58	37	55	53	17	40	19	25	9
1999	78	4258	1802	116	93	80	113	121	85	191	195	61	175	70	117	35
2000	5782	1661	1324	346	518	553	750	537	315	443	379	116	237	139	146	37

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2001	73	5952	3099	309	205	161	197	190	149	199	175	58	115	77	62	25
2002	24	3316	1395	104	54	43	55	63	47	98	88	26	70	37	46	10
2003	1521	203	155	38	26	16	14	10	5	9	9	3	7	3	4	2
2004	32	4268	2243	177	83	68	171	219	186	303	279	89	209	118	125	37
2005	492	1253	702	108	78	46	51	60	51	84	78	25	59	33	35	15
2006	330	7296	7378	1191	85	34	36	56	44	116	112	33	100	43	68	14
2007	90	6646	3990	367	180	106	37	30	18	55	54	16	50	20	35	8
2008	343	1736	1886	629	908	597	329	178	62	202	183	47	158	53	122	28
2009	195	4487	5078	1085	167	103	78	71	26	174	155	37	147	56	113	9
2010	162	24558	13572	1504	792	346	101	85	41	222	365	132	436	76	306	146
2011	394	5730	3656	431	244	163	94	77	38	141	182	61	198	48	140	50
2012	196	11653	5359	384	62	55	160	276	202	620	657	201	638	228	440	140
2013	13	4763	2946	446	439	276	110	59	30	45	49	17	44	16	28	16
2014	198	542	611	767	1131	910	875	626	323	711	913	317	926	228	635	271
2015	83	4207	2430	248	462	516	616	432	233	403	463	158	419	125	281	130
2016	1	23	17	7	6	4	4	3	2	2	2	0.65	1	0.75	0.93	0.24
2017	0.39	16	14	3	2	2	3	2	2	3	3	1	3	1	2	0.76
2018	0.02	15	9	1	1	1	3	3	2	5	7	2	7	2	5	2

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2019	0.1	53	23	1	0.98	1	2	2	1	5	8	3	10	2	7	3

SPNGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1991	0.48		0.25	0.18	0.3	0.25		0.12	0.12		3	3		0.18
1992	56	45	94	64	76	114	98	61	102	49	35	25	71	4
1993	0.58	0.09	0.28	0.29	0.38	0.37	0.09	0.09	0.28		0.09		0.18	0.2
1994	0.87	0.05	0.8	0.27	0.65	0.84	0.05	0.38	0.47		0.05		0.09	0.22
1995	9	0.91	7	4	7	7	1	4	5	0.8	0.91	0.4	2	3
1996	18	5	22	11	18	23	9	15	16	8	4	4	9	3
1997	11	0.14	6	4	7	6	0.14	3	3		0.14		0.27	4
1998	15	4	14	9	13	17	6	7	12	3	5	3	8	4
1999	58	18	65	35	55	77	25	34	57	14	18	7	37	10
2000	91	10	78	37	69	85	18	39	53	7	9	3	18	25
2001	53	6	34	25	38	38	11	17	25	4	5	2	11	17
2002	25	3	24	10	20	26	4	12	16	2	3	0.9	7	6
2003	2	0.83	3	2	2	3	2	2	2	1	0.73	0.5	1	0.42
2004	85	14	63	37	61	76	14	25	52	0.4	14	0.2	28	23
2005	24	4	22	15	22	22	9	16	15	9	4	4	8	6

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2006	32	8	35	14	27	42	9	15	29	2	8	0.9	15	6
2007	15	4	20	8	15	22	7	11	15	4	4	2	8	2
2008	36	10	81	28	54	73	32	63	47	37	9	19	18	0.28
2009	34	6	58	9	34	62	8	29	37	3	6	2	11	1
2010	130	91	206	146	178	245	145	135	213	104	90	52	180	4
2011	59	33	84	50	68	103	48	45	85	27	33	14	66	4
2012	198	73	266	140	215	295	122	161	220	86	71	43	141	26
2013	16	7	21	16	19	22	16	17	18	13	6	6	13	3
2014	291	168	402	271	348	488	259	240	412	163	165	82	329	25
2015	138	74	193	130	166	221	140	127	185	91	67	46	134	17
2016	0.53	0.09	0.49	0.24	0.43	0.56	0.13	0.24	0.38	0.05	0.09	0.02	0.18	0.12
2017	1	0.42	1	0.76	1	1	0.65	0.71	1	0.4	0.42	0.22	0.82	0.15
2018	2	1	3	2	3	4	2	2	3	1	1	0.61	2	0.24
2019	3	2	5	3	4	6	4	3	5	3	2	1	4	0.11

SPPGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2001	4	6	74	48	128	163	290	369	271	650	581	165	482	241	324	62
2002		0.03	0.4	4	29	57	162	201	162	294	272	84	214	112	134	40
2003		1	7	12	21	21	50	69	54	125	126	39	114	47	76	23
2004	1	6	3	3	10	18	66	86	65	146	150	47	135	54	89	27
2005	2	18	18	9	13	17	81	132	103	263	283	90	269	98	181	68
2006	2	137	77	33	53	36	51	84	64	180	200	64	197	67	134	53
2007		12	19	12	14	15	22	24	16	41	47	15	47	15	32	11
2008	1	9	15	13	25	35	72	79	53	130	135	42	124	46	85	27
2009	11	13	5	5	45	91	228	263	197	390	429	143	394	144	257	109
2010	1	19	5	4	15	41	156	167	121	236	236	75	201	84	131	46
2011		0.42	7	11	17	22	109	159	133	261	256	81	216	100	138	48
2012	1	1	2	2	4	10	57	86	72	149	143	44	121	57	78	26
2013	1	19	17	6	3	5	49	103	80	235	239	72	226	88	155	47
2014	19	4	31	38	20	14	219	597	438	1632	1647	478	1602	603	1126	417
2015	2	1	1	0.77	0.84	3	35	67	56	136	142	45	132	52	88	37
2016	0.04	0.02	0.05	0.09	0.06	0.03	0.19	0.45	0.36	1	1	0.36	1	0.4	0.77	0.29
2017	1	0.12	0.08	0.01	0.11	0.19	0.51	0.91	0.58	2	3	0.93	3	0.85	2	1
2018	0.08				0.01	0.07	2	5	4	16	17	5	17	6	12	5

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2019	0.77		0.02	0.04	0.06	0.05	0.74									

SPPGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2001	158	21	170	62	133	183	29	87	112	16	21	8	42	33
2002	80	14	73	40	66	81	20	38	55	12	14	6	28	20
2003	38	12	43	23	36	50	17	24	36	10	12	6	23	7
2004	45	15	49	27	42	59	19	24	44	9	14	4	29	8
2005	88	34	115	68	97	126	62	74	97	45	32	23	64	13
2006	63	26	88	53	74	94	49	60	73	39	26	20	50	8
2007	15	7	19	11	16	23	11	10	19	5	7	3	13	2
2008	40	14	51	27	42	57	24	30	43	16	14	8	27	6
2009	137	54	161	109	146	183	88	102	145	65	53	32	107	23
2010	69	22	79	46	69	89	37	47	66	25	21	12	42	13
2011	78	21	82	48	73	91	37	49	66	24	20	12	41	17
2012	43	10	46	26	40	50	18	28	35	13	10	7	20	9
2013	71	23	93	47	75	102	41	56	74	28	22	15	44	11
2014	476	160	791	417	626	739	420	632	530	423	185	252	288	61
2015	44	19	63	37	52	67	47	45	52	30	14	15	29	8

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2016	0.36	0.16	0.51	0.29	0.41	0.57	0.34	0.32	0.45	0.2	0.14	0.1	0.27	0.05
2017	0.92	0.49	2	1	1	2	1	1	1	1	0.45	0.5	0.91	0.08
2018	5	2	9	5	7	9	5	6	7	4	2	2	4	0.53
2019		0.73								0.75	0.7	0.37	1	0.21

WCSGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986			0.38	0.12												
1987		0.01	0.58	0.64	1	0.76	0.18	0.05	0.01							
1988	0.5															
1989		0.3	0.2													
1990	1	2	10	21	46	39	31	16	7	5	4	2	0.76	0.96	0.12	0.3
1991		2	23	52	175	185	193	105	45	36	28	9	5	5	2	1
1992		2	34	115	616	975	1952	1270	712	662	524	178	157	152	61	41
1993		2	2	4	23	41	80	52	29	26	21	7	6	6	2	2
1994		0.01	0.15	0.34	0.48	0.33	0.13	0.06	0.01	0.09	0.08	0.02	0.08	0.03	0.06	
1995		0.21	3	15	74	114	190	151	103	121	101	33	54	42	27	11
1996	2	5	2	0.03	1	6	67	153	112	391	353	95	318	144	224	29
1997	4	4	11	6	12	22	63	62	47	69	60	19	40	25	23	7

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1998	1	4	4	0.67	1	1	0.72	0.65	0.56	0.45	0.38	0.15	0.15	0.22		0.08
1999	1	5	3	0.8	0.47	0.58	1	0.7	0.4	0.31	0.25	0.09	0.05	0.08		0.02
2000		2	16	41	124	143	179	116	65	68	59	20	30	19	16	7
2001	1	0.11	2	5	17	21	40	44	30	70	67	20	58	25	39	9
2002		6	8	35	291	631	1838	1814	1320	2185	1935	594	1386	781	858	225
2003	1	2	42	28	127	272	867	971	691	1498	1519	476	1339	536	892	248
2004	1	2	16	57	327	770	2590	2686	1983	3447	3359	1079	2693	1240	1707	569
2005	2	15	19	19	53	93	276	325	236	519	501	153	429	188	286	76
2006	4	4	12	39	183	196	341	423	294	781	834	261	795	283	543	172
2007	4	3	14	56	339	638	1707	1727	1220	2309	2385	775	2056	820	1341	522
2008	2	41	110	208	689	989	2324	3054	2082	6013	6662	2108	6560	2164	4517	1712
2009	1	2	100	387	1816	1538	759	363	137	139	136	46	95	43	58	32
2010				17	160	347	785	626	398	580	549	179	394	189	245	87
2011	6	31	531	1086	3514	5387	10238	7369	4589	4924	4157	1403	2004	1489	988	477
2012	1	5	28	97	469	1148	4804	6462	5298	9990	10765	3610	9632	3810	6155	3487
2013	1	0.6	0.43	5	101	381	2420	3378	3003	4670	4228	1361	3064	1852	1769	647
2014	891	55	60	67	509	1549	6999	8472	6502	12849	11622	3475	9135	4722	5898	1390
2015	22	173	73	7	2	3	31	57	49	106	108	34	97	41	63	25

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2016	1	946	2978	1730	751	680	3544	5695	4735	10264	9850	3016	8414	3926	5481	1626
2017																
2018																
2019																

WCSGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1986														
1987														
1988														
1989														
1990	0.63		0.06	0.3	0.33	0.06		0.03	0.03					0.3
1991	3		1	1	2	1		0.5	0.5					1
1992	96		30	41	56	30		15	15					41
1993	4		1	2	2	1	0.05	0.6	0.5	0.1		0.05		2
1994	0.02		0.03		0.02	0.03		0.02	0.02					
1995	27	1	13	11	17	14	1	6	8		1		2	10
1996	94	14	112	29	78	126	14	49	77		14		28	15
1997	17	2	12	7	12	13	2	6	9	0.8	2	0.4	4	5

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1998	0.15			0.08	0.08									0.08
1999	0.05			0.02	0.02									0.02
2000	14	2	8	7	10	10	3	4	7	1	2	0.6	4	5
2001	19	5	21	9	17	25	7	10	18	2	5	1	9	3
2002	528	68	446	225	405	497	85	214	317	33	68	17	136	140
2003	446	143	480	248	401	592	182	215	439	62	140	31	280	77
2004	986	267	957	569	866	1129	387	487	832	190	259	95	517	215
2005	144	37	156	76	130	180	51	79	127	26	36	13	72	27
2006	252	100	322	172	261	379	165	176	290	87	93	43	186	35
2007	715	252	835	522	738	934	439	520	719	305	240	152	480	130
2008	2042	894	2945	1712	2424	3210	1695	1969	2499	1258	872	664	1673	247
2009	37	12	43	32	41	42	28	35	33	26	11	13	22	8
2010	149	41	140	87	130	166	64	72	123	30	38	15	75	35
2011	1016	93	520	477	678	590	124	249	388	47	91	24	182	362
2012	3477	1393	4814	3487	4404	4621	3430	4089	3703	3171	1490	1834	2485	658
2013	1296	179	971	647	999	1064	267	524	712	172	179	86	358	382
2014	3236	508	3097	1390	2616	3468	678	1499	2242	273	497	137	994	757
2015	34	11	41	25	36	44	23	28	33	17	10	9	20	8

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2016	2933	713	3140	1626	2666	3504	1214	1736	2465	697	713	399	1324	616
2017														
2018														
2019														

Table 3.6.3.1. Boarfish in ICES Subareas 27.6, 7, 8. Key parameter estimates from the exploratory Schaeffer state space surplus production model. Posterior parameter distributions are provided in Figure 3.6.3.5.

	Mean	SD	2.5	25	50	75	97.5
r	0.34	0.17	0.05	0.21	0.33	0.46	0.72
K	628454	393579	305500	429025	528400	683100	1659925
F_{MSY}	0.17	0.09	0.03	0.11	0.17	0.23	0.36
B_{MSY}	157000	98400	76400	107000	132000	171000	415000
TSB	480000	202000	222000	345000	436000	567000	992000

Table 3.6.4.1. Boarfish in ICES Subareas 27.6, 7, 8. Pseudo-cohort derived estimates of fishing mortality (F) and total mortality (Z), in comparison with total catch per year. Pearson correlation coefficient of F vs. catch (tonnes) indicated.

Age	Raised Numbers												
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	0	0	1575	2415	0	28	301	0	5556	218	1862	314	17427
2	352	5488	15043	11229	2894	893	7148	695	116135	2385	4387	1736	37620
3	2114	21140	65744	72709	41913	5467	156680	49503	32248	10737	8830	2628	9737
4	40851	105575	338931	294382	28148	41278	58522	127520	16588	25114	34448	13610	9944
5	48915	141300	475619	567689	30116	110272	59797	93705	24564	20263	27266	15570	12682
6	62713	195339	543707	878363	175696	146582	68949	67275	26566	18025	21103	14731	12716
7	26132	104031	307333	522703	143967	492078	302967	193061	74115	61229	55189	38686	29513
8	29766	66570	172783	293719	107126	365840	250341	139124	52052	47573	38229	26821	18819
9	56075	53159	155477	276672	77861	271916	212318	121042	44615	42478	32258	23670	15875
10	44875	46893	130148	232122	60022	173486	160137	94225	34264	35150	25716	19395	11359
11	14019	15289	42521	78588	46079	69396	63025	36078	12999	13297	9560	7148	4272
12	32359	21178	61350	114600	40468	40968	41490	24895	9114	9132	7564	5846	2937
13	4848	11854	39609	59932	24352	58888	59380	36309	13362	13774	10922	8183	4256
14	16837	13570	31569	59060	19724	30277	30355	19064	7152	6682	5924	4554	2164
15+	109481	112947	196967	349320	157707	217260	239366	150688	59139	49589	40797	32130	14864

Age	ln(Raised Numbers)												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	0	0	7	8	0	3	6	0	9	5	8	6	10
2	6	9	10	9	8	7	9	7	12	8	8	7	11
3	8	10	11	11	11	9	12	11	10	9	9	8	9
4	11	12	13	13	10	11	11	12	10	10	10	10	9
5	11	12	13	13	10	12	11	11	10	10	10	10	9
6	11	12	13	14	12	12	11	11	10	10	10	10	9
7	10	12	13	13	12	13	13	12	11	11	11	11	10
8	10	11	12	13	12	13	12	12	11	11	11	10	10
9	11	11	12	13	11	13	12	12	11	11	10	10	10
10	11	11	12	12	11	12	12	11	10	10	10	10	9
11	10	10	11	11	11	11	11	10	9	9	9	9	8
12	10	10	11	12	11	11	11	10	9	9	9	9	8
13	8	9	11	11	10	11	11	10	10	10	9	9	8
14	10	10	10	11	10	10	10	10	9	9	9	8	8
15+	12	12	12	13	12	12	12	12	11	11	11	10	10
Z (7-14)	0.17	0.33	0.36	0.33	0.29	0.45	0.36	0.37	0.31	0.31	0.33	0.36	0.37
F (M=0.16)	0.01	0.17	0.2	0.17	0.13	0.29	0.2	0.21	0.15	0.15	0.17	0.2	0.21

Age	ln(Raised Numbers)												
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Catches (t)	21576	34751	90370	144047	37096	87355	75409	45231	17766	19315	17388	11286	11323
Corr coef landings vs F	0.33												

Table 3.6.5.1. Boarfish in ICES Subareas 27.6, 7, 8. Estimates of total stock biomass and F.

Year	TSB.2.5	TSB.50	TSB.97.5	F.2.5	F.50	F.97.5
1991	99831	187300	417490			
1992	164100	291500	625690			
1993	198500	353600	755587			
1994	233002	418600	908197			
1995	201200	360400	771095			
1996	204500	362400	787985			
1997	174702	305750	654895			
1998	235505	410750	880680			
1999	175702	308150	658430			
2000	149902	264100	563787			
2001	163705	282200	597055			
2002	142000	243400	510680			
2003	127000	216600	463282	0.02	0.05	0.09
2004	180905	311700	662297	0.01	0.02	0.03
2005	176100	301700	638880	0.01	0.02	0.03
2006	223500	376800	795895	0.01	0.02	0.03
2007	195202	331650	699292	0.03	0.07	0.11
2008	246300	410450	850965	0.04	0.08	0.14
2009	252702	419300	866795	0.01	0.22	0.36
2010	368712	607300	1270000	0.11	0.24	0.39
2011	326705	544700	1150925	0.03	0.07	0.11
2012	464902	745200	1538900	0.06	0.12	0.19
2013	318805	523300	1094975	0.07	0.14	0.24
2014	147702	240800	507200	0.09	0.19	0.31
2015	174700	290500	613395	0.03	0.06	0.1
2016	125300	210000	438187	0.04	0.09	0.15
2017	224202	369900	778192	0.02	0.05	0.08
2018	226405	374700	786990	0.01	0.03	0.05

Year	TSB.2.5	TSB.50	TSB.97.5	F.2.5	F.50	F.97.5
2019	206502	347350	730597	0.02	0.03	0.05
202	222000	435900	992500			

3.17 Figures

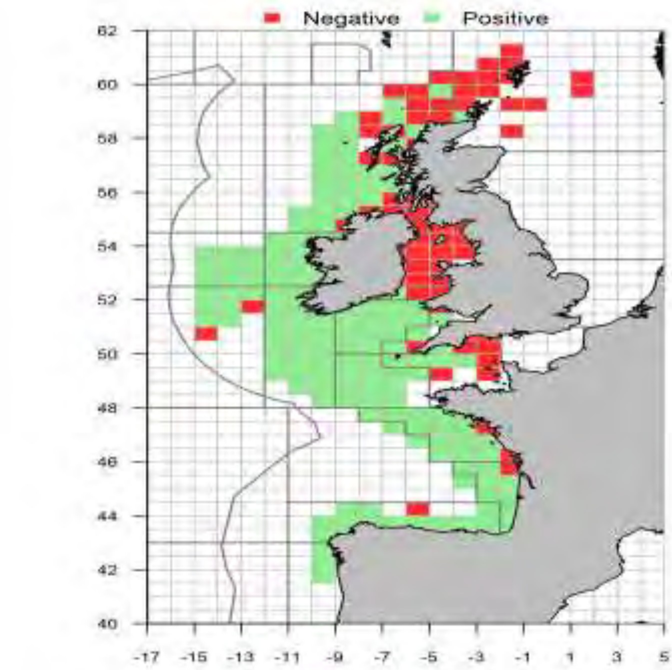

Figure 3.1. Boarfish in ICES Subareas 4, 27.6, 7, 8 and 9. Distribution of boarfish in the NE Atlantic area based on presence and absence in IBTS surveys (all years).

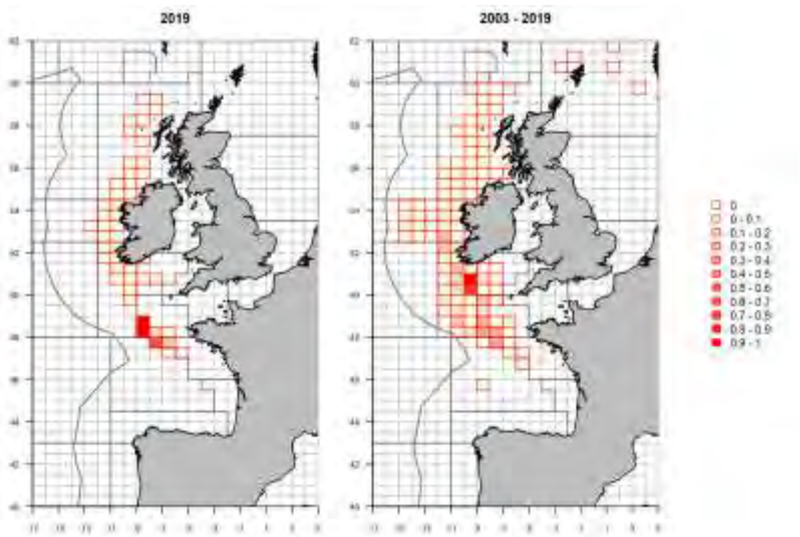

Figure 3.1.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Combined Irish boarfish landings 2003-2019 by ICES rectangle (Right). Irish boarfish landings 2019 by ICES rectangle (Left).

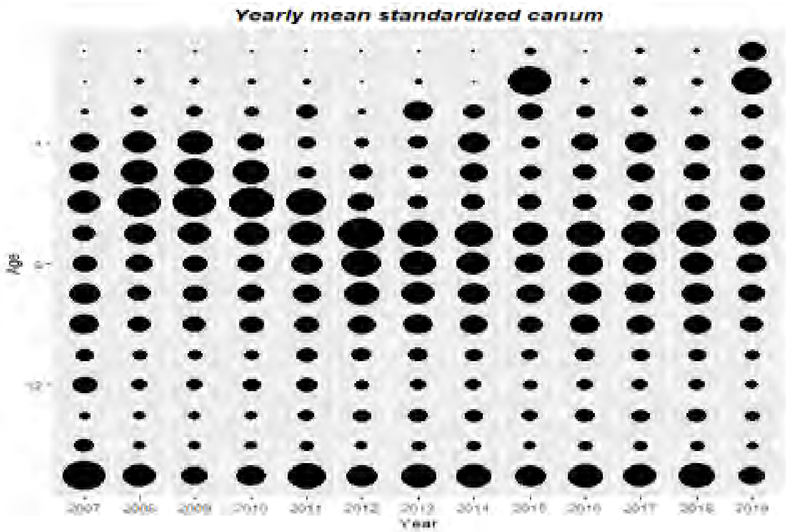

Figure 3.2.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Catch numbers-at-age standardised by yearly mean. 15+ is the plus group.

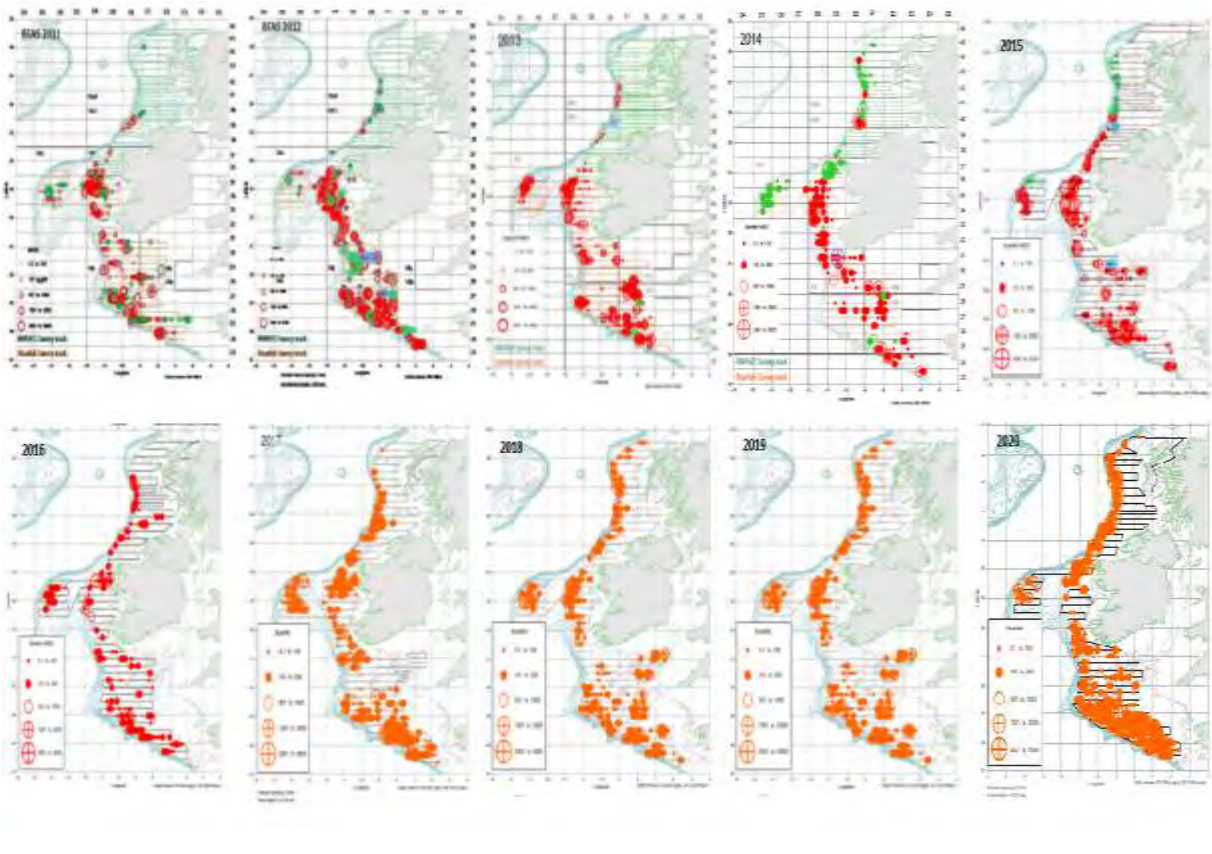

Figure 3.3.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey track and haul positions from acoustic survey 2011-2020.

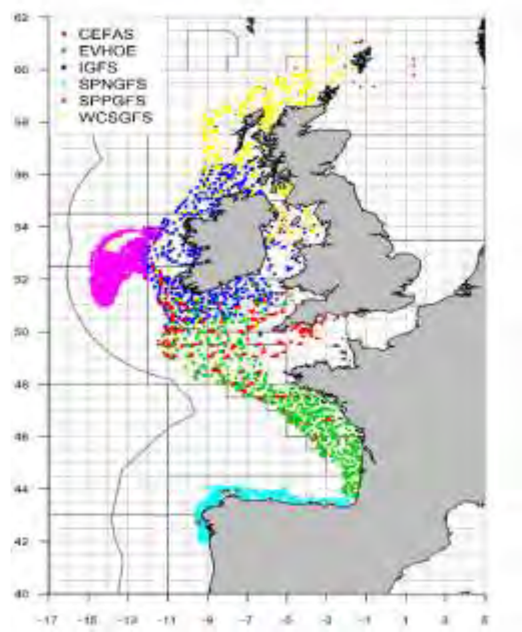

Figure 3.3.2.1. Boarfish in ICES Subareas 27.6, 7, 8. The haul positions of bottom trawl surveys analysed as an index for boarfish abundance. Note the Portuguese Groundfish survey included here was not included in the 2016 assessment.

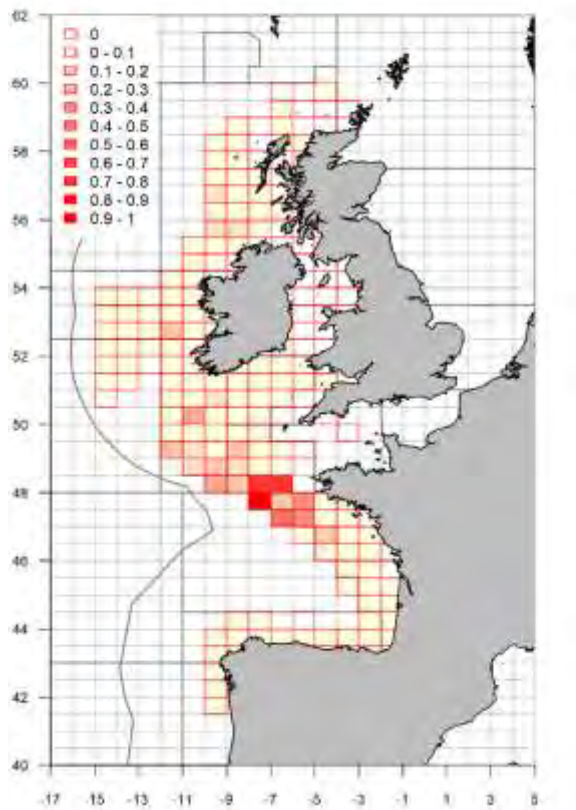

Figure 3.3.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Distribution of boarfish in the NE Atlantic showing proposed management area.

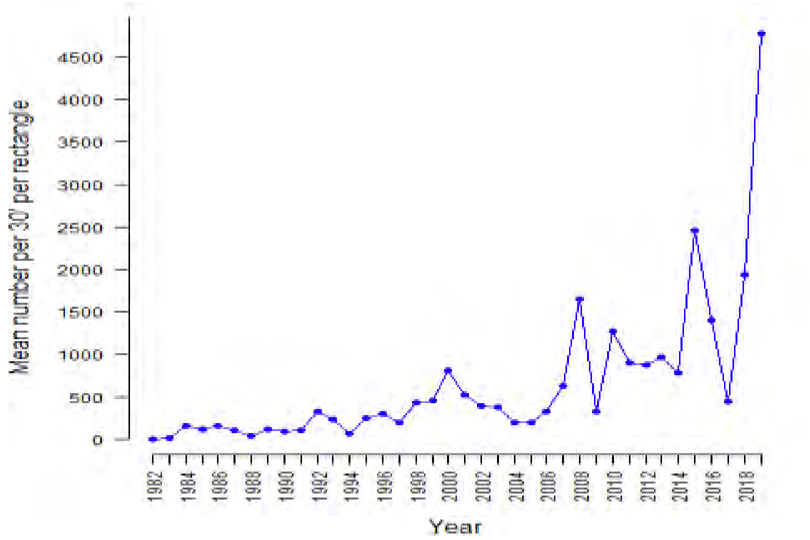

Figure 3.3.2.3. Boarfish in ICES Subareas 27.6, 7, 8. CPUE in number per 30-minute haul of boarfish per rectangle in the western IBTS survey 1982 to 2019.

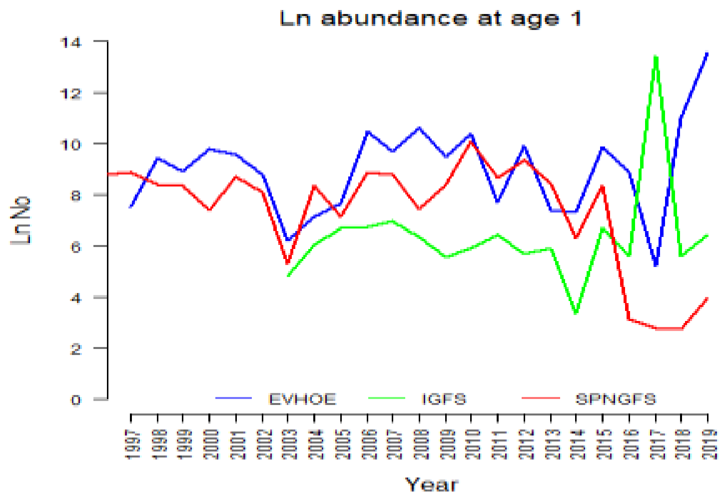

Figure 3.5.1. Boarfish in ICES Subareas 27.6, 7, 8. Recruitment-at-age 1, from various IBTS.

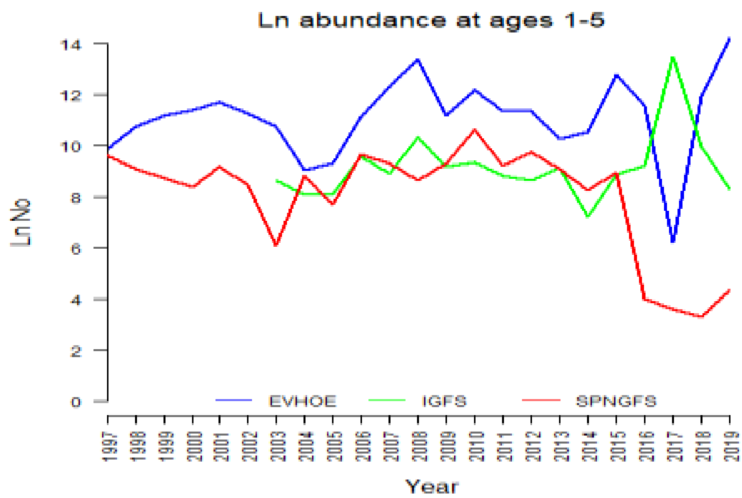

Figure 3.5.2. Boarfish in ICES Subareas 27.6, 7, 8. Recruitment-at-ages 1-5, from various IBTS.

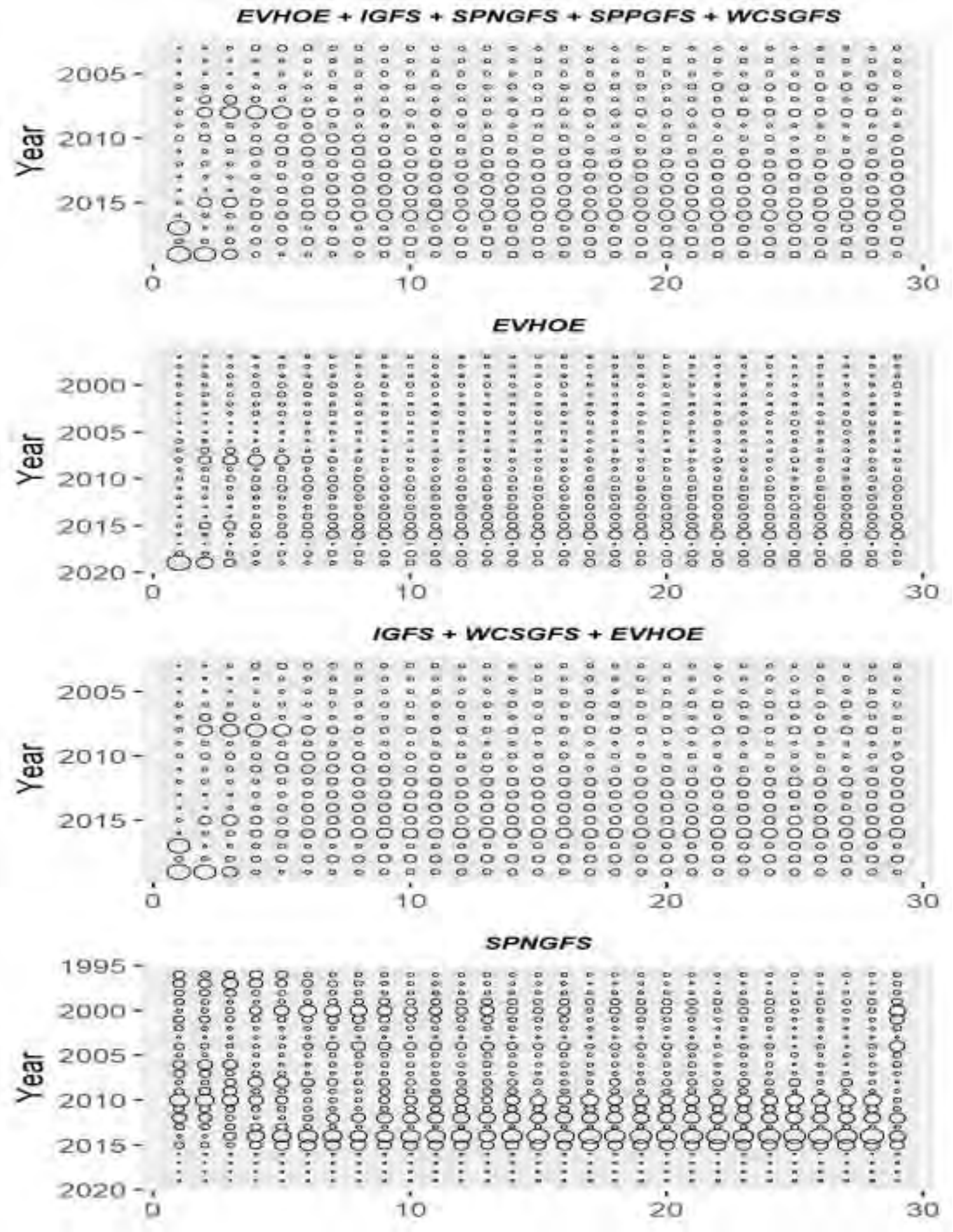

Figure 3.6.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Abundance-at-age in constituent western IBTS. Yearly mean standardised abundance-at-age.

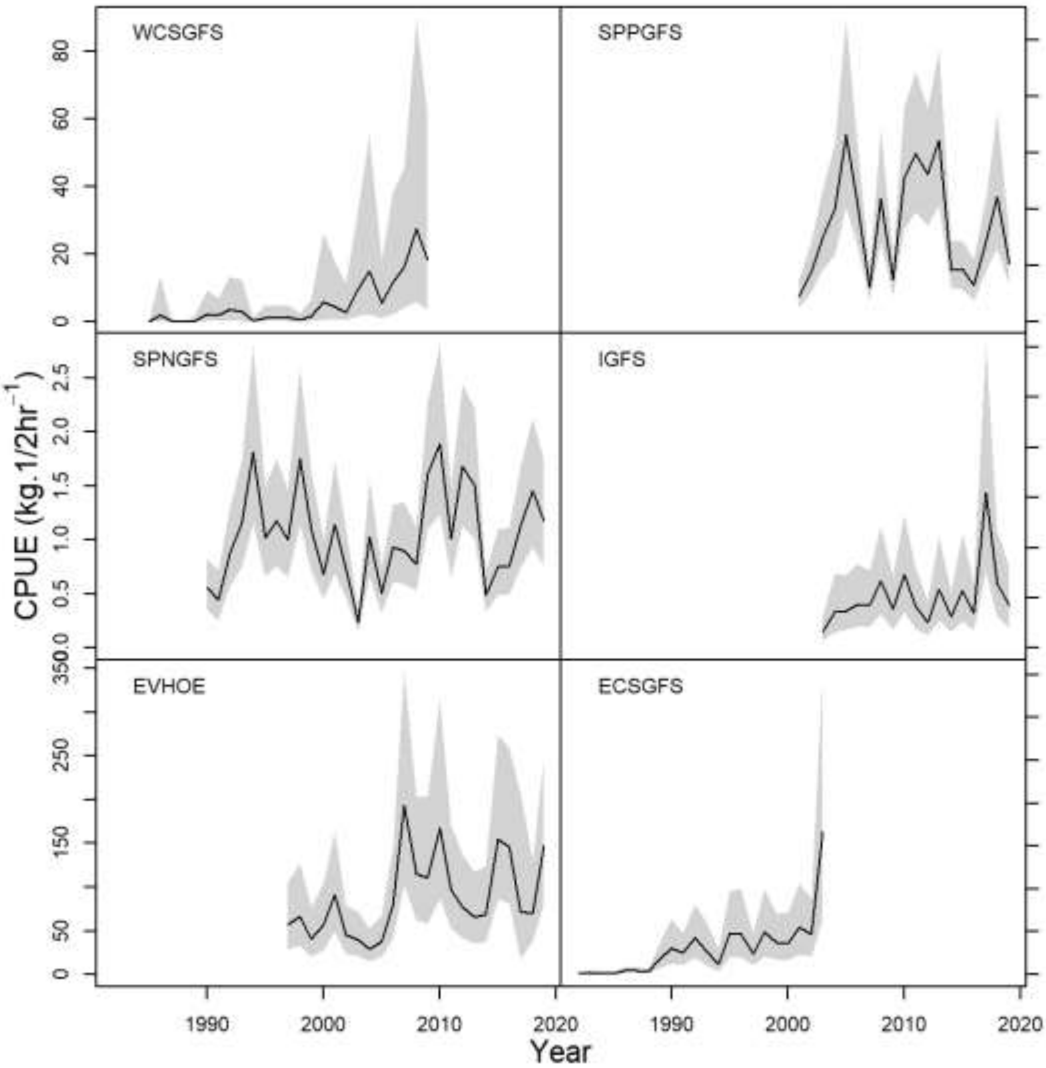

Figure 3.6.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish IBTS survey CPUE fitted delta-lognormal mean (solid line) and 95% credible intervals (grey region).

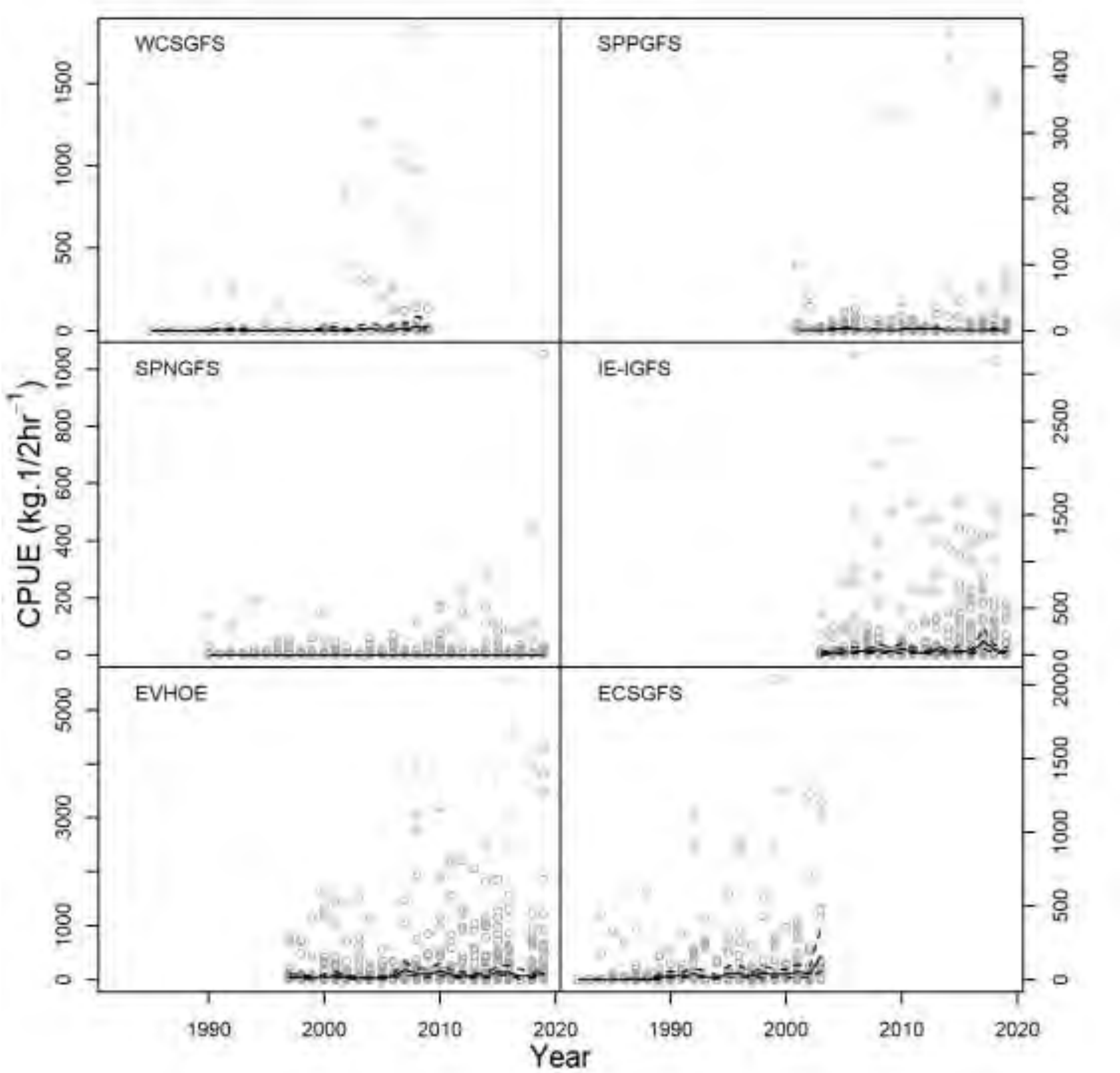

Figure 3.6.1.3. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish IBTS survey CPUE data (grey points) and fitted delta-lognormal mean (solid line) and 95% credible intervals (dashed lines).

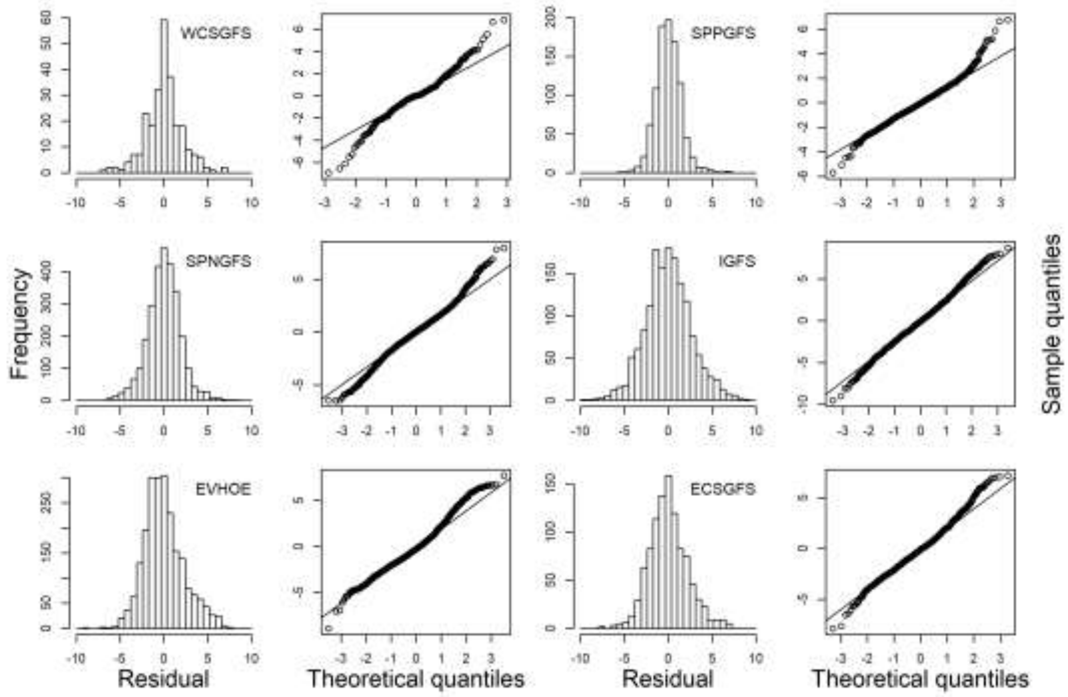

Figure 3.6.1.4. Boarfish in ICES Subareas 27.6, 7, 8. Diagnostics from the positive component of the delta-lognormal fits

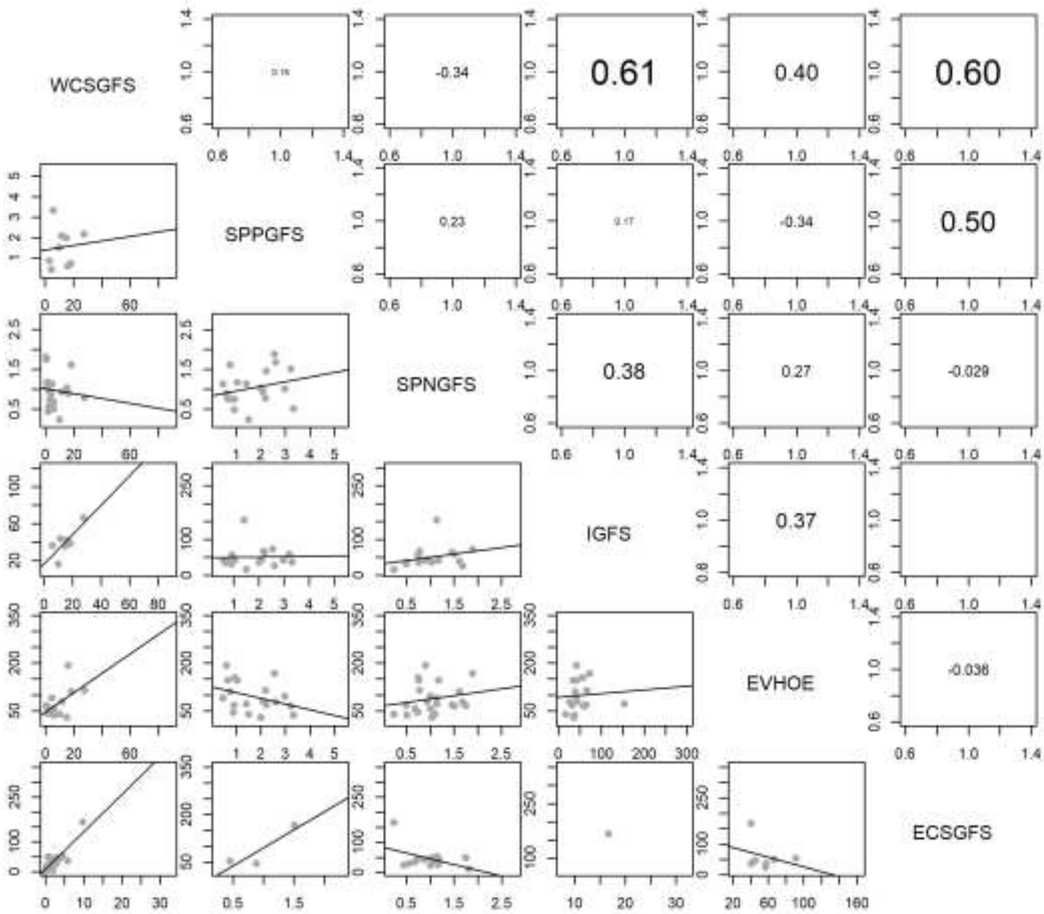

Figure 3.6.1.5. Boarfish in ICES Subareas 27.6, 7, 8. Pair-wise correlation between the annual mean survey indices.

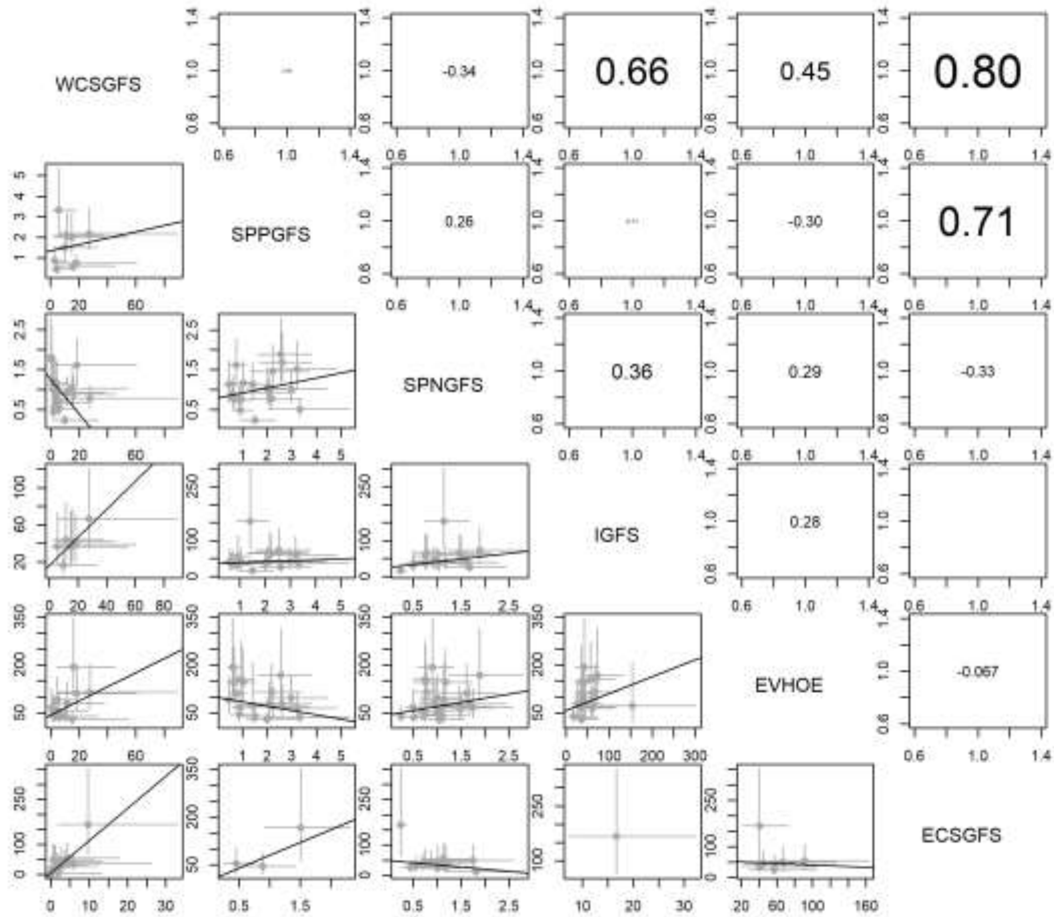

Figure 3.6.1.6. Boarfish in ICES Subareas 27.6, 7, 8. Weighted correlation between the annual mean survey indices. Correlations are weighted by the sum of the pair-wise variances.

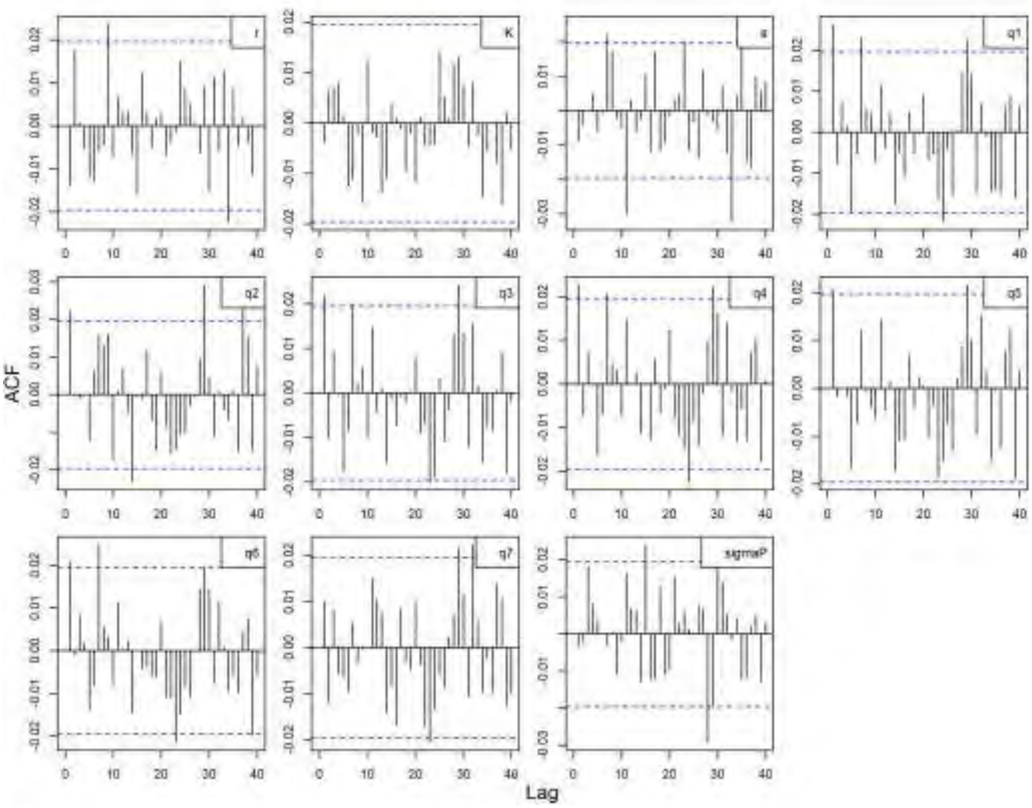

Figure 3.6.3.1. Boarfish in ICES Subareas 27.6, 7, 8. Parameters for final run converged with good mixing of the chains.

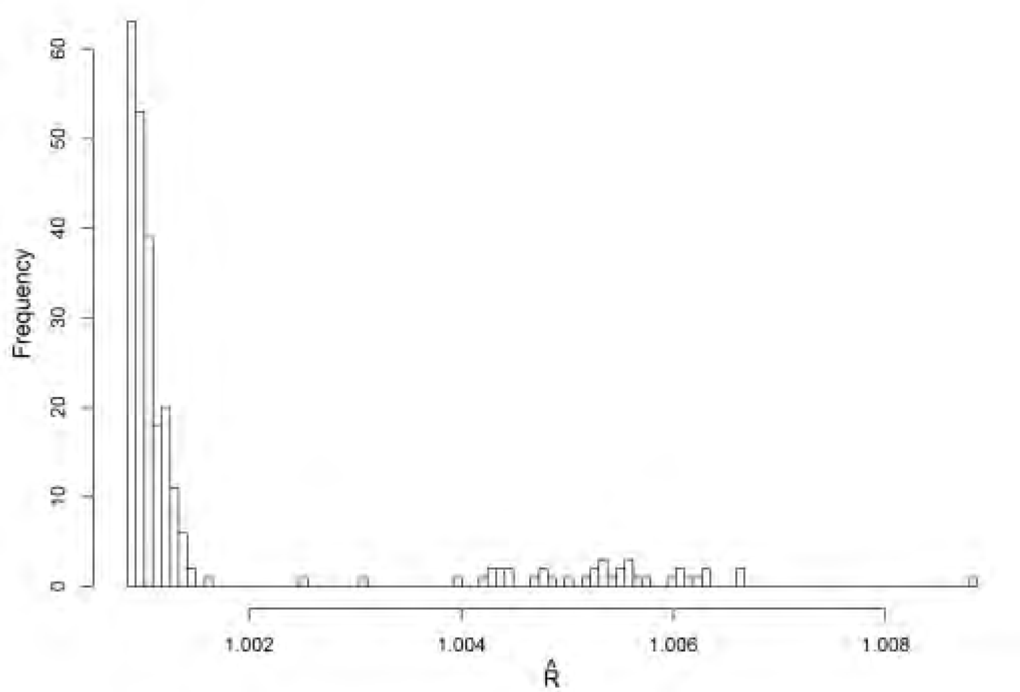

Figure 3.6.3.2. Boarfish in ICES Subareas 27.6, 7, 8. Rhat values lower than 1.1 indicating convergence.

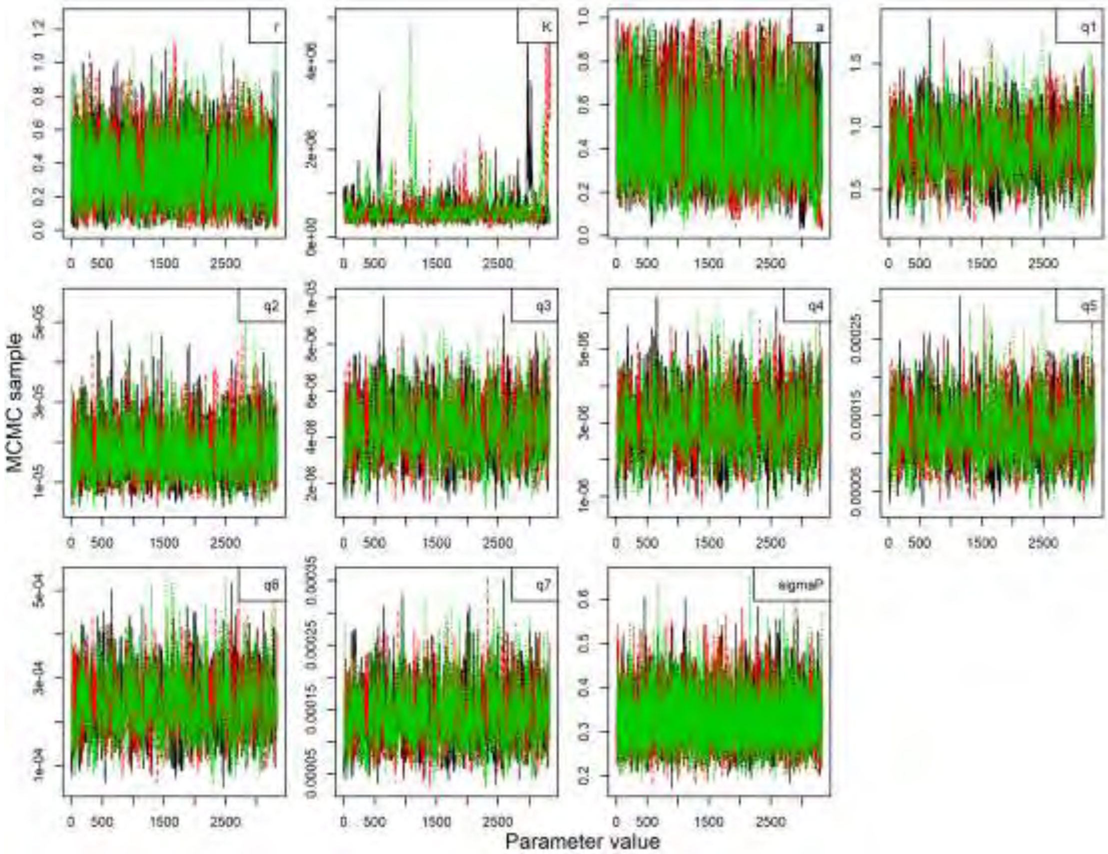

Figure 3.6.3.3. Boarfish in ICES Subareas 27.6, 7, 8. MCMC chain autocorrelation for final run.

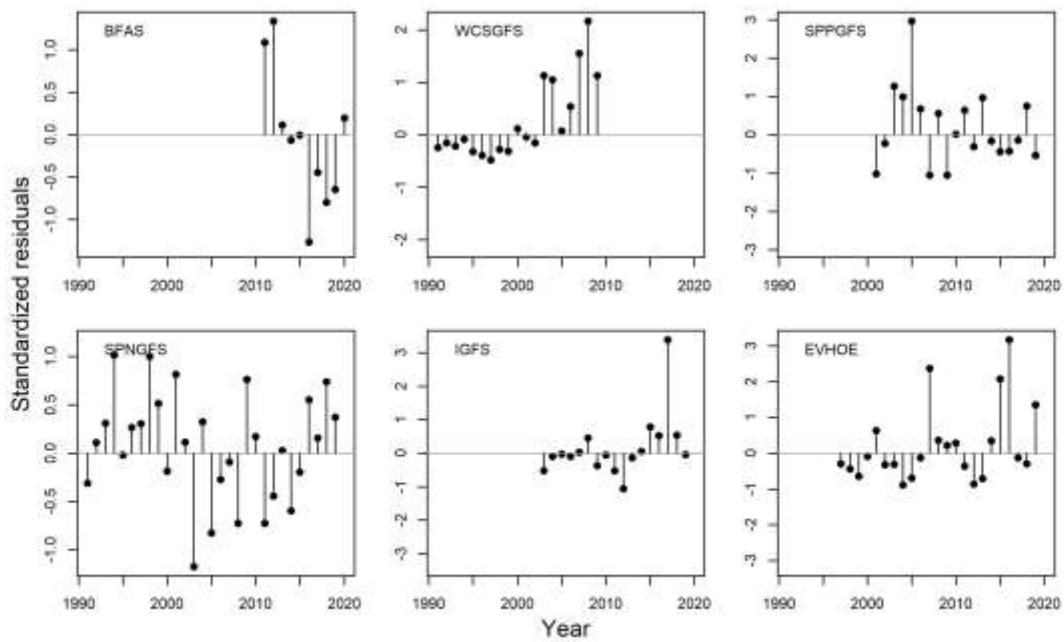

Figure 3.6.3.4. Boarfish in ICES Subareas 27.6, 7, 8. Residuals around the model fit for the final assessment run.

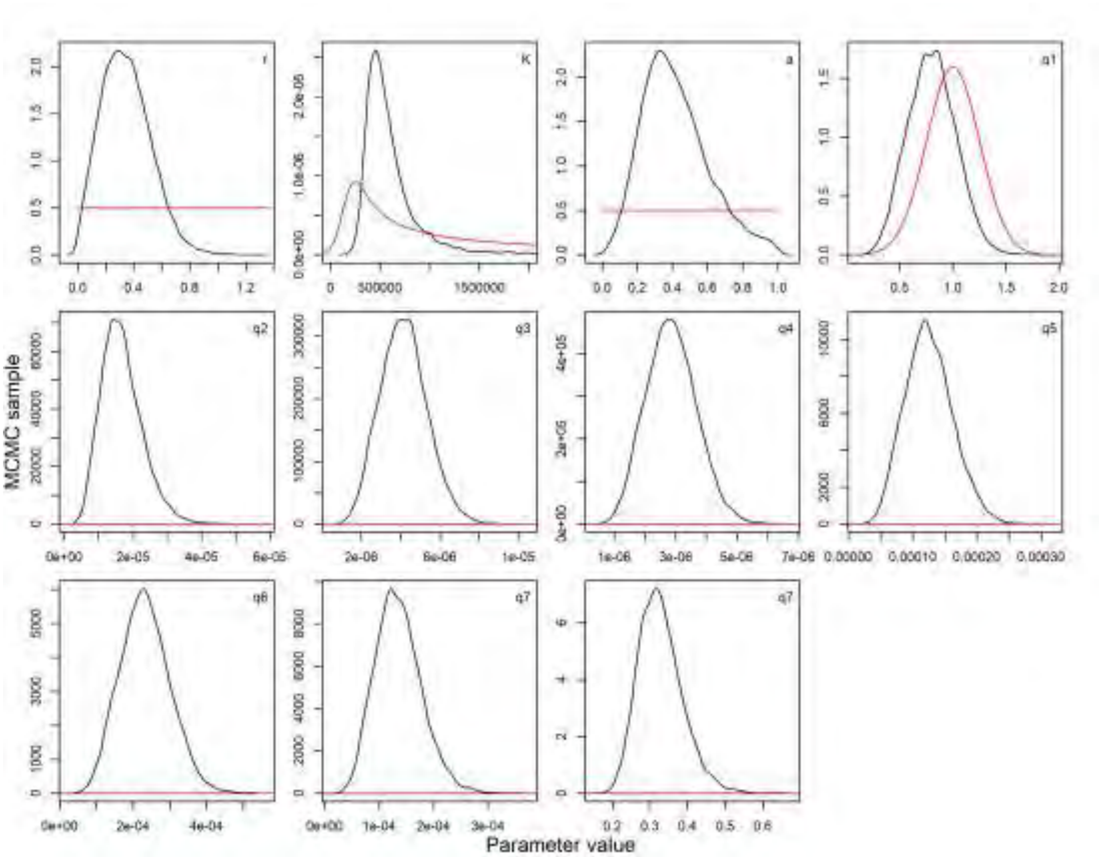

Figure 3.6.3.5. Boarfish in ICES Subareas 27.6, 7, 8. Prior (red) and posterior (black) distributions of the parameters of th e biomass dynamic model.

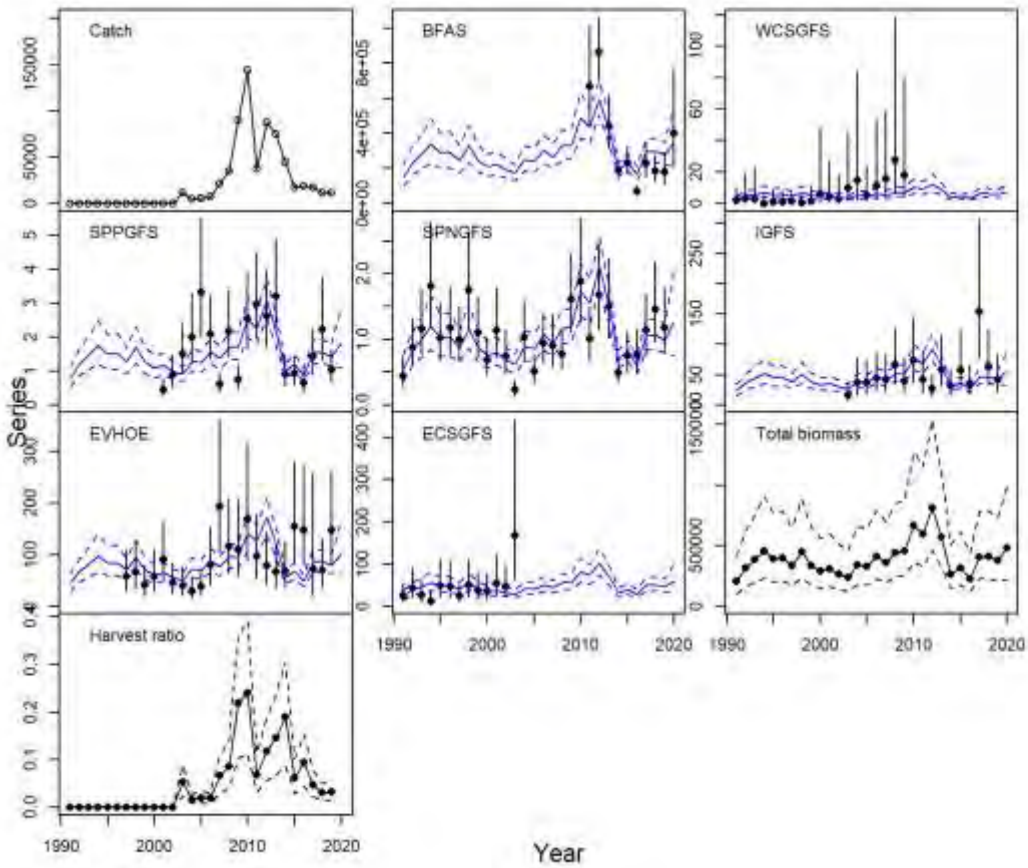

Figure 3.6.3.6. Boarfish in ICES Subareas 27.6, 7, 8. Trajectories of observed and expected indices for the final assessment run. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

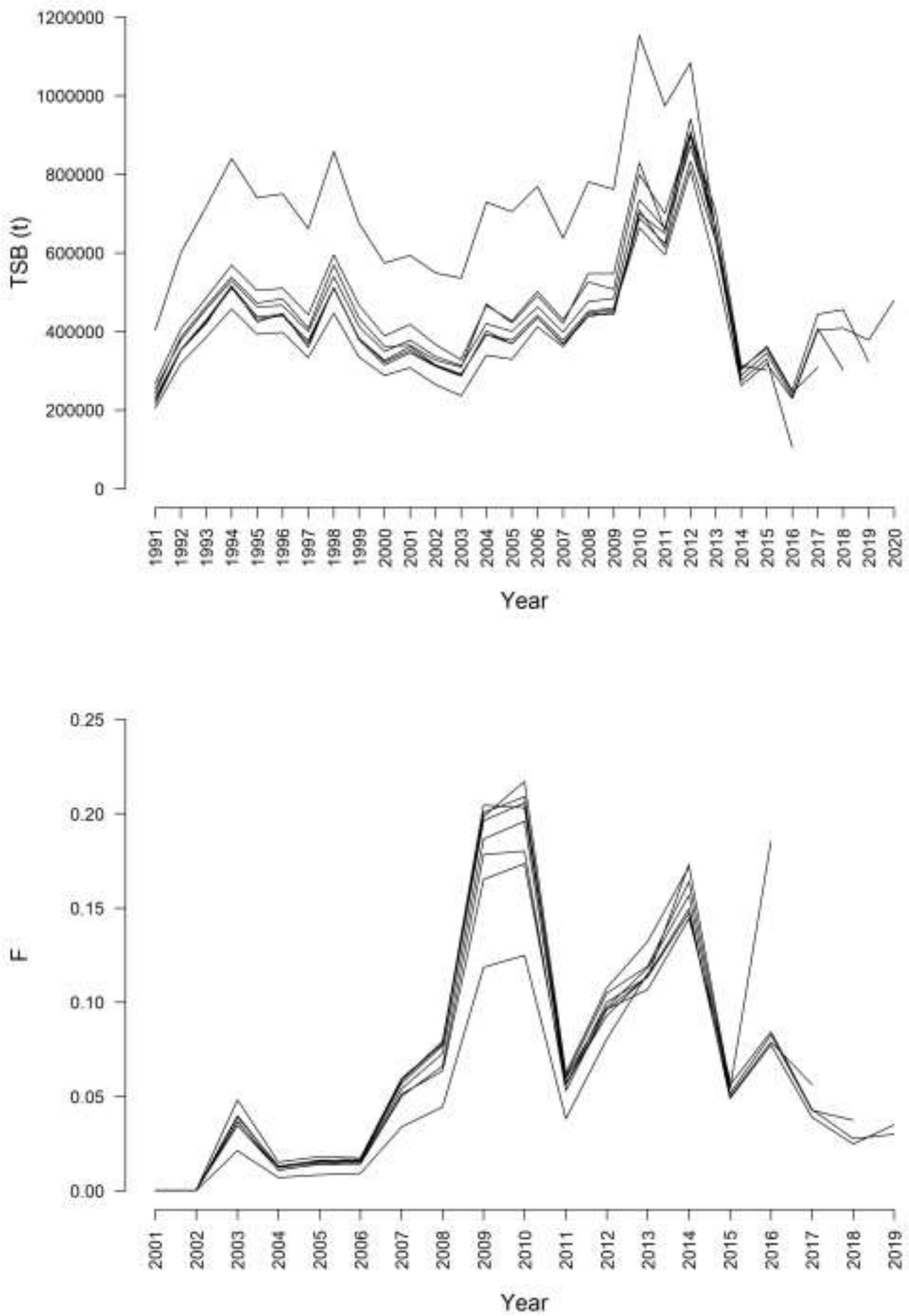

Figure 3.6.3.7. Boarfish in ICES Subareas 27.6, 7, 8. Retrospective plot of total stock biomass (above) and fishing mortality (below) from the surplus production model in 2013-2019.

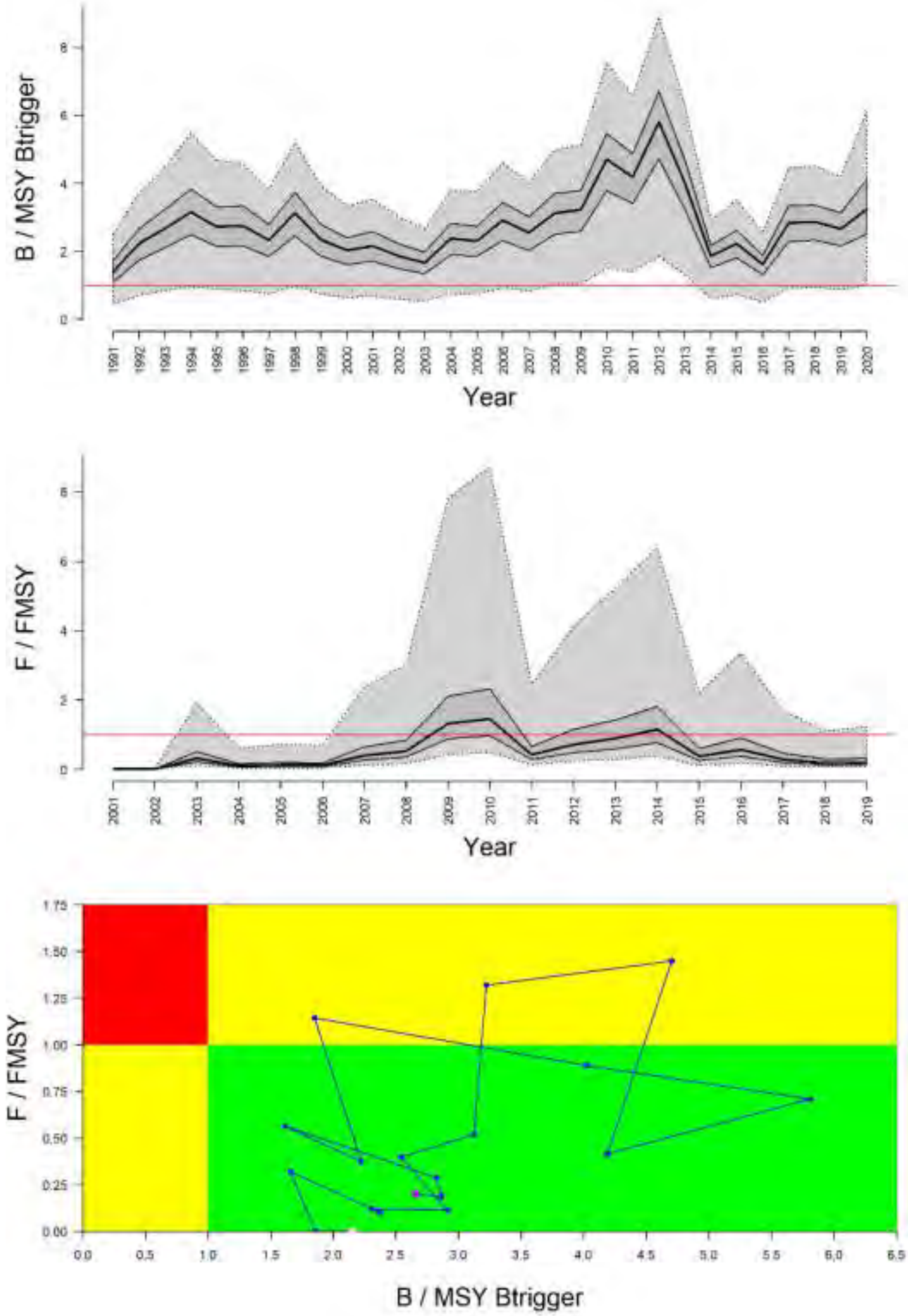

Figure 3.6.6.1. Boarfish in ICES Subareas 27.6, 7, 8. Ratios 'B / MSYBtrigger' and 'F / FMSY' through time and corresponding Kobe plot. Confidence intervals (50 and 95%) are given for the first two panels, the third displays median estimates only with the pink point representing the first point of the time series and the purple point the last.

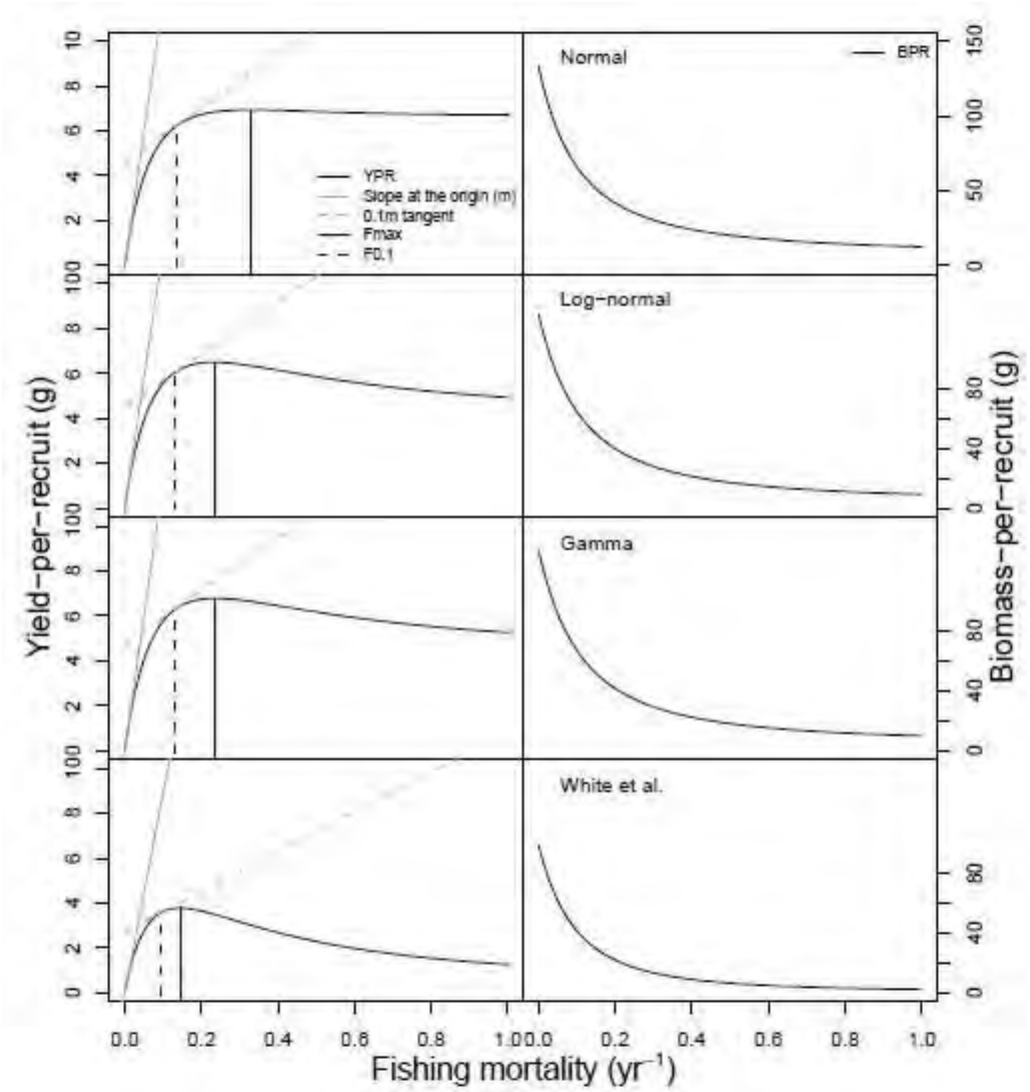

Figure 3.9.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White *et al*. 2011.

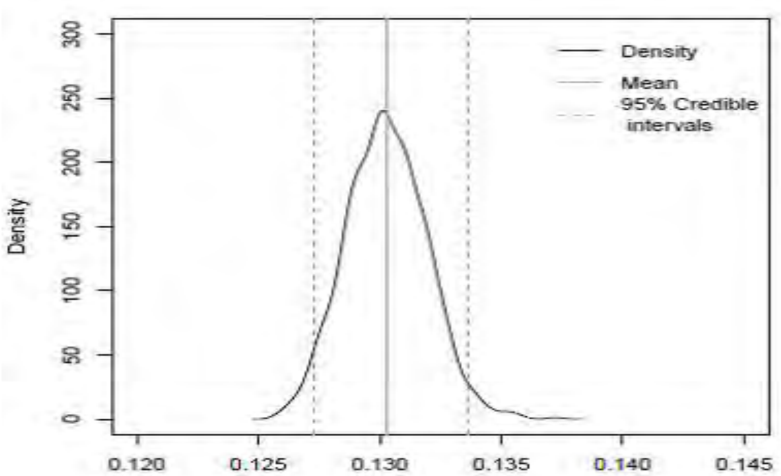

Figure 3.9.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Sensitivity of estimation of F0.1.

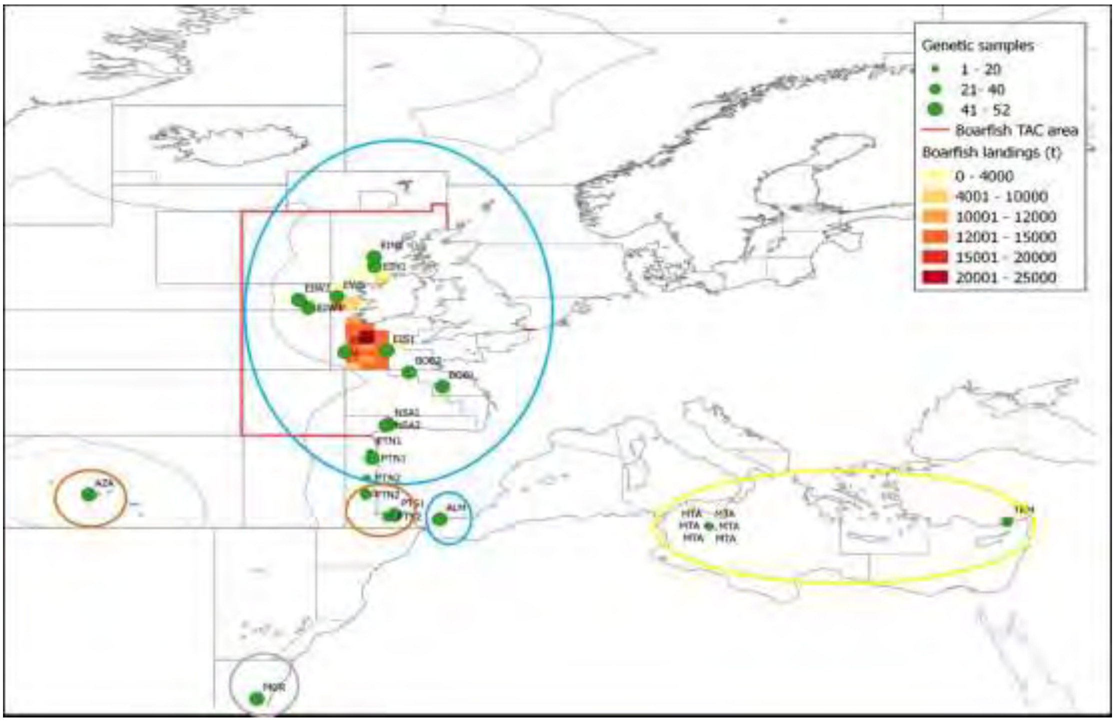

Figure 3.12.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish samples included in the genetic stock identification study are indicated in green. Population clusters identified by the STRUCTURE analyses are indicated by colour coded circles.

4 Herring (*Clupea harengus*) in subareas 1, 2, and 5, and in divisions 4.a and 14.a, (Northeast Atlantic) (Norwegian Spring Spawning)

4.1 ICES advice in 2019

ICES noted that the stock is declining but estimated to be above MSY $B_{trigger}$ (3.184 million tonnes) in 2019. Recruitment was estimated to be average or low since 2007 (2005 year-class). Fishing mortality has increased 2015 but was estimated to be below F_{MSY} in 2018.

A long-term management plan agreed by the European Union, the Faroe Islands, Iceland, Norway and the Russian Federation, is operational since 2019. ICES evaluated the plan and concluded that it is in accordance with the precautionary approach (ICES, 2018b). The management plan implied maximum catches of 525 594 t in 2020.

4.2 The fishery in 2019

4.2.1 Description and development of the fisheries

The distribution of the 2019 Norwegian spring-spawning herring (NSSH) fishery for all countries by ICES rectangles is shown in Figure 4.2.1.1. The catches by ICES statistical rectangle and quarter, are seen in Figure 4.2.1.2. The 2019 herring fishing pattern was similar to recent years and the proportion of landings among quarters was similar to the fishery in 2018. The fishery began in January on the Norwegian shelf and focused on overwintering, pre-spawning, spawning and post-spawning fish (Figure 4.2.1.2 quarter 1). In the second quarter, the fishery was insignificant (Figure 4.2.1.2 quarter 2). In summer, the fishery had moved into Faroese, Icelandic and Greenlandic waters (Figure 4.2.1.2 quarter 3). In autumn, the fishery partly shifted to the overwintering area in the fjords and oceanic areas off Lofoten, and the central part of the Norwegian Sea. 64% of the catches were taken in the fourth quarter, mainly in the international part of the Norwegian Sea (Figure 4.2.1.2 quarter 4). Catches of Norwegian spring-spawning herring inside the NEAFC regulatory area was estimated by the working group to be 281 092 tonnes in 2019, which represents 36% of the total catch.

4.3 Stock Description and management units

4.3.1 Stock description

A description of the stock is given in the Stock Annex.

4.3.2 Changes in migration

Generally, it is not clear what drives the variability in migration of the stock, but the biomass and production of zooplankton are likely factors, as well as feeding competition with other pelagic fish species (*e.g.* mackerel and to a lesser extent blue whiting) and oceanographic conditions (*e.g.* limitations due to cold areas). Besides environmental factors, the age distribution in the stock will also influence the migration. Changes in the migration pattern of NSSH, as well as that of other herring stocks, are often linked to large year classes entering the stock initiating a different migration pattern, which subsequent year classes will follow. The large 2016 year class has now entered the adult stock and was mainly distributed in the eastern and north-eastern part of the Norwegian Sea during this year's ecosystem surveys. These herring concentrations in the eastern part of the Norwegian Sea represent a change in the distribution compared to earlier years, however, the distribution of older herring seems similar to earlier years. In 2017/2018 there was a shift in wintering areas. While wintering has been observed in fjords west of Tromsø (Norway) for several years, the 2013 year-class wintered in fjords farther north (Kvænangen) since 2017/2018 while the older fish seemed to have had an oceanic wintering area. The oldest and largest fish move farthest south and west during feeding, and the older year classes were in May-July 2020 concentrated in the south-western areas during the feeding season.

4.4 Input data

4.4.1 Catch data

Catches in tonnes by ICES division, ICES rectangle and quarter in 2019 were available from Denmark, Faroe Islands, Germany, Greenland, Iceland, Ireland, The Netherlands, Norway, Russia, the UK (Scotland), Poland and Sweden. The total working group catch in 2019 was 777 165 tonnes (Table 4.4.1.1) compared to the ICES-recommended catch of maximum 525 594 tonnes. The majority of the catches (90%) were taken in area 2.a as in previous years. Samples were not provided by Greenland, The Netherlands, UK, Poland or Sweden (less than 2 % of the total catch were taken by these countries). Sampled catches accounted for 97 % of the total catches, which is on a similar level as in previous years. The sampling levels of catches in 2019 in total, by country and by ICES division is shown in Table 4.4.1.2, 4.4.1.3 and 4.4.1.4. Catch by nation, ICES division and quarter are shown in Table 4.4.1.5. The software SALLOC (ICES, 1998) was used to calculate total catches in numbers-at-age and mean weight at age representing the total catch. Samples allocated (termed fill-in in SALLOC) to cells (nation, ICES division and quarter) without sampling information are shown in Table 4.4.1.5.

4.4.2 Discards

In 2008, the Working Group noted that in this fishery an unaccounted mortality caused by fishing operations and underreporting probably exists (ICES, 2008). It has not been possible to assess the magnitude of these extra removals from the stock, and considering the large catches taken after the recovery of the stock, the relative importance of such additional mortality is probably low. Therefore, no extra mortality to account for these factors has been added since 1994. In previous years, when the stock and the quotas were much smaller, an estimated amount of fish was added to the catches.

The Working Group has not had access to comprehensive data to estimate discards of the herring. Although discarding may occur on this stock, it is considered to be low and a minor problem to the assessment. This is confirmed by estimates from sampling programmes carried out by some EU countries in the Data Collection Framework. Estimates on discarding in 2008 and 2009 of about 2% in weight were provided for the trawl fishery carried out by the Netherlands. In 2010 and 2012, this métier was sampled by Germany. No discarding of herring was observed (0%) in either of the two years. An investigation on fisheries induced mortality carried out by IMR with EU partners on fisheries induced and unreported mortality in mackerel and herring fisheries in the North Sea concluded with an estimated level of discarding at around 3%.

In order to provide information on unaccounted mortality caused by fishing operations in the Norwegian fishery, Ipsos Public Affairs, in cooperation with IMR and the fishing industry, conducted a survey in January/February 2016. The survey was done by phoning skippers and interviewing them. A total of 146 herring skippers participated in the survey, 31 skippers representing the bigger vessel group and 115 skippers representing the smaller vessel group. The data provided an indication that there have been periods of increased occurrence of net bursting. This was seen especially in the period 2007–2010. There was, however, no trend in the size of catches where bursting has occurred.

When it comes to slipping, the data showed a steady increase in the percentage that has slipped herring from 2004–2012, and then a significant decline in recent years. The variations in the proportion that have slipped herring were largely driven by the skippers on smaller coastal purse-seiners. Average size of purse-seine hauls slipped seems to be relatively steady over the period. However, the average size of net hauls slipped was lowest in the recent period.

4.4.3 Age composition of the catch

The estimated catch-at-age in numbers by years are shown in Table 4.4.3.1. The numbers are calculated using the SALLOC software. In 2019, about 25 % of the catches (in numbers) were taken from the 2013 year-class, followed by the 2011 and 2006 year classes (both contributing about 10% each).

Catch curves were made on the basis of the international catch-at-age (Figure 4.4.3.1). For comparison, lines corresponding to Z=0.3 are drawn in the background. The big year classes, in the periods of relatively constant effort, show a consistent decline in catch number by cohort, indicating a reasonably good quality of the catch-at-age data. Catch curves for year classes 2005 onwards show a flatter curve than for previous year classes indicating a lower F or a changed exploitation pattern.

4.4.4 Weight at age in catch and in the stock

The weight-at-age in the catches in 2019 was computed from the sampled catches using SALLOC. Trends in weight-at-age in the catch are presented in Figure 4.4.4.1 and Table 4.4.4.1. The mean weights at age for most of the age groups have generally been increasing in 2010–2013 but levelled off around 2014. In the most recent years the weight-at-age seems to have decreased slightly for most ages – earlier for the younger ages than for the older. A similar pattern is observed in weight-at-age in the stock which is presented in Figure 4.4.4.2 and Table 4.4.4.2. The mean weight at age in the stock was based on the survey in the wintering area until 2008. Since then the mean weight at age in the stock was derived from samples taken in the fishery in the same area and at the same time as the wintering surveys were conducted in.

4.4.5 Maturity-at-age

In 2010 the method for estimating maturity-at-age in the stock assessment of NSSH was changed based on work done by the "workshop on estimation of maturity ogive in Norwegian spring-spawning herring" (WKHERMAT; ICES, 2010a). The method which was adopted by WGWIDE in 2010 (ICES, 2010b) is based on work by Engelhard *et al*. (2003) and Engelhard and Heino (2004). They developed a method to back-calculate age at maturity for individual herring based on scale measurements, and used this to construct maturity ogives for the year classes 1930–1992.

The NSSH has irregular recruitment pattern with a few large year classes dominating in the stock when it is on a high level. Most of the year classes are, however, relatively small and referred to as "normal" year classes. The back-calculation dataset indicates that maturation of the large year classes is slower than for "normal" year classes.

WKHERMAT and WGWIDE considered the dataset derived by back calculation as a suitable candidate for use in the assessment because it is conceived in a consistent way over the whole period and can meet standards required in a quality controlled process. However, the back-calculation estimates cannot be used for the most recent years since all year classes have to be fully matured before the calculation can be made. Therefore, assumptions have to be made for the recent year classes. For recent year classes, WGWIDE (2010) decided to use average back-calculated maturity for "normal" and "big" year classes, respectively and thereby reducing maturity-at-age for ages 4, 5 and 6 when strong year classes enter the spawning stock. The default maturity ogives used for "normal" and "big" year-classes are given in the text table below.

age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
normal year class	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
strong year class	0	0	0	0	0.1	0.6	0.9	1	1	1	1	1	1	1	1	1

Assumed values should be replaced by back-calculated values in the annual assessments for each year where updated values are available. In 2020 the year 2015 could be updated with back-calculated values used in the present assessment. Assumed and updated values are shown in figure 4.4.5.1. The 2016 year-class was considered a strong year-class by the working group based on the 2020 assessment where several survey indices of this year-class are included, and maturity at age 4 was set to 0.1 for this year-class in the 2020 assessment according to the table above. The maturity ogives used in the present assessment are presented in Table 4.4.5.1.

4.4.6 Natural mortality

In this year's assessment, the natural mortality M=0.15 was used for ages 3 and older and M=0.9 was used for ages 0–2. These levels of natural mortality are in accordance to previous years and their justification is provided in the stock annex. Information about deviations from these levels in the time-series, *e.g.* due to diseases, are also provided in the stock annex.

4.4.7 Survey data

The surveys available for the assessment are described in the stock annex. Only two of the available surveys are used in the final assessment and will therefore be dealt with in this section:

1) The International Ecosystem Survey in the Nordic Seas (IESNS) in May. This survey covers the entire stock during its migration on the feeding grounds, the adults in the Norwegian Sea and adjacent waters ("Fleet 5") and the juveniles in the Barents Sea ("Fleet 4").

2) The Norwegian acoustic survey on the spawning grounds in February ("Fleet 1").

The cruise reports from the IESNS and spawning survey in 2020 are available as working documents to this report. The spawning survey and IESNS in the Norwegian Sea were carried out successfully in 2020, however, the Barents Sea part of IESNS ("Fleet 4") was not carried out in 2020 due to technical issues with the Russian vessel.

The abundance estimates from "Fleet 1" are shown in Table 4.4.7.1 and Figure 4.4.7.2; from "Fleet 4" in Table 4.4.7.2 and Figure 4.4.7.1 and "Fleet 5" in Table 4.4.7.3 and Figure 4.4.7.1. In 2020 it was decided to use the bootstrap mean values as point estimates of abundance instead of the baseline estimates. This applies to the years were the software Stox is used to estimate abundance. Variance estimates from the bootstrap runs are already being used in the assessment, thus it is more logical to also use point estimates from the bootstrap. A comparison using point estimates for both bootstrap and baseline was made, and the effect on the assessment was negligible.

Catch curves were made on the basis of the abundance estimates from the surveys "Fleet 1" (Figure 4.4.7.3) and "Fleet 5" (Figure 4.4.7.4). The same arguments are valid for the interpretation of the catch curves from the surveys as from the catches. In 2010, the numbers of all age groups decreased suddenly in "Fleet 5" and this is seen as a drop in the catch curves that year. This drop has continued for some of the year classes and the year classes 1998 and 1999 are disappearing faster from the stock than expected. This observed fast reduction in these age classes may also be influenced by the changes in "Fleet 5" catchability, with seemingly higher catchability in years 2006—2009. Like the catch curves from commercial landings, the corresponding curves from "Fleet 5" are also quite flat for year classes 2005 onwards. As "Fleet 1" was not conducted in the years 2009–2014, there is a gap in the catch curves, making it difficult to interpret them.

4.4.8 Sampling error in catches and surveys

Sampling errors for Norwegian catch-at-age for the years 2010-2018 is estimated using ECA (Salthaug and Aanes 2015, Hirst *et al.* 2012). Using the Taylor function (Aanes 2016a) to model the sampling variance of the catches yields a very good fit ($R^2_{adj} = 0.94$) and using this function to impute missing sampling variances for catch-at-age yields relative standard errors shown in Table 4.4.8.1. It is assumed that the relative standard errors in the total catches are equal to the Norwegian catches (which comprise ~60% of the total catches). Sampling errors for survey indices are estimated using StoX (http://www.imr.no/forskning/prosjekter/stox/nb-no) and Johnsen *et al*. (2019). For Fleet 1, estimates are available for the years 1988–1989, 1994–1996, 1998–2000, 2005–2008, and 2015–2019, for Fleet 4 estimates of sampling errors are available for 2009–2019, and for Fleet 5 for 2008–2019. Missing values for sampling variances are imputed using the Taylor function which provides good fits (R^2_{adj}'s are 0.95, 0.98, 0.96, respectively). The resultant relative standard errors are given in Tables 4.4.8.2-4.4.8.4. Due to the very good fits of the Taylor functions, estimates of relative standard where empirical estimates are available, are also replaced by the model predicted values to reduce potential effects of imprecise estimates of errors.

4.4.9 Information from the fishing industry

No information was made available to the working group.

4.5 Stock assessment

The first benchmark of the NSSH took place in 2008. The assessment tool TASACS was then chosen to be the standard assessment tool for the stock. The second benchmark took place in 2016 (ICES, 2016) where three assessment models were explored, TASACS, XSAM and one separable model. WKPELA accepted XSAM as the standard assessment tool for the NSSH.

4.5.1 XSAM final assessment 2020

The XSAM model is documented in Aanes 2016a and 2016b. XSAM includes the option to utilize the prediction of total catch in the assessment year (typically the sum of national quotas) along with the precision of the prediction. This approach was changed in 2017 when it was found that the model estimated a highly variable and significantly lower catch compared to the working group's prediction (sum of national quotas). In addition, this caused an abrupt change in the selection pattern from 2017 and onwards. The abrupt change in the selection pattern was not fully understood by the working group, but the effect was less pronounced if not using the catch prediction from the model for 2017. Therefore, it was decided to not utilize the prediction of total catches in 2017 when fitting the model to data (*i.e.* the assessment) and consequently in the short-term forecast. The same approach is taken in the 2020 assessment, *i.e.* the catch prediction for 2020 is not included when fitting the model to data. The resulting estimated selection pattern is gradual (Figure 4.5.1.1) and in line with the current knowledge about the fishery. It is important to notice that this has marginal effect on the assessment, but larger effects on the prediction and short-term forecast.

This year's XSAM assessment was performed with the same model options as in 2017. In summary, this means that the model was fit with time varying selectivity and effort according to AR(1) models in the model for fishing mortality; the recruitment was modelled as a process with constant mean and variance; the standard errors for all input data were predetermined using sample data (Tables 4.4.8.1–4.4.8.4), but estimating a scaling constant common for all input data to allow additional variability in the input data that is not controlled by sampling. Other details in settings are given in the Stock Annex.

The same input data over the same age ranges was used as in 2017. At the 2016 benchmark, data from 1988 and onwards was used, the considered age-span was 3–12+ with input data catch-at-age, Fleet 1 and Fleet 5 and in WGWIDE 2016 it was decided to start the model at age 2 to enable short-term predictions with reasonable levels of variability. To achieve this, age 2 from Fleet 4, and age 2 in catch-at-age is included in input data. Evaluation of diagnostics including lower ages than 2 and/or other fleets resulted in excluding lower ages than 2 and other fleets for the final assessment. Input data are listed in Table C.1.1 in the Stock Annex.

The parameter estimates are shown in Table 4.5.1.1 and in Figure 4.5.1.10. For a precise definition of the parameters, refer to Aanes 2016a in ICES (2016). Note that the variance components σ_1^2 (variability in the separable model for F) and σ_R^2 (variability in recruitment) is rather imprecise. The estimate of the scaling constant h is larger than 1 showing that the model adds additional variability on the observation errors than explained by the sampling errors alone.

The catchabilities for all the fleets are on average positively correlated indicating some uncertainty due to a common scaling of all surveys to the total abundances although the correlations in general are small (Figure 4.5.1.2). There is a slight negative correlation between σ_1^2 and σ_2^2 (variability in the AR process for time varying selectivity) indicating little contrast in data for separating variability in the separable model from variability due to changes in selection pattern. The slopes in the multivariate AR model for time-varying selectivity gradually changes from negative to positive, but is expected as it is imposed due to the sum to zero constraint for the selection (see Aanes 2016a for details).

The weights each datum is given in the model fit (inverse of the sampling variance) is proportional to the empirical weights derived from sampling variances (Tables 4.4.8.1–4.4.8.4) which shows that the strong year classes in general are given larger weight to the model than weak year classes, and the ordering of the average weights (from high to low) is Catch-at-age, Fleet 5, Fleet 1 and Fleet 4 (Figure 4.5.1.3).

Two types of residuals are considered for this model. The first type is the model prediction (based on all data) vs. the data. In such time-series models, the residuals based on the prediction which uses all data points will be serially correlated although useful as they explain the unexplained part of the model (*cf* Harvey 1990 p 258). This means that patterns in residuals over time is to be expected and questions the use of *e.g.* qq-plots as an additional diagnostic tool to assess distributional assumptions. To obtain residuals which follow the assumptions about the data in the observation models (*e.g.* serially uncorrelated) single joint sample residuals are extracted (ICES, 2017). In short these are obtained by sampling predicted values from the conditional distribution of values given the observations. This sample corresponds to a sample from the joint distribution of latent variables and observations. The third approach could have been to extract the one step ahead observation residuals which are standard for diagnostics for regular state-space models (*cf* Harvey 1990). This is not done here.

The negative residuals tracing the 1983 year-class for catch-at-age represents low fishing mortalities examining the type 1 residuals (Figure 4.5.1.4). This effect is less pronounced considering the type 2 residuals. The type 2 residuals are qualitatively comparable with the type 1 residuals but generally display more mixed residuals as predicted by the theory. Otherwise the residuals for catch-at-age appears fairly mixed apart for some serial correlation for age 2 and 3 (which are very low), and some negative residuals for the plus group the most recent years. The residuals for Fleet 1 in 1994, 1999, 2006 for young and old ages are all of the same signs and may appear as year effects. Also note that the residuals for Fleet 1 for ages 12+ from 2015 are all positive (Figure 4.5.1.4) which shows that the abundance indices from Fleet 1 displays a larger stock size over these ages and years compared to the assessment using all input data. Some serial correlation for residuals for ages 3 and 4 in Fleet 1 can also be detected, but is down weighted as these is found to be uncertain. Serial correlation in residuals for age 2 in Fleet 4 can also be detected indicating trends over time in mismatch between estimates and observations of abundance at age 2. Residuals for Fleet 5 appears adequate compared to previous years although some serial correlations can be detected also here.

The residuals for small values are bigger than residuals for the larger values since smaller values in general have higher variances than larger values (Tables 4.4.8.1–4.4.8.4) (Figure 4.5.1.5). The qq-plots for the standardized residuals show that the distributional assumptions on the observation errors are adequate, except for the smallest and largest values of catch-at-age and indices from Fleet 1. As qq-plots for residuals of type 1 may be questioned (see above) it is noted that qq-plots for residuals of type 2 is more relevant and generally shows a significantly better fit based on a visual inspection compared to using type 1.

The marginal likelihood and the components for each data source (see Aanes 2016b for details) are profiled over a range of the common scaling factor h for all input data (Figure 4.5.1.6). It is apparent that the optimum of the marginal likelihood is clearly defined. The catch component is decreasing with decreasing values of h indicating that the model puts more weight on the catch component than indicated by the comparison of sampling errors for all input data. This is in line with the findings in Aanes (2016a and 2016b) who showed that these types of models tend to put too much weight on the catch data if the weighting is not constrained. However, the likelihood component for the catch is overruled by the information in Fleets 1, 4 and 5 such that the optimum for the marginal likelihood is clearly defined. The point estimates of SSB and F is insensitive to different values of h.

The retrospective runs for this model shows estimates which is within the estimated levels of precision (Figure 4.5.1.7), and has a reasonably low Mohn’s rho value of ~0.01 (Mohn, 1999; Brooks and Legault, 2016). Note that the retrospective estimates are remarkably stable.

Figure 4.5.1.8 illustrates the conflict in data and increased uncertainty in estimates for the most recent years. The spawning-stock biomass shown for each survey index is calculated using the stock weights at age and proportion mature at age, with the abundance indices are scaled to the absolute abundance by the estimated catchabilities. . Here we see a fairly good temporal match between the model estimate of SSB and the survey SSBs except for the years 2015 for Fleet 1, which displays a significantly faster reduction in the stock compared to Fleet 5 which shows a flatter trend in the same years. Both Fleet 1 and Fleet 5 indicate an increase in SSB from 2017 to

2019, but a decrease in 2020. It is worth noticing that although the point estimate of SSB based on Fleet 1 appears very much higher than Fleet 5 in 2015, the uncertainty in the estimates are very high, such that the respective estimates do not appear as significantly different. However, the effect on the final assessment is to lift the point estimate of SSB and increase the uncertainty which is in accordance with the data used (Figure 4.5.1.9).

The final assessment results are shown in Figure 4.5.1.9. The estimate of fishing mortality for 2019 is rather high, as a response to the high catch in 2019 with a point estimate of 0.191. In 2018 the fishing mortality is estimated to be lower than 2017 and 2019 (F=0.131 with 95% confidence interval between 0.098-0.164), but still higher than in 2015. The spawning stock shows a declining trend since 2009, and the 95% confidence interval of the stock level in 2020 ranges from ~2.682 to ~3.948 million tonnes with a point estimate of 3.315 which is barely above B_{mp}=3.184 million tonnes, such that the probability of the stock being above B_{lim}=2.5 million tonnes is high. Note the rather large uncertainty in the absolute levels since the peak in 2009 with the further increase in the most recent years. This high uncertainty is a result of the conflicting signals in data concerning the degree of decrease in the stock over this time period.

The final results of the assessment are also presented in Tables 4.5.1.2 (stock in numbers), 4.5.1.3 (fishing mortality) and Table 4.5.1.4 is the summary table of the assessment.

4.5.2 Exploratory assessments

4.5.2.1 TASACS

TASACS was run according to the benchmark in 2008 using the VPA population model in the TASACS toolbox with the same model options as the benchmark (see Stock Annex). The information used in the TASACS run is catch data and survey data from eight surveys. The analysis was restricted to the years 1988 – 2020. The model was run with catch data from 1988 to 2019, and projected forwards through 2020 assuming Fs in 2020 equal to those in 2019, to include survey data from 2020. The larval survey (SSB fleet) was discontinued in 2017 and no new information is therefore available from this survey. Additionally, no new index was provided for fleet 7 in 2019 (0-group from the autumn survey in the Barents Sea) since this index was not updated by the survey group. This time series (0-group) is presently being re-calculated in StoX. Additionally, there is no new data for fleet 4 since this survey was not conducted in 2020.

Residuals of the tuning series are shown in Figure 4.5.2.1.1. Particularly Survey 8 (larval survey) seems to have a poor fit. This is seen as a block of positive residuals for this survey in later years. The residual plot for survey 5 (IESNS) also shows some pattern with consecutive series of negative and positive residuals indicating year-effects.

The results from TASACS are compared to those from XSAM in Figure 4.5.2.1.2. The time-series of SSB show similar trends for XSAM and TASACS. For most of the years, the estimates from TASACS are within the confidence limits estimated by XSAM. The SSB on 1 January 2020 is estimated by TASACS to be 3.447 million tonnes, which is slightly higher than the estimated value (point estimate) from XSAM.

4.6 NSSH reference points

ICES last reviewed the reference points of Norwegian spring spawning herring in April 2018 by WKNSSHREF (ICES, 2018a). ICES concluded that B_{lim} should remain unchanged at 2.5 million tonnes and $MSYB_{trigger} = B_{pa}$ was estimated at 3.184 million tonnes. F_{MSY} was estimated at the reference point workshop, but during the Management Strategy Evaluation WKNSSHMSE (ICES, 2018b) the fishing mortality reference points were revisited, because issues were found with numerical instability and settings during the reference point workshop. F_{MSY} was re-estimated at 0.157.

4.6.1 PA reference points

The PA reference points for the stock were last estimated by WKNSSHREF and WKNSSHMSE in 2018. The WKNSSHREF group concluded that B_{lim} should be kept at 2.5 million tonnes but B_{pa} was estimated at 3.184 million tonnes. WKNSSHMSE estimated F_{pa}=0.227.

4.6.2 MSY reference points

The MSY reference points were evaluated by WKNSSHREF and WKNSSHMSE in 2018. In the ICES MSY framework Bpa is proposed/adopted as the default trigger biomass $B_{trigger}$ and was estimated by WKNSSHREF at 3.184 million tonnes. F_{MSY} was estimated by WKNSSHMSE at 0.157.

4.6.3 Management reference points

In the current management strategy, which was agreed upon in October 2018, the Coastal States have agreed a target reference point defined at F_{target} = 0.14 when the stock is above B_{pa}. If the SSB is below B_{pa}, a linear reduction in the fishing mortality rate will be applied from 0.14 at B_{pa} to 0.05 at B_{lim}.

4.7 State of the stock

The SSB on 1 January 2020 is estimated by XSAM to be 3.315 million tonnes which is above B_{pa} (3.184 million t). The stock is declining and the SSB time-series from the 2020 assessment is consistent with the SSB time-series from the 2019 assessment. In the last 20 years, several large year classes have been produced (1998, 1999, 2002, and 2004). The year classes 2005-2015 are estimated to be average or small, while the 2016 year-class is estimated to be above average in the 2020 assessment. Fishing mortality in 2019 is estimated to be 0.186 which is above the management plan F (0.140) that was used to give advice for 2019. A new management plan was implemented for the 2019 advisory year.

4.8 NSSH Catch predictions for 2020

4.8.1 Input data for the forecast

Forecasting was conducted using XSAM according to the method described in the Stock Annex and by Aanes (2016c). WGWIDE 2016 decided to use the point estimates from this forecast as basis for the advice. In short, the forecast is made by applying the point estimates of the stock status as input to set TAC, then based on the TAC a stochastic forecast was performed to determine levels of precision in the forecast. Table 4.8.1.1 lists the point estimates of the starting values for the forecast. The input stock numbers-at-age 2 and older were taken from the final assessment. As Fleet 4 was not conducted in 2020, *i.e.* no observation of age 2, the number-at-age 2 from the final assessment is equal to the median stochastic recruitment base on the years 1988-2019. The catch weight-at-age, used in the forecast, is the average of the observed catch weights over the last 3 years (2017—2019).

For the weight-at-age in the stock, the values for 2020 were obtained from the commercial fisheries in the wintering areas in January. For the years 2021 and 2022 the average of the last 3 years (2018 —2020) was used.

Standard values for natural mortality were used. Maturity-at-age was based on the information presented in Section 4.4.5.

The exploitation pattern used in the forecast is taken from the predictions made by the model (see Aanes 2016c for details). The resultant mean annual exploitation pattern is shown in Figure 4.8.1.1 and displays a shift towards older fish in the recent years and further in the prediction. Prediction of recruitment at age 2 is obtained by the model with a mean that in practice represents the long term (1988-2020) estimated mean recruitment (back-transformed mean at log scale) and variance the corresponding recruitment variability over the period. Forecasted values of recruits are highly imprecise but have little influence on the short-term forecast of SSB as the herring starts to mature at age 4. Note that the 2016 year-class is regarded as large; hence, the maturity is set to be lower than for smaller year-classes. This results in the contribution of the 2016 year-class to the SSB being delayed.

The average fishing mortality is defined as the average over the ages 5 to 12+, weighted over the population numbers in the relevant year

$$\bar{F}_y = \sum_{a=5}^{12} N_{a,y} F_{a,y} \Bigg/ \sum_{a=5}^{12} N_{a,y}$$

where $F_{a,y}$and $N_{a,y}$ are fishing mortalities and numbers by age and year. This procedure is in accordance with that used in previous years for this stock although the age range was shifted from 5-11 to 5-12+ from 2018.

There was no agreement between the fishing parties on the sharing of the TAC for 2020. Therefore, to obtain an estimate of the total catch to be used as input for the catch-constraint projections for 2020, the sum of the unilateral quotas was used. In total, the expected outtake from the stock in 2020 amounts to 693 915 tonnes. F in 2020 is estimated by XSAM based on this catch.

4.8.2 Results of the forecast

The Management Options Table with the results of the forecast is presented in Table 4.8.2.1. Assuming a total catch 693 915 tonnes is taken in 2020, it is expected that the SSB will increase from 3.315 million tonnes on 1 January in 2020 to 3.505 million tonnes in 2021. The weighted F over ages 5-12+ is 0.187. The model estimates the catch in 2021 to be dominated by three age groups, age 5 (24.9%), age 8 (19.3%), and age 12+ (23.2%).

4.9 Comparison with previous assessment

A comparison between the assessments 2008—2020 is shown in Figure 4.9.1. In the years 2008—2015 the assessments were made with TASACS, whereas since 2016 XSAM has been applied, as accepted by WKPELA 2016. With the change of the assessment tool in 2016 the age of the recruitment changed from 0 to 2 and the age span in the reference F changed from 5—14 to 5—11. In WKNSSHREF (ICES, 2018a) this was further changed to 5—12+.

The table below shows the SSB (thousand tonnes) on 1 January in 2019 and weighted F in 2018 as estimated in 2019 and 2020.

	ICES 2019	WG 2020	%difference
SSB (2019)	3 965	3 916	-1.2%
Weighted F (2018)	0.128	0.131	2.3%

4.10 Management plans and evaluations

The current management strategy for the Norwegian spring spawning herring fishery was agreed upon by the Coastal States in October 2018.

The implemented long-term management strategy of Norwegian spring spawning herring is consistent with the precautionary approach and the MSY approach (WKNSSHREF, ICES, 2018a; WKNSSHMSE, ICES, 2018b) and aims at ensuring harvest rates within safe biological limits. The management strategy in use contains the following elements:

As a priority, the long-term management strategy shall ensure with high probability that the size of the spawning stock is maintained above B_{lim}.

In the case that the spawning biomass is forecast to be above or equal to $B_{trigger}$ (=B_{pa}) on 1 January of the year for which the TAC (*i.e.* the TAC agreed by Coastal States) is to be set, the TAC shall be fixed to a fishing mortality of F_{mgt} = 0.14.

If F_{mgt} (0.14) would lead to a TAC, that deviates by more than 20% below or 25% above the TAC of the preceding year, the Parties shall fix a TAC that is respectively no more than 20% less or 25% more than the TAC of the preceding year. The TAC constraint shall not apply if the spawning biomass at 1 January in the year for which the TAC is to be set is less than $B_{trigger}$.

If SSB is forecast to be lower than $B_{trigger}$ but above B_{lim} on the 1 January of the TAC-year, TAC is to be set using F, which decreases linearly from F_{mgt} to F = 0.05 over the biomass range from $B_{trigger}$ to B_{lim}.

The Coastal States Parties may transfer 10% of quotas between neighbouring years, except when SSB is less than B_{lim}; those years the management plan does not allow fishing of next year's quota.

The Coastal States Parties, on the basis of ICES advice, shall review the long-term management strategy at intervals not exceeding five years. The first such review shall take place no later than 2023.

A brief history of management strategies is in the stock annex. In general, the stock has been managed in compliance with the management plan. There has, however, been no agreement on sharing of the TAC since 2013, resulting in the total catch being higher than the advised catch.

4.11 Management considerations

Perception of the stock has not changed since last year's assessment (estimated SSB in 2019 is 1.2 % lower in this year's assessment). Results of exploratory runs by another model match with those of XSAM.

Historically, the size of the stock has shown large variations and dependency on the irregular occurrence of very strong year classes. Between 1998 and 2004 the stock produced several strong year classes which lead to an increase in SSB until 2009. Since then, SSB has declined due to absence of strong year classes in 2005-2015. The 2016 year-class is however, estimated to be well above average in the 2020 assessment.

Between 1999 and 2018, catches were regulated through an agreed management. However, since 2013, a lack of agreement by the Coastal States on their share in the TAC has led to unilaterally set quotas which together are higher than the TAC indicated by the management plan resulting in steeper reduction in the SSB than otherwise.

A new management strategy was implemented for the advisory year 2019.

4.12 Ecosystem considerations

NSS herring juveniles and adults are an important part of the ecosystems in the Barents Sea, along the Norwegian coast, in the Norwegian Sea and in adjacent waters. This refers both to predation on zooplankton by herring and herring being a food resource to higher trophic levels (*e.g.* cod, saithe, seabirds, and marine mammals). The predation intensity of and on herring have seasonal, spatial and temporal variation as a consequence of variation in migration pattern, prey density, stock size, size of year classes and stock sizes of competing stocks for resources and predators. Recent features of some of these ecosystem factors of relevance for the stock are summarized below.

- Following a maximum in zooplankton biomass during the early 2000s the biomass declined with a minimum in 2006. From 2010, the trend turned to an increase and the last five years the zooplankton biomass has fluctuated around the long-term mean (ICES, 2020a). Interestingly, all the areas, excluding east of Iceland and on few occasions Jan Mayen, show co-varying changes in zooplankton biomass.

  The Atlantic water mass in the Norwegian Sea was warmer and saltier over the period 2000–2016 than the long-term mean (ICES, 2020c). However, during the period, 2017-2020 the temperature remained relatively warm while the salinity had a marked decrease. Two different mechanisms can explain this, increased fraction of subpolar water (fresh and cold) and low heat loss to the atmosphere in the Norwegian Atlantic flow. Under the assumption that circulation patterns do not change, this situation with anomalously fresh Atlantic water in the Norwegian Sea can be expected to continue and even increase in the coming years. The relative minor cooling is due to the anomalous small local heat loss to the atmosphere during the same period.
- The cumulative spawning-stock biomass (SSB) of the three main pelagic species in the Norwegian Sea (Norwegian Spring Spawning herring, Northeast Atlantic mackerel and Blue whiting) increased from approximately 6 million tonnes in early 1980s to 14 million tonnes in the mid-2000s and has since fluctuated between 13 million tonnes and 15 million tonnes (ICES, 2020c).
- In general, the herring stock has had a more westerly feeding distribution (ICES 2020a; 2020b) in the recent years than what was previously observed. However, the relatively large 2016 year class included a more north-eastern distribution than the older age classes in the stock (ICES 2020a,b). The more westerly distribution might be due to either better feeding opportunities there or a response to feeding competition with mackerel but the consequence is a less spatial overlap of herring and mackerel in Norwegian Sea and adjoining waters since around 2014 (ICES, 2015b; 2020b). In the case of the 2016 year-class in 2020 it is known that incoming strong year classes often have different migratory patterns than the older part of the stock (Huse *et al.* 2010) but the reason for the easterly distribution is unknown.
- Where herring and mackerel overlap spatially they compete for food to some extent (Bachiller *et al*., 2016, 2018; Debes *et al*., 2012; Langøy *et al*., 2012; Óskarsson *et al*., 2016) but studies showing mackerel being more effective feeder might indicate that the herring is forced to the south western and north eastern fringe of Norwegian Sea (ICES,

2015b; 2016b; 2020b). Whilst higher zooplankton biomass in the southwest could also attract the herring in to this location zooplankton biomass is much lower in the north east (ICES, 2020b).

- Results of stomach analyses of mackerel on the Norwegian coastal shelf (between about 66°N and 69°N) suggest that mackerel fed opportunistically on herring larvae, and that predation pressure therefore largely depends on the degree of overlap in time and space (Skaret *et al.*, 2015). Sampling in June 2017 and 2018, specifically studying mackerel predation on herring larvae, found significant numbers of herring larvae in mackerel stomachs in the area just south of Lofoten (IMR, Bergen RECNOR project, *Pers. Comm.*).
- Herring growth (*i.e.* length-at-age) varied over the period 1994-2015 and was negatively related to stock size (Homrum *et al.*, 2016), which indicates interaction between fish density and prey availability. Since 2015 the SSB has continued to decline but mean length of age 6 fish has remained fairly stable, even decreasing slightly (ICES, 2020c) suggesting that factors other than fish density are currently driving changes in fish size.
- The 2016 year class of herring is the strongest since the 2004 year class in the Norwegian Sea as 4 year old based on the IESNS survey 2020 (ICES, 2020a). This is indicative of good recruitment to the stock over the next ~two years.

  In the winter 2017/2018, the overwintering grounds shifted northward along the coast of Norway with older individuals occurring in oceanic areas (ICES, 2020c). Such changes previously coincided with large year classes entering the spawning stock, however this recent change did not. Also, the onset of the overwintering period is later in the year since the end of the 2000s.

4.13 Changes in fishing patterns

The fishery for Norwegian spring spawning herring has previously (before 2013) been described as progressing clockwise in the Nordic Seas during the year. However, the last 5-7 years the annual progression of the fishery has changed into a pendular behaviour, starting in the winter along the Norwegian coast, moving gradually to the west towards Iceland in the summer, and then slightly east again into the central Norwegian Sea in the last quarter of the year.

The fishery reached its lowest catches since the mid-nineties in 2015, after which the catches have increased again (table 4.4.1.1). It is mainly the fishery in the fourth quarter that has increased since 2015, with up to 2/3 of the catches taken in this quarter. This fishery is now mainly in the central Norwegian Sea, north of the Faroes and east of Iceland, whereas before 2015 it used to be stretched out towards the coast of Norway and up towards the Bear Island. Changes in migration have also resulted in late arrival at the Norwegian coast for this part of the stock during the winter in recent years. The Norwegian coastal fleet (smaller vessel that cannot go that far offshore) have therefore not been able to access this herring during the winter fishery and targeted younger fish (mostly of the 2013 year-class) which overwintered in Norwegian fjords.

4.14 Recommendations

For some years there have been issues with age reading of herring. These issues were raised around 2010, and since then two scale/otolith exchanges and a workshop have been held; and a final workshop was planned after the second exchange. There were, however, concerns with the second scale/otolith exchange and the final workshop was postponed indefinitely. It is therefore recommended to organise a new scale/otolith exchange and a follow up workshop.

There are several topics to cover in the recommended work.

Firstly, age-error matrices are needed as input to the stock-assessment, to evaluate sensitivity to ageing errors, and such age-error matrices are an output of age-reading inter-calibrations.

Secondly, stock mixing is an issue. There are several herring stocks surrounding the distribution area of Norwegian spring spawning (NSS) herring *e.g.* North Sea herring, Icelandic summer spawning herring and Faroese autumn spawning herring. Mixing with these other stocks in the fringe areas of the NSS herring distribution area leads to confounding effects on the survey indices of NSS herring in the ecosystem surveys. Methods to separate the NSS herring stock from the other herring stocks are needed – both with regards to get the most accurate age-reading as well as the confounding effect on the survey indices.

Finally, the experience from earlier exchanges is that age of older fish is more prone to be underestimated when aged by otoliths. Some of the institutes mainly sample and read scales, whereas other institutes use the otoliths.

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4.16 Missing surveys and catch data for Covid-19 disruption – some recommended methods and reporting requirements.

This document contains two pieces of information for working groups that encounter issues caused by missing data as a result of the Covid-19 disruption:

1. Proposed approaches to provide ICES advice in the absence of 2020 data in one or more survey abundance series.
2. Template for reporting deviations from stock annex caused by missing information from Covid-19 disruption

1. Proposed approaches to provide ICES advice in the absence of 2020 data in one or more survey abundance series.

With the occurrence of COVID-19 in 2020, a number of scientific surveys for use in ICES stock assessments have been disrupted. In most ICES assessments, this disruption of the surveys in 2020 will only impact in the assessments to be conducted in 2021. However, there are a number of assessments that actually make use of surveys conducted in-year (a 2020 assessment makes use of a survey conducted earlier in 2020).

In cases where a survey used in a stock assessment has not been conducted, it becomes impossible to conform exactly to the methods described in the stock annex to conduct the assessment. In extreme cases, the assessment simply cannot be updated. The following describes some generic guidance for providing advice in these cases in 2020. In all cases where the stock annex was not followed, this should be adequately documented in the expert group report.

Category 1 and 2 stocks

1) All survey indices missing:

When all survey indices are missing for the most recent years, an update of the assessment is not possible. In these cases, advice could be provided by using the results of the previous assessment (e.g. using the results of the 2019 assessment) and making a two-year projection. For the first of the interim years (2019), the actual catch-at-age from the 2019 fishery would be used to calculate the 2020 interim year beginning of the year numbers.

2) Incomplete index because one or more surveys are missing.

In many cases, a number of surveys are combined to derive an index of abundance for use in a category 1 assessment. In such cases, it may be possible to 'fill-in' the index for the year where one of the survey is missing through a model-based approach. One such approach recently developed is the vector autoregressive spatio-temporal (VAST; Thorson 2019) model that can be implemented using the publicly available VAST (www.github.com/james-thorson/VAST) package. This was used in the case of Black-bellied anglerfish in Subarea 7 and divisions 8.a–b and 8.d (ank.27.78abd). Other models such as generalized linear models (GLMs) have also been used as a method of imputation for missing strata in surveys but they require some assumptions on the distribution of catches (see Rago 2005)

3) No survey for the most recent year of an index but other indices available.

In these cases, the index can still be used in the assessment providing that the model can deal with missing values for an index. It should be noted that this could be problematic if the missing value is used to provide an estimate of recruitment.

Alternatively, the index with missing data for 2020 could be left out of the model. This should only be done after a comparison showing that leaving the survey out produces results that are comparable with an analysis that uses all surveys. Comparisons between the previous assessment conducted with all indices and a similar assessment but without the index that is missing data in 2020 would be instructive in that regard.

Category 3 and 4

1) All survey indices missing:

If the advice is biennial and uses the current year survey (note that most advice in cat 3-4 would not be using the 2020 surveys), updated advice could be provided using the most recent data (in 2020, this would be using the survey index up to 2019). This would mean updating the advice on the basis of one additional point only instead of two.

If the advice is annual and uses the current year survey, then there is no additional information. In these cases if the advice was due, to consider the PA buffer (done every 3 years) then advice could be given by applying the PA buffer. If the PA buffer was not to be considered then advice would remain unchanged but the advice sheet should indicate that the survey information was not available.

2) One or more surveys missing in the calculation of a combined index.

Normally, the individual indices would first be normalized to a common period then would be averaged to produce a combined index. In the case of one or more surveys missing in this index in a particular year, the average is calculated over the available surveys. This approach has been used previously when a survey that was part of a combined index was not available.

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2. Template for reporting deviations from stock annex caused by missing information from Covid-19 disruption.

1. Stock: **Herring (*Clupea harengus*) in subareas 1, 2, and 5, and in divisions 4.a and 14.a, Norwegian spring-spawning herring (the Northeast Atlantic and the Arctic Ocean)**

2. Missing or deteriorated survey data: **Fleet 4, index of numbers at age 2 from acoustic survey in the Barents Sea was not conducted in 2020. This tuning series has a minor influence on the assessment of SSB, but since no new data on recruitment, assumptions of recruitment in 2020 had to be made**

3. Missing or deteriorated catch data: **No, 97% of catch covered by sampling programme**

4. Missing or deteriorated commercial *LPUE/CPUE* data: **No**

5. Missing or deteriorated biological data: (e.g. maturity data): **No**

6. Brief description of methods explored to remedy the challenge:

7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)
   Instead of modelled recruitment based on fleet 4, median stochastic recruitment based on the years 1988–2019 was used as basis for recruitment in 2020

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out? **Young year classes contribute very little to the fishery and there is minor effect on advice**

4.17 Tables

Table 4.4.1.1 Total landings (ICES estimate) of Norwegian spring-spawning herring (tons) since 1972. Data provided by Working Group members.

Year	Norway	USSR/ Russia	Denmark	Faroes	Iceland	Ireland	Netherlands	Greenland	UK	Germany	France	Poland	Sweden	Total
1972	13161	-	-	-	-	-	-	-	-	-	-	-	-	13161
1973	7017	-	-	-	-	-	-	-	-	-	-	-	-	7017
1974	7619	-	-	-	-	-	-	-	-	-	-	-	-	7619
1975	13713	-	-	-	-	-	-	-	-	-	-	-	-	13713
1976	10436	-	-	-	-	-	-	-	-	-	-	-	-	10436
1977	22706	-	-	-	-	-	-	-	-	-	-	-	-	22706
1978	19824	-	-	-	-	-	-	-	-	-	-	-	-	19824
1979	12864	-	-	-	-	-	-	-	-	-	-	-	-	12864
1980	18577	-	-	-	-	-	-	-	-	-	-	-	-	18577
1981	13736	-	-	-	-	-	-	-	-	-	-	-	-	13736
1982	16655	-	-	-	-	-	-	-	-	-	-	-	-	16655
1983	23054	-	-	-	-	-	-	-	-	-	-	-	-	23054
1984	53532	-	-	-	-	-	-	-	-	-	-	-	-	53532
1985	167272	2600	-	-	-	-	-	-	-	-	-	-	-	169872
1986	199256	26000	-	-	-	-	-	-	-	-	-	-	-	225256

Year	Norway	USSR/ Russia	Denmark	Faroes	Iceland	Ireland	Netherlands	Greenland	UK	Germany	France	Poland	Sweden	Total
1987	108417	18889	-	-	-	-	-	-	-	-	-	-	-	127306
1988	115076	20225	-	-	-	-	-	-	-	-	-	-	-	135301
1989	88707	15123	-	-	-	-	-	-	-	-	-	-	-	103830
1990	74604	11807	-	-	-	-	-	-	-	-	-	-	-	86411
1991	73683	11000	-	-	-	-	-	-	-	-	-	-	-	84683
1992	91111	13337	-	-	-	-	-	-	-	-	-	-	-	104448
1993	199771	32645	-	-	-	-	-	-	-	-	-	-	-	232457
1994	380771	74400	-	2911	21146	-	-	-	-	-	-	-	-	479228
1995	529838	101987	30577	57084	174109	-	7969	2500	881	556	-	-	-	905501
1996	699161	119290	60681	52788	164957	19541	19664	-	46131	11978	-	-	22424	1220283
1997	860963	168900	44292	59987	220154	11179	8694	-	25149	6190	1500	-	19499	1426507
1998	743925	124049	35519	68136	197789	2437	12827	-	15971	7003	605	-	14863	1223131
1999	740640	157328	37010	55527	203381	2412	5871	-	19207	-	-	-	14057	1235433
2000	713500	163261	34968	68625	186035	8939	-	-	14096	3298	-	-	14749	1207201
2001	495036	109054	24038	34170	77693	6070	6439	-	12230	1588	-	-	9818	766136
2002	487233	113763	18998	32302	127197	1699	9392	-	3482	3017	-	1226	9486	807795
2003*	477573	122846	14144	27943	117910	1400	8678	-	9214	3371	-	-	6431	789510
2004	477076	115876	23111	42771	102787	11	17369	-	1869	4810	400	-	7986	794066

Year	Norway	USSR/ Russia	Denmark	Faroes	Iceland	Ireland	Netherlands	Greenland	UK	Germany	France	Poland	Sweden	Total
2005	580804	132099	28368	65071	156467	-	21517	-	-	17676	0	561	680	1003243
2006	567237	120836	18449	63137	157474	4693	11625	-	12523	9958	80	-	2946	968958
2007	779089	162434	22911	64251	173621	6411	29764	4897	13244	6038	0	4333	0	1266993
2008	961603	193119	31128	74261	217602	7903	28155	3810	19737	8338	0	0	0	1545656
2009	1016675	210105	32320	85098	265479	10014	24021	3730	25477	14452	0	0	0	1687371
2010	871113	199472	26792	80281	205864	8061	26695	3453	24151	11133	0	0	0	1457015
2011	572641	144428	26740	53271	151074	5727	8348	3426	14045	13296	0	0	0	992997
2012	491005	118595	21754	36190	120956	4813	6237	1490	12310	11945	0	0	705	826000
2013	359458	78521	17160	105038	90729	3815	5626	11788	8342	4244	0	0	23	684743
2014	263253	60292	12513	38529	58828	706	9175	13108	4233	669	0	0	0	461306
2015	176321	45853	9105	33031	42625	1400	5255	12434	55	2660	0	0	0	328740
2016	197501	50455	10384	44727	50418	2048	3519	17508	4031	2582	0	0	0	383174
2017	389383	91118	19037	98170	90400	3495	6679	12569	4358	5201	0	1	1155	721566
2018	332028	64185	17052	82062	83393	2428	4290	2465	2582	1989	0	0	425	592899
2019	430507	84364	21207	113945	108045	2775	5111	3190	1801	4188	0	1327	705	777165

***In 2003 the Norwegian catches were raised of 39433 to account for changes in percentages of water content.**

Table 4.4.1.2 Norwegian spring-spawning herring. Sampling coverage by year.

Year	TOTAL CATCH	% catch covered by sampling programme	No. samples	No. Measured	No. Aged
2000	1207201	86	389	55956	10901
2001	766136	86	442	70005	11234
2002	807795	88	184	39332	5405
2003	789510	71	380	34711	11352
2004	794066	79	503	48784	13169
2005	1003243	86	459	49273	14112
2006	968958	93	631	94574	9862
2007	1266993	94	476	56383	14661
2008	1545656	94	722	81609	31438
2009	1686928	94	663	65536	12265
2010	1457015	91	1258	124071	12377
2011	992.997	95	766	79360	10744
2012	825.999	93	649	59327	14768
2013	684.743	91	402	33169	11431
2014	461.306	89	229	18370	5813
2015	328.739	92	177	25156	5039
2016	383.174	91	203	39120	5892
2017	721566	95	335	31755	7241
2018	592899	97	253	22106	6047
2019	777165	97	361	29856	7421

Table 4.4.1.3 Norwegian spring-spawning herring. Sampling coverage by country in 2019.

COUNTRY	OFFICIAL CATCH	% catch covered by sampling programme	NO. SAMPLES	NO. MEASURED	NO. AGED
Denmark	21207	100	9	1024	265
Faroe Islands	113945	90	13	729	690
Germany	4188	100	42	5998	153
Greenland	3190	0	0	0	0
Iceland	108045	100	95	2747	2028
Ireland	2775	40	2	93	71
The Netherlands	5111	0	0	0	0
Norway	430507	100	94	2825	2825
Poland	1327	0	0	0	0
UK_Scotland	1801	0	0	0	0
Sweden	705	0	0	0	0
Russia	84364	100	106	16440	1389
Total for Stock	777165	97	361	29856	7421

Table 4.4.1.4 Norwegian spring-spawning herring. Sampling coverage by ICES Division in 2019.

Area	Official Catch	No Samples	No Aged	No Measured	No Aged/ 1000 tonnes	No Measured/ 1000 tonnes
1	310	0	0	0	0	0
2.a	697777	265	265	23953	9	34
4.a	5	0	0	0	0	0
5.a	77419	64	1260	1361	16	18
5.b	1386	32	186	4542	134	3277
14.a	268	0	0	0	0	0
Total	777165	361	7421	29856	10	38

Table 4.4.1.5 Norwegian spring-spawning herring. Catch data provided by working group members and samples allocated to unsampled catches in SALLOC.

Line	Country	Quarter	Div.	Catch (T)	Samples allocated (line)
1	Norway	1	I	278.2	2
2	Norway	1	IIa	165553.2	
3	Norway	2	IIa	877.2	2
4	Norway	3	IIa	865.6	
5	Norway	4	IIa	262927.7	
6	Norway	1	IVa	1.8	2
7	Norway	4	IVa	3.1	5
8	Iceland	3	IIa	919	
9	Iceland	4	IIa	48638	
10	Iceland	3	Va	56600	
11	Iceland	4	Va	1888	
12	Faroes	2	IIa	940	
13	Faroes	3	IIa	9270	4,8,21
14	Faroes	4	IIa	84531	
15	Faroes	4	Vb	5	11,23
16	Faroes	3	Va	16993	
17	Faroes	4	Va	1938	11
18	Faroes	3	XIVb	268	16
19	Russia	2	I	32	21
20	Russia	2	IIa	31.5	12
21	Russia	3	IIa	14916	
22	Russia	4	IIa	68003	
23	Russia	3	Vb	1381	
24	Germany	4	IIa	4188.465	
25	Denmark	1	IIa	7222.951	
26	Denmark	4	IIa	13984.33	
27	Greenland	3	IIa	991	4,8,21
28	Greenland	4	IIa	2199	5,9,14,22,24,26,30

Line	Country	Quarter	Div.	Catch (T)	Samples allocated (line)
29	Ireland	1	IIa	1676.914	2,25
30	Ireland	4	IIa	1098.5	
31	Netherlands	4	IIa	5110.8	5,9,14,22,24,26,30
32	Poland	4	IIa	1326.6	5,9,14,22,24,26,30
33	Sweden	1	IIa	705	2,25
34	Scotland	1	IIa	1801	2,25

Table 4.4.3.1. Norwegian spring spawning herring. Catch in numbers (thousands).

	AGE															
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1950	5112600	2000000	600000	276200	184800	185500	547000	628600	79500	88600	109500	86900	194500	368300	66400	344300
1951	1635500	7607700	400000	6600	383800	172400	164400	515600	602000	77100	82700	103100	107600	253500	348000	352500
1952	13721600	9149700	1232900	39300	60500	602300	136300	204500	380200	377900	79200	85700	107700	106800	186500	564400
1953	5697200	5055000	581300	740100	46600	100900	355600	81900	110900	314100	394900	61700	91200	94100	98800	730400
1954	10675990	7071090	855400	266300	1435500	142900	236000	490300	128100	199800	440400	460700	88400	100600	133000	803200
1955	5175600	2871100	510100	93000	276400	2045100	114300	189600	274700	85300	193400	295600	203200	58700	84600	580600
1956	5363900	2023700	627100	116500	251600	314200	2555100	110000	203900	264200	130700	198300	272800	163300	63000	565100
1957	5001900	3290800	219500	23300	373300	153800	228500	1985300	72000	127300	182500	88400	121200	149300	131600	281400
1958	9666990	2798100	666400	17500	17900	110900	89300	194400	973500	70700	123000	200900	98700	77400	70900	255600
1959	17896280	198530	325500	15100	26800	25900	146600	114800	240700	1103800	88600	124300	198000	88500	77400	235900
1960	12884310	13580790	392500	121700	18200	28100	24400	96200	73300	203900	1163000	85200	129700	153500	56700	168900
1961	6207500	16075600	2884800	31200	8100	4100	15000	19400	61600	49200	136100	728100	49700	45000	63000	60100
1962	3693200	4081100	1041300	1843800	8000	3100	7200	20200	11900	59100	52600	117000	813500	44200	54700	152300
1963	4807000	2119200	2045300	760400	835800	5300	1800	3600	18300	9300	107700	92500	174100	923700	79600	185300
1964	3613000	2728300	220300	114600	399000	2045800	13700	1500	3000	24900	29300	95600	82400	153000	772800	336800
1965	2303000	3780900	2853600	89900	256200	571100	2199700	19500	14900	7400	19100	40000	100500	107800	138700	883100
1966	3926500	662800	1678000	2048700	26900	466600	1306000	2884500	37900	14300	17400	26200	11000	69100	72100	556700

	AGE															
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1967	426800	9877100	70400	1392300	3254000	26600	421300	1132000	1720800	8900	5700	3500	8500	8900	17500	104400
1968	1783600	437000	388300	99100	1880500	1387400	14220	94000	134100	345100	2000	1100	830	2500	2600	17000
1969	561200	507100	141900	188200	800	8800	4700	700	11700	33600	36000	300	200	200	200	2400
1970	119300	529400	33200	6300	18600	600	3300	3300	1000	13400	26200	28100	300	100	200	2000
1971	30500	42900	85100	1820	1020	1240	360	1110	1130	360	4410	6910	5450	0	20	120
1972	347100	41000	20400	35376	3476	3583	2481	694	1486	198	0	494	593	593	0	0
1973	29300	3500	1700	2389	25200	651	1506	278	178	0	0	0	0	0	180	0
1974	65900	7800	3900	100	241	24505	257	196	0	0	0	0	0	0	0	0
1975	30600	3600	1800	3268	132	910	30667	5	2	0	0	0	0	0	0	0
1976	.20100	2400	1200	23248	5436	0	0	13086	0	0	0	0	0	0	0	0
1977	43000	6200	3100	22103	23595	336	0	419	10766	0	0	0	0	0	0	0
1978	20100	2400	1200	3019	12164	20315	870	0	620	5027	0	0	0	0	0	0
1979	32600	3800	1900	6352	1866	6865	11216	326	0	0	2534	0	0	0	0	0
1980	6900	800	400	6407	5814	2278	8165	15838	441	8	0	2688	0	0	0	0
1981	8300	1100	11900	4166	4591	8596	2200	4512	8280	345	103	114	964	0	0	0
1982	22600	1100	200	13817	7892	4507	6258	1960	5075	6047	121	37	37	121	0	0
1983	127000	4680	1670	3183	21191	9521	6181	6823	1293	4598	7329	143	40	143	860	0

	AGE															
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1984	33860	1700	2490	4483	5388	61543	18202	12638	15608	7215	16338	6478	0	0	0	1650
1985	28570	13150	207220	21500	15500	16500	130000	59000	55000	63000	10000	31000	50000	0	0	2640
1986	13810	1380	3090	539785	17594	14500	15500	105000	75000	42000	77000	19469	66000	80000	0	2470
1987	13850	6330	35770	19776	501393	18672	3502	7058	28000	12000	9500	4500	7834	6500	7000	450
1988	15490	2790	9110	62923	25059	550367	9452	3679	5964	14583	8872	2818	3356	2682	1560	540
1989	7120	1930	25200	2890	3623	5650	324290	3469	800	679	3297	1375	679	321	260	0
1990	1020	400	15540	18633	2658	11875	10854	226280	1289	1519	2036	2415	646	179	590	480
1991	100	3370	3330	8438	2780	1410	14698	8867	218851	2499	461	87	690	103	260	540
1992	1630	150	1340	12586	33100	4980	1193	11981	5748	225677	2483	639	247	1236	0	0
1993	6570	130	7240	28408	106866	87269	8625	3648	29603	18631	410110	0	0	0	0	0
1994	430	20	8100	32500	110090	363920	164800	15580	8140	37330	35660	645410	2830	460	100	2070
1995	0	0	1130	57590	346460	622810	637840	231090	15510	15850	69750	83740	911880	4070	250	450
1996	0	0	30140	34360	713620	1571000	940580	406280	103410	5680	7370	66090	17570	836550	0	0
1997	0	0	21820	130450	270950	1795780	1993620	761210	326490	60870	20020	32400	90520	19120	370330	300
1998	0	0	82891	70323	242365	368310	1760319	1263750	381482	129971	42502	25343	3478	112604	5633	108514
1999	0	0	5029	137626	35820	134813	429433	1604959	1164263	291394	106005	14524	40040	7202	88598	63983
2000	0	0	14395	84016	560379	34933	110719	404460	1299253	1045001	216980	71589	16260	22701	23321	71811

	AGE														
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2001	0	0	2076	102293	160678	426822	38749	95991	296460	839136	507106	73673	23722	3505	3356	22164
2002	0	0	62031	198360	643161	255516	326495	29843	93530	264675	663059	339326	52922	12437	7000	10087
2003	0	3461	4524	75243	323958	730468	175878	167776	22866	74494	217108	567253	219097	38555	8111	6192
2004	125	1846	43800	24299	92300	429510	714433	111022	137940	26656	52467	169196	401564	210547	28028	11883
2005	0	442	20411	447788	94206	170547	643600	930309	121856	123291	37967	65289	139331	344822	126879	15697
2006	0	1968	45438	75824	729898	82107	171370	726041	772217	88701	77115	30339	57882	133665	142240	49128
2007	0	4475	8450	224636	366983	1804495	152916	242923	728836	511664	47215	25384	15316	24488	64755	58465
2008	0	39898	123949	36630	550274	670681	2295912	199592	256132	586583	369620	29633	36025	23775	25195	63176
2009	0	3468	113424	192641	149075	1193781	914748	1929631	142931	262037	423972	238174	45519	9337	10153	70538
2010	0	75981	61673	101948	209295	189784	1064866	711951	1421939	175010	180164	340781	179039	12558	11602	49773
2011	0	126972	249809	61706	104634	234330	210165	755382	543212	642787	90515	117230	136509	45082	6628	11638
2012	0	2680	13083	211630	49999	119627	281908	263330	747839	314694	357902	53109	44982	64273	12420	3604
2013	0	1	20715	60364	276901	71287	112558	283658	242243	591912	169525	145318	24936	10614	9725	2299
2014	0	265	1441	28301	57838	257529	50424	71721	194814	147083	381317	83050	57315	12746	1809	7501
2015	0	647	3244	16139	55749	52369	152347	34046	65728	156075	103393	201141	24310	49373	3369	6397
2016	0	197	2351	45483	43416	112147	85937	164454	52267	73576	174655	96476	179051	38546	32880	8379
2017	0	618	16390	64275	305483	114976	248192	162566	289931	98836	133145	276874	107473	220368	22357	49442

Year	AGE 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2018	0	1261	22414	25638	59802	264182	150759	179628	109121	180968	85954	99061	212052	113841	136096	39249
2019	0	769	2205	148669	64237	185336	557804	146597	217346	119855	167569	133910	104730	220400	91773	121229

Table 4.4.4.1. Norwegian spring spawning herring. Weight at age in the catch (kg).

Year	age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0.007	0.025	0.058	0.110	0.188	0.211	0.234	0.253	0.266	0.280	0.294	0.303	0.312	0.32	0.323	0.334
1951	0.009	0.029	0.068	0.130	0.222	0.249	0.276	0.298	0.314	0.330	0.346	0.357	0.368	0.377	0.381	0.394
1952	0.008	0.026	0.061	0.115	0.197	0.221	0.245	0.265	0.279	0.293	0.308	0.317	0.327	0.335	0.339	0.349
1953	0.008	0.027	0.063	0.120	0.205	0.230	0.255	0.275	0.290	0.305	0.320	0.330	0.34	0.347	0.351	0.363
1954	0.008	0.026	0.062	0.117	0.201	0.225	0.250	0.269	0.284	0.299	0.313	0.323	0.333	0.341	0.345	0.356
1955	0.008	0.027	0.063	0.119	0.204	0.229	0.254	0.274	0.289	0.304	0.318	0.328	0.338	0.346	0.350	0.362
1956	0.008	0.028	0.066	0.126	0.215	0.241	0.268	0.289	0.304	0.320	0.336	0.346	0.357	0.365	0.369	0.382
1957	0.008	0.028	0.066	0.127	0.216	0.243	0.269	0.290	0.306	0.322	0.338	0.348	0.359	0.367	0.371	0.384
1958	0.009	0.030	0.070	0.133	0.227	0.255	0.283	0.305	0.321	0.338	0.355	0.366	0.377	0.386	0.390	0.403
1959	0.009	0.030	0.071	0.135	0.231	0.259	0.287	0.310	0.327	0.344	0.360	0.372	0.383	0.392	0.397	0.409
1960	0.006	0.011	0.074	0.119	0.188	0.277	0.337	0.318	0.363	0.379	0.360	0.420	0.411	0.439	0.450	0.447
1961	0.006	0.010	0.045	0.087	0.159	0.276	0.322	0.372	0.363	0.393	0.407	0.397	0.422	0.447	0.465	0.452

	age															
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1962	0.009	0.023	0.055	0.085	0.148	0.288	0.333	0.360	0.352	0.350	0.374	0.384	0.374	0.394	0.399	0.414
1963	0.008	0.026	0.047	0.098	0.171	0.275	0.268	0.323	0.329	0.336	0.341	0.358	0.385	0.353	0.381	0.386
1964	0.009	0.024	0.059	0.139	0.219	0.239	0.298	0.295	0.339	0.350	0.358	0.351	0.367	0.375	0.372	0.433
1965	0.009	0.016	0.048	0.089	0.217	0.234	0.262	0.331	0.360	0.367	0.386	0.395	0.393	0.404	0.401	0.431
1966	0.008	0.017	0.040	0.063	0.246	0.260	0.265	0.301	0.410	0.425	0.456	0.460	0.467	0.446	0.459	0.472
1967	0.009	0.015	0.036	0.066	0.093	0.305	0.305	0.310	0.333	0.359	0.413	0.446	0.401	0.408	0.439	0.430
1968	0.010	0.027	0.049	0.075	0.108	0.158	0.375	0.383	0.364	0.382	0.441	0.410		0.517	0.491	0.485
1969	0.009	0.021	0.047	0.072		0.152	0.296		0.329	0.329	0.341					0.429
1970	0.008	0.058	0.085	0.105	0.171		0.216	0.277	0.298	0.304	0.305	0.309				0.376
1971	0.011	0.053	0.121	0.177	0.216	0.250		0.305	0.333		0.366	0.377	0.388			
1972	0.011	0.029	0.062	0.103	0.154	0.215	0.258		0.322							
1973	0.006	0.053	0.106	0.161	0.213		0.255									
1974	0.006	0.055	0.117			0.249										
1975	0.009	0.079	0.169	0.241			0.381									
1976	0.007	0.062	0.132	0.189	0.250			0.323								
1977	0.011	0.091	0.193	0.316	0.350				0.511							
1978	0.012	0.100	0.210	0.274	0.424	0.454				0.613						

	age															
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1979	0.010	0.088	0.181	0.293	0.359	0.416	0.436				0.553					
1980	0.012			0.266	0.399	0.449	0.460	0.485				0.608				
1981	0.010	0.082	0.163	0.196	0.291	0.341	0.368	0.380	0.397							
1982	0.010	0.087	0.159	0.256	0.312	0.378	0.415	0.435	0.449	0.448						
1983	0.011	0.090	0.165	0.217	0.265	0.337	0.378	0.410	0.426	0.435	0.444					
1984	0.009	0.047	0.145	0.218	0.262	0.325	0.346	0.381	0.400	0.413	0.405	0.426				0.415
1985	0.009	0.022	0.022	0.214	0.277	0.295	0.338	0.360	0.381	0.397	0.409	0.417	0.435			0.435
1986	0.007	0.077	0.097	0.055	0.249	0.294	0.312	0.352	0.374	0.398	0.402	0.401	0.410	0.410		0.410
1987	0.010	0.075	0.091	0.124	0.173	0.253	0.232	0.312	0.328	0.349	0.353	0.370	0.385	0.385	0.385	
1988	0.008	0.062	0.075	0.124	0.154	0.194	0.241	0.265	0.304	0.305	0.317	0.308	0.334	0.334	0.334	
1989	0.010	0.060	0.204	0.188	0.264	0.260	0.282	0.306			0.422	0.364				
1990	0.007		0.102	0.230	0.239	0.266	0.305	0.308	0.376	0.407	0.412	0.424				
1991		0.015	0.104	0.208	0.250	0.288	0.312	0.316	0.330	0.344						
1992	0.007		0.103	0.191	0.233	0.304	0.337	0.365	0.361	0.371	0.403			0.404		
1993	0.007		0.106	0.153	0.243	0.282	0.320	0.330	0.365	0.373	0.379					
1994			0.102	0.194	0.239	0.280	0.317	0.328	0.356	0.372	0.390	0.379	0.399	0.403		
1995			0.102	0.153	0.192	0.234	0.283	0.328	0.349	0.356	0.374	0.366	0.393	0.387		

	age														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1996			0.136	0.136	0.168	0.206	0.262	0.309	0.337	0.366	0.360	0.361	0.367	0.379		
1997			0.089	0.167	0.184	0.207	0.232	0.277	0.305	0.331	0.328	0.344	0.343	0.397	0.357	
1998			0.111	0.150	0.216	0.221	0.249	0.277	0.316	0.338	0.374	0.372	0.366	0.396	0.377	0.406
1999			0.096	0.173	0.228	0.262	0.274	0.292	0.307	0.335	0.362	0.371	0.399	0.396	0.400	0.404
2000			0.124	0.175	0.222	0.242	0.289	0.303	0.310	0.328	0.349	0.383	0.411	0.410	0.419	0.409
2001			0.105	0.166	0.214	0.252	0.268	0.305	0.308	0.322	0.337	0.363	0.353	0.378	0.400	0.427
2002			0.056	0.128	0.198	0.255	0.281	0.303	0.322	0.323	0.334	0.345	0.369	0.407	0.410	0.435
2003		0.062	0.068	0.169	0.218	0.257	0.288	0.316	0.323	0.348	0.354	0.351	0.363	0.372	0.376	0.429
2004	0.022	0.066	0.143	0.18	0.227	0.26	0.29	0.323	0.355	0.375	0.383	0.399	0.395	0.405	0.429	0.439
2005		0.092	0.106	0.181	0.235	0.266	0.290	0.315	0.344	0.367	0.384	0.372	0.384	0.398	0.402	0.413
2006		0.055	0.102	0.171	0.238	0.268	0.292	0.311	0.330	0.365	0.374	0.376	0.388	0.396	0.398	0.407
2007	0.000	0.074	0.137	0.162	0.228	0.271	0.316	0.332	0.342	0.358	0.361	0.381	0.390	0.400	0.405	0.399
2008	0.000	0.026	0.106	0.145	0.209	0.254	0.296	0.318	0.341	0.353	0.363	0.367	0.395	0.396	0.386	0.413
2009		0.040	0.156	0.184	0.220	0.251	0.291	0.311	0.338	0.347	0.363	0.375	0.382	0.375	0.375	0.387
2010		0.059	0.107	0.177	0.218	0.261	0.279	0.311	0.325	0.343	0.362	0.370	0.388	0.391	0.376	0.441
2011		0.011	0.098	0.200	0.257	0.273	0.300	0.316	0.340	0.348	0.365	0.371	0.387	0.374	0.403	0.401
2012		0.034	0.126	0.211	0.272	0.301	0.308	0.331	0.335	0.351	0.354	0.370	0.389	0.389	0.382	0.388

Year	age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2013		0.048	0.163	0.237	0.276	0.300	0.331	0.339	0.351	0.357	0.370	0.373	0.394	0.391	0.389	0.367
2014		0.057	0.179	0.233	0.271	0.293	0.322	0.342	0.353	0.367	0.365	0.374	0.375	0.378	0.418	0.371
2015		0.059	0.146	0.203	0.272	0.323	0.331	0.358	0.370	0.372	0.383	0.382	0.392	0.386	0.383	0.391
2016		0.048	0.111	0.212	0.255	0.290	0.333	0.339	0.361	0.367	0.370	0.381	0.378	0.388	0.383	0.395
2017		0.092	0.143	0.205	0.241	0.292	0.322	0.350	0.360	0.382	0.392	0.391	0.396	0.399	0.407	0.394
2018		0.068	0.127	0.207	0.240	0.276	0.321	0.348	0.371	0.380	0.399	0.404	0.400	0.407	0.408	0.418
2019		0.135	0.186	0.209	0.235	0.269	0.298	0.327	0.345	0.376	0.387	0.403	0.409	0.423	0.417	0.449

Table 4.4.4.2. Norwegian spring spawning herring. Weight at age in the stock (kg).

Year	AGE 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1951	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1952	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1953	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1954	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1955	0.001	0.008	0.047	0.100	0.195	0.213	0.260	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1956	0.001	0.008	0.047	0.100	0.205	0.230	0.249	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364

	AGE														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1957	0.001	0.008	0.047	0.100	0.136	0.228	0.255	0.262	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1958	0.001	0.008	0.047	0.100	0.204	0.242	0.292	0.295	0.293	0.305	0.315	0.330	0.340	0.345	0.352	0.363
1959	0.001	0.008	0.047	0.100	0.204	0.252	0.260	0.290	0.300	0.305	0.315	0.325	0.330	0.340	0.345	0.358
1960	0.001	0.008	0.047	0.100	0.204	0.270	0.291	0.293	0.321	0.318	0.320	0.344	0.349	0.370	0.379	0.378
1961	0.001	0.008	0.047	0.100	0.232	0.250	0.292	0.302	0.304	0.323	0.322	0.321	0.344	0.357	0.363	0.368
1962	0.001	0.008	0.047	0.100	0.219	0.291	0.300	0.316	0.324	0.326	0.335	0.338	0.334	0.347	0.354	0.358
1963	0.001	0.008	0.047	0.100	0.185	0.253	0.294	0.312	0.329	0.327	0.334	0.341	0.349	0.341	0.358	0.375
1964	0.001	0.008	0.047	0.100	0.194	0.213	0.264	0.317	0.363	0.353	0.349	0.354	0.357	0.359	0.365	0.402
1965	0.001	0.008	0.047	0.100	0.186	0.199	0.236	0.260	0.363	0.350	0.370	0.360	0.378	0.387	0.390	0.394
1966	0.001	0.008	0.047	0.100	0.185	0.219	0.222	0.249	0.306	0.354	0.377	0.391	0.379	0.378	0.361	0.383
1967	0.001	0.008	0.047	0.100	0.180	0.228	0.269	0.270	0.294	0.324	0.420	0.430	0.366	0.368	0.433	0.414
1968	0.001	0.008	0.047	0.100	0.115	0.206	0.266	0.275	0.274	0.285	0.350	0.325	0.363	0.408	0.388	0.378
1969	0.001	0.008	0.047	0.100	0.115	0.145	0.270	0.300	0.306	0.308	0.318	0.340	0.368	0.360	0.393	0.397
1970	0.001	0.008	0.047	0.100	0.209	0.272	0.230	0.295	0.317	0.323	0.325	0.329	0.380	0.370	0.380	0.391
1971	0.001	0.015	0.080	0.100	0.190	0.225	0.250	0.275	0.290	0.310	0.325	0.335	0.345	0.355	0.365	0.390
1972	0.001	0.010	0.070	0.150	0.150	0.140	0.210	0.240	0.270	0.300	0.325	0.335	0.345	0.355	0.365	0.390
1973	0.001	0.010	0.085	0.170	0.259	0.342	0.384	0.409	0.404	0.461	0.520	0.534	0.500	0.500	0.500	0.500

	AGE														
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1974	0.001	0.010	0.085	0.170	0.259	0.342	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1975	0.001	0.010	0.085	0.181	0.259	0.342	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1976	0.001	0.010	0.085	0.181	0.259	0.342	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1977	0.001	0.010	0.085	0.181	0.259	0.343	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1978	0.001	0.010	0.085	0.180	0.294	0.326	0.371	0.409	0.461	0.476	0.520	0.543	0.500	0.500	0.500	0.500
1979	0.001	0.010	0.085	0.178	0.232	0.359	0.385	0.420	0.444	0.505	0.520	0.551	0.500	0.500	0.500	0.500
1980	0.001	0.010	0.085	0.175	0.283	0.347	0.402	0.421	0.465	0.465	0.520	0.534	0.500	0.500	0.500	0.500
1981	0.001	0.010	0.085	0.170	0.224	0.336	0.378	0.387	0.408	0.397	0.520	0.543	0.512	0.512	0.512	0.512
1982	0.001	0.010	0.085	0.170	0.204	0.303	0.355	0.383	0.395	0.413	0.453	0.468	0.506	0.506	0.506	0.506
1983	0.001	0.010	0.085	0.155	0.249	0.304	0.368	0.404	0.424	0.437	0.436	0.493	0.495	0.495	0.495	0.495
1984	0.001	0.010	0.085	0.140	0.204	0.295	0.338	0.376	0.395	0.407	0.413	0.422	0.437	0.437	0.437	0.437
1985	0.001	0.010	0.085	0.148	0.234	0.265	0.312	0.346	0.370	0.395	0.397	0.428	0.428	0.428	0.428	0.428
1986	0.001	0.010	0.085	0.054	0.206	0.265	0.289	0.339	0.368	0.391	0.382	0.388	0.395	0.395	0.395	0.395
1987	0.001	0.010	0.055	0.090	0.143	0.241	0.279	0.299	0.316	0.342	0.343	0.362	0.376	0.376	0.376	0.376
1988	0.001	0.015	0.050	0.098	0.135	0.197	0.277	0.315	0.339	0.343	0.359	0.365	0.376	0.376	0.376	0.376
1989	0.001	0.015	0.100	0.154	0.175	0.209	0.252	0.305	0.367	0.377	0.359	0.395	0.396	0.396	0.396	0.396
1990	0.001	0.008	0.048	0.219	0.198	0.258	0.288	0.309	0.428	0.370	0.403	0.387	0.440	0.440	0.440	0.44

	AGE																
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**		**15+**
1991		0.001	0.011	0.037	0.147	0.210	0.244	0.300	0.324	0.336	0.343	0.382	0.366	0.425	0.425	0.425	0.425
1992		0.001	0.007	0.030	0.128	0.224	0.296	0.327	0.355	0.345	0.367	0.341	0.361	0.430	0.470	0.470	0.46
1993		0.001	0.008	0.025	0.081	0.201	0.265	0.323	0.354	0.358	0.381	0.369	0.396	0.393	0.374	0.403	0.4
1994		0.001	0.010	0.025	0.075	0.151	0.254	0.318	0.371	0.347	0.412	0.382	0.407	0.410	0.410	0.410	0.41
1995		0.001	0.018	0.025	0.066	0.138	0.230	0.296	0.346	0.388	0.363	0.409	0.414	0.422	0.410	0.410	0.426
1996		0.001	0.018	0.025	0.076	0.118	0.188	0.261	0.316	0.346	0.374	0.390	0.390	0.384	0.398	0.398	0.398
1997		0.001	0.018	0.025	0.096	0.118	0.174	0.229	0.286	0.323	0.370	0.378	0.386	0.360	0.393	0.391	0.391
1998		0.001	0.018	0.025	0.074	0.147	0.174	0.217	0.242	0.278	0.304	0.310	0.359	0.340	0.344	0.385	0.369
1999		0.001	0.018	0.025	0.102	0.150	0.223	0.240	0.264	0.283	0.315	0.345	0.386	0.386	0.386	0.382	0.395
2000		0.001	0.018	0.025	0.119	0.178	0.225	0.271	0.285	0.298	0.311	0.339	0.390	0.398	0.406	0.414	0.427
2001		0.001	0.018	0.025	0.075	0.178	0.238	0.247	0.296	0.307	0.314	0.328	0.351	0.376	0.406	0.414	0.425
2002		0.001	0.010	0.023	0.057	0.177	0.241	0.275	0.302	0.311	0.314	0.328	0.341	0.372	0.405	0.415	0.438
2003		0.001	0.010	0.055	0.098	0.159	0.211	0.272	0.305	0.292	0.331	0.337	0.347	0.356	0.381	0.414	0.433
2004		0.001	0.010	0.055	0.106	0.149	0.212	0.241	0.279	0.302	0.337	0.354	0.355	0.360	0.371	0.400	0.429
2005		0.001	0.010	0.046	0.112	0.156	0.234	0.267	0.295	0.330	0.363	0.377	0.414	0.406	0.308	0.420	0.452
2006		0.001	0.010	0.042	0.107	0.179	0.232	0.272	0.297	0.318	0.371	0.365	0.393	0.395	0.399	0.415	0.428
2007		0.001	0.010	0.036	0.086	0.155	0.226	0.265	0.312	0.310	0.364	0.384	0.352	0.386	0.304	0.420	0.412

Year	AGE 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2008**	0.001	0.010	0.044	0.077	0.146	0.212	0.269	0.289	0.327	0.351	0.358	0.372	0.411	0.353	0.389	0.393
2009***	0.001	0.010	0.044	0.077	0.141	0.215	0.270	0.306	0.336	0.346	0.364	0.369	0.411	0.353	0.389	0.393
2010****	0.001	0.01	0.044	0.077	0.188	0.22	0.251	0.286	0.308	0.333	0.344	0.354	0.373	0.353	0.389	0.393
2011	0.001	0.01	0.044	0.118	0.185	0.209	0.246	0.277	0.310	0.322	0.339	0.349	0.364	0.363	0.389	0.393
2012	0.001	0.01	0.044	0.138	0.185	0.256	0.273	0.290	0.305	0.330	0.342	0.361	0.390	0.377	0.389	0.393
2013	0.001	0.01	0.044	0.138	0.204	0.267	0.305	0.309	0.320	0.328	0.346	0.350	0.390	0.377	0.389	0.393
2014	0.001	0.01	0.044	0.138	0.198	0.274	0.301	0.326	0.333	0.339	0.347	0.344	0.362	0.362	0.389	0.393
2015	0.001	0.01	0.044	0.138	0.187	0.243	0.299	0.326	0.319	0.345	0.346	0.354	0.382	0.376	0.389	0.393
2016	0.001	0.01	0.054	0.115	0.186	0.247	0.293	0.320	0.334	0.353	0.354	0.352	0.361	0.370	0.380	0.388
2017	0.001	0.01	0.054	0.115	0.190	0.247	0.282	0.322	0.338	0.351	0.359	0.361	0.361	0.368	0.380	0.386
2018	0.001	0.01	0.054	0.115	0.149	0.225	0.260	0.289	0.312	0.343	0.359	0.361	0.369	0.368	0.377	0.386
2019	0.001	0.01	0.054	0.104	0.151	0.203	0.277	0.311	0.331	0.355	0.353	0.363	0.381	0.376	0.385	0.382
2020	0.001	0.01	0.054	0.104	0.150	0.203	0.266	0.301	0.328	0.343	0.358	0.366	0.374	0.367	0.384	0.391

**** mean weight at ages 11 and 13 are mean of 5 previous years at the same age. These age groups were not present in the catches of the wintering survey from which the stock weight are derived.**

****** derived from catch data from the wintering area north of 69°N during December 2008 – January 2009 for age groups 4—11.**

********derived from catch data from the wintering area north of 69°N during January 2010 for age groups 4—12.**

Table 4.4.5.1. Norwegian Spring-spawning herring. Maturity at age.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
1951	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
1952	0	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1
1953	0	0	0	0	0.3	0.4	0.9	1	1	1	1	1	1	1	1	1
1954	0	0	0	0	0.1	0.7	0.9	1	1	1	1	1	1	1	1	1
1955	0	0	0	0.1	0.4	0.4	1	1	1	1	1	1	1	1	1	1
1956	0	0	0	0	0.5	0.7	0.6	1	1	1	1	1	1	1	1	1
1957	0	0	0	0	0.3	0.8	0.8	0.7	1	1	1	1	1	1	1	1
1958	0	0	0	0	0.3	0.5	0.9	0.9	1	1	1	1	1	1	1	1
1959	0	0	0	0	0.7	0.8	1	0.9	1	1	1	1	1	1	1	1
1960	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
1961	0	0	0	0	0.1	0.8	1	0.9	1	1	1	1	1	1	1	1
1962	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1963	0	0	0	0	0.1	0.4	1	1	1	1	1	1	1	1	1	1
1964	0	0	0	0	0.1	0.4	0.8	1	1	1	1	1	1	1	1	1
1965	0	0	0	0	0.5	0.4	0.9	0.8	1	1	1	1	1	1	1	1
1966	0	0	0	0	0.5	0.7	0.9	1	1	1	1	1	1	1	1	1
1967	0	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1
1968	0	0	0	0	0	0.7	0.9	1	1	1	1	1	1	1	1	1
1969	0	0	0	0.1	0.2	0.3	1	1	1	1	1	1	1	1	1	1
1970	0	0	0	0	0.4	0.3	0.4	1	1	1	1	1	1	1	1	1
1971	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1972	0	0	0	0	0.4	0.3	1	1	1	1	1	1	1	1	1	1
1973	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1	1
1974	0	0	0	0	0.6	0.9	1	1	1	1	1	1	1	1	1	1
1975	0	0	0	0.1	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1976	0	0	0	0.1	0.9	0.9	1	1	1	1	1	1	1	1	1	1
1977	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1	1
1978	0	0	0	0.2	0.9	1	1	1	1	1	1	1	1	1	1	1

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1979	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1980	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1981	0	0	0	0.1	1	1	1	1	1	1	1	1	1	1	1	1
1982	0	0	0	0.1	0.8	1	1	1	1	1	1	1	1	1	1	1
1983	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1984	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1	1
1985	0	0	0	0.1	0.8	0.9	1	1	1	1	1	1	1	1	1	1
1986	0	0	0	0	0.5	0.9	0.9	1	1	1	1	1	1	1	1	1
1987	0	0	0	0	0.1	0.8	0.9	0.9	1	1	1	1	1	1	1	1
1988	0	0	0	0	0.2	0.7	0.9	1	1	1	1	1	1	1	1	1
1989	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
1990	0	0	0	0.2	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1991	0	0	0	0	0.9	0.9	1	1	1	1	1	1	1	1	1	1
1992	0	0	0	0	0.8	1	1	1	1	1	1	1	1	1	1	1
1993	0	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1
1994	0	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1
1995	0	0	0	0	0	0.6	1	1	1	1	1	1	1	1	1	1
1996	0	0	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1
1997	0	0	0	0.1	0	0.4	0.9	1	1	1	1	1	1	1	1	1
1998	0	0	0	0	0.6	0.4	0.9	1	1	1	1	1	1	1	1	1
1999	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
2000	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2001	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
2002	0	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1
2003	0	0	0	0	0.2	0.7	1	1	1	1	1	1	1	1	1	1
2004	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1
2005	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2006	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2007	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2008	0	0	0	0	0.1	0.7	0.9	1	1	1	1	1	1	1	1	1

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2009	0	0	0	0	0.1	0.4	0.9	1	1	1	1	1	1	1	1	1
2010	0	0	0	0	0.2	0.4	0.7	1	1	1	1	1	1	1	1	1
2011	0	0	0	0	0.4	0.7	0.8	0.9	1	1	1	1	1	1	1	1
2012	0	0	0	0	0.5	0.9	0.9	1	1	1	1	1	1	1	1	1
2013	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2014	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
2015	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1
2016	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2017	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2018	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2019	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2020	0	0	0	0	0.1	0.8	1	1	1	1	1	1	1	1	1	1

Table 4.4.7.1. Norwegian Spring-spawning herring. Estimated indices (mean of bootstrap with 1000 iterations in StoX) from the acoustic surveys on the spawning grounds in February-March. Numbers in millions. Biomass in thousand tonnes. "Fleet 1".

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
1988	0	392	307	8015	81	33	12	36	22	45	0	0	0	0	8943	1621
1989	161	16	338	91	3973	101	12	4	55	0	4	42	0	9	4813	1169
1990																
1991																
1992																
1993																
1994	37	100	48	848	483	62	13	144	49	1836	4	4	0	0	3665	1207
1995	4	450	4679	3211	1957	299	20	0	106	55	2327	0	0	0	13745	2860
1996	119	186	1976	7960	2326	875	301	0	0	136	0	1760	0	0	15645	3366
1997																
1998	51	308	978	2982	12859	8133	1851	592	163	43	0	329	0	1400	29705	6886
1999	114	1530	369	1351	2669	9334	7004	1666	511	130	0	0	353	373	25438	6262
2000	1394	691	2600	109	477	1144	4282	2838	493	50	2	0	7	228	14315	3285
2001																
2002																
2003																
2004																

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
2005	38	238	661	2128	5947	8328	613	503	156	92	576	1152	587	9	21026	5260
2006	26	90	6054	548	882	3362	3311	110	86	20	89	58	246	63	14951	3431
2007	33	367	1618	12397	815	655	2956	3205	141	228	40	204	284	470	23427	5350
2008	15	48	2564	2824	8882	522	471	1566	1567	161	102	46	128	136	19090	4553
2009																
2010																
2011																
2012																
2013																
2014																
2015	204	533	2754	744	3267	388	692	2715	784	7222	367	1658	51	237	21662	6365
2016	18	197	237	594	365	2119	240	514	2930	652	3995	199	824	97	12982	4182
2017	19	110	1076	641	880	428	1326	181	206	2026	303	2542	80	729	10550	3314
2018	104	146	1720	2771	459	845	639	1095	444	370	1159	368	1538	354	12013	3262
2019	2	372	310	940	3778	754	879	660	1054	736	412	1807	182	2161	14166	4250
2020	6	44	3502	571	1212	3337	530	609	364	650	131	279	677	825	12750	3274

Table 4.4.7.2. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in May/June from IESNS. Values in the years 2009–2019 are estimated with StoX (mean of bootstrap with 1000 iterations). "Fleet 4".

	AGEe				
Year	1	2	3	4	5
1991	24.3	5.2			
1992	32.6	14	5.7		
1993	102.7	25.8	1.5		
1994	6.6	59.2	18	1.7	
1995	0.5	7.7	8	1.1	
1996*	0.1	0.25	1.8	0.6	0.03
1997**	2.6	0.04	0.4	0.35	0.05
1998	9.5	4.7	0.01	0.01	0
1999	49.5	4.9	0	0	0
2000	105.4	27.9	0	0	0
2001	0.3	7.6	8.8	0	0
2002	0.5	3.9	0	0	0
2003***					
2004***					
2005	23.3	4.5	2.5	0.4	0.3
2006	3.7	35.0	5.3	0.87	0
2007	2.1	3.7	12.5	1.9	0
2008^					
2009	0.289	0.300	0.233	0.060	
2010	5.196	1.380	0.000	0.000	
2011	1.166	3.920	0.041	0.000	
2012	0.787	0.030	0.000	0.000	
2013	0.107	2.190	0.211	0.070	
2014	4.239	3.110	1.728	0.127	0.043
2015	0.345	11.760	1.183	0.206	0.000
2016	1.826	5.620	1.568	0.101	0.038

	AGEe				
Year	1	2	3	4	5
2017	14.522	3.080	0.000	0.000	
2018	7.329	17.420	0.827	0.009	
2019	0.113	2.370	17.481	0.044	
2020***					

***Average of Norwegian and Russian estimates**

****Combination of Norwegian and Russian estimates as described in 1998 WG report, since then only Russian estimates**

*****No surveys**

^Not a full survey

Table 4.4.7.3. Norwegian spring-spawning herring. Estimates from the international acoustic survey on the feeding areas in the Norwegian Sea in May (IESNS). Numbers in millions. Biomass in thousands. Values in the years 2008-2020 are estimated indices by StoX (mean of bootstrap with 1000 iterations). "Fleet 5".

	Age															Total
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass**
1996	0	0	4114	22461	13244	4916	2045	424	14	7	155	0	3134			50514	8532
1997	0	0	1169	3599	18867	13546	2473	1771	178	77	288	190	60	2697		44915	9435
1998	24	1404	367	1099	4410	16378	10160	2059	804	183	0	0	35	0	492	37415	8004
1999	0	215	2191	322	965	3067	11763	6077	853	258	5	14	0	158	128	26016	6299
2000	0	157	1353	2783	92	384	1302	7194	5344	1689	271	0	114	0	75	20758	6001
2001	0	1540	8312	1430	1463	179	204	3215	5433	1220	94	178	0	0	6	23274	3937
2002	0	677	6343	9619	1418	779	375	847	1941	2500	1423	61	78	28	0	26089	4628
2003	32073	8115	6561	9985	9961	1499	732	146	228	1865	2359	1769		287	0	75580	6653
2004	0	13735	1543	5227	12571	10710	1075	580	76	313	362	1294	1120	10	88	48704	7687
2005	0	1293	19679	1353	1765	6205	5371	651	388	139	262	526	1003	364	115	39114	5109
2006	0	19	306	14560	1396	2011	6521	6978	679	713	173	407	921	618	243	35545	9100
2007	0	411	2889	5877	20292	1260	1992	6780	5582	647	488	372	403	1048	1010	49051	12161
2008	0	1213	655	10997	8406	14798	1543	2232	4890	2790	511	148	172	244	529	49187	10655
2009	0	137	1817	2280	12118	8599	9735	2054	1433	2608	1375	237	198	112	248	43057	9692
2010	231	119	572	2296	1828	8395	5918	5676	923	888	1002	550	89	42	62	28772	6649
2011	0	1110	921	1663	3592	2605	9303	4390	4257	771	956	732	269	29	33	30731	7336

	Age															Total
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
2012	0	396	2942	410	668	1736	2633	4328	1884	2148	297	604	303	139	41	18540	4476
2013	0	201	718	3555	425	1161	1859	2905	4449	2772	1865	678	790	222	102	21722	5653
2014	13	515	1258	784	2788	715	1118	2634	2268	2806	1118	703	337	72	212	17350	4504
2015	0	391	432	1316	1132	3535	1309	1191	3156	2526	4457	687	816	290	211	21450	5851
2016	0	75	3550	1538	2229	1749	2631	938	1092	1806	1882	2853	934	436	130	21851	5408
2017	10	131	948	4295	1198	1543	826	1414	317	738	1008	1741	2230	507	237	17159	4152
2018	0	496	1004	1968	5664	970	1409	569	1279	354	675	1564	1464	1498	500	19412	4987
2019	4	157	2625	680	2187	4656	1158	1223	952	1232	823	655	1406	917	803	19487	4805
2020	0	43	472	13065	513	1009	2492	786	629	434	694	324	505	726	902	22616	4210

Table 4.4.8.1 Norwegian spring-spawning herring. Relative standard error of estimated catch-at-age used by XSAM.

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
1988	0.362	0.197	0.263	0.100	0.358	0.482	0.414	0.312	0.365	0.524	0.375
1989	0.263	0.520	0.484	0.421	0.118	0.491	0.779	0.820	0.499	0.657	0.675
1990	0.306	0.289	0.534	0.333	0.343	0.132	0.670	0.636	0.580	0.550	0.594
1991	0.497	0.371	0.526	0.652	0.311	0.365	0.133	0.544	0.926	1.566	0.627
1992	0.662	0.327	0.241	0.438	0.687	0.332	0.419	0.132	0.545	0.836	0.641
1993	0.389	0.253	0.167	0.178	0.368	0.483	0.250	0.289	0.109	NA	NA
1994	0.376	0.243	0.165	0.113	0.145	0.306	0.375	0.232	0.236	0.095	0.425
1995	0.699	0.203	0.115	0.096	0.095	0.131	0.306	0.304	0.191	0.180	0.085
1996	0.248	0.238	0.092	0.072	0.084	0.110	0.168	0.420	0.387	0.194	0.087
1997	0.275	0.157	0.124	0.069	0.066	0.090	0.117	0.199	0.283	0.243	0.104
1998	0.181	0.190	0.129	0.113	0.069	0.077	0.112	0.157	0.223	0.262	0.131
1999	0.437	0.154	0.235	0.155	0.108	0.071	0.079	0.122	0.167	0.313	0.137
2000	0.313	0.180	0.099	0.237	0.165	0.110	0.076	0.081	0.133	0.189	0.155
2001	0.577	0.169	0.147	0.108	0.230	0.172	0.121	0.087	0.102	0.187	0.208
2002	0.198	0.137	0.095	0.127	0.117	0.249	0.174	0.125	0.094	0.116	0.181
2003	0.451	0.186	0.118	0.091	0.143	0.145	0.271	0.187	0.133	0.099	0.124
2004	0.221	0.266	0.175	0.108	0.092	0.165	0.154	0.258	0.209	0.144	0.094
2005	0.281	0.106	0.173	0.144	0.095	0.084	0.16	0.159	0.231	0.195	0.096
2006	0.218	0.186	0.091	0.181	0.144	0.091	0.089	0.177	0.185	0.248	0.112
2007	0.371	0.132	0.113	0.068	0.149	0.129	0.091	0.102	0.216	0.262	0.146
2008	0.159	0.234	0.100	0.094	0.063	0.137	0.127	0.098	0.113	0.250	0.150
2009	0.164	0.139	0.150	0.078	0.085	0.067	0.152	0.126	0.108	0.130	0.155
2010	0.198	0.169	0.135	0.139	0.081	0.092	0.074	0.143	0.141	0.116	0.127
2011	0.128	0.198	0.168	0.130	0.135	0.090	0.100	0.095	0.176	0.162	0.137
2012	0.323	0.134	0.212	0.161	0.123	0.126	0.090	0.119	0.114	0.208	0.159
2013	0.280	0.200	0.124	0.189	0.164	0.123	0.129	0.097	0.144	0.151	0.215
2014	0.647	0.253	0.202	0.126	0.211	0.189	0.138	0.151	0.112	0.181	0.183
2015	0.501	0.302	0.205	0.209	0.149	0.239	0.194	0.148	0.168	0.137	0.18
2016	0.555	0.218	0.221	0.164	0.179	0.146	0.209	0.188	0.143	0.172	0.126

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2017	0.301	0.196	0.120	0.163	0.128	0.146	0.122	0.171	0.156	0.124	0.110
2018	0.273	0.261	0.200	0.125	0.150	0.142	0.166	0.141	0.179	0.171	0.102
2019	0.566	0.150	0.196	0.140	0.099	0.151	0.133	0.161	0.145	0.155	0.100
2020	0.351	0.216	0.189	0.170	0.168	0.181	0.201	0.213	0.228	0.290	0.237

Table 4.4.8.2 Norwegian spring-spawning herring. Relative standard error of Fleet 1 used by XSAM.

Year/Age	3	4	5	6	7	8	9	10	11	12+
1988	0.318	0.336	0.163	0.452	0.551	0.690	0.541	0.603	0.515	NA
1989	0.648	0.329	0.440	0.190	0.430	0.690	0.881	0.492	NA	0.492
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1992	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1993	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1994	0.431	0.507	0.268	0.304	0.479	0.678	0.398	0.505	0.226	0.755
1995	0.309	0.183	0.199	0.223	0.338	0.616	NA	0.426	0.492	0.214
1996	0.376	0.222	0.163	0.214	0.266	0.337	NA	NA	0.403	0.228
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	0.336	0.260	0.203	0.147	0.162	0.225	0.290	0.387	0.520	0.229
1999	0.235	0.323	0.242	0.208	0.157	0.168	0.231	0.300	0.407	0.278
2000	0.281	0.209	0.423	0.305	0.251	0.187	0.205	0.302	0.503	0.356
2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2003	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2005	0.356	0.283	0.219	0.174	0.161	0.288	0.301	0.391	0.439	0.214
2006	0.441	0.173	0.295	0.266	0.197	0.198	0.422	0.446	0.616	0.308
2007	0.323	0.232	0.148	0.270	0.284	0.203	0.200	0.399	0.359	0.259
2008	0.507	0.210	0.205	0.159	0.299	0.306	0.234	0.234	0.388	0.315
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Year/Age	3	4	5	6	7	8	9	10	11	12+
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2014	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2015	0.297	0.206	0.276	0.199	0.319	0.280	0.207	0.273	0.167	0.215
2016	0.371	0.356	0.290	0.323	0.219	0.355	0.300	0.204	0.284	0.180
2017	0.422	0.254	0.285	0.266	0.312	0.243	0.378	0.367	0.221	0.194
2018	0.396	0.229	0.206	0.307	0.268	0.286	0.253	0.310	0.322	0.197
2019	0.322	0.335	0.262	0.192	0.275	0.266	0.283	0.255	0.277	0.184
2020	0.517	0.196	0.293	0.248	0.198	0.298	0.289	0.324	0.284	0.224

Table 4.4.8.3 Norwegian spring-spawning herring. Relative standard error of Fleet 4 used by XSAM.

Year/Age	2
1991	0.430
1992	0.370
1993	0.337
1994	0.298
1995	0.405
1996	0.681
1997	0.899
1998	0.437
1999	0.434
2000	0.334
2001	0.406
2002	0.449
2003	NA
2004	NA
2005	0.440
2006	0.322
2007	0.453

Year/Age	2
2008	0.639
2009	0.662
2010	0.526
2011	0.449
2012	0.939
2013	0.490
2014	0.465
2015	0.380
2016	0.425
2017	0.466
2018	0.358
2019	0.484
2020	NA

Table 4.4.8.4 Norwegian spring-spawning herring. Relative standard error of Fleet 5 used by XSAM.

Year/Age	3	4	5	6	7	8	9	10	11	12+
1996	0.201	0.135	0.152	0.193	0.237	0.345	0.773	0.911	0.437	0.215
1997	0.271	0.208	0.140	0.152	0.227	0.246	0.423	0.516	0.378	0.218
1998	0.357	0.275	0.198	0.145	0.162	0.237	0.296	0.421	NA	0.327
1999	0.234	0.368	0.284	0.216	0.157	0.183	0.292	0.388	0.987	0.374
2000	0.262	0.221	0.495	0.353	0.264	0.176	0.189	0.248	0.383	0.417
2001	0.170	0.258	0.257	0.423	0.410	0.213	0.188	0.268	0.492	0.420
2002	0.182	0.164	0.259	0.298	0.355	0.292	0.240	0.226	0.259	0.430
2003	0.180	0.163	0.163	0.255	0.303	0.444	0.399	0.243	0.229	0.237
2004	0.254	0.190	0.154	0.160	0.276	0.320	0.518	0.370	0.358	0.226
2005	0.139	0.262	0.246	0.182	0.189	0.311	0.352	0.449	0.386	0.238
2006	0.372	0.149	0.260	0.238	0.180	0.177	0.308	0.305	0.426	0.234
2007	0.219	0.185	0.138	0.266	0.239	0.179	0.187	0.312	0.333	0.220
2008	0.311	0.159	0.170	0.148	0.254	0.232	0.193	0.221	0.330	0.275
2009	0.244	0.231	0.156	0.169	0.164	0.237	0.258	0.224	0.261	0.297

Year/Age	3	4	5	6	7	8	9	10	11	12+
2010	0.321	0.231	0.244	0.170	0.185	0.186	0.287	0.289	0.281	0.302
2011	0.287	0.249	0.208	0.224	0.166	0.198	0.200	0.299	0.284	0.277
2012	0.218	0.347	0.309	0.247	0.224	0.199	0.242	0.235	0.375	0.276
2013	0.304	0.208	0.344	0.271	0.243	0.218	0.197	0.221	0.243	0.245
2014	0.266	0.298	0.221	0.304	0.274	0.224	0.232	0.220	0.274	0.263
2015	0.343	0.263	0.273	0.208	0.264	0.270	0.214	0.226	0.197	0.239
2016	0.208	0.254	0.233	0.246	0.224	0.286	0.275	0.244	0.242	0.198
2017	0.285	0.199	0.269	0.254	0.294	0.259	0.369	0.302	0.281	0.195
2018	0.281	0.240	0.186	0.283	0.259	0.321	0.265	0.360	0.309	0.192
2019	0.224	0.308	0.234	0.195	0.272	0.268	0.285	0.268	0.294	0.205
2020	0.336	0.153	0.329	0.281	0.226	0.298	0.314	0.343	0.307	0.227

Table 4.5.1.1. Norwegian spring-spawning herring. Parameter estimates of the final XSAM model fit. The estimates from the final 2019 assessment are also shown.

Parameter	Estimate	Std. Error	CV	Estimate 2019	Std. Error 2019
$\log(N_{3,1988})$	7.079	0.168	0.024	7.075	0.17
$\log(N_{4,1988})$	6.611	0.208	0.031	6.604	0.209
$\log(N_{5,1988})$	9.583	0.070	0.007	9.584	0.076
$\log(N_{6,1988})$	4.813	0.378	0.079	4.812	0.369
$\log(N_{7,1988})$	3.498	0.524	0.150	3.487	0.506
$\log(N_{8,1988})$	3.068	0.583	0.190	3.115	0.554
$\log(N_{9,1988})$	4.062	0.453	0.112	4.08	0.445
$\log(N_{10,1988})$	3.269	0.659	0.202	3.275	0.645
$\log(N_{11,1988})$	3.161	0.690	0.218	3.054	0.693
$\log(N_{12,1988})$	3.557	0.746	0.210	3.502	0.728
$\log(q_3^{F1})$	-9.633	0.182	0.019	-9.594	0.188
$\log(q_4^{F1})$	-8.073	0.130	0.016	-8.102	0.138
$\log(q_5^{F1})$	-7.547	0.120	0.016	-7.555	0.125
$\log(q_6^{F1})$	-7.299	0.119	0.016	-7.31	0.124
$\log(q_7^{F1})$	-7.134	0.130	0.018	-7.165	0.138

Parameter	Estimate	Std. Error	CV	Estimate 2019	Std. Error 2019
$\log(q_8^{F1})$	-6.925	0.094	0.014	-6.925	0.099
$\log(q_2^{F4})$	-14.304	0.179	0.012	-14.304	0.177
$\log(q_3^{F5})$	-7.637	0.108	0.014	-7.609	0.111
$\log(q_4^{F5})$	-7.105	0.097	0.014	-7.157	0.1
$\log(q_5^{F5})$	-6.922	0.096	0.014	-6.911	0.098
$\log(q_6^{F5})$	-6.795	0.098	0.014	-6.779	0.101
$\log(q_7^{F5})$	-6.720	0.104	0.016	-6.707	0.108
$\log(q_8^{F5})$	-6.536	0.111	0.017	-6.533	0.114
$\log(q_9^{F5})$	-6.527	0.123	0.019	-6.517	0.127
$\log(q_{10}^{F5})$	-6.469	0.138	0.021	-6.477	0.143
$\log(q_{11}^{F5})$	-6.424	0.135	0.021	-6.442	0.143
$\log(\sigma_1^2)$	-5.000	1.420	0.284	-5	1.472
$\log(\sigma_2^2)$	-2.730	0.255	0.094	-2.718	0.271
$\log(\sigma_4^2)$	-2.204	0.308	0.140	-2.167	0.31
$\log(\sigma_R^2)$	-0.082	0.261	3.186	-0.146	0.261
$\log(h)$	1.575	0.066	0.042	1.587	0.068
μ_R	9.329	0.176	0.019	9.344	0.173
α_Y	-0.519	0.307	0.591	-0.537	0.311
β_Y	0.808	0.111	0.137	0.806	0.112
α_{2U}	-1.238	0.169	0.137	-1.241	0.172
α_{3U}	-0.625	0.098	0.157	-0.621	0.1
α_{4U}	-0.219	0.062	0.284	-0.215	0.064
α_{5U}	0.045	0.053	1.165	0.046	0.054
α_{6U}	0.200	0.057	0.284	0.201	0.059
α_{7U}	0.264	0.061	0.233	0.265	0.063
α_{8U}	0.326	0.068	0.208	0.324	0.07
α_{9U}	0.365	0.074	0.202	0.364	0.076
α_{10U}	0.415	0.080	0.193	0.431	0.082
β_U	0.604	0.054	0.089	0.602	0.054

Table 4.5.1.2 Norwegian spring-spawning herring. Point estimates of Stock in numbers (millions).

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
1988	660	1187	743	14520	123	33	22	58	26	24	35
1989	1171	255	957	621	12006	101	27	16	40	16	42
1990	4307	471	215	810	521	10003	84	22	12	29	46
1991	11401	1745	400	182	681	435	8356	69	17	10	60
1992	18620	4630	1494	341	154	572	365	6964	57	14	57
1993	49953	7564	3970	1269	286	129	477	303	5758	46	58
1994	59830	20288	6480	3348	1035	231	105	386	244	4561	81
1995	15722	24290	17375	5457	2623	775	177	81	298	183	3430
1996	5704	6375	20751	14548	4164	1751	506	128	59	205	2235
1997	2156	2308	5411	17165	11130	2799	1123	331	89	40	1353
1998	10836	870	1914	4357	13077	7744	1744	658	205	54	753
1999	6446	4375	716	1478	3359	9566	5415	1115	408	121	456
2000	32789	2610	3645	559	1128	2493	6782	3628	696	241	297
2001	28974	13285	2184	2720	418	828	1779	4630	2236	406	264
2002	11399	11747	11267	1740	1994	312	613	1279	3211	1476	443
2003	6675	4615	9925	9097	1282	1396	226	429	868	2134	1277
2004	57781	2706	3909	8204	7143	944	1019	164	302	584	2230
2005	24348	23447	2300	3258	6632	5500	702	738	119	212	1744
2006	42944	9875	19826	1895	2604	5076	3892	478	499	78	1122
2007	12059	17417	8397	16406	1524	2036	3721	2666	330	345	700
2008	17566	4884	14774	6915	12587	1154	1490	2532	1766	222	709
2009	7036	7086	4132	12175	5348	8774	814	1024	1618	1113	618
2010	5004	2822	5931	3391	9410	3804	5700	545	636	964	1063
2011	15176	2008	2352	4873	2701	7093	2649	3548	341	391	1095
2012	5323	6090	1677	1929	3926	2108	5343	1797	2365	221	938
2013	8062	2152	5097	1383	1552	3108	1611	3922	1266	1652	812
2014	5299	3266	1813	4177	1114	1229	2419	1203	2867	913	1922
2015	18059	2150	2778	1512	3390	902	984	1902	921	2159	2264
2016	7769	7332	1835	2338	1249	2764	734	788	1503	713	3528

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2017	4537	3154	6255	1539	1915	1000	2203	579	613	1143	3286
2018	27096	1839	2667	5131	1218	1428	733	1594	418	421	3153
2019	3305	10991	1561	2219	4145	926	1072	540	1179	302	2502
2020	11255	1340	9310	1285	1747	3067	670	744	373	827	1761

Table 4.5.1.3 Norwegian spring-spawning herring. Point estimates of Fishing mortality.

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
1988	0.050	0.065	0.029	0.040	0.045	0.046	0.150	0.231	0.351	0.178	0.178
1989	0.011	0.021	0.017	0.027	0.033	0.036	0.078	0.110	0.153	0.092	0.092
1990	0.004	0.012	0.015	0.024	0.031	0.030	0.053	0.073	0.099	0.071	0.071
1991	0.001	0.005	0.011	0.019	0.025	0.025	0.032	0.044	0.057	0.048	0.048
1992	0.001	0.004	0.013	0.024	0.030	0.030	0.035	0.040	0.055	0.056	0.056
1993	0.001	0.005	0.020	0.054	0.063	0.059	0.064	0.069	0.083	0.104	0.104
1994	0.001	0.005	0.022	0.094	0.140	0.115	0.100	0.108	0.135	0.152	0.152
1995	0.003	0.007	0.028	0.120	0.254	0.275	0.177	0.171	0.222	0.330	0.330
1996	0.005	0.014	0.040	0.118	0.247	0.294	0.274	0.212	0.243	0.440	0.440
1997	0.008	0.037	0.067	0.122	0.213	0.323	0.384	0.328	0.352	0.465	0.465
1998	0.007	0.044	0.108	0.110	0.163	0.208	0.297	0.329	0.381	0.422	0.422
1999	0.004	0.032	0.099	0.120	0.148	0.194	0.250	0.321	0.374	0.512	0.512
2000	0.003	0.028	0.143	0.140	0.160	0.187	0.232	0.334	0.390	0.562	0.562
2001	0.003	0.015	0.078	0.161	0.142	0.150	0.180	0.216	0.266	0.264	0.264
2002	0.004	0.019	0.064	0.155	0.206	0.173	0.206	0.238	0.259	0.257	0.257
2003	0.003	0.016	0.040	0.092	0.156	0.164	0.171	0.204	0.247	0.275	0.275
2004	0.002	0.013	0.032	0.063	0.111	0.145	0.173	0.174	0.204	0.328	0.328
2005	0.002	0.018	0.044	0.074	0.118	0.196	0.235	0.241	0.265	0.405	0.405
2006	0.002	0.012	0.039	0.068	0.096	0.160	0.228	0.220	0.219	0.389	0.389
2007	0.004	0.015	0.044	0.115	0.128	0.162	0.235	0.262	0.247	0.238	0.238
2008	0.008	0.017	0.043	0.107	0.211	0.199	0.225	0.298	0.312	0.260	0.260
2009	0.014	0.028	0.048	0.108	0.191	0.281	0.253	0.326	0.368	0.338	0.338
2010	0.013	0.032	0.046	0.078	0.133	0.212	0.324	0.319	0.337	0.465	0.465

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2011	0.013	0.030	0.048	0.066	0.098	0.133	0.238	0.256	0.281	0.310	0.310
2012	0.006	0.028	0.043	0.068	0.084	0.119	0.159	0.201	0.209	0.206	0.206
2013	0.004	0.021	0.049	0.067	0.083	0.100	0.142	0.163	0.177	0.098	0.098
2014	0.002	0.012	0.032	0.059	0.061	0.072	0.091	0.117	0.134	0.075	0.075
2015	0.001	0.008	0.023	0.041	0.054	0.056	0.073	0.086	0.107	0.076	0.076
2016	0.002	0.009	0.026	0.049	0.072	0.077	0.087	0.101	0.123	0.105	0.105
2017	0.003	0.017	0.048	0.084	0.143	0.161	0.173	0.175	0.225	0.190	0.190
2018	0.002	0.014	0.034	0.064	0.124	0.137	0.156	0.152	0.177	0.206	0.206
2019	0.003	0.016	0.045	0.089	0.151	0.174	0.215	0.218	0.205	0.315	0.315
2020	0.003	0.016	0.045	0.089	0.144	0.166	0.200	0.211	0.215	0.307	0.307

able 4.5.1.4 Norwegian spring spawning herring. Final stock summary table. High and low represent approximate 95 % confidence limits.

Year	Recruitment (Age 2) millions	High	Low	Stock Size: SSB thousnd tonnes	High	Low	Catches thousand tonnes	Fishing Pressure: F Ages 5-12	High	Low
1988	660	977	342	2122	2404	1840	135	0.042	0.06	0.025
1989	1171	1654	687	3281	3717	2844	104	0.033	0.048	0.019
1990	4307	5356	3259	3551	4014	3088	86	0.03	0.043	0.017
1991	11401	13374	9429	3328	3760	2895	85	0.031	0.045	0.017
1992	18620	21410	15830	3354	3767	2941	104	0.039	0.055	0.022
1993	49953	55595	44310	3326	3697	2954	232	0.076	0.101	0.051
1994	59830	66137	53523	3456	3826	3086	479	0.128	0.161	0.095
1995	15722	18168	13277	3524	3879	3169	906	0.218	0.261	0.175
1996	5704	6863	4546	4107	4464	3750	1220	0.191	0.224	0.158
1997	2156	2733	1578	5365	5789	4941	1427	0.194	0.223	0.164
1998	10836	12679	8993	5939	6405	5473	1223	0.188	0.219	0.157
1999	6446	7705	5187	5827	6316	5339	1235	0.214	0.25	0.178
2000	32789	36929	28648	4848	5297	4400	1207	0.258	0.304	0.212
2001	28974	32798	25151	4020	4423	3617	766	0.204	0.244	0.164
2002	11399	13364	9433	3548	3923	3174	808	0.225	0.269	0.181
2003	6675	8002	5348	4180	4595	3766	790	0.152	0.182	0.122

Year	Recruitment (Age 2) millions	High	Low	Stock Size: SSB thousnd tonnes	High	Low	Catches thousand tonnes	Fishing Pressure: F Ages 5-12	High	Low
2004	57781	64349	51213	5272	5774	4769	794	0.128	0.153	0.103
2005	24348	27911	20785	5399	5929	4868	1003	0.173	0.206	0.14
2006	42944	48551	37336	5364	5886	4842	969	0.177	0.212	0.141
2007	12059	14310	9808	6904	7547	6261	1267	0.156	0.185	0.126
2008	17566	20592	14540	6988	7668	6308	1546	0.201	0.238	0.165
2009	7036	8524	5547	6956	7679	6233	1687	0.207	0.243	0.171
2010	5004	6141	3867	6160	6858	5463	1457	0.215	0.256	0.175
2011	15176	17977	12375	5815	6528	5103	993	0.16	0.192	0.128
2012	5323	6570	4076	5650	6384	4916	826	0.142	0.173	0.112
2013	8062	9894	6231	5277	5994	4560	685	0.122	0.15	0.094
2014	5299	6719	3879	5086	5802	4370	461	0.086	0.106	0.065
2015	18059	22277	13841	4719	5400	4038	329	0.069	0.087	0.05
2016	7769	10236	5303	4477	5119	3835	383	0.087	0.11	0.065
2017	4537	6457	2617	4450	5081	3820	722	0.165	0.205	0.125
2018	27096	37286	16906	4072	4697	3447	593	0.131	0.164	0.098
2019	3305	6131	479	3916	4569	3263	777	0.191	0.24	0.141
2020	11255	32781	0	3315	3948	2682				

Year	Recruitment (Age 2) millions	High	Low	Stock Size: SSB thousnd tonnes	High	Low	Catches thousand tonnes	Fishing Pressure: F Ages 5-12	High	Low
Average	16341	19711	13283	4654	5186	4123	791	0.145	0.175	0.114

Table 4.8.1.1 Norwegian Spring-spawning herring. Input to short-term prediction. Stock size is in millions and weight in kg.

Input for	2020							
	Stockno.	Natural	Maturity	Proportion of M	Proportion of F	Weight	Exploitation	Weight
age	1-Jan.	mortality	ogive	before spawning	before spawning	in stock	pattern	in catch
2	11255	0.9	0	0	0	0.054	0.003	0.152
3	1340	0.15	0	0	0	0.104	0.016	0.207
4	9310	0.15	0.1	0	0	0.150	0.043	0.239
5	1285	0.15	0.8	0	0	0.203	0.086	0.279
6	1747	0.15	1	0	0	0.266	0.138	0.314
7	3067	0.15	1	0	0	0.301	0.159	0.341
8	670	0.15	1	0	0	0.328	0.192	0.359
9	744	0.15	1	0	0	0.343	0.203	0.379
10	374	0.15	1	0	0	0.358	0.206	0.393
11	827	0.15	1	0	0	0.366	0.294	0.399
12	1761	0.15	1	0	0	0.379	0.294	0.409

Input for	2021 and 2022							
	Stockno.	**Natural**	**Maturity**	**Proportion of M**	**Proportion of F**	**Weight**	**Exploitation**	**Weight**
age	**1-Jan.**	**mortality**	**ogive (2021/2022)**	**before spawning**	**before spawning**	**in stock**	**pattern**	**in catch**
2	11255	0.9	0/0	0	0	0.054	0.012	0.152
3		0.15	0/0	0	0	0.108	0.057	0.207
4		0.15	0.4/0.4	0	0	0.150	0.158	0.239
5		0.15	0.6/0.8	0	0	0.210	0.312	0.279
6		0.15	1/0.9	0	0	0.268	0.486	0.314
7		0.15	1/1	0	0	0.300	0.565	0.341
8		0.15	1/1	0	0	0.324	0.672	0.359
9		0.15	1/1	0	0	0.347	0.722	0.379
10		0.15	1/1	0	0	0.357	0.767	0.393
11		0.15	1/1	0	0	0.363	1	0.399
12		0.15	1/1	0	0	0.378	1	0.409

Table 4.8.2.1 Norwegian spring spawning herring. Short-term prediction.

Basis:	
SSB (2020):	3.315 million t
Landings(2020):	693 915 t (sum of national quotas)
SSB(2021):	3.505 million t
Fw5-12+(2020)	0.187
Recruitment(2020-2022):	11.255, 11.255, 11.255

The catch options:

Rationale	Catches (2021)	Basis	FW (2021)	SSB (2022)	P(SSB2022 <Blim)	% SSB change	%TAC change	%CATCH change
Management strategy	651033	F=0.14	0.14 (0.110,0.189)*	3.683 (2.780,4.984)*	0.005	5 (-21,42)*	24	-6
Fmsy	722694	F=0.157	0.157 (0.122,0.211)*	3.623 (2.663,4.846)*	0.006	3 (-24,38)*	38	4
Zero Catch	0	F=0	0	4.225(3.330,5.421)*	0	21 (-5,55)*	-100	-100
Fpa	1004581	0.227	0.227 (0.178,0.308)*	3.390 (2.497,4.718)*	0.026	-3 (-29,35)*	91	45
Flim	1242950	0.291	0.232 (0.229,0.408)*	3.195 (2.298,4.356)*	0.086	-9 (-34,24)*	136	79
$SSB_{2022}=B_{lim}$	2099298	F=0.568	0.568 (0.438,0.912)*	2.500 (1.613,3.682)*	0.532	-29 (-54,-5)*	299	203
$SSB_{2022}=B_{pa}$	1256299	F=0.295	0.295 (0.227,0.416)*	3.184 (2.274,4.463)*	0.074	-9 (-35,27)	139	81
Status quo	846569	F=0.187	0.187 (0.143,0.258)*	3.521 (2.585,4.796)*	0.017	0 (-26,37)*	64.1	22

***95% confidence interval**

4.18 Figures

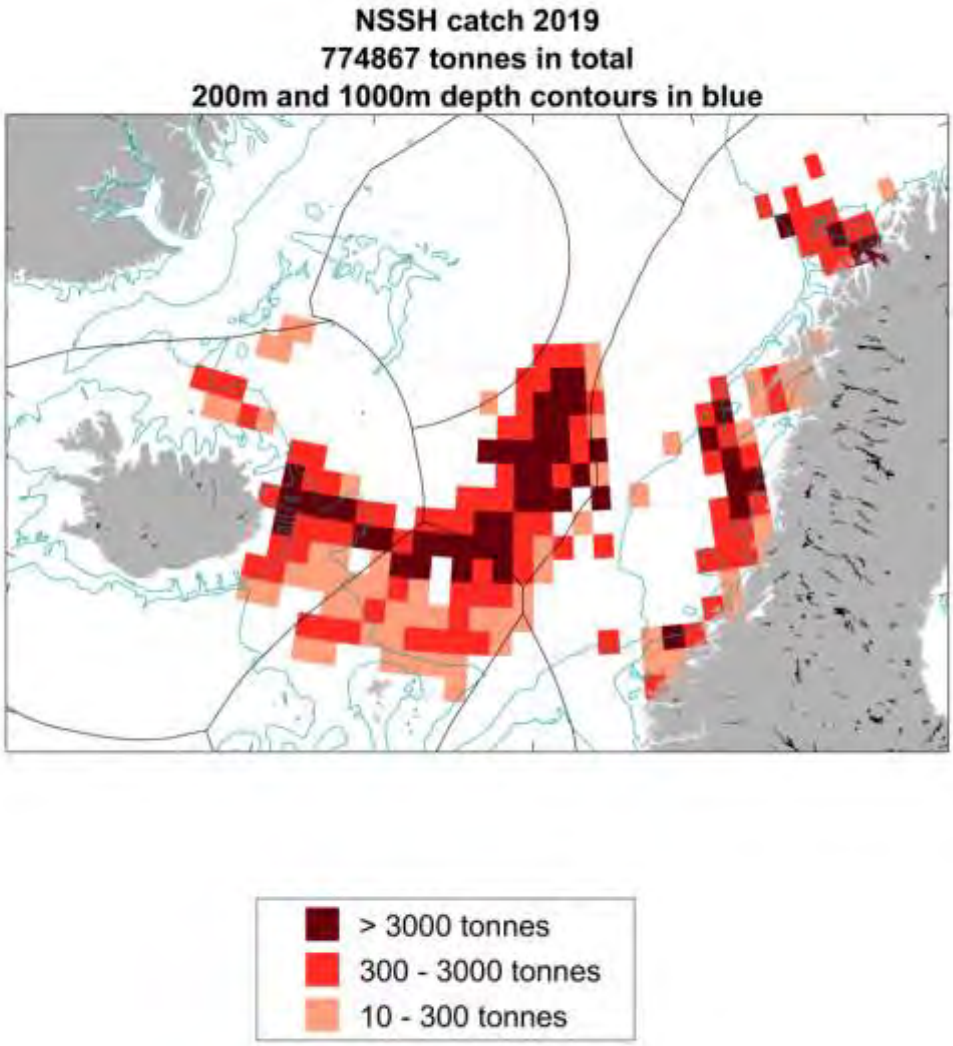

Figure 4.2.1.1. Total reported landings (ICES estimates) of Norwegian spring-spawning herring in 2019 by ICES rectangle. Landings below 10 tonnes per statistical rectangle are not included. The landings with information on statistical rectangle constitute 99.7% of the reported landings.

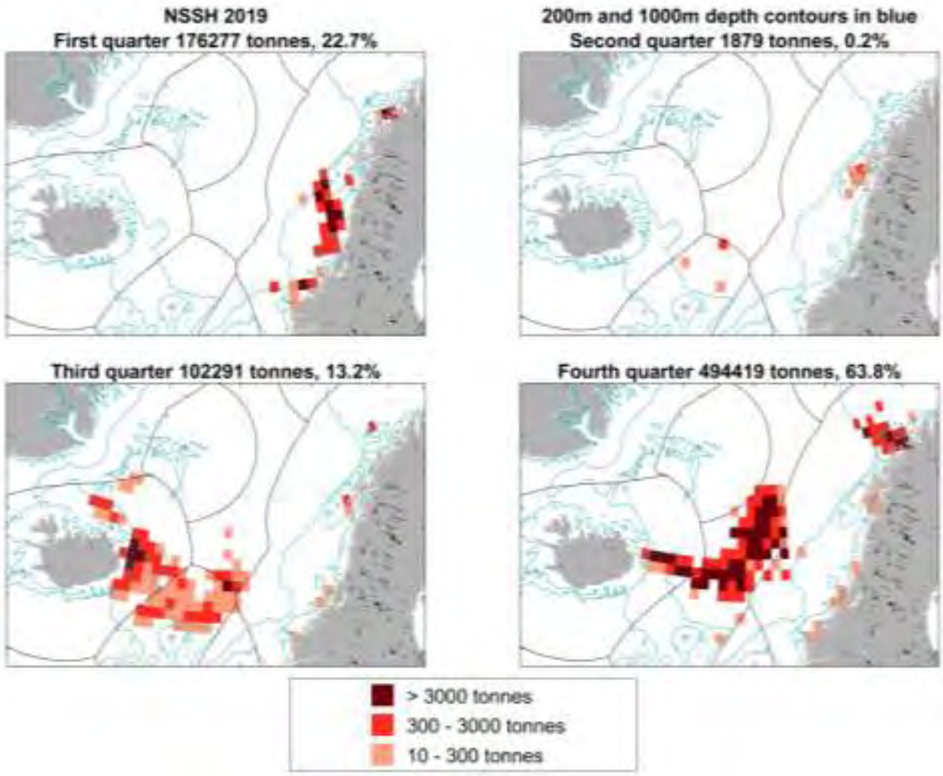

Figure 4.2.1.2. Total reported landings (ICES estimates) of Norwegian spring-spawning herring in 2019 by quarter and ICES rectangle. Landings below 10 tonnes per statistical rectangle are not included. The landings with information on statistical rectangle constitute 99.7% of the reported landings

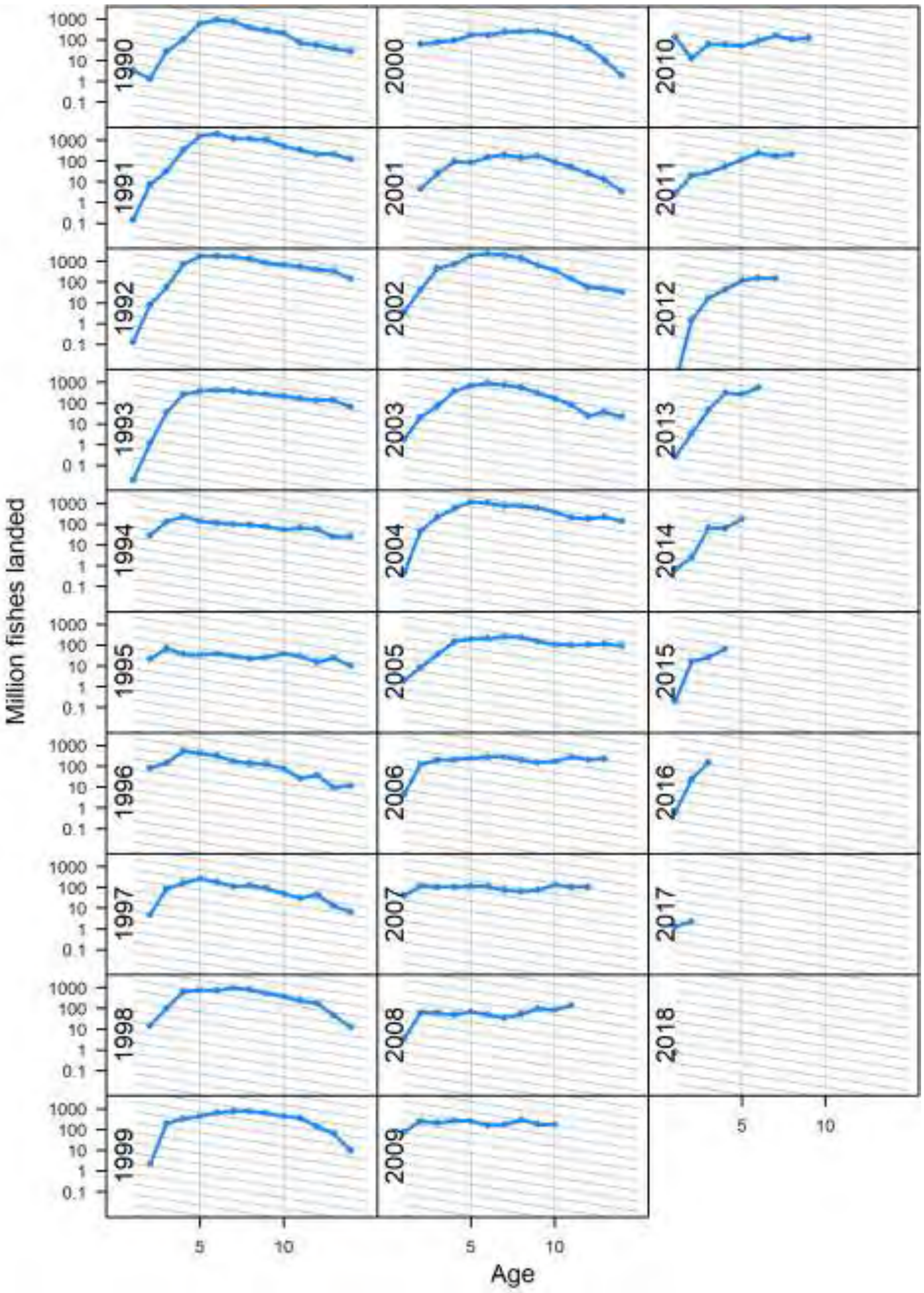

Figure 4.4.3.1. Norwegian spring spawning herring. Age disaggregated landings in numbers plotted on a log scale. Age is on x-axis. The labels indicate year classes and grey lines correspond to Z = 0.3.

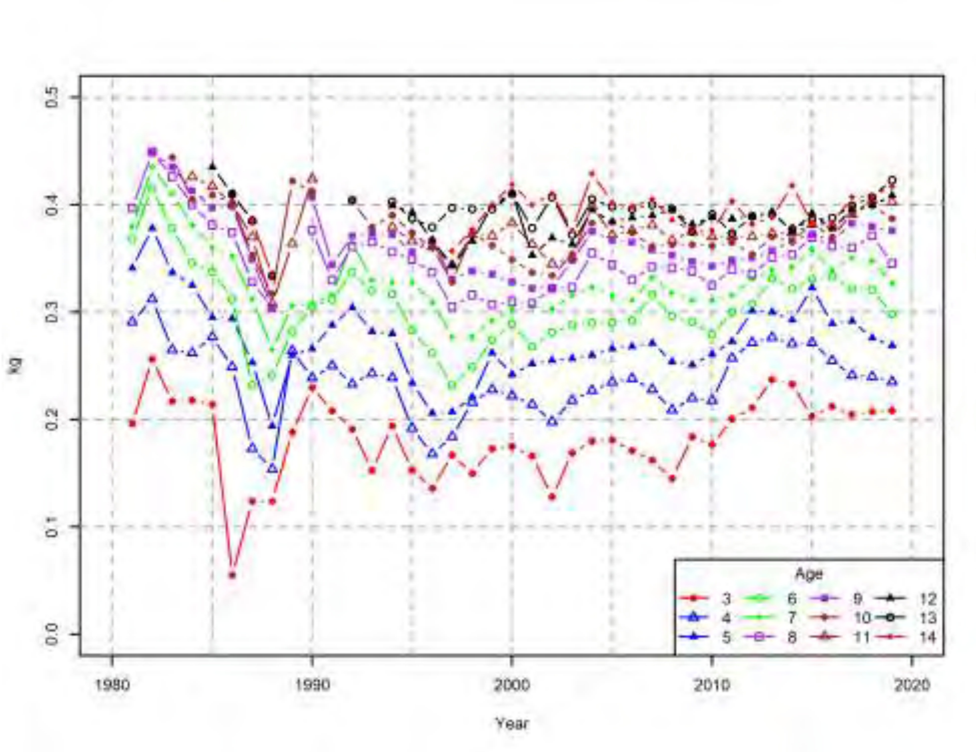

Figure 4.4.4.1. Norwegian spring spawning herring. Mean weight at age by age groups 3–14 in the years 1981—2019 in the landings.

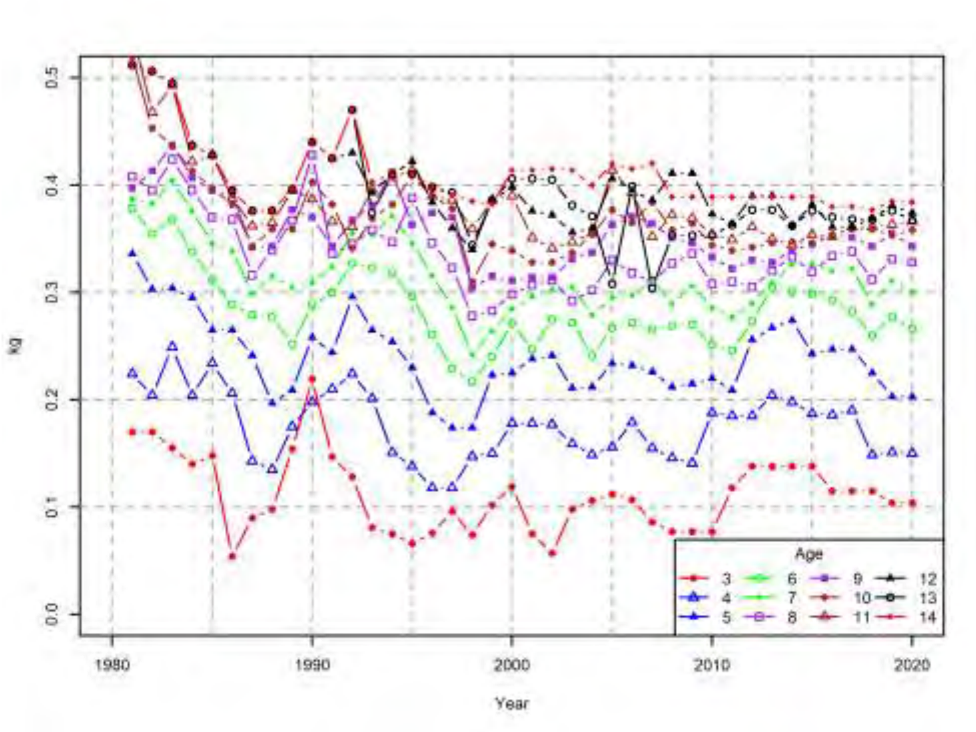

Figure 4.4.4.2. Norwegian spring-spawning herring. Mean weight at age in the stock by age groups 3–14 for the years 1981—2020.

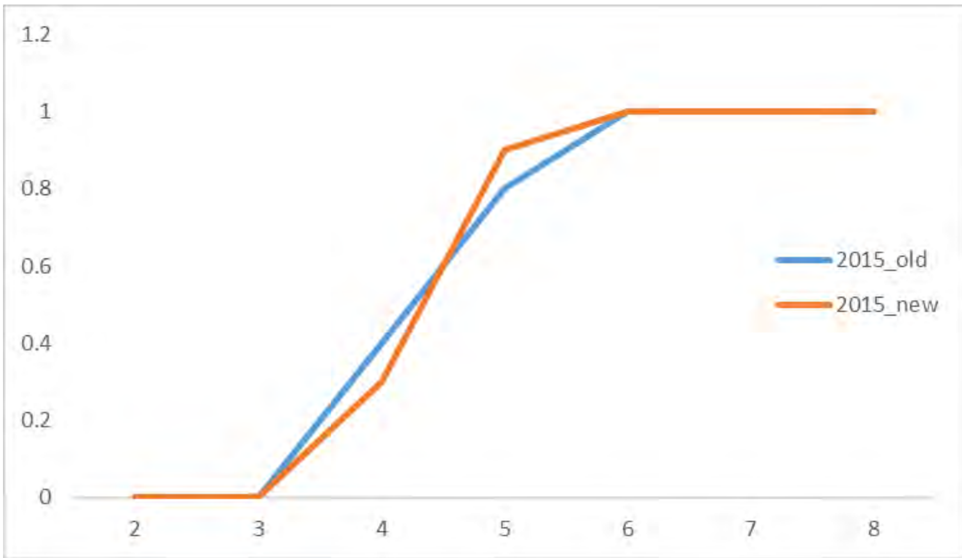

Figure 4.4.5.1. Assumed (blue line) and updated (orange line) maturity-at-age for the year 2015.

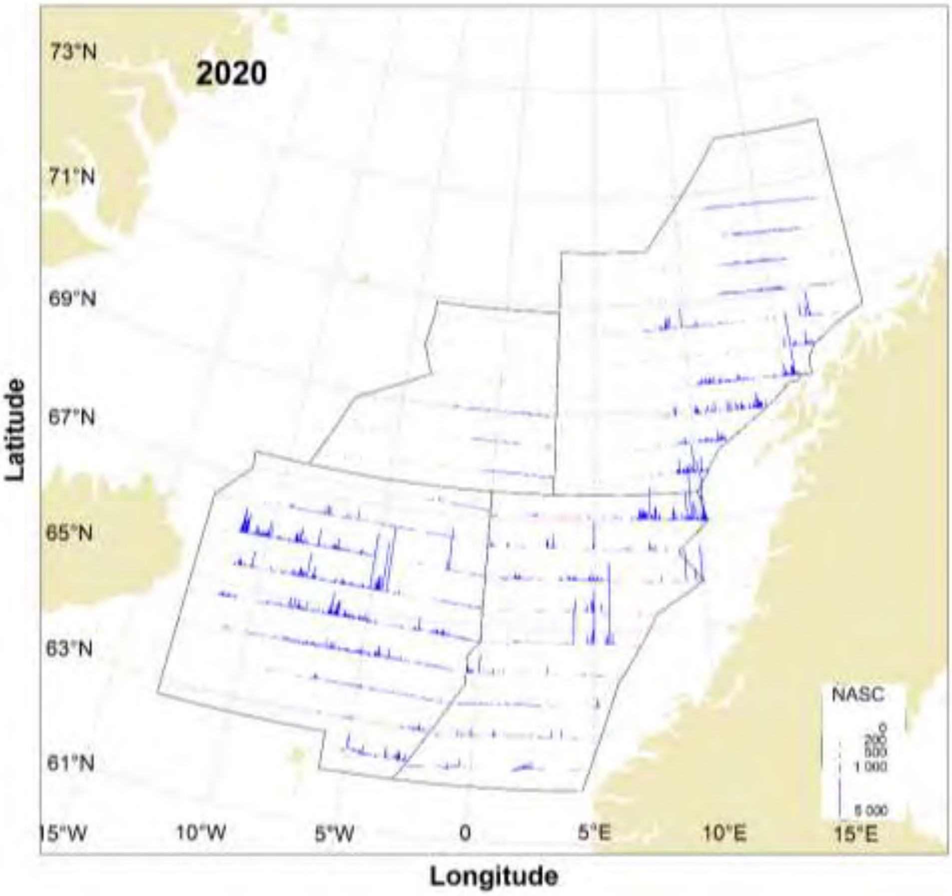

Figure 4.4.7.1. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2020 in terms of NASC values (m^2/nm^2) for every 1 nautical mile.

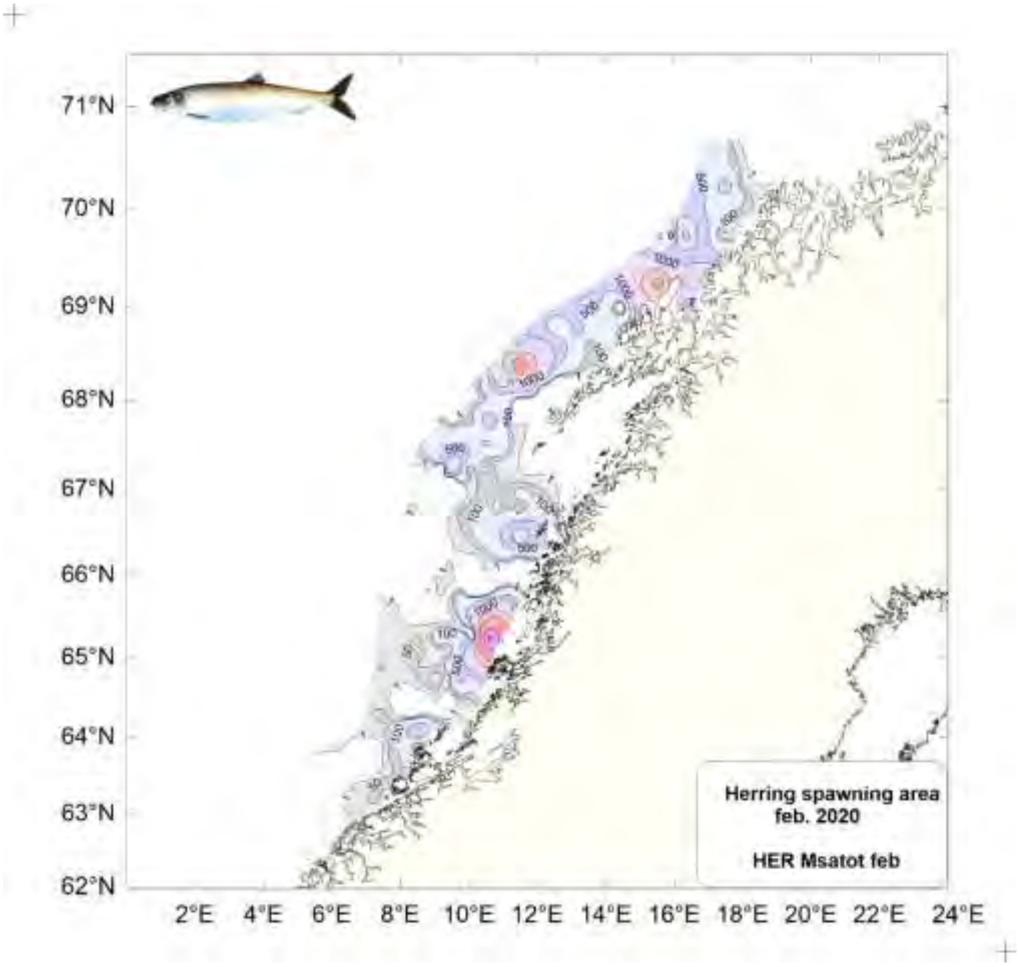

Figure 4.4.7.2. Norwegian acoustic survey on the NSSH spawning grounds. Distribution and acoustic density of herring recorded in 2020.

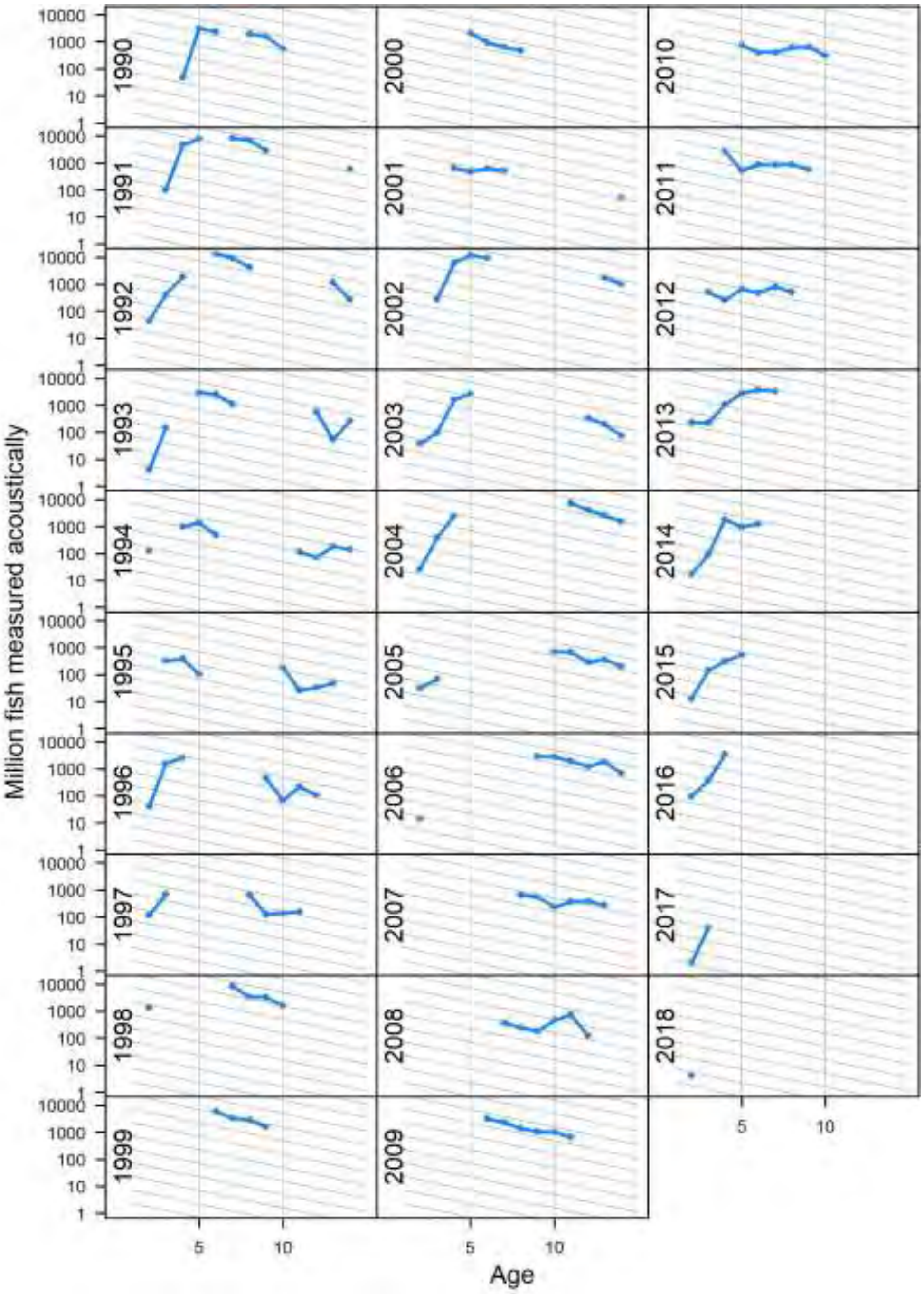

Figure 4.4.7.3. Norwegian spring spawning herring. Age disaggregated abundance indices (millions) from the acoustic survey on the spawning area in February-March (Fleet 1) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z = 0.3. Age is on x-axis.

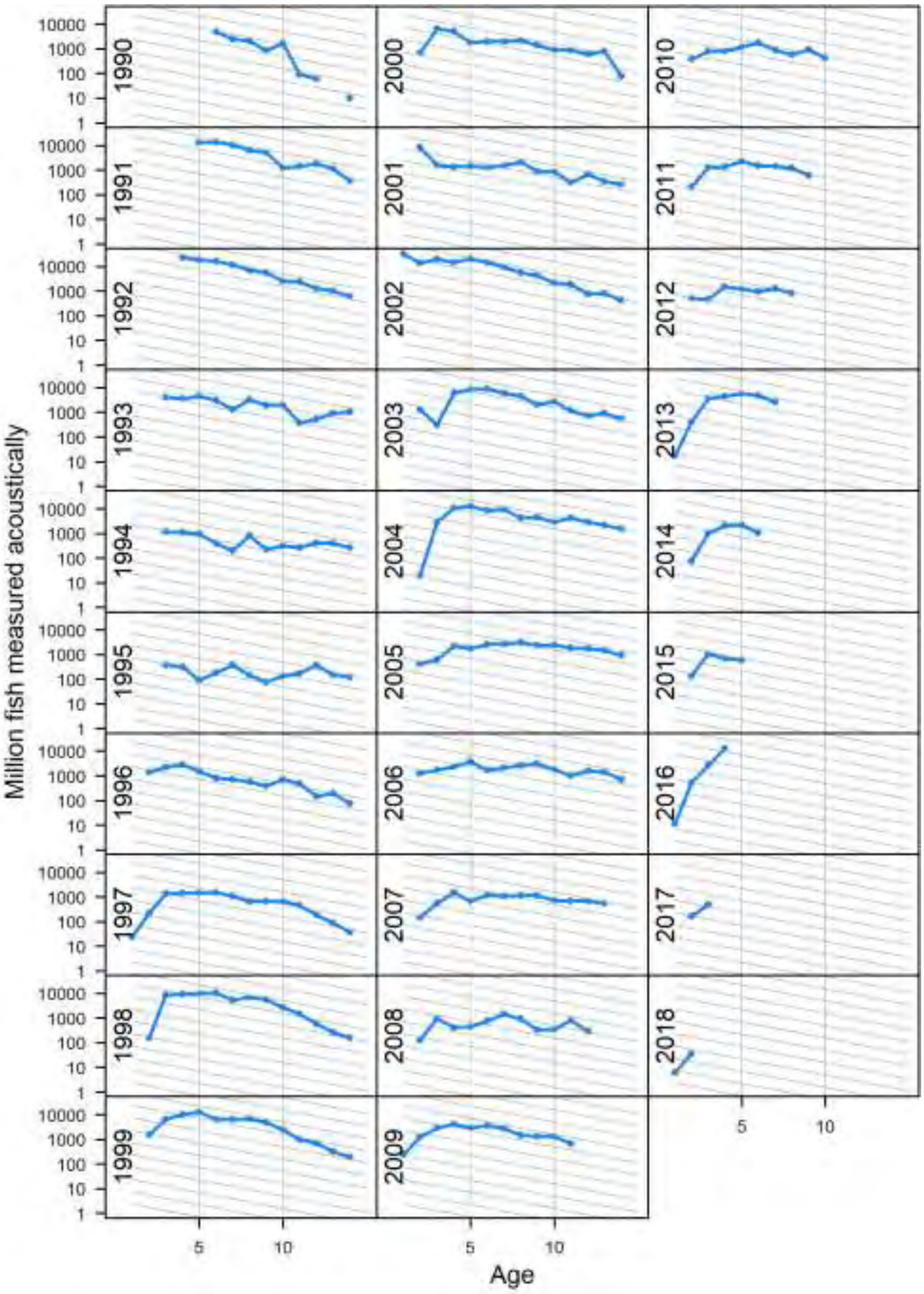

Figure 4.4.7.4. Norwegian spring spawning herring. Age disaggregated abundance indices (millions) from the acoustic survey on the feeding area in the Norwegian Sea in May (Fleet 5) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z = 0.3.

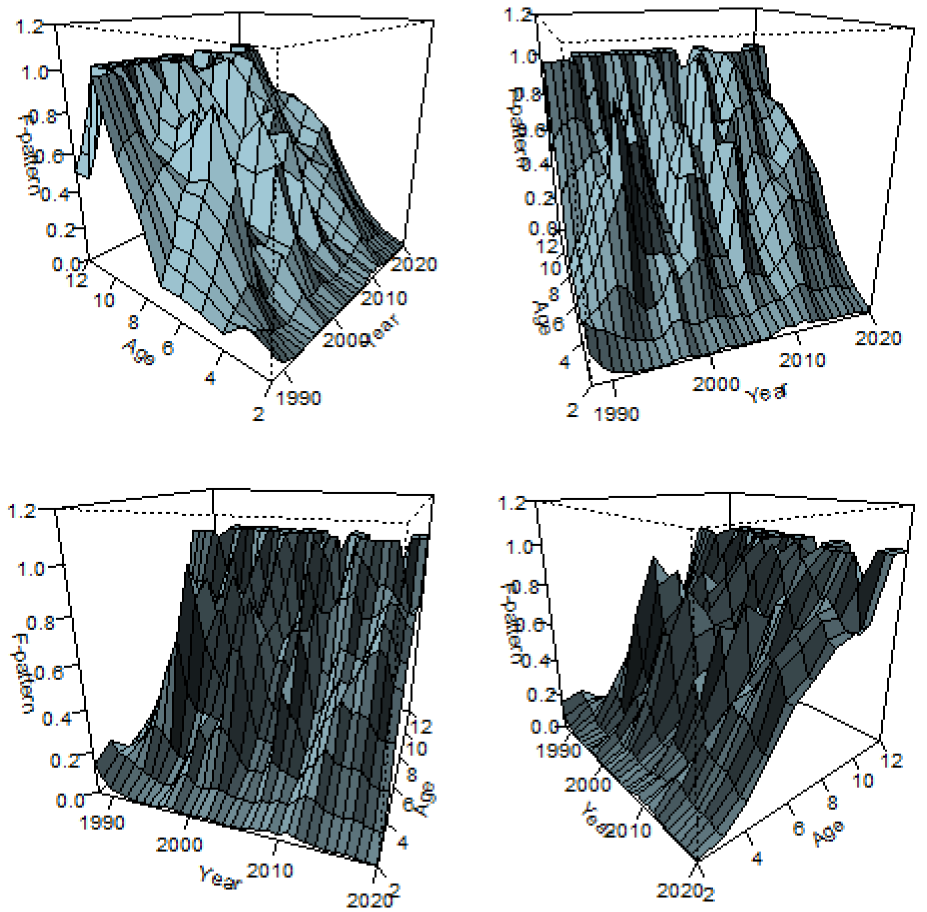

Figure 4.5.1.1. Estimated exploitation pattern for the years 1988–2020 by the XSAM model fit. All panels show the same data, but depicted at different angles to improve visibility at different time periods

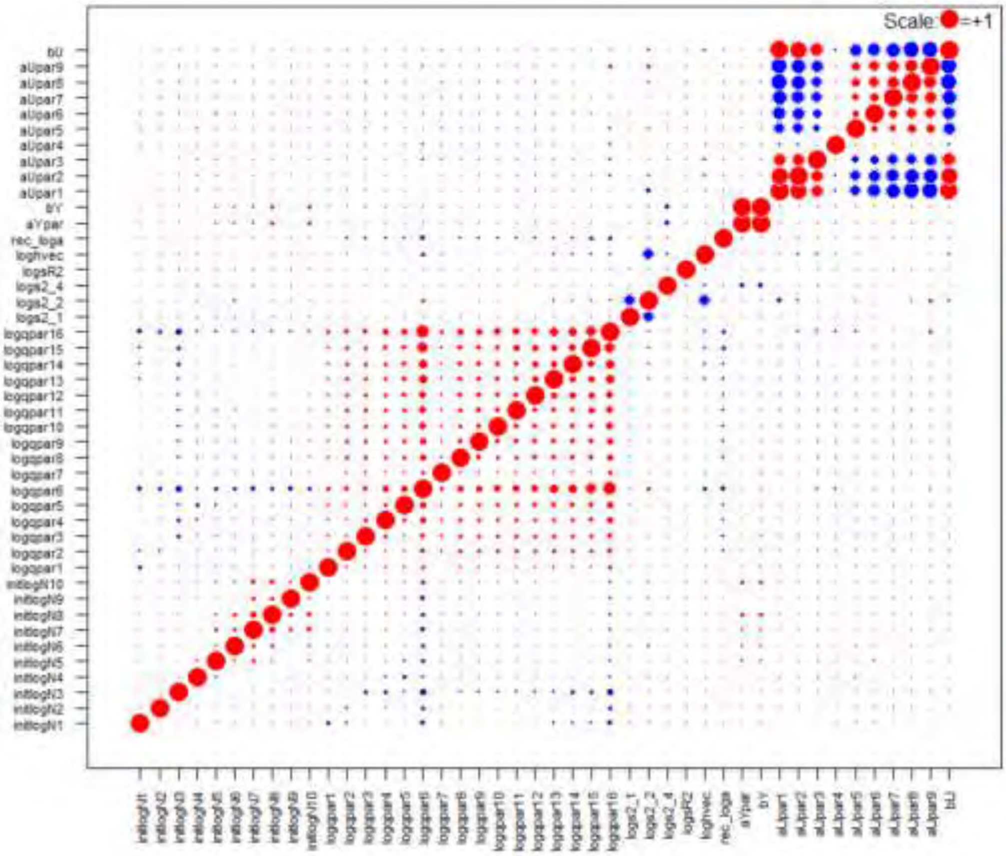

Figure 4.5.1.2. Norwegian spring spawning herring. Correlation between estimated parameters in the final XSAM model fit.

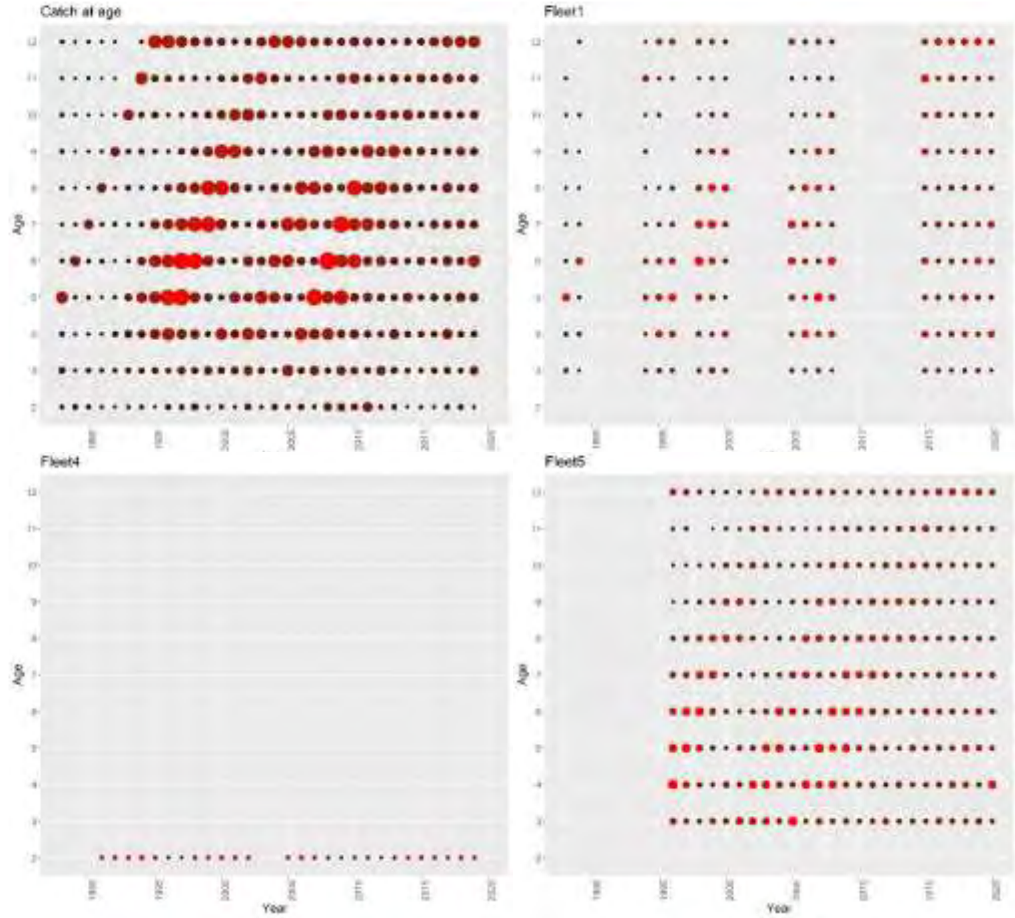

Figure 4.5.1.3. Norwegian spring spawning herring. Weights (inverse of variance) of data-input of the final XSAM model fit.

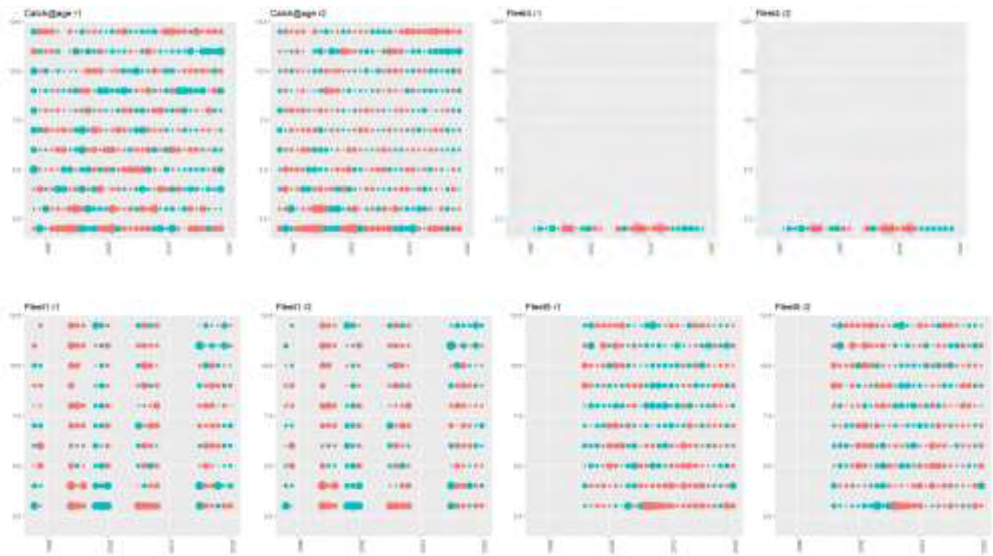

Figure 4.5.1.4. Norwegian spring spawning herring. Standardized residuals type 1 (left) and type 2 (right) (see text) of data-input of the final XSAM model fit. Red is positive and blue is negative residuals.

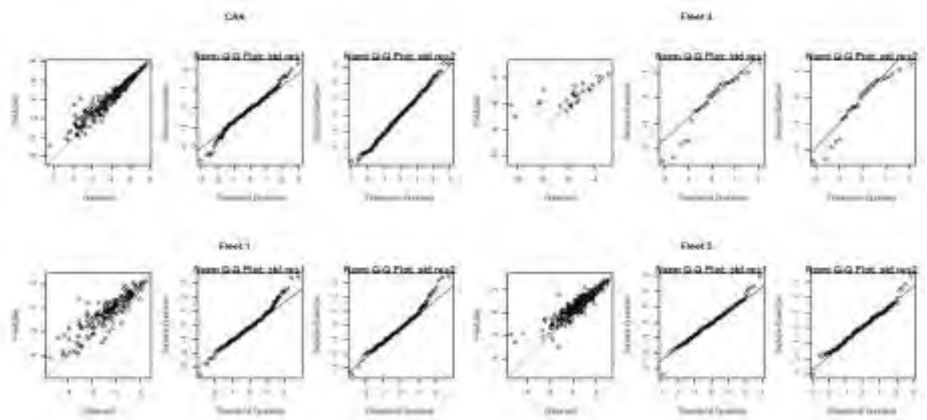

Figure 4.5.1.5. Norwegian spring spawning herring. Observed vs. predicted values (left column) and qq-plot based on type 1 (middle) and type 2 (right) residuals (see text) based on the final XSAM model fit.

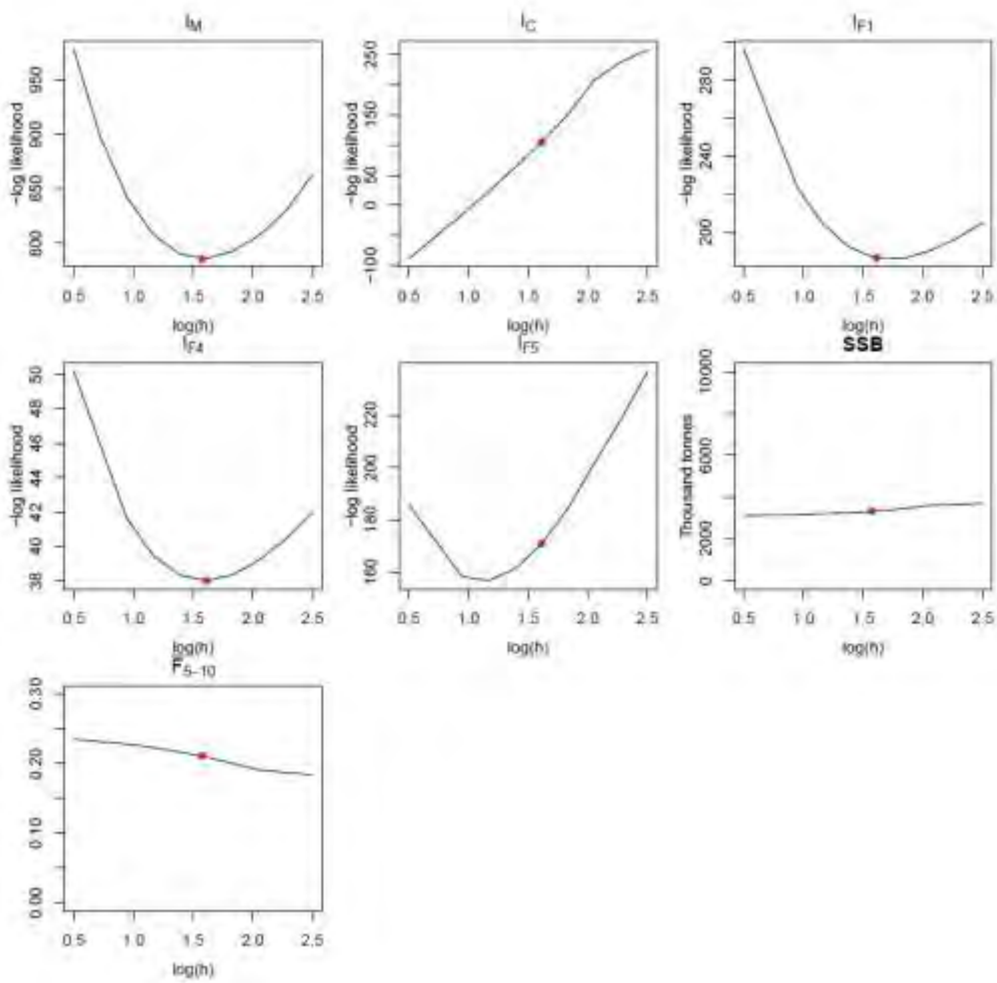

Figure 4.5.1.6. Norwegian spring spawning herring. Profiles of marginal log-likelihood $\mathbf{l_M}$, the catch component $\mathbf{l_C}$, Fleet 1 component $\mathbf{l_{F1}}$, Fleet 4 component $\mathbf{l_{F4}}$, Fleet 5 component $\mathbf{l_{F5}}$, point estimate of SSB and average F (ages 5-12+) in 2020 over the common scaling factor for variance in data $\mathbf{h}$ for the final XSAM fit. The red dots indicate the value of the respective scaling factors for which the log-likelihood is maximized.

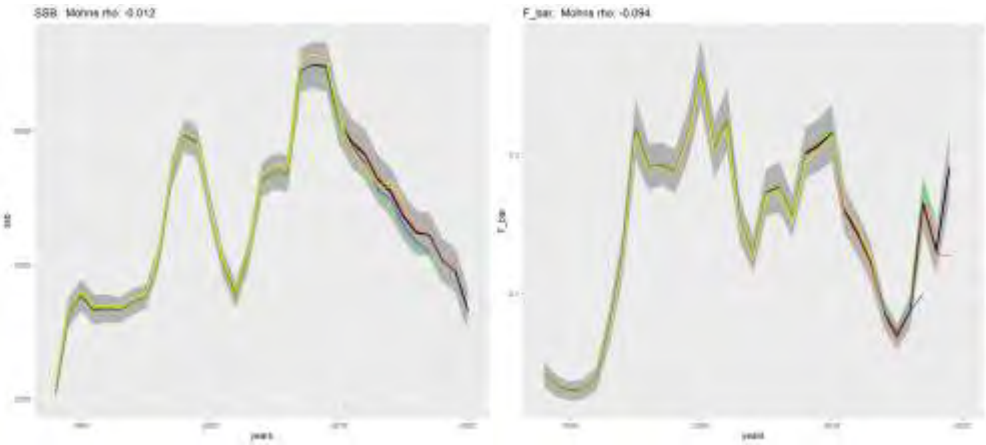

Figure 4.5.1.7. Norwegian spring spawning herring. Retrospective XSAM model fits of SSB and weighted average of fishing mortality ages 5-12 for the years 2015-2020. Mohn's rho is shown in figure title.

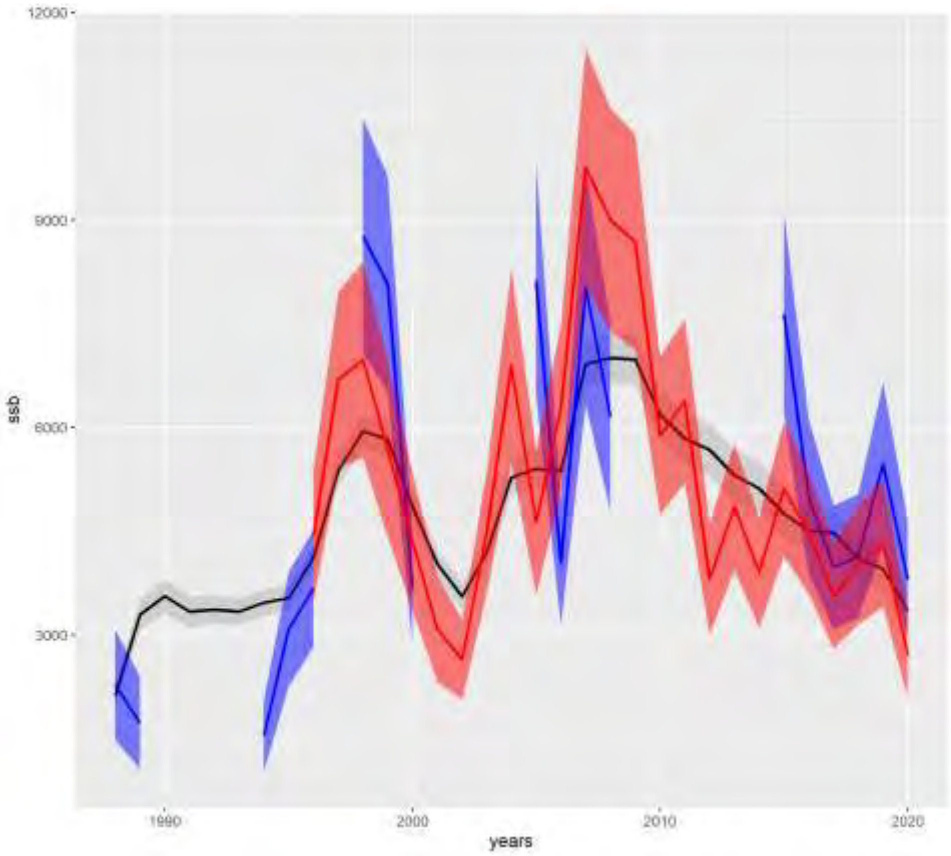

Figure 4.5.1.8. Norwegian spring spawning herring. Point estimates of Spawning-stock biomass by years 1988-2019 from model (black lines) and by survey indices from Fleet 1 (red) and Fleet 5 (blue). Shaded area is approximate to standard deviation.

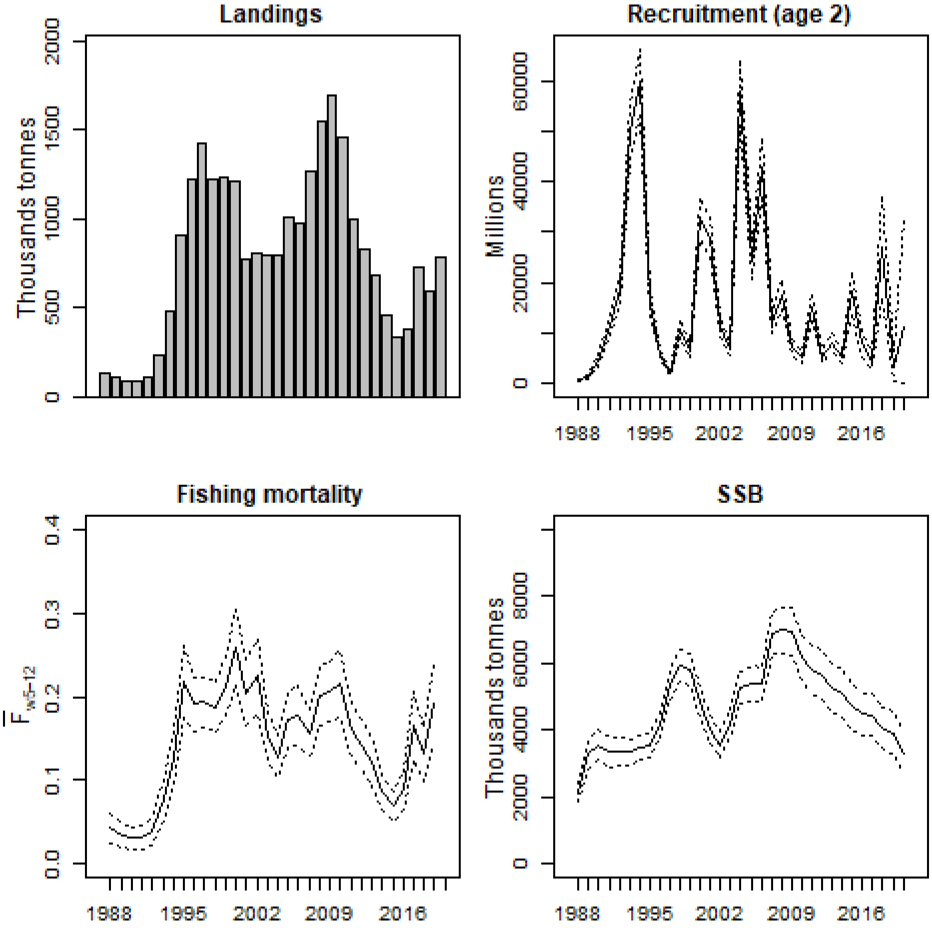

Figure 4.5.1.9. Total reported landings 1988–2019, estimated recruitment, weighted average of fishing mortality (ages 5-12) and spawning-stock biomass for the years 1988–2020 based on the final XSAM model fit.

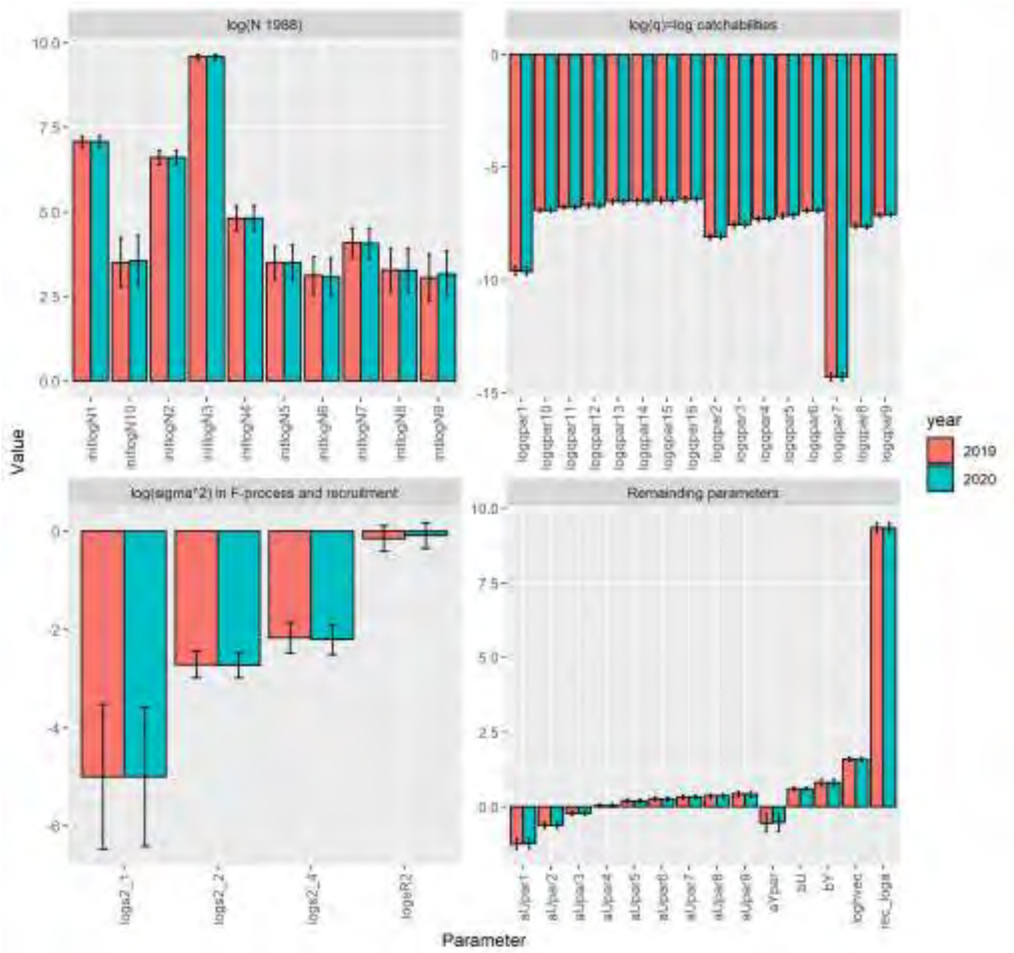

Figure 4.5.1.10. Norwegian spring-spawning herring. A visual representation of parameter estimates of the final XSAM model fit (see table 4.5.1.1). The estimates from the 2019 assessment are also shown (blue).

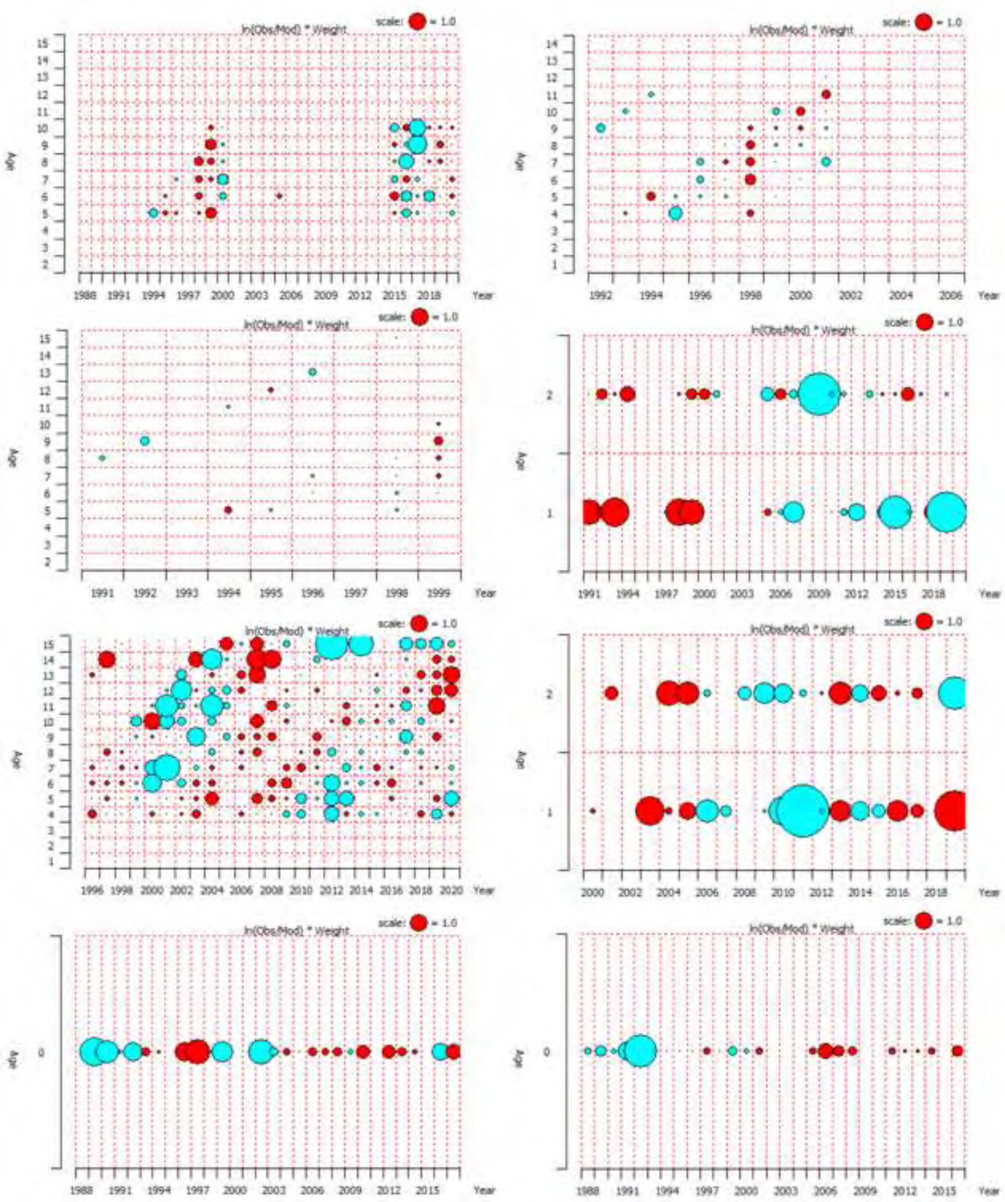

Figure 4.5.2.1.1. Norwegian spring-spawning herring. Residual sum of squares in the surveys separately from TASACS. First row starts with survey 1 and the last one in row four is larval survey.

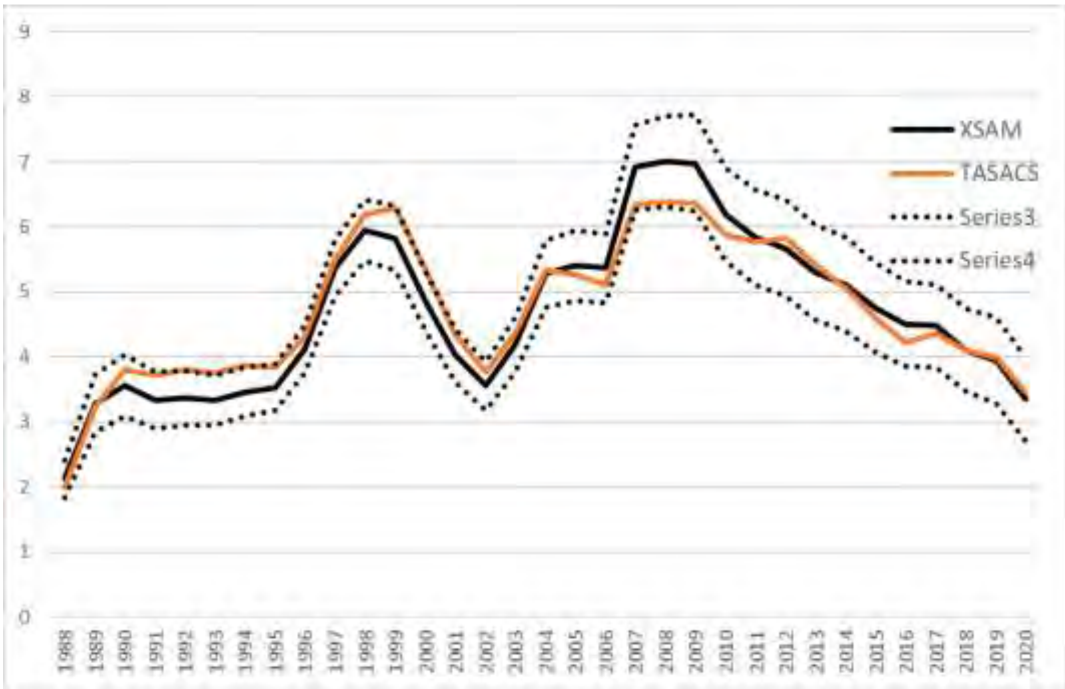

Figure 4.5.2.1.2. Comparison of SSB time-series from the final assessment from XSAM and exploratory runs from TASACS (following the 2008 benchmark procedure). 95% confidence intervals from the XSAM final assessment are shown (dotted lines).

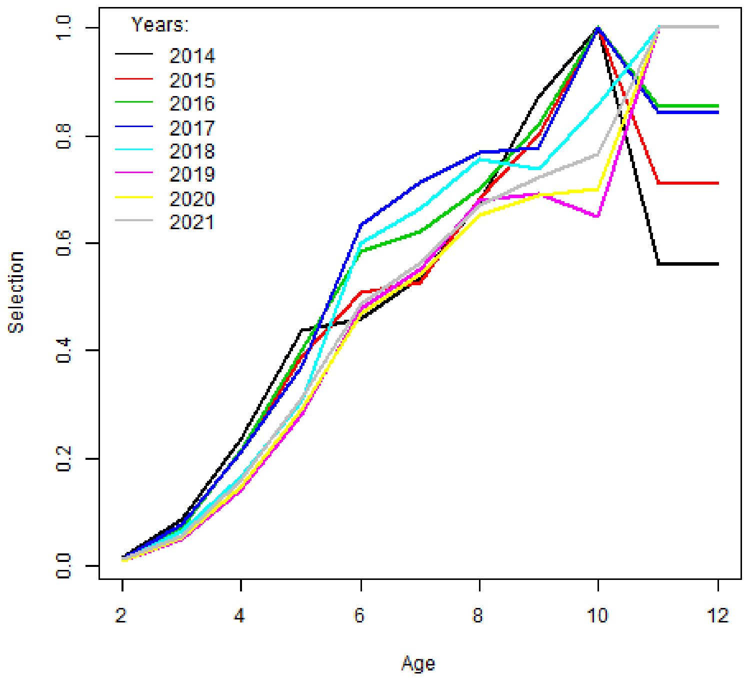

Figure 4.8.1.1. XSAM estimated selection pattern; selected years (estimates for 2014–2019 and predictions for 2020-2021) are shown in colours as indicated in the legend.

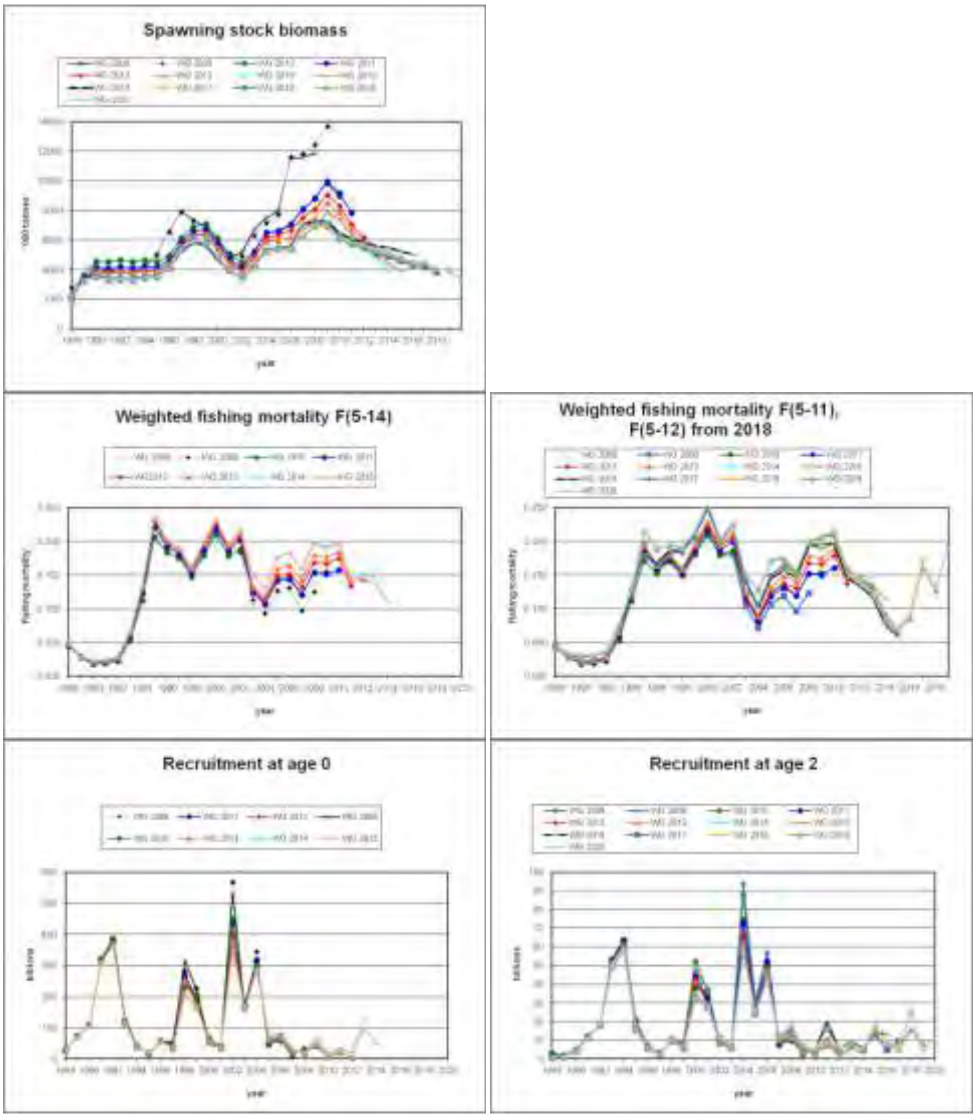

Figure 4.9.1. Norwegian spring spawning herring. Comparisons of spawning stock; weighted fishing mortality F(5-14) and F(5-11/5-12); and recruitment at age 0 and age 2 with previous assessments. In 2016 the proportion mature in the years 2006-2011 was changed; recruitment age changed from 0 to 2 and fishing mortality is calculated over ages 5 to 11. In 2018 (WKNSSHREF) the age range for the fishing mortality changed to ages 5 to 12.

5 Horse Mackerel in the Northeast Atlantic

5.1 Fisheries in 2019

The total international catches of horse mackerel in the North East Atlantic are shown in Table 5.1.1. Since 2011 the southern horse mackerel stock is assessed by ICES WGHANSA. The total catch from all areas in 2019 for the Western and North Sea stock was 136,750 tons which is 20,294 tons more than in 2018 and reaches a similar level as 2014 again. France, Germany and the Netherlands have a directed trawl fishery and Norway and France a directed purse-seine fishery for horse mackerel. Spain has directed as well as mixed trawl and purse-seine fisheries targeting horse mackerel. In earlier years most of the catches were used for meal and oil while in later years most of the catches have been used for human consumption.

The quarterly catches of North Sea and western horse mackerel by Division and Subdivision in 2019 are given in Table 5.1.2 and the distributions of the fisheries are given in Figures 5.1.1.a–d. Note that the figures include catches of southern horse mackerel. The maps are based on data provided by Belgium, France, Germany, Ireland, Netherlands, Norway, Portugal, Spain and Scotland representing 99% of the total catches. The distribution of the fishery is similar to the recent years.

The Dutch, Danish, Irish and German fleets operated mainly in the North and West of Ireland and the Western waters off Scotland. The French fleet were in the Bay of Biscay and West Scotland whereas the Norwegian fleet fished in the North-eastern part of the North Sea. The Spanish fleet operated mainly in waters of Cantabrian Sea and Bay of Biscay.

First quarter: The fishing season with most of the catches 54,068 tons (40% of the total catches of the Western and North Sea horse mackerel catch). The fishery was mainly carried out west of Scotland and West and North of Ireland and along the Spanish coast (Figure 5.1.1.a).

Second quarter: 12,141 tons. As usual, catches were significantly lower than in the first quarter as the second quarter is the main spawning period. Most of the catches were taken West of Ireland and along the Spanish coast. (Figure 5.1.1.b)

Third quarter: 31,403 tons. Most of the catches were taken in Spanish waters, West of Ireland and at the Norwegian coast (Figure 5.1.1.c).

Fourth quarter: Catches were 38,340 tons. The catches were distributed in four main areas (Figure 5.1.1.d):

- Spanish waters,
- Northern Irish waters and West of Scotland
- Norwegian coast
- East part of Channel

5.2 Stock Units

For many years the Working Group has considered the horse mackerel in the Northeast Atlantic as separated into three stocks: the North Sea, the Southern and the Western stocks (ICES 1990, ICES 1991). For further information, see the Western Horse Mackerel Stock Annex and the WD document on horse mackerel stock structure (WD Brunel et al., 2016). The boundaries for the different stocks are given in Figure 5.2.1.

5.3 WG Catch Estimates

In 2017, a review of catch statistics for North Sea and Western horse mackerel stocks was carried out. The results of this report have been reported in previous Working Groups reports. (Costas, 2017a)

As a result of this review catches and catch-at-ages of reported historical data of both North Sea and Western stocks of horse mackerel were updated (Figures 5.3.1 and 5.3.2). Catch statistics were reviewed since 1990 onward for Western stock and since 2000 onward for North Sea stock. Main mismatches between the catch statistics in working group reports and these reviewed data were originated by several reasons such as late availability of some data for the report or the availability of only official catch.

5.4 Allocation of Catches to Stocks

The distribution areas for the three stocks are given in the Stock Annex for the Western Horse Mackerel. The catches in 2019 were allocated to the three stocks as follows:

Western stock: 3 and 4 quarter: Divisions 3.a and 4.a. 1-4 quarter: 2.a, 5.b, 6.a, 7.a–c, e–k and 8.a-e.

North Sea stock: 1 and 2 quarter: Divisions 3.a and 4.a 1-4 quarter: Divisions 4.b, 4.c and 7.d.

Southern stock: Division 9.a. All catches from these areas were allocated to the southern stock. This stock is now dealt with by another working group (ICES WGHANSA).

The catches by stock are given in Table 5.4.1 and Figure 5.4.1. The catches by ICES sub-Area and division for the Western and North Sea stocks for period 1982-2019 are shown in Figures 5.4.2-3. The catches by stock and countries for the period 1997-2019 are given in Table 5.4.2-5.4.3.

5.5 Estimates of discards

Only the Netherlands had provided data on discards over an extended period with occasional estimates from Germany and Spain. However, since 2017 additional countries have provided estimates of discards with 6 countries reporting in 2019. Following the introduction of the European landing obligation for the pelagic fisheries targeting horse mackerel in large areas of the overall fishing area and for Norwegian waters there is general discard ban in place and discards in recent years have decreased. The discard rate is estimated to be less than 2.5 % in weight for the combined Horse mackerel stocks. The discard rate for the North Sea stock is estimated to be 1.6% and for the Western stock 2.5% in 2019.

5.6 *Trachurus* Species Mixing

Three species of genus *Trachurus*: *T. trachurus*, *T. mediterraneus* and *T. picturatus* are found together and are commercially exploited in NE Atlantic waters. Following the Working Group recommendation (ICES 2002/ACFM: 06) special care was taken to ensure that catch and length distributions and numbers-at-age of *T. trachurus* supplied to the Working Group did not include *T. mediterraneus* and/or *T. picturatus*.

The *T. mediterraneus* fishery mainly takes place in the eastern part of ICES Division 8.c. There is no clear trend in *T. mediterraneus* catches in this area although the most recent catch is the second lowest in the time series (Table 5.6.1). Information on the *T. picturatus* fishery is available in the WGHANSA Report (Working Group on Horse Mackerel, Anchovy and Sardine).

Taking into account that the WGWIDE horse mackerel assessments are only made for *T. trachurus*, the Working Group recommends that the TACs and any other management regulations which might be established in the future should be related only to *T. trachurus* and not to Trachurus spp. More information is needed about the *Trachurus spp*. before the fishery and the stock can be evaluated.

5.7 Length Distribution by Fleet and by Country:

Ireland, Germany, Netherlands, France, UK (England), UK (Scotland), Norway and Spain provided length distributions for their catches in 2019. The length distributions cover approximately 91% of the total landings of the Western and North Sea horse mackerel catches and are shown in Table 5.7.1.

5.8 Comparing trends between areas and stocks

Horse mackerel (*Trachurus trachurus*) in the northeast Atlantic is assumed to consist of three separate stocks:

- North Sea (4a part of the year, 4b, 4c and 7d)
- Western (4a part of the year, 5b, 6a, 7a-c,e-k, 8a-d)
- Southern (9a)

Catches in biomass between 2000 and 2019 are shown in figure 5.4.1 and indicate an overall decline in the catches of horse mackerel, but with a relative increase in southern horse mackerel in the recent years.

A detailed analysis on the development of the catch by age group was presented to the 2017 working group (Pastoors, 2017). In this analysis it was indicated that there is an increase in the catches of juveniles in the Western and North Sea stocks in recent years. This could be an indication of a stronger recruitment of horse mackerel which has been reported by surveys and fishermen. However, it is also an alarming signal if a larger proportion of the catch consists of juveniles. This catches could be seen mostly in area 7.d and to a lesser extent, area 7e.

5.9 Quality and Adequacy of fishery and sampling data

Table 5.9.1 shows a summary of the overall sampling intensity on horse mackerel catches in recent. Since 2011 the Southern horse mackerel is dealt with by ICES WGHANSA.

Countries that routinely sample are Ireland, the Netherlands, Germany, Norway and Spain, covering 42—100% of their respective catches. In 2019, France, Germany, Ireland, the Netherlands, Norway, UK (England), UK Scotland, and Spain provided samples and length distributions and Germany, Ireland, the Netherlands, Norway, and Spain provided also age distributions. However, the lack of age and length distribution data for relatively large portions of the horse mackerel catches continues to have a serious effect on the accuracy and reliability of the assessment and the Working Group remain especially concerned about the low number of fish which are aged.

Table 5.9.2 shows the sampling intensity for the Western stock in 2019 and table 5.9.3 shows the sampling intensity for the North Sea stock in 2019 by country.

An analysis on the sampling intensity was carried out for in period 2000-2019 for both the North Sea and the Western stock. Sampling intensity in fisheries can be defined as the ratio of sampled catch to the total catch. The precision and accuracy of sampled catch are of considerable importance to obtain a reliable estimate of the commercial catch. Sampled catch is used to extrapolate to total catch in order to obtain a catch-at-age (or at-length) and weight at age which are often used as inputs for the stock assessment models. In addition, in case of horse mackerel the impact of temporal (quarter) and spatial (area by ICES division) factors have to be taken in account in order to obtain a reliable estimate of the commercial catches.

Figure 5.9.1 shows the proportion of sampled catches by division for the North Sea stock. In general, all ICES divisions show low levels of sampling, especially in recent years. The sampling intensity in relation to the length composition of catch was >60%. In relation to age composition sampling level are dramatically low in recent years (Figure 5.9.2). In addition, divisions that are usually not sampled can affect the precision and accuracy of total catch-at-age and weight at age. For the North Sea stock samples were only available for area 4.a and 7.d. Therefore, these estimates can be biased, especially, since samples are usually less than the recommended 100 fish/sample. (Table 5.9.1)

The proportion of the sampled catches by region for the Western stock are showed in figure 5.9.3. Most of the regions present an adequate level of sampling although the Biscay and Channel regions show low levels of sampling in recent years. However, no samples were available for the Northern regions of the Western stock distribution. The general index of sampling intensity is around 69 %, although divisions (regions) that are not sampled can affect the precision and accuracy of total catch-at-age and weight at age (Figure 9.5.4).

Length distributions were supplied by a number of countries. However, as some countries only deliver catch-at-age distributions and others only length distributions of the catch, the obtained catch-at-age and length distributions are not reflecting the total catch especially in case of North Sea horse mackerel. Furthermore, some of the length distributions are only taken from discards of non-horse mackerel targeting fleets omitting the horse mackerel targeting fleet. This lack of coverage might also have a serious effect on the accuracy and reliability of the assessment and is a matter of concern for the Working Group.

5.10 References

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5.11 Tables

Table 5.1.1 HORSE MACKEREL general. Catches (t) by Sub-area. Data as submitted by Working Group members. Data of limited discard information are only available for some years.

Subarea	1979	1980	1981	1982	1983	1984	1985	1986
2	2	-	+	-	412	23	79	214
4 + 3.a	1,412	2,151	7,245	2,788	4,420	25,987	24,238	20,746
6	7,791	8,724	11,134	6,283	24,881	31,716	33,025	20,455
7	43,525	45,697	34,749	33,478	40,526	42,952	39,034	77,628
8	47,155	37,495	40,073	22,683	28,223	25,629	27,740	43,405
9	37,619	36,903	35,873	39,726	48,733	23,178	20,237	31,159
Total	137,504	130,970	129,074	104,958	147,195	149,485	144,353	193,607

Subarea	1987	1988	1989	1990	1991	1992	1993	1994
2	3,311	6,818	4,809	11,414	3200	13457	0	759
4 + 3.a	20,895	62,892	112,047	145,062	71,195	120,054	145,965	111,899
6	35,157	45,842	34,870	20,904	29,726	39,061	65,397	69,616
7	100,734	90,253	138,890	192,196	150,575	183,458	202,083	196,192
8	37,703	34,177	38,686	46,302	42,840	54,172	44,726	35,501
9	24,540	29,763	29,231	24,023	34,992	27,858	31,521	28,442
Disc					5,440	2,220	9,530	4,565
Total	222,340	269,745	358,533	439,901	337,968	440,280	499,222	446,974

Subarea	1995	1996	1997	1998	1999	2000	2001	2002
2	13151	3366	2601	2544	2557	919	310	1324
4 + 3.a	100,916	25,998	79,761	34,917	58,745	31,435	18,513	52,337
6	83,568	81,311	40,145	35,073	40,381	20,735	24,839	14,843
7	328,995	263,465	326,469	300,723	186,622	140,190	138,428	98,677
8	28,707	48,360	40,806	38,571	48,350	54,197	75,067	55,897
9	25,147	20,400	29,491	41,574	27,733	26,160	24,912	23,665
Disc	2,076	17,082	168	996	0	385	254	307
Total	582,560	459,982	519,441	454,398	364,388	274,022	282,323	247,049

Subarea	2003	2004	2005	2006	2007	2008	2009	2020
2	36	42	176	27	366.34	572	1847	1667
4 + 3.a	34,095	30,736	40,594	37,583	16,226	15,628	78,064	13,600
6	23,772	22,177	22,053	15,722	25,949	25,867	17,775	23,199
7	123,428	115,739	106,671	101,183	93,013	102,755	96,915	148,701
8	41,711	24,126	41,491	34,121	28,396	33,756	33,580	39,659
9	19,570	23,581	23,111	24,557	23,423	23,596	26,496	27,217
Disc	842	2,356	1,864	1,431	509	474	1,483	434
Total	243,455	218,758	235,961	214,624	187,882	202,649	256,161	254,478

Subarea	2011	2012	2013	2014	2015	2016	2017	2018
2	647.588	66.02912	30	424.291	10	45.276	5	718
4 + 3.a	25,158	5,234	8,183	17,270	10,560	11,565	12,609	11,758
6	39,496	44,971	43,266	32,444	24,153	32,186	28,170	38,896
7	120,340	120,476	100,859	66,853	49,644	46,901	33,297	38,816
8	35,245	17,209	26,983	30,844	19,822	17,511	18,307	23,393
9[1]	22,575	25,316	29,382	29,205	33,179	41,081	37,080	31,920
Disc	430	3,279	4,582	1,904	6,232	5,944	5,488	2,873
Total	243,892	216,552	213,285	178,945	143,600	155,232	134,956	148,374

Subarea	2019
2	866,8
4 + 3.a	12,593
6	47,351
7	42,973
8	29,640
9[1]	34,080
Disc	3,326
Total	170,829

[1] - Southern Horse Mackerel (ICES Division 9) is assessed by ICES WGHANSA since 2011

Table 5.1.2 HORSE MACKEREL Western and North Sea Stock combined.
Quarterly catches (t) by Division and Subdivision in 2019.

Division	1Q	2Q	3Q	4Q	TOTAL
2.a+5.b	384	384	18	81	867
3	1	0	143	661	805
4.a	1355	1221	5213	3076	109663*
4.bc	15	193	127	873	1242**
7.d	1630	263	303	5785	8021***
6.a,b	32260	153	2230	12126	47479****
7.a–c,e–k	13353	2790	12059	7860	36062
8.a-e	5070	7138	11309	7879	31396
Sum	54068	12141	31403	38340	136750

*** for the total 50t were added which were only declared as yearly catch**

**** for the total 17t were added which were only declared as yearly catch**

***** for the total 20t were added which were only declared as yearly catch**

****** for the total 709t were added which were only declared as yearly catch**

Table 5.4.1 ORSE MACKEREL general. Landings and discards (t) by year and ICES Division, for the North Sea, Western, and Southern horse mackerel stocks. (Data submitted by Working Group members.)

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)[x]	All sto-cks
1982	2,788[*]		-	1,247		4,035	-		-	6,283	32,231	3,073	-	61,197	65,232	39,726	104,958
1983	4,420[*]		-	3,600		8,020	412		-	24,881	36,926	28,223	-	90,442	98,462	48,733	147,195
1984	25,893[*]		-	3,585		29,478	23		94	31,716	38,782	25,629	500	96,744	126,222	23,178	149,400
1985	-		22,897	2,715		26,750	79		203	33,025	35,296	27,740	7,500	103,843	129,455	20,237	150,830
1986	-		19,496	4,756		24,648	214		776	20,343	72,761	43,405	8,500	145,999	170,251	31,159	201,806
1987	1,138		9,477	1,721		11,634	3,311		11,185	35,197	99,942	37,703	-	187,338	199,674	24,540	223,512
1988	396		18,290	3,120		23,671	6,818		42,174	45,842	81,978	34,177	3,740	214,729	236,535	29,763	268,163
1989	436		25,830	6,522		33,265	4,809		85304**	34,870	131,218	38,686	1,150	296,037	328,825	29,231	358,533
1990	2,261		17,437	1,325		18,762	11,414	14,878	112753**	20,794	182,580	46,302	9,930	398,645	419,668	24,023	441,430
1991	913	0	11,400	600	0	12,913	3,200	2,725	56,157	29,726	149,975	42,840	5,440	290,063	302,976	34,992	337,968
1992	0	0	13,955	688	400	15,043	13,457	2,374	103,725	39,061	182,770	54,172	1,820	397,379	412,422	27,858	440,280

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)[x]	All stocks
1993	0	0	3,895	8,792	930	13,617	0	850	141,220	65,397	193,291	44,726	8,600	454,084	467,701	31,521	499,222
1994	0	0	2,496	2,503	630	5,629	759	2,492	106,911	69,616	193,689	35,501	3,935	412,903	418,532	28,442	446,974
1995	112	0	7,948	8,666	30	16,756	13,151	128	92,728	83,568	320,329	28,707	2,046	540,657	557,413	25,147	582,560
1996	1,657	0	7,558	9,416	212	18,843	3,366	0	16,783	81,311	254,049	48,360	16,870	420,739	439,582	20,400	459,982
1997	0	0	14,078	5,452	10	19,540	2,601	2,037	63,646	40,145	321,017	40,806	158	470,410	489,950	29,491	519,441
1998	3,693	0	10,530	16,194	83	30,500	2,544	3,693	17,001	35,073	284,529	38,571	913	382,324	412,824	41,574	454,398
1999	0	0	9,335	27,889	0	37,224	2,557	2,095	47,315	40,381	158,733	48,350	0	299,431	336,655	27,733	364,388
2000	0	176	25,931	19,019	4	45,130	919	1,014	4,314	20,735	121,171	54,197	382	202,732	247,862	26,160	274,022
2001	43	212	6,686	21,390	0	28,331	310	134	11,438	24,839	117,038	75,067	254	229,081	257,411	24,912	282,323
2002	0	639	15,303	11,323	0	27,264	1,324	174	36,221	14,843	87,354	55,897	307	196,120	223,384	23,665	247,049
2003	49	622	10,309	21,049	0	32,028	36	1,843	21,272	23,772	102,379	41,711	842	191,856	223,885	19,570	243,455
2004	303	133	18,544	16,455	0	35,435	42	48	11,708	22,177	99,284	24,126	2,356	159,742	195,177	23,581	218,758

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)x	All sto-cks
2005	0	1,331	13,995	15,460	62	30,848	176	284	24,983	22,053	91,211	41,491	1,802	182,001	212,850	23,111	235,961
2006	185	2,192	7,996	23,789	78	34,240	27	58	27,152	15,722	77,394	34,121	1,353	155,827	190,067	24,557	214,624
2007	11	2,051	9,114	29,789	139	41,103	366	110	4,940	25,949	63,224	28,396	370	123,356	164,459	23,423	187,882
2008	27	910	2,582	32,185	0	35,704	572	3	12,107	25,867	70,570	33,756	474	143,349	179,053	23,596	202,649
2009	21	314	18,975	25,537	1,036	45,883	1,847	17	58,738	17,775	71,378	33,580	447	183,782	229,665	26,496	256,161
2010	0	100	1,969	22,077	2	24,149	1,667	88	11,442	23,199	126,624	39,659	432	203,112	227,261	27,217	254,478
2011	0	0	10,435	17,184	0	27,619	648	0	14,723	39,496	103,156	35,245	430	193,698	221,317	22,575	243,892
2012	0	355	1,559	19,464	0	21,378	66	9	3,311	44,971	101,012	17,209	3,279	169,858	191,236	25,316	216,552
2013	0	17	1,453	17,175	0	18,645	30	10	6,702	43,266	83,684	26,983	4,582	165,258	183,903	29,382	213,285
2014	1	2	2,597	10,772	7	13,380	424	4,096	10,573	32,444	56,081	30,844	1,896	136,360	149,740	29,205	178,945
2015	3	644	770	8,581	2,004	12,002	10	65	9,078	24,153	41,063	19,822	4,228	98,419	110,421	33,179	143,600
2016	2	1,628	975	11,209	1,527	15,341	45	0	8,960	32,186	35,692	17,511	4,417	98,811	114,151	41,081	155,232

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)[x]	All sto-cks
2017	0	22	2,557	10,787	1,213	14,579	5	697	9,332	28,170	22,510	18,307	3,939	82,961	97,540	37,088	134,956
2018	0	1,418	1,413	11,677	265	14,773	718	380	8,547	38,896	27,140	23,393	2,609	101,683	116,456	31,920	148,376
2019	0.5	2,571	1,217	7,829	185	11,803	867	490	8,314	47,351	35,144	29,640	3,141	124,947	136,750	34,080	170,830

***Divisions 3.a and 4.b,c combined.**

****Norwegian catches in 4.b included in Western horse mackerel.**

[x] Southern Horse Mackerel is assessed by ICES WGHANSA since 2011

Table 5.4.2 National catches of the Western Horse mackerel stock.

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	18	19	21	0	-	-	-	-	-
Denmark	62,897	31,023	26,040	16,385	21,254	10,147	11340	11,667	10,155
Estonia	78	22	-	0	-	-	-	3,826	3,695
Faroe Islands	1,095	216	1,040	24	800	671	4	8,056	10,690
France	39,188	26,667	25,141	20,457	15,145	18,951	10,381	17,744	16,364
Germany, Fed.Rep.	28,533	33,716	23,549	13,014	11,491	12,658	15,696	26,432	34,607
Ireland	74,250	73,672	57,983	55,229	51,874	36,422	35,857	-	-
Lithuania	-	-	-	-	-	-	-	40986	41,057
Netherlands	82,885	103,246	83,450	57,261	73,440	44,997	48,924	10729	24,909
Norway	45,058	13,363	46,648	1,982	7,956	36,164	20,371	16,272	16,636
Russia	554	345	121	80	16	3	2	567	216
Spain	31,087	43,829	39,831	24,204	23,537	24,763	24,599	4,617	3,560
Sweden	1,761	3411	1,957	1009	68	561	1,002	458	210
UK (Engl. + Wales)	19,778	13,068	9,268	4,554	7,096	5,970	4,438	1,522	143
UK (N. Ireland)	-	1,158	-	625	1140	1129	914	14,506	17,962
UK (Scotland)	32,865	18,283	11,197	10,283	8,026	2,905	721	2356	1802
Unallocated	17,158	15,262	23,763	-2757	6,978	472	16,765	159,737	182,006
Discard	158	913	-	382	254	307	842	-	-
Total	437,363	378,213	350,009	202,732	229,075	196,120	191,856	11,667	10,155

Country	2006	2007	2008	2009	2010	2011	2012	2013
Belgium	-	-	-	-	19	2	0.2	14
Denmark	8,411	7,617	5,261	6,027	5,940	6,108	4,002	6,820
Faroe Islands	-	478	841	-	377	349	-	
France	11,031	12,748	12,626	-	260	8,271	1,797	3,595
Germany, Fed.Rep.	10,862	5,784	11,801	15,122	17,688	21,114	17,063	24,835
Ireland	26,779	29,759	35,332	40,754	44,488	38,466	45,239	35,791
Lithuania	6,828	5,467	5,548	-	-	-	-	
Netherlands	37,130	29,462	43,648	39,453	61,504	55,690	66,396	53,697
Norway	27,114	4,182	12,223	59,764	11,978	13,755	3,251	6,596
Spain	13,877	14,277	19,851	21,077	38,745	34,581	13560	22,541
Sweden	-	76	8	258	2	90	-	1
UK (Engl. + Wales)	3,574	5,482	3,365	6,482	12,714	11,716	12,122	3,959
UK (N. Ireland)	103	-	-	-	59	198	-	2,325
UK (Scotland)	468	776	1,077	1,412	2,349	2,928	1,335	504
Unallocated	8,292	6,878	-8,703	-7,014	6,556	-	1815	-
Discard	1353	370	474	447	432	430	3,280	4,582
Total	155,822	123,356	143,352	183,782	203,111	193,698	169,860	165,260

Country	2014	2015	2016	2017	2018	2019
Belgium						-
Denmark	5,945	4,556	321	4,541	6,302	7,764
Faroe Islands	68	-	-	180	-	26
France	3,428	3,247	2,797	3,923	3,443	4,382
Germany, Fed.Rep.	17,161	9,417	11,414	7,172	4,734	9,211
Ireland	32,667	21,654	27,605	23,560	25,347	28,899
Lithuania	-	-	2,596	-	-	-
Netherlands	25,053	24,958	23,792	14,269	25,942	29,656
Norway	14,353	8,897	9,438	9,885	9,319	9,021
Poland	-	-	--	-	-	127
Spain	19,442	13,071	14,235	14,901	20,362	25,776
Sweden	0	10	-	41	23	323
UK (Engl. + Wales)	4,832	2,063	842	549	2,443	4,036
UK (N. Ireland)	1,579	1,204	-		1,080	1,907
UK (Scotland)	1,389	738	970	-	-	678
Unallocated	8,545	4,377	1,010	3,994	74	0
Discard	1,896	4,228	4,417	3,928	2,609	3,141
Total	136,360	98,419	98,810	82,950	101,682	124,947

Table 5.4.3. National catches of the North Sea Horse mackerel stock.

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	-	19	21			30	5	4	4	-
Denmark	180	1,481	3,377	4,403	885	2,315	3,301	8,690	3,987	8,353
Faroe Islands	-	-	135	-	-	28	804	21	-	-
France	3,246	2,399	-	-		1,246	2,326	231	5,236	1,205
Germany, Fed.Rep.	7,847	5,844	5,920	3,728	974	6,532	2,936	5,194	2,725	11,034
Ireland	-	2,861	27	201	338	61	-	1	753	10,863
Lithuania	-	10,711	-	-	-	-	-	-	-	26,779
Netherlands	36,855	-	8,117	8,697	13,867	12,209	24,119	26,303	27,730	6,829
Norway	-	-	238	105	36	525	144	22	204	37,130
Sweden	-	3,401	5	40	46	16	72	98	4	27,114
UK (Engl. + Wales)	269	907	11	1,585	3,425	2,322	1,966	5,633	3,859	-
UK (Scotland)	29	-	-	421	-	2	1	2	-	13,878
Unallocated	-28,896	2,794	19,373	25,944	8,805	1,981	-3,645	-13,064	-13,719	-
Discard	10	83	-	4	-		-	-	62	3,583
Total	19,540	30,500	37,224	45,128	28,376	27,267	32,029	33,135	30,845	155,094

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium				4	16		46	51.077	74
Denmark	1,283	252	57	72	15	142	1514	1,020	552
Faroe Islands	-	-	-	-	-	-	0		
France	4,380	5,349	2,247	-	813	273	1,047	1,010	1,742
Germany, Fed.Rep.	1,125	65	1,081	1,539	3,794	3,461	5,356	2,941	1,619
Ireland	2,077		887	25	-	-	0		0
Lithuania	1,999	297	-	-	-	-	0		0
Netherlands	27,285	31,153	19,439	22,546	17,093	16,289	12,157	8,725	4,925
Norway	113	1,243	21	12,855	526	7,359	129	377	0
Sweden	9	21	36	401	-	-	0		1
UK (Engl. + Wales)	595	6921	1,061	1,435	1,890		935	4,401	4,198

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
UK (Scotland)	300	625	7	4	111	93	240	172	262
Unallocated	-5,004	-4,960	10,869	5,964	-116	0	0	0	
Discard	78	139	-	1,036	2	0	0	0	7
Total	34,240	41,105	35,705	45,881	24,144	27,617	21,424	18,696	13,380

Country	2015	2016	2017	2018	2019
Belgium	63	51	67	44	18
Denmark	800	268	294	397	100
Faroe Islands	0	0	4	0	10
France	934	1,322	1,863	1,443	935
Germany, Fed.Rep.	644	1,879	949	2,766	946
Ireland	0	0	0	0	0
Lithuania	0	0	0	0	1,254
Netherlands	3,305	3,892	5,638	5,184	2,089
Norway	662	1,701	5	1,423	2,543
Sweden	9	0	0	0	0
UK (Engl. + Wales)	3,581	4,697	4,546	3,250	3,632
UK (Northern Ireland)	0	0	0	0	53
UK (Scotland)	0	0	0	0	38
Unallocated	0	0	0	0	0
Discard	2,004	1,527	1,213	265	185
Total	12,002	15,337	14,579	14,773	11,802

Table 5.6.1. Catches (t) of *Trachurus mediterraneus* in Divisions 8.ab, 8.c and Sub-Area 7

	7	8.ab	8.c East	8.c West	TOTAL
1989	0	23	3903		3926
1990	0	298	2943		3241
1991	0	2122	5020		7142
1992	0	1123	4804		5927
1993	0	649	5576		6225

	7	8.ab	8.c East	8.c West	TOTAL
1994	0	1573	3344		4917
1995	0	2271	4585		6856
1996	0	1175	3443		4618
1997	0	557	3264		3821
1998	0	740	3755		4495
1999	0	1100	1592		2692
2000	59	988	808		1854
2001	1	525	1293		1820
2002	1	525	1198		1724
2003	0	340	1699		2039
2004	0	53	841		894
2005	1	155	1005		1162
2006	1	168	794		963
2007	0	126	326		452
2008	0	82	405		487
2009	0	42	1082		1124
2010	0	97	370		467
2011	0	119	1096		1225
2012	0	186	667	116	969
2013	0	52	238	0	290
2014	0	130	1160	0	1290
2015	0	8	890	0	899
2016	0	5	471	0	476
2017	0	18	684	0	702
2018	0.4	38	640	0	678
2019	0.02	81	384	1	466

Table 5.7.1 Horse mackerel general. Length distributions (%) by country, area and fleet in 2019. (0%= <0.5%)

	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Germany	Germany	Germany	France	France	France	France	France	France	France	France	France	France
	6a	7b	7d	7e	7h	7j	4b	4a	6a	7d	7d	7d	8a	8b	7e	8a	8a	7e	8b	8a
cm	All	All	All	All	All	All	All	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTB_DEF_70-99_0_0	OTM_SPF_32-69_0_0_all	OTB_DEF_>=70_0_0	OTB_DEF_>=70_0_0	OTB_DEF_70-99_0_0	OTM_DEF_70-99_0_0_all	OTT_CRU_>=70_0_0	OTT_CRU_>=70_0_0	OTT_CRU_>=70_0_0	SSC_DEF_70-99_0_0_all
5																				
6																				
7																				
8																				
9																				
10													2		0					
11													1		0					
12											0			2	1					2
13											2		1	27	10					17
14											2		3	9	4					28
15											2	3	4	6	3					14
16											0	7	3	3	5					4
17											2	9	2	30	14		2			6
18			4		4						2	13	5	19	10		2	1		5
19			4	12							6	9	5		6		7	2		3
20			12	8	8						17	10	3	3	8		1	3		4
21			20	12	8					5	15	15	3		5		5	2		3
22			16	32	28	0				5	14	3	4		7		4	2		2
23	0		12	16	44	5				2	7	9	2		6		5	6	0	2
24	4		12	16	8	14			0	12	7	11	3		5		7	7	0	1
25	12		12	4		19			3	18	6	4	4		6		6	11	0	1
26	20	7	4			9			10	13	6	4	3	2	5	1	10	11	0	1
27	27	20	4			8			14	7	3	3	7		3	2	16	13	1	2
28	12	23				5		1	8	15	3		5		1	2	5	16	3	1
29	10	12				8	4	0	5	2	3		6		0	2	9	11	5	1
30	4	7				13	17	0	6	12	1		9		0	2	5	8	12	1
31	2	6				10	17	4	7	8	0		7		0	4	2	2	18	1
32	1	8				3	26	14	10	2	0		6		0	6	5	3	23	1
33	1	5				0	17	20	11		0		4		0	7	4	1	17	1
34	1	4				2	13	20	12		0		4		0	10	0		14	0
35	4	5				1		23	7		0		0		0	9	1		3	0
36	0	2					4	10	4		0		1			11	1		2	0
37	0	1						4	2		0		1		1	11	1		1	0
38	0							3	1		0		0		0	9	1		1	0
39	0							0	0				0			7	1			0
40								0	0				0			3	0			
41								0	0						0	3	0			
42+													1			1				

Table 5.7.1 continued

	France	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Ireland	Ireland	Norway
	8b	27.8.c.e	27.8.c.w	27.8.c.e	27.8.c.w	27.8.c.e	27.8.c.w	27.8.a	27.8.c.e	27.8.c.w	27.8.b	27.8.c.e	27.8.c.w	27.8.c.e	27.8.c.w	6.a	7.b	4.a
cm	SSC_DEF_70-99_0_0_all	GNS_DEF_60-79_0_0	GNS_DEF_60-79_0_0	GNS_DEF_80-99_0_0	GNS_DEF_80-99_0_0	OTB_DEF_>=55_0_0	OTB_DEF_>=55_0_0	OTB_DEF_>=70_0_0	OTB_MPD_>=55_0_0	OTB_MPD_>=55_0_0	PS_SPF_0_0_0	PS_SPF_0_0_0	PS_SPF_0_0_0	PTB_MPD_>=55_0_0	OTB_DEF_>=70_0_0 landg	HM-All	HM-All	HM-All
5																		
6																		
7																		
8																		
9																		
10	2																	
11	8																	
12	13											6						
13	30	5										14	0					
14	12	4										14	2					
15	4	3				0						11	3					
16	2	2				1	0					5	2					
17	2	1				1	0					3	1					
18	1	6				2	2			0		2	1					
19	1	4	0			2	3			0		2	3					
20	1	2	0			5	5			0		1	5				1	
21	1	4	1	1	1	7	4	1		1		1	7			1	4	
22	1	2	1	1	0	7	3	1		2		1	9			0	4	
23	2	3	2	1	2	3	4	1		2		2	10			0	1	
24	2	3	1	1	4	2	6	2		1		3	8			2	4	
25	2	1	2	4	1	5	5	7		4	0	4	8			6	7	
26	3	2	4	1	2	7	8	8	10	7	1	3	7			12	11	
27	2	6	5	2	2	7	7	11	35	13	1	3	7		1	19	15	
28	2	7	6	1	3	7	8	8	36	9	3	3	6		3	20	14	
29	2	12	8	2	6	5	7	9	14	13	5	2	5	5	5	14	7	
30	2	7	12	7	3	7	5	11	1	19	7	2	5	6	7	8	4	
31	1	10	13	5	6	10	5	12		9	6	2	4	12	14	6	4	0
32	1	3	13	5	1	7	4	6		10	6	2	3	9	8	3	5	0
33	1	6	10	6	8	5	3	6	0	3	8	2	2	10	10	3	6	3
34	1	3	9	7	8	3	4	5	0	2	11	2	1	19	6	2	6	8
35	1	2	4	8	8	3	4	6	0	1	13	2	0	12	8	1	3	17
36	1	1	4	13	10	2	5	3	1	2	15	2	0	16	9	1	2	23
37		1	2	9	11	1	3	1	0	0	10	1	0	5	6	0	1	27
38		1	1	8	6	1	2	0	0	1	7	1	0	6	6		0	18
39		0	0	4	5	0	1	1	0	0	4	1	0	0	4			4
40			0	4	5		1	0	0	0	2	0	0		3			0
41				5	3	0	0			0	1	0	0		3			0
42+				4	5	0	1	1	0	0		0	0		6			

Table 5.7.1 continued

	UK (E&W)	UK (E&W)	UK (E&W)	UK (E&W)	UK (E&W)	UK (E&W)	UK (E&W)	UK (E&W)	UK (E&W)	UK (Sco)	UK (Sco)	UK (Sco)	
	4.b	4.c	6.a	7.b	7.d	7.e	7.h	7.j	8.a	6.a	6.a	6.b2	
cm	All	All	All	All	All	All	All	All	All	TR1	TR2	TR1	
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18	4	5				3							
19	0	13			1	3				0			
20	2	11			4	7				0			
21	4	23			6	8	4			0			
22	2	11			8	7	13			0		0	
23	10	12			12	1	16			0		0	
24	6	13			16	12	28			0		0	
25	10	7	3	2	16	21	24			0		0	
26	27	3	8	8	13	27	8	12		0	0	0	
27	21	1	9	38	13	8	8	28		0	2	0	
28	8	1	14	17	5	1		32		0	11	2	
29	2		6	16	4	1		11		0	1	3	
30	0		12	6	2			5		2	19	10	
31	2		14	2	0			6		2	20	11	
32	0		3	5	1			3	1	2	24	14	
33	2		7	2				1	10	2	5	9	
34			17					1	11	5	12	8	
35			4	2				1	17	10	2	10	
36			4	1				0	28	11	0	8	
37									4	10	0	7	
38									18	14	4	7	
39									7	8		3	
40									1	13		2	
41									3	6		1	
42+										4		1	

Table5.9.1. Summary of the overall sampling intensity on horse mackerel catches in recent years in all areas 1992—2019

Year	Total Catch (ICES estimate)	% catch covered by sampling programme*	No. samples	No. Measured	No. Aged
1992	436 500	45	1 803	158447	5797
1993	504190	75	1178	158954	7476
1994	447153	61	1453	134269	6571
1995	580000	48	2041	177803	5885
1996	460200	63	2498	208416	4719
1997	518900	75	2572	247207	6391
1998	399700	62	2539	245220	6416
1999	363033	51	2158	208387	7954
2000	247862	50	378	33317	4126
2001	257411	61	467	46885	7141
2002	223384	68	540	79103	6831
2003	223885	77	434	59241	8044
2004	195177	62	518	62720	9273
2005	212850	76	573	67898	8840
2006	190067	75	602	57701	9905
2007	164459	58	397	41046	8061
2008	179053	72	488	46768	8870
2009	229665	84	902	57505	10575
2010	227261	82	710	49307	14159
2011	221317	71	502	40492	7484
2012	191236	69	501	41148	8220
2013	183903	75	686	87300	9776
2014	149740	83	650	53945	8085
2015	110421	68	825	39415	7034
2016	114151	76	1033	93853	6675
2017	97539	63	1113	116722	8221
2018	116455	74	1584	117768	6965
2019	136750	64	1014	77211	7476

***Percentage related to catch (catch at age) according to ICES estimation**

Table 5.9.2. Horse mackerel sampling intensity for the Western stock in 2019.

Country	Catch	% Catch Sampled*	No. Samples	No. Measured	No. Aged
Denmark	8100	0	0	0	0
Faroe Islands	26	0	0	0	0
France**	5527	-*	145	3704	0
Germany	9211	28	15	2923	226
Ireland	29141	96	175	2923	226
Netherlands	29656	76	61	9325	1503
Norway	9021	91	10	269	269
Poland	127	0	0	0	0
Spain	27100	98	962	269	269
Sweden	325	0	0	0	0
UK (England)**	4046	-*	66	557	0
UK(Northern Ireland)	1907	0	0	0	0
UK(Scotland)**	760	-*	40	811	0
Total	124947	69	992	76032	7141

***Percentage based on ICES estimate with regards to age samples**

****provided only length distributions**

Table 5.9.3. Horse mackerel sampling intensity for the North Sea stock in 2019.

Country	Catch	% Catch Sampled*	No. Samples	No. Measured	No. Aged
Belgium	18	0	0	0	0
Denmark	111	0	0	0	0
Faroe Islands	10	0	0	0	0
France**	1106	0	42	583	0
Germany	946	86	52	1179	310
Lithuania	1254	0	0	0	0
Netherlands	2089	0	0	0	0
Norway	2543	98	5	140	140
Sweden	1	0	0	0	0

Country	Catch	% Catch Sampled*	No. Samples	No. Measured	No. Aged
UK (England)	3633	0	0	0	25
UK(Northern Ireland)	53	0	0	0	0
UK(Scotland)***	38	0	0	0	0
Total	11803	28	99	1902	475

***Percentage based on ICES estimate with regards to age samples. ** provided only length distributions ***provided length distributions not incl. in InterCatch**

5.12 Figures

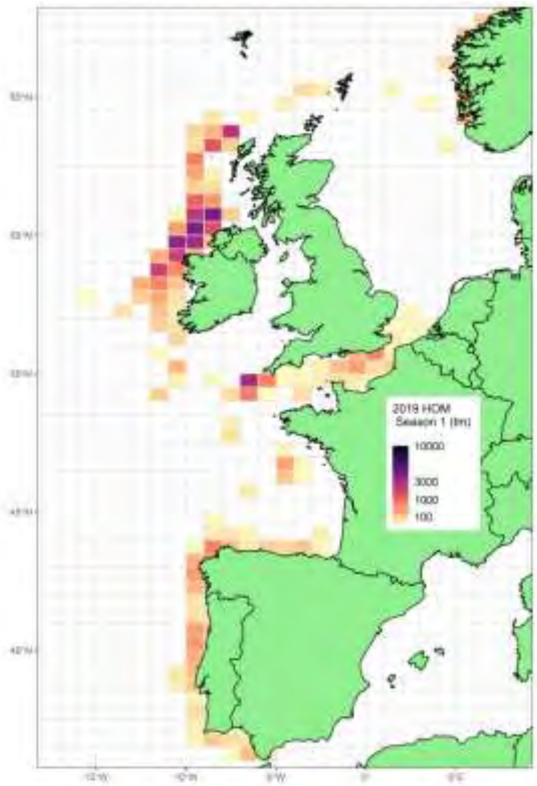

Figure 5.1.1a. Horse mackerel catches 1st quarter 2019.

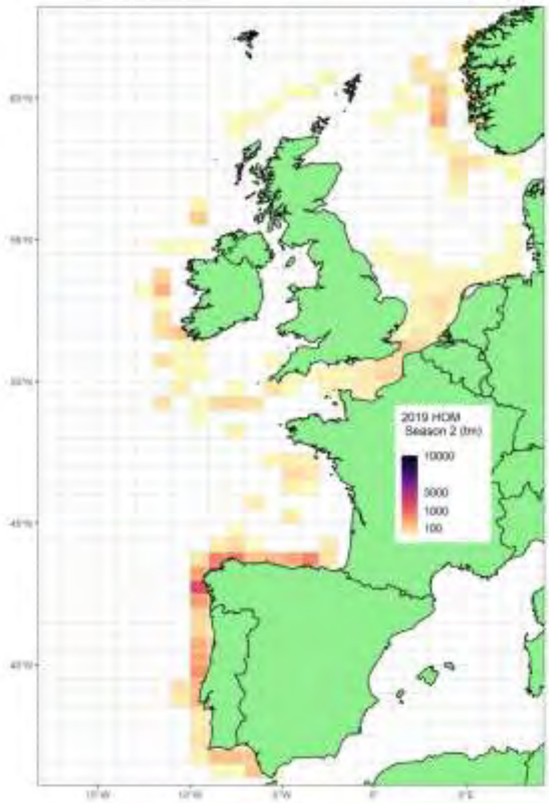

Figure 5.1.1b. Horse mackerel catches 2nd quarter 2019.

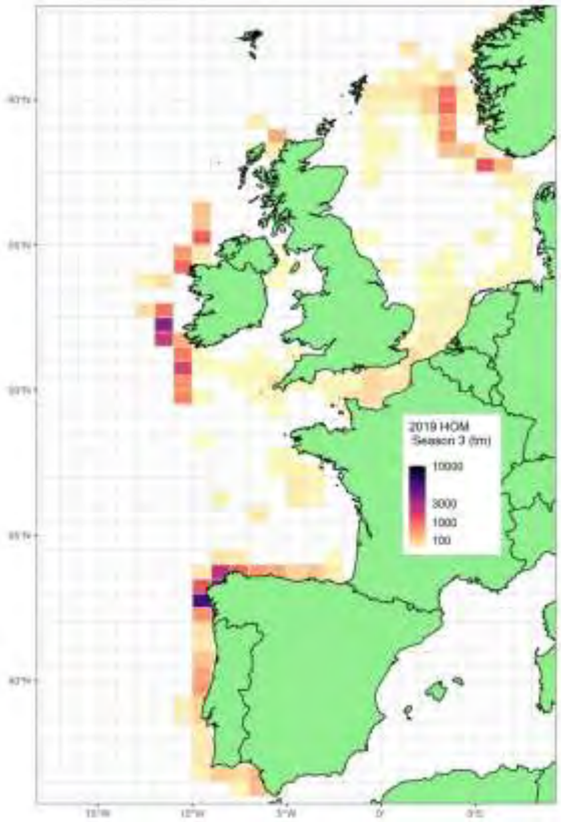

Figure 5.1.1c. Horse mackerel catches 3rd quarter 2019.

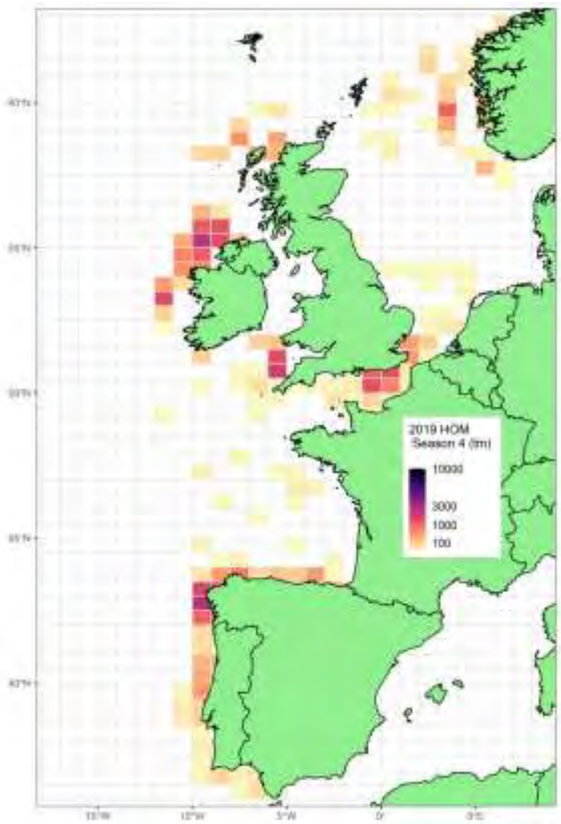

Figure 5.1.1d. Horse mackerel catches 4th quarter 2019.

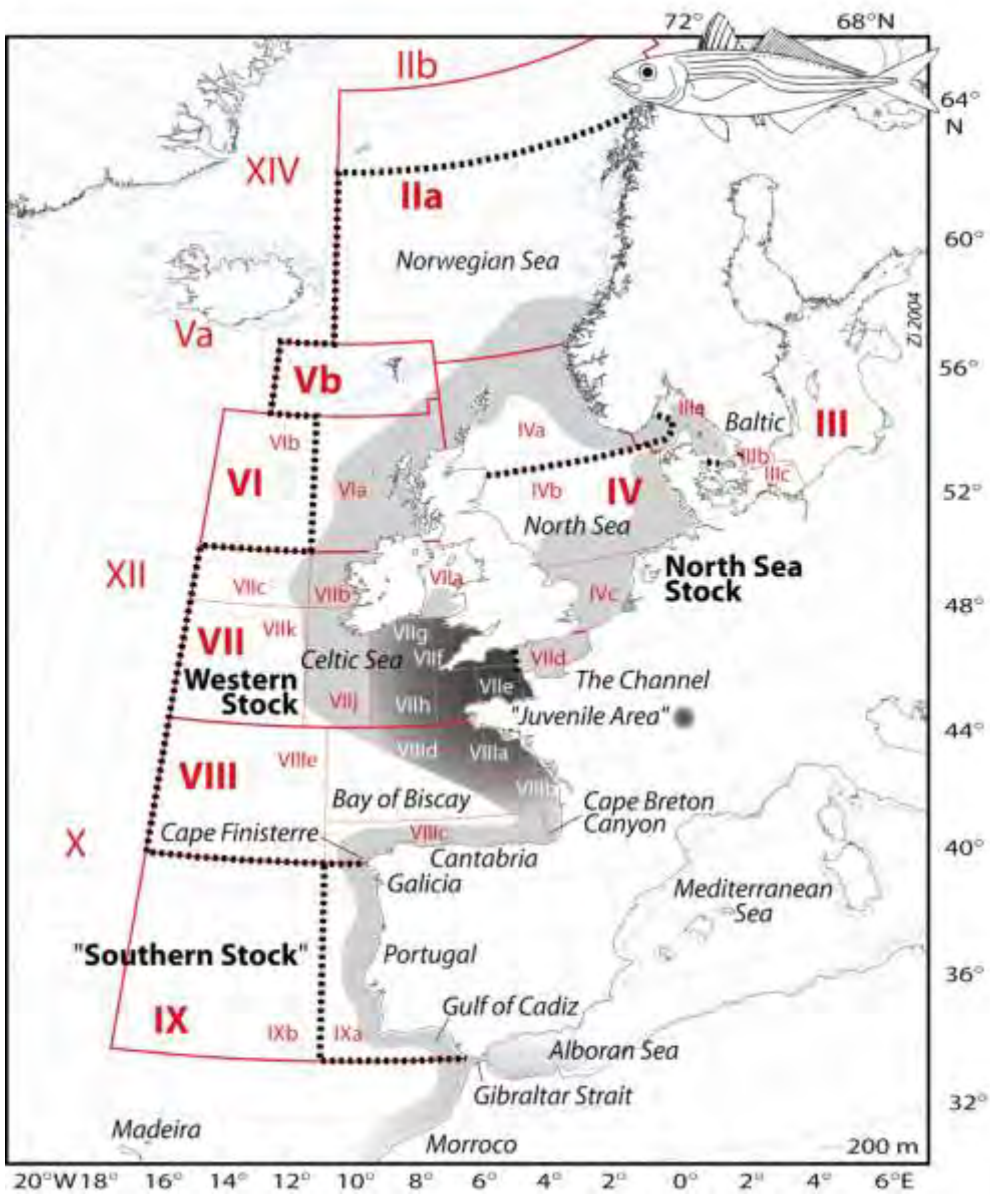

Figure 5.2.1: Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by the 2004 WG MHSA. Note that the "Juvenile Area" is currently only defined for the Western Stock distribution area – juveniles do also occur in other areas (like in Div. 7.d). Map source: GEBCO, polar projection, 200 m depth contour drawn.

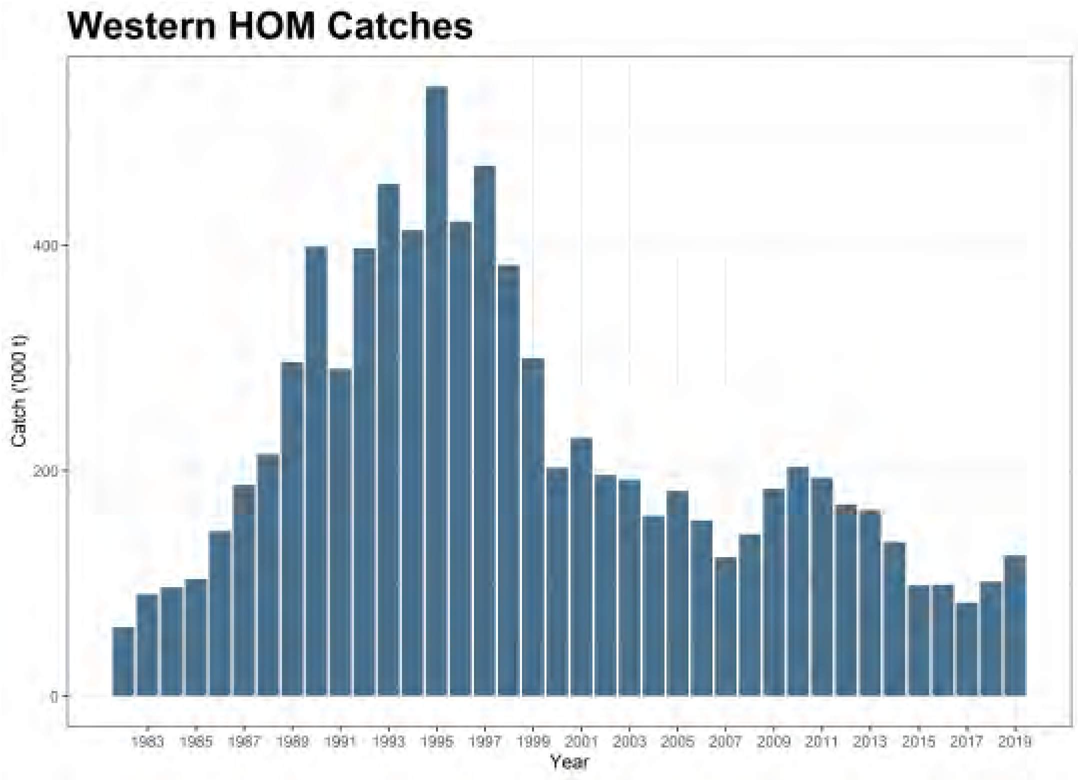

Figure 5.3.1. Total catch for Western Horse Mackerel stock, period 1982–2019.

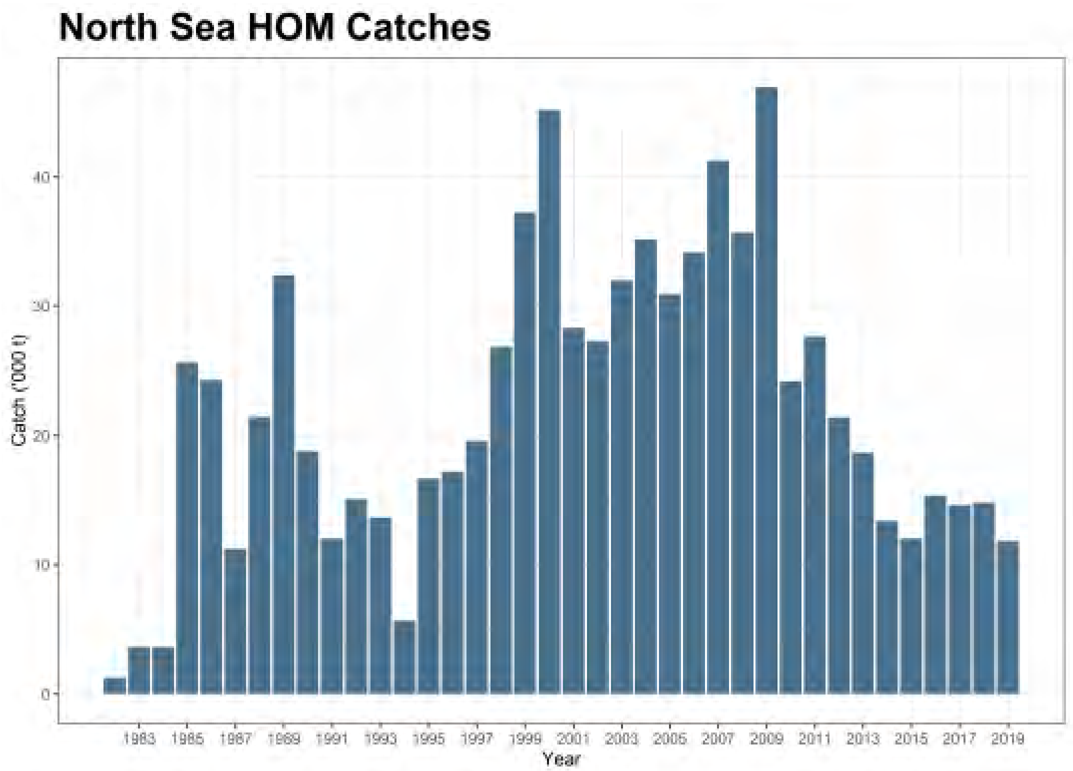

Figure 5.3.4. Total catch for North Sea Horse Mackerel stock, period 1982–2019

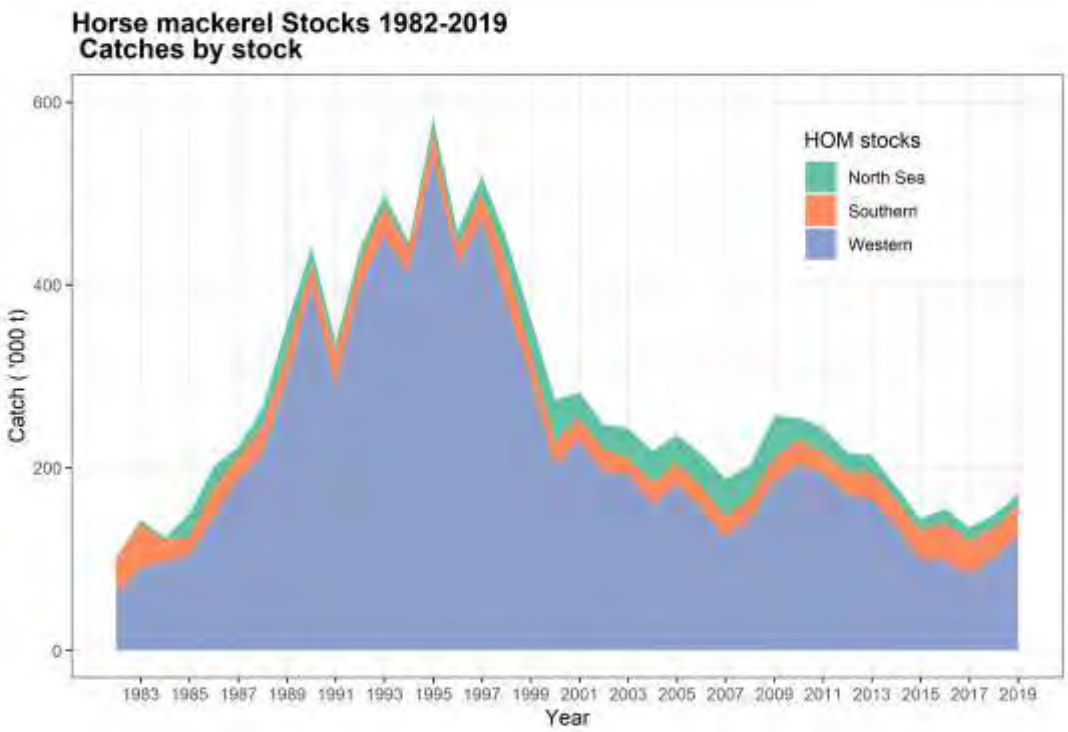

Figure 5.4.1 Horse mackerel general overview. Total catches in the northeast Atlantic during the period 1982—2019. The catches taken from the southern, western and North Sea horse mackerel stocks are shown in relation to the total catches in the northeast Atlantic. Catches from Div. 8.c were transferred from southern stock to western stock from 1982 onwards. Southern horse mackerel is assessed by ICES WGHANSA since 2011.

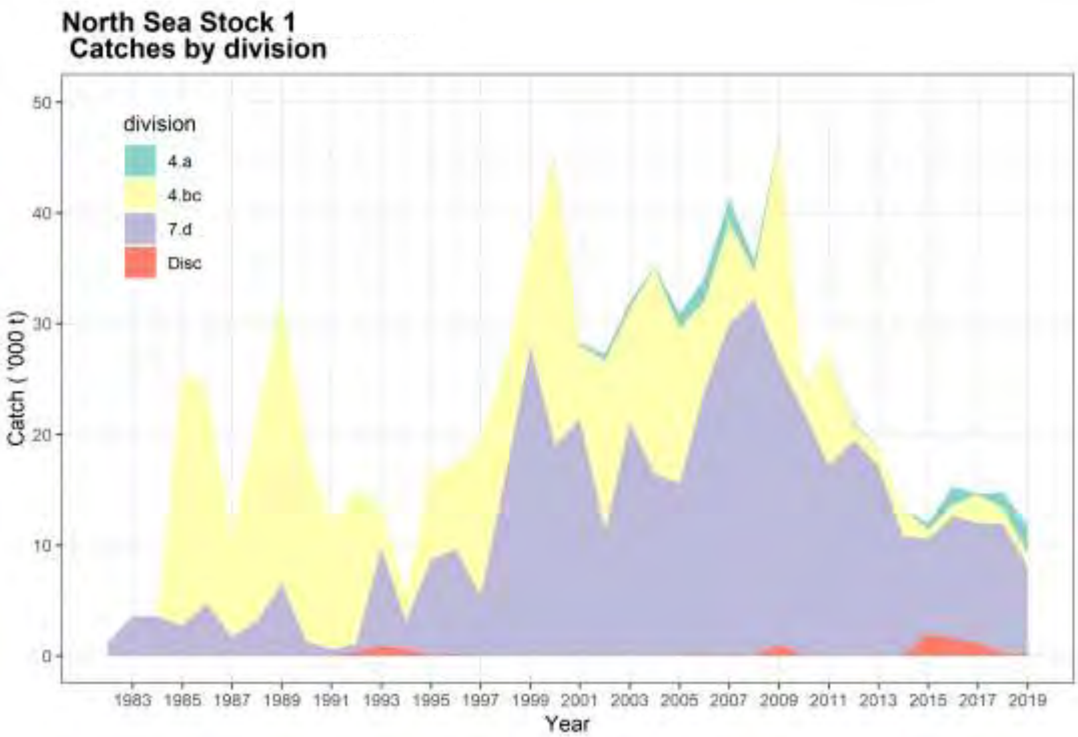

Figure 5.4.2. North Sea horse mackerel stock. Total catches by Division during the period 1982–2019.

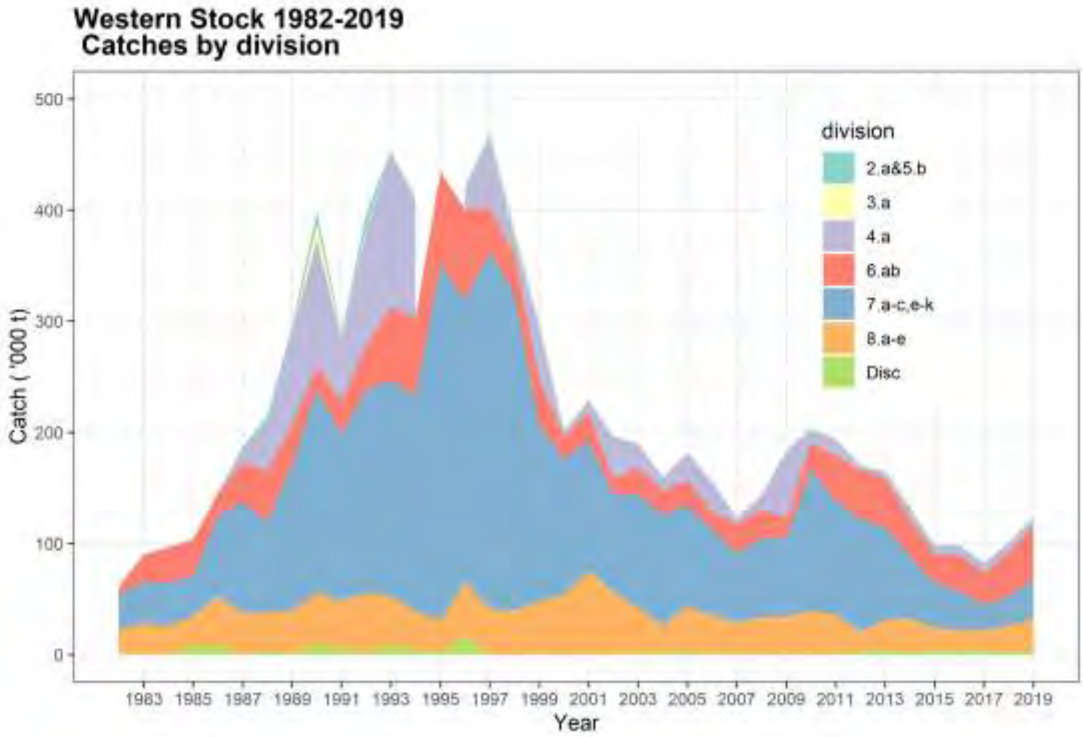

Figure 5.4.3. Western horse mackerel stock. Total catches by Sub-Area during the period 1982–2019.

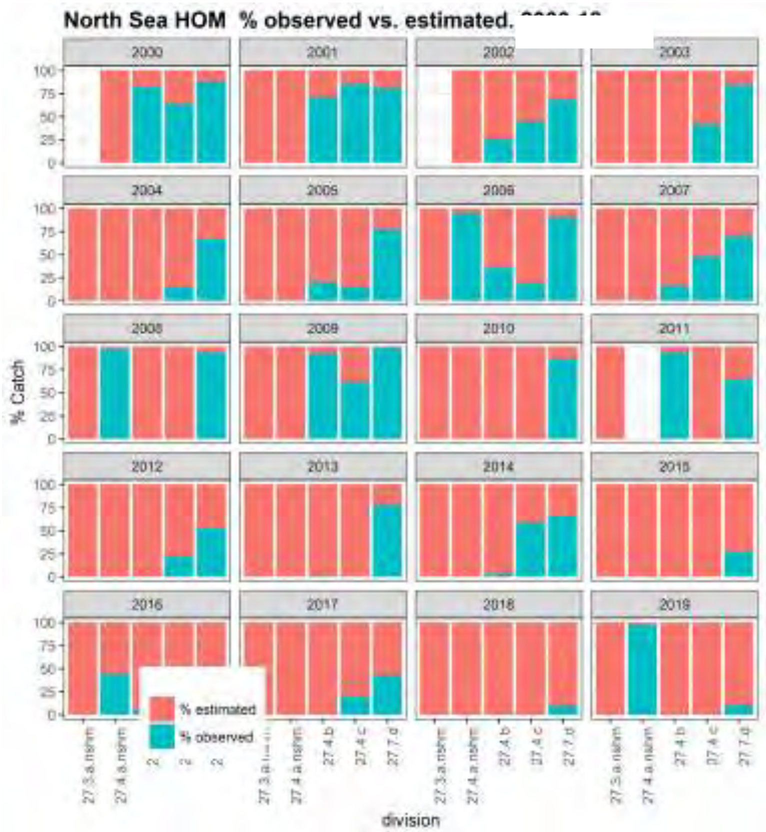

Figure 5.9.1 North Sea horse mackerel stock. Percentage sampled catch (blue) vs. unsampled catch (red) by division and year. Period 2000–2019.

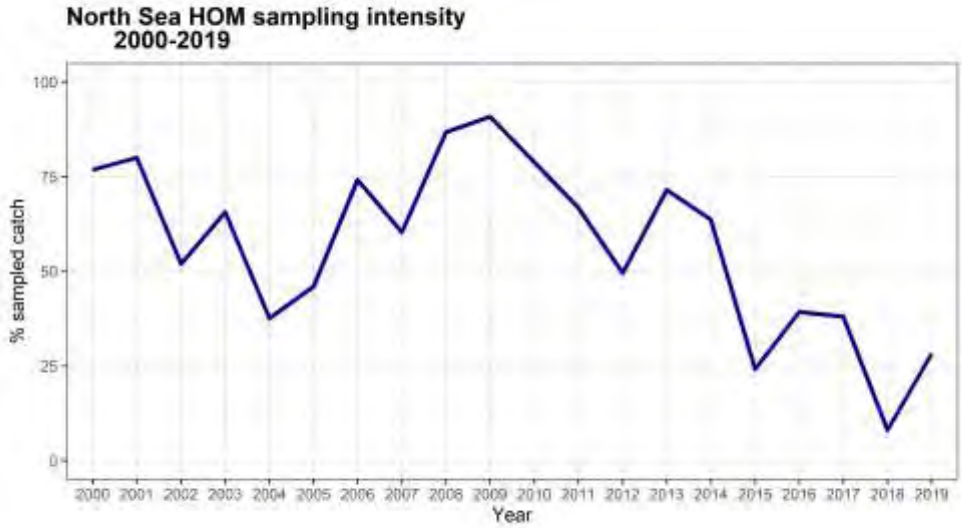

Figure 5.9.2. North Sea horse mackerel stock. Sampling intensity index as percentage sampled catch in total catch by year (Delayed submitted sample unconsidered). Period 2000–2019

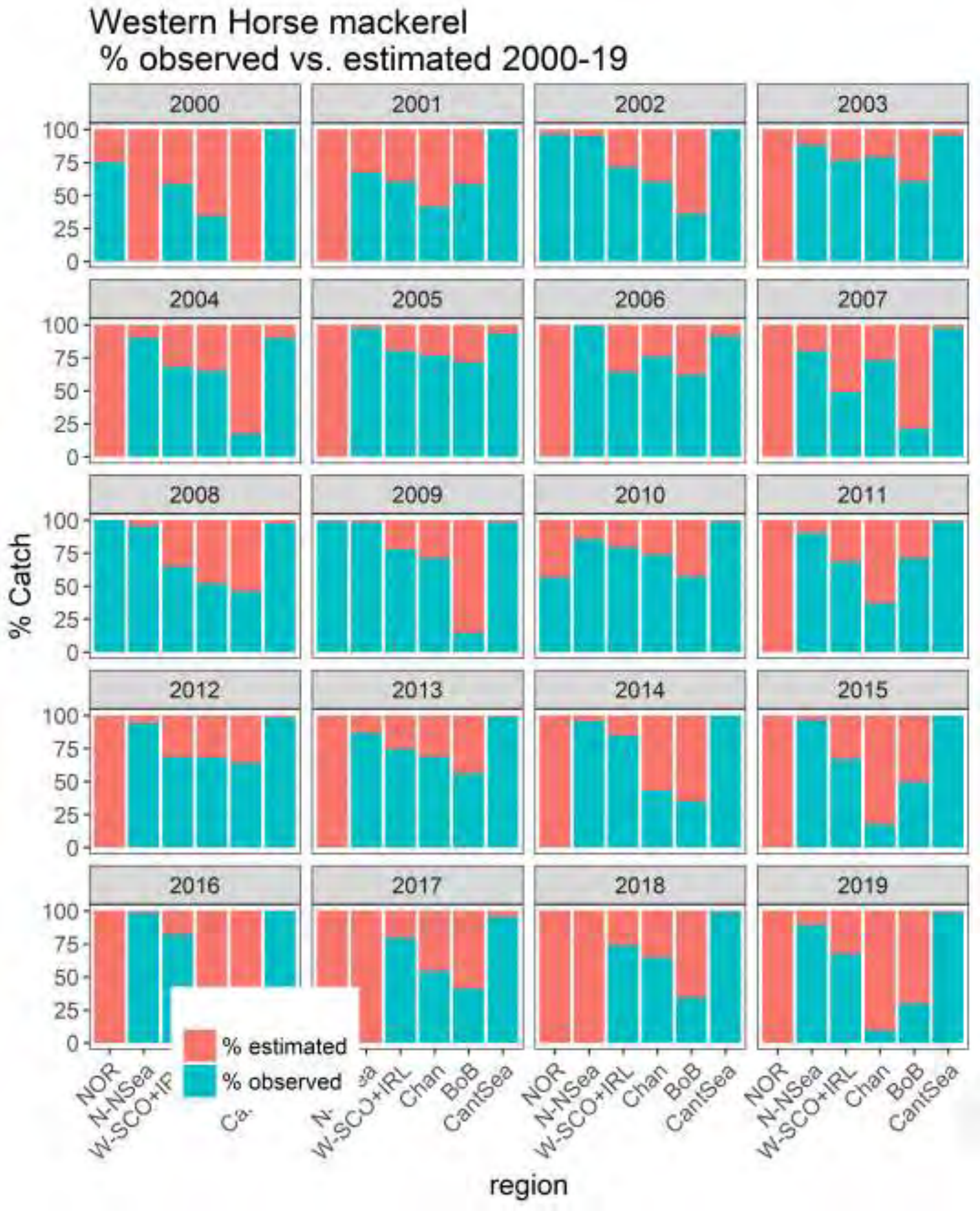

Figure 5.9.5. Western horse mackerel stock. Percentage sampled catch (blue) vs. unsampled catch (red) by division and year. Period 2000–2019. Area of distribution of Western stock was divided into different regions. Chan: (7.e,f,h); W-SCO+IRL (7.a-c, 7.j-k and 6.a); BoB (8.a,b,d); CanSea(8.c); N-Nsea (3.a and 4.a); NOR (2.a and 5.a).

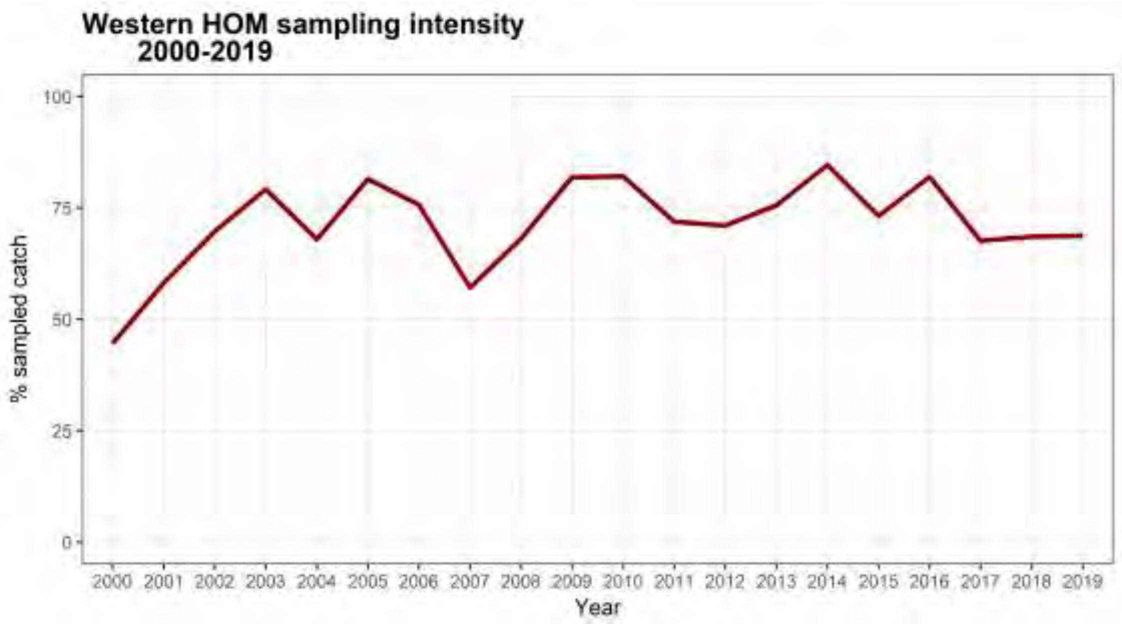

Figure 9.5.6. Western horse mackerel stock. Sampling intensity index as percentage sampled catch in total catch by year. Period 2000–2019.

6 North Sea Horse Mackerel: Divisions 27.4.a (Q1 and Q2), 27.3.a (excluding Western Skagerrak Q3 and Q4), 27.4.b, 27.4.c and 27.7.d

6.1 ICES Advice applicable to 2020 and 2021

In 2012, the North Sea horse mackerel (NSHM) was classified as a category 5 stock, based on the ICES approach to data-limited stocks (DLS). Since then, a progressive reduction in TAC was advised by ICES, from 25 500 tonnes in 2013–2014 to 15 200 tonnes in 2015–2016. This reduction in the advised catch was supported by the analysis of information from the North Sea International Bottom Trawl Survey (NS-IBTS) traditionally used in the assessment, but also new information from the French Channel Ground Fish Survey (CGFS) since 2014. Additionally, in 2015, information on discards in non-directed fisheries became available that has been taken into account in the advice since 2017.

In 2017, this stock was benchmarked and the NS-IBTS and CGFS survey indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHM stock was upgraded to category 3. The joint index showed an increasing trend in 2014 to 2016, but was followed by a decrease again in 2017. In 2018, the index remained at a similar level as in 2017, while the index slightly increased again in 2019. Length-based DLS methods have been applied to data from 2016 onwards. The length-based F/F_{MSY} ratio has been decreasing since 2016, and F was estimated to be still slightly above F_{MSY} in 2019. Stock size relative to reference points is unknown.

Biannual advice for 2020 and 2021 was provided in 2019, based on the data up to 2018 (ICES, 2019). The uncertainty cap was applied, as the index ratio indicated a decrease of more than 20% in 2017-2018 compared to 2014-2016. The precautionary buffer was applied in 2017, and therefore not applied this time. This resulted in a catch advice for 2020 and 2021 of 14 014 tonnes.

6.2 Fishery of North Sea horse mackerel stock

Based on historical catches taken by the Danish industrial fleet for reduction into fish-meal and fish oil in the 1970s and 1980s, approximately 48% of the EU North Sea horse mackerel TAC was taken by Denmark. Catches were taken in the fourth quarter mainly in Divisions 27.4.b and 27.7.d. The 1990s saw a drop in the value of industrial fish, limited fishing opportunities and steep increases in fuel costs that affected the Danish quota uptake. In 2001, an individual quota scheme for a number of species was introduced in Denmark, but not for North Sea horse mackerel. This lead to a rapid restructuring and lower capacity of the Danish fleet, which in combination with the above mentioned factors led to a decrease of the Danish North Sea horse mackerel catches.

Since the 1990's, a larger proportion of the catches has been taken in a directed horse mackerel fishery for human consumption by the Dutch freezer-trawler fleet. This is possible because Denmark has traded parts of its quota with the Netherlands for other species. However, due to the structure of the Danish quota management setup only a limited amount of quota can be made available for swaps with other countries. These practical implications of the management scheme largely explain the consistent underutilisation of the TAC over the period 2010-2014 (approximately 50%; Figure 6.2.1)). However, following the sharp reduction in TAC in 2015 uptake increased significantly in the years thereafter. In 2019, 78% of the TAC was used, with the highest catches taken by the UK, followed by Norway, Netherlands, Lithuania, France and Germany (Figure 6.2.2; Lithuania not shown).

Catches taken in Divisions 27.3.a and 27.4.a during the two first quarters and all year round in Divisions 27.4.b, 4.c and 27.7.d are regarded as North Sea horse mackerel (Section 5, Table 5.4.1). The catches were relatively low during the period 1982—1997 with an average of 18 000 tonnes, but increased between 1998 (30 500 tonnes) and 2000 (451 30 tonnes). From 2000 to 2010, the catches varied between 24 149 and 45 883 tonnes. Since 2014 a steep decline in catches is observed, both due to the reduction in the TAC since 2014 but also due to the underutilization of the quota. In 2019 the catch was 11 803 tonnes, with 68% of the total catch being caught in area 27.7.d, which is a smaller share of the overall catch than in the years before (2018: 80.5%; Figure 6.2.4).

Over the period 1985–2001 most catches were taken in the area 27.4.b (Figure 6.2.3). However, since the early 2000s the proportion of catches from area 27.7.d increased steadily until 2013, when the 92% of total catches were fished in this area (Figure 6.2.4). In 2019, the UK accounted for most of the landings, followed by Norway, the Netherlands, Lithuania, France and Germany (Figure 6.2.5). The majority was still caught in quarter 4 in 27.7d, whereas the Norwegian catches were taken during quarter 1 and 2 in 27.4.a. Most of the discards were reported in 27.7.d by the French bottom-trawl fleet. Discarding in the target pelagic fisheries is considered negligible. New information in 2015 from bottom-trawl fisheries not directed at horse mackerel indicated an overall discard rate of 16.7% for the stock as a whole, while in 2016 this rate was 10%. In 2017 and 2018 the discard rate was 8.3% and 1.8%, respectively, while it decreased to 1.6% in 2019. However, due to a coding mistake in the French data some 2019 discards in quarter 3 in 27.7.d had to be excluded from the overall amount such that actual discards may be higher. Complete discard information for earlier years has not been submitted to ICES. Information from national discard reports for the non-directed bottom-trawl fisheries indicates a similar level of discarding in earlier years.

6.3 Biological Data

6.3.1 Catch in Numbers at Age

In 2019, as in recent years, the coverage of biological sampling remains very low. Samples were available from two countries with regards to Q1 and Q2 in area 27.4.a and in Q4 in area 27.7.d. Overall, only a small proportion (1/3) of landings was sampled, in comparison to 2013 and 2014 when 71% and 63% were sampled respectively (Section 5, Figure 5.9.1). Although most landed catch was taken from 27.7.d in Q4 and in 4a in Q1 and 2, parts of the landings were fished in other areas and quarters (Figure 6.2.5). In order to avoid a biased perception of the age distribution of catches over the year and areas, this partial and uneven sampling effort should be avoided in future years.

Annual catch numbers at age are shown in Table 6.3.1. Catch-at-age for the whole period 1995-2019 are given in Table 6.3.2 and in Figures 6.3.1 and 6.3.2. These data show that since 2005 the age distribution of catches has experienced a reduction, with a decrease in the range of ages of importance in total catches. However, this decrease could be due to the low age sampling, in particular in 2018 (maximum age observed 7 years). In parallel to the rejuvenation of catches, the comparison of catch-at-age data after 1998 by area (Figure 6.3.2) shows that since 2010 commercial catches have increased in area 27.7.d in comparison to the areas 27.3.a and 4.a,b and c where the opposite pattern was found. Due to the low level of sampling effort in 2018, data for this year are only based on a single sample from area 27.7.d in Q4.

Although the 2015 cohort seems to be clear in the catch-at-age distribution, in general, cohort structure is not clearly detectable in the data. In addition to the low sampling levels, this may partly be due to the shifts in the distribution of the fishery. In addition, it may partly be due to age reading difficulties, which are a known to be encountered (e.g. Bolle *et al*., 2011). Most clearly detectable is the relatively large 2001 year-class, although it is not clearly present in the catch data in all years. There are indications that environmental conditions may be an important factor (possibly stronger than stock size) contributing to spawning success of horse mackerel. This is, for example, illustrated by the largest year-classes (1982 and 2001) observed in the Western stock which were produced at the lowest observed stock sizes. Since 2001 is considered to have been a relatively strong year class in the Western stock as well, it is plausible that circumstances in the North Sea were similar to those in Western areas and also allowed for relatively high spawning success in the North Sea.

Lastly, potential mixing of fish from the Western and North Sea stock in area 27.7.d and 27.7.e in winter may also confuse the cohort signals. For example, the large recruitment in the Western stock may have led to more of these fish being located in the North Sea stock area as age 1 fish in 2002. On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated in 2015 with University College Dublin (Ireland) with the intention of clarifying the mixing among the North Sea and the Western horse mackerel stocks. Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015, 2016, and 2017, with a specific focus on the separation between horse mackerel in the western waters and horse mackerel in the North Sea. The results of the whole-genome sequencing indicated that the North Sea horse mackerel stock is clearly genetically different from the Western stock (Farrell and Carlsson, 2019; Fuentes-Pardo *et al*., 2020). Markers were identified that could distinguish with up to 95% accuracy between individuals collected in the North Sea and Western stocks. Follow-up work on this project with a large-scale analysis of samples and a greater temporal and spatial coverage will improve stock delineation further.

6.3.2 Mean weight at age and mean length at age

The mean weight and mean length-at-age in the commercial catches of 2019 are presented in Tables 6.3.3 and 6.3.4 respectively by quarter.

The mean annual weight and length over the period 2000–2019 are presented in Table 6.3.2 and Figures 6.3.3 and 6.3.4, respectively. Although there are no strong differences over this period, since 2010 there seems to be a slight increase in weight of age for age 3-6 years and in length-at-age for age 2-5 years.

6.3.3 Maturity-at-age

Peak spawning in the North Sea occurs in May and June (Macer, 1974), and spawning occurs in the coastal regions of the southern North Sea along the coasts of Belgium, the Netherlands, Germany, and Denmark.

There is no information available about the maturity-at-age of the North Sea Horse mackerel stock.

6.3.4 Natural mortality

There is no specific information available about natural mortality of this stock.

6.4 Data Exploration

6.4.1 Catch curves

The log-catch numbers were plotted by cohort to calculate the negative slope to get an estimate of total mortality (Z). Fully selected ages 3 to 15+ from the 1992–2008 period provide complete data for the 1992 to 2008 cohorts (Figure 6.4.1). The estimated negative slopes by cohort (Figure 6.4.2) indicate an increasing trend in total mortality up to the late 1990s, after which Z fluctuates from year to year. However, due to the low quality of the signals for some cohorts these Z estimates have to be considered with caution.

An analysis of the catch number at age data carried out in 2011 showed that only the 1vs.2, 2vs.3, 7vs.8 and 9vs.10 age groups were positively and significantly correlated in the catch. This analysis has not been updated since, but these results suggest limitations in the catch-at-age data.

6.4.2 Assessment models and alternative methods to estimate the biomass

In 2002 Rückert *et al.* estimated the North Sea horse mackerel biomass based on a ratio estimate that related CPUE data from the IBTS to CPUE data of whiting (*Merlangius merlangus*). The applied method assumes that length specific catchability of whiting and horse mackerel are the same for the IBTS gear. Subsequently, they use the total biomass of whiting derived from an analytical stock assessment (MSVPA) to estimate the relationship between CPUE and biomass.

At the 2014 WGWIDE meeting some exploratory model fits were attempted with the JAXass model, using the data available. The JAXass (JAX assessment) model is a simple statistical catch-at-age model fitted to an age-aggregated index of (2+) biomass, total catch data and proportions at age from the catch. It is based on Per Sparre's "separable VPA" model, an *ad hoc* method tested for the first time at WGWIDE in 2003, and later 2004. A new analysis using this model was also done in 2007 using an IBTS index. In 2014 the model has been coded in ADMB (Fournier *et al.*, 2012) and updated with an improved objective function (dnorm), extra years of data and new methods for calculating the index (see above).

Difficulties in fitting an assessment model for this stock include:

- Unclear stock boundaries
- Difficulty aging horse mackerel
- Lack of strong cohort signals in catch-at-age data
- Scientific index derived from a survey not specifically designed for horse mackerel and not covering one of the main fishing grounds for the stock (7.d)

Catches taken in area 27.7.d are close to the management boundary between the (larger) Western horse mackerel stock and the NS horse mackerel stock. It is quite possible that given changes in oceanographic conditions, or changes in abundance of either of the two stocks, that some proportion of the catches taken in area 27.7.d actually originated from the Western horse mackerel stock. Nevertheless, all assessment models used assume that 100% of fish caught in area 27.7.d belong to the North Sea horse mackerel stock. This is in agreement with stock and management definitions.

In 2018, the working group tried applying the Surplus Production model in Continuous Time (SPiCT) model to North Sea horse mackerel. SPiCT is one of the methods in the ICES guidelines to estimate MSY reference points for category 3 and 4 stocks (ICES, 2018). The model was run using the joint survey index as input or with separate survey indices (NS-IBTS and CGFS). The model with the joint survey index led to conflicting results with the perception of the stock, as B was estimated to be above B_{MSY} and F below F_{MSY}. The model with two separate indices resulted in stock biomass and fishing mortality that were more in line with the perception of the stock. However, there were strong retrospective patterns and wide confidence intervals in recent years. Furthermore, more work is necessary on the setting of the priors, and on ensuring that model assumptions are not violated.

6.4.3 Survey data

6.4.3.1 Egg Surveys

No egg surveys for horse mackerel have been carried out in the North Sea since 1991. Such surveys were carried out during the period 1988—1991. SSB estimates are available historically. However, they were calculated assuming horse mackerel to be a determinate spawner. Horse mackerel is now considered an indeterminate spawner (Gordo *et al.* 2008). Therefore, egg abundance could only be considered a relative index of SSB. The mackerel egg surveys in the North Sea do not cover the spawning area of horse mackerel.

6.4.3.2 North Sea International Bottom Trawl Survey

Many pelagic species are frequently found close to the bottom during daytime (which is when the North Sea IBTS survey operates) and migrate upwards predominantly during the night when they are susceptible to semi-pelagic fishing gear and to bottom trawls (Barange *et al.* 1998). Macer (1977) observed hat dense shoals are formed close to the bottom during daytime, but the top of the shoals may extend into midwater. Eaton *et al.* (1983) argued that horse mackerel of 2 years and older are predominantly demersal in habit. Therefore, in the absence of a targeted survey for this stock, the IBTS is considered a reasonable alternative.

IBTS data from quarter Q3 were obtained from DATRAS and analysed. Based on a comparison of IBTS data from all 4 quarters in the period 1991—1996, Rückert *et al.* (2002) showed that horse mackerel catches in the IBTS were most abundant in the third quarter of the year. In 2013 WGWIDE considered that using an 'exploitable biomass index' estimated with the abundance by haul of individuals larger than 20 cm is the most appropriate for the purpose of interpreting trend in the stock.

To create indices, a subset of ICES rectangles were selected. Rectangles that were not covered by the survey more than once during the period 1991—2012 were excluded from the index area. In 2012, WGWIDE expressed concern that the previously selected index area did not sufficiently cover the distribution area of the stock, especially in years that the stock would be relatively more abundant and spread out more. Rückert *et al.* (2002) also identified a larger distribution area of the North Sea stock. Based on the above, WGWIDE 2013 identified 61 rectangles to be included in the index area as shown in Figure 6.4.3.

6.4.3.3 French Channel Groundfish Survey

In order to improve data basis for the North Sea horse mackerel assessment, alternative survey indices have been explored. Previous indices only covered the North Sea distribution of the stock, while the majority of catches in recent years come from the eastern English Channel (27.7.d). We evaluated the potential contribution of the French Channel Groundfish Survey in 27.7.d in Quarter 4. The CGFS is carried out since 1990 and has frequent captures of horse mackerel. Though this survey is conducted in a different quarter than the North Sea IBTS, the observed seasonal migration patterns of horse mackerel indicate that fish move into the channel following quarter Q3, so the timing is considered appropriate.

In 2015, the RV "Gwen Drez" was replaced by the RV "Thalassa" to carry out the CGFS. In 2014 an inter-calibration process was conducted to quantify the differences in catchability for a large number of species. ICES reviewed this inter-calibration exercise and found a number of drawbacks that may undermine the reliability of the estimated conversion factors. The main concerns were:

- The analyses were limited in the number of tows. Considering that a number of these tows could be zeros for one of the two vessels and possibly resulting in highly uncertain estimates.
- Lack of length-specific correction factor.
- At a standardized depth of 50 m and above, wing spread estimates for the R/V Thalassa as measured by the MARPORT sensor were deemed erroneous, which may question the validity of estimated area swept by the net on the R/V Thalassa and the effect it may have on correction factors for species caught at depth at 50m and greater.
- A number of tow locations including areas outside 27.7.d were excluded. Changing the depth range of a survey can add serious bias in the calibration and the current approach seems to be ignoring this issue.
- Correction coefficients were not measured without error.

However, these limitations were considered by WGWIDE to be of minor importance for the North Sea horse mackerel since:

- Despite being still a low sample size the North Sea horse mackerel was present in all the 32 paired hauls.
- There are no important differences in size distribution (Figure 6.4.4).
- The analysis with and without the areas excluded in the new sampling design did not show important differences (ICES, 2017).
- CPUE of North Sea horse mackerel for hauls deeper than 50 m was relatively low (Figure 6.4.5), and it is expected than the potential problems in determining the conversion factor below that depth range would have a relatively minor impact in the estimated abundance.

For these reasons it was considered appropriate to continue using the CGFS, standardizing the time-series of abundance for the period 1990–2015 with the estimated conversion factor 10.363.

6.4.3.4 Modelling the survey data

In January 2017, a benchmark of the NS horse mackerel assessment was conducted (ICES, 2017). Based on a capacity to model the over-dispersion and the high proportion of zero values in the survey catch data, the hurdle model was considered the best option of all model alternatives tested. The log-likelihood ratio test, the AIC and the evidence ratio statistic supported that the model that best represented the data was a hurdle model with Year and Survey as explanatory factors (including the interaction term) in the count model (GLM-negative binomial), and Year and Survey (without the interaction) in the zero model (GLM-binomial).

The probability of having a CPUE of zero was modelled by a logistic regression with a GLM-binomial distribution model:

$$logit(\pi_i) = Intercept_{zero} + Year_{i,zero} + Survey_{i,zero}$$

where π_i is the mean probability of having a CPUE of zero in haul *i* as a function Year and Survey.

The expected CPUE of North Sea horse mackerel per haul i, conditional to not having a zero in hurdle models (not having a false zero in zero-inflated models), was modelled with a GLM-negative binomial distribution model:

$$\log(CPUE_i) = Intercept_{count} + Year_{i,count}\ x\ Survey_{i,count}$$

This model was used to synthesise the information from both the CGFS and IBTS and predict the average annual CPUE index as an indicator of trends in stock abundance. Separate models sre fit to the juvenile (<20cm) and adult exploitable (≥20cm) sub-stocks. The contribution of the two surveys to the combined index is weighted taken into consideration their respective area coverage as well as the mean wing spread. This index model allowed upgrading of the NSHM to a category 3 stock within the ICES classification.

Similar to the 2019 assessment (ICES, 2019), the model for the adult sub-stock that was run this year returned a warning despite the fact that the model converged. All parameter coefficients were estimated, but not the standard error for the intercept and the parameter θ of the count model. To check the robustness of the hurdle model with the warning, a zero-inflated model was run with the same set-up as the hurdle model. This zero-inflated model was considered to be the second-best model during the benchmark process in 2017 and performed almost equally well as the hurdle model (ICES, 2017). The fitted values of the zero-inflated model were very similar to that of the hurdle model with warning (Figure 6.4.6). The hurdle model from this year and its resulting index values where thus considered robust. Should the warning continue to occur in future assessments, additional testing and investigation should be conducted..

6.4.4 Summary of index trends and length distribution

The survey index for both the juvenile and exploitable sub-stock experienced a marked decline in the early 1990s and fluctuated at relatively low levels thereafter (Figures 6.4.7; Table 6.4.1). This reduction was partly due to the decline of the average abundance per haul over time, but also due to the increase of hauls with zero catch of the adult sub-stock (Figure 6.4.8). The survey index was at its third and second lowest in 2017 and 2018 (lowest in 2009), but shows a slight increase again in 2019 (Figure 6.4.7).

The index trend for the juvenile sub-stock shows large fluctuations since 2015 (Figure 6.4.7). These are mainly attributed to the fluctuating trend of juveniles in the IBTS (Figure 6.4.9), caused by some hauls with high catches of small horse mackerel in 2016 and 2018 (Figure 6.4.10). Fitted values for juveniles in the CGFS show decreasing trend since 2014 (Figure 6.4.9).

The highest proportion of fish caught in 2019 in the IBTS and CGFS were around 17-20 cm (Figure 6.4.10, 6.4.11). Considering the length-at-age for this stock (Figure 6.3.4), this could be the result of the strong year class from 2018 (Figure. 6.4.7, 6.4.10, 6.4.11). Proportions of 0-year old fish were low in both the IBTS and CGFS in 2019 (Figure 6.4.10, 6.4.11), suggesting low recruitment in 2019. The index of abundance of individuals <20 cm could be considered a recruitment index, but future analyses should be carried out to study the correlation between the abundances and survey indices of year classes over time in more detail.

6.4.5 Length distributions of commercial catches and Pelagic Freezer-trawler Association

Currently, length distributions from catch data are only available from 2016 to 2019. Future work is needed to retrieve historic length data in order to present a longer time series. The data used for the analysis come from the commercial catch sampling by countries. For comparison, the analysis is also run with length data from the self-sampling programme of the Pelagic-Freezer-trawler Association (PFA).

The length distributions based on the commercial catch data from 27.7.d show a consistent distribution in time with a mean length between 21.8 and 22.7 cm each year (Figure 6.4.12). Lengths in 27.4.a (caught in Q1 and Q2 only) are higher than those of 27.7.d, with a mean length of 32.9 cm in 2018 and 35.6 cm in 2019 (Figure 6.4.13). The length distributions of the PFA in 27.7.d are similar to those from the commercial catch data (Figure 6.4.14). Mean length per year in the PFA data varies between 20.8 and 23.8 cm. The commercial catch data have a higher proportion of smaller fish (<20 cm) that the PFA data, as discards from the French demersal fisheries are included (Figure 6.4.14).

6.4.6 Data Limited Stock methods and MSY proxy reference points

As part of the ICES approach to provide advice within the MSY framework for stocks of category 3 and 4, different Data Limited Stock (DLS) methods to estimate MSY proxy reference points (ICES, 2012, 2018) for the North Sea horse mackerel were previously explored (Pérez-Rodríguez, 2017). The Length Based Indicators analysis is the DLS method used in this assessment.

As most length samples and catches originate from area 27.7d, only length distributions from this area were used to calculate the MSY proxy. In 2019, the F/F_{MSY} proxy based on the commercial catch samples indicated that fishing mortality was still slightly above F_{MSY}, with F/F_{MSY}=1.025 (Figure 6.4.15), although there has been a decreasing trend since 2016 (Figure 6.4.16). The proxy was also calculated for comparison with length frequencies from the PFA from area 27.7.d. There was a decline in the PFA proxy from 2016 to 2017 (Figure 6.4.16), while the values in 2018 and 2019 were similar to those of 2017, with F/F_{MSY} being 1.045 in 2019.

6.4.7 Ongoing work

On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated in 2015 with University College Dublin (Ireland). Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015, 2016, and 2017, with a specific focus on the separation between horse mackerel in the western waters and horse mackerel in the North Sea. The result of the research indicated that the western horse mackerel stock is clearly genetically different from the North Sea stock (Farrell and Carlsson, 2019; Fuentes-Pardo *et al*., 2020). Markers were identified that will be able to reveal the stock identity of individual horse mackerel from potential mixing areas, namely Division 7.d, 7.e and 4.a. Horse mackerel from 7.d and 7.e will be collected by the PFA on board of commercial vessels in the Autumn of 2020, while during the same period horse mackerel from 4.a will be collected during the NS-IBTS in Q3. The stock identity of the sampled fish will be investigated, and results can be expected in 2021.

6.5 Basis for 2019 and 2020 Advice. ICES DLS approach.

Stock advice for North Sea horse mackerel is biannual. In 2019 the advice for years 2020 and 2021 was provided (ICES, 2019). In 2016, the IBTS and CGFS were modelled together to produce a joint abundance index for the first time. The index indicated that the adult sub-stock did not further decline in 2018, but remained at similar low levels as in 2017, compared to higher levels in 2014 to 2016.

There are some signs of improved recruitment in some years (e.g. 2016, 2018), but the trend of the abundance index for the juvenile sub-stock is fluctuating and, when separated, the two surveys, NS-IBTS and CGFS, do not show the same trend. It remains to be seen if the weak signs of improved recruitment result in higher adult abundance, and the slight increase in the index of the exploitable sub-stock in 2019 suggests this may be the case.

The fisheries in Division 7.d, where most catches take place, mainly catches horse mackerel between 15 and 25 cm (Figure 6.4.12, 6.4.14). With this pattern of exploitation, mostly immature individuals are caught (length at maturity considered to be around 23 cm), which may hinders the recovery of the stock by removing an important portion of the recent year classes before they enter the spawning stock. Related to this concern and starting in the autumn of 2018, the Pelagic Freezer-trawler Association (PFA, the Netherlands) implemented a voluntary move-away scheme in an attempt to avoid catches of small horse mackerel in 27.7.d. The trigger in the move-away scheme is a catch of more than 25% in a haul consisting of small fish (more than 250 fish in a carton of 23 kg, equating to around 18 cm). When the trigger is reached, all vessels of the PFA are notified and instructed to move out of the area with a distance of at least 5 nautical miles. The move-away scheme has been triggered 17 times during the period October – December 2018 and 11 times in 2019.

The index ratio (A/B ratio or 2-over-3 ratio) for the adult sub-stock in the 2019 assessment was 0.39. This indicates that the decline in the abundance index was more than 20%, and therefore, an 80% uncertainty cap was applied. The F/F_{MSY} ratio in 2018 was higher than 1, indicating that the fishing mortality is higher than F_{MSY}. Because the precautionary buffer was last applied in 2017 (*i.e.*, within the last three years), the buffer was not applied in the 2019 advice. Under these circumstances and based on the last year's catch advice of 17 517 tonnes, ICES advised in 2019 that catches of North Sea horse mackerel in 2020 and 2021 should be no more than 14 014 tonnes.

6.6 Management considerations

In the past, Division 27.7.d was included in the management area for Western horse mackerel together with Divisions 27.2.a, 27.7.a–c, 27.7.e–k, 27.8.a, 27.8.b, 27.8.d, 27.8.e, Subarea 6, EU and international waters of Division 5.b, and international waters of Subareas 12 and 14. ICES considers Division 27.7.d now to be part of the North Sea horse mackerel distribution area. Since 2010, the TAC for the North Sea area has included Divisions 27.4.bc and 27.7.d. Considering that a majority of the catches are taken in Division 27.7.d, the total North Sea horse mackerel catches are effectively constrained by the TAC since the realignment of the management areas in 2010.

Catches in Divisions 27.3.a (Western Skagerrak) and 27.4.a in quarters 3 and 4 are considered to be from the Western horse mackerel stock, while catches in quarters 1 and 2 are considered to be from the North Sea horse mackerel stock. Catches in area 27.4.a and 27.3.a are variable. In recent years only Norway has had significant catches in this area, but these are only taken in some years.

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6.8 Tables

Table 6.3.1. North Sea Horse Mackerel stock. Catch in numbers (1000) by quarter and area in 2019

	Number/1000					
1Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0.03	0.03	0.00	0.57	58.87	59.50
3	0.18	0.18	0.02	3.32	346.17	349.87
4	0.09	0.09	0.01	1.73	180.20	182.13
5	0.37	2.06	0.05	6.95	724.35	733.78
6	0.07	40.56	0.01	1.37	142.77	184.78
7	0.08	87.46	0.01	1.60	166.24	255.40
8	0.05	24.01	0.01	0.88	91.64	116.58
9	0.18	109.69	0.02	3.39	353.32	466.61
10	0.22	379.05	0.03	4.08	424.54	807.91
11	0.20	272.13	0.03	3.81	396.42	672.58
12	0.09	197.59	0.01	1.72	178.85	378.26
13	0.08	181.73	0.01	1.58	164.46	347.86
14	0.04	93.17	0.01	0.81	84.32	178.35
15	0.85	1788.72	0.11	16.15	1682.27	3488.11
Sum	2.54	3176.48	0.33	47.95	4994.42	8221.71
2Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.01	0.01
4	0.00	0.00	0.01	0.02	0.04	0.07
5	0.00	1.75	0.09	0.18	0.37	2.39

6	0.01	36.27	1.84	3.91	7.84	49.87
7	0.02	78.52	3.97	8.44	16.92	107.88
8	0.01	21.81	1.10	2.33	4.67	29.91
9	0.03	98.68	4.98	10.60	21.25	135.53
10	0.10	341.05	17.23	36.63	73.44	468.45
11	0.07	243.88	12.34	26.25	52.62	335.17
12	0.05	176.97	8.96	19.05	38.20	243.24
13	0.05	162.70	8.24	17.52	35.13	223.64
14	0.02	83.43	4.23	8.98	18.01	114.67
15	0.47	1602.49	81.14	172.51	345.88	2202.48
Sum	0.84	2847.54	144.12	306.43	614.39	3913.33
3Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0	0	5.56	4.91	17.89	28.35
3	0	0	14.50	28.85	105.19	148.54
4	0	0	97.27	15.03	54.81	167.12
5	0	0	43.16	60.30	219.87	323.33
6	0	0	25.21	10.32	37.64	73.17
7	0	0	0.28	10.45	38.09	48.81
8	0	0	0.18	6.70	24.44	31.32
9	0	0	17.29	25.17	91.80	134.26
10	0	0	0.54	20.61	75.14	96.29
11	0	0	0.59	22.43	81.79	104.81
12	0	0	0.19	7.20	26.27	33.66
13	0	0	0.17	6.62	24.15	30.94
14	0	0	0.09	3.40	12.38	15.87
15	0	0	1.86	70.48	256.99	329.32
Sum	0	0	206.90	292.46	1066.45	1565.80

4Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0	0				
1	0	0				
2	0	0	0.46	49.23	850.83	900.52
3	0	0	2.72	289.46	5003.50	5295.69
4	0	0	1.42	150.83	2604.59	2756.84
5	0	0	5.68	604.99	10445.75	11056.42
6	0	0	0.98	104.60	1533.66	1639.24
7	0	0	1.00	106.93	1257.66	1365.59
8	0	0	0.64	67.72	1008.55	1076.90
9	0	0	2.40	255.15	3669.67	3927.22
10	0	0	2.03	215.67	1166.55	1384.25
11	0	0	2.18	231.84	2169.01	2403.04
12	0	0	0.73	77.26	0.02	78.00
13	0	0	0.67	71.06	0.02	71.74
14	0	0	0.34	36.43	0.01	36.78
15	0	0	7.07	752.10	911.50	1670.66
Sum	0	0	28.31	3013.27	30621.32	33662.90

14Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0.03	0.03	6.02	55.33	928.33	989.75
3	0.18	0.18	17.25	325.35	5459.24	5802.19
4	0.09	0.09	98.71	169.56	2841.92	3110.37
5	0.37	3.81	48.98	680.21	11399.47	12132.84
6	0.08	76.83	28.04	121.74	1723.70	1950.39
7	0.11	165.98	5.26	129.20	1481.01	1781.56
8	0.05	45.82	1.91	78.61	1130.46	1256.85

9	0.21	208.36	24.70	298.10	4140.50	4671.87
10	0.32	720.10	19.83	281.54	1745.02	2766.80
11	0.27	516.02	15.14	288.58	2704.84	3524.85
12	0.14	374.57	9.89	107.15	245.58	737.34
13	0.13	344.43	9.09	98.55	225.82	678.03
14	0.07	176.60	4.66	50.52	115.78	347.64
15	1.33	3391.21	90.17	1029.30	3217.82	7729.84
Sum	3.38	6024.02	379.66	3713.76	37359.49	47480.31

Table 6.3.2. Numbers at age (millions), weight at age (kg) and length at age (cm) for the North Sea horse mackerel 1995-2019 in the commercial fleet catches (2018 distribution based on one sample only due to low sampling level).

Catch	**no**																								
Age	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	1.8	4.6	12.6	2.3	12.4	70.2	12.8	60.4	13.8	15.7	52.4	5	3.4	1.7	34.1	3.3	8.1	9.5	7.6	15.4	49.7	3.6	20.7	27.42	0
2	3.1	13.8	27.2	22.1	31.5	78	36.4	16.8	56.2	17.5	29.8	23.7	15.5	8.8	13.9	22.5	23.3	24.3	10	15.3	23.8	65.2	20.9	49.12	0.99
3	7.2	11	14.1	36.7	23.1	28.4	174.3	19.3	23.4	34.4	27.8	61.5	22.8	36.1	28.4	10.7	76.5	20.4	21.3	8.7	10.1	15.9	62.6	13.19	5.80
4	10.3	11.9	14.9	38.8	17.6	21.4	87.8	11.9	33.2	14.5	12.6	40.9	82.6	16.7	22.1	15.7	37.3	40.2	22.2	30.2	5.8	9.8	10.2	32.74	3.11
5	12.1	9.6	14.6	20.8	23.1	31.3	18.5	5.6	26.9	27.8	16.7	73	71.2	36.4	17.3	23.7	14.6	25.8	27.1	13.8	7.2	7.7	6	4.53	12.13
6	13.2	12.5	12.4	12.1	26.2	19.6	11.5	5.8	10.6	20.2	5.2	23.4	30.5	36.1	16.3	15.9	9.9	20.8	6	7.1	3.8	5.7	3.4	0.69	1.95
7	11.4	8	10.1	14	20.6	19.5	18.3	5.5	6.3	10.6	2.9	13.7	23.9	27.3	21.5	27.6	5.8	3.1	7.2	2.7	3.3	2.5	2.8	0.71	1.78
8	12.6	6.6	8.6	10.8	21.8	9	14.7	10.5	9.6	3.8	2.4	5.9	17.3	21.9	47.1	5.6	6	5	4.3	3.4	1.4	5.1	2.4		1.26
9	7.3	1.5	2.5	8.3	12.9	11.5	10.2	6.3	10.9	5.4	3.8	1.6	7.9	10.2	11.2	6.3	3.4	4.6	4	0.9	1.6	1.2	0.9		4.67
10	5.9	5.3	0.8	4	8.2	9	10	6.8	1.5	11	5.8	1.4	1.7	7.5	9.3	8.3	10.1	1.5	5.4	1	0.9	0.1	0.3		2.77
11	0	0.3	0.3	2.7	2.1	7	9.6	5.1	3.4	6.2	2.3	0.2	0.6	1.9	7.2	2.9	6.9	0.5	3.7	1.3	0.2	0.1	0.5		3.52
12	8.8	1.3	0.3	0.7	0.4	3.1	5.4	3	3.3	4.5	4.1	1.7	0.2	2.1	3.7	0.3	3.6	0.1	1	0.4	0.9	0.4	0		0.74
13	0.2	8.9		1.8	1.4	1.6	3.7	2.2	2.3	6.2	2.5	0.6	0.7	0.4	0.3	0.3	0.8		0.6	0	0.2	1.4	0		0.68
14	4.4	8	1.4	0.3	3.8		2	1.3	3.4	2.3	9.9	1	0.7	2.4	0.9	0.2	0.3	0.2	0	0.2	0.2	0.5	0.3		0.35
15+				5.1	4	12.2	5.8	2.7	4.7	8.5	9.6	0.8		1	6.1	1.1	0.5		0.1	0.1			0.3		7.73

kg	weight																								
Age	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	0.076	0.107	0.063	0.063	0.063	0.075	0.067	0.066	0.075	0.076	0.07	0.074	0.615	0.063	0.074	0.077	0.061	0.069	0.077	0.078	0.062	0.07	0.06	0.061	0
2	0.126	0.123	0.102	0.102	0.102	0.1	0.09	0.096	0.105	0.105	0.087	0.098	0.081	0.096	0.087	0.101	0.092	0.09	0.099	0.11	0.099	0.093	0.086	0.093	0.111
3	0.125	0.143	0.126	0.126	0.126	0.137	0.094	0.129	0.122	0.122	0.104	0.116	0.104	0.109	0.113	0.118	0.096	0.118	0.112	0.113	0.13	0.115	0.113	0.131	0.125
4	0.133	0.156	0.142	0.142	0.142	0.152	0.117	0.155	0.136	0.146	0.133	0.124	0.115	0.125	0.134	0.137	0.115	0.142	0.138	0.135	0.15	0.126	0.131	0.147	0.155
5	0.146	0.177	0.16	0.16	0.16	0.165	0.159	0.171	0.164	0.174	0.159	0.141	0.13	0.145	0.152	0.155	0.145	0.152	0.166	0.144	0.169	0.158	0.173	0.170	0.165
6	0.164	0.187	0.175	0.175	0.175	0.192	0.183	0.195	0.18	0.198	0.197	0.178	0.163	0.161	0.182	0.183	0.166	0.172	0.18	0.177	0.196	0.155	0.189	0.189	0.202
7	0.161	0.203	0.199	0.199	0.199	0.194	0.198	0.216	0.193	0.224	0.238	0.212	0.192	0.193	0.195	0.206	0.193	0.183	0.2	0.184	0.26	0.162	0.177	0.201	0.261
8	0.178	0.195	0.231	0.231	0.231	0.216	0.201	0.227	0.212	0.229	0.248	0.247	0.197	0.221	0.258	0.199	0.193	0.188	0.216	0.201	0.29	0.235	0.188		0.248
9	0.165	0.218	0.25	0.25	0.25	0.244	0.237	0.228	0.24	0.256	0.259	0.236	0.257	0.286	0.253	0.241	0.305	0.212	0.223	0.222	0.265	0.246	0.222		0.261
10	0.173	0.241	0.259	0.259	0.259	0.283	0.246	0.253	0.27	0.29	0.287	0.286	0.255	0.295	0.322	0.227	0.334	0.204	0.226	0.22	0.312	0.359	0.233		0.304
11	0.317	0.307	0.3	0.3	0.3	0.286	0.26	0.303	0.24	0.3	0.335	0.237	0.517	0.273	0.422	0.284	0.345	0.275	0.242	0.264	0.262	0.369	0.257		0.301
12	0.233	0.211	0.329	0.329	0.329	0.354	0.286	0.293	0.298	0.297	0.349	0.261	0.279	0.309	0.447	0.234	0.408	0.195	0.263	0.287	0.318	0.379			0.411
13	0.241	0.258	0.367	0.367	0.367	0.316	0.287	0.317	0.356	0.301	0.338	0.267	0.339	0.375	0.383	0.288	0.474		0.262	0.252	0.351	0.242			0.420
14	0.348	0.277	0.299	0.299	0.299		0.295	0.32	0.316	0.338	0.373	0.302	0.414	0.277	0.362	0.315	0.415	0.187	0.559	0.408	0.235	0.39	0.214		0.429
15+	0.348	0.277	0.36	0.36	0.36	0.35	0.336	0.389	0.353	0.402	0.375	0.404		0.389	0.46	0.351	0.475		0.339	0.273		0.378	0.26		0.431

kg	weight																								
cm	**length**																								
Age	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2018**
1	19.2	19.2	19.2	19.2	19.2	19.1	19.5	19.4	20.3	19.8	18.1	20.1	19.9	20	20.3	20.8	19.2	19.9	20.9	20.4	19.8	20	19.1	19.5	
2	22	22	22	22	22	21.5	21.5	21.7	22.3	22.2	21.5	22	20.8	21.6	21.6	22.6	21.7	21.7	22.4	22.9	22.9	22	21.3	22.2	23.5
3	23.5	23.5	23.5	23.5	23.5	23.9	21.9	23.8	23.7	23.6	22.9	23.4	22.5	23.2	23.2	23.9	23	23.5	23.5	23.6	24.6	23.6	23.3	24.7	24.4
4	24.8	24.8	24.8	24.8	24.8	24.9	23.4	25.4	24.6	25.2	24.7	24.1	23.6	24.1	24.6	25	24.5	25	25.3	24.8	25.8	24.8	24.1	25.6	26.1
5	25.5	25.5	25.5	25.5	25.5	26	26.7	26.3	26.2	26.6	25.9	25.4	24.4	25.6	25.8	25.7	25.9	25.7	27	25.4	26.6	26.4	26.7	26.8	26.6
6	26.4	26.4	26.4	26.4	26.4	27.6	27.5	27.4	27.3	27.5	27.7	27	26.6	26.3	27.2	27.1	27.6	27	27.1	27.3	28.2	26.1	27.5	27.5	28.1
7	27.2	27.2	27.2	27.2	27.2	28.1	28.1	28.6	28.2	28.8	29.8	28.6	27.8	28.1	28.1	28.3	27.7	27.1	28.3	27.5	30.4	27.5	27.5	28.0	30.6
8	29.2	29.2	29.2	29.2	29.2	28.6	28.5	29.3	29	29.2	30.4	29.8	28.1	28.8	30.6	28.4	27.8	27	28.9	28	31.7	30.2	28		30.0
9	29.5	29.5	29.5	29.5	29.5	29.9	29.8	29.4	29.9	30.4	30.8	30.8	30.1	31.2	31.1	30.2	31.9	28.6	29.2	28.8	30.5	30.5	29.1		30.6
10	29.5	29.5	29.5	29.5	29.5	31.2	30.2	30.3	30.9	31.4	31.8	31.5	31	31.8	32.5	30	32.5	28	29.5	29.2	32.5	34.7	29.5		32.1
11	30.6	30.6	30.6	30.6	30.6	31.5	30.7	31.4	30.7	31.9	33.8	31.2	39.5	31.6	35	32.2	33.2	30.1	30	30.7	31.5	35.2	31.1		32.1
12	32.1	32.1	32.1	32.1	32.1	33.6	32	31.6	31.9	31.7	35.6	30.8	31.5	32.2	35.3	30.8	34.6	27.5	30.4	30.6	32.3	35.5			36.0
13	33.3	33.3	33.3	33.3	33.3	33.3	31.7	32.4	32.8	31.9	34	32.1	33.4	33.9	34	31.8	36.4		32.1	30	32.5	31.5			36.3
14	31.1	31.1	31.1	31.1	31.1		32.1	32.4	32.5	33	34.4	32.5	34.5	32.3	34.2	33	36	27.5	38.5	36	30.5	36.1	30.5		36.6
15+	32.5	32.5	32.5	32.5	32.5	33.8	33.4	34.3	33.6	34.8	35.2	35.3		35.1	36.1	34.5	36.9		34.2	32.5		36.1	31.5		36.5

Table 6.3.3. North Sea Horse Mackerel stock. Mean weight at age (kg) in the catch by area for all quarters in 2019

Q1-Q4						
Ages	27.3.a (Q1,2)	27.4.a(Q1,2)	27.4.b	27.4.c	27.7.d	Total
0						
1						
2	0.111	0.111	0.167	0.111	0.111	0.111
3	0.125	0.125	0.161	0.125	0.125	0.125
4	0.154	0.154	0.198	0.154	0.154	0.155
5	0.165	0.184	0.191	0.165	0.165	0.165
6	0.242	0.338	0.243	0.217	0.194	0.202
7	0.307	0.353	0.334	0.281	0.248	0.261
8	0.271	0.328	0.297	0.256	0.244	0.248
9	0.299	0.379	0.309	0.275	0.253	0.261
10	0.367	0.390	0.383	0.342	0.261	0.304
11	0.362	0.401	0.387	0.332	0.278	0.301
12	0.411	0.411	0.411	0.410	0.411	0.411
13	0.420	0.420	0.420	0.420	0.421	0.420
14	0.429	0.429	0.429	0.429	0.429	0.429
15	0.450	0.454	0.452	0.444	0.403	0.431

Table 6.3.4. North Sea Horse Mackerel stock. Mean length (cm) at age in the catch by area for all quarters in 2019

1-4Q						
Ages	27.3.a (Q1,2)	27.4.a(Q1,2)	27.4.b	27.4.c	27.7.d	Total
0						
1						
2	23.5	23.5	25.3	23.5	23.5	23.5
3	24.4	24.4	25.3	24.4	24.4	24.4
4	26.1	26.1	27.0	26.1	26.1	26.1
5	26.6	20.0	26.8	26.6	26.6	26.6
6	29.7	33.4	29.1	28.7	27.9	28.1

1-4Q						
7	32.2	33.9	33.2	31.3	30.1	30.6
8	30.2	30.8	30.5	30.1	30.0	30.0
9	32.0	34.9	32.8	31.1	30.3	30.6
10	34.4	35.3	35.0	33.5	30.5	32.1
11	34.2	35.7	35.1	33.2	31.2	32.1
12	36.0	36.0	36.0	36.0	36.0	36.0
13	36.3	36.3	36.3	36.3	36.3	36.3
14	36.6	36.6	36.6	36.6	36.6	36.6
15	37.2	37.3	37.3	37.0	35.5	36.5

Table 6.4.1. North Sea Horse Mackerel. CPUE Indices of abundance (number/hour) for juvenile (<20cm) and exploitable (≥20cm) sub-stocks, estimated as a combined index for the NS-IBTS Q3 and the French Channel Ground Fish Survey in Q4. The survey indices are derived from the prediction of a hurdle model fit to data over the period 1992-2019 and include a 95% confidence interval based on a bootstrapping procedure (CI_low = lower bound, CI_high = upper bound).

	Juvenile sub-stock (<20 cm)			Exploitable sub-stock (>20 cm)		
Year	**Index**	**CI_low**	**CI_high**	**Index**	**CI_low**	**CI_high**
1992	4281	2069	9018	1376	586	2798
1993	1860	919	3707	556	279	977
1994	2593	1263	5200	1169	553	2203
1995	2026	1132	4004	1347	534	2659
1996	735	319	1583	1055	492	1913
1997	2159	942	4950	626	280	1131
1998	650	322	1251	407	188	744
1999	1441	789	2527	447	209	806
2000	1568	802	3085	422	209	768
2001	2170	1168	4658	517	257	920
2002	2389	1191	4778	425	209	809
2003	1788	943	3202	288	142	570
2004	1005	530	1774	351	160	649
2005	804	426	1459	658	302	1257
2006	532	275	958	697	332	1347
2007	603	315	1034	345	155	761

	Juvenile sub-stock (<20 cm)			Exploitable sub-stock (>20 cm)		
2008	533	277	928	163	81	365
2009	692	366	1260	98	42	195
2010	2262	1148	4486	195	79	396
2011	499	274	1021	226	100	465
2012	319	169	676	153	86	414
2013	1058	560	2091	185	77	424
2014	1534	819	2935	325	147	729
2015	1479	697	3082	433	176	855
2016	3073	1558	6339	438	190	827
2017	946	453	1964	134	57	295
2018	3247	1640	7949	110	45	212
2019	810	380	1633	195	85	423

6.9 Figures

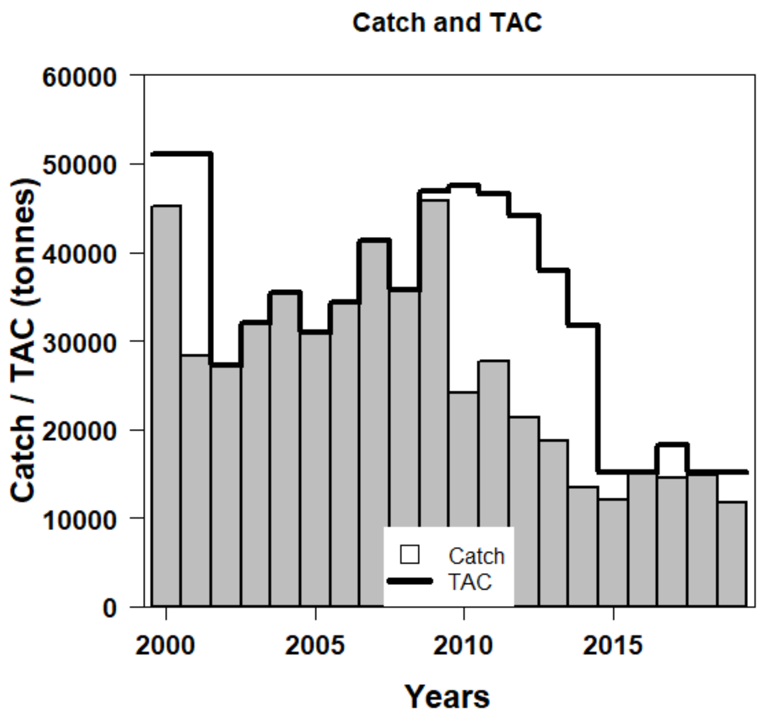

Figure 6.2.1. North Sea horse mackerel. Utilisation of quota from 2000 to 2019.

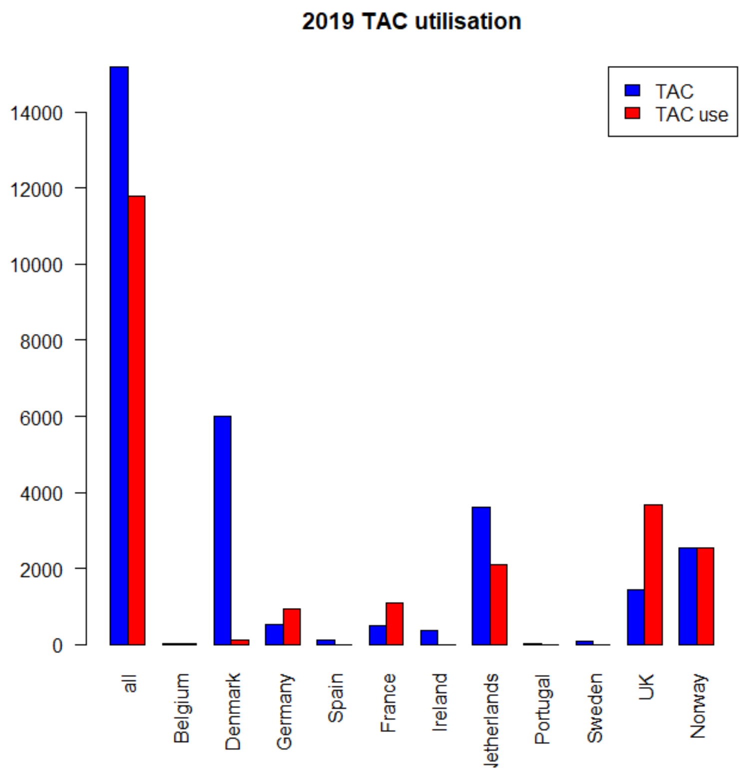

Figure 6.2.2. North Sea horse mackerel. Utilisation of quota by country in 2019.

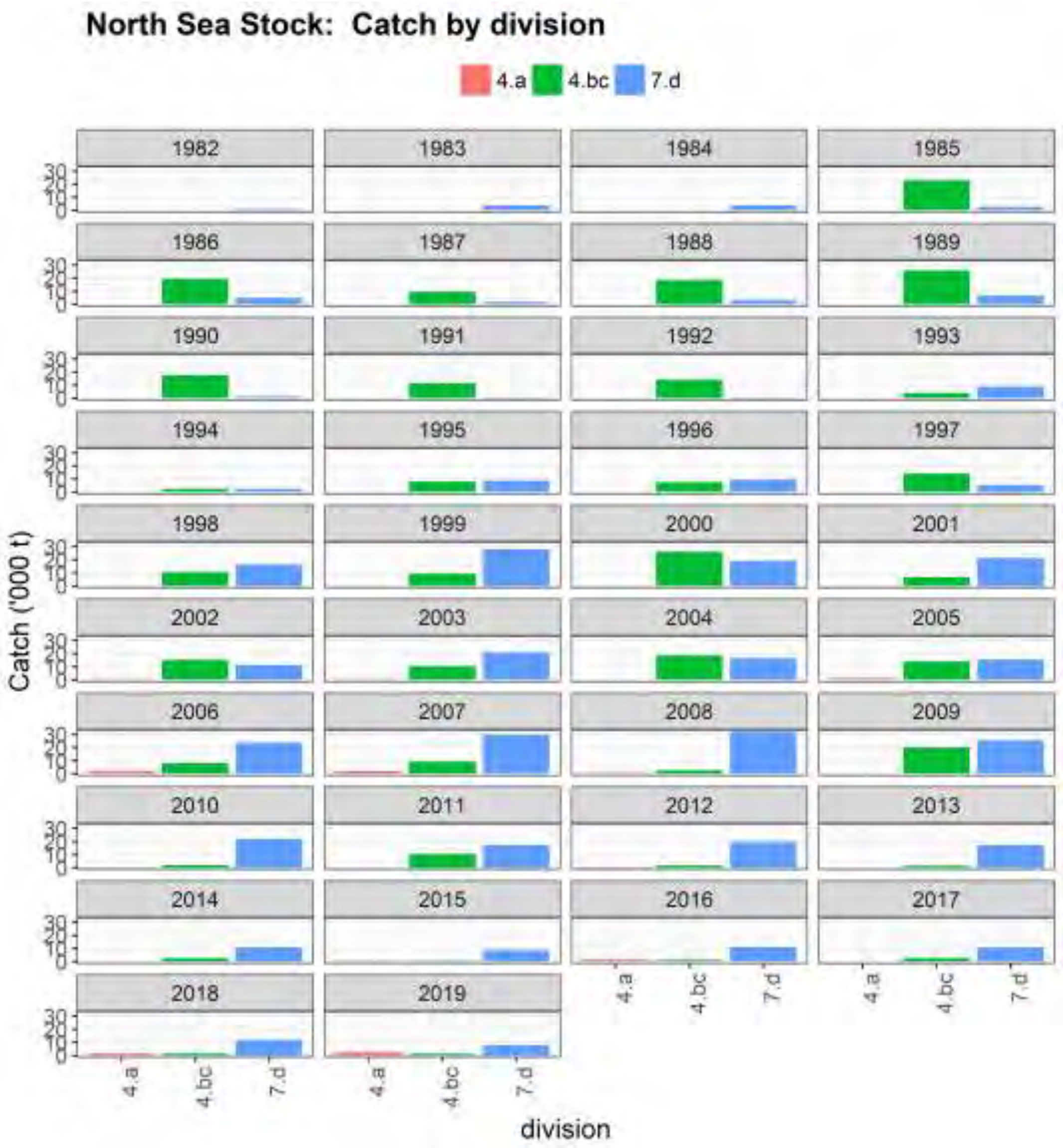

Figure 6.2.3. North Sea horse mackerel. Catch in (1000 t) by division and year from 1982 to 2019.

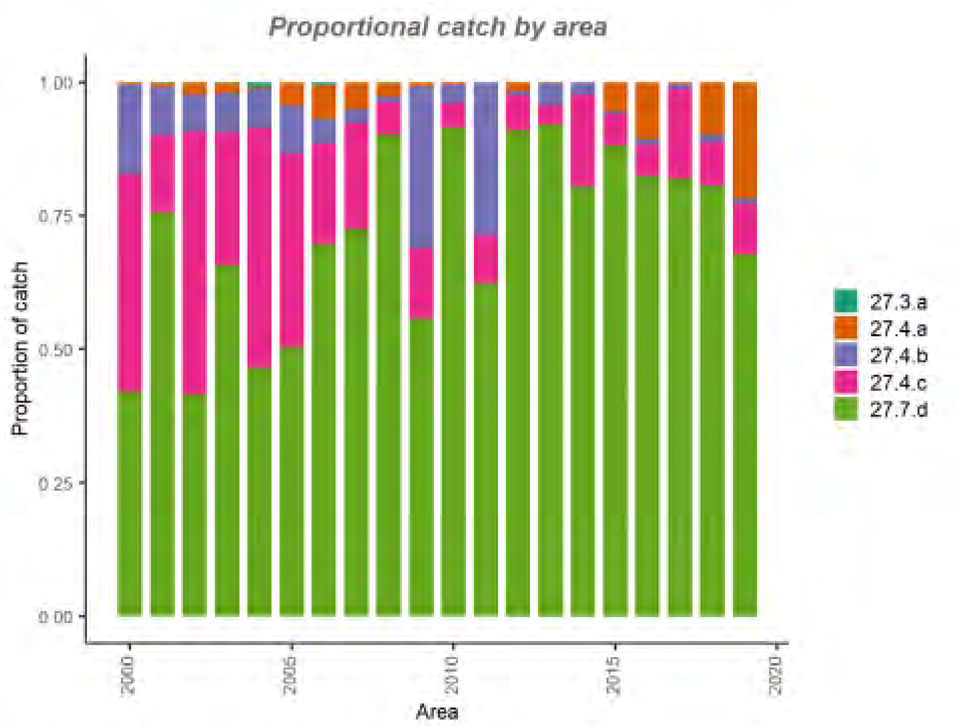

Figure 6.2.4. North Sea horse mackerel. Proportion of catches by ICES division from 2000 to 2019.

Figure 6.2.5. North Sea Horse Mackerel. Total catch (in tonnes) by ICES division, quarter, catch category and country in 2019.

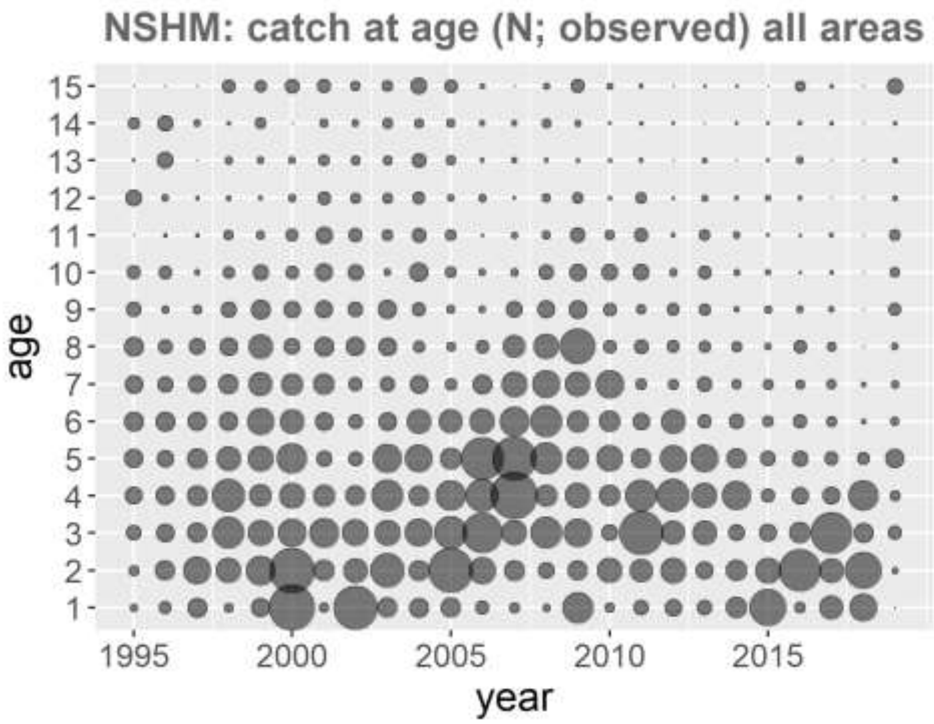

Figure 6.3.1. North Sea horse mackerel age distribution in the catch for 1995-2019. The size of bubbles is proportional to the catch number. Note that age 15 is a plus group.

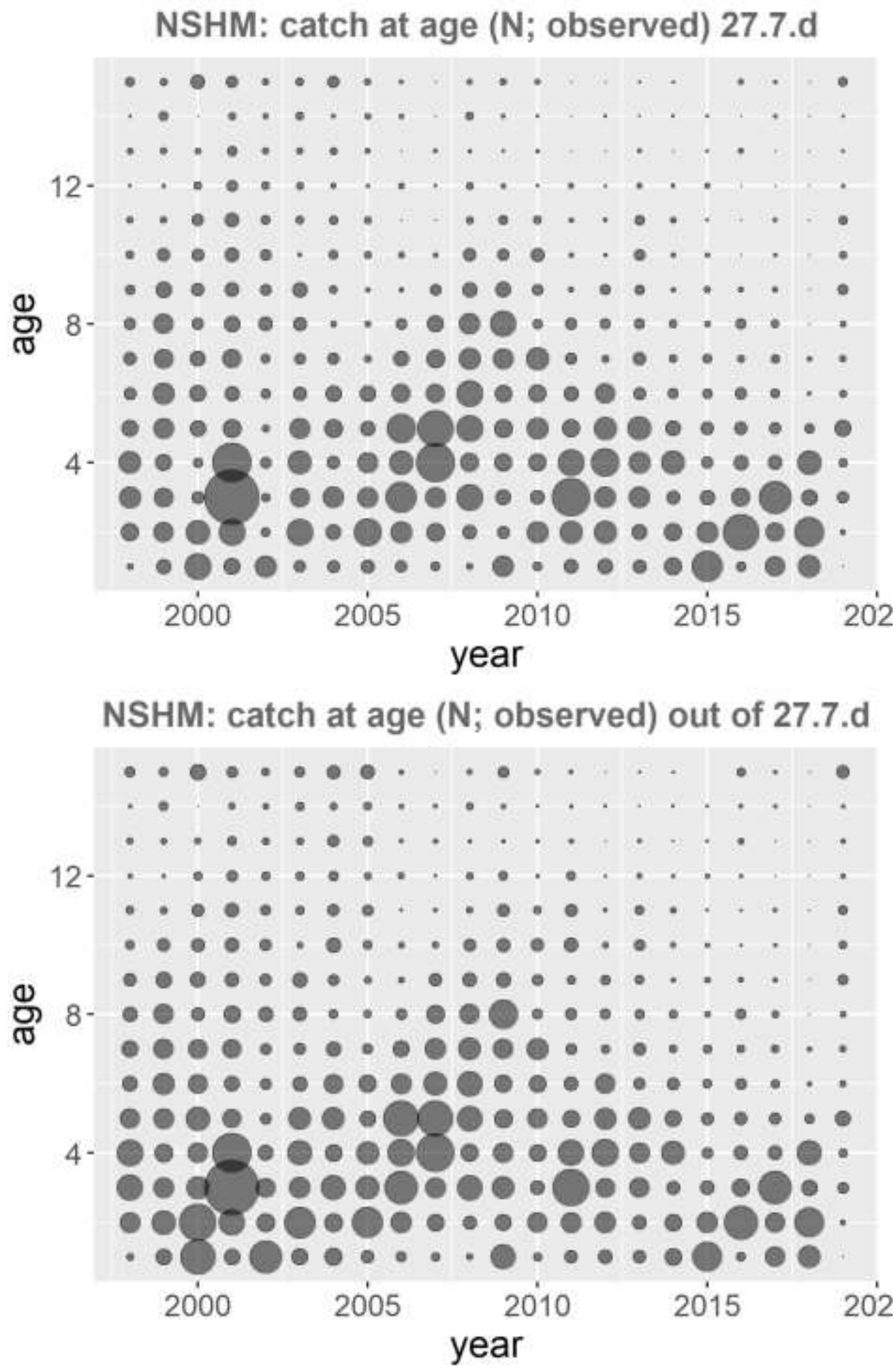

Figure 6.3.2. North Sea horse mackerel. Bubble plots of age distribution in the catch by area for 1998-2019 for area 7.d (upper panel) and out of 7.d (bottom panel). The size of bubbles is proportional to the catch numbers. Note that age 15 is a plus group.

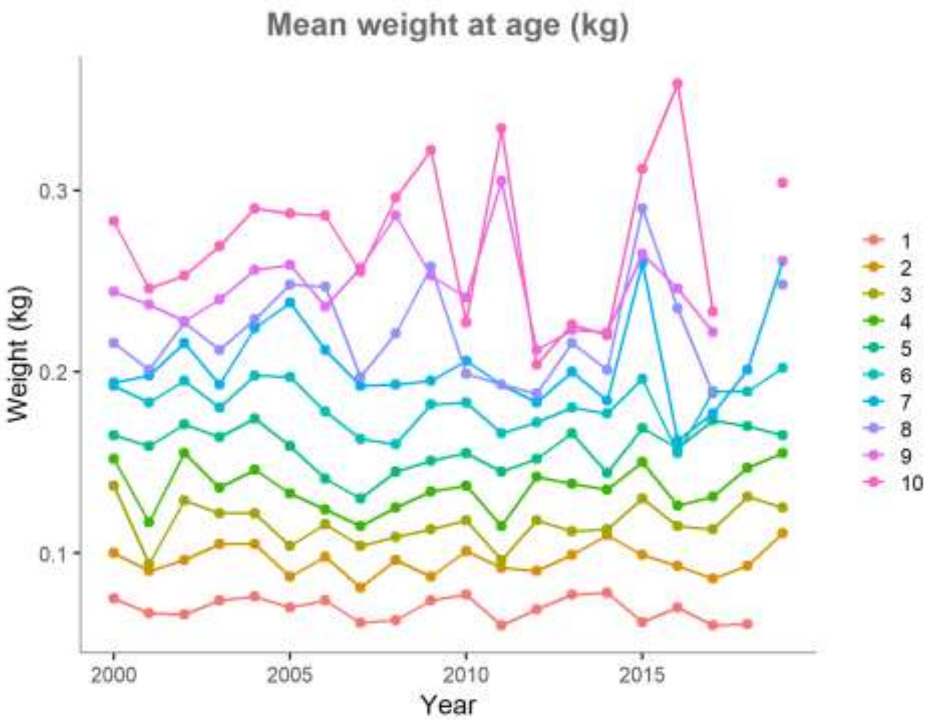

Figure 6.3.3. North Sea horse mackerel. Mean weight at age in commercial catches over the period 2000-2019. Note that only age 1-10 are presented and that 10 is not a plus group.

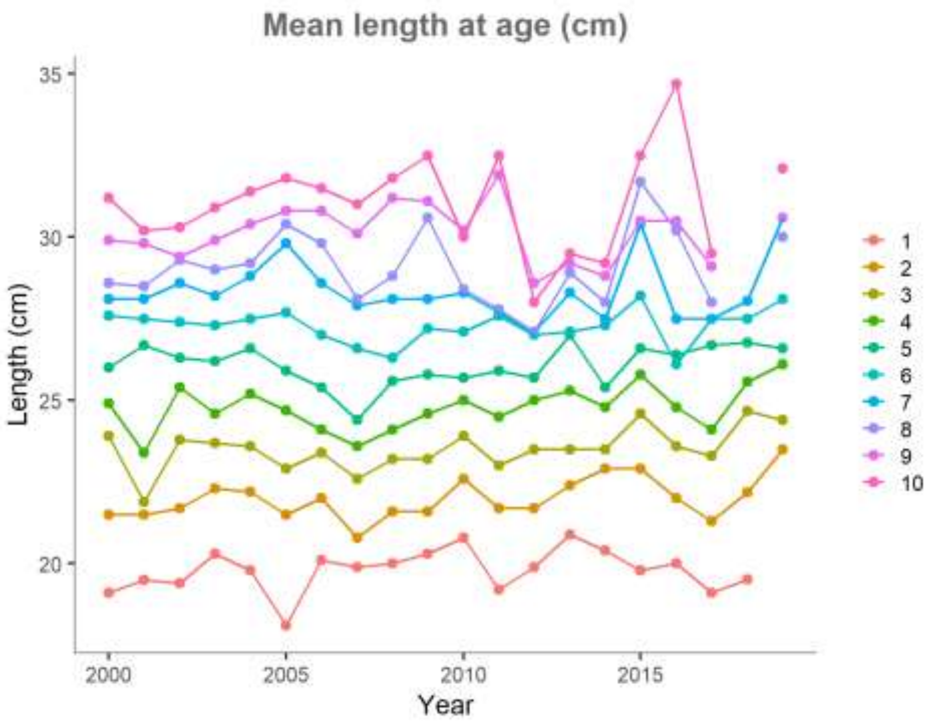

Figure 6.3.4. North Sea horse mackerel. Mean length at age in commercial catches over the period 2000-2019. Note that only age 1-10 are presented and that 10 is not a plus group.

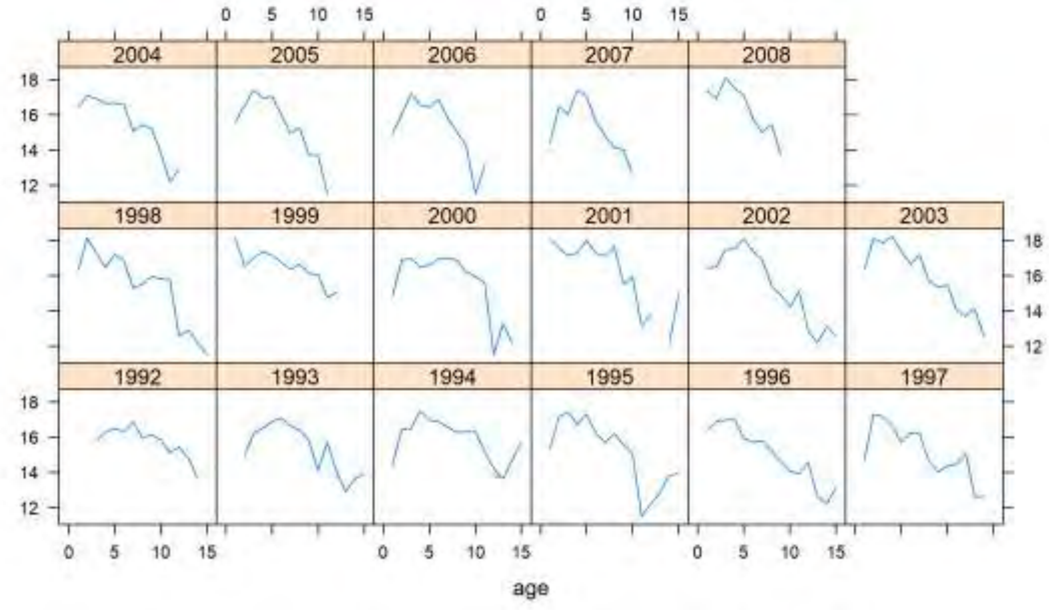

Figure 6.4.1. North Sea Horse Mackerel. Catch curves for the 1992 to 2008 cohorts, ages from 3 to 15+. Values plotted on the vertical axis are the log(catch) values for each cohort in each year. The negative slope of these curves estimates total mortality (Z) in the cohort.

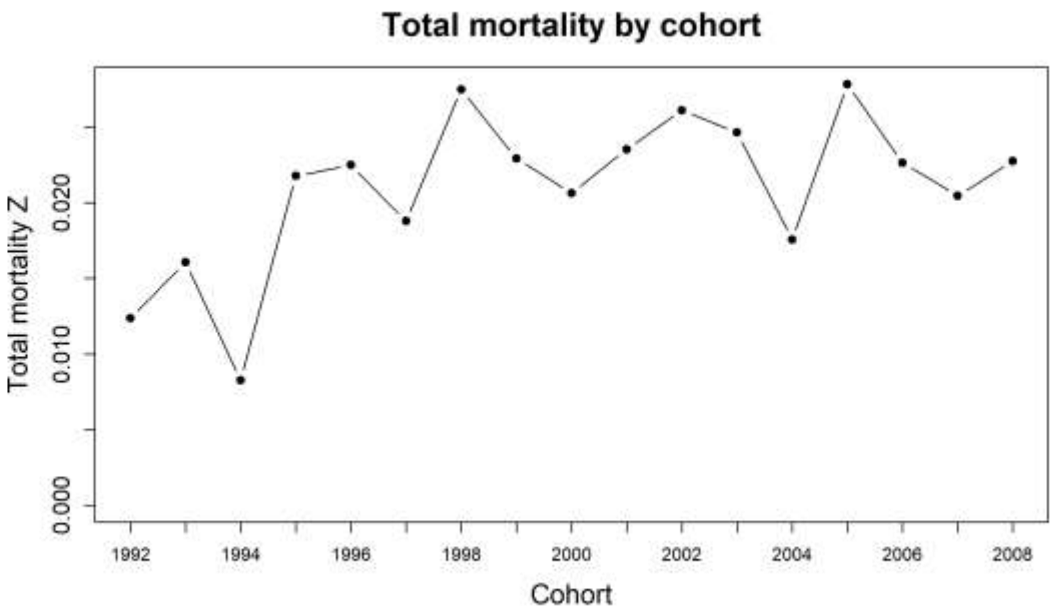

Figure 6.4.2. North Sea Horse Mackerel. Total mortality by cohort (Z) estimated from the negative gradients of the 1992—2008 cohort catch curves (Figure 6.4.1).

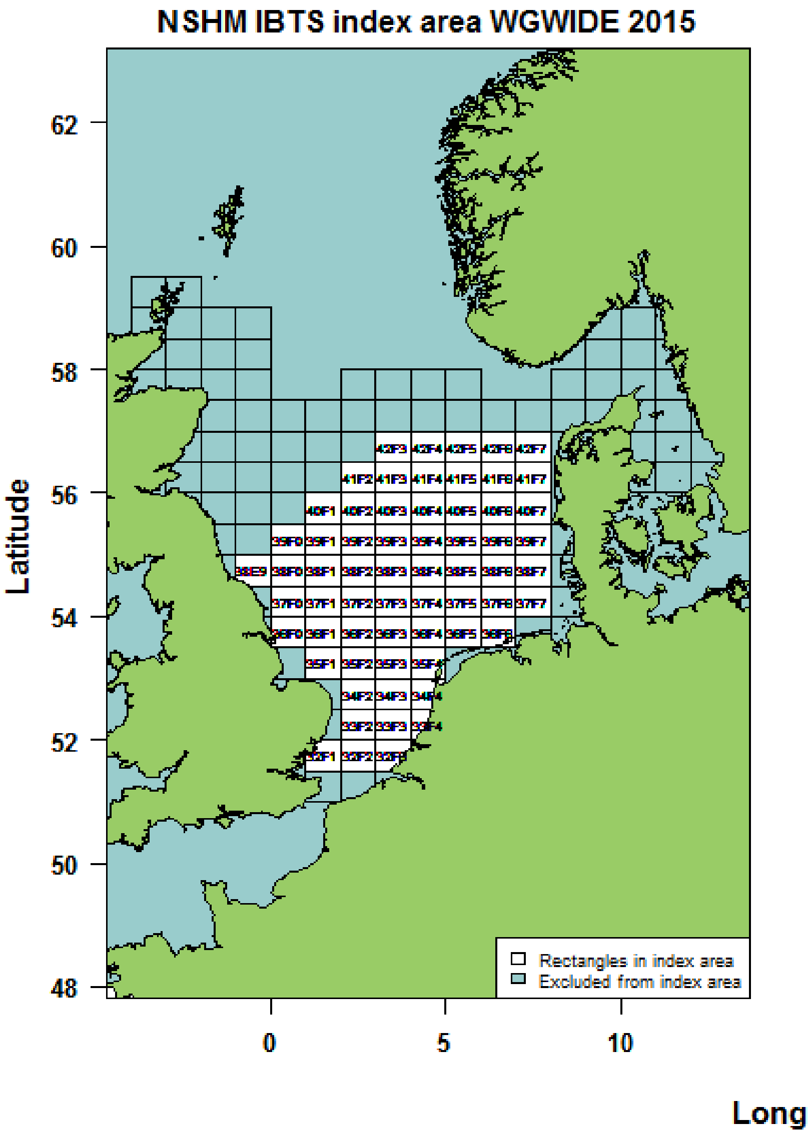

Figure 6.4.3. North Sea horse mackerel. ICES rectangles selected by WGWIDE in 2013 and currently used by the working group.

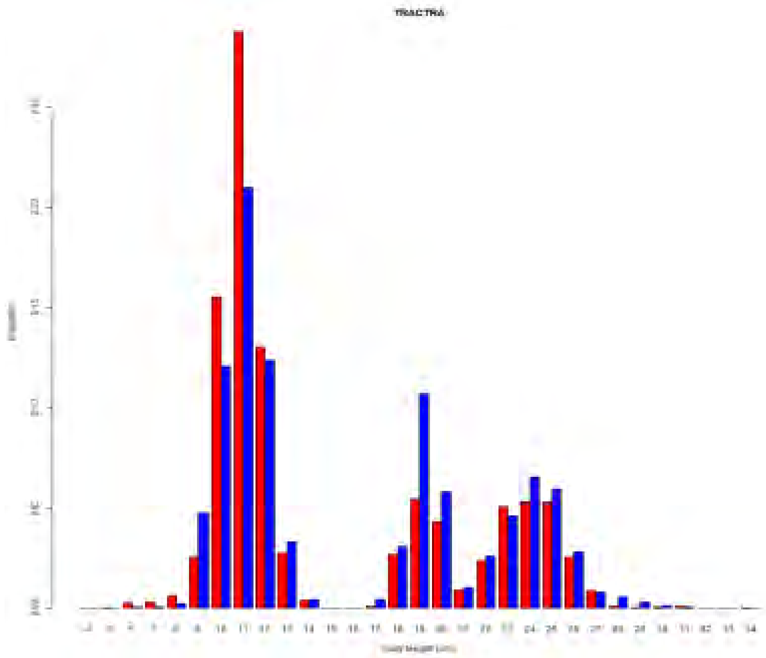

Figure 6.4.4. North Sea horse mackerel. Size distribution of North Sea horse mackerel catches during the inter-calibration exercise conducted in 2014 between the RV Gwen Drez (red bars) and Thalassa (blue bars).

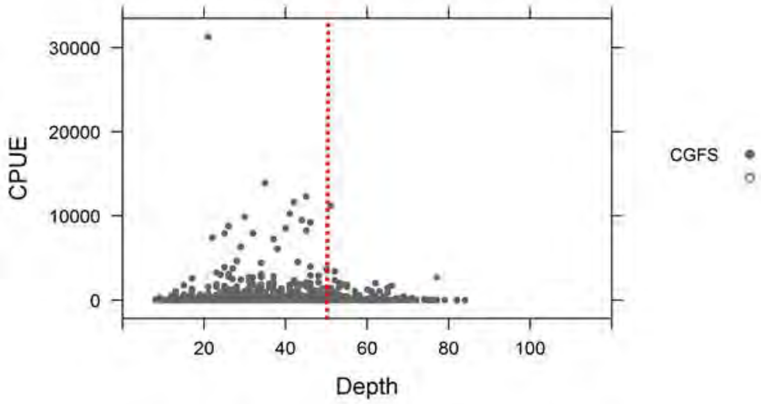

Figure 6.4.5. North Sea horse mackerel. CPUE by depth for the CGFS survey from 1992 to 2017.

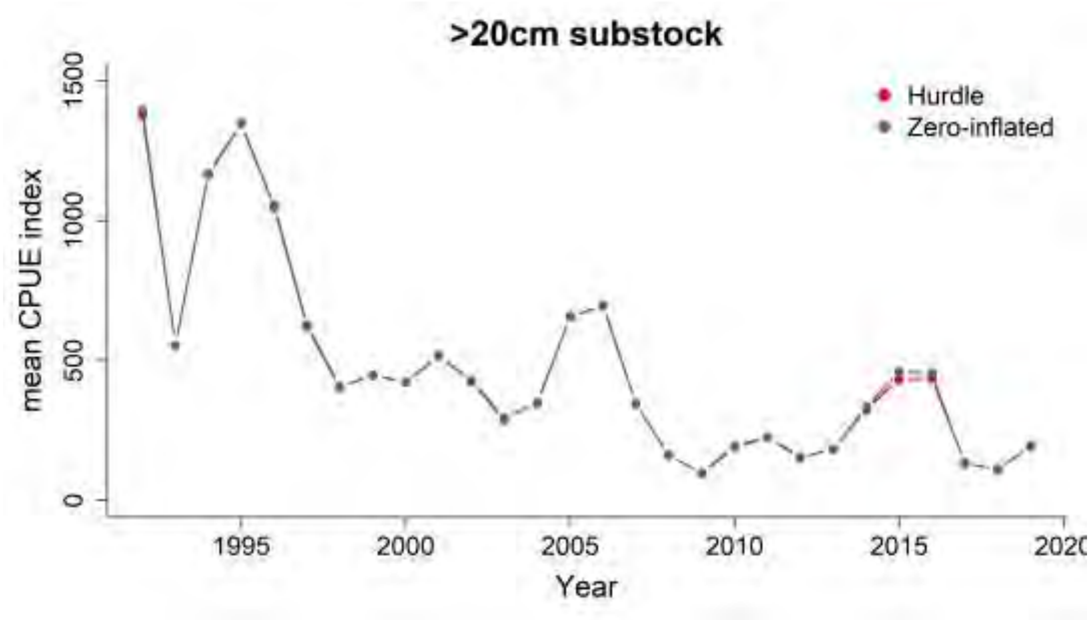

Figure 6.4.6. North Sea horse mackerel. CPUE per year of the exploitable sub-stock (≥20 cm) from 1992 to 2019 as modelled by the hurdle model (red) that returned a warning when ran, and the zero-inflated model.

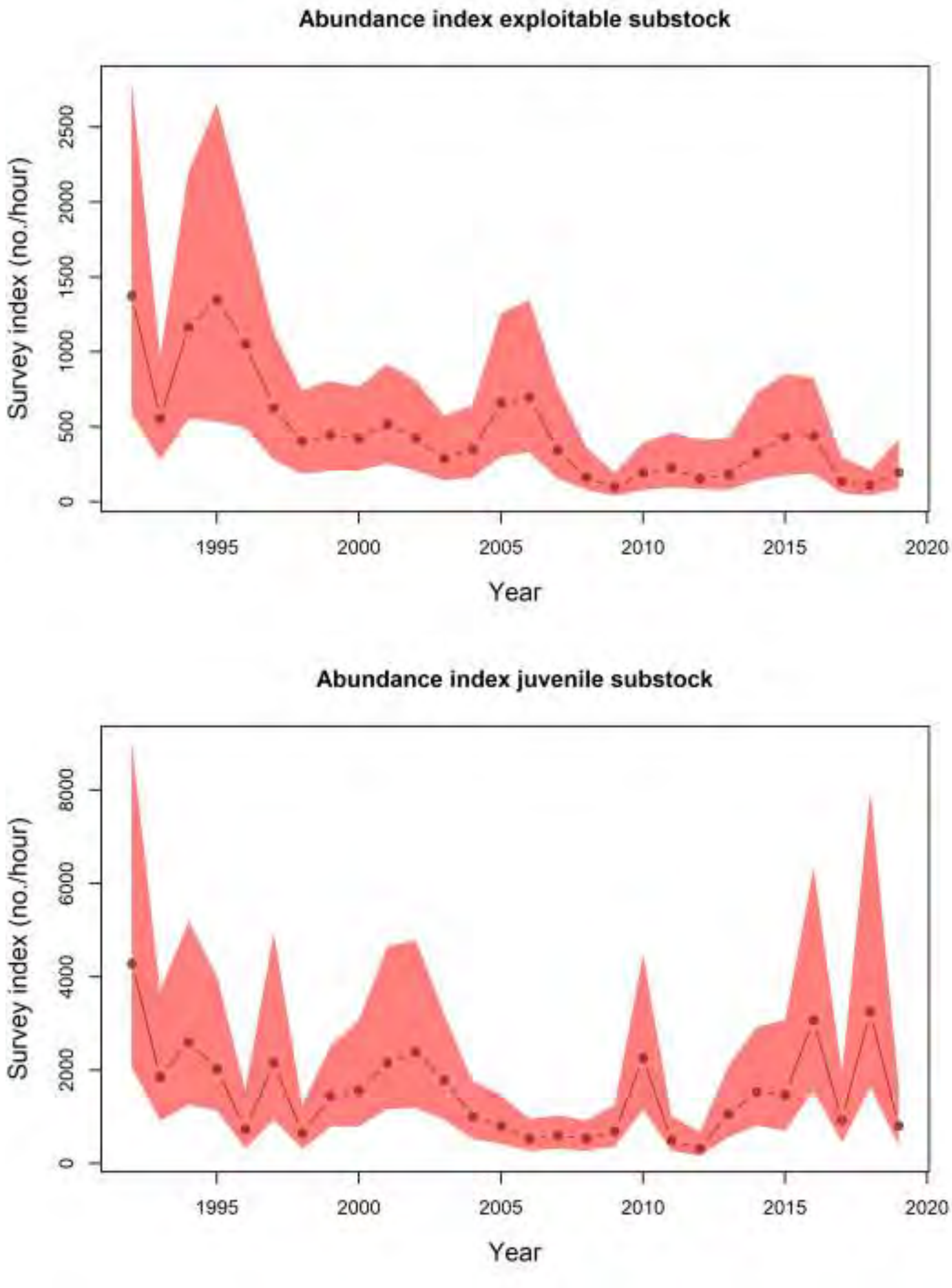

Figure 6.4.7. North Sea Horse Mackerel. Joint CPUE survey index (number/hour) derived from the hurdle model fit to the IBTS survey in the North Sea and the CGFS survey in the Eastern English channel. Top: exploitable sub-stock (≥20 cm), bottom: juvenile sub-stock (<20 cm). The red shaded area represents the 95% confidence interval, which is determined by bootstrap resampling of Pearson residuals with 999 iterations.

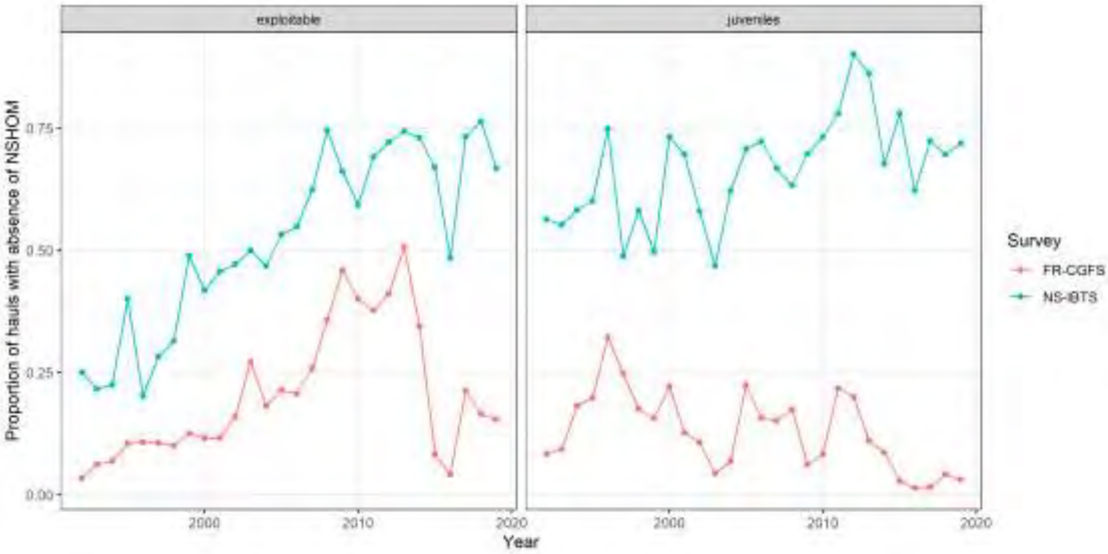

Figure 6.4.8. North Sea horse mackerel. Proportion of hauls with zero catch for the exploitable (≥20cm) and juvenile (<20 cm) sub-stocks in the NS-IBTS (blue) and the CGFS (red) from 1992 to 2019.

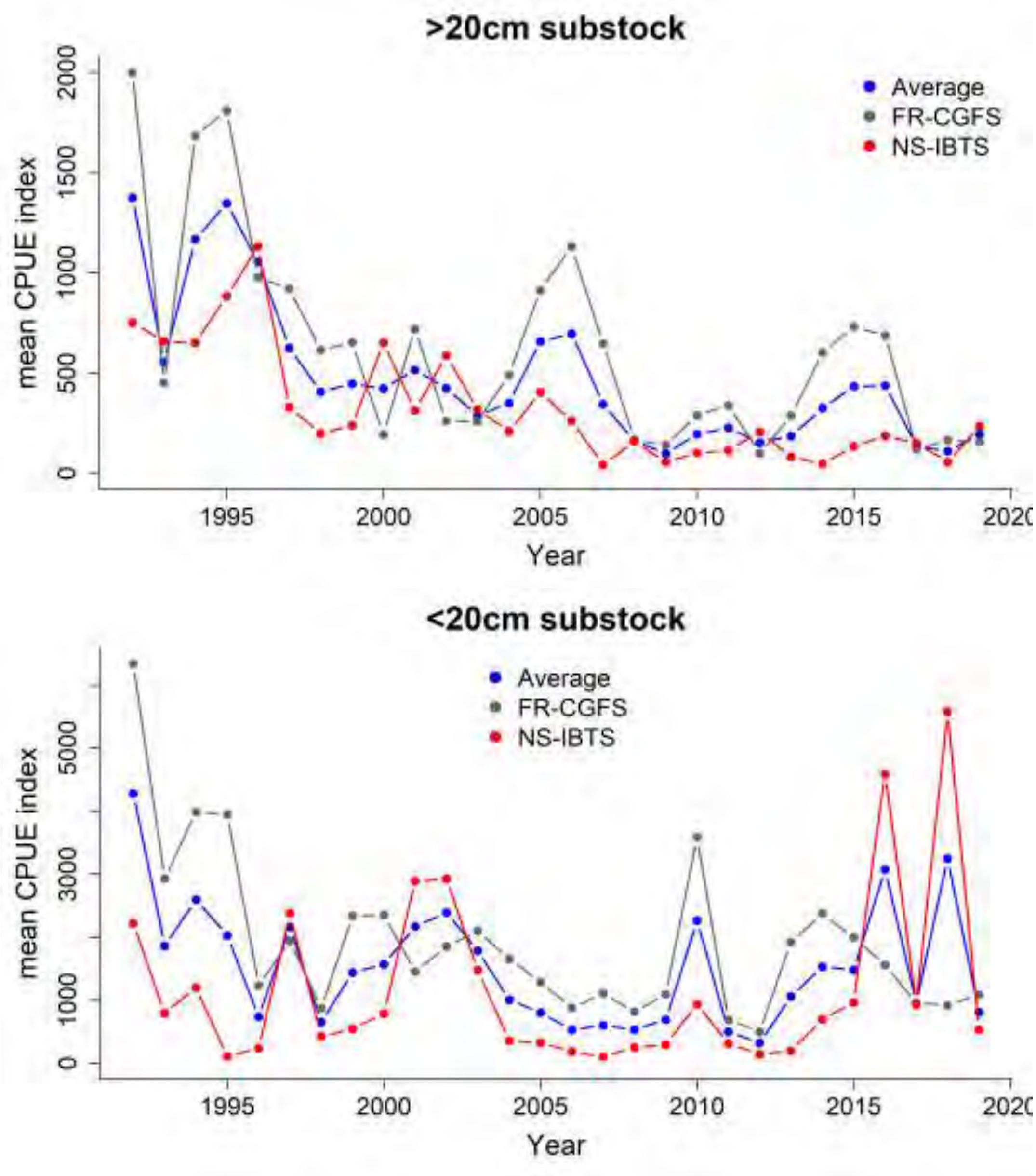

Figure 6.4.9. North Sea Horse Mackerel. Mean CPUE survey index (number/hour) obtained from the hurdle model fit to the IBTS survey in the North Sea (in red), the CGFS survey in the English channel (in grey) and the joint survey index (in blue). Top: exploitable sub-stock (≥20cm), bottom: juvenile sub-stock (<20 cm).

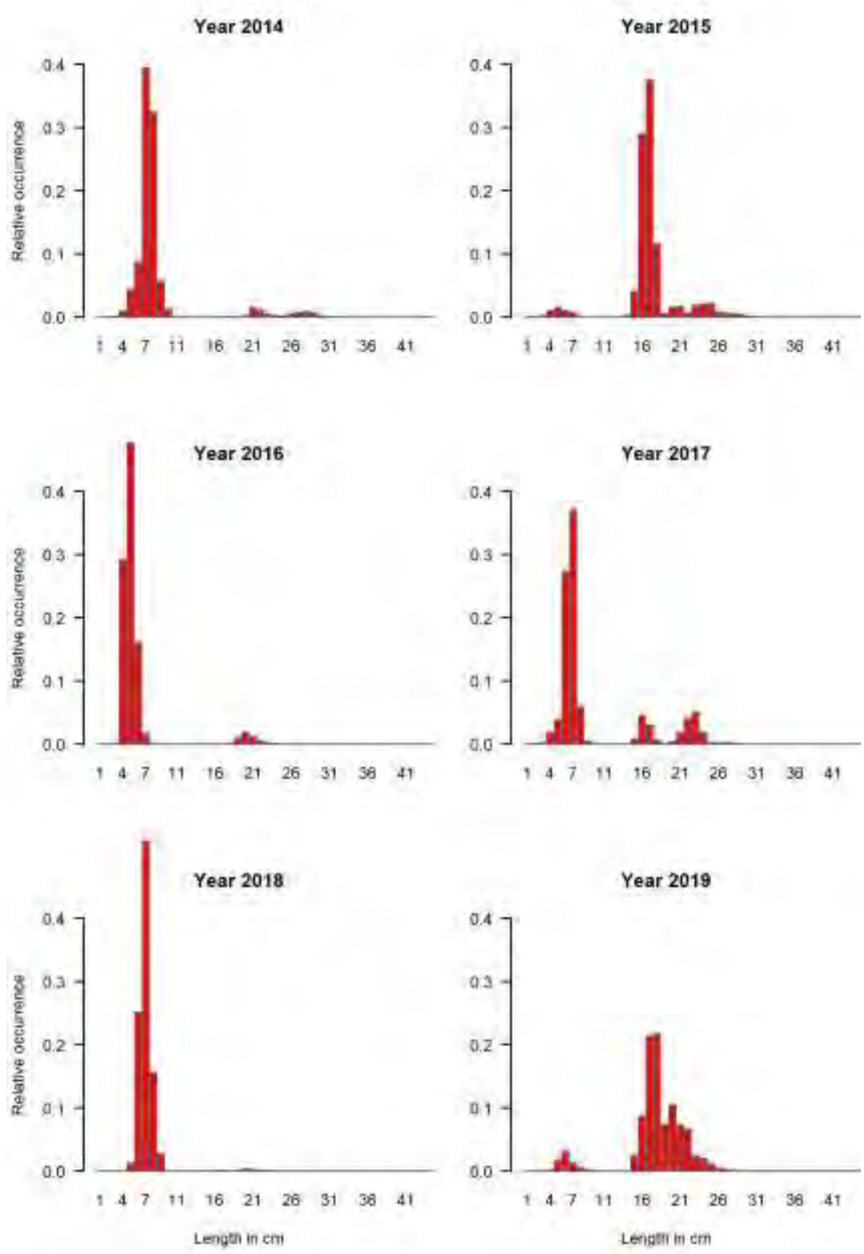

Figure 6.4.10. North Sea horse mackerel. Relative occurrence by length for the period 2014-2019 in the NS-IBTS.

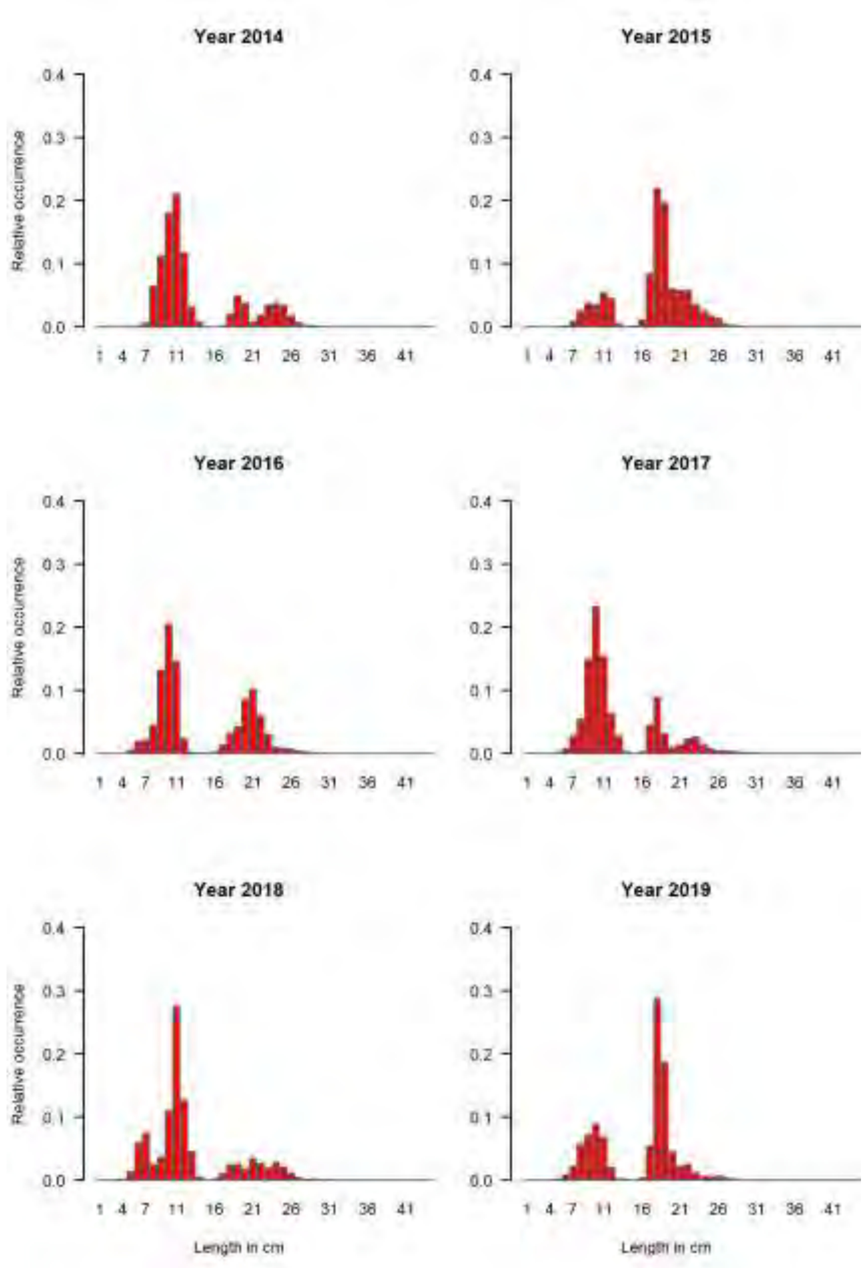

Figure 6.4.11. North Sea horse mackerel. Relative occurrence by length for the period 2014-2019 in the CGFS.

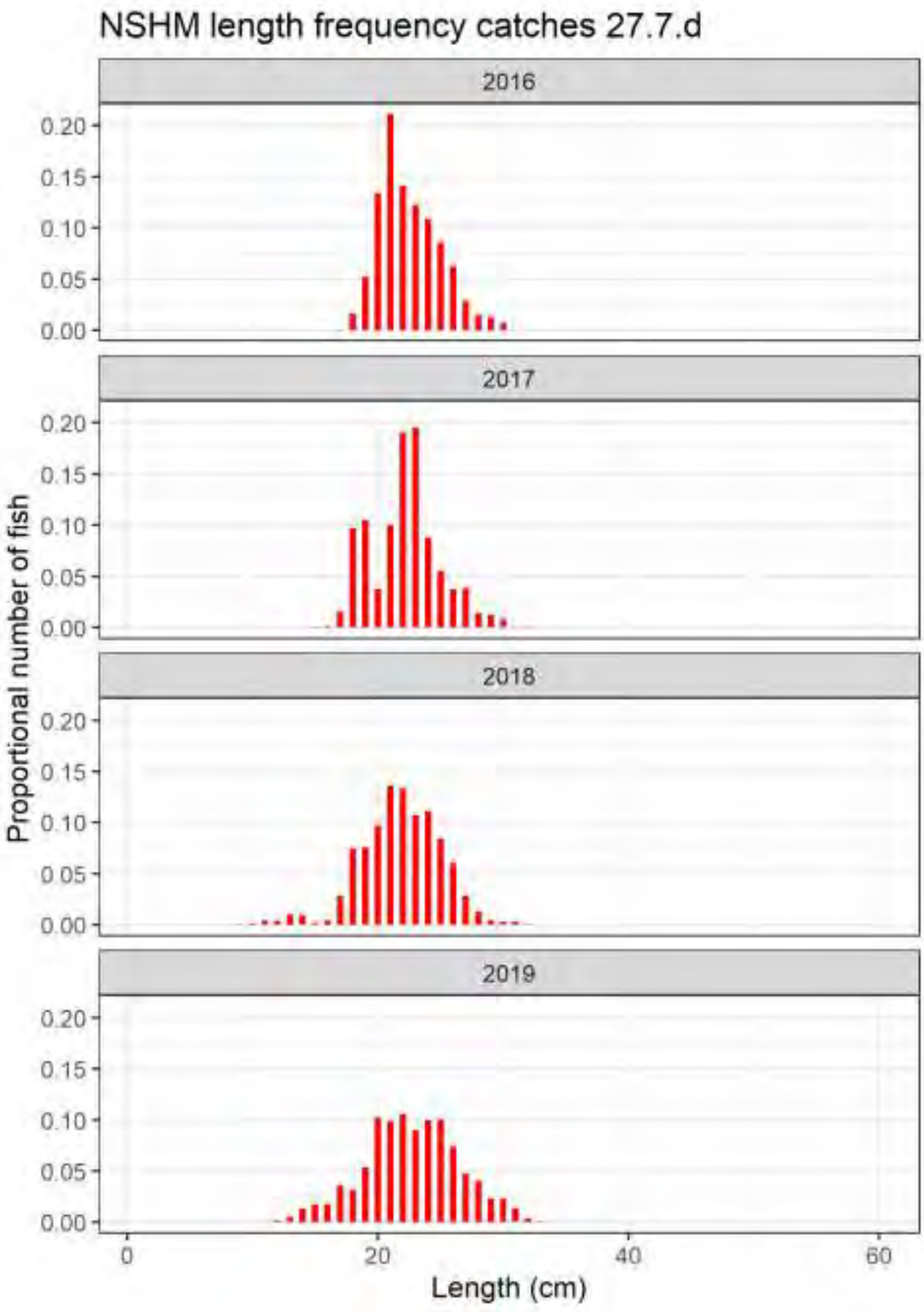

Figure 6.4.12. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.7.d for the period 2016-2019.

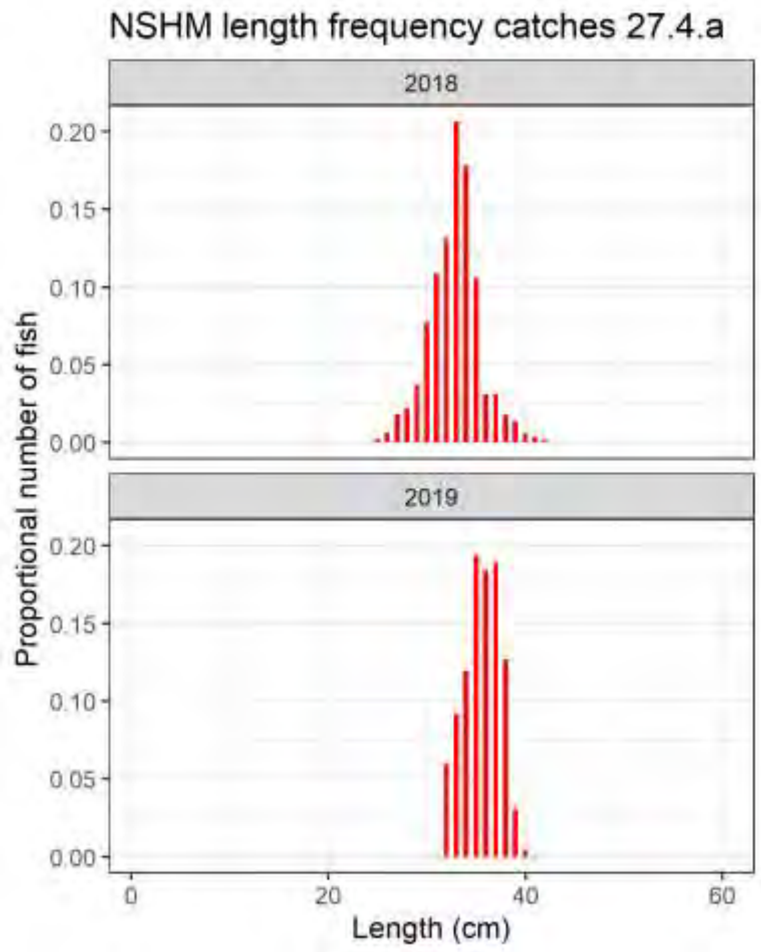

Figure 6.4.13. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.4.a in 2018 and 2019.

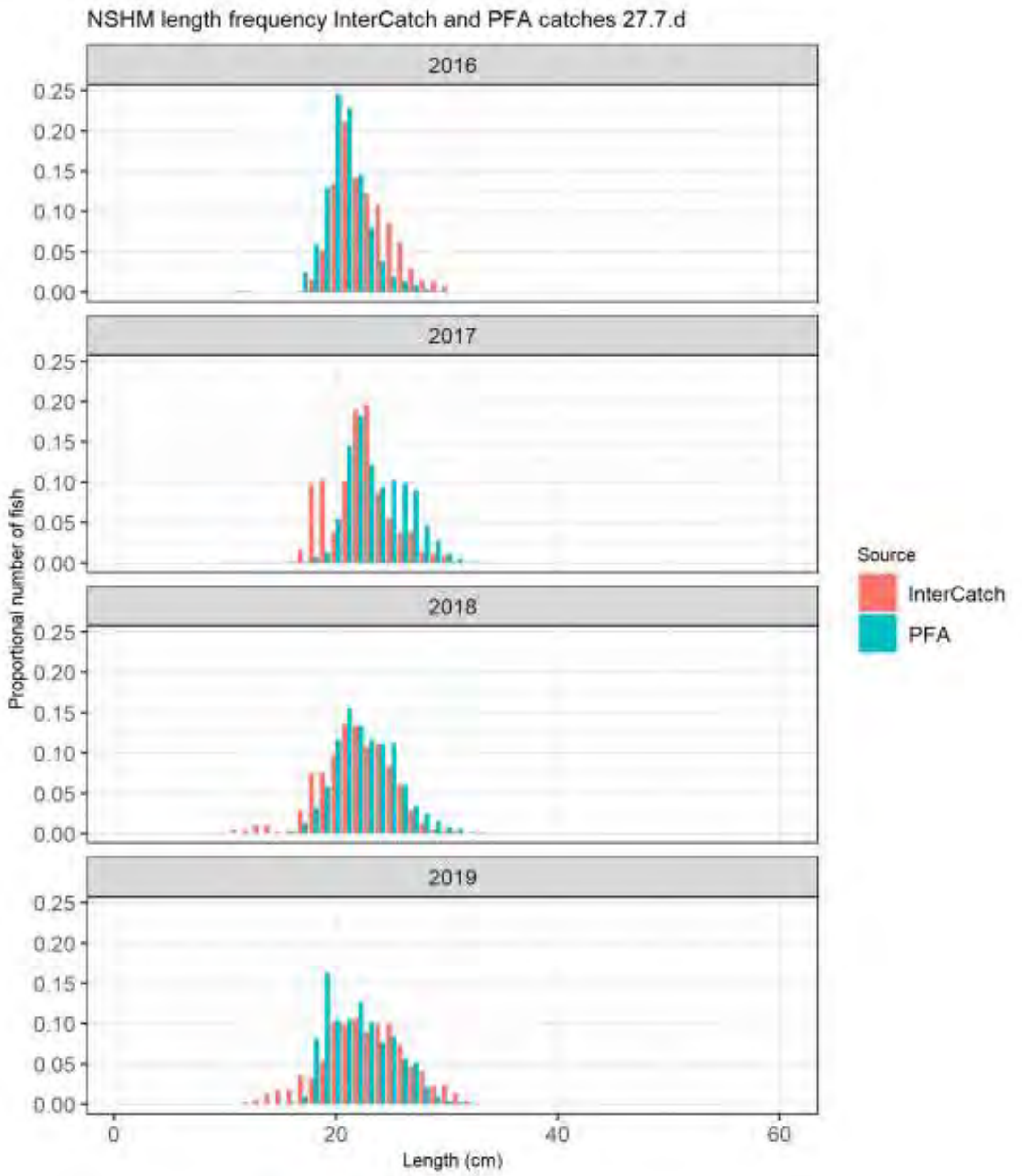

Figure 6.4.14. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches (submitted by countries; blue) and from the self-sampling programme of the Pelagic Freezer-trawler Association (PFA; red) in 27.7.d for the period 2016-2019.

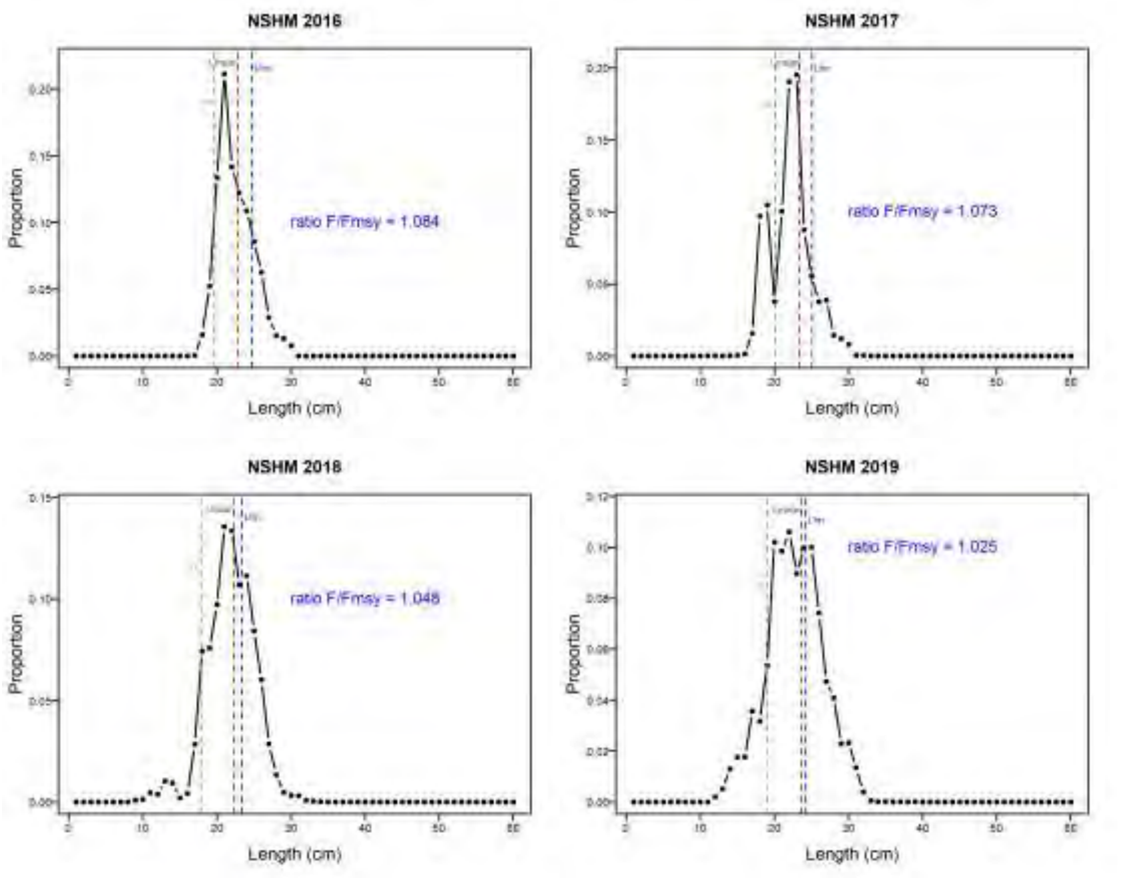

Figure 6.4.15. Length distribution (cm), estimated parameters L_c, L_{mean}, $L_{f=m}$ (cm) and F/F_{MSY} ratio for 2016-2019. Length samples from commercial catches in ICES division 27.7.d.

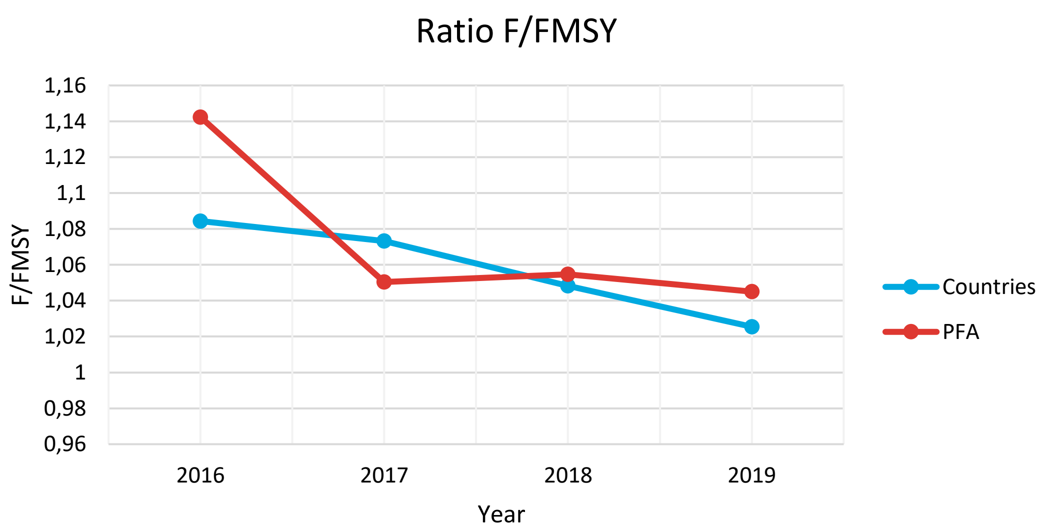

Figure 6.4.16. Trends in F/F_{MSY} proxy based on length samples from commercial catches from countries (blue) and from the Pelagic Freezer-trawler Association (PFA; red) in 27.7.d from 2016-2019. Note that only the MSY proxy based on data from countries is used in the assessment.

7 Western Horse Mackerel –in Subarea 8 and divisions 2.a, 3.a (Western Part), 4.a, 5.b, 6.a, 7.a–c and 7.e–k

7.1 ICES advice applicable to 2019 and 2020

Since 2011, the TACs cover areas in line with the distribution areas of the stock.

For 2019 the TAC set in EU waters (EU 2019/124) was the following:

Areas in EU waters	TAC 2019	Stocks fished in this area
2.a, 4.a, 5.b, 6, 7.a-c, 7.e-k, 8.abde, 12, 14	119 118 t	Western stock & North Sea stock in 4.a 1-2 quarters
4.b,c, 7.d	15 179 t	North Sea stocks
Division 8.c	18 858 t	Western stock

For 2020 the TAC set in EU waters (EU 2020/123) was the following:

Areas in EU waters	TAC 2020	Stocks fished in this area
2.a, 4.a, 5.b, 6, 7.a-c, 7.e-k, 8.abde, 12, 14	70 617	Western stock & North Sea stock in 4.a 1-2 quarters
4.b,c, 7.d	13 763	North Sea stocks
Division 8.c	11 179	Western stock

The TAC for the western stock should apply to the distribution area of western horse mackerel as follows:

All Quarters: 2.a, 5.b, 6.a, 7.a-c, 7.e-k, 8.a-e

Quarters 3&4: 3.a (west), 4.a

The TAC for the North Sea stock should apply to the distribution area of North Sea horse mackerel as follows:

All Quarters: 3.a (east), 4.b-c, 7.d

Quarters 1&2: 3.a (west), 4.a

In 2019 ICES advised on the basis of MSY approach that Western horse mackerel catches in 2020 should be no more than 83 954 tonnes. The Western horse mackerel TAC for 2020 is 81 796 tonnes, the TAC for EU waters only is 80 196 tonnes. The TAC should apply to the total distribution area of this stock. The EU horse mackerel catches in Division 3.a are taken outside the horse mackerel TACs.

7.1.1 The fishery in 2019

Information on the development of the fisheries by quarter and division is shown in Tables 5.1.1 and 5.1.2 and in Figures 5.1.1.a–d. The total catch allocated to Western horse mackerel in 2019 was 124 947 t which is 23 265 t more than in 2018 and 20 290 t less than ICES advice. The catches of horse mackerel by country and area are shown in Tables 7.1.1.1-5 while the catches by quarter since 2000 are shown in Figure 7.1.1.1

7.1.2 Estimates of discards

Discard data are available since 2000 for few countries. Until 2013, the estimates available are considered an underestimation of the overall amount (Figure 7.1.2.1).

In 2019, most countries have submitted discard information. Countries that reported discard estimates for horse mackerel were Denmark, France, Ireland, Spain, Sweden and UK (England and Wales) and UK (Scotland). 2019 discard estimates for Germany, the Netherlands and Norway are considered to be equal to zero. Total discards for western horse mackerel were 3 141 tonnes, equal to 2.5 % in weight of the total catches, a decrease in comparison to last year.

Discard data are included in the assessment as part of the total catches.

Length frequency distributions of discards were provided by Spain, France and UK but are not included in the assessment length-frequency input data.

7.1.3 Stock description and management units

The Western horse mackerel stock spawns in the Bay of Biscay, and in UK and Irish waters. After spawning, parts of the stock migrate northwards into the Norwegian Sea and the North Sea, where they are fished in the third and fourth quarter (for area 4.a, only catches taken in quarters 3 and 4 are considered to be from the western stock). The stock is distributed in divisions 2.a, 5.b, 3.a, 4.a, 6.a, 7.a-c, 7.e-k and 8.a-e. The geographical catch distribution is described in Section 5.3 (Figure 7.1.3.1). The western stock is considered a management unit and advised accordingly. At present there are no international agreed management measures. The EU regulates the fishery by TAC. This TAC is now set in accordance with the distribution of the stock although catches in division 3.a are taken outside the TAC.

7.2 Scientific data

7.2.1 Egg survey estimates

In 2019, the triennial mackerel and horse mackerel egg survey was carried out in the western and southern spawning areas. A working document with preliminary results of the survey was presented to WGWIDE members in 2019 (O'Hea *et al*. 2019). On finalisation, results were revised slightly by WGMEGS in April 2020.

An overview of the spawning distribution of each survey period for the Western horse mackerel stock is presented in Figure 7.2.1.1.

The mean daily stage I egg production estimates (DEP) for each survey period are plotted in figures 7.2.1.2 and 7.2.1.3. with the results from previous surveys included for comparison. The period number and duration are the same as those used to estimate the egg production for the western component NEA mackerel, as are the dates defining the start and end of spawning.

Total Annual Egg Production (TAEP) in 2019 was estimated at $1.78*10^{14}$. This is a decrease of almost 54% compared to the value observed in 2016 and the lowest production in the historic time-series (Figure 7.2.1.4 and Table 7.2.1.1).

The daily egg production curve revealed a spawning maximum in the last survey period and the shape of the egg production curve (Figure 7.2.1.2) and trend of bar plot (Figure 7.2.1.3) suggest that some spawning may have continued after the survey ended and therefore the entire temporal extent of horse mackerel spawning may not have been covered during the survey period.

Fecundity investigations

WGMEGS had planned to collect samples of 1300 female horse mackerel in periods 6 and 7 of the 2019 egg survey, for batch fecundity and POF analyses. In total, 625 horse mackerel were caught in these periods combined and very few female samples showed the necessary oocyte development for batch fecundity estimation. Only 4 female samples were in the spent stage with the majority of the females sampled in an early oocyte development stage, even in period 7. This would indicate that the peak spawning was not reached in period 7.

7.2.2 Other surveys for western horse mackerel

Bottom-trawl surveys

An updated bottom-trawl survey index for recruitment was available for 2019: the index is based on IBTS surveys conducted by Ireland, France and Scotland covering the main distribution of the stock (Bay of Biscay, Celtic Sea, West of Ireland and West of Scotland) from 2003 to 2019, and uses a Bayesian Delta-GLMM for the calculation of an index of juvenile abundance based on catch rates (ICES 2017b). The updated index is shown in Figure 7.2.2.1 (middle panel) and data for 2017-2019 indices given in Table 7.2.2.1. The 2017 data point was highly uncertain due to very limited coverage of the French survey: the French research vessel had technical issue and could therefore only cover less than 1/3 of the stations usually sampled. Despite this high uncertainty, the 2017 data point suggested a very strong recruitment to be expected the following year. This perception was confirmed by the presence of numerous small fish in the 2017 and 2018 catch data. The overall trend suggests an increase in recruitment from 2013 to 2017 and a decrease back down to 2015 levels in 2018 and subsequent decrease in 2019.

Acoustic surveys

In the Bay of Biscay two coordinated acoustic surveys are taking place it spring, PELGAS (Ifremer-France) and PELACUS (IEO-Spain).

The 2020 Spanish survey (PELACUS0320), normally carried out on the RV “Miguel Oliver” and covering ICES division 8c, was cancelled due to the coronavirus (COVID-19) pandemic, a few days before its planned start in March, as was the 2020 French PELGAS survey.

7.2.3 Effort and catch per unit effort

No new information was presented on effort and catch per unit effort. Further information can be found in the stock annex.

7.2.4 Catch in numbers

In 2019, the Netherlands (6.a, 7.behj), Ireland (6.a, 7.b), Norway (4.a), Germany (6.a) and Spain (8.bc) provided catch in numbers-at-age (Figure 7.2.4.1). The catch sampled for age readings in 2019 covered 72%, in 2018 covered 69% and in 2017 covered 68%. Catch in number-at-length were available from the Netherlands (6.a, 7.behj), Ireland (6.a, 7.b), Norway (4.a), Germany (6.a) and Spain (8.bc) as well as from France (7.e, 8.ab), England (7.eg) and Scotland (4.a, 6.a).

The total annual and quarterly catches in number for western horse mackerel in 2019 are shown in Table 7.2.4.1. The sampling intensity is discussed in Section 5.9.

The catch-at-age matrix is given in Table 7.2.4.2 and illustrated in Figures 7.2.4.2 and 7.2.4.3. The latter shows the dominance of the 1982-year class in the catches since 1984 until it entered the plus group in 1997. Since 2002, the 2001-year class, which entered the plus group in 2016, has been caught in considerable numbers. The 2008-year class can be followed in the catch data suggesting it was stronger than other year classes subsequent to the 2001.

Germany, Spain, Ireland, the Netherlands and UK (England) also provided the age length keys (ALK) which were used in 2019.

7.2.5 Length and age data

Mean length-at-age and mean weight-at-age in the catches

The mean weight- and mean length-at-age in the catches by area, and by quarter in 2019 are shown in Tables 7.2.5.1 and 7.2.5.2. Weight-at-age time-series is shown in Figure 7.2.5.1.

Mean weight at age in the stock

Prior to 2017, estimates of mean weight-at-age in the stock for the assessment were based on catch weight-at-age from Q1 and Q2, (Table 7.2.5.3). At present, the stock weight-at-age used in the forecast is an output of the assessment (presented in Table 7.4.1). Further information can be found in the stock annex.

7.2.6 Maturity ogive

Maturity-at-age is presented in Table 7.2.6.1. In the assessment model a constant logistic function was used (Figure 7.2.6.1). Further information can be found in the stock annex.

7.2.7 Natural mortality

A fixed natural mortality of 0.15 year^{-1} is assumed for all ages and years in the assessment. Further information can be found in the stock annex.

7.2.8 Fecundity data

Potential fecundity data (10^6 eggs) per kg spawning females are available for the years 1987, 1992, 1995, 1998, 2000, 2001: the data are presented in Table 7.2.8.1 but were not used in the assessment model. In the assessment the fecundity is modelled as linear eggs/kg on body weight. Further information can be found in the stock annex.

7.2.9 Information from stakeholders

The EU fishing industry, partly in conjunction with the Pelagic Advisory Council (PELAC), has been working on a number of research projects relevant to Western horse mackerel that are briefly reported here. More details can be found in section 1.5.5 of this report.

In 2018, the results of a large-scale genetic analysis of horse mackerel were published (Farrell *et al.* 2018) which concluded that the spawners of North Sea and Western horse mackerel can be genetically identified as two distinct stocks. However, at that stage it was not yet possible to separate the two stocks when they occur in mixed samples. Therefore, a follow-up project was initiated to carry out a full genome sequencing of horse mackerel in order to increase the genetic resolution. Results have been published in 2020 (Farrell *et al.* 2020) and confirm the separation between North Sea and Western horse mackerel. In addition, the samples from the Western stock, west of Ireland and the northern Spanish shelf, and the northern part of the Southern stock, northern Portugal, appear to form a genetically close group. There was significant genetic differentiation between the northern Portuguese samples and those collected in Southern Portuguese waters, with those in the south representing a separate population. The North African and Alboran Sea samples were distinct from each other and from all other samples. Based on the full genome sequencing, it is expected that mixed samples of horse mackerel can now be investigated on the contributing stock components. This work is foreseen for the end of 2020 in the Channel area and in the Northern North Sea.

Working Document 08 to this report summarizes the status of the industry-science collaboration aimed at improving the knowledge on gonad development of mackerel and horse mackerel. The work is based on samples taken by the fishing industry (PFA) on targeted or by-catches of mackerel and/or horse mackerel. For horse mackerel, the aim is to investigate when western horse mackerel spawning occurred in 2020. To date, 1365 mackerel have been sampled and 197 horse mackerel (horse mackerel only started in 2020). Final results for mackerel are expected in October 2020 and for horse mackerel in the first half of 2021.

The Pelagic Freezer-trawler Association (PFA) provided an annual report on the self-sampling programme that started in 2015. The horse mackerel fishery takes place from October through to March of the subsequent year. Overall, the self-sampling activities for the horse mackerel fisheries during the years 2015 – 2020 (up to August) covered 457 fishing trips with 3,454 hauls, a total catch of 140,633 tonnes and 125,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 21% and 40% of the catch), division 27.7.b (7%-22%) and division 27.7.d (19%-34%, note that this is considered as the North Sea horse mackerel stock). Horse mackerel have a wide range in the length distributions in the catch. Median lengths have fluctuated between 22.8 and 30.0 cm. In 2019 and 2020 there are some indications of a stronger year class being available to the fishery, with a narrower length distribution.

7.2.10 Data exploration

The length frequency distributions of the catches for the whole fleet included in the model are shown in Figures 7.2.10.1-2. The length distributions available for 2015-2018 show a considerable amount of very small fish, mostly from Spanish catches. Length frequency distribution from discards was analysed alongside the length frequency distribution from the landings during the 2018 assessment. The large number of small individuals from the discard estimates had a significant impact on the overall LFD of the catches. These data were not available at the benchmark (2017) and to include those in the assessment model would require substantial changes in the modelling structure. For this reason these data were only used in the explorative analysis in 2018. Such large numbers of discards were not seen in the 2018 and 2019 lengths data.

Within-cohort consistency of the catch-at-age matrix is investigated in Figure 7.2.10.3: this shows that the catch-at-age data contains information on year-class strength that could form the basis for an age-structured model.

The numbers at age in the catch by decade show a slight trend towards younger individuals when moving from the beginning of the time-series towards the end (Figure 7.2.10.4).

The indices of abundance used in the assessment cover different areas and therefore represent different parts of the stock. Negative correlations between indices that should represent the same portion of the population may lead to problems in the fitting of the model. The correlation between time-series was therefore estimated and is presented in Figure 7.2.10.5. There was no strong correlation between the IBTS recruitment index and the other two surveys with a weakly positive correlation between IBTS and PELACUS, and a negative but highly uncertain correlation between IBTS and the egg survey. The egg survey index, which aims to represent the adult portion of the stock was strongly positively correlated with the PELACUS acoustic survey biomass estimate.

7.2.11 Assessment model, diagnostics

A one fleet, one sex, one area stock synthesis model (SS; Stock Synthesis v3.30) is used for the assessment of western horse mackerel stock in the Northeast Atlantic. A description of the model can be found in the stock annex. The assessment is presented as an update to the 2019 assessment and sees the inclusion of the 2019 estimates for the IBTS recruitment index, PELACUS biomass estimate and egg surveys index used, the 2019 length frequency distribution from the landings component of the catches and of the PELACUS survey and the 2019 total catch and conditional ALKs.

Fits to the available data are given in Figure 7.2.11.1, and model estimates with associated precision in Figure 7.2.11.2. Model estimates and residual patterns are similar to those presented in the benchmark (ICES, 2017b) and remain unchanged from last year's assessment for almost all variables, except for some patterns noted in the 2018 ALK that is no longer evident in 2019. Recruitment estimates were unchanged from last year's assessment. The model fitting to the most recent length frequency distributions and the conditional ALKs remains sub-optimal, and there may be an increase in smaller fish in recent years.

Retrospective plots are shown for 5 years with the associated Mohn's rho values (Figure 7.2.11.3). Major rescaling of the estimates was observed in correspondence of the availability of a new egg survey data points (available every three years) in previous assessments of this stock. The current 2020 assessment shows strong retrospective patterns, with a couple of peels falling just outside the confidence intervals in the latest years of SSB and recruitment estimates. The Mohn's rho values are on the limit of the tolerance threshold with 0.22 for SSB and -0.155 for F.

7.3 State of the Stock

7.3.1 Stock assessment

The SS model with new length and age data from the commercial fleet, and the 2019 information from the 3 surveys available, is presented as the final assessment model. Stock numbers-at-age and fishing mortality-at-age are given in Tables 7.3.1.1 and 7.3.1.2, and a stock-summary is provided in Table 7.3.1.3, and illustrated in Figure 7.2.11.2. SSB peaked in 1988 following the recruitment of the exceptionally strong 1982 year-class. Subsequently, SSB slowly declined until 2003 and then recovered again following the moderate-to-strong year-class of 2001 (a third of the size of the 1982 year-class). Year classes following 2001 have been weak: 2009-2011, and 2013 recruitments in particular have been estimated as the lowest values in the time-series together with that in 1983. The 2008 year-class has been estimated to be fairly strong. Recruitment estimates for 2014-2018 are the highest observed since 2008 and are higher than the geometric mean estimated over the years 1983-2019. 2019 appears to be low again. SSB in 2017 is estimated as the lowest in the time-series. Fishing mortality increased after 2007 as a result of increasing catches and decreasing biomass as the 2001 year-class was reduced. Between 2013 and 2017 fishing mortality then decreased, due to lower catches and a reduced proportion of the adult population in the exploited stock. Since 2017 it has increased again and appears above F_{MSY} in the current assessment.

7.4 Short-term forecast

A deterministic short-term forecast was conducted using the 'fwd()' method in FLR (Flash R add-on package).

Input

Table 7.4.1. lists the input data for the short–term predictions. Weight at age in the stock and weight at age in the catch are equal to the year invariant weight at age function used in the stock synthesis model. Exploitation pattern is based on estimated fishing mortality in 2019 and is the average of ages 1 to 10. Natural mortality is assumed to be 0.15 across all ages. The proportion mature for this stock has a logistic form with fully mature individuals at age 4 as used in the assessment model. In 2019 the expected landings for the intermediate year were set at 80% of the total TAC, to reflect the catch uptake of the past 3 years. Similarly, this year it was set at 85% of the total TAC to reflect the increasing uptake of 2017-2019. Note that -despite the plus group in the catch being equal to 15+- the true population in SS model is set to arrive up to age 20 (as from literature) and is therefore estimated accordingly.

Output

A range of predicted catch and SSB options from the short-term forecast are presented in Table 7.4.2.

7.5 Uncertainties in the assessment and forecast

Despite the increased amount of data used and information available to the stock assessment, the model still suffers from a retrospective pattern whenever a new year of data is included. This year rescaling is relatively significant with a pattern over the past 5 years (rescaling biomass down and vice-versa for F_{1-10}).

The fitting to the fishery independent indices remains good for two of the three surveys used: a degradation of the fitting to the IBTS recruitment index was observed the past couple of years, but the estimates remained within the confidence intervals provided. The fit to the acoustic index remains poor.

The change in selectivity, which is detected from both the length and the age composition of the catch data, is not entirely picked up from the model. In general, the model tends to overestimate the mean age of the last decade. The selectivity issue should be further investigated and somehow addressed: for example, it is not clear whether the high presence of small specimen in the landings data is due to the inclusion of BMS individuals in the overall catch instead of having it as discard (the discard ban was implemented in 2015 for pelagic species) or if this is due to an effective change in selectivity (i.e. catchability of the gear and availability of the stock).

The 2020 assessment model suffered from being sensitive to variance adjustment factors which led to gradient and hessian inversion issues. The final model had the lowest likelihood and was tuned with the Francis reweighting approach, rather than using the McAllister and Ianelli approach which did not perform well here. At the benchmark, both methods performed equally and McAllister and Ianelli weights had been used since. The final model outputs showed similar trends to the outputs of another framework, SAM, which was tested for comparison and did not rely on any lengths data.

The model fixes the realised fecundity with a constant number of eggs/kg independently of the individual weight. However, western horse mackerel is known to be an indeterminate spawner, which implies this relationship being not appropriate when it comes to the use of an egg survey as index of spawning biomass. During the benchmark it was attempted to estimate the parameters relative to fecundity, but the information provided was not sufficient. The inclusion of this feature, whenever appropriate data become available, would help to improve the reliability of the assessment.

The assumed value for M should be investigated. However, there is no data available (such as tagging) that could assist in estimating M more accurately. Nevertheless, total mortality appears to be low, given the persistence of the 1982-year class in the catch data.

The assessment, as was developed at the benchmark, has an increased amount of information for providing more robust estimates of recruitment, which is also informed by the strong, occasional year classes observed in the catch. On the contrary, the SSB is informed only by the triennial egg survey and by the acoustic survey (which only covers a small part of the stock distribution and size ranges, has a really low weight in the model and is really noisy): a new index for the spawning biomass would therefore be beneficial for the future stability of this assessment. The development of a SSB index from the IBTS survey as well as merging the information available from the PELACUS and the PELGAS acoustic survey in the Bay of Biscay should be pursued.

7.6 Comparison with previous assessment and forecast

A comparison of the update assessment with the historic ones (previous 4 years) is shown in Figure 7.2.11.4: the new information created a downward rescaling of the assessment biomass and upward revision of F. Recruitment, on the other hand, remains fairly stable until 2015 but a downward revision is estimated from then on.

7.7 Management Options

7.7.1 MSY approach

In 2017 stochastic equilibrium analyses were carried out using the *EqSim* software (WKWIDE 2017) to provide an estimate for F_{MSY} and other biological reference points. During WGWIDE 2017 further investigations were carried out and summarised in a Working Document attached to WGWIDE 2017 report (ICES, 2017a).

Reference points were subsequently revised during an inter-benchmark workshop carried out in July-August 2019 as those derived during the 2017 benchmark were deemed no longer appropriate in light of the retrospective pattern observed in the model. More robust reference points were therefore put forward after a number of alternatives were examined, following ICES guidelines, and based on the 2018 assessment. The detailed rationale can be found in the inter-benchmark report (ICES, 2019).

SSB in 2003 was adopted as a proxy for B_{pa} on the basis that fishing mortality had been relatively low for the data period (F_{bar} mean ~0.11, natural mortality = 0.15), and there was no indication of impaired recruitment below the associated B_{lim}, despite a continuing decline in SSB. F_{MSY} was derived from stochastic simulations as before and evaluated at 0.074. These updated reference points were used to set the 2020 advised catch.

7.7.2 Management plans and evaluations

An overview of earlier management plans and management plan evaluations was presented at WGWIDE 2017. To date, no agreed management plan is available for this stock despite several attempts to develop such management plans.

The Pelagic Advisory Council (PELAC), together with several researchers have carried out an evaluation of potential harvest control rules for western horse mackerel. The HCR analyses represented two different assessment methods (SS3 and SAM) and two different HCR evaluation tools (EqSim and SAM HCR). Both HCR evaluation tools are of the 'short-cut' type with appropriate conditioning of the uncertainties in the assessment based on historical CV and autocorrelation in line with the recommendations from ICES workshops WKMSYREF3 and WKMSYREF4. The evaluations followed the guidelines from WKGMSE2 (ICES, 2019c) and WKREBUILD (ICES, 2020). Overall, the results of the different HCR tools and the different assessment inputs gave comparable results, although there were some differences in the absolute levels. Given that the EqSim with SS3 evaluation is closest to the ICES advisory practice, this was used as the basis for the suggested rebuilding plan by the PELAC. The proposed rebuilding plan and the scientific evaluation that underpins it (see Working Document 02), have been submitted to the European Commission with the request to commission a scientific review by ICES.

7.8 Management considerations

The 2001 year-class has now entered the plus group and there are indications of 2014 being of comparable size, but no other detectable very strong year-classes entering the fishery, even though a higher amount of age 1-2 fish have been observed in the catches in the past 4-5 years.

The downward rescaling of the assessment combined with the lower catches estimated for the interim year (2020) lead to an advice for 2021 that is very similar to 2020 advice last year.

A TAC has only been agreed for parts of the distribution and fishing areas (EU waters). The Working Group advises that the TAC should apply to all areas where western horse mackerel are caught. Note that subarea 8.c is included in the ICES advice for Western horse mackerel.

7.9 Ecosystem considerations

Knowledge about the distribution of the western horse mackerel stock is mostly gained from the egg surveys and the seasonal changes in the fishery. Based on these observations it is not possible to infer a similar changing trend in the distribution of western horse mackerel as for NEA mackerel. However, from catch data it appears that the stock is concentrated in the southern areas and it is mostly characterized by small individuals.

7.10 Regulations and their effects

There are no horse mackerel management agreements between EU and non EU countries. The TAC set by EU therefore only apply to EU waters and the EU fleet in international waters. The minimum landing size of horse mackerel by the EU fleet is 15 cm (10% undersized allowed in the catches). In Norwegian waters there is no quota for horse mackerel but existing regulations on bycatch proportions as well as a general discard prohibition (for all species) apply to horse mackerel.

An overview of the scientific advice, the TACs (or sum of unilateral quota) and the catches is shown in figure 7.10.1. From 2001 onwards, TACs and catches have fluctuated around the scientific advice, where in some years the TACs were set higher and in other years lower than the scientific advice.

The stock allocations were changed in 2005 following the results of the HOMSIR project (Abaunza *et al.* 2003) and 8.c is considered to be the western stock. Landings from 7.d are now allocated to the North Sea horse mackerel. Results of a recent genetic research project on stock structure of horse mackerel has been reported in sections 1.5.5 and 7.2.9 of this report.

7.11 Changes in fishing technology and fishing patterns

The description of the fishery is given in Section 5.1 and no large changes in fishing areas or patterns have taken place.

7.12 Changes in the environment

Migrations are closely associated with the slope current, and horse mackerel migrations are known to be modulated by temperature. Continued warming of the slope current is likely to affect the timing and spatial extent of this migration.

After the strong 1982 year-class of the western stock started to appear in the North Sea in 1987 a good correspondence between the modelled influx of Atlantic water to the North Sea in the first quarter and the horse mackerel catches taken by Norwegian purse-seiners in the Norwegian EEZ (NEZ) later (October-November) the same year (Iversen *et al.* 2002, Iversen WD presented in ICES 2007/ACFM:31) was noted in most years.

7.13 References

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7.14 Tables

Table 7.1.1.1. Western horse mackerel. Catches (t) in Subarea 2 by country (Data as submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987
Denmark	-	-	-	-	-	-	-	39
France	-	-	-	-	1	1	-[2]	-[2]
Germany, Fed.Rep	-	+	-	-	-	-	-	-
Norway	-	-	-	412	22	78	214	3,272
USSR	-	-	-	-	-	-	-	-
Total	-	+	-	412	23	79	214	3,311

	1988	1989	1990	1991	1992	1993	1994	1995
Faroe Islands	-	-	9643	1,115	9,157[3]	1,068	-	950
Denmark	-	-	-	-	-	-	-	200
France	-[2]	-	-	-	-	-	55	-
Germany, Fed. Rep.	64	12	+	-	-	-	-	-
Norway	6,285	4,770	9,135	3,200	4,300	2,100	4	11,300
USSR / Russia (1992 -)	469	27	1,298	172	-	-	700	1,633
UK (England + Wales)	-	-	17		-	-	-	-
Total	6,818	4,809	11,414	4,487	13,457	3,168	759	14,083

	1996	1997	1998	1999	2000	2001	2002	2003
Faroe Islands	1,598	799[3]	188[3]	132[3]		-	-	-
Denmark	-	-	1,755[3]	-		-	-	-
France	-	-	-	-		-	-	-
Germany	-	-	-	-		-	-	-
Norway	887	1,170	234	2,304	841	44	1,321	22
Russia	881	554	345	121	78	16	3	2
UK (England + Wales)	-	-	-	-	-	-	-	-
Estonia	-	78	22	-	-	-	-	-
Total	3,366	2,601	2,544	2557	919	60	1,324	24

	2004	2005	2006	2007	2008	2009	2010	2011
Faroe Islands	-	-	3	-	-	-	222	224
Denmark	-	-	-	-	-	-	-	-
France	-	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-	-	1
Norway	42	176	27	-	572	1,847	1,364	298
Russia	-	-	-	-	-	-	-	-
UK (England + Wales)	-	-	-	-	-	-	-	-
Estonia	-	-	-	-	-	-	-	-
Total	42	176	27	0	572	1,847	1,586	-

	2012	2013	2014	2015	2016	2017	2018	2019[1]
Faroe Islands	-	-	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	-	-
France	+	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-
Netherlands	-	-	107	-	-	-	-	-
Norway	66	30	302	10	45	5	718	867
Russia	-	-		-	-	-	-	-
UK (England + Wales)	-	-		-	-	-	-	-
Estonia	-	-		-	-	-	-	-
Total	66	30	409	10	45	5	718	867

[1]Preliminary
[2]Included in 4.
[3]Includes catches in Div. 5.b.
[4]Taken in Div. 5.b.

Table 7.1.1.2. Western horse mackerel. Catches (t) in North Sea Subarea 4 and Skagerrak Division 3.a by country (Data submitted by Working Group members). Catches partly concern the North Sea horse mackerel.

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Belgium	8	34	7	55	20	13	13	9	10
Denmark	199	3,576	1,612	1,590	23,730	22,495	18,652	7,290	20,323
Faroe Islands	260	-	-	-	-	-	-	-	-
France	292	421	567	366	827	298	2312	1891	7841
Germany, Fed.Rep.	+	139	30	52	+	+	-	3	153
Ireland	1,161	412	-	-	-	-	-	-	-
Netherlands	101	355	559	2,0292	824	1602	6002	8503	1,0603
Norway2	119	2,292	7	322	2	203	776	11,7283	34,4253
Poland	-	-	-	2	94	-	-	-	-
Sweden	-	-	-	-	-	-	2	-	-
UK (Engl. + Wales)	11	15	6	4	-	71	3	339	373
UK (Scotland)	-	-	-	-	3	998	531	487	5,749
USSR	-	-	-	-	489	-	-	-	-
Total	2,151	7,253	2,788	4,420	25,987	24,238	20,808	20,895	62,877

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belgium	10	13	-	+	74	57	51	28	-
Denmark	23,329	20,605	6,982	7,755	6,120	3,921	2,432	1,433	976
Estonia	-	-	-	293	-	-	17	-	-
Faroe Islands	-	942	340	-	360	275	-	-	296
France	248	220	174	162	302	-	-	-	-
Germany, Fed.Rep.	506	2,469[4]	5,995	2,801	1,570	1,014	1,600	7	37
Ireland	-	687	2,657	2,600	4,086	415	220	1,100	8,152
Netherlands	14,172	1,970	3,852	3,000	2,470	1,329	5,285	6,205	52
Norway	84,161	117,903	50,000	96,000	126,800	94,000	84,747	14,639	43,888
Poland	-	-	-	-	-	-	-	-	-
Sweden	-	102	953	800	697	2,087	-	95	1761
UK (Engl. + Wales)	10	10	132	4	115	389	478	40	10
UK (N. Ireland)	-	-	350	-	-	-	-	-	-
UK (Scotland)	2,093	458	7,309	996	1,059	7,582	3,650	2,442	10,511
USSR / Russia (1992 -)	-	-	-	-	-	-	-	-	-
Unallocated+discards	12,482[3]	-317[3]	-750[3]	-278[5]	-3,270	1,511	-28	136	-31,615[6]
Total	112,047	145,062	77,904	114,133	140,383	112,580	98,452	26,125	34,068

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	19	21	-	-	-	-	-	-	-
Denmark	2,048	2,026	7	98	53	841	48	216	60
Estonia	-	-	-	-	-	-	-	-	-
Faroe Islands	28	908	24	0	671	5	76	35	0
France	379	60	49	-	-	255	-	1	-
Germany	4,620	4,072	0	0	4	534	0	44	1
Ireland	-	404	32	332	11	93	378	-	-
Lithuania	-	-	-	-	-	-	-	-	-
Netherlands	4,548	3,285	10	1	0	36	0	0	0
Norway	13,129	44,344	1,141	7,912	34,843	20,349	10,687	24,733	27,087
Russia	-	-	2	-	-	-	-	-	-
Sweden	1,761	1,957	1,009	68	561	1,002	567	216	0
UK (Engl. + Wales)	1	12	-	-	-	-	0	-	-
UK (Scotland)	3,041	1,658	3,054	3,161	252	0	0	22	61
Unallocated+discards	737	-325	10	0	0	-36	0	0	0
Total	30,311	58,422	5,338	11,572	36,395	23,079	11,756	25,267	27,210

[1] Includes Division 2.a. [2] Estimated from biological sampling. [3] Assumed to be misreported. [4] Includes 13 t from the German Democratic Republic. [5] Includes a negative unallocated catch of -4,000 t. [6] Negative values when there were overestimations of catch when comparing scientific with official data

Country	2007	2008	2009	2010	2011	2012	2013	2014
Denmark	74	2	207	61	19	9	0	23
Faroe Islands	3	55	0	8	0	0	0	53
France	-	1	-	-	268	-	-	17
Germany, Fed.Rep.	6	93	0	4	0	0	20	0
Ireland	651	298	342	14	755	25	7	-
Netherlands	-	-	-	-	-	-	-	-
Lithuania	22	0	7	339	81	92	0	310
Norway	4180	11631	57890	10556	13409	3183	6566	14051
Sweden	76	9	258	2	90	0	1	0
UK (Engl. + Wales)	31	-	-	-	-	-	16	203
UK (Scotland)	7	20	51	546	101	12	102	11
Unallocated +discards	0	0	0	0	0	0	0	30
Total	5050	12110	58755	11531	14723	3320	6712	14699

Country	2015	2016	2017	2018	2019[1]
Denmark	37	7	21	289	183
Faroe Islands	0	0	67	0	6
France	12	4	1	2	98
Germany, Fed.Rep.	6	28	1	1	5
Ireland	8	-	-	-	-
Netherlands	-	0	14	7	72
Lithuania	12	130	-	-	
Norway	8,887	8,765	9,880	8,601	8,154
Sweden	10	0	41	23	323
UK (Engl. + Wales)	134	13	4	0	
UK (Scotland)	36	14	-	-	50
Unallocated +discards	32	97	87	162**	339
Total	9,175	9,057	10,117	9,085	9144

[1]Preliminary ** 3t landings from UK (Northern Ireland incl.)

Table 7.1.1.3 Western horse mackerel. Catches (t) in Subarea 6 by country (Data submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Denmark	734	341	2,785	7	-	-	-	769	1,655
Faroe Islands	-	-	1,248	-	-	4,014	1,992	4,450[2]	4,000[2]
France	45	454	4	10	14	13	12	20	10
Germany, Fed. Rep.	5,550	10,212	2,113	4,146	130	191	354	174	615
Ireland	-	-	-	15,086	13,858	27,102	28,125	29,743	27,872
Netherlands	2,385	100	50	94	17,500	18,450	3,450	5,750	3,340
Norway	-	5	-	-	-		83	75	41
Spain	-	-	-	-	-		-[1]	-[1]	-[1]
UK (Engl. + Wales)	9	5	+	38	+	996	198	404	475
UK (N. Ireland)						-	-	-	-
UK (Scotland)	1	17	83	-	214	1,427	138	1,027	7,834
USSR.	-	-	-	-	-	-	-	-	-
Unallocated + disc						-19,168	-13,897	-7,255	-
Total	8,724	11,134	6,283	19,381	31,716	33,025	20,455	35,157	45,842

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	973	615	-	42	-	294	106	114	780
Faroe Islands	3,059	628	255	-	820	80	-	-	-
France	2	17	4	3	+	-	-	-	53
Germany, Fed. Rep.	1,162	2,474	2,500	6,281	10,023	1,430	1,368	943	229
Ireland	19,493	15,911	24,766	32,994	44,802	65,564	120,124	87,872	22,474
Netherlands	1,907	660	3,369	2,150	590	341	2,326	572	1335
Norway	-	-	-	-	-	-	-	-	-
Spain	-[1]	-[1]	1	3	-	-	-	-	-
UK (Engl. + Wales)	44	145	1,229	577	144	109	208	612	56
UK (N.Ireland)	-	-	1,970	273	-	-	-	-	767
UK (Scotland)	1,737	267	1,640	86	4,523	1,760	789	2,669	14,452
USSR/Russia (1992-)	-	44	-	-	-	-	-	-	-
Unallocated + disc.	6,493	143	-1,278	-1,940	-6,960[3]	-51	-41,326	-11,523	837

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Total	34,870	20,904	34,456	40,469	53,942	69,527	83,595	81,259	40,983

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark		79							
Faroe Islands	-	-							
France	221			428	55	209	172	41	411
Germany	414	1031	209	265	149	1337	1413	1958	1025
Ireland	21951	31736	15843	20162	12341	20903	15702	12395	9780
Lithuania									2822
Netherlands	983	2646	686	600	450	847	3702	6039	1892
Spain	-	-						0	0
UK (Engl.+Wales)	227	344	41	91		46	5	52	
UK (N.Ireland)	1132	-	79	272	654	530	249	210	82
UK (Scotland)	10147	4544	1839	3111	1192	453	377	62	43
Unallocated+disc.	98	1507	0	0	0	0	0	0	0
Total	34815	41887	18697	24929	14840	24325	21619	20757	16055

[1]Included in Subarea 7. [2]Includes Divisions 3.a, 4.a, b and 6.b. [3]Includes a negative unallocated catch of -7000 t.

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015
Denmark					58	1,131	433	856	3,045
Faroe Islands		573		66					
France		73			246			195	65
Germany	1,835	5,097	635	773	6,508	671	8,616	4,194	1,980
Ireland	20,010	18,751	16,596	19,985	23,556	29,282	19,979	15,745	10,894
Lithuania	80	641							
Netherlands	2,177	3,904	2,332	1,684	6,353	12,653	11,078	8,580	6,211
Norway	2	20	27	18	48	2			
Spain	0								
UK (Engl. + Wales)	332			463			451	18	58
UK (N.Ireland)				59	198		2,325	1,579	1,204
UK (Scotland)	38	588	243	89	2,528	1,231	385	1,277	696
Unallocated+disc.	0	0	0	0	230	2	-	123	
Total	24,474	29,648	19,833	23,136	39,726	44,973	43,266	32,567	24,153

Country	2016	2017	2018	2019[1]
Denmark		3,462	4,982	6,467
Faroe Islands		113		20
France	23	1,025	197	550
Germany	4,069	2,884	2,779	1,418
Ireland	15,381	15,123	17,959	21,109
Lithuania	2,510			
Netherlands	9,246	5,497	11,921	14,421
Norway				
Spain				
UK (Engl. + Wales)		66	32	830
UK (N.Ireland)	0		1,026	1,907
UK (Scotland)	956			627

Country	2016	2017	2018	2019[1]
Unallocated+disc.		116	55	129
Total	32,186	28,286	38,950	47,480

[1]**Preliminary.**

Table 7.1.1.4. Western horse mackerel. Catches (t) in Subarea 7 by country (Data submitted by the Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Belgium	-	1	1	-	-	+	+	2	-
Denmark	5,045	3,099	877	993	732	1477	30408	27,368	33,202
France	1,983	2,800	2,314	1,834	2,387	1,881	3,801	2,197	1,523
Germany, Fed.Rep.	2,289	1,079	12	1,977	228	-	5	374	4,705
Ireland	-	16	-	-	65	100	703	15	481
Netherlands	23,002	25,000	27500	34,350	38,700	33,550	40,750	69,400	43,560
Norway	394	-	-	-	-	-	-	-	-
Spain	50	234	104	142	560	275	137	148	150
UK (Engl. + Wales)	12,933	2,520	2,670	1,230	279	1,630	1,824	1,228	3,759
UK (Scotland)	1	-	-	-	1	1	+	2	2,873
USSR	-	-	-	-	-	120	-	-	-
Total	45,697	34,749	33,478	40,526	42,952	39,034	77,628	100,734	90,253

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Faroe Islands	-	28	-	-	-	-	-	-	-
Belgium	-	+	-	-	-	1	-	-	18
Denmark	34,474	30,594	28,888	18,984	16,978	41,605	28,300	43,330	60,412
France	4,576	2,538	1,230	1,198	1,001	-	-	-	30,571
Germany, Fed.Rep.	7,743	8,109	12,919	12,951	15,684	14,828	17,436	15,949	28,267
Ireland	12,645	17,887	19,074	15,568	16,363	15,281	58,011	38,455	43,624
Netherlands	43,582	111,900	104,107	109,197	157,110	92,903	116,126	114,692	131,701
Norway	-	-	-	-	-	-	-	-	-
Spain	14	16	113	106	54	29	25	33	6
UK (Engl. + Wales)	4,488	13,371	6,436	7,870	6,090	12,418	31,641	28,605	17,464

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
UK (N.Ireland)	-	-	2,026	1,690	587	119	-	-	1,093
UK (Scotland)	+	139	1,992	5,008	3,123	9,015	10,522	11,241	7,902
Unallocated + discards	28,368	7,614	24,541	15,563	4,010	14,057	68,644	26,795	58,718
Total	135,890	192,196	201,326	188,135	221,000	200,256	330,705	279,100	379,776

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Faroe Islands	-	-		550	-	-	3,750	3,660	
Belgium	-	-	-	-		-			
Denmark	25,492	19,166	13,794	20,574	10,094	10,499	11,619	9,939	6,838
France	22,095	25,007	20,401	9,401	5,220	5,010	5,726	7,108	6,680
Germany	24,012	13,392	9,045	7,583	10,212	13,319	16,259	9,582	6,511
Ireland	48,860	25,816	32,869	29,897	23,366	13,533	8,469	20,405	16,841
Lithuania	-	-							3,606
Netherlands	95,753	63,091	44,806	37,733	32,123	38,808	32,130	26,424	29,165
Spain	-	58	50	7	11	1	27	12	3
UK (Engl. + Wales)	11,925	7,249	4,391	5,913	4,393	3,411	4,097	2,670	2,754
UK (N.Ireland)	27	-	546	868	475	384	209		21
UK (Scotland)	5,095	4,994	5,142	1,757	1,461	268	1,146	59	365
Unallocated+discards	12,706	31,239	-9,515	2,888	434	17,146	16,553	11,875	4,679
Total	245,965	190,012	121,530	117,170	87,788	102,379	99,985	91,733	77,463

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015
Faroe Islands	475	212		-	-	-	0		
Belgium				19	2		14		
Denmark	4856	1970	2710	5247	5831	2281	6373	5066	1474
France	2007	9703		260	7431	579	744	940	1552
Germany	3943	5693	14205	16847	14545	16391	15781	12948	7382
Ireland	8039	16282	23816	24491	14154	15893	15805	16922	10751
Lithuania	5387	4907				-	0		
Netherlands	32654	28077	23263	65865	49207	53644	41562	15529	18100
Norway	-	-	-	40		-	0		
Spain	11	11	6	3		10	0		
UK (Engl. + Wales)	5119	3245	6257	12139	11688	12122	3388	4576	1798
UK (Scotland)		469	1119	1713	299	91	17	101	6
Unallocated+discards	6012	-4624	-10891	6511	1	3038	4399	974	1929
Total	68504	65946	60487	133136	103157	104049	88083	57055	42992

Country	2016	2017	2018	2019[1]
Denmark	314	1057	1,031	690
France	551	595	1,067	907
Germany	7313	4077	1,401	7,673
Ireland	12193	7857	7,169	7,753
Lithuania	86			
Netherlands	14415	8445	14,009	15,159
Poland				127
Spain	0		0	1
UK (Engl. + Wales)	820	478	2,410	2,862
UK (Scotland)				
UK (Northern Ireland)			52	0
Unallocated+discards	1692	830	548	918
Total	37384	23340	27,687	36,062

[1]Preliminary. [2]French catches landed in the Netherlands

Table 7.1.1.5. Western horse mackerel. Catches (t) in Subarea 8 by country (Data submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Denmark	-	-	-	-	-	-	446	3,283	2,793
France	3,361	3,711	3.073	2,643	2,489	4,305	3,534	3,983	4,502
Netherlands	-	-	-	-	-[2]	-[2]	-[2]	-[2]	-
Spain	34,134	36,362	19,610	25,580	23,119	23,292	40,334	30,098	26,629
UK (Engl.+Wales)	-	+	1	-	1	143	392	339	253
USSR	-	-	-	-	20	-	656	-	-
Total	37,495	40,073	22,684	28,223	25,629	27,740	45,362	37,703	34,177
Country	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Denmark	6,729	5,726	1,349	5,778	1,955	-	340	140	729
France	4,719	5,082	6,164	6,220	4,010	28	-	7	8,564
Germany, Fed. Rep.	-	-	80	62	-		-	-	-
Netherlands	-	6,000	12,437	9,339	19,000	7,272	-	14,187	-
Spain	27,170	25,182	23,733	27,688	27,921	25,409	28,349	29,428	31,082
UK (Engl.+Wales)	68	6	70	88	123	753	20	924	430
Unallocated+discards	-	1,500	2,563	5,011	700	2,038	-	3,583	-2,944
Total	38,686	43,496	46,396	54,186	53,709	35,500	28,709	48,269	37,861
Country	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Denmark	1,728	4,769	2,584	582					1,513
France	1,844	74	7	5,316	13,676	4,908	2,161	3,540	3,944
Germany	3,268	3,197	3,760	3,645	2,293	504	72	4,776	3,326
Ireland	-	-	6,485	1,483	704	1,314	1,882	1,808	158
Lithuania	-	-							401
Netherlands	8,123	13,821	11,769	35,106	12,538	6,620	1,047	6,372	6,073
Spain	23,599	24,461	24,154	23,531	24,752	24,598	16,245	16,624	13,874
UK (Engl. + Wales)	9	28	121	1,092	1,578	982	516	838	821
UK (Scotland)	-	-	249						
Unallocated+discards	1,884	-8658	5,093	4,365	1,705	2,785	2,202	7,302	4,013

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	40,455	37,692	54,222	75,120	57,246	41,711	24,125	41,260	34,122

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Denmark	2,687	3,289	3,109	632	200	581	14			
France	10,741	2,848			326	1,218	2,849	2,277	1,618	2,219
Germany		918	281	64	61		417	19	49	4
Ireland	694					39			0	32
Netherlands	211	6,269	1,848	98	49	7	1,057	526	635	1
Spain	14,265	19,840	21,071	38,742	34,581	13,502	22,542	19,443	13,072	14,235
UK (Engl. + Wales)		120	224	112	28		104	35	72	9
Unallocated+dis-cards		67	913	7,412	417	431	2,055	182	9,314	6,643
Total	28,598	33,352	27,447	47,060	35,662	15,777	29,039	22,483	24,760	23,143

Country	2017	2018	2019[1]
Denmark	1		422
France	2,303	2,176	2,914
Germany	210	554	144
Ireland	580	219	36
Netherlands	313	6	3
Spain	14,901	20,362	25,775
UK (Engl. + Wales)		2	344
Unallocated+discards	2,907	1,921	1,755
Total	21,213	25,240	31,396

[1]Preliminary. [2]Included in Subarea 7. [3]French catches landed in the Netherlands

Table 7.2.1.1. Western horse mackerel. The time series of Total Annual Egg Production (TAEP) estimates (10^{12} eggs).

Year	TAEP	CV
1992	2094	0.14
1995	1344	0.76
1998	1242	0.46
2001	864	0.32
2004	884	0.32
2007	1486	0.61
2010	1033	0.37
2013	366	0.34
2016	331	0.36
2019	178	0.48

Table 7.2.2.1. Western horse mackerel. The time series of recruitment estimates from the IBTS Survey 2017-2019.

Year	2020	2020 CV	2019	2018
2003	724708	0.3001	684217	649889
2004	2439512	0.3064	2295299	2232665
2005	2148828	0.3229	2027050	1947555
2006	1482969	0.3267	1397314	1344055
2007	3088715	0.2840	2886675	2791339
2008	7272792	0.2946	6888222	6725228
2009	1135301	0.2735	1061126	1010931
2010	860652	0.2912	808159	773303
2011	180361	0.3475	169028	162735
2012	4356450	0.3091	4102691	3947958
2013	1092849	0.2367	1034260	979157
2014	2922237	0.2381	2688011	2636896
2015	4030569	0.2698	3789317	3650668
2016	5216531	0.2942	4913923	4742525
2017	9450737	0.4633	8855563	8446544
2018	4000271	0.2982	3750158	

Year	2020	2020 CV	2019	2018
2019	1636554	0.2851		

Table 7.2.2.2. Western horse mackerel. The time series of biomass for the PELACUS acoustic survey (in tonnes).

Year	Biomass	CV
1992	57188	0.32
1993	25028	0.32
1995	93825	0.32
1997	74364	0.32
1998	139395	0.32
1999	71744	0.32
2000	26192	0.32
2001	40864	0.32
2002	41788	0.32
2003	26647	0.32
2004	23992	0.32
2005	40082	0.32
2006	13934	0.32
2007	28173	0.32
2008	33614	0.32
2009	24020	0.32
2010	53417	0.32
2011	7687	0.32
2012	15479	0.32
2013	5532	0.32
2014	30454	0.32
2015	67068	0.32
2016	32581	0.32
2017	13845	0.32
2018	9270	0.32
2019	13075	0.32

Year	Biomass	CV
2020	NA	NA

Table 7.2.4.1. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2019 (15 = 15+ group)

Q1																					
Age	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	Total
0														0	0		0		0		0
1			2	0	1	8	0	0	3	0	1	0	0	4623	10753	1	116	4	26	5	15543
2	17	557	378	4	192	3136	1	1	766	37	248	1	15	4808	3097	29	194	414	28	19	13943
3	4	185	439	5	224	6022	2	1	2122	44	290	1	18	4121	375	6	422	1557	24	6	15866
4	47	3233	866	3	140	2954	1	1	993	27	181	1	11	1740	112	2	289	1314	10	1	11923
5	1364	127357	15751	22	1065	11530	8	5	3951	208	1377	5	85	1043	85	0	230	1154	6	0	165245
6	131	11706	1687	2	83	801	1	0	296	16	108	0	7	852	90	1	243	879	5	0	16907
7	139	12805	3090	3	142	1363	1	1	504	237	183	1	11	418	38	1	128	506	2	0	19573
8	31	2659	802	1	34	324	0	0	120	33	44	0	3	423	30	1	132	564	2		5201
9	19	1742	339	0	15	146	0	0	54	55	20	0	1	430	26	0	115	614	3		3579
10	43	3691	949	1	36	345	0	0	128	85	46	0	3	462	27	0	144	590	3		6554
11	114	10080	3718	3	151	1451	1	1	536	212	195	1	12	407	19		79	457	2		17440
12	20	1572	761	1	31	297	0	0	110	32	40	0	2	392	17		50	424	2		3753
13	10	612	256	0	11	104	0	0	39	54	14	0	1	191	6		10	142	1		1451
14	8	459	55	0	3	26	0	0	10	1	4	0	0	220	9		14	166	1		976
15	103	7775	2326	2	89	860	1	0	318	44	116	0	7	392	12		14	243	2		12302
sum	2050	184432	31419	46	2217	29369	16	10	9948	1085	2867	10	176	20520	14696	40	2179	9027	120	31	310256

Q2																			
Age	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.h	27.7.j	27.7.j.2	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0												0	0	0	0	0	0	0	1
1			3	0	0	1	0	1	2	14	0	506	485	1	11856	4627	4	0	17503
2	3	1	37	0	0	16	0	16	30	176	0	560	674	79	6817	10442	5	0	18857
3	2	1	165	0	0	69	0	70	135	786	0	510	502	93	797	12537	4	0	15672
4	29	12	339	0	0	142	1	144	276	1610	0	274	425	83	741	3993	2	0	8072
5	1308	523	670	0	0	281	1	284	783	3182	0	206	418	84	995	1601	1	0	10338
6	122	49	105	0	0	44	0	45	119	499	0	210	506	78	1337	1014	1	0	4129
7	133	53	111	0	0	47	0	47	113	528	0	119	231	20	599	614	1	0	2615
8	34	13	27	0	0	11	0	11	32	129	0	133	170	7	353	921	1	0	1842
9	24	10	18	0	0	8	0	8	16	87	0	123	128	5	225	934	1	0	1585
10	51	20	71	0	0	30	0	30	60	335	0	117	116	2	282	537	1	0	1651
11	114	46	140	0	0	59	0	60	125	667	0	77	80	1	204	298	0	0	1870
12	25	10	35	0	0	15	0	15	32	168	0	61	97	0	265	239	0	0	963
13	13	5	11	0	0	4	0	4	11	50	0	20	24	0	66	90	0	0	299
14	9	4	4	0	0	1	0	1	5	17	0	29	89	1	212	95	0	0	467
15	132	53	88	0	0	37	0	37	81	416	0	31	74	0	261	178	0	0	1388
sum	2000	800	1825	0	1	765	3	773	1819	8663	1	2978	4018	454	25010	38119	22	1	87252

Table 7.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2019 (15 = 15+ group)

Q3 Age	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	Total
0																	4	102		26	0		132
1					0	25	0	1	1	1	0	0	128	24	0	0	986	702	0	609	6758	0	9234
2	1	11	8	58	0	682	3	23	24	16	7	2	401	655	0	1	1062	143	0	632	8297	0	12027
3	0	3	2	37	0	324	1	11	11	8	4	1	1178	311	0	1	895	109	0	905	7737	0	11537
4	2	18	12	158	0	1997	8	66	69	48	22	6	11155	1920	0	3	425	62	0	598	5100	0	21671
5	32	252	383	7267	1	4168	17	138	144	101	46	12	12108	4007	0	7	286	55	0	371	4356	0	33750
6	4	30	528	461	0	557	2	18	19	13	6	2	2698	535	0	1	306	74	0	310	5347	0	10913
7	4	28	473	455	0	340	1	11	12	8	4	1	1310	327	0	1	183	54	0	183	3430	0	6825
8	2	12	707	68	0	68	0	2	2	2	1	0	281	66	0	0	194	60	0	229	3657	0	5351
9	1	9	386	303	0	67	0	2	2	2	1	0	364	64	0	0	174	53	0	227	3116	0	4772
10	3	21	1366	111	0	305	1	10	11	7	3	1	1858	293	0	1	160	44	0	316	2670	0	7180
11	4	34	1460	200	0	373	2	12	13	9	4	1	1850	358	0	1	118	38	0	385	1573	0	6436
12	2	13	879	67	0	126	1	4	4	3	1	0	668	121	0	0	85	30	0	364	723	0	3090
13	1	10	671	50	0	20	0	1	1	0	0	0	117	19	0	0	43	19	0	230	265	0	1445
14	1	7	473	43	0	19	0	1	1	0	0	0	91	18	0	0	46	15	0	215	275	0	1206
15	10	74	4920	630	0	235	1	8	8	6	3	1	1224	226	0	0	84	20	0	425	440	0	8314
sum	67	524	12270	9906	2	9304	38	307	321	225	102	27	35432	8944	0	16	5050	1580	0	6026	53742	0	143883

Q4 Age	27.2.a	27.3.a	27.4.a	27.6.a	27.7.b	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	Total
0												190	7283	37	0	0	7510
1					22	4	16	14	0	0	1	480	7512	44	236	2435	10764
2	3	25	1	1528	3756	171	594	543	0	4	26	377	715	4	357	6311	14415
3	1	7	0	344	798	232	808	738	0	5	35	406	169		388	3930	7862
4	9	70	4	2529	1029	455	1584	1448	1	10	69	282	133		348	3001	10971
5	255	2078	229	39063	13082	1259	4381	4003	3	27	191	236	126		393	3241	68568
6	25	203	310	3995	666	152	527	482	0	3	23	269	165		515	3480	10815
7	26	213	279	3878	742	162	564	515	0	4	25	172	125		363	1693	8763
8	7	56	416	762	127	38	131	119	0	1	6	190	150		473	1357	3832
9	5	38	227	468	44	24	84	77	0	1	4	171	153		463	1013	2772
10	10	84	804	926	0	88	305	278	0	2	13	160	184		544	692	4089
11	23	189	859	3126	414	188	654	597	0	4	29	118	200		591	342	7333
12	5	43	517	482	95	47	164	150	0	1	7	82	182		574	214	2563
13	3	25	394	279	0	13	45	41	0	0	2	41	137		380	105	1466
14	2	19	277	267	22	5	18	16	0	0	1	40	115		388	102	1270
15	28	229	2892	2444	200	115	401	366	0	3	17	73	220		866	97	7951
sum	403	3279	7211	60090	20999	2953	10276	9388	6	64	448	3286	17568	84	6879	28011	170944

Table 7.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2019 (15 = 15+ group)

all Q																								
Age	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	27.8.e	Total
0																	194	7385	37	26	0	0		0	7643
1					0	51	0	2	14	16	15	4	131	40	0	0	6595	19452	46	12818	13824	31	5	0	53043
2	25	36	11	2171	0	4853	7	215	3346	612	551	784	473	1105	1	16	6807	4630	112	8000	25464	33	19	0	59271
3	7	9	3	574	0	1726	6	235	6335	817	742	2193	1362	1422	1	18	5932	1155	99	2512	25761	28	6	0	50945
4	88	87	21	6007	0	4231	11	206	3620	1634	1470	1143	11469	3779	1	15	2721	732	84	1976	13408	12	1	0	52717
5	2959	2331	771	176441	1	33671	39	1204	13214	4491	4053	4250	13126	8757	5	92	1771	684	84	1989	10352	8	0	0	280292
6	282	233	853	16428	0	3016	4	102	1016	542	488	342	2837	1165	0	8	1637	834	78	2404	10720	6	0	0	42996
7	301	242	769	17420	0	4283	4	153	1584	573	520	552	1663	1063	1	12	893	448	21	1273	6242	3	0	0	38021
8	73	68	1127	3562	0	1025	1	36	375	133	120	131	346	244	0	3	941	410	7	1187	6499	3		0	16292
9	50	47	616	2564	0	468	1	17	180	86	78	62	435	175	0	1	897	360	5	1030	5676	3		0	12752
10	107	105	2175	4838	0	1325	2	46	473	313	282	159	2005	688	0	3	899	371	2	1286	4489	3		0	19572
11	256	223	2334	13653	0	4646	5	163	1711	664	602	597	2192	1249	1	13	719	336	1	1259	2670	3		0	33296
12	52	56	1400	2177	0	1017	1	35	363	167	151	125	733	336	0	3	619	326	0	1253	1600	3		0	10418
13	27	35	1068	972	0	286	0	11	122	46	42	43	182	85	0	1	294	186	0	686	602	1		0	4690
14	21	26	751	792	0	100	0	3	34	18	16	11	96	39	0	0	335	228	1	829	637	1		0	3940
15	273	304	7830	11148	0	2849	3	97	1020	407	369	356	1351	775	0	8	579	325	0	1567	956	2		0	30219
sum	4520	3803	19730	258747	2	63546	84	2526	33408	10520	9499	10754	38400	20922	10	193	31834	37862	578	40094	128899	142	31	1	716105

Table 7.2.4.2. Western horse mackerel. Catch-at-age (thousands).

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1982	0	3713	21072	134743	11515	13197	11741	8848	1651	414	1651	6582	18483	28679	19432	8210
1983	0	7903	2269	32900	53508	15345	44539	52673	17923	3291	5505	3386	17017	23902	38352	46482
1984	0	0	241360	4439	36294	149798	22350	38244	34020	14756	4101	0	639	1757	5080	50895
1985	0	1633	4901	602992	4463	41822	100376	12644	16172	6200	9224	339	850	3723	1250	34814
1986	0	0	0	1548	676208	8727	65147	109747	25712	21179	15271	3116	1031	855	292	51531
1987	0	99	493	0	2950	891660	2061	41564	90814	11740	9549	19363	8917	1398	200	32899
1988	876	27369	6112	2099	4402	18968	941725	12115	39913	67869	9739	16326	17304	5179	4892	32396
1989	0	0	0	20766	18282	5308	14500	1276730	12046	59357	83125	13905	24196	13731	8987	18132
1990	0	20406	45036	138929	61442	33298	10549	20607	1384850	37011	70512	101945	14987	34687	18077	56598
1991	20176	24021	56066	17977	159643	97147	49515	21713	17148	1028420	20309	12161	43665	8141	7053	25553
1992	14888	229694	36332	80550	56280	255874	126816	48711	18992	23447	1099780	13409	23002	65250	11967	33246
1993	46	131108	109807	16738	62342	105760	325674	141148	68418	55289	30689	1075610	11373	24018	68137	32140
1994	3686	60759	911713	115729	53056	44520	38769	221863	106390	40988	43083	22380	918512	10143	14599	36635
1995	2702	233030	646753	526053	269658	74592	114649	36076	228687	113304	96624	59874	63187	951901	39278	148243
1996	10729	19774	659641	864188	189273	87562	52050	55914	53835	57361	56962	91690	67114	56012	349086	165611
1997	4860	110451	471611	732959	408648	256563	141168	143166	143769	123044	133166	96058	176730	98196	51674	283110
1998	744	91505	184443	488661	359590	217571	153136	119309	77494	67072	50108	58791	30535	65839	57583	141362

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1999	14822	97561	83715	176919	265820	254516	212217	187196	147271	77622	35582	22909	34440	29743	41830	122176
2000	565	66210	130897	64801	119297	232346	202175	165745	109218	54365	14594	17509	18642	18585	10031	73174
2001	60561	93125	204360	166641	113659	120410	141419	259974	218002	110319	38576	22749	17102	14092	18857	64868
2002	14044	505717	122603	158114	123258	66640	68890	95052	132743	87285	46167	29692	25333	11305	12753	72682
2003	1913	323194	509889	141442	148989	89122	59047	48582	52305	102089	57089	31748	27158	8832	7683	40641
2004	22237	159011	116055	486195	81099	98855	69441	48969	32589	51953	54542	33298	12581	13407	4305	21278
2005	1305	74538	171420	310767	540649	69957	74746	61889	44443	22726	27019	42746	23677	6849	7491	18626
2006	1905	53322	58091	75505	91274	482229	57377	37222	41970	16865	11828	17073	32025	12877	7464	24645
2007	5121	32399	38598	40530	61938	112724	347284	48160	29112	21504	8728	7015	8462	14021	7618	18335
2008	30155	78121	24456	53525	57125	84358	54701	297879	49889	36692	25172	14466	12787	9269	13194	24124
2009	47421	86053	31431	56816	40104	36174	62700	57683	273217	68318	42063	30583	21230	8266	6811	39752
2010	4331	68198	122386	69381	29371	30496	51312	110033	73973	285281	70041	34486	24421	14887	14942	44201
2011	1136	17035	61864	106032	51259	35380	38626	59428	59031	61017	239472	88764	29187	17731	9783	35379
2012	5350	48100	42653	64221	171284	56012	37917	28132	25608	45490	41255	162118	50523	24043	11621	30567
2013	94165	138663	34651	34171	76847	248958	67370	25070	18447	20746	31217	20836	106242	21316	16279	24536
2014	19215	26080	83034	34591	28200	62102	152650	56679	21786	16441	23876	23654	24509	57284	25197	23878
2015	85629	108174	25416	51631	31604	24613	46201	118679	27331	12698	10883	12584	11794	7272	48586	15935
2016	133936	168323	97368	18662	31033	18762	14519	22754	80818	19004	10531	10298	14703	16212	18451	62769

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2017	104771	135690	26426	132175	34464	49849	23046	14115	22170	52786	12603	6491	6110	6919	7284	33718
2018	25736	107004	42957	54376	257565	43887	39837	14438	8809	19014	44833	10875	8065	4589	3645	35529
2019	7643	53043	59271	50945	52717	280292	42996	38021	16292	12752	19572	33296	10418	4690	3940	30219

Table 7.2.4.3. Western horse mackerel. Marginal age-distribution.

year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Timing	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Fleet	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
catch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sample size	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	4.5	7.5	6.1	4.8	6.3	7.5	6.2	5.1	2.8	3.2	3.6
0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.013	0.007	0.000	0.001	0.001	0.004	0.001	0.000	0.008	0.000	0.036	0.009
1	0.013	0.022	0.000	0.002	0.000	0.000	0.023	0.000	0.010	0.015	0.107	0.058	0.023	0.065	0.007	0.033	0.042	0.054	0.051	0.056	0.322
2	0.073	0.006	0.400	0.006	0.000	0.000	0.005	0.000	0.022	0.035	0.017	0.049	0.345	0.179	0.233	0.140	0.085	0.046	0.101	0.123	0.078
3	0.465	0.090	0.007	0.717	0.002	0.000	0.002	0.013	0.068	0.011	0.038	0.007	0.044	0.146	0.305	0.217	0.226	0.098	0.050	0.100	0.101
4	0.040	0.147	0.060	0.005	0.690	0.003	0.004	0.012	0.030	0.099	0.026	0.028	0.020	0.075	0.067	0.121	0.166	0.147	0.092	0.068	0.078
5	0.046	0.042	0.248	0.050	0.009	0.801	0.016	0.003	0.016	0.060	0.120	0.047	0.017	0.021	0.031	0.076	0.101	0.141	0.179	0.072	0.042
6	0.040	0.122	0.037	0.119	0.066	0.002	0.780	0.009	0.005	0.031	0.059	0.144	0.015	0.032	0.018	0.042	0.071	0.118	0.156	0.085	0.044
7	0.031	0.144	0.063	0.015	0.112	0.037	0.010	0.814	0.010	0.013	0.023	0.063	0.084	0.010	0.020	0.042	0.055	0.104	0.128	0.156	0.060

year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
8	0.006	0.049	0.056	0.019	0.026	0.082	0.033	0.008	0.676	0.011	0.009	0.030	0.040	0.063	0.019	0.043	0.036	0.082	0.084	0.131	0.084
9	0.001	0.009	0.024	0.007	0.022	0.011	0.056	0.038	0.018	0.639	0.011	0.024	0.016	0.031	0.020	0.036	0.031	0.043	0.042	0.066	0.056
10	0.006	0.015	0.007	0.011	0.016	0.009	0.008	0.053	0.034	0.013	0.514	0.014	0.016	0.027	0.020	0.039	0.023	0.020	0.011	0.023	0.029
11	0.023	0.009	0.000	0.000	0.003	0.017	0.014	0.009	0.050	0.008	0.006	0.476	0.008	0.017	0.032	0.028	0.027	0.013	0.013	0.014	0.019
12	0.064	0.047	0.001	0.001	0.001	0.008	0.014	0.015	0.007	0.027	0.011	0.005	0.348	0.018	0.024	0.052	0.014	0.019	0.014	0.010	0.016
13	0.099	0.065	0.003	0.004	0.001	0.001	0.004	0.009	0.017	0.005	0.031	0.011	0.004	0.264	0.020	0.029	0.030	0.016	0.014	0.008	0.007
14	0.067	0.105	0.008	0.001	0.000	0.000	0.004	0.006	0.009	0.004	0.006	0.030	0.006	0.011	0.123	0.015	0.027	0.023	0.008	0.011	0.008
15	0.028	0.127	0.084	0.041	0.053	0.030	0.027	0.012	0.028	0.016	0.016	0.014	0.014	0.041	0.058	0.084	0.065	0.068	0.056	0.039	0.046

year	2003*	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Timing	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Fleet	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Sex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
catch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sample size	7.9	6.8	7.8	7.2	6.2	7.7	8.7	7.8	6.2	6.8	7.7	8.1	6.4	8.2	6.8	6.9	6.6
0	0.001	0.017	0.001	0.002	0.006	0.035	0.052	0.004	0.001	0.006	0.096	0.028	0.134	0.181	0.157	0.036	0.011
1	0.196	0.122	0.050	0.052	0.040	0.090	0.095	0.065	0.019	0.057	0.142	0.038	0.169	0.228	0.203	0.148	0.074
2	0.309	0.089	0.114	0.057	0.048	0.028	0.035	0.117	0.068	0.050	0.035	0.122	0.040	0.132	0.040	0.060	0.083

year	2003*	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3	0.086	0.372	0.207	0.074	0.051	0.062	0.063	0.066	0.116	0.076	0.035	0.051	0.081	0.025	0.198	0.075	0.071
4	0.090	0.062	0.361	0.089	0.077	0.066	0.044	0.028	0.056	0.203	0.078	0.042	0.049	0.042	0.052	0.357	0.074
5	0.054	0.076	0.047	0.472	0.141	0.097	0.040	0.029	0.039	0.066	0.254	0.091	0.039	0.025	0.075	0.061	0.391
6	0.036	0.053	0.050	0.056	0.433	0.063	0.069	0.049	0.042	0.045	0.069	0.225	0.072	0.020	0.034	0.055	0.060
7	0.029	0.038	0.041	0.036	0.060	0.344	0.063	0.105	0.065	0.033	0.026	0.083	0.186	0.031	0.021	0.020	0.053
8	0.032	0.025	0.030	0.041	0.036	0.058	0.301	0.071	0.065	0.030	0.019	0.032	0.043	0.109	0.033	0.012	0.023
9	0.062	0.040	0.015	0.017	0.027	0.042	0.075	0.272	0.067	0.054	0.021	0.024	0.020	0.026	0.079	0.026	0.018
10	0.035	0.042	0.018	0.012	0.011	0.029	0.046	0.067	0.263	0.049	0.032	0.035	0.017	0.014	0.019	0.062	0.027
11	0.019	0.025	0.029	0.017	0.009	0.017	0.034	0.033	0.097	0.192	0.021	0.035	0.020	0.014	0.010	0.015	0.046
12	0.016	0.010	0.016	0.031	0.011	0.015	0.023	0.023	0.032	0.060	0.108	0.036	0.018	0.020	0.009	0.011	0.015
13	0.005	0.010	0.005	0.013	0.017	0.011	0.009	0.014	0.019	0.028	0.022	0.084	0.011	0.022	0.010	0.006	0.007
14	0.005	0.003	0.005	0.007	0.010	0.015	0.007	0.014	0.011	0.014	0.017	0.037	0.076	0.025	0.011	0.005	0.006
15	0.025	0.016	0.012	0.024	0.023	0.028	0.044	0.042	0.039	0.036	0.025	0.035	0.025	0.085	0.050	0.049	0.042

***From 2003 the marginal age composition is replaced by the age-length key in the assessment.**

Table 7.2.4.4. Western horse mackerel. Conditional age-length key.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2003	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	2	11	1	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	3	18	9	0	0	0	0	0	0	0	0	0	0	0	0
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2013	0	0	0	0	0	11	20	13	14	26	18	2	90	5	6	3
2013	0	0	0	0	0	3	10	13	10	15	13	7	119	4	2	3
2013	0	0	0	0	0	1	2	4	11	13	11	3	91	7	6	5
2013	0	0	0	0	0	0	2	4	0	0	9	3	68	5	7	3
2013	0	0	0	0	0	0	0	0	0	3	1	2	60	3	4	8
2013	0	0	0	0	0	0	0	0	2	2	2	0	49	6	3	9
2013	0	0	0	0	0	0	0	0	0	0	0	1	29	4	9	7
2013	0	0	0	0	0	0	0	0	0	0	1	0	23	3	2	12
2013	0	0	0	0	0	0	0	0	0	0	0	1	13	3	8	8
2013	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	7
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
2013	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2014	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	5	6	2	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	8	22	4	9	8	0	0	0	0	0	0	0	0	0
2014	0	0	6	17	10	16	27	2	1	0	0	0	0	0	0	0
2014	0	0	4	6	8	34	54	7	0	0	0	0	0	0	0	0
2014	0	0	0	0	8	24	83	21	0	0	0	0	0	0	0	0
2014	0	0	0	0	2	17	76	35	2	1	2	1	0	3	0	0
2014	0	0	0	0	0	8	65	30	7	6	3	5	5	9	1	0
2014	0	0	0	0	1	4	38	23	3	5	8	6	10	27	6	3
2014	0	0	0	0	0	2	9	10	9	11	13	9	13	42	3	2
2014	0	0	0	0	0	0	2	5	3	3	9	12	10	27	8	7
2014	0	0	0	0	0	0	0	1	6	2	3	6	8	31	4	5
2014	0	0	0	0	0	0	0	0	0	0	4	2	5	24	2	6
2014	0	0	0	0	0	0	0	0	0	1	0	3	4	16	8	5
2014	0	0	0	0	0	0	0	0	0	0	2	0	2	13	4	5
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	3

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	3
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2015	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	8	2	2	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	22	5	4	2	0	0	0	0	0	0	0	0	0
2015	0	0	0	15	22	4	2	2	0	0	0	0	0	0	0	0
2015	0	0	0	8	12	13	11	16	0	0	0	0	0	0	0	0
2015	0	0	0	5	16	9	11	43	1	1	0	0	0	0	0	0
2015	0	0	0	3	4	3	18	82	3	1	1	0	0	0	1	0
2015	0	0	0	0	1	5	15	85	8	2	2	1	1	1	5	1
2015	0	0	0	0	0	0	12	75	11	3	0	0	4	4	15	5
2015	0	0	0	0	0	1	4	36	10	6	1	5	9	5	34	5

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2015	0	0	0	0	0	0	2	20	7	4	5	7	9	3	51	7
2015	0	0	0	0	0	1	0	9	0	10	6	5	10	4	43	12
2015	0	0	0	0	0	0	0	2	1	4	5	7	6	6	42	11
2015	0	0	0	0	0	0	0	0	0	2	2	1	2	1	32	9
2015	0	0	0	0	0	0	0	1	0	0	0	1	3	2	18	4
2015	0	0	0	0	0	0	0	0	0	0	1	0	2	1	5	5
2015	0	0	0	0	0	0	0	0	0	0	0	1	1	0	6	3
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
2016	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	22	1	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	21	3	2	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	16	13	6	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	9	14	9	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	10	13	3	1	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2016	0	0	0	3	12	4	4	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	4	0	2	1	1	0	0	0	0	0	0	0
2016	0	0	0	0	1	1	4	4	5	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	2	12	12	0	0	0	1	0	0	0
2016	0	0	0	0	0	0	1	8	15	2	0	0	1	0	0	0
2016	0	0	0	0	0	0	1	7	15	4	1	1	2	2	7	4
2016	0	0	0	0	0	0	1	7	7	2	0	2	5	3	5	7
2016	0	0	0	0	0	0	0	0	2	0	3	2	5	5	5	7
2016	0	0	0	0	0	0	0	0	1	1	1	1	2	4	7	6
2016	0	0	0	0	0	0	0	1	0	0	0	0	3	6	5	7
2016	0	0	0	0	0	0	0	0	0	0	0	0	1	5	13	7
2016	0	0	0	0	0	0	0	0	0	0	0	0	1	3	9	3
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7
2016	0	0	0	0	0	0	0	0	0	2	0	0	0	1	6	5
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2017	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2017	10	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	10	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	10	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	10	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	4	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	29	10	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	22	34	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	23	74	3	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	19	79	35	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	7	40	70	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	1	22	98	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	8	97	2	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	4	104	11	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	112	23	1	0	0	0	0	0	0	0	0	0	0
2017	0	0	1	105	53	11	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	69	112	44	13	0	0	0	0	0	0	0	0	0
2017	0	0	1	47	88	128	39	5	1	0	0	0	0	0	0	0
2017	0	0	0	27	50	145	83	12	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2017	0	0	0	6	29	117	136	50	4	7	1	0	0	0	0	2
2017	0	0	0	3	20	107	53	83	21	28	1	0	0	0	0	1
2017	0	0	0	0	6	73	24	27	99	74	11	0	0	0	1	2
2017	0	0	0	0	3	33	13	7	46	137	14	1	2	2	2	5
2017	0	0	0	0	2	7	3	11	40	97	80	7	2	3	8	6
2017	0	0	0	0	0	2	4	2	30	69	22	35	9	10	7	8
2017	0	0	0	0	0	0	1	2	10	47	16	20	31	16	15	6
2017	0	0	0	0	0	0	0	1	9	16	7	12	16	16	17	5
2017	0	0	0	0	0	0	0	0	3	14	6	10	6	9	27	4
2017	0	0	0	0	0	0	0	0	2	4	3	2	10	4	10	2
2017	0	0	0	0	0	0	0	0	0	5	3	2	0	1	2	1
2017	0	0	0	0	0	0	0	0	0	3	0	0	3	1	1	1
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2018	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2018	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	13	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	14	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	3	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	2	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	18	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	18	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	11	83	8	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	54	42	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	56	31	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	66	24	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	55	61	19	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	42	102	41	5	0	0	0	0	0	0	0	0	0	0	0
2018	0	21	184	100	49	0	0	0	0	0	0	0	0	0	0	0
2018	0	10	112	104	167	1	0	0	0	0	0	0	0	0	0	0
2018	0	0	70	119	431	11	1	0	0	0	0	0	0	0	0	0
2018	0	0	15	113	584	52	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	52	531	79	27	3	3	2	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2018	0	0	0	6	409	146	49	10	3	3	0	0	0	0	0	0
2018	0	0	0	3	175	203	140	39	13	6	0	1	0	0	0	1
2018	0	0	0	0	81	145	217	93	15	15	4	0	0	0	0	0
2018	0	0	0	0	24	74	177	158	54	12	19	1	1	0	0	0
2018	0	0	0	0	3	34	130	59	138	61	55	8	0	0	0	2
2018	0	0	0	0	3	15	78	25	43	139	121	30	9	4	3	13
2018	0	0	0	0	0	3	41	40	16	65	229	39	16	8	4	40
2018	0	0	0	0	0	2	13	12	14	40	192	116	33	10	8	62
2018	0	0	0	0	0	0	2	7	4	27	102	63	91	27	18	106
2018	0	0	0	0	0	0	1	1	2	16	62	21	70	47	32	115
2018	0	0	0	0	0	0	0	2	1	6	26	15	16	15	45	135
2018	0	0	0	0	0	0	0	0	0	0	4	8	8	7	11	128
2018	0	0	0	0	0	0	0	0	0	1	5	1	4	7	3	79
2018	0	0	0	0	0	0	0	0	0	0	1	0	4	6	5	37
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	32
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	9
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
2019	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	12	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	6	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	2	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	25	13	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2019	0	29	33	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	17	47	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	23	52	1	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	26	52	1	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	25	80	23	1	0	0	0	0	0	0	0	0	0	0	0
2019	0	19	99	63	2	2	0	0	0	0	0	0	0	0	0	0
2019	0	3	92	101	17	2	0	0	0	0	0	0	0	0	0	0
2019	0	2	67	101	45	31	1	0	0	0	0	0	0	0	0	0
2019	0	0	30	107	77	145	1	0	0	0	0	0	0	0	0	0
2019	0	0	5	67	108	358	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	12	114	509	20	2	0	0	0	0	0	0	0	1
2019	0	0	0	1	83	526	80	18	0	0	1	1	0	0	0	3
2019	0	0	0	2	63	404	119	48	6	3	1	1	0	0	0	0
2019	0	0	0	2	28	219	103	88	22	4	6	5	0	0	0	0
2019	0	0	0	1	7	98	78	93	78	38	8	26	3	0	0	3
2019	0	0	0	0	2	40	42	110	33	75	49	61	7	0	0	3
2019	0	0	0	0	0	14	24	75	19	22	110	96	12	5	2	14
2019	0	0	0	0	0	2	8	53	17	11	54	136	29	3	2	38

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2019	0	0	0	0	0	1	3	25	15	8	17	88	68	22	7	56
2019	0	0	0	0	0	1	1	10	9	8	15	45	35	37	21	71
2019	0	0	0	0	0	0	0	0	5	1	8	24	10	12	34	60
2019	0	0	0	0	0	0	1	0	2	1	2	13	8	3	11	71
2019	0	0	0	0	0	0	0	1	0	2	2	8	2	4	2	54
2019	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	34
2019	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	18
2019	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	9
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

Table 7.2.4.5. Western horse mackerel. Catch-at-length distribution from the commercial fleet.

year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Timing		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Fleet		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sex		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
catch		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sample number		34	42	50	40	47	53	57	37	46	87	68	49	48	66	63	82	101	108	104	96
Length bins (cm)	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	6	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	7	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
	8	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000
	9	0.000	0.001	0.006	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.001	0.000	0.000	0.000
	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.001	0.000	0.000	0.000
	11	0.000	0.009	0.007	0.000	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.001	0.000	0.000	0.000
	12	0.001	0.035	0.034	0.000	0.010	0.004	0.002	0.001	0.003	0.000	0.002	0.000	0.000	0.001	0.000	0.020	0.004	0.000	0.001	0.004
	13	0.018	0.014	0.055	0.001	0.018	0.003	0.002	0.002	0.003	0.002	0.005	0.000	0.000	0.004	0.000	0.016	0.007	0.002	0.007	0.011
	14	0.035	0.008	0.045	0.002	0.016	0.007	0.004	0.002	0.004	0.044	0.006	0.001	0.001	0.020	0.000	0.010	0.009	0.028	0.016	0.017
	15	0.034	0.016	0.039	0.007	0.022	0.017	0.007	0.001	0.033	0.054	0.010	0.003	0.002	0.048	0.001	0.012	0.014	0.017	0.026	0.016
	16	0.025	0.024	0.040	0.011	0.029	0.014	0.010	0.004	0.045	0.012	0.009	0.004	0.005	0.067	0.002	0.012	0.012	0.010	0.010	0.009

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
17	0.019	0.042	0.049	0.011	0.020	0.006	0.014	0.008	0.021	0.008	0.009	0.010	0.009	0.052	0.002	0.008	0.018	0.010	0.003	0.008
18	0.016	0.044	0.054	0.016	0.025	0.007	0.013	0.012	0.020	0.014	0.009	0.017	0.009	0.043	0.003	0.011	0.019	0.022	0.008	0.005
19	0.053	0.044	0.037	0.021	0.035	0.012	0.012	0.012	0.008	0.024	0.010	0.017	0.022	0.026	0.006	0.024	0.028	0.027	0.013	0.011
20	0.070	0.052	0.030	0.031	0.042	0.018	0.012	0.024	0.009	0.036	0.026	0.016	0.034	0.022	0.015	0.024	0.047	0.029	0.029	0.018
21	0.022	0.061	0.033	0.027	0.091	0.054	0.023	0.036	0.014	0.019	0.057	0.030	0.046	0.022	0.025	0.021	0.055	0.043	0.051	0.030
22	0.023	0.072	0.031	0.027	0.109	0.120	0.039	0.076	0.044	0.024	0.062	0.041	0.035	0.022	0.028	0.019	0.041	0.060	0.069	0.038
23	0.031	0.098	0.034	0.032	0.117	0.120	0.086	0.123	0.065	0.032	0.044	0.048	0.039	0.026	0.024	0.026	0.023	0.072	0.121	0.038
24	0.054	0.112	0.054	0.026	0.092	0.113	0.161	0.102	0.067	0.031	0.034	0.059	0.049	0.026	0.026	0.031	0.016	0.065	0.135	0.053
25	0.086	0.087	0.077	0.029	0.088	0.084	0.139	0.109	0.081	0.037	0.033	0.051	0.072	0.045	0.030	0.032	0.022	0.058	0.109	0.097
26	0.106	0.069	0.063	0.040	0.069	0.071	0.086	0.114	0.101	0.049	0.041	0.041	0.076	0.075	0.036	0.031	0.026	0.039	0.077	0.126
27	0.105	0.059	0.044	0.071	0.063	0.058	0.068	0.099	0.110	0.084	0.067	0.050	0.066	0.087	0.060	0.038	0.033	0.042	0.048	0.132
28	0.086	0.043	0.032	0.094	0.042	0.048	0.049	0.069	0.097	0.105	0.092	0.055	0.052	0.076	0.102	0.060	0.037	0.050	0.033	0.103
29	0.065	0.027	0.026	0.106	0.031	0.038	0.034	0.048	0.072	0.098	0.119	0.083	0.064	0.058	0.118	0.075	0.060	0.056	0.032	0.067
30	0.041	0.021	0.025	0.107	0.019	0.028	0.024	0.030	0.053	0.066	0.106	0.117	0.087	0.050	0.112	0.093	0.083	0.069	0.032	0.050
31	0.025	0.014	0.021	0.111	0.014	0.024	0.017	0.020	0.041	0.043	0.078	0.101	0.094	0.054	0.109	0.095	0.092	0.074	0.039	0.042
32	0.024	0.012	0.023	0.098	0.008	0.019	0.022	0.016	0.033	0.035	0.062	0.072	0.073	0.046	0.096	0.063	0.098	0.066	0.039	0.034
33	0.017	0.009	0.025	0.047	0.009	0.021	0.028	0.013	0.023	0.033	0.041	0.052	0.055	0.035	0.077	0.063	0.088	0.057	0.032	0.032
34	0.016	0.008	0.029	0.027	0.010	0.024	0.031	0.014	0.016	0.032	0.026	0.043	0.036	0.025	0.047	0.029	0.069	0.045	0.028	0.025

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
35	0.012	0.004	0.027	0.004	0.008	0.027	0.035	0.016	0.010	0.036	0.020	0.031	0.025	0.020	0.030	0.021	0.041	0.028	0.018	0.017
36	0.008	0.003	0.022	0.023	0.006	0.020	0.027	0.013	0.009	0.029	0.011	0.020	0.018	0.015	0.019	0.010	0.028	0.015	0.010	0.009
37	0.004	0.001	0.014	0.018	0.006	0.014	0.020	0.011	0.007	0.021	0.007	0.014	0.013	0.014	0.012	0.006	0.014	0.008	0.005	0.005
38	0.002	0.001	0.008	0.006	0.002	0.013	0.017	0.010	0.004	0.012	0.005	0.009	0.007	0.010	0.007	0.005	0.005	0.003	0.003	0.003
39	0.000	0.000	0.005	0.004	0.001	0.006	0.008	0.005	0.003	0.009	0.004	0.005	0.003	0.005	0.006	0.002	0.003	0.002	0.001	0.001
40	0.000	0.000	0.004	0.000	0.000	0.005	0.006	0.004	0.002	0.005	0.003	0.004	0.005	0.002	0.003	0.002	0.001	0.001	0.001	0.001
41	0.000	0.000	0.002	0.000	0.000	0.002	0.003	0.002	0.001	0.003	0.002	0.002	0.001	0.003	0.001	0.001	0.000	0.000	0.000	0.000
42	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
43	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 7.2.4.6. Western horse mackerel. Catch-at-length distribution from the PELACUS survey.

year		1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018	2019
Timing		5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08
Fleet		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sex		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
catch		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sample number		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Length bins (cm)	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	7	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
	8	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000
	9	0.000	0.000	0.000	0.000	0.000	0.038	0.000	0.000	0.002	0.000	0.000	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.002	0.000
	10	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.000	0.207	0.000	0.004	0.148	0.000	0.000	0.004	0.000	0.049	0.000	0.047	0.017	0.003
	11	0.000	0.024	0.002	0.000	0.002	0.006	0.014	0.000	0.257	0.000	0.006	0.113	0.000	0.000	0.009	0.003	0.058	0.009	0.112	0.101	0.077
	12	0.000	0.128	0.043	0.017	0.009	0.002	0.046	0.000	0.092	0.000	0.001	0.025	0.000	0.000	0.024	0.015	0.108	0.014	0.097	0.068	0.144
	13	0.000	0.055	0.066	0.028	0.016	0.002	0.025	0.000	0.063	0.000	0.000	0.007	0.001	0.000	0.080	0.012	0.126	0.003	0.060	0.081	0.096
	14	0.000	0.016	0.047	0.084	0.013	0.000	0.006	0.000	0.038	0.000	0.000	0.009	0.000	0.001	0.083	0.003	0.095	0.009	0.034	0.087	0.038
	15	0.000	0.011	0.029	0.140	0.005	0.000	0.019	0.000	0.018	0.000	0.000	0.017	0.004	0.003	0.020	0.001	0.035	0.053	0.014	0.124	0.051
	16	0.000	0.020	0.018	0.123	0.000	0.000	0.025	0.000	0.005	0.000	0.001	0.034	0.020	0.004	0.027	0.011	0.007	0.165	0.017	0.184	0.068

year	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018	2019
17	0.000	0.081	0.079	0.089	0.001	0.000	0.018	0.000	0.002	0.017	0.000	0.020	0.018	0.001	0.023	0.039	0.012	0.144	0.106	0.130	0.081
18	0.000	0.015	0.148	0.045	0.005	0.000	0.003	0.000	0.004	0.024	0.000	0.012	0.019	0.003	0.021	0.066	0.020	0.059	0.120	0.039	0.091
19	0.004	0.009	0.163	0.073	0.005	0.000	0.001	0.000	0.002	0.019	0.001	0.001	0.017	0.012	0.020	0.081	0.022	0.059	0.076	0.029	0.072
20	0.026	0.000	0.083	0.008	0.005	0.000	0.007	0.000	0.005	0.016	0.018	0.002	0.009	0.057	0.024	0.195	0.036	0.057	0.043	0.036	0.039
21	0.089	0.002	0.032	0.031	0.007	0.002	0.012	0.000	0.013	0.018	0.126	0.002	0.047	0.117	0.013	0.235	0.053	0.059	0.034	0.032	0.050
22	0.298	0.000	0.012	0.017	0.003	0.007	0.007	0.002	0.010	0.030	0.123	0.008	0.087	0.171	0.011	0.089	0.059	0.052	0.031	0.028	0.032
23	0.337	0.003	0.014	0.026	0.007	0.035	0.023	0.004	0.004	0.056	0.129	0.026	0.073	0.142	0.022	0.039	0.083	0.073	0.035	0.024	0.019
24	0.159	0.003	0.028	0.032	0.011	0.066	0.064	0.025	0.008	0.073	0.078	0.035	0.072	0.070	0.026	0.009	0.100	0.061	0.031	0.012	0.027
25	0.055	0.003	0.042	0.053	0.003	0.076	0.125	0.109	0.047	0.098	0.083	0.063	0.071	0.064	0.024	0.034	0.068	0.053	0.021	0.001	0.024
26	0.013	0.023	0.042	0.040	0.008	0.039	0.123	0.244	0.083	0.179	0.136	0.087	0.090	0.086	0.038	0.028	0.026	0.045	0.028	0.000	0.020
27	0.011	0.077	0.025	0.042	0.029	0.029	0.109	0.293	0.074	0.134	0.141	0.091	0.136	0.083	0.048	0.027	0.011	0.039	0.027	0.000	0.013
28	0.004	0.183	0.023	0.030	0.099	0.044	0.084	0.141	0.037	0.098	0.058	0.088	0.103	0.076	0.077	0.016	0.007	0.017	0.022	0.001	0.013
29	0.000	0.168	0.031	0.044	0.212	0.146	0.094	0.089	0.015	0.097	0.037	0.069	0.077	0.051	0.127	0.027	0.007	0.009	0.013	0.001	0.009
30	0.001	0.080	0.029	0.047	0.275	0.179	0.100	0.062	0.008	0.061	0.029	0.059	0.056	0.039	0.134	0.021	0.003	0.002	0.007	0.001	0.012
31	0.001	0.045	0.017	0.016	0.166	0.120	0.067	0.021	0.001	0.041	0.022	0.033	0.042	0.014	0.080	0.013	0.006	0.000	0.002	0.000	0.012
32	0.000	0.019	0.009	0.017	0.078	0.062	0.016	0.008	0.001	0.028	0.005	0.017	0.040	0.004	0.047	0.016	0.005	0.003	0.003	0.000	0.005
33	0.000	0.002	0.005	0.000	0.024	0.029	0.010	0.002	0.000	0.006	0.003	0.009	0.014	0.002	0.014	0.008	0.003	0.002	0.004	0.000	0.001
34	0.000	0.012	0.004	0.000	0.009	0.021	0.003	0.000	0.000	0.002	0.000	0.002	0.003	0.000	0.006	0.009	0.001	0.001	0.002	0.003	0.001

year	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018	2019
35	0.000	0.007	0.004	0.000	0.004	0.012	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.002	0.001	0.004	0.001	0.000	0.000
36	0.000	0.008	0.002	0.000	0.003	0.011	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.000	0.000
37	0.000	0.002	0.001	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000
38	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 7.2.5.1. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2019 (15 = 15+ group)

Q1 weight	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	Total
0														0.021	0.021		0.021	0.021	0.021		0.021
1			0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.024	0.016	0.045	0.024	0.033	0.024	0.023	0.018
2	0.077	0.060	0.070	0.072	0.072	0.065	0.072	0.072	0.070	0.072	0.072	0.072	0.072	0.060	0.040	0.055	0.064	0.087	0.061	0.048	0.059
3	0.117	0.087	0.085	0.085	0.085	0.082	0.085	0.085	0.082	0.085	0.085	0.085	0.085	0.103	0.091	0.084	0.100	0.113	0.103	0.083	0.091
4	0.144	0.129	0.126	0.114	0.114	0.103	0.114	0.114	0.104	0.114	0.114	0.114	0.114	0.126	0.122	0.118	0.127	0.133	0.126	0.095	0.120
5	0.148	0.140	0.145	0.156	0.156	0.151	0.156	0.156	0.154	0.156	0.156	0.156	0.156	0.160	0.162	0.134	0.160	0.162	0.160	0.177	0.142
6	0.197	0.189	0.200	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.203	0.183	0.186	0.218	0.189	0.176	0.182	0.177	0.190
7	0.240	0.235	0.240	0.241	0.241	0.241	0.241	0.241	0.241	0.270	0.241	0.241	0.241	0.204	0.204	0.218	0.209	0.203	0.204	0.177	0.235
8	0.298	0.287	0.284	0.290	0.290	0.290	0.290	0.290	0.290	0.340	0.290	0.290	0.290	0.235	0.233	0.218	0.234	0.231	0.235		0.275
9	0.287	0.274	0.269	0.274	0.274	0.274	0.274	0.274	0.274	0.251	0.274	0.274	0.274	0.258	0.255	0.218	0.258	0.257	0.258		0.267
10	0.296	0.274	0.293	0.296	0.296	0.296	0.296	0.296	0.296	0.326	0.296	0.296	0.296	0.292	0.286	0.218	0.286	0.294	0.292		0.283
11	0.301	0.293	0.289	0.290	0.290	0.290	0.290	0.290	0.290	0.324	0.290	0.290	0.290	0.320	0.318		0.313	0.317	0.320		0.293
12	0.347	0.320	0.324	0.320	0.320	0.320	0.320	0.320	0.320	0.379	0.320	0.320	0.320	0.350	0.352		0.352	0.342	0.350		0.328
13	0.389	0.367	0.356	0.362	0.362	0.362	0.362	0.362	0.362	0.394	0.362	0.362	0.362	0.383	0.383		0.382	0.394	0.383		0.370
14	0.384	0.352	0.271	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.415	0.416		0.416	0.417	0.415		0.372
15	0.374	0.341	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.362	0.343	0.343	0.343	0.493	0.486		0.476	0.538	0.491		0.351

Q2 weight	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.h	27.7.j	27.7.j.2	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0												0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1			0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.032	0.027	0.048	0.023	0.027	0.032	0.032	0.024
2	0.039	0.039	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.074	0.058	0.067	0.041	0.071	0.074	0.074	0.060
3	0.082	0.082	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.111	0.108	0.104	0.093	0.102	0.111	0.111	0.101
4	0.125	0.125	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.137	0.133	0.131	0.134	0.121	0.137	0.137	0.141
5	0.142	0.142	0.168	0.168	0.168	0.168	0.168	0.168	0.177	0.168	0.168	0.167	0.164	0.161	0.164	0.156	0.168	0.168	0.161
6	0.196	0.196	0.228	0.228	0.228	0.228	0.228	0.228	0.231	0.228	0.228	0.191	0.189	0.182	0.189	0.175	0.192	0.192	0.194
7	0.239	0.239	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.211	0.206	0.194	0.205	0.202	0.211	0.211	0.221
8	0.308	0.308	0.294	0.294	0.294	0.294	0.294	0.294	0.295	0.294	0.294	0.238	0.233	0.223	0.228	0.234	0.239	0.239	0.242
9	0.303	0.303	0.314	0.314	0.314	0.314	0.314	0.314	0.315	0.314	0.314	0.259	0.253	0.238	0.248	0.255	0.259	0.259	0.260
10	0.311	0.311	0.304	0.304	0.304	0.304	0.304	0.304	0.305	0.304	0.304	0.286	0.283	0.275	0.285	0.288	0.287	0.287	0.293
11	0.309	0.309	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.315	0.319	0.310	0.320	0.315	0.314	0.314	0.309
12	0.359	0.359	0.311	0.311	0.311	0.311	0.311	0.311	0.312	0.311	0.311	0.350	0.356	0.331	0.360	0.339	0.343	0.343	0.340
13	0.404	0.404	0.349	0.349	0.349	0.349	0.349	0.349	0.334	0.349	0.349	0.380	0.381	0.398	0.381	0.397	0.380	0.380	0.378
14	0.400	0.400	0.296	0.296	0.296	0.296	0.296	0.296	0.304	0.296	0.296	0.416	0.422	0.426	0.425	0.414	0.414	0.414	0.413
15	0.391	0.391	0.355	0.355	0.355	0.355	0.355	0.355	0.353	0.355	0.355	0.506	0.482	0.460	0.497	0.532	0.491	0.491	0.419

Table 7.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2019 (15 = 15+ group)

Q3 weight	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	Total
0																	0.021	0.021	0.020	0.020	0.020	0.020	0.020
1					0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.070	0.066	0.066	0.066	0.032	0.032	0.032	0.041	0.052	0.032	0.048
2	0.084	0.084	0.084	0.084	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.074	0.073	0.074	0.093	0.103	0.074	0.096
3	0.138	0.138	0.138	0.153	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.175	0.152	0.152	0.152	0.111	0.113	0.111	0.124	0.127	0.111	0.132
4	0.169	0.169	0.169	0.172	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.199	0.195	0.195	0.195	0.138	0.141	0.138	0.145	0.151	0.138	0.184
5	0.193	0.193	0.270	0.194	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.207	0.191	0.191	0.191	0.170	0.175	0.170	0.168	0.177	0.170	0.196
6	0.248	0.248	0.349	0.228	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.245	0.238	0.238	0.238	0.195	0.196	0.195	0.194	0.199	0.195	0.223
7	0.277	0.277	0.364	0.252	0.256	0.256	0.256	0.256	0.256	0.256	0.256	0.256	0.266	0.256	0.256	0.256	0.212	0.214	0.212	0.213	0.214	0.212	0.242
8	0.358	0.358	0.380	0.355	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.317	0.316	0.316	0.316	0.240	0.240	0.240	0.243	0.241	0.240	0.267
9	0.363	0.363	0.392	0.349	0.366	0.366	0.366	0.366	0.366	0.366	0.366	0.366	0.368	0.366	0.366	0.366	0.260	0.257	0.260	0.262	0.260	0.260	0.288
10	0.389	0.389	0.404	0.384	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.286	0.287	0.286	0.293	0.284	0.286	0.317
11	0.362	0.362	0.414	0.352	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.330	0.320	0.320	0.320	0.316	0.317	0.316	0.323	0.311	0.316	0.343
12	0.418	0.418	0.425	0.418	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.292	0.290	0.290	0.290	0.347	0.345	0.347	0.352	0.334	0.347	0.352
13	0.427	0.427	0.434	0.427	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.314	0.313	0.313	0.313	0.379	0.373	0.379	0.381	0.371	0.379	0.398
14	0.432	0.432	0.443	0.416	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.330	0.315	0.330	0.330	0.330	0.412	0.408	0.412	0.410	0.409	0.412	0.413
15	0.456	0.456	0.469	0.400	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.380	0.375	0.375	0.375	0.489	0.469	0.489	0.496	0.479	0.489	0.447

Q4 weight	27.2.a	27.3.a	27.4.a	27.6.a	27.7.b	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	Total
0												0.010	0.011	0.015	0.020	0.020	0.011
1					0.046	0.066	0.066	0.066	0.066	0.066	0.066	0.045	0.037	0.040	0.048	0.076	0.046
2	0.077	0.077	0.077	0.083	0.079	0.072	0.072	0.072	0.072	0.072	0.072	0.100	0.071	0.069	0.093	0.096	0.087
3	0.119	0.119	0.119	0.134	0.119	0.099	0.099	0.099	0.099	0.099	0.099	0.124	0.122		0.124	0.126	0.119
4	0.145	0.145	0.145	0.164	0.147	0.176	0.176	0.176	0.176	0.176	0.176	0.146	0.146		0.150	0.153	0.162
5	0.150	0.150	0.251	0.174	0.175	0.170	0.170	0.170	0.170	0.170	0.170	0.173	0.175		0.178	0.177	0.173
6	0.204	0.204	0.351	0.212	0.209	0.225	0.225	0.225	0.225	0.225	0.225	0.196	0.196		0.199	0.193	0.210
7	0.244	0.244	0.366	0.249	0.238	0.247	0.247	0.247	0.247	0.247	0.247	0.213	0.214		0.216	0.208	0.241
8	0.315	0.315	0.383	0.300	0.314	0.296	0.296	0.296	0.296	0.296	0.296	0.240	0.241		0.243	0.239	0.275
9	0.310	0.310	0.395	0.299	0.347	0.316	0.316	0.316	0.316	0.316	0.316	0.260	0.259		0.261	0.258	0.283
10	0.323	0.323	0.406	0.306	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.287	0.292		0.291	0.280	0.318
11	0.314	0.314	0.416	0.302	0.276	0.302	0.302	0.302	0.302	0.302	0.302	0.316	0.320		0.323	0.313	0.317
12	0.371	0.371	0.427	0.364	0.273	0.308	0.308	0.308	0.308	0.308	0.308	0.345	0.348		0.354	0.345	0.360
13	0.408	0.408	0.436	0.385	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.379	0.374		0.382	0.378	0.394
14	0.407	0.407	0.445	0.388	0.395	0.310	0.310	0.310	0.310	0.310	0.310	0.411	0.409		0.412	0.404	0.410
15	0.405	0.405	0.471	0.388	0.348	0.355	0.355	0.355	0.355	0.355	0.355	0.487	0.474		0.491	0.488	0.430

Table 7.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2019 (15 = 15+ group)

all Q																									
weight	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	27.8.e	Total
0																	0.011	0.011	0.015	0.020	0.020	0.020		0.020	0.011
1					0.066	0.057	0.063	0.056	0.056	0.066	0.066	0.054	0.070	0.067	0.048	0.054	0.027	0.025	0.040	0.024	0.048	0.025	0.023	0.032	0.031
2	0.073	0.079	0.082	0.077	0.079	0.078	0.075	0.073	0.065	0.072	0.072	0.069	0.077	0.073	0.072	0.073	0.066	0.048	0.064	0.048	0.088	0.062	0.048	0.074	0.073
3	0.111	0.125	0.132	0.119	0.152	0.114	0.100	0.088	0.083	0.099	0.099	0.083	0.164	0.106	0.086	0.087	0.106	0.105	0.103	0.110	0.114	0.104	0.083	0.111	0.108
4	0.139	0.150	0.159	0.145	0.195	0.168	0.174	0.140	0.117	0.177	0.177	0.114	0.198	0.184	0.117	0.133	0.131	0.134	0.131	0.139	0.141	0.128	0.095	0.137	0.158
5	0.146	0.155	0.240	0.150	0.191	0.163	0.171	0.160	0.153	0.170	0.170	0.155	0.205	0.176	0.157	0.159	0.164	0.167	0.161	0.167	0.172	0.162	0.177	0.168	0.157
6	0.198	0.210	0.347	0.196	0.238	0.210	0.223	0.209	0.208	0.225	0.225	0.207	0.244	0.230	0.204	0.208	0.188	0.191	0.182	0.192	0.193	0.185	0.177	0.192	0.204
7	0.240	0.248	0.362	0.239	0.256	0.241	0.246	0.242	0.242	0.248	0.247	0.242	0.266	0.250	0.241	0.242	0.209	0.209	0.195	0.210	0.211	0.206	0.177	0.211	0.237
8	0.306	0.323	0.381	0.292	0.316	0.290	0.298	0.292	0.291	0.296	0.296	0.291	0.317	0.299	0.291	0.291	0.237	0.237	0.223	0.238	0.238	0.236		0.239	0.269
9	0.299	0.320	0.393	0.288	0.366	0.292	0.317	0.286	0.283	0.317	0.317	0.280	0.351	0.329	0.276	0.282	0.259	0.256	0.237	0.258	0.258	0.258		0.259	0.278
10	0.308	0.336	0.405	0.284	0.308	0.297	0.304	0.299	0.298	0.304	0.304	0.298	0.309	0.305	0.296	0.298	0.289	0.288	0.272	0.290	0.285	0.291		0.287	0.304
11	0.307	0.322	0.414	0.296	0.320	0.291	0.300	0.292	0.292	0.302	0.302	0.291	0.328	0.306	0.290	0.291	0.318	0.319	0.310	0.322	0.313	0.319		0.314	0.309
12	0.358	0.382	0.425	0.334	0.290	0.314	0.307	0.317	0.318	0.308	0.308	0.319	0.297	0.304	0.320	0.318	0.349	0.350	0.331	0.355	0.338	0.349		0.343	0.344
13	0.400	0.414	0.435	0.376	0.313	0.352	0.349	0.359	0.360	0.349	0.349	0.360	0.339	0.343	0.361	0.360	0.382	0.375	0.398	0.382	0.382	0.383		0.380	0.387
14	0.396	0.414	0.444	0.369	0.330	0.310	0.320	0.311	0.307	0.310	0.310	0.305	0.315	0.313	0.307	0.309	0.414	0.414	0.426	0.415	0.411	0.415		0.414	0.402
15	0.389	0.417	0.470	0.356	0.375	0.346	0.354	0.346	0.345	0.355	0.355	0.345	0.378	0.359	0.344	0.345	0.493	0.476	0.460	0.493	0.505	0.491		0.491	0.402

Table 7.2.5.2. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2019 (15 = 15+ group)

Q1																				
cm	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	Total
0														13.5	13.5		13.5	13.5	13.5		13.5
1			18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	14.1	12.0	17.4	14.2	15.5	14.1	13.6	12.7
2	21.4	19.7	21.1	21.3	21.3	20.6	21.3	21.3	21.0	21.3	21.3	21.3	21.3	18.9	16.7	18.5	19.3	21.6	18.9	17.7	19.2
3	24.4	22.3	22.6	22.6	22.6	22.4	22.6	22.6	22.5	22.6	22.6	22.6	22.6	22.9	22.0	21.4	22.7	23.7	22.9	21.4	22.7
4	26.5	25.8	25.6	24.8	24.8	24.1	24.8	24.8	24.3	24.8	24.8	24.8	24.8	24.5	24.2	24.0	24.6	25.0	24.5	22.3	24.9
5	27.0	26.7	27.0	27.4	27.4	27.1	27.4	27.4	27.2	27.4	27.4	27.4	27.4	26.6	26.7	25.1	26.6	26.7	26.6	27.5	26.7
6	29.4	29.2	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	27.8	27.9	29.5	28.1	27.5	27.8	27.5	29.2
7	31.3	31.2	31.4	31.4	31.4	31.4	31.4	31.4	31.4	32.4	31.4	31.4	31.4	28.8	28.8	29.5	29.1	28.8	28.8	27.5	31.1
8	33.0	32.8	32.9	33.0	33.0	33.0	33.0	33.0	33.0	34.2	33.0	33.0	33.0	30.2	30.1	29.5	30.2	30.0	30.2		32.2
9	32.9	32.6	32.6	32.7	32.7	32.7	32.7	32.7	32.7	31.6	32.7	32.7	32.7	31.2	31.0	29.5	31.2	31.1	31.2		32.1
10	33.1	32.7	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.8	33.9	33.9	33.9	32.5	32.3	29.5	32.2	32.5	32.5		33.0
11	33.5	33.4	33.3	33.3	33.3	33.3	33.3	33.3	33.3	34.2	33.3	33.3	33.3	33.5	33.4		33.2	33.4	33.5		33.4
12	34.6	34.1	34.4	34.2	34.2	34.2	34.2	34.2	34.2	34.4	34.2	34.2	34.2	34.5	34.6		34.6	34.2	34.5		34.2
13	35.7	35.5	35.5	35.6	35.6	35.6	35.6	35.6	35.6	36.0	35.6	35.6	35.6	35.6	35.5		35.5	35.9	35.6		35.6
14	35.7	35.2	32.6	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	36.5	36.5		36.6	36.6	36.5		35.6
15	35.5	34.9	35.2	35.2	35.2	35.2	35.2	35.2	35.2	34.2	35.2	35.2	35.2	38.6	38.4		38.2	39.7	38.6		35.2

Q2																		
cm	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.h	27.7.j	27.7.j.2	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0												13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
1			20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	15.3	14.3	17.7	13.9	14.7	15.3	15.3	14.1
2	17.7	17.7	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	20.2	18.6	19.8	16.8	20.1	20.2	20.2	18.8
3	21.8	21.8	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.5	23.2	23.0	22.1	22.8	23.5	23.5	22.9
4	25.6	25.6	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	25.2	24.9	24.9	25.0	24.2	25.2	25.2	25.3
5	26.7	26.7	27.5	27.5	27.5	27.5	27.5	27.5	27.8	27.5	27.5	27.0	26.8	26.6	26.8	26.3	27.0	27.0	27.1
6	29.4	29.4	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	28.2	28.1	27.7	28.1	27.4	28.3	28.3	28.4
7	31.3	31.3	31.6	31.6	31.6	31.6	31.6	31.6	31.4	31.6	31.6	29.1	28.9	28.3	28.9	28.7	29.2	29.2	29.9
8	33.2	33.2	33.0	33.0	33.0	33.0	33.0	33.0	33.1	33.0	33.0	30.4	30.1	29.7	29.9	30.2	30.4	30.4	30.5
9	33.4	33.4	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	31.2	31.0	30.3	30.8	31.0	31.2	31.2	31.3
10	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	32.3	32.1	31.8	32.2	32.3	32.3	32.3	32.7
11	33.7	33.7	33.6	33.6	33.6	33.6	33.6	33.6	33.6	33.6	33.6	33.3	33.4	33.1	33.5	33.3	33.3	33.3	33.5
12	34.8	34.8	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	34.5	34.7	33.9	34.8	34.1	34.3	34.3	34.3
13	36.0	36.0	35.3	35.3	35.3	35.3	35.3	35.3	34.8	35.3	35.3	35.5	35.5	36.0	35.5	36.0	35.4	35.4	35.6
14	35.9	35.9	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3	36.5	36.7	36.8	36.8	36.5	36.5	36.5	36.5
15	35.9	35.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	38.8	38.3	37.8	38.7	39.6	38.6	38.6	36.6

Table 7.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2019 (15 = 15+ group)

Q3																						
cm	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	Total
0																	13.5	13.4	13.4	13.4	13.4	13.4	13.4
1					20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.5	20.2	20.2	20.2	15.3	15.5	15.3	16.8	18.1	15.3	17.5
2	22.0	22.0	22.0	22.0	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	20.2	20.1	20.2	22.1	22.9	20.2	22.4
3	25.8	25.8	25.8	26.1	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	27.5	26.4	26.4	26.4	23.5	23.6	23.5	24.4	24.6	23.5	24.9
4	27.6	27.6	27.6	27.4	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	28.0	27.9	27.9	27.9	25.3	25.4	25.3	25.7	26.1	25.3	27.4
5	28.6	28.6	30.9	28.0	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.7	28.4	28.4	28.4	27.1	27.4	27.1	27.0	27.5	27.1	28.3
6	30.7	30.7	33.4	29.4	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.3	30.2	30.2	30.2	28.4	28.5	28.4	28.4	28.6	28.4	29.4
7	31.9	31.9	33.9	31.1	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.9	31.5	31.5	31.5	29.2	29.3	29.2	29.2	29.3	29.2	30.5
8	34.1	34.1	34.5	34.0	33.6	33.6	33.6	33.6	33.6	33.6	33.6	33.6	33.5	33.6	33.6	33.6	30.4	30.4	30.4	30.6	30.5	30.4	31.3
9	34.7	34.7	34.9	35.3	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	31.2	31.1	31.2	31.3	31.2	31.2	32.2
10	35.0	35.0	35.3	34.8	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	32.3	32.3	32.3	32.5	32.2	32.3	33.2
11	34.5	34.5	35.7	34.2	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	34.0	33.7	33.7	33.7	33.3	33.4	33.3	33.6	33.2	33.3	34.1
12	35.9	35.9	36.0	35.9	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.8	32.7	32.7	32.7	34.4	34.3	34.4	34.6	34.0	34.4	34.3
13	36.2	36.2	36.3	36.2	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	35.4	35.2	35.4	35.5	35.2	35.4	35.7
14	36.5	36.5	36.6	36.0	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.5	35.7	35.7	35.7	36.4	36.3	36.4	36.4	36.3	36.4	36.4
15	37.2	37.2	37.4	36.5	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.3	34.4	34.4	34.4	38.5	38.0	38.5	38.7	38.3	38.5	36.8

Q4																	
cm	27.2.a	27.3.a	27.4.a	27.6.a	27.7.b	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	Total
0												10.5	10.6	12.2	13.4	13.4	10.6
1					18.5	20.2	20.2	20.2	20.2	20.2	20.2	17.2	16.2	16.6	17.7	20.7	17.3
2	21.4	21.4	21.4	21.9	21.9	21.3	21.3	21.3	21.3	21.3	21.3	22.6	20.2	20.1	22.1	22.4	22.0
3	24.5	24.5	24.5	25.6	24.9	23.4	23.4	23.4	23.4	23.4	23.4	24.4	24.3		24.4	24.5	24.3
4	26.5	26.5	26.5	27.4	26.7	27.2	27.2	27.2	27.2	27.2	27.2	25.8	25.8		26.0	26.2	26.8
5	27.0	27.0	30.2	28.0	28.1	27.7	27.7	27.7	27.7	27.7	27.7	27.3	27.4		27.5	27.5	27.9
6	29.6	29.6	33.5	29.8	29.8	30.1	30.1	30.1	30.1	30.1	30.1	28.4	28.5		28.6	28.3	29.3
7	31.4	31.4	34.0	31.4	30.9	31.5	31.5	31.5	31.5	31.5	31.5	29.3	29.3		29.4	29.0	30.8
8	33.3	33.3	34.6	33.0	33.8	33.1	33.1	33.1	33.1	33.1	33.1	30.4	30.5		30.5	30.4	31.8
9	33.5	33.5	35.0	33.1	35.0	33.7	33.7	33.7	33.7	33.7	33.7	31.2	31.2		31.3	31.2	32.1
10	33.7	33.7	35.4	33.2	33.5	33.5	33.5	33.5	33.5	33.5	33.5	32.3	32.5		32.4	32.0	33.3
11	33.7	33.7	35.7	33.3	32.4	33.5	33.5	33.5	33.5	33.5	33.5	33.3	33.5		33.6	33.2	33.6
12	35.0	35.0	36.1	35.0	32.3	33.6	33.6	33.6	33.6	33.6	33.6	34.3	34.4		34.6	34.3	34.7
13	36.0	36.0	36.4	35.5	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.4	35.3		35.5	35.4	35.7
14	36.1	36.1	36.7	35.8	36.5	34.7	34.7	34.7	34.7	34.7	34.7	36.4	36.3		36.4	36.2	36.3
15	36.2	36.2	37.5	35.8	35.0	34.9	34.9	34.9	34.9	34.9	34.9	38.5	38.1		38.6	38.5	36.7

Table 7.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2019 (15 = 15+ group)

all Q																								
cm	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	27.8.e	Total
0																	10.6	10.6	12.2	13.4	13.4	13.4		13.4	10.7
1					20.2	19.4	19.9	19.3	19.3	20.2	20.2	19.1	20.5	20.3	18.6	19.2	14.6	13.8	16.7	14.1	17.4	14.3	13.6	15.3	14.9
2	20.9	21.6	21.8	21.4	21.9	21.8	21.5	21.3	20.7	21.3	21.3	20.9	21.7	21.4	21.3	21.3	19.4	17.6	19.5	17.5	21.6	19.1	17.7	20.2	20.4
3	23.9	24.9	25.4	24.6	26.4	24.4	23.5	22.8	22.4	23.4	23.4	22.5	26.9	23.8	22.7	22.8	23.2	23.0	22.9	23.4	23.7	23.0	21.4	23.5	23.5
4	26.2	26.7	27.2	26.5	27.9	27.1	27.1	25.8	24.7	27.2	27.2	24.7	28.0	27.5	24.9	25.5	24.9	25.0	24.8	25.3	25.4	24.6	22.3	25.2	26.4
5	26.9	27.2	29.9	27.0	28.4	27.6	27.8	27.5	27.1	27.7	27.7	27.2	28.6	27.9	27.4	27.5	26.8	26.9	26.6	26.9	27.2	26.7	27.5	27.0	27.2
6	29.4	29.7	33.3	29.4	30.2	29.9	30.1	29.9	29.9	30.1	30.1	29.9	30.3	30.2	29.9	29.9	28.0	28.2	27.8	28.2	28.3	27.9	27.5	28.3	29.2
7	31.3	31.4	33.9	31.3	31.5	31.4	31.4	31.4	31.4	31.5	31.5	31.4	31.9	31.5	31.4	31.4	29.0	29.1	28.4	29.1	29.1	28.9	27.5	29.2	30.9
8	33.1	33.4	34.5	32.9	33.6	33.0	33.2	33.1	33.1	33.1	33.1	33.0	33.5	33.2	33.0	33.1	30.3	30.3	29.7	30.3	30.4	30.2		30.4	31.6
9	33.2	33.7	34.9	33.1	35.0	33.2	33.8	33.0	32.9	33.8	33.8	32.9	34.5	34.1	32.8	32.9	31.2	31.1	30.3	31.2	31.2	31.2		31.2	32.1
10	33.4	33.9	35.3	32.9	33.3	33.7	33.5	33.7	33.8	33.5	33.5	33.8	33.3	33.4	33.9	33.8	32.4	32.3	31.7	32.4	32.2	32.4		32.3	33.1
11	33.6	33.9	35.7	33.4	33.7	33.3	33.4	33.3	33.3	33.5	33.5	33.3	34.0	33.6	33.3	33.3	33.4	33.4	33.1	33.5	33.2	33.4		33.3	33.6
12	34.8	35.2	36.0	34.4	32.7	34.0	33.6	34.0	34.1	33.6	33.6	34.1	32.9	33.4	34.2	34.1	34.5	34.5	33.9	34.6	34.1	34.5		34.3	34.4
13	35.9	36.0	36.4	35.5	34.5	35.4	35.3	35.5	35.5	35.3	35.3	35.5	35.0	35.2	35.6	35.5	35.5	35.3	36.0	35.5	35.5	35.5		35.4	35.7
14	35.9	36.2	36.6	35.5	35.7	34.1	34.9	34.1	33.9	34.7	34.7	33.8	35.5	34.9	33.8	34.0	36.5	36.5	36.8	36.5	36.4	36.5		36.5	36.1
15	35.8	36.4	37.4	35.2	34.4	35.1	34.9	35.1	35.1	34.9	34.9	35.1	34.4	34.8	35.2	35.1	38.6	38.2	37.8	38.6	38.9	38.6		38.6	36.1

Table 7.2.5.3. Western horse mackerel. Catch weights-at-age (kg), from Q1 and Q2 data.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1982	0.024	0.052	0.066	0.080	0.207	0.232	0.269	0.280	0.292	0.305	0.369	0.348	0.348	0.348	0.356	0.366
1983	0.024	0.052	0.066	0.080	0.171	0.227	0.257	0.276	0.270	0.243	0.390	0.348	0.348	0.348	0.356	0.366
1984	0.024	0.052	0.064	0.077	0.122	0.155	0.201	0.223	0.253	0.246	0.338	0.348	0.348	0.348	0.356	0.366
1985	0.024	0.052	0.066	0.081	0.148	0.140	0.193	0.236	0.242	0.289	0.247	0.241	0.251	0.314	0.346	0.321
1986	0.024	0.052	0.066	0.080	0.105	0.134	0.169	0.195	0.242	0.292	0.262	0.319	0.287	0.345	0.260	0.360
1987	0.024	0.052	0.066	0.080	0.105	0.126	0.150	0.171	0.218	0.254	0.281	0.336	0.244	0.328	0.245	0.373
1988	0.024	0.052	0.066	0.080	0.105	0.126	0.141	0.143	0.217	0.274	0.305	0.434	0.404	0.331	0.392	0.424
1989	0.024	0.052	0.066	0.080	0.105	0.103	0.131	0.159	0.127	0.210	0.252	0.381	0.400	0.421	0.448	0.516
1990	0.024	0.052	0.066	0.080	0.105	0.127	0.135	0.124	0.154	0.174	0.282	0.328	0.355	0.399	0.388	0.379
1991	0.024	0.052	0.066	0.080	0.121	0.137	0.143	0.144	0.150	0.182	0.189	0.303	0.323	0.354	0.365	0.330
1992	0.024	0.052	0.066	0.080	0.105	0.133	0.151	0.150	0.158	0.160	0.182	0.288	0.306	0.359	0.393	0.401

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1993	0.024	0.052	0.066	0.080	0.105	0.153	0.166	0.173	0.172	0.170	0.206	0.238	0.308	0.327	0.376	0.421
1994	0.024	0.052	0.066	0.080	0.105	0.147	0.185	0.169	0.191	0.191	0.190	0.275	0.240	0.326	0.342	0.383
1995	0.024	0.052	0.059	0.066	0.119	0.096	0.152	0.166	0.178	0.187	0.197	0.222	0.215	0.246	0.237	0.298
1996	0.024	0.052	0.073	0.095	0.118	0.129	0.148	0.172	0.183	0.185	0.202	0.224	0.233	0.229	0.280	0.332
1997	0.024	0.052	0.066	0.080	0.112	0.124	0.162	0.169	0.184	0.188	0.208	0.241	0.229	0.268	0.286	0.266
1998	0.024	0.052	0.071	0.090	0.108	0.129	0.142	0.151	0.162	0.174	0.191	0.220	0.229	0.268	0.286	0.271
1999	0.024	0.052	0.081	0.110	0.120	0.130	0.160	0.170	0.180	0.190	0.210	0.241	0.233	0.268	0.286	0.274
2000	0.024	0.052	0.102	0.115	0.128	0.158	0.169	0.181	0.208	0.224	0.225	0.227	0.247	0.247	0.272	0.378
2001	0.020	0.048	0.077	0.109	0.133	0.160	0.169	0.176	0.187	0.205	0.220	0.241	0.265	0.244	0.266	0.308
2002	0.020	0.039	0.067	0.133	0.152	0.164	0.175	0.194	0.202	0.222	0.242	0.275	0.299	0.307	0.306	0.329
2003	0.022	0.060	0.089	0.114	0.142	0.160	0.175	0.178	0.194	0.205	0.226	0.249	0.267	0.286	0.278	0.317
2004	0.036	0.064	0.100	0.120	0.148	0.168	0.186	0.201	0.219	0.209	0.221	0.233	0.262	0.260	0.322	0.303
2005	0.023	0.053	0.071	0.114	0.136	0.158	0.184	0.196	0.197	0.202	0.222	0.230	0.247	0.281	0.268	0.344
2006	0.019	0.038	0.078	0.114	0.141	0.154	0.180	0.199	0.212	0.222	0.235	0.229	0.235	0.248	0.253	0.304
2007	0.024	0.048	0.067	0.092	0.130	0.150	0.163	0.186	0.210	0.233	0.248	0.256	0.264	0.286	0.310	0.347
2008	0.031	0.051	0.082	0.116	0.144	0.164	0.176	0.190	0.240	0.251	0.251	0.281	0.279	0.289	0.293	0.352
2009	0.025	0.047	0.070	0.107	0.156	0.177	0.187	0.203	0.225	0.252	0.270	0.292	0.306	0.322	0.316	0.370
2010	0.026	0.048	0.087	0.118	0.151	0.178	0.201	0.212	0.229	0.248	0.274	0.305	0.312	0.335	0.329	0.376

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2011	0.028	0.051	0.079	0.112	0.151	0.172	0.192	0.211	0.223	0.243	0.261	0.288	0.305	0.324	0.329	0.330
2012	0.044	0.060	0.087	0.118	0.151	0.175	0.198	0.213	0.232	0.256	0.266	0.286	0.312	0.307	0.347	0.357
2013	0.040	0.058	0.102	0.130	0.154	0.172	0.195	0.228	0.243	0.249	0.248	0.288	0.288	0.321	0.348	0.355
2014	0.032	0.053	0.094	0.127	0.143	0.180	0.201	0.224	0.247	0.259	0.273	0.278	0.289	0.311	0.304	0.353
2015	0.021	0.082	0.083	0.137	0.144	0.176	0.200	0.219	0.235	0.256	0.279	0.285	0.297	0.313	0.312	0.348
2016	0.016	0.055	0.096	0.133	0.164	0.192	0.200	0.225	0.249	0.254	0.306	0.295	0.310	0.335	0.337	0.339
2017	0.016	0.039	0.077	0.098	0.124	0.173	0.199	0.216	0.249	0.266	0.286	0.307	0.333	0.334	0.337	0.370
2018	0.013	0.028	0.074	0.092	0.113	0.161	0.207	0.236	0.231	0.270	0.282	0.295	0.336	0.339	0.327	0.358
2019	0.011	0.032	0.074	0.108	0.156	0.159	0.205	0.237	0.268	0.277	0.304	0.309	0.346	0.386	0.400	0.402

Table 7.2.6.1. Western horse mackerel. Maturity-at-age.

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0	0	0.4	0.8	1	1	1	1	1	1	1	1
1983	0	0	0.3	0.7	1	1	1	1	1	1	1	1
1984	0	0	0.1	0.6	0.85	1	1	1	1	1	1	1
1985	0	0	0.1	0.4	0.8	0.95	1	1	1	1	1	1
1986	0	0	0.1	0.4	0.6	0.9	1	1	1	1	1	1
1987	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1988	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1989	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1990	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1991	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1992	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1993	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1994	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1995	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1996	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1997	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1998	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
1999	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2000	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2001	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2002	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2003	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2004	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2005	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2006	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2007	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2008	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2009	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2010	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2011	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2012	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2013	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2014	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2015	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2016	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2017	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2018	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2019	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1

Table 7.2.8.1. Western horse mackerel. Potential fecundity (10^6 eggs) per kg spawning female vs. weight in kg.

	1987		1992		1995		1998		2000		2001		2001 (cont)	
	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.
1	0.168	1.524	0.105	1.317	0.13	1.307	0.172	1.318	0.258	0.841	0.086	0.688	0.165	1.382
2	0.179	0.916	0.109	2.056	0.157	1.246	0.104	0.867	0.268	0.747	0.08	0.812	0.166	1.579
3	0.192	2.083	0.11	1.869	0.168	1.699	0.112	1.312	0.304	1.188	0.081	0.535	0.167	1.479
4	0.233	1.644	0.112	1.772	0.179	1.135	0.206	0.382	0.311	1.411	0.095	0.88	0.113	0.527
5	0.213	1.066	0.115	1.188	0.189	1.529	0.207	0.78	0.337	0.613	0.11	1.164	0.14	0.876
6	0.217	2.392	0.119	1.317	0.168	1.1	0.109	1.133	0.339	1.571	0.113	1.106	0.122	0.589
7	0.277	1.617	0.12	1.413	0.209	1.497	0.132	1.02	0.341	1.522	0.095	0.823	0.12	0.68
8	0.279	1.018	0.123	1.293	0.215	1.524	0.2	1.088	0.355	1.056	0.11	0.883	0.121	0.578
9	0.274	1.62	0.123	1.991	0.218	1.616	0.152	1.417	0.357	0.604	0.108	0.823	0.139	0.723
10	0.3	1.513	0.131	1.617	0.226	1.883	0.149	1.004	0.367	1.15	0.097	0.741	0.144	1.213
11	0.32	1.647	0.135	0.793	0.22	1.324			0.393	1.279	0.101	0.853	0.144	1.265
12	0.273	1.956	0.131	1.039	0.236	1.221			0.393	0.668	0.106	1.133	0.171	0.956
13	0.212	2.83	0.136	1.06	0.261	1.21			0.413	0.694	0.107	0.935	0.121	0.607
14	0.268	1.687	0.138	1.489	0.245	1.445			0.421	1.339	0.107	0.494	0.122	0.689
15	0.32	1.088	0.147	1.214	0.306	1.693			0.423	0.798	0.11	0.85	0.139	0.915
16	0.318	1.208	0.151	1.158	0.314	1.312			0.445	1.03	0.111	0.67	0.153	0.943
17	0.343	1.933	0.16	1.349	0.46	1.575			0.446	1.208	0.103	0.632	0.154	0.709
18	0.378	1.429	0.165	1.359	0.449	1.43			0.152	0.643	0.111	0.547	0.156	0.773
19	0.404	1.849	0.165	0.945					0.165	0.579	0.118	0.88	0.162	1.158
20	0.428	2.236	0.167	1					0.175	0.596	0.107	0.944	0.174	1.389
21	0.398	1.538	0.168	1.545					0.179	0.997	0.104	0.724	0.175	1.426
22	0.431	1.223	0.18	1.299					0.19	0.744	0.111	0.86	0.179	1.248
23	0.432	1.465	0.174	1.487					0.197	0.613	0.11	0.728	0.179	1.236
24	0.421	1.843	0.178	1.594					0.203	0.702	0.111	0.544	0.18	2.353
25	0.481	1.757	0.185	1.475					0.219	0.472	0.129	0.935	0.184	2.255
26	0.494	1.611	0.195	1.41					0.223	0.806	0.114	0.901	0.139	0.931
27	0.54	1.754	0.203	1.937					0.227	0.606	0.114	0.557	0.161	1.037

	1987		1992		1995		1998		2000		2001		2001 (cont)	
28	0.564	2.255	0.205	1.534					0.289	1.273	0.151	1.377	0.162	0.893
29	0.585	1.221	0.213	1.577					0.294	1.395	0.153	1.596	0.169	0.691
30			0.222	0.958					0.3	1.305	0.154	1.699	0.18	1.609
31			0.275	2.444							0.103	0.679	0.185	1.776
32											0.12	1.14	0.211	2.102
33											0.12	0.631	0.224	1.466
34											0.121	0.834	0.162	0.849
35											0.144	0.626	0.17	0.668
36											0.116	0.668	0.187	1.453
37											0.118	1.194	0.198	1.371
38											0.112	0.779	0.219	1.847
39											0.126	0.782	0.22	1.578
40											0.139	1.244	0.201	0.878
41											0.119	1.212	0.206	1.196
42											0.109	0.755	0.223	1.115
43											0.122	0.841	0.225	1.43
44											0.131	0.929	0.233	1.724
45	8										0.135	0.862	0.241	1.131
46											0.142	1.834	0.219	0.96
47											0.146	1.689	0.237	1.33
48											0.148	1.357	0.241	0.918
49											0.151	1.817	0.34	0.605
50											0.164	1.631	0.407	1.189
51											0.164	1.052		

Table 7.3.1.1. Western horse mackerel. Final assessment. Numbers-at-age (thousands).

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	49133200	1349300	2620060	5945940	1160810	1466530	1338810	823304	547967	491299	454429	515775	605038	740588	432484	285366	252509	223561	196418	172296	1248960
1983	1642070	42259700	1157570	2237150	5050480	981983	1237550	1128390	693530	461488	413724	382659	434308	509467	623602	364166	240288	212621	188245	165390	1196740
1984	1748540	1411980	36209700	985396	1890690	4244350	822447	1034740	942761	579257	385398	345489	319539	362664	425421	520725	304088	200646	177543	157189	1137410
1985	2258230	1503660	1210340	30855100	834183	1592390	3563700	689491	866876	789592	485088	322727	289301	267568	303677	356225	436027	254626	168010	148665	1084020
1986	2852830	1942280	1289860	1033190	26197100	705279	1342910	3001560	580406	729556	664449	408188	271561	243432	225143	255526	299741	366889	214252	141370	1037220
1987	6183440	2453260	1664780	1098920	874386	22055500	591916	1125290	2513420	485875	610658	556132	341638	227283	203739	188432	213860	250865	307063	179315	986407
1988	4287780	5316040	2100300	1414280	925615	731594	18379600	492276	935035	2087700	403514	507110	461815	283693	188732	169181	156470	177584	208312	254978	967985
1989	3615060	3685770	4548120	1781300	1187970	771676	607163	15219100	407218	773151	1725950	333568	419192	381743	234502	156006	139845	129337	146790	172190	1010890
1990	2109570	3107390	3152840	3855830	1495280	989554	639805	502238	12576200	336355	638495	1425230	275440	346136	315210	193631	128815	115470	106794	121205	976873
1991	3784560	1812390	2651720	2657270	3205400	1229800	808619	521136	408502	10222900	273347	518831	1158060	223801	281239	256110	157325	104662	93819	86770	892180
1992	8157360	3250710	1545060	2229410	2200020	2622240	998822	654382	421063	329838	8251980	220620	418728	934599	180613	226965	206684	126963	84463	75713	790017
1993	6960790	6999410	2757820	1283660	1809860	1754080	2068100	783485	512074	329164	257740	6447010	172349	327096	730061	141083	177289	161446	99174	65976	676239
1994	6146510	5967090	5912210	2266830	1023790	1409940	1347250	1577250	595664	388807	249790	195542	4890650	130735	248111	553760	107012	134474	122456	75223	562963
1995	4253020	5268510	5037810	4853900	1804390	795527	1079770	1024310	1195340	450825	294101	188898	147857	3697810	98845	187587	418671	80906	101668	92582	482492
1996	2255450	3638500	4408340	4046220	3725870	1337020	577053	774958	731710	852203	321146	209426	134490	105261	2632390	70364	133533	298027	57592	72371	409353
1997	1575040	1931140	3056070	3573830	3154200	2817120	992465	424424	567675	535083	622751	234605	152969	98227	76876	1922480	51387	97519	217648	42059	351798
1998	2816340	1345700	1606040	2418220	2676430	2262980	1969500	684948	291249	388621	365940	425708	160341	104536	67122	52531	1313640	35113	66634	148717	269116
1999	2783680	2411920	1131500	1305420	1893280	2035140	1690700	1458570	505290	214507	286025	269252	313183	117951	76896	49374	38640	966269	25828	49013	307338

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2000	1952670	2383790	2027330	918962	1020680	1437110	1517440	1249430	1073640	371328	157527	209984	197642	229873	86571	56438	36237	28359	709168	18956	261533
2001	12198800	1674320	2015780	1670960	736249	799868	1111300	1165630	956946	821297	283905	120413	160494	151052	175680	66161	43131	27693	21673	541959	214353
2002	2542750	10450500	1409970	1644630	1316400	564411	603171	831164	868643	712043	610718	211053	89502	119286	112265	130566	49170	32055	20581	16107	562077
2003	1285310	2179180	8816420	1155460	1305160	1018850	430291	456388	626808	654159	535912	459532	158787	67334	89737	84454	98220	36989	24113	15482	434937
2004	2533740	1101620	1839170	7232100	918450	1012310	778632	326418	345088	473300	493669	404330	346663	119779	50791	67689	63703	74086	27900	18188	339741
2005	1634550	2173550	933559	1523890	5844890	728010	793062	606443	253578	267792	367118	382841	313529	268800	92873	39381	52483	49392	57443	21632	277517
2006	1332670	1401740	1839220	770716	1224210	4596670	565240	611819	466528	194843	205662	281882	293924	240698	206353	71296	30231	40289	37916	44096	229642
2007	2195570	1143460	1189010	1527450	625263	975220	3621710	442914	478252	364309	152087	160501	219965	229352	187815	161014	55631	23589	31436	29585	213588
2008	5132080	1884960	972618	994184	1253190	505474	781393	2889010	352616	380436	289697	120920	127602	174870	182329	149306	128000	44224	18752	24990	193311
2009	1300760	4403620	1599240	808179	807277	999475	398794	613156	2261590	275761	297391	226418	94499	99716	136652	142479	116673	100022	34558	14653	170585
2010	986262	1114820	3715760	1311180	641860	625443	762855	302119	462986	1705340	207815	224059	170566	71184	75112	102932	107320	87881	75339	26030	139524
2011	384303	844553	936927	3016760	1024600	486846	465945	563240	222182	339921	1251170	152423	164313	125075	52197	55076	75474	78691	64437	55241	121388
2012	2489660	329029	709222	759195	2349800	773881	360950	342267	412046	162262	248069	912795	111184	119848	91225	38070	40169	55045	57391	46995	128818
2013	1041060	2132060	276598	576175	593890	1784800	577447	266952	252144	303052	119258	182268	670580	81675	88036	67009	27964	29505	40432	42155	129139
2014	3689230	891128	1788570	223562	446919	446118	1315010	421366	193967	182880	219639	86404	132036	485734	59159	63765	48534	20254	21370	29284	124063
2015	2695410	3159110	748879	1451880	174652	338868	332219	970507	309744	142347	134117	161024	63337	96779	356017	43359	46735	35571	14844	15662	112389
2016	2885610	2310670	2668670	615696	1158390	136128	260423	253523	738314	235332	108090	101817	122230	48075	73456	270216	32909	35471	26998	11266	97187
2017	3829570	2473430	1950880	2191130	490151	900267	104270	198037	192174	558902	178045	81758	77003	92436	36355	55549	204339	24886	26823	20416	82012
2018	2880560	3285050	2095720	1615750	1769590	388161	704548	81121	153669	148956	433012	137913	63323	59638	71589	28156	43020	158249	19273	20773	79324

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2019	1571340	2469710	2776720	1725540	1292280	1383650	299389	539729	61957	117218	113563	330049	105108	48258	45449	54555	21456	32783	120592	14687	76277

Table 7.3.1.2. Western horse mackerel. Final assessment. Fishing mortality-at-age.

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0.001	0.003	0.008	0.013	0.017	0.020	0.021	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1983	0.001	0.005	0.011	0.018	0.024	0.027	0.029	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
1984	0.001	0.004	0.010	0.017	0.022	0.025	0.026	0.027	0.027	0.027	0.027	0.027	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
1985	0.001	0.003	0.008	0.014	0.018	0.020	0.022	0.022	0.022	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
1986	0.001	0.004	0.010	0.017	0.022	0.025	0.027	0.027	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
1987	0.001	0.005	0.013	0.022	0.028	0.032	0.034	0.035	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1988	0.001	0.006	0.015	0.024	0.032	0.036	0.039	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
1989	0.001	0.006	0.015	0.025	0.033	0.037	0.040	0.041	0.041	0.041	0.041	0.041	0.041	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1990	0.002	0.009	0.021	0.035	0.045	0.052	0.055	0.057	0.057	0.057	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
1991	0.002	0.010	0.023	0.039	0.051	0.058	0.062	0.063	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
1992	0.003	0.014	0.035	0.058	0.077	0.087	0.093	0.095	0.096	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
1993	0.004	0.019	0.046	0.076	0.100	0.114	0.121	0.124	0.125	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
1994	0.004	0.019	0.047	0.078	0.102	0.117	0.124	0.127	0.129	0.129	0.129	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
1995	0.006	0.028	0.069	0.114	0.150	0.171	0.182	0.186	0.188	0.189	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190
1996	0.005	0.024	0.060	0.099	0.130	0.148	0.157	0.161	0.163	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1997	0.007	0.034	0.084	0.139	0.182	0.208	0.221	0.227	0.229	0.230	0.230	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
1998	0.005	0.023	0.057	0.095	0.124	0.142	0.150	0.154	0.156	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
1999	0.005	0.024	0.058	0.096	0.126	0.144	0.152	0.156	0.158	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
2000	0.004	0.018	0.043	0.072	0.094	0.107	0.114	0.117	0.118	0.118	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
2001	0.005	0.022	0.053	0.089	0.116	0.132	0.140	0.144	0.146	0.146	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147
2002	0.004	0.020	0.049	0.081	0.106	0.121	0.129	0.132	0.134	0.134	0.134	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135
2003	0.004	0.020	0.048	0.080	0.104	0.119	0.126	0.130	0.131	0.131	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132
2004	0.003	0.016	0.038	0.063	0.082	0.094	0.100	0.103	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
2005	0.004	0.017	0.042	0.069	0.090	0.103	0.109	0.112	0.113	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
2006	0.003	0.015	0.036	0.059	0.077	0.088	0.094	0.096	0.097	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
2007	0.003	0.012	0.029	0.048	0.063	0.072	0.076	0.078	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079
2008	0.003	0.014	0.035	0.058	0.076	0.087	0.092	0.095	0.096	0.096	0.096	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
2009	0.004	0.020	0.049	0.080	0.105	0.120	0.128	0.131	0.132	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133
2010	0.005	0.024	0.058	0.097	0.126	0.144	0.153	0.157	0.159	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
2011	0.005	0.025	0.060	0.100	0.131	0.149	0.158	0.163	0.164	0.165	0.165	0.165	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166
2012	0.005	0.024	0.058	0.096	0.125	0.143	0.152	0.156	0.157	0.158	0.158	0.158	0.158	0.158	0.158	0.159	0.159	0.159	0.159	0.159	0.159
2013	0.006	0.026	0.063	0.104	0.136	0.155	0.165	0.169	0.171	0.172	0.172	0.172	0.172	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
2014	0.005	0.024	0.059	0.097	0.127	0.145	0.154	0.158	0.159	0.160	0.160	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2015	0.004	0.019	0.046	0.076	0.099	0.113	0.120	0.123	0.125	0.125	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
2016	0.004	0.019	0.047	0.078	0.102	0.117	0.124	0.127	0.128	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129
2017	0.003	0.016	0.038	0.064	0.083	0.095	0.101	0.104	0.105	0.105	0.105	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
2018	0.004	0.018	0.044	0.073	0.096	0.110	0.116	0.119	0.121	0.121	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
2019	0.004	0.021	0.051	0.085	0.111	0.127	0.135	0.138	0.140	0.140	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141

Table 7.3.1.3. Western horse mackerel. Final assessment. Stock summary table.

Year	Recruit (thousands)	Total Biomass	Spawning biomass	Catch	Yield/SSB	Fbar(1-3)	Fbar(4-8)	Fbar(1-10)
1982	49133200	3217300	2623180	61197	0.023	0.008	0.020	0.017
1983	1642070	3687170	2739660	90442	0.033	0.011	0.028	0.023
1984	1748540	4343350	2850000	96244	0.034	0.010	0.025	0.021
1985	2258230	4966940	3277190	96343	0.029	0.008	0.021	0.018
1986	2852830	5416610	4535850	137499	0.030	0.010	0.026	0.022
1987	6183440	5621800	5279930	187338	0.035	0.013	0.033	0.028
1988	4287780	5617750	5324630	210989	0.040	0.015	0.037	0.031
1989	3615060	5480700	5114970	209583	0.041	0.015	0.038	0.032
1990	2109570	5267270	4851740	275968	0.057	0.021	0.053	0.045
1991	3784560	4932030	4561780	287438	0.063	0.024	0.060	0.050
1992	8157360	4569850	4248040	393631	0.093	0.036	0.090	0.075
1993	6960790	4148240	3792300	453246	0.120	0.047	0.117	0.098
1994	6146510	3749390	3269610	412291	0.126	0.048	0.120	0.100
1995	4253020	3465180	2883260	538950	0.187	0.071	0.175	0.147
1996	2255450	3094560	2549950	422396	0.166	0.061	0.152	0.127
1997	1575040	2829030	2391820	534673	0.224	0.086	0.213	0.178
1998	2816340	2418860	2115690	325340	0.154	0.058	0.145	0.121
1999	2783680	2182890	1961890	298992	0.152	0.059	0.147	0.123
2000	1952670	1956680	1753740	202732	0.116	0.044	0.110	0.092
2001	12198800	1842980	1598450	229081	0.143	0.055	0.136	0.113
2002	2542750	1778730	1437080	196120	0.136	0.050	0.124	0.104
2003	1285310	1800060	1335770	191856	0.144	0.049	0.122	0.102
2004	2533740	1824200	1329740	159742	0.120	0.039	0.096	0.081
2005	1634550	1844520	1524910	182001	0.119	0.043	0.106	0.088
2006	1332670	1796470	1599100	155827	0.097	0.036	0.091	0.076
2007	2195570	1730840	1557620	123356	0.079	0.030	0.073	0.061
2008	5132080	1677390	1508820	143349	0.095	0.036	0.089	0.075

Year	Recruit (thousands)	Total Biomass	Spawning biomass	Catch	Yield/SSB	Fbar(1-3)	Fbar(4-8)	Fbar(1-10)
2009	1300760	1613210	1413300	183782	0.130	0.050	0.123	0.103
2010	986262	1515440	1268900	203112	0.160	0.060	0.148	0.124
2011	384303	1387390	1152140	193698	0.168	0.062	0.153	0.128
2012	2489660	1248410	1100250	169859	0.154	0.059	0.146	0.123
2013	1041060	1121980	1018290	165258	0.162	0.064	0.159	0.133
2014	3689230	1002900	885328	136360	0.154	0.060	0.149	0.124
2015	2695410	934449	770242	98419	0.128	0.047	0.116	0.097
2016	2885610	932424	726361	98810	0.136	0.048	0.120	0.100
2017	3829570	958281	707114	82961	0.117	0.039	0.098	0.082
2018	2880560	1025340	755274	101682	0.135	0.045	0.112	0.094
2019	1571340	1086810	808972	124947	0.154	0.052	0.130	0.109

Table 7.4.1. Western Horse Mackerel. Short term prediction: INPUT DATA. *geometric mean of the recruitment time series from 1983 to 2019. ** from assessment output

Age	N	Mat	M	PF	PM	Stock weight at age**
0	2584096*	0.000	0.150	0	0	0.002626
1	1346400	0.000	0.150	0	0	0.015047
2	2081580	0.047	0.150	0	0	0.038697
3	2270280	0.269	0.150	0	0	0.069972
4	1364160	0.731	0.150	0	0	0.104589
5	995214	0.953	0.150	0	0	0.139179
6	1048870	0.993	0.150	0	0	0.171573
7	225167	0.999	0.150	0	0	0.200615
8	404512	1.000	0.150	0	0	0.225865
9	46367	1.000	0.150	0	0	0.247334
10	87670	1.000	0.150	0	0	0.265292
11	84913	1.000	0.150	0	0	0.280128
12	246752	1.000	0.150	0	0	0.292271
13	78577	1.000	0.150	0	0	0.302138
14	36076	1.000	0.150	0	0	0.310111

Age	N	Mat	M	PF	PM	Stock weight at age**
15	33974	1.000	0.150	0	0	0.316525
16	40781	1.000	0.150	0	0	0.321669
17	16039	1.000	0.150	0	0	0.325782
18	24506	1.000	0.150	0	0	0.329066
19	90145	1.000	0.150	0	0	0.331681
20	67996	1.000	0.150	0	0	0.335422

Table 7.4.2. Western Horse Mackerel. Short term prediction; single area management option table. OPTION: Catch constraint 110 381 t (85% of 2020 TOTAL TAC).

Scenarios	F_{factor}	F_{bar}	Catch_2020	Catch_2021	SSB_2021	SSB_2022	Change_SSB_2021-2022(%)	Change_Catch_2020-2021(%)
B2022=B_{pa}	cannot be reached even by setting F to 0							
F = 0	0.00	0.000	69527	0	961512	1112225	15.67	-100.00
	0.10	0.011	69527	14971	961512	1098482	14.25	-78.47
	0.20	0.022	69527	29761	961512	1084914	12.83	-57.20
	0.30	0.033	69527	44372	961512	1071518	11.44	-36.18
	0.40	0.044	69527	58808	961512	1058291	10.07	-15.42
	0.50	0.054	69527	73069	961512	1045233	8.71	5.10
Fsq	0.52	0.056	69527	75352	961512	1043144	8.49	8.38
	0.6	0.065	69527	87159	961512	1032341	7.37	25.36
F_{MSY}	0.68	0.074	69527	98167	961512	1022274	6.32	41.19
	0.7	0.076	69527	101080	961512	1019611	6.04	45.38
	0.80	0.087	69527	114832	961512	1007044	4.74	65.16
	0.90	0.098	69527	128420	961512	994635	3.44	84.71
F_{lim}	0.95	0.103	69527	134489	961512	989095	2.87	93.44
	1	0.109	69527	141844	961512	982384	2.17	104.01
	1.10	0.120	69527	155107	961512	970288	0.91	123.09
	1.20	0.131	69527	168211	961512	958345	-0.33	141.94

Scenarios	F_{factor}	F_{bar}	Catch_2020	Catch_2021	SSB_2021	SSB_2022	Change_SSB_2021-2022(%)	Change_Catch_2020-2021(%)
	1.30	0.142	69527	181158	961512	946554	-1.56	160.56
	1.40	0.153	69527	193950	961512	934912	-2.77	178.96
	1.50	0.163	69527	206589	961512	923417	-3.96	197.14
	1.60	0.174	69527	219076	961512	912068	-5.14	215.10
	1.70	0.185	69527	231414	961512	900862	-6.31	232.84
	1.80	0.196	69527	243604	961512	889798	-7.46	250.38
	1.90	0.207	69527	255649	961512	878874	-8.59	267.70
	2.00	0.218	69527	267550	961512	868088	-9.72	284.82
$B2022=B_{lim}$	2.32	0.253	69527	304688	961512	834480	-13.21	338.23

7.15 Figures

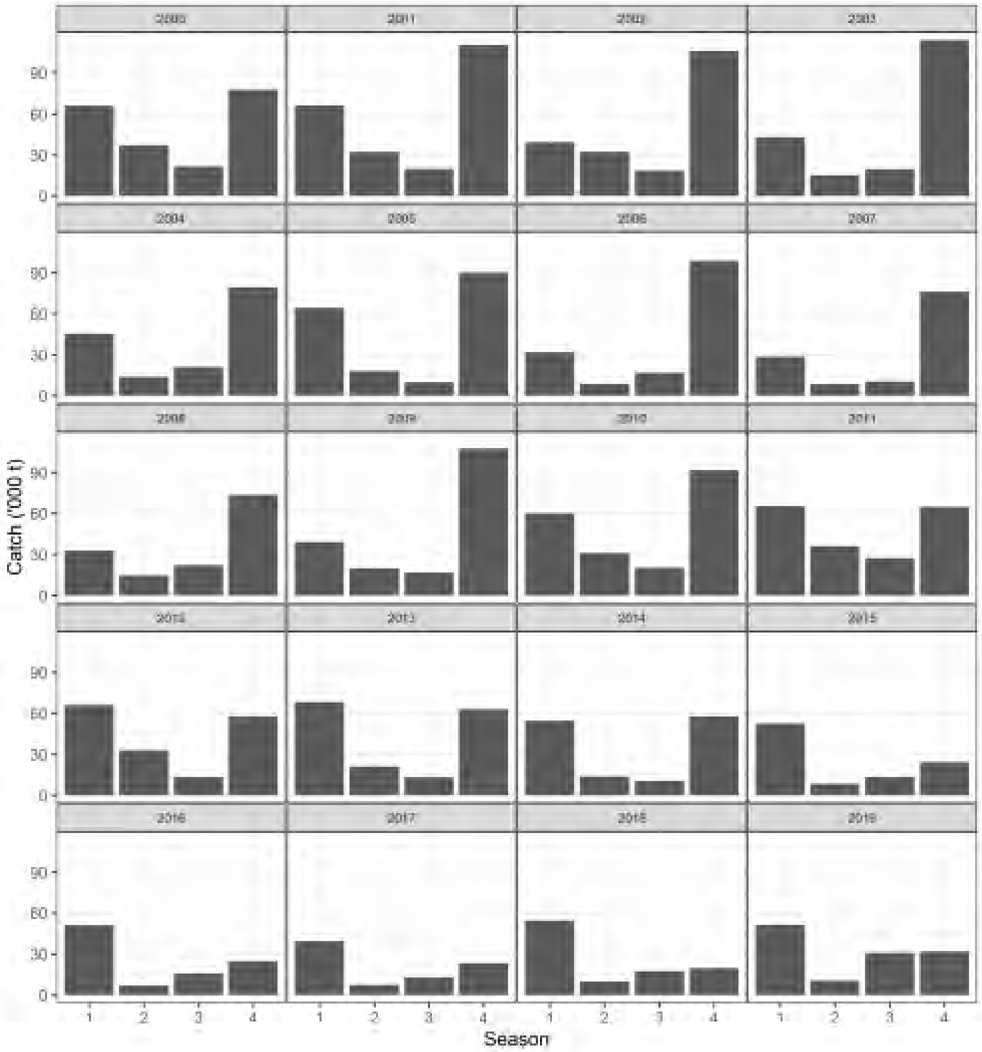


Figure 7.1.1.1: Western horse mackerel. Catch by quarter and year for 2000-2019.

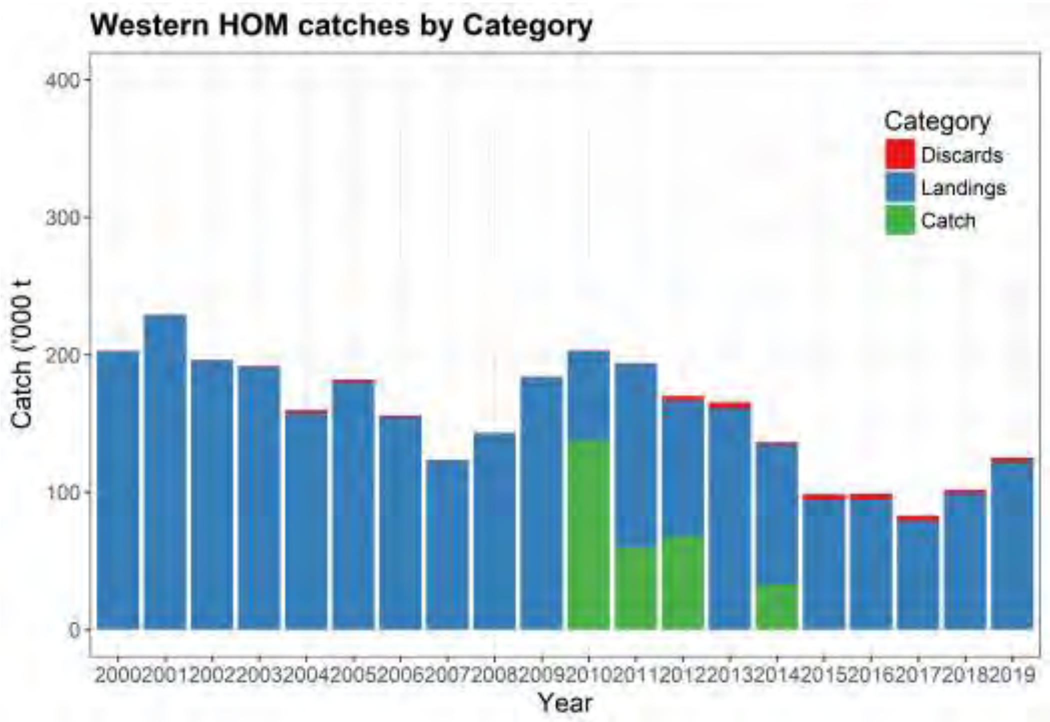


Figure 7.1.2.1. Western horse mackerel. Catch categories since 2000.

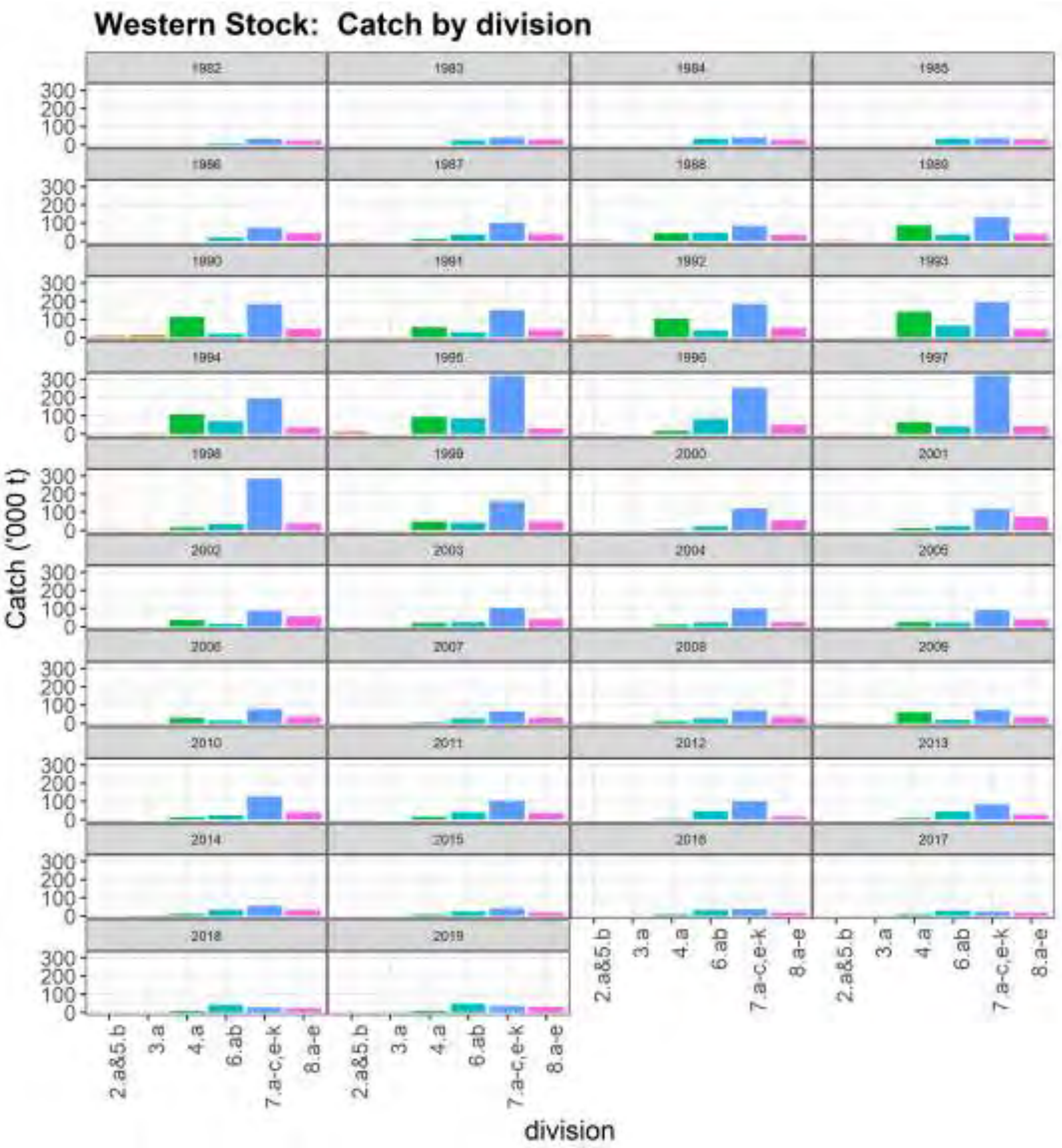


Figure 7.1.3.1: Western horse mackerel. Catch by ICES Division and year for 1982-2019.

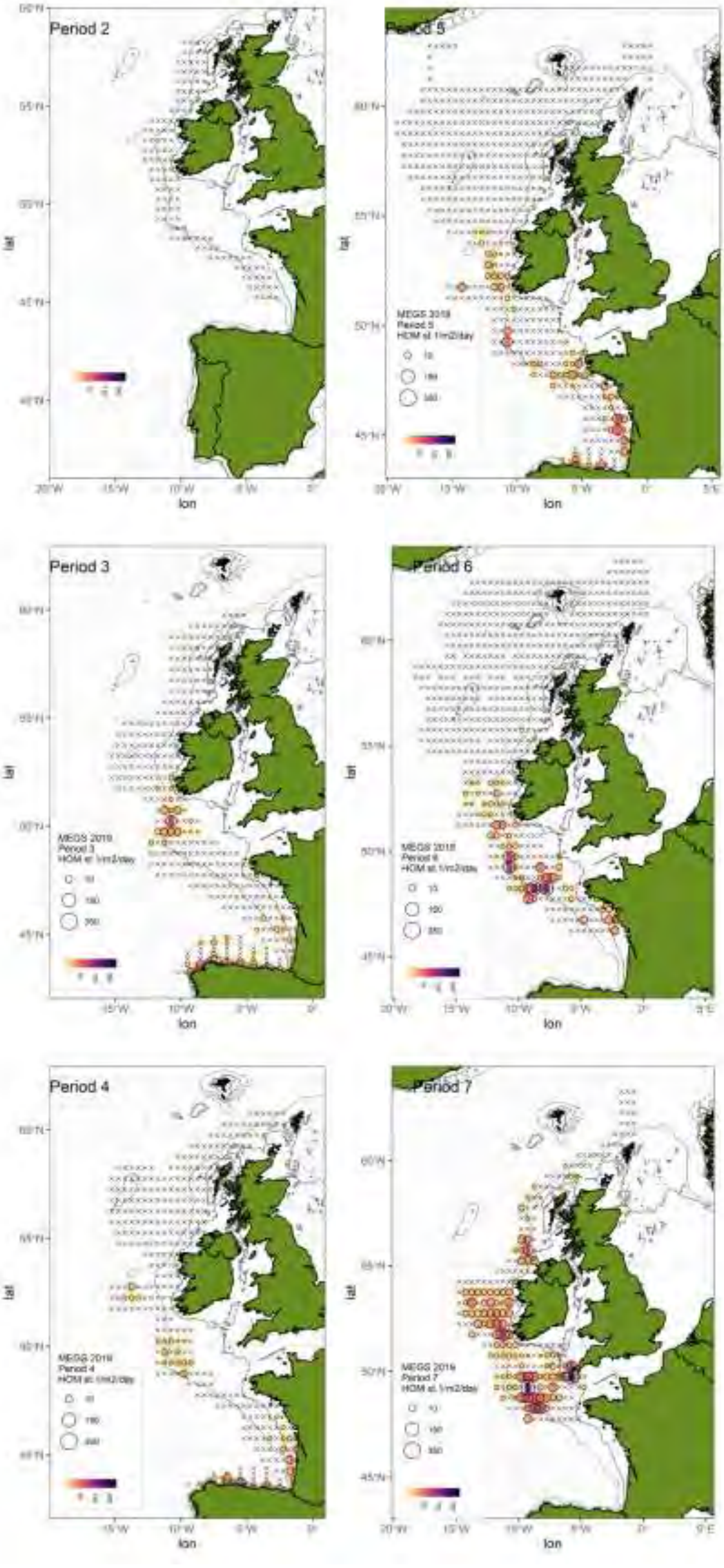


Figure 7.2.1.1: Western horse mackerel egg production by half rectangle for all periods. Circle areas and colour scale represent horse mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

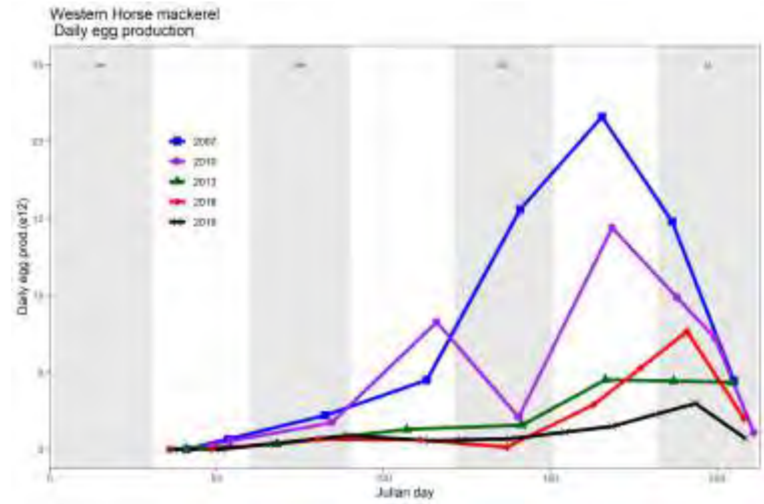


Figure 7.2.1.2: Annual egg production curve for western horse mackerel for 2019 (black line). The curves for 2007, 2010, 2013, and 2016 are included for comparison. Production in numbers exponential 12.

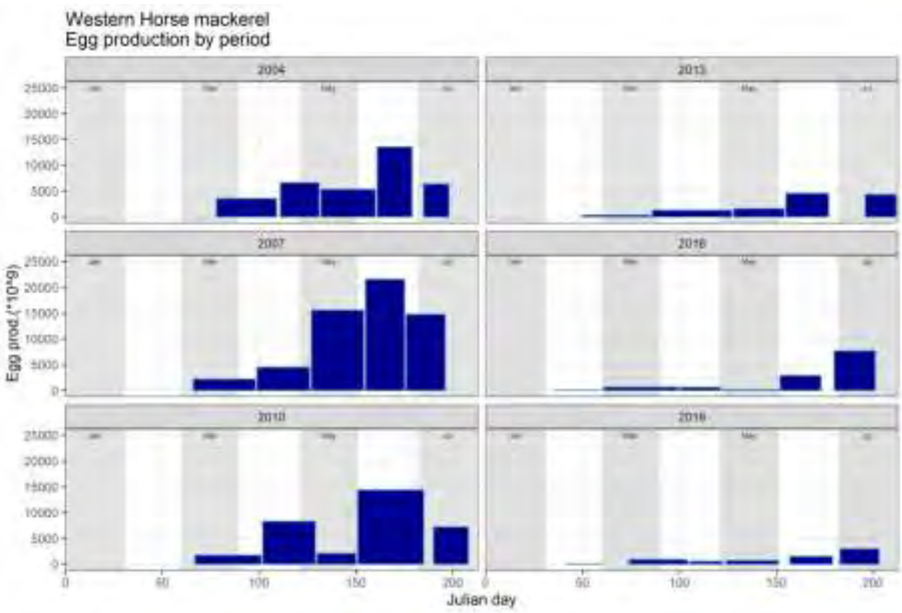


Figure 7.2.1.3: Western horse mackerel egg production by period. Bar area represents its value. Months of January, March, May and July are highlighted in grey background.

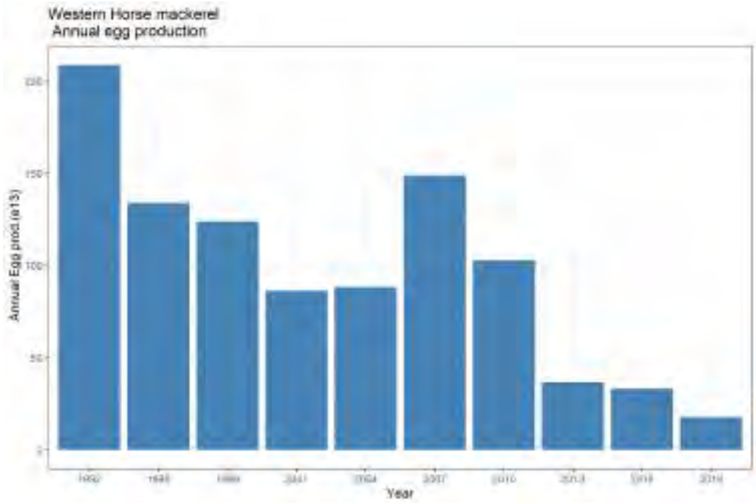


Figure 7.2.1.4. Total Annual Egg Production estimates for western horse mackerel stock. 1992–2019.

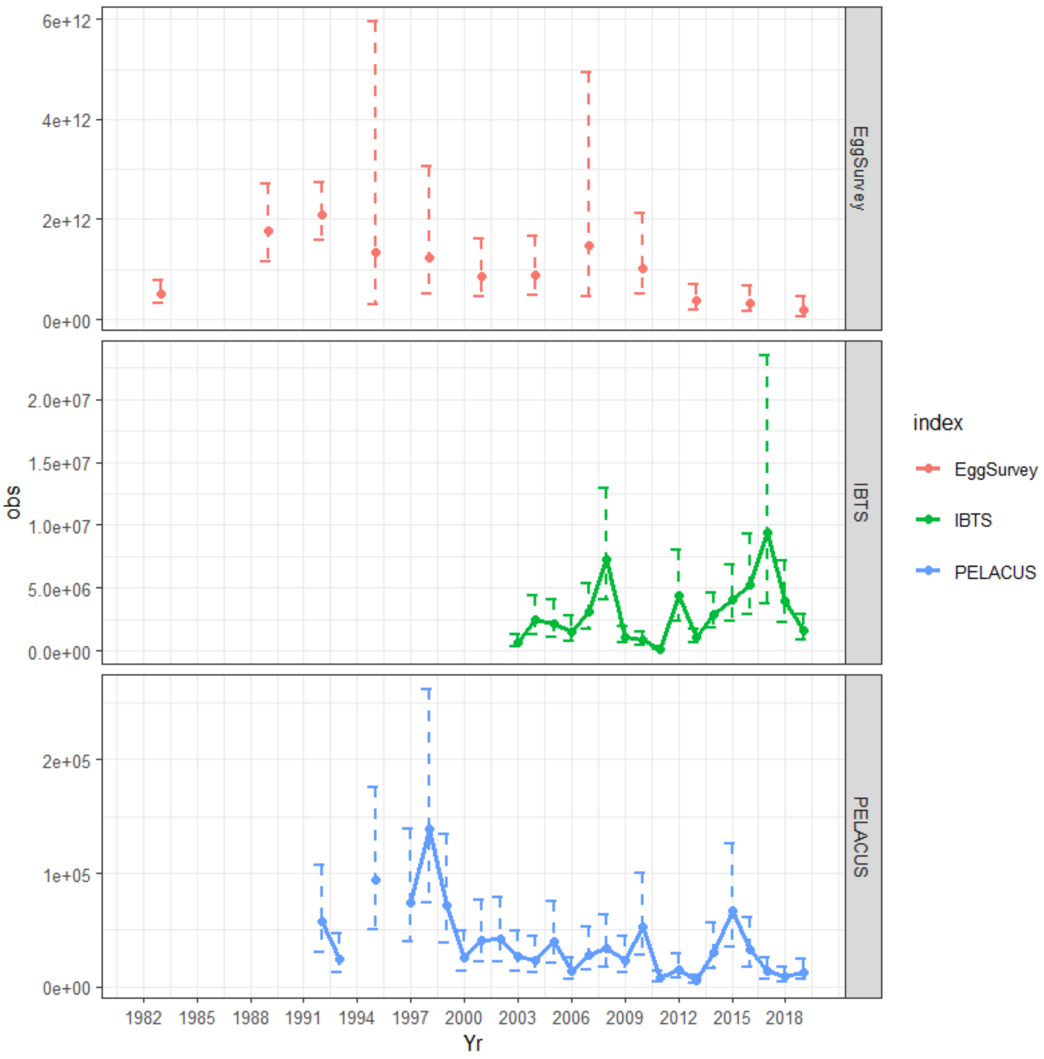


Figure 7.2.2.1: Western horse mackerel. Trend of the fisheries independent indices of abundance used in the assessment of Western Horse mackerel -- Plot on top: Spawning index from egg survey; plot in the middle: recruitment index from IBTS survey; plot at the bottom: biomass estimates from Pelacus acoustic survey. Confidence intervals are shown as well.

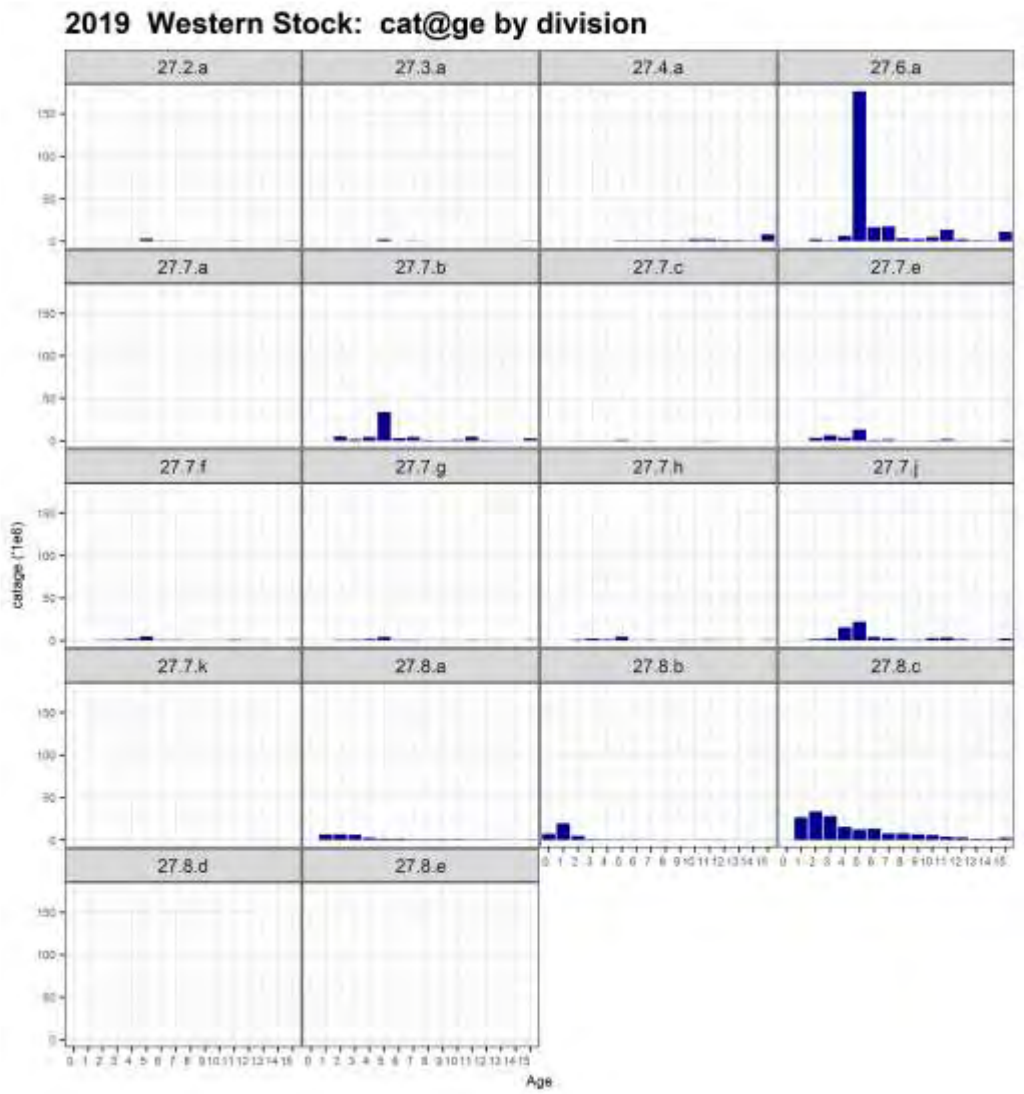


Figure 7.2.4.1: Western horse mackerel. Catch-at-age matrix by division in 2019, expressed as numbers (millions)

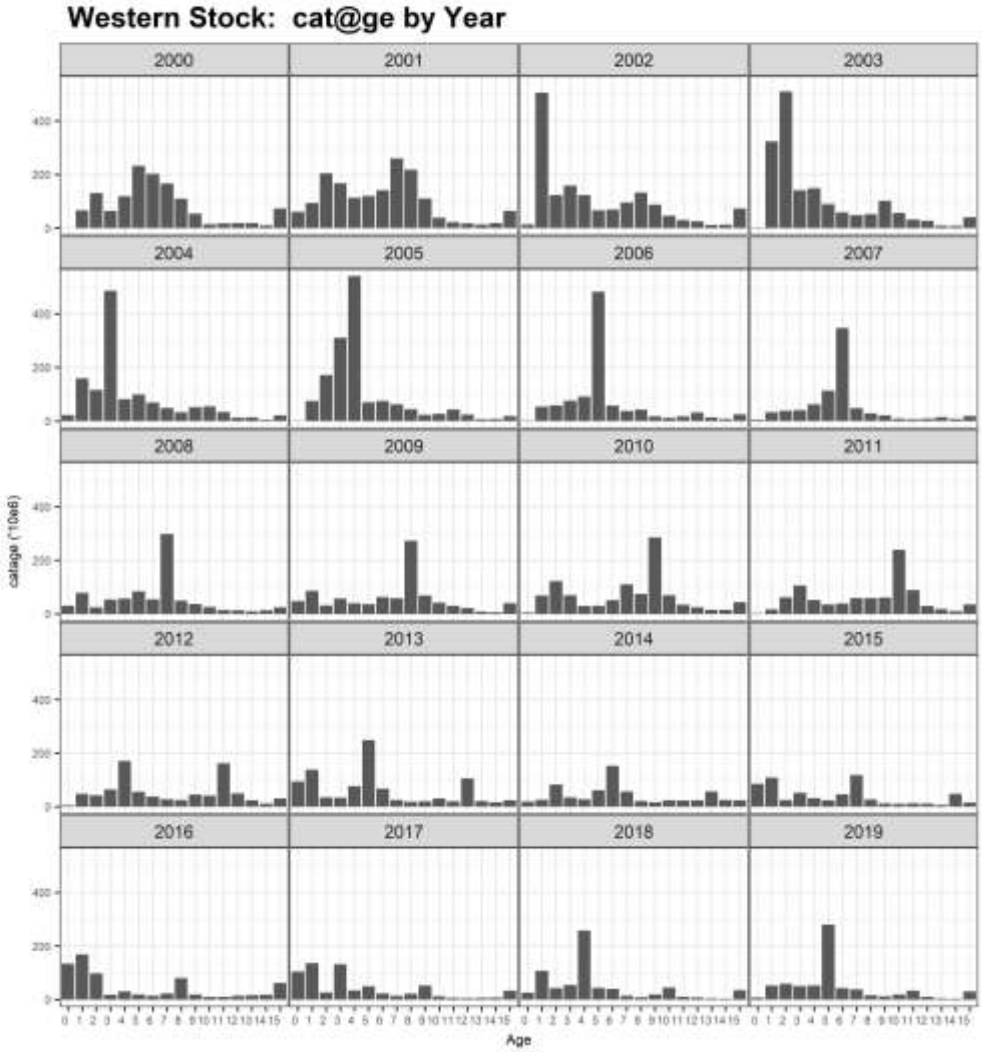


Figure 7.2.4.2: Western horse mackerel. Catch-at-age matrix by year, expressed as numbers (millions)

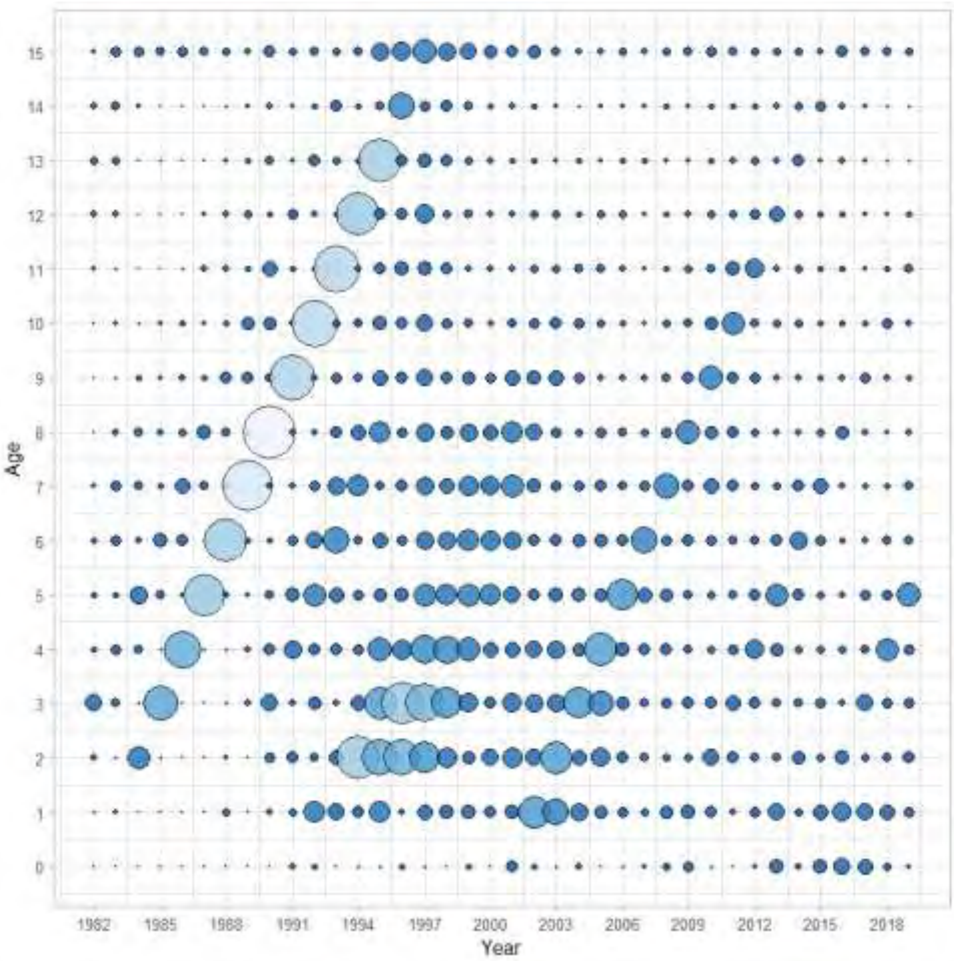


Figure 7.2.4.3: Western horse mackerel. Catch-at-age matrix, expressed as numbers. The area of bubbles is proportional to the catch number. Note that age 15 is a plus group.

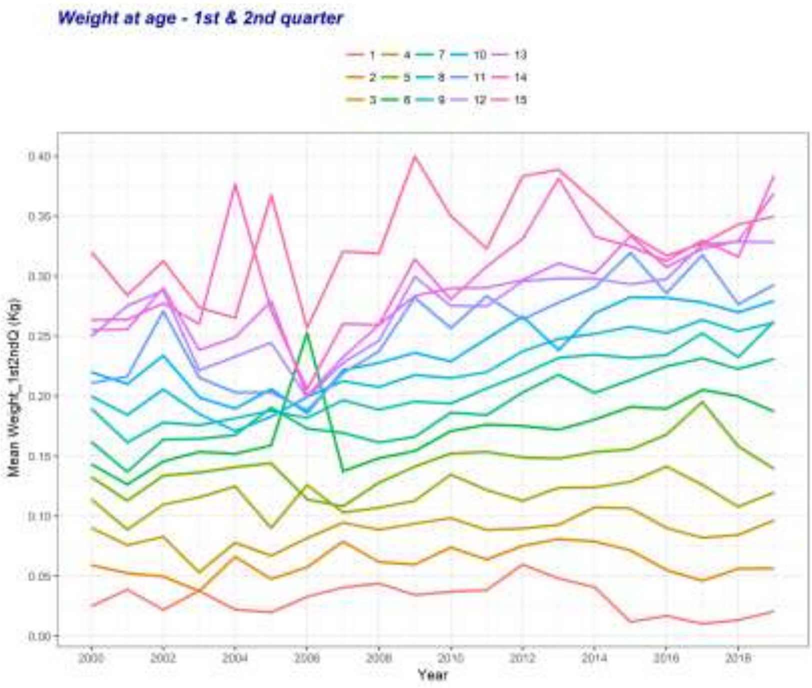


Figure 7.2.5.1: Western horse mackerel. Weight at age in the catch (kg) by year.

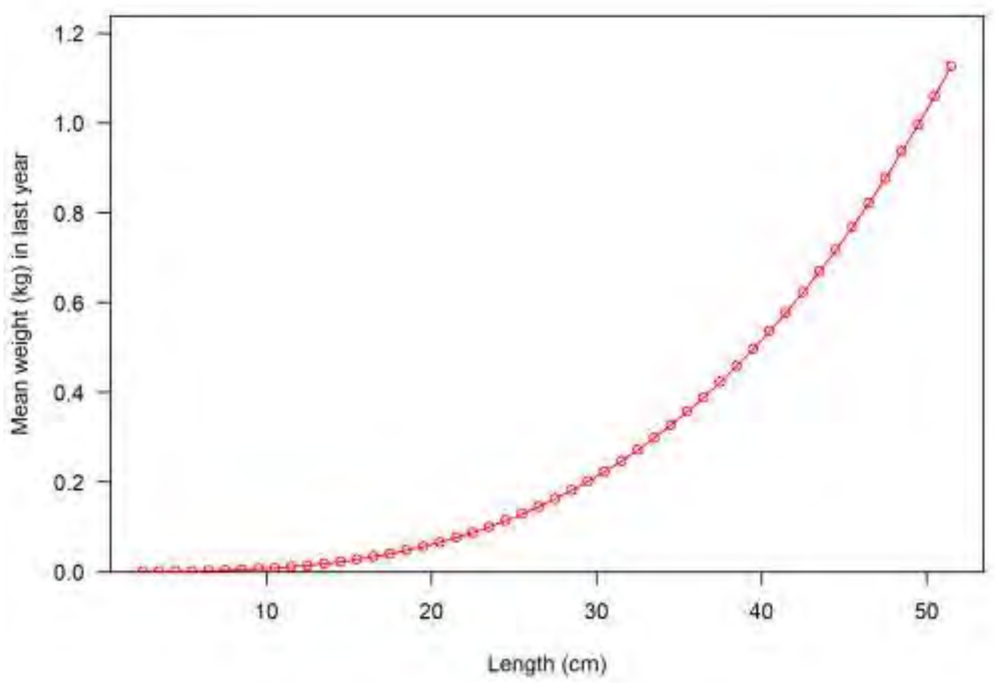


Figure 7.2.5.2: Western horse mackerel. Weight at length in the stock (kg) as estimated by SS.

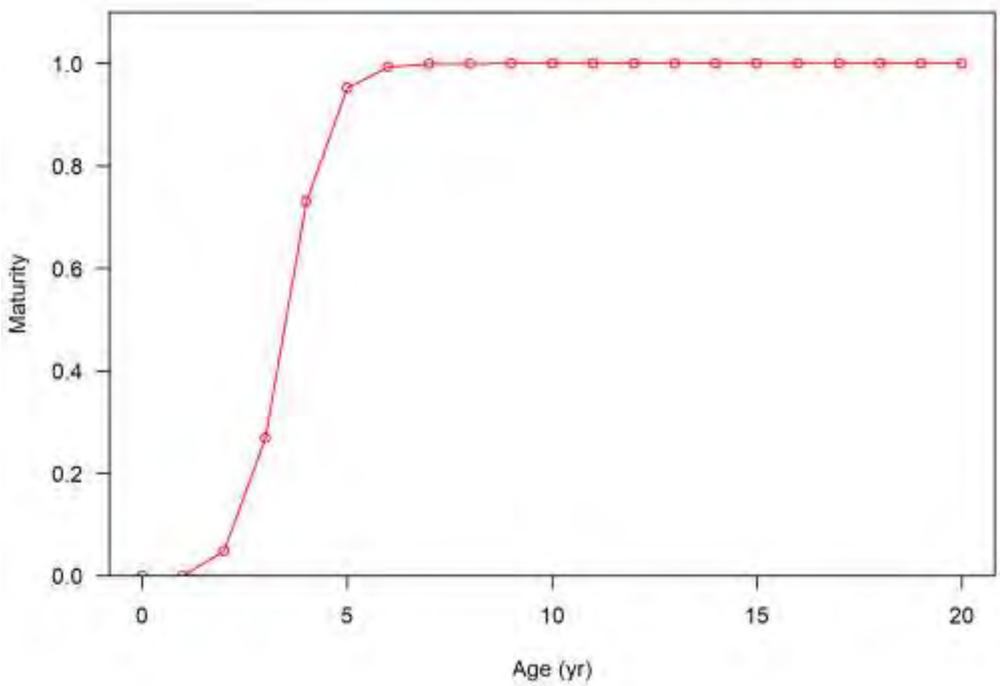


Figure 7.2.6.1: Western horse mackerel. Maturity at age as used in the assessment model.

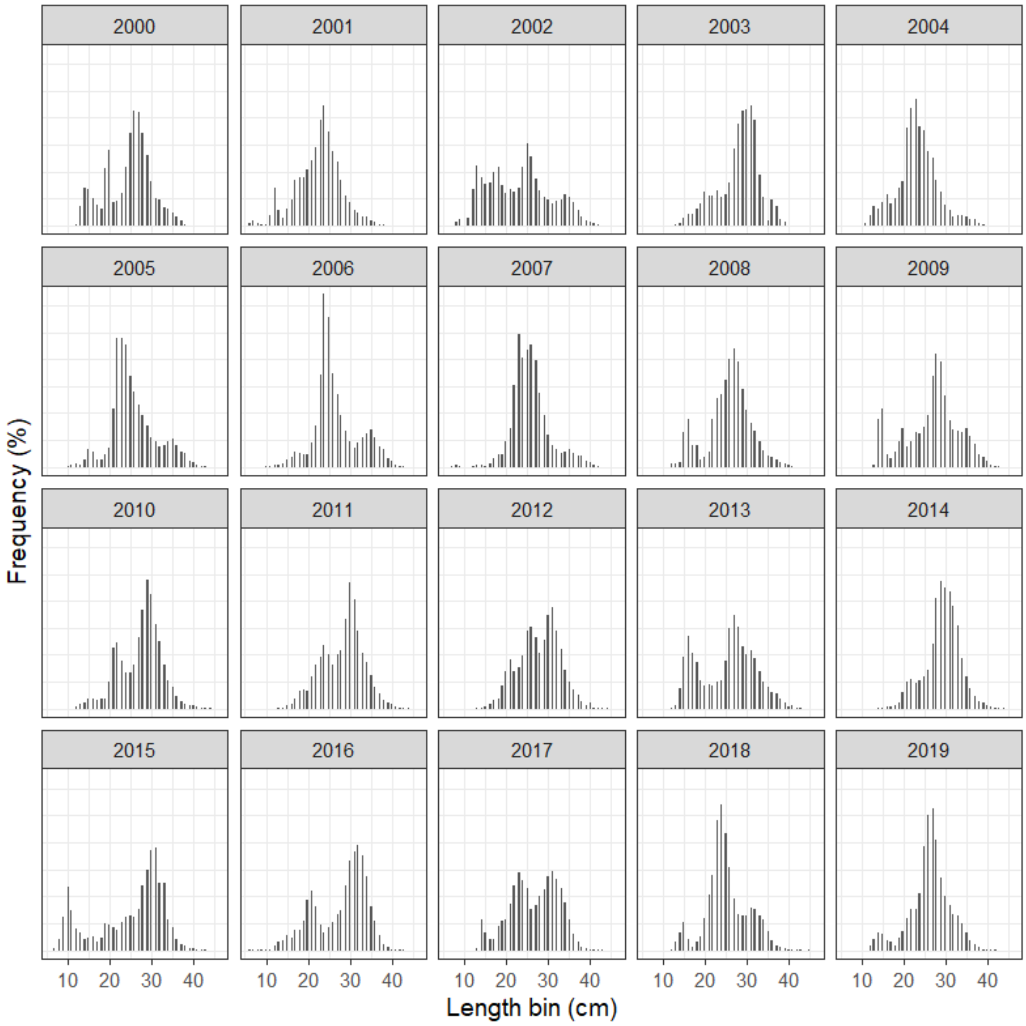


Figure 7.2.10.1: Western horse mackerel. Length frequency distribution of the catch data as used in the assessment model.

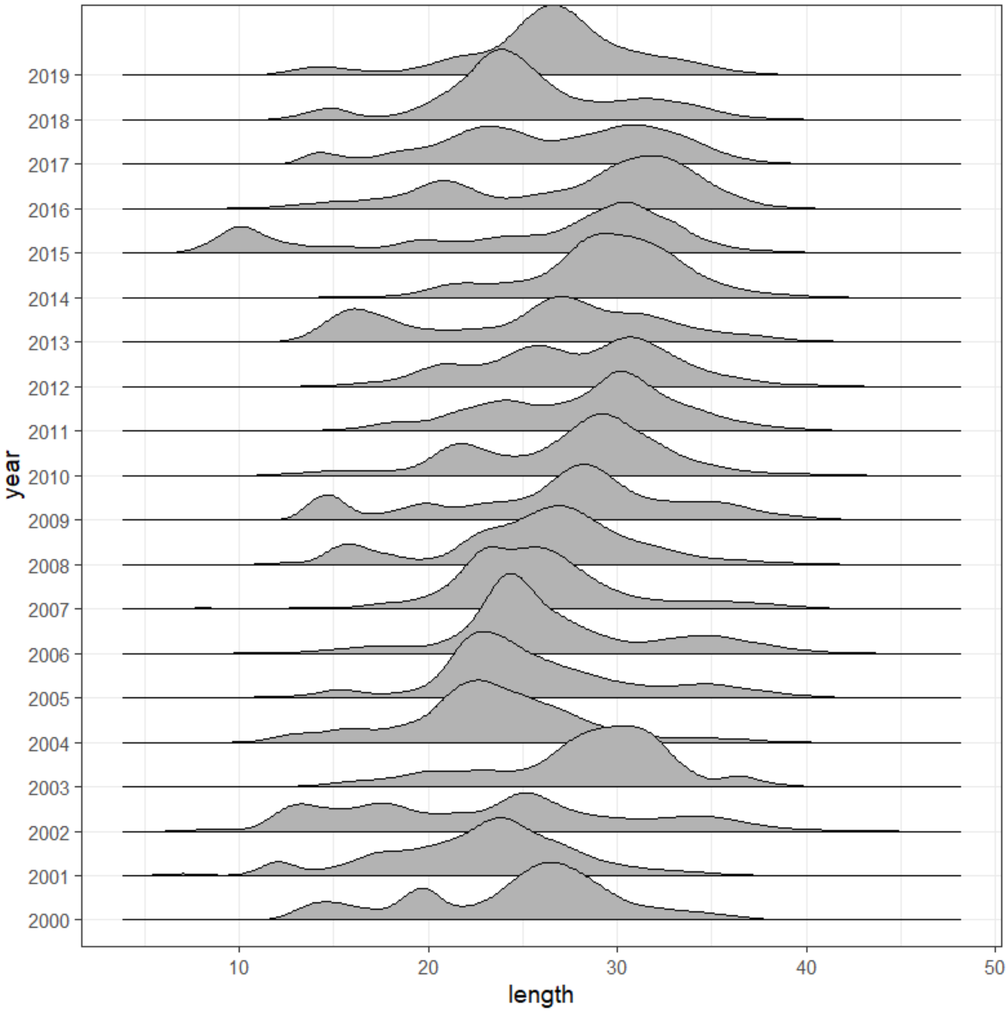


Figure 7.2.10.2: Western horse mackerel. Stacked length frequency distribution of the catch data as used in the assessment model.

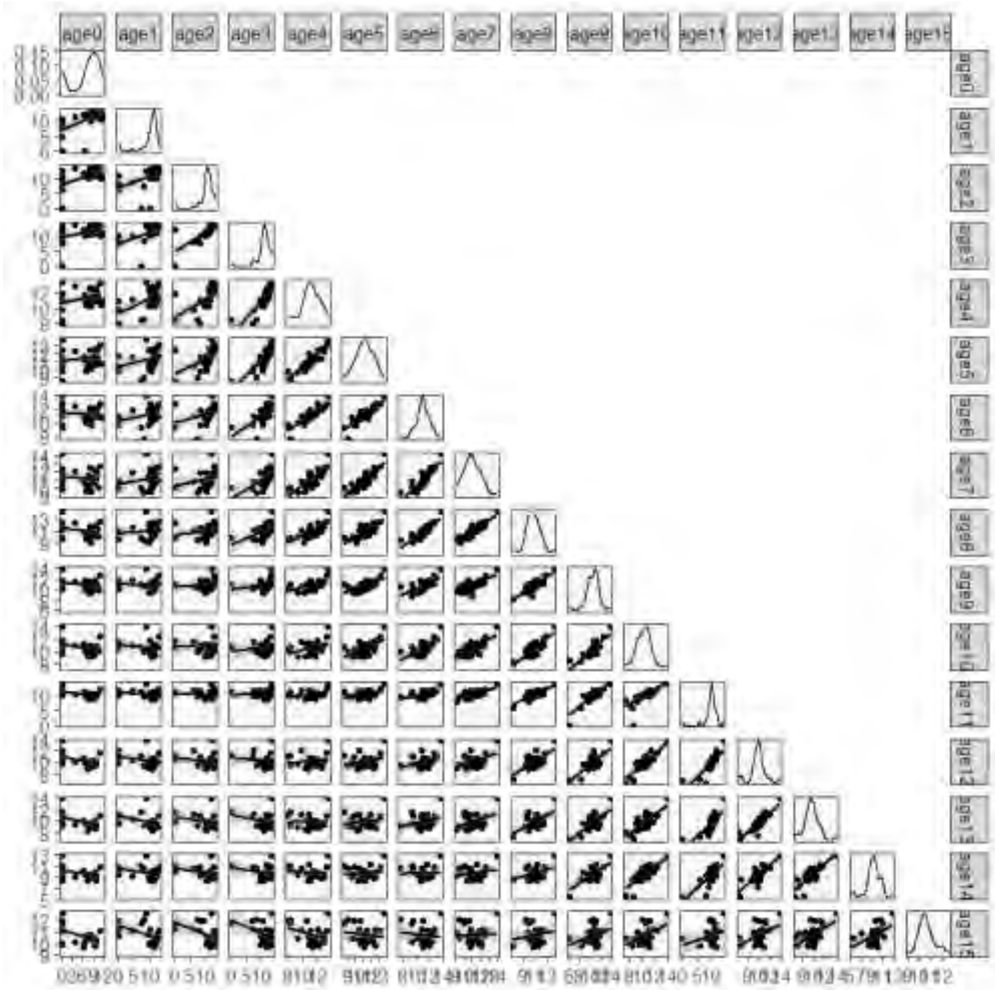


Figure 7.2.10.3: Western horse mackerel. Within-cohort consistency in the catch-at-age matrix, shown by plotting the log-catch of a cohort at a particular age against the log-catch of the same cohort at subsequent ages.

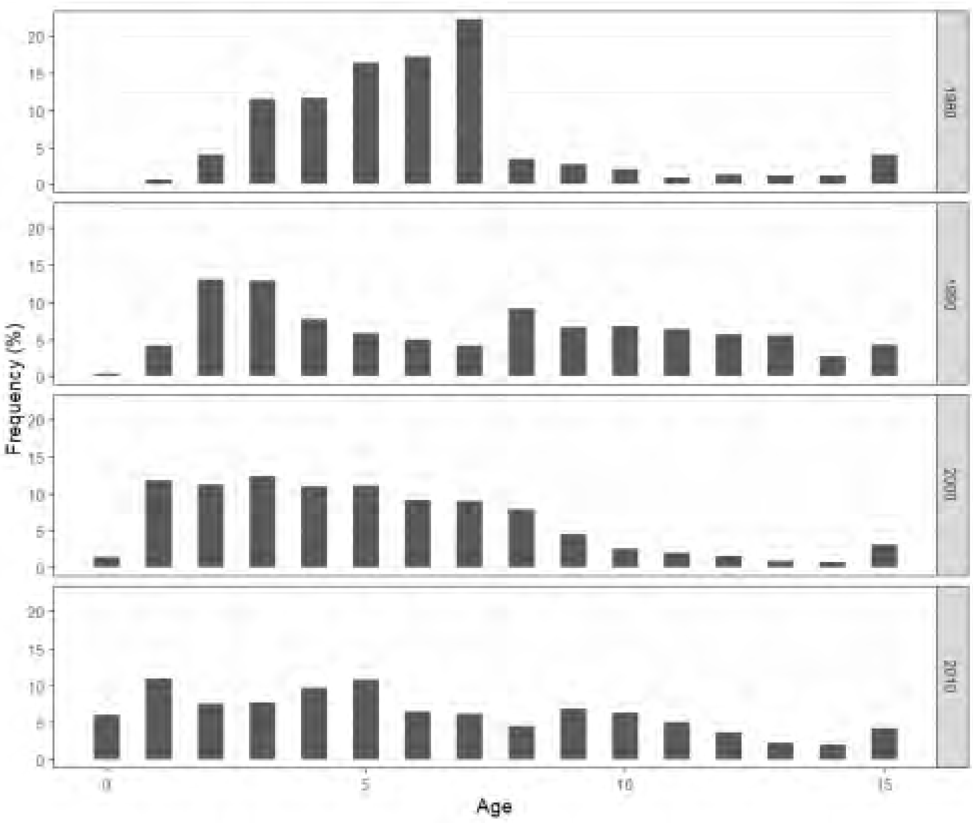


Figure 7.2.10.4: Western horse mackerel. Catch numbers at age composition by decade.

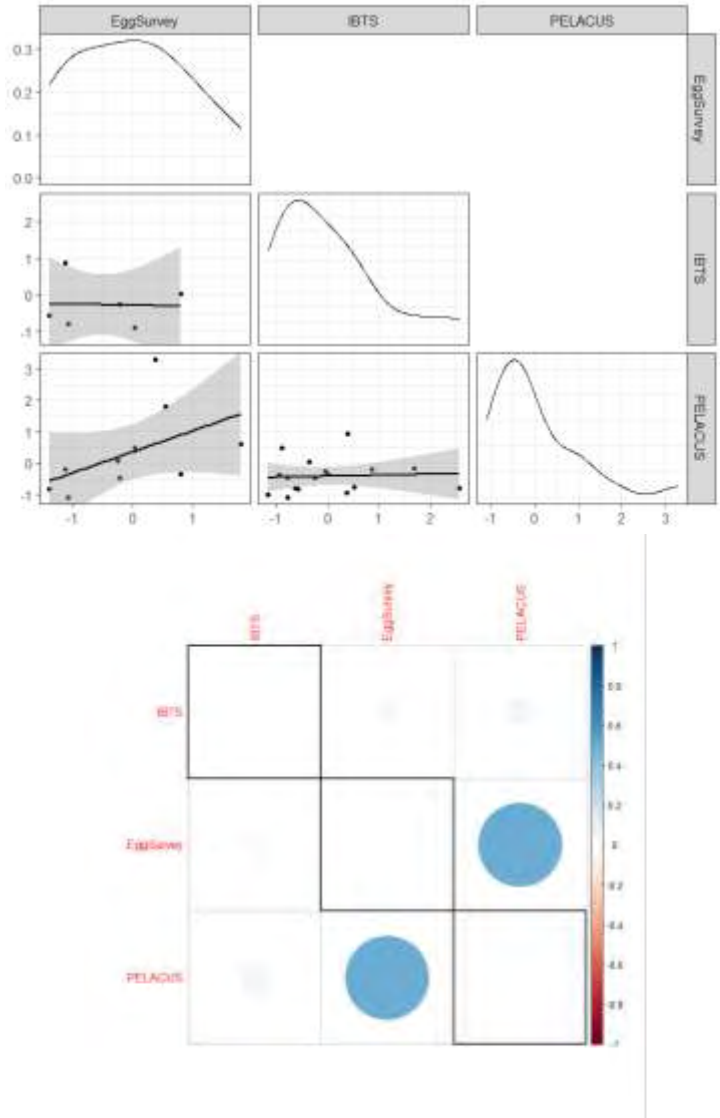


Figure 7.2.10.5: Western horse mackerel. Data exploration. Correlation plots between indices of abundance (including 2019 data points).

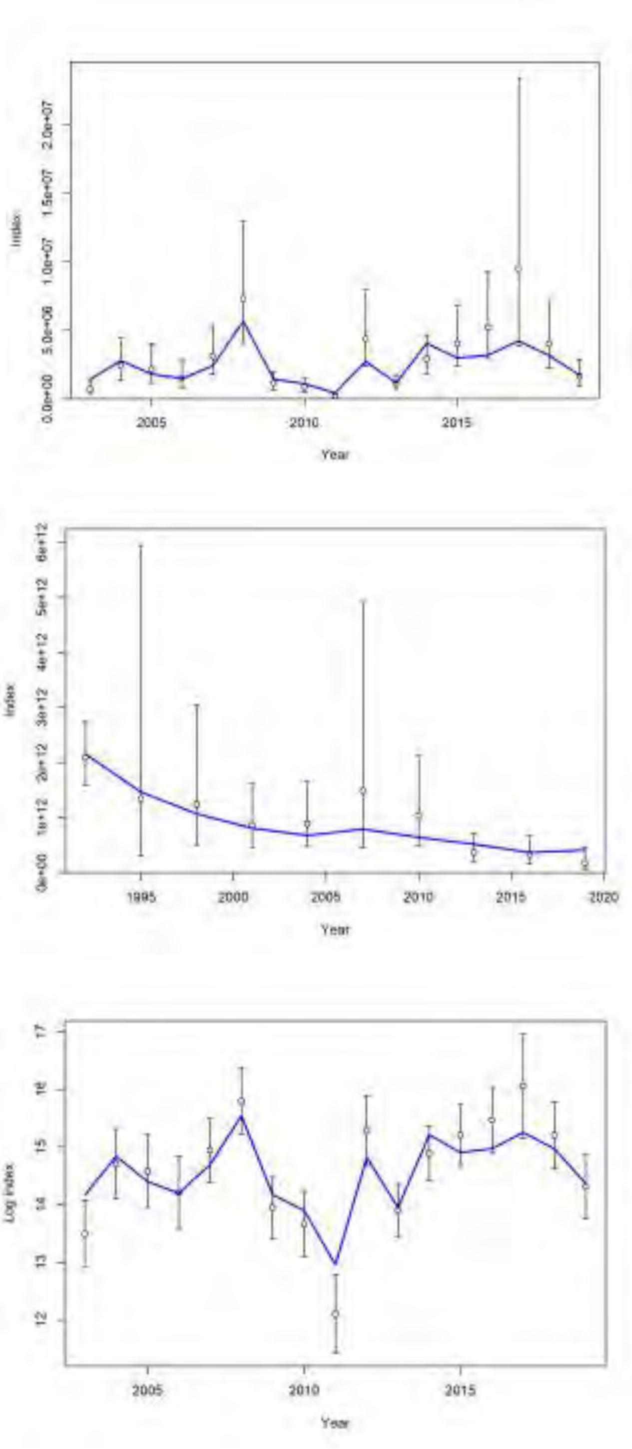


Figure 7.2.11.1: Western horse mackerel. Model fitting. Fitting of the model to the fisheries-independent indices. From top to bottom: IBTS, egg survey, PELACUS.

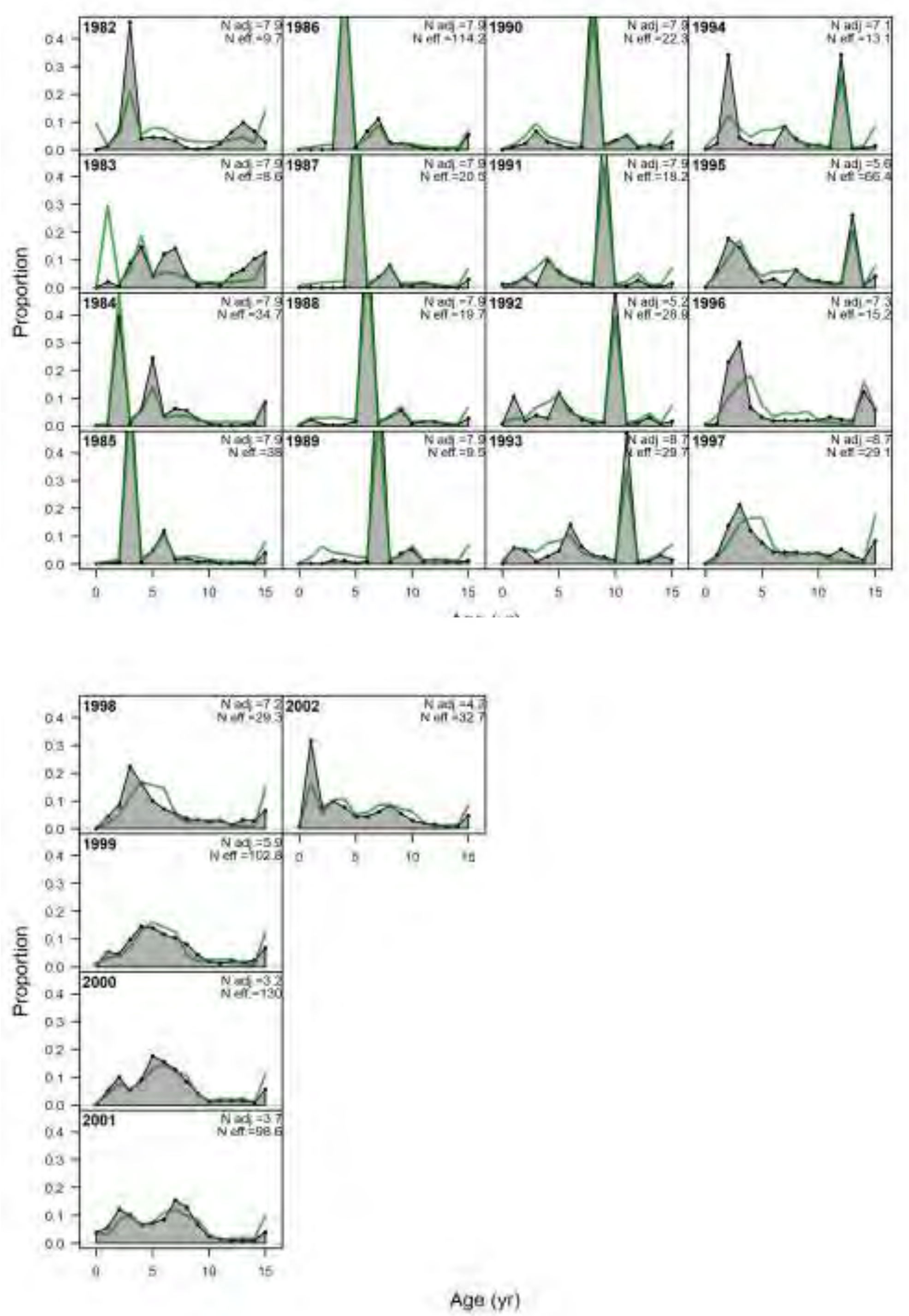


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the catch at age matrix from 1982 to 2002.

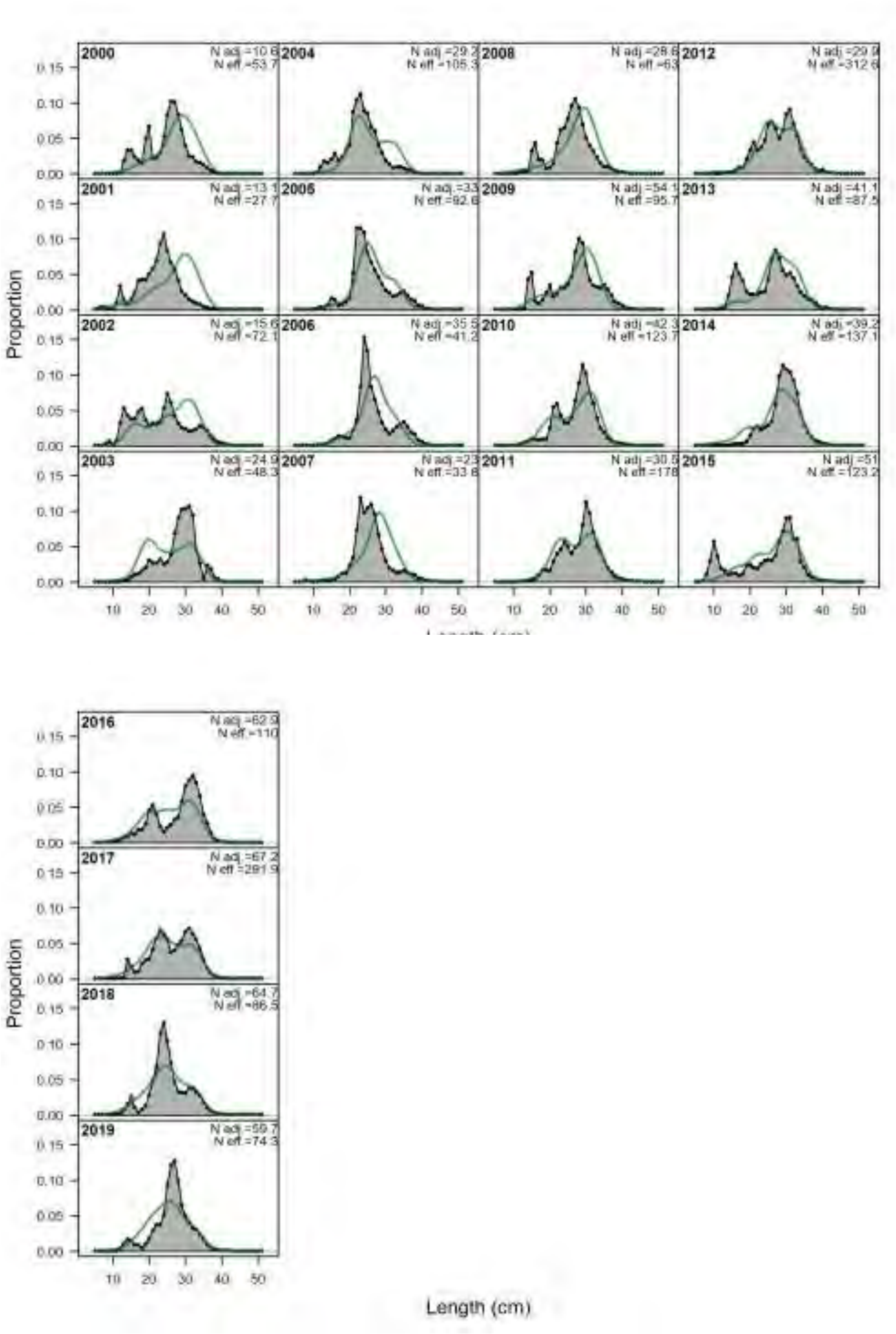
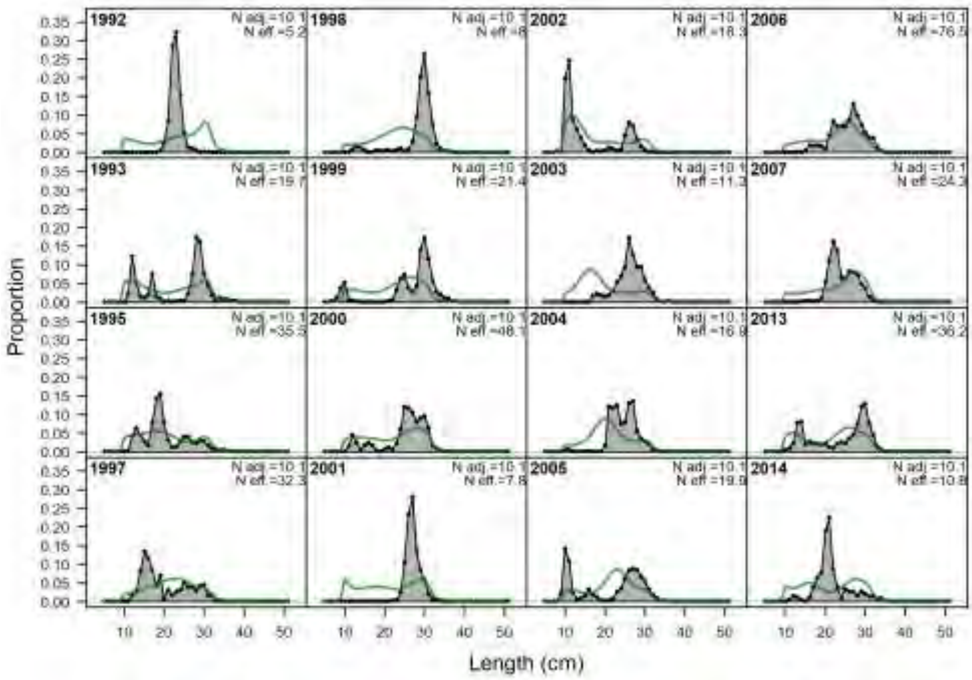


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the length composition of the catch data from 2002 to 2019.



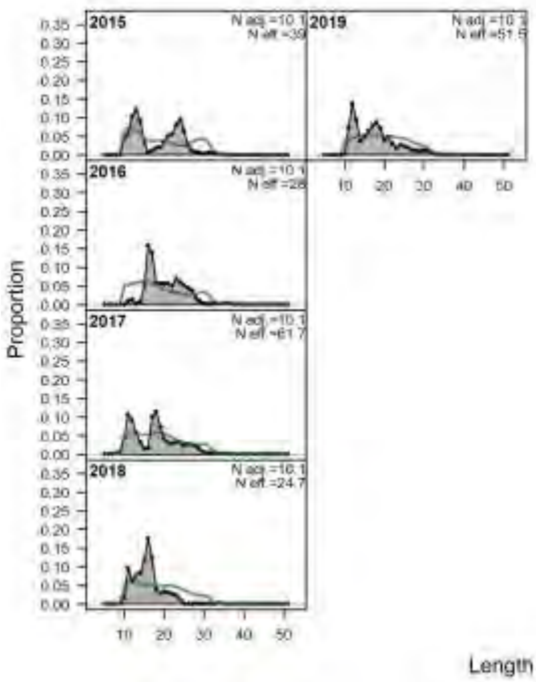


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the length composition of the acoustic survey.

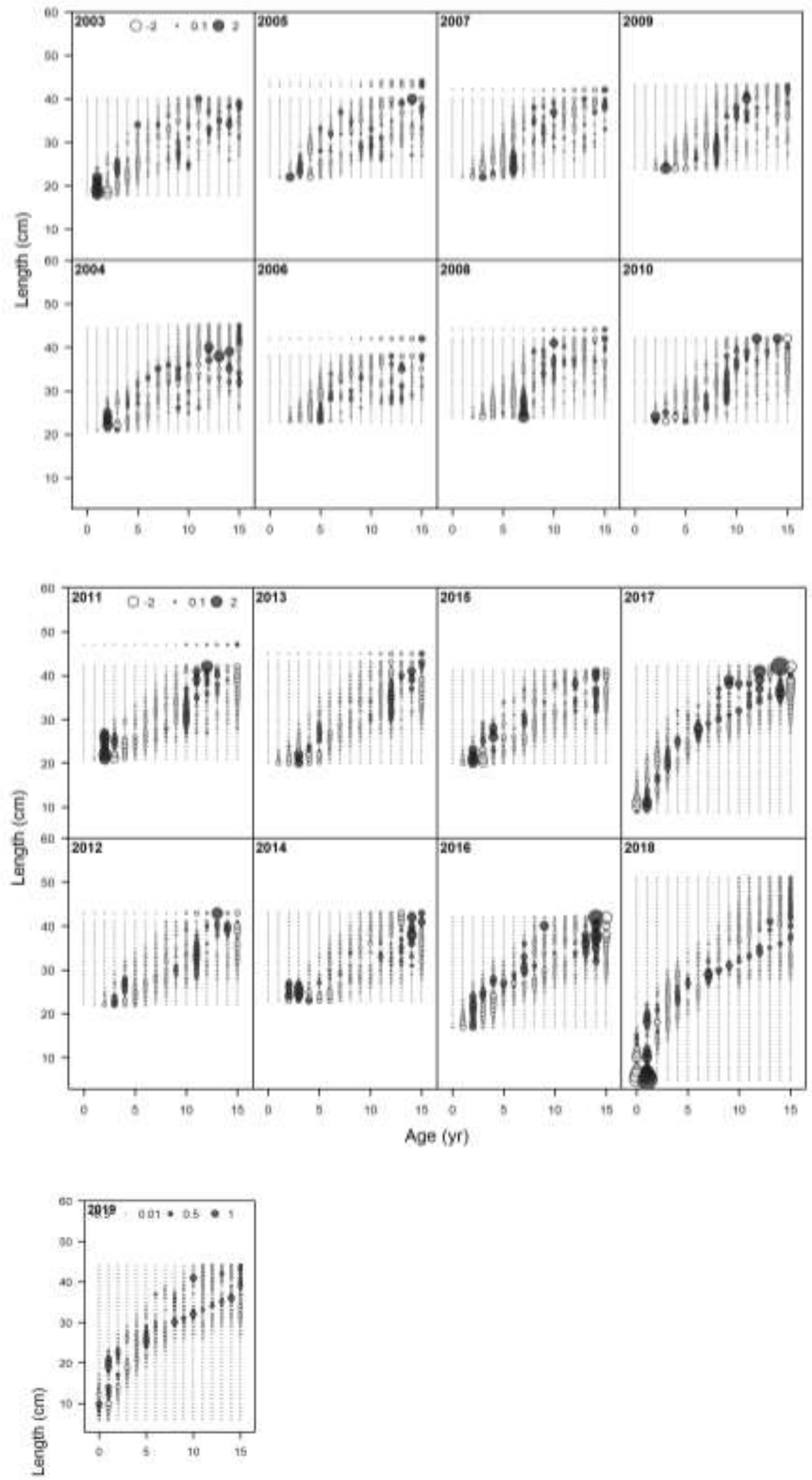


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the Age length comp of the catch.

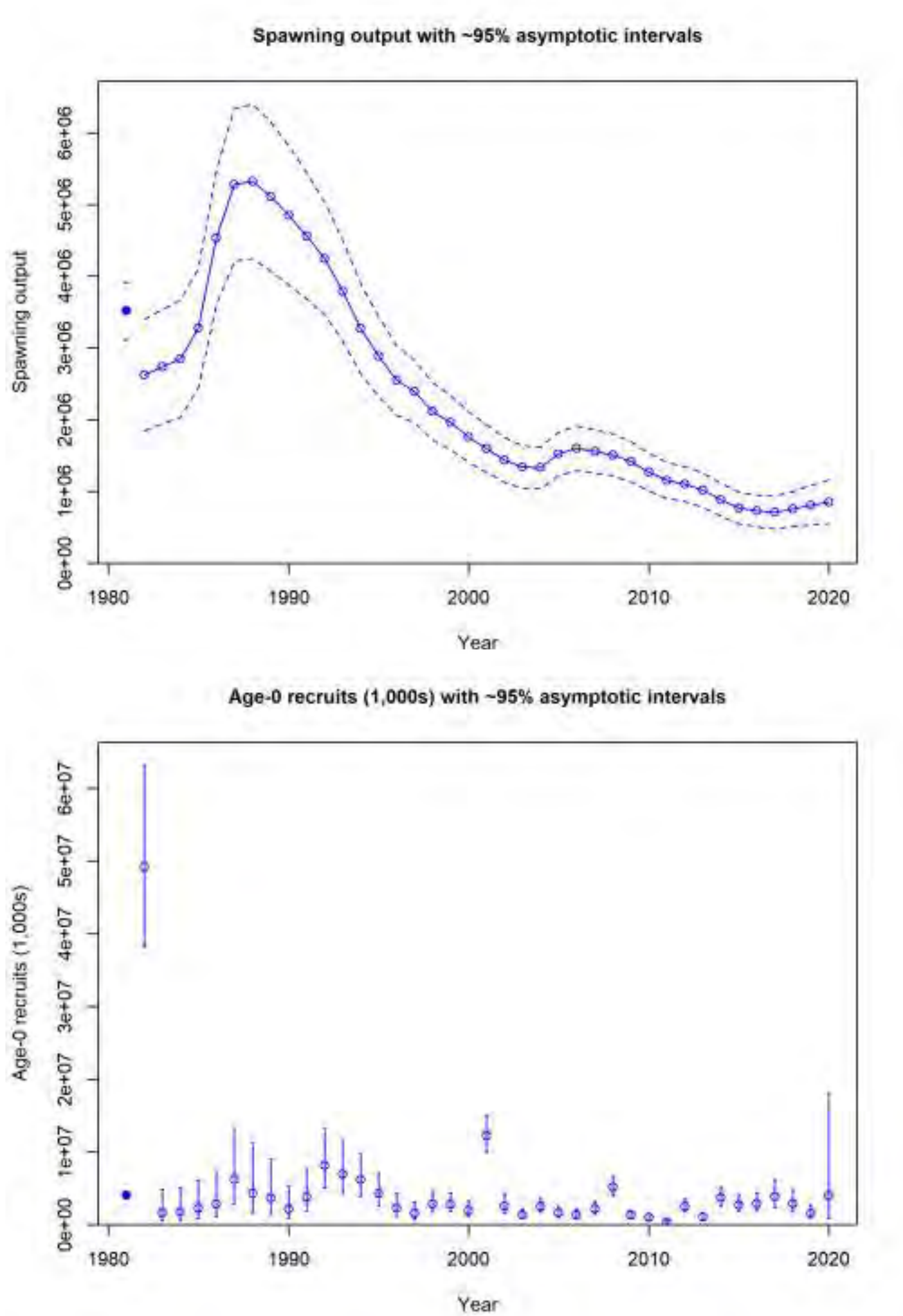


Figure 7.2.11.2: Western horse mackerel. Model results. Spawning stock biomass (0.5 of the overall SSB only is shown; plot on the left) and recruitment estimates (plot on the right) from the assessment model from 1982 to 2019. 95% CI are shown as well.

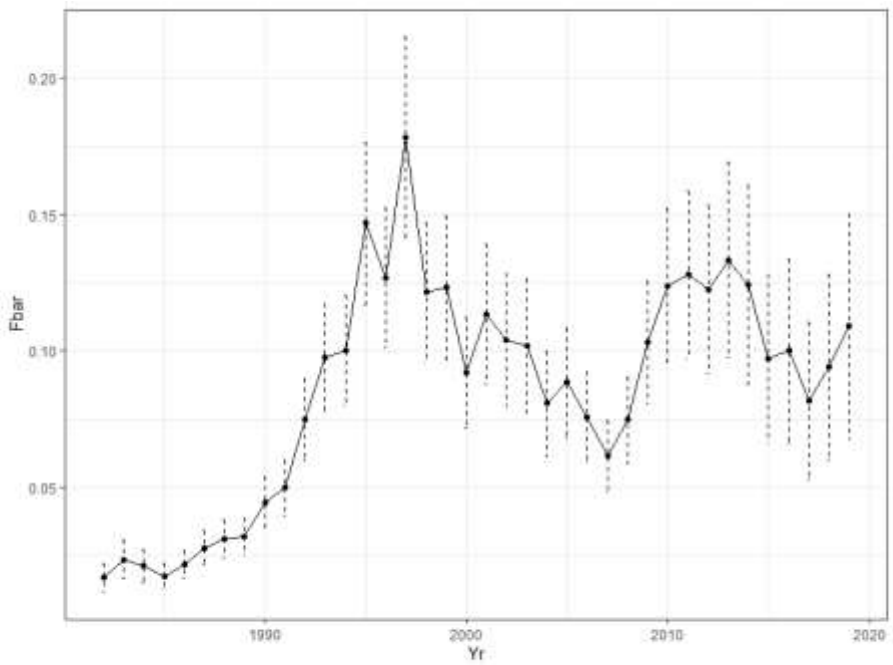


Figure 7.2.11.2 cont.: Western horse mackerel. Model results. Fishing mortality estimates (Fbar ages 1-10) from the assessment model from 1982 to 2019. 95% CI intervals are shown as well.

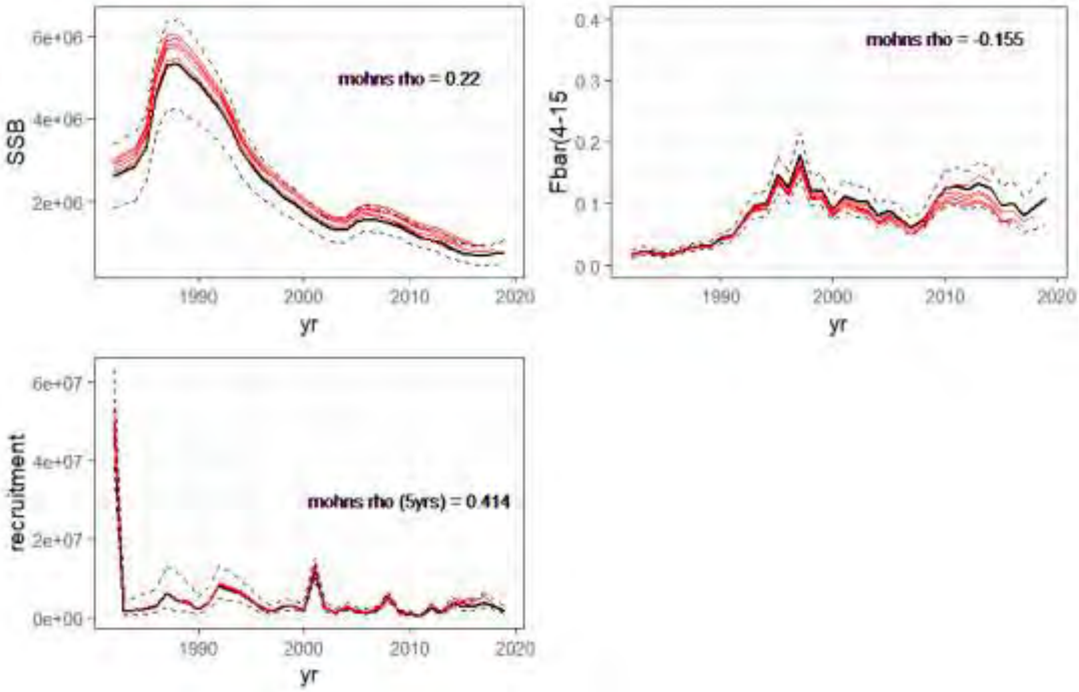


Figure 7.2.11.3: Western horse mackerel. Retrospective analysis. 5 years of retrospective analysis for SSB, F and Recruitment, and F. Dash lines are the 2020 assessment confidence intervals.

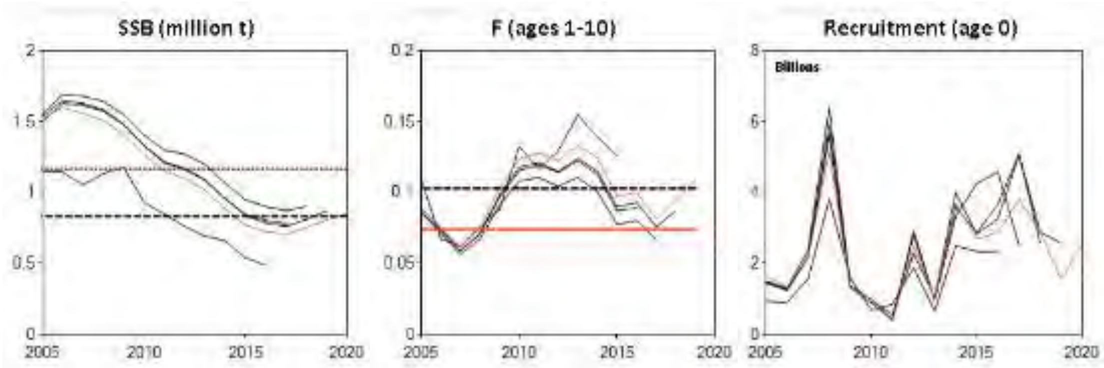


Figure 7.2.11.4: Western horse mackerel. Model results. Historical assessment results. Note: since the 2017 assessment, SSB is estimated on 1st of January. Prior to 2017 SSB has been estimated in May (spawning time).

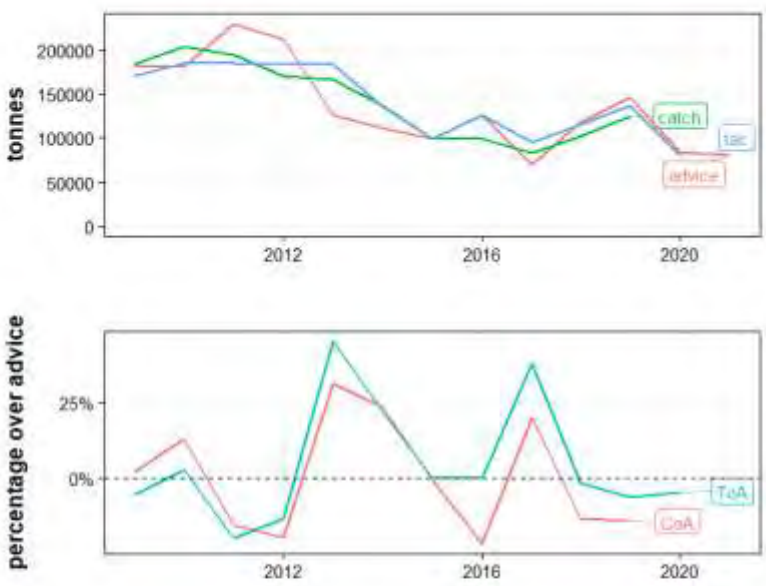


Figure 7.10.1. Western horse mackerel. Top: comparison of (max) scientific advice, TAC (or sum of unilateral quota) and Total Catch. Bottom: percentage deviation from ICES advice, CoA is Catch over Advice, ToA is TAC over Advice.

8 Northeast Atlantic Mackerel

8.1 ICES Advice and International Management Applicable to 2019

From 2001 to 2007, the internationally agreed TACs covered most of the distribution area of the Northeast Atlantic mackerel. From 2008 to 2014, no agreement was reached among the Coastal States on the sharing of the mackerel quotas. In 2014, three of the Coastal States (European Union, Norway and the Faroe Islands) agreed on a Management Strategy for 2014 to 2018. In November 2018, the agreement from 2014 was extended for two further years until 2020. However, the total declared quotas in each of 2015 to 2020 all exceeded the TAC advised by ICES. An overview of the declared quotas and transfers for 2020, as available to WGWIDE, is given in the text table below. Total removals of mackerel are expected to be approximately 1.09 million tonnes in 2020, exceeding the ICES advice for 2020 by about 169 000 t.

Estimation of 2020 catch	Tonnes	Reference
EU quota	454 482	EU-NO-FO agreement 17. Oct. 2019
Inter-annual quota transfer 2019->2020 (EU)	2 136	European Council Regulation2020/123
Norwegian quota	207 551	EU-NO-FO agreement 17. Oct. 2019
Inter-annual quota transfer 2019->2020 (NO)	-12 567	Fiskeridirektoratet 18. Dec. 2019
Russian quota	130 282	NEAFC HOD 20/15
Discards	7 807	Previous years estimate
Icelandic quota	135 428	Icelandic regulation No. 277/2020 and WGWIDE
Inter-annual quota transfer 2019->2020 (IC)	19 572	Iceland Fisheries Directorate webpage
Faroese quota	116 188	EU-NO-FO agreement 17. Oct. 2019
Greenland expected catch	30 000	Ministry of Fisheries, Hunting and Agriculture in Greenland
Total expected catch (incl. discards) [1,2]	1 090 879	

[1] No estimates of banking from 2020 to 2021.
[2] Quotas refer to claims by each party for 2020 and include exchange to other parties

The quota figures and transfers in the text table above were based on various national regulations, official press releases, and discard estimates.

Various international and national measures to protect mackerel are in operation throughout the mackerel catching countries. Refer to Table 8.2.4.1 for an overview.

8.2 The Fishery

8.2.1 Fleet Composition in 2019

A description of the fleets operated by the major mackerel catching nations is given in Table 8.2.1.

The total fleet can be considered to consist of the following components:

Freezer trawlers. These are commonly large vessels (up to 150 m) that usually operate a single mid-water pelagic trawl, although smaller vessels may also work as pair trawlers. These vessels are at sea for several weeks and sort and process the catch on board, storing the mackerel in frozen 20 kg blocks. The Dutch, German and the majority of the French and English fleets consist of these vessels which are owned and operated by a small number of Dutch companies. They fish in the North Sea, west of the UK and Ireland and also in the English Channel and further south along the western coast of France. The Russian summer fishery in Division 2.a is also prosecuted by freezer trawlers and partly the Icelandic fishery in Division 5.a and in some years in 14.b.

Purse seiners. The majority of the Norwegian catch is taken by these vessels, targeting mackerel overwintering close to the Norwegian coastline. The largest vessels (> 20 m) used refrigerated seawater (RSW), storing the catch in tanks containing RSW. Smaller purse seiners use ice to chill their catch which they take on prior to departure. A purse seine fleet is also the most important component of the Spanish fleet. They are numerous and target mackerel early in the year close to the northern Spanish coast. These are dry hold vessels, chilling the catch with ice. Denmark also has a purse seine fleet operating in the northern North Sea.

Pelagic trawlers. These vessels vary in size from 20—100 m and operate both individually and as pairs. The largest of the pelagic trawlers use RSW tanks for storage. Iceland, Greenland, Faroes, Scotland and Ireland fish mackerel using pelagic trawlers. Scottish and Icelandic vessels mostly operate as single trawlers whereas Ireland and Faroese vessels tend to use pair trawls. Spain also has a significant trawler fleet which target mackerel with a demersal trawl in Subarea 8 and Division 9.a.N.

Lines and jigging. Norway and England have handline fleets operating inshore in the Skagerrak (Norway) and in Divisions 7.e/f (England) around the coast of Cornwall, where other fishing methods are not permitted. Spain also has a large artisanal handline fleet as do France and Portugal. A small proportion of the total catch reported by Scotland (Divisions 4.a and 4.b) and Iceland (Division 5.a) is taken by a handline fleet.

Gillnets. Gillnet fleets are operated by Norway and Spain.

8.2.2 Fleet Behaviour in 2019

The northern summer fishery in Subareas 2, 5 and 14 continued in 2019. Fishing in the North Sea and west of the British Isles followed a traditional pattern, targeting mackerel on their spawning migration from the Norwegian deep in the northern North Sea, westwards around the north coast of Scotland and down the west coast of Scotland and Ireland.

The Russian freezer trawler fleet operates over a wide area in northern international waters. This fleet targets herring and blue whiting in addition to mackerel. In the third quarter of 2019 the Russian vessels took the vast majority of their catch in Division 2.a.

Total catches from Icelandic vessels were similar to those in recent years and were in excess of 100 kt. The majority of the catch was taken in Division 2.a in 2019 with catch also taken in 5.a in waters to the south, east and west of Iceland. In 2019 Greenland targeted mackerel in Division

14.b, with 1% of the total catch coming from this area. This is a decrease from 2018 when the catch accounted for 6% of the total. In 2018, Iceland and Greenland both fished in this area. Catches from Greenland have decreased in 2019 to 30 kt. In 2018 catches were almost 63 kt. This is a reduction from the peak of 78 kt in 2014 which was the highest catch by this fleet. The Faroese fleet is targeting mackerel in the Faroese EEZ during late summer and early autumn with nearly half of the catches taken there, with some catches in international waters. Later in the autumn season they switch to purse seining in EU waters where nearly the second half of the catch is taken with the remainder taken in international waters.

Concerning the Spanish fisheries, no new regulations have been implemented since 2010 when a new control regime was enforced. The 2019 fishery has started at the beginning of March, as in previous years.

8.2.3 Recent Changes in Fishing Technology and Fishing Patterns

Northeast Atlantic mackerel, as a widely distributed species, is targeted by a number of different fishing métiers. Most of the fishing patterns of these métiers have remained unchanged during the most recent years, although the timing of the spawning migration and geographical distribution can change from year to year and this affects the fishery in various areas.

The most important changes in recent years are related to the geographical expansion of the northern summer fishery (Subareas 2, 5 and 14) and changes in southern waters due to stricter TAC compliance by Spanish authorities.

As a result of this expansion, Icelandic vessels have increased effort and catch dramatically in recent years from 4 kt in 2006 to an average 160 kt annually since 2011. This fishery operates over a wide area E, NE, SE, S and SW of Iceland. Since 2011, there has been less fishing activity to the north and north-east and an increase in catches taken south and west of Iceland. Greenland has reported catches from Division 14.b since 2011, and reached the biggest catch by this fleet to date in 2014, with a catch of 78 kt.

In 2010, the Faroese fleet switched from purse-seining in Norwegian and EU waters to pair trawling in the Faroese area. The Faroese fleet used to catch their mackerel quota in Divisions 4.a and 6.a during September-October with purse-seiners. However, as no agreement has been reached between the Coastal States since 2009, the mackerel quota has been taken in Faroese waters during June-October by the same fleet using pair trawls. The mackerel distribution is more scattered during summer and pair trawls seem to be effective in such circumstances. However, since the agreement between the three of the Coastal States for the fisheries in 2015, parts of the Faroese quota are now again taken with purse-seines in Divisions 5.a and 6.a.

In Spain, part of the purse seiner fleet is using hand lines instead of nets. Although, neither the number of vessels and its evolution nor the reason for such change were deeply analysed, it seems market reasons are driving this shift.

8.2.4 Regulations and their Effects

An overview of the major existing technical measures, effort controls and management plans are given in Table 8.2.4.1. Note that there may be additional existing international and national regulations that are not listed here.

Between 2010 and 2019 no overarching Coastal States Agreement/NEAFC Agreement was in place and no overall international regulation on catch limitation was in force. Currently there is no agreement on a management strategy covering all parties fishing mackerel. In 2014, three of the Coastal States (The EU, Faroes and Norway) agreed on a Management Strategy for 2015 and the subsequent five years. In November 2018, the agreement from 2014 was extended for two more years until 2020. However, the total declared quotas taken by all parties since 2015 have greatly exceeded the TAC advised by ICES (see Section 8.1).

Management aimed at a fishing mortality in the range of 0.15—0.20 in the period 1998—2008. The current management plan aims at a fishing mortality in the range 0.20—0.22. The fishing mortality realised during 1998—2008 was in the range of 0.27 to 0.46. Implementation of the management plan resulted in a reduced fishing mortality and increased biomass. Since 2008 catches have greatly exceeded those given by the plan.

The measures advised by ICES to protect the North Sea spawning component aim at setting the conditions for making a recovery of this component possible. Before the late 1960s, the North Sea spawning biomass of mackerel was estimated at above 2.5 million tonnes. The collapse of mackerel in the North Sea in the late 1960s was most likely driven by very high catches and associated fishing mortality. However, the lack of recovery of mackerel in the North Sea was probably associated with unfavourable environmental conditions, particularly reduced temperatures (unfavourable for spawning), lower zooplankton availability in the North Sea and increased wind-stress induced turbulence (Jansen, 2014). These unfavourable environmental conditions probably led the mackerel to spawn in western waters instead of in the North Sea.

A review of the mackerel in the North Sea, carried out during WKWIDE 2017 (ICES, 2017b) concluded that Northeast Atlantic mackerel should be considered as a single population (stock) with individuals that show stronger or weaker affinity for spawning in certain parts of the spawning area. Management should ensure that fisheries do not decrease genetic and behavioural diversity, since this could reduce future production. Protection of mackerel that tend to spawn in the north-eastern parts of the spawning area is therefore still advisable to some extent.

In the southern area, a Spanish national regulation affecting mackerel catches of Spanish fisheries has been implemented since 2010. In 2015, fishing opportunities were distributed by region and gear and for the bottom trawl fleet, by individual vessel. This year, Spanish mackerel fishing opportunities in Divisions 8.c and 9.a were established at 39 674 t resulting from the quota established (Commission Regulation (EU) No 104/2015). This was reduced by 9 797 t due to the scheduling payback quota due to overfishing of the mackerel quota allocated to Spain in 2010 (Commission Regulation No 976/2012).

Within the area of the southwest Mackerel Box off Cornwall in southern England only handliners are permitted to target mackerel. This area was set up at a time of high fishing effort in the area in 1981 by Council Regulation to protect juvenile mackerel, as the area is a well-known nursery. The area of the box was extended to its present size in 1989.

Additionally, there are various other national measures in operation in some of the mackerel catching countries.

The first phase of a landing obligation came into force in 2015 for all EU vessels in pelagic and industrial fisheries. Since 2019, all species that are managed through TACs and quotas must be landed under the obligation unless there is a specific exemption such as *de minimis*. There are *de minimis* exemptions for mackerel caught in bottom-trawl fisheries in the North Western Waters (EC 2018/2034) and in the North Sea (EC 2018/2035).

8.3 Quality and Adequacy of sampling Data from Commercial Fishery

The sampling of the commercial catch of Northeast Atlantic mackerel is summarised below:

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
1992	760000	85	920	77000	11800
1993	825000	83	890	80411	12922
1994	822000	80	807	72541	13360
1995	755000	85	1008	102383	14481
1996	563600	79	1492	171830	14130
1997	569600	83	1067	138845	16355
1998	666700	80	1252	130011	19371
1999	608928	86	1109	116978	17432
2000	667158	76	1182	122769	15923
2001	677708	83	1419	142517	19824
2002	717882	87	1450	184101	26146
2003	617330	80	1212	148501	19779
2004	611461	79	1380	177812	24173
2005	543486	83	1229	164593	20217
2006	472652	85	1604	183767	23467
2007	579379	87	1267	139789	21791
2008	611063	88	1234	141425	24350
2009	734889	87	1231	139867	28722
2010	869451	91	1241	124695	29462
2011	938819	88	923	97818	22817
2012	894684	89	1216	135610	38365
2013	933165	89	1092	115870	25178
2014	1394454	90	1506	117250	43475
2015	1208990	88	2132	137871	24283
2016	1094066	89	2200	149216	21456

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
2017	1155944	87	2183	151548	24104
2018	1026437	83	1858	139590	20703
2019	840021	88	1835	141561	17646

Overall sampling effort in 2019 was similar to previous years with 88 % of the catch sampled. It should be noted that this proportion is based on the total sampled catch. Nations with large, directed fisheries are capable of sampling 100 % of their catch which may conceal deficiencies in sampling elsewhere.

The 2019 sampling levels by country are shown below.

Country	Official catch	% WG catch covered by sampling programme	No. Samples	No. Measured	No. Aged
Belgium	66	0%	0	0	0
Denmark	30605	75%	13	1096	1101
Faroe Islands	62665	92%	17	845	940
France	20975	0%	0	0	0
Germany	16904	83%	106	1081	11661
Greenland	30259	100%	6	59	3406
Iceland	128077	100%	122	2997	5422
Ireland	53384	94%	38	1438	7410
Netherlands	22698	71%	27	675	2792
Norway	159107	98%	61	1892	1892
Poland	3706	0%	0	0	0
Portugal	3940	18%	115	988	3919
Russia	126544	99%	190	1250	60447
Sweden	2967	0%	0	0	0
Spain	23866	96%	1025	4426	36179
UK (England & Wales)	17871	2%	63	217	3997
UK (Northern Ireland)	11879	59%	1	49	173
UK (Scotland)	124507	88%	20	633	2222

The majority of countries achieved a high level of sampling coverage. Belgian catches consist of by-catch in the demersal fisheries in the North Sea. France supplied a quantity of length-frequency data to the working group which can be utilised to characterise the selection of the fleet but requires an allocation of catch at age proportions from another sampled fleet in order to raise the data for use in the assessment. Sweden and Poland did not supply sampling information in 2019. Portugal sampled landings from 9.a only. England only samples landings from the handline fleet operating off the Cornish coast, representing only a small proportion of the national catch, the remainder reported from freezer trawlers. Cooperation between the Dutch and German sampling programmes (which sampled 71% and 83% respectively) is designed to provide complete coverage for the freezer trawlers operating under these national flags and also those of England and France. Catch sampling levels per ICES Division (for those with a WG catch of >100 t) are shown below.

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
2.a	269328	269328	280	65351	3569
3.a	501	501	0	0	0
4.a	302841	302841	128	10910	4034
4.b	3978	3978	0	0	0
4.c	703	703	0	0	0
5.a	58101	58101	56	2463	1385
5.b	10957	10957	5	497	338
6.a	123112	123112	73	12687	1828
7.b	17993	17993	16	2982	645
7.c	179	179	0	0	0
7.d	4933	4933	42	265	136
7.e	3125	3125	25	1508	53
7.f	642	642	38	2489	164
7.g	104	104	0	0	0
7.h	207	207	0	0	0
7.j	4749	4749	2	135	50
8.a	2839	2839	3	3	3
8.b	4181	4181	244	5798	472
8.c	16672	16672	272	8519	2364
8.c.E	6478	6478	213	17649	832
9.a	706	706	115	3919	988
9.a.N	921	921	291	4208	753
14.b	6651	6651	30	2176	30

In general, areas with insufficient sampling have relatively low levels of catch.

8.4 Catch Data

8.4.1 ICES Catch Estimates

The total ICES estimated catch for 2019 was 840 021 t, a decrease of 186 416 t on the estimated catch in 2018. Catches in 2019 were the lowest since 2009. Catches increased substantially from 2006—2010 and have averaged 1 050 kt since from 2011.

The combined 2019 TAC, arising from agreements and autonomous quotas, amounts to 864 000 t). The ICES catch estimate (840 021 t) represents an undershoot of this but is still above the ICES advice of 770 358 t. The combined fishable TAC for 2020, as best ascertained by the Working Group (see Section 8.1), amounts to 1 090 879 t.

Catches reported for 2019 and in previous Working Group reports are considered to be best estimates. In most cases, catch information comes from official logbook records. Other sources of information include catch processors. Some countries provide information on discards and slipped catch from observer programs, logbooks and compliance reports. In several countries discarding is illegal. Spanish data is based on the official data supplied by the Fisheries General Secretary (SGP) but supplemented by scientific estimates which are recorded as unallocated catch in the ICES estimates.

The text table below gives a brief overview of the basis for the ICES catch estimates.

Country	Official Log Book	Other Sources	Discard Information
Denmark	Y (landings)	Y (sale slips)	Y
Faroe[1]	Y (catches)	Y (coast guard)	NA
France	Y (landings)		Y
Germany	Y (landings)		Y
Greenland	Y (catches)	Y (sale slips)	Y
Iceland[1]	Y (landings)		NA
Ireland	Y (landings)		Y
Netherlands	Y (landings)	Y	Y
Norway[1]	Y (catches)		NA
Portugal		Y (sale slips)	Y
Russia[1]	Y (catches)		NA
Spain	Y	Y	Y
Sweden	Y (landings)		Y
UK	Y (landings)	Y	Y

[1]For these nations a discarding ban is in place such that official landings are considered to be equal to catches.

The Working Group considers that the estimates of catch are likely to be an underestimate for the following reasons:

- Estimates of discarding or slipping are either not available or incomplete for most countries. Anecdotal evidence suggests that discarding and slipping can occur for a number of reasons including high-grading (larger fish attract a premium price), lack of quota, storage or processing capacity and when mackerel is taken as by-catch.
- Confidential information suggests substantial under-reported landings for which numerical information is not available for most countries. A study carried out in 2010 indicated considerable uncertainty in true catch figures (Simmonds *et al.*, 2010) for the period studied.

- Estimates of the magnitude and precision of unaccounted mortality suggests that, on average for the period prior to 2007, total catch related removals were equivalent to 1.7 to 3.6 times the reported catch (Simmonds *et al.,* 2010).
- Reliance on logbook data from EU countries implies (even with 100% compliance) a precision of recorded landings of 89% from 2004 and 82% previous to this (Council Regulation (EC) Nos. 2807/83 & 2287/2003). Given that over reporting of mackerel landings is unlikely for economic reasons; the WG considers that the reported landings may be an underestimate of up to 18% (11% from 2004), based on logbook figures. Where inspections were not carried out there is a possibility of a 56 % under reporting, without there being an obvious illegal record in the logsheets. Without information on the percentage of the landings inspected it is not possible for the Working Group to evaluate the underestimate in its figures due to this technicality. EU landings represent about 65 % of the total estimated NEA mackerel catch.
- The accuracy of logbooks from countries outside the EU has not been evaluated by WGWIDE. Monitoring of logbook records is the responsibility of the national control and enforcement agencies.

The total catch as estimated by ICES is shown in Table 8.4.1.1. It is broken down by ICES area group and illustrates the development of the fishery since 1969.

Discard Estimates

With a few exceptions, estimates of discards have been provided to the Working Group for the ICES Subareas and Divisions 6, 7/8.a,b,d,e and 3/4 (see Table 8.4.1.1) since 1978. Historical discard estimates were revised during the data compilation exercise undertaken for the 2014 benchmark assessment (ICES, 2014). The Working Group considers that the estimates for these areas are incomplete. In 2019, discard data for mackerel were provided by The Netherlands, France, Germany, Ireland, Spain, Portugal, Greenland, Denmark, England, Scotland and Sweden. Total discards amounted to 7 807 t which is an increase from 2018. Higher discards were reported by France mainly due to a change in raising procedures. Other countries reported smaller increases. The German, Dutch and Portuguese pelagic discard monitoring programmes did not record any instances of discarding of mackerel. Estimates from the other countries supplying data include results from the sampling of demersal fleets.

Age-disaggregated discard data was limited but data available indicates that, in Divisions 8.a, 8.b and 8.c the majority of discarded fish were aged 0 to 3. In Division 9.a, the majority of the discarded fish were 0 group.

Discarding of small mackerel has historically been a major problem in the mackerel fishery and was largely responsible for the introduction of the south-west mackerel box. In the years prior to 1994, there was evidence of large-scale discarding and slipping of small mackerel in the fisheries in Division 2.a and Subarea 4, mainly because of the very high prices paid for larger mackerel (> 600 g) for the Japanese market. This factor was put forward as a possible reason for the very low abundance of the 1991 year-class in the 1993 catches. Anecdotal evidence from the fleet suggests that since 1994, discarding/slipping has been reduced in these areas.

In some of the horse mackerel directed fisheries, *e.g.* those in Subareas 6 and 7, mackerel is taken as by-catch. Reports from these fisheries have suggested that discarding may be significant because of the low mackerel quota relative to the high horse mackerel quota, particularly in those fisheries carried out by freezer trawlers in the fourth quarter. The level of discards is greatly influenced by the market price and by quotas.

8.4.2 Distribution of Catches

A significant change in the fishery took place between 2007 and 2009 with a greatly expanded northern fishery becoming established. This fishery has continued to the present but with a clear tendency for an eastern retraction, especially from the Greenlandic area and also western parts of the Icelandic area in the most recent three years. Of the total catch in 2019, Norway accounted for the greatest proportion (19%) followed by Scotland (15%), Iceland (15%), Russia (15%) and Faroe (7%). In the absence of an international agreement, Greenland, Iceland and Russia declared unilateral quotas in 2019. Russia and Iceland both had catches over 100 kt with Faroes catching 62 kt. Greenlandic catches decreased from 63 kt to 30 kt. Scotland had catch in excess of 100 kt and Ireland caught almost 53 kt. Denmark had catches of around 30 kt. The Netherlands and Spain caught around 23 kt while France had catches of the order of 20 kt. Germany and England had catches around 17 kt.

In 2019, catches in the northern areas (Subareas 2, 5, 14) amounted to 345 037 t (see Table 8.4.2.1), a decrease of 110 704 t on the 2018 catch. Icelandic, Norwegian and Russian catches were all over 100 kt. Catches from Division 2.a accounted for 32% of the total catch in 2019, similar to 2018. Almost all the Russian catch in 2019 was taken in Division 2.a. The wide geographical distribution of the fishery noted in previous years has continued.

The time series of catches by country from the North Sea, Skagerrak and Kattegat (Subarea 4, Division 3.a) is given in Table 8.4.2.2. Catches in 2019 amounted to 308 049 t and represents a decrease from the 2018 catch figure (342 147 t). The majority of the catch is from Subarea 4 with small catches were also reported in Divisions 3.a-d.

Catches in the western area (Subareas 6, 7 and Divisions 8.a,b,d and e) decreased again in 2019 to 162 159 t. This is a decrease of around 32 000 t from 2018. The catches are detailed in Table 8.4.2.3.

Table 8.4.2.4 details the catches in the southern areas (Divisions 8.c and 9.a) which are taken almost exclusively by Spain and Portugal. The reported catch of 24 776 t represents a decrease from 2017. The catch is lower than the long-term average.

The distribution of catches by quarter (%) is described in the text table below:

Year	Q1	Q2	Q3	Q4	Year	Q1	Q2	Q3	Q4
1990	28	6	26	40	2005	46	6	25	23
1991	38	5	25	32	2006	41	5	18	36
1992	34	5	24	37	2007	34	5	21	40
1993	29	7	25	39	2008	34	4	35	27
1994	32	6	28	34	2009	38	11	31	20
1995	37	8	27	28	2010	26	5	54	15
1996	37	8	32	23	2011	22	7	54	17
1997	34	11	33	22	2012	22	6	48	24
1998	38	12	24	27	2013	19	5	52	24
1999	36	9	28	27	2014	20	4	46	30
2000	41	4	21	33	2015	20	5	44	31
2001	40	6	23	30	2016	23	4	44	29
2002	37	5	29	28	2017	24	3	45	28
2003	36	5	22	37	2018	20	3	40	37
2004	37	6	28	29	2019	28	5	42	26

The quarterly distribution of catch in 2019 is similar to recent years (since 2010) with the northern summer fishery in Q3 accounting for the greatest proportion of the total catch.

Catches per ICES statistical rectangle are shown in Figures 8.4.2.1 to 8.4.2.4. It should be noted that these figures are a combination of official catches and ICES estimates and may not indicate the true location of the catches or represent the location of the entire stock. These data are based on catches reported by all the major catching nations and represents almost the entire ICES estimated catch.

- First quarter 2019 (233 940 t – 28 %)

The distribution of catches in the first quarter is shown in Figure 8.4.2.1. The proportion of the fishery taken in quarter 1 has increased in 2019 with the Scottish and Irish pelagic fleets targeting mackerel in Divisions 6.a, 7.b and 7.j. Substantial catches are also taken by the Dutch owned freezer trawler fleet. The largest catches were taken in Division 6.a, as in recent years. An increase in catch from 4.a and 7.b Q1 was seen in 2019 compared to 2018. The Spanish fisheries also take significant catches along the north coast of Spain during the first quarter.

- Second quarter 2019 (384 195 t – 5 %)

The distribution of catches in the second quarter is shown in Figure 8.4.2.2. The quarter 2 fishery is traditionally the smallest and this was also the case in 2019. The most significant catches where those in Division 8.c and at the start of the summer fishery in northern waters by Icelandic, Norwegian and Russian fleets.

- Third quarter 2019 (379 456 t – 42 %)

Figure 8.4.2.3 shows the distribution of the quarter 3 catches. Large catches were taken throughout Divisions 2.a (Russian, Norwegian vessels), 4.a (Norwegian, Scottish vessels), 5.a (Icelandic vessels). Catch was also taken in Division 14.b in quarter 3.

- Fourth quarter 2019 (379 757 t – 26 %)

The fourth quarter distribution of catches is shown in Figure 8.4.2.4. The proportion of the catch taken in the fourth quarter has decreased from 37% in 2018 to 26% in 2019. The summer fishery in northern waters has largely finished with very small catches reported from Division 2.a. The largest catches are taken by Norway and Scotland around the Shetland Isles. Irish vessels did not participate in the quarter 4 fishery in 4.a in 2019.

ICES cannot split the reported mackerel catches into different stock components because there is no clear distinction between components upon which a split could be determined. Mackerel with a preference for spawning in the northeast area, including the North Sea, cannot presently be identified morphometrically or genetically (Jansen and Gislason, 2013). Separation based on time and area of the catch is not a precise way of splitting mackerel with different spawning preferences, because of the mixing and migration dynamics including inter-annual (and possibly seasonal) variation of the spawning location, combined with the post-spawning immigration of mackerel from the south-west where spawning ends earlier than in the North Sea.

8.4.3 Catch-at-Age

The 2019 catches in number-at-age by quarter and ICES area are given in Table 8.4.3.1. This catch in numbers relates to a total ICES estimated catch of 840 021 t. These figures have been appended to the catch-at-age assessment table (see Table 8.7.1.2).

Age distributions of commercial catch were provided by Denmark, England, Germany, Faroes, Iceland, Ireland, the Netherlands, Norway, Portugal, Russia, Scotland, Northern Ireland and Spain. There remain gaps in the age sampling of catches, notably from France (length samples were provided), Sweden and Poland.

Catches for which there were no sampling data were converted into numbers-at-age using data from the most appropriate fleets. Accurate national fleet descriptions are required for the allocation of sample data to unsampled catches.

The percentage catch numbers-at-age by quarter and area are given in Table 8.4.3.2.

As in previous years, over 80% of the catch in numbers in 2019 consists of 3 to 9-year olds with all year classes between 2010 and 2014 contributing over 10 % to the total catch by number. The 2016 year-class was strong in the fishery in 2019 and accounts for 17 % of the catch numbers at age.

There is a small presence of juvenile (age 0) fish within the 2019 catch. As in previous years catches from Divisions 8.c and 9.a have contained a proportion of juveniles.

8.5 Biological Data

8.5.1 Length Composition of Catch

The mean length-at-age in the catch per quarter and area for 2019 are given in Table 8.5.1.1.

For the most common ages which are well sampled there is little difference to recent years. The length of juveniles is traditionally rather variable. The range of lengths recorded in 2019 for 0 group mackerel (172 mm-267 mm) are higher than those in 2018 (162 mm-254 mm) and 2017 (131 mm-212 mm). The rapid growth of 0-group fish combined with variations in sampling (in recent years more juvenile fish have been sampled in northern waters whereas previously these fish were only caught in southern waters) will contribute to the observed variability in the observed size of 0-group fish. Growth is also affected by fish density as indicated by a recent study which demonstrated a link between growth of juveniles and adults (0—4 years) and the abundance of juveniles and adults (Jansen and Burns, 2015). A similar result was obtained for mature 3- to 8-year-old mackerel where a study over 1988—2014 showed declining growth rate since the mid-2000s to 2014, which was negatively related to both mackerel stock size and the stock size of Norwegian spring spawning herring (Ólafsdóttir *et al*., 2015).

Length distributions of the 2019 catches were provided by England, France, Iceland, Ireland, Denmark, Germany, the Netherlands, Portugal, Russia, Scotland and Spain. The length distributions were available from most of the fishing fleets and account for over 90% of the catches. These distributions are only intended to give an indication of the size of mackerel caught by the various fleets and are used as an aid in allocating sample information to unsampled catches. Length distributions by country and fleet for 2019 catches are given in Table 8.5.1.2.

8.5.2 Weights at Age in the Catch and Stock

The mean weight-at-age in the catch per quarter and area for 2019 are given in Table 8.5.2.1. There is a trend towards lighter weight-at-age for the most age classes (except 0 to 2 years old) starting around 2005, continuing until 2013 (Figure 8.5.2.1). This decrease in the catch mean weight-at-age seems to have stopped since 2013 and values for the last six years do not show any particular trend for the older ages (age 6 and older) and are slightly increasing for younger ages (ages 1 to 5). These variations in weight-at-age are consistent with the changes noted in length in Section 8.5.1.

The Working Group used weight-at-age in the stock calculated as the average of the weight-at-age in the three spawning components, weighted by the relative size of each component (as estimated by the 2019 egg survey for the southern and western components and the 2017 egg survey for the North Sea component). Mean weight-at-age in 2019 for the western component are estimated from Dutch, Irish and German commercial catch data, the biological sampling data taken during the egg surveys and during the Norwegian tagging survey. Only samples corresponding to mature fish, coming from areas and periods corresponding to spawning, as defined at the 2014 benchmark assessment (ICES, 2014) and laid out in the Stock Annex, were used to compute the mean weight-at-age in the western spawning component. For the North Sea spawning component, mean weight-at-age in 2019 were calculated from samples of the commercial catches collected from Divisions 4.a and 4.b in the second quarter of 2019. Stock weights for the southern component, are based on samples from the Spanish catch taken in Divisions 8.c and 9.a in the 2nd quarter of the year. The mean weights in the three component and in the stock in 2018 are shown in the text table below.

As for the catch weights, the decreasing trend observed since 2005 for fish of age 3 and older seems to have stopped in 2013 and values in the last six years do not show any specific trend (except for weights of ages 2 to 5 which have been increasing, Figure 8.5.2.2).

	North Sea Component	Western Component	Southern Component	NEA Mackerel 2017
Age				**Weighted mean**
0				0.000
1			0.108	0.069
2	0.219	0.202	0.149	0.191
3	0.252	0.241	0.275	0.250
4	0.262	0.284	0.332	0.293
5	0.313	0.308	0.320	0.311
6	0.350	0.337	0.368	0.346
7	0.350	0.364	0.374	0.365
8	0.346	0.370	0.383	0.371
9	0.396	0.394	0.404	0.397
10	0.423	0.424	0.443	0.428
11	0.433	0.424	0.452	0.431
12+		0.471	0.510	0.481
Component Weighting	8.5%	67.9%	23.6%	
Number of fish sampled	133	777	1897	

8.5.3 Natural Mortality and Maturity Ogive

Natural mortality is assumed to be 0.15 for all age groups and constant over time.

The maturity ogive for 2019 was calculated as the average of the ogives of the three spawning components weighted by the relative size of each component calculated as described above for the stock weights. The ogives for the North Sea and Southern components are fixed over time. For the Western component the ogive is updated every year, using maturity data from commercial catch samples from Germany, Ireland, the Netherlands and the UK collected during the first and second quarters (ICES, 2014 and Stock Annex). The 2019 maturity ogives for the three components and for the mackerel stock are shown in the text table below.

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel
0	0	0	0	0
1	0	0.12	0.02	0.09
2	0.37	0.41	0.54	0.43
3	1	0.92	0.70	0.87
4	1	1	1	1.00
5	1	1	1	1.00
6	1	1	1	1.00
7	1	1	1	1.00
8	1	1	1	1.00
9	1	1	1	1.00
10	1	1	1	1
11	1	1	1	1
12+	1	1	1	1
Component Weighting	8.5%	68.1%	23.4%	

A trend towards earlier maturation (increasing proportion mature at age 2) has been observed from around 2008 to 2015. A change in the opposite direction has been observed since then and the proportion of fish mature at age in 2019 are now markedly lower than in the previous years, and are now at levels comparable with the ones observed at the end of the 2000s (Figure 8.5.3.1).

8.6 Fishery Independent Data

8.6.1 International Mackerel Egg Survey

8.6.1.1 Final results of the 2019 Mackerel Egg Survey

Due to the COVID disruption the meeting of the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) was split into two parts in 2020. The first part was held through a web conference from 28–29 April 2020, chaired by Matthias Kloppmann (Thünen Institut, Germany) and Gersom Costas (IEO, Spain), to finalize the results of the Mackerel and Horse Mackerel Egg Survey 2019 and to plan the North Sea Mackerel Egg Survey in 2020. The second part of WGMEGS will be held through a web conference from 4 -6 November in order to finalize the rest of the topics of the terms of reference.

The 2019 mackerel and horse mackerel egg survey was designed to cover the whole spawning area of the two species, within six sampling periods of differing geographical coverage (WGMEGS: ICES, 2019d; Figure 8.6.1.1.1). Nine institutes from eight countries, Germany, Ireland, the Netherlands, Scotland, Portugal, Spain, Faroes, and Norway participated. The return of Norway was welcomed and provided additional coverage in the northern area compared to 2016. The application of an alternate transect survey design made it possible to survey the increasingly wide area that became necessary due to the expansion of mackerel spawning area and season. A provisional egg production for mackerel was provided to the WGWIDE meeting in 2019 (O'Hea *et al.*, 2019).

In 2019 peak spawning was found to have occurred in period 4 for the western spawning component (Figure 8.6.1.1.2 and Figure 8.6.1.1.3) and in period 3 for the southern spawning component (Figure 8.6.1.1.4 and Figure 8.6.1.1.5). Although the northern and northwestern spawning boundaries for mackerel during periods 5 and 6 were not fully delineated the analyses of the survey results showed that the mackerel core spawning area was covered and a reliable estimate of mackerel annual egg production was delivered. The estimate of total mackerel egg production (southern and western spawning components combined) was 1.64 * 10^{15} which is a decrease of 7.6% compared to that of 2016 (Table 8.6.1.1.1 & Figure 8.6.1.1.6).

During the 2019 survey 1 391 mackerel were collected from the entire survey area during all periods and 895 ovary samples were used to estimate the mackerel fecundity parameters (Figure 8.6.1.1.7). The analyses of relative potential fecundity gave a value of 1 191 eggs per gram female for mackerel for the western and southern components combined. The overall prevalence of atresia as a percentage of the population was 28% and the potential fecundity lost in the spawning season was 20 eggs/g. This reduced the potential fecundity by 4%. (Table 8.6.1.1.2).

Total spawning stock biomass (SSB) for the NEA mackerel stock was estimated using the realised fecundity estimate of 1 147 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert pre-spawning to spawning fish.

This gave a final estimate of spawning-stock biomass (SSB) in 2019 of

- 2.29 million tonnes for the western component;
- 0.80 million tonnes for the southern component; and
- a combined estimate of 3.09 million tonnes. This is a decrease by 12% in comparison to the 2016 estimate (Table 8.6.1.1.1, Figure 8.6.1.1.8).

8.6.1.2 2020 Mackerel Egg Survey in the North Sea

In 2020 the planning for the North Sea mackerel egg survey was conducted prior and discussed and finalized during the WGMEGS meeting in April. The survey was due to be executed in May and June 2020 with the participation of Denmark and The Netherlands. Cindy van Damme (NL) was appointed to coordinate the survey. However, due to the COVID-19 pandemic, the survey had to be cancelled and postponed to 2021.

8.6.2 Demersal trawl surveys in October – March (IBTS Q4 and Q1)

The data and the model

An index of survivors in the first autumn-winter (recruitment index) was derived from a geostatistical model fitted to catch data from bottom trawl surveys conducted during autumn and winter. A complete description of the data and model can be found in Jansen *et al*. (2015) and the NEA mackerel Stock Annex.

The data were compiled from several bottom trawl surveys conducted between October and March from 1998—2019 by research institutes in Denmark, England, France, Germany, Ireland, Netherlands, Norway, Scotland and Sweden. Surveys conducted on the European shelf in the first and fourth quarters are collectively known as the International Bottom Trawl Survey (IBTS), although several of the surveys use different names. All surveys sample the fish community on the continental shelf and upper shelf slope. IBTS Q4 covers the shelf from the Bay of Biscay to North of Scotland, excluding the North Sea, while IBTS Q1 covers the shelf waters from north of Ireland, around Scotland, the North Sea, Skagerrak and Kattegat.

Trawl operations during the IBTS have largely been standardized through the relevant ICES working group (ICES, 2013). Furthermore, the effects of variation in wing-spread and trawl speed were included in the model (Jansen *et al*., 2015). Trawling speed was generally 3.5—4.0 knots, and trawl gear is also standardized and collectively known as the Grande Ouverture Verticale (GOV) trawl. Some countries use modified trawl gear to suit the particular conditions in the respective survey areas, although this was not expected to change catchability significantly.

However, in other cases, the trawl design deviated more significantly from the standard GOV type, namely the Spanish BAKA trawl, the French GOV trawl, and the Irish mini-GOV trawl. The BAKA trawl had a vertical opening of only 2.1—2.2 m and was towed at only 3 knots. This was considered substantially less suitable for catching juvenile mackerel and, therefore, was excluded from the analysis. The French GOV trawl was rigged without a kite and typically had a reduced vertical opening, which may have reduced the catchability of pelagic species like mackerel. Catchability was assumed to equal the catchability of the standard GOV trawl because testing has shown that the recruitment index was not very sensitive to this assumption (Jansen *et al.*, 2015). Finally, the Irish mini-GOV trawl, used during 1998—2002, was a GOV trawl in reduced dimensions which was accounted for by inclusion of the wing-spread parameter in the model.

All surveys in 2018 Q4 and 2019 Q1 were conducted according to standards. Figure 8.6.2.1 provides an overview of the distribution and number of samples.

A geostatistical log-Gaussian Cox process model (LGC) with spatiotemporal correlations was used to estimate the catch rates of mackerel recruits through space and time.

Results

The index of survivors in the first autumn-winter (recruitment index) was updated with data from surveys in 2018 Q4 and 2019 Q1. Parameter estimates and standard errors in the final model are listed in Table 8.6.2.1. An overview of the IBTS survey is given in Figure 8.6.2.1. The modelled average recruitment index (squared CPUE) surfaces were mapped in Figure 8.6.2.2a and b. The time series of spatially integrated recruitment index values is used in the assessment as a relative abundance index of mackerel at age 0 (recruits). All annual index values were estimated to be slightly higher than during the previous model fit (IBPNeaMAC: ICES, 2019a), but with the same interannual pattern ($p < 0.001$, $r = 0.9986$). This increase does not affect the stock assessment because it is used in the assessment as a relative abundance index. The estimated index value for the 2019 year-class is above average (Figure 8.6.2.3).

Discussion

The combined demersal surveys have incomplete spatial coverage in some areas that can be important for the estimation of age-0 mackerel abundance, namely: (i) Since 2011, the English survey (covering the Irish sea and the central-eastern part of the Celtic sea including the area around Cornwall) has been discontinued, (ii) the Scottish survey has not consistently covered the area around Donegal Bay, (iii) the IBTS has observed high catch rates in some years at the north-eastern edge of the survey area (towards the Norwegian trench) in winter. It is therefore possible that some recruits are also overwintering on the other side of the trench along the south western shelf edge of Norway. Consequently, the NS-IBTS in Q1 should be extended to include the south-western Norwegian shelf and shelf edge in proximity to the Norwegian trench.

Finally, WGWIDE encourages studies of vertical distribution and catchability of age-0 mackerel in the Q4 and Q1 surveys, to evaluate if it is comparable in all areas (see acoustic information in Jansen et al., 2015).

8.6.3 Ecosystem surveys in the Nordic Seas in July-August (IESSNS)

The IESSNS was successfully conducted in the summer of 2020 (Figure 8.6.3.1). Six vessels sampled 315 predetermined surface trawl stations during the period from 1st July to August 4 which covered an area of 2.9 mill. km^2, excluding the North Sea. This was similar coverage to 2018 and 2019. At each surface trawl station, a standardized trawl (Multpelt 832) is deployed for 30-min according to a standardized operation protocol which is designed to catch mackerel. Additionally, abundance of herring and blue whiting was measured using acoustic methods and backscatter was verified by trawling on registrations as needed. The aim is to establish an age-segregated abundance index for blue whiting and herring to be used in stock assessment in the future. The IESSNS 2020 cruise report is available as a working document to the current report (WD03 in Annex 6) and a detailed survey description is in the NEA mackerel Stock Annex.

The IESSNS provides an annual age-segregated index for mackerel abundance for age classes 1-14+ in Nordic Seas since 2010 and in the North Sea since 2018 (ICES, 2019a). In the current chapter and the cruise report, the North Sea mackerel data are reported separately from the longer time series available from Nordic Seas.

In Nordic Seas, total stock abundance was estimated 26.4 billion and biomass was estimated 11.5 million tonnes which compared to 2019 is an increase of 0.3% and 7.0%, respectively (Table 8.6.3.1 and Figure 8.6.3.2a-b). Age classes 3-11, which are included in the stock assessment, decreased 4% in 2020 compared to 2019. Estimated stock abundance in 2020 is the second highest for the time series and the highest for estimated biomass. Abundance in 2020 was in similar range as estimates for the period from 2013 to 2019, whereas biomass has gradually increased from 2015 to 2020, excluding 2018. This suggests increasing proportion of older fish in the stock in recent years which is supported by increasing numbers-at-age for fish age 8+ and no clear trend of changing weight-at-age.

Internal consistency of year classes is highly variable with correlation values ranging from 0.10 to 0.93 (Figure 8.6.3.3). There is a good to strong internal consistency for the younger ages (1-5 years) and older ages (8-14+ years) with r between 0.73 and 0.93. However, the internal consistency is poor to moderate ($0.10 < r < 0.63$) between age 5 to 8 as in previous years. The reason for this poor consistency is not understood.

In 2020, the most abundant year classes were 2010, 2016 and 2011 respectively presenting 14%, 13% and 11% of the total stock in numbers (Figure 8.6.3.4a, b). These same three cohorts were also the most abundant in 2019. The 2010 and 2011year-classes have been the largest cohorts in the stock since they were recruited to the survey (age 3-4).

Mackerel density, per predetermined surface trawl station, ranged from 0 to 62 tonnes/km^2 with the highest densities recorded in the central and northern Norwegian See (Figure 8.6.3.5a). Mackerel geographical distribution began shifting eastward in 2018, compared to the period from 2010 to 2017 (Figure 8.6.3.5b). This eastward distributional shift continued in 2019 and in 2020 when negligible amounts of mackerel were caught west of longitude 10°W. For comparison, the westward boundary of mackerel was at longitude 43°W in 2014 which is the survey year with the largest geographical distribution range.

Catch curve analysis of cohort numbers for the period 2010 to 2020 (excl. 2011) displays "a dip" for all age classes in 2018 (Figure 8.6.3.6), indicating annual effects in the survey this particular survey year. Annual effects were not visible in the 2020 IESSNS.

The North Sea (south of latitude 60 °N) was part of the IESSNS for the third time in July 2020. 35 predetermined surface trawl stations were sampled in a survey area covering 0.26 mill. km^2 (Figure 8.6.3.5a). The mackerel abundance index was 1.3 billion and the biomass index was 0.26 million t which was represents increases of 29% and 15% compared to 2019.

8.6.4 Tag Recapture data

Steel-tags

The Institute of Marine Research in Bergen (IMR) has conducted tagging experiments on mackerel on annual basis since 1968, both in the North Sea and to the west of Ireland during the spawning season May–June. Information from steel-tagged mackerel tagged west of Ireland and British

Isles was introduced in the mackerel assessment during ICES WKPELA 2014 (ICES, 2014), and data from release years 1980-2004, and recapture years 1986-2006 has been used in the update assessments after this. The steel tag experiments continued to 2009, with recaptures to 2010, but this part of the data was at the time considered less representative and was excluded.

What is used in the SAM stock assessment is a table of data showing numbers of steel tagged fish per year class in each release year, and the corresponding numbers scanned and recaptured of the same year classes in all years after release. The steel tag data and the corresponding trends in the data in terms of index of total biomass and year class abundance by year is described in (Tenningen *et al*., 2011).

The steel tag methodology involved a whole lot of manual processes, demanding a lot of effort and reducing the possibility to scan larger proportions of the landings. The tags were recovered at metal detector/deflector gate systems installed at plants processing mackerel for human consumption. This system demanded external personnel to stay at the plants supervising the systems during processing. Among the typical 50 fish deflected, the hired personnel had to find the tagged fish with a hand-hold detector and send the fish to IMR for further analysis. It was decided in the end to go for a change in methodology to radio-frequency identification (RFID), which would allow for more automatic processes and increased proportion of scanned landings.

RFID tags

The RFID tagging project on NEA mackerel was initiated in 2011 by IMR, and the data were used in update assessments after the ICES WKWIDE 2017 benchmark meeting (ICES, 2017b). The data format was the same as for steel tags, but the time series were treated with a different scaling parameter in the assessment.

RFID is a technology that uses radio waves to transfer data from an electronic tag, called an RFID tag, through a reader for the purpose of identifying and tracking the object. The tag itself is passive but information to the reader is released as it passes an electric field in the antenna system, and information is automatically updated in an IMR database over internet. When tagging and releasing the fish, information is also synced to the IMR database regularly over internet.

There is a web-based software solution and database that is used to track the different scanning systems at the factories, import data on catch information, and biological sampling data of released fish and screened catches. Based on this information the software is used to allocate the biological data to releases and catches, and to further estimate numbers released every year, and the concurrent numbers screened and recaptured over the next years (by year class).

The development of the tagging data time series is dependent on the work from each country's research institutes, fisheries authorities or industry to provide additional data about catches screened through the RFID systems, such as total catch weight, position of catch (ICES rectangle), mean weight in catch, *etc*. Regular biological sampling of the catches landed at these factories is also needed. Altogether, these data are essential for the estimation of numbers screened per year class. Responsible scientists in Norway, Iceland, Faroes and Scotland have been following up the factories, and delivering the catch data and biological data. In the future it is planned that annual workshops should occur prior to the assessment, where more scientists go through the new data being updated from new tagging experiments, as well as recaptures from all previous experiments, undertake quality assurance of the data and other analyses of the trends in the data outside of the assessment model.

The RFID tagging technology is clearly a more cost-effective than the old steel tag technology. We are now scanning about 10 times more biomass than during the period with steel tags. An overview of the RFID tagging data in terms of numbers tagged, biomass scanned, and numbers recaptured is given in Tables 8.6.4.1-3, and geographical distributions of data in Figures 8.6.4.1-2.

During the period 2011— 20th Aug 2020 as many as 457 295 mackerel have been tagged with RFID (Table 8.6.4.1). This includes an experiment off the Norwegian Coast on young mackerel in September 2011 as well as five experiments carried out in August in Iceland 2015-2019, none of which are included as input data in the assessment. Data from the releases at the spawning grounds in May-June of Ireland and the Hebrides are the only data included in the assessment.

The 5 738 RFID-tagged mackerel recaptured up to 20th August 2020 came from 24 European factories processing mackerel for human consumption (Table 8.6.4.2-3). The project started with RFID antenna reader systems connected to conveyor belt systems at 8 Norwegian factories in 2012. Now there are 5 operational systems at 4 factories in UK (Denholm has 2 RFID systems) and 3 in Iceland. Norway has installed RFID systems at 8 more factories in 2017-2018, most of which with the purpose of scanning Norwegian spring spawning herring catches (IMR started tagging herring in 2016), but some also processing mackerel. More systems are also bought by Ireland (3), which up to now has been non-operational.

There are at times problems with some of the factories that has led to the exclusion of data for use in stock assessment. The data from factories used in the 2020 assessment is marked in Tables 8.6.4.2-3. The exclusion is due to systems not working properly, or that the efficiency is found to be too low after testing. In 2018 and 2019 tests where 10 fish are tagged and mixed in 10 different catches prior to scanning, was carried out to estimate efficiency at all factories. Currently IMR is installing newly developed equipment at Norwegian factories, where antenna-reader systems are tested automatically, and their functioning monitored over internet on continuous basis. This is major step forward to reduce the manual work and monitoring needed with testing and securing quality of future data. Hopefully, this equipment will also be installed at factories in Iceland and Scotland for the 2021 catch year.

During ICES WGWIDE 2018 (ICES, 2018d) meeting bias issues were described for RFID tag data, in addition to potential weighting issues of the tag data inside the model. After the intermediate benchmark meeting ICES IBPNEAMac 2019 (ICES, 2019a), these issues were overcome by using a subset of data for release years (exclude 2011-2012), recapture years (only use recaptures from year 1 and 2 after release) and age groups (exclude youngest fish ages 2-4, use ages 5-11). This is now the subset of data to be used in update assessments. Distributions of recaptured and tagged fish now used in stock assessment are shown in Figures 8.6.4.1. Also shown in the current report are the differences between data excluded and included for distributions of catches scanned (Figure 8.6.4.2), for the age structures of tagged, recaptured and scanned fish (Figure 8.6.4.3), and for actual trends of year class abundance (Figure 8.6.4.4) and age aggregated biomass indices (Figure 8.6.4.5).

It is apparent from Figure 8.6.4.2 that in recapture years 2014-2019, now included in the assessment, the distribution of scanned landings is comparable, whereas the excluded years 2012-2013 do not cover the same distribution of fishery.

Figure 8.6.4.3 shows the relative distributions of year classes tagged per year and scanned/recaptured year 1 and 2 after release for the subset years used in current update assessment. The figure illustrates the problem that the tagged/recaptured fish are skewed towards older fish than scanned. Especially the large year classes 2010-2011 were tagged in low numbers at ages 2-4 compared with the scanned numbers. However, for the latest release years used in the assessment (2017-2018), it seems that this tendency is less pronounced, i.e. one is tagging on the same distribution as scanned.

Estimates of year class abundance for the subset of RFID tag-recapture data used in the current assessment also show differences in year class levels and trends over time that seems informative, and with a year class development tending to be in line with a total mortality of approximately Z=0.4 (Figure 8.6.4.4). There are also indications in these estimates that fish of younger ages not included in the assessment may have trends for recent years that are informative.

However, the information coming from the RFID tag data is easier to interpret when comparing age aggregated biomass indices estimated from the RFID data with SSB from the stock assessment, as shown in Figure 8.6.4.5. During ICES WGWIDE 2018 (ICES, 2018d) the RFID tag data had high weight, and the SSB trend in the assessment showed a clear tendency to decrease from 2011-2016. This is consistent with the observed biomass trend in the RFID tag data when using aggregated data from age 2-11. By including only release years 2013 onwards as in current assessments, and excluding ages 2-4, the biomass trend in the RFID tag data are more in line with the SSB of the assessment. However, Figure 8.6.4.5 also illustrates that from 2014 onwards the inclusion of the younger fish of ages 2-4 in the biomass indices from the RFID tag data show trends that in fact are quite in line with SSB of stock assessment. This signifies that over time, and in a future benchmark process, information of tag recaptures from these younger age groups may be included again should the bias issues tend to disappear.

8.6.5 Other surveys

8.6.5.1 International Ecosystem survey in the Norwegian Sea (IESNS)

After the mid-2000s an increasing amount of NEA mackerel has been observed in catches in the Norwegian Sea during the combined survey in May during the International Ecosystem survey in the Norwegian Sea (IESNS) targeting herring and blue whiting (Salthaug *et al*. 2019; 2020). The spatial distribution pattern of mackerel was quite similar in 2020 compared to 2019 Salthaug *et al*., 2019). Mackerel was caught within a more expended area and in more trawl stations of the Norwegian Sea in May 2020 compared to May 2019 (Salthaug *et al*., 2019; 2020). In 2020, the northernmost mackerel catch was at 69°N and the westernmost catch was around 4°W, which is further north and west than recorded in 2019 (Salthaug *et al*. 2019; 2020). Mackerel of age 4 dominated, followed by age 6 in 2020, whereas there was found more 1-year olds compared to last year, particularly in the north (Salthaug *et al*., 2020).

The IESNS survey provides valuable, although limited, quantitative information on mackerel. This acoustic based survey is not designed to monitor mackerel, and does not provide proper mackerel sampling in the vertical dimension and involves too low trawl speed for representative sampling of all size groups of mackerel. The trawl hauls are mainly targeting acoustic registrations of herring and blue whiting during the survey in May (IESNS) (Salthaug *et al*., 2019; 2020).

8.6.5.2 Acoustic estimates of mackerel in the Iberian Peninsula and Bay of Biscay (PELACUS)

Due to the Covid-19 pandemic, this year PELACUS was cancelled (as well as PELGAS surveys). Therefore, no new information from the Bay of Biscay on mackerel distribution and abundance during spawning time is available

8.7 Stock Assessment

8.7.1 Update assessment in 2019

The update assessment was carried out by fitting the state-space assessment model SAM (Nielsen and Berg, 2014) using the R library *stockassessment*, downloadable from github via install_github("fishfollower/SAM/stockassessment")

and adopting the configuration described in the Stock Annex.

The assessment model is fitted to catch-at-age data for ages 0 to 12 (plus group) for the period 1980 to 2019 (with a strong down-weighting of the catches for the period 1980-1999) and three surveys: 1) the SSB estimates from the triennial Mackerel Egg survey (every three years in the period 1992-2019); 2) the recruitment index from the western Europe bottom trawl IBTS Q1 and Q4 surveys (1998-2019); and 3) the abundance estimates for ages 3 to 11 from the IESSNS survey (2010, 2012-2020). The model also incorporates tagging-recapture data from the Norwegian tagging program (for fish recaptured between 1980 and 2005 for the steel tags time series, and fish recaptured between 2014 and 2019 (age 5 and older at release) for the radio frequency tags time series).

Fishing mortality-at-age and recruitment are modelled as random walks, and there is a process error term on abundances at ages 1-11.

The differences in the new data used in this assessment compared to the last year's assessment were:

- Update of the recruitment index until 2019.
- The final 2019 MEGS SSB index is used instead of the preliminary value (-0.2% difference).
- Addition of the 2020 survey data in the IESSNS indices.
- Addition of the 2019 catch-at-age, weights-at-age in the catch and in the stock and maturity ogive, proportions of natural and fishing mortality occurring before spawning.
- The inclusion of data on numbers tagged per year class in 2018, as well as data on numbers scanned and recaptured in 2019 from year classes tagged in 2017 and 2018.

Input parameters and configurations are summarized in Table 8.7.1.1. The input data are given in Tables 8.7.1.2 to 8.7.1.10. Given the size of the tagging data base, only the data from the last year of recaptures is given in this report (Table 8.7.1.10). Earlier tagging data are not presented in this report, but are available on www.stockassessment.org in the data section (files named tag_steel.dat and tag_RFID.dat).

8.7.2 Model diagnostics

Parameter estimates

The estimated parameters and their uncertainty estimates are shown in Table 8.7.2.1 and Figure 8.7.2.1. The model estimates different observation standard deviations for young fish and for older fish. Reflecting the suspected high uncertainty in the catches of age 0 fish (mainly discards), the model gives a very poor fit to this data (large observation standard deviation). The standard deviation of the observation errors on catches of age 1 is lower, though still high, indicating a better fit. For the age 2 and older, the fit to the catch data is very good, with a very low observation standard deviation.

The observation standard deviations for the egg survey and the IESSNS surveys ages 4 to 11 are higher indicating that the assessment gives a lower weight to the information coming from these surveys compared to the catches. The IESSNS age 3 is very poorly fitted in the assessment (high observation standard deviation). Overdispersion of the tag recaptures has the same meaning as the observation standard deviations, but is not directly comparable.

The catchability of the egg survey is 1.26, larger than 1, which implies that the assessment considers the egg survey index to be an overestimate. The catchabilities at age for the IESSNS increase from 0.87 for age 3 to 2.37 for age 10. Since the IESSNS index is expressed as fish abundance, this also means that the assessment considers the IESSNS to provide over-estimated abundance values for the oldest ages. The post tagging mortality estimate is higher for the steel tags (around 40%) than for the RFID tags (around13 %).

The process error standard deviation (ages 1-11) is moderate as well as the standard deviation of the F random walks.

The catchability parameters for the egg survey, recruitment index and post tagging survival appear to be estimated more precisely than other parameters (Table 8.7.2.1). The catchability for the IESSNS have a slightly higher standard deviation, except for the catchability of the IESSNS at age 3 which has a much higher standard deviation. Uncertainty on the observation standard deviations is larger for the egg survey, the IESSNS age 3, for the recruitment index and for the catches at age 1 than for the other observations. Uncertainty on the overdispersion of the RFID tag data is high. The standard deviation on the estimate of process error is low, and the standard deviations for the estimates of F random walk variances of age 0 and 1 are both very high.

The estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11 has a high correlation between the errors of adjacent ages (r=0.81), then decreasing exponentially with age difference (Figure 8.7.2.2). This high error correlation implies that the weight of this survey in the assessment in lower than for a model without correlation structure, which is also reflects in the high observation standard deviation for this survey.

There are some correlations between parameter estimates (Figure 8.7.2.3):

- Catchabilities are positively correlated (especially for the IESSNS age 4 to 11), and negatively correlated to the survival rate for the RFID tags. This simply represents the fact that all scaling parameters are linked, which is to be expected.
- The observation variance for the IESSNS age 4-11 is positively correlated to the autocorrelation in the errors for these observations. This implies that when the model estimates highly correlated errors between age-groups, the survey is considered more noisy.

Residuals

The "one step ahead" (uncorrelated) residuals for the catches did not show any temporal pattern (Figure 8.7.2.4) except for 2014 for which they were mainly positive for 2014 (modelled catches lower than the observed ones). This may result from the random walk that constraints the variations of the fishing mortality, which prevents the model from increasing the fishing mortality suddenly (which probably happened given the sharp increase in the catches in 2014). Residuals are of a similar size for all ages, indicating that the model configuration with respect to the decoupling of the observation variances for the catches is appropriate.

The residuals for the egg survey show a strong temporal pattern with large positive residuals for the period 2007-2010-2013, followed by large negative residuals in 2016 and 2019. This pattern reflects the fact that the model, based on all the information available, does not follow the recent trend present in the egg survey (with an historical low estimate for 2019) and considers those two last years as large negative observation errors. The relatively high observation variance for this survey indicates a poor fit with the egg survey due mainly to these two observations which point towards a very different direction from the other observations. Residuals for the IESSNS indices are relatively well balanced for most of the years, except for the last 2 years, where residuals tend to be mainly positive. Residuals to the recruitment index show no particular pattern, and appear to be relatively randomly distributed, except for the recent years where residuals are mainly positive.

Finally, inspection of the residuals for the tag recaptures (Figure 8.7.2.5) did not show any specific pattern for the RFID data. For the steel tags, there is a tendency to have more positive residuals at the end of the period which could indicate that using a constant survival rate for this dataset may not be appropriate.

Leave one out runs

In order to visualise the respective impact of the different surveys on the estimated stock trajectories, the assessment was run leaving out successively each of the data sources (Figure 8.7.2.6).

All leave one out runs showed parallel trajectories in SSB and F_{bar}. For recruitment, all runs also resulted in similar trajectories, except the run without the recruitment index, which had a much less variable recruitment. This specific run corresponds to a quite different model than the other runs: as there is no information to inform the model on recruitment, the recruitment variance is estimated to be very low and the recruitment estimated is a highly correlated random walk.

Removing the IESSNS resulted in lower SSB estimates and higher F_{bar} estimates for the period covered by the survey. On the opposite, removing the egg survey results in a larger estimated stock, exploited with a lower fishing mortality. In both cases, the estimated stock trajectories are well within the confidence interval of the assessment using all data sources. The final assessment seems to make a trade-off between the information coming from the IESSNS which leads to a more optimistic perception of the stock, and the information from the egg survey which suggests a more pessimistic perception of the stock. The run leaving out the RFID data gave a perception of the SSB very similar to the assessment using all data, and slightly higher fishing mortality over the last decade. This is a contrasting situation compared to the 2018 WGWIDE assessment, in which the RFID had a very strong influence on the assessment, and is the consequence of the changes made during the interbenchmark process detailed above. Closer inspection of the results of the run without the RFID data show that estimated abundances at age are very similar to the full model, but associated uncertainties are much larger. Uncertainties on the SSB and F_{bar} in the recent years are around 30% higher when the RFID data is not included in the assessment (Figure 8.7.2.7).

8.7.3 State of the Stock

The stock summary is presented in Figure 8.7.3.1 and Table 8.7.3.1. The stock numbers-at-age and fishing mortality-at-age are presented in Tables 8.7.3.2-3. The spawning stock biomass is estimated to have increased almost continuously from just above 2 million tonnes in the late 1990s and early 2000s to 5.16 million tonnes in 2014 and subsequently declined continuously to reach a level just above 3.7 million tonnes in 2019. The fishing mortality has declined from levels between F_{pa} (0.36) and F_{lim} (0.46) in the mid-2000s to levels just below F_{MSY} since 2016. The recruitment time series from the assessment shows a clear increasing trend since the late 1990s with a succession of large year classes (2002, 2005-2006, 2011 and 2016-2018). There is insufficient information to estimate accurately the size of the 2019 year-class. The estimate is very high but highly uncertain.

There is some indication of changes in the selectivity of the fishery over the last 30 years (Figure 8.7.3.2). In the 1990s, the fishery seems to have had a steeper selection pattern (more rapid increase in fishing mortality with age). Between the end of the 1990s and the end of the 2000s, the selection pattern became less steep (decreasing selection on ages 2-5). After 2008, the pattern changed again towards a steeper selection pattern.

8.7.4 Quality of the assessment

Parametric uncertainty

Large confidence intervals are associated with the SSB in the years before 1992 (Figure 8.7.3.1 and Figure 8.7.2.7). This results from the absence of information from the egg survey index, the down-weighting of the information from the catches and the assessment being only driven by the tagging data and natural mortality in the early period. The confidence intervals become narrower from the early 1990s to the mid-2000s, corresponding to the period where information is available from the egg survey index, the tagging data and (partially) catches. The uncertainty increases slightly in the most recent years and the SSB estimate for 2019 is estimated with a precision of +/- 21% (Figure 8.7.3.1 and Table 8.7.3.1). There is generally also a corresponding large uncertainty on the fishing mortality, especially before 1995. The estimate of $F_{bar4\text{-}8}$ in 2019 has a precision of +/- 24%. The uncertainty on the recruitment is high for the years before 1998 (precision of on average +/- 45%). The precision improves for the years for which the recruitment index is available (+/- 32%) except for the most recent recruitments (+/- 48%).

Model instability

The retrospective analysis was carried out for 6 retro years, by fitting the assessment using the 2020 data, removing successively 1 year of data (Figure 8.7.4.1.). There is a systematic retrospective pattern found in F_{bar} which is revised downwards with each new year of data (Mohn's rho of 0.20). There is a retrospective pattern in the opposite direction for the SSB in the first 5 retro peels, however this pattern has disappeared in the more recent peels which explains the low value for the Mohn's rho on SSB (0.05). Recruitment appears to be quite consistently estimated.

Given that the RFID series is currently composed of only 6 years of recapture data, a degree of retrospective instability is to be expected (and retrospective runs removing 5 or more years would maybe not be meaningful as only 1 recapture year or none would be available for model fitting).

Model behaviour

The realisation of the process error in the model was also inspected. The process error expressed as annual deviations in abundances-at-age (Figure 8.7.4.2) shows indications of some pattern across time and ages. There is a predominance of positive deviations in the recent years for age-classes 5 to 8. While process error is assumed to be independent and identically distributed, there is clear evidence of correlations in the realisation of the process error in the mackerel assessment, which appears to be correlated both across age-classes and temporarily.

The temporal autocorrelation can also be visualised if the process error is expressed in term of biomass (process error expressed as deviations in abundances-at-age multiplied by weight at age and summed over all age classes, Figure 8.7.4.3). Periods with positive values (when the model globally estimates larger abundances-at-age than corresponding to the survival equation) have been alternating with periods with negative values (1991-1994 and 2004 and 2006). For the years between 2008 and 2016, the biomass cumulated process error remains positive, and large (reaching in 2013 almost the weight of the catches). The reason for this behaviour of the model could not be identified.

8.8 Short term forecast

The short-term forecast provides estimates of SSB and catch in 2021 and 2022, given assumption of the current year's (also called intermediate year) catch and a range of management options for the catch in 2021.

All procedures used this year follow those used in the benchmark of 2014 as described in the Stock Annex.

8.8.1 Intermediate year catch estimation

Estimation of catch in the intermediate year (2020) is based on declared quotas and interannual transfers as shown in the text table in Section 8.1.

8.8.2 Initial abundances at age

The recruitment estimate at age 0 from the assessment in the terminal assessment year (2019) was considered too uncertain to be used directly, because this year class has not yet fully recruited into the fishery. The last recruitment estimate is therefore replaced by predictions from the RCT3 software (Shepherd, 1997). The RCT3 software evaluates the historical performance of the IBTS recruitment index, by performing a linear regression between the index and the SAM estimates over the period 1998 to the year before the terminal year. The recruitment is then calculated as a weighted mean of the prediction from this linear regression based on the IBTS index value, and a time tapered geometric mean of the SAM estimates from 1990 to the year before the terminal year. The time tapered geometric mean gives the latest years more weight than a geometric mean. This is done because the recent productivity of the stock appears different than in the 1990's.

The weighting calculated by RCT3 was 75 % (recruitment index) and 25 % (time tapered geometric mean), which leads to an expected recruitment of 7 057 million.

8.8.3 Short term forecast

A deterministic short-term forecast was calculated using FLR (www.flr-project.org). Table 8.8.3.1 lists the input data and Tables 8.8.3.2 and 8.8.3.3 provide projections for various fishing mortality multipliers and catch constraints in 2021.

Assuming catches for 2020 of 1 091 kt, F was estimated at 0.32 (above F_{MSY}) and SSB at 3.69 Mt (above B_{pa}) in spring 2020. If catches in 2021 equal the catch in 2020, F is expected to increase to 0.34 (below F_{pa}) in 2021 with a corresponding decrease in SSB to 3.58 Mt in spring 2021. Assuming an F of 0.34 again in 2022, the SSB will further decrease to 3.40 Mt in spring 2022.

Following the MSY approach, exploitation in 2021 shall be at F_{MSY} (0.26). This is equivalent to catches of 852 kt and a decrease in SSB to 3.64 Mt in spring 2021 (1% decrease). During the subsequent year, SSB will remain at a similar level (3.63 Mt) in spring 2022.

8.9 Biological Reference Points

A management strategy evaluation Workshop on northeast Atlantic mackerel (MKMSEMAC) was conducted during 2020 (ICES, 2020) which resulted in the adoption of new reference points for NEA mackerel stock by ICES.

8.9.1 Precautionary reference points

B_{lim} **-** There is no evidence of significant reduction in recruitment at low SSB within the time series hence the previous basis for B_{lim} was retained. B_{lim} is taken as B_{loss}, the lowest estimate of spawning stock biomass from the revised assessment. This was estimated in the 2019-assessment to have occurred in 2003; B_{loss} = 2.00 Mt.

F_{lim} **-** F_{lim} is derived from B_{lim} and is determined from the long-term equilibrium simulations as the F that on average would bring the stock to B_{lim}; F_{lim} = 0.46.

B_{pa} **-** The ICES basis for advice requires that a precautionary safety margin incorporating the uncertainty in actual stock estimates leads to a precautionary reference point B_{pa}, which is a biomass reference point with a high probability of being above B_{lim}. B_{pa} was calculated as $B_{lim} \cdot exp(1.645 \cdot \sigma)$ where $\sigma = 0.15$ (the estimate of uncertainty associated with spawning biomass in the terminal year in the assessment, 2019, as estimated by WGWIDE in 2019); B_{pa} = 2 580 000 t.

F_{pa} **-**The ICES basis for advice requires that a precautionary safety margin incorporating the uncertainty in actual stock estimates leads to a precautionary reference point $F_{pa.}$ F_{pa} is the estimate of fishing mortality which is designed to ensure that the true F is above F_{lim} with a 95% probability. Following the updated Technical guidelines on ICES fisheries management reference points for category 1 and 2 stocks in 2020, F_{pa} was set equal to F_{p05} (0.36).

8.9.2 MSY reference points

The ICES MSY framework specifies a target fishing mortality, F_{MSY}, which, over the long term, maximises yield, and also a spawning biomass, MSY $B_{trigger}$, below which target fishing mortality is reduced linearly relative to the SSB $B_{trigger}$ ratio.

Following the ICES guidelines (ICES, 2017a), long term equilibrium simulations indicated that F=0.26 would be an appropriate F_{MSY} target as on average it resulted in the highest mean yields in the long term, with a low probability (less than 5%) of reducing the spawning biomass below B_{lim}.

The ICES basis for advice notes that, in general, F_{MSY} should be lower than F_{pa}, and MSY $B_{trigger}$ should be equal to or higher than B_{pa}. Simulations indicated that potential values for MSY $B_{trigger}$ were above B_{pa}. However, fishing mortality has been significantly greater than the F_{MSY} estimate for a number of years, and particularly in the most recent period. Following the ICES procedure MSY $B_{trigger}$ was set equal to $B_{pa,}$ 2 580 000 t.

Updated ICES reference points for NEA mackerel			
Type		Value	Technical basis
MSY approach	MSY $B_{trigger}$	2.58 million tonnes	B_{pa} [1]
	F_{MSY}	0.26	Stochastic simulations [1]
Precautionary approach	B_{lim}	2.00 million tonnes	B_{loss} from (2003) [1]
	B_{pa}	2.58 million tonnes	$B_{lim} \times \exp(1.654 \times \sigma)$, $\sigma_{SSB} = 0.15$ [1]
	F_{lim}	0.46	F that, on average, leads to B_{lim} [1]
	F_{pa}	0.36	F_{p05}

[1] ICES WKMSEMAC (ICES, 2020)

8.10 Comparison with previous assessment and forecast

The last assessment used to provide advice was carried out during the WGWIDE in 2019. The new 2020 WGWIDE assessment is generally consistent with the 2019 assessment (Figure 8.10.1). The SSB and F_{bar} trajectories are nearly identical with the exception of the SSB estimate in 2019. The WGWIDE 2019 assessment estimate is based primarily on the (in-year) 2019 IESSNS index and has been revised downwards in the WGWIDE 2020 assessment with the inclusion of additional data sources. The estimated recruitment time series have been revised downward in the most recent years (particularly for the 2017 and 2018 year classes). The updated recruitment index series has not been revised compared to last year's assessment, and indicates very large abundances for these year classes (also 2016 and 2019, see figure 8.6.2.3). This downward revision of the size of the 2017 and 2018 year classes in the assessment suggests that the new information available on these cohorts, (2019 catch data, 2020 IESSNS index) may be in contradiction with the perception from the recruitment index, and indicate smaller year classes. A comparison of the abundances in 2019 from the 2019 and 2020 assessments (figure 8.6.2.4) shows that these year classes are actually revised downward also at age 1 (for year-class 2018) and age 2 (for year-class 2017). Furthermore, the recent recruitment index values are considered as overestimates by the SAM model (positive residuals in 2016-2019, figure 8.7.2.4). This increased discrepancy between the signal from the recruitment index and the estimates of the SAM model is also reflected by an (although small) increase in the observation variance of this survey (figure 8.10.2), indicating a poorer fit to this data series.

The differences in the 2018 TSB and SSB estimates between the previous and the present assessments are small, at -4.8 and -3.0% respectively. The 2018 fishing mortality is almost unchanged (0.2% difference).

	TSB 2018	SSB 2018	F_{BAR4-8} 2018
Values			
2019 WGWIDE	5 684 879 tonnes	4 279 185 tonnes	0.238
2020 WGWIDE	5 410 637 tonnes	4 152 849 tonnes	0.239
% difference	-4.8%	-3.0%	0.2%

The addition of a new year of data has slightly modified the relative weight of the different data sources: the estimated observation standard deviation has increased for the IESSNS survey and the recruitment index (although not significantly), and decreased (also not significantly) for the egg survey. This decreasing influence of the IESSNS survey on the assessment may be related to the increasing conflict between the IESSNS (indicating record high biomass in 2019) and the egg survey index (at its lowest), and the fact that both the catch data and the RFID seem to point towards a decrease of the stock in the recent years. These changes in the weight of the different data sources did not this year result in a large the revision of stock trajectories, contrary to what has been observed in previous years.

The uncertainty on the parameter estimates has decreased for some parameters (standard deviations of the F random walk for age 0 and 1, Figure 8.10.2), but increased for others (recruitment variance, catchability of the IESSNS for ages 4-8, and observation variances for the IESSNS). The uncertainty on SSB and $F_{bar4\text{-}8}$ in this year's assessment is similar to the previous assessment, except for the terminal year estimate for which the 2020 assessment has a higher uncertainty (Figure 8.10.3).

The prediction of the total catch of mackerel for 2019 used for the short-term forecast in the advice given last year was very close to the actual 2019 catch reported for WGIWIDE 2020 and used in the present assessment (text table below). The new assessment produced an estimate of the SSB in 2019 which was markedly lower than the 2019 WGWIDE forecast prediction (-15%). This large discrepancy in the SSB is explained by the revision of the perception of the abundance at age 1 and 2 (Figure 8.10.4). The estimates used last year as the basis of the short-term forecast were informed by no data (the only data from 2019 available then was the IESSNS index ages 3-11). This year's estimates of 2019 abundance at age are now based also on catch information and therefore more reliable. The fishing mortality $F_{bar4\text{-}8}$ for 2019 estimated at the WGWIDE 2020 is 6.4% higher than the value estimated by the short-term forecast in the previous assessment.

	Catch (2019)	SSB (2019)	$F_{bar4\text{-}8}$ (2019)
2019 WGWIDE forecast	834 954t	4 389 601t	0.21
2020 WGWIDE assessment	840 021 t	3 731 510 t	0.22
% difference	0.6%	-15.0%	6.4%

8.11 Management Considerations

Details and discussion on quality issues in this year's assessment is given in Section 8.7 above.

From 2001 to 2007, the internationally agreed TACs covered most of the distribution area of the Northeast Atlantic mackerel. From 2008 to 2014, no agreement was reached among the Coastal States on the sharing of the mackerel quotas. In 2014, three of the Coastal States (EU, NO and FO) agreed on a Management Strategy for 2014 to 2018. In November 2018, the agreement from 2014 was extended for two more years until 2020. However, the total declared quotas for 2015 to 2019 all exceed the TAC advised by ICES (Figure 8.11.1).

The mackerel in the Northeast Atlantic is traditionally characterised as three distinct 'spawning components': the southern component, the western component and the North Sea component. The basis for the components is derived from tagging experiments (ICES, 1974). However, the methods normally used to identify stocks or components (*e.g.* ectoparasite infections, blood phenotypes, otolith shapes and genetics) have not been able to demonstrate significant differences between animals from different components. The mackerel in the Northeast Atlantic appears on one hand to mix extensively whilst, on the other hand, exhibit some tendency for homing (Jansen *et al.*, 2013; Jansen and Gislason, 2013). Consequently, it cannot be considered either a panmictic population, nor a population that is composed of isolated components (Jansen and Gislason, 2013). A review of the mackerel in the North Sea, carried out during WKWIDE 2017 (ICES, 2017b) concluded that Northeast Atlantic mackerel should be considered as a single population (stock) with individuals that show stronger or weaker affinity for spawning in certain parts of the spawning area.

Nevertheless, stock components are still being used to identify the different spawning areas where mackerel are known to spawn. The trends in the different components is derived from the triennial egg survey in the western and southern area and a dedicated egg survey in the North Sea the year following the western survey.

Since the mid-1970s, ICES has continuously recommended conservation measures for the North Sea component of the Northeast Atlantic mackerel stock (*e.g.* ICES, 1974; ICES, 1981). The measures advised by ICES to protect the North Sea spawning component (*i.e.* closed areas and minimum landing size) aimed to promote the conditions that make a recovery of this component possible.

The recommended closure of Division 4.a for fishing during the first half of the year is based on the perception that the western mackerel enter the North Sea in July/August, and remain there until December before migrating to their spawning areas. Updated observations from the late 1990s suggested that this return migration actually started in mid- to late February (Jansen *et al.*, 2012). The EU TAC regulations stated that within the limits of the quota for the western component (ICES Subareas and Divisions 6, 7, 8.a,b,d,e, 5.b (EU), 2.a (non-EU), 12, 14), a certain quantity of this stock may be caught in 4.a between 1 September and 15 February. Up to 2010, 30% of the EU TAC of mackerel (MAC/2CX14-) could be taken in 4.a. From 2011 until 2014, this percentage increased to 40% and from 2015 onwards this increased to 60%.

The minimum landing size (MLS) for mackerel is currently set at 30 cm for the North Sea and 20 cm in the western area. The MLS of 30 cm in the North Sea was originally introduced by Norway in 1971 and was intended to protect the very strong 1969 year-class from exploitation in the industrial fishery (Pastoors, 2015). The 30 cm later became the norm for the North Sea MLS while the MLS for mackerel in western waters was set at 20 cm. In the early 1990s, ICES recommended that, because of mixing of juvenile and adult mackerel on western waters fishing grounds, the adoption of a 30 cm minimum landing size for mackerel was not desirable as it could lead to increased discarding (ICES, 1990; 1991). A substantial part of the catch of (western) NEA mackerel is taken in ICES division 4.a during the period October until mid-February to which the 30 cm MLS applies even though there is limited understanding on the effectiveness of minimum landing sizes in achieving certain conservation benefits (STECF, 2015).

8.12 Ecosystem considerations

An overview of the main ecosystem drivers possibly affecting the different life-stages of Northeast Atlantic mackerel and relevant observations are given in the Stock Annex. The discussion here is limited to recent features of relevance.

Production (recruitment and growth)

Mackerel recruitment (age 1) has been high since 2001 compared to previous decades, with several very large cohorts (Jansen, 2016). Increasing stock size was suggested to have an effect through density driven expansion of the spawning area into new areas with Calanus in oceanic areas west of the North European continental shelf (Jansen, 2016). There are several indications of a shift in spawning and mackerel recruitment/larvae and juvenile areas towards northern and north-eastern areas preceding the 2016 mackerel spawning (ICES, 2016; Nøttestad *et al.*, 2018;

Bjørdal, 2019). This northerly shift in spawning and recruitment pattern of NEA mackerel seems to have continued also in 2017 (Nøttestad *et al*., 2018), but has reversed in 2018 (Figure 8.6.2.2).

The recruitment index indicates high recruitment in 2016-2019. For the two first year classes, this is also indicated by high CPUE at age 1 and 2 in the IESSNS. CPUE of the 2018 year-class in the IESSNS suggests it to be of an average size, however, this could also reflect a more south-western distribution of the recruits (partly outside the IESSNS survey area) from the 2018-year class as observed in the IBTS-surveys.

During the last decade, mackerel length- and weight-at-age declined substantially for all ages (Jansen and Burns, 2015; Ólafsdóttir *et al*., 2015). Growth of 0–3 years old mackerel decreased from 1998 to 2012. Mean length at age 0 decreased by 3.6 cm, however the growth differed substantially among cohorts (Jansen and Burns, 2015). For the 3-8 years old mackerel, the average size was reduced by 3.7 cm and 175 g from 2002 to 2013 (Ólafsdóttir *et al*., 2015). The variations in growth of mackerel in all ages are correlated with mackerel density. Furthermore, the density dependent regulation of growth from younger juveniles to older adult mackerel, appears to reflect the spatial dynamics observed in the migration patterns during the feeding season (Jansen and Burns, 2015; Ólafsdóttir *et al*., 2015). Growth rates of the juveniles were tightly correlated with the density of juveniles in the nursery areas (Jansen and Burns, 2015). For adult mackerel (age 3-8) growth rates were correlated with the combined effects of mackerel and herring stock sizes (Ólafsdóttir *et al*., 2015). Conspecific density-dependence was most likely mediated via intensified competition associated with greater mackerel density. Nevertheless, weight at age of mackerel both from the catches and the surveys have increased during the last few years, particularly for the younger year classes from 2 to 5 years of age (ICES, 2019a; 2020).

The growth (mean weights per age group) has slightly increased during the last 34 years for several age groups (ICES, 2018c; ICES, 2019a). However, this does not include the 0-year olds which supports the finding of high abundance at age 0 (Figure 8.5.2.1.).

Spatial mackerel distribution and timing

In the mid-2000s, the summer feeding distribution of Northeast Atlantic mackerel (*Scomber scombrus*) in Nordic Seas began expanding into new areas (Nøttestad *et al*., 2016). During the period 2007 - 2016 the mackerel distribution range increased three-fold and the centre-of-gravity shifted westward by 1650 km and northward by 400 km. Distribution range peaked in 2014 and was positively correlated to Spawning Stock Biomass (SSB).

After a mackerel stock expansion during the feeding season in summer from 1.3 million km^2 in 2007 to at least 2.9 million km^2 in 2014, mainly towards western and northern regions of the Nordic seas (Nøttestad *et al*., 2016), a slight decrease in distribution area of mackerel in the Nordic Seas was observed in 2017 and 2018 with 2.8 million square kilometres (Nøttestad *et al*., 2017; ICES, 2018a). The mackerel distribution slightly increased to 2.9 million km^2 in 2019 (Nøttestad *et al*., 2019). However, we witnessed a substantial shift in mackerel concentrations and distribution during summer 2020, when no mackerel were registered in Greenland waters, and a substantial decline was documented in Icelandic waters, whereas increased biomasses of mackerel were distributed in the central and northern part of the Norwegian Sea (Nøttestad *et al*., 2020b). The mackerel was less patchily distributed within the survey area in 2020 compared to 2019. Overall, we have witnessed that mackerel had a much more eastern distribution in 2018 to 2020 compared to 2014-2017 (ICES, 2018a; Nøttestad *et al*., 2019; 2020b). Geographical distribution of the 2016 cohort at age 0 and 1 extended more to the north than normally along the coast and offshore areas of Norway based on various survey data and fishing data (Nøttestad *et al*., 2018; Bjørdal, 2019).

Spatial mackerel distribution related to environmental conditions

Ólafsdóttir *et al*. (2018) analysed the IESSNS data from 2007 to 2016 with the following results: Mackerel was present in temperatures ranging from 5 °C to 15 °C, but preferred areas with temperatures between 9 °C and 13 °C according to univariate quotient analysis. Generalized additive models showed that both mackerel occurrence and density were positively related to location, ambient temperature, meso-zooplankton density and SSB, explaining 47% and 32% of deviance, respectively. This seem to have changed during 2019 and particularly 2020 where higher concentrations of mackerel were caught in lower temperatures (7-8 °C) (Nøttestad *et al*., 2019; 2020b). Mackerel relative mean weight-at-length was positively related to location, day-of-year, temperature and SSB, but not with meso-zooplankton density, explaining 40% of the deviance. Geographical expansion of mackerel during the summer feeding season in Nordic Seas was driven by increasing mackerel stock size and constrained by availability of preferred temperature and abundance of meso-zooplankton. Marine climate with multidecadal variability probably impacted the observed distributional changes but were not evaluated. Our results were limited to the direct effects of temperature, meso-zooplankton abundance, and SSB on distribution range during the last two decades (1997-2016) and should be viewed as such (Olafsdottir *et al.* 2019). It is not clear what causes this distributional shift, but the SST were 1-2°C lower in the western and south-western areas as compared to a 20-years mean (1999-2009), and substantially lower zooplankton concentrations in Icelandic and Greenland waters in 2019 and 2020 than 2018, might partly explain such changes (ICES, 2018a; Nøttestad *et al*., 2019; 2020a).

Trophic interactions

There are strong indications for interspecific competition for food between NSS-herring, blue whiting and mackerel (Huse *et al*., 2012). According to Langøy *et al*. (2012), Debes *et al*. (2012), Óskarsson *et al*. (2015) and Bachiller *et al*. (2016), the herring may suffer from this competition, as mackerel had higher stomach fullness index than herring and the herring stomach composition is different from previous periods when mackerel stock size was smaller. Langøy *et al*. (2012) and Debes *et al*. (2012) also found that mackerel consumed a wider range of prey species than herring. Mackerel may thus be thriving better in periods with low zooplankton abundances. Feeding incidence increased with decreasing temperature as well as stomach filling degree, indicating that feeding activity is highest in areas associated with colder water masses (Bachiller *et al*., 2016). A bioenergetics model developed by Bachiller *et al*. (2018) estimated that the NEA mackerel, NSS herring and blue whiting can consume between 122 and 135 million tonnes of zooplankton per year (2005-2010) This is higher than that estimated in previous studies (e.g. Utne *et al*., 2012; Skjoldal *et al*., 2004). NEA mackerel feeding rate can consequently be as high as that of the NSS herring in some years. Geographical distribution overlap between mackerel and NSS herring during the summer feeding season is highest in the south-western part of the Norwegian Sea (Faroe and east Icelandic area) (Nøttestad *et al*., 2016; 2017; Ólafsdóttir *et al*., 2017). The spatio-temporal overlap between mackerel and herring was highest in the southern and south-western part of the Norwegian Sea in 2018 and 2019 (ICES, 2018a, Nøttestad *et al*., 2019). This is similar as seen in previous years (Nøttestad *et al*., 2016; 2017). A change was seen in the northern Norwegian Sea in 2019 where we had some overlap between mackerel and herring (mainly 2013- and 2016- year classes) (Nøttestad *et al*., 2019). There was, on the other hand, practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea in 2018 and previous years, mainly because of very limited amounts of herring in this area (ICES, 2018a).

There seem to be rather limited spatial overlap between marine mammals and mackerel during summers in the Nordic Seas (Nøttestad *et al*., 2019; Løviknes, 2019). There is spatial overlap between killer whales and mackerel in the Norwegian Sea, and killer whales are actively hunting for mackerel schools close to the surface during summer (Nøttestad *et al*., 2014; Nøttestad *et al*., 2020a). The increase of 0- and 1-groups of NEA mackerel found along major coastlines of Norway both in 2016 and 2017 (Nøttestad *et al*., 2018) and 2018 (Bjørdal, 2019), has created some interesting new trophic interactions. Increasingly numbers of adult Atlantic bluefin tuna (*Thynnus thunnus*), with an average size of approximately 200 kg, have been documented to feed on 0-group mackerel from the 2016, 2017-year classes during the commercial bluefin tuna fishery in Norway (Boge, 2019; Nøttestad *et al*., 2020b). Additionally, the new situation of numerous 0- and 1-group mackerel in Norwegian coastal waters in 2018 (Bjørdal, 2019), have created favourable feeding possibilities for larger cod, saithe, marine mammals and seabirds in these waters. Repeated stomach samples from several species document that smaller sized mackerel is now eaten by different predators in northern waters (60-70°N) (Bjørdal, 2019). Although much fewer 1-groups of NEA mackerel was found along the coast in Norway during the IESSNS 2019 (Nøttestad *et al*., 2019) and to some extent in 2020 (Nøttestad *et al*., 2020b), the Atlantic bluefin tuna is still indeed targeting schools of 1-group mackerel during their intense feeding migration in Norwegian waters (Nøttestad *et al*., 2020a). The predation pressure and mortality from and increasing Atlantic bluefin tuna stock on NEA mackerel (both juveniles and adults) are unknown, but could have ecological impact on both regional and population level (ICCAT, 2019; Nøttestad *et al*., 2020b).

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8.14 Tables

Table 8.2.1. 2019 Mackerel fleet composition of major mackerel catching nations.

Country	Len (m)	Engine power (hp)	Gear	Storage	No vessels
Denmark	57-88	4077-10469	Trawl	Tank	9
Faroe Islands	60-100	3460-8000 kw	Purse Seine/Trawl	RSW	9
	60-100	3920-6005 kw	Purse Seine/Trawl	Freezer	2
	60-100	3400-7680 kw	Trawl/Pair trawl	RSW	4
	< 50	1800 kw	Trawl	Dry hold with ice	1
France		110529	Pair Trawl		56
		442400	Trawl		654
		6525	Nets		447
		7294	Lines		257
		22662	Other gears		245
Germany	90-140	3800-12000	Single Midwater Trawl	Freezer	3
Greenland	65-121	3072-9517	Midwater Trawl	Freezer	14
	70-78	3002-4076	Midwater Trawl	RSW	3
Iceland	55-70	500-1500	Single Midwater Trawl	RSW, Freezer	3
	55-70	1500-3000	Single Midwater Trawl	RSW, Freezer	9
	70-85	3500-4500	Single Midwater Trawl	RSW, Freezer	6
Ireland	50m-71	1007-3460	Single Midwater Trawl	RSW and dryhold	8
	21m-65	368-2720	Pair Midwater Trawl	RSW and dryhold	36
Netherlands	88-145	4400-10455	Single Midwater Trawl	Freezer	7
Norway	60-85 m		Purse seiner	RSW	74
	30-40 m		Purse seiner	Dryhold, RSW	16
	10-17 m		Purse seiner	Dryhold	178
	10-17 m		Hook and line/nets	Dryhold	170
	10-17 m		PS/hooks/nets	Dryhold	205
	30-40 m		Trawl	Dryhold.Tankhold	17
Portugal	0-10		Other		94
	10-20		OTB		3

Country	Len (m)	Engine power (hp)	Gear	Storage	No vessels
	10-20		Other		86
	20-30		OTB		27
	20-30		Other		16
	30-40		Trawl		7
Spain	12-18	80-294	Trawl	Dryhold with ice	2
	18-24	96-344	Trawl	Dryhold with ice	12
	24-40	191-876	Trawl	Dryhold with ice	110
	>40	353	Trawl	Dryhold with ice	2
	0-10	34-44	Purse Seine	Dryhold with ice	2
	10-12	20-106	Purse Seine	Dryhold with ice	12
	12-18	21-245	Purse Seine	Dryhold with ice	91
	18-24	70-397	Purse Seine	Dryhold with ice	169
	24-40	140-809	Purse Seine	Dryhold with ice	149
	0-10	3-74	Artisanal	Dryhold with ice	382
	10-12	12-118	Artisanal	Dryhold with ice	234
	12-18	18-239	Artisanal	Dryhold with ice	247
	18-24	59-368	Artisanal	Dryhold with ice	49
	24-40	129-368	Artisanal	Dryhold with ice	15
UK Scotland	55 - 90	2950 - 7200	Trawl	RSW	19
Russian Federation	45 -120	1766-8000	Midwater Trawl	Freezer	30

RSW = refrigerated seawater.

Table 8.2.4.1. Overview of major existing regulations on mackerel catches.

Technical measure	National/International level	Specification	Note
Catch limitation	Coastal States/NEAFC	2010-2019	Not agreed
Management strategy (EU, NO, FO agreement London 12. Oct. 2014)	European (EU, NO, FO)	If SSB >= 3.000.000t, F = 0.24 If SSB is less than 3.000.000t, F = 0.24 * SSB/3.000.000 TAC should not be changed more than 20% A party may transfer up to 10% of unutilised quota to the next year	Not agreed by all parties
Management strategy with updated reference points 2019 (EU, NO, FO agreement London 17. Oct. 2019)	European (EU, NO, FO)	If SSB >= 2.500.000t, F = 0.23 If SSB is less than 2.500.000t, F = 0.23 * SSB/2.500.000 TAC should not be changed more than +25% or -20% A party may transfer up to 10% of unutilised quota to the next year A party may fish up to 10% beyond the allocated quota, that have to be deduced from next year's quota.	Not agreed by all parties
Minimum size (North Sea)	European (EU, NO)	30 cm in the North Sea	
Minimum size (all areas except North Sea)	European (EU, NO)	20 cm in all areas except North Sea	10% undersized allowed
Minimum size	National (NO)	30 cm in all areas	
Catch limitation	European (EU, NO)	Within the limits of the quota for the western component (6, 7, 8.a-b,d,e, 5.b (EC), 2.a (nonEC), 12, 14), a certain quantity may be taken from 4.a but only during the periods 1 January to 15 February and 1 October to 31 December.	
Area closure	National (UK)	South-West Mackerel Box off Cornwall	Except where the weight of the mackerel does not exceed 15 % by liveweight of the total quantities of mackerel and other marine organisms onboard which have been caught in this area
Area limitations	National (IS)	Pelagic trawl fishery only allowed outside of 200 m depth contours around Iceland and/or 12 nm from the coast.	

Technical measure	National/International level	Specification	Note
National catch limitations by gear, semester and area	National (ES)	28.74 % of the Spanish national quota is assigned for the trawl fishery, 34.29 % for purse seiners and 36.97% for the artisanal fishery	Since 2015, the trawl fishery has the individual quotas assigned by vessel.
Discard prohibition	National (NO, IS, FO)	All discarding is prohibited for Norwegian, Icelandic and Faroese vessels	
Landing Obligation	European	From 2015 onwards a landing obligation for European Union fisheries is in place for small pelagics including mackerel, horse mackerel, blue whiting and herring. In 2016 it was extended to certain demersal fisheries and since 2019 it applies to all TAC species.	There are de minimis exemptions for mackerel caught in bottom-trawl fisheries in the North Western Waters (EC 2018/2034) and in the North Sea (EC 2018/2035).

Table 8.4.1.1. NE Atlantic Mackerel. ICES estimated catches by area (t). Discards not estimated prior to 1978 (data submitted by Working Group members).

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
1969	4800		4800	47404		47404	739175		739175	7		7	42526		42526	833912		833912
1970	3900		3900	72822		72822	322451		322451	163		163	70172		70172	469508		469508
1971	10200		10200	89745		89745	243673		243673	358		358	32942		32942	376918		376918
1972	13000		13000	130280		130280	188599		188599	88		88	29262		29262	361229		361229
1973	52200		52200	144807		144807	326519		326519	21600		21600	25967		25967	571093		571093
1974	64100		64100	207665		207665	298391		298391	6800		6800	30630		30630	607586		607586
1975	64800		64800	395995		395995	263062		263062	34700		34700	25457		25457	784014		784014
1976	67800		67800	420920		420920	305709		305709	10500		10500	23306		23306	828235		828235
1977	74800		74800	259100		259100	259531		259531	1400		1400	25416		25416	620247		620247
1978	151700	15100	166800	355500	35500	391000	148817		148817	4200		4200	25909		25909	686126	50600	736726
1979	203300	20300	223600	398000	39800	437800	152323	500	152823	7000		7000	21932		21932	782555	60600	843155
1980	218700	6000	224700	386100	15600	401700	87931		87931	8300		8300	12280		12280	713311	21600	734911
1981	335100	2500	337600	274300	39800	314100	64172	3216	67388	18700		18700	16688		16688	708960	45516	754476
1982	340400	4100	344500	257800	20800	278600	35033	450	35483	37600		37600	21076		21076	691909	25350	717259
1983	320500	2300	322800	235000	9000	244000	40889	96	40985	49000		49000	14853		14853	660242	11396	671638
1984	306100	1600	307700	161400	10500	171900	43696	202	43898	98222		98222	20208		20208	629626	12302	641928

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
1985	388140	2735	390875	75043	1800	76843	46790	3656	50446	78000		78000	18111		18111	606084	8191	614275
1986	104100		104100	128499		128499	236309	7431	243740	101000		101000	24789		24789	594697	7431	602128
1987	183700		183700	100300		100300	290829	10789	301618	47000		47000	22187		22187	644016	10789	654805
1988	115600	3100	118700	75600	2700	78300	308550	29766	338316	120404		120404	24772		24772	644926	35566	680492
1989	121300	2600	123900	72900	2300	75200	279410	2190	281600	90488		90488	18321		18321	582419	7090	589509
1990	114800	5800	120600	56300	5500	61800	300800	4300	305100	118700		118700	21311		21311	611911	15600	627511
1991	109500	10700	120200	50500	12800	63300	358700	7200	365900	97800		97800	20683		20683	637183	30700	667883
1992	141906	9620	151526	72153	12400	84553	364184	2980	367164	139062		139062	18046		18046	735351	25000	760351
1993	133497	2670	136167	99828	12790	112618	387838	2720	390558	165973		165973	19720		19720	806856	18180	825036
1994	134338	1390	135728	113088	2830	115918	471247	1150	472397	72309		72309	25043		25043	816025	5370	821395
1995	145626	74	145700	117883	6917	124800	321474	730	322204	135496		135496	27600		27600	748079	7721	755800
1996	129895	255	130150	73351	9773	83124	211451	1387	212838	103376		103376	34123		34123	552196	11415	563611
1997	65044	2240	67284	114719	13817	128536	226680	2807	229487	103598		103598	40708		40708	550749	18864	569613
1998	110141	71	110212	105181	3206	108387	264947	4735	269682	134219		134219	44164		44164	658652	8012	666664
1999	116362		116362	94290		94290	313014		313014	72848		72848	43796		43796	640311		640311
2000	187595	1	187595	115566	1918	117484	285567	165	304898	92557		92557	36074		36074	736524	2084	738608
2001	143142	83	143142	142890	1081	143971	327200	24	339971	67097		67097	43198		43198	736274	1188	737462

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
2002	136847	12931	149778	102484	2260	104744	375708	8583	394878	73929		73929	49576		49576	749131	23774	772905
2003	135690	1399	137089	90356	5712	96068	354109	11785	365894	53883		53883	25823	531	26354	659831	19427	679288
2004	134033	1705	134738	103703	5991	109694	306040	11329	317369	62913	9	62922	34840	928	35769	640529	19962	660491
2005	79960	8201	88162	90278	12158	102436	249741	4633	254374	54129		54129	49618	796	50414	523726	25788	549514
2006	88077	6081	94158	66209	8642	74851	200929	8263	209192	46716		46716	52751	3607	56358	454587	26594	481181
2007	110788	2450	113238	71235	7727	78962	253013	4195	257208	72891		72891	62834	1072	63906	570762	15444	586206
2008	76358	21889	98247	73954	5462	79416	227252	8862	236113	148669	112	148781	59859	750	60609	586090	37075	623165
2009	135468	3927	139395	88287	2921	91208	226928	8120	235049	163604		163604	107747	966	108713	722035	15934	737969
2010	106732	2904	109636	104128	4614	108741	246818	883	247700	355725	5	355729	49068	4640	53708	862470	13045	875515
2011	160756	1836	162592	51098	5317	56415	301746	1906	303652	398132	28	398160	24036	1807	25843	935767	10894	946661
2012	121115	952	122067	65728	9701	75429	218400	1089	219489	449325	1	449326	24941	3431	28372	879510	15174	894684
2013	132062	273	132335	49871	1652	51523	260921	337	261258	465714	15	465729	19733	2455	22188	928433	4732	933165
2014	180068	340	180408	93709	1402	95111	383887	334	384221	684082	91	684173	46257	4284	50541	1388003	6451	1394454
2015	134728	30	134757	98563	3155	101718	295877	34	295911	632493	78	632571	36899	7133	44033	1198560	10431	1208990
2016	206326	200	206526	37300	1927	39227	248041	570	248611	563440	54	563494	32987	3220	36207	1088094	5971	1094066
2017	225959	151	226110	21128	1992	23119	269404	400	269804	603806	62	603869	32815	227	33042	1153112	2832	1155944

Table 8.4.1.1. NE Atlantic Mackerel. ICES estimated catches by area (t). Discards not estimated prior to 1978 (data submitted by Working Group members). Continued.

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
2018	157239	90	157329	35240	1611	36851	341527	620	342147	455689	51	455740	33851	518	34369	1023547	2890	1026437
2019	122995	144	123139	33118	5902	39020	307238	812	308049	345019	18	345037	23844	932	24776	832214	7807	840021

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Subareas 1, 2, 5 and 14, 1984 – 2019 (Data submitted by Working Group members).

Country	1984	1985	1986	1987	1988	1989	1990	1991	1992
Denmark	11787	7610	1653	3133	4265	6433	6800	1098	251
Estonia									216
Faroe Islands	137				22	1247	3100	5793	3347
France		16				11		23	6
Germany Fed. Rep.			99		380				
Germany Dem. Rep.			16	292		2409			
Iceland									
Ireland									
Latvia									100
Lithuania									
Netherlands									
Norway	82005	61065	85400	25000	86400	68300	77200	76760	91900
Poland									
Sweden									
United Kingdom			2131	157	1413		400	514	802
USSR/Russia	4293	9405	11813	18604	27924	12088	28900	13361	42440
Misreported (Area 4.a)									
Misreported (Area 6.a)									
Misreported (Unknown)									
Unallocated									
Discards									
Total	98222	78096	101112	47186	120404	90488	118700	97819	139062

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Areas 1, 2, 5 and 14, 1984 – 2019. Continued.

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001
Denmark			4746	3198	37	2090	106	1375	7
Estonia		3302	1925	3741	4422	7356	3595	2673	219
Faroe Islands	1167	6258	9032	2965	5777	2716	3011	5546	3272
France	6	5	5		270				
Germany									
Greenland				1					
Iceland				92	925	357			
Ireland							100		
Latvia	4700	1508	389	233					
Lithuania								2085	
Netherlands				561			661		
Norway	100500	141114	93315	47992	41000	54477	53821	31778	21971
Poland					22				
Sweden									8
United Kingdom		1706	194	48	938	199	662		54
Russia	49600	28041	44537	44545	50207	67201	51003	491001	41566
Misreported (Area 4.a)		-109625	-18647			-177	-40011		
Misreported (Area 6.a)							-100		
Misreported (Un-known)									
Unallocated									
Discards									
Total	165973	72309	135496	103376	103598	134219	72848	92557	67097

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Areas 1, 2, 5, and 14, 1984 – 2019. Continued.

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010
Denmark	1								4845
Estonia									
Faroe Islands	4730		650	30		278	123	2992	66312
France			2	1					
Germany						7			
Greenland									
Iceland	53	122		363	4222	36706	112286	116160	121008
Ireland		495	471						
Latvia									
Lithuania									
Netherlands	569	44	34	2393		10	72		90
Norway	22670	125481	10295	13244	8914	493	3474	3038	104858
Poland									
Sweden									
United Kingdom	665	692	2493				4		
Russia	45811	40026	49489	40491	33580	35408	32728	41414	58613
Misreported (Area 4.a)									
Misreported (Area 6.a)									
Misreported (Unknown)	-570		-553						
Unallocated		-44	32	-2393		-10	-18		
Discards			9				112		5
Total	73929	53883	62922	54129	46716	72891	148781	163604	355729

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Areas 1, 2, 5, and 14, 1984 – 2019. Continued.

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019
Denmark	269		391	2345	4321	1	2	289	
Estonia			13671		0				
Faroe Islands	121499	107198	142976	103896	76889	61901	66194	52061	37418
France	2		197	8	36			733	
Germany		107	74		2963	3499	4064	577	190
Greenland	621	74021	541481	875811	30351	36142	46388	62973	30241
Iceland	159263	149282	151103	172960	169333	170374	167366	168330	128008
Ireland	90			1725	6	2			
Latvia									
Lithuania				1082		1931			
Netherlands	178	5	1	5887	6996	8599	7671	2697	13
Norway	43168	110741	33817	192322	204574	153228	167739	46853	22605
Poland								2	
Sweden		4	825	3310	740	730	1720	910	
United Kingdom			2	5534	7851	5240	4601	2009	
Russia	73601	74587	80812	116433	128433	121614	138061	118255	126543
Misreported (Area 4.a)									
Misreported (Area 6.a)									
Misreported (Unknown)									
Unallocated									
Discards	28	1	151	911	78	54	62	51	18
Total	398160	449326	465729	684173	632571	563315	603869	455740	345036

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Subarea 4 and Division 3.a), 1988-2019 (Data submitted by Working Group members).

Country	1988	1989	1990	1991	1992	1993	1994	1995
Belgium	20	37		125	102	191	351	106
Denmark	32588	26831	29000	38834	41719	42502	47852	30891
Estonia					400			
Faroe Islands		2685	5900	5338		11408	11027	17883
France	1806	2200	1600	2362	956	1480	1570	1599
Germany Fed. Rep.	177	6312	3500	4173	4610	4940	1497	712
Iceland								
Ireland		8880	12800	13000	13136	13206	9032	5607
Latvia					211			
Lithuania								
Netherlands	2564	7343	13700	4591	6547	7770	3637	1275
Norway	59750	81400	74500	102350	115700	112700	114428	108890
Poland								
Romania							2903	
Sweden	1003	6601	6400	4227	5100	5934	7099	6285
United Kingdom	1002	38660	30800	36917	35137	41010	27479	21609
USSR (Russia from 1990)								
Misreported (Area 2.a)							109625	18647
Misreported (Area 6.a)	180000	92000	126000	130000	127000	146697	134765	106987
Misreported (Unknown)								
Unallocated	29630	6461	-3400	16758	13566			983
Discards	29776	2190	4300	7200	2980	2720	1150	730
Total	338316	281600	305100	365875	367164	390558	472397	322204

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Sub-area 4 and Division 3.a), 1988-2019. Continued.

Country	1996	1997	1998	1999	2000	2001	2002
Belgium	62	114	125	177	146	97	22
Denmark	24057	21934	25326	29353	27720	21680	343751
Estonia							
Faroe Islands	13886	32882	4832	4370	10614	18751	12548
France	1316	1532	1908	2056	1588	1981	2152
Germany	542	213	423	473	78	4514	3902
Iceland				357			
Ireland	5280	280	145	11293	9956	10284	20715
Latvia							
Lithuania							
Netherlands	1996	951	1373	2819	2262	2441	11044
Norway	88444	96300	103700	106917	142320	158401	161621
Poland							
Romania							
Sweden	5307	4714	5146	5233	49941	5090	52321
United Kingdom	18545	19204	19755	32396	58282	52988	61781
Russia		3525	635	345	1672	1	
Misreported (Area 2.a)				40000			
Misreported (Area 6.a)	51781	73523	98432	59882	8591	39024	49918
Misreported (Unknown)							
Unallocated	236	1102	3147	17344	34761	24873	22985
Discards	1387	2807	4753		1912	24	8583
Total	212839	229487	269700	313015	304896	339970	394878

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Subarea 4 and Division 3.a), 1988-2019. Continued.

Country	2003	2004	2005	2006	2007	2008	2009	2010
Belgium	2	4	1	3	1	2	3	27
Denmark	275081	25665	232121	242191	252171	26716	23491	36552
Estonia								
Faroe Islands	11754	11705	9739	12008	11818	7627	6648	4639
France	1467	1538	1004	285	7549	490	1493	686
Germany	4859	4515	4442	2389	5383	4668	5158	25621
Iceland								
Ireland	17145	18901	15605	4125	13337	11628	12901	14639
Latvia								
Lithuania								
Netherlands	6784	6366	3915	4093	5973	1980	2039	1300
Norway	150858	147068	106434	113079	131191	114102	118070	129064
Poland			109					
Romania								
Sweden	4450	4437	3204	3209	38581	36641	73031	34291
United Kingdom	67083	62932	37118	28628	46264	37055	47863	52563
Russia			4					696
Misreported (Area 2.a)								
Misreported (Area 6.a)	62928	23692	37911	8719		17280	1959	
Misreported (Unknown)								
Unallocated	-730	-783	7043	171	2421	2039	-629	660
Discards	11785	11329	4633	8263	4195	8862	8120	883
Total	365894	317369	254374	209192	257208	236111	235049	247700

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Subarea 4 and Division 3.a), 1988-2019. Continued.

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019
Belgium	21	39	62	56	38	99	107	110	13
Denmark	32800	36492	31924	21340	35809	21696	27457	22207	25374
Estonia									
Faroe Islands	543	432	25	42919	25672	18193	12915	15475	17460
France	1416	5736	1788	4912	7827	3448	5942	6714	5455
Germany	52911	4560	5755	4979	6056	10172	11185	12091	7778
Iceland									
Ireland	15810	20422	13523	45167	34167	24437	35957	24567	1678
Latvia									
Lithuania				8340		596			
Netherlands	9881	6018	4863	24536	17547	11434	17401	13844	8957
Norway	162878	64181	130056	85409	36344	55089	51960	135715	135083
Poland					24		0.721	4041	1394
Romania									
Sweden	32481	4560	2081	1112	3190	2933	1981	3056	2155
United Kingdom	69858	75959	70840	145119	129203	99945	104499	103707	101890
Russia			4						0.12
Misreported (Area 2.a)									
Misreported (Area 6.a)									
Misreported (Unknown)									
Unallocated									
Discards	1906	1089	337	334	34	559	400	620	812
Total	303652	219489	261258	384221	295911	248611	269804	342147	308049

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Subareas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2019 (Data submitted by Working Group members).

Country	1985	1986	1987	1988	1989	1990	1991	1992
Belgium								
Denmark	400	300	100		1000		1573	194
Estonia								
Faroe Islands	9900	1400	7100	2600	1100	1000		
France	7400	11200	11100	8900	12700	17400	4095	
Germany	11800	7700	13300	15900	16200	18100	10364	9109
Guernsey								
Ireland	91400	74500	89500	85800	61100	61500	17138	21952
Isle of Man								
Jersey								
Lithuania								
Netherlands	37000	58900	31700	26100	24000	24500	64827	76313
Norway	24300	21000	21600	17300	700		29156	32365
Poland								
Spain				1500	1400	400	4020	2764
United Kingdom	205900	156300	200700	208400	149100	162700	162588	196890
Misreported (Area 4.a)		-148000	-117000	-180000	-92000	-126000	-130000	-127000
Misreported (Unknown)								
Unallocated	75100	49299	26000	4700	18900	11500	-3802	1472
Discards	4500			5800	4900	11300	23550	22020
Total	467700	232599	284100	197000	199100	182400	183509	236079

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Subareas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2019 (Data submitted by Working Group members). Continued.

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001
Belgium									
Denmark		2239	1143	1271			552	82	835
Estonia			361						
Faroe Islands		4283	4284		24481	3681	4239	4863	2161
France	2350	9998	10178	14347	19114	15927	14311	17857	18975
Germany	8296	25011	23703	15685	15161	20989	19476	22901	20793
Guernsey									
Ireland	23776	79996	72927	49033	52849	66505	48282	61277	60168
Isle of Man									
Jersey									
Lithuania									
Netherlands	81773	40698	34514	34203	22749	28790	25141	30123	33654
Norway	44600	2552			223				
Poland	600								
Spain	3162	4126	4509	2271	7842	3340	4120	4500	
United Kingdom	215265	208656	190344	127612	128836	165994	127094	126620	4063
Misreported (Area 4.a)	-146697	-134765	-106987	-51781	-73523	-98255	-59982	-3775	139589
Misreported (Unknown)									-39024
Unallocated		4632	28245	10603	4577	8351	21652	31564	37952
Discards	15660	4220	6991	10028	16057	3277		1920	1164
Total	248785	251646	270212	213272	196110	218599	204885	297932	280553

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Subareas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2019 (Data submitted by Working Group members). Continued.

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010
Belgium			1					1	2
Denmark		113				6	10		48
Estonia									
Faroe Islands	2490	2260	674		59	1333	3539	4421	36
France	19726	21213	18549	15182	14625	12434	14944	16464	10301
Germany	22630	19200	18730	14598	14219	12831	10834	17545	16493
Guernsey					10				
Ireland	51457	49715	41730	30082	36539	35923	33132	48155	43355
Isle of Man									14
Jersey				9	8	6	7	8	6
Lithuania					95	7			
Netherlands	21831	23640	21132	18819	20064	18261	17920	20900	21699
Norway						7	3948	121	30
Poland				461	1368	978			
Russia									1
Spain	3483			4795	4048	2772	7327	8462	6532
United Kingdom	131599	167246	149346	115586	67187	87424	768821	109147	107840
Misreported (Area 4a)	-43339	-62928	-23139	-37911	-8719		-17280	-1959	
Misreported (Unknown)									
Unallocated	27558	5587	9714	13412	4783	10042	-952	490	4503
Discards	15191	7111	7696	20359	14723	10177	27351	6848	7518
Total	252620	233157	244432	190597	169009	192201	177662	230603	218377

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Subareas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2019 (Data submitted by Working Group members). Continued.

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019
Belgium					14	44	21	58	53
Denmark	2889	8	903	18538	6741	19443	12569	8194	5189
Estonia									
Faroe Islands	8			3421	5851	13173	20559	13543	7787
France	11304	14448	12438	16627	17820	16634	16925	13974	12646
Germany	18792	14277	15102	23478	19238	9740	9608	7214	8936
Guernsey	10	5	9	9	4			12	9
Iceland									69
Ireland	45696	42627	42988	56286	54571	52087	48957	42181	51637
Isle of Man	11	11	8	3		8	2	3	3
Jersey	7	8	8	7	3	3	0.003	3	2
Lithuania	23			176	554	13			
Netherlands	18336	19794	16295	16242	15264	17896	18694	13851	13727
Norway	2019	1101	734		1313	1035	2657	4639	1420
Poland								14	2312
Portugal									46
Russia						30			1
Spain	1257	773	635	1796	951	1253	786	4471	1220
Sweden									805
United Kingdom	111103	93775	92957	137195	110932	112268	116308	84309	50253
Misreported (Area 4.a)									
Misreported (Unknown)									
Unallocated	399	16	-144		34			13	
Discards	7153	10654	2105	1742	3185	2126	2142	1701	6046
Total	219007	197496	183857	275519	236475	245754	249229	194180	162159

Table 8.4.2.4. NE Atlantic Mackerel. ICES estimated catch (t) in Divisions 8.c and 9.a, 1977–2019 (Data submitted by Working Group members).

Country	Div	1977	1978	1979	1980	1981	1982	1983	1984	1985
France	8.c									
Poland	9.a	8								
Portugal	9.a	1743	1555	1071	1929	3108	3018	2239	2250	4178
Spain	8.c	19852	18543	15013	11316	12834	15621	10390	13852	11810
Spain	9.a	2935	6221	6280	2719	2111	2437	2224	4206	2123
USSR	9.a	2879	189	111						
Total	9.a	7565	7965	7462	4648	5219	5455	4463	6456	6301
Total		27417	26508	22475	15964	18053	21076	14853	20308	18111
Country	**Div**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
France	8.c									
Poland	9.a									
Portugal	9.a	6419	5714	4388	3112	3819	2789	3576	2015	2158
Spain	8.c	16533	15982	16844	13446	16086	16940	12043	16675	21246
Spain	9.a	1837	491	3540	1763	1406	1051	2427	1027	1741
USSR	9.a									
Total	9.a	8256	6205	7928	4875	5225	3840	6003	3042	3899
Total		24789	22187	24772	18321	21311	20780	18046	19719	25045
Country	**Div**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
France	8.c									226
Poland	9.a									
Portugal	9.a	2893	3023	2080	2897	2002	2253	3119	2934	2749
Spain	8.c	23631	28386	35015	36174	37631	30061	38205	38703	17384
Spain	9.a	1025	2714	3613	5093	4164	3760	1874	7938	5464
Discards	8.c									531
Discards	9.a	3918	5737	5693	7990	6165	6013	4993	10873	8213
Total	9.a	27549	34123	40708	44164	43796	36074	43198	49575	26354

Table 8.4.2.4. NE Atlantic Mackerel. ICES estimated catch (t) in Divisions 8.c and 9.a, 1977 – 2019 (Data submitted by Working Group members). Continued.

Country	Div	2004	2005	2006	2007	2008	2009	2010	2011	2012
France	8.c	177	151	43	55	168	383	392	44	283
Poland	9.a									
Portugal	9.a	2289	1509	2620	2605	2381	1753	2363	962	824
Spain	8.c			43063	53401	50455	91043	38858	14709	17768
Spain	9.a			7025	6773	6855	14569	7347	2759	845
Discards	8.c	928	391	3606	156	73	725	4408	563	2187
Discards	9.a		405	1	916	677	241	232	1245	1244
Unallocated	8.c	28429	42851						4691	4144
Unallocated	9.a	3946	5107					108	871	1076
Total	9.a	6234	7021	9646	10293	9913	16562	10049	5836	3989
Total		35768	50414	56358	63906	60609	108713	53708	25843	28372

Country	Div	2013	2014	2015	2016	2017	2018	2019
France	8.c	220	171	21	106	83	50	43
Portugal	8.c						3709	3188
Portugal	9.a	254	618	1456	619	634	855	706
Spain	8.c	14617	33783	29726	26553	30893	27250	19158
Spain	9.a	1162	2227	3853	2229	1206	1687	749
Discards	8.c	1428	2821	4724	2469	84	324	760
Discards	9.a	1027	1463	2409	751	143	194	172
Unallocated	8.c	-573	8795	11	1357		300	
Unallocated	9.a	4053	662	1831	2123			
Total	9.a	6497	4308	9550	5722	1983	2736	1627
Total		22188	45570	44033	36207	33042	34369	24776

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2019. Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a

0	847.0	0	0	0	0	137.5	0	0	0
1	1786.6	4.8	0.1	0.0	0	6240.0	14.6	5.9	0
2	51845.8	138.8	5.1	4.1	0.5	41844.6	858.6	196.5	1604.1
3	144470.2	233.4	7.5	5.3	0.8	112758.4	3626.5	1212.1	2204.2
4	50771.1	147.8	5.5	4.6	0.6	34015.6	2244.7	464.3	3221.2
5	77189.7	196.9	5.7	4.8	0.6	113726.0	1511.1	248.1	12355.3
6	69343.9	143.0	3.8	3.7	0.4	83835.4	2063.0	297.8	18857.3
7	53972.8	88.7	1.9	1.5	0.2	79852.9	731.8	43.5	25447.2
8	67967.7	81.4	1.2	0.6	0.1	99790.1	350.3	72.0	20729.8
9	54028.2	61.3	0.6	0.1	0.1	80399.5	224.0	75.6	19553.1
10	32790.2	18.1	0.1	0	0	30335.9	84.7	23.3	8772.2
11	15450.9	20.6	0.3	0	0	25839.8	39.3	9.3	6861.5
12	12366.3	31.6	0.8	0	0	17799.5	30.4	6.6	2808.8
13	4188.6	13.1	0.3	0	0	7448.4	9.6	4.7	689.6
14	884.9	6.8	0.2	0	0	3016.3	3.1	1.3	0
15+	1799.3	3.3	0.1	0	0	2766.9	7.1	6.9	0
Catch	269329	500	14	11	1	303065	3997	703	58101
SOP	269328	501	14	11	1	302841	3978	703	58101
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q 1-4

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0.16	0	0.84	0	0	126.6	271.3	436.75
1	1044.8	261.7	0.1	7.3	232.3	0.1	1715.5	3586.6	1670.1
2	12071.1	5195.1	3.6	4.4	1949.8	41.6	2148.9	1688.9	574.8
3	7413.1	47233.1	23.8	43.6	13223.7	278.3	2131.5	1289.1	324.6
4	1020.4	12037.9	3.4	4.8	1637.2	28.1	211.0	586.2	166.2
5	1131.2	53981.4	10.6	9.7	8081.5	47.7	2865.3	656.3	82.4
6	1300.1	30454.9	8.0	5.9	3941.5	63.5	928.5	896.0	20.0
7	1302.4	46411.5	7.3	5.0	3877.8	38.3	1339.4	505.9	28.4
8	1782.8	52556.6	10.8	4.8	7601.6	54.5	134.3	1204.0	11.2
9	3383.7	30240.8	6.3	3.1	5951.4	25.1	821.5	683.0	43.8
10	648.6	23427.4	4.7	0.9	2805.6	18.2	11.8	346.8	4.2
11	1360.4	12044.3	2.7	0.8	2228.0	11.3	354.5	105.3	8.99
12	1428.2	8340.7	1.3	0.1	774.4	0.3	182.4	0.7	2.86

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
13	718.8	4494.1	0.7	0.2	671.2	0.2	0.0	0.0	0.01
14	346.3	647.9	0.2	0.0	448.7	0.2	0.0	0.0	0
15+	664.1	769.6	0.1	0.0	68.8	0.0	0.0	0.0	0
Catch	10957	123112	28	24	17993	179	4933	3125	642
SOP	10953	123339	28	24	17994	179	4933	3126	642
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2019 (cont.). Q 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	1.4	0.5	0.0	0.0	3322.4	836.2	1.0	4.4
1	218.9	272.6	8949.1	0.6	8485.1	3864.9	555.5	1103.1
2	29.8	10.7	245.1	0.0	911.0	808.1	1444.1	13.6
3	34.6	39.1	1798.7	0.2	2721.3	2785.9	3663.0	524.3
4	5.2	15.9	393.3	0.0	335.9	477.9	2678.8	468.4
5	49.6	93.1	1968.7	0.4	1376.1	2546.3	10685.3	3952.2
6	23.0	65.2	1374.3	0.1	451.5	1135.5	6328.3	2422.0
7	29.4	57.7	1076.3	0.2	514.6	1559.7	8266.6	3698.1
8	17.5	88.7	1862.1	0.3	443.2	1307.4	7057.4	2988.8
9	20.8	71.9	1514.1	0.3	283.0	843.0	4505.8	2043.7
10	4.8	30.7	677.4	0.1	92.3	301.0	1776.6	786.4
11	6.7	20.5	473.6	0.1	47.3	165.0	1061.6	443.7
12	2.6	4.4	102.6	0.0	17.2	79.4	481.3	203.2
13	0.4	3.6	88.9	0.0	7.1	38.1	165.5	88.4
14	0.2	2.3	59.4	0.0	1.3	12.5	52.8	35.6
15+	0.0	0.4	9.1	0.0	0.0	0.0	0.0	0.0
Catch	104	207	4749	1	2839	4181	16672	6478
SOP	104	207	4748	1	2846	4186	16680	6478
SOP%	100%	100%	100%	99%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2019 (cont.). Q 1-4

Age	8.d	9.a	9.a.N	14.b	All

0	0	125.0	327.5	0	6439
1	50.6	165.8	2160.8	0	42398
2	18.6	337.7	2050.7	61.2	126107
3	79.0	720.5	347.3	1494	350687
4	9.0	283.6	146.7	3245	114630
5	30.2	250.0	195.2	2637	295888
6	5.4	106.0	86.3	2564	226728
7	2.5	70.4	96.7	810	229838
8	2.2	31.3	83.9	1354	267591
9	1.2	25.1	56.3	19	204885
10	0.1	26.7	24.4	2	103015
11	0.0	3.5	16.8	414	66990
12	0.0	0.0	10.0	0.0	44676
13	0.0	0.0	2.8	0.0	18634
14	0.0	0.0	1.2	0.0	5521
15+	0.0	0.0	0.0	0.0	6096
Catch	43	706	921	6651	840021
SOP	43	706	920	6651	840526
SOP%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2019 (cont.). Q1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0.0	0.0		0.00	0.00	0.0		0.0	
1	0.0	0.1		0.00	0.00	1590.6		0.1	
2	0.1	0.2		0.00	0.00	5146.0		0.2	
3	0.1	0.6		0.01	0.02	17833.3	0.3	0.7	
4	0.0	0.3		0.00	0.01	11278.6	0.1	0.4	
5	0.1	0.8		0.01	0.03	33863.1	0.4	1.5	
6	0.1	0.5		0.01	0.02	28168.9	0.4	1.0	
7	0.1	0.3		0.01	0.03	27374.8	0.4	0.8	
8	0.1	1.3		0.01	0.02	24253.8	0.3	1.2	
9	0.1	1.2		0.00	0.01	13170.9	0.1	0.5	

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
10	0.1	0.4		0.00	0.00	5751.9		0.3	
11	0.0	0.3		0.00	0.01	5840.2	0.1	0.4	
12	0.0	0.2		0.00	0.02	8328.7	0.2	0.3	
13	0.0	0.2		0.00	0.01	3081.6	0.1	0.1	
14	0.0	0.1		0.00	0.00	1389.6		0.0	
15+	0.0	0.0		0.00	0.00	811.6		0.1	
Catch	0.377	2.375		0.022	0.072	71655.271	0.972	2.855	
SOP	0.375	2.372		0.018	0.071	71646.705	0.966	2.852	
SOP%	99%	100%		83%	98%	100%	99%	100%	

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q1

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0	0	0	0	0	34	45	47
1	0	258	0	3	230	0	456	422	449
2	83	5121	3	1	1703	30	571	203	209
3	1531	45069	22	1	11607	199	574	167	127
4	0	11335	2	1	1483	19	58	80	65
5	554	52360	4	1	7804	25	761	79	6
6	389	27967	4	0	3625	38	254	83	2
7	116	45269	3	1	3674	22	358	54	2
8	116	50678	4	1	7307	31	57	98	0
9	556	29345	2	1	5809	11	223	74	11
10	140	23320	1	0	2704	10	8	32	1
11	47	11877	1	0	2156	6	93	14	1
12	240	8304	0	0	765	0	49	0	0
13	233	4474	0	0	663	0	0	0	0
14	0	644	0	0	443	0	0	0	0
15+	93	766	0	0	68	0	0	0	0
Catch	1265	119524	14	3	16987	111	1327	351	180
SOP	1265	119722	14	3	16988	111	1327	351	180
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0	0	0	0	0	0	0	0
1	200	268	8932	0	8408	3077	269	0
2	6	8	204	0	512	614	361	11
3	8	36	1150	0	1435	2508	1272	425
4	1	15	174	0	187	369	1176	379
5	11	90	1030	0	873	1727	5705	3221
6	7	62	449	0	358	640	3419	1995
7	10	56	454	0	466	786	4645	3051
8	9	86	1067	0	401	658	4044	2469
9	6	69	807	0	259	408	2689	1679
10	2	30	373	0	88	130	1131	638
11	1	20	260	0	46	67	687	358
12	0	4	100	0	17	31	327	164
13	0	4	87	0	7	14	113	72
14	0	2	58	0	1	3	37	26
15+	0	0	9	0	0	0	0	0
Catch	35	199	2722	0	2010	2640	9147	5261
SOP	35	199	2721	0	2010	2640	9150	5262
SOP%	100%	100%	100%	99%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q1

Age	8.d	9.a	9.a.N	14.b	All
0	0	0	0		125.6
1	50.5	0.0	1189.6		25802.3
2	17.3	72.7	532.6		15410.7
3	73.6	325.6	41.4		84407.1
4	8.4	130.9	8.1		26772.1
5	28.1	140.4	16.1		108301.8
6	5.0	20.2	7.9		67496.3

Age	8.d	9.a	9.a.N	14.b	All
7	2.3	17.3	10.1		86374.3
8	2.1	6.8	8.8		91301.1
9	1.1	2.7	5.9		55131.7
10	0.1	2.7	2.6		34365.7
11	0.0	0.0	1.3		21476.3
12	0.0	0.0	1.1		18333.1
13	0.0	0.0	0.3		8749.4
14	0.0	0.0	0.1		2604.3
15+	0.0	0.0	0.0		1748.6
Catch	40	252	212		233940
SOP	40	252	212		234133
SOP%	100%	100%	100%		100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0	0	0	0	0	0	0	0	
1	17	3	0	0	0	41	2	0	
2	142	19	1	1	0	184	534	18	
3	3251	71	2	1	0	599	3049	808	
4	779	25	1	1	0	248	2036	448	
5	2843	73	2	1	0	585	1139	21	
6	3562	57	1	1	0	443	1900	286	
7	5804	59	1	1	0	337	655	20	
8	4071	54	1	0	0	802	268	20	
9	5780	41	1	0	0	716	176	50	
10	3676	12	0	0	0	241	78	23	
11	1232	16	0	0	0	201	35	9	
12	1401	29	1	0	0	158	28	6	
13	23	12	0	0	0	87	4	0	
14	103	6	0	0	0	28	2	0	
15+	9	3	0	0	0	23	1	0	
Catch	12917	194	4	2	0	1787	3269	410	

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
SOP	12918	193	4	2	0	1795	3289	411	
SOP%	100%	100%	99%	101%	100%	100%	101%	100%	

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q2

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0	0	0.2	0	0	24	114	30
1	0.0	0.5	0.1	1.9	2.5	0.1	321	1071	278
2	46.8	32.0	0.1	1.9	221.8	0.8	402	508	132
3	668.1	1679.1	1.2	41.1	1450.5	5.9	398	626	80
4	23.2	550.4	0.8	3.1	136.8	0.8	39	267	41
5	325.3	1028.0	4.9	7.1	244.2	2.7	534	257	4
6	301.7	2018.0	2.3	2.2	277.3	1.9	172	448	1
7	232.9	801.3	2.9	3.3	178.9	1.5	249	235	2
8	198.9	1469.5	4.7	1.8	258.5	3.3	23	839	1
9	377.8	617.1	3.4	1.5	123.4	2.1	152	361	7
10	122.8	55.5	2.2	0.5	89.1	1.1	1	217	1
11	69.3	73.9	1.2	0.5	63.3	0.7	66	12	1
12	122.4	14.0	0.8	0.0	8.4	0.2	34	0	0
13	104.1	10.2	0.5	0.1	7.3	0.2	0	0	0
14	0.0	1.3	0.2	0.0	4.9	0.1	0	0	0
15+	39.7	1.3	0.1	0.0	0.8	0.0	0	0	0
Catch	957.9	2636.8	9.7	17.0	891.6	7.1	919	1395	114
SOP	958	2659	10	16.99	892	7	919	1395	114
SOP%	100%	101%	100%	100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0	1	0	0	3107	0	0	0
1	0	5	1	0	51	770	266	1103
2	0	2	41	0	216	38	976	2
3	1	2	597	0	572	262	2268	96
4	1	1	179	0	66	103	1438	88
5	4	2	689	0	226	800	4954	729

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
6	2	2	732	0	43	482	2887	427
7	2	2	475	0	25	751	3615	647
8	4	2	750	0	22	629	3009	520
9	3	2	554	0	13	420	1805	364
10	1	1	259	0	3	165	646	148
11	1	1	146	0	1	95	375	85
12	0	0	2	0	1	47	154	39
13	0	0	2	0	0	23	52	17
14	0	0	1	0	0	9	16	10
15+	0	0	0	0	0	0	0	0
Catch	7	7	1621	0	454	1421	7399	1213
SOP	7	7	1622	0	462	1423	7404	1213
SOP%	100%	100%	100%	99%	102%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2019 (cont.). Q2

Age	8.d	9.a	9.a.N	14.b	All
0	0.0	0.0	0.0		3275.5
1	0.2	1.6	284.3		4221.6
2	1.2	89.5	335.7		3944.8
3	5.1	236.9	130.1		16902.8
4	0.6	92.2	67.3		6636.4
5	2.0	77.2	164.2		14719.8
6	0.4	58.5	70.3		14180.5
7	0.2	50.5	83.9		14233.6
8	0.2	22.4	73.0		13046.7
9	0.1	21.1	47.3		11639.0
10	0.0	23.9	21.9		5788.7
11	0.0	3.5	15.4		2502.1
12	0.0	0.0	8.9		2053.6
13	0.0	0.0	2.6		345.3

Age	8.d	9.a	9.a.N	14.b	All
14	0.0	0.0	1.1		183.7
15+	0.0	0.0	0.0		77.3
Catch	3	240	299		38195
SOP	3	240	299		38258
SOP%	100%	100%	100%		100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0	0	0	0	0	0	0	0	0
1	1746	1	0	0	0	596	10	3	0
2	51275	111	4	3	0	5093	286	94	1604
3	140944	150	5	4	1	12215	498	212	2204
4	49903	108	4	3	0	2027	186	8	3221
5	74248	100	3	3	0	8808	306	117	12355
6	65703	68	2	2	0	5937	134	4	18857
7	48078	19	0	0	0	4360	56	11	25447
8	63739	21	0	0	0	9246	65	26	20730
9	48109	16	0	0	0	9442	37	13	19553
10	28997	5	0	0	0	3052	5	0	8772
11	14139	4	0	0	0	2346	3	0	6862
12	10929	2	0	0	0	1436	2	0	2809
13	4088	1	0	0	0	785	4	2	690
14	745	0	0	0	0	231	1	1	0
15+	1736	1	0	0	0	331	5	4	0
Catch	255689	262	8	7	1	27335	601	150	58101
SOP	255688	262	8	7	1	27336	601	150	58101
SOP%	100%	100%	100%	100%	99%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q3

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0	0	0.27	0	0	45.4	78.510	25.95
1	71.0	0.1	0.0	2.5	0.1	0	615.6	739.3	243.6
2	823.3	10.8	0.0	1.2	24.7	10.4	771.1	352.7	115.5
3	572.6	96.1	0.2	1.6	165.4	73.1	760.0	240.1	69.9
4	67.8	62.2	0.2	1.1	16.9	8.8	74.0	123.6	35.8
5	96.1	283.3	0.8	1.7	31.2	19.5	1023.9	95.6	3.4
6	96.9	214.7	0.48	3.14	38.4	23.7	326.1	75.7	1.1
7	81.3	125.0	0.620	1.19	23.9	14.7	476.9	57.0	1.40
8	116.3	159.4	0.8	2.21	33.4	20.5	35.7	41.5	0.03
9	245.8	117.0	0.5	1.07	16.9	12.1	289.5	76.1	6.34
10	46.2	5.6	0.4	0.01	11.5	7.0	1.0	22.4	0.7
11	91.2	33.3	0.2	0.14	7.6	4.4	126.9	22.8	0.68
12	106.6	1.9	0.1	0.00	0.4	0.0	65.5	0.3	0
13	59.1	0.9	0.1	0.00	0.4	0.0	0.0	0.0	0
14	23.5	0.2	0.0	0.00	0.3	0.0	0.0	0.0	0
15+	49.4	0.2	0.0	0.00	0.0	0.0	0.0	0.0	0
Catch	774	332	2	4.50	110	61	1755	458	99
SOP	769	334	2	4.53	111	62	1755	458	99
SOP%	99%	100%	100%	101%	101%	101%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0	0	0	0	4	132	1	4
1	0	0	16	1	14	0	0	0
2	0	0	0	0	105	1	31	0
3	1	0	52	0	452	5	56	1
4	0	0	40	0	52	2	28	0
5	1	0	250	0	175	13	12	1
6	1	0	193	0	32	9	10	0
7	1	0	148	0	15	16	3	0
8	1	0	46	0	13	14	2	0
9	1	0	153	0	7	11	5	0

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
10	0	0	45	0	1	4	0	0
11	0	0	68	0	0	3	0	0
12	0	0	0	0	0	1	0	0
13	0	0	0	0	0	1	0	0
14	0	0	0	0	0	0	0	0
15+	0	0	0	0	0	0	0	0
Catch	3	0	406	0	228	35	53	1
SOP	3	0	406	0	228	35	53	1
SOP%	100%	100%	100%	98%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q3

Age	8.d	9.a	9.a.N	14.b	All
0	0.0	73.5	327.0	0.0	692.9
1	0.0	5.9	231.1	0.0	4297.1
2	0.1	86.0	458.1	61.2	61323.8
3	0.3	108.6	135.6	1494.1	160516.6
4	0.0	43.7	58.7	3245.0	59321.4
5	0.1	24.7	13.1	2636.5	100622.4
6	0.0	21.9	7.5	2564.4	94327.3
7	0.0	2.6	2.4	810.0	79751.0
8	0.0	2.1	1.8	1354.3	95670.7
9	0.0	1.3	3.0	18.6	78134.4
10	0.0	0.0	0.0	2.0	40978.8
11	0.0	0.0	0.0	413.7	24125.8
12	0.0	0.0	0.0	0.0	15353.9
13	0.0	0.0	0.0	0.0	5631.3
14	0.0	0.0	0.0	0.0	1002.5
15+	0.0	0.0	0.0	0.0	2125.5
Catch	0	119	210	6651	353456
SOP	0	119	210	6651	353476

Age	8.d	9.a	9.a.N	14.b	All
SOP%	99%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	847.0	0.0	0.0	0.0	0.0	137.2	0.0	0.0	
1	23.3	0.4	0.0	0.0	0.0	4012.1	2.2	2.8	
2	429.1	8.5	0.3	0.3	0.1	31421.6	38.3	84.0	
3	275.1	11.5	0.4	0.4	0.1	82110.7	78.9	191.4	
4	88.9	15.3	0.6	0.6	0.2	20461.6	22.5	7.6	
5	98.7	23.2	0.8	0.9	0.2	70469.9	65.6	108.6	
6	78.8	17.7	0.6	0.7	0.2	49286.6	28.5	6.2	
7	90.9	10.6	0.4	0.4	0.1	47780.8	19.7	12.1	
8	157.2	4.8	0.1	0.2	0.0	65488.3	17.3	24.9	
9	139.7	2.9	0.1	0.1	0.0	57070.8	10.6	12.4	
10	117.2	0.8	0.0	0.0	0.0	21291.6	1.9	0.3	
11	79.2	0.6	0.0	0.0	0.0	17453.1	1.4	0.3	
12	36.8	0.2	0.0	0.0	0.0	7877.2	0.5	0.0	
13	78.0	0.1	0.0	0.0	0.0	3494.7	1.0	2.2	
14	36.7	0.1	0.0	0.0	0.0	1367.8	0.3	0.6	
15+	54.6	0.0	0.0	0.0	0.0	1601.6	1.1	3.2	
Catch	721	43	1	2	0	202064	107	140	
SOP	721	43	1	2	0	202278	107	140	
SOP%	100%	100%	100%	100%	99%	100%	100%	100%	

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q4

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0	0	0	0	0	24	34	334
1	974	3	0	0	0	0	323	1354	699
2	11118	31	0	0	0	0	404	626	118
3	4641	389	0	0	0	0	400	256	48
4	929	90	0	0	0	0	40	116	25

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
5	155	311	1	0	2	0	545	224	70
6	513	255	1	0	1	0	177	289	16
7	872	216	1	0	1	0	255	160	23
8	1352	249	1	0	2	0	19	225	10
9	2204	162	1	0	2	0	157	172	19
10	340	47	1	0	1	0	2	75	1
11	1153	60	0	0	1	0	69	56	7
12	960	21	0	0	0	0	34	0	3
13	323	9	0	0	0	0	0	0	0
14	323	2	0	0	0	0	0	0	0
15+	482	2	0	0	0	0	0	0	0
Catch	7960	619	3	0.09	4	0	933	922	248
SOP	7961	629	3	0.09	4	0	933	922	248
SOP%	100%	102%	100%	96%	100%	98%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2019 (cont.). Q4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	1	0	0	0	210	704	0	0
1	19	0	0	0	12	18	19	0
2	24	0	0	0	78	156	77	1
3	25	0	0	0	263	11	67	2
4	3	0	0	0	30	3	36	1
5	34	0	0	0	102	6	14	1
6	13	0	0	0	18	4	12	0
7	16	0	0	0	9	7	4	0
8	4	0	0	0	8	6	2	0
9	11	0	0	0	4	4	6	0
10	1	0	0	0	0	2	0	0
11	4	0	0	0	0	1	0	0
12	2	0	0	0	0	1	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
15+	0	0	0	0	0	0	0	0
Catch	59	1	0	0	147	85	73	2
SOP	59	1	0	0	147	88	73	2
SOP%	100%	100%	97%	84%	100%	104%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2019 (cont.). Q4

Age	8.d	9.a	9.a.N	14.b	All
0		51.5	0.5		2344.6
1		158.4	455.8		8076.7
2		89.5	724.4		45427.5
3		49.4	40.2		88860.6
4		16.8	12.6		21900.1
5		7.7	1.9		72243.9
6		5.5	0.7		50724.3
7		0.0	0.3		49479.6
8		0.0	0.3		67572.3
9		0.0	0.2		59980.1
10		0.1	0.0		21882.1
11		0.0	0.0		18886.2
12		0.0	0.0		8935.2
13		0.0	0.0		3908.2
14		0.0	0.0		1730.9
15+		0.0	0.0		2144.2
Catch		95	199		214430
SOP		95	199		214666
SOP%		100%	100%		100%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1%.

Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0%					0%			
1	0%	0%	0%	0%	0%	1%	0%	0%	
2	8%	12%	15%	16%	15%	6%	7%	7%	1%
3	23%	20%	23%	21%	24%	15%	31%	45%	2%
4	8%	12%	17%	19%	16%	5%	19%	17%	3%
5	12%	17%	17%	20%	19%	15%	13%	9%	10%
6	11%	12%	12%	15%	13%	11%	17%	11%	15%
7	8%	7%	6%	6%	6%	11%	6%	2%	21%
8	11%	7%	4%	2%	3%	13%	3%	3%	17%
9	8%	5%	2%	0%	1%	11%	2%	3%	16%
10	5%	2%	0%	0%	0%	4%	1%	1%	7%
11	2%	2%	1%	0%	0%	3%	0%	0%	6%
12	2%	3%	2%		1%	2%	0%	0%	2%
13	1%	1%	1%		0%	1%	0%	0%	1%
14	0%	1%	1%		0%	0%	0%	0%	
15+	0%	0%	0%			0%	0%	0%	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0%	0%		1%			1%	2%	13%
1	3%	0%	0%	8%	0%	0%	13%	30%	49%
2	34%	2%	4%	5%	4%	7%	17%	14%	17%
3	21%	14%	28%	48%	25%	46%	16%	11%	10%
4	3%	4%	4%	5%	3%	5%	2%	5%	5%
5	3%	16%	13%	11%	15%	8%	22%	6%	2%
6	4%	9%	10%	6%	7%	10%	7%	8%	1%
7	4%	14%	9%	6%	7%	6%	10%	4%	1%
8	5%	16%	13%	5%	14%	9%	1%	10%	0%
9	10%	9%	8%	3%	11%	4%	6%	6%	1%
10	2%	7%	6%	1%	5%	3%	0%	3%	0%
11	4%	4%	3%	1%	4%	2%	3%	1%	0%
12	4%	3%	2%	0%	1%	0%	1%	0%	0%
13	2%	1%	1%	0%	1%	0%			0%
14	1%	0%	0%	0%	1%	0%			
15+	2%	0%	0%	0%	0%	0%			

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarters 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0%	0%			17%	5%	0%	0%
1	49%	35%	43%	24%	45%	23%	1%	6%
2	7%	1%	1%	1%	5%	5%	3%	0%
3	8%	5%	9%	7%	14%	17%	8%	3%
4	1%	2%	2%	2%	2%	3%	5%	2%
5	11%	12%	10%	15%	7%	15%	22%	21%
6	5%	8%	7%	5%	2%	7%	13%	13%
7	7%	7%	5%	6%	3%	9%	17%	20%
8	4%	11%	9%	14%	2%	8%	14%	16%
9	5%	9%	7%	12%	1%	5%	9%	11%
10	1%	4%	3%	5%	0%	2%	4%	4%
11	2%	3%	2%	4%	0%	1%	2%	2%
12	1%	1%	0%	2%	0%	0%	1%	1%
13	0%	0%	0%	2%	0%	0%	0%	0%
14	0%	0%	0%	1%	0%	0%	0%	0%
15+	0%	0%	0%					

Age	8.d	9.a	9.a.N	14.b	All
0		6%	6%		0%
1	25%	8%	39%		2%
2	9%	16%	37%	0%	6%
3	40%	34%	6%	12%	17%
4	5%	13%	3%	26%	5%
5	15%	12%	3%	21%	14%
6	3%	5%	2%	20%	11%
7	1%	3%	2%	6%	11%
8	1%	1%	1%	11%	13%
9	1%	1%	1%	0%	10%
10	0%	1%	0%	0%	5%
11	0%	0%	0%	3%	3%
12	0%		0%		2%
13			0%		1%
14			0%		0%
15+					0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	1%	1%				1%	1%	1%	
2	6%	3%				3%	1%	3%	
3	16%	9%		20%	11%	9%	12%	9%	
4	2%	4%			6%	6%	5%	5%	
5	12%	12%		20%	17%	18%	18%	19%	
6	10%	7%		20%	11%	15%	14%	14%	
7	8%	4%		20%	17%	15%	17%	10%	
8	16%	21%		20%	11%	13%	10%	16%	
9	16%	19%			6%	7%	6%	7%	
10	6%	6%				3%	1%	4%	
11	4%	5%			6%	3%	3%	5%	
12	2%	4%			11%	4%	8%	4%	
13	1%	3%			6%	2%	3%	1%	
14	0%	1%				1%	2%	0%	
15+	0%	1%				0%	1%	1%	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				3%			1%	3%	5%
1	0%	0%	0%	27%	0%	0%	13%	31%	49%
2	2%	2%	7%	13%	3%	8%	16%	15%	23%
3	37%	14%	47%	10%	23%	51%	16%	12%	14%
4	0%	4%	5%	6%	3%	5%	2%	6%	7%
5	14%	17%	8%	9%	16%	6%	22%	6%	1%
6	9%	9%	9%	5%	7%	10%	7%	6%	0%
7	3%	14%	6%	6%	7%	6%	10%	4%	0%
8	3%	16%	8%	8%	15%	8%	2%	7%	0%
9	14%	9%	4%	6%	12%	3%	6%	5%	1%
10	3%	7%	3%	4%	5%	3%	0%	2%	0%
11	1%	4%	2%	2%	4%	2%	3%	1%	0%
12	6%	3%	0%	1%	2%	0%	1%	0%	0%
13	6%	1%	0%	1%	1%	0%			0%
14	0%	0%	0%	0%	1%	0%			
15+	2%	0%	0%	0%	0%	0%			

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					0%			
1	76%	36%	59%	1%	64%	28%	1%	0%
2	2%	1%	1%	1%	4%	6%	1%	0%
3	3%	5%	8%	10%	11%	23%	5%	3%
4	1%	2%	1%	2%	1%	3%	5%	3%
5	4%	12%	7%	19%	7%	16%	22%	22%
6	3%	8%	3%	7%	3%	6%	13%	14%
7	4%	7%	3%	8%	4%	7%	18%	21%
8	3%	11%	7%	19%	3%	6%	16%	17%

9	2%	9%	5%	16%	2%	4%	10%	12%
10	1%	4%	2%	7%	1%	1%	4%	4%
11	0%	3%	2%	6%	0%	1%	3%	2%
12	0%	1%	1%	2%	0%	0%	1%	1%
13	0%	0%	1%	2%	0%	0%	0%	0%
14	0%	0%	0%	1%	0%	0%	0%	0%
15+		0%	0%	0%	0%	0%	0%	0%

Age	8.d	9.a	9.a.N	14.b	All
0					0%
1	27%	0%	65%		4%
2	9%	10%	29%		2%
3	39%	45%	2%		13%
4	4%	18%	0%		4%
5	15%	20%	1%		17%
6	3%	3%	0%		10%
7	1%	2%	1%		13%
8	1%	1%	0%		14%
9	1%	0%	0%		9%
10	0%	0%	0%		5%
11	0%		0%		3%
12	0%		0%		3%
13			0%		1%
14			0%		0%
15+					0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	0%	1%	1%			1%	0%	0%	
2	0%	4%	7%	10%	4%	4%	5%	1%	
3	10%	15%	19%	13%	32%	13%	31%	47%	
4	2%	5%	9%	15%	21%	5%	21%	26%	
5	9%	15%	15%	23%	11%	12%	11%	1%	
6	11%	12%	9%	22%	18%	9%	19%	17%	
7	18%	12%	11%	12%	7%	7%	7%	1%	
8	12%	11%	8%	4%	4%	17%	3%	1%	
9	18%	9%	5%		4%	15%	2%	3%	
10	11%	2%	1%			5%	1%	1%	
11	4%	3%	3%			4%	0%	1%	
12	4%	6%	7%			3%	0%	0%	
13	0%	2%	3%			2%	0%		
14	0%	1%	2%			1%	0%		
15+	0%	1%	1%			0%	0%		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				0%			1%	2%	5%
1	0%	0%	0.0	3%	0%	0%	13%	22%	48%
2	2%	0%	0.0	3%	7%	4%	17%	10%	23%
3	25%	20%	0.0	63%	47%	27%	16%	13%	14%
4	1%	7%	0.0	5%	4%	4%	2%	5%	7%
5	12%	12%	0.2	11%	8%	13%	22%	5%	1%
6	11%	24%	0.1	3%	9%	9%	7%	9%	0%
7	9%	10%	0.1	5%	6%	7%	10%	5%	0%
8	8%	18%	0.2	3%	8%	15%	1%	17%	0%
9	14%	7%	0.1	2%	4%	10%	6%	7%	1%
10	5%	1%	0.1	1%	3%	5%	0%	4%	0%
11	3%	1%	0.0	1%	2%	3%	3%	0%	0%
12	5%	0%	0.0	0%	0%	1%	1%		
13	4%	0%	0.0	0%	0%	1%			
14		0%	0.0		0%	1%			
15+	2%	0%	0.0		0%	0%			

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		2%			72%			
1	0%	20%	0%	1%	1%	17%	1%	26%
2	0%	10%	1%	0%	5%	1%	4%	0%
3	6%	11%	13%	4%	13%	6%	10%	2%
4	3%	5%	4%	1%	2%	2%	6%	2%
5	19%	10%	16%	22%	5%	17%	22%	17%
6	12%	10%	17%	6%	1%	10%	13%	10%
7	10%	7%	11%	8%	1%	16%	16%	15%
8	19%	10%	17%	19%	1%	14%	13%	12%
9	16%	8%	13%	18%	0%	9%	8%	9%
10	7%	4%	6%	7%	0%	4%	3%	3%
11	5%	2%	3%	6%	0%	2%	2%	2%
12	1%		0%	3%	0%	1%	1%	1%
13	1%		0%	3%	0%	1%	0%	0%
14	1%		0%	1%	0%	0%	0%	0%
15+	0%		0%					

Age	8.d	9.a	9.a.N	14.b	All
0					3%
1	2%	0%	22%		4%
2	12%	13%	26%		3%
3	52%	35%	10%		15%
4	6%	14%	5%		6%
5	20%	11%	13%		13%
6	4%	9%	5%		12%
7	2%	7%	6%		13%
8	2%	3%	6%		11%
9	1%	3%	4%		10%
10		4%	2%		5%
11		1%	1%		2%
12			1%		2%
13			0%		0%
14					0%
15+					0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						0%			
1	0%	0%				1%	1%	1%	0%
2	8%	18%	21%	21%	20%	8%	18%	19%	1%
3	23%	25%	26%	26%	30%	19%	31%	43%	2%
4	8%	18%	21%	21%	17%	3%	12%	2%	3%
5	12%	16%	17%	17%	19%	13%	19%	24%	10%
6	11%	11%	11%	12%	9%	9%	8%	1%	15%
7	8%	3%	2%	2%	2%	7%	4%	2%	21%
8	11%	3%	1%	1%	2%	14%	4%	5%	17%
9	8%	3%			1%	14%	2%	3%	16%
10	5%	1%				5%	0%		7%
11	2%	1%				4%	0%		6%
12	2%	0%				2%	0%		2%
13	1%	0%				1%	0%	0%	1%
14	0%	0%				0%	0%	0%	
15+	0%	0%				1%	0%	1%	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				2%			1%	4%	5%
1	3%	0%		16%	0%	0%	13%	38%	48%
2	32%	1%	1%	7%	7%	5%	17%	18%	23%
3	22%	9%	5%	10%	45%	38%	16%	12%	14%
4	3%	6%	4%	7%	5%	5%	2%	6%	7%
5	4%	26%	18%	11%	8%	10%	22%	5%	1%
6	4%	19%	11%	19%	10%	12%	7%	4%	0%
7	3%	11%	14%	7%	6%	8%	10%	3%	0%
8	5%	14%	19%	14%	9%	11%	1%	2%	0%
9	10%	11%	11%	7%	5%	6%	6%	4%	1%
10	2%	1%	9%	0%	3%	4%	0%	1%	0%
11	4%	3%	4%	1%	2%	2%	3%	1%	0%
12	4%	0%	3%		0%	0%	1%		
13	2%	0%	1%		0%				
14	1%	0%	0%		0%				
15+	2%	0%	0%		0%				

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					1%	63%	1%	64%
1			2%	95%	2%	0%	0%	0%
2			0%	2%	12%	0%	21%	1%
3	8%	8%	5%	3%	52%	2%	38%	16%
4	4%	4%	4%		6%	1%	19%	5%
5	18%	17%	25%		20%	6%	8%	7%
6	18%	18%	19%		4%	4%	7%	0%
7	12%	12%	15%		2%	8%	2%	1%
8	17%	17%	5%		2%	7%	1%	1%
9	14%	14%	15%		1%	5%	4%	4%
10	6%	6%	4%		0%	2%	0%	
11	4%	4%	7%		0%	1%	0%	
12					0%	1%	0%	
13						0%		
14						0%		
15+								

Age	8.d	9.a	9.a.N	14.b	All
0		20%	26%		0%
1	2%	2%	19%		1%
2	12%	23%	37%	0%	7%
3	53%	29%	11%	12%	19%
4	7%	12%	5%	26%	7%
5	20%	7%	1%	21%	12%
6	3%	6%	1%	20%	11%
7	2%	1%	0%	6%	10%
8	2%	1%	0%	11%	12%
9		0%	0%	0%	9%
10				0%	5%
11				3%	3%
12					2%
13					1%
14					0%
15+					0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	32%					0%			
1	1%	0%	0%	0%	0%	1%	1%	1%	
2	16%	9%	9%	9%	9%	7%	13%	18%	
3	10%	12%	12%	11%	12%	17%	27%	42%	
4	3%	16%	17%	16%	16%	4%	8%	2%	
5	4%	24%	24%	24%	25%	15%	23%	24%	
6	3%	18%	19%	19%	19%	10%	10%	1%	
7	3%	11%	11%	11%	12%	10%	7%	3%	
8	6%	5%	4%	5%	4%	14%	6%	5%	
9	5%	3%	2%	2%	2%	12%	4%	3%	
10	4%	1%	1%	1%	1%	4%	1%	0%	
11	3%	1%	0%	1%		4%	0%	0%	
12	1%	0%				2%	0%	0%	
13	3%	0%				1%	0%	0%	
14	1%	0%				0%	0%	0%	
15+	2%	0%				0%	0%	1%	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		0%		16%			1%	1%	24%
1	4%	0%	0%	58%	1%		13%	38%	51%
2	42%	2%	1%	16%	0%		17%	17%	9%
3	18%	21%	4%	4%	4%	3%	16%	7%	3%
4	4%	5%	4%	2%	2%	3%	2%	3%	2%
5	1%	17%	18%	2%	22%	28%	22%	6%	5%
6	2%	14%	11%	2%	6%	22%	7%	8%	1%
7	3%	12%	13%	0%	9%	16%	10%	4%	2%
8	5%	14%	19%		20%	0%	1%	6%	1%
9	8%	9%	11%		18%	16%	6%	5%	1%
10	1%	3%	9%		7%	3%	0%	2%	0%
11	4%	3%	5%		6%	9%	3%	2%	0%
12	4%	1%	3%		3%		1%	0%	0%
13	1%	0%	1%		2%				
14	1%	0%	0%		1%				
15+	2%	0%	0%		0%				

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2019. Zeros represent values <1% (cont.).

Quarter 4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	1%				29%	76%	0%	
1	12%				2%	2%		0%
2	15%				11%	17%	32%	13%
3	16%	8%	17%	50%	36%	1%	28%	44%
4	2%	4%	0%	0%	4%	0%	15%	15%
5	22%	18%	17%	0%	14%	1%	6%	17%
6	8%	18%	17%	25%	2%	0%	5%	0%
7	10%	12%	17%	0%	1%	1%	2%	2%
8	3%	16%	17%	25%	1%	1%	1%	2%
9	7%	14%	17%		1%	0%	3%	8%
10	1%	6%			0%	0%		
11	3%	4%			0%	0%		
12	1%				0%	0%		
13						0%		
14						0%		
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0		14%	0%		0%	
1		42%	37%		2%	
2		24%	59%		9%	
3		13%	3%		17%	
4		4%	1%		4%	
5		2%	0%		14%	
6		1%	0%		10%	
7		0%	0%		9%	
8		0%	0%		13%	
9		0%			11%	
10					4%	
11					4%	
12					2%	
13					1%	
14					0%	
15+					0%	

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019.

Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	187					190	190	190	
1	280	277	256	305	283	280	243	264	
2	310	324	321	325	320	310	315	291	300
3	321	340	343	347	333	325	297	290	341
4	333	357	358	357	354	347	330	315	359
5	352	364	369	371	366	354	362	343	360
6	362	372	378	379	375	363	360	340	367
7	365	372	379	384	379	370	379	358	368
8	369	374	375	384	378	372	376	362	371
9	371	375	374	390	373	377	358	351	373
10	374	384	393	412	399	385	375	374	381
11	382	382	378	405	388	387	371	365	385
12	388	387	386	386	386	389	386	385	389
13	392	393	393	393	386	393	378	356	399
14	389	390	388	401	389	396	388	376	
15+	395	391	385	385	384	394	383	383	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		190		218			254	217	216
1	295	215	202	259	223	223	290	260	259
2	304	296	291	291	292	292	326	289	291
3	319	317	315	315	315	316	343	319	327
4	344	348	340	340	337	334	360	341	340
5	348	352	352	351	354	353	367	358	349
6	359	365	370	362	371	374	370	362	368
7	368	370	369	374	368	374	378	389	378
8	374	373	373	367	372	374	374	371	359
9	367	377	376	382	373	387	406	387	383
10	381	387	384	393	380	386	379	379	362
11	384	387	387	392	387	387	414	372	402
12	387	394	393	395	386	386	395	395	395
13	391	390	394	395	391	391		392	395
14	391	404	398	398	396	396		399	409
15+	407	410	402	406	397	397		397	

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarters 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	254	220			184	191	177	177
1	204	197	187	187	197	195	232	177
2	319	291	293	292	296	299	293	315
3	336	324	320	320	322	324	323	337
4	356	356	350	346	335	340	343	349
5	363	358	357	354	344	349	354	354
6	368	366	367	366	358	362	367	366
7	376	380	380	368	369	371	372	372
8	372	371	372	371	370	371	375	373
9	392	381	380	373	374	377	381	379
10	381	378	378	378	384	387	390	389
11	400	379	380	387	390	393	393	393
12	393	387	386	386	389	399	402	399
13	393	391	391	391	396	404	396	401
14	398	396	396	396	409	428	409	416
15+	397	397	397	397				

Age	8.d	9.a	9.a.N	14.b	All
0		256	198		192
1	190	297	236		227
2	303	307	276	295	307
3	322	334	328	355	322
4	333	364	339	375	341
5	339	373	348	373	354
6	343	378	366	380	364
7	355	382	374	390	369
8	354	382	376	395	372
9	349	391	384	425	375
10	357	398	396	435	381
11	365	405	394	425	386
12	365		410		390
13			405		392
14			409		396
15+					398

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	296	278		245	245	232	245	210	
2	316	303		265	265	283	266	306	
3	330	319		316	316	316	316	321	
4	341	332		349	349	346	348	347	
5	350	342		351	351	351	351	351	
6	358	351		361	361	363	362	360	
7	365	359		367	367	369	368	364	
8	371	364		374	374	371	376	372	
9	376	369		372	372	371	372	369	
10	382	374		390	390	382	390	382	
11	386	379		377	377	380	377	375	
12	390	384		386	386	386	386	378	
13	395	388		393	393	393	393	398	
14	397	391		388	388	391	388	410	
15+	401	347		385	385	382	385	397	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				220			254	220	220
1		214	203	259	223	223	290	260	258
2	271	295	292	289	292	292	326	290	290
3	310	317	314	324	315	315	343	325	325
4		348	332	345	337	331	360	344	339
5	344	352	352	351	354	352	367	357	302
6	357	365	375	365	371	376	370	364	361
7	362	370	370	369	368	372	378	388	381
8	361	373	374	372	372	375	373	371	371
9	367	377	382	374	373	388	406	386	373
10	383	387	386	383	379	388	380	378	362
11	383	387	389	386	387	390	415	373	383
12	380	394	393	395	386	386	395	395	389
13	384	390	394	396	391	391		395	395
14		404	398	398	396	396		409	409
15+	387	410	404	406	397	397			

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					254			
1	196	196	187	223	196	196	232	
2	292	292	293	291	297	302	294	315
3	317	324	318	318	321	323	328	336
4	346	357	342	345	337	338	346	349
5	355	358	353	354	347	346	354	354
6	366	366	366	366	361	360	367	366
7	371	379	370	368	370	369	373	372
8	372	371	372	372	371	369	376	373
9	378	380	374	373	376	374	382	379
10	386	378	379	378	385	384	391	388
11	390	379	387	387	390	391	395	393
12	389	387	386	386	389	397	404	398
13	395	391	391	391	395	402	400	401
14	409	396	396	396	409	409	410	414
15+		397	397	397				

Age	8.d	9.a	9.a.N	14.b	All
0					229
1	190		227		201
2	303	316	269		291
3	322	332	304		317
4	333	368	329		346
5	339	374	348		352
6	343	375	367		364
7	355	393	375		370
8	354	396	376		372
9	349	400	385		375
10	357	400	395		385
11	365		391		386
12	365		415		390
13			403		391
14			407		396
15+					395

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	296	267	245		245	277	257	210	
2	298	315	296	326	309	301	318	256	
3	310	325	327	335	290	315	291	279	
4	326	351	353	353	324	333	327	313	
5	341	353	359	365	363	347	364	355	
6	352	362	370	375	355	353	359	339	
7	358	367	374	383	377	364	380	358	
8	362	373	372	387	373	367	377	355	
9	367	374	372		359	372	356	353	
10	365	384	390		377	378	374	374	
11	377	381	377		372	382	368	363	
12	385	386	386		386	387	386	385	
13	395	393	393		393	391	392	405	
14	391	389	388		388	394	392		
15+	401	390	385		385	367	373		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		190		220			254	220	220
1		197	203	260	223	223	290	260	260
2	278	295	276	293	292	292	326	290	290
3	311	316	320	314	314	316	343	322	325
4	359	352	355	338	331	340	360	346	339
5	349	361	353	350	352	354	367	353	307
6	361	366	364	366	376	370	370	358	363
7	366	376	368	377	370	372	378	390	384
8	369	367	372	379	374	373	374	371	371
9	369	389	373	387	380	377	406	387	374
10	382	389	382	402	385	381	378	380	364
11	384	361	386	414	389	387	414	372	381
12	381	396	391	395	386	386	395	396	
13	385	395	393	395	391	391		399	
14		403	397	398	396	396		460	
15+									

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		220			183			
1	223	260	223	223	242	189	232	177
2	285	290	292	290	291	311	291	315
3	327	326	321	323	322	332	319	337
4	358	348	356	350	333	348	340	348
5	358	360	361	354	339	354	353	353
6	366	366	367	364	346	366	367	366
7	380	389	387	367	360	372	372	372
8	371	371	372	371	359	373	373	373
9	379	387	387	372	359	379	379	380
10	377	377	378	378	378	389	388	390
11	380	370	372	387	394	394	391	395
12	386		386	386	399	401	399	400
13	391		391	391	407	405	389	401
14	396		396	396	409	434	408	421
15+	397		397	397				

Age	8.d	9.a	9.a.N	14.b	All
0					185
1	269	250	231		224
2	303	305	268		297
3	322	332	323		311
4	333	355	334		334
5	339	371	347		352
6	343	379	365		361
7	355	379	373		367
8	354	379	376		368
9	349	390	383		373
10	357	397	396		372
11	365	405	395		381
12	365		409		387
13			405		391
14			409		397
15+					383

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						190			
1	280	296			265	295	237	265	
2	310	325	326	326	320	312	312	294	300
3	322	348	350	350	340	328	329	314	341
4	333	359	359	359	359	348	358	357	359
5	353	372	375	375	367	351	357	342	360
6	362	380	383	383	383	360	378	367	367
7	366	381	390	390	384	365	372	355	368
8	369	373	380	380	372	371	371	364	371
9	372	376			346	376	363	346	373
10	375	382				382	383		381
11	383	386				386	386		385
12	388	391				391	391		389
13	392	395			355	393	367	355	399
14	388	398			375	398	381	375	
15+	395	401			383	399	385	383	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				220			254	220	220
1	295	199	193	260	223	223	290	260	260
2	296	324	280	290	292	292	326	290	290
3	320	289	316	317	316	319	343	326	325
4	344	311	350	340	335	341	360	342	339
5	352	322	349	357	353	354	367	359	309
6	358	339	361	359	374	372	371	370	365
7	367	340	367	369	374	377	377	387	384
8	372	328	371	356	374	374	375	371	360
9	367	337	372	379	385	387	406	385	374
10	380	384	386	360	385	384	375	375	362
11	384	330	384	327	387	384	414	372	380
12	387	395	396		386	386	395	395	
13	395	395	394		391	391		391	
14	391	400	403		396	396		396	
15+	407	407	409		397	397		397	

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					172	172	177	177
1			187	187	264	245	296	
2			295	295	303	338	309	331
3	327	325	331	321	322	347	343	360
4	360	360	364	325	333	355	355	360
5	362	363	367	326	339	360	373	376
6	367	366	373	328	343	369	380	
7	389	389	388		355	376	379	385
8	371	371	371		354	376	368	375
9	388	388	388	335	349	384	398	404
10	377	378	376		357	391	455	
11	370	370	370		367	396		
12			386		366	404	455	
13			391		395	408		
14			396		409	409		
15+			397					

Age	8.d	9.a	9.a.N	14.b	All
0		248	198		205
1	269	325	256		277
2	303	317	287	295	310
3	322	340	339	355	323
4	333	368	345	375	337
5	339	378	365	373	354
6	343	381	380	380	363
7	355	385	378	390	367
8	354	370	360	395	370
9	349	380	395	425	373
10	357			435	376
11	365			425	384
12	365				389
13					393
14					391
15+					396

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	187					190	190	190	
1	235	306	308	307	307	297	260	266	
2	311	323	324	324	324	314	302	294	
3	323	336	337	336	336	326	318	313	
4	335	357	357	356	356	347	356	355	
5	347	367	368	368	368	356	353	342	
6	356	373	374	373	373	364	372	367	
7	363	381	382	381	381	371	374	360	
8	371	382	385	385	385	373	373	365	
9	374	386	391	391	391	379	370	349	
10	386	399	413	412	412	387	394	400	
11	378	398	408	408	408	389	396	398	
12	388	392				393	392	400	
13	390	394				394	367	355	
14	395	403	410	410	410	400	386	376	
15+	395	400				399	385	383	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		190		203			254	195	215
1	295	269	196	258	223		290	260	258
2	305	306	275	285	289		326	287	296
3	323	315	321	311	325	335	343	303	341
4	344	336	357	322	350	365	361	328	343
5	355	352	353	354	354	368	367	362	357
6	359	357	365	360	364	375	371	365	370
7	369	367	368	374	367	388	378	387	377
8	376	358	372	358	371		375	370	358
9	367	375	374	382	372	388	406	388	395
10	380	387	384	360	377	375	375	377	361
11	384	378	386	383	387	370	413	372	409
12	390	388	395		386		395	395	395
13	398	392	396		391				
14	391	401	398		396				
15+	413	397	406		397				

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2019 (cont.).

Quarter 4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	254				193	195	231	
1	290				260	245	251	
2	326			292	296	285	294	315
3	342	327	327	319	322	342	345	352
4	360	360	360	342	333	349	355	356
5	367	362	361	355	339	358	372	371
6	370	367	366	373	343	369	379	
7	379	389	389	378	355	379	380	385
8	372	371	371	374	354	375	366	375
9	403	388	388	388	349	385	396	398
10	378	377	378	384	357	391		
11	409	370	370	385	365	396		
12	395				365	404		
13						408		
14						409		
15+								

Age	8.d	9.a	9.a.N	14.b	All
0		267	206		197
1		297	256		284
2		294	279		310
3		343	332		326
4		369	340		347
5		372	357		356
6		372	374		364
7			373		371
8			358		373
9			393		378
10		410			387
11					389
12					393
13					394
14					398
15+					402

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1%. Handline Fleet. UKE=UK England and Wales.

	UKE lines							
	7.e				7.f			
Length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
15								
16								
17					0%			
18					0%			0%
19					0%			0%
20					0%		0%	3%
21					4%		0%	4%
22	1%	0%	0%	1%	10%	0%	1%	7%
23	2%	2%	1%	3%	6%	1%	3%	9%
24	0%	5%	2%	2%	3%	1%	1%	6%
25	0%	8%	8%	3%	1%	3%	2%	5%
26	0%	15%	20%	2%	0%	5%	16%	20%
27	1%	9%	27%	3%	2%	7%	17%	21%
28	7%	6%	14%	3%	7%	10%	8%	11%
29	15%	5%	10%	13%	13%	13%	6%	5%
30	31%	5%	6%	20%	22%	17%	7%	3%
31	16%	6%	4%	14%	19%	16%	13%	3%
32	12%	6%	3%	9%	6%	8%	12%	2%
33	6%	5%	1%	6%	3%	6%	7%	1%
34	3%	8%	1%	6%	1%	3%	2%	0%
35	2%	4%	1%	6%	1%	5%	2%	0%
36	1%	5%	0%	4%	0%	2%	1%	0%
37	1%	4%	0%	3%	0%	1%	1%	0%
38	1%	3%	0%	1%	0	1%	0%	0%
39	0%	1%	0%	1%	0%	1%	0%	
40		0%	0%	0%			0%	

	UKE lines							
	7.e				7.f			
Length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
41		0%	0	0%		0%		
42		0%						

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Southern Fleets. ES=Spain.

	ES All fleets			
length cm	Q1	Q2	Q3	Q4
16				
17			0%	
18			0%	
19			0%	
20			0%	
21			0%	
22	0%		0%	
23	1%	0%	0%	
24	1%	1%	2%	5%
25	1%	1%	8%	20%
26	1%	1%	11%	27%
27	1%	1%	8%	9%
28	0%	1%	9%	11%
29	1%	2%	12%	8%
30	1%	3%	7%	3%
31	2%	5%	4%	2%
32	2%	5%	5%	3%
33	4%	4%	8%	2%
34	10%	9%	9%	2%
35	16%	15%	6%	2%
36	17%	18%	4%	1%
37	16%	16%	3%	2%

	ES All fleets			
length cm	Q1	Q2	Q3	Q4
38	12%	9%	2%	1%
39	9%	5%	1%	0%
40	4%	2%	0%	0%
41	1%	1%	0%	0%
42	1%	0%	0%	0%
43	0%	0%	0%	0%
44	0%	0%		

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Southern Fleets (cont.). BQ=Basque

	BQ Purse Seine				BQ Artisanal		BQ Trawl		
length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q1	Q2	Q4
14		2%	2%						
15		7%	8%						
16		11%	13%						
17		11%	12%						
18		11%	13%						
19		7%	8%						
20		4%	4%	0%					
21		1%	2%	0%					
22		1%	1%						
23				1%					
24				1%					2%
25				3%					15%
26				11%			0%		22%
27				15%			0%		20%
28	0%			12%			1%		18%
29	0%		0%	6%			1%		11%
30	0%	0%	0%	3%	0%	0%	1%		7%

	BQ Purse Seine				BQ Artisanal		BQ Trawl		
length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q1	Q2	Q4
31	0%	0%	0%	3%	0%	0%	4%		3%
32	1%	1%	1%	6%	1%	1%	10%		1%
33	4%	2%	2%	7%	3%	4%	12%	1%	
34	10%	5%	4%	10%	8%	11%	15%	4%	
35	18%	8%	5%	7%	16%	17%	12%	14%	
36	23%	9%	8%	6%	24%	24%	20%	16%	0%
37	21%	9%	7%	4%	22%	22%	10%	26%	0%
38	13%	5%	3%	2%	14%	11%	9%	15%	0%
39	7%	3%	2%	1%	7%	6%	3%	13%	0%
40	2%	1%	1%	1%	3%	2%	0%	8%	0%
41	1%	2%	1%	0%	1%	1%	1%	1%	0%
42	0%	0%	0%		1%	0%		1%	
43	0%	0%	0%		0%	0%		0%	
44		0%	0%		0%		0%		
45					0%	0%			

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Southern Fleets (cont.). PT=Portugal.

	PT All			
length cm	**Q1**	**Q2**	**Q3**	**Q4**
20				
21				
22			3%	1%
23				
24		0%	2%	0%
25		0%	10%	3%
26	0%	0%	3%	3%
27	0%	0%	0%	5%
28	0%	0%	5%	17%

	PT All			
length cm	Q1	Q2	Q3	Q4
29	2%	3%	5%	22%
30	4%	6%	2%	14%
31	6%	11%	5%	5%
32	13%	8%	0%	3%
33	10%	6%	19%	7%
34	11%	3%	7%	3%
35	2%	5%	9%	7%
36	5%	9%	2%	1%
37	28%	20%	16%	6%
38	7%	14%	8%	2%
39	6%	9%	2%	1%
40	3%	4%	2%	1%
41	1%	1%	0%	0%
42	0%			
43	0%			
44			0%	

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Pelagic Trawl Fleets. IE=Ireland, UKS=UK Scotland, IS=Iceland

	IE			UKS			IS
	6.a	7.b	4.a	4.a	6.a	2.a	5.a
Length cm	Q1	Q1	Q1	Q4	Q1	Q3	Q3
15							
16							
17	0%						
18	0%		0%	0%			
19	0%	0%	0%	0%			
20		0%	0%	0%			
21	0%	0%	0%	0%			
22		0%	0%	0%			

	IE			UKS			IS
	6.a	7.b	4.a	4.a	6.a	2.a	5.a
Length cm	Q1	Q1	Q1	Q4	Q1	Q3	Q3
23	0%	0%	0%	0%			
24	0%	0%	0%	0%			
25	0%		1%	0%			
26	0%		1%	0%	0%	0%	
27	0%	0%	1%	0%	0%	0%	
28	0%	0%	1%	0%	0%	0%	0%
29	0%		2%	0%	1%	1%	1%
30	1%	0%	4%	1%	1%	2%	0%
31	1%	0%	3%	2%	1%	4%	0%
32	1%	1%	3%	5%	2%	6%	0%
33	3%	2%	5%	5%	3%	5%	0%
34	7%	8%	11%	6%	5%	5%	3%
35	16%	17%	18%	12%	13%	11%	8%
36	26%	27%	20%	20%	18%	20%	26%
37	21%	22%	14%	21%	22%	21%	29%
38	13%	12%	7%	14%	17%	15%	19%
39	7%	6%	5%	8%	10%	7%	9%
40	3%	2%	2%	3%	4%	2%	4%
41	1%	1%	1%	1%	2%	1%	1%
42	0%	0%	0%	0%	1%	0%	0%
43	0%	0%	0%	0%		0%	0%
44	0%						0%

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Pelagic Trawl Fleets. DK=Denmark, RU=Russia

		DK			RU
	4.a	4.a	4.a	2.a	2.a
length cm	Q1	Q3	Q4	Q3	Q4
23					
24					0%
25					0%
26				0%	0%
27				0%	0%
28				1%	1%
29				1%	2%
30	0%	1%	2%	1%	5%
31	0%	2%	2%	2%	8%
32	1%	6%	4%	2%	10%
33	2%	10%	6%	4%	9%
34	7%	10%	6%	8%	9%
35	18%	14%	9%	19%	12%
36	22%	21%	20%	28%	17%
37	25%	15%	23%	21%	14%
38	13%	11%	17%	9%	8%
39	6%	8%	8%	3%	3%
40	4%	0%	3%	1%	1%
41	1%	1%	1%	0%	0%
42	0%	0%	0%	0%	0%
43	0%	0%	0%	0%	0%
44					0%
45					0%

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Freezer Trawlers. DE=Germany,

		DE		
length cm	**6.a**	**4.a**	**4.a**	**4.a**
	Q1	**Q1**	**Q2**	**Q3**
16				
17				
18				
19				
20		0%		
21	0%	0%		
22	0%	0%		
23	0%	0%	0%	
24	0%	0%	1%	
25	0%	0%	6%	
26	0%	0%	10%	0%
27	0%	1%	11%	1%
28	0%	1%	6%	5%
29	1%	1%	5%	8%
30	2%	2%	7%	9%
31	2%	3%	12%	15%
32	3%	3%	8%	16%
33	3%	3%	10%	9%
34	7%	6%	9%	15%
35	14%	14%	8%	11%
36	22%	20%	2%	5%
37	21%	20%	1%	4%
38	12%	14%	1%	1%
39	7%	8%	1%	1%
40	3%	3%	0%	0%
41	1%	1%	0%	

length cm	6.a	4.a	4.a	4.a
		DE		
	Q1	Q1	Q2	Q3
42	0%	0%		
43	0%	0%		
44				
45		0%		

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2019. Zeros represent values <1% (cont.). Freezer Trawlers. NL=The Netherlands.

		NL					
	4.a	6.a	6.a	6.a	7.b	7.j	7.j
length cm	Q1	Q1	Q2	Q3	Q1	Q2	Q3
24	0%						
25	0%			4%			
26	1%						
27	1%			4%	2%		
28	1%	0%		4%	2%		
29	1%	5%		4%	3%		
30	2%	17%	2%	16%	18%		
31	3%	30%	2%	20%	25%	8%	
32	3%	14%	2%	20%	8%	4%	
33	4%	8%	0%	24%	4%		8%
34	9%	4%	0%	4%	5%	8%	12%
35	18%	5%	6%		6%	12%	4%
36	22%	5%	24%		7%	24%	20%
37	15%	5%	28%		9%	12%	8%
38	9%	2%	18%		6%	24%	16%
39	4%	3%	10%		2%	8%	20%
40	2%	1%	6%		2%		12%
41	1%	1%	0%		2%		
42		0%	2%				

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019.

Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	47					46	46	46	
1	193	175	121	234	193	191	124	176	
2	288	314	307	322	306	262	294	226	280
3	327	372	385	404	352	299	229	208	373
4	362	428	429	430	419	364	317	261	436
5	429	444	471	482	459	390	435	354	442
6	462	455	483	487	476	424	409	334	463
7	478	457	511	543	509	443	509	403	465
8	495	457	459	511	481	457	459	405	479
9	500	469	432	541	460	481	392	370	485
10	518	509	514	628	559	511	448	439	511
11	553	488	447	629	515	517	439	414	526
12	577	492	478	478	478	519	493	485	541
13	602	525	511	511	487	540	476	391	582
14	568	504	490	591	500	546	503	451	
15+	613	530	472.7	473	473	565	489	474	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		46		80			118	78	86
1	192	71	52	146	69	69	184	149	147
2	212	194	163	222	163	164	284	231	237
3	247	234	228	219	229	230	338	249	275
4	322	325	302	293	290	285	407	309	304
5	322	340	331	321	332	326	431	354	331
6	372	378	398	350	399	410	440	342	427
7	407	406	384	405	379	391	474	449	473
8	430	412	398	366	392	388	446	374	376
9	406	431	410	422	399	426	610	428	477
10	454	472	432	500	413	394	368	364	389
11	469	471	449	472	448	426	671	431	596
12	473	504	483	493	453	453	567	567	566
13	494	491	487	488	470	470		468	435
14	490	544	503	506	488	488		496	474
15+	569	580	519	537	494	494		494	

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarters 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	118	81			48	54	43	43
1	82	73	62	62	73	71	98	55
2	266	205	180	174	206	212	186	241
3	310	256	237	235	255	260	247	287
4	364	340	327	312	284	294	294	315
5	398	348	349	334	303	315	318	326
6	396	363	373	374	336	348	355	356
7	431	412	417	381	363	368	370	372
8	381	380	384	392	366	370	376	375
9	495	415	417	397	378	385	394	391
10	396	395	396	415	405	412	423	417
11	569	436	439	452	421	428	432	430
12	535	449	453	453	419	448	462	446
13	455	468	470	470	437	461	443	453
14	486	488	488	488	474	541	482	498
15+	494	494	494	494				

Age	8.d	9.a	9.a.N	14.b	All
0		141	55		56
1	67	225	102		112
2	218	249	163	214	260
3	256	312	279	452	297
4	278	401	305	524	360
5	291	427	309	507	388
6	302	452	359	552	429
7	328	454	375	503	441
8	326	453	381	578	453
9	314	485	410	730	472
10	334	506	442	832	497
11	353	534	438	736	514
12	353		488		530
13			472		537
14			482		539
15+					

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	225	167		96	96	87	96	55	
1	278	220		127	127	171	128	217	
2	319	259		246	246	245	246	262	
3	355	295		344	344	340	347	338	
4	386	324		354	354	359	359	344	
5	415	352		386	386	400	394	378	
6	440	378		410	410	416	415	391	
7	465	393		428	428	417	432	420	
8	488	412		418	418	421	418	412	
9	509	432		498	498	463	498	463	
10	528	449		440	440	454	440	442	
11	544	467		478	478	478	478	453	
12	564	484		511	511	511	511	561	
13	575	498		490	490	503	490	597	
14	615	460		473	473	494	473	538	
15+									

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				81			118	82	81
1		70	53	145	69	69	184	146	144
2	133	194	163	234	163	164	284	237	236
3	214	235	227	261	229	226	336	261	265
4		327	279	315	291	276	404	311	299
5	298	341	322	335	332	319	431	360	298
6	341	382	418	376	397	419	435	354	381
7	356	407	380	389	379	382	474	450	469
8	356	415	393	402	392	389	419	374	375
9	387	432	419	410	399	427	606	434	419
10	446	472	411	444	414	396	355	371	388
11	446	472	434	457	449	426	675	440	475
12	427	504	482	493	453	453	567	567	418
13	448	491	488	496	470	470		435	435
14		544	502	506	488	488		474	474
15+	446	580	528	537	494	494			

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					118			
1	72	72	62	69	72	72	94	
2	198	197	184	163	208	217	188	240
3	246	256	232	228	254	257	258	286
4	310	342	302	311	289	289	301	315
5	328	348	330	334	310	308	320	326
6	356	363	369	376	344	341	356	357
7	369	411	387	382	366	363	372	372
8	373	380	390	392	369	365	379	375
9	387	414	400	398	382	378	398	391
10	408	395	408	414	406	405	426	416
11	421	437	451	452	421	423	436	429
12	418	449	453	453	418	441	467	444
13	435	468	470	470	435	455	453	452
14	474	488	488	488	474	475	484	492
15+		494	494	494				

Age	8.d	9.a	9.a.N	14.a	14.b	All
0					91	
1	66		89		75	
2	218	260	143		187	
3	256	300	205		238	
4	278	403	259		329	
5	291	422	304		344	
6	301	432	353		387	
7	328	490	377		405	
8	326	500	379		410	
9	314	515	407		422	
10	334	515	439		462	
11	353		425		463	
12	353		506		488	
13			466		494	
14			476		510	
15+					529	

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	227	153	96		96	174	137	55	
2	239	284	226	323	276	224	303	158	
3	264	297	300	348	205	260	210	172	
4	307	380	380	399	295	310	306	256	
5	349	377	405	447	433	350	442	396	
6	387	404	433	465	389	371	404	330	
7	399	419	471	529	499	406	514	405	
8	411	445	436	501	446	421	464	380	
9	431	459	418		387	439	383	372	
10	432	506	498		449	462	441	437	
11	473	475	440		428	479	425	408	
12	492	487	478		479	495	487	486	
13	567	520	511		511	514	516	640	
14	519	498	490		490	526	515		
15+	619	514	473		473	515	509		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		46		81			118	81	81
1		51	53	146	69	69	184	146	146
2	169	177	147	206	164	163	284	236	236
3	218	224	240	217	227	222	339	233	265
4	436	302	342	290	276	297	408	313	299
5	338	322	335	321	322	331	432	329	305
6	396	337	372	373	420	387	441	316	379
7	442	375	385	426	379	391	474	454	479
8	448	330	399	419	391	389	455	373	375
9	424	401	405	456	412	405	612	420	421
10	480	480	437	550	403	403	377	357	385
11	503	398	455	528	434	446	672	433	469
12	446	500	477	493	453	453	567	438	
13	455	491	483	484	470	470		446	
14		532	500	506	488	488		656	
15+	446	558	506	537	494	494			

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		81			48			
1	69	146	69	69	120	65	100	55
2	160	236	164	162	196	235	182	240
3	261	263	241	243	256	277	236	287
4	345	323	341	322	278	313	284	314
5	349	363	360	335	292	327	316	325
6	365	365	367	369	307	356	353	355
7	419	446	440	380	341	372	366	373
8	383	373	375	393	340	374	372	375
9	414	434	433	396	340	391	388	393
10	398	377	379	416	387	417	417	422
11	441	424	424	453	431	431	426	434
12	453		453	453	447	452	451	451
13	470		470	470	471	464	421	453
14	488		488	488	475	562	478	514
15+	494		494	494				

Age	8.d	9.a	9.a.N	14.b	All
0					50
1	160	130	96		104
2	219	233	141		220
3	256	302	245		237
4	278	368	270		300
5	291	412	300		342
6	302	438	347		370
7	328	438	372		396
8	326	438	381		387
9	314	480	402		421
10	334	505	442		427
11	353	534	439		462
12	353		486		486
13			473		477
14			482		516
15+					492

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						46			
1	194	227			179	225	113	179	
2	288	320	323	323	307	275	281	233	280
3	329	411	421	421	381	319	337	279	373
4	363	439	440	440	440	390	429	409	436
5	432	491	505	505	466	389	417	349	442
6	466	491	504	504	502	422	471	439	463
7	488	543	604	604	564	443	465	391	465
8	500	476	504	504	456	464	441	412	479
9	509	488			361	486	418	361	485
10	529	510				510	506		511
11	561	530				530	530		526
12	588	549				549	549		541
13	603	567			387	561	443	387	582
14	576	585			447	580	484	447	
15+	616	618			473	600	485	473	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0				81			118	81	81
1	192	49	45	146	69	69	184	146	146
2	194	316	162	236	164	164	284	236	236
3	250	220	243	244	232	240	339	267	265
4	320	269	337	290	287	305	409	307	299
5	342	293	335	314	328	335	432	380	312
6	371	323	375	329	411	399	443	389	398
7	394	325	390	356	391	404	474	445	478
8	416	297	406	310	388	385	472	374	386
9	403	320	414	380	423	428	614	440	421
10	448	451	460	386	396	390	400	384	388
11	463	322	460	317	429	424	671	433	466
12	473	495	500		453	453	567	567	
13	514	493	493		470	470		470	
14	490	514	535		488	488		488	
15+	564	547	560		494	494		494	

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					39	39	43	43
1			62	62	154	115	206	
2			206	206	219	294	241	297
3	263	245	297	253	256	317	340	384
4	354	352	368	260	278	335	382	385
5	367	374	398	264	291	347	447	442
6	368	366	407	268	302	364	474	
7	444	444	437		328	389	469	473
8	373	373	373		326	387	425	436
9	436	436	448	282	314	413	554	555
10	378	373	392		334	423	862	
11	423	423	423		359	437		
12			453		355	461	862	
13			470		435	472		
14			488		474	475		
15+			494					

Age	8.d	9.a	9.a.N	14.a	14.b	All
0		128	55		68	
1	160	301	127		181	
2	219	284	188	214	284	
3	256	349	326	452	329	
4	278	447	345	524	377	
5	291	491	419	507	431	
6	302	502	474	552	464	
7	328	517	466	503	477	
8	326	454	397	578	492	
9	314	495	538	730	499	
10	334			832	523	
11	353			736	550	
12	353				575	
13					594	
14					575	
15+					611	

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	47					46	46	46	
1	111	238	238	237	237	227	157	181	
2	248	306	309	309	309	275	251	232	
3	304	346	353	348	348	308	290	277	
4	342	427	428	424	424	375	413	402	
5	385	461	466	465	465	405	398	350	
6	426	484	487	485	485	438	466	448	
7	434	516	523	516	516	459	476	410	
8	464	521	535	535	535	471	462	417	
9	480	526	548	546	546	494	453	372	
10	518	580	634	633	633	525	558	575	
11	479	595	651	649	649	537	582	576	
12	530	553				558	554	584	
13	517	565				561	443	387	
14	533	617	659	659	659	584	515	452	
15+	534	605				594	486	473	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0		46		66			118	56	88
1	192	161	49	151	69		184	153	150
2	214	231	148	223	162		284	222	241
3	262	237	246	291	252	324	339	263	333
4	320	302	350	289	323	374	408	301	328
5	357	337	337	289	335	406	431	369	336
6	381	349	376	383	369	420	442	368	438
7	406	396	388	448	379	435	473	443	473
8	435	357	403	376	393		472	375	376
9	408	413	410	471	396	452	609	436	551
10	449	494	446	394	417	400	400	378	395
11	469	454	457	470	453	423	662	426	642
12	489	498	494		453		567	567	567
13	536	498	496		470				
14	490	556	508		488				
15+	604	536	540		494				

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2019 (cont.).

Quarter 4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	118				56	57	96	
1	184				144	115	120	
2	284			164	206	187	204	255
3	335	264	261	241	256	323	344	359
4	396	355	353	305	278	339	381	372
5	427	370	364	336	291	359	443	425
6	425	371	365	400	302	364	469	
7	471	444	445	405	328	420	475	473
8	401	373	373	386	326	406	419	436
9	579	437	435	430	314	438	544	528
10	377	379	377	389	334	423		
11	641	423	423	425	353	437		
12	567				353	461		
13						472		
14						475		
15+								

Age	8.d	9.a	9.a.N	14.b	All
0		161	64		60
1		223	127		195
2		222	170		257
3		359	304		306
4		453	329		372
5		466	389		404
6		464	453		437
7			447		457
8			390		470
9			531		491
10		633			523
11					532
12					550
13					558
14					565
15+					595

Table 8.6.1.1.1. NE Atlantic Mackerel SSB (kt) and Total Annual egg production (TAEP) derived from the mackerel egg surveys for the Southern, Western and combined survey area.

Year	Component	TAEP	SSB (kt)
1992	Combined	2.57*e15	3874.5
1995	Combined	2.23*e15	3766.4
1998	Combined	2.02*e15	4198.6
2001	Combined	1.67*e15	3233.8
2004	Combined	1.50*e15	3106.8
2007	Combined	1.77*e15	3783.0
2010	Combined	2.38*e15	4810.8
2013	Combined	2.70*e15	4831.9
2016	Combined	1.77*e15	3524.1
2019	Combined	1.64*e15	3087.5

Year	Component	TAEP	SSB (kt)
1992	Southern	3.36*e14	507.2
1995	Southern	1.86*e14	370.4
1998	Southern	4.79*e14	882.9
2001	Southern	3.18*e14	417.5
2004	Southern	1.38*e14	309.2
2007	Southern	3.48*e14	744.7
2010	Southern	4.59*e14	926.3
2013	Southern	5.06*e14	904.0
2016	Southern	2.25*e14	447.3
2019	Southern	4.23*e14	796.7
1992	Western	2.23*e15	3367.2
1995	Western	2.05*e15	3396.0
1998	Western	1.54*e15	3315.8
2001	Western	1.35*e15	2816.4
2004	Western	1.36*e15	2797.6
2007	Western	1.42*e15	3038.3
2010	Western	1.92*e15	3884.4
2013	Western	2.20*e15	3927.9
2016	Western	1.55*e15	3076.8
2019	Western	1.22*e15	2290.8

Table 8.6.1.1.2. Fecundity and atresia for the assessment years, from 1998 to 2019. n is the number of samples used, n/g refers to the number of oocytes or atretic oocytes by gram of fish

Parameter	1998	2001	2004	2007	2010	2013	2016	2019
Fecundity samples (n)	96	187	205	176	74	132	97	*62*
Prevalence of atresia (n)	112	290	348	416	511	735	713	*895*
Intensity of atresia (n)	112	290	348	416	511	56	66	*64*
Relative potential fecundity (n/g)	1206	1097	1127	1098	1140	1257	1159	*1191*
Prevalence of atresia	0.55	0.2	0.28	0.38	0.33	0.22	0.3	*0.28*
Geometric mean intensity of atresia (n/g)	46	40	33	30	26	27	30	*19*
Potential fecundity lost per day (n/g)	3.37	1.07	1.25	1.48	1.16	0.8	1.2	*0.73*

Parameter	1998	2001	2004	2007	2010	2013	2016	2019
Potential fecundity lost (n/g)	202	64	75	89	70	48	72	*44*
Relative potential fecundity lost (%)	17	6	7	9	6	4	6	*4*
Realised fecundity (n/g)	1002	1033	1052	1009	1070	1209	1087	*1147*

Table 8.6.2.1. Model parameter estimates and standard errors.

Symbol	Description	Unit	Estimate	Std.Error
T	Decorrelation time	year	2	0.4
H	Spatial decorrelation distance	km	466	88
WS	Log Wing spread	nmi	-1.1	0.6
σ_N^2	Variance of the nugget effect	1	3.8	
σ_{xy}^2	Spatial variance parameter (year specific surfaces)	1	5.4	
σ_x^2	Spatial variance parameter (intercept surface)	1	5.5	

Table 8.6.3.1. Mackerel abundance index, mean weight-at-age, and biomass index from the IESSNS in 2007 and from 2010 to 2020, excluding North Sea. Values in 2007 and from 2010 to 2019 are the old StoX baseline whereas value from 2020 are the new StoX baseline values.

	2007			2010			2011			2012		
Age	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)
1	1.33	133	0.18	0.01	248	0.00	0.21	133	0.03	0.92	107	0.10
2	1.86	233	0.43	3.58	208	0.74	0.26	278	0.07	5.42	186	1.01
3	0.9	323	0.29	1.62	289	0.47	0.87	318	0.28	1.28	289	0.37
4	0.24	390	0.09	4.04	351	1.42	1.11	371	0.41	2.38	351	0.84
5	1	472	0.47	3.06	390	1.19	1.64	412	0.67	2.16	390	0.84
6	0.16	532	0.09	1.59	439	0.70	1.22	440	0.54	2.85	414	1.18
7	0.06	536	0.03	0.69	511	0.35	0.57	502	0.29	1.78	434	0.77
8	0.04	585	0.02	0.41	521	0.22	0.28	537	0.15	0.74	466	0.35
9	0.03	591	0.02	0.20	572	0.11	0.12	564	0.07	0.30	474	0.14
10	0.01	640	0.01	0.07	584	0.04	0.07	541	0.04	0.15	542	0.08

Age	2007 Number (billions)	2007 W (g)	2007 Biom. t (million)	2010 Number (billions)	2010 W (g)	2010 Biom. t (million)	2011 Number (billions)	2011 W (g)	2011 Biom. t (million)	2012 Number (billions)	2012 W (g)	2012 Biom. t (million)
11	0.01	727	0.01	0.02	652	0.02	0.06	570	0.03	0.08	491	0.04
12	0	656	0	0.03	673	0.02	0.02	632	0.01	0.04	582	0.02
13	0.01	685	0.01	0.01	660	0.01	0.01	622	0.01	0.00	525	0.00
14+	0	671	0	0.01	520**	0.00	0	612	0	0.00	577**	0.00
TOTAL	**5.65**	**512**	**1.64**	**15.32**	**345*****	**5.29**	**6.42**	**467**	**2.69**	**18.12**	**317*****	**5.75**

Age	2013 Number (billions)	2013 W (g)	2013 Biom. t (million)	2014 Number (billions)	2014 W (g)	2014 Biom. t (million)	2015 Number (billions)	2015 W (g)	2015 Biom. t (million)	2016 Number (billions)	2016 W (g)	2016 Biom. t (million)
1	0.04	107	0.00	0.01	206	0.00	0.86	111	0.10	<0.01	95	<0.01
2	6.39	187	1.19	0.56	275	0.15	0.84	283	0.24	4.98	231	1.15
3	9.20	259	2.39	7.03	287	2.02	2.54	325	0.83	1.37	324	0.45
4	2.46	323	0.79	4.90	336	1.65	6.41	335	2.15	2.64	360	0.95
5	3.07	379	1.16	2.66	402	1.07	4.80	379	1.82	5.24	371	1.95
6	3.22	403	1.30	2.63	433	1.14	1.80	434	0.78	4.37	394	1.72
7	2.54	432	1.10	2.77	455	1.26	1.63	463	0.75	1.89	440	0.83
8	1.09	447	0.49	1.91	471	0.90	1.25	470	0.59	1.66	458	0.76
9	0.38	488	0.18	0.85	492	0.42	0.73	485	0.35	1.11	479	0.53
10	0.14	524	0.08	0.38	534	0.20	0.27	498	0.13	0.75	488	0.37
11	0.15	478	0.07	0.10	534	0.05	0.07	548	0.04	0.45	494	0.22
12	0.04	564	0.02	0.07	610	0.04	0.06	541	0.04	0.2	523	0.1
13	0.01	654	0.00	0.04	503	0.02	0.01	563	0.00	0.07	511	0.04
14+	0.02	626**	0.01	0.00	665**	0.00				0.07	664	0.04
TOTAL	28.74	306***	8.79	23.91	373***	8.93	21.28	367***	7.81	24.81	367	9.11

Table 8.6.3.1. Mackerel abundance index, mean weight-at-age, and biomass index from the IESSNS in 2007 and from 2010 to 2020, excluding North Sea. Values in 2007 and from 2010 to 2019 are the old StoX baseline whereas value from 2020 are the new StoX baseline values. Cont.

	2017			2018			2019			2020*		
Age	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)
1	0.86	86	0.07	2.18	67	0.15	0.08	153	0.01	0.04	99	0.00
2	0.12	292	0.03	2.5	229	0.57	1.35	212	0.29	1.10	213	0.23
3	3.56	330	1.18	0.5	330	0.16	3.81	325	1.24	1.43	315	0.45
4	1.95	373	0.73	2.38	390	0.93	1.21	352	0.43	3.36	369	1.24
5	3.32	431	1.43	1.2	420	0.5	2.92	428	1.25	2.13	394	0.84
6	4.68	437	2.04	1.41	449	0.63	2.86	440	1.26	2.53	468	1.18
7	4.65	462	2.15	2.33	458	1.07	1.95	472	0.92	2.53	483	1.22
8	1.75	487	0.86	1.79	477	0.85	3.91	477	1.86	2.03	507	1.03
9	1.94	536	1.04	1.05	486	0.51	3.82	490	1.87	2.90	520	1.51
10	0.63	534	0.33	0.5	515	0.26	1.50	511	0.77	3.84	529	2.03
11	0.51	542	0.28	0.56	534	0.3	1.25	524	0.65	1.50	539	0.81
12	0.12	574	0.07	0.29	543	0.16	0.58	564	0.33	1.18	567	0.67
13	0.08	589	0.05	0.14	575	0.08	0.59	545	0.32	0.92	575	0.53
14+	0.04	626	0.03	0.09	643	0.05	0.57	579	0.32	0.98	593**	0.58
TOTAL	24.22	425	10.29	16.92	368	6.22	26.40	436	11.52	26.47	466***	12.33

***individuals of unknown age are estimated 0.01% of total stock size and are included in total estimates of abundance and biomass but excluded from abundance/biomass per age.**

****average weight for 14+ is mean weight per age weighted by numbers per age.**

*****average weight for all age classes including individuals of unknown age, calculated in StoX.**

Table 8.6.4.1. Overview of numbers released in the different RFID tagging experiments, and numbers recaptured per year (year 2020 shows update per 20th August to demonstrate ongoing process). Recaptures from experiments and recapture years used in 2020 stock assessment, based on decisions in the ICES IBPNEAMac 2019 (ICES, 2019a) are outlined and marked grey. However, note that these numbers also include recaptures from some factories excluded in the final estimation of tag table used in the stock assessment 2020 (see Tables 8.6.4.2-3), due to low efficiency or misfunctions.

Survey	N-Released	2012	2013	2014	2015	2016	2017	2018	2019	2020	All years
Iceland2015	806	0	0	0	6	2	3	0	0	0	11
Iceland2016	4884	0	0	0	0	59	48	28	19	4	158
Iceland2017	3890	0	0	0	0	0	28	27	9	9	73
Iceland2018	1872	0	0	0	0	0	0	5	16	3	24
Iceland2019	3614	0	0	0	0	0	0	0	5	13	18
Ireland-Hebrides2011	18645	27	24	31	24	17	5	9	7	2	146
Norway2011	31253	9	31	24	34	26	16	20	5	5	170
Ireland-Hebrides2012	32136	31	57	60	67	34	21	12	5	1	288
Ireland-Hebrides2013	22792	0	26	**89**	**109**	61	31	21	10	5	352
Ireland-Hebrides2014	55184	0	0	112	**321**	**277**	139	91	44	24	1008
Ireland-Hebrides2015	43905	0	0	0	117	**219**	**177**	93	49	26	681
Ireland-Hebrides2016	43956	0	0	0	0	124	**326**	**185**	121	59	815
Ireland-Hebrides2017	56073	0	0	0	0	0	137	**344**	**175**	69	725
Ireland-Hebrides2018	38136	0	0	0	0	0	0	204	**249**	131	584
Ireland-Hebrides2019	51179	0	0	0	0	0	0	0	293	270	563
Hebrides2020	48970	0	0	0	0	0	0	0	0	122	122
All surveys	457295	67	138	316	678	819	931	1039	1007	743	5738

Table 8.6.4.2. Overview of numbers of tonnes scanned for RFID tags per factory per year. Data from years used in 2020 stock assessment (2014 and onwards), based on decisions in the ICES IBPNEAMac 2019 (ICES, 2019a), are outlined and marked grey. Based on an evaluation of efficiency of the scanners, data from some factories are excluded as they were not functioning or having poor data quality, and these are not marked grey.

Factory	2012[1]	2013[1]	2014	2015	2016	2017	2018	2019	All years
FO01 Vardin Pelagic	0	0	**10460**	**11565**	**7895**	**4844**	0	0	34763
GB01 Denholm Coldstore	0	0	0	**4377**	**4710**	**5365**	**7806**	**5191**	27449
GB01 Denholm Factory	0	0	**14939**	**17509**	**18840**	**17913**	**13609**	**12018**	94829
GB02 Lunar Freezing Peterhead	0	0	**22586**	**17830**	**16473**	**9745**	**9857**	**14300**	90791
GB03 Lunar Freezing Fraserburgh	0	0	0	8797	14282	12684	**9452**	**5729**	50943
GB04 Pelagia Shetland	0	0	**21436**	**41117**	**40200**	**26935**	**25350**	**15128**	170166
GB05 Northbay Pelagic	0	0	0	0	0	0	**15353**	**12667**	28020
IC01 Vopnafjord	0	0	**18577**	**18772**	**21716**	**22935**	**18869**	**18547**	119416
IC02 Neskaupstad	0	0	0	**6288**	**21887**	**19558**	**16757**	**26633**	91123
IC03 Höfn	0	0	0	**0**	**0**	**0**	**0**	**10592**	10592
NO01 Pelagia Egersund Seafood	20930	21442	36724	14375	15905	0	**48373**	**25404**	183152
NO02 Skude Fryseri	7546	8250	**16719**	**14172**	**8671**	**16760**	3108	1285	76511
NO03 Pelagia Austevoll	6405	6134	10314	4203	2216	0	**7293**	**3533**	40097
NO04 Pelagia Florø	9986	12838	**17379**	**12592**	**7749**	0	0	0	60544
NO05 Pelagia Måløy	13344	14632	**13942**	**21051**	**15762**	**22405**	**13341**	**8591**	123068
NO06 Pelagia Selje	17731	26878	**39525**	**41209**	**29897**	**35416**	**28972**	**32047**	251676
NO07 Pelagia Liavågen	9442	10968	**22395**	**18144**	**13911**	**19989**	**12398**	**11888**	119136
NO08 Brødrene Sperre	14425	15048	**20182**	**34307**	**36736**	**18814**	33960	8515	181988
NO09 Lofoten Viking	0	0	0	0	0	0	3380	2457	5837
NO14 Nils Sperre	0	0	0	0	0	0	**28304**	**26272**	54576
NO15 Grøntvedt Pelagic	0	0	0	0	0	0	6411	0	6411
NO16 Vikomar	0	0	0	0	0	0	12512	**6480**	18992
All factories	99808	116190	265178	286310	276850	233363	315105	247277	1840082

[1] In years 2012-2013 all factories except NO03Austevoll had acceptable efficiency. However, data from these years are not used for stock assessment as distribution of catches scanned were different than in years 2014 onwards in addition to other bias issues.

Table 8.6.4.3. Overview of numbers of RFID tagged mackerel recaptured per factory per year. Only recaptures from Ireland surveys (Table 8.6.4.1) that are used as basis stock assessment are shown. Recaptures from years used in 2020 stock assessment from 2014 and onwards, based on decisions in the ICES IBPNEAMac 2019 (ICES, 2019a), are outlined and marked grey. Based on an evaluation of efficiency of the scanners, data from some factories are excluded as they were not functioning or having poor data quality, and these are not marked grey.

Factory	2013[1]	2014[1]	2015	2016	2017	2018	2019	2020[2]	All years
FO01 Vardin Pelagic	0	**13**	**35**	**20**	**12**	0	0	0	80
GB01 Denholm Coldstore	0	0	**10**	**10**	**25**	**36**	**19**	21	121
GB01 Denholm Factory	0	**25**	**62**	**77**	**113**	**54**	**54**	35	420
GB02 Lunar Freezing Peterhead	0	**32**	**49**	**60**	**38**	**41**	**54**	68	342
GB03 Lunar Freezing Fraserburgh	0	0	9	14	7	**25**	**34**	0	89
GB04 Pelagia Shetland	0	**21**	**124**	**148**	**138**	**98**	**82**	60	671
GB05 Northbay Pelagic	0	0	0	0	0	**57**	**62**	33	152
IC01 Vopnafjord	0	**22**	**55**	**65**	**59**	**62**	**54**	96	413
IC02 Neskaupstad	0	0	**19**	**65**	**54**	**35**	**115**	98	386
IC03 Höfn	0	0	1	0	1	1	**44**	50	97
NO01 Pelagia Egersund Seafood	22	18	7	1	0	**137**	**80**	62	337
NO02 Skude Fryseri	6	**21**	**17**	**25**	**51**	14	3	0	142
NO03 Pelagia Austevoll	1	7	4	1	0	**28**	**17**	0	59
NO04 Pelagia Florø	12	**27**	**21**	**17**	0	0	0	0	82
NO05 Pelagia Måløy	13	**20**	**43**	**37**	**79**	**36**	**28**	35	296
NO06 Pelagia Selje	27	**37**	**76**	**59**	**85**	**87**	**153**	59	598
NO07 Pelagia Liavågen	11	**29**	**31**	**26**	**97**	**48**	**51**	12	315
NO08 Brødrene Sperre	15	**20**	**56**	**107**	**77**	52	12	0	346
NO09 Lofoten Viking	0	0	0	0	0	10	3	5	18
NO12 Pelagia Lødingen	0	0	0	0	0	0	0	1	1
NO13 Pelagia Tromsø	0	0	0	0	0	0	0	1	1
NO14 Nils Sperre	0	0	0	0	0	**109**	**68**	48	225
NO15 Grøntvedt Pelagic	0	0	0	0	0	11	0	0	11
NO16 Vikomar	0	0	0	0	0	18	**20**	25	63
All factories	107	292	619	732	836	959	953	709	5265

[1] **In years 2012-2013 all factories except NO03Austevoll had acceptable efficiency. However, data from these years are not used for stock assessment as distribution of catches scanned were different than in years 2014 onwards in addition to other bias issues.**

[2] **Preliminary by 20th August.**

Table 8.7.1.1. NE Atlantic mackerel. Input data and parameters and the model configurations for the assessment.

Input data types and characteristics:			
Name	Year range	Age range	Variable from year to year
Catch in tonnes	1980 -2019		Yes
Catch-at-age in numbers	1980 -2019	0-12+	Yes
Weight-at-age in the commercial catch	1980 –2019	0-12+	Yes
Weight-at-age of the spawning stock at spawning time.	1980 –2019	0-12+	Yes
Proportion of natural mortality before spawning	1980 -2020	0-12+	Yes
Proportion of fishing mortality before spawning	1980 -2020	0-12+	Yes
Proportion mature-at-age	1980 -2020	0-12+	Yes
Natural mortality	1980 -2020	0-12+	No, fixed at 0.15

Tuning data:			
Type	Name	Year range	Age range
Survey (SSB)	ICES Triennial Mackerel and Horse Mackerel Egg Survey	1992, 1995, 1998, 2001, 2004, 2007, 2010, 2013,2016,2019.	Not applicable (gives SSB)
Survey (abundance index)	IBTS Recruitment index (log transformed)	1998-2019	Age 0
Survey (abundance index)	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)	2010, 2012-2020	Ages 3-11
Tagging/recapture	Norwegian tagging program	Steal tags : 1980 (release year)-2006 (recapture years) RFID tags : 2013 (release year) 2019 (recapture year)	Ages 5 and older (age at release)

SAM parameter configuration		
Setting	Value	Description
Coupling of fishing mortality states	1/2/3/4/5/6/7/8/8/8/8/8/8	Different F states for ages 0 to 6, one same F state for ages 7 and older
Correlated random walks for the fishing mortalities	0	F random walk of different ages are independent
Coupling of catchability parameters	0/0/0/0/0/0/0/0/0/0/0/0/0 1/0/0/0/0/0/0/0/0/0/0/0/0 2/0/0/0/0/0/0/0/0/0/0/0/0 0/0/0/3/4/5/6/7/8/9/10/10/0	No catchability parameter for the catches One catchability parameter estimated for the egg One catchability parameter estimated for the recruitment index One catchability parameter for each age group estimated for the IESSNS (age 3 to11)
Power law model	0	No power law model used for any of the surveys
Coupling of fishing mortality random walk variances	1/2/3/3/3/3/3/3/3/3/3/3	Separate F random walk variances for age 0, age 1 and a same variance for older ages
Coupling of log abundance random walk variances	1/2/2/2/2/2/2/2/2/2/2/2	Same variance used for the log abundance random walk of all ages except for the recruits (age 0)
Coupling of the observation variances	1/2/3/3/3/3/3/3/3/3/3/3 0/0/0/0/0/0/0/0/0/0/0/0 4/0/0/0/0/0/0/0/0/0/0/0/0 0/0/0/5/6/6/6/6/6/6/6/0	Separate observation variances for age 0 and 1 than for the older ages in the catches One observation variance for the egg survey One observation variance for the recruitment index 2 observation variances for the IESSNS (age 3 and ages 4 and older)
Stock recruitment model	0	No stock-recruiment model
Correlation structure	"ID", "ID", "ID", "AR"	Auto-regressive correlation structure for the IESSNS index, independent observations assumed for the other data sources

Table 8.7.1.2. NE Atlantic Mackerel. CATCH IN NUMBER

Units : thousands

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	33101	56682	11180	7333	287287	81799	49983	7403	57644	65400
1	411327	276229	213936	47914	31901	268960	58126	40126	152656	64263
2	393025	502365	432867	668909	86064	20893	424563	156670	137635	312739
3	64549	231814	472457	433744	682491	58346	38387	663378	190403	207689
4	328206	32814	184581	373262	387582	445357	76545	56680	538394	167588
5	254172	184867	26544	126533	251503	252217	364119	89003	72914	362469
6	142978	173349	138970	20175	98063	165219	208021	244570	87323	48696
7	145385	116328	112476	90151	22086	62363	126174	150588	201021	58116
8	54778	125548	89672	72031	61813	19562	42569	85863	122496	111251
9	130771	41186	88726	48668	47925	47560	13533	34795	55913	68240

10	39920	146186	27552	49252	37482	37607	32786	19658	20710	32228
11	56210	31639	91743	19745	30105	26965	22971	25747	13178	13904
12	104927	199615	156121	132040	69183	97652	81153	63146	57494	35814

	year									
age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	24246	10007	43447	19354	25368	14759	37956	36012	61127	67003
1	140534	58459	83583	128144	147315	81529	119852	144390	99352	73597
2	209848	212521	156292	210319	221489	340898	168882	186481	229767	132994
3	410751	206421	356209	266677	306979	340215	333365	238426	264566	223639
4	208146	375451	266591	398240	267420	275031	279182	378881	323186	261778
5	156742	188623	306143	244285	301346	186855	177667	246781	361945	281041
6	254015	129145	156070	255472	184925	197856	96303	135059	207619	244212
7	42549	197888	113899	149932	189847	142342	119831	84378	118388	159019
8	49698	51077	138458	97746	106108	113413	55812	66504	72745	86739
9	85447	43415	51208	121400	80054	69191	59801	39450	47353	50613
10	33041	70839	36612	38794	57622	42441	25803	26735	24386	30363
11	16587	29743	40956	29067	20407	37960	18353	13950	16551	17048
12	27905	52986	68205	68217	57551	39753	30648	24974	22932	32446

	year									
age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	36345	26034	70409	14744	11553	12426	75651	19302	25886	17615
1	102407	40315	222577	187997	31421	46840	149425	88439	59899	36514
2	142898	158943	70041	275661	453133	135648	173646	190857	167748	113574
3	275376	234186	367902	91075	529753	668588	159455	220575	399086	455113
4	390858	297206	350163	295777	147973	293579	470063	215655	284660	616963
5	295516	309937	262716	235052	258177	120538	195594	455131	260314	319465
6	241550	231804	237066	183036	145899	121477	97061	203492	255675	224848
7	175608	195250	151320	133595	89856	63612	73510	77859	124382	194326
8	106291	120241	118870	94168	65669	38763	33399	59652	57297	73171
9	52394	72205	79945	75701	40443	23947	18961	30494	32343	29738
10	31280	42529	43789	45951	35654	18612	13987	16039	19482	14989
11	18918	20546	21611	25797	16430	7955	8334	11416	6798	7470
12	34202	40706	40280	30890	19509	10669	10186	12801	9581	5003

	year									
age	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	23453	30429	23872	11325	62100	6732	716	28306	9453	6439
1	78605	62708	66196	47020	43173	104019	45199	43458	46107	42398
2	137101	115346	200167	235411	137788	124411	203753	87739	238898	126107
3	303928	322725	214043	399751	669949	248852	257293	458301	137575	350687
4	739221	469953	415884	370551	829399	579835	424843	351779	378240	114630
5	611729	654395	456404	442597	564508	646894	589549	396862	257689	295888
6	284788	488713	511270	429324	549985	450344	532890	503601	295537	226728
7	143039	244210	323835	336701	503300	415107	340155	431014	425922	229838
8	102072	113012	142948	188910	339538	355997	269962	261959	317671	267591
9	45841	53363	69551	112765	141344	205691	170373	188950	198527	204885
10	21222	25046	30619	45938	63614	107685	94778	138143	140781	103015
11	6255	12311	11603	18928	21294	26939	33896	59211	83063	66990
12	8523	10775	11678	17857	13136	22700	24420	51090	60587	74927

Table 8.7.1.3. NE Atlantic Mackerel. WEIGHTS AT AGE IN THE CATCH

Units : Kg

age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.057	0.060	0.053	0.050	0.031	0.055	0.039	0.076	0.055	0.049	0.085	0.068
1	0.131	0.132	0.131	0.168	0.102	0.144	0.146	0.179	0.133	0.136	0.156	0.156
2	0.249	0.248	0.249	0.219	0.184	0.262	0.245	0.223	0.259	0.237	0.233	0.253
3	0.285	0.287	0.285	0.276	0.295	0.357	0.335	0.318	0.323	0.320	0.336	0.327
4	0.345	0.344	0.345	0.310	0.326	0.418	0.423	0.399	0.388	0.377	0.379	0.394
5	0.378	0.377	0.378	0.386	0.344	0.417	0.471	0.474	0.456	0.433	0.423	0.423
6	0.454	0.454	0.454	0.425	0.431	0.436	0.444	0.512	0.524	0.456	0.467	0.469
7	0.498	0.499	0.496	0.435	0.542	0.521	0.457	0.493	0.555	0.543	0.528	0.506
8	0.520	0.513	0.513	0.498	0.480	0.555	0.543	0.498	0.555	0.592	0.552	0.554
9	0.542	0.543	0.541	0.545	0.569	0.564	0.591	0.580	0.562	0.578	0.606	0.609
10	0.574	0.573	0.574	0.606	0.628	0.629	0.552	0.634	0.613	0.581	0.606	0.630
11	0.590	0.576	0.574	0.608	0.636	0.679	0.694	0.635	0.624	0.648	0.591	0.649
12	0.580	0.584	0.582	0.614	0.663	0.710	0.688	0.718	0.697	0.739	0.713	0.708

age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.051	0.061	0.046	0.072	0.058	0.076	0.065	0.062	0.063	0.069	0.052	0.081
1	0.167	0.134	0.136	0.143	0.143	0.143	0.157	0.176	0.135	0.172	0.160	0.170
2	0.239	0.240	0.255	0.234	0.226	0.230	0.227	0.235	0.227	0.224	0.256	0.267
3	0.333	0.317	0.339	0.333	0.313	0.295	0.310	0.306	0.306	0.305	0.307	0.336
4	0.397	0.376	0.390	0.390	0.377	0.359	0.354	0.361	0.363	0.376	0.368	0.385
5	0.460	0.436	0.448	0.452	0.425	0.415	0.408	0.404	0.427	0.424	0.424	0.438
6	0.495	0.483	0.512	0.501	0.484	0.453	0.452	0.452	0.463	0.474	0.461	0.477
7	0.532	0.527	0.543	0.539	0.518	0.481	0.462	0.500	0.501	0.496	0.512	0.522
8	0.555	0.548	0.590	0.577	0.551	0.524	0.518	0.536	0.534	0.540	0.536	0.572
9	0.597	0.583	0.583	0.594	0.576	0.553	0.550	0.569	0.567	0.577	0.580	0.612
10	0.651	0.595	0.627	0.606	0.596	0.577	0.573	0.586	0.586	0.603	0.600	0.631
11	0.663	0.647	0.678	0.631	0.603	0.591	0.591	0.607	0.594	0.611	0.629	0.648
12	0.669	0.679	0.713	0.672	0.670	0.636	0.631	0.687	0.644	0.666	0.665	0.715

age	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.067	0.048	0.038	0.089	0.051	0.104	0.048	0.029	0.089	0.091	0.043	0.051
1	0.156	0.151	0.071	0.120	0.105	0.153	0.118	0.113	0.123	0.173	0.127	0.154
2	0.263	0.268	0.197	0.215	0.222	0.213	0.221	0.231	0.187	0.234	0.232	0.242
3	0.323	0.306	0.307	0.292	0.292	0.283	0.291	0.282	0.285	0.277	0.282	0.294
4	0.400	0.366	0.357	0.372	0.370	0.331	0.331	0.334	0.340	0.336	0.324	0.320
5	0.419	0.434	0.428	0.408	0.418	0.389	0.365	0.368	0.375	0.360	0.362	0.351
6	0.485	0.440	0.479	0.456	0.444	0.424	0.418	0.411	0.401	0.386	0.395	0.392
7	0.519	0.496	0.494	0.512	0.497	0.450	0.471	0.451	0.431	0.406	0.422	0.420
8	0.554	0.539	0.543	0.534	0.551	0.497	0.487	0.494	0.469	0.431	0.444	0.443
9	0.573	0.556	0.584	0.573	0.571	0.538	0.515	0.540	0.503	0.454	0.468	0.465
10	0.595	0.583	0.625	0.571	0.620	0.586	0.573	0.580	0.537	0.472	0.482	0.489
11	0.630	0.632	0.636	0.585	0.595	0.599	0.604	0.611	0.538	0.493	0.523	0.522
12	0.684	0.655	0.689	0.666	0.662	0.630	0.630	0.664	0.585	0.554	0.583	0.560

age	2016	2017	2018	2019
0	0.035	0.018	0.055	0.056
1	0.158	0.178	0.133	0.112
2	0.240	0.266	0.246	0.260
3	0.297	0.312	0.319	0.297

4	0.329	0.356	0.354	0.360
5	0.356	0.377	0.396	0.388
6	0.383	0.397	0.410	0.429
7	0.411	0.415	0.426	0.441
8	0.438	0.444	0.446	0.453
9	0.453	0.466	0.469	0.472
10	0.479	0.484	0.491	0.497
11	0.499	0.497	0.507	0.514
12	0.520	0.531	0.537	0.537

Table 8.7.1.4. NE Atlantic Mackerel. WEIGHTS AT AGE IN THE STOCK

Units : Kg

	year											
age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.063	0.063	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.114	0.112	0.112	0.111	0.108	0.111	0.104	0.075	0.099	0.058	0.096	0.174
2	0.205	0.179	0.159	0.179	0.204	0.244	0.184	0.157	0.181	0.162	0.166	0.184
3	0.287	0.258	0.217	0.233	0.251	0.281	0.269	0.234	0.238	0.230	0.247	0.243
4	0.322	0.312	0.300	0.282	0.293	0.308	0.301	0.318	0.298	0.272	0.290	0.303
5	0.356	0.335	0.368	0.341	0.326	0.336	0.350	0.368	0.348	0.338	0.332	0.347
6	0.377	0.376	0.362	0.416	0.395	0.356	0.350	0.414	0.392	0.392	0.383	0.392
7	0.402	0.415	0.411	0.404	0.430	0.407	0.374	0.415	0.445	0.388	0.435	0.423
8	0.434	0.431	0.456	0.438	0.455	0.455	0.434	0.431	0.442	0.449	0.447	0.492
9	0.438	0.454	0.455	0.475	0.489	0.447	0.428	0.483	0.466	0.432	0.494	0.500
10	0.484	0.450	0.473	0.467	0.507	0.519	0.467	0.487	0.506	0.429	0.473	0.546
11	0.520	0.524	0.536	0.544	0.513	0.538	0.506	0.492	0.567	0.482	0.495	0.526
12	0.532	0.530	0.542	0.528	0.566	0.590	0.541	0.581	0.594	0.556	0.536	0.619

	year											
age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.130	0.145	0.114	0.116	0.097	0.084	0.083	0.087	0.093	0.113	0.109	0.112
2	0.201	0.190	0.163	0.200	0.185	0.196	0.170	0.210	0.194	0.190	0.206	0.181
3	0.260	0.266	0.240	0.278	0.250	0.257	0.251	0.260	0.253	0.246	0.245	0.251
4	0.308	0.323	0.306	0.327	0.322	0.310	0.300	0.317	0.301	0.303	0.288	0.277
5	0.360	0.359	0.368	0.385	0.372	0.356	0.348	0.356	0.357	0.342	0.333	0.341
6	0.397	0.410	0.418	0.432	0.425	0.401	0.384	0.392	0.394	0.398	0.360	0.401
7	0.419	0.432	0.459	0.458	0.446	0.460	0.409	0.424	0.415	0.417	0.418	0.407
8	0.458	0.459	0.480	0.491	0.471	0.473	0.455	0.456	0.438	0.451	0.429	0.489
9	0.487	0.480	0.496	0.511	0.513	0.505	0.475	0.489	0.464	0.484	0.458	0.490
10	0.513	0.515	0.550	0.517	0.508	0.511	0.530	0.508	0.489	0.521	0.511	0.488
11	0.543	0.547	0.592	0.560	0.538	0.546	0.500	0.545	0.514	0.535	0.523	0.521
12	0.572	0.580	0.608	0.603	0.573	0.583	0.549	0.575	0.551	0.572	0.558	0.540

	year											
age	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.112	0.114	0.114	0.095	0.133	0.112	0.096	0.080	0.089	0.076	0.107	0.078
2	0.157	0.140	0.164	0.148	0.160	0.162	0.159	0.175	0.155	0.144	0.165	0.207
3	0.258	0.221	0.236	0.206	0.207	0.214	0.199	0.223	0.216	0.179	0.199	0.247
4	0.319	0.328	0.291	0.285	0.260	0.268	0.246	0.274	0.255	0.249	0.238	0.254
5	0.356	0.378	0.333	0.329	0.346	0.295	0.296	0.332	0.288	0.280	0.291	0.288
6	0.406	0.403	0.400	0.363	0.354	0.351	0.345	0.369	0.312	0.319	0.321	0.336
7	0.449	0.464	0.413	0.448	0.393	0.386	0.389	0.389	0.360	0.341	0.341	0.350
8	0.482	0.481	0.437	0.452	0.448	0.437	0.407	0.430	0.390	0.375	0.387	0.381

9	0.506	0.547	0.455	0.514	0.452	0.461	0.439	0.452	0.453	0.416	0.416	0.412
10	0.519	0.538	0.469	0.538	0.478	0.517	0.489	0.495	0.498	0.441	0.466	0.447
11	0.579	0.509	0.531	0.542	0.487	0.548	0.532	0.518	0.503	0.496	0.472	0.485
12	0.588	0.603	0.566	0.585	0.510	0.557	0.572	0.525	0.558	0.522	0.517	0.551

year

age	2016	2017	2018	2019
0	0.000	0.000	0.000	0.000
1	0.059	0.058	0.063	0.069
2	0.182	0.204	0.190	0.191
3	0.238	0.237	0.266	0.250
4	0.282	0.278	0.283	0.293
5	0.298	0.308	0.314	0.311
6	0.340	0.308	0.327	0.346
7	0.368	0.338	0.346	0.365
8	0.385	0.377	0.364	0.371
9	0.404	0.394	0.389	0.397
10	0.424	0.426	0.419	0.428
11	0.440	0.430	0.437	0.431
12	0.473	0.499	0.491	0.481

Table 8.7.1.5. NE Atlantic Mackerel. NATURAL MORTALITY

Units : NA

year

age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

year

age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

year

age	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Table 8.7.1.6. NE Atlantic Mackerel. PROPORTION MATURE

	year											
age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.093	0.097	0.097	0.098	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
2	0.521	0.497	0.498	0.485	0.467	0.516	0.522	0.352	0.360	0.372	0.392	0.435
3	0.872	0.837	0.857	0.863	0.853	0.885	0.926	0.922	0.901	0.915	0.909	0.912
4	0.949	0.934	0.930	0.940	0.938	0.940	0.983	0.994	0.989	0.994	0.996	0.991
5	0.972	0.976	0.969	0.972	0.966	0.966	0.965	0.997	0.994	0.996	0.998	0.996
6	0.984	0.984	0.987	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996
7	0.990	0.987	0.985	0.984	0.975	0.976	1.000	1.000	1.000	1.000	1.000	1.000
8	1.000	0.999	0.999	0.999	0.999	0.999	0.991	0.992	0.991	0.993	0.995	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	year											
age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.102	0.102	0.102	0.102	0.102	0.097	0.097	0.097	0.104	0.104	0.104	0.106
2	0.520	0.534	0.621	0.599	0.586	0.621	0.688	0.669	0.692	0.675	0.710	0.690
3	0.928	0.934	0.938	0.931	0.936	0.880	0.886	0.876	0.909	0.909	0.937	0.940
4	0.996	0.996	0.994	0.993	1.000	0.993	0.994	0.989	0.989	0.987	0.992	0.988
5	0.997	0.997	0.997	0.994	1.000	0.998	0.999	0.999	0.998	0.998	1.000	1.000
6	0.994	0.994	0.993	0.987	0.994	0.999	0.999	0.999	0.999	0.999	1.000	1.000
7	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	0.999	1.000	0.999
8	1.000	1.000	1.000	1.000	1.000	0.994	0.995	0.996	0.997	0.997	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	year											
age	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.106	0.106	0.095	0.095	0.095	0.096	0.096	0.096	0.094	0.092	0.092	0.104
2	0.761	0.616	0.589	0.546	0.524	0.541	0.667	0.655	0.604	0.683	0.675	0.763
3	0.962	0.959	0.928	0.921	0.917	0.919	0.930	0.927	0.926	0.921	0.916	0.944
4	0.993	0.993	0.994	0.994	0.999	0.999	0.999	0.999	0.999	0.998	0.999	0.998

age												
5	0.999	0.999	1.000	1.000	0.999	1.000	1.000	1.000	0.999	1.000	1.000	0.999
6	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.999	0.999	1.000
7	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

age \ year	2016	2017	2018	2019
0	0.000	0.000	0.000	0.000
1	0.103	0.101	0.086	0.086
2	0.632	0.624	0.459	0.434
3	0.937	0.931	0.877	0.873
4	0.997	0.997	0.998	0.997
5	0.999	1.000	1.000	1.000
6	1.000	1.000	1.000	1.000
7	0.999	1.000	1.000	1.000
8	1.000	1.000	1.000	0.999
9	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000

Table 8.7.1.7. NE Atlantic Mackerel. FRACTION OF HARVEST BEFORE SPAWNING

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.139	0.111
2	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.240	0.272
3	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.240	0.272
4	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.240	0.272
5	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
6	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
7	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
8	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
9	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
10	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
11	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
12	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406

age \ year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.084	0.165	0.249	0.331	0.269	0.206	0.144	0.125	0.106	0.088	0.142	0.197
2	0.304	0.301	0.298	0.296	0.295	0.295	0.295	0.320	0.347	0.373	0.360	0.347
3	0.304	0.301	0.298	0.296	0.295	0.295	0.295	0.320	0.347	0.373	0.360	0.347
4	0.304	0.301	0.298	0.296	0.295	0.295	0.295	0.320	0.347	0.373	0.360	0.347
5	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
6	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
7	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
8	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
9	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
10	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425

11	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
12	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425

age \ year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.251	0.262	0.274	0.285	0.206	0.125	0.047	0.092	0.138	0.183	0.170	0.156
2	0.334	0.317	0.300	0.284	0.266	0.249	0.232	0.176	0.119	0.064	0.117	0.171
3	0.334	0.317	0.300	0.284	0.266	0.249	0.232	0.176	0.119	0.064	0.117	0.171
4	0.334	0.317	0.300	0.284	0.266	0.249	0.232	0.176	0.119	0.064	0.117	0.171
5	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
6	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
7	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
8	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
9	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
10	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
11	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
12	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189

age \ year	2016	2017	2018	2019
0	0.000	0.000	0.000	0.000
1	0.143	0.232	0.393	0.581
2	0.224	0.153	0.179	0.182
3	0.224	0.153	0.179	0.182
4	0.224	0.153	0.179	0.182
5	0.176	0.292	0.194	0.298
6	0.176	0.292	0.194	0.298
7	0.176	0.292	0.194	0.298
8	0.176	0.292	0.194	0.298
9	0.176	0.292	0.194	0.298
10	0.176	0.292	0.194	0.298
11	0.176	0.292	0.194	0.298
12	0.176	0.292	0.194	0.298

Table 8.7.1.8. NE Atlantic Mackerel. FRACTION OF NATURAL MORTALITY BEFORE SPAWNING

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
1	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
2	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
3	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
4	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
5	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
6	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
7	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
8	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
9	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
10	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
11	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
12	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345

age \ year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
1	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355

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  2  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  3  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  4  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  5  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  6  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  7  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  8  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  9  0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  10 0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  11 0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
  12 0.333 0.341 0.349 0.357 0.339 0.322 0.304 0.325 0.346 0.366 0.361 0.355
    year
age  2004  2005  2006  2007  2008  2009  2010  2011  2012  2013  2014  2015
  0  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  1  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  2  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  3  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  4  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  5  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  6  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  7  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  8  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  9  0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  10 0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  11 0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
  12 0.350 0.346 0.342 0.339 0.311 0.283 0.255 0.252 0.249 0.246 0.278 0.311
    year
age  2016  2017  2018  2019
  0  0.343 0.327 0.312 0.296
  1  0.343 0.327 0.312 0.296
  2  0.343 0.327 0.312 0.296
  3  0.343 0.327 0.312 0.296
  4  0.343 0.327 0.312 0.296
  5  0.343 0.327 0.312 0.296
  6  0.343 0.327 0.312 0.296
  7  0.343 0.327 0.312 0.296
  8  0.343 0.327 0.312 0.296
  9  0.343 0.327 0.312 0.296
  10 0.343 0.327 0.312 0.296
  11 0.343 0.327 0.312 0.296
  12 0.343 0.327 0.312 0.296
```

Table 8.7.1.9. NE Atlantic Mackerel. SURVEY INDICES

```
Some random text

103

SSB-egg-based-survey

1992           2019

1              1              0              0
```

-1	-1		
1	3874476.93		
1	-1		
1	-1		
1	3766378.516		
1	-1		
1	-1		
1	4198626.531		
1	-1		
1	-1		
1	3233833.244		
1	-1		
1	-1		
1	3106808.703		
1	-1		
1	-1		
1	3782966.707		
1	-1		
1	-1		
1	4810751.571		
1	-1		
1	-1		
1	4831948.353		
1	-1		
1	-1		
1	3524054.85		
1	-1		
1	-1		
1	3087517.078		
R-idx			
1998	2019		
1	1	0	0
0	0		
1	0.009803925		
1	0.014577022		
1	0.010404596		
1	0.016275242		
1	0.020658814		
1	0.010053545		
1	0.023450373		
1	0.030321897		
1	0.027468238		
1	0.017962249		
1	0.016393821		
1	0.011593404		
1	0.017765551		
1	0.029744946		
1	0.021683204		

```
1               0.023765241
1               0.017731574
1               0.019571796
1               0.034173138
1               0.034918376
1               0.03092552
1               0.034394165
Swept-idx

2010            2020

1               1               0.58            0.75

3               11

1               1617005         4035646         3059146         1591100         691936          413253
                198106          65803           24747
1               -1              -1              -1              -1              -1              -1
                -1              -1              -1
1               1283247         2383260         2164365         2850847         1783942         740361
                299490          149282          84344
1               9201746         2456618         3073772         3218990         2540444         1087937
                377406          144695          146826
1               7034162         4896456         2659443         2630617         2768227         1910160
                849010          379745          95304
1               2539963         6409324         4802298         1795564         1628872         1254859
                727691          270562          72410
1               1374705         2635033         5243607         4368491         1893026         1658839
                1107866         754993          450100
1               3562908         1953609         3318099         4680603         4653944         1754954
                1944991         626406          507546
1               496595          2384310         1200541         1408582         2330520         1787503
                1049868         499295          557573
1               3814661         1211770         2920591         2856932         1948653         3906891
                3824410         1499778         1248160
1               1430995         3361778         2134411         2528651         2525460         2032783
                2904239         3835479         1495649
```

Table 8.7.1.10. NE Atlantic Mackerel. RFID recapture data for the year 2019

Release Yr	Recapture Yr	Year-class	age at release	Numbers scanned in recapture Yr	Numbers Released in Release Year	Numbers recaptured
2017	2019	2012	5	47038270	2628	8.13
2017	2019	2011	6	87331478	8210	26.31
2017	2019	2010	7	77710596	9859	31.43
2017	2019	2009	8	29651341	4146	13.10
2017	2019	2008	9	22475425	7259	22.19
2017	2019	2007	10	15337423	3585	10.87
2017	2019	2006	11	7230909	5351	14.01
2018	2019	2013	5	50910310	3049	15.74
2018	2019	2012	6	47038270	2290	14.29
2018	2019	2011	7	87331478	7924	56.24
2018	2019	2010	8	77710596	6506	45.99
2018	2019	2009	9	29651341	3274	19.60
2018	2019	2008	10	22475425	4093	25.13
2018	2019	2007	11	15337423	1670	7.65

Table 8.7.2.1. NE Atlantic Mackerel. SAM parameter estimates for the 2020 update.

	estimate	**std.dev**	**confidence interval lower bound**	**confidence interval upper bound**
observation standard deviations				
Catches age 0	0.94	0.18	0.65	1.36
Catches age 1	0.36	0.24	0.22	0.58
Catches age 2-12	0.11	0.16	0.08	0.15
Egg survey	0.30	0.26	0.18	0.50
Recruitment index	0.22	0.32	0.12	0.42
IESSNS age 3	0.69	0.27	0.41	1.18
IESSNS ages 4-11	0.41	0.17	0.29	0.58
Recapture overdispersion tags	1.22	0.25	1.37	1.13
random walk standard deviation				
F age 0	0.24	0.58	0.07	0.76
F age 1	0.17	0.48	0.07	0.45
F age 2+	0.12	0.20	0.08	0.17
N@age0	0.27	0.29	0.15	0.49
process error standard deviation				
N@age1-12+	0.20	0.09	0.17	0.24

	estimate	std.dev	confidence interval lower bound	confidence interval upper bound
catchabilities				
egg survey	1.26	0.11	1.01	1.56
recruitment index	3.84E-09	1.15E-01	3.06E-09	4.83E-09
IESSNS age 3	0.87	0.25	0.53	1.44
IESSNS age 4	1.29	0.17	0.91	1.83
IESSNS age 5	1.82	0.17	1.28	2.58
IESSNS age 6	2.11	0.18	1.48	3.00
IESSNS age 7	2.30	0.18	1.61	3.28
IESSNS age 8	2.29	0.18	1.60	3.28
IESSNS age 9	2.37	0.18	1.66	3.37
IESSNS ages 10-11	2.10	0.17	1.48	2.97
post tagging survival steal tags	0.40	0.11	0.35	0.45
post tagging survival RFID tags	0.13	0.11	0.11	0.15

Table 8.7.3.1. NE Atlantic Mackerel. STOCK SUMMARY. Low = lower limit and High = higher limit of 95% confidence interval.

Year	Recruitment (age0)			SSB***			Total Catch	Fbar4-8		
	Value	High	Low	Value	High	Low		Value	High	Low
	thousands			tonnes			tonnes			
1980	5572936	10727303	2895194	4130557	8637217	1975347	734950	0.23	0.34	0.150
1981	4966060	8515561	2896081	3611497	6693109	1948707	754045	0.23	0.34	0.153
1982	3741521	6513628	2149183	3475871	5772932	2092815	716987	0.23	0.33	0.156
1983	3519462	6220803	1991160	3707488	5520614	2489845	672283	0.23	0.33	0.159
1984	4307916	6952674	2669209	3991764	5565543	2863006	641928	0.23	0.32	0.163
1985	4132124	6519946	2618802	3973102	5311215	2972115	614371	0.23	0.32	0.168
1986	4112682	6370616	2655026	3558998	4661684	2717144	602201	0.24	0.32	0.174
1987	4298594	6652654	2777525	3522335	4610074	2691246	654992	0.24	0.32	0.180
1988	3765039	5710694	2482277	3465632	4427463	2712751	680491	0.25	0.32	0.188
1989	3574276	5425495	2354706	3239641	4073462	2576499	585920	0.26	0.33	0.198
1990	3257247	5026441	2110769	3327113	4111708	2692234	626107	0.27	0.34	0.21

Year	Recruitment (age0)			SSB***			Total Catch	Fbar4-8		
	Value	High	Low	Value	High	Low		Value	High	Low
	thousands			tonnes			tonnes			
1991	3345760	5058755	2212820	3223833	3943199	2635703	675665	0.28	0.35	0.22
1992	3415441	5168969	2256783	2967654	3595659	2449334	760690	0.29	0.36	0.23
1993	3114294	4680828	2072032	2648249	3189148	2199089	824568	0.30	0.37	0.24
1994	2954974	4437266	1967849	2328879	2785266	1947274	819087	0.31	0.38	0.25
1995	2820793	4267666	1864456	2304722	2734993	1942141	756277	0.31	0.38	0.26
1996	2978741	4516989	1964339	2188968	2589632	1850294	563472	0.31	0.37	0.26
1997	2921373	4340664	1966156	2152980	2515835	1842459	573029	0.30	0.36	0.26
1998	2960497	4093330	2141176	2125366	2488697	1815079	666316	0.31	0.36	0.26
1999	3368150	4639896	2444976	2307589	2695494	1975508	640309	0.32	0.37	0.28
2000	2984820	4295521	2074056	2282430	2607157	1998149	738606	0.34	0.38	0.29
2001	4620927	6454857	3308046	2169060	2473101	1902397	737463	0.36	0.42	0.31
2002	5395320	7791439	3736085	2070613	2389340	1794402	771422	0.38	0.45	0.33
2003	3744163	5676313	2469694	1995321	2304925	1727304	679287	0.40	0.48	0.34
2004	5033082	7034533	3601080	2606407	3054854	2223791	660491	0.37	0.44	0.32
2005	6498029	9816243	4301480	2352444	2765016	2001432	549514	0.32	0.37	0.27
2006	6383515	9361051	4353065	2140762	2513446	1823339	481181	0.30	0.35	0.26
2007	5015005	6967214	3609804	2254547	2628082	1934102	586206	0.33	0.38	0.28
2008	4550703	6385587	3243069	2618575	3097246	2213881	623165	0.32	0.37	0.28
2009	4285860	6372587	2882439	3230003	3830012	2723991	737969	0.30	0.35	0.26
2010	5444074	7656107	3871150	3579017	4213284	3040233	875515	0.29	0.34	0.25
2011	6714868	9956508	4528641	4063019	4795796	3442207	946661	0.29	0.34	0.25
2012	5749246	8016197	4123380	3730890	4436867	3137246	892353	0.28	0.33	0.23
2013	5542105	7748556	3963955	4123080	4934630	3444998	931732	0.28	0.34	0.23
2014	5649315	7903794	4037904	5161009	6170029	4316999	1393000	0.28	0.34	0.23
2015	5094374	7187990	3610557	5148898	6210213	4268960	1208990	0.27	0.33	0.22
2016	6599783	10111607	4307638	4884807	5943050	4014998	1094066	0.24	0.30	0.194
2017	7085600	10816190	4641720	4747484	5819768	3872767	1155944	0.24	0.30	0.191

Year	Recruitment (age0)			SSB***			Total Catch	Fbar4-8		
	Value	High	Low	Value	High	Low		Value	High	Low
	thousands			tonnes			tonnes			
2018	7451634	11259749	4931447	4152849	5193354	3320813	1026437	0.24	0.31	0.185
2019	7057000*			3731510	4924356	2827612	840021	0.22	0.30	0.165
2020	4430112**			3681413†						

* RCT3 estimate.

** Geometric mean 1990–2018.

*** SSB at spawning time.

† Estimated value from the forecast.

Table 8.7.3.2. NE Atlantic Mackerel. ESTIMATED POPULATION ABUNDANCE

Units : Thousands

age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	5572936	4966060	3741521	3519462	4307916	4132124	4112682	4298594	3765039	3574276
1	5059703	5156096	4751452	2751455	2519004	4312198	3425431	3388021	4169732	3032119
2	2366103	4200755	4647301	4432318	1980390	1767144	4204690	2780853	2737326	3948713
3	972617	1907207	3505106	4330549	4401661	1382422	1248325	4094916	2194615	2365721
4	1670355	745579	1432234	2919114	3854844	4070008	1031163	852185	3742853	1691953
5	3540051	1229675	533788	982660	2204833	3102217	3165340	803289	539280	2968855
6	2724560	2460783	872768	387809	669542	1620563	2243664	2163825	606646	347333
7	795585	1809916	1632974	583760	268437	459435	1071907	1496891	1404158	459843
8	294394	541619	1234353	1111319	394264	190575	306124	749740	1025700	1043380
9	816193	200404	368380	841506	754654	270488	132877	203092	522697	706760
10	218593	555943	136360	250270	572819	511456	186991	90031	134082	353101
11	320045	148814	378130	92744	169926	388461	344831	125898	60645	86320
12	669213	674165	559725	635942	493458	448983	563036	606425	487099	362287

age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	3257247	3345760	3415441	3114294	2954974	2820793	2978741	2921373	2960497	3368150
1	3127474	2560910	2879523	3145471	2589204	2511345	2250092	2670847	2434188	2624697
2	2389105	2669178	1969105	2420713	2826323	2097342	2081206	1749338	2334228	1975858
3	3918840	2126393	2540092	1628246	1980730	2396165	2165389	1936745	1253369	2364122
4	1843359	3033656	1518849	2022140	1095400	1427237	1810909	1782181	1636758	1257978
5	1089708	1256098	1920333	986309	1382150	684726	976060	1210849	1506954	1262950
6	1959594	773918	937302	1148175	586521	964922	494013	727274	859894	903537
7	215222	1210244	470372	563212	643228	345096	571441	323347	479061	610664
8	343803	137143	726816	307980	336370	286160	216051	345632	261630	308553
9	706915	241483	88432	412727	183495	179555	141082	152011	210399	178852
10	457129	477034	155305	53267	220945	111202	95698	88336	101807	129818
11	233709	287577	299699	95445	30455	135687	64911	51296	54276	62748
12	294216	341835	400351	436829	326384	216495	214492	173874	143032	125690

age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	2984820	4620927	5395320	3744163	5033082	6498029	6383515	5015005	4550703	4285860

1	3088791	1828992	5174297	6383423	2756758	3914370	5964390	5567172	4142420	3948696
2	2274794	2606397	1155531	4810464	6804138	2336716	3368928	4796576	4781373	3396133
3	1843905	1759278	2508150	795368	3916446	5307049	1669941	2431298	4331205	4889319
4	1841696	1311896	1544963	1562621	744657	1846932	3111634	1427964	1911146	3811730
5	1032173	1247383	986326	913096	994532	528705	1008728	2023714	1190342	1537271
6	858325	675176	805658	575942	473550	472208	365594	727922	1072750	867800
7	613370	599291	410775	381031	266168	227947	274604	249178	409959	660334
8	371066	407858	345897	241823	184146	132334	128547	179731	172411	253059
9	188910	237187	228067	194603	116354	85856	71562	92336	98870	104916
10	112064	126085	127339	117360	91727	61308	51346	46143	56778	50443
11	69372	67936	62992	66566	47317	30879	31147	33350	21459	27569
12	120860	125630	111587	81515	56940	39751	37502	38743	30481	19779

	year									
age	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	5444074	6714868	5749246	5542105	5649315	5094374	6599783	7085600	7451634	8076757
1	3969788	5399307	6504051	4548831	4237175	5805860	3470984	5728555	4839044	5942755
2	3823419	3228433	5435066	6545156	3691941	3334168	5174081	2223628	5361504	3268565
3	3282211	3548370	2613722	5124994	6758175	2888362	2676402	4491903	1451594	3837308
4	4549133	2937621	2867672	2312816	4839479	4502280	2662097	2110303	2942207	1003149
5	2831488	3222021	2255704	2300062	2196323	3332275	3164784	2029934	1405068	1670009
6	1196460	1994304	2226237	1989501	2070860	1729451	2516843	2548650	1366488	1173744
7	538050	851652	1246767	1450411	1767781	1599255	1344641	2178284	1797655	950071
8	354723	385010	545776	765779	1174371	1303366	1146203	1054256	1416843	1257321
9	160305	193316	243234	363435	528759	834725	767930	900159	803881	1032645
10	70064	88237	114403	148229	237245	398262	454963	553315	537506	488384
11	24090	42879	48010	72986	80740	119204	195565	306993	378265	338521
12	30218	36536	45081	61342	55925	87406	115353	219148	276903	367467

Table 8.7.3.3. NE Atlantic Mackerel. ESTIMATED FISHING MORTALITY

	year													
age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1	0.032	0.032	0.032	0.032	0.032	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
2	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.060	0.060	0.060	0.061	0.062
3	0.115	0.115	0.115	0.115	0.116	0.118	0.120	0.121	0.123	0.126	0.128	0.131	0.134	0.136
4	0.186	0.186	0.187	0.187	0.188	0.190	0.194	0.199	0.203	0.209	0.214	0.219	0.222	0.225
5	0.214	0.214	0.215	0.216	0.218	0.220	0.224	0.227	0.233	0.237	0.242	0.247	0.255	0.261
6	0.261	0.261	0.262	0.263	0.266	0.270	0.274	0.279	0.284	0.293	0.302	0.311	0.319	0.326
7	0.235	0.235	0.235	0.236	0.237	0.240	0.244	0.250	0.257	0.268	0.284	0.305	0.327	0.348
8	0.235	0.235	0.235	0.236	0.237	0.240	0.244	0.250	0.257	0.268	0.284	0.305	0.327	0.348
9	0.235	0.235	0.235	0.236	0.237	0.240	0.244	0.250	0.257	0.268	0.284	0.305	0.327	0.348
10	0.235	0.235	0.235	0.236	0.237	0.240	0.244	0.250	0.257	0.268	0.284	0.305	0.327	0.348
11	0.235	0.235	0.235	0.236	0.237	0.240	0.244	0.250	0.257	0.268	0.284	0.305	0.327	0.348
12	0.235	0.235	0.235	0.236	0.237	0.240	0.244	0.250	0.257	0.268	0.284	0.305	0.327	0.348

	year													
age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.005	0.005	0.005	0.005
1	0.031	0.031	0.031	0.031	0.030	0.030	0.030	0.028	0.028	0.024	0.020	0.019	0.019	0.017
2	0.062	0.063	0.064	0.065	0.066	0.067	0.068	0.068	0.067	0.066	0.067	0.062	0.055	0.046
3	0.139	0.141	0.143	0.146	0.149	0.155	0.162	0.158	0.158	0.144	0.146	0.136	0.117	0.108
4	0.228	0.229	0.230	0.231	0.235	0.242	0.254	0.261	0.258	0.237	0.224	0.200	0.186	0.181
5	0.264	0.269	0.276	0.287	0.301	0.314	0.331	0.323	0.328	0.323	0.313	0.284	0.262	0.268
6	0.330	0.331	0.332	0.334	0.340	0.351	0.368	0.401	0.399	0.403	0.386	0.351	0.340	0.337

```
  7  0.362 0.360 0.346 0.335 0.338 0.350 0.362 0.413 0.470 0.516 0.475 0.375 0.353 0.423
  8  0.362 0.360 0.346 0.335 0.338 0.350 0.362 0.413 0.470 0.516 0.475 0.375 0.353 0.423
  9  0.362 0.360 0.346 0.335 0.338 0.350 0.362 0.413 0.470 0.516 0.475 0.375 0.353 0.423
  10 0.362 0.360 0.346 0.335 0.338 0.350 0.362 0.413 0.470 0.516 0.475 0.375 0.353 0.423
  11 0.362 0.360 0.346 0.335 0.338 0.350 0.362 0.413 0.470 0.516 0.475 0.375 0.353 0.423
  12 0.362 0.360 0.346 0.335 0.338 0.350 0.362 0.413 0.470 0.516 0.475 0.375 0.353 0.423
    year
age  2008  2009  2010  2011  2012  2013  2014  2015  2016  2017  2018  2019
  0  0.004 0.004 0.004 0.004 0.003 0.003 0.003 0.002 0.002 0.002 0.002 0.002
  1  0.016 0.015 0.015 0.014 0.013 0.012 0.012 0.013 0.012 0.011 0.010 0.010
  2  0.041 0.039 0.039 0.039 0.040 0.040 0.041 0.042 0.043 0.044 0.046 0.044
  3  0.105 0.104 0.103 0.100 0.096 0.095 0.103 0.102 0.107 0.111 0.108 0.106
  4  0.180 0.186 0.187 0.184 0.179 0.183 0.185 0.170 0.177 0.176 0.156 0.143
  5  0.263 0.256 0.256 0.249 0.246 0.245 0.263 0.241 0.229 0.228 0.221 0.216
  6  0.316 0.313 0.300 0.297 0.287 0.281 0.299 0.294 0.265 0.252 0.252 0.241
  7  0.419 0.368 0.359 0.362 0.336 0.343 0.333 0.317 0.270 0.272 0.282 0.259
  8  0.419 0.368 0.359 0.362 0.336 0.343 0.333 0.317 0.270 0.272 0.282 0.259
  9  0.419 0.368 0.359 0.362 0.336 0.343 0.333 0.317 0.270 0.272 0.282 0.259
  10 0.419 0.368 0.359 0.362 0.336 0.343 0.333 0.317 0.270 0.272 0.282 0.259
  11 0.419 0.368 0.359 0.362 0.336 0.343 0.333 0.317 0.270 0.272 0.282 0.259
  12 0.419 0.368 0.359 0.362 0.336 0.343 0.333 0.317 0.270 0.272 0.282 0.259
```

Table 8.8.3.1. NE Atlantic Mackerel. Short-term prediction: INPUT DATA

	Stock Numbers	M	Maturity ogive	Prop of F before spw.	Prop of M before spw.	Weights in the stock	Exploita-tion pat-tern	Weights in the catch
2020								
0	4430112	0.15	0.000	0.000	0.312	0.000	0.002	0.043
1	6064337	0.15	0.091	0.402	0.312	0.063	0.010	0.141
2	5065488	0.15	0.506	0.171	0.312	0.195	0.045	0.257
3	2450408	0.15	0.894	0.171	0.312	0.251	0.108	0.309
4	2822877	0.15	0.998	0.171	0.312	0.285	0.158	0.357
5	949832	0.15	1.000	0.261	0.312	0.311	0.221	0.387
6	1045059	0.15	1.000	0.261	0.312	0.327	0.248	0.412
7	836320	0.15	1.000	0.261	0.312	0.350	0.271	0.427
8	625709	0.15	0.999	0.261	0.312	0.371	0.271	0.448
9	771079	0.15	1.000	0.261	0.312	0.393	0.271	0.469
10	859918	0.15	1.000	0.261	0.312	0.424	0.271	0.491
11	356221	0.15	1.000	0.261	0.312	0.433	0.271	0.506
12+	469103	0.15	1.000	0.261	0.312	0.490	0.271	0.535

	Stock Numbers	M	Maturity ogive	Prop of F before spw.	Prop of M before spw.	Weights in the stock	Exploita-tion pat-tern	Weights in the catch
2021								
0	4430112	0.15	0.000	0.000	0.312	0.000	0.002	0.043
1	-	0.15	0.091	0.402	0.312	0.063	0.010	0.141
2	-	0.15	0.506	0.171	0.312	0.195	0.045	0.257
3	-	0.15	0.894	0.171	0.312	0.251	0.108	0.309
4	-	0.15	0.998	0.171	0.312	0.285	0.158	0.357
5	-	0.15	1.000	0.261	0.312	0.311	0.221	0.387
6	-	0.15	1.000	0.261	0.312	0.327	0.248	0.412
7	-	0.15	1.000	0.261	0.312	0.350	0.271	0.427
8	-	0.15	0.999	0.261	0.312	0.371	0.271	0.448
9	-	0.15	1.000	0.261	0.312	0.393	0.271	0.469
10	-	0.15	1.000	0.261	0.312	0.424	0.271	0.491
11	-	0.15	1.000	0.261	0.312	0.433	0.271	0.506
12+	-	0.15	1.000	0.261	0.312	0.490	0.271	0.535
2022								
0	4430112	0.15	0.000	0.000	0.312	0.000	0.002	0.043
1	-	0.15	0.091	0.402	0.312	0.063	0.010	0.141
2	-	0.15	0.506	0.171	0.312	0.195	0.045	0.257
3	-	0.15	0.894	0.171	0.312	0.251	0.108	0.309
4	-	0.15	0.998	0.171	0.312	0.285	0.158	0.357
5	-	0.15	1.000	0.261	0.312	0.311	0.221	0.387
6	-	0.15	1.000	0.261	0.312	0.327	0.248	0.412
7	-	0.15	1.000	0.261	0.312	0.350	0.271	0.427
8	-	0.15	0.999	0.261	0.312	0.371	0.271	0.448
9	-	0.15	1.000	0.261	0.312	0.393	0.271	0.469
10	-	0.15	1.000	0.261	0.312	0.424	0.271	0.491
11	-	0.15	1.000	0.261	0.312	0.433	0.271	0.506
12+	-	0.15	1.000	0.261	0.312	0.490	0.271	0.535

Table 8.8.3.2. NE Atlantic Mackerel. Short-term prediction: Multi-option table for 1 090 879 t catch in 2020 and a range of F-values in 2021.

2020			
TSB	**SSB**	**F_{bar}**	**Catch**
5 004 319	3 681 413	0.316	1 090 879

2021				2022		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
4818501	3810530	0	0	5327305	4458501	-100.0%
-	3803628	0.01	36401	5297077	4421805	-96.7%
-	3796743	0.02	72490	5267114	4385520	-93.4%
-	3789874	0.03	108269	5237412	4349641	-90.1%
-	3783023	0.04	143741	5207969	4314161	-86.8%
-	3776188	0.05	178909	5178782	4279077	-83.6%
-	3769370	0.06	213776	5149848	4244383	-80.4%
-	3762568	0.07	248346	5121166	4210074	-77.2%
-	3755784	0.08	282621	5092732	4176146	-74.1%
-	3749015	0.09	316603	5064545	4142593	-71.0%
-	3742264	0.10	350297	5036601	4109412	-67.9%
-	3735528	0.11	383704	5008899	4076597	-64.8%
-	3728809	0.12	416828	4981435	4044144	-61.8%
-	3722107	0.13	449670	4954209	4012048	-58.8%
-	3715421	0.14	482235	4927216	3980304	-55.8%
-	3708751	0.15	514525	4900455	3948910	-52.8%
-	3702097	0.16	546541	4873924	3917859	-49.9%
-	3695460	0.17	578288	4847621	3887148	-47.0%
-	3688839	0.18	609768	4821542	3856772	-44.1%
-	3682233	0.19	640982	4795687	3826728	-41.2%
-	3675644	0.20	671935	4770052	3797011	-38.4%
-	3669071	0.21	702628	4744635	3767617	-35.6%

2021				2022		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	3662514	0.22	733063	4719436	3738543	-32.8%
-	3655973	0.23	763244	4694450	3709783	-30.0%
-	3649448	0.24	793173	4669677	3681335	-27.3%
-	3642939	0.25	822852	4645113	3653194	-24.6%
-	3636445	0.26	852284	4620758	3625357	-21.9%
-	3629967	0.27	881471	4596609	3597820	-19.2%
-	3623505	0.28	910416	4572663	3570579	-16.5%
-	3617059	0.29	939120	4548920	3543630	-13.9%
-	3610628	0.30	967586	4525377	3516970	-11.3%
-	3604213	0.31	995817	4502032	3490595	-8.7%
-	3597813	0.32	1023814	4478883	3464503	-6.1%
-	3591429	0.33	1051581	4455928	3438688	-3.6%
-	3585061	0.34	1079118	4433165	3413148	-1.1%
-	3578708	0.35	1106429	4410593	3387880	1.4%
-	3572370	0.36	1133515	4388209	3362880	3.9%
-	3566047	0.37	1160380	4366012	3338145	6.4%
-	3559740	0.38	1187023	4344000	3313672	8.8%
-	3553448	0.39	1213449	4322172	3289457	11.2%
-	3547172	0.40	1239659	4300524	3265497	13.6%
-	3540910	0.41	1265655	4279056	3241789	16.0%
-	3534664	0.42	1291439	4257766	3218331	18.4%
-	3528433	0.43	1317014	4236653	3195118	20.7%
-	3522216	0.44	1342380	4215713	3172148	23.1%
-	3516015	0.45	1367541	4194946	3149419	25.4%
-	3509829	0.46	1392498	4174351	3126926	27.6%
-	3503658	0.47	1417253	4153924	3104668	29.9%
-	3497501	0.48	1441807	4133666	3082641	32.2%
-	3491360	0.49	1466164	4113574	3060843	34.4%

2021				2022		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
-	3485233	0.50	1490325	4093646	3039270	36.6%
-	3479121	0.51	1514291	4073881	3017921	38.8%
-	3473024	0.52	1538065	4054278	2996792	41.0%
-	3466941	0.53	1561648	4034834	2975880	43.2%
-	3460874	0.54	1585042	4015549	2955184	45.3%
-	3454820	0.55	1608249	3996420	2934700	47.4%
-	3448782	0.56	1631271	3977447	2914426	49.5%
-	3442757	0.57	1654110	3958627	2894359	51.6%
-	3436748	0.58	1676766	3939960	2874497	53.7%
-	3430753	0.59	1699243	3921444	2854838	55.8%
-	3424772	0.60	1721541	3903077	2835378	57.8%
-	3418805	0.61	1743662	3884858	2816116	59.8%
-	3412853	0.62	1765609	3866785	2797049	61.9%
-	3406915	0.63	1787382	3848858	2778175	63.8%
-	3400992	0.64	1808983	3831074	2759492	65.8%
-	3395083	0.65	1830414	3813433	2740996	67.8%
-	3389187	0.66	1851677	3795933	2722687	69.7%
-	3383306	0.67	1872772	3778572	2704562	71.7%
-	3377440	0.68	1893703	3761350	2686618	73.6%
-	3371587	0.69	1914469	3744265	2668853	75.5%
-	3365748	0.70	1935073	3727316	2651266	77.4%
-	3359923	0.71	1955517	3710501	2633854	79.3%
-	3354112	0.72	1975801	3693819	2616614	81.1%
-	3348315	0.73	1995927	3677270	2599546	83.0%
-	3342532	0.74	2015898	3660850	2582647	84.8%
-	3336763	0.75	2035713	3644561	2565915	86.6%
-	3331008	0.76	2055375	3628399	2549348	88.4%
-	3325266	0.77	2074885	3612365	2532944	90.2%

2021				2022		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	3319538	0.78	2094244	3596456	2516701	92.0%
-	3313824	0.79	2113454	3580672	2500617	93.7%
-	3308123	0.80	2132517	3565011	2484691	95.5%
-	3302436	0.81	2151433	3549472	2468920	97.2%
-	3296763	0.82	2170204	3534055	2453303	98.9%
-	3291103	0.83	2188832	3518758	2437837	100.6%
-	3285456	0.84	2207317	3503579	2422522	102.3%
-	3279824	0.85	2225661	3488518	2407355	104.0%
-	3274204	0.86	2243865	3473574	2392335	105.7%
-	3268598	0.87	2261931	3458745	2377459	107.3%
-	3263005	0.88	2279860	3444031	2362726	109.0%
-	3257426	0.89	2297653	3429430	2348135	110.6%
-	3251860	0.90	2315311	3414941	2333684	112.2%
-	3246307	0.91	2332836	3400564	2319371	113.8%
-	3240767	0.92	2350228	3386297	2305195	115.4%
-	3235241	0.93	2367490	3372139	2291154	117.0%
-	3229728	0.94	2384622	3358089	2277246	118.6%
-	3224227	0.95	2401626	3344146	2263470	120.2%
-	3218740	0.96	2418502	3330310	2249824	121.7%
-	3213266	0.97	2435252	3316578	2236307	123.2%
-	3207805	0.98	2451877	3302951	2222917	124.8%
-	3202357	0.99	2468378	3289427	2209654	126.3%
-	3196922	1.00	2484756	3276006	2196515	127.8%
-	3191500	1.01	2501012	3262685	2183498	129.3%
-	3186090	1.02	2517148	3249465	2170604	130.7%
-	3180694	1.03	2533165	3236345	2157829	132.2%
-	3175310	1.04	2549063	3223323	2145174	133.7%
-	3169939	1.05	2564844	3210399	2132635	135.1%

2021				2022		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
-	3164580	1.06	2580509	3197571	2120213	136.6%
-	3159235	1.07	2596059	3184839	2107906	138.0%
-	3153902	1.08	2611494	3172202	2095712	139.4%
-	3148582	1.09	2626817	3159660	2083630	140.8%

Table 8.8.3.3. NE Atlantic Mackerel. Short-term prediction: Management option table for 1 090 879 t catch in 2020 and a range of catch options in 2021.

Rationale	Catch (2021)	F_{bar} (2021)	SSB (2021)	SSB (2022)	% SSB change	% catch change	% advice change
MSY approach: F = FMSY	852284	0.26	3636445	3625357	-0.3	-21.9	-7.6
Norway-EU-Faroes LTMS Catch(2021) = 2020 TAC -20%^	737651	0.22	3661522	3734166	2.0	-32.4	-20.0
Fbar(2021) = 0.21(LTMS target F)	702628	0.21	3669071	3767617	2.7	-35.6	-23.8
Catch(2021) = 2020 TAC	922064	0.28	3620894	3559635	-1.7	-15.5	0.0
Catch(2021) = 2020 TAC +25%	1152580	0.37	3567887	3345321	-6.2	5.7	25.0
Catch(2021) = Zero	0	0	3810530	4458501	17.0	-100.0	-100.0
Catch(2021) = 2020 catch -20%	872703	0.27	3631917	3606085	-0.7	-20.0	-5.4
Catch(2021) = 2020 catch	1090879	0.34	3582329	3402260	-5.0	0.0	18.3
Catch(2021) = 2020 catch +25%	1363599	0.45	3516989	3152976	-10.4	25.0	47.9
Fbar(2021) = Fbar(2020)	1012503	0.32	3600404	3475037	-3.5	-7.2	9.8
Fbar(2021) = 0.36 (Fpa)	1133515	0.36	3572370	3362880	-5.9	3.9	22.9
Fbar(2021) = 0.46 (Flim)	1392498	0.46	3509829	3126926	-10.9	27.6	51.0

*** SSB 2022 relative to SSB 2021.**

**** Catch in 2021 relative to estimated catches in 2020 (1 090 879 t). There is no internationally agreed TAC for 2020.**

***** Advice value for 2021 relative to the advice value for 2020 (922 064 t).**

^ Following the consultations between Norway, the European Union, and the Faroe Islands on the management of mackerel in the northeast Atlantic, a total catch of 922 064 t was set for 2020 (Anon., 2019).

8.15 Figures

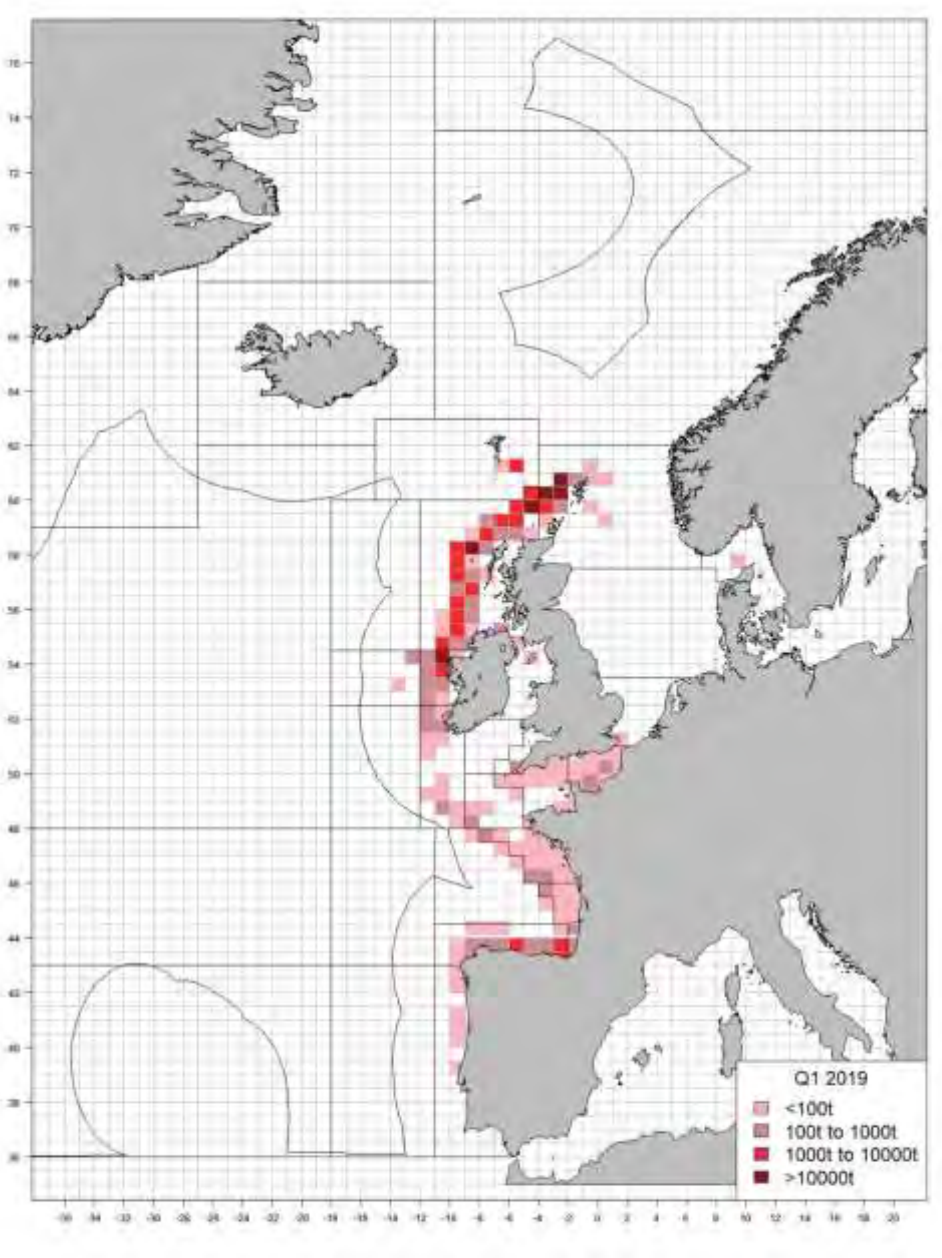

Figure 8.4.2.1. NE Atlantic Mackerel. Commercial catches in 2019, quarter 1.

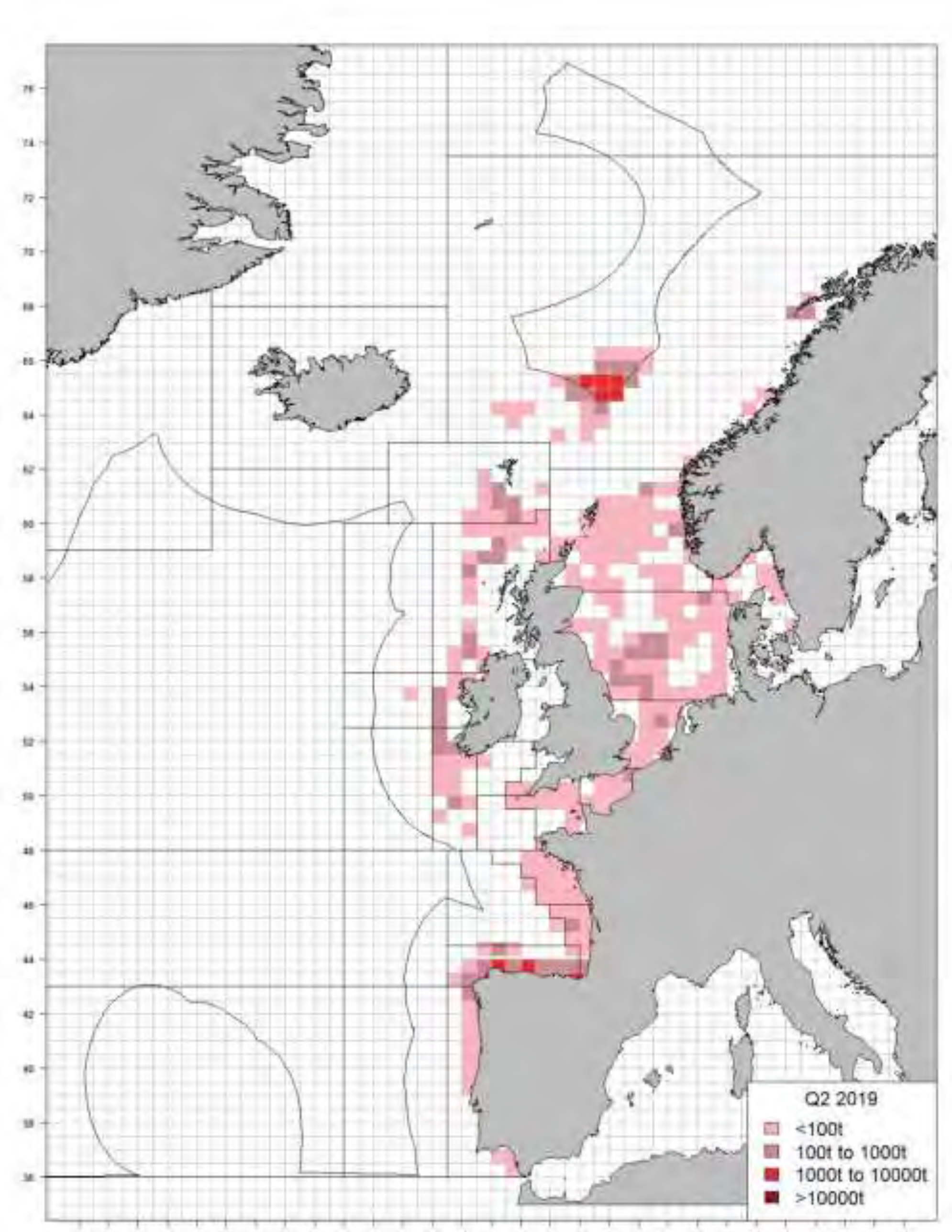

Figure 8.4.2.2. NE Atlantic Mackerel. Commercial catches in 2019, quarter 2.

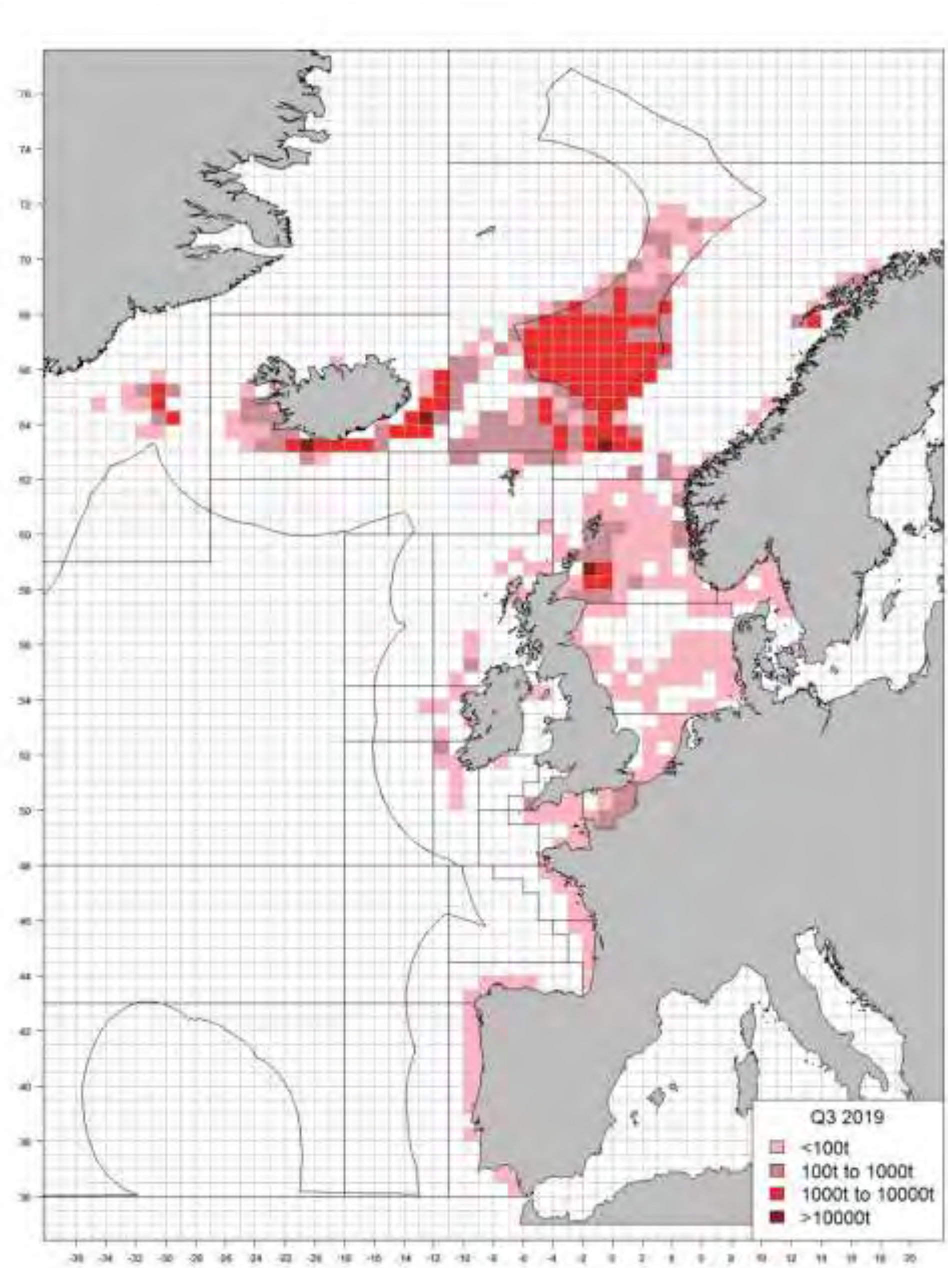

Figure 8.4.2.3. NE Atlantic Mackerel. Commercial catches in 2019, quarter 3.

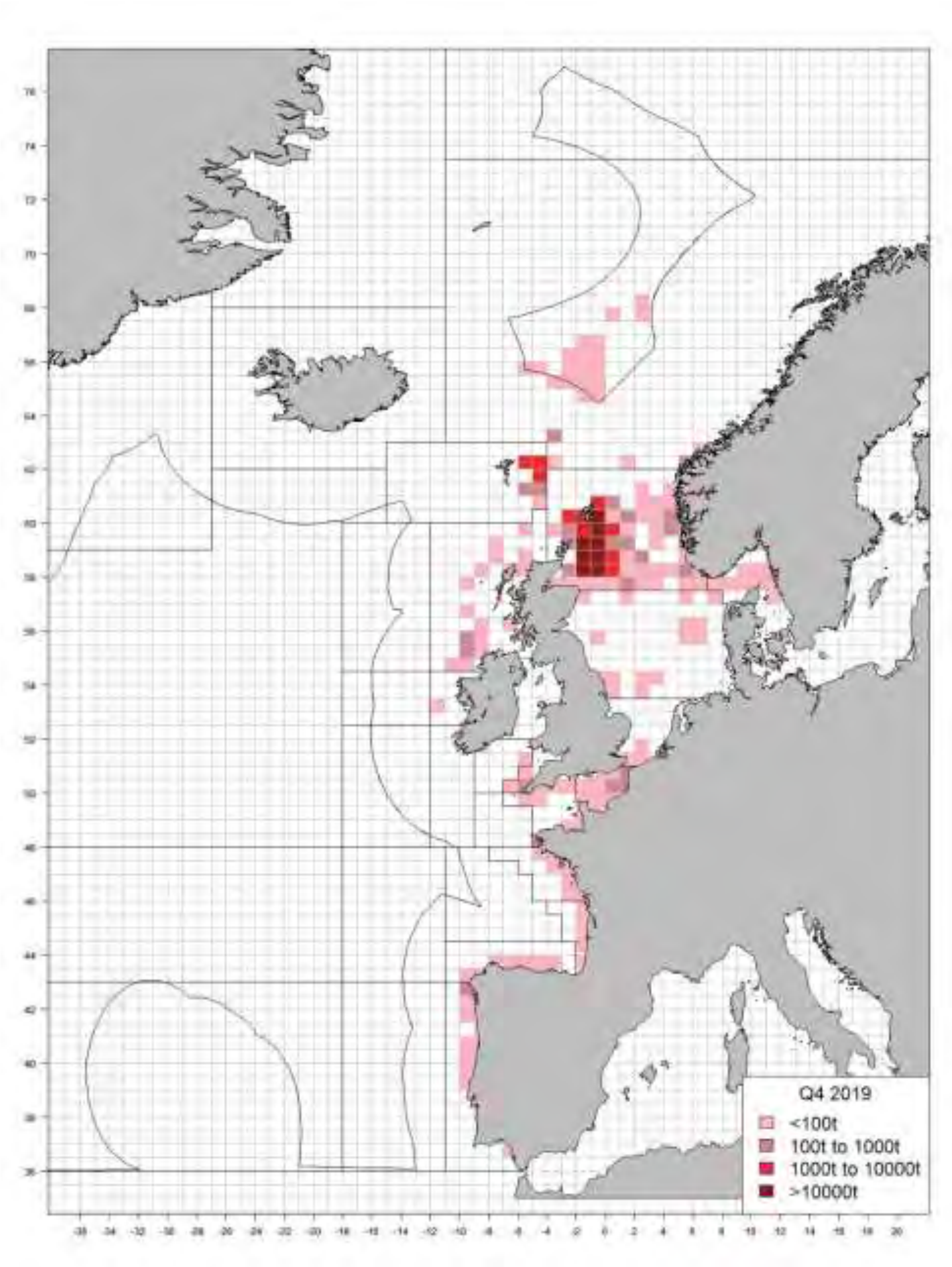

Figure 8.4.2.4. NE Atlantic Mackerel. Commercial catches in 2019, quarter 4.

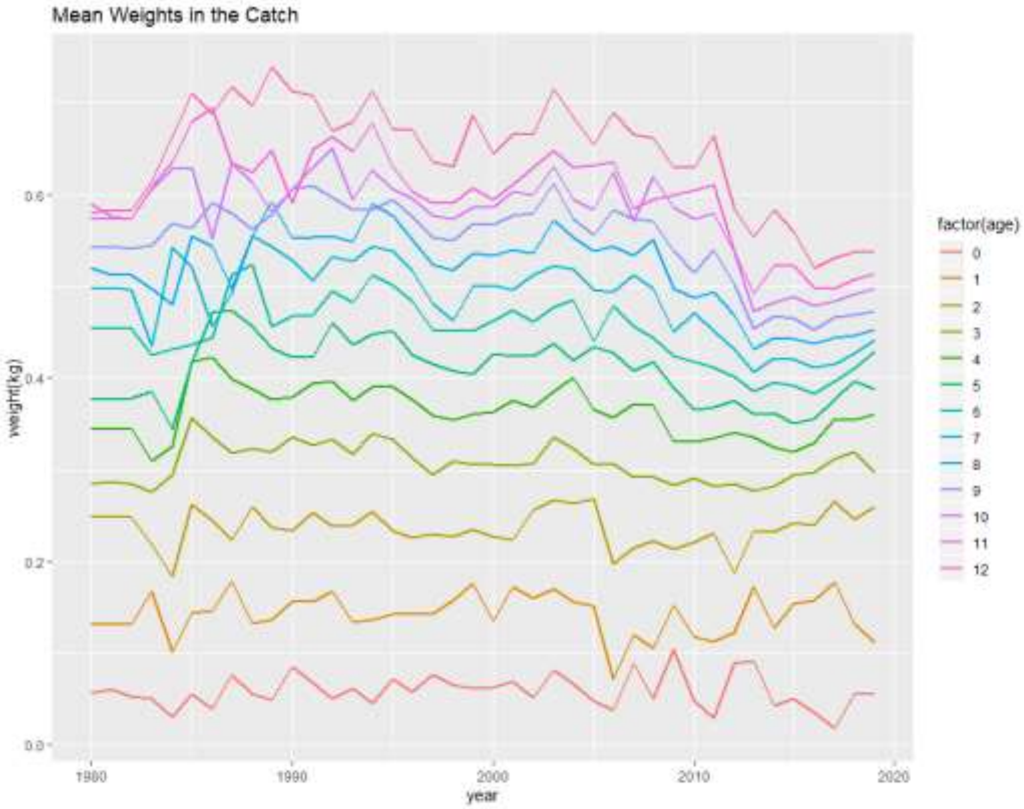

Figure 8.5.2.1. NE Atlantic mackerel. Weights-at-age in the catch.

Figure 8.5.2.2. NE Atlantic mackerel. Weights-at-age in the stock.

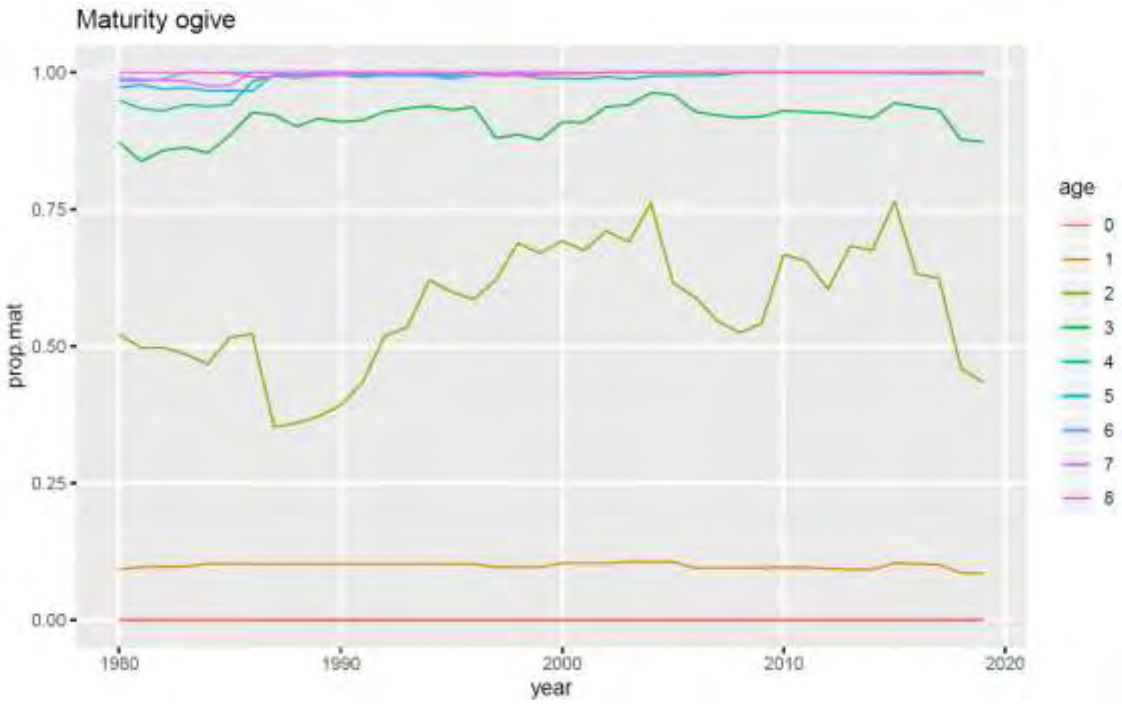

Figure 8.5.3.1. NE Atlantic mackerel. Proportion of mature fish at age.

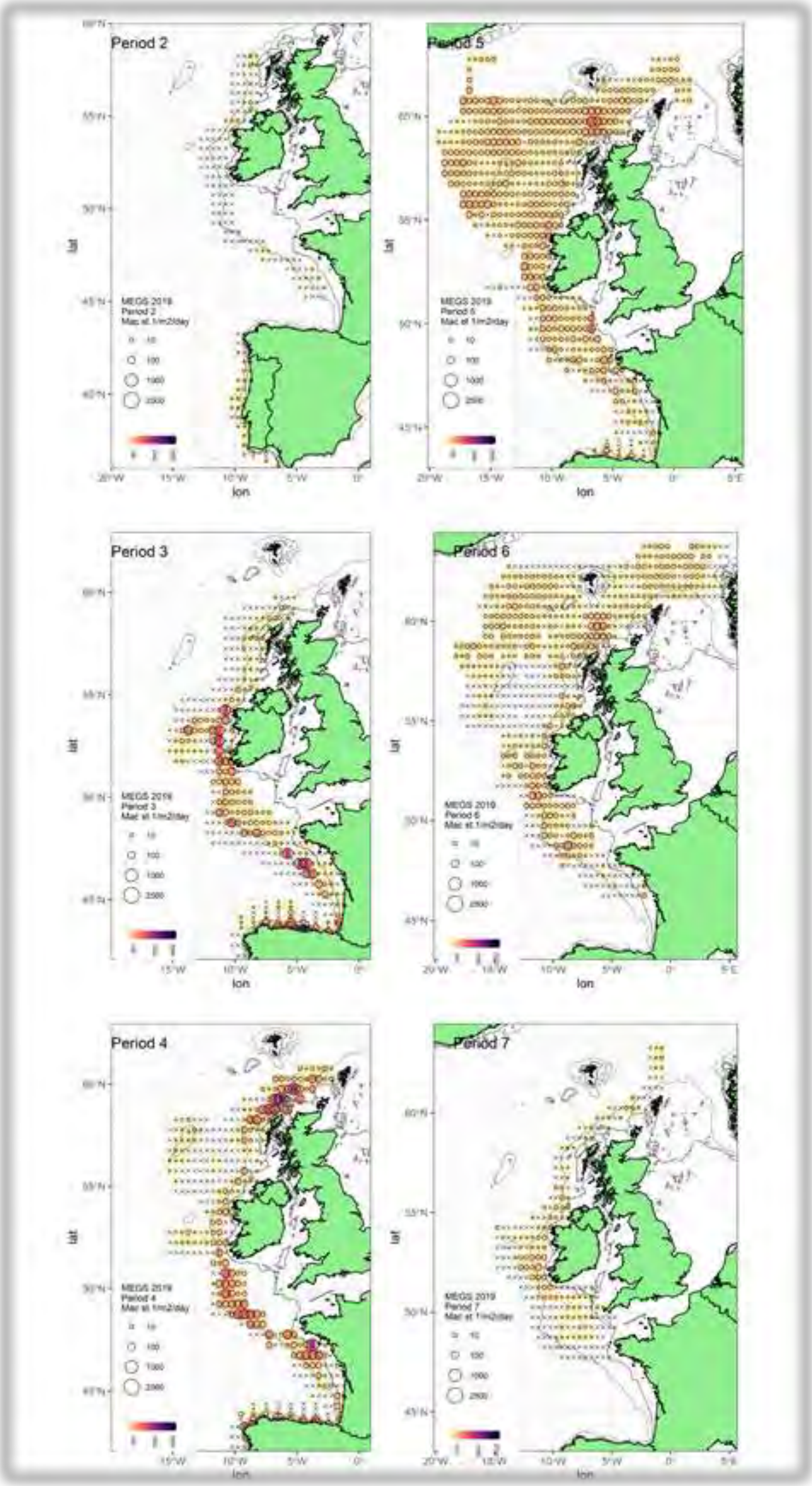

Figure 8.6.1.1.1. Mackerel egg production by half rectangle for all periods from MEGS survey in 2019. Circle areas and colour scale represent mackerel stage I eggs/m²/day by half rectangle. Crosses represent zero values.

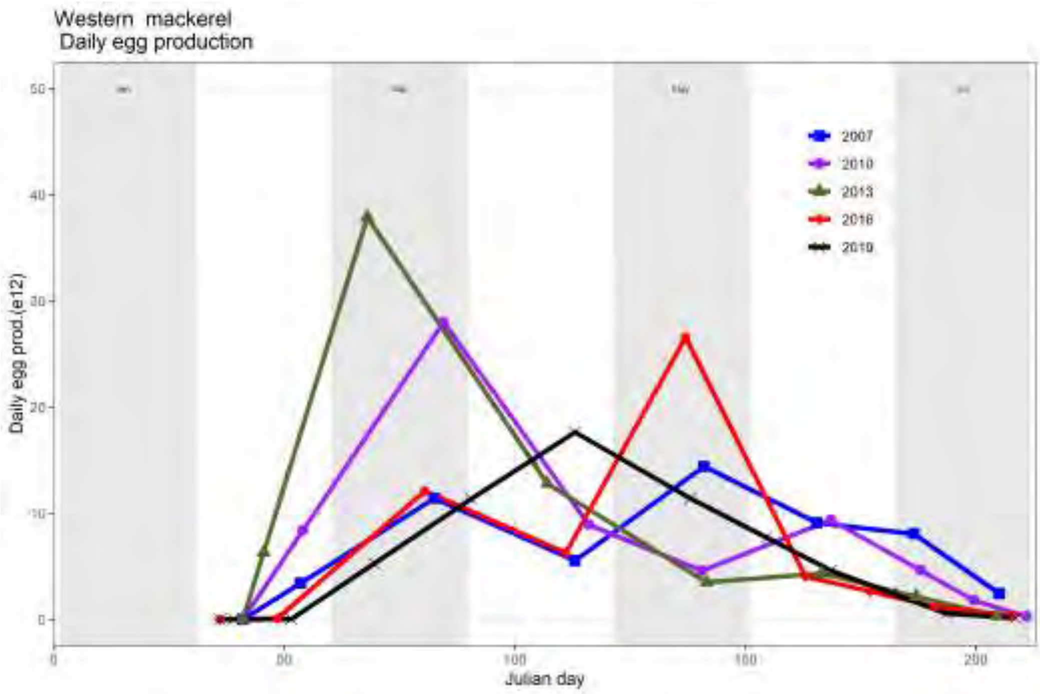

Figure 8.6.1.1.2. The mean daily stage I egg production estimates (DEP) in the mackerel western spawning component for each survey period plotted against the mid-period. The curves for 2007, 2010 2013 and 2016 are included for comparison. Odd months are highlighted in grey background.

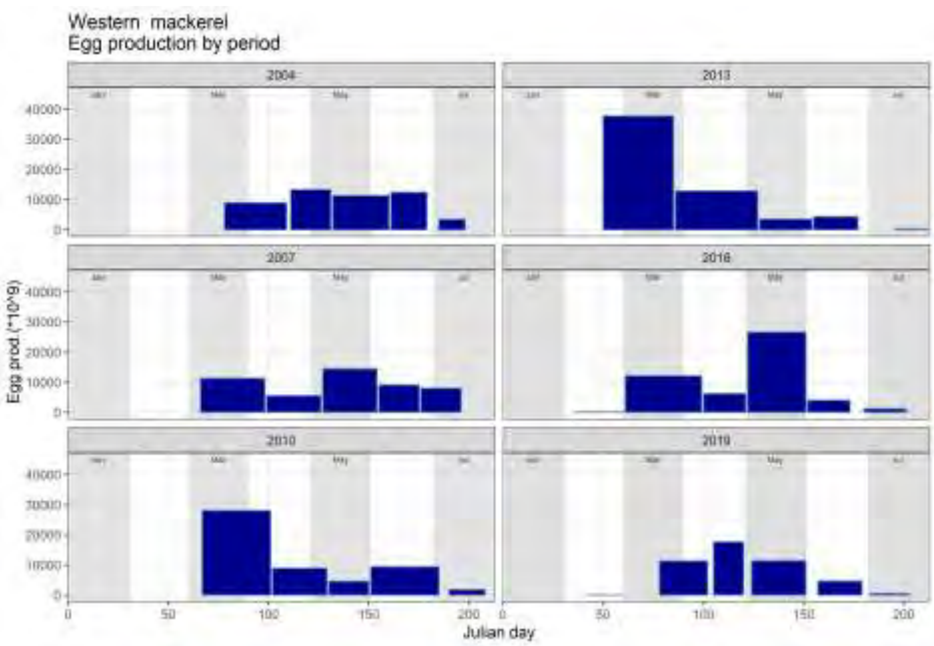

Figure 8.6.1.1.3. Egg production by period for NEA mackerel in the western spawning component. Bar area represents egg production by period. Odd months are highlighted in grey background.

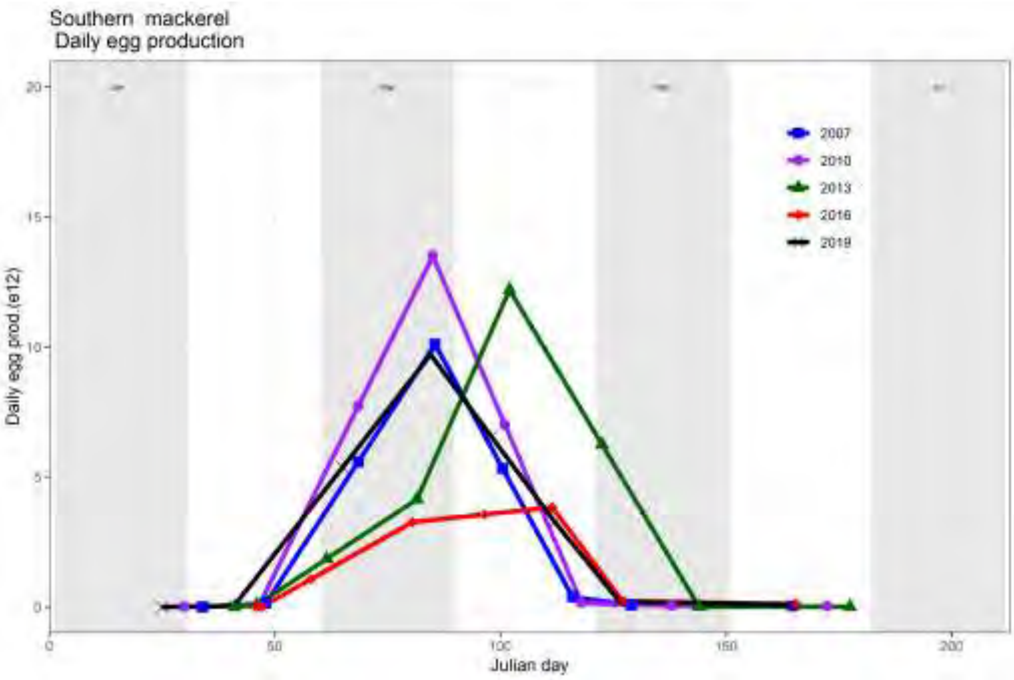

Figure 8.6.1.1.4. The mean daily stage I egg production estimates (DEP) in the mackerel southern spawning component for each survey period plotted against the mid-period. The curves for 2007, 2010 2013 and 2016 are included for comparison. Odd months are highlighted in grey background.

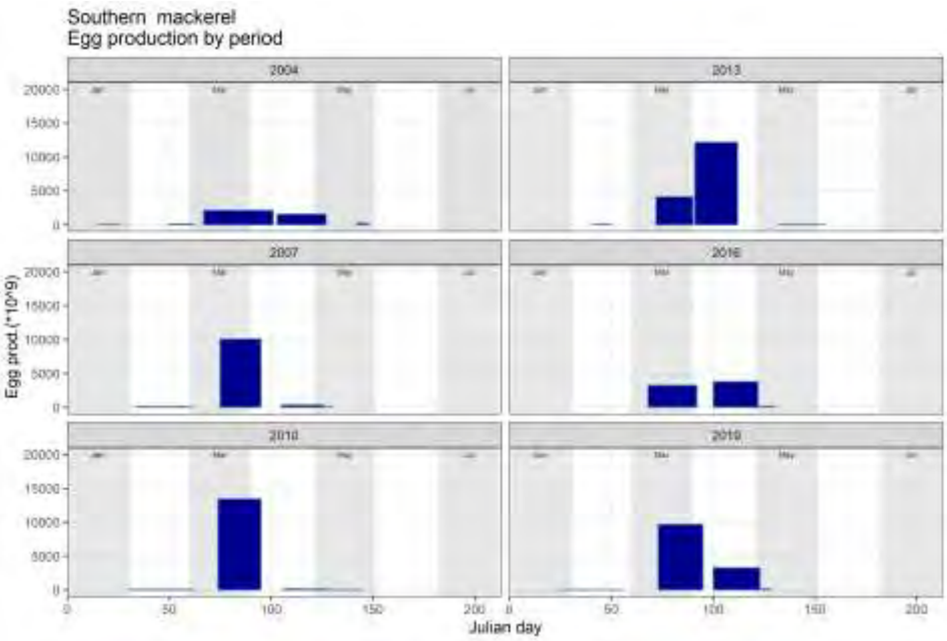

Figure 8.6.1.1.5. Egg production by period for NEA mackerel in the southern spawning component. Bar area represents egg production by period. Odd months are highlighted in grey background.

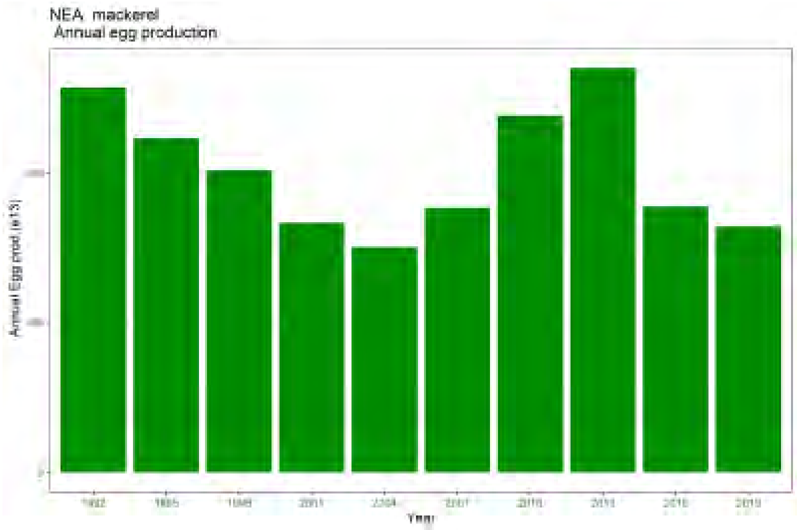

Figure 8.6.1.1.6. Combined NEA mackerel Total Annual Egg Production estimates (*10¹³) - 1992 – 2019.

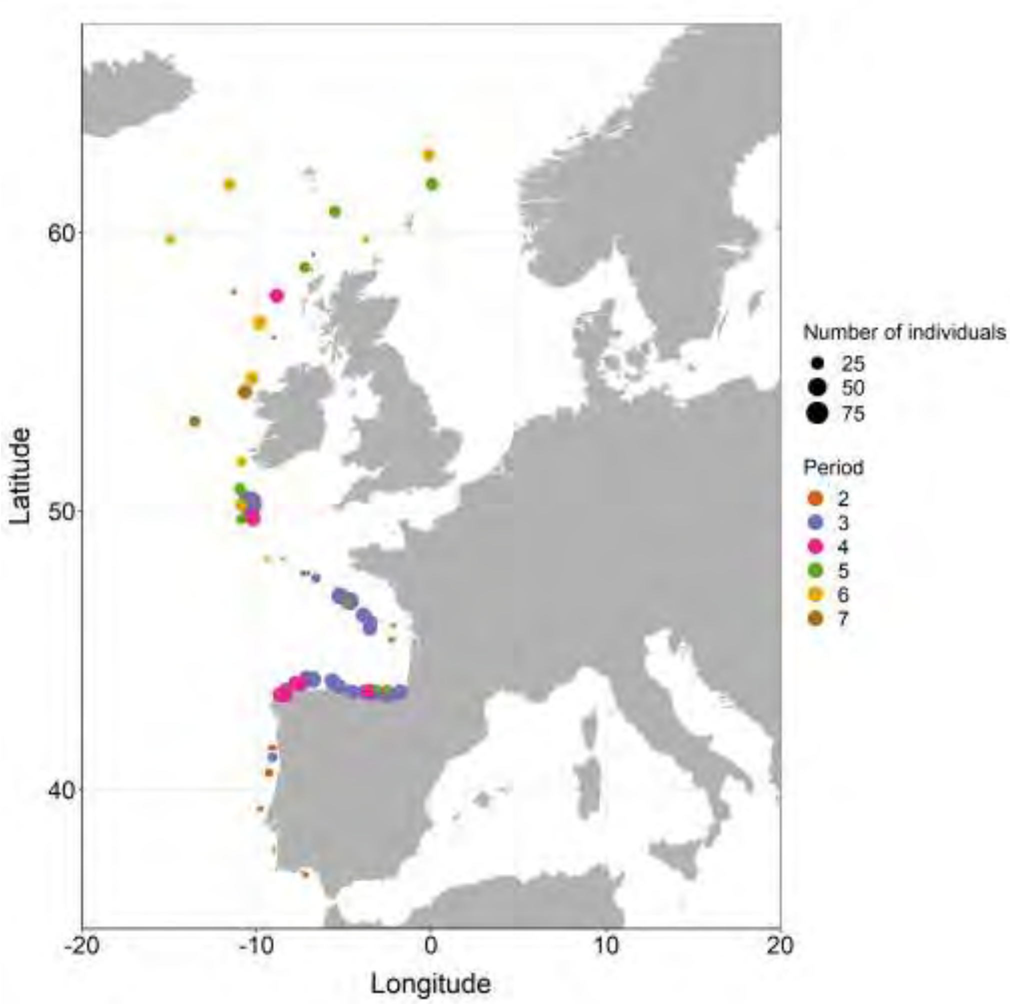

Figure 8.6.1.1.7. Adult females sampled by period for mackerel during 2019 survey.

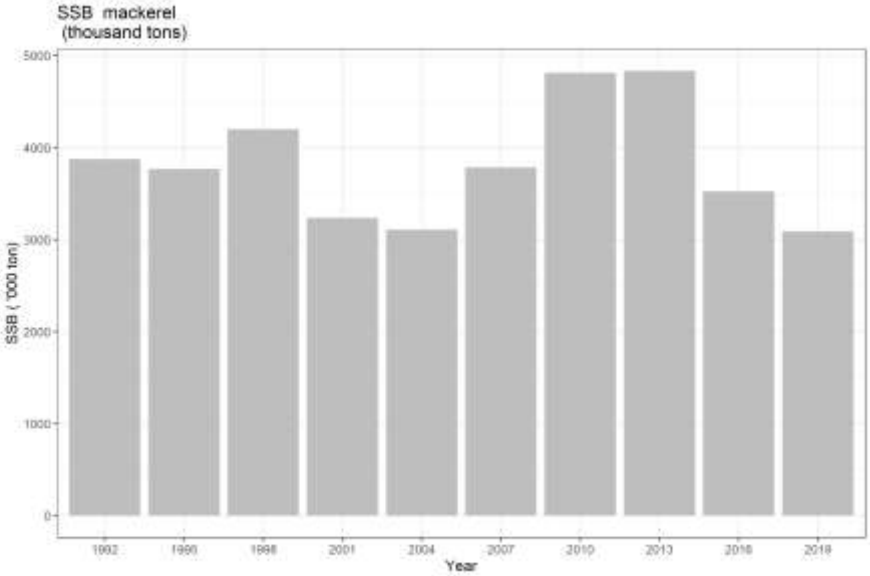

Figure 8.6.1.1.8. Mackerel SSB estimates derived from the mackerel egg surveys for the combined survey area (1992-2019).

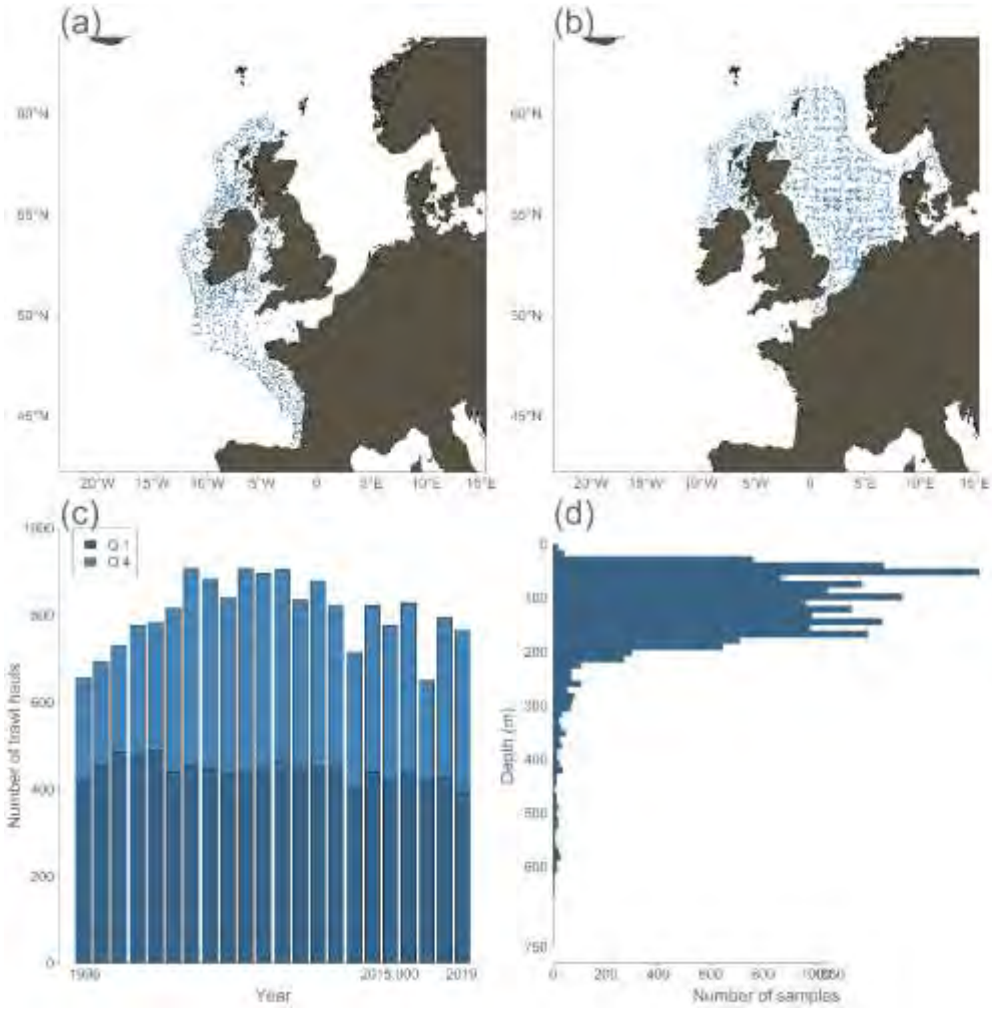

Figure 8.6.2.1. Demersal trawl survey data used to derive the abundance index of age-0 mackerel. (a) Trawl sample locations in the fourth quarter (Q4, October - November, blue dots); (b) trawl sample locations in the first quarter (Q1, January - March, light blue dots); (c) number of samples by year and quarter; and (d) depth.

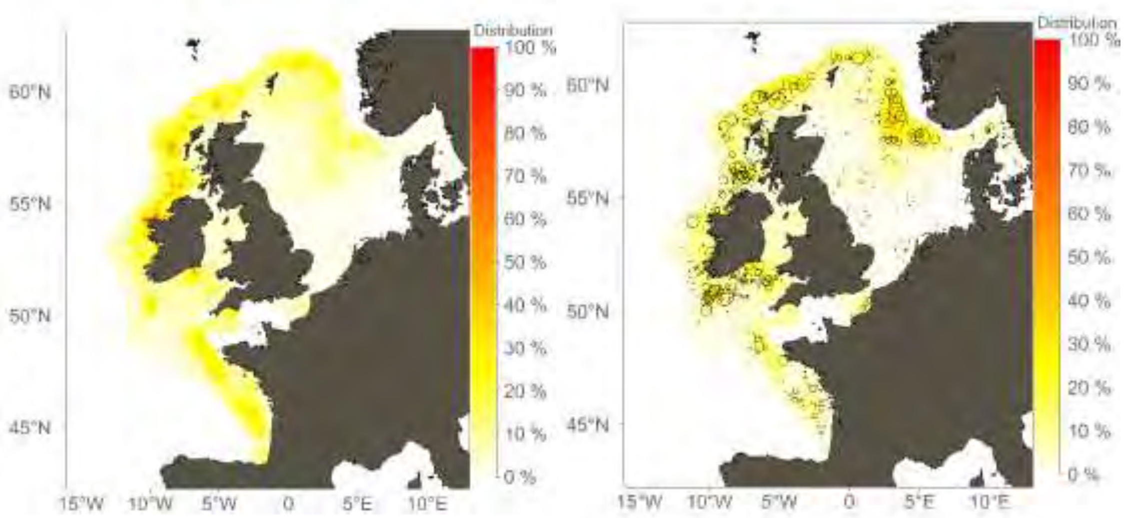

Figure 8.6.2.2. Spatial distribution of mackerel juveniles at age 0 in October to March. Left) average for cohorts from 1998-2019; and Right) 2019 cohort. Mackerel squared catch rates by trawl haul (circle areas represent catch rates in kg/km2) overlaid on modelled squared catch rates per 10 x 10 km rectangle. Each rectangle is coloured according to the expected squared catch rate in percent of the highest value for that year. See Jansen *et al.* (2015) for details.

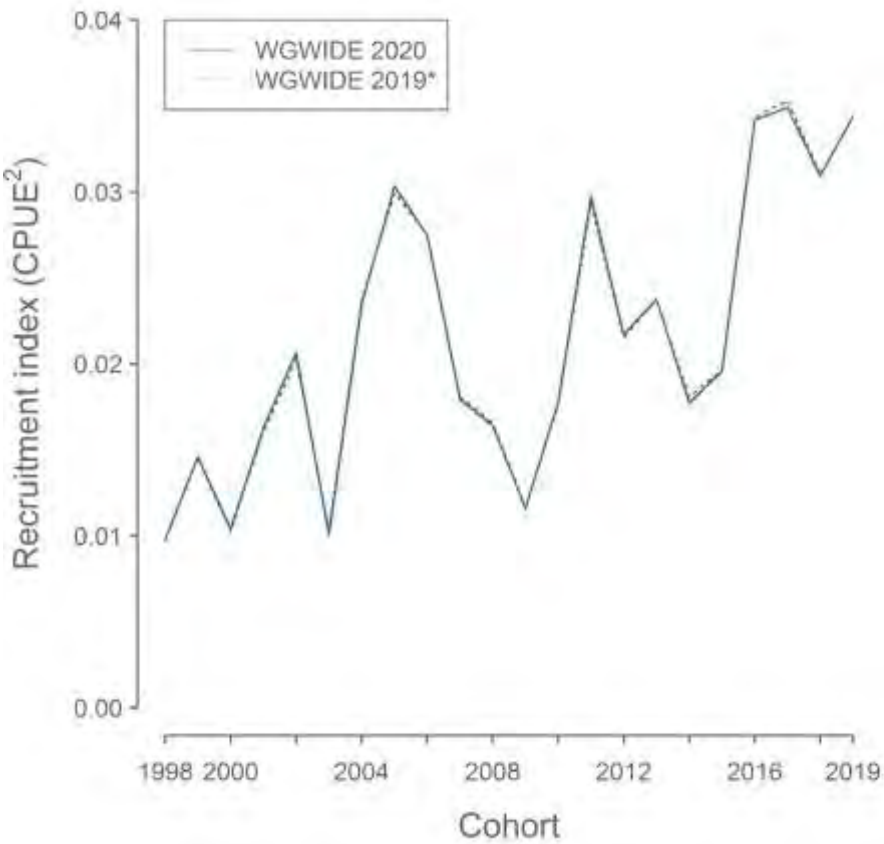

Figure 8.6.2.3. Index of mackerel juveniles at age 0 in October to March proxied by annual integration of square root of expected catch in demersal trawl surveys (Blue lines). See Jansen *et al.* (2015) for details. * Rescaled

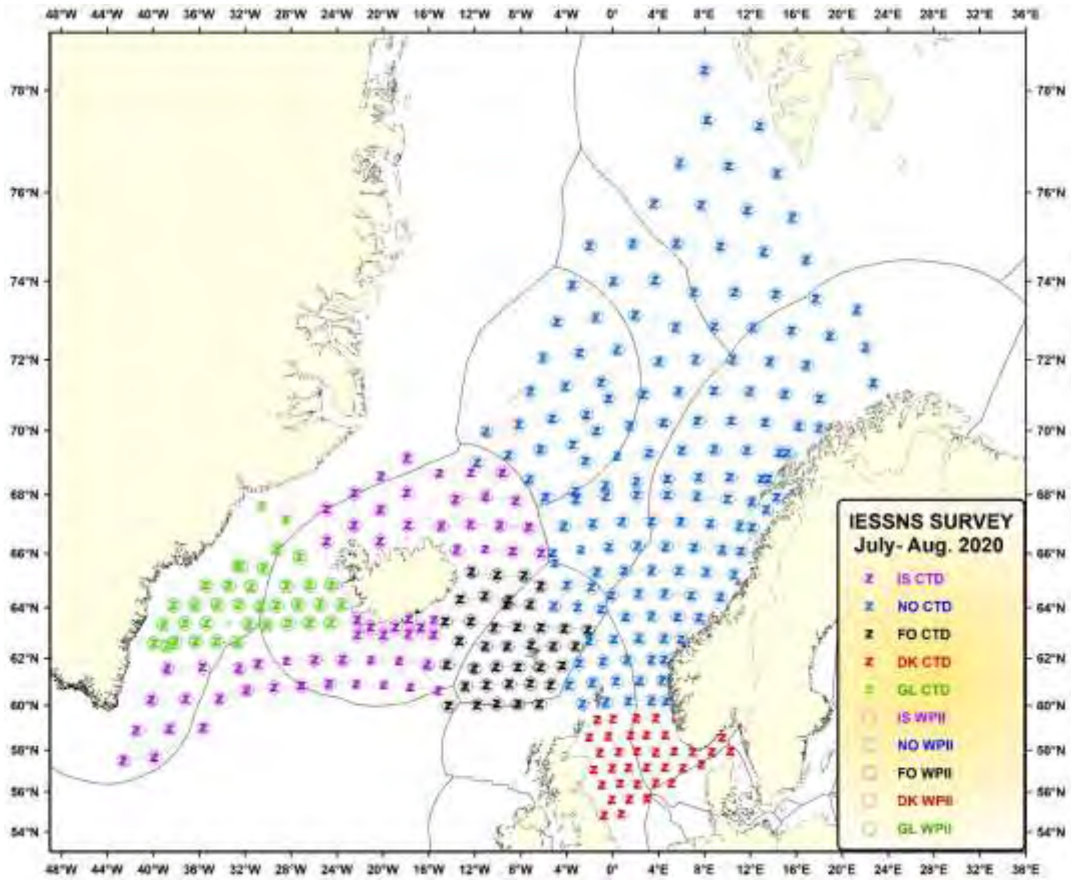

Figure 8.6.3.1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 1st July – 4th August 2020. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) were performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue), Eros (green) and Ceton (red).

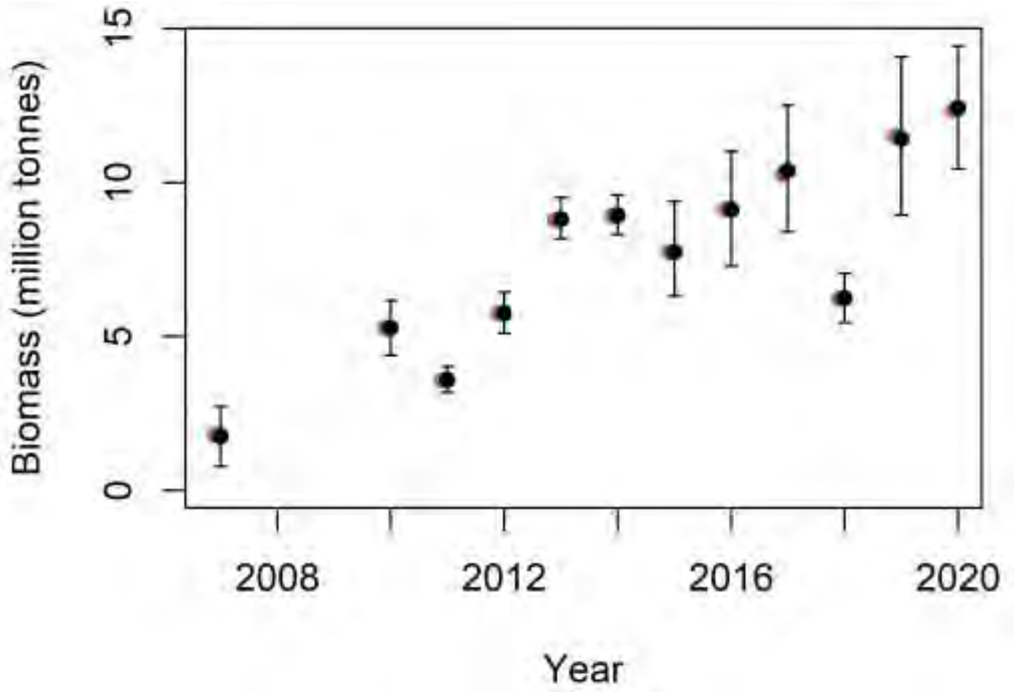

Figure 8.6.3.2a. Estimated total stock biomass of mackerel from IESSNS calculated using StoX for the years 2010 and from 2012 to 2020. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea.

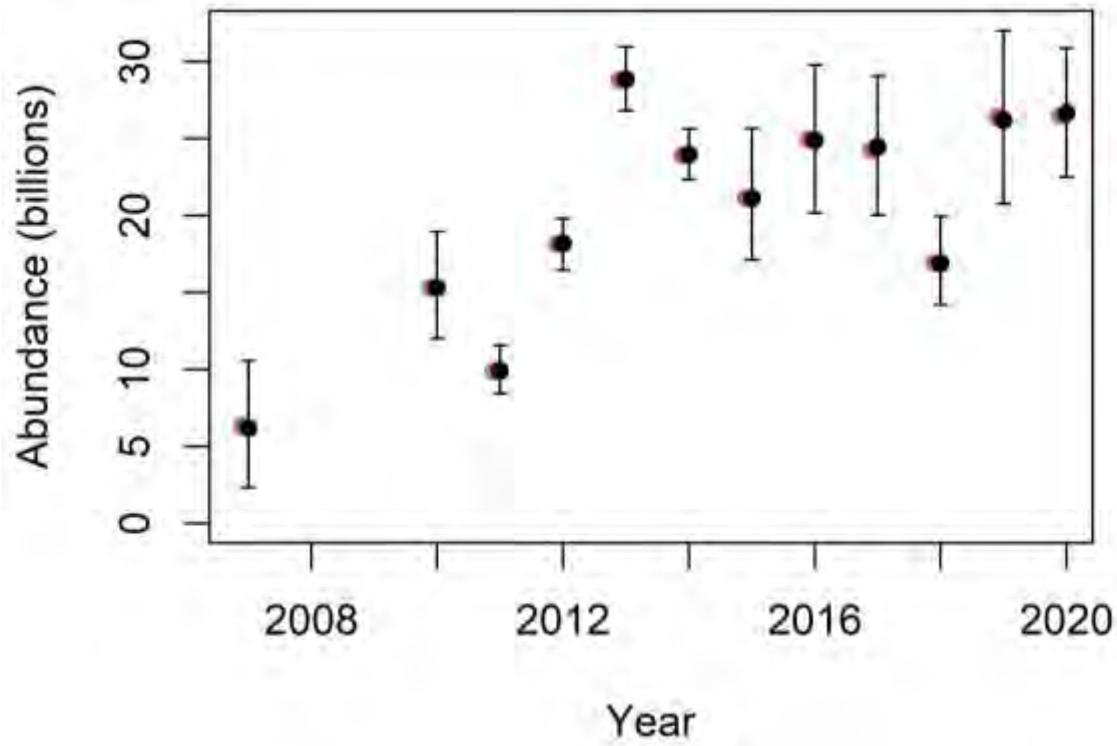

Figure 8.6.3.2b. Estimated total stock numbers (TSN) of mackerel from IESSNS calculated using StoX for the years 2010 and from 2012 to 2020. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea.

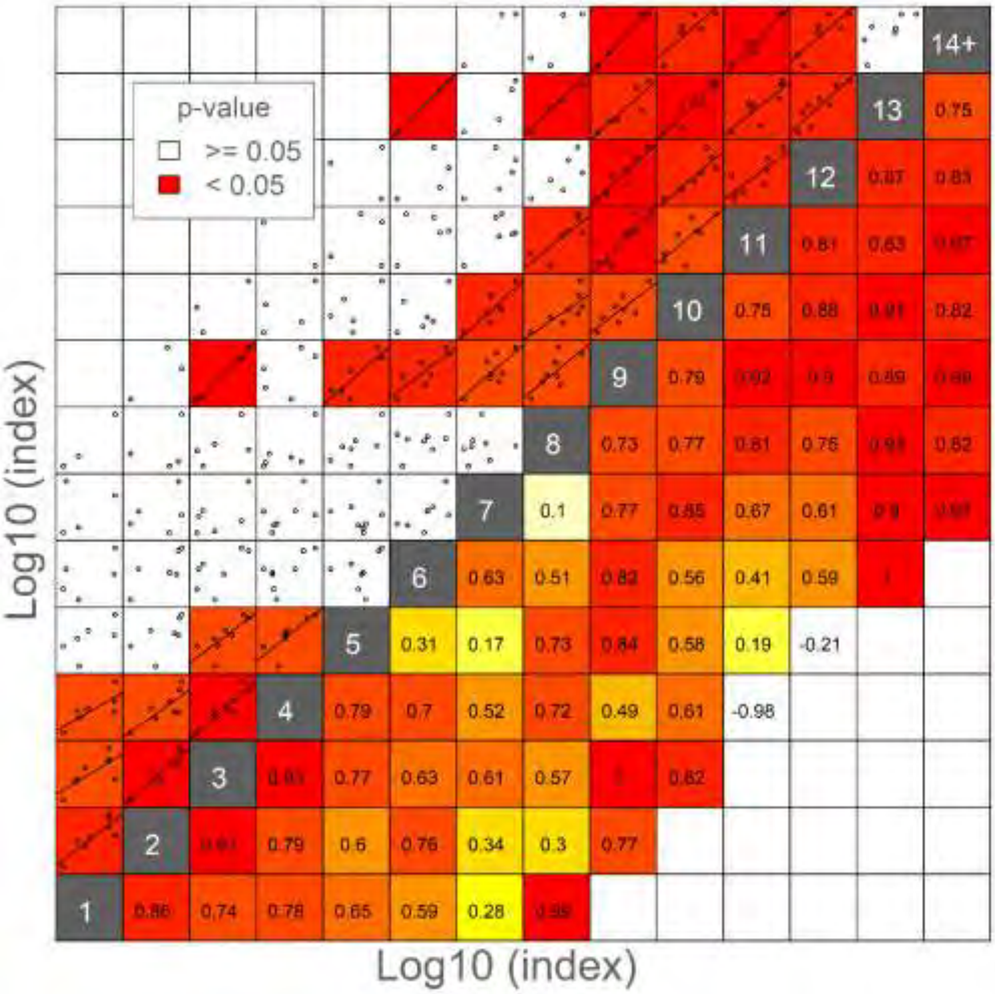

Figure 8.6.3.3. Internal consistency of the mackerel abundance index from the IESSNS surveys including data from 2012 to 2020, excluding North Sea. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

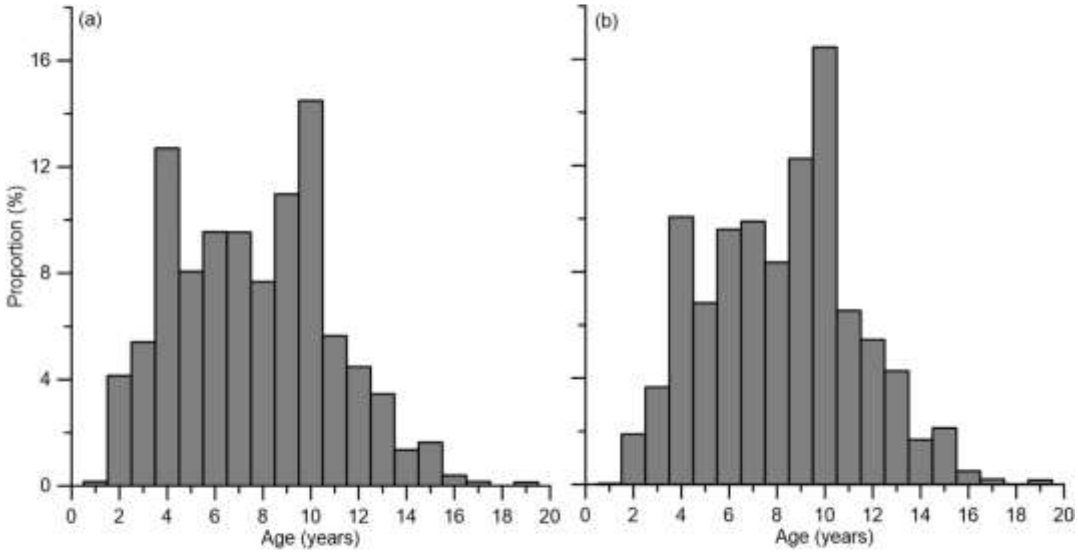

Figure 8.6.3.4a. Mackerel age distribution from IESSNS 2020 represented for abundance (a: % in numbers) and for biomass (b: % in biomass). Age index in calculated using the baseline estimate in StoX and excluding the North Sea.

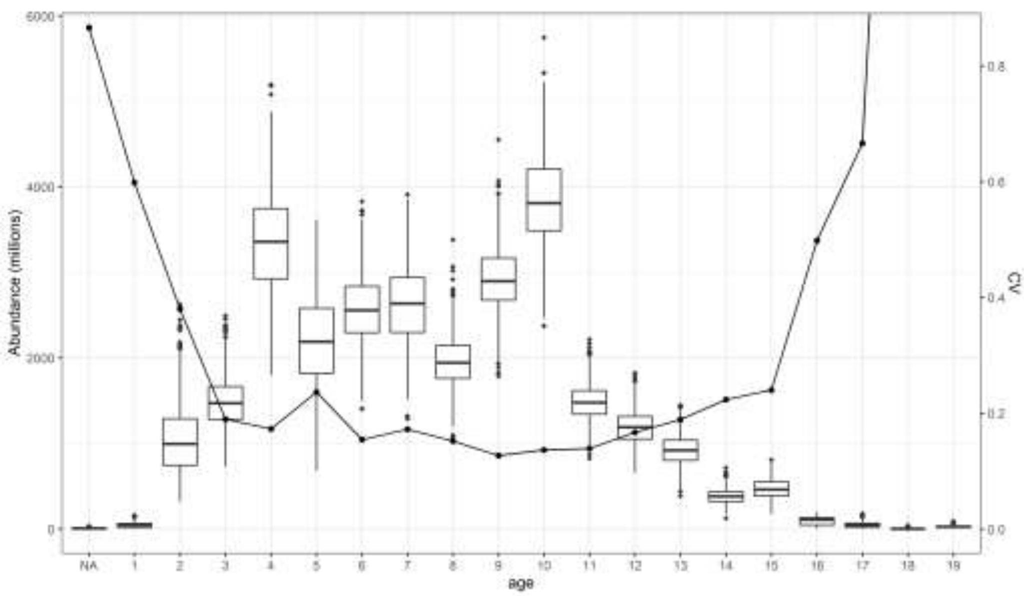

Figure 8.6.3.4b. Mackerel numbers by age from the IESSNS survey in 2020, excluding North Sea. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software (http://www.imr.no/forskning/prosjekter/stox/nb-no).

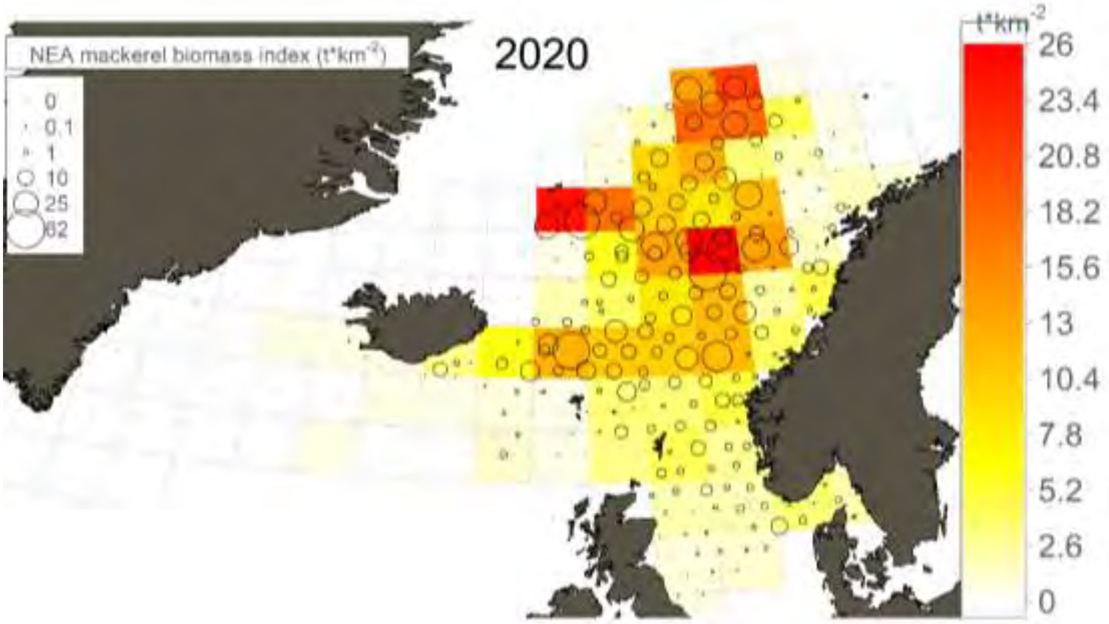

Figure 8.6.3.5a. Mackerel catch rates from predetermined surface trawl stations (circle size represents catch rate in kg/km2) overlaid on mean catch rate per standardized rectangle (2° lat. x 4° lon.) from the 2020 IESSNS, including North Sea.

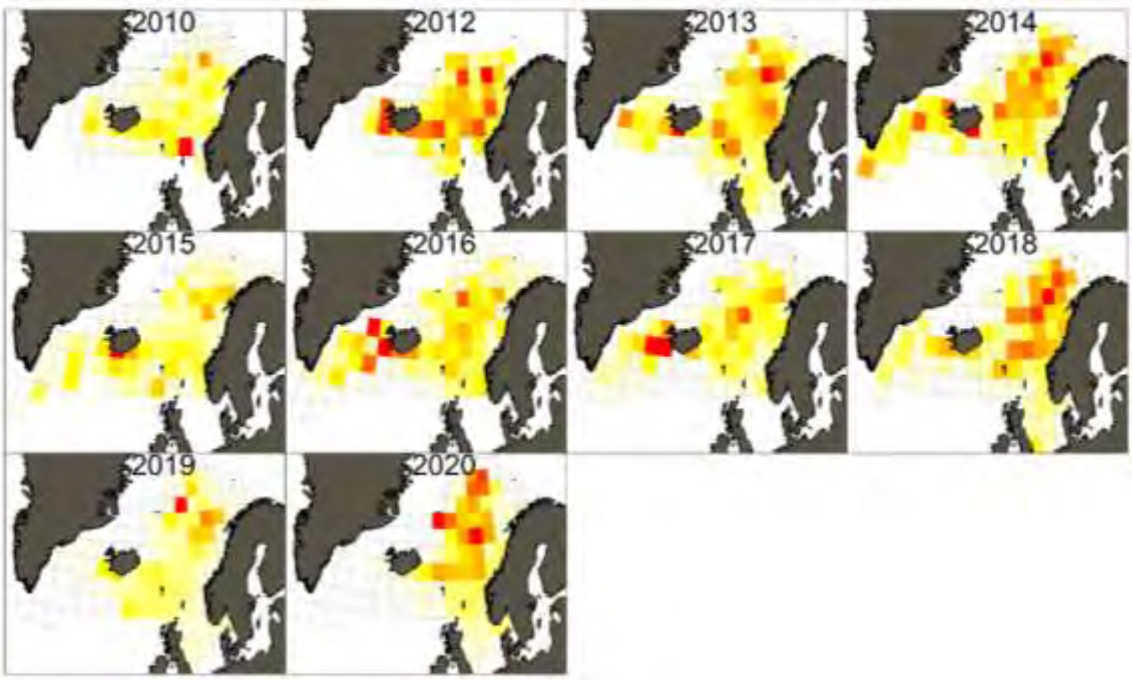

Figure 8.6.3.5b. Mackerel annual distribution proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from predetermined surface trawl stations from IESSNS in 2010 to 2020, including North Sea. Colour scale goes from white (= 0) to red (= maximum value for the given year).

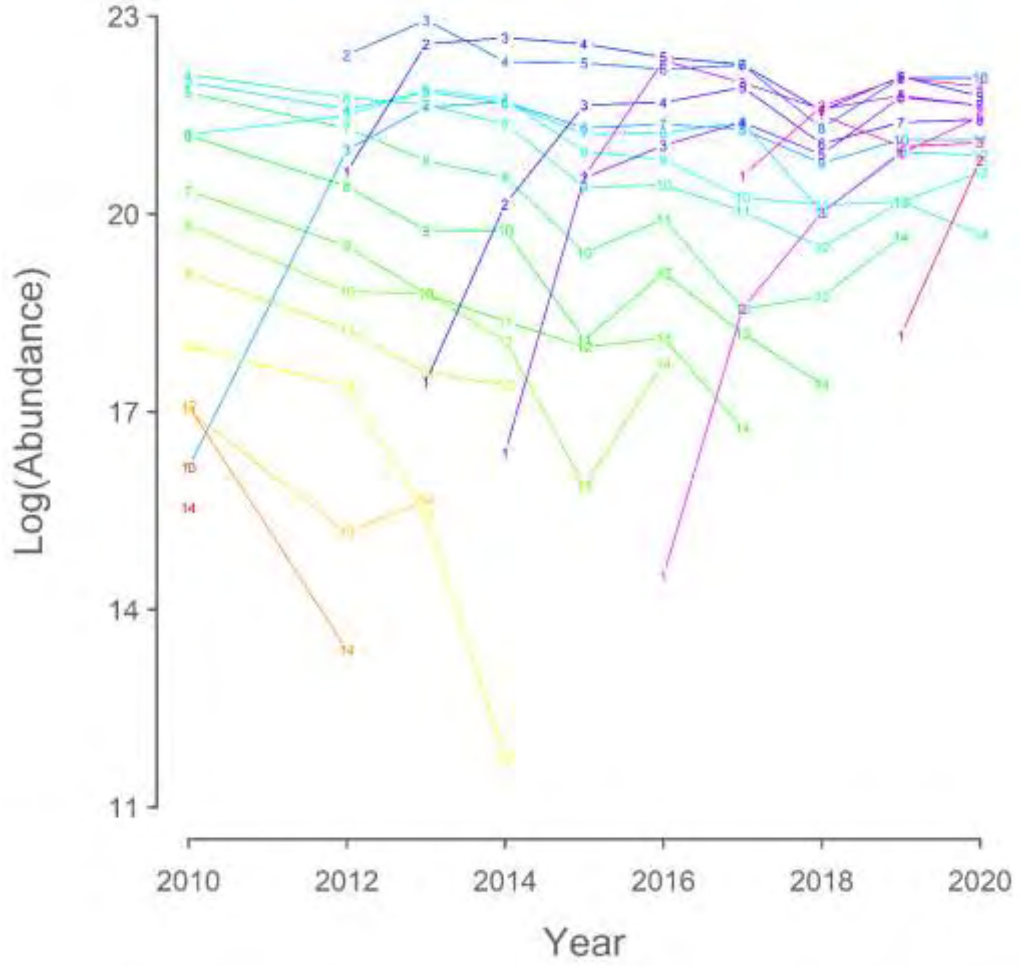

Figure 8.6.3.6. Mackerel catch curves from the estimate stock size at age from the IESSNS in 2010 and from 2012 to 2020, excluding the North Sea. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

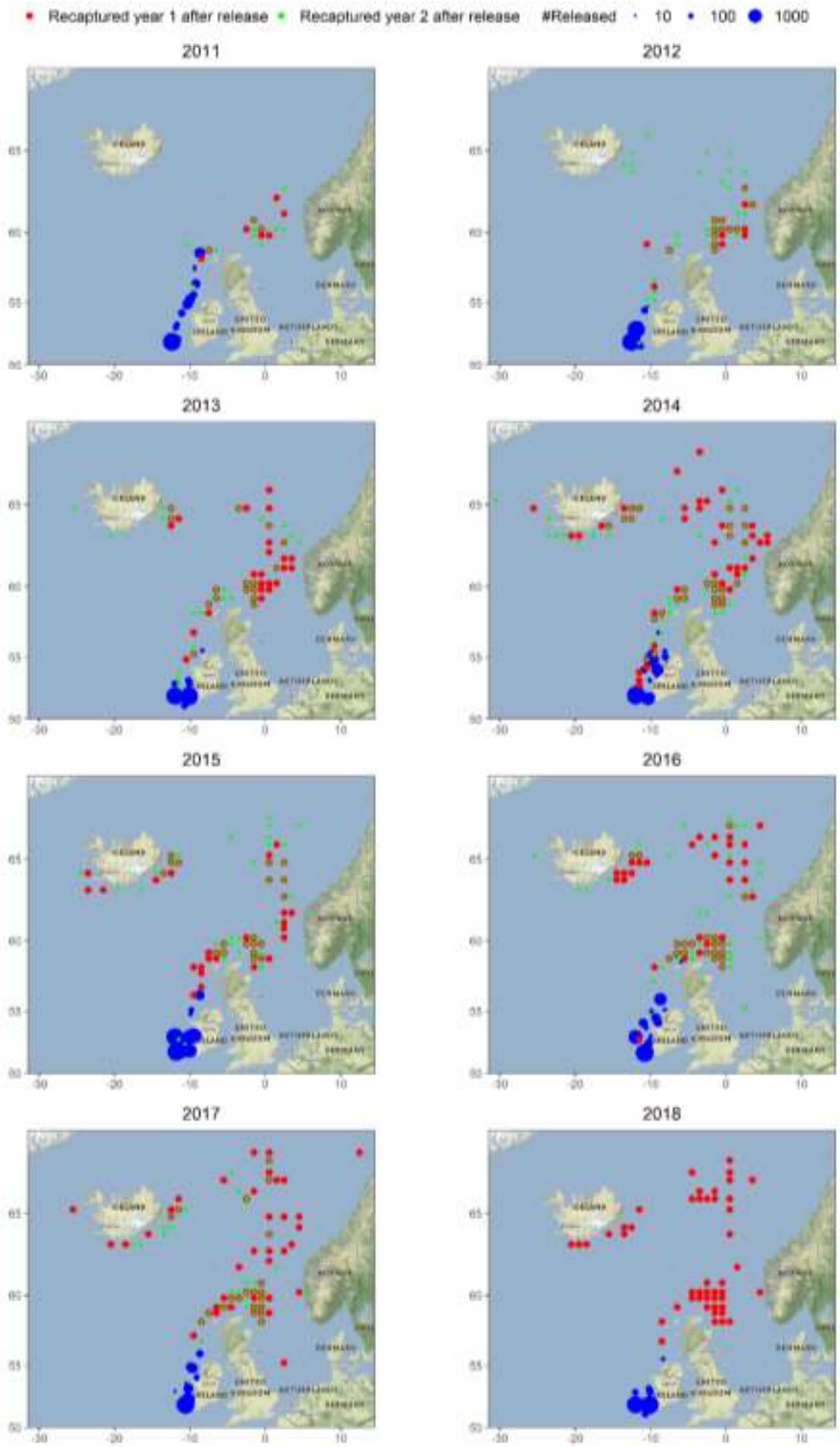

Figure 8.6.4.1. Distribution of RFID tagged mackerel from experiments west of Ireland-Hebrides during 2011-2018, and the distribution of recaptures year 1 and year 2 after release. Positions are per ICES rectangle. See Table 8.6.4.1 for details on numbers released and recaptured, Table 8.6.4.2 for details on scanned biomass, and Figure 8.6.4.2 for distribution of catches scanned. Note that data from releases 2011–2012 are not used in the stock assessment, based on decisions in the ICES IBPNEAMac 2019 meeting (ICES, 2019a).

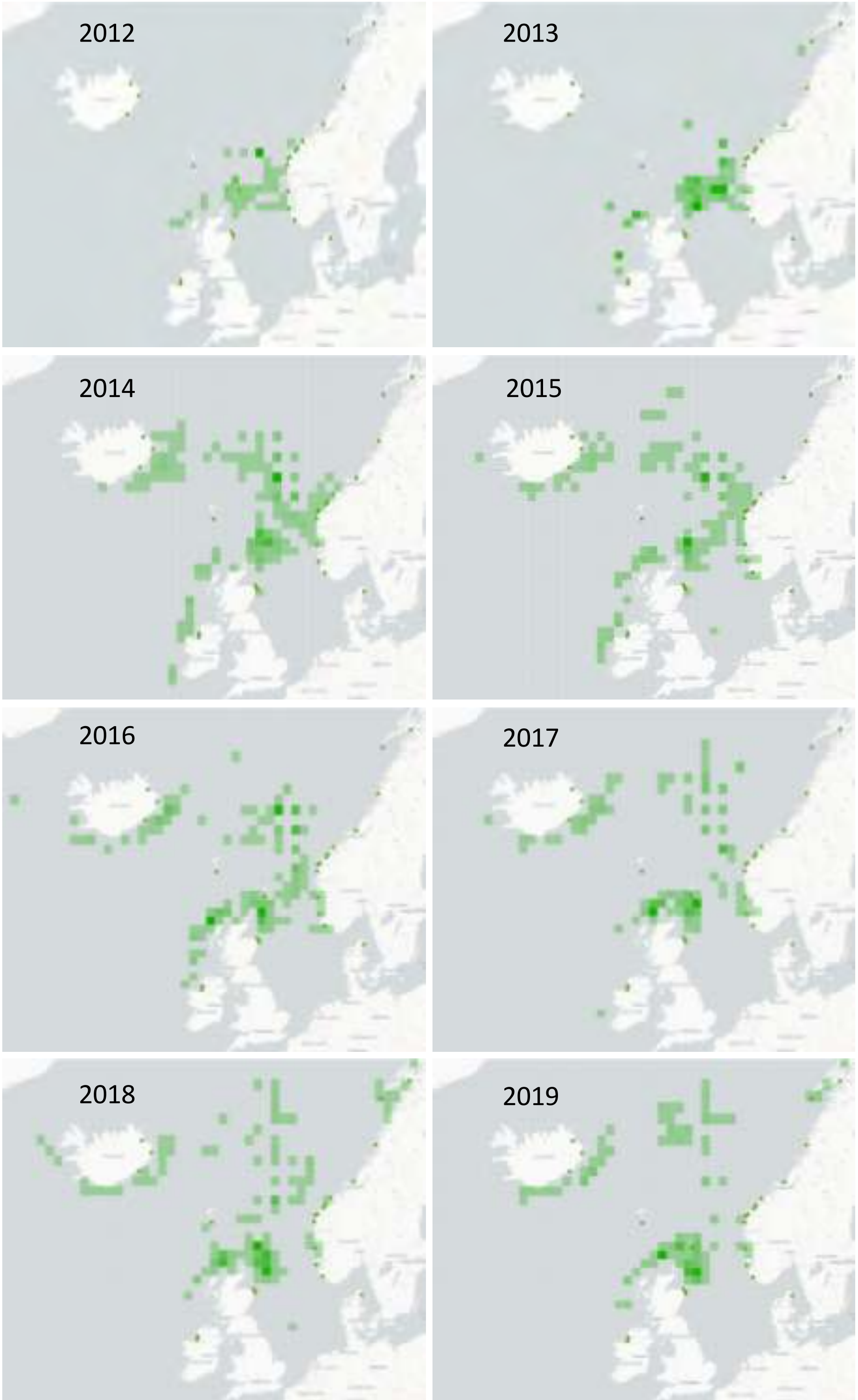

Figure 8.6.4.2. Distribution (summed per ICES rectangle) of catches scanned for RFID tagged mackerel during 2012-2019. Darker colors mean means higher biomass. Note that data on scanned catches and recaptures from 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES, 2019a). Positions of factories with RFID scanners are shown as green dots on map (Irish scanners are not operational). Detailed data on scanned catch and recaptures per factory are given in Tables 8.6.4.2-3.

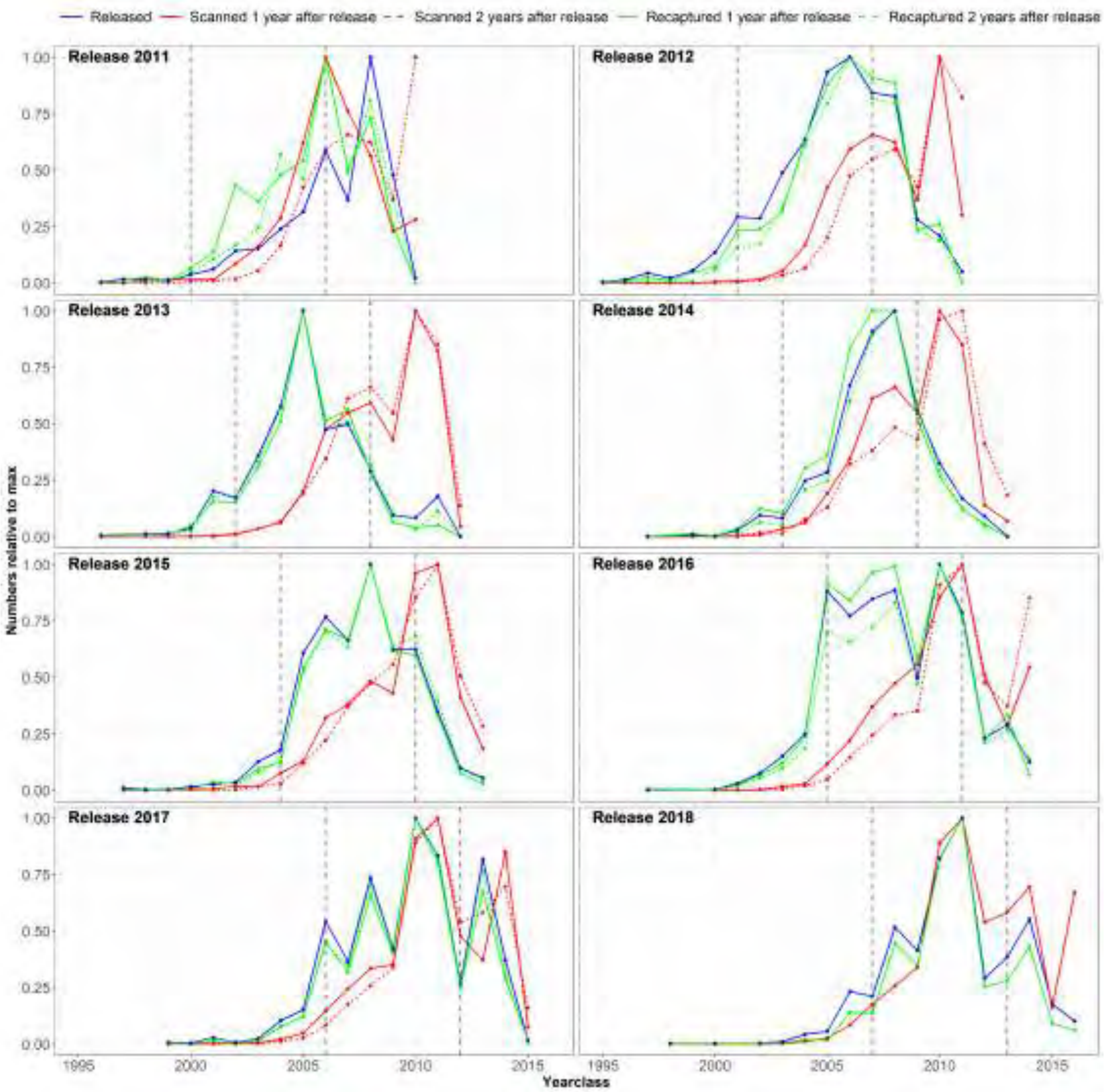

Figure 8.6.4.3. Overview of the relative year class distribution among RFID tagged mackerel per release year from experiments west of Ireland-Hebrides in May-June, compared with the number scanned and recaptured in year 1 and 2 after release of the same year classes. See Figures 8.6.4.1 for distribution of the tagged fish in year 1 and 2 after release, respectively. See Figure 8.6.4.3 for distribution of the scanned fish. Note that data from releases in 2011-2012 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES, 2019a). Note also that it was decided to only use ages 5-11 in updated assessments, and limits for this age span is marked (vertical grey dotted lines) for each release year. Details on actual numbers released and recaptured are given in Table 8.6.4.1, also for other tagging experiments not included in the stock assessment.

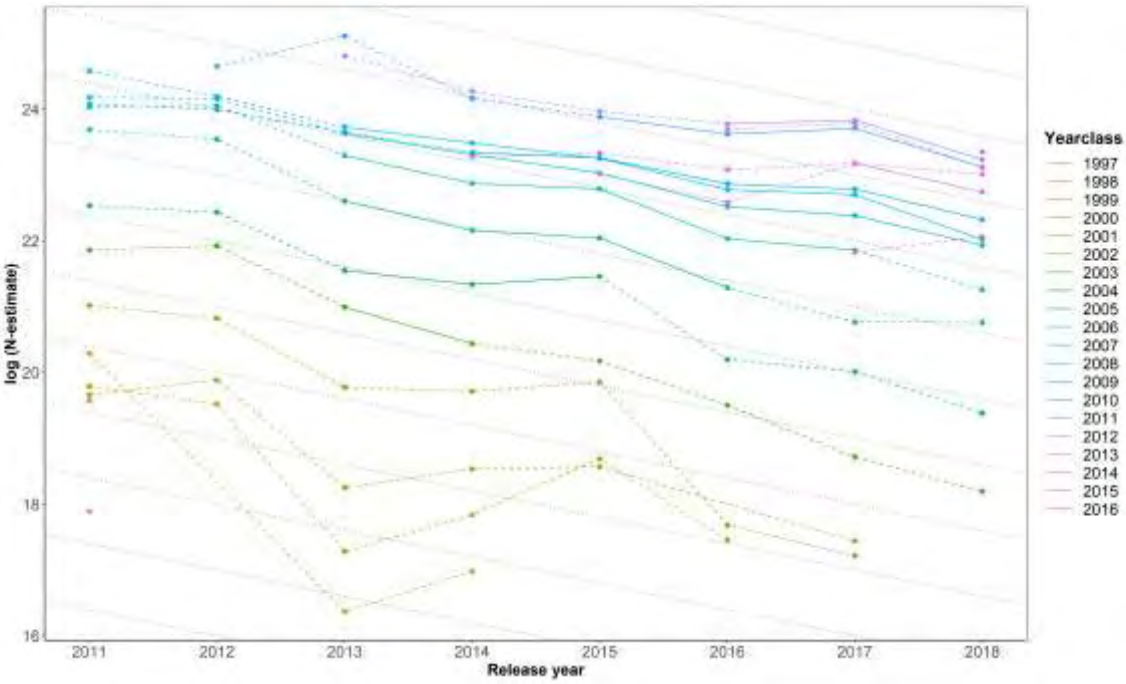

Figure 8.6.4.4. Trends in year class abundance (N=numbers released/numbers recaptured*numbers scanned) from RFID tag-recapture data using aggregated data on recaptures and scanned numbers in year 1 and 2 after release. Data excluded in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES, 2019a), release years 2011-2012 and ages 2-4 and 12+, are marked with dotted lines in year class trends. Note that dotted grey lines are showing a total mortality Z=0.4 for comparison with year class trends.

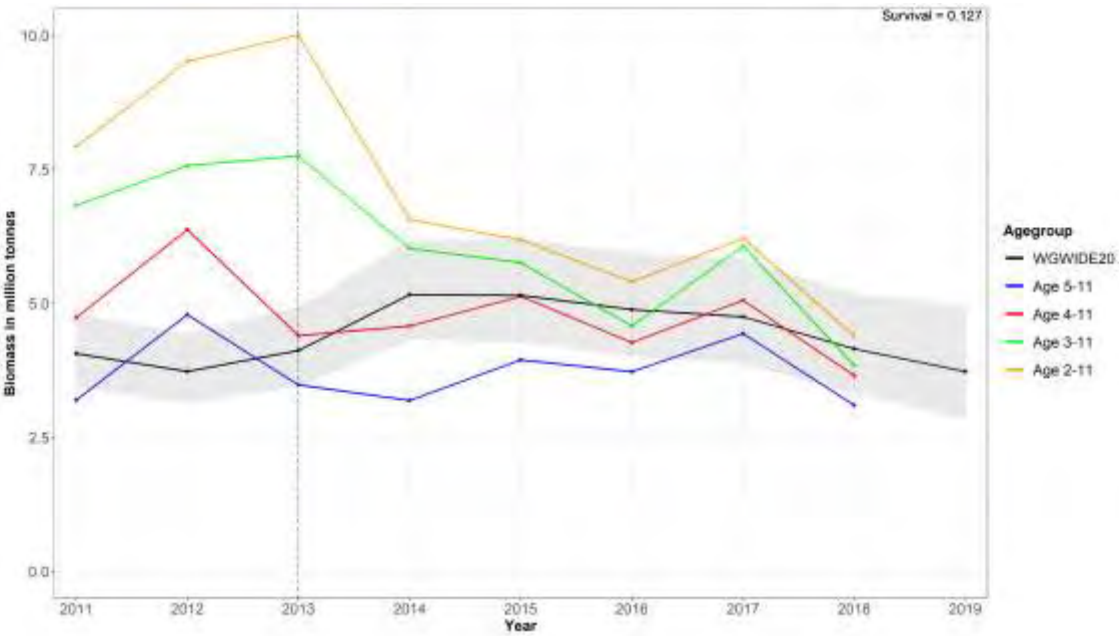

Figure 8.6.4.5. Trends various age aggregated biomass indices from RFID tag-recapture data compared with the SSB (±95 confidence intervals) from the WGWIDE 2020 stock assessment. Data are based on estimated numbers by year class from Figure 8.6.4.4 scaled by the survival parameter estimated by SAM in WGWIDE 2020 (0.1272129), and mean weight of the tagged fish in release year of these year classes. Vertical dotted line marks the starting year where RFID tagging experiments are used in the stock assessment based on decisions in the ICES IBPNEAMac 2019. meeting (ICES, 2019a). Note also that the trend of ages 5-11 is representing the subset of ages used in the assessment after this meeting.

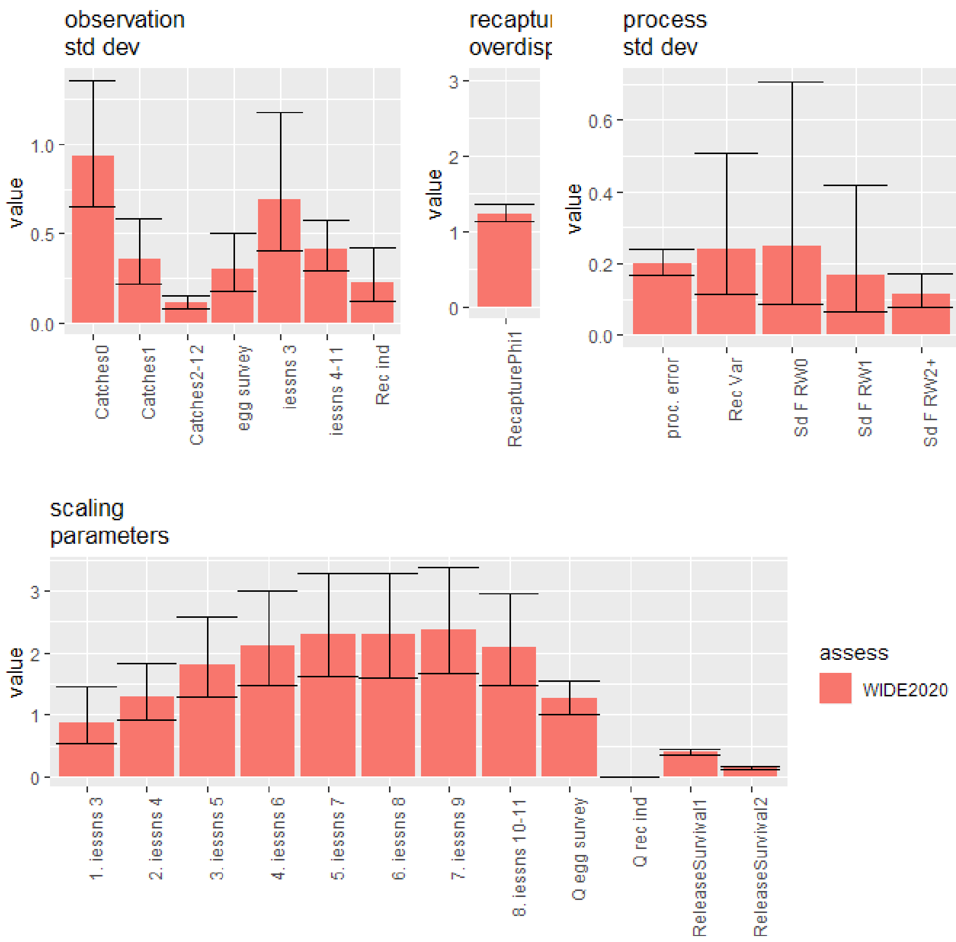

Figure 8.7.2.1. NE Atlantic mackerel. Parameter estimates from the SAM model (and associated confidence intervals) for the WGWIDE 2020 update assessment. top left: estimated standard deviation for the observation errors, top centre: estimated overdispersion for the errors on the tag recaptures, top right: standard deviation for the processes, bottom: survey catchabilities and post-release survival of tagged fish.

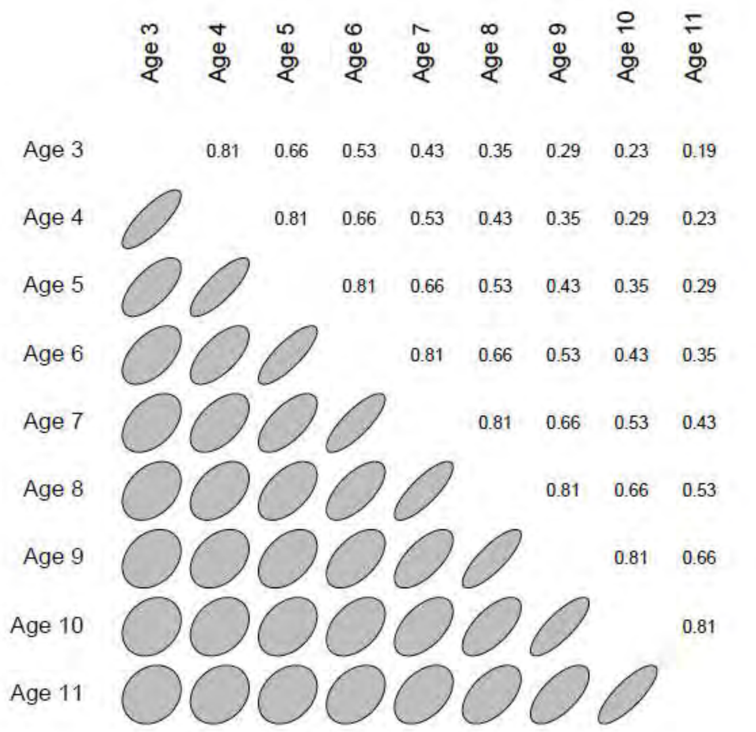

Figure 8.7.2.2. NE Atlantic mackerel. Estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11.

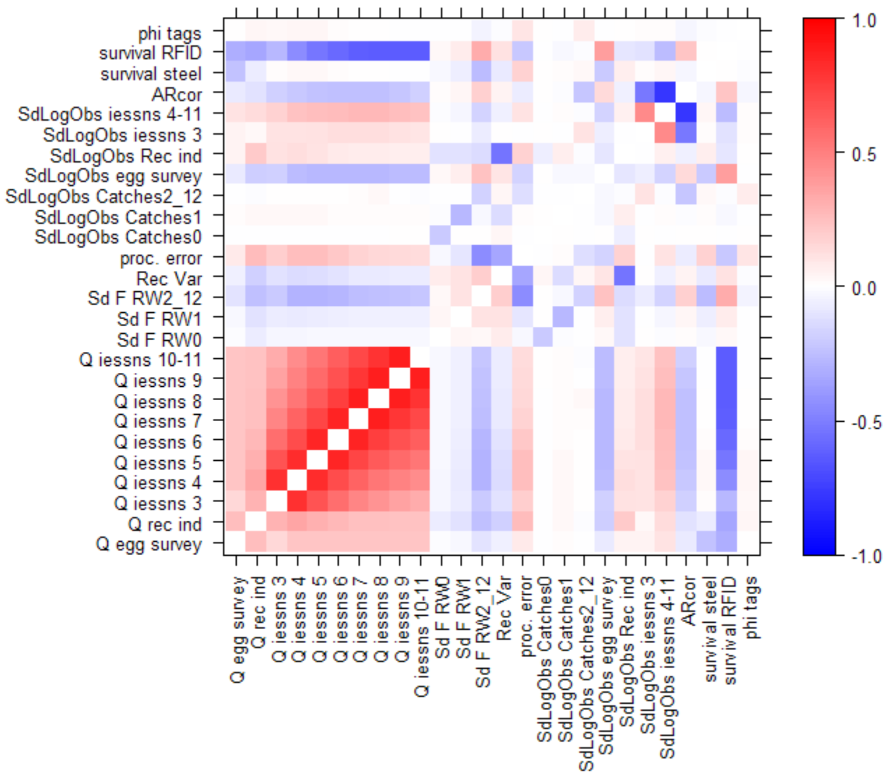

Figure 8.7.2.3. NE Atlantic mackerel. Correlation between parameter estimates from the SAM model for the WGWIDE 2020 update assessment

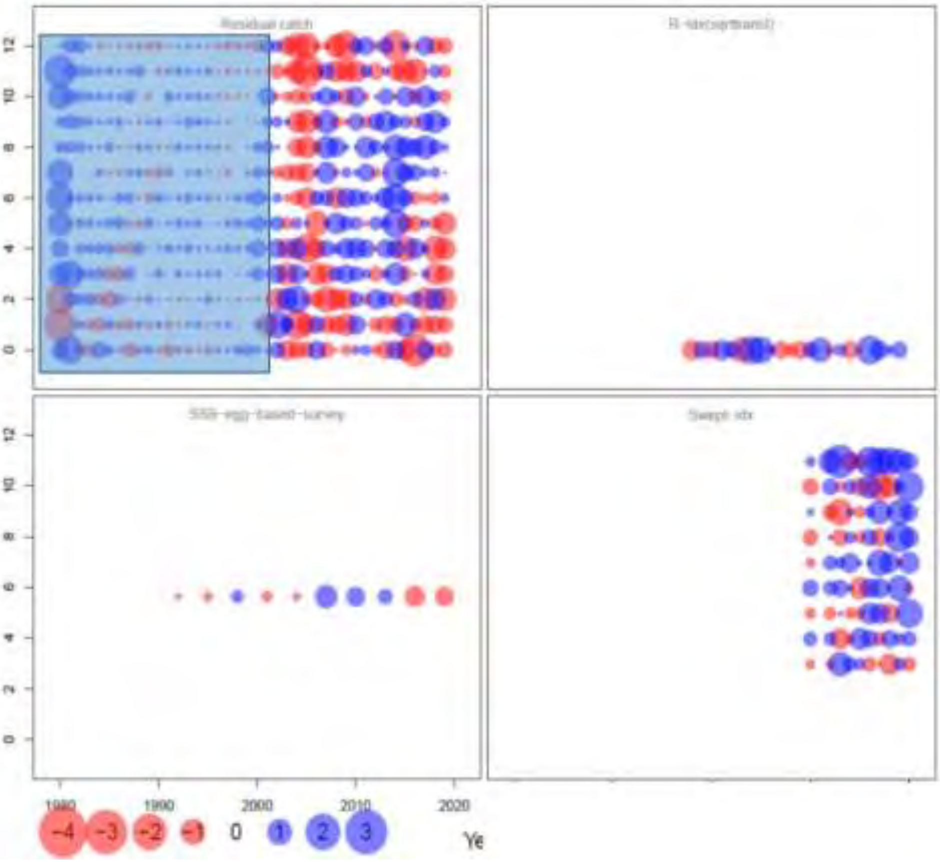

Figure 8.7.2.4. NE Atlantic mackerel. One Step Ahead Normalized residuals for the fit to the catch data (catch data prior to 2000 in blue rectangle were not used to fit the model). Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

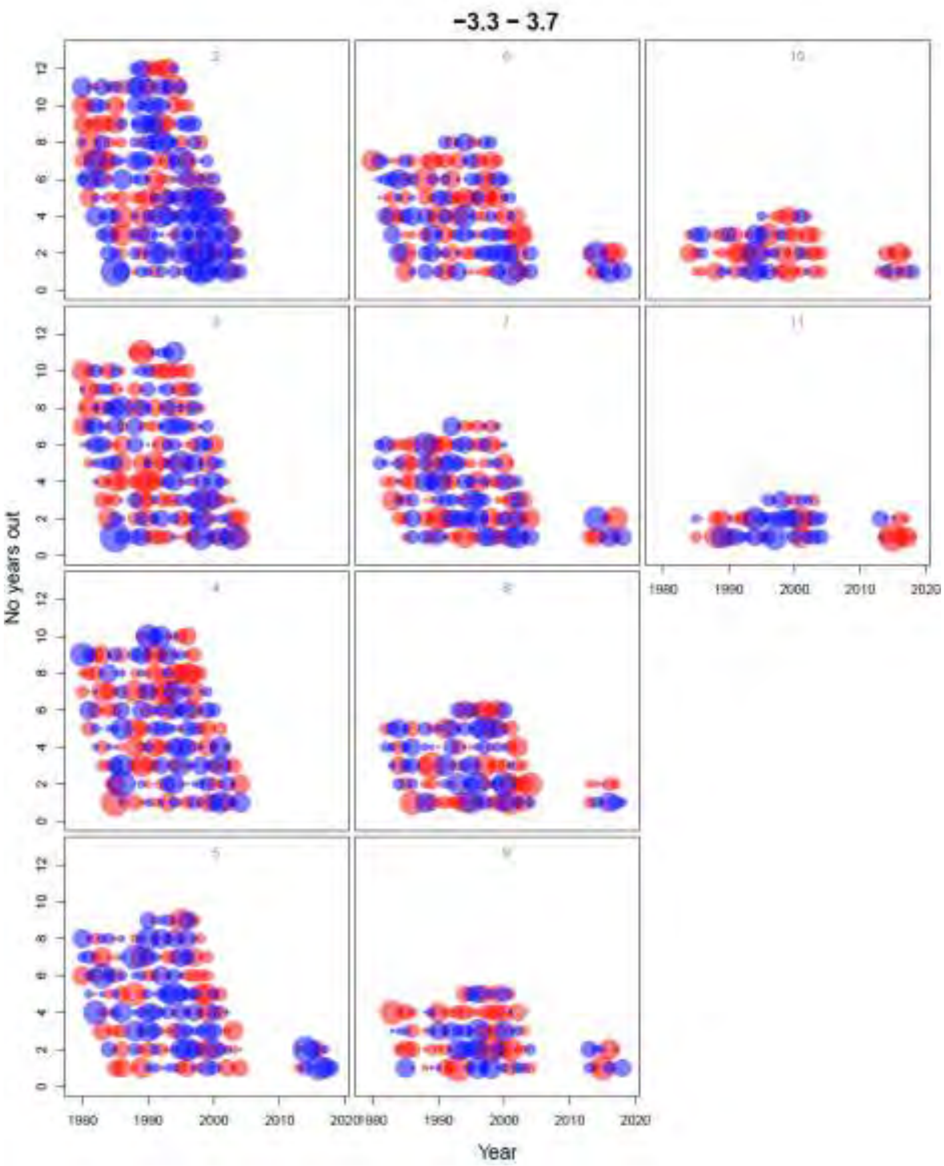

Figure 8.7.2.5. NE Atlantic mackerel. One step ahead residuals for the fit to the recaptures of tags in the final assessment. The x-axis represents the release year, and the y-axis is the number of years between tagging and recapture. Each panel correspond to a given age at release. Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

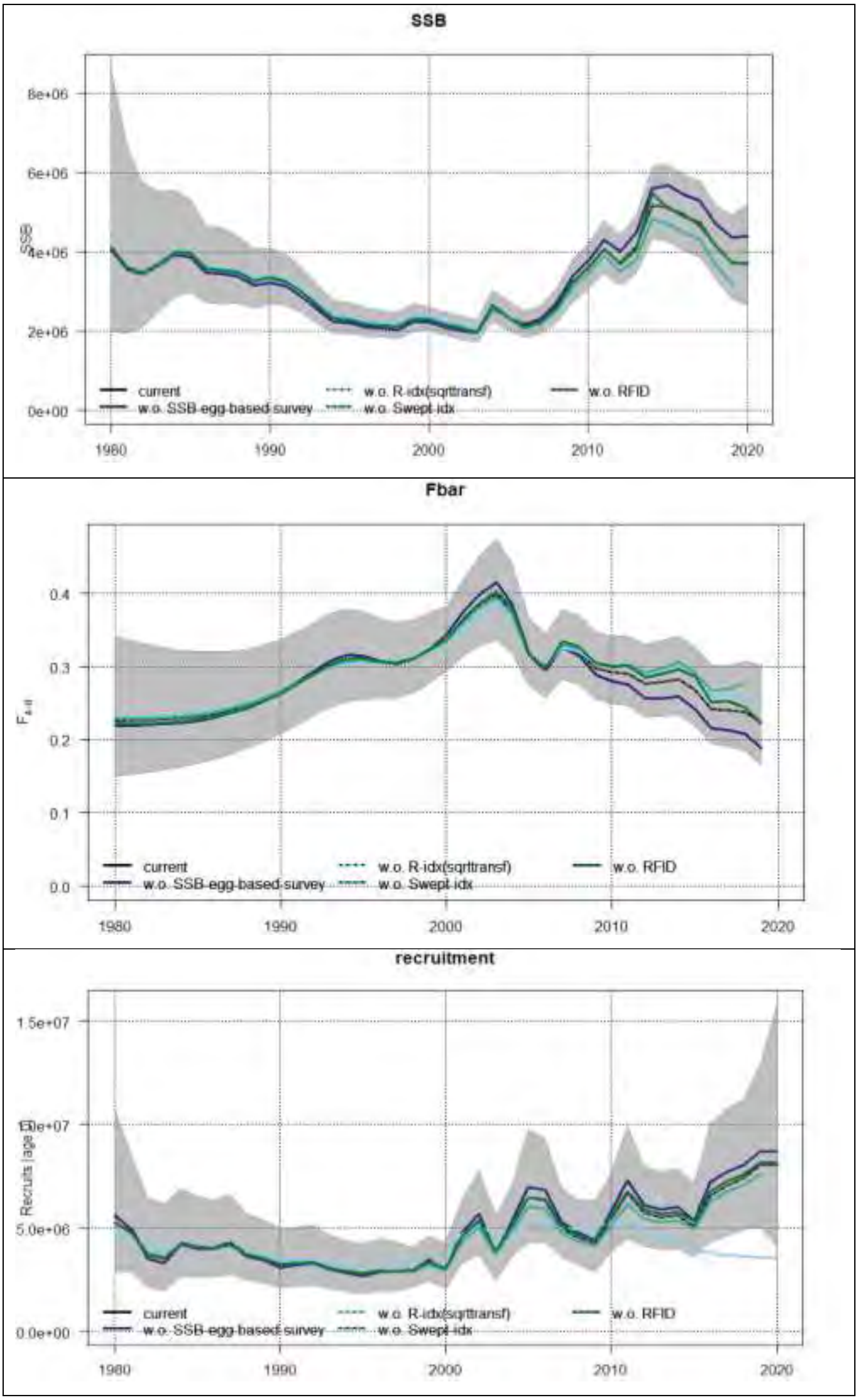

Figure 8.7.2.6. NE Atlantic mackerel. Leave one out assessment runs. SAM estimates of SSB, Fbar and recruitment, for assessments runs leaving out one of the observation data sets.

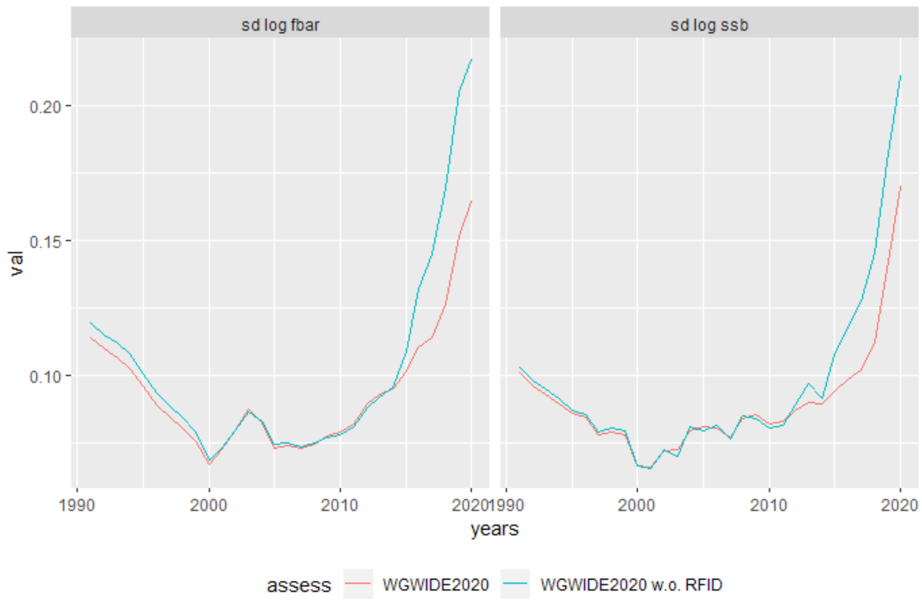

Figure 8.7.2.7. NE Atlantic mackerel. Uncertainty (standard deviation of the log values) of the estimates of SSB and F_{bar} from the SAM for the 2020 WGWIDE assessment and from the SAM assessment run without the RFID tagging information.

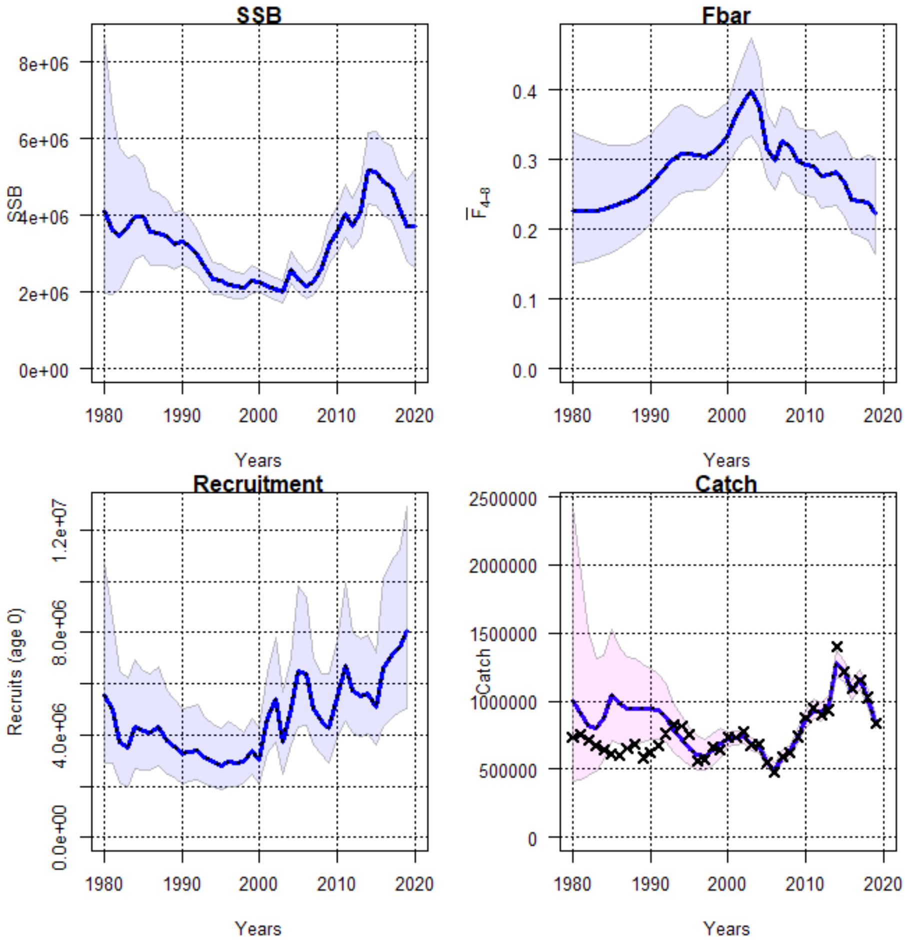

Figure 8.7.3.1. NE Atlantic mackerel. Perception of the NEA mackerel stock, showing the SSB, F_{bar4-8} and recruitment (with 95% confidence intervals) from the SAM assessment.

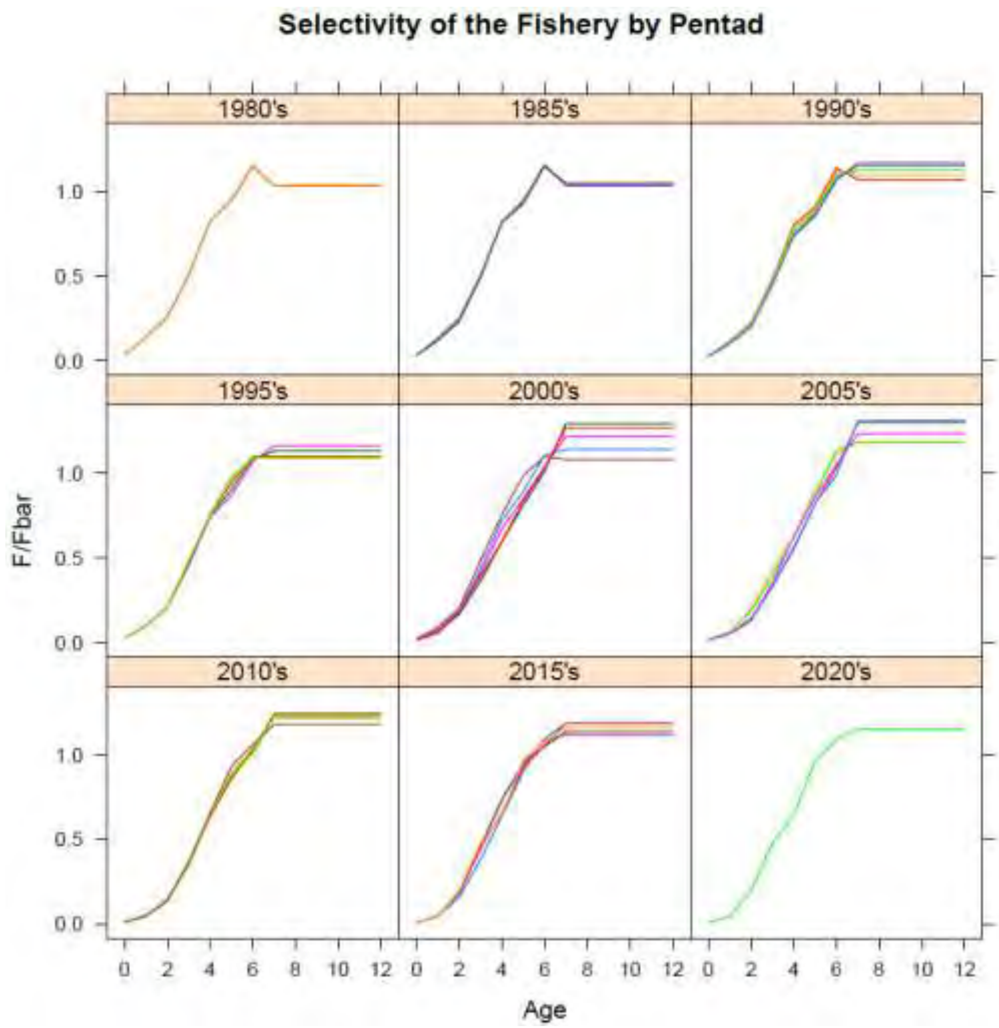

Figure 8.7.3.2. NE Atlantic mackerel. Estimated selectivity for the period 1990 to 2020, calculated as the ratio of the estimated fishing mortality-at-age and the Fbar4-8 value in the corresponding year.

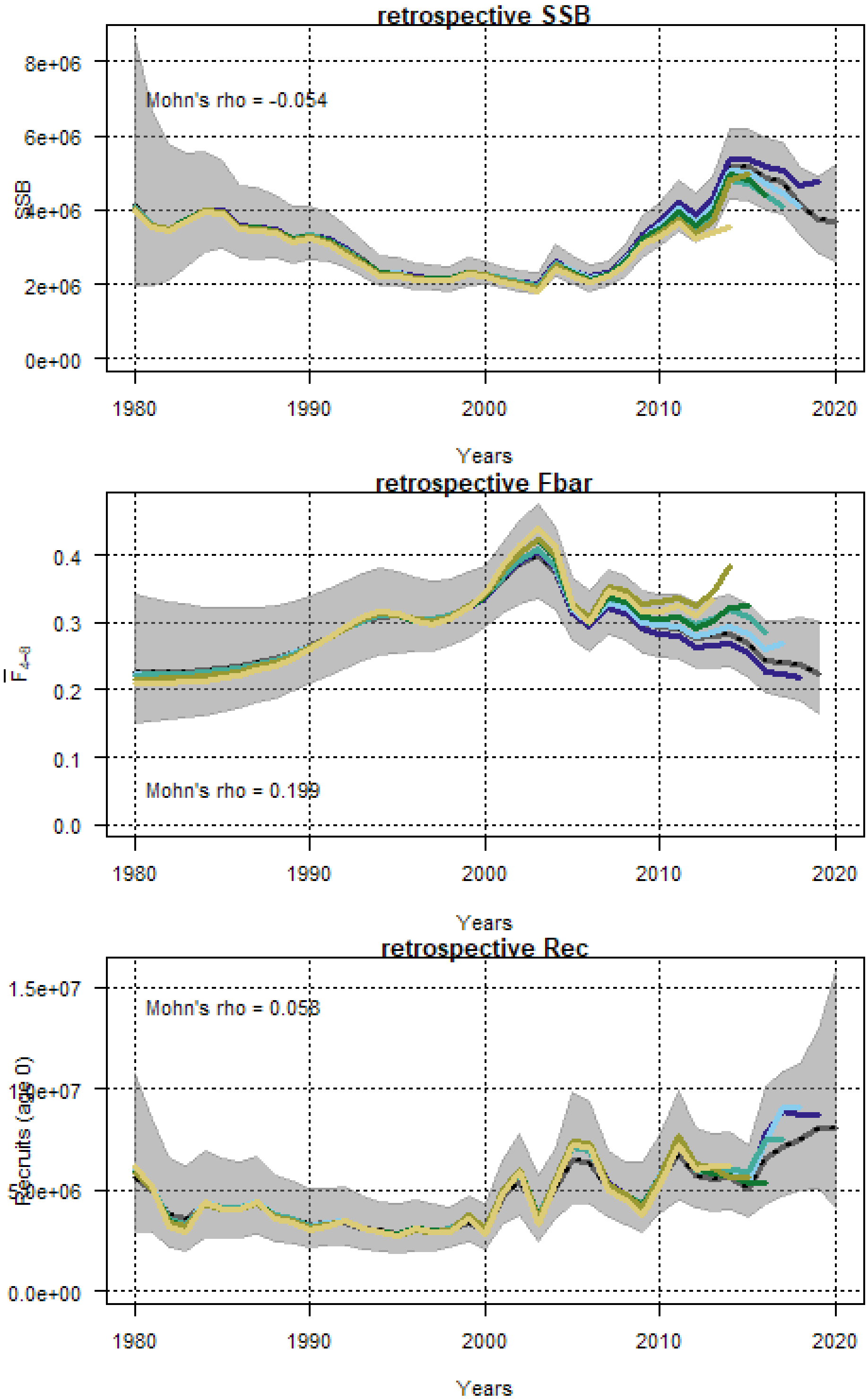

Figure 8.7.4.1. NE Atlantic mackerel. Analytical retrospective patterns (3 years back) of SSB, $F_{bar4\text{-}8}$ and recruitment from the WGWIDE 2020 update assessment.

Figure 8.7.4.2. NE Atlantic mackerel. Process error expressed as annual deviations of abundances at age, for the 2020 WGWIDE assessment and from the 2019 WGWIDE assessment.

Figure 8.7.4.3. NE Atlantic mackerel. Model process error expressed in biomass cumulated across age-group for the 2020 WGWIDE assessment and for the 2019 WGWIDE assessment.

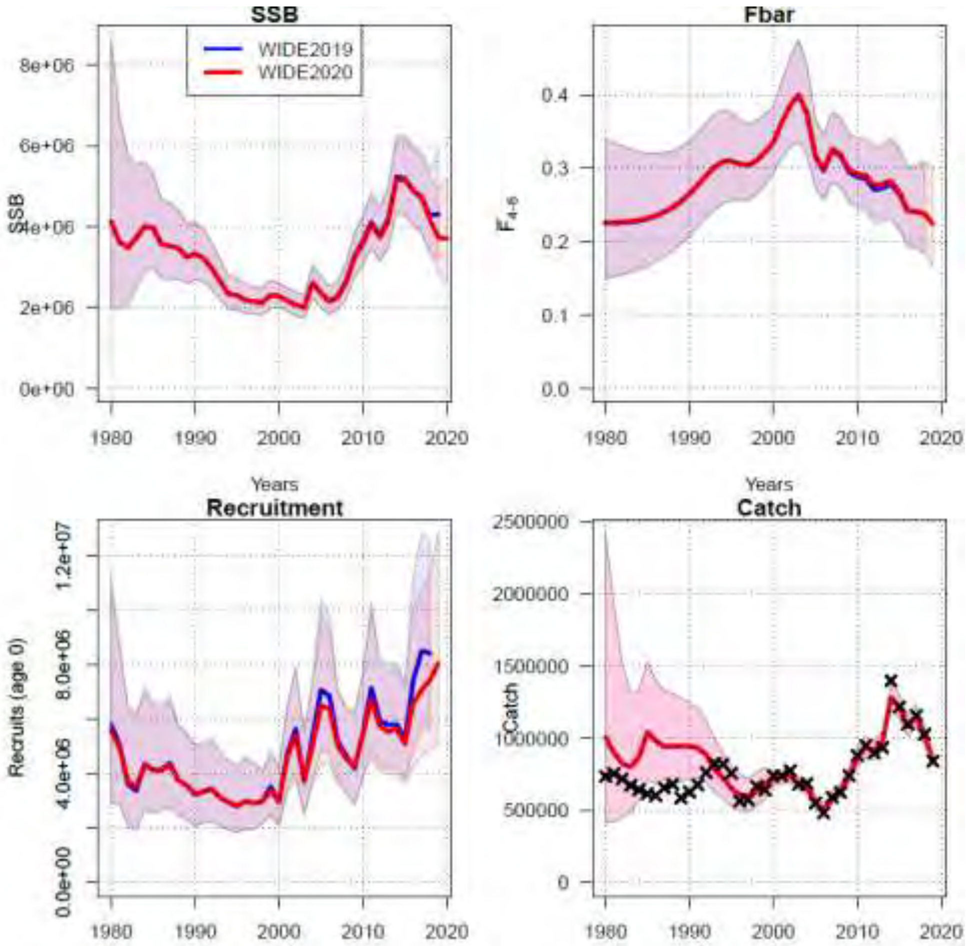

Figure 8.10.1. NE Atlantic mackerel. Comparison of the stock trajectories between the 2020 WGWIDE assessment and the 2019 WGWIDE assessment.

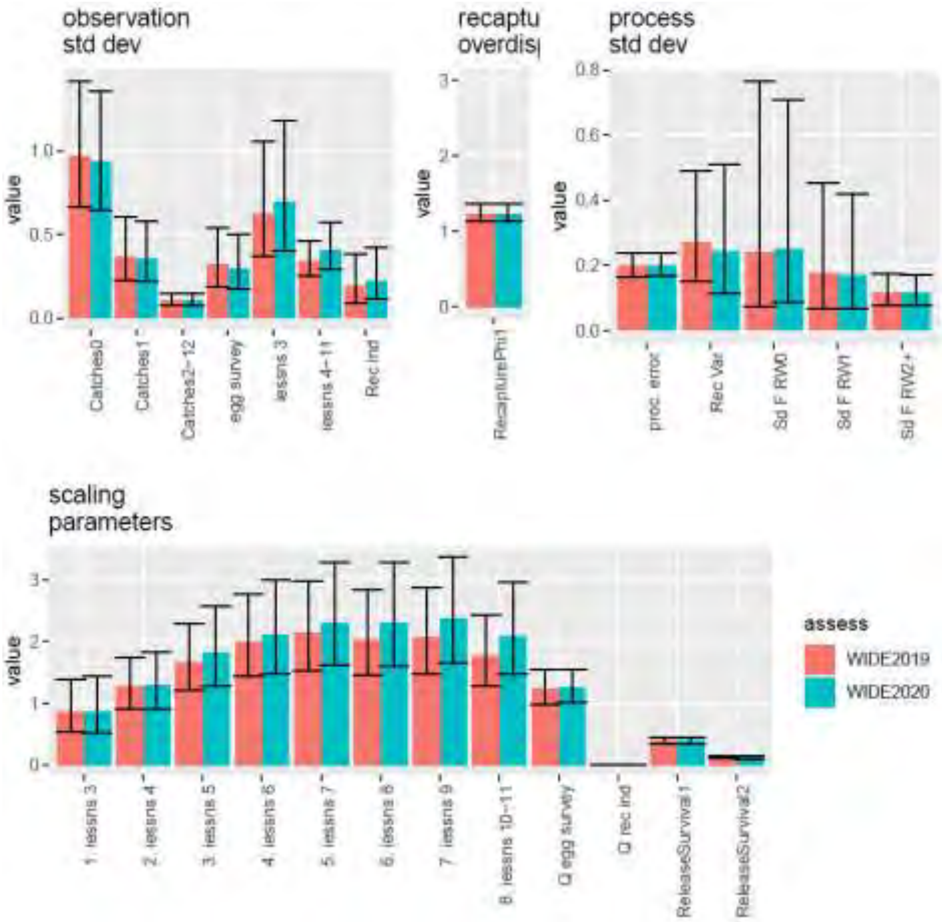

Figure 8.10.2. NE Atlantic mackerel. Comparison of model parameters and their uncertainty for the 2020 WGWIDE and the 2019 WGWIDE assessment

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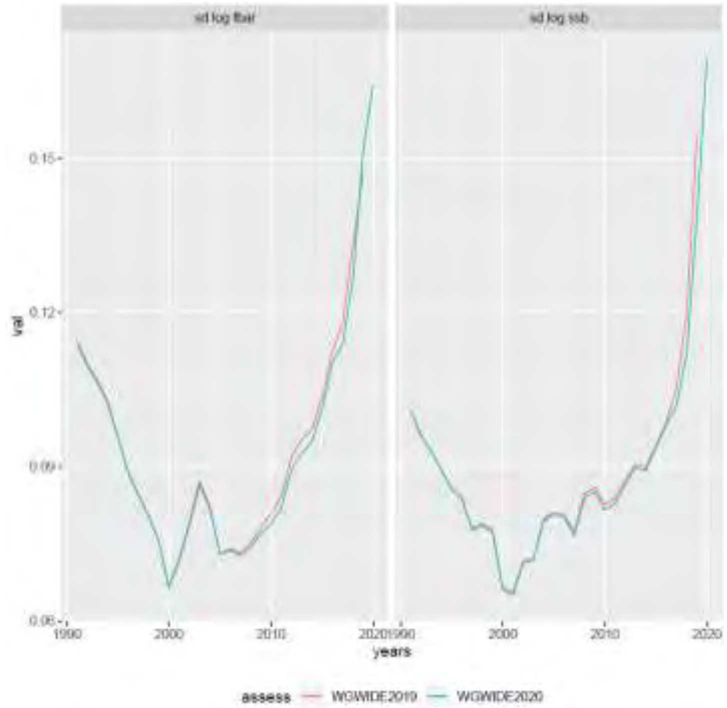

Figure 8.10.3. NE Atlantic mackerel. Comparison of the uncertainty on estimates of SSB and F_{bar} for the WGWIDE 2020 update assessment and the 2019 WGWIDE.

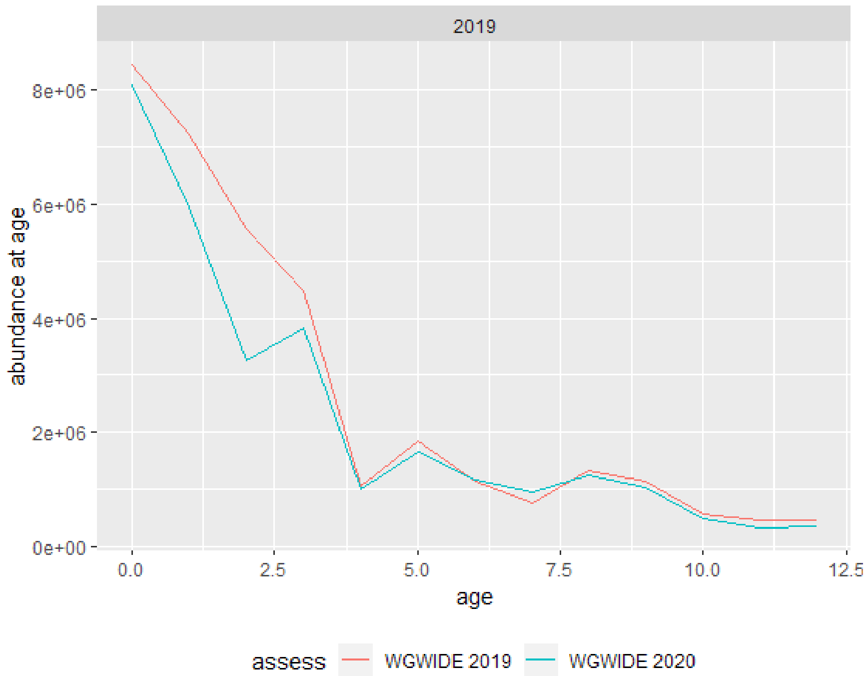

Figure 8.10.4. NE Atlantic mackerel. Comparison of the abundances at age in 2019 estimated from the 2019 and 2020 assessments.

Figure 8.11.1. NE Atlantic mackerel. Top: comparison of the ICES advice, the agreed TAC (or the sum of the unilateral quota) and total catch. Bottom: calculated percentage of Catch over Advice (CoA) and TAC over Advice (ToA).

9 Red gurnard in the Northeast Atlantic

9.1 General biology

The main biological features known for red gurnard (*Aspitrigla (Chelidonichthys) cuculus*) are described in the stock annex. This species is widely distributed in the North-east Atlantic from South Norway and North of the British Isles to Mauritania on grounds between 20 and 250 m. This benthic species is abundant in the Channel (7de) and on the shelf West of Brittany (7h, 8a), living on gravel or coarse sand. In the Channel, the size at first maturity is ~25cm at 3 years old (Dorel, 1986).

9.2 Stock identity and possible assessments areas

A compilation of datasets from bottom-trawl surveys undertaken within the project 'Atlas of the marine fishes of the northern European shelf' has produced a distribution map of red gurnard. Higher occurrences of red gurnard with patchy distribution have been observed along the Western approaches from the Shetlands Islands to the Celtic Seas and the Channel.

A continuous distribution of fish crossing the Channel and the area West of Brittany does not suggest a separation of the Divisions 7d from 7e and 7h. Therefore, a split of the population between the Ecoregions does not seem appropriate. Similar temporal signals observed in NS-IBTS and SCO-WCIBTS surveys, which are not seen in other survey series, may suggest a linkage between subareas 4 and 6. Further investigations are needed to progress on stocks boundaries such as morphometric studies, tagging and genetic population studies.

9.3 Management regulations

There is currently no technical measure specifically applied to red gurnard or other gurnard species. The exploitation of red gurnard is submitted to the general regulation in the areas where they are caught. There is no minimum landing size set.

9.4 Fisheries data

Red gurnard is mainly landed as by-catch by demersal trawlers in mixed fisheries, predominantly in Divisions 7d, 7e and 7h (Figure 9.1). High discard rates and lack of resolution at a species level make interpretation of spatial trends in catches in other areas problematic.

9.4.1 Historical landings

Official landings reported at ICES are available in Table 9.1 and Table 9.2. Before 1977, red gurnard was not specifically reported. Landings of gurnards are still not always reported at a species level, but rather as mixed gurnards. For those countries who do report landings at a species level, only Portugal has presented information on how this is achieved. This makes interpretation of the records of official landings difficult.

International landings have fluctuated between 3452 - 5171 tonnes since 2006. France is the main contributor of 'red gurnard' landings, with around 80% of landings coming from ICES Subarea 7d-h (Celtic Sea/English Channel). In the North Sea red gurnard landings are variable, but roughly evenly distributed between Divisions 4a,b and c. Landings from the west of Scotland

and Ireland, and the Irish Sea (ICES Subarea 6a-b, 7a-c, 7j) and Bay of Biscay (ICES Division 8) have been consistently low. The distribution of landings by statistical rectangle is shown in Fig. 9.1.

9.4.2 Discards

Discard data for red gurnard has been provided for 2015 - 2019 through Intercatch (Table 9.3). For those countries which provided data, discard rates are variable but high, ranging between from 48% and 91% of catch in 2017, 21% and 95% in 2018, and 56% and 95% in 2019 (Table 9.4).

9.5 Survey data

Information on gurnard abundance are available in DATRAS for the IBTS-Q1 survey in the North Sea, Scottish West Coast Groundfish Survey (WCGFS), Irish Groundfish Survey (IGFS) and the French EVHOE-WIBTS-Q4 survey in the Celtic Sea and Bay of Biscay and CGFS-Q4 in Division 7d. Each of these surveys covers a specific area of red gurnard distribution. Lengths at age are available from CGFS-Q4 in and IGFS-Q4

9.6 Biological sampling

Number at length information was provided by French and Portuguese landings and discards. There remains a lack of regular sampling for red gurnard in commercial landings and discarding to provide series of length or age compositions usable for a preliminary analytical assessment.

9.7 Biological parameters and other research

There is no update of growth parameters and available parameters from several authors are summarized in the Stock Annex. They vary widely. Available length–weight relationships are also shown in Stock Annex. Natural mortality has not been estimated in the areas studied at this Working Group.

9.8 Analyses of stock trends

NS- IBTS-Q1 series. Before 1990, red gurnard was scarce in North Sea and the abundance index was close to 0. The abundance index of red gurnard has trended generally upwards between 1994 – 2013, before declining, although it remains well above long-term average values. This change reflects an increase of the abundance in the northern North Sea (4a). It is interesting to contrast these trends with the apparent very low abundances in the NS-IBTS-Q3 series.

SCO-WCGFS series. Before 1996, red gurnard was also scarce on the west of Scotland. The abundance index trended strongly upwards after 1997, reaching a peak in 2013, before declining to around the series average in recent years.

IGFS series. The abundance index of red gurnard in the IGFS series has varied around the series mean without trend between 2002 and 2018.

CGFS-Q4 series. Over the time-series 1988—2011, the abundance index has fluctuated, peaked in 1994, reached a low in 2011, but is above long term mean in 2016.

EVHOE-WIBTS-Q4 series. Over the period 1997—2011, the abundance index in Nb or kg/hr has increased over time. Age reading of red gurnards caught during EVHOE survey has been carried out in 2006 and routinely since 2008. They indicate that the individuals caught are mainly of age 1 and 2.

SP-PORC and SP-NSGFS. Both survey indices are variable, but show an overall upwards trend over time in numbers and weight per tow.

9.9 Data requirements

Gurnards are still not always reported by species, but rather as mixed gurnards. National approaches to validating composition of gurnard landings is undocumented, other than for Portuguese landings. This makes interpretations of the records of official landings difficult. Extending the studied area by a survey in 7e and collecting length and age data of red gurnard in the main area of production should help in better understanding the biology and dynamics of this species.

9.10 References

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9.11 Tables

Table 9.1. Red gurnard in the Northeast Atlantic. Official landings by country in tonnes.

Year	Bel-gium	Spain	France	Jer-sey	Guern-sey	Ire-land	IM	Nether-lands	Portugal	UK	Total
2006	313	0	4552	0	10	0	0	57	125	115	5172
2007	328	0	4494	1	4	0	0	66	127	156	5176
2008	352	0	4045	0	8	0	0	92	112	166	4775
2009	227	0	3310	0	6	0	1	160	150	263	4117
2010	237	0	3437	0	2	0	0	251	115	362	4404
2011	306	0	3176	1	2	0	1	295	134	257	4172
2012	306	0	2706	3	4	26	0	329	148	257	3779
2013	288	576	3154	3	9	16	2	267	113	329	4757
2014	263	399	3782	3	6	0	5	241	108	283	5090
2015	187	91	2919	2	3	0	0	210	122	341	3875
2016	238	87	2598	3	2	9	1	224	106	381	3646
2017	265	104	2396	0	1	9	4	226	113	335	3454
2018	314	89	2968	0	0	13	1	306	114	342	4147
2019*	289	84	2438	0	0	9	0	238	117	478	3653
2019**	289	35	2464	0	6	9	0	237		470	3509

*Preliminary Data,

**Intercatch Data

Table 9.2. Red gurnard in the Northeast Atlantic. Official landings by area in tonnes.

Year	4a	4b	4c	5b	6a	6b	7a	7b	7c	7d	7e	7f	7g	7h	7j	7nk	8a	8b	8c	8d	9a	9nk	10a	10nk	14a	Total
2006	13	83	64	0	32	1	11	9	12	1101	2803	229	16	446	5	0	153	60	1	5	9	115	0	1	0	5054
2007	12	120	55	2	21	0	7	7	15	1229	2674	246	15	437	4	0	139	59	3	2	125	0	0	2	0	5174
2008	34	64	54	0	28	3	5	7	16	1236	2451	249	9	408	5	0	66	24	3	1	109	0	3	0	0	4772
2009	58	59	92	0	94	2	4	8	6	1293	1557	112	22	510	7	0	98	40	1	3	148	0	1	0	0	4115
2010	79	63	86	0	101	46	13	8	10	1531	1608	132	23	433	9	0	100	33	0	2	114	0	0	1	0	4392
2011	66	29	51	0	69	54	13	5	6	1295	1753	124	20	372	9	0	112	46	1	3	133	0	1	0	1	4163
2012	83	71	78	0	51	7	8	2	5	1244	1441	145	53	294	2	0	83	50	8	1	136	4	1	0	1	3768
2013	88	109	60	0	47	0	10	2	6	1193	1692	170	58	477	2	0	79	72	532	1	155	0	2	0	0	4755
2014	102	52	68	0	47	3	7	1	2	1294	1642	115	19	1069	1	0	82	75	363	3	139	0	3	0	0	5087
2015	133	102	53	0	58	1	4	3	1	790	1553	87	6	703	1	0	95	70	81	2	128	0	2	0	0	3873
2016	112	83	117	0	76	1	11	3	1	906	1270	114	16	608	1	0	87	63	56	1	120	0	1	0	0	3645
2017	53	44	90	0	27	1	14	1	0	874	1424	83	38	473	3	0	78	48	59	1	142	0	1	0	0	3454
2018	109	40	113	0	43	0	7	0	0	903	1785	164	28	631	4	0	80	43	62	2	116	0	1	0	0	4131
2019*	127	19	73	0	76	0	13	1	0	952	1499	74	28	477	0	5	74	37	65	0	121	0	0	0	2	3646

***Preliminary Data**

Table 9.3. Red gurnard in the Northeast Atlantic. Discards (t) by country, 2015 – 2019.

Country	2015	2016	2017	2018	2019
France	1323	2249	2232	770	3132
Ireland	10	147	93	251	180
Spain		286	272	189	122
UK (ENG)	74	30		207	506
UK (SCO)	649	411	198	512	331
Total	2056	3123	2795	1929	4270

Table 9.4. Discarding of Red gurnard in the Northeast Atlantic, as a percentage of catch, by country, in 2017–19.

Country	Discard rate (%)		
	2017	2018	2019
France	48	21	56
Ireland	91	95	95
Spain	72	68	78
UK (England)			67
UK (Scotland)	68	92	60

9.12 Figures

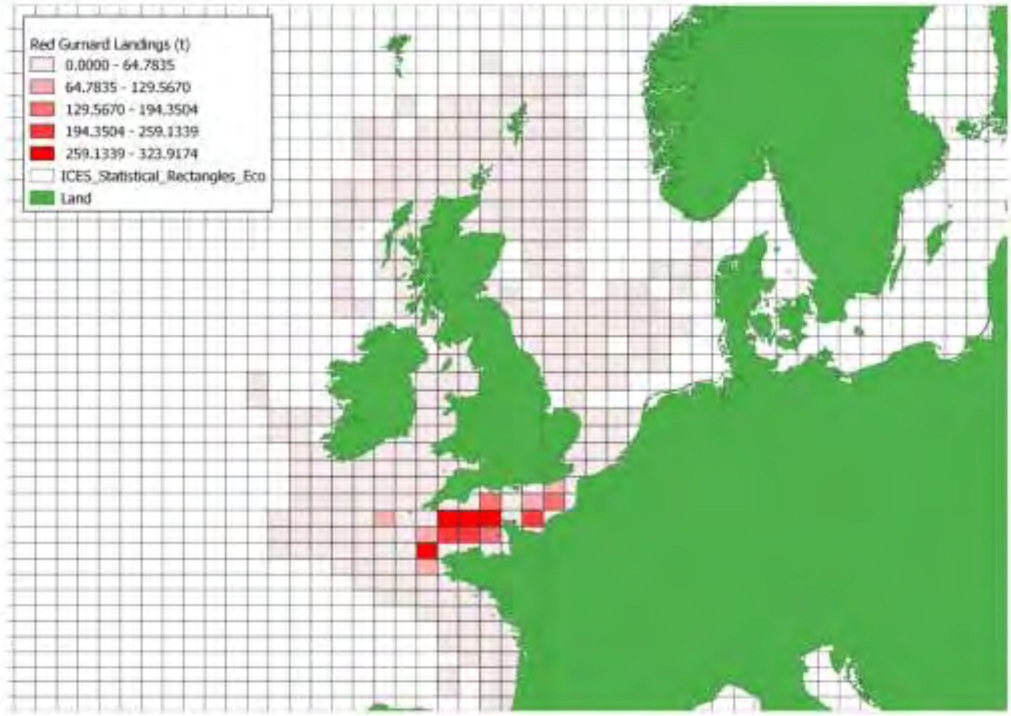

Figure 9.1. Red gurnard in the Northeast Atlantic. Landings in 2018, by statistical rectangle, from BEL, FRA, IRE, UK(E&W), UK(IoM) & UK(SCO).

10 Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a

10.1 General biology

Striped red mullet (*Mullus surmuletus*) is a predominantly benthic species found along the coasts of Europe, southern Norway and northern Scotland (northern Atlantic, Baltic Sea, North Sea and the English Channel), up to the Northern part of West Africa, in the Mediterranean Basin, and in the Black Sea (Hureau, 1986; Mahé *et al.*, 2005). Young fish are distributed in lower salinity coastal areas, while adults have a more offshore distribution.

Adult red mullet feed on small crustaceans, annelid worms and molluscs, using their chin barbels to detect prey and search the mud. As a consequence, striped red mullet are typically found on sandy, gravelly and shelly sediments where they can excavate sediment with their barbels and dislodge the small invertebrates. The main natural predators of striped red mullet are sea basses, pollacks, barracudas, monkfish, congers and sharks (Caill-Milly *et al.*, 2017).

Sexual maturity is reached at the beginning of the second year for males, followed by a marked decrease in growth rates, and at the end of the second or beginning of the third year for females which therefore continue their rapid growth a little longer (Déniel, 1991). In the English Channel, this species matures at approximately 16 cm (Mahé *et al.*, 2005), while in the Bay of Biscay, the sizes of first sexual maturity are given by Dorel (1986) as: males 16 cm, females 18 cm and a length at which 50% of the individuals are mature (the distinction between the two sexes is not mentioned) of 22cm.

Spawning occurs in the spring and early summer (May to June according to Desbrosses, 1935) with a spawning peak in June in the northern Bay of Biscay (N'Da & Déniel, 1993). Eggs and larvae average 2.8mm and are pelagic (Sabates *et al.*, 2015). The hatching takes place after three days at 18°C and after eight days at a temperature of 9°C (Quéro & Vayne, 1997). After metamorphosis juveniles become first demersal then benthic. At the age of one month, they measure about 5cm and weigh 0.9 to 1.6g. They show rapid growth during their first four months of life between July and October. Increases in length and mass are about 7cm and 25g on average during this period (N'Da & Déniel, 2005). The rate of growth declines sharply in October due to the cooling of water and the scarcity of trophic resources in the environment. These conditions contribute to the initiation of migration of red mullets to greater depths offshore. Until the age of two, there is no significant difference in size between males and females; they then measure 20-23cm. Sexual dimorphism is observed from the age of first maturity due to growth rates that will then differ between the two sexes. From age three, females exceed males in length by 4 cm on average and 7cm beyond 5 years (N'Da & Déniel, 2006).

The maximum reported age of the striped red mullet is 11 years (Quéro & Vayne, 1997; ICES, 2012), while the maximum length given is 44.5cm in the Bay of Biscay (Dorel, 1986) and 40cm elsewhere (Hureau, 1986; Bauchot, 1987). The maximum reported mass is 1kg (Muus and Nielsen, 1999).

10.2 Management regulations

Prior to 2002, France enforced a minimum landing size of 16cm. Since this minimal size requirement has been removed, immature individuals (< 14cm) have been recorded in landings. There is no TAC for this stock.

10.3 Stock ID and possible management areas

In 2004 and 2005, a study using fish geometrical morphometry was carried out in the Eastern English Channel and the Bay of Biscay. It pointed out a morphological difference on striped red mullets between those from the Eastern English Channel and those from the Bay of Biscay.

Benzinou *et al.* (2013) conducted stock identification studies based on otolith and fish shape in European waters and showed that striped red mullet can be geographically divided into three zones:

- The Bay of Biscay (Northern Bay of Biscay – NBB, and Southern Bay of Biscay - SBB)
- A mixing zone composed of the Celtic Sea and the Western English Channel (CS + WEC)
- A northern zone composed of the Eastern English Channel and the North Sea (EEC + NS)

The distinction between the putative Biscay and Western Channel/Celtic Sea populations is supported by the distribution of landings at a statistical rectangle level (Fig. 10.1). Examination of catch from surveys suggests striped red mullet in Div. 9a are geographically distinct, with an area of higher abundance between Cabo Sao Vicente and the Tagus estuary, and an area where this species is mostly absent to the north (Fig. 10.2). This assessment treats these putative components as one population. At present there are no management measures in place, however this structuring should be taken into account if measures are considered.

10.4 Fisheries data

Official landings have been recorded since 1975 and after early increases they have declined in recent years. Landings are mainly taken from Subarea 7 and 8 and France accounts for the majority of removals (Table 10.1). The striped red mullet is one species among set of benthic (demersal) species targeted by the French fleet, and is mainly caught by bottom trawlers with a mesh size of 70—99mm. In the Western English Channel striped red mullet is also caught by gillnets. Danish seine appeared in 2008 as a result of some trawlers converting to use seine gears.

The average characteristics of vessels in French fleets that caught red mullet from 2000 to 2015 are: 41.1 GRT, 191.1kW engine power, 12.9m length and 22 years of service. Net vessels are made up of the smallest units (85% are less than 12m long), while 52% of bottom trawlers are less than 15m; the seiners are by far the largest and the oldest vessels (Caill-Milly *et al.*, 2017).

The French activity on this species differs between the area composed by West Scotland/Celtic sea (including West Channel) and the area comprising the Bay of Biscay. In the first one, landings are mainly taken by bottom trawlers, followed by gillnet. In the second one, they are mainly done by bottom trawls, seine and nets. French activity in the Atlantic Iberian waters remains limited. The Spanish activity is located in the north (8.a,b) and the south (8.c) of the Bay of Biscay.

Prior to 2015 this species was not recorded as being discarded by French or Portuguese vessels and was infrequent in Spanish sampling. Discarding represented between 9% and 68% of UK catches in 2014–17 (table 10.3). however there are concerns about how these discards have been estimated – the 2016 figure is based on a sample of 2 fishes. French discard estimates for 2017 represented 7% of catch. For French demersal trawls (70-99mm mesh size), discards are essentially composed of individuals measuring between 8 and 17cm (fig. 10.3).

10.5 Survey data, recruit series

Exchange data is available in DATRAS during 1997-2019 for the French EVHOE survey, covering the Bay of Biscay and Celtic Sea (Fig. 10.4), during 2001–2016 for the northern Spanish groundfish survey (SP-NSGFS) (Fig. 10.5), and from 2002 onwards for the Portuguese groundfish survey (PT-IBTS), covering the Portuguese coast (Fig 10.6). Standardised catch rates in the EVHOE survey are variable around the series mean between 1997–2011, before falling to a lower level thereafter. Similarly, catch rates in the PT-IBTS are at a low level in 2005, peak in 2010, before falling back to near the series mean in recent years (Fig. 10.3).

Abundance indices per size class during EVHOE-WIBTS-Q4 show mainly fish between 8 and 17 cm (TL).

10.6 Biological sampling

In the Bay of Biscay sexual maturity and length measures were taken in 2009 by AZTI. French samplings started in 2004 in the Eastern Channel and in the south North Sea, and since 2008 in the Bay of Biscay.

10.7 Biological parameters and other research

Since 2004, data (age, length, sexual maturity) are usually collected by France for the Eastern English Channel and the southern North Sea. France started to collect data for 8a,b at the end of 2007. In 2007—2008, the striped red mullet otolith exchange had for goal to optimize age estimation between countries.

In 2011, an Otolith Exchange Scheme was carried out, which was the second exercise for the Striped red mullet (*Mullus surmuletus*). Four readers of this exchange interpreted an images collection coming from the Bay of Biscay, the Spanish coasts and the Mediterranean coasts (Spain and Italy). A set of *Mullus surmuletus* otoliths (N=75) from the Bay of Biscay presented highest percentage of agreement (82%). On 75 otoliths, 34 were read with 100% agreement (45%) and thus a CV of 0%. Modal age of these fishes was comprised between 0 and 3 years (Mahé *et al.*, 2012).

10.8 Analysis of stock trends/ assessment

Currently, an age structured analytical stock assessment has not been developed due to a short time-series of available data.

10.9 Data requirements

Regular sampling of biological parameters of striped red mullet catches must be continued under DCF. Sampling in the Celtic Sea and in the Bay of Biscay started in 2008. In 2010 and 2011, sampling for age and maturity data was reduced compared to 2009, due to the end of the Nespman project. Since 2009, a concurrent sampling design carried out, should provide more data (length compositions) than in recent years.

10.10 References

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10.11 Tables

Table 10.1. Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a. Official landings by country in tonnes.

Year	Belgium	Spain	France	Guernsey	Ire-land	Jersey	Netherlands	Portugal	UK	Total
2006	33	379	1937	8	15	1	115	11	170	2668
2007	43	390	1926	9	17	1	148	222	193	2949
2008	26	379	1384	9	17	0	165	169	164	2314
2009	20	490	1539	5	10	0	110	199	131	2504
2010	20	465	1725	5	5	0	128	276	132	2756
2011	21	504	1722	0	5	0	130	245	154	2782
2012	37	328	1318	0	4	1	125	217	122	2152
2013	28	245	925	5	3	0	50	187	70	1514
2014	12	265	914	5	2	0	1	221	53	1474
2015	23	248	1207	5	3	0	110	282	102	1980
2016	28	194	1166	15	4	0	69	204	83	1763
2017	35	152	988	0	10	0	16	150	64	1415
2018	36	185	880	0	0	0	93	153	67	1415
2019*	29	167	1333	0	12	0	99	159	55	1855
2019**	30	268	1358		12		90		55	1813

*** Preliminary Data**

**** Intercatch Data**

Table 10.2. Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a. Official landings by area in tonnes.

Year	6a	6b	7a	7b	7c	7e	7f	7g	7h	7j	7k	8a	8b	8c	8d	8e	9a	Total
2006	0	0	1	1	0	869	50	24	103	5	0	1023	468	71	14	0	39	2668
2007	1	0	1	1	1	1047	54	22	104	12	0	861	473	90	16	0	267	2949
2008	0	0	1	1	0	880	46	16	73	13	0	639	246	87	18	0	296	2314
2009	2	0	1	2	1	592	25	9	74	17	0	879	460	156	44	0	243	2504
2010	2	0	1	3	1	642	26	10	59	16	1	1033	467	146	19	0	331	2756
2011	1	1	1	0	0	665	20	10	55	6	0	970	513	214	17	0	310	2782
2012	0	0	0	0	0	493	23	7	34	4	0	696	387	200	27	0	280	2152
2013	0	0	0	1	0	232	23	7	36	2	0	473	328	166	6	0	241	1514
2014	1	0	0	0	0	192	15	3	40	1	0	523	240	151	12	0	297	1474
2015	0	0	0	1	0	595	10	2	35	1	0	506	327	127	7	0	369	1980
2016	0	0	0	2	0	432	21	7	35	3	0	549	311	117	10	0	277	1763
2017	0	0	0	1	0	279	26	21	36	3	0	505	244	96	5	0	198	1415
2018*	0	0	0	0	0	356	26	7	40	2	0	437	219	83	2	0	243	1415
2019*	0	0	1	0	0	374	22	19	34	1	0	762	314	100	4	0	224	1855

*** Preliminary Data**

**** Intercatch Data**

Table 10.3. Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a. Discards (t) by country in 2012-2019.

Country	2012	2013	2014	2015	2016	2017	2018	2019
BE						2	3	3
ES			4	5	8	0	2	1
FR				115	213	74	34	67
IE						0	0	0
NL							0	0
PT	0	0	0		0	0	0	0
UK	2	1	5	77	171	11	1	29
Total	2	1	9	197	392	87	40	100

10.12 Figures

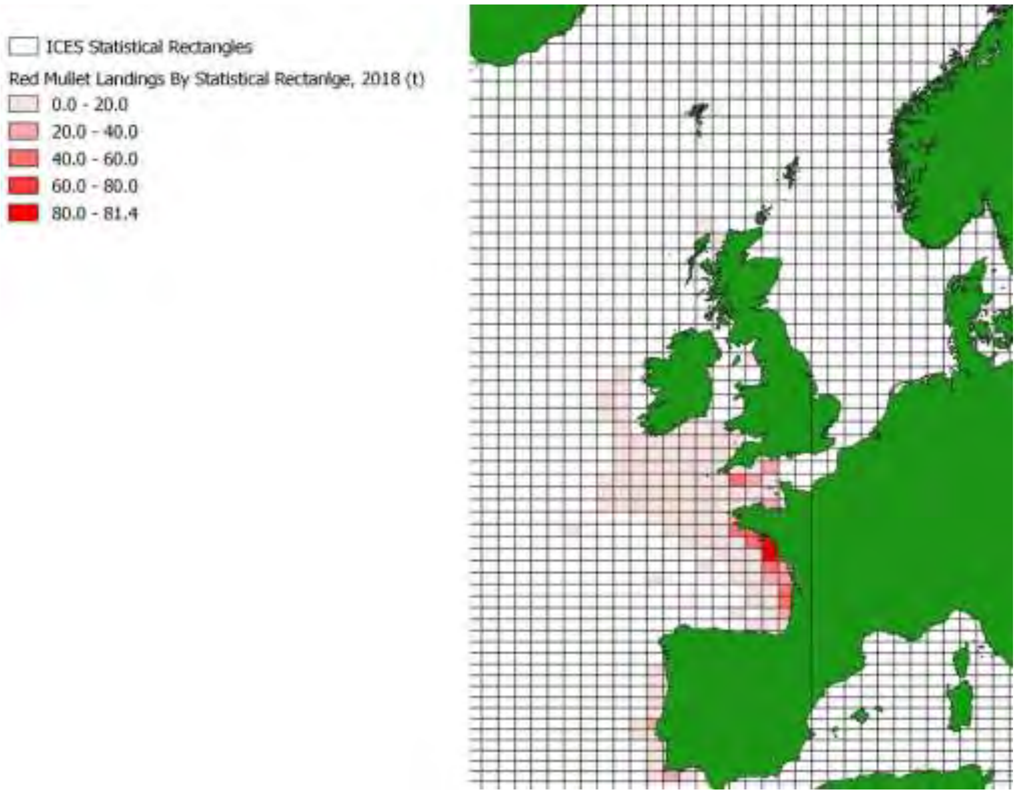

Figure 10.1. Striped red mullet in Subareas and Divisions 6, 7a-c, e-f, 8 and 9a. Landings by statistical rectangle for BEL, FRA, IRE, PT, UK (E&W), UK (SCO).

Figure 10.2. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Survey catches of Striped red mullet in the Portuguese Groundfish Survey (PT-IBTS), 2015 – 2017.

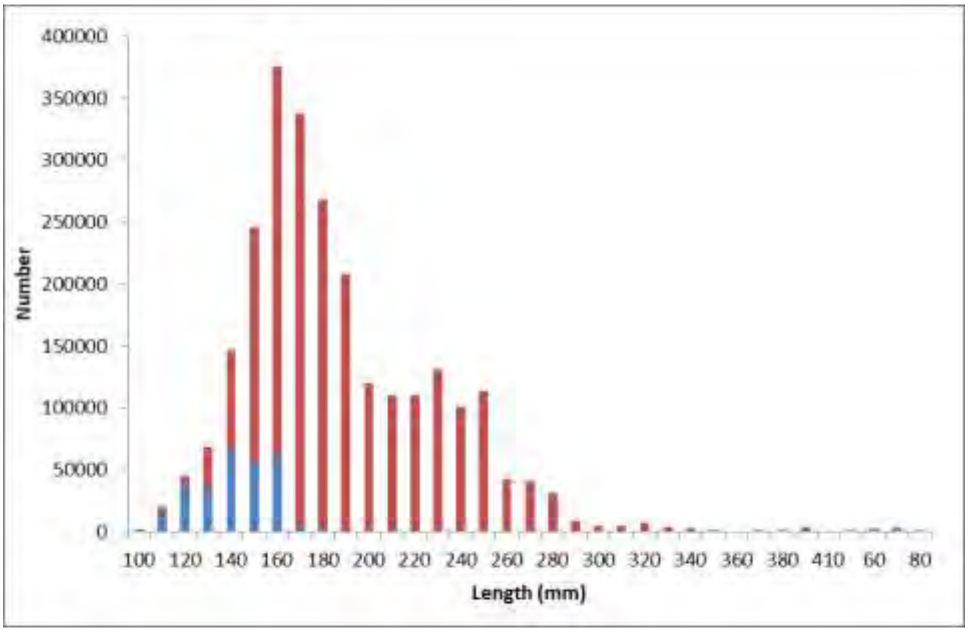

Figure 10.3. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Length distribution in 2018 of French catches from OTB_DEF_>=70 (landings – red, discards – blue).

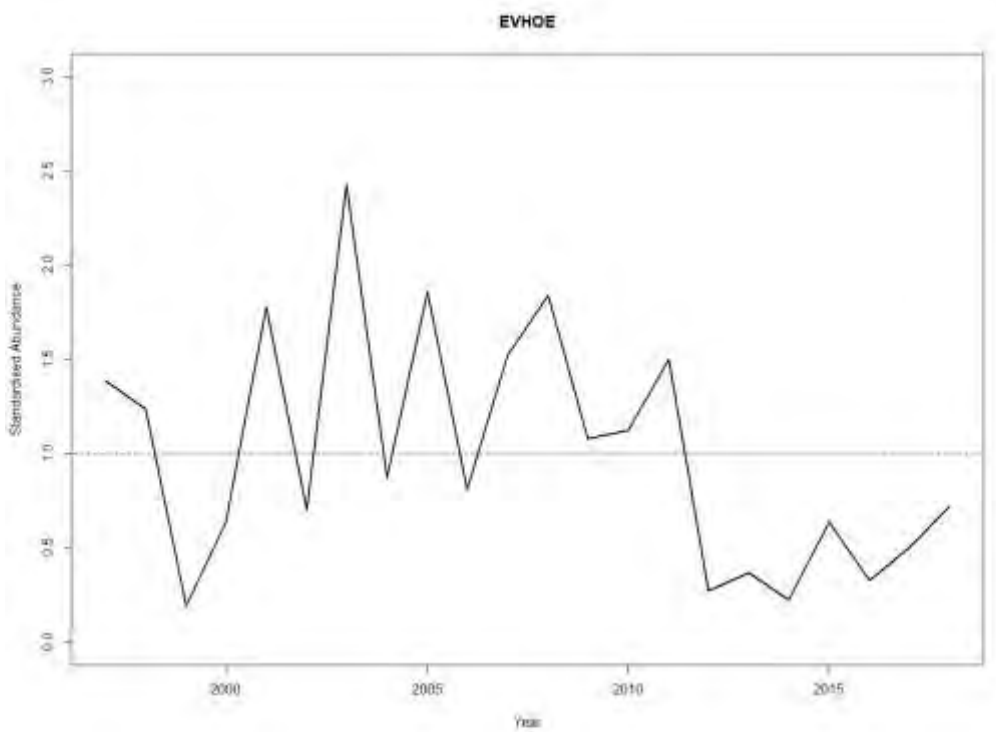

Figure 10.4. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Standardised survey abundances for French Southern Atlantic Bottom Trawl (EVHOE) survey, 1997 – 2018.

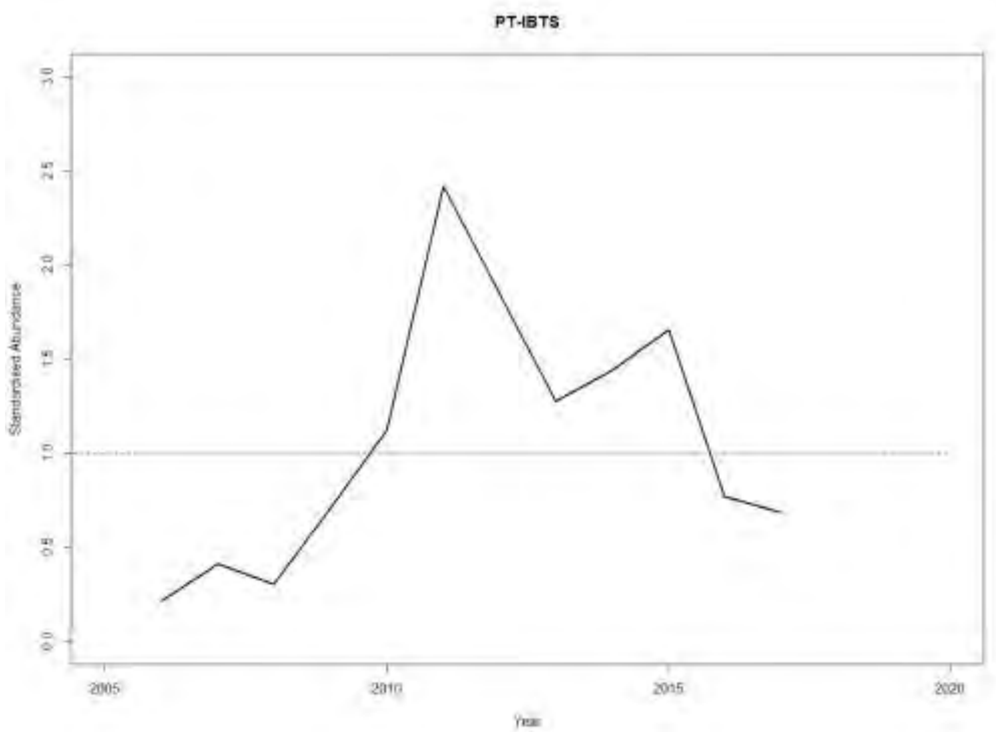

Figure 10.5. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Standardised survey abundances for Portuguese International Bottom Trawl Survey (PT-IBTS), 2006 - 2017.

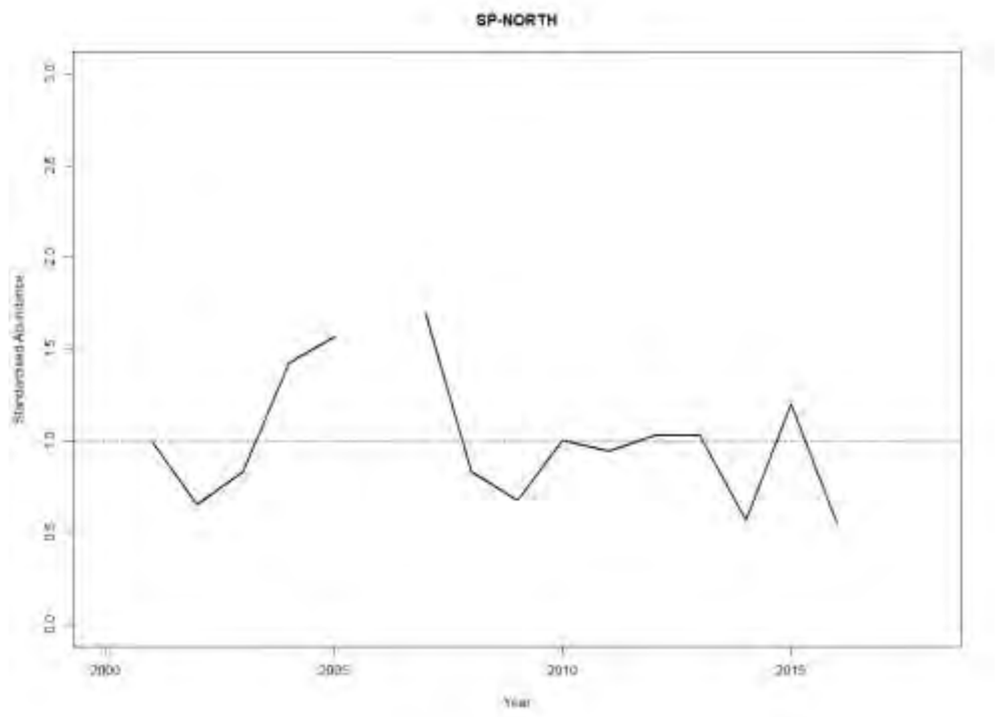

Figure 10.6. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Standardised survey abundances for Spanish North Coast Bottom Trawl Survey (SP-NORTH). 2001 - 2016.

Annex 1: List of Participants

Name	Institute	E-mail	Country of Institute
Afra Egan	Marine Institute	afra.egan@marine.ie	Ireland
Åge Højnes	Institute of Marine Research	aageh@hi.no	Norway
Alessandro Orio	Institute of Marine Research	alessandro.orio@slu.se	Sweden
Alexander Krysov	Polar Branch of the VNIRO ("PINRO" named after N.M. Knipovich)	a_krysov@pinro.ru	Russian Federation
Anatoly Chetyrkin	Polar branch of the VNIRO	chaa@pinro.ru	Russian Federation
Andrew Campbell (chair)	Marine Institute	andrew.campbell@marine.ie	Ireland
Anna H. Olafsdottir	Marine and Freshwater Research Institute	anna.olafsdottir@hafogvatn.is	Iceland
Are Salthaug	Institute of Marine Research	are.salthaug@hi.no	Norway
Aril Slotte	Institute of Marine Research	aril.slotte@hi.no	Norway
Bernhard Kühn	Thünen Institute of Sea Fisheries	bernhard.kuehn@thuenen.de	Germany
Claus Sparrevohn	Danish Pelagic Producers' Organisation	crs@pelagisk.dk	Denmark
David Miller	ICES	david.miller@ices.dk	Denmark
Erling Kåre Stenevik	Institute of Marine Research	erling.kaare.stenevik@hi.no	Norway
Esther Beukhof	Wageningen UR Centre for Marine Policy	esther.beukhof@wur.nl	Netherlands
Eydna í Homrum	Faroe Marine Research Institute	eydnap@hav.fo	Faroe Islands
Gersom Costas	Instituto Español de Oceanografía	gersom.costas@ieo.es	Spain
Gwladys Lambert	Cefas	gwladys.lambert@cefas.co.uk	UK
Höskuldur Björnsson	Marine and Freshwater Research Institute	hafogvatn@hafogvatn.is	Iceland
Jan Arge Jacobsen	Faroe Marine Research Institute	janarge@hav.fo	Faroe Islands
Jens Ulleweit	Thünen Institute of Sea Fisheries	jens.ulleweit@thuenen.de	Germany

Name	Institute	E-mail	Country of Institute
Laurent Dubroca	Ifremer	laurent.dubroca@ifremer.fr	France
Leif Nøttestad	Institute of Marine Research	leif.noettestad@hi.no	Norway
Lisa Anne Libungan	Marine and Freshwater Research Institute	lisa.libungan@hafogvatn.is	Iceland
Martin Pastoors	Pelagic Freezer-Trawler Association	mpastoors@pelagicfish.eu	The Netherlands
Morten Vinther	DTU Aqua	mv@aqua.dtu.dk	Denmark
Neil Campbell	Marine Science Scotland	neil.campbell@gov.scot	Scotland
Nikolay Timoshenko	AtlantNIRO	timoshenko@atlantniro.ru	Russia
Pablo Carrera	Instituto Español de Oceanografía	pablo.carrera@ieo.es	Spain
Patricia Goncalves	Portuguese Institute for the Sea and the Atmosphere (IPMA)	patricia@ipma.pt	Portugal
Richard Nash	Cefas	richard.Nash@cefas.co.uk	UK
Roxanne Duncan	Marine Institute	roxanne.duncan@marine.ie	Ireland
Rui Catarino	ICES	rui.catarino@ices.dk	Denmark
Sindre Vatnehol	Institute of Marine Research	sindre.vatnehol@hi.no	Norway
Sólva Eliasen	Faroe Marine Research Institute	solvae@hav.fo	Faroe Islands
Sondre Hølleland	Institute of Marine Research	sondre.hoelleland@hi.no	Norway
Sonia Sanchez	AZTI Pasaia	ssanchez@azti.es	Spain
Stanislovas Jonusas (observer)	DGMARE	stanislovas.jonusas@ec.europa.eu	EU commission
Teunis Jansen	Greenland Institute for Natural Resources	tej@aqua.dtu.dk	Greenland
Thomas Brunel	Wageningen University & Research	thomas.brunel@wur.nl	The Netherlands

Annex 2: Recommendations

Recommendations from WGWIDE 2020

Recommendations from WGWIDE 2020 are listed in the table below. Background information for the recommendations is in the relevant chapters for the respective species.

Recommendation	Recipient:
1. It is recommended that an age reading exchange and a following workshop are held for Norwegian spring spawning herring. The work should also deal with issues related to the mixing of NSSH with adjacent herring stocks in the fringes of the distribution area. The workshop participants should be both age readers and participants with statistical, stock identification and stock assessment expertise. This relates to section 4.14 in the report.	WGBIOP; WGIPS
2. It is recommended to organise a workshop on evaluation of NEA mackerel stock components and regional management measures. The aim is to review information on stock identification, formulate scenarios for mackerel components and evaluate the basis and provide recommendations on how the results could be used in the context of the ICES advice.	ACOM; SIMWG

Comments to recommendation 2

Below is a suggestion for Terms of Reference for a workshop on evaluation of NEA mackerel stock components and regional management unit.

WKEVALMAC– Workshop on the Evaluation of NEA Mackerel stock components and regional management measures.

2020/2/FRSG43 A **Workshop on the Evaluation of NEA Mackerel stock components and regional management measures (WKEVALMAC)** chaired by xxx, yyy will meet from xxx by correspondence (Webex) to:

a) Review information on stock identification of NEA Mackerel and comparative review of Atlantic mackerel population structure, including critical evaluation of inferences from each source of information, to build up a picture of mackerel components in the Northeast Atlantic, based on the following:
   i) Distribution and movements of different life-stages of mackerel, including changes over time, inferred from:
      1) Mackerel Tagging
      2) Scientific Surveys
      3) Commercial landings
      4) Dispersal models (e.g. of mackerel eggs and larva/juveniles)
   ii) Genetic analyses
   iii) Other approaches not listed above

b) Based on the evidence from ToR a, formulate scenarios for mackerel components in the Northeast Atlantic, and assess the evidence-based plausibility of each of these scenarios (including current definitions).

c) Consider the practical implications, for data, particularly historical time-series of catch data, of each of the scenarios in ToR b and how any difficulties might be dealt with. For example, considering spatial components with mixing in a single model has different implications for data compared to split stock units. Considerations should include how to deal with changes over time.

d) Make recommendations for which mackerel stock scenario(s) to take forward in a future mackerel benchmark, including in what format data should be requested and prepared.

e) Review and evaluate the basis and potential impacts of management measures targeted at specific areas or components of NEA mackerel (e.g. minimum landing size, closed areas, closed seasons, quota measures) and provide recommendations on how the results could be in the context of the ICES advice

The Workshop will report by xx for the attention of ACOM and FRSG.

Recommendations to WGWIDE 2020

There were two recommendations to WGWIDE 2020. They are listed in the table below together with the main response.

Recommendation	Recipient:	Response from WGWIDE 2020
ID141 from WGISDAA WGISDAA requests that WGWIDE produce a rerun of the latest NE Atlantic mackerel assessment with a shortened time series for the MEGS SSB index of the recent 5 surveys (2007-2019) to compare F, SSB and recruitment and management reference point estimates with the current full assessment.	WGWIDE	WGISDAA has been supplied with data and code to assess the impact of a shortened series of 'egg tuning series', on the NE Atlantic mackerel assessment.
ID207 from WGIPS Aim: To improve information sharing between WGIPS and assessment working groups with Survey Summary Tables Survey Summary Sheets have been developed by WGIPS in response to a previous request from assessment working groups. WGIPS requests that these groups (HAWG and WGWIDE) answer the assessment related questions at the bottom of the existing Survey Summary Sheet and return to WGIPS for review and feedback. The group would benefit greatly from feedback on any issues with annual survey data from WGIPS coordinated surveys and whether the WGIPS Survey Summary Sheets are fit for purpose.	WGWIDE; HAWG	The assessment related fields of the Survey Summary Tables will be filled in.

Status and follow-up on recommendations from WGWIDE 2019

Last year's meeting made five recommendations for other working groups. In the table below they are listed together with the status of the work.

Recommendation	Recipient:	Status
ID126. WGWIDE recommends that an age reading workshop on blue whiting must be conducted in the next years. Therefore it is important that the planned age-reading workshop for blue whiting will take place.	WGBIOP	Work is on-going with otolith exchange planned in winter 2020/2021 and workshop in summer 2021.
ID127. It is recommended that WGBIOP provides WGWIDE with the variance-covariance matrix for	WGBIOP	A discussion on some clarifying questions from WGBIOP revealed that WGWIDE needs age-error

Recommendation	Recipient:	Status
results of the age-reading by species (NSS herring, blue whiting NEA mackerel), for use in exploration of effects of ageing-errors on the assessments.		matrices for the three species - preferably with possibility for having separate age-error matrix for each catch-data deliverer.
ID128. It is recommended that a method is developed to calculate and provide uncertainty estimates around the SSB-estimate from the mackerel egg survey.	WGMEGS	Due to COVID a 1st part of the WGMEGS meeting was held in April 2020 in order to finalize results of the MEGS surveys. 2nd part of the meeting will be held 4-6 November to discuss other topics and answer recommendations.
ID129. It is recommended to undertake feasibility study with regard to surveys conducted in summer south of 60N to potentially extend swept area coverage outside the southern boundary of the current IESSNS-survey.	WGIPS	It is not possible to use the existing acoustic surveys in the area, due to time limitations and possibly also engine-power limitations to operate the Multpelt trawl. Secondly, WGIPS recommended organising a workshop for analysing existing data, in order to establish the scientific value of swept-area estimates of mackerel in the top 30-40 m in the shelf-area south of 60°N, because mackerel is also found in the deeper layers in this region. This recommendation from WGIPS was found useful and preparations will take place in autumn 2020 to organise a workshop.
ID130. It is recommended to increase the spatial coverage of NS-IBTS Q1 or very late Q4 to include the south-western Norwegian shelf and shelf edge in proximity to the Norwegian trench. The IBTS has observed high catch rates in some years at the north-eastern edge of the survey area (towards the Norwegian trench) in winter. It is therefore possible that some recruits are also overwintering on the other side of the trench along the south western shelf edge of Norway.	IBTSWG	No conclusive answer could be given. Swedish and Norwegian vessels have taken extra stations on the shelf edge of the Norwegian trench in winter 2018/2019. Probably, this will only be possible in years with additional time at sea.

Annex 3: Resolutions

2020 Terms of Reference

WGWIDE– Working Group on Widely Distributed Stocks

This resolution was approved 1 October 2019

2019/2/FRSG21 The **Working Group on Widely Distributed Stocks** (WGWIDE), chaired by Andrew Campbell*, Ireland, will meet by correspondence 26 August – 1 September 2020 to:

a) Address generic ToRs for Regional and Species Working Groups.

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group no later than 14 days prior to the starting date.

WGWIDE will report by 10 September 2020 for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group

Due to the COVID-19 disruption that started early 2020, ACOM drafted a "spring 2020 approach" for recurring fishing opportunities advice. The generic Terms of Reference have been adjusted as described in the letter to ICES chairs below.

Chairs of Expert Groups

Our Ref: C 4 e/MDC/mo 13 March 2020

Subject: **Spring 2020 approach to advice production**

Dear Expert Group Chair,

I am writing this letter to keep you up to date about the approach of ACOM to the COVID-19 disruption. Many of our institutes now have travel bans and/or working from home policies. ACOM has developed a "spring 2020 approach" to this year's spring advice season. This letter covers the recurrent fishing opportunities advice. Any special request processes and non-fisheries advice will be dealt with separately. The expert groups effected are listed in Annex 1.

ACOM is encouraging all expert groups to keep working, and stick broadly to the time line, but clearly this needs to be through virtual meetings. ICES secretariat will support your efforts and make WebEx available. They will also produce a broad training document on WebEx. We know that the use of virtual meetings will result in an increased burden on the Chairs and members of the expert groups, therefore we have made changes to the generic terms of reference (see Annex 2 below) categorizing them as high, medium and low priority for this year's work. We also suggest that the expert group works virtually through smaller subgroups, and only hold larger virtual meetings when necessary.

The requesters of advice have been informed that there will be disruption/change to the delivery of advice for the spring 2020 season.

ACOM will also change the way that ICES gives advice for the spring 2020 season. There will be three types of advice:

- **Standard advice** sheet (the advice sheet following the January 2020 guidelines)
- **Abbreviated advice** sheet (a shortened advice sheet)
- **Rollover advice** (the same advice as in 2019)

International Council for the Exploration of the Sea
H. C. Andersens Boulevard 44-46, 1553 Copenhagen V, Denmark
+45 33 38 67 00
info@ices.dk | www.ices.dk

The choice of which type of advice to apply to a stock is based on criteria determined by ACOM:

a. **Standard advice** - stocks with 2020 benchmarked methods
b. **Abbreviated advice** – most stocks, including management plan and MSY advice stocks, and some Cat 3 stocks. The abbreviated advice will contain the advice of the headline advice, catch scenario tables, plots and automated tables (last years' advice will be added as an annex to each sheet). The guidance for abbreviated advice is being written now and you should receive it in a few days.
c. **Rollover advice** – same as 2019 advice. This will be provided for stocks in the following categories:
    - zero TAC has been advised in recent years and no change likely,
    - category 3 or greater roll over advice, except if due to be reviewed in 2020
    - long lived stable stocks, with no strong trends in dynamics in recent years
    - some non-standard stocks (e.g. North Atlantic salmon)

We need to consult both you and the requesters of advice about which type of advice to apply to each stock. Today the ACOM criteria are being used by the secretariat to allocate advice types to stocks. This is the first version. We would like you to consider this list and comment if you think that the allocation needs changing. Please remember that the abbreviated advice is being developed to help your processes and also the ACOM processes during the disruption. The list of allocated advice type for each stock will hopefully be sent to you today or Monday. Please reply with your comments by 19th March so that we can start the dialogue with requesters. ACOM hopes that we could have a definitive list by 25th March. (This is too late for HAWG, so we suggest that HAWG use the list compiled in cooperation with Secretariat expecting requesters of advice to agree).

ACOM is recommending that for North Sea stocks with re-opening of advice in the autumn, the stock assessments be carried out in the spring but not the forecasts (postponed until early autumn). The advice would be delivered in the autumn of 2020.

You will shortly receive the first version of the **list of advice types allocated to stocks** and the **guidelines for abbreviated advice**. Please respond by 19th March with your comments on the first version of the list.
Your professional officer has been briefed about these changes. The changes are designed to reduce both expert group and ACOM workload. Lotte, your professional officer, the ACOM leadership and the FRSG Chair are available for further explanation.

Best regards

Mark

Mark Dickey-Collas
ACOM Chair

Annex 1. Expert groups associated with 2020 spring advice season

Herring Assessment Working Group for the Area South of 62°N
Working Group on North Atlantic Salmon*
Assessment Working Group on Baltic Salmon and Trout*
Baltic Fisheries Assessment Working Group
Arctic Fisheries Working Group
Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak
North-Western Working Group
Working Group on the Biology and Assessment of Deep-sea Fisheries Resources
Working Group for the Bay of Biscay and the Iberian Waters Ecoregion
Working Group for the Celtic Seas Ecoregion
Working Group on Southern Horse Mackerel, Anchovy, and Sardine
Working Group on Elasmobranch Fishes

* These groups already have different approaches.

Annex 2. Spring 2020 adapted generic terms of reference. [Agreed by ACOM 12 March 2020]

In light of the disruptions caused by COVID-19 in 2020, the generic terms of reference for the FRSG stock assessment groups have been re-prioritised. This applies to expert groups that feed into the spring advice season process[1]. ACOM is encouraging expert groups to use virtual meetings (e.g. WebEx) and subgroups to deliver the high priority terms of reference. See letter from the ACOM Chair to expert groups.

High Priority for spring 2020 advice season

c) Conduct an assessment on the stock(s) to be addressed in 2020 using the method (analytical, forecast or trends indicators) as described in the stock annex and produce a brief report of the work carried out regarding the stock, summarising where the item is relevant. **Check the list of the stocks to be done in detail and those to roll over.**
   - i) Input data and examination of data quality;
   - ii) Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;
   - iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area) estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2019.
   - v) The developments in spawning stock biomass, total stock biomass, fishing mortality, catches (wanted and unwanted landings and discards) using the method described in the stock annex;
   - vi) The state of the stocks against relevant reference points;
   - vii) Catch scenarios for next year(s) for the stocks for which ICES has been requested to provide advice on fishing opportunities;
   - viii) Historical and analytical performance of the assessment and catch options with a succinct description of quality issues with these. For the analytical performance of category 1 and 2 age-structured assessment, report the mean Mohn's rho (assessment retrospective (bias) analysis) values for R, SSB and F. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

d) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines. Check list to confirm whether the stock requires a concise advice sheet or a traditional advice sheet.

f) Prepare the data calls for the next year update assessment and for planned data evaluation workshops;

j) Audit all data and methods used to produce stock assessments and projections.

[1] These do not apply to Assessment Working Group on Baltic Salmon and Trout and Working Group on North Atlantic Salmon.

Medium Priority for spring 2020 advice season

a) Consider and comment on Ecosystem and Fisheries overviews where available;

b) For the aim of providing input for the Fisheries Overviews, consider and comment for the fisheries relevant to the working group on:

   i) descriptions of ecosystem impacts of fisheries

   ii) descriptions of developments and recent changes to the fisheries

   iii) mixed fisheries considerations, and

   iv) emerging issues of relevance for the management of the fisheries;

e) Review progress on benchmark processes of relevance to the Expert Group; High for application;

Low Priority for spring 2020 advice season

c iv) Estimate MSY proxy reference points for the category 3 and 4 stocks

g) Identify research needs of relevance for the work of the Expert Group.

h) Review and update information regarding operational issues and research priorities and the Fisheries Resources Steering Group SharePoint site.

i) Take 15 minutes, and fill a line in the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity'; for stocks with less information that do not fit into this approach (e.g. higher categories >3) briefly note in the report where and how productivity, species interactions, habitat and distributional changes, including those related to climate-change, have been considered in the advice. ACOM would encourage expert groups to carry out this term of reference later in the year through a webex.

WGWIDE– Working Group on Widely Distributed Stocks

2020/2/FRSG20 The **Working Group on Widely Distributed Stocks** (WGWIDE), chaired by Andrew Campbell*, Ireland, will meet 25-31 August 2021 in ICES HQ in Copenhagen to:

a) Address generic ToRs for Regional and Species Working Groups.

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group no later than 14 days prior to the starting date.

WGWIDE will report by 8 September 2021 for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group

Annex 4: List of Stock Annexes

The table below provides an overview of the WGWIDEStock Annexes. Stock Annexes for other stocks are available on the ICES website Library under the Publication Type "Stock Annexes". Use the search facility to find a particular Stock Annex, refining your search in the left-hand column to include the year, ecoregion, species, and acronym of the relevant ICES expert group.

STOCK ID	STOCK NAME	LAST UP-DATED	LINK
boc.27.6-8	Boarfish (*Capros aper*) in Sub areas 6– 8 (Celtic Seas, English Channel, and Bay of Biscay)	September 2020	boc.27.6-8_SA
gur.27.3-8	Red gurnard (*Chelidonichthys cuculus*) in subareas 3–8 (Northeast Atlantic)	March 2012	gur.27.3-8
her.27.1-24a514a	Herring (*Clupea harengus*) in subareas 1, 2, and 5, and in divisions 4.a and 14.a, Norwegian spring-spawning herring (the North-east Atlantic and Arctic Ocean)	March 2016	her.27.1-24a514a_SA
hom.27.3a4bc7d	Horse mackerel (*Trachurus trachurus*) in divisions 3.a, 4.b-c, and 7.d (Skagerrak and Kattegat, southern and central North Sea, eastern English Channel)	September 2020	hom.27.3a4bc7d_SA
hom.27.2a4a5b6a7a-ce-k8	Horse mackerel (*Trachurus trachurus*) in Subarea 8 and divisions 2.a, 4.a, 5.b, 6.a, 7.a-c,e-k (the Northeast Atlantic)	September 2020	hom.27.2a4a5b6a7a-ce-k8_SA
mac.27.nea	Mackerel (*Scomber scombrus*) in subareas 1-7 and 14 and divisions 8.a-e, 9.a (the Northeast Atlantic and adjacent waters)	September 2020	mac.27.nea_SA
whb.27.1-91214	Blue whiting (*Micromesistius poutassou*) in subareas 1-9, 12, and 14 (Northeast Atlantic and adjacent waters)	September 2020	whb.27.1-91214_SA

Annex 5: Audit Reports

Audit of (Boarfish in subareas 6-8 boc.27.6-8)

Date: 02/09/20

Auditors: Afra Egan, Eydna í Homrum and Jens Ulleweit

General

This is an update assessment with advice provided in 2019 for 2020 and 2021.

For single stock summary sheet advice:

1) **Assessment type:** update
2) **Assessment**: trends - Category 3 with biennial advice. No advice sheet in 2020.
3) **Forecast**: Not presented
1) **Assessment model**: Bayesian Schaefer state space surplus production model fitted using catch data, 6 delta-lognormal estimated IBTS survey indices, and 1 acoustic survey estimate. Key parameters (r, K, Fmsy, Bmsy and TSB) have been estimated using the exploratory Schaeffer state space surplus production model. The assessment has been run by the WinBUGS14 program.
2) **Data issues:** The stock assessment input data and the r-scripts used in the assessment are all available on Sharepoint in the folder "06.Data/boc.27.6-8".
3) **Consistency**: This updated assessment is consistent with the assessment carried out in 2019.
4) **Stock status**: ICES cannot assess the stock and exploitation status relative to MSY and PA reference points because the reference points are undefined.
5) **Management Plan**: A management strategy has been proposed by the Pelagic AC. ICES provides advice for this stock following the standard procedures which conforms to the proposed strategy from the Pelagic AC.

General comments

This was a well-documented, well ordered chapter and is easy to follow and interpret. There are some minor corrections outlined below.

Technical comments

- Correct Table 3.1.2.1 total discard figure for 2019 and correct the total catch and discards in the text section 3.1.3.
- Correct Table 3.1.2.3 discard figures for 2019.
- Table 3.2.1.2 column 2 has a mix of catch and landings. Should all be landings.
- Check values for 2016, 2019 and 2020 for the CV on the acoustic survey in Table 3.3.1.1. Values different from the assessment input file.
- Format the figures in Table 3.6.3.1.
- In table 3.2.1.6 age is missing in the leftmost column
- In table 3.2.2.1 length group is missing in the leftmost column (Total over years could probably be omitted)
- There are some unexplained abbreviations – e.g. DCMAP, MCMC – it is suggested to write in full when first mentioned.
- The first in text table in section 3.4 is a bit difficult to read because only the ages in the top row are highlighted (this may be more of a ICES-formatting issue rather than text-writing)
- Section 3.6.2 – end of first paragraph. The last sentence states that 2016 may look like an outlier. It is not easy for the reader to evaluate this until Figure 3.6.3.6 is shown. It is suggested to aid the reader with a figure already in section 3.6.2 or reference to Table 3.3.1.1).

- Section 3.6.3 – Results. Figure 3.6.3.7. In the report text and Figure caption it says TSB – but the y-axis text says SSB.
- Section 3.6.4. The table in the text has not been updated to 2019.
- Section 3.9.2. 'F130 625 t' – looks like there is some formatting missing
- Section 3.14 – some shift in the bullet levels (bullet **2** should probably be bullet **iv** in bullet **1**)

Conclusions

The assessment has been performed correctly

Audit of Red Gurnard in subareas 3-8

Date: 03.09.2020
Auditor: Bernhard Kuehn

General

Information on gurnard abundance are available in DATRAS for the IBTS-Q1 survey in the North Sea, Scottish West Coast Groundfish Survey (WCGFS), Irish Groundfish Survey (IGFS) and the French EVHOE-WIBTS-Q4 survey in the Celtic Sea and Bay of Biscay and CGFS-Q4 in Division 7d. Each of these surveys covers a specific area of red gurnard distribution. Lengths at age are available from CGFS-Q4 in and IGFS-Q4.

In the North Sea, the appearance of red gurnard in the index of the IBTS Survey since 1990 is in line with an increase of the abundance in 4a. In Eastern Channel, the abundance index of the CGFS-Q4 survey has widely fluctuated, with a weak decline. The EVHOE-WIBTS-Q4 survey has slightly increased since its beginning in the 1990s.

The landings data are not species-specific in the fisheries and there are currently no technical measures specifically for managing the fishery. There is need for regular sampling of red gurnard in commercial landings and discarding to provide series of length or age compositions to conduct analytical assessment.

For single stock summary sheet advice:

1) **Assessment type:** updated
2) **Assessment**: no analytical assessment
3) **Forecast**: None
4) **Assessment model**: None
5) **Data issues:** landings data are not species-specific, lack of biological sampling in commercial landings and discarding
6) **Consistency**: NA
7) **Stock status**: unknown
8) **Management Plan**: NA

General comments
It is a well-structured and documented section, which gives information on the available data and perceived situation as well as outlining the known issues for the stock. There are some minor corrections listed below.

Technical comments
There were some inconsistencies in the landings data presented in the report (table 9.1. and 9.2) and in the data sheets from the sharepoint, most of them rounding issues. Corrections were made and reported to the chair and stock co-ordinator.

Conclusions
The assessment has been performed correctly, but has to include some minor corrections on the landings tables.

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Audit of Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a

Date: 08.092020

Auditor: Laurent Dubroca

General

Assessment of this stock is not possible due to the short time-series of the data provided to this group : landings by country and divisions are available from 2006 to 2020, 3 survey abundances index for the species area presented from 1997 to 2017. However, it seems that fishery dependent data have been collected for several years by some countries (France since 2004) and that it would be appropriate to request them as part of a benchmark.

For single stock summary sheet advice:

1)
2) **Assessment type:** no assessment due to lack of age structured analytical input data provided to the WG.
3) **Assessment**: limited data available to evaluate stock trends.
4) **Forecast**: not presented
5) **Assessment model**: none
6) **Data issues:** general lack of data
7) **Consistency:** undefined
8) **Stock status**: undefined.
9) **Management Plan**: there is no management plan.

General comments

Well structured and documented section pointing out the lack of data regarding this stock.

Technical comments

Table 10.1 : The preliminary landings total for 2019 has some truncation problem : the total is 1854 tons, not 1855.

Table 10.2 : landings total for 2019 has some truncation problem: the total is 1854 tons not 1855.

Conclusions

The absence of assessment has been performed correctly

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Audit of NEA Mackerel

Date: September 7, 2020
Auditor: Jan Arge Jacobsen, Sólvá Eliasen, Martin Pastoors

General

This audit focuses on the advice sheet and the WGWIDE report section on NEA Mackerel. The advice sheet is consistent with the report section.

ICES currently consider the NEA mackerel stock to consist of three spawning components: western, southern, and North Sea, although the stock structure and spawning behaviour is likely to be more dynamic. The group questioned the effect of the regulations in the North Sea, and given the new knowledge on stock structure of mackerel that is currently becoming available, a review of the appropriateness of the use of stock components and the association protection measures should be carried out (at the earliest convenience/next benchmark).

As in previous years, the assessment indicates conflicting signals between some of the data sources. The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) index has remained at high levels since 2013, while the egg survey index has been at low levels since 2016. This contradictory information led to a decrease in the influence of those data sources in the assessment, and a poor fit to both data sources. As a result, the assessment mainly relies on the catch data.

For single stock summary sheet advice:

6) **Assessment type:** update (inter-benchmarked in 2019)
7) **Assessment**: analytical
8) **Forecast**: presented
9) **Assessment model**: SAM, modified to utilise tag/recapture dataset – tuning by steel tagging data (1980–2006) and RFID tagging data (2014–2019), and three survey indices.
10) **Data issues:** All data available as described in stock annex and in the report text. Catch data prior to 2000 are downweighted in the assessment.
11) **Consistency**: The retrospective bias, where the F has consistently been overestimated and SSB underestimated, has decreased for the 2020 assessment.
12) **Stock status**: The fishing pressure on the stock is below FMSY; and spawning stock size is above MSY Btrigger, Bpa and Blim.
13) **Management Plan**: There is no management strategy agreed for the stock, therefore ICES based its advice on the MSY approach. EU, NO and FO asked ICES in 2019 to evaluate a new long term management strategy for the stock. ICES has evaluated and sent it back to the recipients in August 2020 to decide on.

General comments

The report section is readable and all information is there, but it is rather long. The advice sheet is well documented.

Technical comments

The assessment is done according to the stock annex.

The code and input data for the SAM assessment, the RCT3 analysis and the short term forecast are all available on the sharepoint data folder:
https://community.ices.dk/ExpertGroups/WGWIDE/2020%20Meeting%20Docs/06.%20Data/mac.27.nea. While it has been possible by the auditors to rerun the assessment, RCT3 and STF, it is noted that the documentation of the assessment procedures is rather sparse. The code would benefit from a more integrated approach between assessment, recruitment estimation and STF, e.g. with stepwise and documented code segments.

It was also noted that the code for the STF utilized a target F of 0.23 for the ICES AR option but that the correct value of 0.26 has been used to generate the values for the WG report and the ICES advice document. Likewise, the MSY Btrigger has not been updated in the code, and was still at 2.5 Mt.

The data on mackerel is presented in different levels of detail. There are 105 pages of catch data in the report, which is partly due to the formatting, but still one may wonder if this level of detail is required. On the other hand, for the survey indices, the information is perhaps a bit too scarce.

- There is no presentation of the index values generated from the recruitment analysis (only the index values in the input to the assessment; thus it is not possible to check if the appropriate transformation has been carried out).
- There is likewise no presentation of the results of the tagging analysis, only the input values to the assessment are shown.
- There appear to be mismatches between the IESSNS index values in table 8.6.3.1 and in the input to the assessment (8.7.19). A direct comparison of the values by year and age yields the following discrepancies:

COMPARE	3	4	5	6	7	8	9	10	11
2010	-0.1	-0.02	0	-0.24	-0.16	-0.02	0	-0.02	0.01
2011									
2012	-0.06	-0.27	-0.34	-0.43	-0.14	-0.09	0.04	-0.03	-0.01
2013	-0.21	-0.32	-0.16	-0.35	0.14	0.18	0.07	0.05	0.01
2014	0.77	0.24	-0.05	-0.01	-0.1	-0.22	-0.11	-0.02	-0.01
2015	-0.13	-0.64	-0.24	0.14	0.2	-0.21	-0.11	0.05	0.01
2016	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0

Table and figure numbers and references to them in the text has been checked.

Conclusions

The assessment has been performed correctly according to stock annex. Small discrepancies with the IESSNS values need to be checked.

Audit of North Seas Horse mackerel stock (hom.27.3a4bc7d)

Date: September 4th , 2020
Auditor: Gersom Costas

General

In 2012 the North Sea horse mackerel (NSHM) was classified as a category 5 stock, based on the ICES approach to data-limited stocks (DLS). Since then, a progressive reduction of TAC was advised by ICES. In 2017, this stock was benchmarked and the North Sea International Bottom Trawl Survey (NS-IBTS) and the Channel Ground Fish Survey (CGFS) indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHM stock was upgraded to category 3.

This stock has a biennial advice for 2020 and 2021 therefore this is an update assessment.The advice sheet was provided in 2019 and report was well written and well documented., however the Stock Annex is rather icomplete and poorly documented.

For single stock summary sheet advice:

14) **Assessment type:** update
15) **Assessment**: category 3 (survey based method)
16) **Forecast**: not presented
17) **Assessment model**: Hurdle model
    Formed by two sub-models
    - Modelling probability of zeroes (GLM binomial)
        - With Year + Survey
    - Modelling count data (GLM negative binomial)
        - With Year * Survey

    Weighting factors (based on survey area and wingspread of gears):
    - 0.86 * IBTS survey index estimate
    - 0.24 * CGFS survey index estimate
18) **Data issues:**
    Data is available, but:
    - Catch at age data questionable due to low sampling coverage
    - discard information is considered to be incomplete
    - index area did not sufficiently cover the distribution area of the stock.
19) **Consistency**: it is consintent with the assessment carried out last year
20) **Stock status**:
    - no reference points for stock size have been defined
21) **Management Plan**: There is no management plan for horse mackerel in this area. ICES evaluated a proposed harvest control rule for a multi-annual plan for horse mackerel in the North Sea. None of the options were considered as being in accordance with the precautionary approach.

General comments

The advice sheet and report was well written and well documented.

Technical comments

The majority of the Stock Annex is missing,

Conclusions

The assessment has been performed correctly

Audit of North Seas Horse mackerel stock (hom.27.3a4bc7d)

Date: 01. September 2020

Auditor: Leif Nøttestad

General

In 2017, this stock was benchmarked and the North Sea International Bottom Trawl Survey (NS-IBTS) and the Channel Ground Fish Survey (CGFS) indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHM stock was upgraded to category 3. In 2018, the index remained at similar levels in 2016 and 2017. The application of the HCR resulted in an index ratio (mean index value of two most recent years (A) over mean index value of three preceding years (B); A/B ratio) of 0.39, meaning that an 80% uncertainty cap was applied. Length Based DLS methods indicated that the F in 2018 was slightly above the F_{MSY} proxy, and stock size relative to reference points was unknown. However, since the precautionary buffer was already applied to the advice in 2017, the precautionary buffer was not applied this time. This resulted in a catch advice for 2020 and 2021 of 14014 tonnes. Thus, no new catch advice will be given for NSHM for 2021.

There are some signs of improved recruitment in some years (e.g. 2016, 2018), but the trend of the abundance index for the juvenile sub-stock is fluctuating and, when separated, the two surveys, NS-IBTS and CGFS, do not show the same trend. It remains to be seen if the weak signs of improved recruitment result in higher adult abundance, but the slight increase in the index of the exploitable sub-stock in 2019 suggests this might be the case.

Furthermore, the fisheries in the area mainly catches on horse mackerel between 15 and 25 cm. With this pattern of exploitation, mostly immature individuals are caught and exploited, which might hinder the recovery of the stock by removing an important portion of the recent year classes before they enter the spawning stock. Related to this concern and starting in the autumn of 2018, the Pelagic Freezer-trawler Association (PFA, the Netherlands) has implemented a voluntary move-away scheme to avoid the catch of small horse mackerel in 27.7.d.

The advice sheet and report is generally well written and well documented. However, the majority of the Stock Annex seem to be still missing, which make it difficult to check if the assessment is done according to this.

For single stock summary sheet advice:

22) **Assessment type:** update. Catch advice provided for two years (2020 and 2021).
23) **Assessment**: Survey trend-based assessment (Category 3)
24) **Forecast**: Not presented
25) **Assessment model**: Hurdle model

    Formed by two sub-models
    - Modelling probability of zeroes (GLM binomial)
        - With Year + Survey
    - Modelling count data (GLM negative binomial)
        - With Year * Survey

    Weighting factors (based on survey area and wingspread of gears):

    - 0.86 * IBTS survey index estimate

    - 0.24 * CGFS survey index estimate
26) **Data issues:**

    Data is available, but:

- Bad catch sampling coverage
- Discard information is considered to be incomplete, and discard numbers from earlier years have not been submitted to ICES.

27) **Consistency**:
    - Mistake found in the calculation of CPUE in the last assessment for 2016 and 2017, however the 2017 advice would have resulted in the same catch advice.
28) **Stock status**:

    No reference points, but
    - Still low abundance index with no sign of recovery
    - F/Fmsy slightly above 1 in both 2019 and 2020
29) **Management Plan**: There is no management plan for horse mackerel in this area. ICES evaluated a proposed harvest control rule for a multi-annual plan for horse mackerel in the North Sea. None of the options were considered as being in accordance with the precautionary approach.

General comments

The advice sheet and report were well written and well documented.

Technical comments

The majority of the Stock Annex is still missing, which make it difficult to check if the assessment is done according to this.

Conclusions

The assessment has been performed correctly. Stock advice for NSHM is biennial (2020 and 2021).

Audit of 6 North Sea Horse Mackerel: Divisions 27.4.a (Q1 and Q2), 27.3.a (excluding Western Skagerrak Q3 and Q4), 27.4.b, 27.4.c and 27.7.d

Date: 4/09/20

Auditor: Pablo Carrera

General

- Stock benchmarked in 2017, category 3
  - NS-IBTS and CGFS bottom trawl surveys used as joined survey index
- Information on discards, available since 2015
- Information on non-directed fishery, available since 2017
- Danish fishery for fish-meal and oil decreased in 1980's while increased the Dutch freezer fishery for human consumption. In most recent years, highest catches are taken by the UK
  - There is an underutilization of the fishing opportunities
  - Bulk of the catches in 27.7.d

For single stock summary sheet advice:

1) **Assessment type: update/SALY** (Catch advice provided for two years (2020 and 2021).
2) **Assessment**: Survey trend-based assessment (Category 3)
3) **Forecast**: Not presented
4) **Assessment model**: survey data (overdispersion and high proportion of zero values) modeled using a hurdle model with:
   a. Year and Survey as explanatory factors (including the interaction term) in the count model (GLM-negative binomial), and Year and Survey (without the interaction) in the zero model (GLM-binomial)
   b. Two sub-stocks are considered: juveniles (<20cm) and the exploitable stock (>20 cm) treated in sub-models
   c. Relative contribution of each survey (NS-IBTS and CGFS) to the index, as function of both survey area and wingspread of gears (86% and 24% respectively).
5) **Data issues:**
   a. Surveys not specifically designed for horse mackerel and not covering one of the main fishing grounds for the stock (7.d)
   b. Complete discard information was not submitted to ICES, and the available information should be revised as long as may underestimate the discard proportion
   c. Very low coverage of biological sampling (e.g. lack of data in some areas and quarters).
   d. Only a third of the landings was sampled in most recent years,
   e. Potential mixing of fish from the Western and Northern Sea stocks in areas 27.7d-e in winter may also confuse the cohort signals.
6) **Consistency**:
   a. The index survey is considered robust, but the standard error for the intercept and the parameter θ of the count model were not estimated for the adult sub-stock model
7) **Stock status**:
   a. Survey index for adult sub-stock did not further decline in 2018, but remained at similar low levels as in 2017, compared to higher levels in 2014 to 2016.
   b. Conflicting trends for juveniles when surveys are considered separately, but the sub-model for juvenile did not show significant trend, rather fluctuating with some years (e..g 2018) with improved signal
   c. Index ratio (A/B ratio or 2-over-3 ratio) for the adult sub-stock in the 2019 assessment was 0.39. Therefore, an 80% uncertainty cap was applied.
8) **Management Plan**:
   a. There is no management plan, nor reference points
   b. Length based indicator used as MSY proxy. Data source: length frequencies from the Pelagic Freezer trawler Association PFA and whole commercial data
   c. F/F_{MSY} ratio, higher than 1.

General comments

Report is well written and ordered. All references are included.

- In section 6.4.3.1 (Egg surveys) a reference should be included to explain why North sea mackerel is now considered an indeterminate spawner
- Reference ICES. 2018. (ICES reference points for stocks in categories 3 and 4. ICES Technical Guidelines. 13 February 2018) is missing in the text. Probably should be included in section 6.4.6.

Technical comments

Most of the stock annex is missing. This has to be updated, including all the available information from the 2017 benchmark.

As mentioned in the report, recent main fishing grounds match with the main spatial distribution of the juvenile (e.g. area 27.7d). The recovery of this stock would likely dependent on the fishing effort done in this area.

Conclusions

The assessment has been performed correctly

Audit of Norwegian Spring Spawning Herring

Date: 04.09.2020

Auditor: Are Salthaug

General

The Norwegian springs-pawning herring is carried out using the XSAM model. This audit focuses on input data and assessment.

For single stock summary sheet advice:

9) **Assessment type: update/SALY**
10) **Assessment**: analytical
11) **Forecast**: presented
12) **Assessment model**: XSAM with 3 survey fleets
13) **Data issues:** Input data are generally available as described in the stock annex, however, the IESNS in the Barents Sea was not carried out this year so the age 2 index from Fleet 4 does not exist for 2020.
14) **Consistency**: This years' assessment is consistent with last years' assessment and the WG accepted the assessment.
15) **Stock status**: The fishing pressure on the stock is above FMSY and FMGT, but below Fpa (and Flim). Spawning-stock size is above MSY Btrigger,Bpa, and Blim.
16) **Management Plan**: Agreed by the Coastal States in October 2018: the TAC shall be fixed to a fishing mortality of Fmgt = 0.14, with a constraint of maximum 20% reduction and 25% increase relative to the TAC in the preceding year. If SSB is forecast to be lower than MSY Btrigger in the beginning of the quota year, F decreases linearly from F_{mgt} to F = 0.05 over the biomass range from $B_{trigger}$ to B_{lim}. The long-term management strategy has been evaluated by ICES and found to be consistent with the precautionary approach.
17)

General comments

The input data and assessment are documented as described in the stock annex and the report sections are well ordered.

Technical comments

There is a rather strong upward revision of the 2016 year class in this years' assessment compared to last year's assessment.

Conclusions

The assessment has been performed correctly

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Audit of Norwegian Spring Spawning Herring

Date: September 3, 2020

Auditors: Sondre Hølleland and Åge Høines

General

This audit focuses on the advice sheet and the WGWIDE report section on Norwegian spring spawning herring. The advice sheet is consistent with the report section.

For single stock summary sheet advice:

1) **Assessment type:** update (last benchmark in 2016)
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: XSAM – tuning by 3 surveys. TASACS is used as control in accordance with stock annex.
5) **Data issues:** The Barents Sea part of IESNS ("fleet 4") is missing for 2020 due to technical issues with the Russian vessel. The recruitment index for 2020 was therefore not estimated and set to the median recruitment. A conflict in catchability between old and new observations in the Fleet 1 data was discussed during WGWIDE.
6) **Consistency**: The retrospective plots indicates strong consistency in both SSB and F. The estimated SSB from TASACS and XSAM are mutually consistent.
7) **Stock status**: The SSB point estimate, 3.315 million tonnes, is barely above the management plan, 3.184, and well above Blim of 2.5. The fishing pressure is above Fmsy and Fmgt, but below Fpa.
8) **Management Plan**: Agreed upon by the Coastal States in October 2018. Target F = 0.14 if B > Bpa. If B < Bpa, a linear reduction of F will be applied. Advice is given according to management plan.

General comments

The advice sheet and report section are well-documented and well-written. It is easy to follow and interpret.

Technical comments

The auditors have also considered the R-code used to run XSAM and find this to be executed according to the stock annex.

Conclusions

Assessment is performed in compliance with stock annex.

Audit of Blue whiting (*Micromesistius poutassou*) in subareas 27.1–9, 12, and 14 (Northeast Atlantic)

Date: September 4th, 2020
Auditor: Anna Olafsdottir

general

The WG accepted the update assessment as a basis for advice for 2021.

For single stock summary sheet advice:

18) **Assessment type:** Update assessment. Benchmarked in 2012 and went through an inter benchmark in 2016.
19) **Assessment**: Age based analytical assessment.
20) **Forecast**: Presented.
21) **Assessment model**: SAM assessment with catch data from 1981-2020, the last year has preliminary data for quarter 1 and quarter 2, and one tuning series, the International Blue whiting spawning stock survey (IBWSS) from 2004-2019, excluding 2010. The IBWESS scheduled for spring 2020 got cancelled due to the COVID-19 pandemic.
22) **Data issues:** Data used in the assessment, as described in the stock annex, source code for the SAM model, and model configuration are available on ICES SharePoint and https://www.stockassessment.org. Forecast was neither found online nor on sharepoint.

There was no IBWSS survey in 2020. WGWIDE decided to use the best guess of total catch in 2020, observed catch-at-age in quarter 1 and quarter 2 raised to best guess of total catch in 2020, and estimated F in the assessment. Exploratory assessment runs, using 2017 and 2018 as the last assessment year, with no survey data used for the intermediate year show "preliminary catches" gives a result closer to the "Final" results than a run with just catch data for the final survey year. Further justification for using preliminary catches for 2020 is that they have been used since the 2016 inter-benchmark, hence no need to change the assessment method and no need to make new as decisions on intermediate year assumptions except that quality of catch data in 2020 is similar to previous years.

IBWSS age segregated survey indices were recalculated recently for the whole time series using a new version of the StoX software (v2.7). This was done to correct errors in the original analysis and the preserve repeatability of the StoX analysis. The newer version of StoX could not run the older version StoX projects, hence all analyses were recalculated in the new version of StoX. Furthermore, the indices were also calculated using bootstrap estimates. Assessment test run showed that all three index versions give the same results. The meeting decided to use the recalculated index for future repeatability and the fact that switching to bootstrap index demands a benchmark according to ICES guidelines.

23) **Consistency**: The assessment shows the same trend as last year with a minor upward revision in recruitment.
24) **Stock status**: SBB > MSY Btrigger, Blim and Bpa; Fmsy < F< Flim, Fpa, R low in last four years.
25) **Management Plan**: A long-term management strategy was agreed in 2016. According to the plan catch is set at F_{MSY} when SSB is forecast to be above or equal to $B_{trigger,}$ F is reduced when SSB is less than $B_{trigger}$, and when SSB is less than B_{lim} F = 0.05. TAC constraints of 20% less or 25% more than the TAC of the preceding year apply. The strategy was evaluated by ICES and found to be precautionary**.** The 20% TAC constrain was applied when calculating TAC for 2021.

General comments

This was a well-documented, well ordered, concise chapter and is easy to follow and interpret.

Technical comments

Technical comments are provided in the advice sheet and the report text using track changes.

Conclusions

The assessment has been performed correctly

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Audit of Blue whiting (*Micromesistius poutassou*) in subareas 27.1–9, 12, and 14 (Northeast Atlantic) - whb.27.1-91214)

Date: 5th September 2020
Auditor: Richard D.M. Nash

General

For single stock summary sheet advice:

1) **Assessment type: update assessment**
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: SAM, age based, normally uses one tuning series – IBWSS, however this was not available this year due to being cancelled because of the Covid-19 situation
5) **Data issues:** The tuning series (survey) were updated to include variance. This change did not change to perceptions in the assessment
6) **Consistency**: Last years assessment was accepted
7) **Stock status**: The fishing pressure on the stock is above F_{MSY} but below Fpa and Flim. The spawning-stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}.
8) **Management Plan**: A long-term management strategy was agreed by the European Union, the Faroe Islands, Iceland, and Norway in 2016. This was evaluated by ICES.
   The harvest control rule (HCR) has a B_{lim} of 1.5 million t and a B_{pa} of 2.25 million t, and F_{MSY} 0.32. There is a 20% TAC change limit above B_{pa}.

General comments

This was a well documented, well ordered and considered section. It was easy to follow and interpret.

Technical comments

The only changes from the stock annex were the use of the updated survey series data and the lack of the most recent survey data (2020 survey).

Conclusions

The assessment has been performed correctly

Audit of Western horse mackerel (hom.27.2a4a5b6a7a-ce-k8)

Date: 4/09/2020

Auditor: Patrícia Gonçalves

General

The western stock of horse mackerel is assessed with length- and age-based analytical assessment (Stock Synthesis 3 – SS3). The stock is considered in category 1.

The input data for assessment are:

- commercial catches: international catches, length and age data from catch sampling;
- three survey indices: Triennial egg survey index; IBTS recruitment index; PELACUS acoustic biomass index;
- length frequency distribution from the PELACUS survey;
- constant maturity-at-age;
- natural mortality: constant = 0.15

The stock was benchmarked in 2017.

The reference points were updated in 2019.

For single stock summary sheet advice:

26) **Assessment type:** update.
27) **Assessment**: analytical.
28) **Forecast**: presented.
29) **Assessment model**: SS3 model; Fishery dependent data: catch-at-age and catch-at-length; Fishery independent data, survey indexes from: triennial egg surveys (1992-2019), IBTS recruitment index (2003-2019), PELACUS acoustic biomass (1992-2019).
30) **Data issues:** Errors on length distribution have been detected and corrected.
31) **Consistency**: The assessment has been accepted by the WG.
32) **Stock status**: F is above Fmsy, Flim and Fpa; stock size is below MSYBtrigger; the recruitment remains in a low level.
33) **Management Plan**: No management plan.

General comments

The report is well written and includes a well-documented section of the results. The main subjects that have been discussed were considered and mentioned on the report.

Technical comments

Section 5, comments on figures:

Figure 5.4.1 is mentioned in section 5.1 suggestion: (a) remove the referencing on the text from this section; or (b) keep the referencing in this section and renumbering as Figure 5.1.1.

Figures 5.3.1 and 5.3.4 are not mentioned in the text, should be added to section 5.3. Figure 5.3.4 should be renamed/renumbered as 5.3.2.

Figures 5.4.2, 5.4.3, 5.9.1 and 5.9.2 need to be updated with the 2019 data.

On figure 5.9.5 the legend is above the plot. Figure 5.9.5 should be renamed/renumbered as 5.9.3. Figure 9.5.6 should be renamed/renumbered as 5.9.4.

Section 7:

Table 7.2.4.1 the values presented in the last table in relation to all quarters must be revised.

Tables 7.2.4.4, 7.2.4.5 and 7.2.4.6 are not mentioned on the text.

Advice sheet (Section: Stock and Exploitation Status): Stock size for 2019 in relation to Bpa, Blim should be in yellow, to be in accordance with the 2019 advice sheet.

Conclusions

The assessment has been performed correctly.

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
  Yes.
- Is the assessment according to the stock annex description?
  The SA need to be updated.
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
  No management plan is available for this species.
- Have the data been used as specified in the stock annex?
  Yes.
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
  Yes.
- Is there any **major** reason to deviate from the standard procedure for this stock?
  No.
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?
  Yes, it gives.

Audit of Western horse mackerel (hom.27.2a4a5b6a7a-ce-k8)

Date: 07/09/2020

Auditor: Claus R. Sparrevohn

General

The western stock of horse mackerel is Stock Synthesis 3 – SS3 asssessent. The stock is considered in category 1 and SSB is just above Blim in 2020. The triannual egg-survey conducted in 2019 was not part of the 2019 assessment but is included in this 2020 assessment.

The stock was benchmarked in 2017.

The reference points were updated in 2019. Blim is defined as Bpa/1.4. Fmsy is 0.074 and based on a recruitment timeseries where the large 1083 yearclass is not imcluded.

For single stock summary sheet advice:

34) **Assessment type:** update.
35) **Assessment**: analytical.
36) **Forecast**: presented.
37) **Assessment model**: Stock synthesis
38) **Data issues:** Duing the meeting an error in the length distribution data was found and corrected. The effect was minor especially for the most recent years.
39) **Consistency**: Mohn's Rho is 0.22 for SSB and -0.155 for F. Major retrospective pattern?
40) **Stock status**: SSB in 2020 is estimated to be 853457 tons which is just above Blim (834480 tons). F in 2019 is estimated to be above Fmsy.
41) **Management Plan**: No management plan.

General comments

God report but I miss the information on Mohn's rho which is shown in one of the presentations.

Technical comments

Advice sheet.

Table 2. Total TAC is used to derive the 2020 catch, but it is not explicit what "Total TAC" means.

In the forecast table an option "PELAC proposed HCR" is added.

Conclusions

The assessment has been performed correctly, but the Mohn's rho might be of concern together with the low SSB.

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
  YES
- Is the assessment according to the stock annex description?
  YES
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
  NA
- Have the data been used as specified in the stock annex?
  YES
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

YES

- Is there any **major** reason to deviate from the standard procedure for this stock?
  NO.
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?
  YES.

Audit of Western Horse Mackerel data and assessment

Date: 02/09/2020
Auditor: Alessandro Orio

General

Western horse mackerel is assessed as a Category 1 stock. An SS3 model is run to determine the state of the stock in relation to reference points for western horse mackerel.

For single stock summary sheet advice:

9) **Assessment type:** update
10) **Assessment**: analytical.
11) **Forecast**: presented
12) **Assessment model**: SS3 model with commercial catches (length and age data) and three survey indices: Triennial egg survey index (1992–2019); IBTS recruitment index; PELACUS acoustic biomass.
13) **Data issues:** Errors in the length frequency distributions of Scotland were detected and fixed in the assessment.
14) **Consistency**: The view of the WG was that the assessment should be accepted. The Stock annex needs to be updated both for the initial values of the estimated parameters but especially for the new reference points obtained during the interbenchmark of 2019. Also the weight at age used in the forecast should be updated in the stock annex.
15) **Stock status**: Fishing pressure on the stock is above F_{MSY}, F_{pa} and F_{lim}. Spawning stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.
16) **Management Plan**: No management plan

General comments

The assessment and forecast have been available for review. Input and output data were correct.

Technical comments

Few inconsistencies are present in the stock annex. Initial values for estimated paramenters are different but these do not change the results of the assessment. The entire section on reference points needs to be updated with the new results obtained during the interbenchmark of 2019. Weight at age used in the forecast should also be updated in the stock annex since the values fome SS are the ones used.
Weighting procedure of the data has been difficult during this iteration of WGWIDE. Therefore, a thorough revision of the number of samples used for the different age and length frequency distributions in the assessment needs to be done. There is a need to inspect the potential problems caused by the reweighting of both age length keys and age frequency distribution of the commercial catches using the same parameter. Main recruitment deviations stops in 2013 but should be changed to the last data point available. The fishing mortality estimated by the model is weighted by the population numbers but now the unweighted F can be obtained so it would be preferable to switch to that in the future to avoid extra calculations. Forecasts run directly in SS should be also considered during the next benchmark.

Conclusions

The assessment has been performed correctly.

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
  Yes
- Is the assessment according to the stock annex description?
  Yes but it needs to be updated

- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
  Yes, no management plan
- Have the data been used as specified in the stock annex?
  Yes
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
  Yes
- Is there any **major** reason to deviate from the standard procedure for this stock?
  No
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?
  Yes.

Annex 6: WGWIDE 2020 productivity changes survey

Expert group	Stock code	Biomass/stock trend/assessment; catch/bycatch status/trend				
		Variability/ change in length distribution	Variability/ change in weight-at-age	Variability/ change in maturity-at-age	Variability/ change in natural mortality	Variability/ change in sex ratio
WGWIDE	boc.27.6-8	2	2	2	1	0
WGWIDE	gur.27.3-8					
WGWIDE	her.27.1-24a514a					
WGWIDE	hom.27.2a4a5b6a7a-ce-k8	3	1	0	0	0
WGWIDE	hom.27.3a4bc7d	3	1	0	0	0
WGWIDE	mac.27.nea	3	3	3	0	0
WGWIDE	mur.27.67a-ce-k89a					
WGWIDE	whb.27.1-91214	3	3	1	1	1

Expert group	Stock code	Short term forecast				
		Environmentally driven recruitment	Truncating recruitment time-series	Recent or trend in weight-at-age	Recent or trend in maturity-at-age	Recent or trend in natural mortality
WGWIDE	boc.27.6-8	0	0	0	0	0
WGWIDE	gur.27.3-8					
WGWIDE	her.27.1-24a514a					
WGWIDE	hom.27.2a4a5b6a7a-ce-k8	0	0	0	0	0
WGWIDE	hom.27.3a4bc7d	0	0	0	0	0
WGWIDE	mac.27.nea	0	0	3	3	0
WGWIDE	mur.27.67a-ce-k89a					
WGWIDE	whb.27.1-91214	1	1	1	0	0

Expert group	Stock code	MSE (management/re-building plans). Uncertainty or differing operating models				
		Environmentally driven recruitment	Truncating recruitment time series	Variable weight-at-age (environment or density driven)	Recent or trend in maturity-at-age (environment or density driven)	Dynamics in natural mortality
WGWIDE	boc.27.6-8	0	0	0	0	0
WGWIDE	gur.27.3-8					
WGWIDE	her.27.1-24a514a					
WGWIDE	hom.27.2a4a5b6a7a-ce-k8	0	0	0	0	0
WGWIDE	hom.27.3a4bc7d	0	0	0	0	0
WGWIDE	mac.27.nea	0	3	3	3	0
WGWIDE	mur.27.67a-ce-k89a					
WGWIDE	whb.27.1-91214	3	3	1	0	0

Expert group	Stock code	Advice	Distribution and habitats		
		Specific productivity information used (e.g. escapement rule)	Influence of population state	Habitat suitability/quality	Within-species stock mixing
WGWIDE	boc.27.6-8	0	1	1	1
WGWIDE	gur.27.3-8				
WGWIDE	her.27.1-24a514a				
WGWIDE	hom.27.2a4a5b6a7a-ce-k8	0	0	0	1
WGWIDE	hom.27.3a4bc7d	0	0	1	1
WGWIDE	mac.27.nea	0	1	1	0
WGWIDE	mur.27.67a-ce-k89a				
WGWIDE	whb.27.1-91214	0	3	3	0

Expert group	Stock code	Mixed fisheries			Climate
		Catch and bycatch of target species	Bycatch of non-target species	Consideration of mixed fisheries advice	Consideration of changes due to climate variability/change
WGWIDE	boc.27.6-8	1	1	0	0
WGWIDE	gur.27.3-8				
WGWIDE	her.27.1-24a514a				
WGWIDE	hom.27.2a4a5b6a7a-ce-k8	0	0	0	1
WGWIDE	hom.27.3a4bc7d	1	0	0	1
WGWIDE	mac.27.nea	2	2	2	1
WGWIDE	mur.27.67a-ce-k89a				
WGWIDE	whb.27.1-91214	1	1	0	1

Annex 7: Working Documents presented to WGWIDE 2020

WD01 PFA self-sampling report for WGWIDE, 2015-2020. M.A. Pastoors and F.J.Quirijns. 53pp.

WD02 Western Horse Mackerel Technical Focus Group On Harvest Control Rule Evaluations 2020. M.A. Pastoors, A. Campbell, V. Trijoulet, D. Skagen, M. Gras, G.I. Lambert, C.R. Sparrevohn and S. Mackinson. 43pp.

WD03 Cruise Report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS), L.Nøttestad, Valantine Anthonypillai, Are Salthaug, Åge Høines, Anna Heiða Ólafsdóttir, James Kennedy, Eydna í Homrum, Leon Smith, Teunis Jansen, Søren Post and Kai Wieland. 55pp.

WD04 Update of Striped Red Mullet Abundance Indices from Professional Fishing Data (2016-2018). Nathalie Caill-Milly, Muriel Lissardy and Noëlle Bru. 9pp.

WD05 Overview of Spatial Distribution of Catches of Mackerel, Horse Mackerel, Blue Whiting and Herring. M.A.Pastoors 14pp.

WD06 Distribution and Abundance of Norwegian Spring-Spawning Herring during the Spawning Season in 2020. Are Salthaug, Erling Kåre Stenevik, Sindre Vatnehol, Valantine Anthonypillai, Egil Ona and Aril Slotte. 40pp

WD07 Inventory of Industry-Acoustic Data for Potential Application on Blue Whiting Biomass Estimates. Benoit Berges, Serdar Sakanin, Sytse Ybema, Gert-Jan Kooij and Martin Pastoors. 7pp.

WD08 Progress Report on Industry Gonad Research in the Context of the "Year of the Mackerel and Horse Mackerel 2019-2020". Cindy van Damme, Ewout Blom and Martin Pastoors, 24pp.

WD09 NEA Mackerel Alternative Assessment. Höskuldur Björnsson. 9pp.

WD10 International Ecosystem Survey in Nordic Sea (IESNS). Are Salthaug, Erling Kåre Stnevik, Sindre Vatnehol, Åge Høines, Valantine Anthonypillai, Kjell Arne Mork, Cecile Thorsen Broms, Øystein Skagseth, Kai Wieland, Karl-Johan Stæhr, Susan Mærsk Lusseau, Benoit Berges, Sigurvin Bjarnason, Anna Heiða Ólafsdóttir, Sólvá Káradóttir Eliasen, Jan Arge Jacobsen and Leon Smith, 51pp.

WD11 Population Structure of the Atlantic Horse Mackerel (Trachurus trachurus) Revealed by Whole-Genome Sequencing. Angela P. Fuentes-Pardo, Mats Pettersson, C. Grace Sprehn, Leif Andersson and Edward Farrell. 38pp.

PFA
PELAGIC FREEZER-TRAWLER ASSOCIATION

REPORT

PFA self-sampling report for WGWIDE, 2015-2020

M.A. Pastoors and F.J. Quirijns

25-8-2020

(Cover image: mackerel self-sampled for gonad analysis, 2019)

Pelagic Freezer-trawler Association (PFA)

Louis Braillelaan 80
2719 EK Zoetermeer
The Netherlands
www.pelagicfish.eu
info@pelagicfish.eu

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PFA self-sampling report for WGWIDE, 2015-2020

Martin Pastoors and Floor Quirijns, 25/08/2020

(PFA report 2020_10)

Executive summary

The Pelagic Freezer-trawler Association (PFA) is an association that has nine member companies that together operate 17 (in 2019) freezer trawlers in six European countries (www.pelagicfish.eu). In 2015, the PFA has initiated a self-sampling programme that ex-pands the ongoing monitoring programmes on board of pelagic freezer-trawlers aimed at assessing the quality of fish. The expansion in the self-sampling programme consists of recording of haul information, recording the species compositions by haul and regularly taking length measurements from the catch. The self-sampling is carried out by the vessel quality managers on board of the vessels, who have a long experience in assessing the quality of fish, and by the skippers/officers with respect to the haul information. The scien-tific coordination of the self-sampling programme is carried out by Martin Pastoors (PFA chief science officer) with support of Floor Quirijns (contractor).

The self-sampling programme has been incrementally implemented in the fishery. The increase in the number of vessel, hauls and catch over the years 2015-2017 is due to the build-up of the self-sampling programme. From 2018 onwards, the self-sampling programme has been implemented on all vessels in the fleet.

This report for WGWIDE 2020 presents an overview of the results of the Pelagic Freezer-Trawler Association (PFA) self-sampling program for the fisheries for widely-distributed pelagic stocks: Northeast Atlantic mackerel, Blue whiting, Horse mackerel and Atlanto-scandian herring (herring caught north of 62 degrees). The selection of hauls to be included in the analyses was based on first summing all catches by vessel, trip, species and week. For each vessel-trip-species-week combination, the proportion of the species in the catch were calculated. The following filter criteria have applied to the weekly data:

- for horse mackerel: latitude > 45, proportion in the catch > 10%, catch > 10 tonnes

- for mackerel : latitude > 45, proportion in the catch > 10%, catch > 10 tonnes
- for blue whiting : latitude > 50, proportion in the catch > 10%, catch > 10 tonnes
- for herring : division = 27.2.a, proportion in the catch > 10%, catch > 10 tonnes

The **Mackerel fishery** takes place from October through to March of the subsequent year. Minor bycatches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2015 – 2020 (up to August) covered 323 fishing trips with 4,725 hauls, a total catch of 286,957 tonnes and 91,000 individual length measurements. The main fishing areas are ICES division 27.4.a (between 27 and 54% of the catch) and division 27.6.a (between 25 and 44% of the catch). Compared to the previous years, mackerel in the catch have been relatively large in 2020 with median length of 36.4 cm compared to 32.4-35.4 in the preceding years. Also, the median weight has been somewhat higher with median weight of 417 gram compared to 379-400 gram the preceding years. Average annual fat content ranges from 17 to 21% with individual measurements reaching up to 30%

The **horse mackerel fishery** takes place from October through to March of the subsequent year. Overall, the self-sampling activities for the horse mackerel fisheries during the years 2015 – 2020 (up to August) covered 457 fishing trips with 3,454 hauls, a total catch of 140,633 tonnes and 125,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 21% and 40% of the catch), division 27.7.b (7%-22%) and division 27.7.d (19%-34%, note that this is considered as the North Sea horse mackerel stock). Horse mackerel have a wide range in the length distributions in the catch. Median lengths have fluctuated between 22.8 and 30.0 cm. In 2019 and 2020 there are some indications of a stronger year class being available to the fishery, with a more narrow length distribution. For example, in 27.6.a the mode was 26.6 cm in 2019 and 27.5 cm in 2020. Average annual fat content ranges from 5 to 7.5% with individual measurements reaching up to 15%.

The **blue whiting** fishery takes place from February through to May although some minor fisheries for blue whiting may remain over the other months. Overall, the self-sampling activities for the blue whiting fisheries during the years 2015 – 2020 (up to August) covered 365 fishing trips with 5,836 hauls, a total catch of 561,888 tonnes and 128,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 41% and 65% of the catch), division 27.7.c (6%-36%) and division 27.7.k (2%-32%). Blue whiting have a wide range in the length distributions in the catch. Median lengths have fluctuated between 23 cm (2016) and 30 cm (2015). During the period 2016 - 2020, the median length is consistently increasing (from 23 to 28 cm), indicating that the fishery is probably concentrating on a strong year class going without new year classes coming in. Fat content for blue whiting is generally low (on average less than 1%).

The fishery for **Atlanto-Scandian herring** (ASH) is a relatively smaller fishery for PFA and takes place mostly in October. Overall, the self-sampling activities for the ASH fisheries during the years 2015 – 2020 (up to August) covered 27 fishing trips with 406 hauls, a total catch of 30,234 tonnes and 8,918 individual length measurements. Only the herring fishery in ICES division 27.2.a is considered for ASH. Note that there are herring catches in other divisions within the selected trips. These are trips where North Sea herring has been fished with some bycatches of mackerel for example. Atlanto-Scandian herring have a narrow range in the length distributions in the catch. Median lengths have fluctuated between 32 and 36 cm. Average annual fat content for ASH has been between 17 and 20% with individual measurements going up to 25%).

1 Introduction

The Pelagic Freezer-trawler Association (PFA) is an association that has nine member companies that together operate 19 freezer trawlers in five European countries (www.pelagicfish.eu). In 2015, the PFA has initiated a self-sampling programme that expands the ongoing monitoring programmes on board of pelagic freezer-trawlers by the specialized crew of the vessels. The primary objective of that monitoring programme is to assess the quality of fish. The expansion in the self-sampling programme consists of recording of haul information, recording the species compositions per haul and regularly taking random length-samples from the catch. The self-sampling is carried out by the vessel quality managers on board of the vessels, who have a long experience in assessing the quality of fish, and by the skippers/officers with respect to the haul information. The scientific coordination of the self-sampling programme is carried out by Martin Pastoors (PFA chief science officer) with support of Floor Quirijns (contractor).

2 Material and methods

The PFA self-sampling programme has been implemented incrementally on many vessels that belong to the members of the PFA. The self-sampling programme is designed in such a way that it follows as closely as possible the working practices on board of the different vessels and that it delivers relevant information for documenting the performance of the fishery and to assist stock assessments of the stocks involved. The following main elements can be distinguished in the self-sampling protocol:

- haul information (date, time, position, weather conditions, environmental conditions, gear attributed, estimated catch, optionally: species composition)
- batch information (total catch per batch=production unit, including variables like species, average size, average weight, fat content, gonads y/n and stomach fill)
- linking batch and haul information (essentially a key of how much of a batch is caught in which of the hauls)
- length information (length frequency measurements, either by batch or by haul)

The self-sampling information is collected using standardized Excel worksheets. Each participating vessel will send in the information collected during a trip by the end of the trip. The data will be checked and added to the database by Floor Quirijns and/or Martin Pastoors, who will also generate standardized trip reports (using RMarkdown) which will be sent back to the vessel within one or two days. The compiled data for all vessels is being used for specific purposes, e.g. reporting to expert groups, addressing specific fishery or biological questions and supporting detailed biological studies. The PFA publishes an annual report on the self-sampling programme.

A major feature of the PFA self-sampling programme is that it is tuned to the capacity of the vessel-crew to collect certain kinds of data. Depending on the number of crew and the space available on the vessel, certain types of measurements can or cannot be carried out. That is why the programme is essentially tuned to each vessel separately. And that is also the reason that the totals presented in this report can be somewhat different dependent on which variable is used. For example the estimate of total catch is different from the sum of the catch per species because not all vessels have supplied data on the species composition of the catch.

Because the self-sampling programme has been under development over the years, different numbers of vessels have been participating in the programme over different years. Results should not be interpreted as a census of the PFA fleet, but rather as an indicator of relative distributions and samples of catch and catch compositions.

In order to supply relevant information to WGWIDE 2019, the PFA self-sampling data has been filtered using the following approach. First, all catches per vessel, trip and species have been summed by week. For each vessel-trip-species-week combination, the proportion of the species in the catch were calculated. Then the following filter criteria have applied to the weekly data:

- for horse mackerel: latitude > 45, proportion in the catch > 10%, catch > 10 tonnes
- for mackerel : latitude > 45, proportion in the catch > 10%, catch > 10 tonnes
- for blue whiting : latitude > 50, proportion in the catch > 10%, catch > 10 tonnes
- for herring : division = 27.2.a, proportion in the catch > 10%, catch > 10 tonnes

Data have been processed up to 20 August 2020.

3 Results

3.1 General

An overview of all the selected self-sampling hauls between 2015 and (August) 2020 is shown in Table 3.1.1. The increase in the number of vessel, hauls and catch over the years 2015-2017 is due to the build-up of the self-sampling programme. From 2018 onwards, the self-sampling programme has been implemented on all vessels in the fleet.

The percentage non-target catch (defined as the proportion of non-pelagic and unwanted pelagic catch relative to the total catch) has been low (between 0.2 and 1.1%).

year	nvessels	ntrips	ndays	nhauls	catch	catch/day	nontarget	nlength
2015	6	26	390	869	65,899	168	1.10%	69,680
2016	9	47	647	1,456	126,997	196	0.50%	78,708
2017	12	64	887	1,886	184,460	207	0.20%	95,190
2018	16	88	1,330	2,901	272,416	204	0.20%	176,455
2019	16	101	1,423	3,109	252,973	177	0.30%	150,806
2020*	13	65	908	2,092	215,627	237	0.40%	178,114
(all)		391	5,585	12,313	1,118,372			748,953

*Table 3.1.1: PFA selfsampling summary of hauls in widely distributed pelagic fisheries with the number of vessels, trips, days, hauls, catch (tonnes), catch per day (tonnes), %non-target catch and number of fish measured. * denotes incomplete year*

Number of self-sampled hauls in widely distributed pelagic fisheries by year and division

The majority of hauls for widely distributed species have been recorded in division 27.6.a (39%), 27.4.a (12%), 27.7.c (10%) and 27.2.a (7%).

division	2015	2016	2017	2018	2019	2020*	all	perc
27.6.a	242	411	668	1,268	1,281	962	4,832	39.2431%
27.4.a	120	194	191	376	439	191	1,511	12.2716%
27.7.c	32	87	256	243	252	329	1,199	9.7377%
27.2.a	51	148	264	249	174	18	904	7.3418%
27.7.d	99	167	157	190	206	7	826	6.7084%
27.7.b	50	101	140	88	175	205	759	6.1642%
27.7.j	84	62	20	60	138	203	567	4.6049%
27.7.k	56	77	3	59	17	91	303	2.4608%
27.7.e	47	90	45	32	79	4	297	2.4121%
27.5.b	28	57	66	82	38	7	278	2.2578%
27.7.h	5	25	30	96	24	4	184	1.4944%
27.8.a	15	1	1	41	97	9	164	1.3319%
27.4.b	8	15	19	24	53	0	119	0.9665%
27.4.c	5	12	22	16	25	11	91	0.7391%
27.7.g	21	9	0	9	39	5	83	0.6741%
27.6.b	0	0	2	50	10	7	69	0.5604%
27.7.f	3	0	0	4	31	0	38	0.3086%
27.8.b	3	0	0	6	4	24	37	0.3005%
27.8.d	0	0	2	2	13	15	32	0.2599%
27.7.a	0	0	0	6	12	0	18	0.1462%
27.3.a	0	0	0	0	1	0	1	0.0081%
27.8.c	0	0	0	0	1	0	1	0.0081%
(all)	869	1,456	1,886	2,901	3,109	2,092	12,313	100.0000%

*Table 3.1.2: PFA selfsampling summary: number of hauls per year and division in widely distributed pelagic fisheries. * denotes incomplete year*

Number of self-sampled hauls in widely distributed pelagic fisheries by year and month

The overview of number of hauls for widely distributed species by month indicates that the main periods for the fisheries are January until May and October until November. The other months are usually spent on North Sea herring fisheries or repair works.

month	2015	2016	2017	2018	2019	2020*	all	perc
Jan	109	174	315	309	470	374	1,751	14.221%
Feb	127	143	208	333	413	290	1,514	12.296%
Mar	23	161	232	391	413	455	1,675	13.604%
Apr	74	125	201	494	289	580	1,763	14.318%
May	67	105	145	372	251	250	1,190	9.665%
Jun	14	15	0	77	23	103	232	1.884%
Jul	53	26	15	10	75	26	205	1.665%
Aug	0	28	68	39	42	14	191	1.551%
Sep	34	77	153	170	207	0	641	5.206%
Oct	157	240	247	301	410	0	1,355	11.005%
Nov	149	237	271	319	412	0	1,388	11.273%
Dec	62	125	31	86	104	0	408	3.314%
(all)	869	1,456	1,886	2,901	3,109	2,092	12,313	100.000%

*Table 3.1.3: PFA selfsampling summary: number of hauls per year and division in widely distributed pelagic fisheries. * denotes incomplete year*

Catch compositions in widely distributed pelagic fisheries by year and species

Within the widely-distributed pelagic fisheries, as defined in this report, around half of the catch volume has been generated with blue whiting, followed by mackerel (26%), horse mackerel (13%) and herring (8%). Note that the herring catches in 27.2.a are normally only taken in the second part of the year and are therefore not included yet for 2020.

species	english_name	scientific_name	2015	2016	2017	2018	2019	2020*	all	perc
whb	blue whiting	Micromesistius poutassou	15,546	49,378	78,802	162,542	115,672	139,949	561,890	50.2416%
mac	mackerel	Scomber scombrus	26,481	34,298	63,654	57,958	55,055	49,582	287,028	25.6647%
hom	horse mackerel	Trachurus trachurus	10,586	22,966	21,266	30,295	40,899	14,842	140,854	12.5945%
her	herring	Clupea harengus	6,859	7,838	8,621	11,135	23,540	4,323	62,317	5.5721%
her_ash	herring	Clupea harengus	1,369	3,362	7,950	5,278	12,249	26	30,235	2.7035%
arg	argentines	Argentina spp	2,669	1,560	2,596	4,097	4,575	5,453	20,950	1.8732%
pil	pilchard	Sardina pilchardus	1,311	6,134	818	514	169	8	8,953	0.8006%
boc	boarfish	Capros aper	216	234	247	161	351	479	1,688	0.1509%
spr	sprat	Sprattus sprattus	59	539	257	7	32	653	1,547	0.1383%
hke	hake	Merluccius merluccius	392	286	107	274	208	177	1,444	0.1291%
oth	NA	NA	413	401	141	156	224	134	1,469	0.1313%
(all)	(all)	(all)	65,900	126,998	184,460	272,416	252,974	215,627	1,118,375	100.0000%

*Table 3.1.4: PFA selfsampling catch per species in widely distributed pelagic fisheries. OTH refers to all other species that are not the main target species, * denotes incomplete year*

Haul positions

An overview of all self-sampled hauls in PFA widely distributed fisheries.

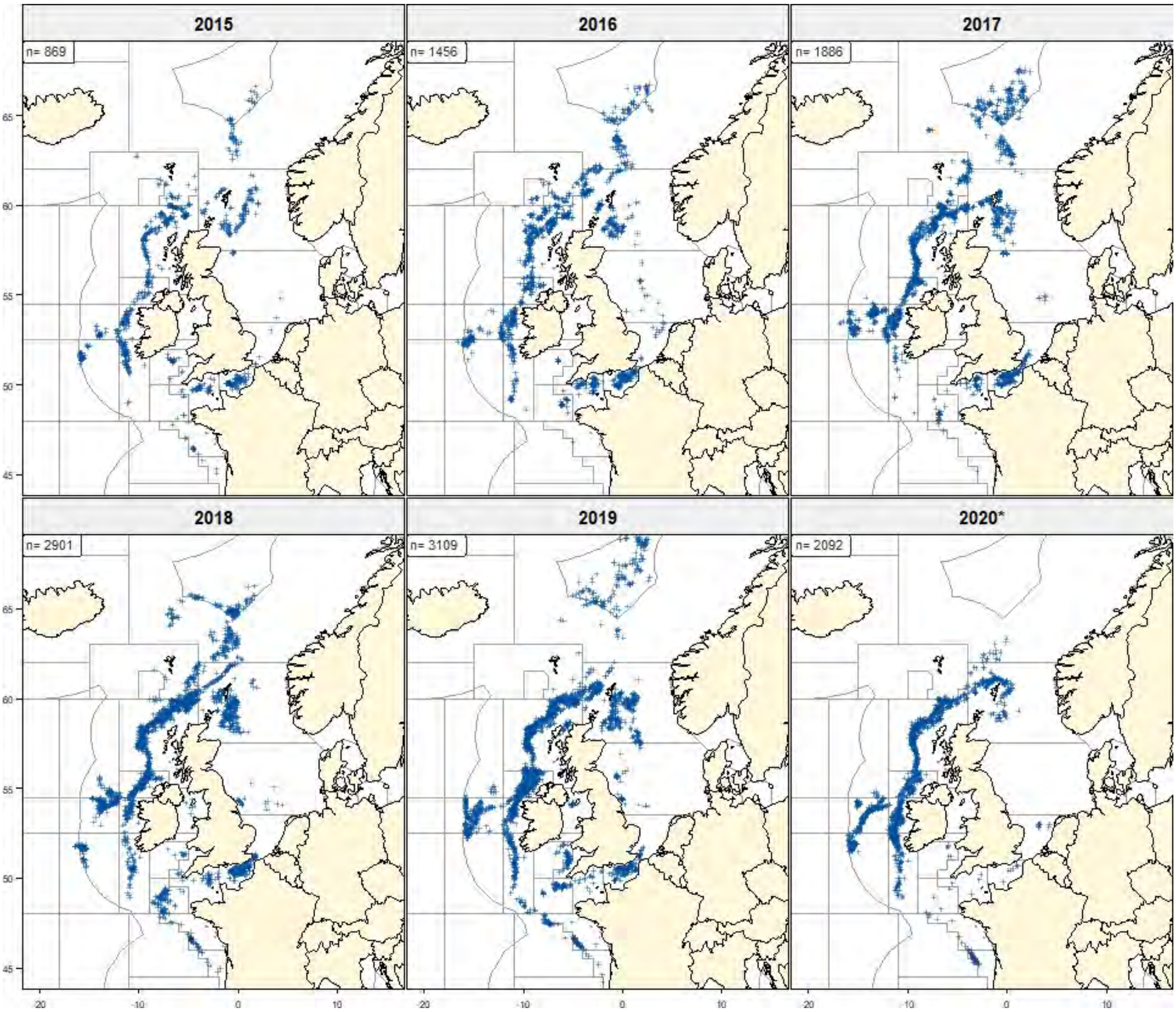


*Figure 3.1.1: Haul positions in PFA self-sampled widely distributed pelagic fisheries. N indicates the number of hauls. * denotes incomplete year*

Total catch per rectangle for the main target species

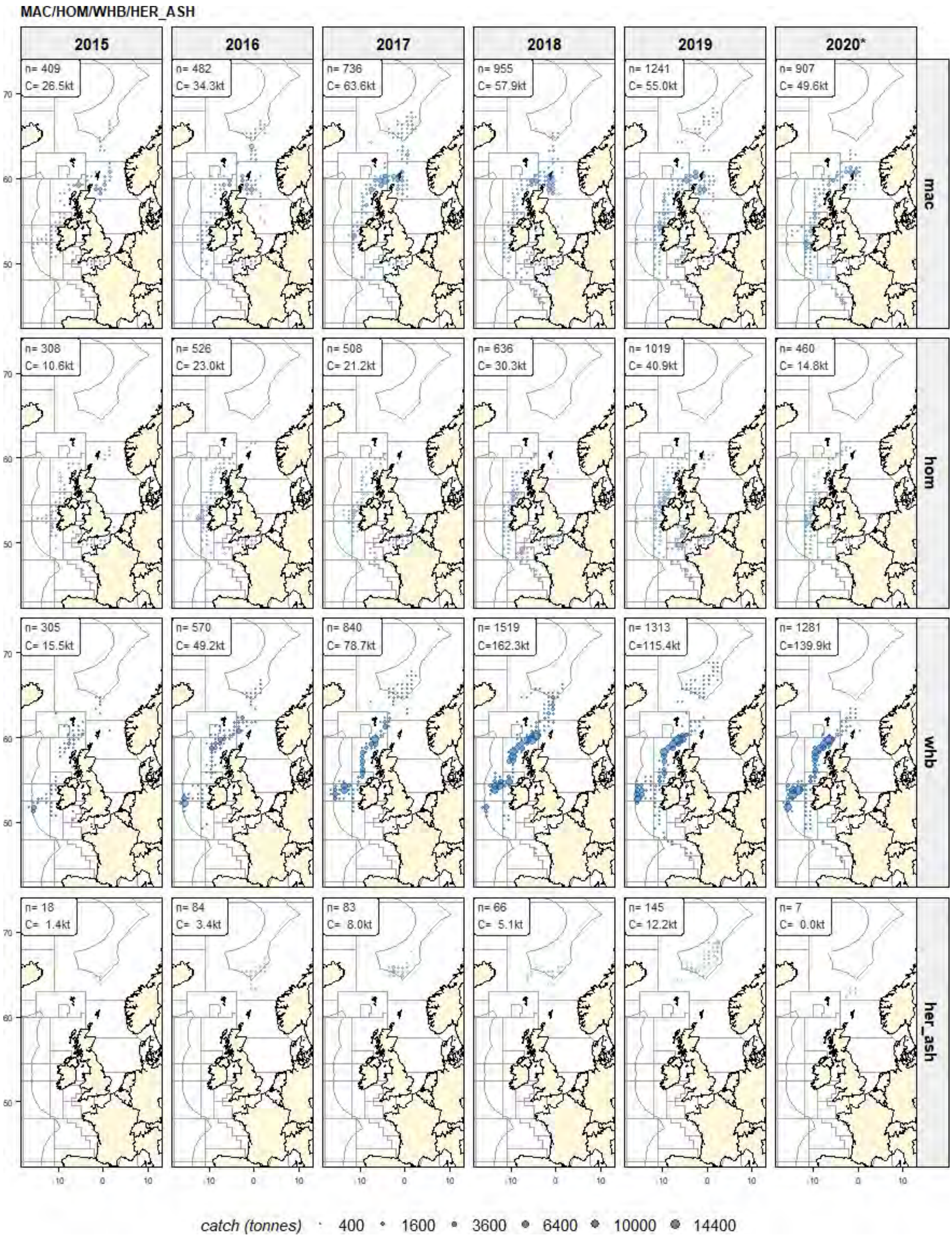


*Figure 3.1.2: Total catch per species and per rectangle in PFA self-sampled widely distributed pelagic fisheries. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Total catch per rectangle for the main target species

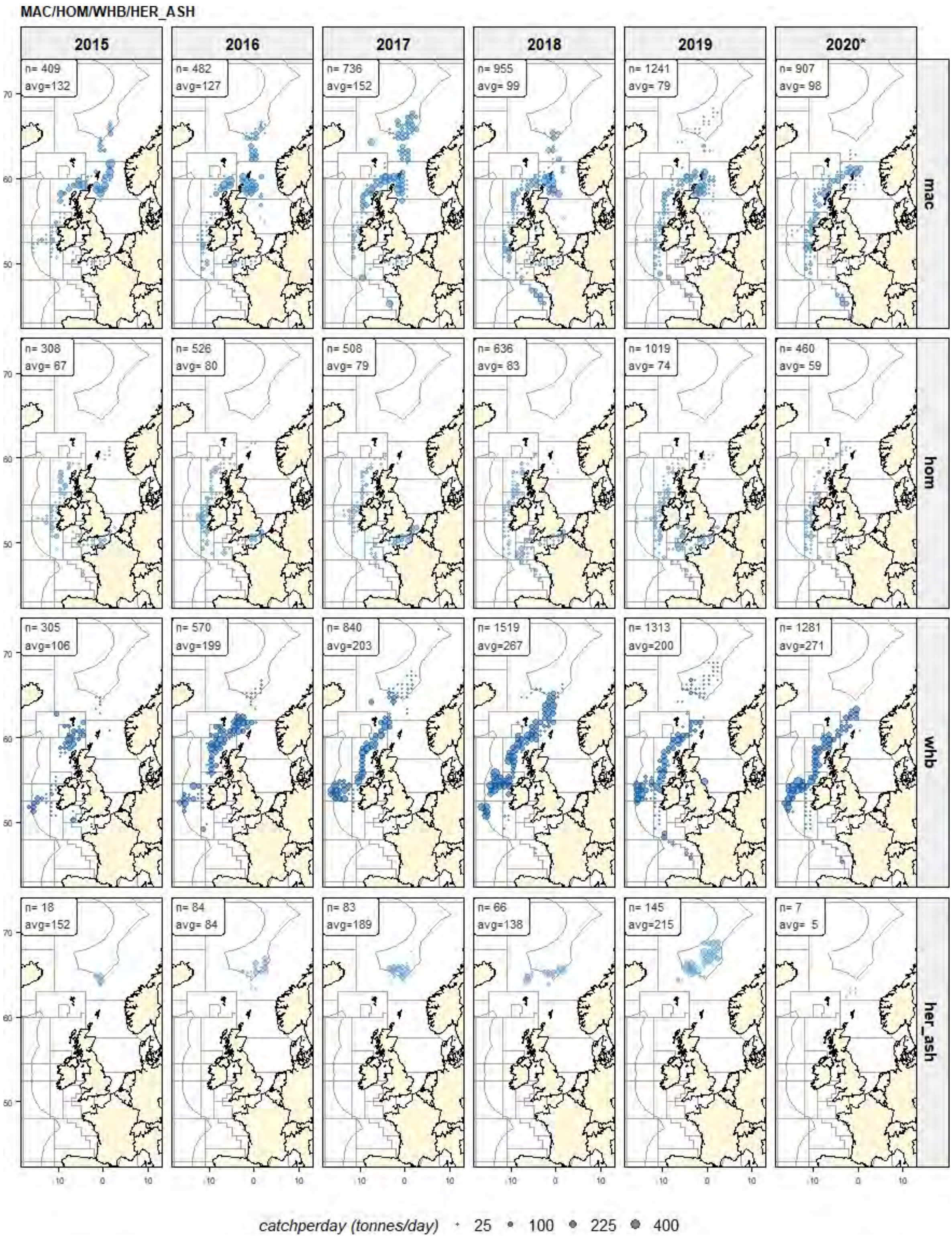


*Figure 3.1.3: Average catch per day, per species and per rectangle in PFA self-sampled widely distributed pelagic fisheries. N indicates the number of hauls; avg refers to the average catch per day; * denotes incomplete year*

Average fishing depth by rectangle

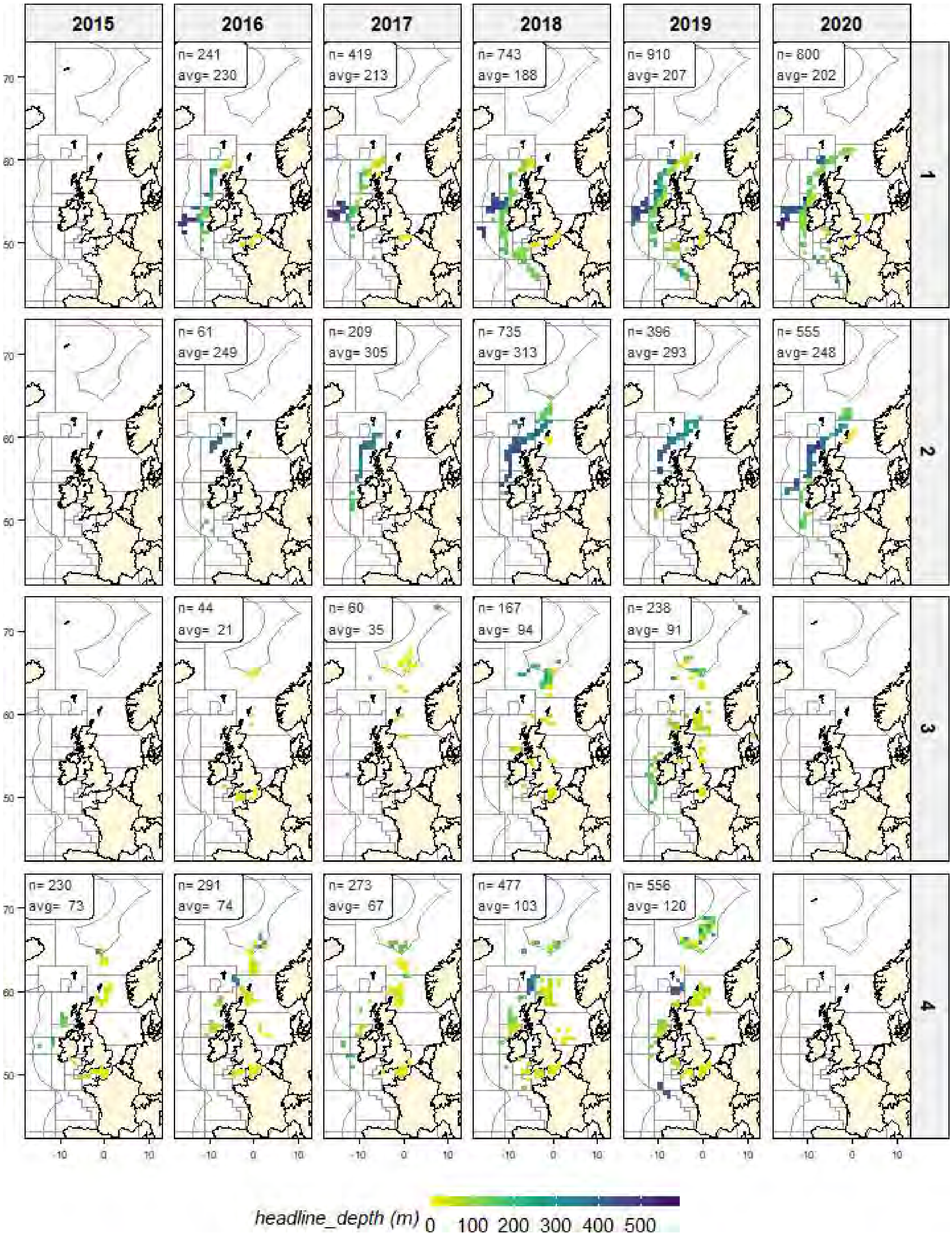


Figure 3.1.4: Average fishing depth (m) in PFA self-sampled widely distributed fisheries, by year and quarter.

Average temperature at fishing depth by rectangle

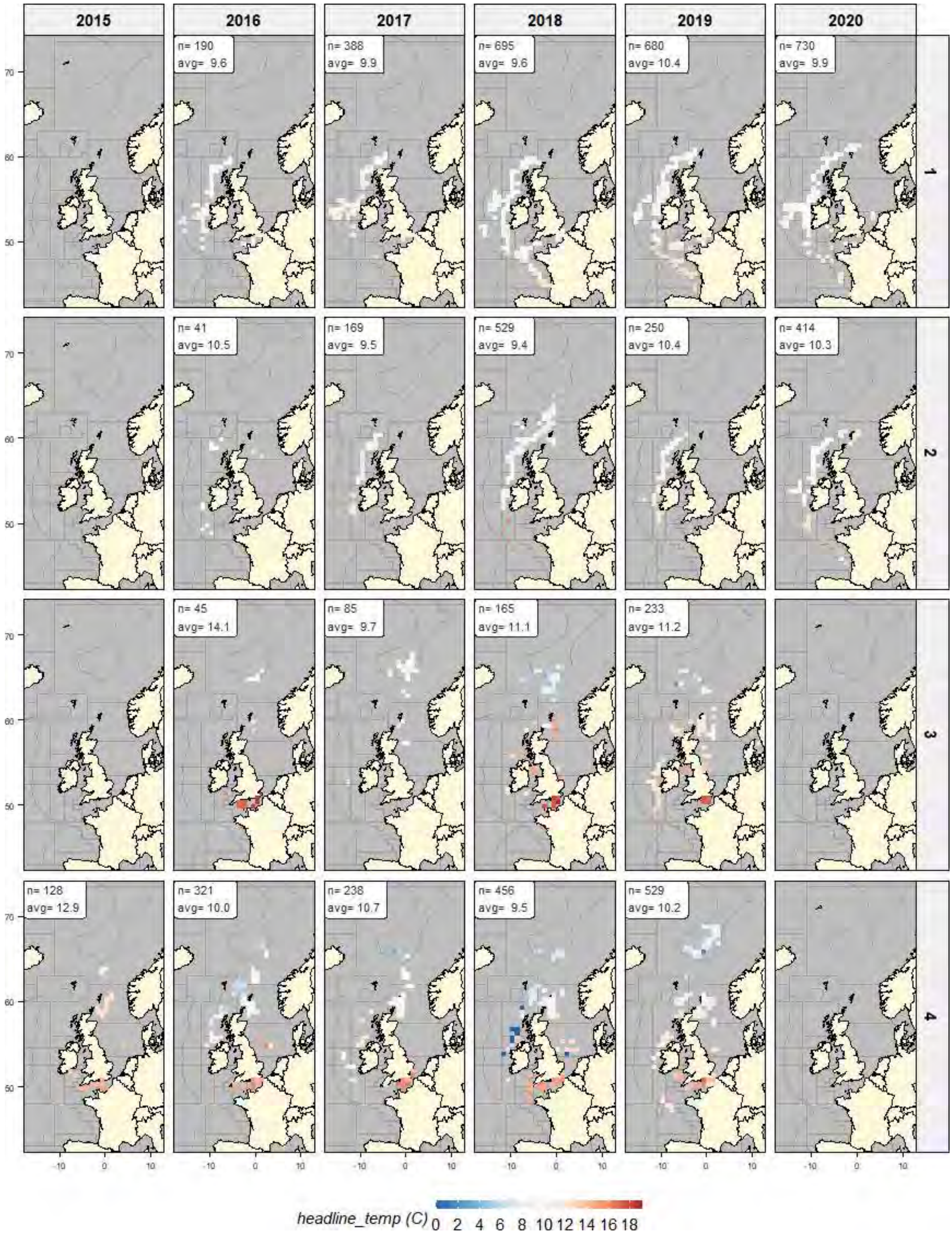


Figure 3.1.5: Average temperature at fishing depth in PFA self-sampled widely distributed fisheries.

Average windspeed by rectangle

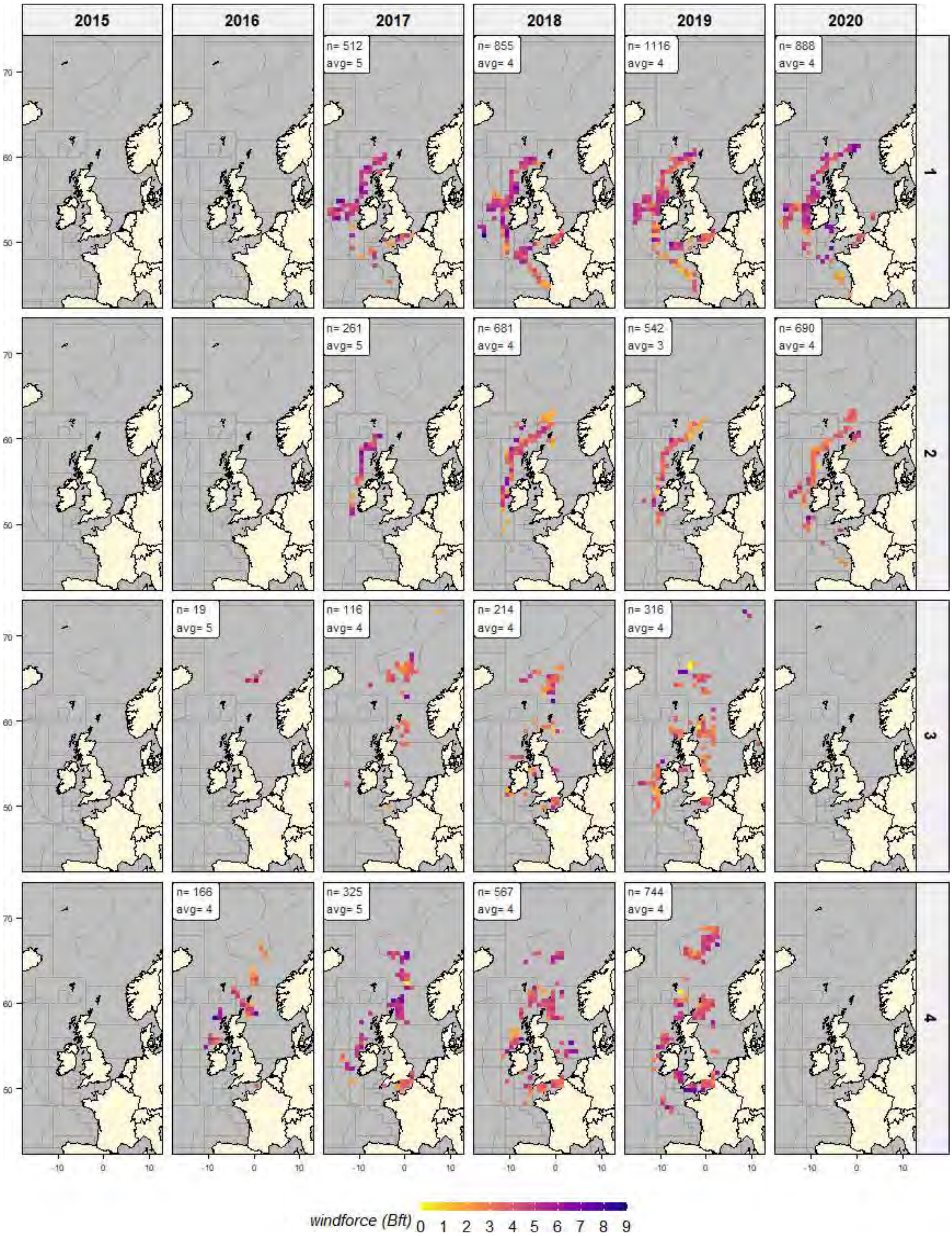


Figure 3.1.6: Average windforce in PFA self-sampled widely distributed fisheries.

3.2 Mackerel (MAC, Scomber scombrus)

The Mackerel fishery takes place from October through to March of the subsequent year. Minor bycatches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2015 – 2020 (up to August) covered 323 fishing trips with 4,725 hauls, a total catch of 286,957 tonnes and 91,000 individual length measurements. The main fishing areas are ICES division 27.4.a (between 27 and 54% of the catch) and division 27.6.a (between 25 and 44% of the catch).

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	catch/day	nlength
mac	27.2.a	2015	3	3	18	35	2,041	8	113	1,561
mac	27.2.a	2016	6	7	48	98	7,442	22	155	2,843
mac	27.2.a	2017	6	9	81	164	13,020	20	161	1,948
mac	27.2.a	2018	5	7	39	66	4,831	8	124	9
mac	27.2.a	2019	4	4	26	45	205	0	8	291
mac	27.2.a	2020*	1	1	4	4	1	0	0	0
mac	27.4.a	2015	5	7	51	111	14,324	54	281	4,926
mac	27.4.a	2016	8	11	66	120	15,705	46	238	1,775
mac	27.4.a	2017	8	17	93	155	17,325	27	186	4,475
mac	27.4.a	2018	13	24	170	296	28,511	49	168	5,651
mac	27.4.a	2019	14	27	182	341	24,300	44	134	7,016
mac	27.4.a	2020*	10	16	83	160	14,979	30	180	13,813
mac	27.6.a	2015	4	7	41	77	7,904	30	193	2,453
mac	27.6.a	2016	6	15	56	94	8,689	25	155	2,647
mac	27.6.a	2017	10	25	156	264	28,288	44	181	5,443
mac	27.6.a	2018	16	31	238	392	18,024	31	76	7,905
mac	27.6.a	2019	15	43	307	517	21,305	39	69	7,691
mac	27.6.a	2020*	13	36	222	407	15,619	32	70	5,553
mac	27.7.b	2015	2	4	19	34	811	3	43	158
mac	27.7.b	2016	5	7	35	68	186	1	5	125
mac	27.7.b	2017	6	9	51	98	3,640	6	71	276
mac	27.7.b	2018	6	9	33	51	1,111	2	34	37
mac	27.7.b	2019	12	22	73	124	5,389	10	74	1,849
mac	27.7.b	2020*	12	22	85	140	6,047	12	71	2,913
mac	27.7.j	2015	4	7	33	69	764	3	23	821
mac	27.7.j	2016	3	6	20	29	1,413	4	71	122
mac	27.7.j	2017	3	4	6	11	496	1	83	170
mac	27.7.j	2018	8	11	26	38	2,662	5	102	314
mac	27.7.j	2019	8	11	47	89	2,357	4	50	1,514
mac	27.7.j	2020*	12	24	78	134	10,705	22	137	2,495
mac	other	2015	5	15	48	83	637	2	13	293
mac	other	2016	6	19	49	74	864	3	18	205
mac	other	2017	8	21	39	52	886	1	23	60
mac	other	2018	8	17	80	114	2,819	5	35	1,083
mac	other	2019	12	27	83	127	1,498	3	18	2,417
mac	other	2020*	10	15	49	63	2,230	4	46	650
mac	(all)	2015		43	210	409	26,481	100	126	10,212
mac	(all)	2016		65	274	483	34,299	101	125	7,717
mac	(all)	2017		85	426	744	63,655	99	149	12,372
mac	(all)	2018		99	586	957	57,958	100	99	14,999
mac	(all)	2019		134	718	1,243	55,054	100	77	20,778
mac	(all)	2020*		114	521	908	49,581	100	95	25,424
mac	(all)	(all)		540	2,735	4,744	287,028		105	91,502

*Table 3.2.1: Mackerel. Self-sampling summary with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). * denotes incomplete year*

Mackerel (MAC). Catch by month

species	month	2015	2016	2017	2018	2019	2020*	all	perc
mac	Jan	7,557	7,847	18,594	11,592	18,766	20,769	85,125	29.6608%
mac	Feb	1,483	1,189	8,198	7,613	11,872	19,410	49,765	17.3400%
mac	Mar	519	150	4,724	3,307	5,507	7,087	21,294	7.4196%
mac	Apr	240	789	1,025	1,225	1,327	797	5,403	1.8826%
mac	May	70	34	296	191	489	1,218	2,298	0.8007%
mac	Jun	0	179	0	60	96	175	510	0.1777%
mac	Jul	223	194	88	0	327	83	915	0.3188%
mac	Aug	0	147	247	59	431	39	923	0.3216%
mac	Sep	755	1,091	9,388	4,849	3,063	0	19,146	6.6712%
mac	Oct	14,670	14,150	7,972	19,465	11,559	0	67,816	23.6297%
mac	Nov	944	8,358	11,653	9,229	1,613	0	31,797	11.0793%
mac	Dec	15	163	1,463	362	0	0	2,003	0.6979%
mac	(all)	26,476	34,291	63,648	57,952	55,050	49,578	286,995	100.0000%

*Table 3.2.2: Mackerel. Self-sampling summary with the catch (tonnes) by year and month. * denotes incomplete year*

Mackerel (MAC). Catch by rectangle

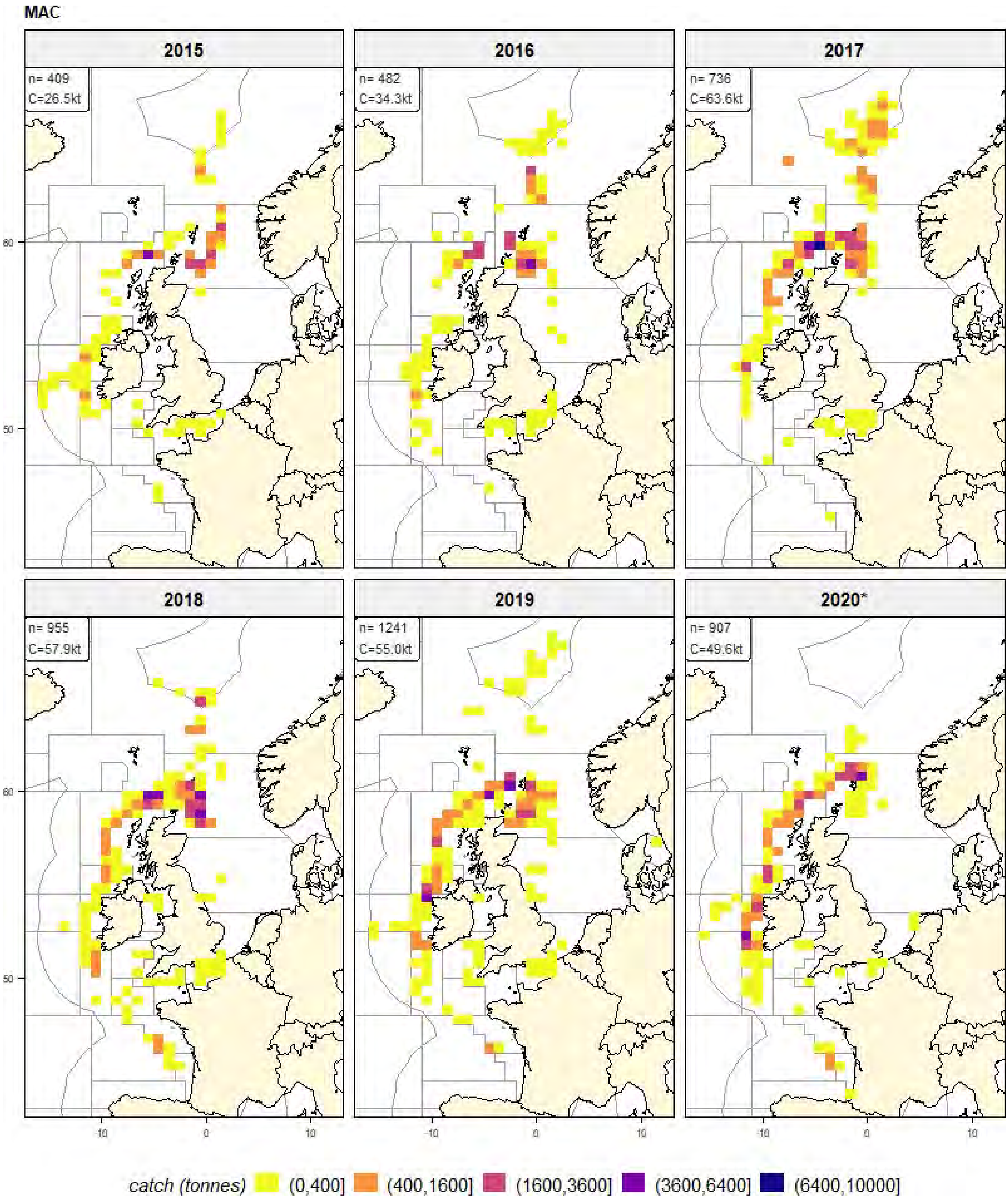


*Figure 3.2.1: Mackerel. Catch per per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Mackerel (MAC). Average catch per day

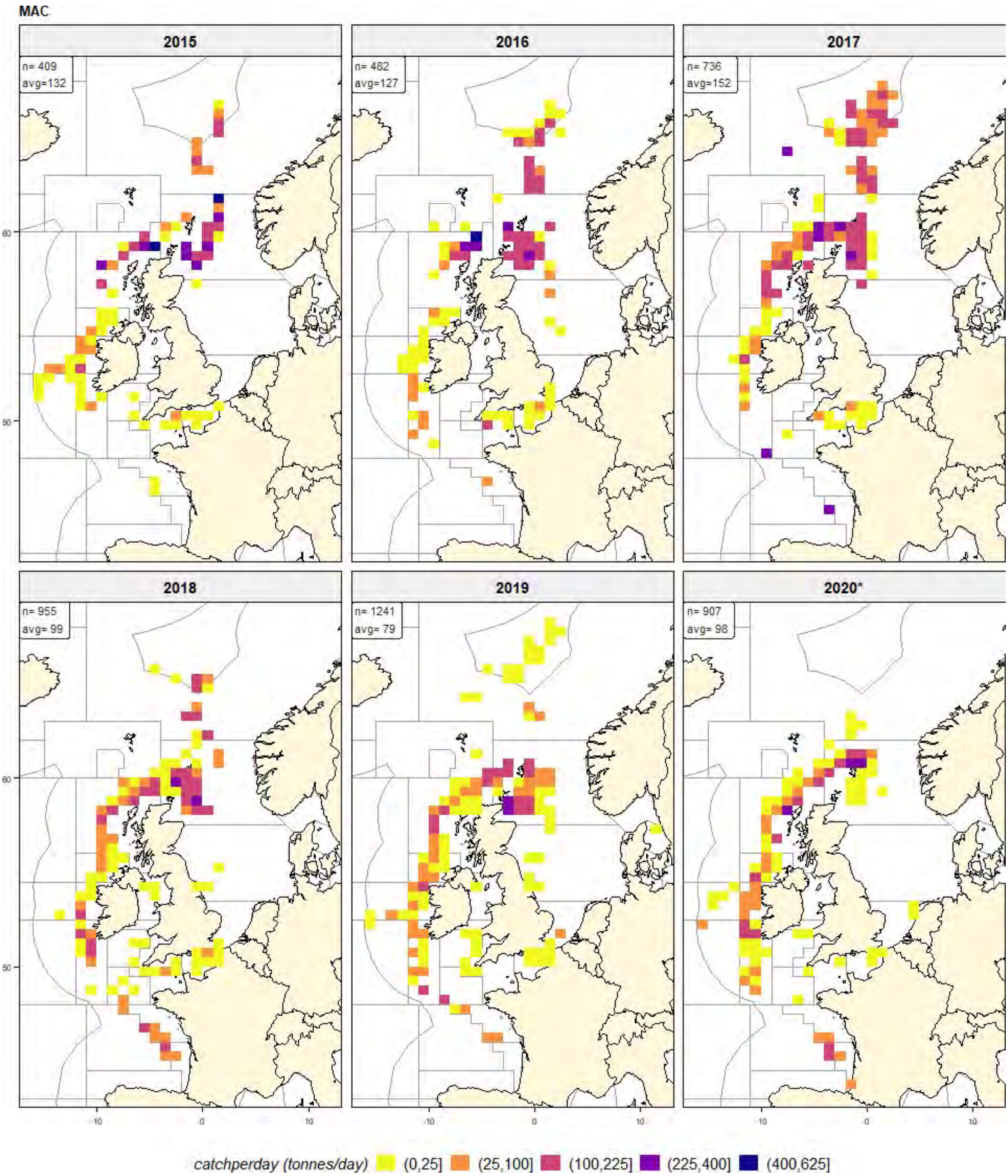


*Figure 3.2.2: Mackerel. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Mackerel (MAC). Spatial-temporal evolution of the fishery

Spatial-temporal evolution of the fishery by year and month from the haul-by-haul catch information. Fishing season is from October until March the following year. The midpoint of the distribution is indicated by the blue triangle. The catch has been used as weighting factor in the calculation of the midpoint.

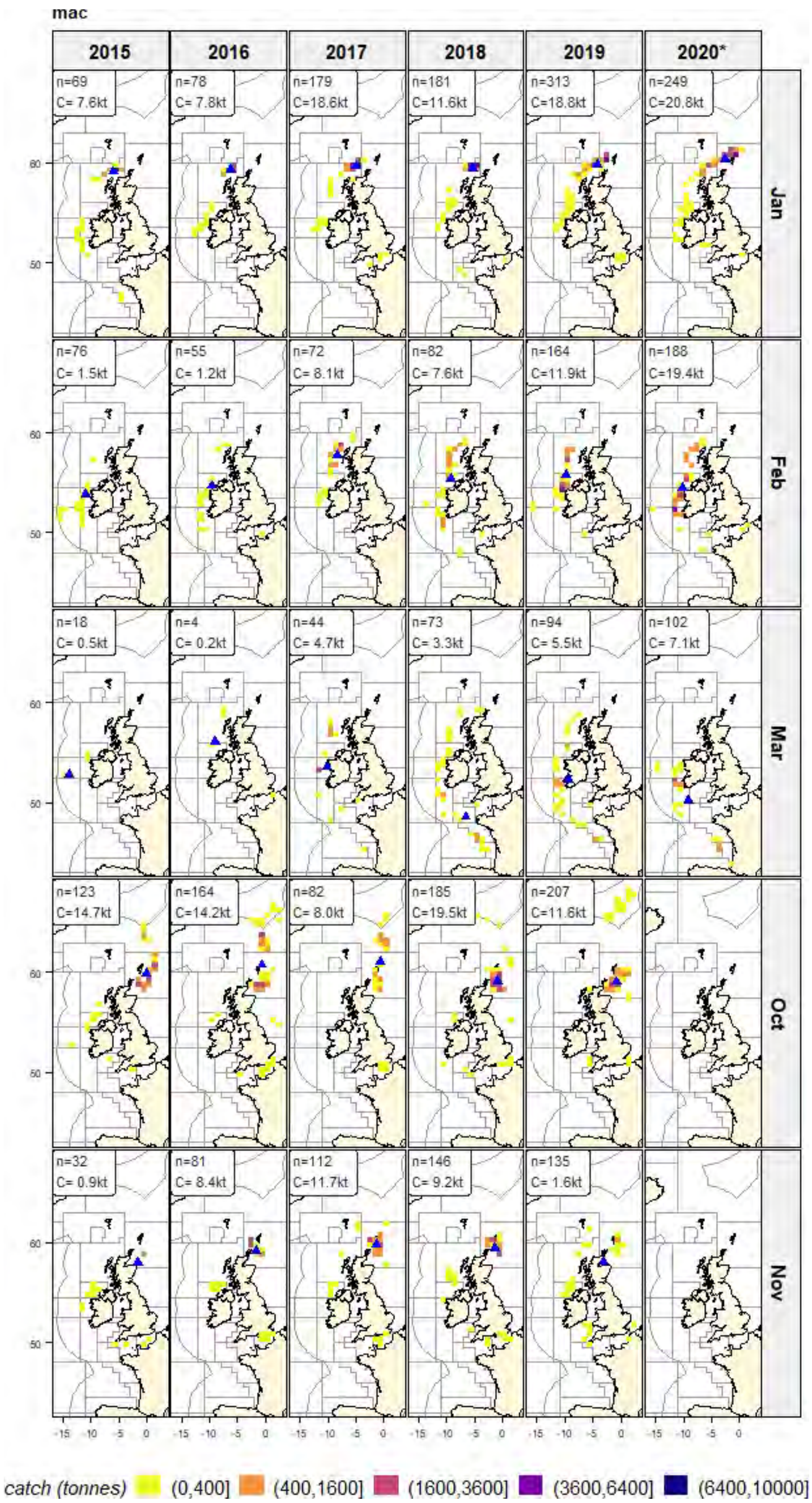


*Figure 3.2.3: Mackerel. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Mackerel (MAC). Length distributions of the catch

Compared to the previous years, mackerel in the catch have been relatively large in 2020 with median length of 36.4 cm compared to 32.4-35.4 in the preceding years. Note that the catch in 2020 is only for the first half of the year.

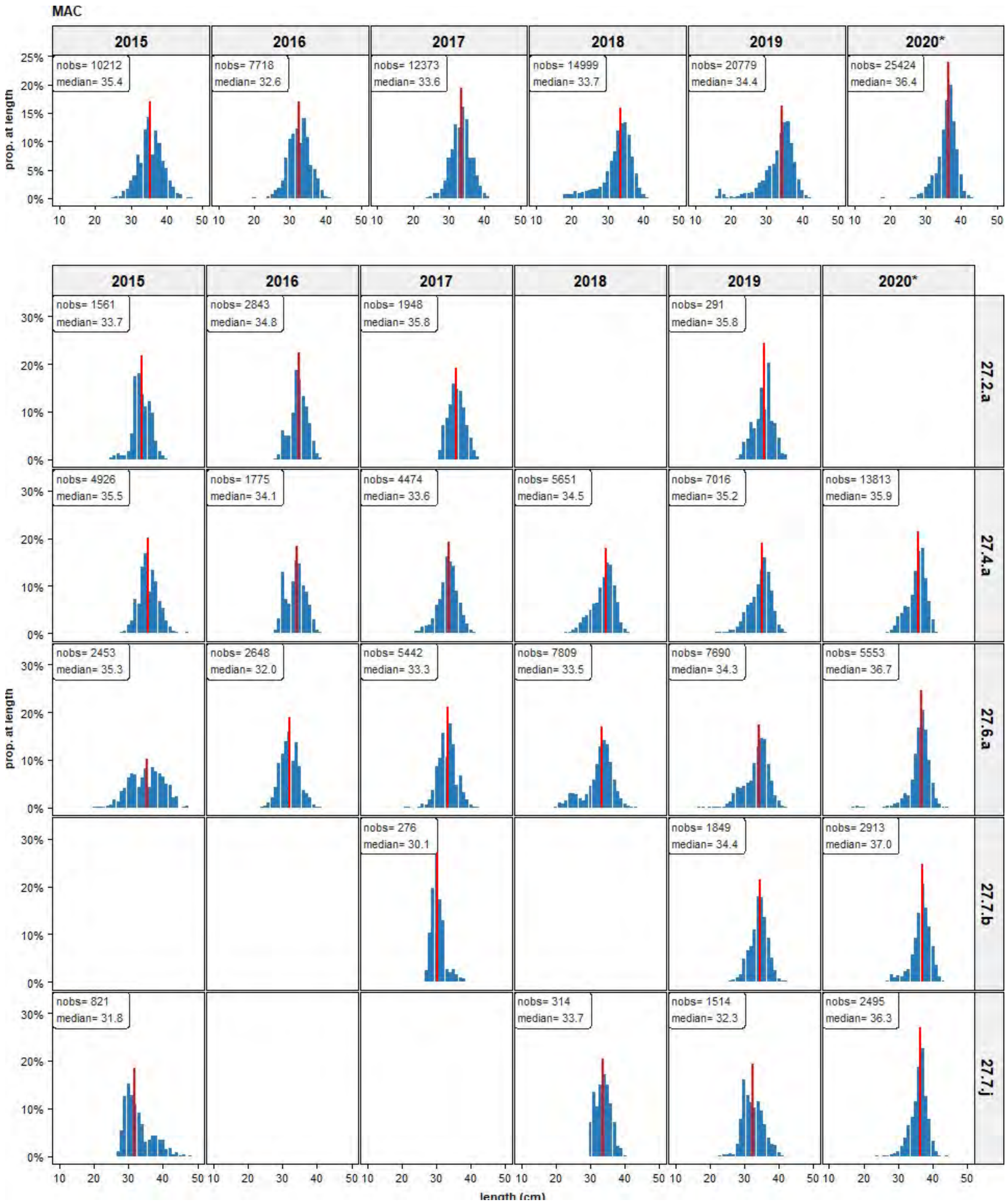


*Figure 3.2.4: Mackerel. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Mackerel (MAC). Length frequencies by year and quarter

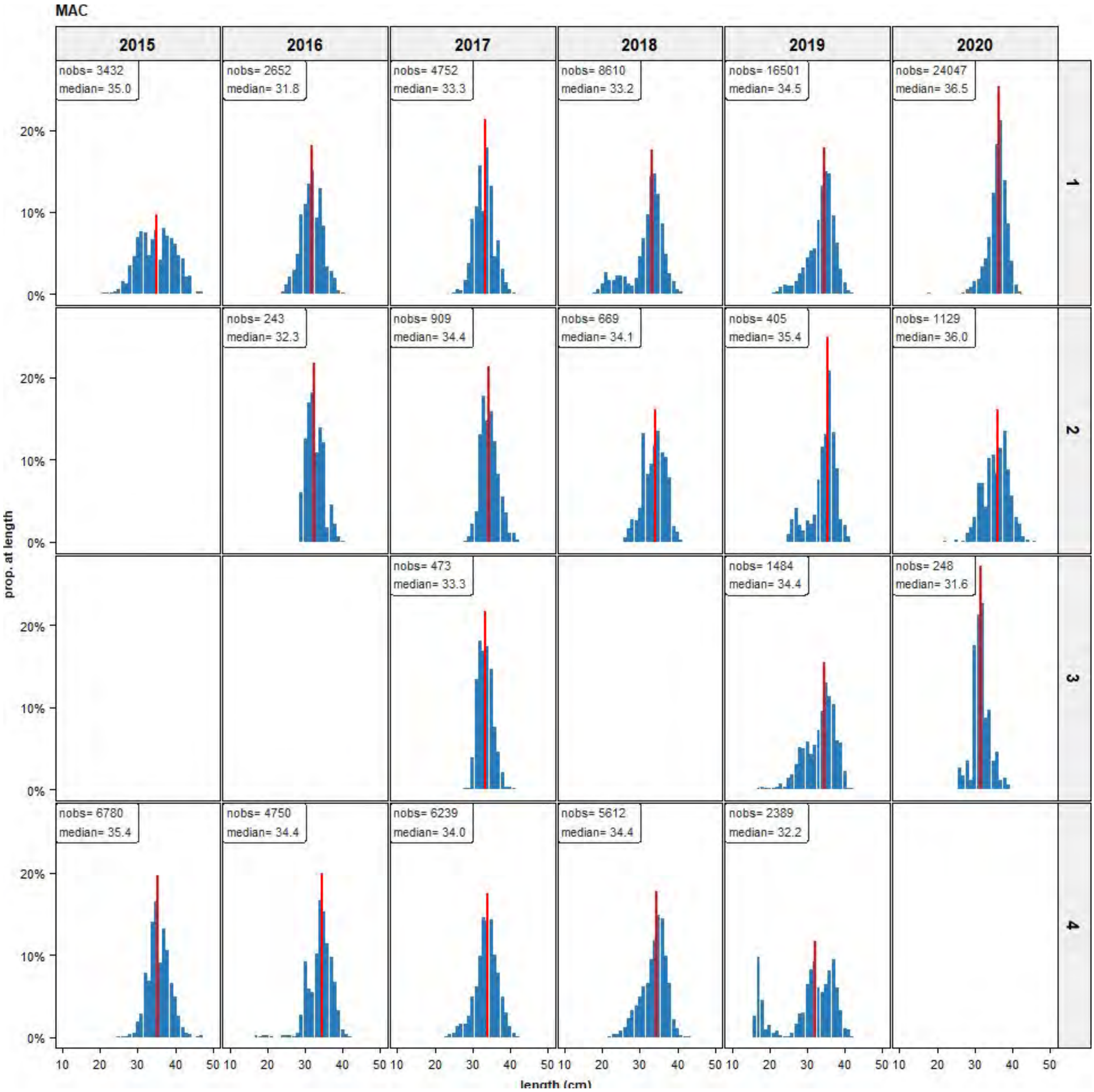


Figure 3.2.5: Mackerel. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length

Mackerel (MAC). Weight distributions

In line with the observation that the median length of mackerel in 2020 has been larger than in the preceding years, also the median weight has been somewhat higher with median weight of 417 gram compared to 379-400 gram the preceding years.

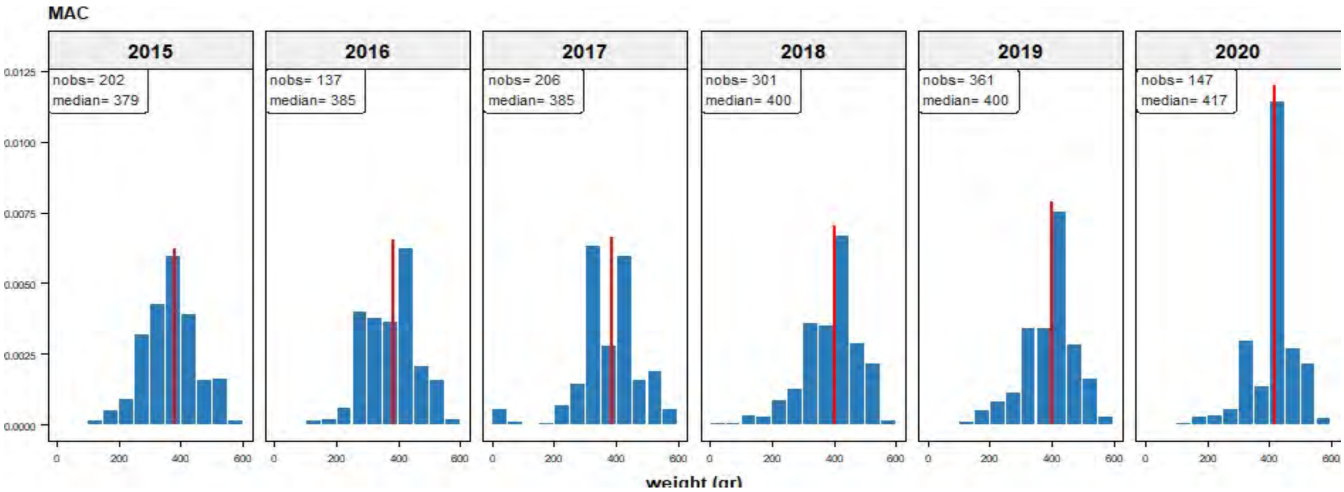


*Figure 3.2.6: Mackerel. Weight distributions (50 gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Mackerel (MAC). Fat percentages by year

Average annual fat content ranges from 17 to 21% with individual measurements reaching up to 30%.

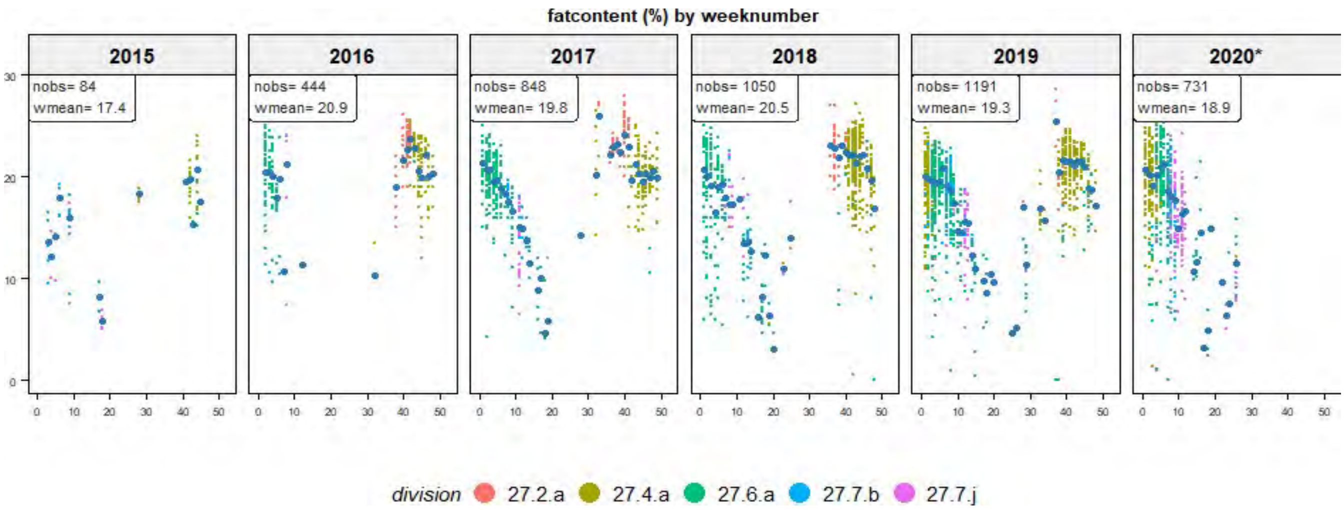


*Figure 3.2.7: Mackerel. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; blue dots indicate the weekly averages; * denotes incomplete year*

Mackerel (MAC). Fishing depth distributions.

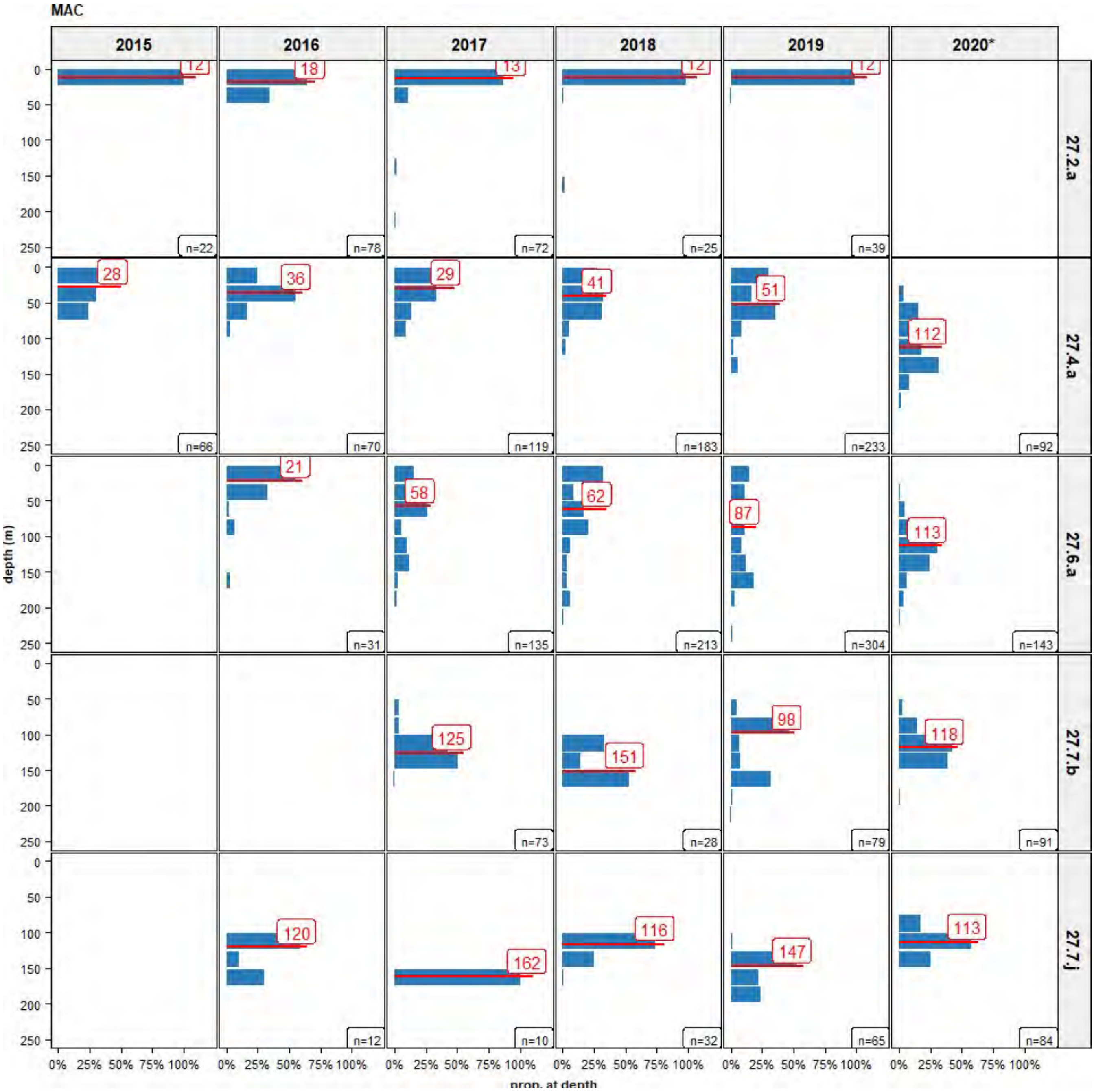


*Figure 3.2.8: Mackerel. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

3.3 Horse mackerel (HOM, Trachurus trachurus)

The horse mackerel fishery takes place from October through to March of the subsequent year. Overall, the self-sampling activities for the horse mackerel fisheries during the years 2015 – 2020 (up to August) covered 457 fishing trips with 3,454 hauls, a total catch of 140,633 tonnes and 125,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 21% and 40% of the catch), division 27.7.b (7%-22%) and division 27.7.d (19%-34%, note that this is considered as the North Sea horse mackerel stock).

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	catch/day	nlength
hom	27.6.a	2015	3	6	39	66	2,746	26	70	2,934
hom	27.6.a	2016	6	17	93	153	4,753	21	51	4,983
hom	27.6.a	2017	8	13	82	159	5,343	25	65	5,213
hom	27.6.a	2018	13	23	125	235	12,053	40	96	12,015
hom	27.6.a	2019	14	30	212	384	13,878	34	65	7,443
hom	27.6.a	2020*	8	17	68	112	4,255	29	63	3,668
hom	27.7.b	2015	4	6	27	48	1,483	14	55	927
hom	27.7.b	2016	5	8	47	92	4,313	19	92	3,390
hom	27.7.b	2017	6	12	57	104	4,729	22	83	3,459
hom	27.7.b	2018	9	11	39	60	2,250	7	58	1,663
hom	27.7.b	2019	12	24	78	129	4,268	10	55	2,678
hom	27.7.b	2020*	12	23	84	147	5,231	35	62	5,478
hom	27.7.d	2015	4	6	30	50	2,012	19	67	3,864
hom	27.7.d	2016	5	15	76	130	7,225	31	95	6,313
hom	27.7.d	2017	6	15	75	139	7,202	34	96	1,013
hom	27.7.d	2018	5	13	73	138	6,234	21	85	3,898
hom	27.7.d	2019	8	14	76	141	7,102	17	93	9,123
hom	27.7.d	2020*	3	3	3	4	12	0	4	106
hom	27.7.h	2016	1	1	8	16	1,297	6	162	5,043
hom	27.7.h	2017	2	5	18	30	1,329	6	74	0
hom	27.7.h	2018	9	13	50	89	6,326	21	127	7,804
hom	27.7.h	2019	6	6	13	21	984	2	76	2,663
hom	27.7.h	2020*	2	2	2	2	55	0	28	0
hom	27.7.j	2015	4	6	35	79	3,082	29	88	5,640
hom	27.7.j	2016	4	8	29	55	3,091	13	107	761
hom	27.7.j	2017	3	5	7	13	160	1	23	463
hom	27.7.j	2018	7	10	30	45	813	3	27	519
hom	27.7.j	2019	10	14	58	110	5,076	12	88	1,520
hom	27.7.j	2020*	12	26	92	168	5,067	34	55	4,261
hom	other	2015	6	14	37	65	1,263	12	34	1,005
hom	other	2016	8	16	45	81	2,287	10	51	1,627
hom	other	2017	7	18	41	64	2,503	12	61	1,100
hom	other	2018	7	13	51	70	2,619	9	51	576
hom	other	2019	12	31	131	236	9,590	23	73	14,059
hom	other	2020*	8	14	21	27	222	1	11	438
hom	(all)	2015		38	168	308	10,586	100	63	14,370
hom	(all)	2016		65	298	527	22,966	100	77	22,117
hom	(all)	2017		68	280	509	21,266	100	76	11,248
hom	(all)	2018		83	368	637	30,295	101	82	26,475
hom	(all)	2019		119	568	1,021	40,898	98	72	37,486
hom	(all)	2020*		85	270	460	14,842	99	55	13,951
hom	(all)	(all)		458	1,952	3,462	140,853		72	125,647

*Table 3.3.1: Horse mackerel. Self-sampling summary with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). * denotes incomplete year*

Horse mackerel (HOM). Catch by month

species	month	2015	2016	2017	2018	2019	2020*	all	perc
hom	Jan	3,053	4,722	9,613	11,518	11,547	7,178	47,631	33.82%
hom	Feb	2,929	6,941	3,112	5,961	5,304	4,804	29,051	20.63%
hom	Mar	145	111	227	3,626	4,083	1,259	9,451	6.71%
hom	Apr	495	256	0	31	45	0	827	0.59%
hom	May	114	175	155	6	41	529	1,020	0.72%
hom	Jun	0	1	0	226	1,357	649	2,233	1.59%
hom	Jul	0	1,733	186	15	5,671	419	8,024	5.70%
hom	Aug	0	15	58	0	8	0	81	0.06%
hom	Sep	71	560	134	1,910	2,343	0	5,018	3.56%
hom	Oct	234	1,838	4,620	1,954	3,555	0	12,201	8.66%
hom	Nov	2,890	5,086	3,027	3,925	5,950	0	20,878	14.83%
hom	Dec	650	1,520	129	1,117	990	0	4,406	3.13%
hom	(all)	10,581	22,958	21,261	30,289	40,894	14,838	140,821	100.00%

*Table 3.3.2: Horse mackerel. Self-sampling summary with the catch (tonnes) by year and month. * denotes incomplete year*

Horse mackerel (HOM). Catch by rectangle

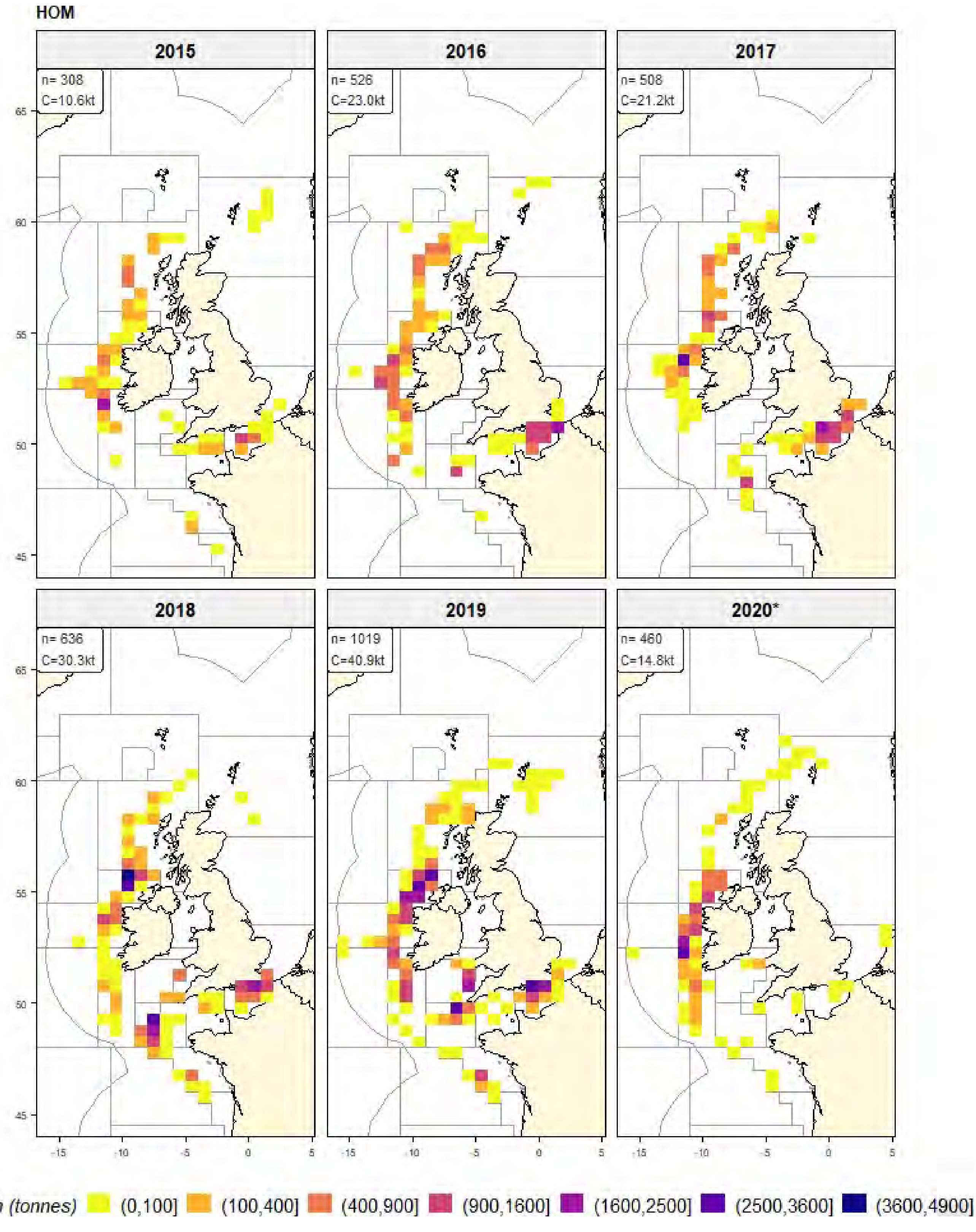


*Figure 3.3.1: Horse mackerel. Catch per per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Horse mackerel (HOM). Average catch per day

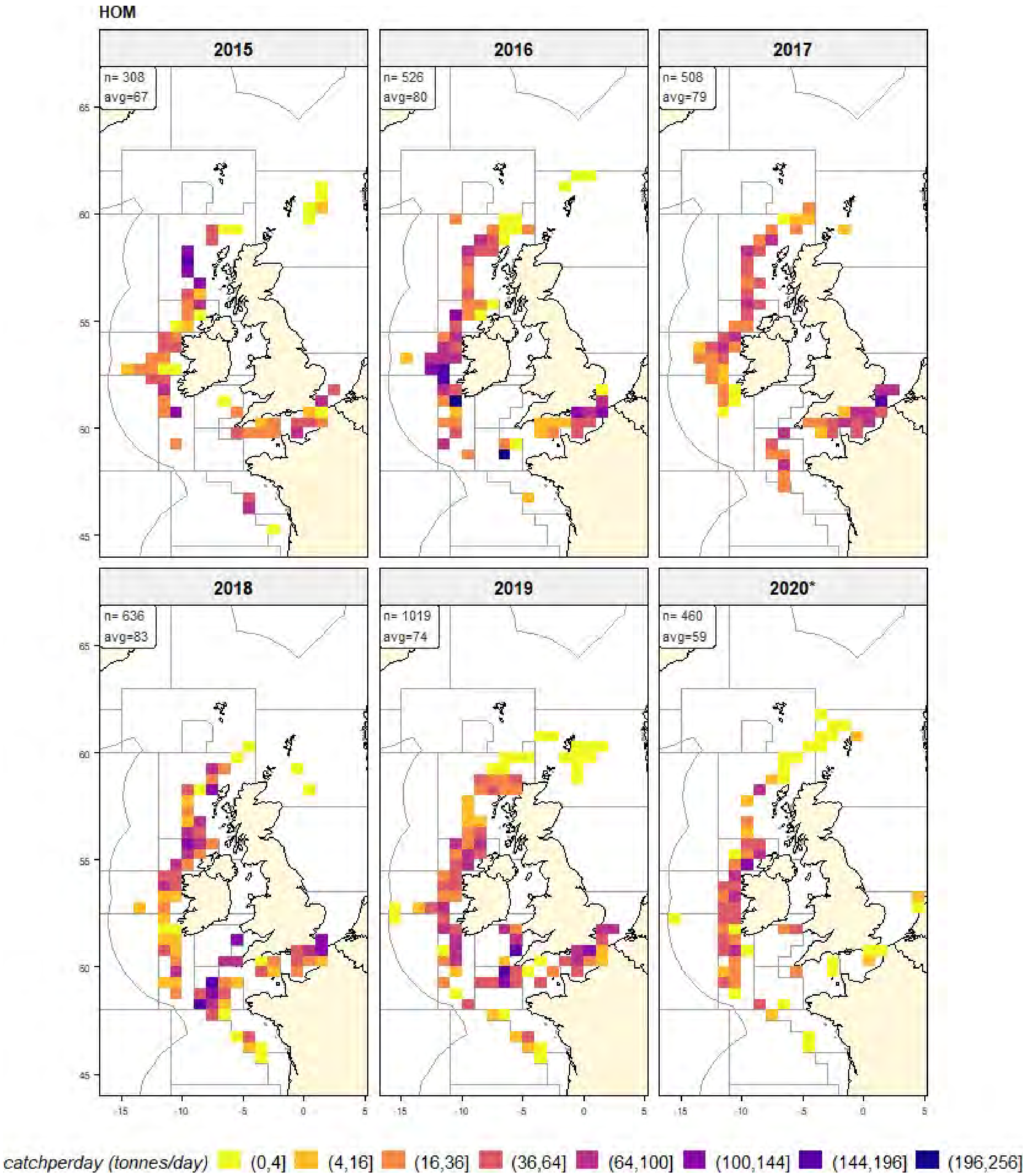


*Figure 3.3.2: Horse mackerel. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Horse mackerel (HOM). Spatial-temporal evolution of the fishery

Spatial-temporal evolution of the fishery by year and month from the haul-by-haul catch information. Fishing season is from October until March the following year. The midpoint of the distribution is indicated by the blue triangle. The catch has been used as weighting factor in the calculation of the midpoint.

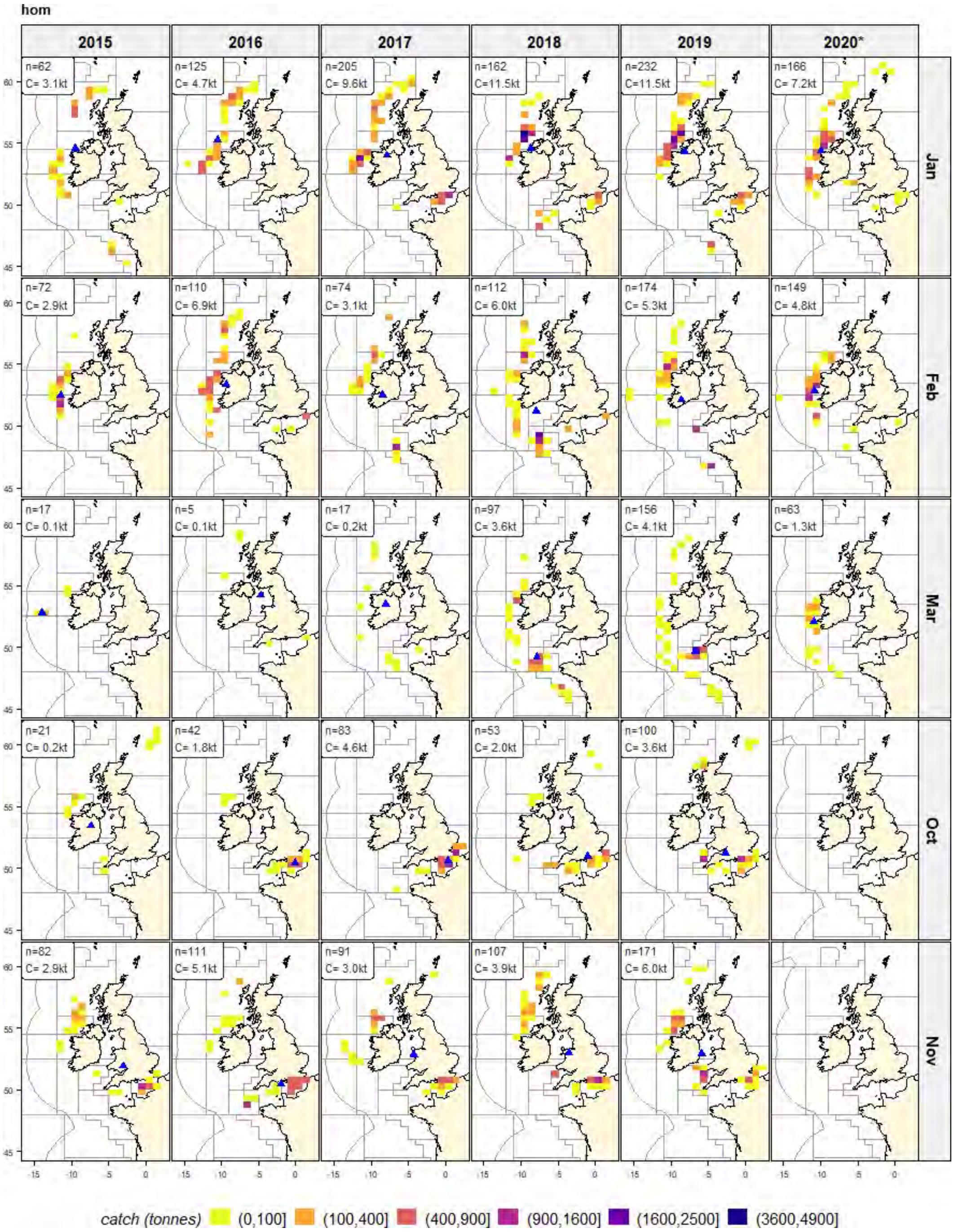


*Figure 3.3.3: Horse mackerel. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Horse mackerel (HOM). Length distributions of the catch

Horse mackerel have a wide range in the length distributions in the catch. Median lengths have fluctuated between 22.8 and 30.0 cm.In 2019 and 2020 there are some indications of a stronger year class being available to the fishery, with a more narrow length distribution. For example, in 27.6.a the mode was 26.6 cm in 2019 and 27.5 cm in 2020. Note that the catch in 2020 is only for the first half of the year.

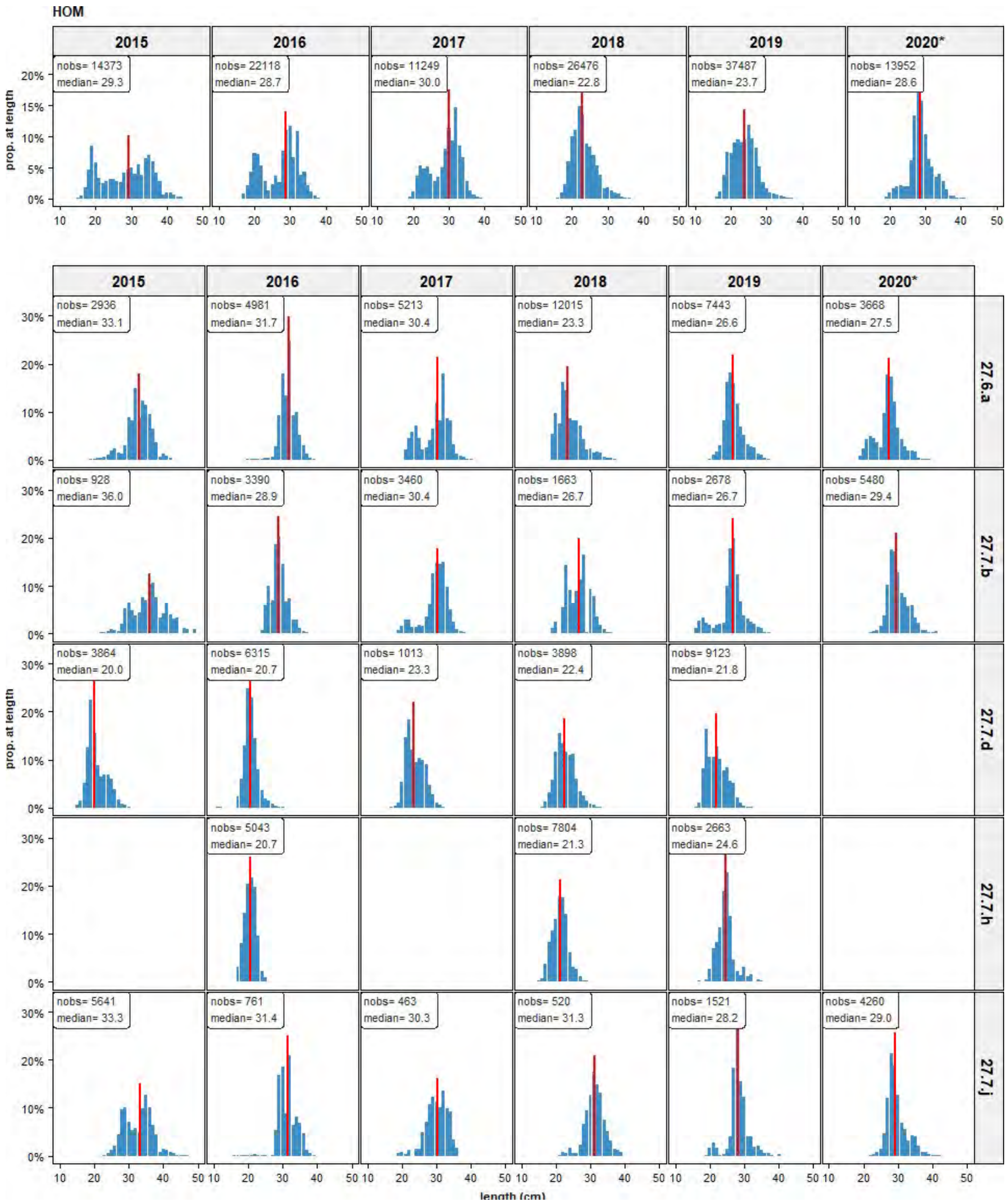


*Figure 3.3.4: Horse mackerel. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Horse mackerel (HOM). Length frequencies by year and quarter

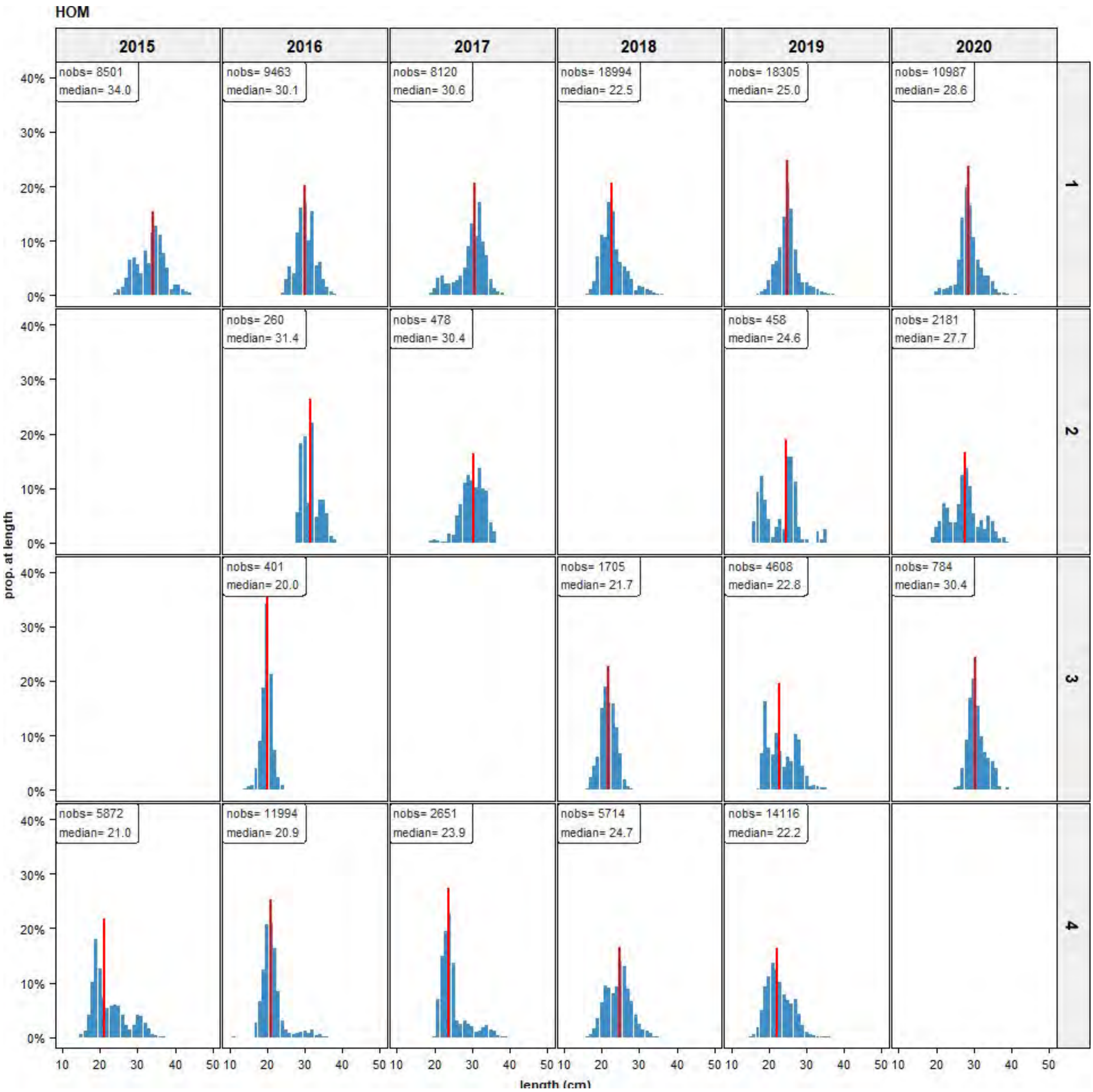


Figure 3.3.5: Horse mackerel. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length

Horse mackerel (HOM). Weight distributions

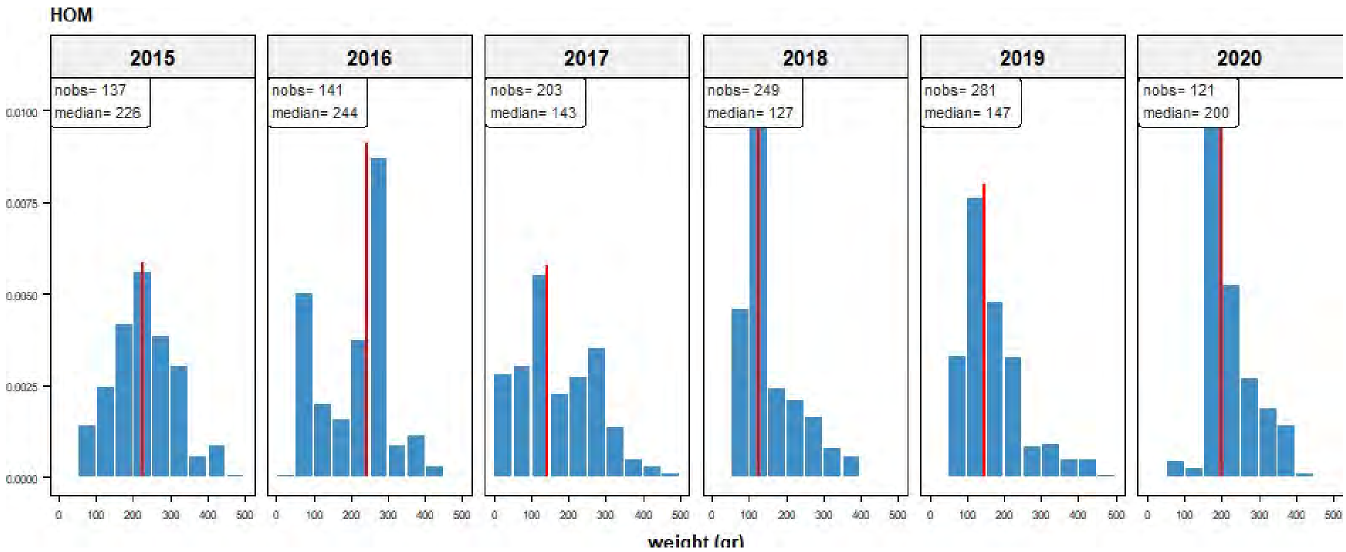


*Figure 3.3.6: Horse mackerel. Weight distributions (50 gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Horse mackerel (HOM). Fat percentages by year

Average annual fat content ranges from 5 to 7.5% with individual measurements reaching up to 15%.

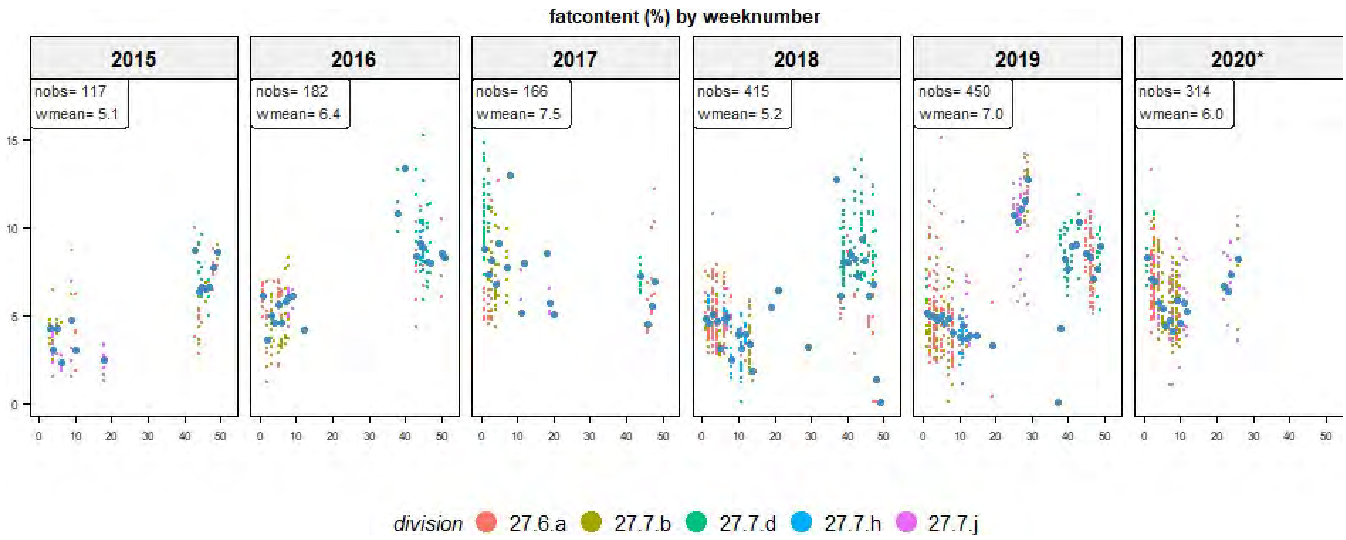


*Figure 3.3.7: Horse mackerel. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; blue dots indicate the weekly averages; * denotes incomplete year*

Horse mackerel (HOM). Fishing depth distributions.

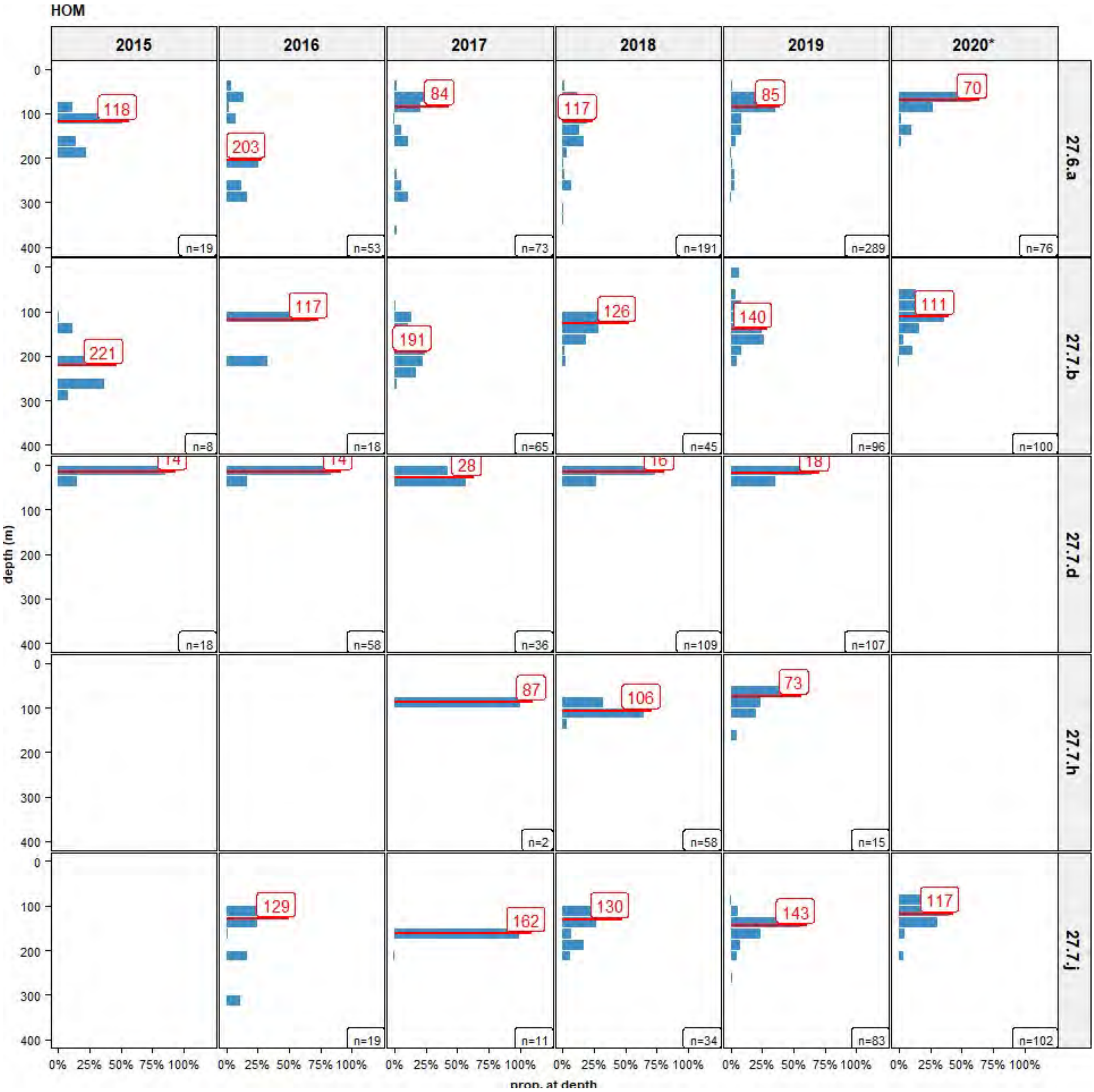


*Figure 3.3.8: Horse mackerel. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

3.4 Blue whiting (WHB, Micromesistius poutassou)

The blue whiting fishery takes place from February through to May although some minor fisheries for blue whiting may remain over the other months. Overall, the self-sampling activities for the blue whiting fisheries during the years 2015 – 2020 (up to August) covered 365 fishing trips with 5,836 hauls, a total catch of 561,888 tonnes and 128,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 41% and 65% of the catch), division 27.7.c (6%-36%) and division 27.7.k (2%-32%).

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	catch/day	nlength
whb	27.6.a	2015	3	7	55	127	7,377	47	134	9,384
whb	27.6.a	2016	4	11	89	206	20,300	41	228	13,397
whb	27.6.a	2017	7	16	163	378	39,085	50	240	36,456
whb	27.6.a	2018	12	29	340	860	91,738	56	270	74,164
whb	27.6.a	2019	14	35	310	724	75,757	65	244	37,899
whb	27.6.a	2020*	12	32	287	744	78,067	56	272	66,432
whb	27.7.c	2015	2	4	13	22	889	6	68	0
whb	27.7.c	2016	4	8	37	66	5,472	11	148	6,283
whb	27.7.c	2017	6	10	97	231	28,230	36	291	16,945
whb	27.7.c	2018	6	9	77	235	30,504	19	396	21,392
whb	27.7.c	2019	10	16	99	246	26,587	23	269	14,222
whb	27.7.c	2020*	10	16	128	327	44,639	32	349	42,790
whb	27.7.k	2015	3	3	24	56	4,973	32	207	11,216
whb	27.7.k	2016	3	3	29	77	7,489	15	258	6,993
whb	27.7.k	2018	3	3	20	59	7,646	5	382	3,077
whb	27.7.k	2019	4	4	11	17	2,036	2	185	401
whb	27.7.k	2020*	4	4	34	90	10,961	8	322	10,401
whb	27.5.b	2015	2	3	20	28	1,872	12	94	7,287
whb	27.5.b	2016	3	4	29	57	5,577	11	192	4,685
whb	27.5.b	2017	5	6	40	64	7,960	10	199	8,226
whb	27.5.b	2018	5	7	52	82	7,928	5	152	5,204
whb	27.5.b	2019	4	8	26	34	3,906	3	150	2,331
whb	27.5.b	2020*	2	2	6	7	798	1	133	1,014
whb	27.2.a	2015	3	3	11	20	96	1	9	573
whb	27.2.a	2016	6	6	32	62	2,345	5	73	1,369
whb	27.2.a	2017	5	9	56	92	2,587	3	46	2,597
whb	27.2.a	2018	6	8	90	158	12,032	7	134	12,352
whb	27.2.a	2019	4	7	61	130	1,417	1	23	1,640
whb	27.2.a	2020*	1	1	8	18	2,032	1	254	2,876
whb	other	2015	4	11	32	52	339	2	11	0
whb	other	2016	6	12	55	105	8,196	17	149	6,614
whb	other	2017	6	9	44	76	941	1	21	577
whb	other	2018	11	20	65	128	12,693	8	195	10,087
whb	other	2019	14	25	100	167	5,969	5	60	10,524
whb	other	2020*	9	15	61	95	3,452	2	57	4,958
whb	(all)	2015		31	155	305	15,546	100	100	28,460
whb	(all)	2016		44	271	573	49,379	100	182	39,341
whb	(all)	2017		50	400	841	78,803	100	197	64,801
whb	(all)	2018		76	644	1,522	162,541	100	252	126,276
whb	(all)	2019		95	607	1,318	115,672	99	191	67,017
whb	(all)	2020*		70	524	1,281	139,949	100	267	128,471
whb	(all)	(all)		366	2,601	5,840	561,890		216	454,366

*Table 3.4.1: Blue whiting. Self-sampling summary with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). * denotes incomplete year*

Blue whiting (WHB). Catch by month

species	month	2015	2016	2017	2018	2019	2020*	all	perc
whb	Jan	24	112	211	956	4,286	9,526	15,115	2.69%
whb	Feb	5,108	1,994	7,693	19,108	17,700	4,050	55,653	9.91%
whb	Mar	867	15,562	24,696	35,934	23,289	42,848	143,196	25.49%
whb	Apr	5,594	13,745	27,316	56,296	26,395	61,755	191,101	34.01%
whb	May	2,202	6,170	9,395	26,731	17,341	20,828	82,667	14.71%
whb	Jun	942	696	0	5,094	13	878	7,623	1.36%
whb	Jul	693	10	0	0	133	61	897	0.16%
whb	Aug	0	0	1,265	4,218	337	0	5,820	1.04%
whb	Sep	13	50	537	413	463	0	1,476	0.26%
whb	Oct	97	316	76	217	1,993	0	2,699	0.48%
whb	Nov	0	3,005	5,934	6,618	14,085	0	29,642	5.28%
whb	Dec	1	7,712	1,674	6,951	9,631	0	25,969	4.62%
whb	(all)	15,541	49,372	78,797	162,536	115,666	139,946	561,858	100.00%

*Table 3.4.2: Blue whiting. Self-sampling summary with the catch (tonnes) by year and month. * denotes incomplete year*

Blue whiting (WHB). Catch by rectangle

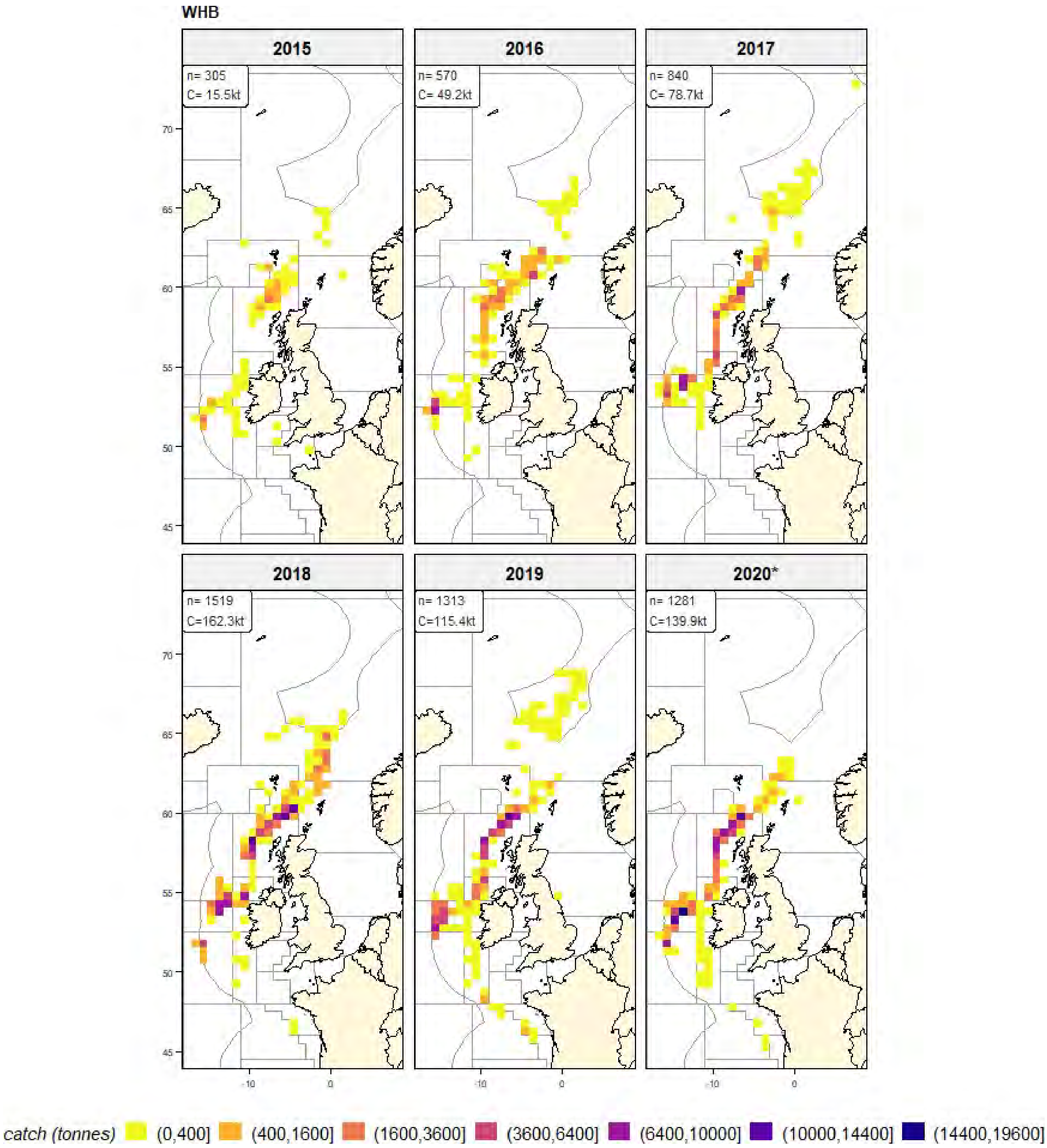


*Figure 3.4.1: Blue whiting. Catch per per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Blue whiting (WHB). Average catch per day

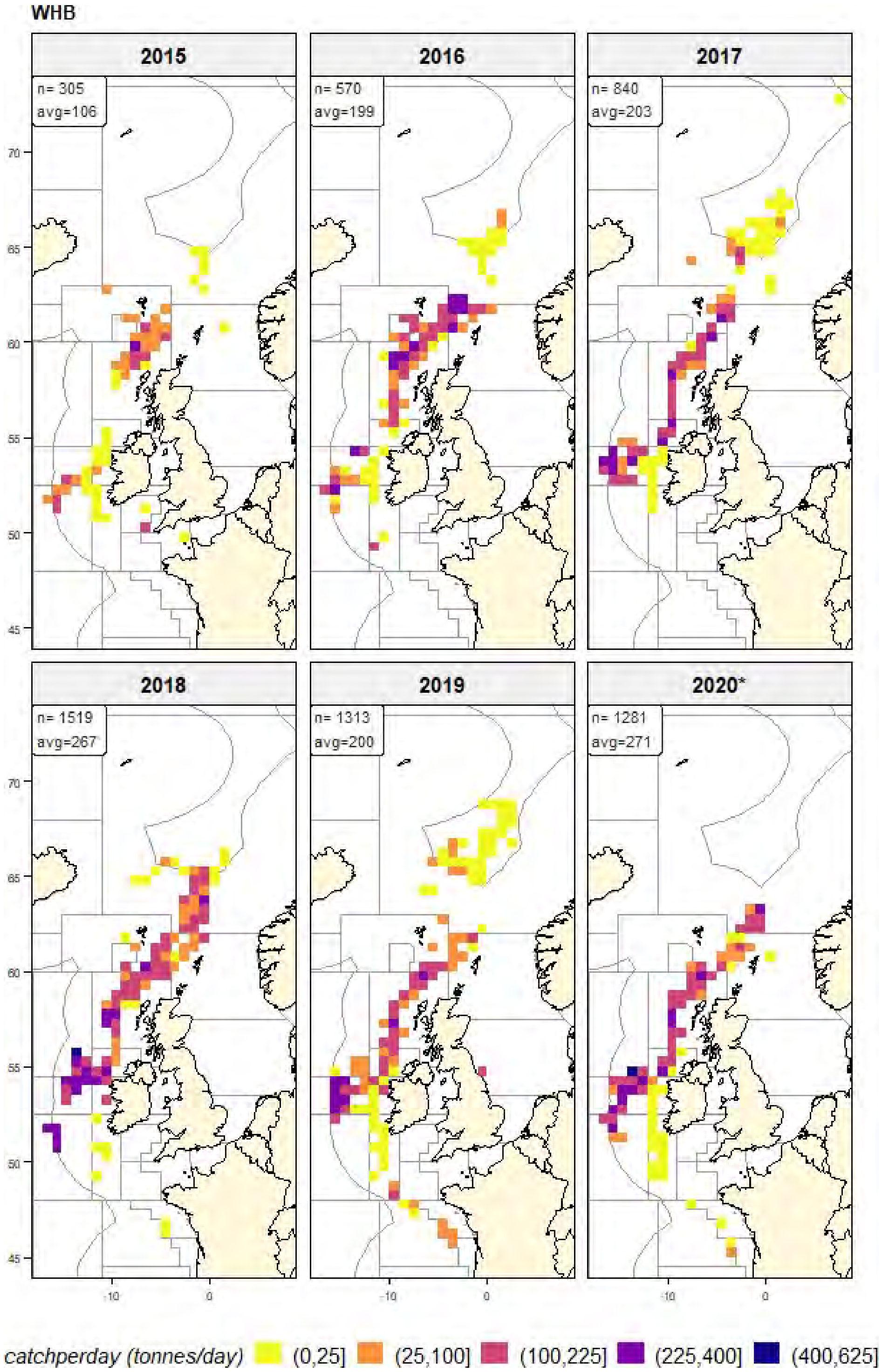


*Figure 3.4.2: Blue whiting. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Blue whiting (WHB). Spatial-temporal evolution of the fishery

Spatial-temporal evolution of the fishery by year and month from the haul-by-haul catch information. Fishing season is from February until May. The midpoint of the distribution is indicated by the blue triangle. The catch has been used as weighting factor in the calculation of the midpoint.

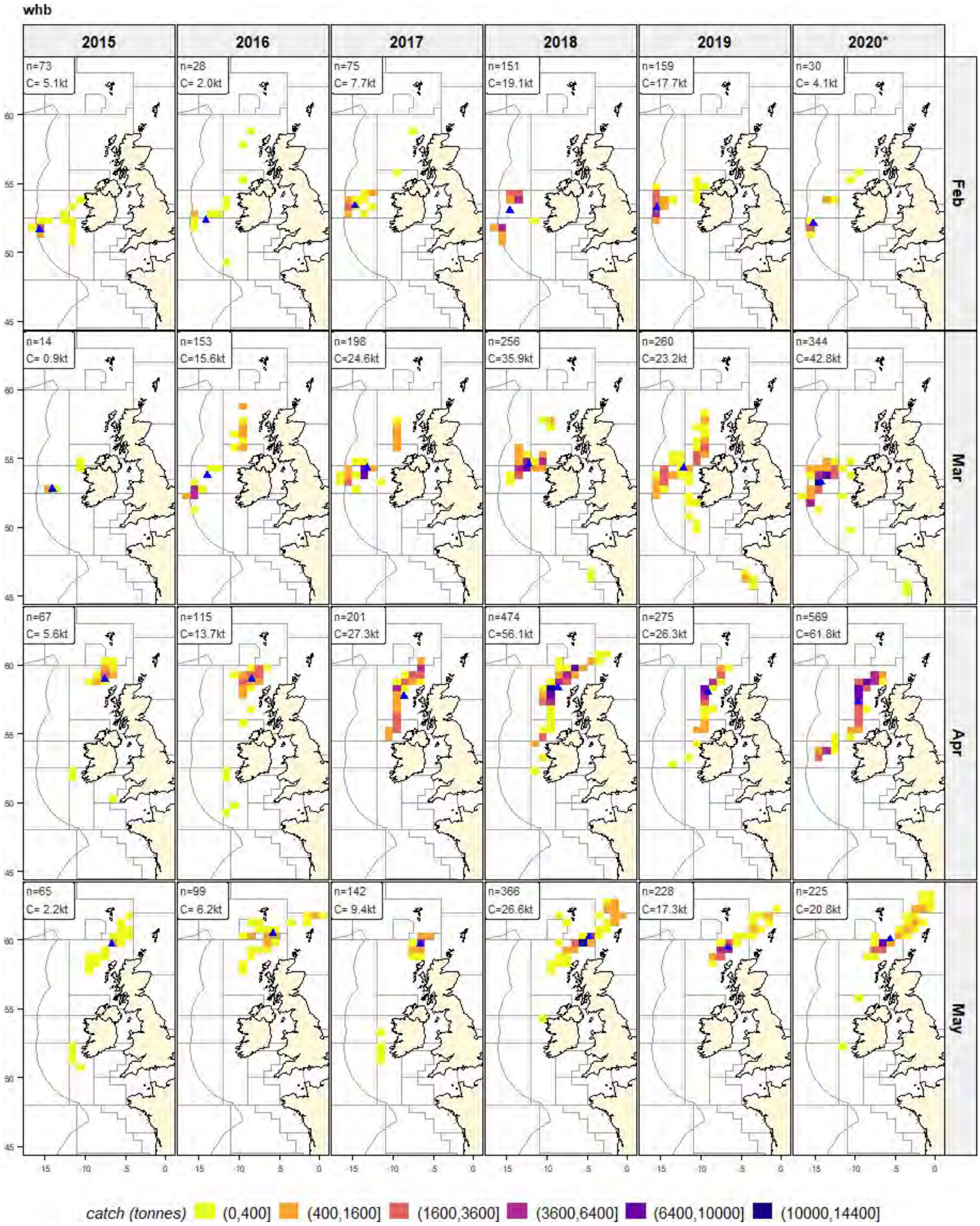


*Figure 3.4.3: Blue whiting. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Blue whiting (WHB). Length distributions of the catch

Blue whiting have a wide range in the length distributions in the catch. Median lengths have fluctuated between 23 cm (2016) and 30 cm (2015). During the period 2016 - 2020, the median length is consistently increasing (from 23 to 28 cm), indicating that the fishery is probably concentrating on a strong year class going without new year classes coming in.

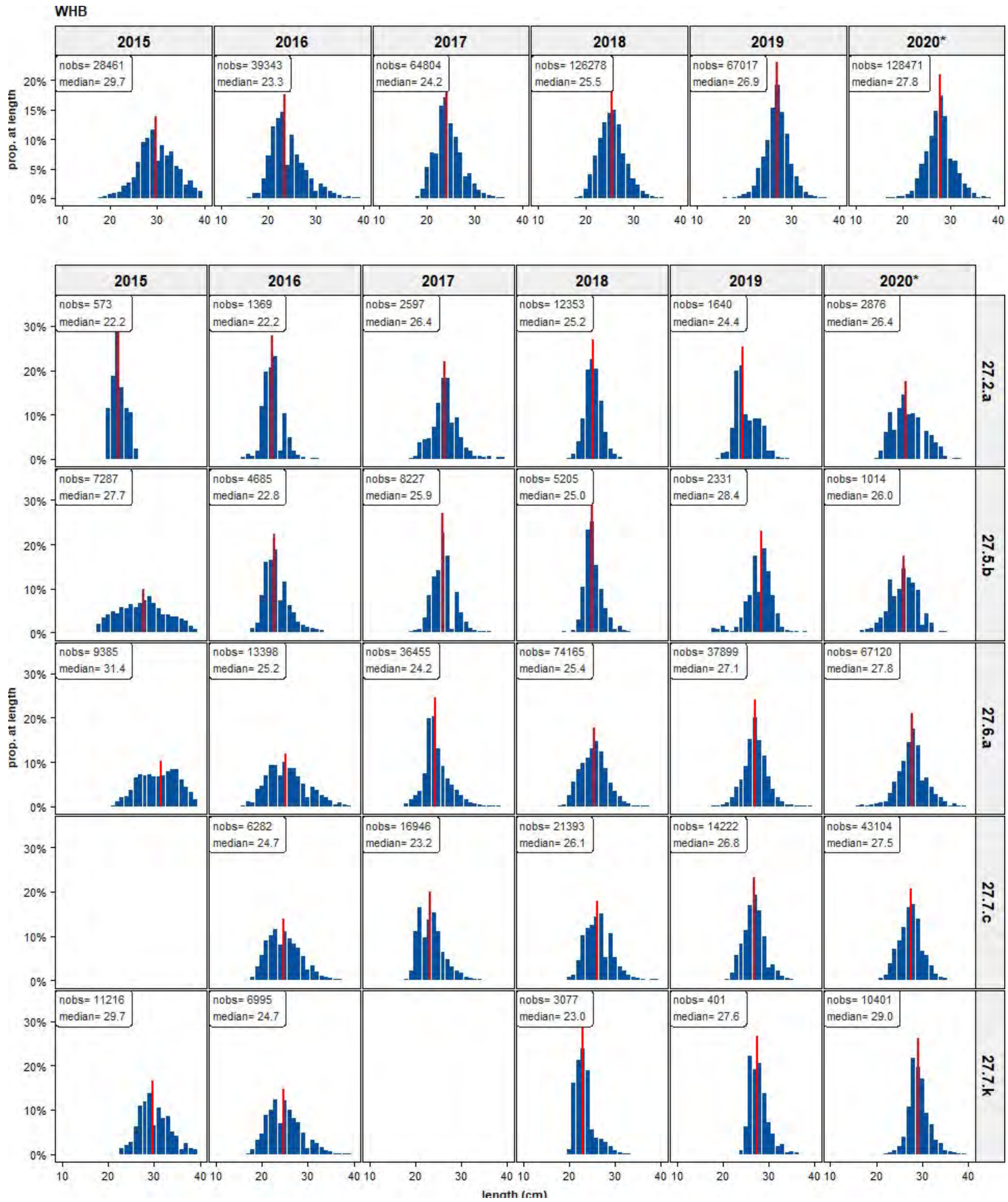


*Figure 3.4.4: Blue whiting. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Blue whiting (WHB). Length frequencies by year and quarter

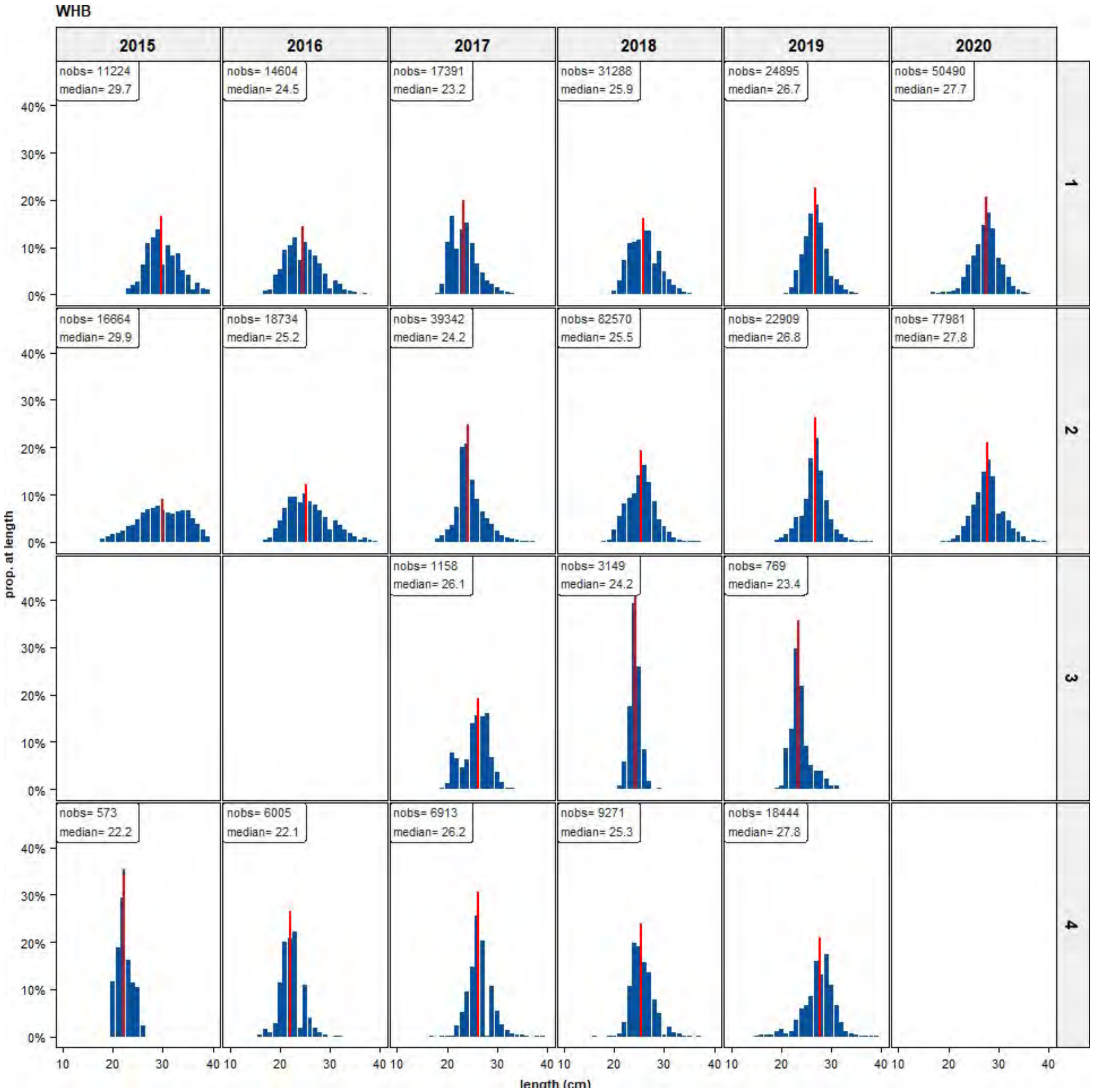


Figure 3.4.5: Blue whiting. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length

Blue whiting (WHB). Weight distributions

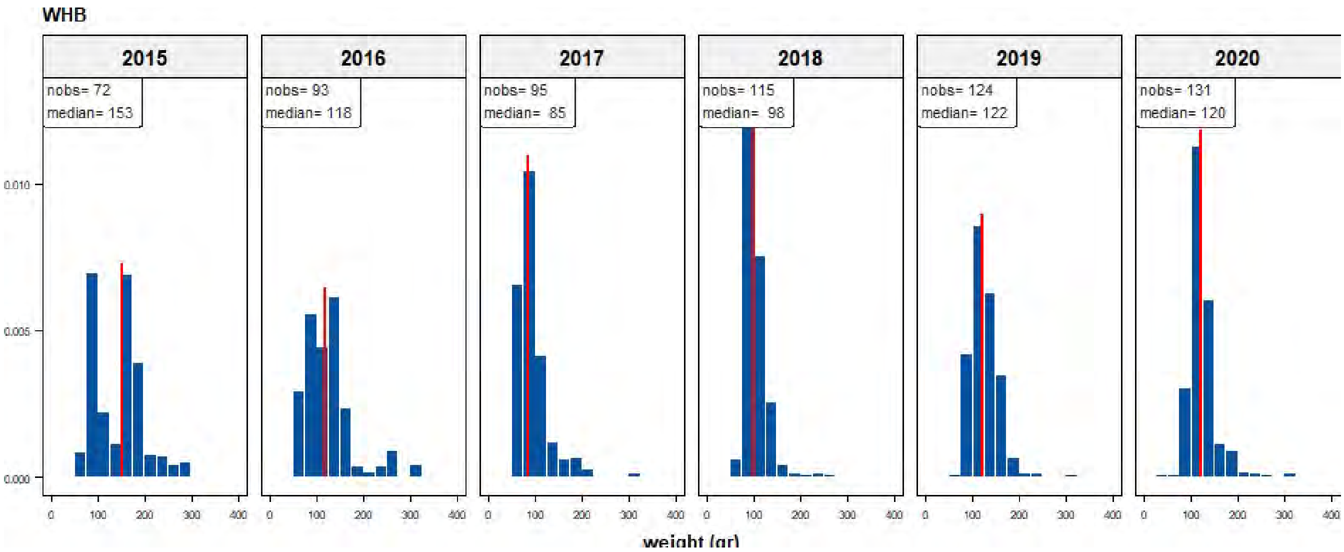


*Figure 3.4.6: Blue whiting. Weight distributions (25 gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Blue whiting (WHB). Fat percentages by year

Fat content for blue whiting is generally low (on average less than 1%)

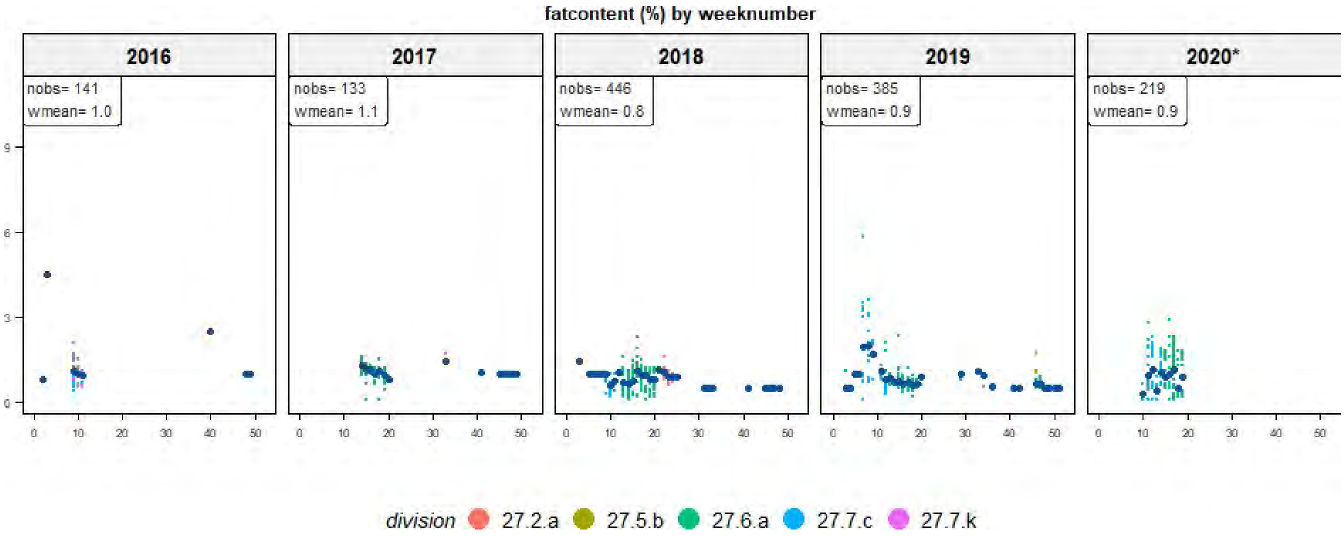


*Figure 3.4.7: Blue whiting. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; Wmean refers to the weighted mean fat content. Blue dots indicate the weekly averages; * denotes incomplete year*

Blue whiting (WHB). Fishing depth distributions.

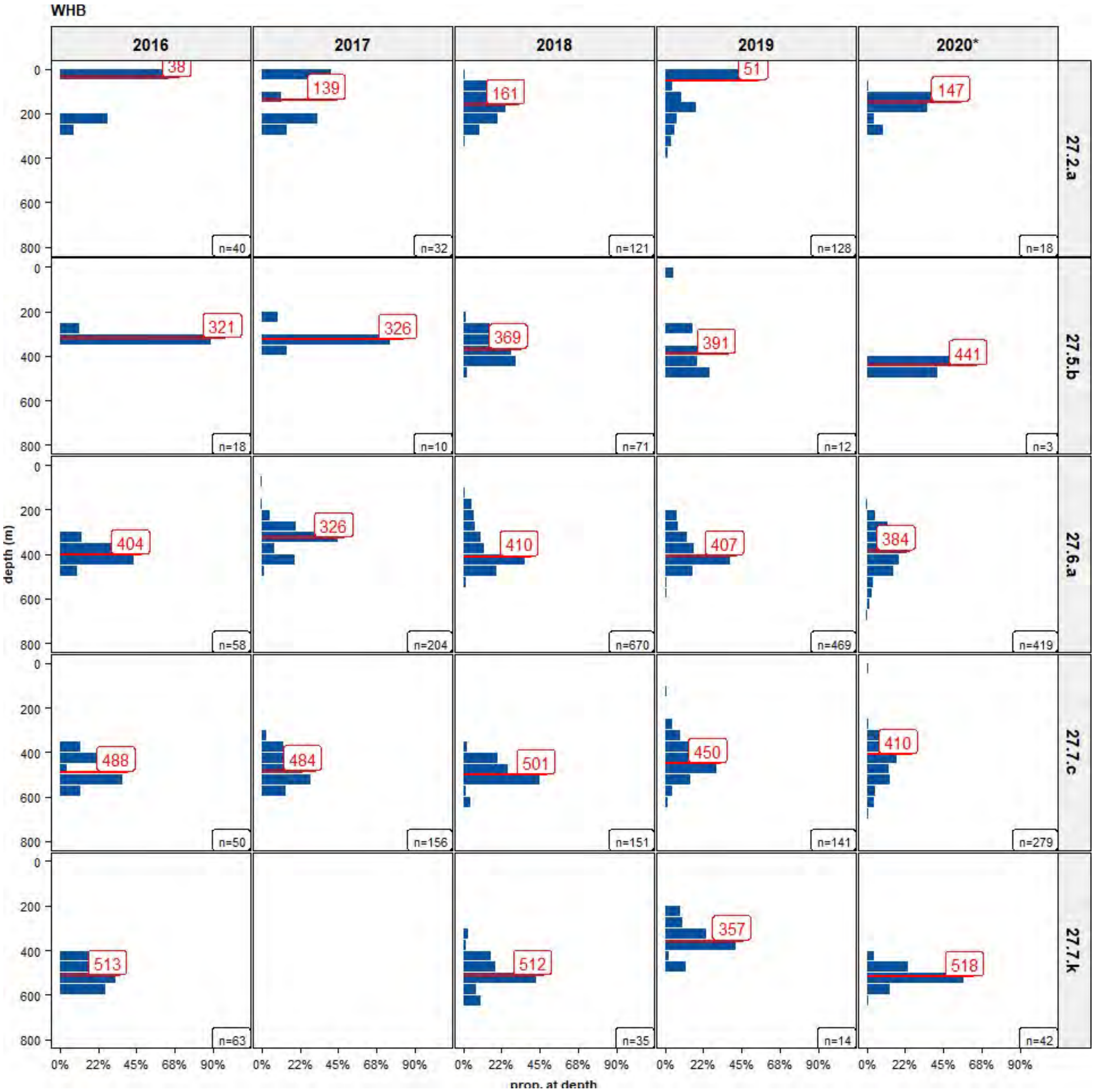


*Figure 3.4.8: Blue whiting. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

3.5 Herring 'Atlanto scandian' (HER_ASH, Clupea harengus)

The fishery for Atlanto-Scandian herring (ASH) is a relatively smaller fishery for PFA and takes place mostly in October. Overall, the self-sampling activities for the ASH fisheries during the years 2015 – 2020 (up to August) covered 27 fishing trips with 406 hauls, a total catch of 30,234 tonnes and 8,918 individual length measurements. Only the herring fishery in ICES division 27.2.a is considered for ASH. Note that there are herring catches in other divisions within the selected trips. These are trips where North Sea herring has been fished with some bycatches of mackerel for example.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	catch/day	nlength
her_ash	27.2.a	2015	2	2	9	18	1,369	100	152	1,260
her_ash	27.2.a	2016	6	7	40	85	3,362	100	84	1,206
her_ash	27.2.a	2017	4	7	42	83	7,950	100	189	2,210
her_ash	27.2.a	2018	4	5	37	68	5,278	100	143	490
her_ash	27.2.a	2019	4	5	57	145	12,249	100	215	3,714
her_ash	27.2.a	2020*	1	1	5	7	26	100	5	38
her_ash	(all)	2015		2	9	18	1,369	100	152	1,260
her_ash	(all)	2016		7	40	85	3,362	100	84	1,206
her_ash	(all)	2017		7	42	83	7,950	100	189	2,210
her_ash	(all)	2018		5	37	68	5,278	100	143	490
her_ash	(all)	2019		5	57	145	12,249	100	215	3,714
her_ash	(all)	2020*		1	5	7	26	100	5	38
her_ash	(all)	(all)		27	190	406	30,234		159	8,918

*Table 3.5.1: Herring 'Atlanto scandian'. Self-sampling summary with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). Top: by year. * denotes incomplete year*

Herring 'Atlanto scandian' (HER_ASH). Catch by month

species	month	2015	2016	2017	2018	2019	2020*	all	perc
her_ash	May	0	0	0	0	0	26	26	0.09%
her_ash	Aug	0	0	118	51	0	0	169	0.56%
her_ash	Sep	0	53	6	405	361	0	825	2.73%
her_ash	Oct	1,369	3,308	7,825	4,820	8,066	0	25,388	83.99%
her_ash	Nov	0	0	0	0	3,821	0	3,821	12.64%
her_ash	(all)	1,369	3,361	7,949	5,276	12,248	26	30,229	100.00%

*Table 3.5.2: Herring 'Atlanto scandian'. Self-sampling summary with the catch (tonnes) by year and month. * denotes incomplete year*

Herring 'Atlanto scandian' (HER_ASH). Catch by rectangle

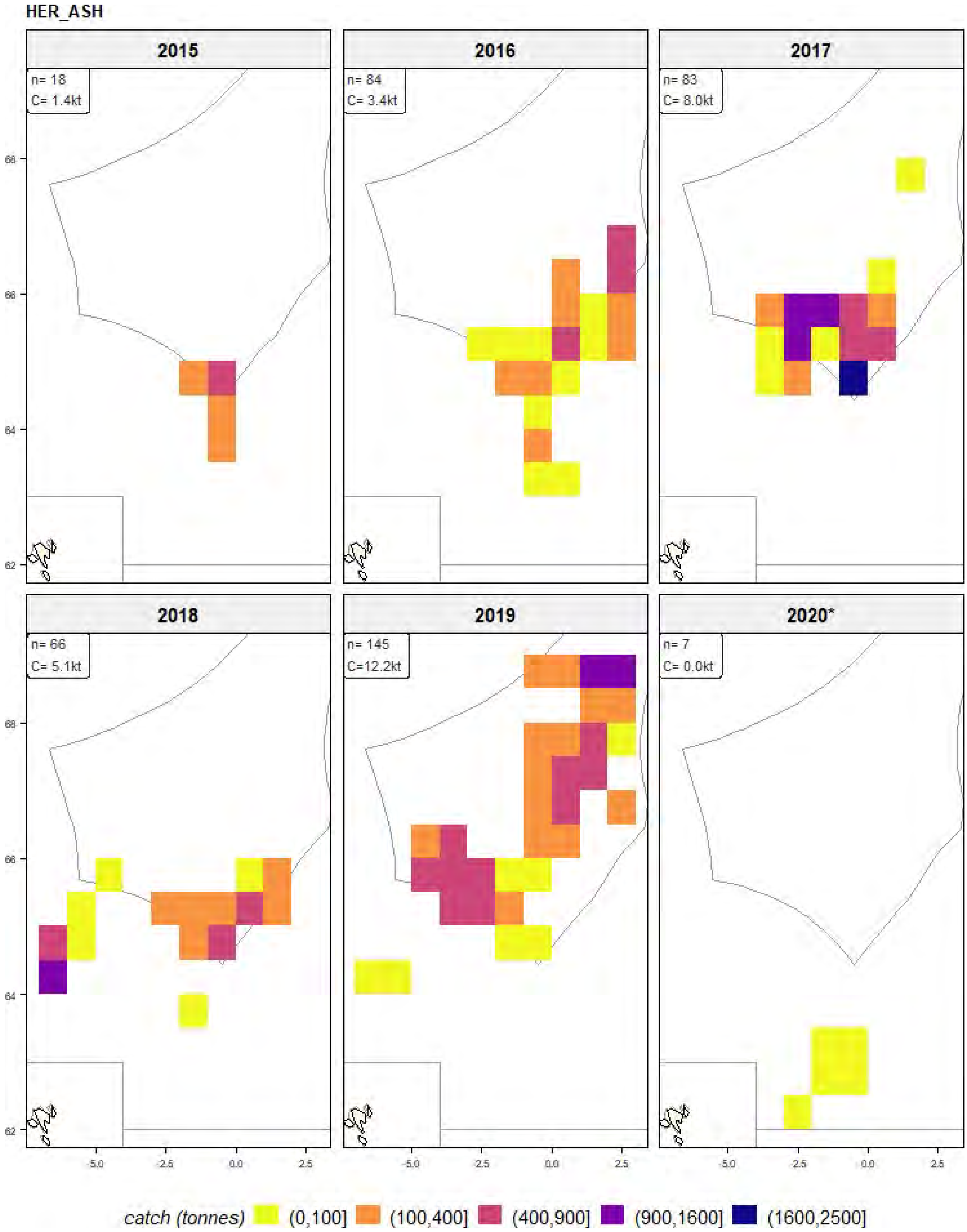


*Figure 3.5.1: Herring 'Atlanto scandian'. Catch per per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Herring ‘Atlanto scandian’ (HER_ASH). Average catch per day

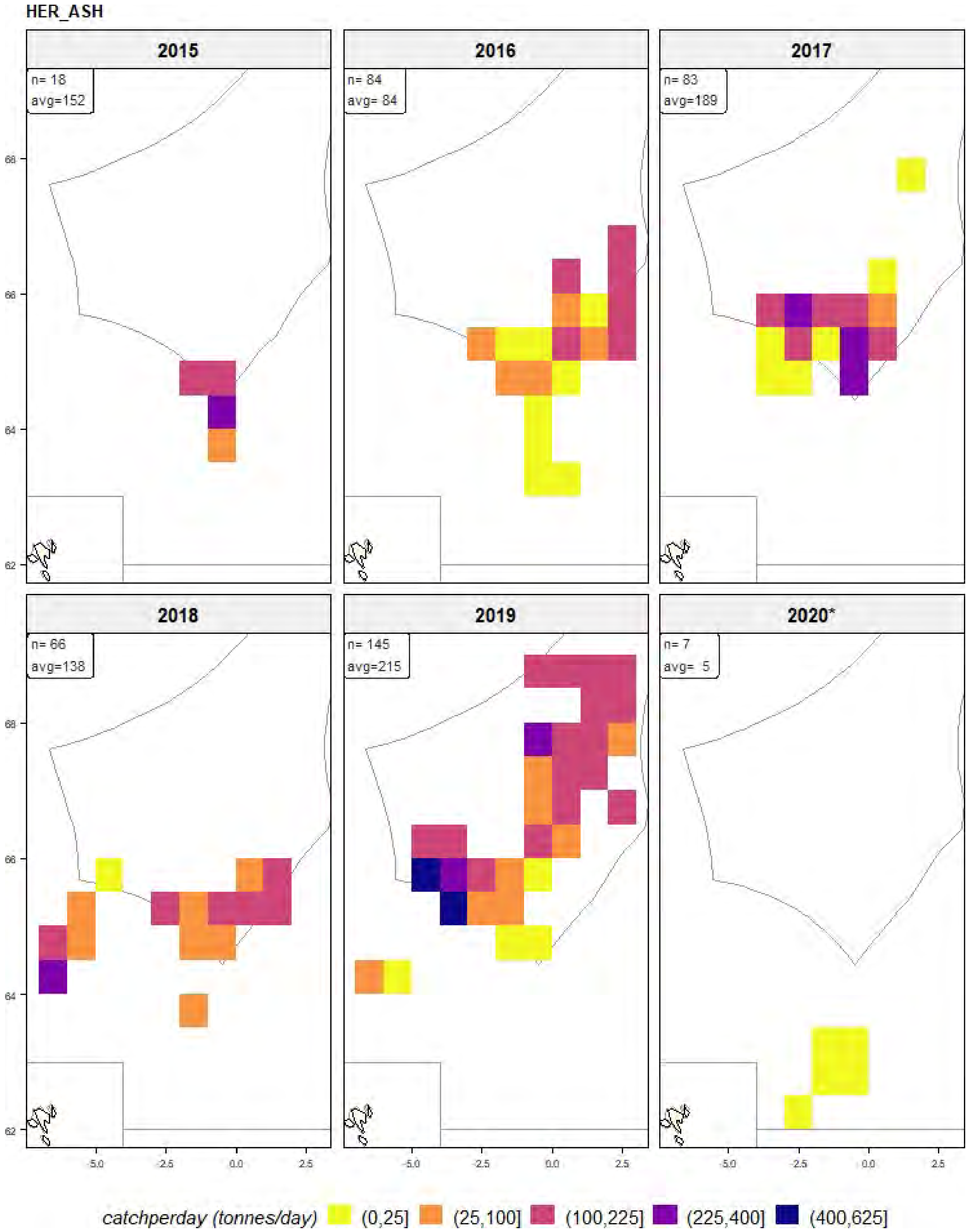


*Figure 3.5.2: Herring ‘Atlanto scandian’. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Herring ‘Atlanto scandian’ (HER_ASH). Spatial-temporal evolution of the fishery

Spatial-temporal evolution of the fishery by year and month from the haul-by-haul catch information. Fishing season is from September until November. The midpoint of the distribution is indicated by the blue triangle. The catch has been used as weighting factor in the calculation of the midpoint.

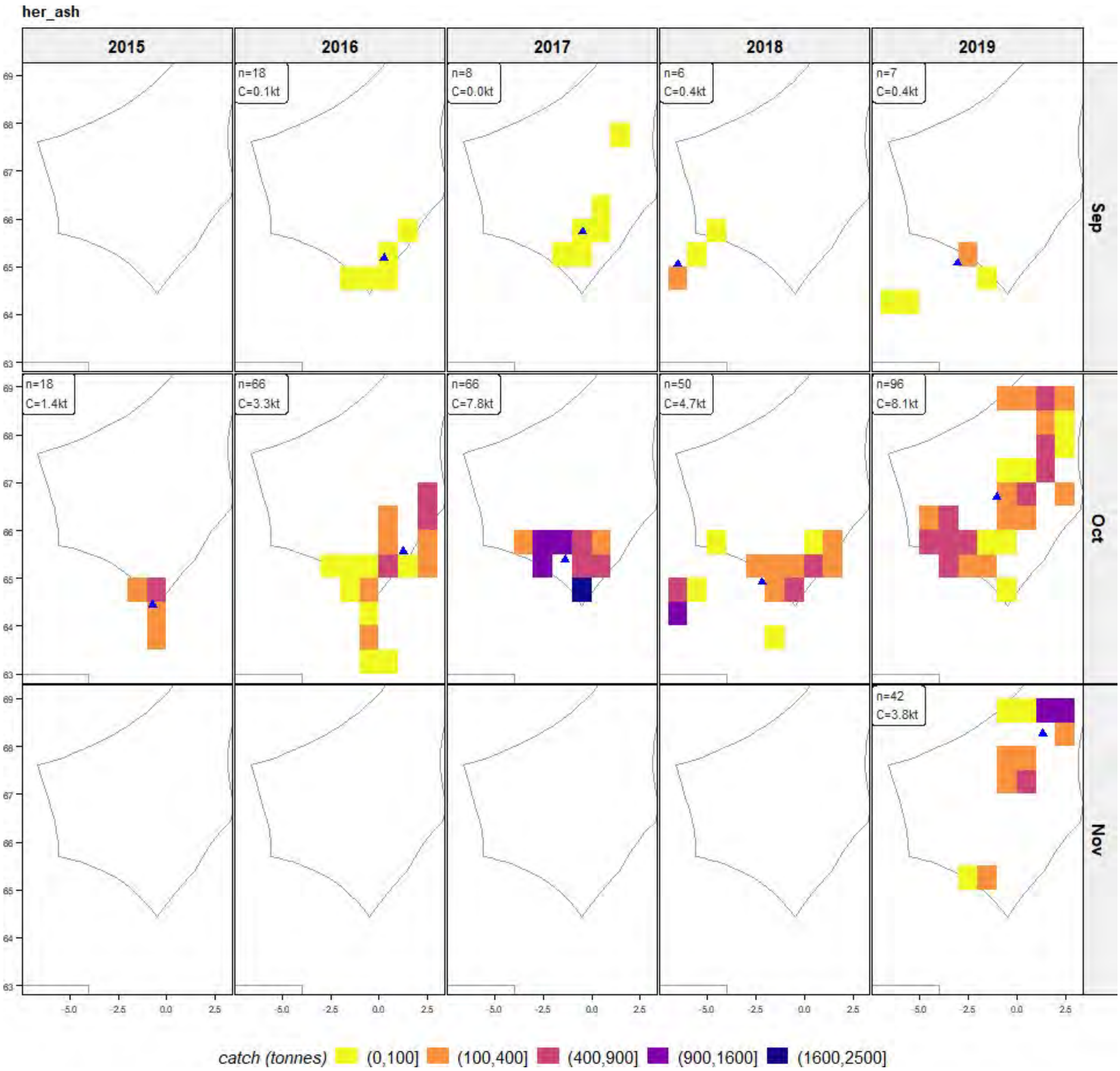


*Figure 3.5.3: Herring ‘Atlanto scandian’. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Herring ‘Atlanto scandian’ (HER_ASH). Length distributions of the catch

Atlanto-Scandian herring have a narrow range in the length distributions in the catch. Median lengths have fluctuated between 32 and 36 cm. No data is available yet from the autumn 2020 fishery.

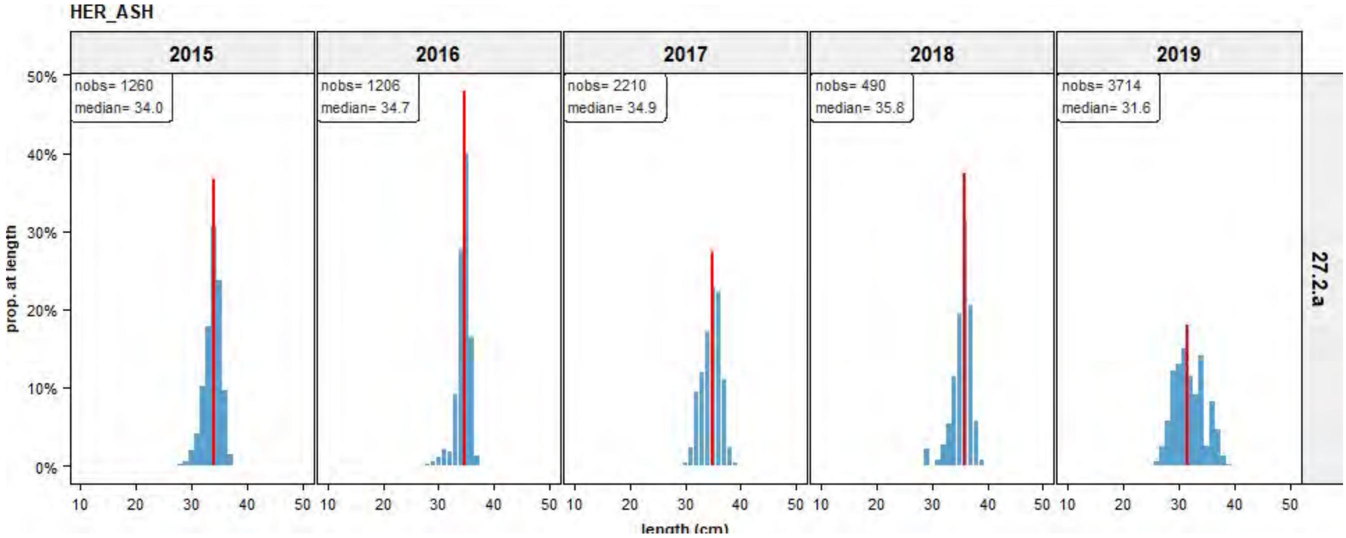


*Figure 3.5.4: Herring ‘Atlanto scandian’. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Herring ‘Atlanto scandian’ (HER_ASH). Length frequencies by year and quarter

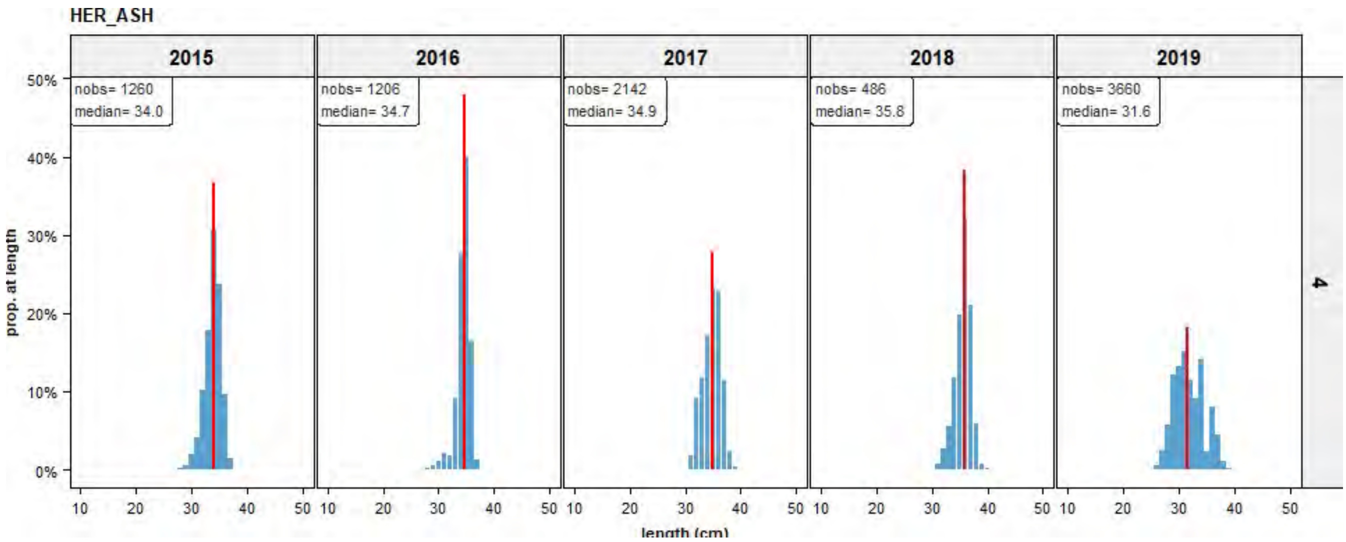


Figure 3.5.5: Herring ‘Atlanto scandian’. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length

Herring ‘Atlanto scandian’ (HER_ASH). Weight distributions

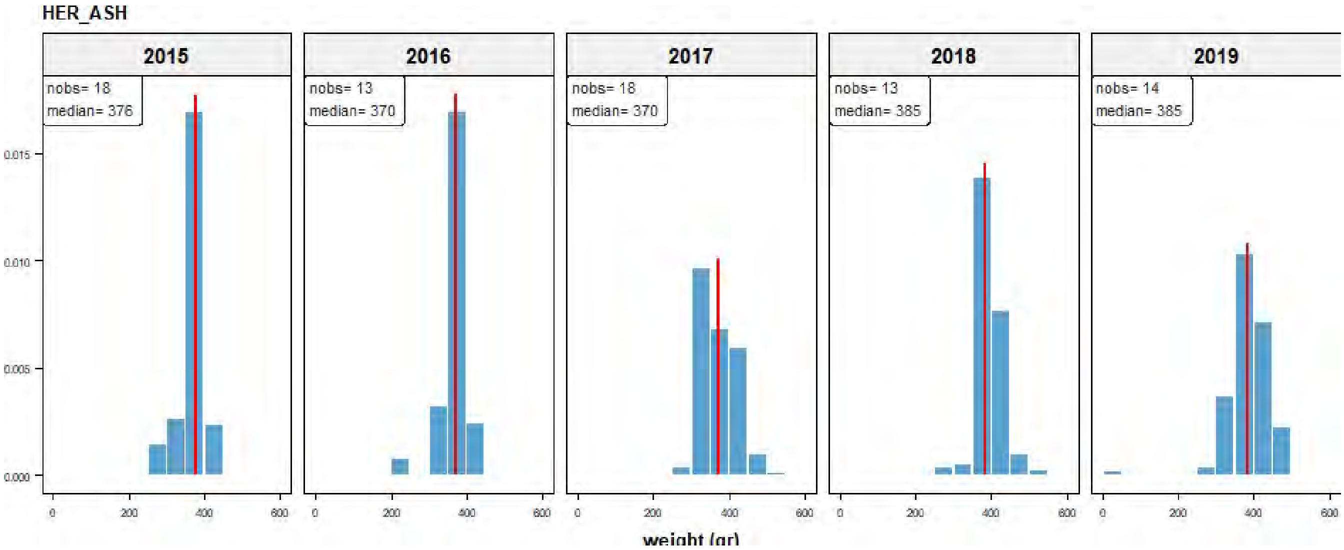


*Figure 3.5.6: Herring ‘Atlanto scandian’. Weight distributions (50 gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Herring ‘Atlanto scandian’ (HER_ASH). Fat percentages by year

Average annual fat content for ASH has been between 17 and 20% with individual measurements going up to 25%)

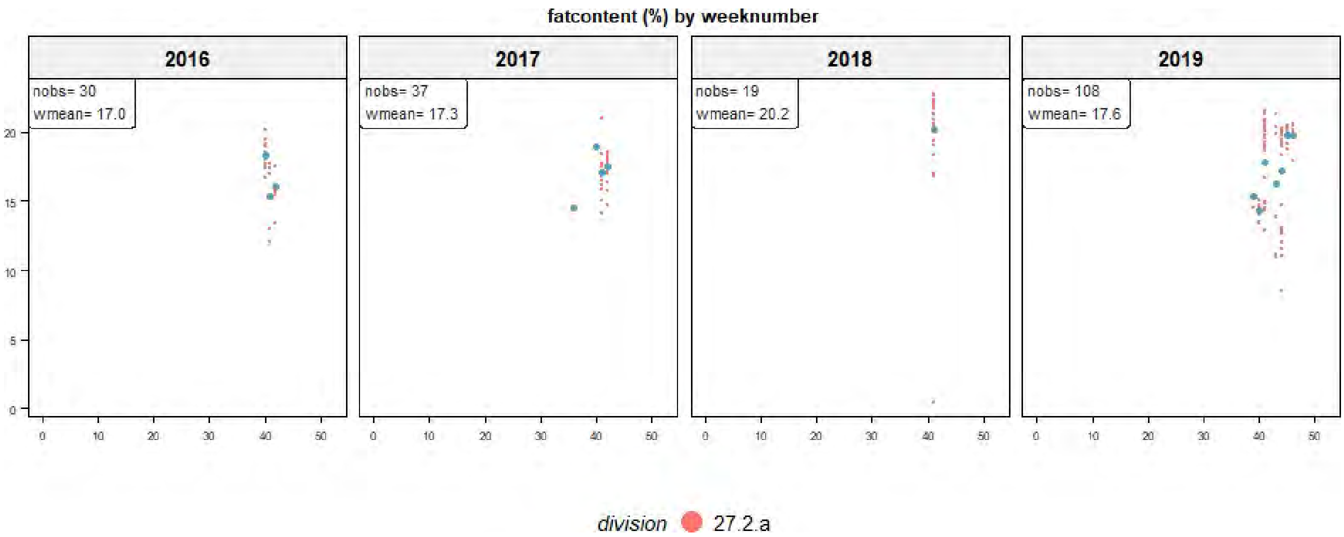


*Figure 3.5.7: Herring ‘Atlanto scandian’. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; blue dots indicate the weekly averages; * denotes incomplete year*

Herring 'Atlanto scandian' (HER_ASH). Fishing depth distributions.

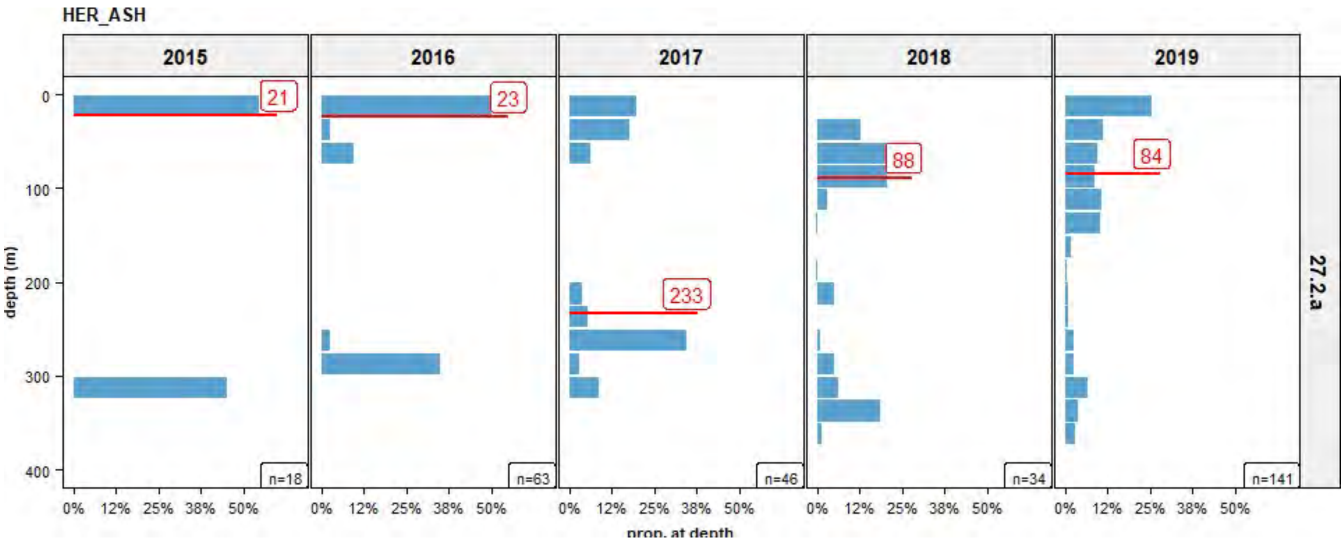


*Figure 3.5.8: Herring 'Atlanto scandian'. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

4 Discussion and conclusions

The PFA self-sampling programme has been carried out for the sixth year in a row (2015-2020). The results are presented in terms of meta-information on the sampling (number of vessels, trips, days and length measurements per area and/or season), in terms of the spatio-temporal distribution of catches and the length and weight compositions by area and/or season.

The definition of what constitutes ‘a fishery’ for a certain species is still not well specified. In this report we selected all combination of vessel-trip-week where hauls were taken in a certain area and where the catch composition consisted of a minimum percentage of certain species and a minimum catch of 10 tons. Although for herring we aimed to select only trips for Atlanto-scandian herring (in division 27.2.a) some trips with North Sea herring have been included because they were combined with some fishing for mackerel.

The Mackerel fishery takes place from October through to March of the subsequent year. Minor bycatches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2015 – 2020 (up to August) covered 323 fishing trips with 4,725 hauls, a total catch of 286,957 tonnes and 91,000 individual length measurements. The main fishing areas are ICES division 27.4.a (between 27 and 54% of the catch) and division 27.6.a (between 25 and 44% of the catch). Compared to the previous years, mackerel in the catch have been relatively large in 2020 with median length of 36.4 cm compared to 32.4-35.4 in the preceding years. Also, the median weight has been somewhat higher with median weight of 417 gram compared to 379-400 gram the preceding years. Average annual fat content ranges from 17 to 21% with individual measurements reaching up to 30%.

The horse mackerel fishery takes place from October through to March of the subsequent year. Overall, the self-sampling activities for the horse mackerel fisheries during the years 2015 – 2020 (up to August) covered 457 fishing trips with 3,454 hauls, a total catch of 140,633 tonnes and 125,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 21% and 40% of the catch), division 27.7.b (7%-22%) and division 27.7.d (19%-34%, note that this is considered as the North Sea horse mackerel stock). Horse mackerel have a wide range in the length distributions in the catch. Median lengths have fluctuated between 22.8 and 30.0 cm. In 2019 and 2020 there are some indications of a stronger year class being available to the fishery, with a more narrow length distribution. For example, in 27.6.a the mode was 26.6 cm in 2019 and 27.5 cm in 2020. Average annual fat content ranges from 5 to 7.5% with individual measurements reaching up to 15%.

The blue whiting fishery takes place from February through to May although some minor fisheries for blue whiting may remain over the other months. Overall, the self-sampling activities for the blue whiting fisheries during the years 2015 – 2020 (up to August) covered 365 fishing trips with 5,836 hauls, a total catch of 561,888 tonnes and 128,000 individual length measurements. The main fishing areas are ICES division 27.6.a (between 41% and 65% of the catch), division 27.7.c (6%-36%) and division 27.7.k (2%-32%). Blue whiting have a wide range in the length distributions in the catch. Median lengths have fluctuated between 23 cm (2016) and 30 cm (2015). During the period 2016 - 2020, the median length is consistently increasing (from 23 to 28 cm), indicating that the fishery is probably concentrating on a strong year class going without new year classes coming in. Fat content for blue whiting is generally low (on average less than 1%).

The fishery for Atlanto-Scandian herring (ASH) is a relatively smaller fishery for PFA and takes place mostly in October. Overall, the self-sampling activities for the ASH fisheries during the years 2015 – 2020 (up to August) covered 27 fishing trips with 406 hauls, a total catch of 30,234 tonnes and 8,918 individual length measurements. Only the herring fishery in ICES division 27.2.a is considered for ASH. Note that there are herring catches in other divisions within the selected trips. These are trips where North Sea herring has been fished with some bycatches of mackerel for example. Atlanto-Scandian herring have a narrow range in the length distributions in the catch. Median lengths have fluctuated between 32 and 36 cm. Average annual fat content for ASH has been between 17 and 20% with individual measurements going up to 25%).

5 Acknowledgements

The skippers, officers and the quality managers of many of the PFA vessels have put in a lot of effort to make the PFA the self-sampling work. Without their efforts, there would be no self-sampling.

6 More information

Please contact Martin Pastoors (mpastoors@pelagicfish.eu) if you would have any questions on the PFA self-sampling programme or the specific results presented here. Detailed length compositions (e.g. CSV files) can also be made available on request.

WESTERN HORSE MACKEREL TECHNICAL FOCUS GROUP ON HARVEST CONTROL RULE EVALUATIONS 2020

M.A. Pastoors, A. Campbell, V. Trijoulet, D. Skagen, M. Gras, G.I. Lambert, C.R. Sparrevohn, S. Mackinson

14/8/2020

Contents

The Western horse mackerel technical Focus Group consisted of the following members:

Martin Pastoors, PFA (acting chair)

Andrew Campbell, MI, Ireland

Vanessa Trijoulet, DTU-AQUA, Denmark

Dankert Skagen, Fisheries Science Consultant, Norway

Michael Gras, MI, Ireland

Gwladys Lambert, CEFAS, England

Claus Sparrevohn, DPPO, Denmark

Steve Mackinson, SPFA, Scotland

The group met during the period June 2019 – August 2020 to collate information, carry out analyses and report findings that are embedded in the current report.

Executive summary

This report has brought together many different topics that are related to the western horse mackerel stock in an attempt to develop a potential rebuilding plan for the stock. Even though western horse mackerel was not classified by ICES as in need of rebuilding in their latest advice (ICES, 2019a), the general perception within the fishing industries has been that the stock has been in a poor state but that there have been some positive signals in recent recruitment. Using the new recruitments to improve the stock status requires a careful management approach. The PELAC has been a proponent of developing management plans for all stocks in their remit. In this case, the PELAC has termed the approach a rebuilding plan because of the current stock status of the stock.

Substantial progress has been made over the past few years on horse mackerel stock ID (Farrell et al., 2020). The full genome sequencing of horse mackerel from samples taken all the way from the Skagerrak to the Mediterranean and North Africa, has yielded a suitable panel of SNP markers that can be used to differentiate between the different horse mackerel stocks. The strongest differentiation between populations was between the northern and southern populations, with the boundary being in the middle of Portugal. The North Sea population is clearly distinct from the Western population and it should be possible to tell the difference from mixed samples with a high probability (>93%). This would also allow screening of catches in 7d and 7e on the contribution of western and North Sea populations. The separation between the northern and southern populations could mean that the current division between western and southern horse mackerel is not adequate, as the northern part of 9a is currently included in the southern population. A similar split in the middle of Portugal has also been observed for boarfish (Farrell et al., 2016) and could indicate a biogeographical feature.

Length compositions of the catches are an important element of the assessment approach for western horse mackerel, because Stock Synthesis uses length composition in combination with age-length key to estimate the age compositions within the model. Part of a rebuilding plan for western horse mackerel could be to evaluate differences in length compositions in the catches in certain areas and to take specific measures to protect incoming recruitment. Therefore, we planned to carry out an analysis of length compositions by area and season. However, we found that such data is not currently available for all years. Length data for western horse mackerel is currently not included in the ICES InterCatch database. Instead, length data has been processed on a year by year basis in non-standardized Excel spreadsheets. A time series of length compositions by area and season can therefore only be derived by manually working through the spreadsheets and extracting the required information. This was not feasible as part of the project to develop and evaluate a rebuilding plan for western horse mackerel. We recommend to WGWIDE that the full time series of catch at length by country is recreated from the Excel spreadsheets and input into InterCatch to allow for future interrogations of the data and an underpinning of the input data to the stock assessment.

In order to understand how a stock would respond to recovery measures, it is useful to consider the age composition in the spawning stock which illustrates how recruitment in the previous years contributed to the present spawning stock. To this end, an SSB per recruit analysis has been carried out. As one should expect for a relatively long-lived species with low mortality, the spawning stock is currently rather old. At F =0.075, the mean age is about 9 years, 80% is older than 5 years and 20% older than 12 years. So, an improved recruitment will take some time to materialize as increased SSB.

The current stock assessment method for western horse mackerel is Stock Synthesis 3, as agreed in the WKWIDE benchmark of 2017 (ICES, 2017b). Reference point were also set at WKWIDE 2017 but have subsequently been updated in the IBPWHM 2019 (ICES, 2019b). In addition, an exploratory SAM assessment has been carried out as part of IBPWHM 2019. This was done in order to get a second view on stock trends but also to be able to run the SAM HCR forecast as part of the development of a potential rebuilding plan. The exploratory SAM assessment (https://www.stockassessment.org/setStock.php?stock=WHOM2018) was initiated with the same input data as was used for the Stock Synthesis assessment of WGWIDE 2018 (ICES, 2018) with the exception of the length frequency data, which was not used. The PELACUS survey data was therefore only used as an index of biomass within SAM. The process of fine-tuning the assessment lead to the binding of the observation variances for certain variables and to the application of a fixed selectivity pattern (correlation coefficient ϱ=1 in the F random process (https://github.com/martinpastoors/wgwide/blob/master/R/HOM%20optimization_SAM.R). A comparison of Fbar and SSB between the SS3 assessments of WG2018 and 2019 with the SAM assessment (WG18SAM, WG19SAM), shows that the general trends are the same but that there are some deviations in certain periods (e.g. the SSB in the late 1980s is estimated substantially higher in SAM compared to SS3). The Stock Synthesis results are in general a bit smoother compared to SAM.

In order to be able to use the SAM assessment as an alternative assessment in the rebuilding plan evaluation, we needed to estimate reference point for this assessment. In doing so, we aimed to follow the same procedure as during IBPWHM 2019 (ICES, 2019b). However, one of the elements of the reference point estimation, triggered a more in-depth study: the role of assessment uncertainty parameter Fcv and Fphi. There has been little standardization in how Fcv and Fphi have been calculated in different benchmarks where reference points were estimated. Fcv is expected to capture the assessment error in the advisory year and Fphi is the autocorrelation in assessment error in the advisory year (ICES, 2014a). We documented the method for generating the input data for the calculations and explored the sensitivity of Fcv and Fphi to the assessment that was used (both for western horse mackerel and for Atlantic mackerel). We found that there can be a high dependence of Fphi on the assessment that is used to compare against the Fset (the fishing mortalities that are back-calculated from the observed catches and the annual forecasts). When the assessment that is used has values that are all higher or lower than the Fset values, then Fphi will be close to zero. To our knowledge, this behaviour of Fphi was unknown so far. We also found that the number of years that is used for calculating Fcv and Fphi may have an impact on the values. In the recommendations from WKMSYREF3 it is stated that 10 years (or more) should be taken. A further study should be undertaken to assessment the impacts of using different time periods for estimating Fcv and Fphi.

During the IBPWHM 2019, reference points were estimated for western horse mackerel based on the 2018 WGWIDE assessment and using default values for Fcv and Fphi (0.212 and 0.423) and using a segmented regression through Blim (segregBlim). In order to calculate reference points for the exploratory SAM assessment and to explore the sensitivity to the assessment year, reference points were calculated on the basis of the 2018 or 2019 assessments for SS and SAM. The reference points for the SAM assessment are based on the 2018 assessment. Bpa and Blim are lower than the values for the SS assessment, while the Fmsy is higher. The calculated reference points were not sensitive to the assessmentyear that was used for the calculation for both the SS and SAM assessments.

Note that the calculated value for FMSY_final for the 2018 SS WGWIDE option (0.079) differs slightly from the value in IBPWHM 2019 (0.074). While a full explanation for this difference could not be arrived at, it is expected that this could have to do with the random seed and the instability of some of the calculations.

RP	WG18	WG18SAM	WG19	WG19SAM
Blim	834480	611814	885341	612635
Flim	0.1107	0.1612	0.1049	0.1756
Fpa	0.07909	0.1152	0.07493	0.1254
MSYBtrigger	1168272	856540	1239478	857689
FMSY	0.09102	0.1262	0.08665	0.1353
FP05	0.08398	0.1255	0.07826	0.1402
FMSY_final	0.07909	0.1152	0.07493	0.1254

HCR evaluations

The HCR analyses represent two different assessment methods (SS3 and SAM) and two different HCR evaluation tools (EqSim and SAM HCR). Both HCR evaluation tools are of the type 'short-cut' with appropriate conditioning of the uncertainties in the assessment based on historical CV and autocorrelation in line with the recommendations from WKMSYREF3 and WKMSYREF4 . The evaluations followed the guidelines from WKGMSE2 (ICES, 2019c) and WKREBUILD (ICES, 2020).

Three different types of harvest control rules were evaluated:

- Constant F strategy: fixed Ftarget independent of biomass level
- ICES Advice Rule: breakpoint at Btrigger and straight decline in F to zero below Btrigger.
- Double Breakpoint rule: breakpoint at Btrigger and straight decline in F to 20% of Ftarget at Blim. Below Blim continued fishing at F = 0.2 * Ftarget.

For each of the HCRs, a number of different target fishing mortalities were explored (0.0, 0.05, 0.075, 0.1, 0.125, 0.15). No evaluation of different Btrigger values was carried out, so that all evaluations used MSY Btrigger as the trigger point. All HCRs where evaluated with three variants:

- Without any additional constraints
- With a minimum TAC of 50 kT
- With a maximum 20% inter-annual variation (IAV) in TAC, but only when the stock is above Btrigger)

Two simulation tools were used: the EqSim simulator and the SAM HCR forecast. The EqSim simulator is a further worked up version of the SimpSIM approach that was used for the blue whiting MSE in 2016 (ICES, 2016). The code was further developed by Andrew Campbell and Martin Pastoors to improve standardization, documentation and visualization of results. EqSim makes use of an Operating Model (OM) and a Management Procedure (MP). The SAM HCR forecast is a simple stochastic forecast with HCR to evaluate management for fish stocks that need rebuilding in the short-term. The stochastic forecasts start from what we believe is the current level of the stock, i.e. the assessment estimates currently used for tactical management advice, with consideration of the uncertainty in these estimates. Rebuilding is evaluated forward for a specified number of years and for different target fishing mortality values.

The EqSim with SS3 results indicate that the constant F strategy is the least cautious rule and the double breakpoint rule is the most cautious rule. Under the F strategy rule with a Ftarget of 0.075, rebuilding to Bpa is only just being achieved (probability just above 50%) by 2025, while in the double breakpoint rule this is expected to be achieved in 2024 with substantially higher probabilities of remaining above Bpa. The first year of rebuilding to Bpa in the double breakpoint rule with target fishing mortalities up to 0.1 is the same as the first year of rebuilding under the zero fishing scenarios.

Similar results have been obtained with the EqSim with SAM evaluations although the levels of SSB are slightly higher and risk to Blim is slightly lower. According to these evaluations, rebuilding to Bpa could be obtained by 2022 in all scenarios.

The SAM HCR with SAM evaluations have only been carried out for the ICES Advice Rule scenario, as this was intended more as a contrasting study rather than a full analysis of HCR evaluation. Again, we find similar patterns in simulated stock trends, but SSB is estimated higher in the SAM evaluation than in the EqSim evaluations and risk to Blim stays below the 0.05 threshold in SAM HCR for all target fishing mortalities that have been explored.

Given that the EqSim with SS3 evaluation is closest to the ICES advisory practice, this was used as the basis for the preferred rebuilding plan by the PELAC. The PELAC preferred options are:

- Target fishing mortality at Fmsy = 0.074 (approximated by 0.075 in the simulations)
- Blim at ICES Blim (834 480 t)
- Btrigger at ICES MSY Btrigger (1 168 272 t)
- Double breakpoint rule with 20% constraint on IAV above Btrigger
- Minimum F when stock is below Blim at 20% of Fmsy = 0.015

The selected rebuilding plan has a 50% probability of rebuilding to Blim by 2021 (similar to zero catch option) and a 50% probability of rebuilding to Bpa/MSY Btrigger by 2024 (similar to the zero-catch option). Furthermore, the probability of being below Blim remains well below 5% for the duration of the simulation.

In this scenario, the average catch in the years 2021-2025 is expected to be lower than recent catches. However, after rebuilding, catches should be able to be maintained around 100 000 tonnes.

1 Introduction

1.1 Challenge

The Western Horse mackerel Focus Group of the Pelagic Advisory Council (PELAC) has been set up in 2015 already to a develop a PELAC proposal for a rebuilding plan or management plan for Western Horse mackerel. After several iterations (see below), the Focus Group initiated a technical working group to develop an operational evaluation tools for management plan evaluation and to evaluate potential Harvest Control Rules, so that PELAC could come to a recommended procedure. Such a recommended procedure, including the evaluation that was carried out, would need to be submitted for review to ICES to establish whether the evaluation procedure is in line with scientific standards and that the results of the HCR are in conformity with the precautionary approach and the MSY approach.

1.2 What happened before

An overview is presented of the attempt to develop a management plan for Western horse mackerel in the ICES area. After an initial egg-survey based management rule had been agreed and evaluated in 2008 (ICES, 2008), the management plan was called into question in 2011 which lead to the statement by ICES in 2013 that the plan was no longer precautionary (ICES, 2013a). In the years 2014-2015, CEFAS and the Marine Institute were commissioned by the Pelagic Regional Advisory Committee to evaluate potential new management plans (Campbell et al., 2015). The SAD assessment that was used to assess the stock in those years, and that underpinned the MSEs for Western horse mackerel, was so uncertain, that the results were that in the case of no-fishing, the stock was expected to increase, but the uncertainty in the stock was also increasing, to the effect that the probability of being below B_{lim} was larger than 5% for the next 40 years to come. Apparently, the framing of those MSEs could not resolve to a meaningful and acceptable management plan.

A second iteration occurred after the stock had been benchmarked in 2017 and was using the Stock synthesis model for the assessment (ICES, 2017). Using the methods described by Cox et al. (Cox and Kronlund, 2008), a proof-of-concept full-feedback MSE[1] was commissioned with Landmark Fisheries Research, Canada (Cox et al., 2018). The evaluations were directed at different fishing strategies, including strategies where fishing would continue when the biomass would be below B_{lim}. The results of the analysis demonstrated a clear recovery potential of the stock under different fishing scenarios, mostly dependent on the recruitment assumptions and the target fishing mortality. However, the starting conditions of the simulated populations did not include uncertainty, and therefore the behaviour of the MSE may have been estimated too positively.

For a final iteration of the management plan evaluation, it was anticipated to use the guidelines from WKGMSE2 (ICES, 2019c) and WKREBUILD (ICES, 2020) to plan for the next step in the development of the management plan. This work is embedded in the current report.

[1] A full-feedback MSE means that the assessment (and forecast) are run within the Management Strategy Evaluation (MSE) framework for each year and for each iteration.

1.3 Approach

The approach during the Focus Group on Western Horse mackerel was to convene a number of physical meetings to identify the main issues and to plan regular updates. In June 2019, a technical subgroup was set up to further carry out the technical analyses that were required. This subgroup was closely affiliated with the ICES WKREBUILD workshop that was going to take place in February 2020.

The first technical subgroup meeting was held on 20-21 June 2019. After presenting the state of affairs during WKREBUILD 2020, a series of online meetings was held during May and June 2020 to finalize the evaluation tools and to carry out the studies and evaluations. Specific focus was paid to the following topics:

- Stock ID (through the genetic work coordinated by Edward Farrell, UCD)
- Analysis of length compositions of catches (Gwladys Lambert, Martin Pastoors)
- Analysis of SSB per recruit (Dankert Skagen)
- Stock assessment (with focus on exploratory SAM assessment; Vanessa Trijoulet and Martin Pastoors)
- Reference points and calculation of Fcv and Fphi (Martin Pastoors)
- Development of HCR evaluation tools
    - EqSim (Andrew Campbell, Martin Pastoors)
    - SAM HCR (Vanessa Trijoulet)
- Application of HCR tools to evaluate different potential rebuilding plan (Andrew Campbell, Vanessa Trijoulet, Martin Pastoors)
- Presentation of results to the PELAC western horse mackerel focus group (Martin Pastoors, Andrew Campbell)

2 Horse mackerel stock ID

Recently, a study has been completed on the population structure of the Atlantic horse mackerel (*Trachurus trachurus*) as revealed by whole-genome sequencing (Farrell et al., 2020). The executive summary of that report is repeated below:

"The Atlantic horse mackerel, Trachurus (Linnaeus, 1758) is a species of jack mackerel distributed in the East Atlantic, from Norway to west Africa and the Mediterranean Sea. It is a pelagic shoaling species found on the continental shelf and it is one of the most widely distributed species in shelf waters in the northeast Atlantic, where it is targeted in pelagic fisheries. In the northeast Atlantic region, the species is assessed and managed as three stocks: the Western, the North Sea and the Southern. Despite the commercial importance of the horse mackerel, the accuracy of alignment of these stock divisions with biological units is still uncertain.

The aims of this study were to identify informative genetic markers for the stock identification of horse mackerel and to estimate the extent of genetic differentiation among populations distributed across the distribution range of the species. For this we used modern sequencing techniques that allowed us to assess genetic variants in the entire genome. We discovered that while the populations differ in a small fraction of their DNA (< 1.5%), such genetic differences are significant as they likely represent natural selection and might be involved in local adaptation. We validated a small fraction of these highly differentiated genetic variants by a SNP assay and demonstrated that they can be used as informative molecular markers for the genetic identification of the main stock divisions of the Atlantic horse mackerel.

The results, based on the analysed samples, indicated that the North Sea horse mackerel are a separate and distinct population. The samples from the Western stock, west of Ireland and the *northern Spanish shelf, and the northern part of the Southern stock, northern Portugal, appear to form a genetically close group. There was significant genetic differentiation between the northern Portuguese samples and those collected in Southern Portuguese waters, with those in the south representing a separate population. The North African and Alboran Sea samples were distinct from each other and from all other samples.*

These results indicate that a further large-scale analysis of samples, with a greater temporal and spatial coverage, with the newly identified molecular markers is required to test and reassess the current stock delineations."

The main conclusions of the genetic work can be summarized as follows:

- A suitable panel of SNP markers can be identified to carry out routine population assignments of mixed samples.
- Main differentiation between populations is between northern and southern populations, with the boundary being in the middle of Portugal. Although more work needs to be done on this finding, this could imply that the current division between western and southern horse mackerel is not adequate, as the northern part of 9a is currently included in the southern population.
- The North Sea population is clearly distinct from the Western population and it should be possible to tell the difference from mixed samples with a high probability (>93%?). This allows screening of catches in 7d and 7e on the contribution of western and North Sea populations.

3 Length compositions of catches

A short study was initiated to analyse the length composition of catches by country, area, year and quarter. Length compositions could be informative on selectivity in different areas and fisheries and could therefore also be used to generate specific management measures as part of a rebuilding plan.

In the current SS assessment framework, length compositions are used as the key metric for catches in combination with age-length keys to generate age compositions dynamically. So, while it might be expected that the length information is readily available, this turned out to be not the case. The length data that is submitted by country, is not submitted in a standardized format and not included in the InterCatch database. Historical length data by country has been processed on an annual basis using ad hoc Excel spreadsheets and cannot be easily extracted. Therefore, no real progress has been made on this topic.

Recommendation:

- The Western Horse Mackerel Focus Group recommends to WGWIDE that the full time series of catch at length by country is recreated from the Excel spreadsheets and converted into InterCatch to allow for future interrogations of the data and an underpinning of the input data to the stock assessment.

4 Contribution of recruitment to SSB

Dankert W. Skagen, June 2020

For the understanding of how a stock responds to recovery measures, it is useful to consider the age composition in the spawning stock, to illustrate how recruitment in the previous years contribute to the present spawning stock. When we calculate SSB per recruit, we do this by calculating the sequence of numbers at age as they are reduced by mortality, starting with one recruit. Then we multiply numbers at each age with weight and maturity at that age to get biomass per recruit of the spawners at each age. The sum of these over all ages is the total SSB per recruit, which is normally what is presented, but the age profile of the SSB per recruit can also be interesting in itself. For example, when we consider a rebuilding strategy, it gives us an indication of how fast SSB can be expected to improve when recruitment improves. The age distribution in the spawning stock of course depends on the fishing mortality level, as does the total SSB per recruit.

The actual SSB at some age is the SSB per recruit at that age, multiplied with the number of recruits born in that cohort. Accordingly, the total SSB in any year is a weighted sum of previous recruitments. The products of cohort recruitment times SSB per recruit at age, summed over all ages. In an equilibrium where all weighting factors are constant, SSB is proportional to the mean recruitment, since it is the sum of SSB per recruit at age, raised by the recruitment.

This simple relation also gives us an easy direct means of calculating how the variation in recruitment carries over to variation in SSB. In probability theory, there is a very simple formula for variance of a weighted sum of independent components. Here the components are annual recruitment, with a presumably known variance, and the weightings are the SSB per recruit at age. Although this only covers the effect of one source of variation in SSB, the recruitment variation is a major source so a direct calculation of the variance, without elaborate bootstrap procedures, can be useful as a proxy in the early phase of management plan developments, and also for understanding the effect of variable recruitment.

Below is a set of age distributions in the SSB per recruit for Western horse mackerel (Figure 2). The data on weights, maturities, natural mortality and selection were those used as input to the short-term prediction by WGWIDE in 2019.

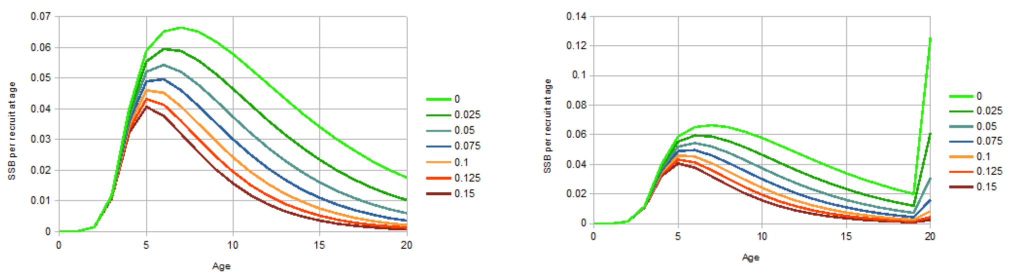


Figure 1 *SSB at age for a range of fishing mortalities (F1-10) With (right) and without (left) regarding age 20 as a plus group.*

Figure 3 shows SSB per recruit as function of F1-10, with the same input data, and in addition the 95 % confidence interval assuming a CV on recruitment of 0.6. which is slightly lower than the CV of the recruitments 1983 – 2018 according to the WGWIDE assessment in 2019, excluding the strong 2001 year class. In the same figure, the mean age in the SSB as function of the F1-10 is also shown.

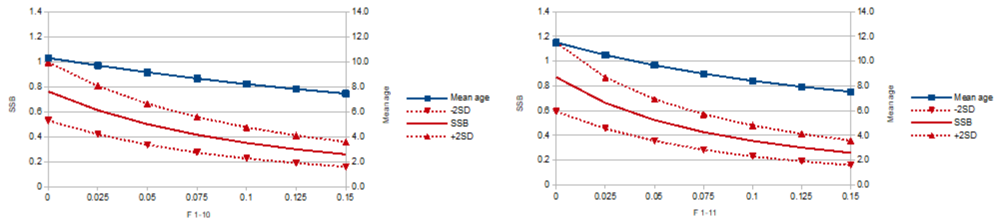


Figure 2 *Mean age (blue) and SSB (Mean ±2SD) for a range of fishing mortalities (1-10). Using only age up to 20 (left, without a plusgroup) and using all ages (right, with a plusgroup at 20). The SDs are the effect of recruitment variation, assuming a CV of 0.6*

As one should expect for a relatively long-lived species with low mortality, the spawning stock is rather old. At F =0.075, the mean age is about 9 years, 80% is older than 5 years and 20% older than 12 years. So, an improved recruitment will take some time to materialize as increased SSB. The results also indicate that with a low F, the plus group still does matter. Finally, the historical variation in recruitment translates into a confidence interval for long term equilibrium SSB that for F=0.075 ranges from approximately 700 to 1400 when the mean recruitment is 2500.

5 Stock assessment of Western horse mackerel

5.1 Stock synthesis assessment

WGWIDE 2019: The SS model with new length and age data from the commercial fleet, and the 2018 information from the 2 surveys available, is presented as the final assessment model. Stock numbers-at-age and fishing mortality-at-age are given in Tables 7.3.1.1 and 7.3.1.2, and a stock-summary is provided in Table 7.3.1.3 and illustrated in Figure 7.2.11.2. SSB peaked in 1988 following the very strong 1982 year class. Subsequently SSB slowly declined till 2003 and then recovered again following the moderate-to-strong year class of 2001 (a third of the size of the 1982 year class). Year classes following 2001 have been weak: 2010 2011, and 2013 recruitments in particular have been estimated as the lowest values in the time-series together with the 1983. The 2008 year class has been estimated to be fairly strong. Recruitment estimates for 2014-2018 are the highest observed since 2008 and are higher than the geometric mean estimated over the years 1983-2018. SSB in 2017 is estimated as the lowest in the time-series. Fishing mortality was increasing after 2007 as a result of increasing catches and decreasing biomass as the 2001 year class was reduced. Since 2012 F has then been decreasing, dropping to low values in 2015-2018 due to lower catches and a reduced proportion of the adult population in the exploited stock.

5.2 SAM assessment

IBPWHM 2019: Since the benchmark in 2017 (ICES, 2017b), the Western horse mackerel assessment has been carried out using the Stock Synthesis method. This method allows for the incorporation of length frequency information and the dynamic estimation of growth. The Stock Synthesis assessment of western horse mackerel utilizes the length distributions of the commercial catch and from the samples obtained during the PELACUS survey, while the other information is provided as biomass (total catch, egg survey) or age specific data (recruitment index). The SS assessments that have been carried out since the benchmark in 2017 have generally shown narrow confidence intervals, yet the annual revisions in estimated stock size and fishing mortality between subsequent assessments has been substantial. These retrospective revisions are not well understood. In addition, there has been some concern about the complex nature of the input data to the Stock Synthesis method and the ability to adequately quality control the input data and model performance.

As part of the Interbenchmark of Western horse mackerel, it was agreed to explore the possibility of an alternative assessment approach to Stock Synthesis. The intention was to test methods that are more familiar to members of the WGWIDE assessment group. It was decided to use the SAM model as the alternative approach because it is already being used for mackerel and blue whiting and because it will allow for an evaluation of harvest control rules in a similar manner as is currently being applied for Western Baltic Spring Spawning herring.

The exploratory SAM assessment (https://www.stockassessment.org/setStock.php?stock=WHOM2018) was initiated with the same input data as was used for the Stock Synthesis assessment of WGWIDE 2018 (ICES, 2018) with the exception of the length frequency data, which was not used. The PELACUS survey data was therefore only used as an index of biomass within SAM. When using the default SAM configuration, the assessment output displayed a strong retrospective pattern and very large uncertainty in both F and SSB. A process of fine-tuning the assessment lead to the binding of the observation variances for certain variables and the application of a fixed selectivity pattern (correlation coefficient ϱ=1 in the F random process, that was originally allowed to change by year (https://github.com/martinpastoors/wgwide/blob/master/R/HOM%20optimization_SAM.R). The only aged-structured observation available for this stock is for the commercial catch. As a result, the model has a tendency to over-fit these observations, notably for the older ages. This induced important variations in fishing selectivity over time that seemed inconsistent and led to very large retrospective patterns in both SSB and F. Fixing the fishing selectivity over time resulted in a significant improvement in these retrospective patterns for only a slightly larger AIC (1217.453 vs. 1212.974 with variable relative fishing mortality). The final exploratory assessment from this exercise was selected on the basis of the trade-off between a low AIC and reduced retrospective pattern.

A comparison of Fbar and SSB between the SS3 assessments of WG2018 and 2019 with the SAM assessment (WG18SAM, WG19SAM).

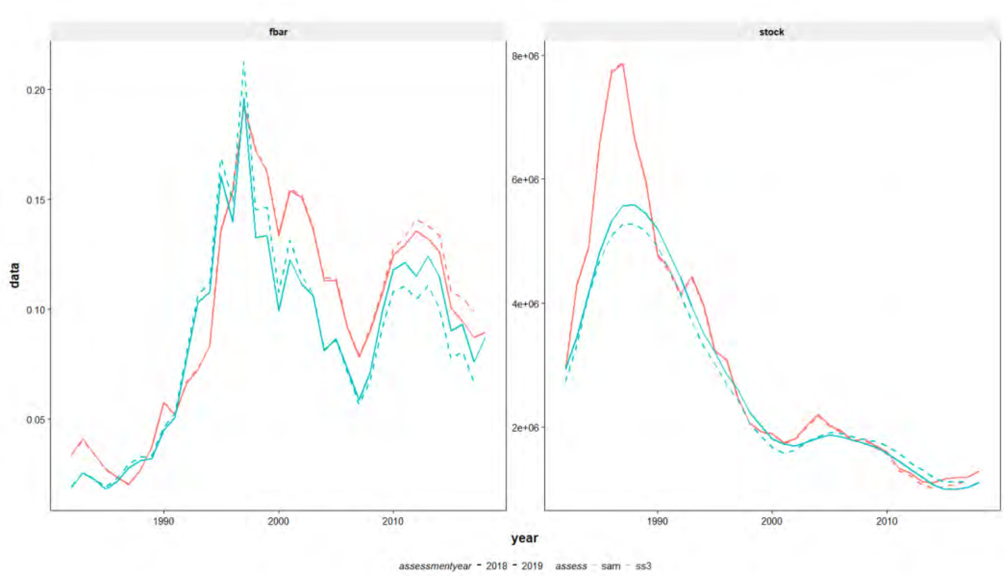


Figure 3 Time trends for Fbar and SSB for the SS3 (red) and SAM (blue) assessments for WG2018 and 2019.

6 Fcv and Fphi uncertainty parameters

The standard approach in ICES for estimating biological reference points is based on the EqSim software conditioned on the most recent assessment. Uncertainties in the assessment are included through two parameters: Fcv and Fphi, where Fcv is expected to capture the assessment error in the advisory year and Fphi is the autocorrelation in assessment error in the advisory year (ICES, 2014a). Methods for deriving Fcv and Fphi are loosely described in the WKMSYREF3 report (ICES, 2014a, p. 11):

"The estimated realised catch and F (Fyr) for the previous 10 years (or more) are taken from the most recent assessment. The annual ICES advice sheets issued in y-1 are consulted to estimate the F_{ya} that would have been advised to obtain the estimated catch. Where the appropriate catch is not available in the catch option table linear interpolation is used to estimate the F_{ya}. The deviation in year y d_y is calculated as $log_e(F_{yr}/F_{ya})$, the standard deviation σ_m of the log deviations gives the marginal distribution. The conditional standard deviation σ_c is calculated as $\sigma_m \sqrt{(1-\varphi^2)}$, where φ is the autocorrelation of the AR(1) process. Then σ_c [and] φ are input parameters for Eqsim."

The role of Fcv and Fphi in the process of estimating reference points is that they are used to calculate Fp05 which is used as the precautionary buffer on Fmsy, because Fp05 is the value whereby a (less than) 5% annual probability exists that SSB will be below Blim in the long term If the directly estimated Fmsy is larger than Fp05, then Fmsy needs to be reduced to Fp05.

When applying this approach to the western horse mackerel data, we found that there were important sensitivities in calculating the parameters Fcv and Fphi. This initial finding let us to carry out a broader review of the behaviour of Fcv and Fphi for a number of widely distributed pelagic stocks where reference points were recently estimated (western horse mackerel and Atlantic mackerel). The results will be summarized in a working document to ACOM in September 2020. While there has in general been ample attention during benchmark workshops to the estimation of reference point – albeit they are often carried out AFTER the benchmark instead of DURING the benchmark – we found that the documentation of the selection of data and the method to calculate the Fcv and Fphi has been mostly lacking. In most cases it is not clear how many years have been used, nor how the values for the interpolated fishing mortalities have been generated.

Western horse mackerel

Fset and SSBset were calculated from the historical assessment data. Realized catch by year was taken from the most recent advice document. Catch1fcy and Catch2fcy are the two catch options that bracket the actual realized catch in the forecast year and F1fcy and F2fcy are the associated fishing mortalities. Fset is the interpolated fishing mortality that matches the realized catch in a particular forecast.

In the case of horse mackerel, this procedure could not be followed for estimating the SSBset, because only one value of SSB in the forecast year is presented in the forecast tables.

tacyear	catchrealized	catch1fcy	catch2fcy	f1fcy	f2fcy	ssb1fcy	ssb2fcy	fset	ssbset
2011	193268	186433	201312	0.1048	0.1135	-	-	0.108797	1911900
2012	166579	155125	174007	0.0944	0.1064	-	-	0.101679	1879742
2013	165258	155633	170000	0.1638	0.18	-	-	0.174653	1568380
2014	136360	129640	144621	0.1541	0.1734	-	-	0.162757	749334
2015	98419	85820	99304	0.1053	0.1229	-	-	0.121745	601099
2016	98811	98544	99710	0.0997	0.1009	-	-	0.099975	718285
2017	82961	82526	84289	0.1105	0.113	-	-	0.111117	511789
2018	101682	99129	108515	0.081	0.089	-	-	0.083176	818082

The calculation of cv and phi for fishing mortality and SSB is shown below (figure 4). Fassess and SSBassess are taken from the WGWIDE 2019 assessment. The explanations below are only given for fishing mortality, but the same procedures apply to SSB.

The F deviation in year y d_y is calculated as ln(Fassess/Fset). The standard deviation σ_m (=lnSTD) of the log deviations gives the marginal distribution. The autocorrelation in the log deviations φ (=Fphi) is calculated by correlating the deviations 2011-2017 with the deviations 2012-2018 (this is the autocorrelation of the AR(1) process). The conditional standard deviation σ_c (=Fcv) is calculated as $\sigma_m \sqrt{(1-\varphi^2)}$.

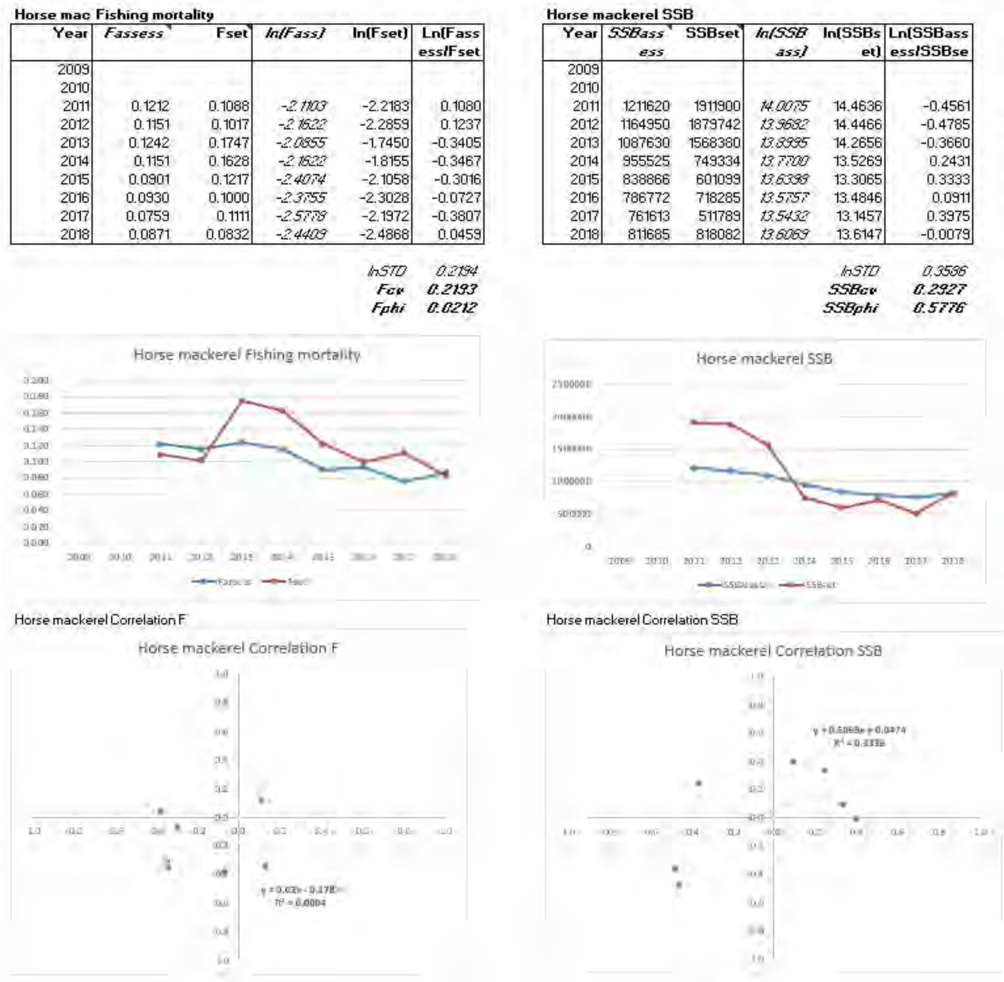
In the case of western horse mackerel, Fcv is estimated at 0.2193 and Fphi at the very low value of 0.0212. This can be explained by the almost complete lack of overlap between Fassess and Fset because the most recent assessment estimates a substantially lower fishing mortality than was assumed in the forecasts. The F correlation plot below therefore shows a close to flat line. During IBPWHM 2019, reference points have been calculated using Fcv = 0.212 and Fphi = 0.423 (the default EqSim values) and thus substantially different from the calculated values.

Note that SSBcv and SSBphi have been calculated in the same way, but they are not currently used in the EqSim approach for estimating reference points.

A simulation study on the impact of different values of Fcv and Fphi on the Fmsy for western horse mackerel is shown below (figure 5). Fcv is on the horizontal axis, while the coloured lines indicate the values of Fphi. The five panels demonstrate the five steps in arriving at the final Fmsy.

- Estimate Fmsy without constraints
- Calculate Fpa (has been done previously).
- If Fmsy is larger than Fpa, set Fmsy_interim to Fpa
- Calculate Fp05 with Eqsim using Fcv, Fphi and Blim
- The final Fmsy is the minimum of Fp05 and Fmsy_interim.

The simulation study demonstrates that a larger Fcv leads to a lower Fp05 and also that a larger Fphi leads to the Fp05 being more sensitive to the impact of Fcv. Therefore, the estimated values of Fcv and Fphi can have an important impact on the Fmsy that is calculated in EqSim.



Horse mac Fishing mortality

Year	Fassess	Fset	ln(Fass)	ln(Fset)	Ln(Fassess/Fset
2009					
2010					
2011	0.1212	0.1088	-2.1103	-2.2183	0.1080
2012	0.1151	0.1017	-2.1622	-2.2859	0.1237
2013	0.1242	0.1747	-2.0855	-1.7450	-0.3405
2014	0.1151	0.1628	-2.1622	-1.8155	-0.3467
2015	0.0901	0.1217	-2.4074	-2.1058	-0.3016
2016	0.0930	0.1000	-2.3755	-2.3028	-0.0727
2017	0.0759	0.1111	-2.5778	-2.1972	-0.3807
2018	0.0871	0.0832	-2.4403	-2.4868	0.0459

lnSTD	0.2194
Fcv	0.2193
Fphi	0.0212

Horse mackerel SSB

Year	SSBassess	SSBset	ln(SSBass)	ln(SSBset)	Ln(SSBassess/SSBse
2009					
2010					
2011	1211620	1911900	14.0075	14.4636	-0.4561
2012	1164950	1879742	13.9682	14.4466	-0.4785
2013	1087630	1568380	13.8995	14.2656	-0.3660
2014	955525	749334	13.7700	13.5269	0.2431
2015	838866	601099	13.6398	13.3065	0.3333
2016	786772	718285	13.5757	13.4846	0.0911
2017	761613	511789	13.5432	13.1457	0.3975
2018	811685	818082	13.6069	13.6147	-0.0079

lnSTD	0.3586
SSBcv	0.2927
SSBphi	0.5776

Figure 4 Calculation of Fcv, Fphi, SSBcv and SSBphi for western horse mackerel

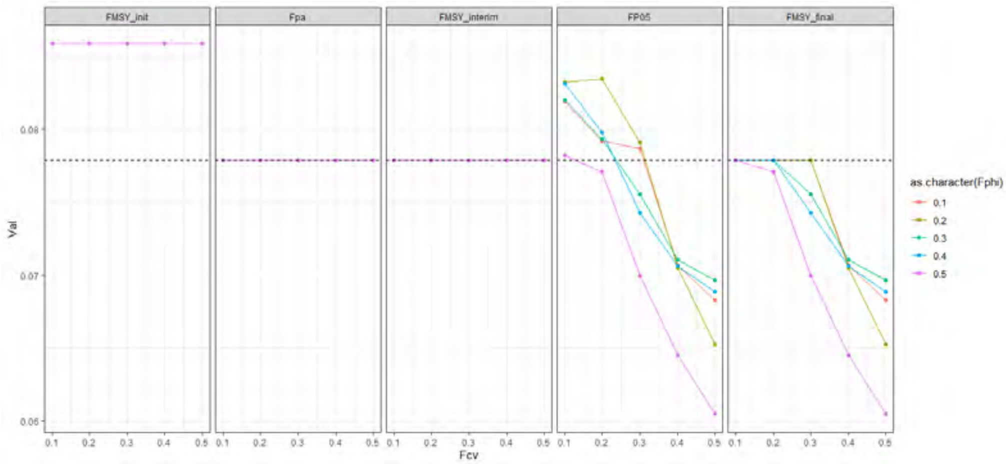


Figure 5 *Simulated values of the impact of Fcv and Fphi on the reference points for western horse mackerel.*

Atlantic mackerel

Following the same procedure as outlined above, we obtained the following values for Fset and SSBset for Atlantic mackerel.

tacyear	catchrealized	catch1fcy	catch2fcy	f1fcy	f2fcy	ssb1fcy	ssb2fcy	fset	ssbset
2009	737969	707000	831000	0.25	0.3	2891000	2842000	0.262488	2878762
2010	875515	726000	996000	0.29	0.42	2397000	2293000	0.361989	2339409
2011	946661	884093	959773	0.31	0.34	2697368	2668541	0.334802	2673535
2012	892353	742000	927000	0.26	0.34	2710000	2638000	0.325018	2651484
2013	931732	930000	1116000	0.41	0.51	2390000	2310000	0.410931	2389255
2014	1393000	1300000	1400000	0.291	0.318	4594000	4573000	0.31611	4574470
2015	1208990	1054000	1396000	0.26	0.36	4344000	4276000	0.305319	4313183
2016	1094066	960009	1235608	0.28	0.38	3766022	3712034	0.328642	3739761
2017	1155944	1067828	1281394	0.28	0.35	4398536	4358095	0.308882	4381850
2018	1026437	977765	1122906	0.405	0.48	3043254	3013235	0.430151	3033187

In the case of mackerel, we were particularly interested in the effect of the assessment year on the calculation of Fcv and Fphi because of the substantial change in perception between the 2018 and the 2019 assessments. Therefore, we calculated Fcv and Fphi for each assessment year separately.

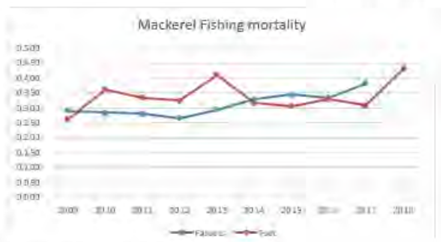
Similar to the observations for Western horse mackerel, the impact of the final assessment year is noticeable here. Due to the revision of the assessment in 2019, there is almost no overlap between the fishing mortalities from the assessment and those derived from the historical forecasts. This impacts on the estimated Fphi (0.3080 using the 2018 assessment, 0.0076 using the 2019 assessment).

Mackerel 2018

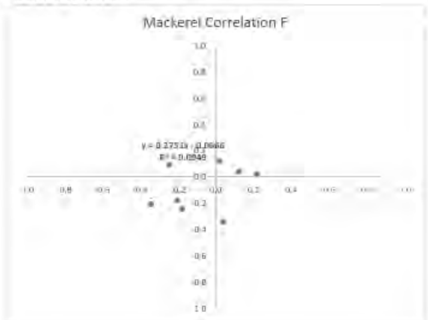
Mackerel Fishing mortality

Year	*Fassess*	Fset	*ln(Fass)*	ln(Fset)	Ln(Fassess/Fset
2009	0.290	0.2625	*-1.2389*	-1.3376	0.0986
2010	0.283	0.3620	*-1.2626*	-1.0161	-0.2464
2011	0.280	0.3348	*-1.2744*	-1.0942	-0.1801
2012	0.265	0.3250	*-1.3291*	-1.1239	-0.2052
2013	0.293	0.4109	*-1.2282*	-0.8893	-0.3389
2014	0.329	0.3161	*-1.1117*	-1.1517	0.0400
2015	0.345	0.3053	*-1.0647*	-1.1864	0.1217
2016	0.33507	0.3286	*-1.0934*	-1.1128	0.0194
2017	0.38298	0.3089	*-0.9598*	-1.1748	0.2150
2018		0.4302			

lnSTD	*0.1929*
Fcv	***0.1835***
Fphi	***0.3080***



Mackerel Correlation F

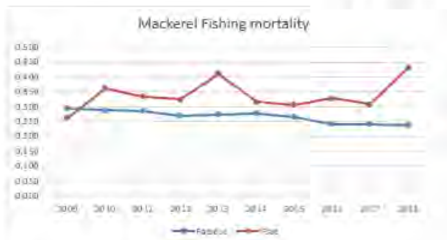


Mackerel 2019

Mackerel Fishing mortality

Year	*Fassess*	Fset	*ln(Fass)*	ln(Fset)	Ln(Fassess/Fset
2009	0.294	0.2625	*-1.2242*	-1.3376	0.1134
2010	0.288	0.3620	*-1.2448*	-1.0161	-0.2287
2011	0.286	0.3348	*-1.2518*	-1.0942	-0.1575
2012	0.270	0.3250	*-1.3093*	-1.1239	-0.1855
2013	0.273	0.4109	*-1.2983*	-0.8893	-0.4090
2014	0.278	0.3161	*-1.2801*	-1.1517	-0.1285
2015	0.265	0.3053	*-1.3280*	-1.1864	-0.1416
2016	0.241	0.3286	*-1.4230*	-1.1128	-0.3102
2017	0.241	0.3089	*-1.4230*	-1.1748	-0.2482
2018	0.238	0.4302	*-1.4355*	-0.8436	-0.5919

lnSTD	*0.1865*
Fcv	***0.1865***
Fphi	***0.0076***



Mackerel Correlation F

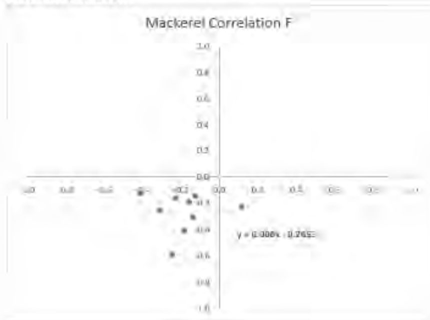


Figure 6 Comparison of Fcv and Fphi for Mackerel based on the assessments of 2018 and 2019.

Conclusions

While an elaborate procedure has been outlined to derive reference points for category 1 and 2 stocks in ICES (ICES, 2017a) based on the work of MSYREF workshops (ICES, 2013b; ICES, 2014a; ICES, 2014b; ICES, 2015), we conclude from our studies on western horse mackerel and Atlantic mackerel that insufficient attention has been given to the method of estimating forecast uncertainty and the impact of that uncertainty on the estimated reference points (notably Fmsy). Here we started with a method for documenting how the Fset is being derived from the historical data, so that at least the estimates of Fcv and Fphi are transparent and can be recreated.

We also note that there can be a high dependence of Fphi on the assessment that is used to compare against the Fset. When the assessment that is used has values that are all higher or lower than the Fset values, then Fphi will be close to zero. To our knowledge, this behaviour of Fphi was unknown so far.

Finally, we note that the number of years that is used for calculating Fcv and Fphi may have an impact on the values. In the recommendations from WKMSYREF3 it is stated that 10 years (or more) should be taken. A further study should be undertaken to assessment the impacts of using different time periods for estimating Fcv and Fphi.

7 Estimation of reference points for SS and SAM assessments

During the IBPWHM 2019, reference points were estimated for western horse mackerel based on the 2018 WGWIDE assessment and using default values for Fcv and Fphi (0.212 and 0.423) and using a segmented regression through Blim (segregBlim). In order to calculate reference points for the exploratory SAM assessment and to explore the sensitivity to the assessment year, reference points were calculated on the basis of the 2018 or 2019 assessments for SS and SAM.

The reference points for the SAM assessment are based on the 2018 assessment. Bpa and Blim are lower than the values for the SS assessment, while the Fmsy is higher. These values will be used in the subsequent evaluations (section 8)

The changes due the assessment year were minor for both the SS and SAM assessments.

RP	WG18	WG18SAM	WG19	WG19SAM
Blim	834480	611814	885341	612635
Flim	0.1107	0.1612	0.1049	0.1756
Fpa	0.07909	0.1152	0.07493	0.1254
MSYBtrigger	1168272	856540	1239478	857689
FMSY	0.09102	0.1262	0.08665	0.1353
FP05	0.08398	0.1255	0.07826	0.1402
FMSY_final	0.07909	0.1152	0.07493	0.1254

8 HCR evaluations

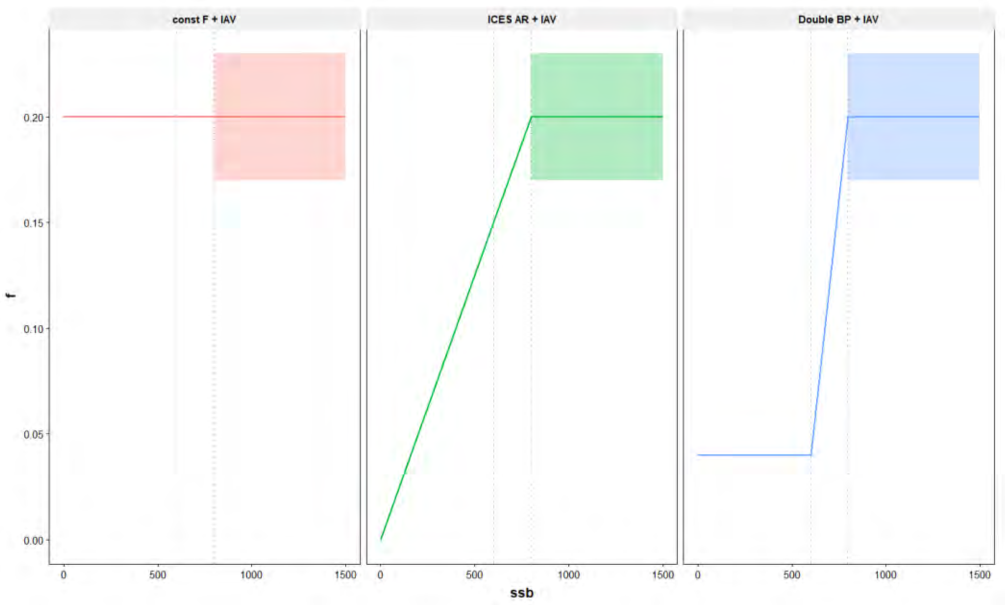
8.1 Type of HCRs evaluated

Three different types of harvest control rules were evaluated:

- Constant F strategy: fixed Ftarget independent of biomass level
- ICES Advice Rule: breakpoint at Btrigger and straight decline in F to zero below Btrigger.
- Double Breakpoint rule: breakpoint at Btrigger and straight decline in F to 20% of Ftarget at Blim. Below Blim continued fishing at F = 0.2 * Ftarget.

For each of the HCRs, a number of different target fishing mortalities were explored (0.0, 0.05, 0.075, 0.1, 0.125, 0.15). No evaluation of different Btrigger values was carried out, so that all evaluations used MSY Btrigger as the trigger point. All HCRs where evaluated with three variants:

- Without any additional constraints
- With a minimum TAC of 50 kT
- With a maximum 20% inter-annual variation (IAV) in TAC, but only when the stock is above Btrigger)



8.2 HCR evaluation tools

The base assessments ("Operating model") of the evaluations were either the WGWIDE 2019 SS3 assessment (ICES, 2019d) or the exploratory SAM assessment that was carried out as part of the IBPWHM 2019 (ICES, 2019b).

As input to the SS3 simulations, 1000 iterations were generated from respective assessments. For SS3 this was done by generating 10000 iterations and then resampling 1000 of them so as to end up with the same starting conditions as in the stock assessment itself.

The 1000 SAM iterations were generated by using the SAM simulate function, based on the IBPWHM 2019 exploratory SAM assessment; these were then converted to FLSAM objects which were again converted to 1000 FLStock objects[2]

The SRR model was the constrained segmented regression (SegRegBlim), similar to the IBPWHM 2019, while leaving out the exceptionally strong 1982 year class.

Two simulation tools were used: the EqSim simulator and the SAM HCR forecast

The EqSim simulator is a further worked up version of the SimpSIM approach that was used for the blue whiting MSE in 2016 (ICES, 2016). The code was further developed by Andrew Campbell and Martin Pastoors to improve standardization, documentation and visualization of results. Some key improvements where:

- the development of standardized codes for Operating Models (OM) a Management Procedures (MP), including new types of HCR elements.
- the development of standardized codes for statistical outputs and visualization thereof.

The SAM HCR forecast is a simple stochastic forecast with HCR to evaluate management for fish stocks that need rebuilding in the short-term. This method enables the investigation of several management strategies without the need of intensive computer power, while still accounting for different sources of uncertainty. The stochastic forecasts start from what we believe is the current level of the stock, i.e. the assessment estimates currently used for tactical management advice, with consideration of the uncertainty in these estimates. Rebuilding is evaluated forward for a specified number of years (here: 23 years) and for different target fishing mortality values (Ftarget)

The method was developed as an extension to the stockassessment R package for the SAM model (Nielsen and Berg, 2014; Berg and Nielsen, 2016) and applied to western horse mackerel[3].

We applied two different assessments to two different evaluation tools as follows:

	WGWIDE19 SS3	WGWIDE19 SAM
EqSim simulator	Yes	Yes
SAM HCR forecast	No	Yes

For each evaluation, we scanned over different F target values: 0, 0.05, 0.075, 0.10, 0.125, 0.15.

Each simulation was run over 23 year, split into the following periods:

[2] https://github.com/ices-eg/wk_WKREBUILD/blob/master/EqSimWHM/Scripts/HOM%20SAM%20simulator.r
Note: running the code required running it in batches of around 200 iterations due to unexplained errors arising when running for larger batches. This issue has not been solved, except by running it in multiple batches.

[3] https://github.com/vtrijoulet/SAM/tree/master2

- Current period (CU): 2018-2020
- Short term (ST): 2021-2025
- Medium term (MT): 2026-2030
- Long term (LT): 2031-2040

8.3 EqSim simulator tool

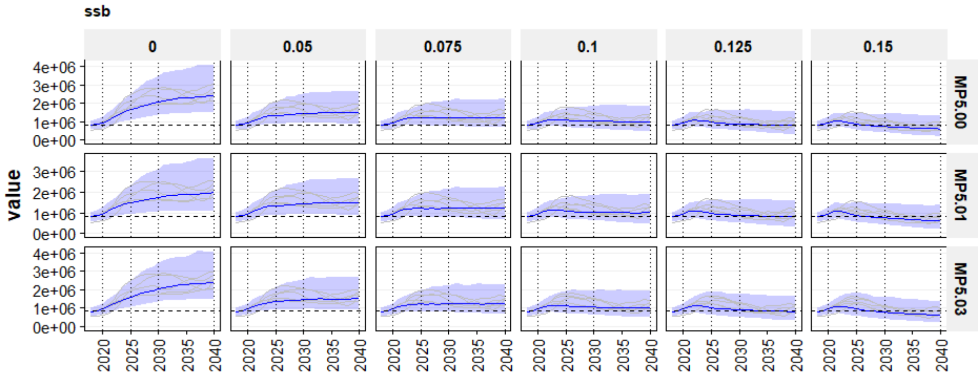
8.3.1 Eqsim applied to SS3 assessment

The SS3 assessment was run with OM2.2:

```
#WGWIDE2019 Update assessment, IBPWHM reference points, stochastic bio and selection
OM2.2 <- list("code" = "OM2.2",
            "desc" = "WGWIDE19",
            "IM" = NA,
            "SRR" = "SRR.WG19.SegReg_Blim.exterm", "RecAR" = TRUE, maxRecRes = c(3,-3),
            "BioYrs" = c(2008,2017), "BioConst" = FALSE,
            "SelYrs" = c(2008,2017), "SelConst" = FALSE,
            "Obs" = NA,
            refPts = list("Fpa" = 0.074, "Flim" = 0.103, "Fmsy" = 0.074, "Bpa" = 1168272,
                          "Blim" = 834480, "MSYBtrigger" = 1168272, "Bloss" = 761613),
            "pBlim" = 0.05)
```

8.3.1.1 Constant F strategy

- MP5.00 constant F;
- MP5.01 constant F with minimum TAC of 50kT;
- MP5.03 constant F with 20% IAV on TAC constraint above Btrigger.



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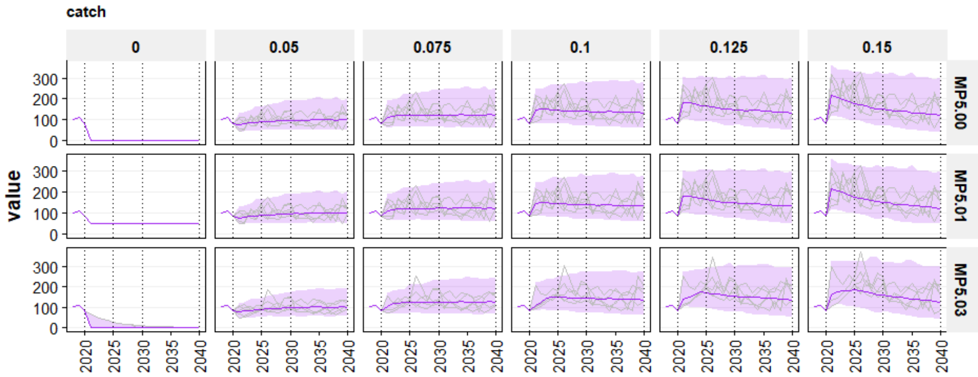
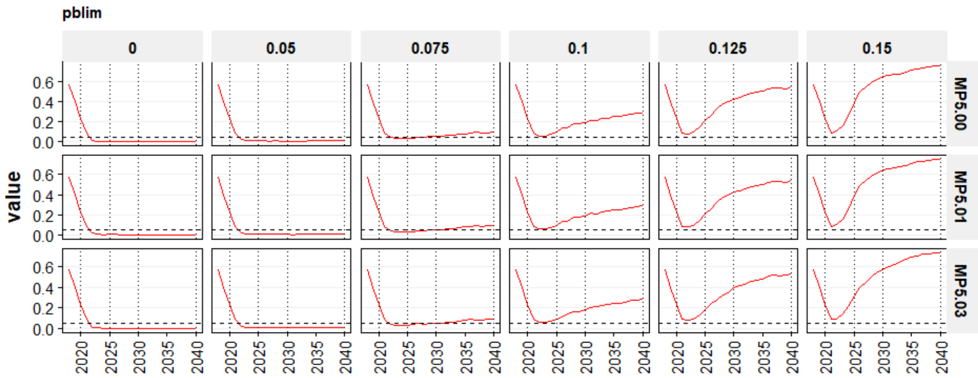
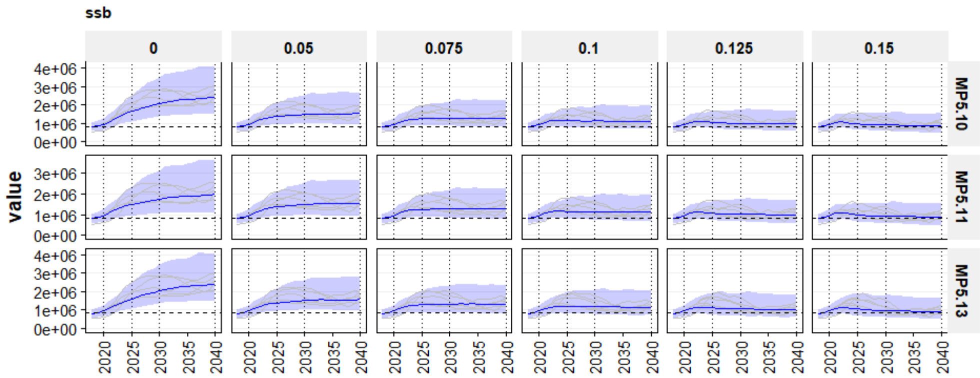


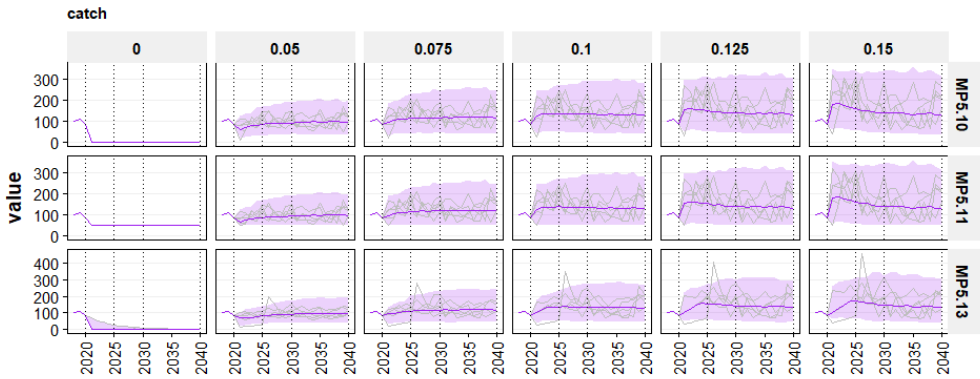


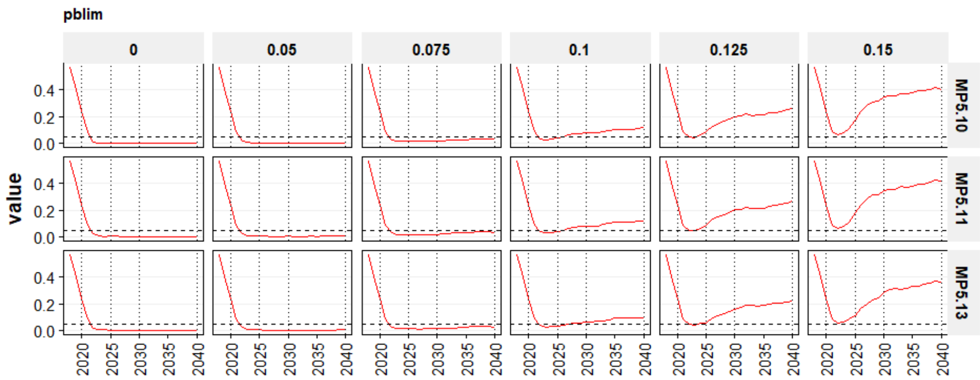
8.3.1.2 ICES Advice Rule

Scenarios 5.1, 5.11 and 5.13 (ICES advice rule variants)

- MP5.10 ICES AR
- MP5.11 ICES AR, min TAC = 50kt
- MP5.13 ICES AR, 20% IAV, only above Btrigger





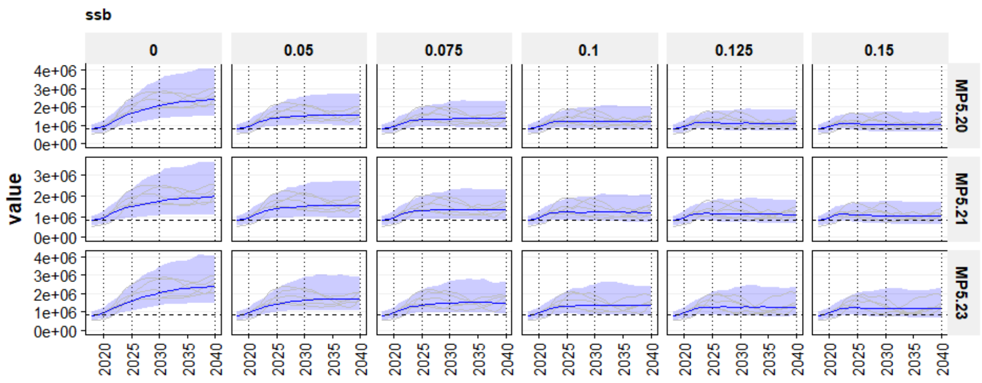


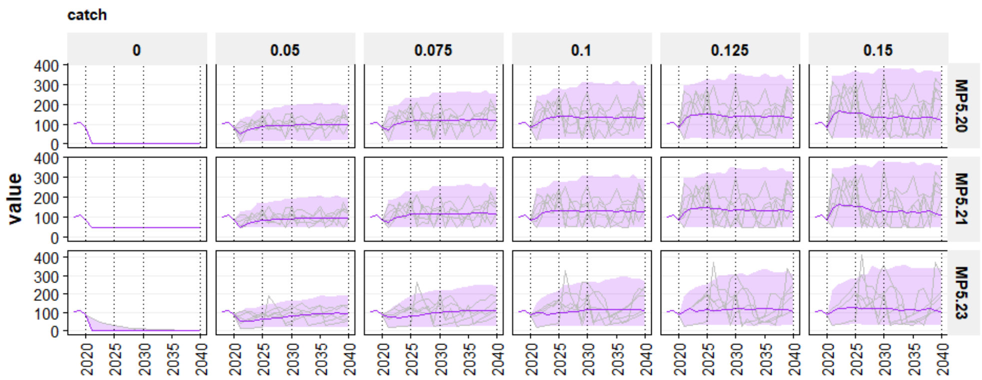
8.3.1.3 Double Breakpoint Rule

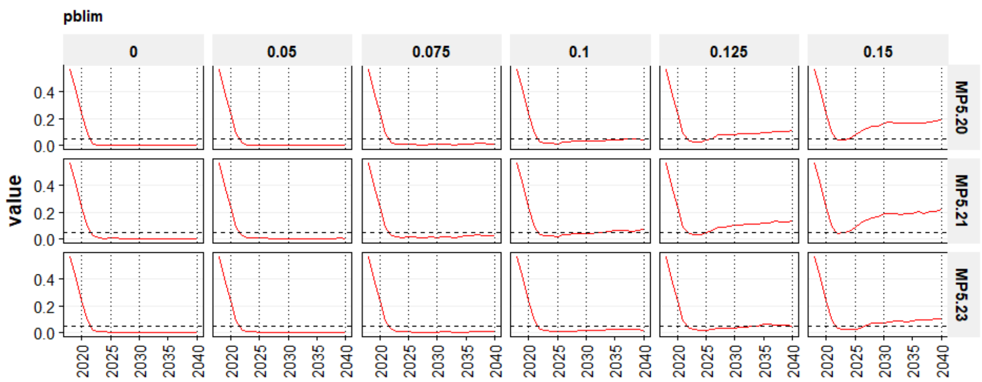
This HCR is similar to the blue whiting HCR that was evaluated in 2016 (ICES, 2016).

- MP5.20 Double BP
- MP5.11 Double BP with minimum TAC of 50kT
- MP5.13 Double BP with 20% IAV constraint above Btrigger.

Minimum F in the Double breakpoint rule is 20% of Ftarget.





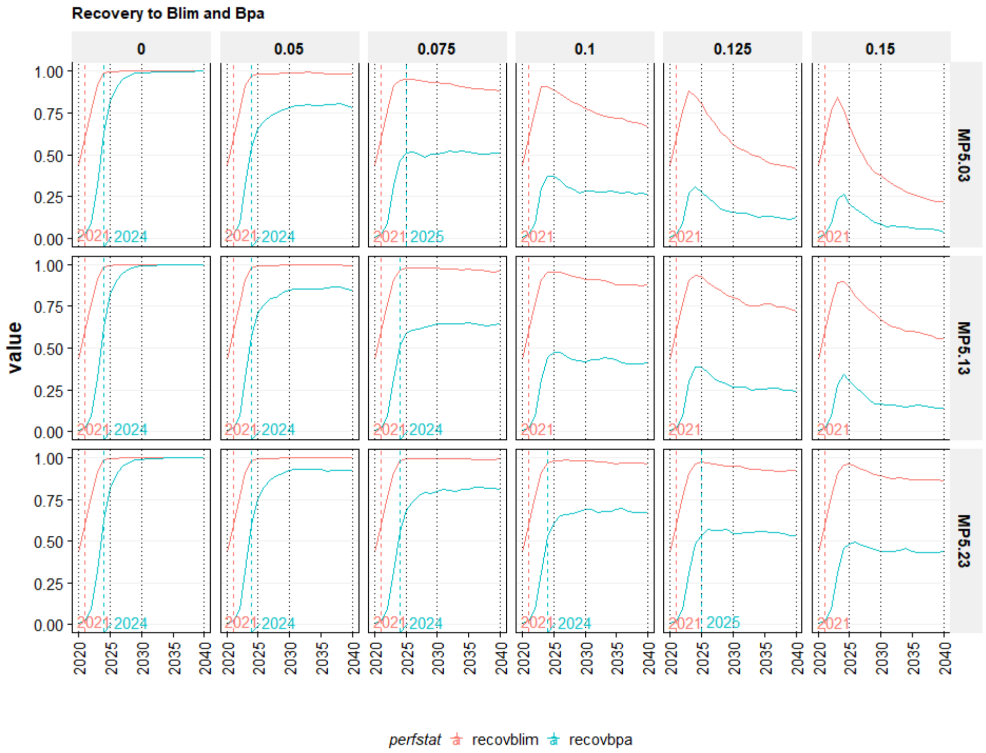


8.3.1.4 First year of achieving rebuilding with 20% IAV constraint scenarios

The first year of achieving rebuilding to Blim and Bpa was calculated as the first year where the probability of being above Blim or Bpa was larger than 50%. The analysis was carried out for the following scenarios:

- MP5.03 constant F with 20% IAV on TAC constraint above Btrigger.
- MP5.13 ICES AR, 20% IAV, only above Btrigger
- MP5.13 Double BP with 20% IAV constraint above Btrigger.

Results indicate that the constant F strategy is the least cautious rule and the double breakpoint rule is the most cautious rule. Under the F strategy rule with a Ftarget of 0.075, rebuilding to Bpa is expected to be achieved is only just being achieved (probability just above 50%) by 2025, while in the double breakpoint rule this is expected to be achieved in 2024 with substantially higher probabilities of remaining above Bpa. The first year of rebuilding to Bpa in the double breakpoint rule with target fishing mortalities up to 0.1 is the same as the first year of rebuilding under the zero fishing scenarios.



8.3.2 Eqsim applied to SAM assessment

The SS3 assessment was run with OM2.2:

```
#WGWIDE2019 SAM assessment, IBPWHM method for reference points, stochastic bio and selection
OM2.3 <- list("code" = "OM2.3",
              "desc" = "WGWIDE19_sam",
              "IM" = NA,
              "SRR" = "SRR.WG19.SegReg_Blim.exterm", "RecAR" = TRUE, maxRecRes = c(3,-3),
              "BioYrs" = c(2008,2017), "BioConst" = FALSE,
              "SelYrs" = c(2008,2017), "SelConst" = FALSE,
              "Obs" = NA,
              refPts = list("Fpa" = 0.115, "Flim" = 0.161, "Fmsy" = 0.115, "Bpa" = 856540,
                            "Blim" = 611814, "MSYBtrigger" = 856540, "Bloss" = 604476),
              "pBlim" = 0.05)
```

Note that the biomass reference points have been estimated separately for the SAM assessment, and are a bit lower than for the SS assessment (see section 7).

8.3.2.1 Constant F rule with SAM assessment

Results for the constant F rule are not presented because it was clear that this option would not be selected by the PELAC for the potential rebuilding plan.

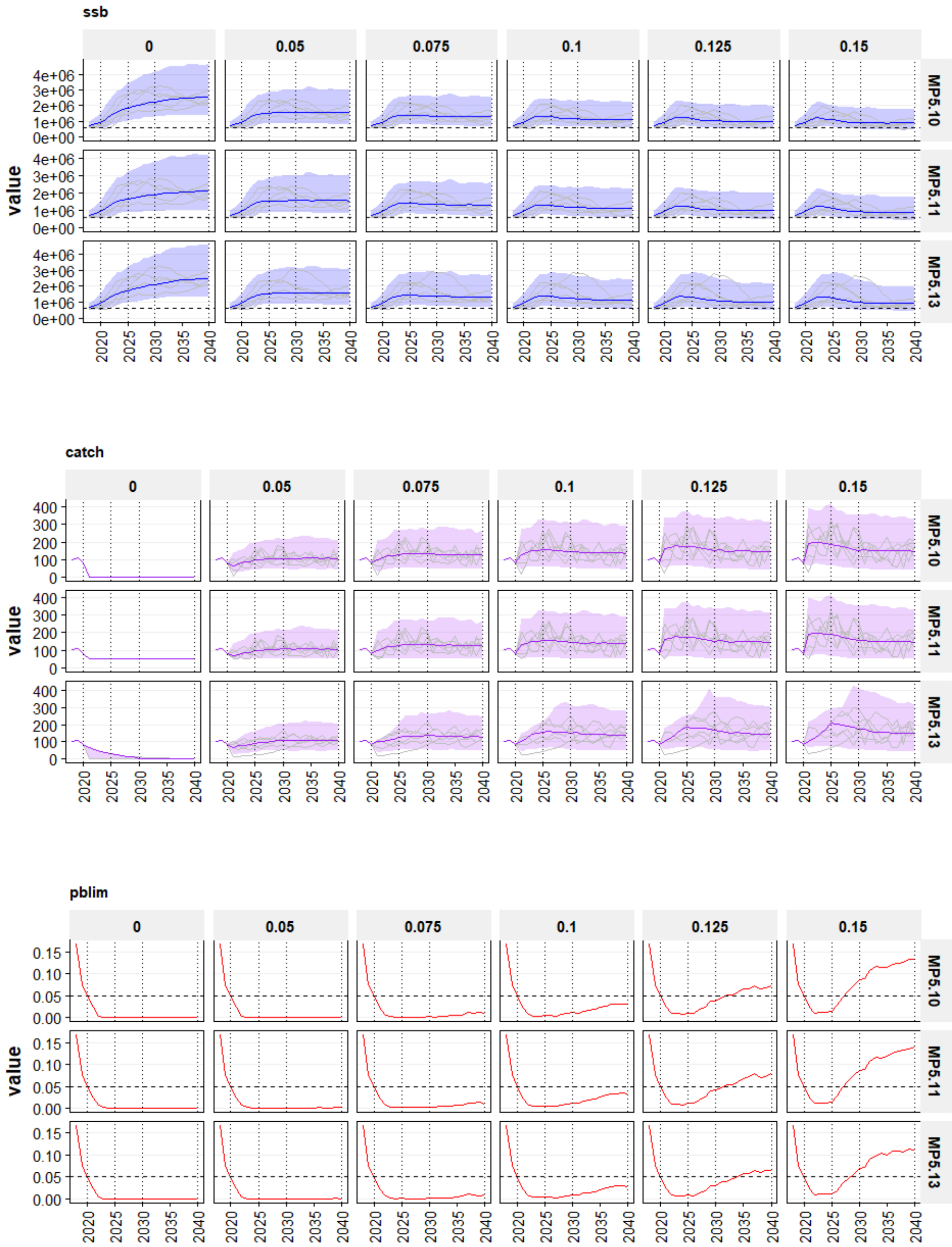
8.3.2.2 ICES Advice Rule with SAM assessment

Scenarios 5.10, 5.11 and 5.13 (ICES advice rule variants)

- MP5.10 ICES AR;

- MP5.11 ICES AR with minimum TAC of 50kT;
- MP5.13 ICES AR with 20% IAV constraint above Btrigger.

While the probability of being below Blim decreases in the beginning of the simulation period, for all F targets, the probability of being below Blim start to increase again after 2025 when target fishing mortalities are too high (e.g. > 0.075).



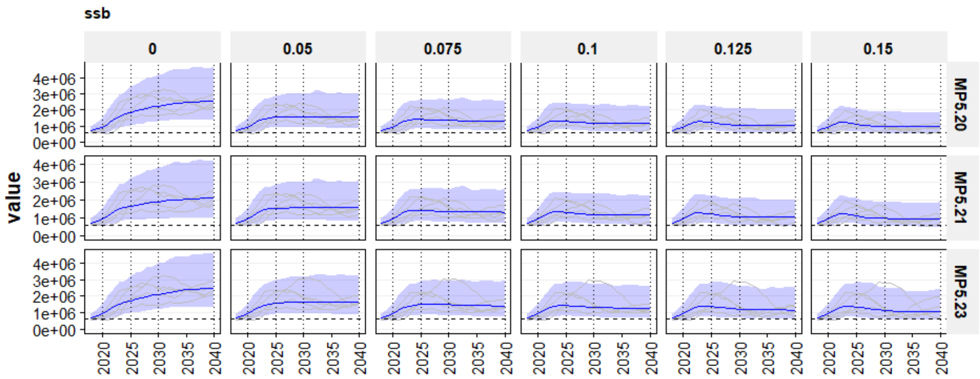
8.3.2.3 Double Breakpoint Rule with SAM assessment

This HCR is similar to the blue whiting HCR that was evaluated in 2016 (ICES, 2016).

- MP5.20 Double BP
- MP5.11 Double BP with minimum TAC of 50kT;

- MP5.13 Double BP with 20% IAV constraint above Btrigger. Minimum F in Double BP is 20% of Fmsy.

Generally, what we find is that the SAM assessment has a somewhat more optimistic view of the stock size in relation to the reference points. This means that the stock is estimated to be above Blim with a high probability in most of the scenarios. It also means that expected recovery to Bpa is in 2022 in all scenarios.



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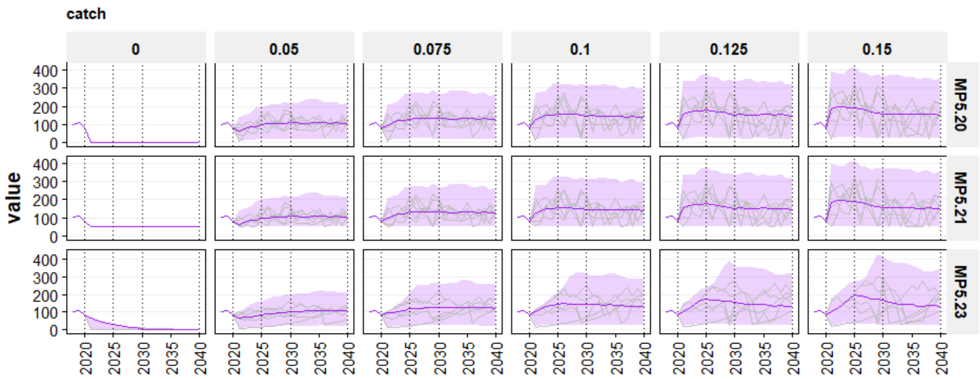
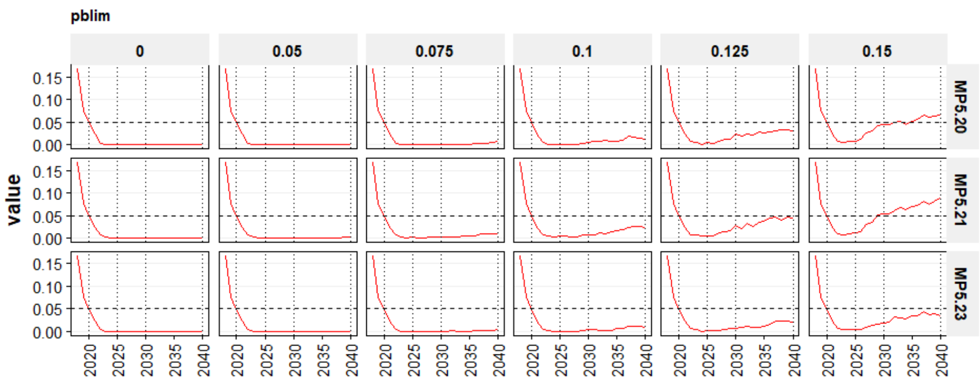
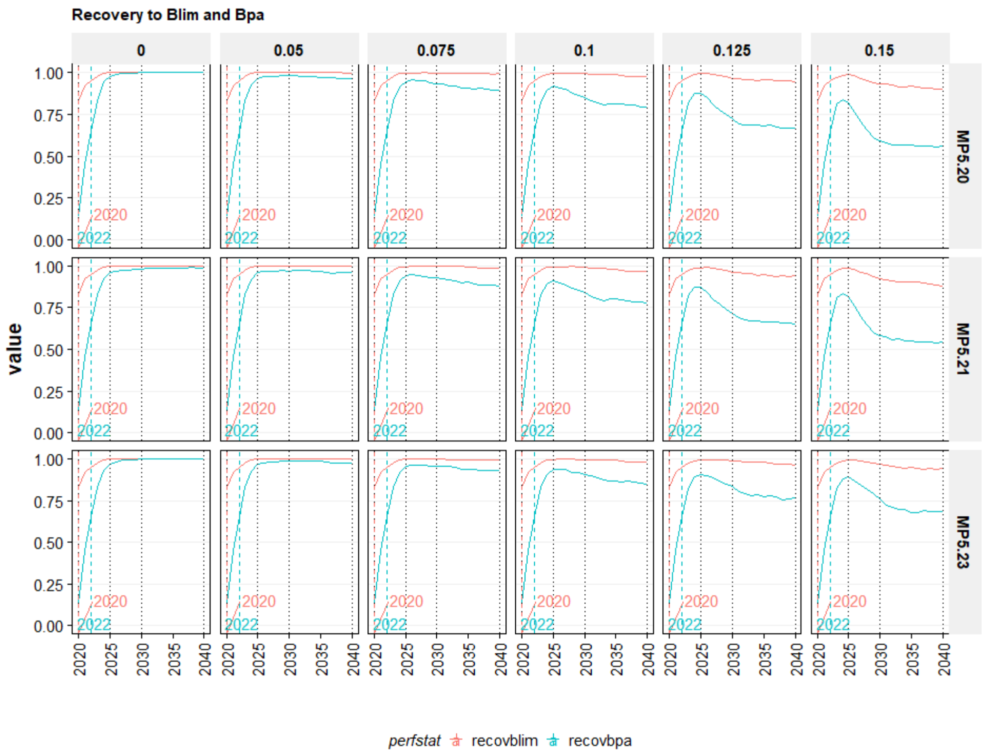






8.4 SAM HCR forecast tool

8.4.1 Description of the method

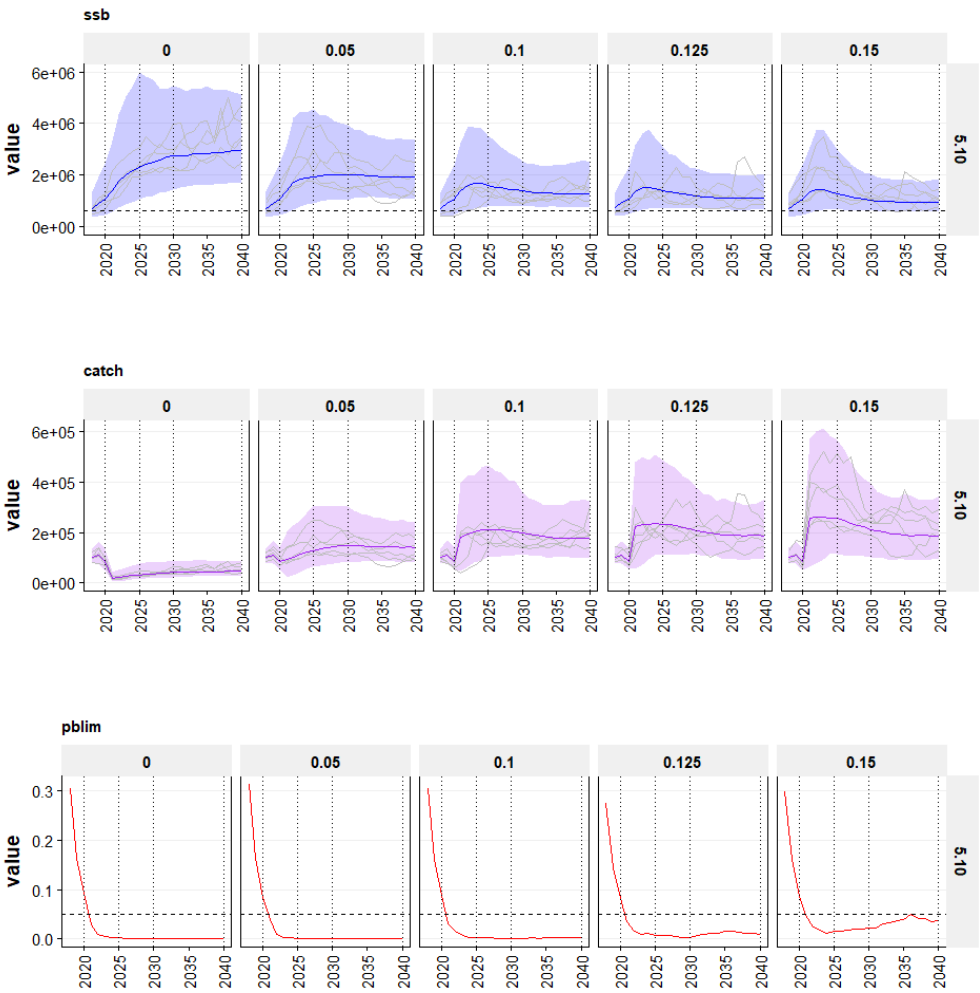
The SAM HCR was applied to the exploratory SAM assessment (IBPWHM 2019) that was also used for the EqSim with SAM analysis. The SAM HCR forecast can only be run on a SAM assessment[4].

8.4.2 SAM HCR with ICES Advice Rule

Here we only present the simple ICES AR scenario without any additional constraints as the main purpose is only to show the feasibility of using this simple method while generating similar results from more complicated methods.

- MP5.10 ICES AR.

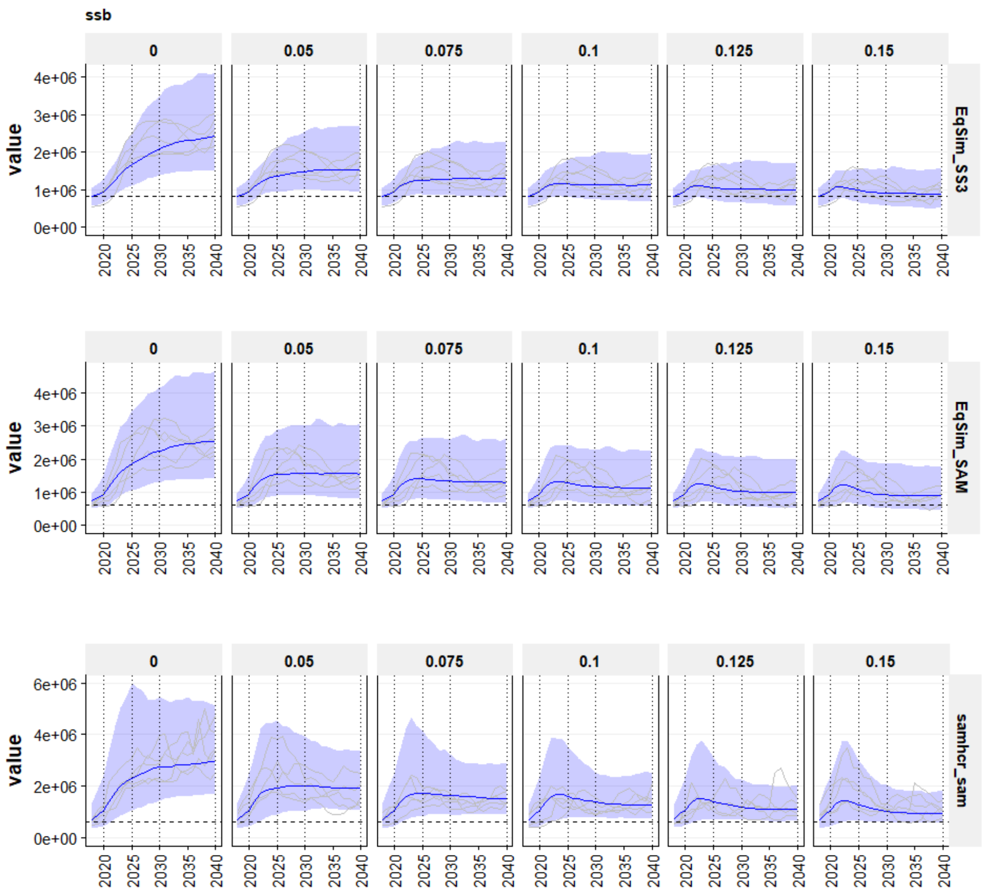
[4] Note that with the SAM HCR it was not possible to run the forecast with F = 0; therefore F = 0.01 has been run for the results denoted below with F = 0 .

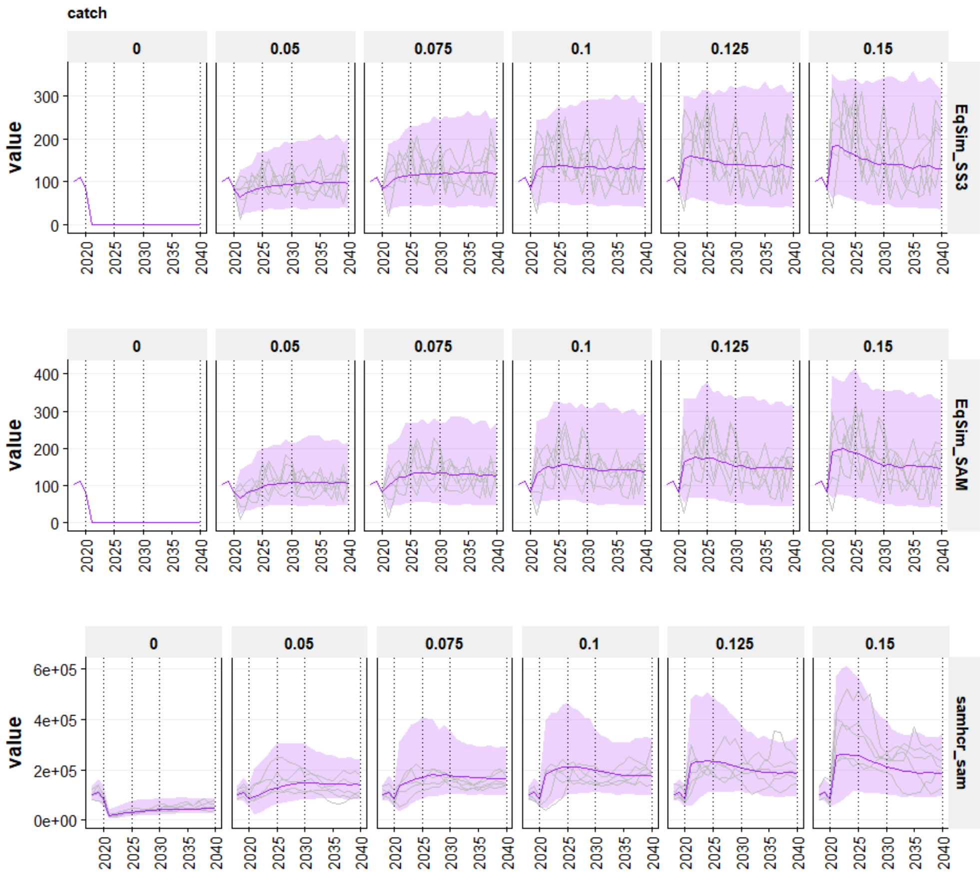


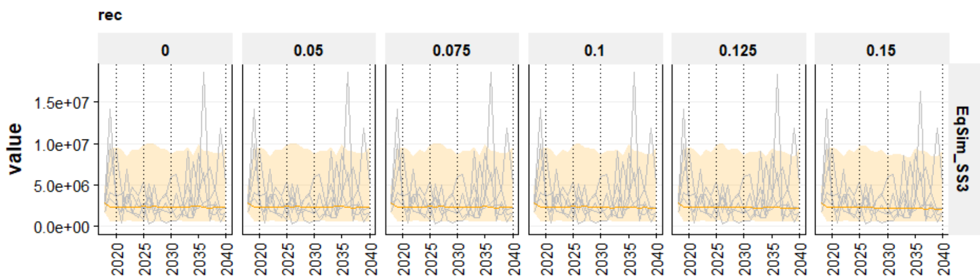
8.5 Comparison of results for different simulation tools and assessments

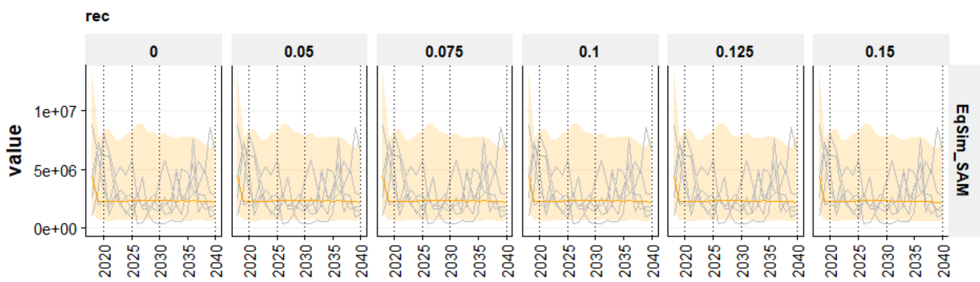
To compare the behaviour of evaluation tools (EqSim or SAM HCR) and assessment method (SAM or SS3), we compared the simple ICES AR scenarios for the three possible combinations:

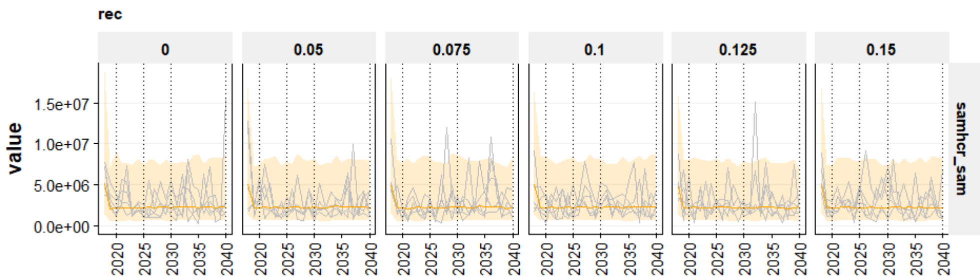
- EqSim – SAM – MP5.1 (ICES AR)
- EqSim – SS3 – MP5.1 (ICES AR)
- SAM HCR – SAM – MP5.1 (ICES AR)

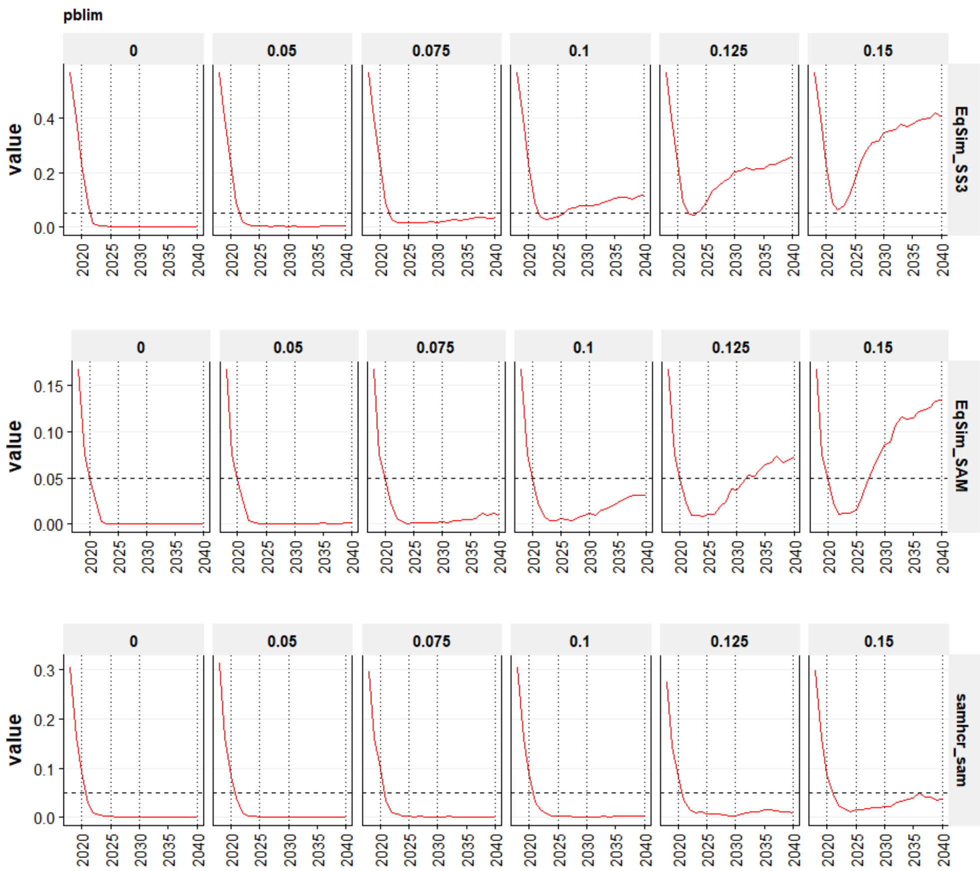

ssb
0
0.05
0.075
0.1
0.125
0.15
value
EqSim_SS3
EqSim_SAM
samhcr_sam
0e+00
1e+06
2e+06
3e+06
4e+06
6e+06
2020
2025
2030
2035
2040


catch
0
0.05
0.075
0.1
0.125
0.15
EqSim_SS3
EqSim_SAM
samhcr_sam
value
2020
2025
2030
2035
2040


rec
0
0.05
0.075
0.1
0.125
0.15
EqSim_SS3
value
1.5e+07
1.0e+07
5.0e+06
0.0e+00
2020
2025
2030
2035
2040


rec
0
0.05
0.075
0.1
0.125
0.15
EqSim_SAM
value
1e+07
5e+06
0e+00
2020
2025
2030
2035
2040


rec
0
0.05
0.075
0.1
0.125
0.15
samhcr_sam
value
1.5e+07
1.0e+07
5.0e+06
0.0e+00
2020
2025
2030
2035
2040



The probability of being below Blim broadly follows the same pattern across the three different evaluation method although the levels do differ between the evaluations. Because the SAM assessment estimates the most recent SSBs higher than year where Bloss was calculated, the probability of currently being below Blim is smaller. The patterns observed for the EqSim_SS and EqSim_SAM runs are qualitatively similar albeit at different levels. The SAMHCR_SAM run exhibits a slightly different pattern because the forecasted SSB is expected to remain above Blim with a high probability in all F scenarios. This may be due to the fact that the SAMHCR is operating as a forecast only and therefore lacks the feature that the management perception of the stock differs from the real stock, so that the implemented HCR in the simulation does not suffer from the mismatch between perception and reality.

9 Selection of preferred HCRs for Western Horse mackerel

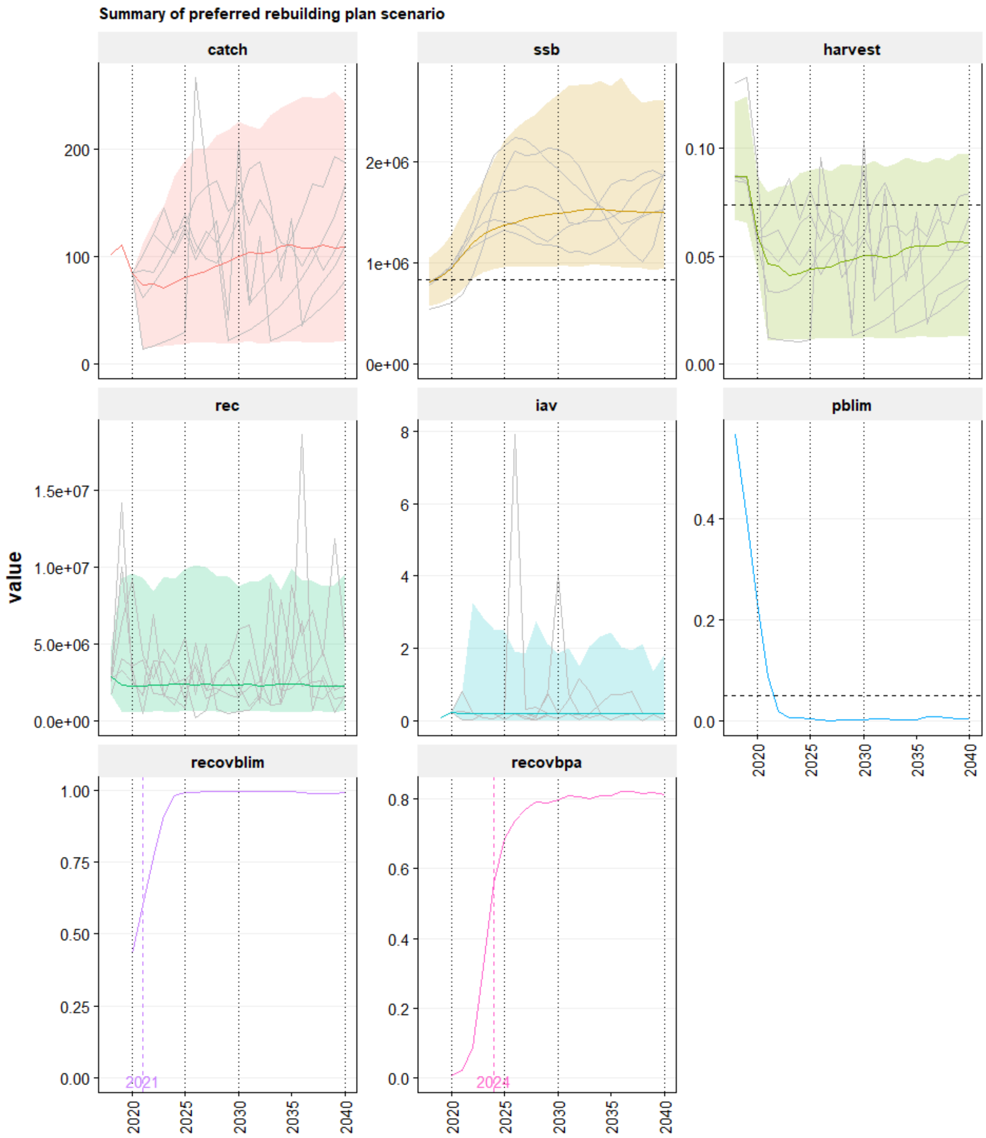
The PELAC selected the following preferred option for the Western horse mackerel rebuilding plan:

- Evaluation method: EqSim
- Assessment: Stock Synthesis (WGWIDE 2019), because this is the basis for the assessment and advice.
- Target fishing mortality at Fmsy = 0.074 (approximated by 0.075 in the simulations)
- Blim at ICES Blim (834 480 t)
- Btrigger at ICES MSY Btrigger (1 168 272 t)

- Double breakpoint rule with 20% constraint on IAV above Btrigger
- Minimum F when stock is below Blim at 20% of Fmsy = 0.015

The selected rebuilding plan has a 50% probability of rebuilding to Blim by 2021 (similar to zero catch option) and a 50% probability of rebuilding to Bpa/MSY Btrigger by 2024 (similar to the zero-catch option). Furthermore, the probability of being below Blim remains well below 5% for the duration of the simulation.

In this scenario, the average catch in the years 2021-2025 is expected to be lower than recent catches. However, after rebuilding, catches should be able to be maintained around 100 000 tonnes.



Summary of results of the preferred rebuilding plan

```
statistic  yearrange   period  median      range
---------- ----------- -------- ----------- --------------------

catch      2018-2020   CU      102         84 - 110            * in kT
catch      2021-2025   ST      75          17 - 167
```

```
catch      2026-2030   MT      92          20 - 210
catch      2031-2040   LT      107         21 - 242

ssb        2018-2020   CU      872,454     608,164 - 1,210,564
ssb        2021-2025   ST      1,249,710   832,465 - 1,902,950
ssb        2026-2030   MT      1,451,882   966,840 - 2,506,102
ssb        2031-2040   LT      1,514,418   958,213 - 2,740,040

harvest    2018-2020   CU      0.080       0.048 - 0.118
harvest    2021-2025   ST      0.044       0.011 - 0.085
harvest    2026-2030   MT      0.047       0.012 - 0.092
harvest    2031-2040   LT      0.054       0.012 - 0.095

rec        2018-2020   CU      2,599,180   696,645 - 7,944,499
rec        2021-2025   ST      2,363,631   606,888 - 9,317,602
rec        2026-2030   MT      2,361,298   599,077 - 9,438,791
rec        2031-2040   LT      2,321,690   612,371 - 9,088,107

iav        2018-2020   CU      0.162       0.086 - 0.239
iav        2021-2025   ST      0.200       0.021 - 2.576
iav        2026-2030   MT      0.200       0.018 - 2.083
iav        2031-2040   LT      0.200       0.017 - 2.032

pblim      2018-2020   CU      0.401       0.243 - 0.560
pblim      2021-2025   ST      0.006       0.005 - 0.082
pblim      2026-2030   MT      0.002       0.001 - 0.003
pblim      2031-2040   LT      0.004       0.002 - 0.009
```

Table of settings used in the evaluation

```
class   desc                 value
------- -------------------- ------------------------------------
OM      code                 OM2.2
OM      desc                 WGWIDE19
OM      IM
OM      SRR                  SRR.WG19.SegReg_Blim.exterm
OM      RecAR                TRUE
OM      maxRecRes1           3
OM      maxRecRes2           -3
OM      BioYrs1              2008
OM      BioYrs2              2017
OM      BioConst             FALSE
OM      SelYrs1              2008
OM      SelYrs2              2017
OM      SelConst             FALSE
OM      Obs
OM      refPts.Fpa           0.074
OM      refPts.Flim          0.103
OM      refPts.Fmsy          0.074
OM      refPts.Bpa           1168272
OM      refPts.Blim          834480
OM      refPts.MSYBtrigger   1168272
OM      refPts.Bloss         761613
OM      pBlim                0.05


MP      code                 MP5.23
MP      desc                 Double BP HCR
MP      xlab                 Double BP IAVBtrig
MP      HCRName              DoubleBP
MP      F_target1            0
MP      F_target2            0.025
MP      F_target3            0.05
MP      F_target4            0.075
MP      F_target5            0.1
MP      F_target6            0.125
MP      F_target7            0.15
MP      B_trigger            MSYBtrigger
MP      minTAC
```

```
MP      maxTAC
MP      TAC_IAV1           0.2
MP      TAC_IAV2           0.2
MP      Obs.cvF            0.22
MP      Obs.phiF           0.03
MP      Obs.cvSSB          0.36
MP      Obs.phiSSB         0.51

OTHER   niters             1000
OTHER   nyr                23
OTHER   CU                 2018-2020
OTHER   ST                 2021-2025
OTHER   MT                 2026-2030
OTHER   LT                 2031-2040
OTHER   flstock            WGWIDE19.RData
OTHER   flstock_sim        MSE_WGWIDE19_FLStocks_1k15PG.RData
```

10 Summary and conclusions

This report has brought together many different topics that are related to the western horse mackerel stock in an attempt to develop a potential rebuilding plan for the stock. Even though western horse mackerel was not classified by ICES as in need of rebuilding in their latest advice (ICES, 2019a), the general perception within the fishing industries has been that the stock has been in a poor state but that there have been some positive signals in recent recruitment. Using the new recruitments to improve the stock status requires a careful management approach. The PELAC has been a proponent of developing management plans for all stocks in their remit. In this case, the PELAC has termed the approach a rebuilding plan because of the current stock status of the stock.

Substantial progress has been made over the past few years on horse mackerel stock ID (Farrell et al., 2020). The full genome sequencing of horse mackerel from samples taken all the way from the Skagerrak to the Mediterranean and North Africa, has yielded a suitable panel of SNP markers that can be used to differentiate between the different horse mackerel stocks. The strongest differentiation between populations was between the northern and southern populations, with the boundary being in the middle of Portugal. The North Sea population is clearly distinct from the Western population and it should be possible to tell the difference from mixed samples with a high probability (>93%). This would also allow screening of catches in 7d and 7e on the contribution of western and North Sea populations. The separation between the northern and southern populations could mean that the current division between western and southern horse mackerel is not adequate, at the northern part of 9a is currently included in the southern population. A similar split in the middle of Portugal has also been observed for boarfish (Farrell et al., 2016) and could indicate a biogeographical feature.

Length compositions of the catches are an important element of the assessment approach for western horse mackerel, because Stock Synthesis uses length composition in combination with age-length key to estimate the age compositions within the model. Part of a rebuilding plan for western horse mackerel could be to evaluate differences in length compositions in the catches in certain areas and to take specific measures to protect incoming recruitment. Therefore, we planned to carry out an analysis of length compositions by area and season. However, we found that such data is not currently available for all years. Length data for western horse mackerel is not included in the ICES InterCatch database. Instead, length data has been processed on a year by year basis in non-standardized Excel spreadsheets. A time series of length compositions by area and season can therefore only be derived by manually working through the spreadsheets and extracting the required information. This was not feasible as part of the project to develop and evaluate a rebuilding plan for western horse mackerel. We recommend to WGWIDE that the full time series of catch at length by country is recreated from the Excel spreadsheets and converted in a standardized database format to allow for future interrogations of the data and an underpinning of the input data to the stock assessment.

In order to understand how a stock would respond to recovery measures, it is useful to consider the age composition in the spawning stock which illustrates how recruitment in the previous years contributed to the present spawning stock. To this end, an SSB per recruit analysis has been carried out. As one should expect for a relatively long-lived species with low mortality, the spawning stock is currently rather old. At F =0.075, the mean age is about 9 years, 80% is older than 5 years and 20% older than 12 years. So, an improved recruitment will take some time to materialize as increased SSB. The results also indicate that with a low F, the plus group still does matter.

The current stock assessment method for western horse mackerel is Stock Synthesis 3, as agreed in the WKWIDE benchmark of 2017 (ICES, 2017b). Reference point were also set at WKWIDE 2017 but have subsequently been updated in the IBPWHM 2019 (ICES, 2019b). In addition, an exploratory SAM assessment has been carried out as part of IBPWHM 2019. This was done in order to get a second view on stock trends but also to be able to run the SAM HCR forecast as part of the development of a potential rebuilding plan. The exploratory SAM assessment (https://www.stockassessment.org/setStock.php?stock=WHOM2018) was initiated with the same input data as was used for the Stock Synthesis assessment of WGWIDE 2018 (ICES, 2018) with the exception of the length frequency data, which was not used. The PELACUS survey data was therefore only used as an index of biomass within SAM. The process of fine-tuning the assessment lead to the binding of the observation variances for certain variables and to the application of a fixed selectivity pattern (correlation coefficient ρ=1 in the F random process (https://github.com/martinpastoors/wgwide/blob/master/R/HOM%20optimization_SAM.R). A comparison of Fbar and SSB between the SS3 assessments of WG2018 and 2019 with the SAM assessment (WG18SAM, WG19SAM), shows that the general trends are the same but that there are some deviations in certain periods (e.g. the SSB in the late 1980s is estimated substantially higher in SAM compared to SS3). The Stock Synthesis results are in general a bit smoother compared to SAM.

In order to be able to use the SAM assessment as an alternative assessment in the rebuilding plan evaluation, we needed to estimate reference point for this assessment. In doing so, we aimed to follow the same procedure as during IBPWHM 2019 (ICES, 2019b). However, one of the elements of the reference point estimation, triggered a more in-depth study: the role of assessment uncertainty parameter Fcv and Fphi. There has been little standardization in how Fcv and Fphi have been calculated in different benchmarks where reference points were estimated. Fcv is expected to capture the assessment error in the advisory year and Fphi is the autocorrelation in assessment error in the advisory year (ICES, 2014a). We documented the method for generating the input data for the calculations and explored the sensitivity of Fcv and Fphi to the assessment that was used (both for western horse mackerel and for Atlantic mackerel). We found that there can be a high dependence of Fphi on the assessment that is used to compare against the Fset. When the assessment that is used has values that are all higher or lower than the Fset values, then Fphi will be close to zero. To our knowledge, this behaviour of Fphi was unknown so far. We also found that the number of years that is used for calculating Fcv and Fphi may have an impact on the values. In the recommendations from WKMSYREF3 it is stated that 10 years (or more) should be taken. A further study should be undertaken to assessment the impacts of using different time periods for estimating Fcv and Fphi.

During the IBPWHM 2019, reference points were estimated for western horse mackerel based on the 2018 WGWIDE assessment and using default values for Fcv and Fphi (0.212 and 0.423) and using a segmented regression through Blim (segregBlim). In order to calculate reference points for the exploratory SAM assessment and to explore the sensitivity to the assessment year, reference points were calculated on the basis of the 2018 or 2019 assessments for SS and SAM. The reference points for the SAM assessment are based on the 2018 assessment. Bpa and Blim are lower than the values for the SS assessment, while the Fmsy is higher. The changes due the assessment year were minor for both the SS and SAM assessments.

RP	WG18	WG18SAM	WG19	WG19SAM
Blim	834480	611814	885341	612635
Flim	0.1107	0.1612	0.1049	0.1756
Fpa	0.07909	0.1152	0.07493	0.1254
MSYBtrigger	1168272	856540	1239478	857689
FMSY	0.09102	0.1262	0.08665	0.1353
FP05	0.08398	0.1255	0.07826	0.1402
FMSY_final	0.07909	0.1152	0.07493	0.1254

HCR evaluations

The HCR analyses represent two different assessment methods (SS3 and SAM) and two different HCR evaluation tools (EqSim and SAM HCR). Both HCR evaluation tools are of the type ‘short-cut’ with appropriate conditioning of the uncertainties in the assessment based on historical CV and autocorrelation in line with the recommendations from WKMSYREF3 and WKMSYREF4 . The evaluations followed the guidelines from WKGMSE2 (ICES, 2019c) and WKREBUILD (ICES, 2020).

Three different types of harvest control rules were evaluated:

- Constant F strategy: fixed Ftarget independent of biomass level
- ICES Advice Rule: breakpoint at Btrigger and straight decline in F to zero below Btrigger.
- Double Breakpoint rule: breakpoint at Btrigger and straight decline in F to 20% of Ftarget at Blim. Below Blim continued fishing at F = 0.2 * Ftarget.

For each of the HCRs, a number of different target fishing mortalities were explored (0.0, 0.05, 0.075, 0.1, 0.125, 0.15). No evaluation of different Btrigger values was carried out, so that all evaluations used MSY Btrigger as the trigger point. All HCRs where evaluated with three variants:

- Without any additional constraints

- With a minimum TAC of 50 kT
- With a maximum 20% inter-annual variation (IAV) in TAC, but only when the stock is above Btrigger)

Two simulation tools were used: the EqSim simulator and the SAM HCR forecast. The EqSim simulator is a further worked up version of the SimpSIM approach that was used for the blue whiting MSE in 2016 (ICES, 2016). The code was further developed by Andrew Campbell and Martin Pastoors to improve standardization, documentation and visualization of results. EqSim makes use of an Operating Model (OM) and a Management Procedure (MP). The SAM HCR forecast is a simple stochastic forecast with HCR to evaluate management for fish stocks that need rebuilding in the short-term. The stochastic forecasts start from what we believe is the current level of the stock with appropriate uncertainty, i.e. the assessment estimates currently used for tactical management advice, with consideration of the uncertainty in these estimates. Rebuilding is evaluated forward for a specified number of years and for different target fishing mortality values.

The EqSim with SS3 results indicate that the constant F strategy is the least cautious rule and the double breakpoint rule is the most cautious rule. Under the F strategy rule with a Ftarget of 0.075, rebuilding to Bpa is expected to be achieved is only just being achieved (probability just above 50%) by 2025, while in the double breakpoint rule this is expected to be achieved in 2024 with substantially higher probabilities of remaining above Bpa. The first year of rebuilding to Bpa in the double breakpoint rule with target fishing mortalities up to 0.1 is the same as the first year of rebuilding under the zero fishing scenarios.

Similar results have been obtained with the EqSim with SAM evaluations although the levels of SSB are slightly higher and risk to Blim is slightly lower. According to these evaluations, rebuilding to Bpa could be obtained by 2022 in all scenarios.

The SAM HCR with SAM evaluations have only been carried out for the ICES Advice Rule scenario, as this was intended more as a contrasting study rather than a full analysis of HCR evaluation. Again, we find similar patterns in simulated stock trends, but SSB is estimated higher than in the EqSim with SAM evaluations and risk to Blim stays below Blim for all target fishing mortalities that have been explored.

Given that the EqSim with SS3 evaluation is closest to the ICES advisory practice, this was used as the basis for the preferred rebuilding plan by the PELAC. The PELAC preferred options are:

- Target fishing mortality at Fmsy = 0.074 (approximated by 0.075 in the simulations)
- Blim at ICES Blim (834 480 t)
- Btrigger at ICES MSY Btrigger (1 168 272 t)
- Double breakpoint rule with 20% constraint on IAV above Btrigger
- Minimum F when stock is below Blim at 20% of Fmsy = 0.015

The selected rebuilding plan has a 50% probability of rebuilding to Blim by 2021 (similar to zero catch option) and a 50% probability of rebuilding to Bpa/MSY Btrigger by 2024 (similar to the zero-catch option). Furthermore, the probability of being below Blim remains well below 5% for the duration of the simulation.

In this scenario, the average catch in the years 2021-2025 is expected to be lower than recent catches. However, after rebuilding, catches should be able to be maintained around 100 000 tonnes.

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Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE, No. 5) ICES HQ, Copenhagen, Denmark, (digital meeting) 26. August – 1. September 2020

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 1st July – 4th August 2020

Leif Nøttestad, Valantine Anthonypillai, Are Salthaug, Åge Høines
Institute of Marine Research, Bergen, Norway

Anna Heiða Ólafsdóttir, James Kennedy
Marine and Freshwater Research Institute, Hafnarfjörður, Iceland

Eydna í Homrum, Leon Smith
Faroe Marine Research Institute, Tórshavn, Faroe Islands

Teunis Jansen, Søren Post
Greenland Institute of Natural Resources, Nuuk, Greenland

Kai Wieland
National Institute of Aquatic Resources, Denmark

Contents

1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from July 1st to August 4th in 2020 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 and 2019 ICES mackerel benchmarks. A standardised pelagic swept area trawl method is used to obtain the abundance index and to study the spatial distribution of mackerel in relation to other abundant pelagic fish stocks and to environmental factors in the Nordic Seas, as has been done annually since 2010. Another aim is to construct a new time series for blue whiting (*Micromesistius poutassou*) abundance index and for Norwegian spring-spawning herring (NSSH) (*Clupea harengus*) abundance index. This is obtained by utilizing standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations. The time series for blue whiting and NSSH have now been conducted for five years (2016-2020).

The mackerel index increased by 7.0% for biomass and 0.3% for abundance (numbers of individuals) compared to the 2019 index. In 2020, the most abundant year classes were 2010, 2016, 2011, 2013 and 2014, respectively. Overall, the cohort internal consistency continues to improve with a longer time series (2010-2020).

The survey coverage area was 2.9 million km² in 2020, which is similar as in previous years from 2017 to 2019. Furthermore, 0.26 million km² was surveyed in the North Sea in July 2020. Distribution zero boundaries were found in majority of the survey area with an exception of high mackerel abundance in the northwestern region of the Norwegian Sea into the Fram Strait west of Svalbard. The mackerel appeared less patchily distributed within the survey area and had a pronounced distribution in the central and northern Norwegian Sea in 2020 compared to previous years. This major difference in distribution consists of a substantial decline of mackerel in the west and corresponding increase in the central and northern part of the Norwegian Sea.

The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2020 was 20.3 billion and the total biomass index was 5.93 million tonnes, which is significantly higher than in 2019 (34% and 24%, respectively). The increase was due to the recruiting 2016 year-class coming strongly into the survey area. The herring stock is dominated by 4-year old herring (year class 2016) in terms of numbers (40%) and biomass (33%), but this year class is still mainly in the northeastern part of the Norwegian Sea. The 2013 year class (7 year old) is distributed in all areas with herring in the survey and it contributes 22% and 20% to the total biomass and abundance, respectively.

The total biomass of blue whiting registered during IESSNS 2020 was 1.8 million tons, which is an 11% decrease since 2019. The stock estimate in number of age groups 1+ for 2020 is 16.5 billion compared to 16.2 billion in 2019. Age group 1 is dominating the estimate in 2020 (22% and 35% of the biomass and by numbers, respectively, looking at age groups 1+). A good sign of recruiting year class (0-group) was also seen in the survey this year. Of the older age groups 6 year old blue whiting was most abundant.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred in the southern and south-western parts of the Norwegian Sea, and with the strong 2016 year class of NSSH, there was also overlap in the central and north eastern part of the Norwegian Sea. In the eastern Norwegian sea between 62-67°N, mackerel were present but herring were in low abundance, in contrast, in areas north of Iceland, herring were present while mackerel were absent. Older and younger herring were spatially segregated with larger herring distributed to the east and north of Iceland and in the southern Norwegian Sea, while young herring were found in the northeastern Norwegian Sea.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 74% of surface trawl stations distributed across the surveyed area from Cape

Farwell, Greenland, to western part of the Barents Sea. Abundance was greater north of latitude 66 °N compared to southern areas. A total of 54 Atlantic salmon were caught in 30 stations both in coastal and offshore areas from 60°N to >77°N in the upper 30 m of the water column. The salmon ranged from 0.084 kg to 2.73 kg in weight, dominated by postsmolt weighing 100-180 grams and 1 sea-winter individuals weighing 1-2 kg.

Satellite measurements of the sea surface temperature (SST) showed that the eastern part of the Norwegian Sea and coastal waters of east Greenland in July 2020 was higher, while the western part of the Norwegian Sea, the waters south of Iceland, in the Irminger Sea and around the Faroe islands in July 2020 was broadly similar, to the average for July 1990-2009. The upper layer (10 m depth) was 1.0-2.0°C colder in 2020 compared to 2019 in most of Icelandic and Greenland waters but along the Norwegian coast, the temperature was 1.0-2.0°C warmer in 2020 compared to 2019.

Zooplankton biomass decreased from 2018-2020 in both Greenlandic and Icelandic waters. Average zooplankton biomass in the Norwegian Sea has been relatively stable over the years of the survey.

2 Introduction

During approximately five weeks of survey in 2020 (1st of July to 4th of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Tróndur í Gøtu" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland, the M/V "Eros" operating in Greenland waters and M/V "Ceton" operating in the North Sea by Danish scientists, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS).

The main aim of the coordinated IESSNS was to collect data on abundance, distribution, migration and ecology of Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) during its summer feeding migration phase in the Nordic Seas. The resulting abundance index will be used in the stock assessment of NEA mackerel at the annual meeting of ICES working group of widely distributed stocks (WGWIDE). The IESSNS mackerel index time series goes back to 2010. Since 2016, systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) have also been conducted. This is considered as potential input for stock assessment, when the time series are sufficiently long. Furthermore, the IESSNS is a pelagic ecosystem survey collecting data on physical oceanography, plankton and other fish species such as lumpfish and Atlantic salmon. Opportunistic whale observations are also recorded. The wide geographical coverage, standardization of methods, sampling on many trophic levels and international cooperation around this survey facilitates research on the pelagic ecosystem in the Nordic Seas, see e.g. Nøttestad et al. (2016), Olafsdottir et al. (2019), Bachiller et al. (2018), Jansen et al. (2016), Nikolioudakis et al. (2019).

The methods have evolved over time since the survey was initiated by Norway in the Norwegian Sea in the beginning of the 1990s. The main elements of standardization were conducted in 2010. Smaller improvements have been implemented since 2010. Faroe Islands and Iceland have participated in the joint mackerel-ecosystem survey since 2009. Greenland since 2013 and Denmark from 2018.

The North Sea was included in the survey area for the third time in 2020, following the recommendations of WGWIDE. This was done by scientists from DTU Aqua, Denmark. The commercial fishing vessels "Ceton S205" was used, and in total 35 stations (CTD and fishing with the pelagic Multpelt 832 trawl) were successfully conducted. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths deeper than 50 m and no plankton samples were taken (see Appendix 1 for comparison with 2018 and 2019 results).

3 Material and methods

Coordination of the IESSNS 2020 was done during the WGIPS 2020 meeting in January 2020 in Bergen, Norway, and by correspondence in spring and summer 2020. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calm with good survey conditions for all six vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. However, several of the vessels experienced more wind than in previous years. The weather was fairly good and calm for the two Norwegian vessels except for a few days of fog in the northernmost part of the Norwegian Sea influencing the visual observations. The Icelandic vessel, operating in Icelandic waters, the Iceland basin and the Irminger Sea, encounter unusually many stormy days with a total of 6 days where wind conditions hampered plankton sampling and demanded reduced sailing speed for acoustic recordings. The weather was mostly calm for the Faroese vessel operating mainly in Faroese waters. The chartered vessel Ceton had excellent weather throughout the survey.

During the IESSNS, the special designed pelagic trawl, Multpelt 832, has now been applied by all participating vessels since 2012. This trawl is a product of cooperation between participating institutes in designing and constructing a standardized sampling trawl for the IESSNS. The work was lead by trawl gear scientist John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway (Valdemarsen et al. 2014). The design of the trawl was finalized during meetings of fishing gear experts and skippers at meetings in January and May 2011. Further discussions on modifications in standardization between the rigging and operation of Multpelt 832 was done during a trawl expert meeting in Copenhagen 17-18 August 2012, in parallel with the post-cruise meeting for the joint ecosystem survey, and then at the WKNAMMM workshop and tank experiments on a prototype (1:32) of the Multpelt 832 pelagic trawl, conducted as a sequence of trials in Hirtshals, Denmark from 26 to 28 February 2013 (ICES 2013a). The swept area methodology was also presented and discussed during the WGISDAA workshop in Dublin, Ireland in May 2013 (ICES 2013b). The standardization and quantification of catchability from the Multpelt 832 pelagic trawl was further discussed during the mackerel benchmark in Copenhagen in February 2014. Recommendations and requests coming out of the mackerel benchmark in February 2014, were considered and implemented during the IESSNS survey in July-August 2014 and in the surveys thereafter. Furthermore, recommendations and requests resulting from the mackerel benchmark in January-February 2017 (ICES 2017), were carefully considered and implemented during the IESSNS survey in July-August 2017. In 2018, the Faroese and Icelandic vessels employed new, redesigned cod-ends with the capacity to hold 50 tonnes. This was done to avoid the cod-end from bursting during hauling of large catches as occurred at three stations in the 2017 IESSNS.

Table 1. Survey effort by each of the five vessels during the IESSNS 2020. The number of predetermined ("fixed") trawl stations being part of the swept-area stations for mackerel in the IESSNS are shown after the total number of trawl stations (* including 2 days of capelin study).

Vessel	Effective survey period	Length of cruise track (nmi)	Total trawl stations/ Fixed stations	CTD stations	Plankton stations
Árni Friðriksson	1/7-30/7	5596	65/58	60	48
Tróndur í Gøtu	2-17/7	2600	43/38	38	38
Eros	16/7-4/8	2535*	34/33	37	33
Ceton	1/7-9/7	1720	35/35	35	-
Vendla	3/7-3/8	5346	90/77	78	78
Kings Bay	3/7-3/8	5377	86/74	74	70
Total	1/7-4/8	23174	353/315	322	267

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Árni Friðriksson was equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. Tróndur í Gøtu was equipped with a mini SEABIRD SBE 25+ CTD sensor, Kings Bay and Vendla were both equipped with Seabird CTD sensors. Eros used a SEABIRD 19+V2 CTD sensor. Ceton used a Seabird SeaCat 4 CTD. The CTD-sensors were used for recording temperature, salinity and pressure (depth) from the surface down to 500 m, or to the bottom when at shallower depths.

Zooplankton was sampled with a WP2-net on 5 of 6 vessels, Ceton did not take any plankton samples. Mesh sizes were 180 µm (Kings Bay and Vendla) and 200 µm (Árni Friðriksson, Tróndur í Gøtu and Eros). The net was hauled vertically from a depth of 200 m (or bottom depth at shallower stations) to the surface at a speed of 0.5 m/s. All samples were split in two, one half preserved for species identification and enumeration, and the other half dried and weighed. Detailed description of the zooplankton and CTD sampling is provided in the survey manual (ICES 2014a).

Not all planned CTD and plankton stations were taken due to bad weather. The number of stations taken by the different vessels is provided in Table 1.

3.2 Trawl sampling

All vessels used the standardized Multpelt 832 pelagic trawl (ICES 2013a; Valdemarsen et al. 2014; Nøttestad et al. 2016) for trawling, both for fixed surface stations and for trawling at greater depths to confirm acoustic registrations. Standardization of trawl deployment was emphasised during the survey as in previous years (ICES 2013a; ICES 2014b; ICES 2017). Sensors on the trawl doors, headrope and ground rope of the Multpelt 832 trawl recorded data, and allowed live monitoring, of effective trawl width (actually door spread) and trawl depth. The properties of the Multpelt 832 trawl and rigging on each vessel is reported in Table 2.

Trawl catch was sorted to the highest taxonomical level possible, usually to species for fish, and total weight per species recorded. The processing of trawl catch varied between nations as the Norwegian, Icelandic and Greenlandic vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting. Sub-sample size ranged from 60 kg (if it was clean catch of either herring or mackerel) to 150 kg (if it was a mixture of herring and mackerel), however, all lumpfish were picked out from the total catch. The biological sampling protocol for trawl catch varied between nations in number of specimens sampled per station (Table 3).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 1st July to 4th August 2020. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Kings Bay**	**Árni Friðriksson**	**Vendla**	**Ceton**	**Tróndur í Gøtu**	**Eros**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynex	Dynema – 30 mm	Dynex-34 mm	+
Warp length during towing	350	350	350	300-350	350	340-347	0
Difference in warp length port/starb. (m)	2-10	16	2-10	10	0-15	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×400	2×500	0
Setback (m)	6	14	6	6	6	6	+
Type of trawl door	Seaflex 7.5 m² adjustable hatches	Jupiter	Seaflex 7.5 m² adjustable hatches	Thybron type 15	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	1970	2000	2000	+
Area trawl door (m²)	7.5 with 25% hatches (effective 6.5)	6	7.5 with 25% hatches (effective 6.5)	7	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	4.72 (4.3-5.3)	5.1 (4.5-5.8)	4.89 (4.1-5.5)	4.8 (4.0-5.3)	4.9 (4.4-5.4)	4.9 (4.1-5.9)	+
Trawl height (m) mean (min-max)	28-40	36 (28-45)	28-37	31 (24-39)	45.5 (40.5-49.5)	-	+
Door distance (m) mean (min-max)	118.3 (115-120)	101.3 (90 - 113)	121.8 (118-126)	127 (115-139)	99.1 (94 – 104)	118 (113-121)	+
Trawl width (m)*	65.8	60.6	68.0	70.54	57.2	66.5	+
Turn radius (degrees)	5-10	5	5-12	5-10	5-10 BB turn	6-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	5-15, 7-18	12-12, 4-31	6-22, 8-23	4-16	4-20, 5-19	(11.4-11)	+
Headline depth (m)	0	0	0	0	0	0-1	+
Float arrangements on the headline	Kite with fender buoy +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite with fender buoy +2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite with fender buoy + 1 buoy on each wingtip	Kite + 1 buoy on each wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	All weighed	All weighted	+

* calculated from door distance

Table 3. Protocol of biological sampling during the IESSNS 2020. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Greenland	Iceland	Norway	Denmark
Length measurements	Mackerel	100	100/50*	150	100	≥ 100 (separated in small and large category if appropriate)
	Herring	100	100/50*	200	100	
	Blue whiting	100	100/50*	100	100	
	Lumpfish	All	All	all	all	all
	Salmon	-	All	all	all	-
	Other fish sp.	100	25/25	50	25	As appropriate
Weight, sex and maturity determination	Mackerel	15-25	25	50	25	***
	Herring	15-25	25	50	25	0
	Blue whiting	5-50	25	50	25	0
	Lumpfish	10		1^	25	0
	Salmon	-		0	25	0
	Other fish sp.	0	0	0	0	0
Otoliths/scales collected	Mackerel	15-25	25	25	25	***
	Herring	15-25	25	50	25	0
	Blue whiting	5-50	25	50	25	0
	Lumpfish	0	0	1	0	0
	Salmon	-	0	0	0	0
	Other fish sp.	0	0	0	0	0
Fat content	Mackerel	0	50	10**	0	0
	Herring	0	0	10**	0	0
	Blue whiting	0	50	10	0	0
Stomach sampling	Mackerel	5	20	10**	10	0
	Herring	5	20	10**	10	0
	Blue whiting	5	20	10	10	0
	Other fish sp.	0	0	0	10	0
Tissue for genotyping	Mackerel	0	0	0	0	0
	Herring	0	0	0	0	0

*Length measurements / weighed individuals
**Sampled at every third station
*** One fish per cm-group ≤ 25 cm and two fish > 25 cm from each station was weighed and aged.
^All live lumpfish were tagged and released, only otoliths taken from fish which were dead when brought aboard

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 and 5 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and possible escapement from the cod end and through meshes. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. No light source was employed with cameras; hence, recordings were limited to day light hours. Some recordings were also taken during nighttime when there was midnight sun and good underwater visibility. Video recordings were collected at 89 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by scientific personnel and crew members from the bridge between 3rd July and 2nd August 2020 onboard M/V "Kings Bay" and M/V "Vendla". Marine mammal observations were conducted, during the day (weather permitting), by a dedicated whale observer aboard R/V Árni Friðriksson from 1st until 13th July 2020. Opportunistic observations were also done from the bridge by crew members between 1st and 30th July 2020.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson", M/V "Eros", M/V "Kings Bay" and M/V "Vendla" were tagged with Peterson disc tags and released. When the catch was brought aboard, any lumpfish caught were transferred to a tank with flow-through sea water. After the catch of other species had been processed, all live lumpfish larger than ~15 cm were tagged. The tags consisted of a plastic disc secured with a titanium pin which was inserted through the rear of the dorsal hump. Contact details of Biopol (www.biopol.is) were printed on the tag. The fish were returned to the tank until all fish were tagged. The fish were then released, and the time of release was noted which was used to determine the latitude and longitude of the release location.

3.5 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 2nd July 2020 for 18, 38, 70, 120 and 200 kHz. Onboard Kings Bay there were permanent noise challenges on the multifrequency acoustics including the 38kHz transducer during the entire survey. This noise problem predominantly influenced waters deeper than 200 m and could not be solved during the survey. The noise problem was much less at low speed (<5 knots) compared to high cruising speed (10 knots). Árni Friðriksson was calibrated in early May 2020 for the frequencies 18, 38, 70, 120 and 200 kHz. On Árni, EK80 transceivers were installed recently, there were some unusual noise problems in the backscatter and intermittent technical problems which prevented acoustic recordings a few times when vessel was on transport transect causing lack of acoustic track. Tróndur í Gøtu was calibrated on 26th June 2020 for 38 kHz and due to noise problems the first week; it was again calibrated 8th July after the issue had been resolved. Because of the noise issues, data from Tróndur í Gøtu south of Faroes were only usable down to 150 m. Calibration of the acoustic equipment onboard Eros was done after the cruise on the 2nd of August. All frequencies were calibrated successfully. Ceton did not conduct any acoustic data collection because no calibrated equipment was available. All the other vessels used standard hydro-acoustic calibration procedure for each operating frequency (Foote 1987). CTD measurements were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

Acoustic recordings were scrutinized to herring and blue whiting on daily basis using the post-processing software (LSSS, see Table 4 for details of the acoustic settings by vessel). Acoustic measurements were not conducted onboard Ceton in the North Sea. Species were identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms.

To estimate the abundance from the allocated NASC-values the following target strengths (TS) relationships were used.

Blue whiting: TS = 20 log(L) – 65.2 dB (rev. acc. ICES CM 2012/SSGESST:01)
Herring: TS = 20.0 log(L) – 71.9 dB

Table 4. Acoustic instruments and settings for the primary frequency (38 kHz) during IESSNS 2020.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu 250620	M/V Tróndur í Gøtu 080720	Eros
Echo sounder	Simrad EK80	Simrad EK 80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	38,120, 200	38,120, 200	18, 38, 70, 120, 200, 333
Primary transducer	ES38-7	ES38-7	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull	Hull
Transducer depth (m)	9	8	9	7	7	8
Upper integration limit (m)	15	15	15	Not used	Not used	15
Absorption coeff. (dB/km)	9.6	10.0	10.1	9.7	9.7	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43		2.43	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.90	18	21.90	21.9	21.9	21.9
2-way beam angle (dB)	-20.70	-20.3	-20.70	-20.6	-20.6	-20.7
TS Transducer gain (dB)	26.33	26.9	25.46	23.44	24.09	25.50
s_A correction (dB)	-0.03	-0.02	-0.02	-0.65	-0.65	-0.6
alongship:	-0.28	6.53	0.19	7.42	7.20	6.86
athw. ship:	0.00	6.5	0.08	7.09	7.03	7.05
Maximum range (m)	500	500	500	500	500	750 for 18 and 38 kHz 500 for 70, 120 and 200 kHz
Post processing software	LSSS v.2.8.1	LSSS v.2.8	LSSS v.2.8.1	LSSS 2.8.0	LSSS 2.8.0	LSSS v.2.8

* No acoustic data collection

Multibeam sonar

Both M/V Kings Bay and M/V Vendla were equipped with the Simrad fisheries sonar SH90 (frequency range: 111.5-115.5 kHz), with a scientific output incorporated which allow the storing of the beam data for post-processing. Acoustic multibeam sonar data was stored continuously onboard Kings Bay and Vendla for the entire survey.

Cruise tracks

The six participating vessels followed predetermined survey lines with predetermined surface trawl stations (Figure 1). Calculations of the mackerel index are based on swept area approach with the survey area split into 13 strata, permanent and dynamic strata (Figure 2). Distance between predetermined surface trawl stations is constant within stratum but variable between strata and ranged from 35-90 nmi. The survey design using different strata is done to allow the calculation of abundance indices with uncertainty estimates, both overall and from each stratum in the software program StoX (see Salthaug et al. 2017). Temporal survey progression by vessel along the cruise tracks in July-August 2020 is shown in Figure 3. The cruising speed was between 10-12 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

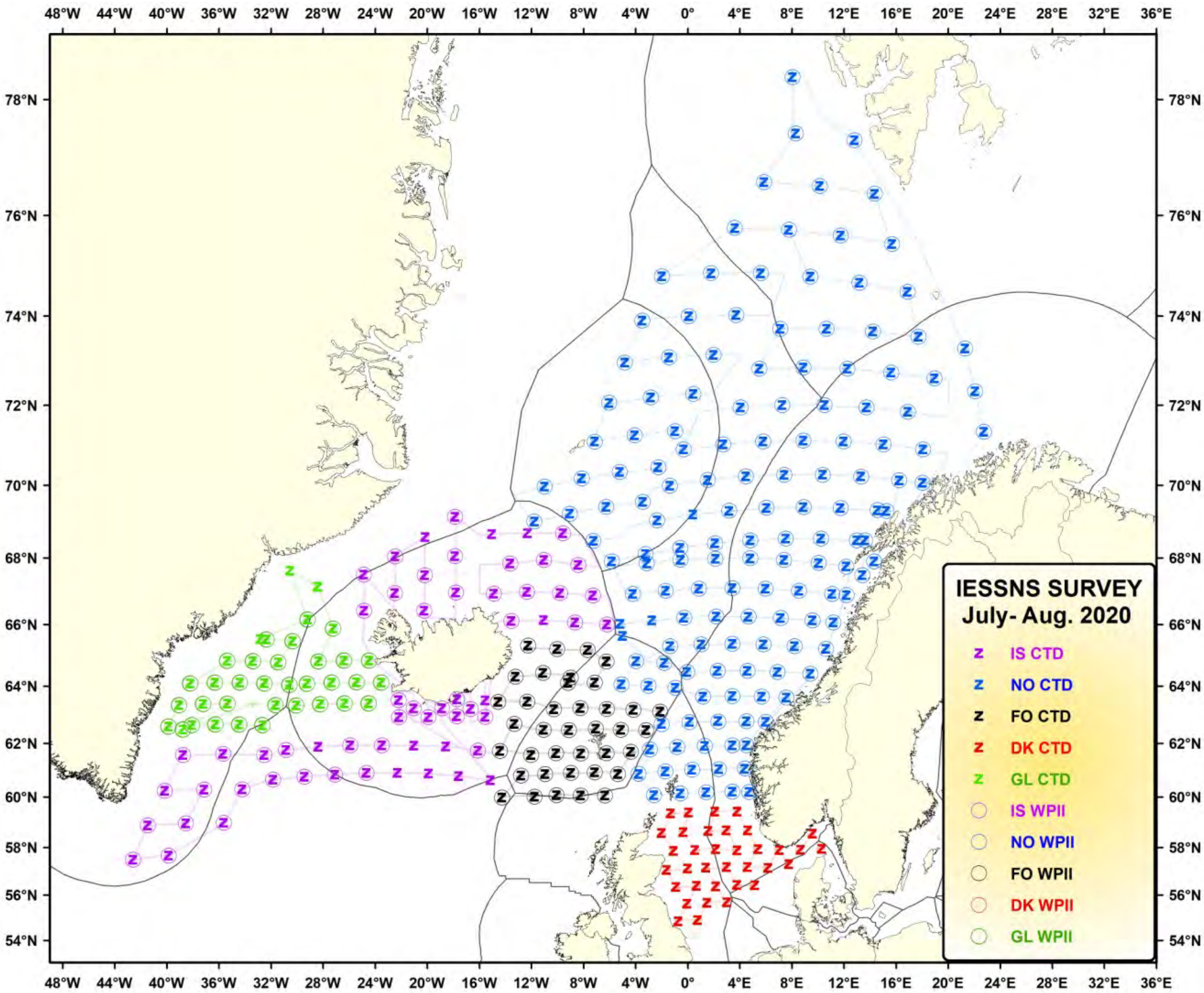

Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 1st July – 4th August 2020. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue), Eros (green) and Ceton (red).

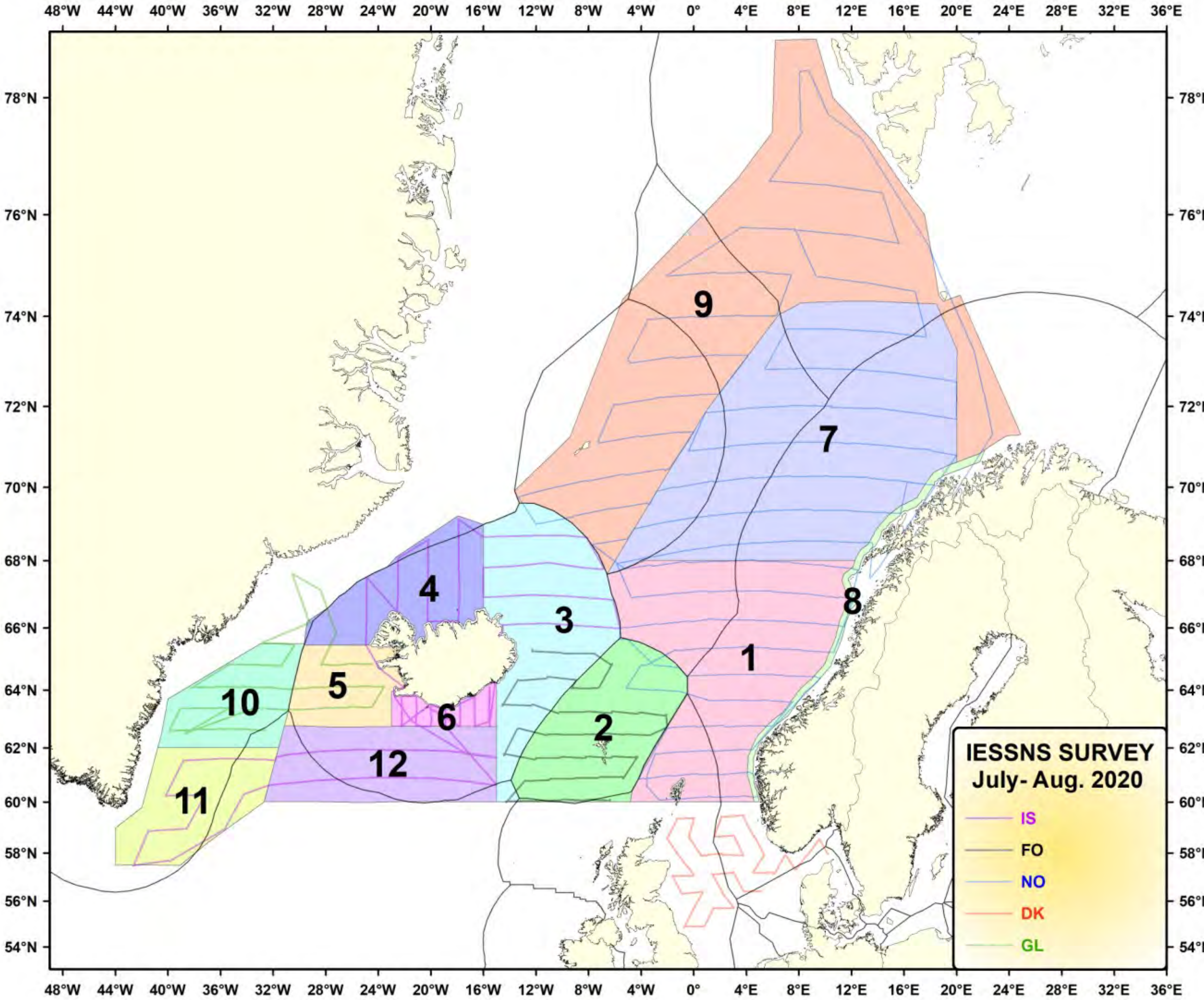

Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2020. The dynamic strata are: 4, 9 and 11.

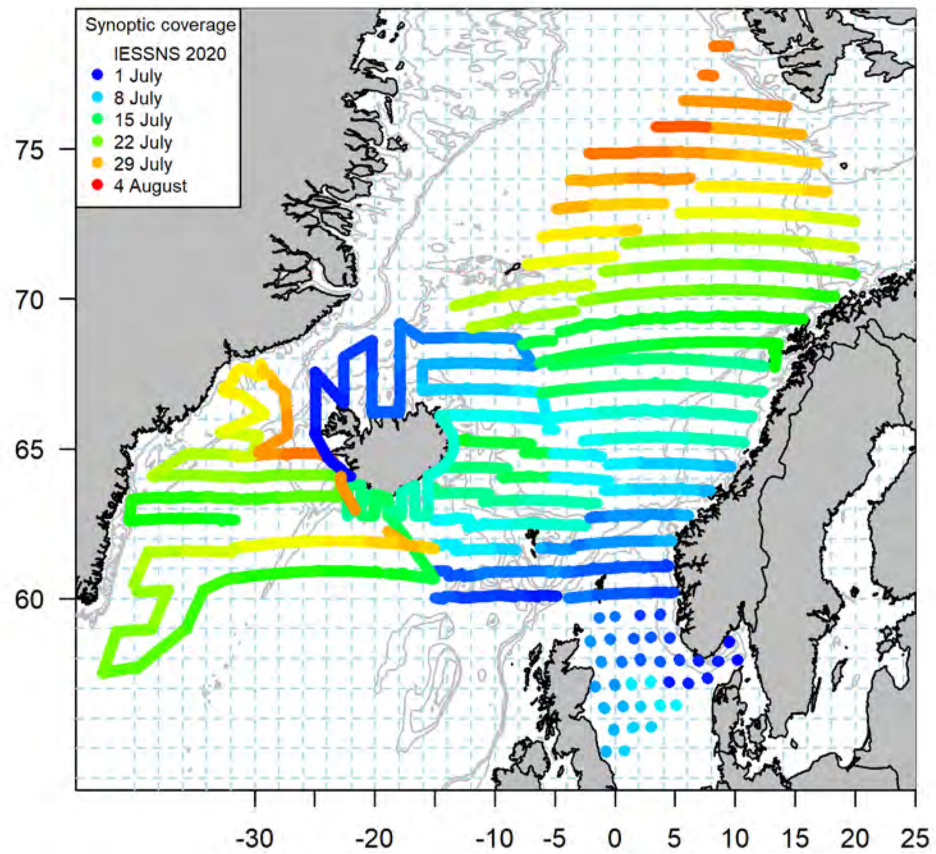

Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2020: blue represents effective survey start (1st of July) progressing to red representing a five-week span (survey ended 4th of August). As Ceton did not record acoustics, they have been represented by station positions.

3.6 StoX

Stox is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. A description of Stox can be found in Johnsen et al. (2019). The software, with examples and documentation, can be found at: http://www.imr.no/forskning/prosjekter/stox/nb-no. The program is a stand-alone application built with Java for easy sharing and further development in cooperation with other institutes. The underlying high-resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high-resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990) is implemented. Mackerel, herring and blue whiting indices were calculated using the StoX software package (version 2.7).

3.7 Swept area index and biomass estimation

The swept area age segregated index is calculated separately for each stratum (see stratum definition in Figure 2). Individual stratum estimates are added together to get the total estimate for the whole survey area which is approximately defined by the area between 55°N and 79°N and 43°W and 23°E in 2020. The density of mackerel on a trawl stations is calculated by dividing the total number caught by the assumed area swept by the trawl. The area swept is calculated by multiplying the towed distance by the horizontal opening of the trawl. The horizontal opening of the trawl is vessel specific, and the average value across all hauls is calculated based on door spread (Table 5 and Table 6). An estimate of total number of mackerel in a stratum is obtained by taking the average density based on the trawl stations in the stratum and multiplying this with the area of the stratum.

Table 5. Descriptive statistics for trawl door spread, vertical trawl opening and tow speed for each vessel during IESSNS 2020. Number of trawl stations used in calculations is also reported. Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (details in Table 6).

	Tróndur í Gøtu	RV Árni Friðriksson	Kings Bay	Vendla	Eros	Ceton
Trawl doors horizontal spread (m)						
Number of stations	37	58	74	78	33	35
Mean	99.1	101.3	118.3	121.8	115.2	127
max	104	113	135	129	134	139
min	94	90	110	107	100	114
st. dev.	2.2	5.1	2.84	4.6	5.2	5.7
Vertical trawl opening (m)						
Number of stations	37	58	74	78	33	35
Mean	45.5	36.4	33.6	30.3	34.9	31
max	49.5	45.0	40	40	44.8	39
min	40.5	27.5	29	25	29.2	24
st. dev.	2.0	3.8	2.9	3.0	3.2	3.9
Horizontal trawl opening (m)						
mean	57.2	60.6	65.8	68.0	67.4	70.5
Speed (over ground, nmi)						
Number of stations	38	58	74	78	33	35
mean	4.55	5.1	4.72	4.89	4.9	4.8
max	4.8	4.5	5.7	5.7	5.4	5.3
min	4.3	5.8	4.1	4.4	4.4	4.0
st. dev.	0.1	0.2	0.30	0.29	0.3	0.3

Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (Table 6). The estimates in the formulae were based on flume tank simulations in 2013 (Hirtshals, Denmark) where formulas were developed from the horizontal trawl opening as a function of door spread, for two towing speeds, 4.5 and 5 knots:

Towing speed 4.5 knots: Horizontal opening (m) = 0.441 * Door spread (m) + 13.094

Towing speed 5.0 knots: Horizontal opening (m) = 0.3959 * Door spread (m) + 20.094

Table 6. Horizontal trawl opening as a function of trawl door spread and towing speed. Relationship based on simulations of horizontal opening of the Multpelt 832 trawl towed at 4.5 and 5 knots, representing the speed range in the 2014 survey, for various door spread. See text for details. In 2017, the towing speed range was extended from 5.0 to 5.2, and in 2020 the door spread was extended to 122 m.

	Towing speed							
Door spread(m)	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2
100	57.2	57.7	58.2	58.7	59.2	59.7	60.2	60.7
101	57.6	58.1	58.6	59.1	59.6	60.1	60.6	61.1
102	58.1	58.6	59.0	59.5	60.0	60.5	61.0	61.4
103	58.5	59.0	59.5	59.9	60.4	60.9	61.3	61.8
104	59.0	59.4	59.9	60.3	60.8	61.3	61.7	62.2
105	59.4	59.9	60.3	60.8	61.2	61.7	62.1	62.6
106	59.8	60.3	60.7	61.2	61.6	62.1	62.5	62.9
107	60.3	60.7	61.2	61.6	62.0	62.5	62.9	63.3
108	60.7	61.1	61.6	62.0	62.4	62.9	63.3	63.7
109	61.2	61.6	62.0	62.4	62.8	63.2	63.7	64.1
110	61.6	62.0	62.4	62.8	63.2	63.6	64.1	64.5
111	62.0	62.4	62.8	63.2	63.6	64.0	64.4	64.8
112	62.5	62.9	63.3	63.7	64.0	64.4	64.8	65.2
113	62.9	63.3	63.7	64.1	64.4	64.8	65.2	65.6
114	63.4	63.7	64.1	64.5	64.9	65.2	65.6	66.0
115	63.8	64.2	64.5	64.9	65.3	65.6	66.0	66.3
116	64.3	64.6	65.0	65.3	65.7	66.0	66.4	66.7
117	64.7	65.0	65.4	65.7	66.1	66.4	66.8	67.1
118	65.1	65.5	65.8	66.1	66.5	66.8	67.1	67.5
119	65.6	65.9	66.2	66.6	66.9	67.2	67.5	67.9
120	66.0	66.3	66.6	67.0	67.3	67.6	67.9	68.2
121	66.5	66.8	67.1	67.4	67.7	68.0	68.3	68.6
122	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0

4 Results and discussion

4.1 Hydrography

Satellite measurements of sea surface temperature (SST) in the eastern part of the Norwegian Sea in July 2020 was slightly higher (0.5-1°C) compared to the average for July 1990-2009 based on SST anomaly plot (Figure 4). Surface temperature in the western part of the Norwegian Sea in July 2020 was broadly similar compared to the average (Figure 4). The coastal regions of Greenland were 1-2°C warmer than the average while in the waters south of Iceland, in the Irminger Sea and around the Faroe islands, the SST was similar to the average for July 1990-2009 (Figure 4). This contrasts with the situation in 2019 when SST in the coastal areas of Greenland were 2-3°C warmer and the waters south of Iceland, in the Irminger Sea and around the Faroe islands were 1-2°C warmer than the average. The pattern of anomalies of Sea Surface Temperature in July 2020 was quite different from the other years in the time series from 2010 to 2019.

It must be mentioned that the NOAA SST are sensitive to the weather condition (i.e. wind and cloudiness) prior to and during the observations and do therefore not necessarily reflect the oceanographic condition of the water masses in the areas, as seen when comparing detailed in situ features of SSTs between years (Figures 5-8). However, since the anomaly is based on the average for the whole month of July, it should give representative results of the surface temperature.

In situ measurements showed the upper layer (10 m depth) was 1.0-2.0°C colder in 2020 compared to 2019 in most of Icelandic and Greenland waters but 1.0-2.0°C warmer in 2020 compared to 2019 along the Norwegian coast (Figure 5). The temperature in the upper layer was higher than 8°C in most of the surveyed area, except along the north-western fringes of the surveyed areas north of Iceland where it was lower. In the deeper layers (50 m and deeper; Figure 6-8), the hydrographical features in the area were similar to the last four years (2014-2018) except around the Faroe Islands where temperature at 100 m depth was about 1°C warmer. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

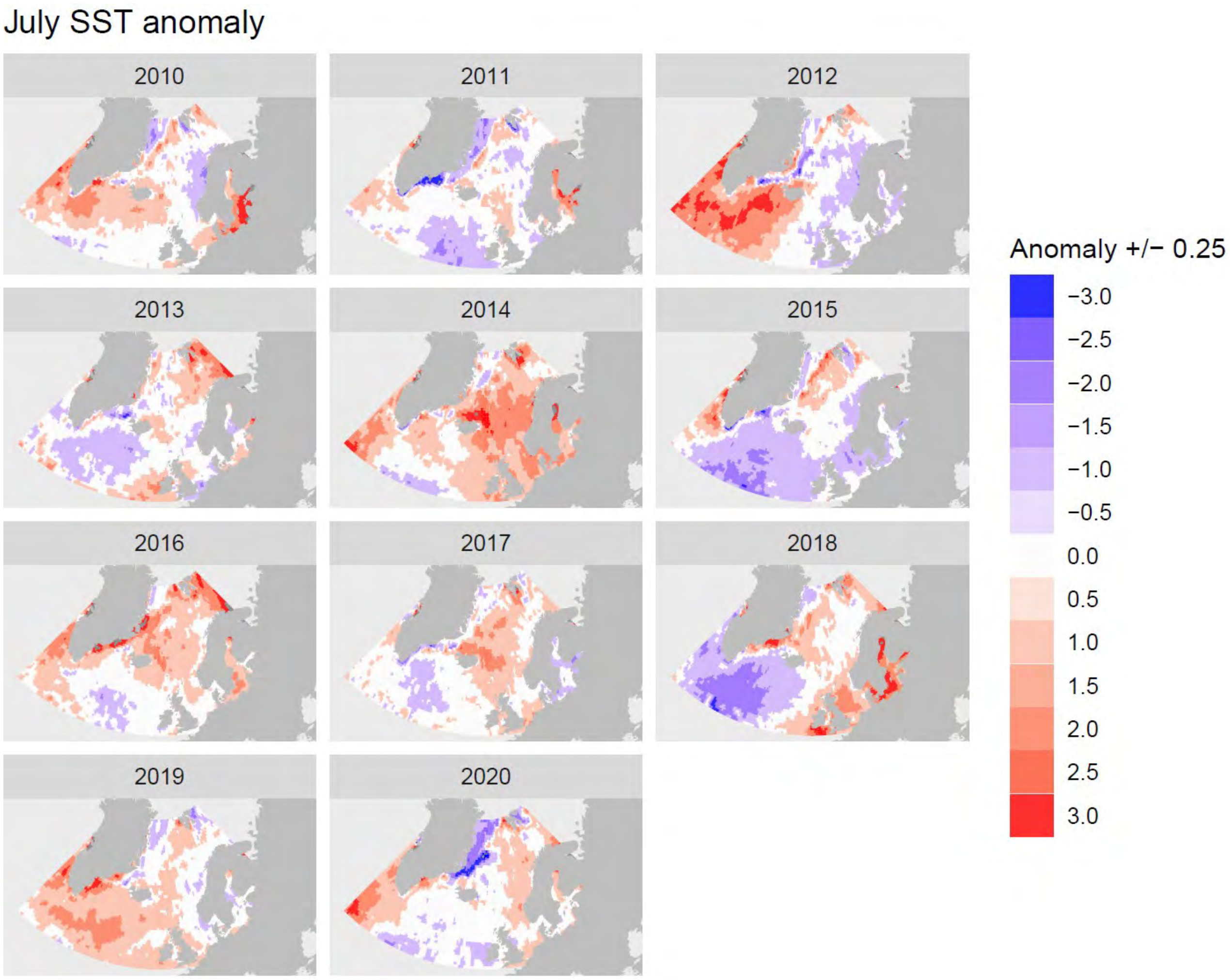

Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2020 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

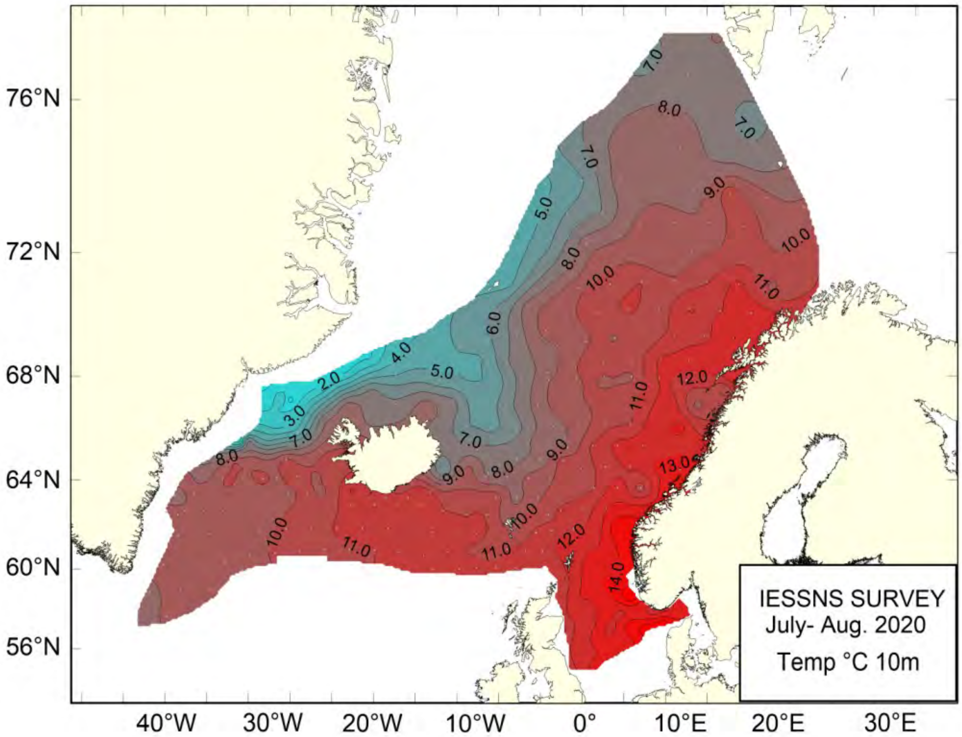

Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2020.

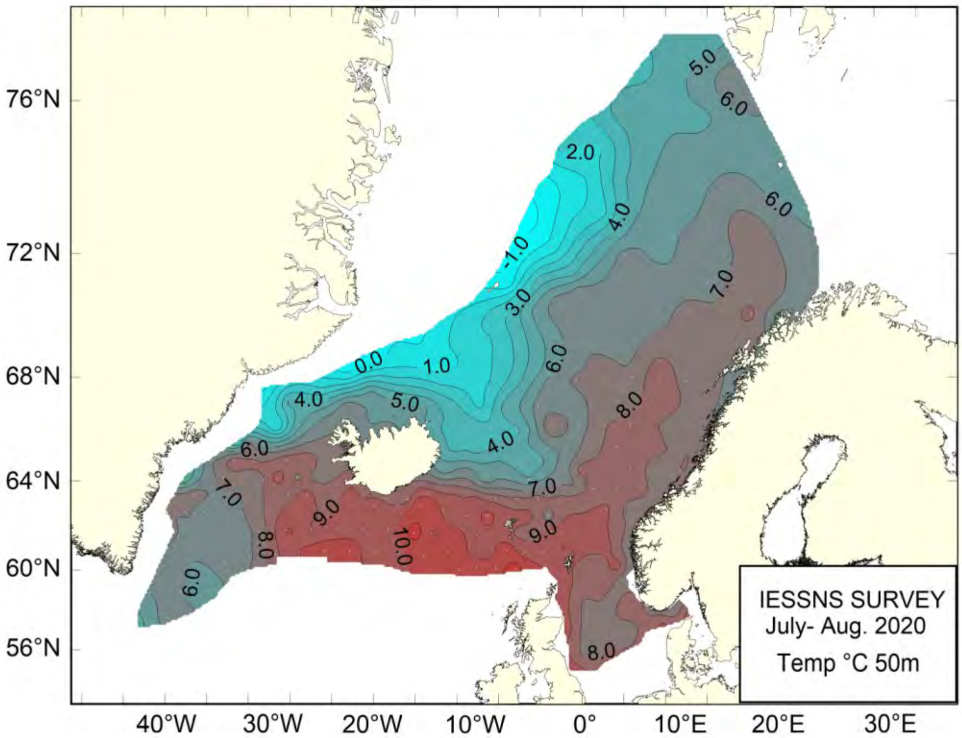

Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2020.

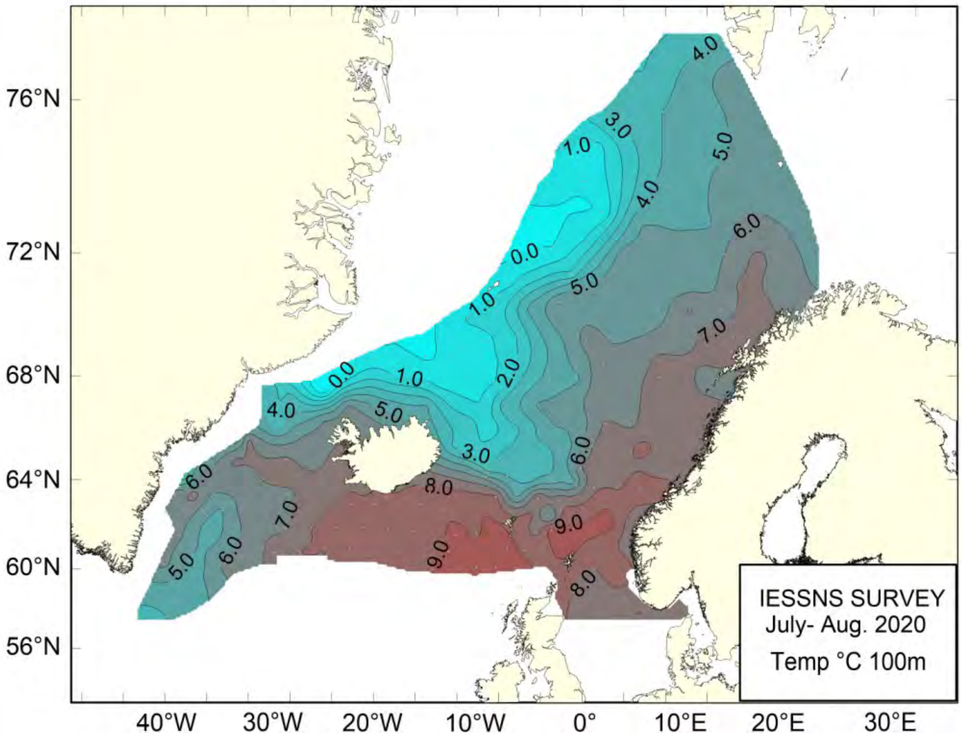

Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2020.

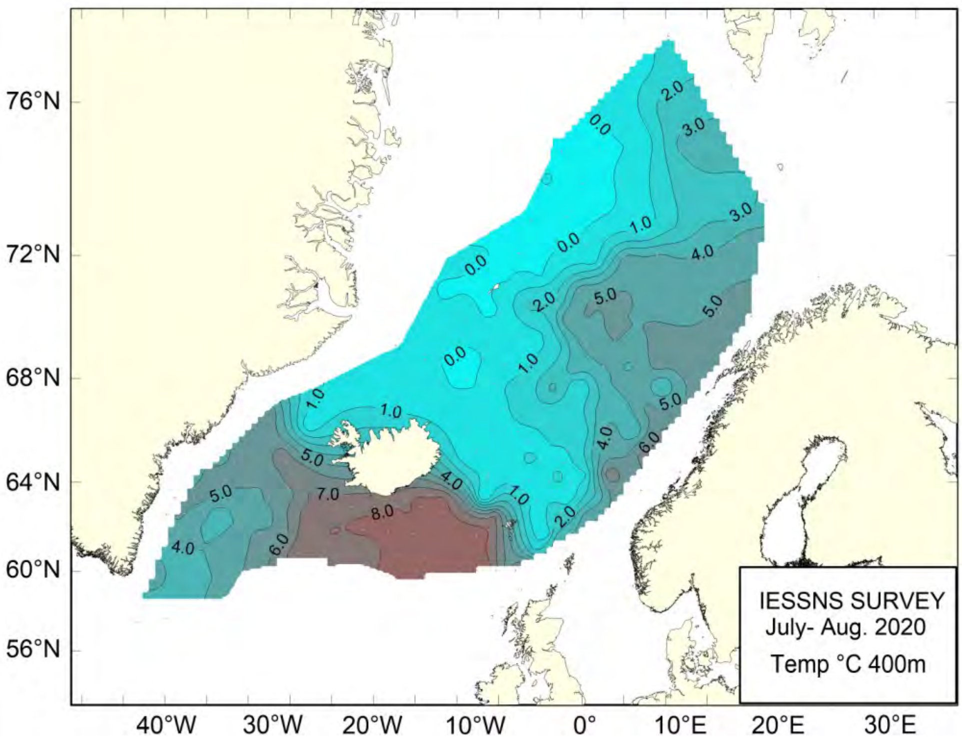

Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2020.

4.2 Zooplankton

Zooplankton biomass varied between areas and was lowest in Greenland waters, which contrasts with the previous 3 years where zooplankton biomass was the highest of the three areas (Figure 9a). In Greenland waters in 2020, the average zooplankton biomass has decreased substantially from 2018, it was 5.5 g m^{-2} in 2020 compared to 10.0 g m^{-2} in 2019 and 16.4 g m^{-2} in 2018. Average zooplankton biomass in Icelandic waters also showed a decrease from 2018 through to 2020, respectively declining from 10.8 g m^{-2} to 6.1 g m^{-2}. Through the time series from 2012-2020, the average zooplankton biomass is correlated in Icelandic and Greenlandic waters ($R^2 = 0.73$).

The average zooplankton biomass in Norwegian waters was similar to the average biomass in 2019. In this relatively short time-series, there is greater fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea.

These plankton indices should be treated with some caution as it is only a snapshot of the standing stock biomass, not of the actual production in the area, which complicates spatio-temporal comparisons.

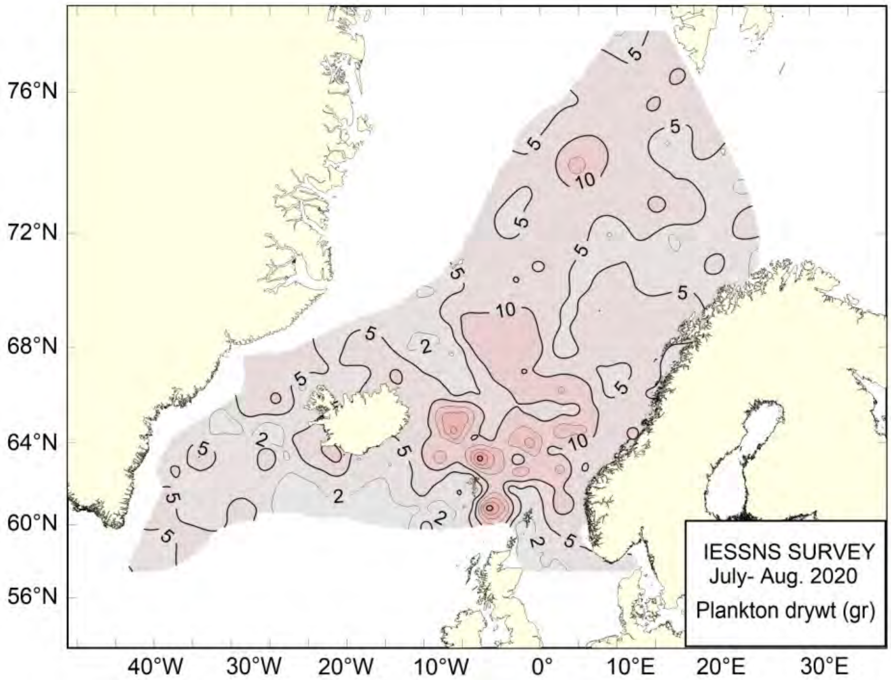

Figure 9a. Zooplankton biomass indices (g dw/m^2, 0-200 m) in Nordic Seas in July-August.

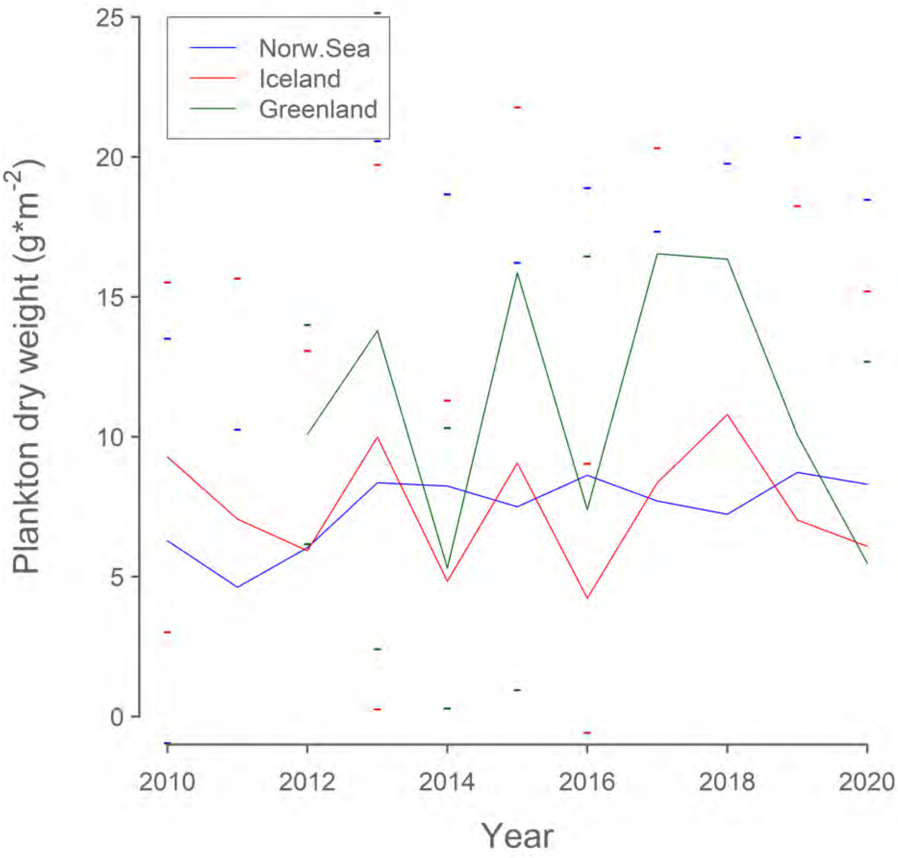

Figure 9b. Zooplankton biomass indices (g dw/m², 0-200 m). Time-series of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W).

4.3 Mackerel

The mackerel biomass index i.e. catch rates by trawl station (kg/km²) measured at predetermined surface trawl stations is presented in Figure 10 together with the mean catch rates per 2° lat. x 4° lon. rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 62 tonnes/km² (mean = 4.0). High density areas were found in the central and northern Norwegian Sea in 2020, with very small concentrations of mackerel in the western part compared to previous years (Figure 11 & 12). This was both apparent in Greenland waters with no mackerel catches taken and a large decline of mackerel catches in Icelandic waters.

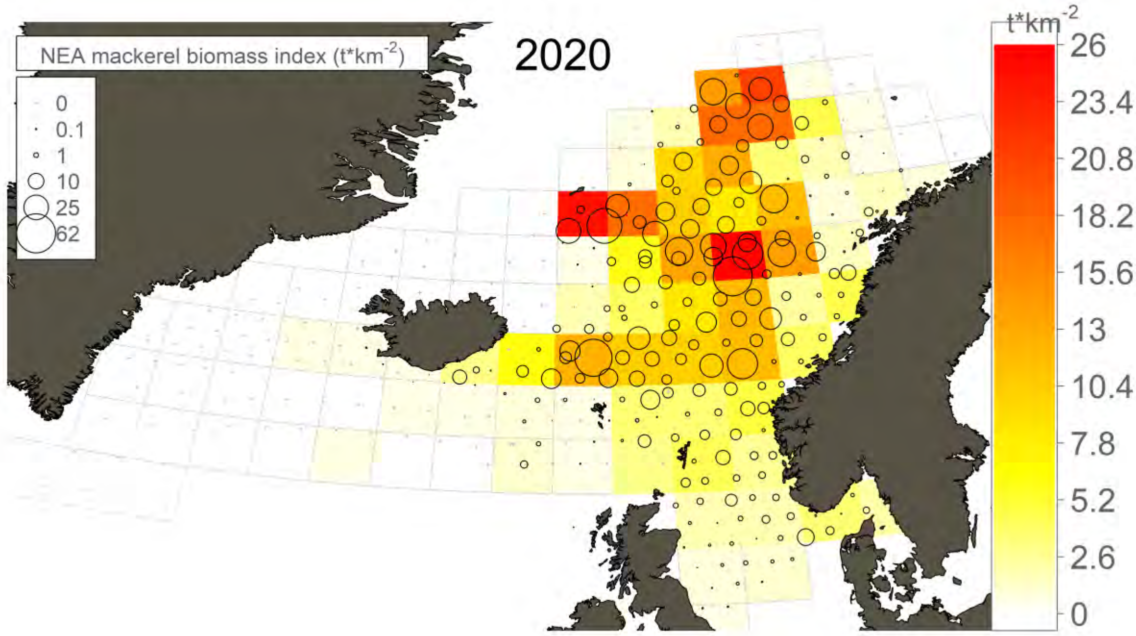

Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

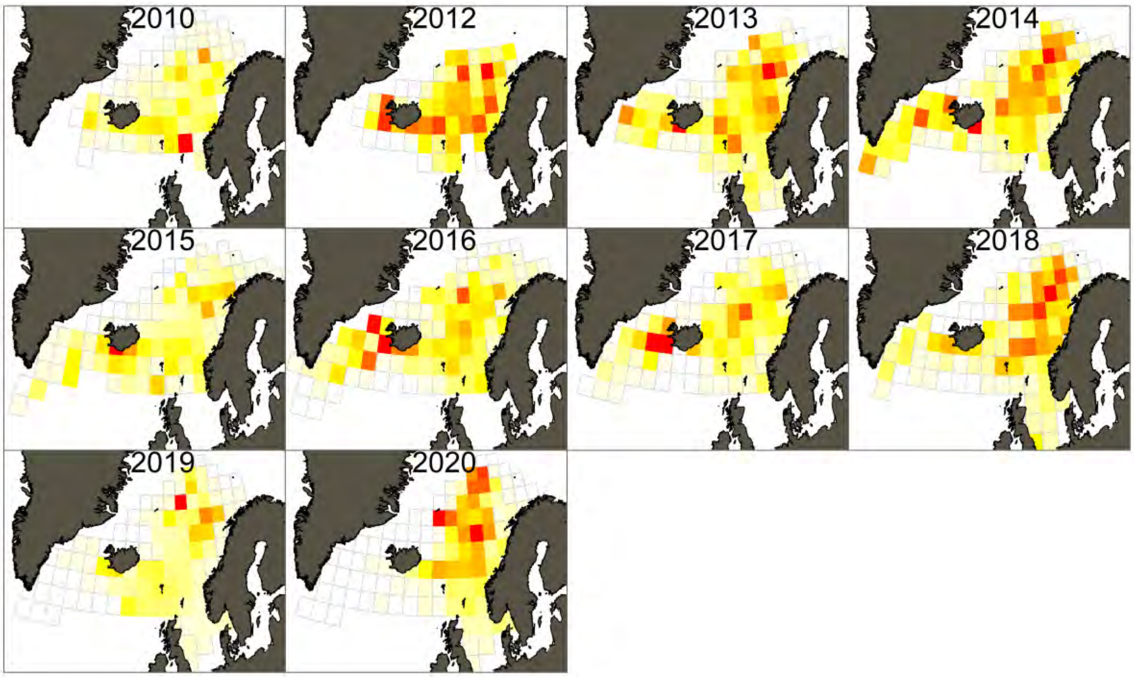

Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the highest year).

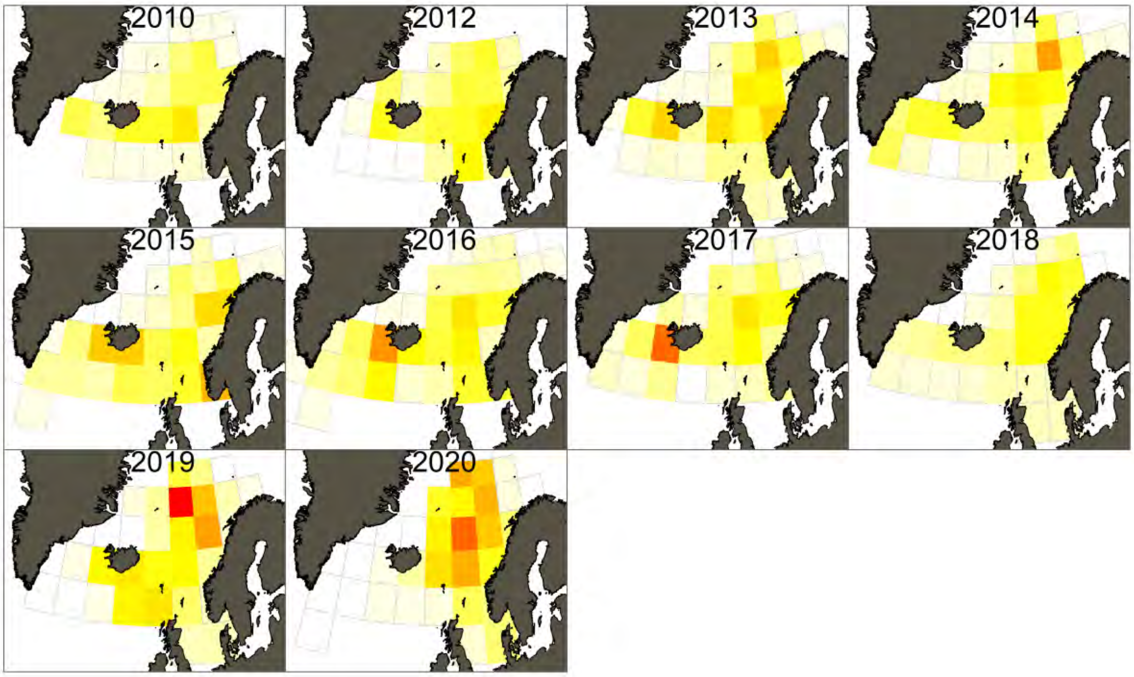

Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (4° lat. x 8° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the given year).

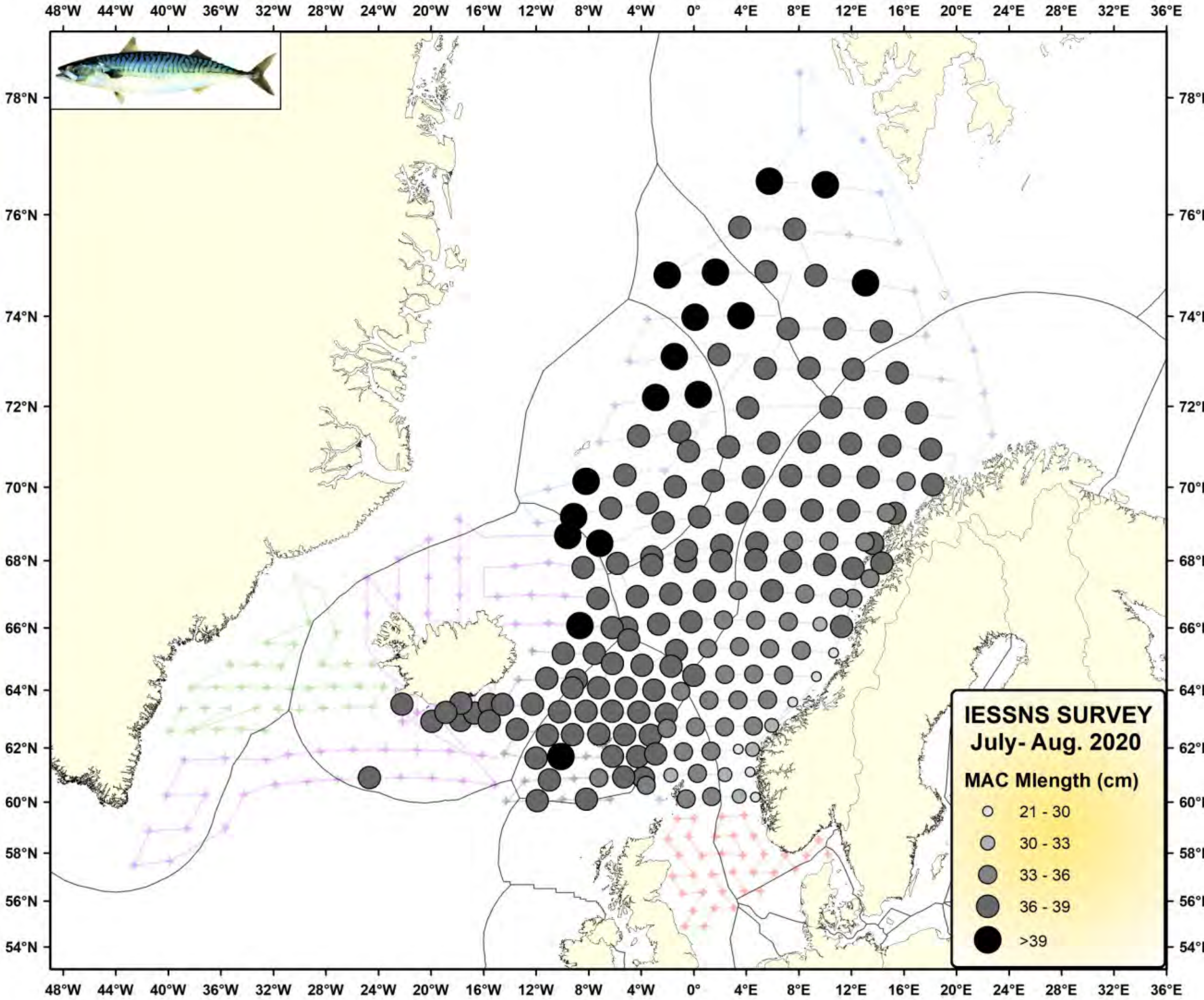

Figure 13. Average length of mackerel at predetermined surface trawl stations during IESSNS 2020.

The length of mackerel caught in the pelagic trawl hauls onboard the six vessels varied from 24.4 to 39.8 cm, with an average of 36.3 cm. Individuals in the length range 33–37 cm dominated in numbers and biomass. The mackerel weight varied between 123 to 642 g with an average of 456 g. Mackerel length distribution followed the same overall pattern as previous years in the Norwegian Sea, with increasing size towards the distribution boundaries in the north and the north-west (Figure 13). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon and lumpfish) in 2020 according to the catches are shown in Figure 14.

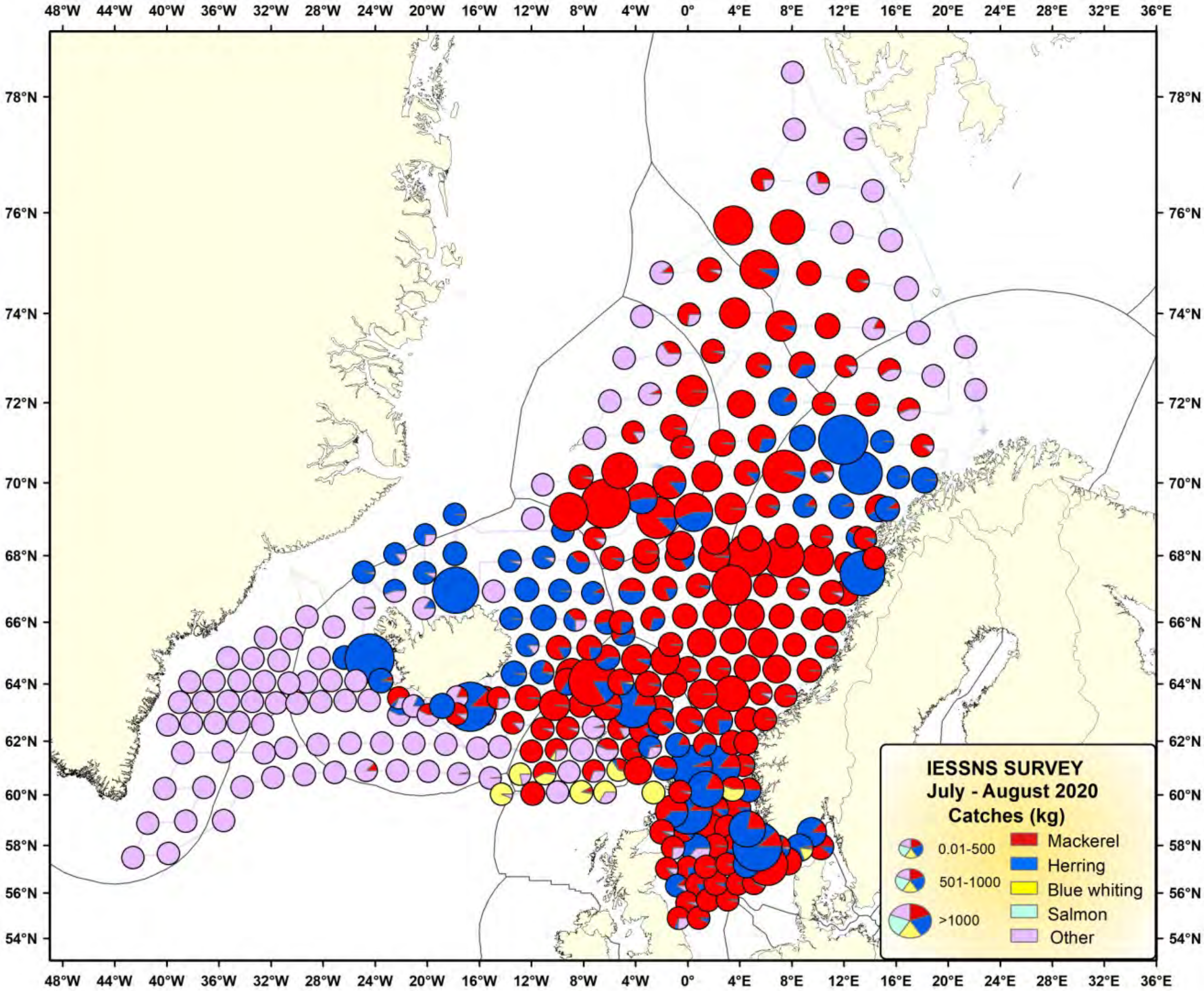

Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, and other (lumpfish)) in 2020 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2020 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX. The mackerel biomass and abundance indices in 2020 were the highest in the time series that started in 2010 (Table 7, Figure 15). Comparing the 2020 estimate to the 2019 estimate shows a 0.3% increase in abundance and 7.0% increase in biomass. The survey coverage area (excl. the North Sea, 0.27 million km^2) was 2.9 million km^2 in 2020, which is similar to the years 2017-2019. The most abundant year classes were 2010, 2016, 2011, 2013 and 2014 (Figure 16). Mackerel of age 1, 2 and to some extent also age 3 are not completely recruited to the survey (Figure 18), information on recruitment is therefore uncertain. However, the abundance of 1-3 year olds from the 2016 and 2017 year classes have consistently been high suggesting that these year classes are large. The 2018 year class appears to be closer to average. Variance in age index estimation is provided in Figure 17.

The overall internal consistency plot for age-disaggregated year classes is improved compared to last year (Figure 19), especially for the ages older than 8 years. There is a good to strong internal consistency for the younger ages (1-5 years) and older ages (8-14+ years) with r between 0.73 and 0.93. However, the internal consistency is poor to moderate (0.10 < r < 0.63) between age 5 to 8 as in previous years. The reason for this poor consistency is not clear.

Mackerel index calculations from the catch in the North Sea (stratum 13 in Figure 2) were excluded from the index calculations presented in the current chapter to facilitate comparison to previous years and because the 2017 mackerel benchmark stipulated that trawl stations south of latitude 60 °N be excluded from index calculations (ICES 2017). Results from the mackerel index calculations for the North Sea are presented in Appendix 1.

The indices used for NEA mackerel stock assessment in WGIWIDE are the number-at-age indices for age 3 to 11 year (Table 7a).

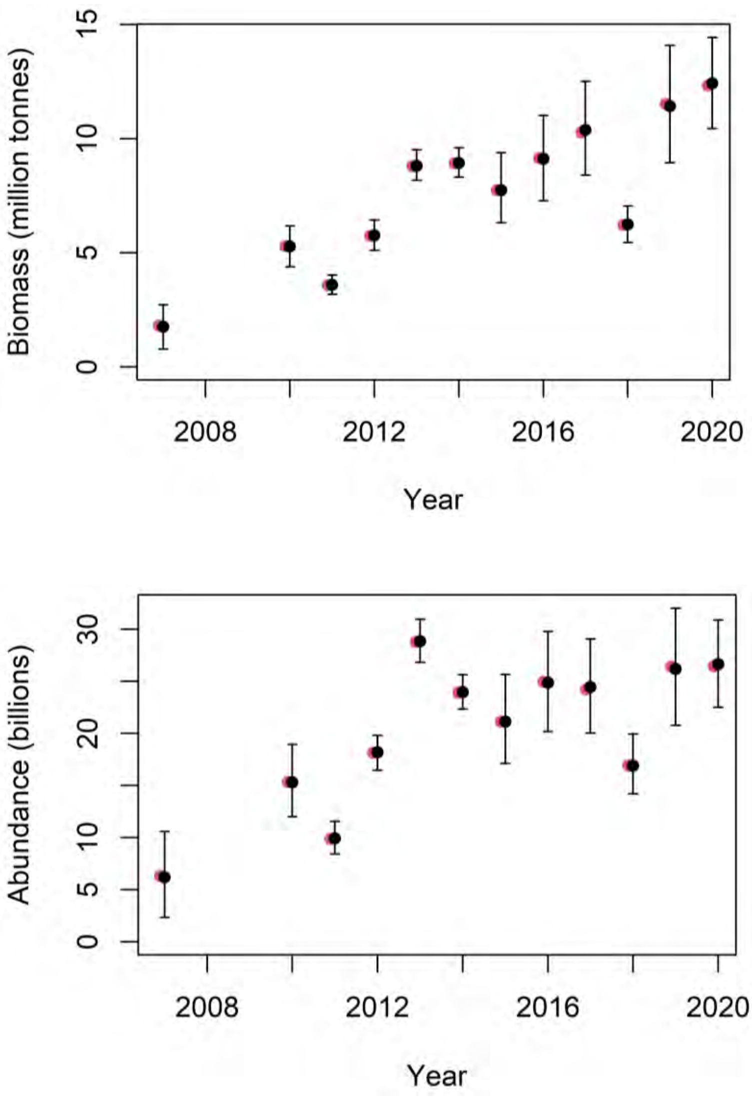

Figure 15. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX . The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap.

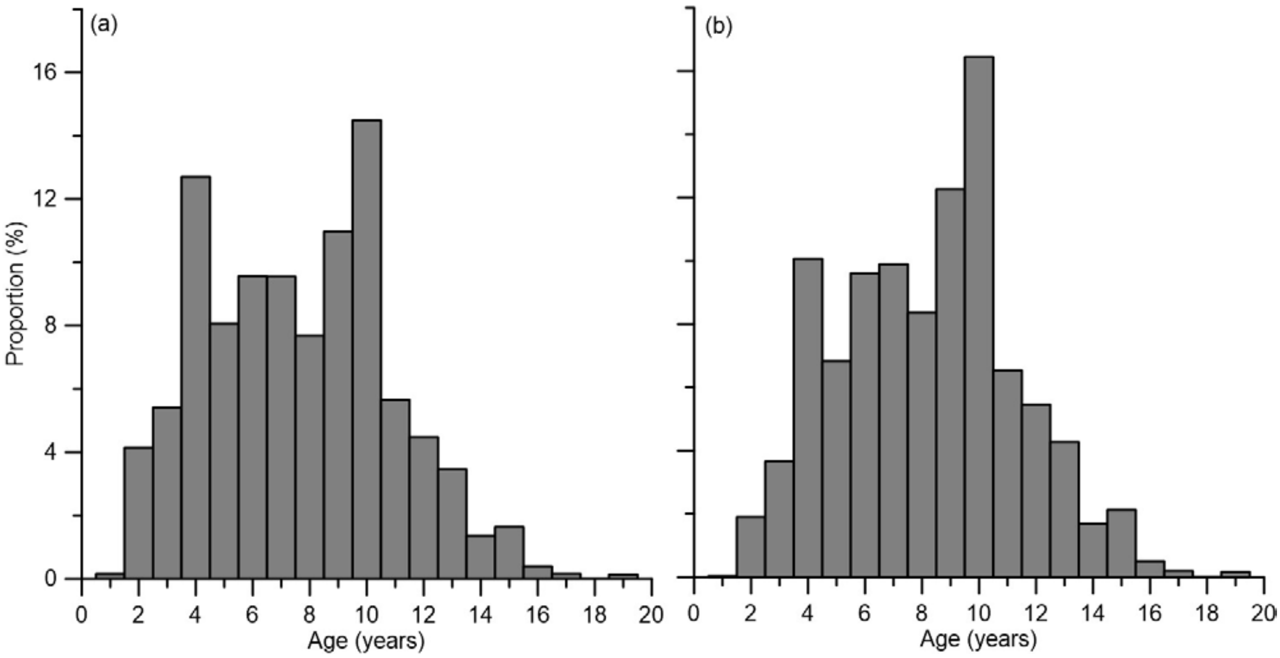

Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2020.

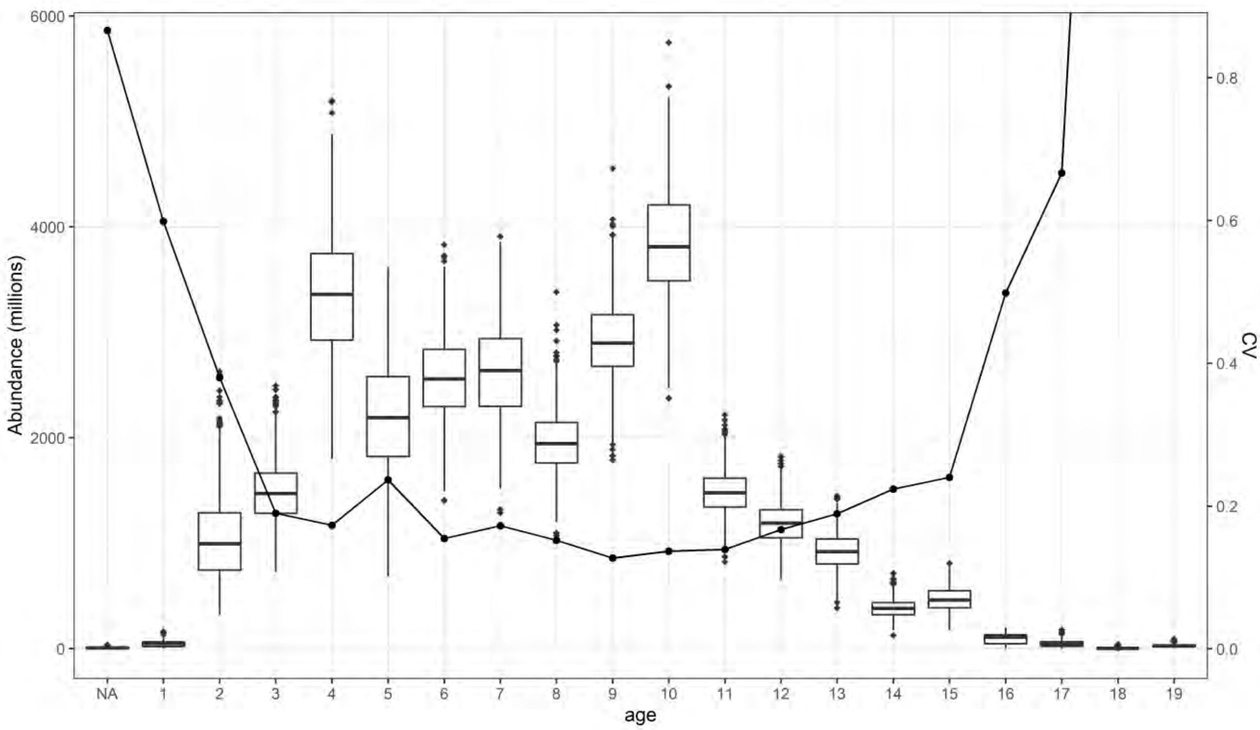

Figure 17. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-d) StoX baseline time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (g) per age and (c) estimated biomass at age (million tonnes) from 2007 to 2020. d) Output from StoX.

a)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot N
2007	1.33	1.86	0.90	0.24	1.00	0.16	0.06	0.04	0.03	0.01	0.01	0.00	0.01	0.00	5.65
2010	0.03	2.80	1.52	4.02	3.06	1.35	0.53	0.39	0.20	0.05	0.03	0.02	0.01	0.01	13.99
2011	0.21	0.26	0.87	1.11	1.64	1.22	0.57	0.28	0.12	0.07	0.06	0.02	0.01	0.00	6.42
2012	0.50	4.99	1.22	2.11	1.82	2.42	1.64	0.65	0.34	0.12	0.07	0.02	0.01	0.01	15.91
2013	0.06	7.78	8.99	2.14	2.91	2.87	2.68	1.27	0.45	0.19	0.16	0.04	0.01	0.02	29.57
2014	0.01	0.58	7.80	5.14	2.61	2.62	2.67	1.69	0.74	0.36	0.09	0.05	0.02	0.00	24.37
2015	1.20	0.83	2.41	5.77	4.56	1.94	1.83	1.04	0.62	0.32	0.08	0.07	0.04	0.02	20.72
2016	<0.01	4.98	1.37	2.64	5.24	4.37	1.89	1.66	1.11	0.75	0.45	0.20	0.07	0.07	24.81
2017	0.86	0.12	3.56	1.95	3.32	4.68	4.65	1.75	1.94	0.63	0.51	0.12	0.08	0.04	24.22
2018	2.18	2.50	0.50	2.38	1.20	1.41	2.33	1.79	1.05	0.50	0.56	0.29	0.14	0.09	16.92
2019	0.08	1.35	3.81	1.21	2.92	2.86	1.95	3.91	3.82	1.50	1.25	0.58	0.59	0.57	26.4
2020	0.04	1.10	1.43	3.36	2.13	2.53	2.53	2.03	2.90	3.84	1.50	1.18	0.92	0.98	26.47

b)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)
2007	133	233	323	390	472	532	536	585	591	640	727	656	685	671
2010	133	212	290	353	388	438	512	527	548	580	645	683	665	596
2011	133	278	318	371	412	440	502	537	564	541	570	632	622	612
2012	112	188	286	347	397	414	437	458	488	523	514	615	509	677
2013	96	184	259	326	374	399	428	445	486	523	499	547	677	607
2014	228	275	288	335	402	433	459	477	488	533	603	544	537	569
2015	128	290	333	342	386	449	463	479	488	505	559	568	583	466
2016	95	231	324	360	371	394	440	458	479	488	494	523	511	664
2017	86	292	330	373	431	437	462	487	536	534	542	574	589	626
2018	67	229	330	390	420	449	458	477	486	515	534	543	575	643
2019	153	212	325	352	428	440	472	477	490	511	524	564	545	579
2020	99	213	315	369	394	468	483	507	520	529	539	567	575	593

c)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot B
2007	0.18	0.43	0.29	0.09	0.47	0.09	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.00	1.64
2010	0.00	0.59	0.44	1.42	1.19	0.59	0.27	0.20	0.11	0.03	0.02	0.01	0.01	0.00	4.89
2011	0.03	0.07	0.28	0.41	0.67	0.54	0.29	0.15	0.07	0.04	0.03	0.01	0.01	0.00	2.69
2012	0.06	0.94	0.35	0.73	0.72	1.00	0.72	0.30	0.17	0.06	0.03	0.01	0.00	0.00	5.09
2013	0.01	1.43	2.32	0.70	1.09	1.15	1.15	0.56	0.22	0.10	0.08	0.02	0.01	0.01	8.85
2014	0.00	0.16	2.24	1.72	1.05	1.14	1.23	0.80	0.36	0.19	0.05	0.03	0.01	0.00	8.98
2015	0.15	0.24	0.80	1.97	1.76	0.87	0.85	0.50	0.30	0.16	0.04	0.04	0.02	0.01	7.72
2016	<0.01	1.15	0.45	0.95	1.95	1.72	0.83	0.76	0.53	0.37	0.22	0.10	0.04	0.04	9.11
2017	0.07	0.03	1.18	0.73	1.43	2.04	2.15	0.86	1.04	0.33	0.28	0.07	0.05	0.03	10.29
2018	0.15	0.57	0.16	0.93	0.50	0.63	1.07	0.85	0.51	0.26	0.30	0.16	0.08	0.05	6.22
2019	0.01	0.29	1.24	0.43	1.25	1.26	0.92	1.86	1.87	0.77	0.65	0.33	0.32	0.32	11.52
2020	<0.01	0.23	0.45	1.24	0.84	1.18	1.22	1.03	1.51	2.03	0.81	0.67	0.53	0.58	12.33

Table 7d) IESSNS 2020. StoX baseline estimates of mackerel abundance, mean weight and mean length.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: makrell

age

LenGrp	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	393	393	19.6	50.00
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	393	393	21.2	54.00
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	909	909	57.1	62.84
20-21	4052	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4052	282.8	69.81
21-22	8023	7247	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15270	1165.8	76.35
22-23	10030	22198	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32228	2962.1	91.91
23-24	7565	111117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	118681	11701.7	98.60
24-25	7310	183431	-	1008	336	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	192085	22156.8	115.35
25-26	2690	123171	11765	-	1669	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	139295	17949.6	128.86
26-27	1862	65554	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67416	9474.6	140.54
27-28	881	3699	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4580	757.6	165.41
28-29	-	17564	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17564	3501.4	199.35
29-30	-	25790	53653	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79444	17383.5	218.82
30-31	-	103227	72012	115359	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290598	74688.6	257.02
31-32	-	83435	292521	246781	1141	2324	-	-	-	-	-	-	-	-	-	-	-	-	-	-	626201	177386.6	283.27
32-33	-	215024	542203	572880	107105	-	9922	-	-	-	-	-	-	-	-	-	-	-	-	-	1447134	454841.9	314.31
33-34	-	84119	257712	724062	649131	7306	26677	-	4140	-	-	-	15167	-	-	-	-	-	-	-	1768314	609438.2	344.64
34-35	-	47238	96933	751455	505451	121005	78200	23241	-	-	-	-	-	-	-	-	-	-	-	-	1623524	616341.5	379.63
35-36	-	4399	79195	524047	472886	382463	166463	49074	51302	11993	2579	-	-	-	-	-	-	-	-	-	1744401	731706.0	419.46
36-37	-	-	3654	351209	262547	712252	696102	484937	147595	295261	42807	19532	-	3932	-	-	-	-	-	-	3019827	1386576.9	459.16
37-38	-	-	21347	54617	122176	866143	814695	573593	949691	1013723	296145	96365	10683	12836	-	-	-	-	-	-	4832014	2377172.0	491.96
38-39	-	-	-	13638	8232	398085	624742	597232	1086693	1305787	539570	261743	243535	100280	39644	17118	2952	144	-	-	5239394	2766655.1	528.05
39-40	-	-	-	141	3737	39029	53003	191022	562466	850989	375653	426225	252322	98605	85067	55565	31515	-	36000	-	3061339	1725434.6	563.62
40-41	-	-	-	6581	-	43	55389	111204	88355	291356	192351	269252	263156	63588	185140	13199	1128	-	-	-	1540743	920775.2	597.62
41-42	-	-	-	-	-	-	203	2251	13923	52584	38870	103846	77423	53161	96072	9620	5888	-	-	-	453840	292985.8	645.57
42-43	-	-	-	-	-	-	64	228	-	10518	5611	7922	18106	26678	10654	42	1571	-	-	-	81394	55052.9	676.38
43-44	-	-	-	-	-	-	-	-	73	1022	2064	-	29226	-	15338	8177	-	1898	-	-	57798	42299.0	731.84
44-45	-	-	-	-	-	-	-	-	-	2249	-	-	-	-	-	-	-	-	-	-	2249	1652.2	734.80
45-46	-	-	-	-	-	-	-	-	-	-	-	-	6013	-	-	-	-	-	-	-	6013	4875.6	810.79
46-47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48-49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1500	1500	1524.5	1016.00
TSN(1000)	42414	1097212	1430995	3361778	2134411	2528651	2525460	2032783	2904239	3835479	1495649	1184884	915631	359080	431915	103721	43054	2041	36000	3195	26468594	-	-
TSB(1000 kg)	4214.6	233291.1	451303.1	1240926.0	841504.4	1183109.7	1219891.1	1029686.5	1510848.4	2027319.3	806035.6	671778.4	526625.0	208291.0	261661.8	62120.9	24499.0	1458.5	20653.9	1622.5	-	12326840.6	-
Mean length (cm)	22.87	28.37	32.35	33.81	34.54	36.69	37.04	37.51	37.97	38.21	38.53	39.15	39.47	39.51	40.18	39.72	39.60	42.70	39.36	32.52	-	-	-
Mean weight (g)	99.37	212.62	315.38	369.13	394.26	467.88	483.04	506.54	520.22	528.57	538.92	566.96	575.15	580.07	605.82	598.92	569.03	714.50	573.71	507.79	-	-	465.72

Table 8. Bootstrap estimates from StoX (based on 1000 replicates) of mackerel. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in million tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
1	7.8	47.2	93.4	45.7	27.4	0.60
2	533.0	994.5	1835.8	1054.7	400.3	0.38
3	1068.7	1468.2	1994.3	1491.9	282.5	0.19
4	2401.5	3359.1	4298.3	3351.8	578.5	0.17
5	1358.1	2189.3	3031.9	2193.4	517.6	0.24
6	1923.0	2556.7	3194.6	2558.8	394.7	0.15
7	1837.6	2635.6	3363.3	2626.8	451.6	0.17
8	1468.6	1942.4	2434.8	1950.1	295.8	0.15
9	2337.5	2897.5	3543.4	2919.9	369.5	0.13
10	3048.3	3811.0	4752.4	3858.5	526.0	0.14
11	1175.6	1476.2	1824.7	1483.6	206.0	0.14
12	861.8	1189.3	1511.5	1187.9	198.0	0.17
13	645.9	917.4	1214.9	921.8	174.0	0.19
14	240.2	379.6	517.3	380.6	84.9	0.22
15	292.5	459.7	660.7	468.3	112.3	0.24
16	19.9	106.2	157.6	93.2	46.4	0.50
17	4.7	42.8	98.4	45.8	30.5	0.67
18	0.0	0.4	16.7	2.7	5.7	2.10
19	0.0	15.3	44.0	16.3	16.4	1.01
Unknown	0.5	4.9	19.7	6.8	5.9	0.87
TSN	22513.1	26682.4	30875.5	26658.6	2511.3	0.09
TSB	10.45	12.41	14.43	12.42	1.23	0.10

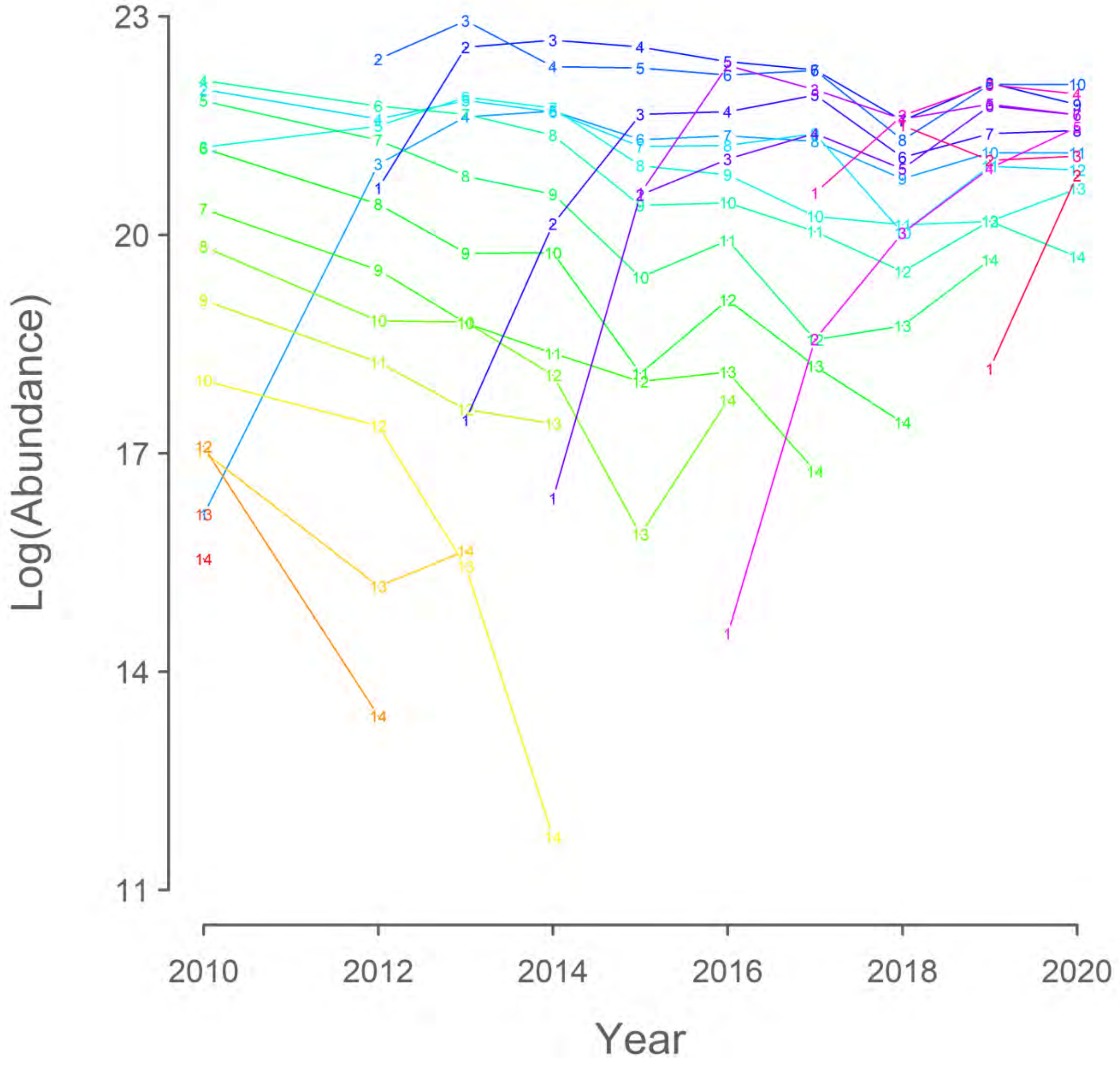

Figure 18. Catch curves. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

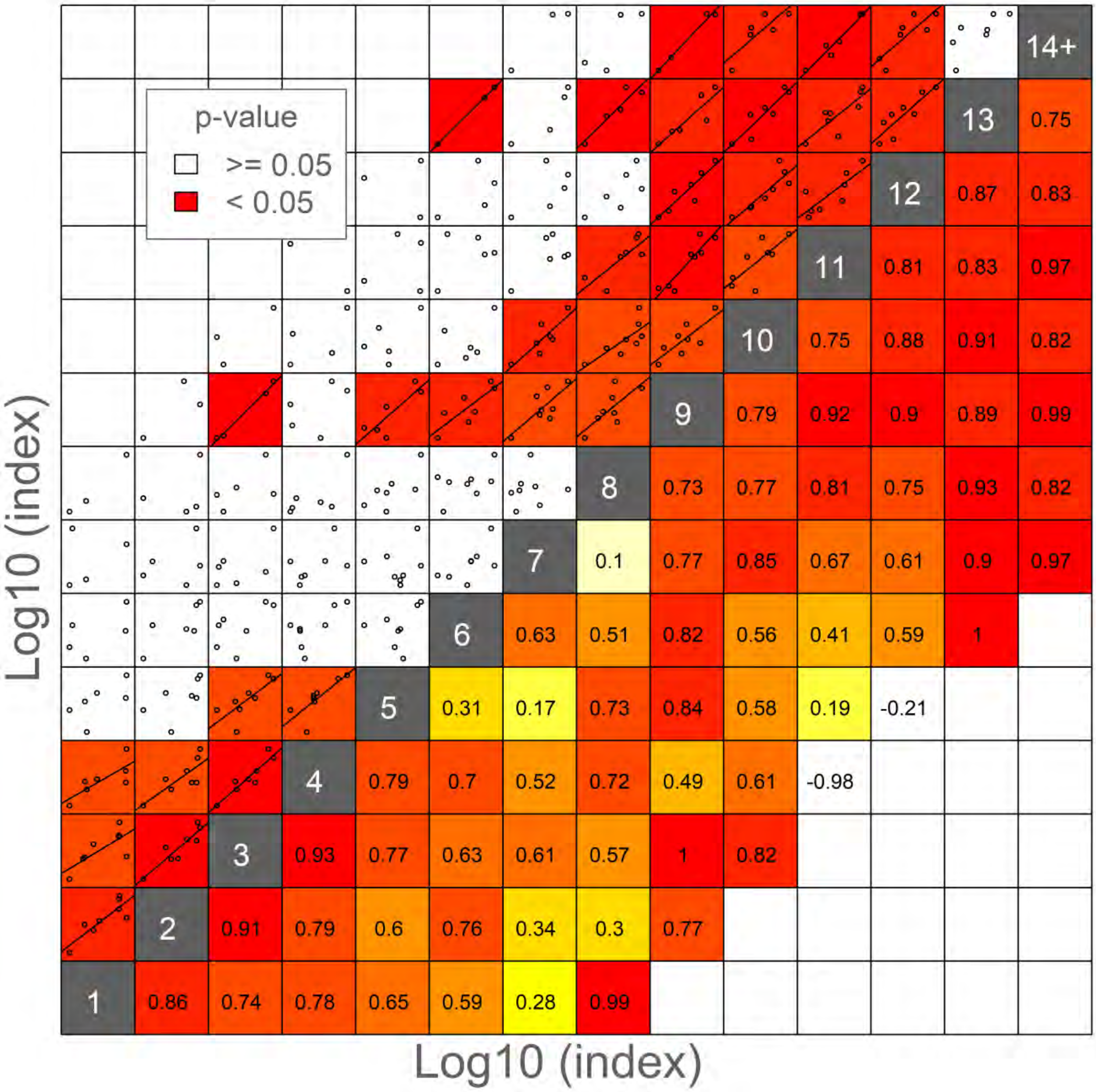

Figure 19. Internal consistency of the of mackerel density index from 2012 to 2020. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

Distribution zero boundaries were found in majority of survey area with a notable exception of high mackerel abundance in the north-western region towards the Fram Strait west of Svalbard.

The mackerel appeared less patchily distributed within the survey area and was distributed more in the central and northern Norwegian Sea in 2020 compared to 2018 and 2019. This difference in distribution primarily consists of a marked biomass decline in the west and an increase in the central and northern part of the Norwegian Sea. Furthermore, there was also a northerly and north-westerly shift in densities of mackerel within the Norwegian Sea.

The marked decrease since 2017 and now even disappearance of mackerel in major western areas in 2020 likely has several causes. In 2019 there were practically no mackerel in Greenland waters during the survey, and in 2020 the mackerel had disappeared altogether from Greenland waters according to our survey results. A similar pattern has also taken place in Icelandic waters, where the abundance of mackerel has declined substantially during the last few years from 2017 to 2020. Why is this happening? First of all, we measured lower mesozooplankton biomasses in both Icelandic and Greenland waters in 2020 compared to previous years, which may have reduced mackerel feeding opportunities in the western area. The temperature was 1-2°C lower in parts of Icelandic and Greenland waters in summer 2020 compared to 2019. This accounts for both the sea surface temperatures (SSTs) and in situ temperature measurements from 10 m depth. However, there should be warm enough for the mackerel to migrate to and feed in these areas. The increase of mackerel in the Norwegian Sea, particularly in the central and northern part of the Norwegian Sea, cannot be explained by improved feeding conditions, as the zooplankton biomasses in summer (at the time of IESSNS) have varied little among the recent years. Neither can it be explained by reduced abundance, as the present survey estimate is the highest on record.

The swept area method assumes that potential distribution of mackerel outside the survey area – both vertically and horizontally – is a constant percentage of the total biomass. In some years, this assumption may be violated, e.g. when mackerel may be distributed below the lower limit of the trawl or if the proportion of mackerel outside the survey coverage varies among years. In order to improve the precision of the swept-area estimate it would be beneficial to extend the survey coverage further south covering the southwestern waters south of 60°N.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred in the southern and south-western parts of the Norwegian Sea, and with the strong 2016 year class of NSSH, there was also overlap in the central and north eastern part of the Norwegian Sea. In the eastern Norwegian Sea between 62-67°N, mackerel were present but herring were in low abundance, in contrast, in areas north of Iceland, herring were present while mackerel were absent.

The swept-area estimate was, as in previous years, based on the standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 57.2.5-70.5.4m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

Results from the survey expansion southward into the North Sea is analysed separately from the traditional survey grounds north of latitude 60°N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017). We have now available IESSNS survey data from 2018, 2019 and 2020 for the northern part of the North Sea.

This year's survey was well synchronized in time and was conducted over a relatively short period (less than 5 weeks) given the large spatial coverage of around 2.9 million km^2 (Figure 1). This was in line with recommendations put forward in 2016 that the survey period should be around four weeks with mid-point around 20. July. The main argument for this time period was to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southern (north of the Faroes and east and north of Iceland) and northern part of the Norwegian Sea basin (Figure 20). The fish in the northeast consisted of young adults (mainly 4 year olds) while the fish further southwest are a range of age groups, although also in this southwestern area significant amounts of the 4- year old as well as 7- year old herring were present. Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring while the herring closer to the Faroes south of 62°N were Faroese autumn spawners.

Also, herring to the west in Icelandic waters (west of 14°W south of Iceland) were allocated to Icelandic summer-spawners. The abundance and biomass of NSSH was distributed with slightly more than half of the biomass in the north-eastern part (mainly young herring) and slightly less than half in the south-western area. The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. However, the most abundant year class in the survey estimate, the 2016- year class (4- year olds) may not be fully covered in this survey. Some of this young year class may still not be fully recruited to the survey area.

The NSSH stock is dominated by 4 and 7-year old herring (year classes 2016 and 2013) in terms of numbers and biomass (Table 9). The 2013 year class is distributed in all areas with herring in the survey whereas the 2016 year class was mainly found in the north-eastern part. The 2013 year-class contributed 22% and 20% to the total biomass and total abundance, respectively, whereas the 2016 year-class contributed 33% and 40% to the total biomass and total abundance, respectively. The total number of herring recorded in the Norwegian Sea was 20.3 billion and the total biomass index was 5.93 million tonnes in 2020, in comparison to 15.2 billion and a total biomass index of 4.78 million tonnes in 2019. The increase was due to the recruiting 2016 year-class coming strongly into the survey area. Number by age, with uncertainty estimates, for NSSH is shown in Figure 21. The group considered the acoustic biomass estimate of herring to be of good quality in the 2020 IESSNS as in the previous survey years.

Bootstrap estimates of numbers by age of herring are shown in table 10 and the baseline point estimates from 2016-2020 are shown in table 11. The internal consistency among year classes is shown in Figure 22.

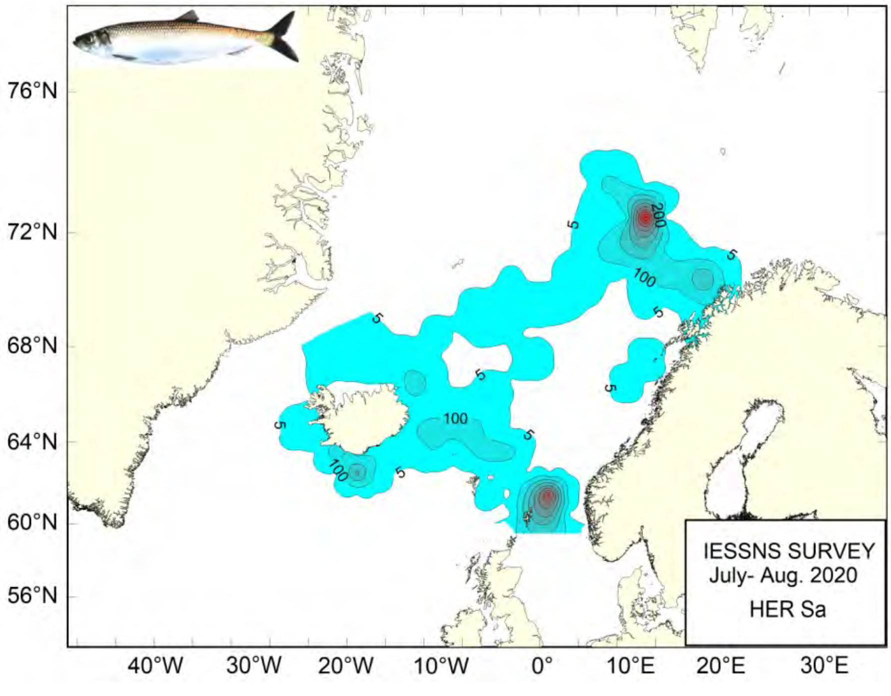

Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2020. Presented as contour lines. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

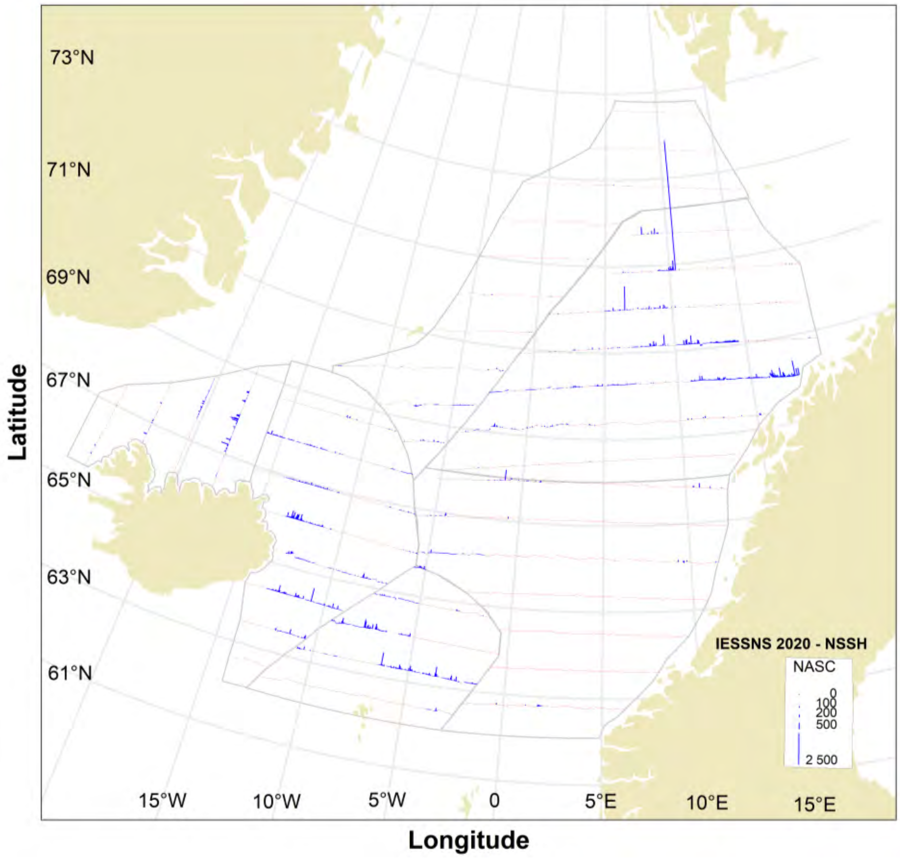

Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2020. Presented as bar plot. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

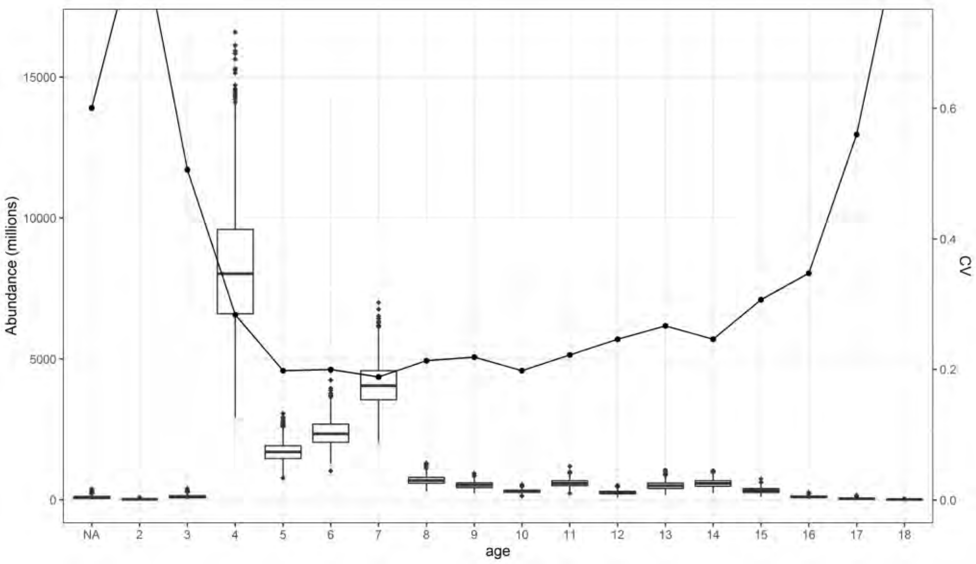

Figure 21. Number by age for Norwegian spring-spawning herring during IESSNS 2020. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 9. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2020.

LenGrp	age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
23-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8096	8096	1214.4	150.00
24-25	-	8096	1245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9341	1213.7	129.93
25-26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78567	78567	12099.8	154.01
26-27	3375	27307	351715	-	11208	-	-	-	-	-	-	-	-	-	-	-	-	-	393604	68895.1	175.04
27-28	-	24446	836562	99166	3492	-	-	-	-	-	-	-	-	-	-	-	-	-	963667	181071.1	187.90
28-29	3379	16894	1117284	63398	-	25315	3361	6758	7283	-	-	-	-	-	-	-	-	-	1243672	258390.6	207.76
29-30	-	27259	1659886	40066	7109	13661	5715	-	11105	-	-	-	-	-	-	-	-	-	1764802	412482.5	233.73
30-31	-	7425	2265337	210515	57260	24416	30560	3439	3595	17197	-	-	3595	-	-	-	-	-	2623338	672023.4	256.17
31-32	-	-	1490880	466629	293454	133664	19253	2627	6213	2102	2627	-	-	-	525	-	-	-	2417976	667635.7	276.11
32-33	-	-	256258	656657	1062980	820021	49599	25652	2447	9536	15645	979	1958	3789	3789	-	-	-	2909309	867854.8	298.30
33-34	-	-	51102	141466	649300	1796292	167355	22699	9237	18390	5873	-	-	-	-	-	-	-	2861712	910369.8	318.12
34-35	-	-	39963	5198	182740	1064853	186269	87278	9070	56884	10899	598	465	3859	-	-	-	-	1648074	553397.8	335.78
35-36	-	-	-	12888	59750	213889	219024	134632	37843	92581	8328	52787	20612	32823	-	11277	-	-	896432	321715.6	358.88
36-37	-	-	-	1485	7364	9469	29872	134729	126028	200909	66365	190091	201609	68316	2763	-	-	-	1039001	394231.3	379.43
37-38	-	-	11302	-	-	-	1295	65134	63493	156242	106558	182404	228486	58252	54793	2182	-	-	930141	370334.6	398.15
38-39	-	-	-	-	-	-	2049	7654	17207	35751	30464	66722	107175	100662	37800	29396	5000	-	439879	185616.9	421.97
39-40	-	-	-	-	-	-	-	-	-	-	1368	12316	28053	48916	12316	-	-	-	102969	46454.8	451.15
40-41	-	-	-	-	-	-	-	-	-	-	-	-	5170	-	4579	654	-	-	10402	5147.3	494.83
TSN(1000)	6754	111426	8081535	1697468	2334655	4101580	714352	490601	293521	589590	248127	505896	597123	316616	116565	43509	5000	86663	20340981	-	-
TSB(1000 kg)	1263.0	21354.6	1942260.4	465900.3	711503.7	1307705.0	236374.2	174051.4	108720.0	222214.0	93474.7	199884.1	234966.8	129554.8	47528.2	17760.3	2319.5	13314.2	-	5930149.1	-
Mean length (cm)	27.25	27.60	29.56	31.29	32.52	33.24	33.87	35.09	35.50	35.84	36.24	36.64	36.87	37.19	37.53	37.33	38.00	25.08	-	-	-
Mean weight (g)	187.01	191.65	240.33	274.47	304.76	318.83	330.89	354.77	370.40	376.90	376.72	395.11	393.50	409.19	407.74	408.20	463.95	153.63	-	-	291.54

Table 10. Bootstrap estimates of Norwegian spring-spawning herring in IESSNS 2020 from StoX based on 1000 replicates. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tonnes.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	0.0	11.9	42.7	15.5	13.7	0.89
3	40.7	106.5	232.6	117.2	59.3	0.51
4	4841.3	8022.4	12501.3	8280.3	2350.6	0.28
5	1182.0	1698.4	2276.3	1709.8	338.7	0.20
6	1633.7	2336.4	3144.4	2367.2	472.7	0.20
7	2938.4	4043.9	5406.8	4087.3	770.0	0.19
8	475.2	687.4	950.7	695.9	148.4	0.21
9	348.8	516.0	711.3	520.1	113.9	0.22
10	213.1	301.1	402.8	304.9	60.4	0.20
11	400.2	581.6	823.4	593.7	131.8	0.22
12	157.6	256.3	364.3	259.1	63.8	0.25
13	293.1	494.7	734.7	502.6	134.1	0.27
14	354.6	578.0	831.3	580.5	142.9	0.25
15	174.4	320.2	496.4	327.3	100.4	0.31
TSN	14655.8	20497.9	27132.4	20611.4	3829.6	0.19
TSB	4353.7	5981.3	7740.8	5990.8	1028.2	0.17

Table 11. IESSNS baseline time series from 2016 to 2020. StoX abundance estimates of Norwegian spring-spawning herring (millions).

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12+	TSB(1000 t)
2016	41	146	752	604	1 637	1 559	2 010	1 614	1 190	2 023	2 151	6 467	6 753
2017	1 216	248	1 285	4 586	1 056	1 188	816	1 794	1 022	1 131	1 653	4 119	5 885
2018	0	577	722	879	3 078	931	1 264	734	948	1 070	694	2 792	4 465
2019	0	153	1 870	590	1 067	3 475	859	702	520	700	463	4 808	4 780
2020	0	7	111	8 082	1 697	2 335	4 102	714	491	294	590	1 833	5 930

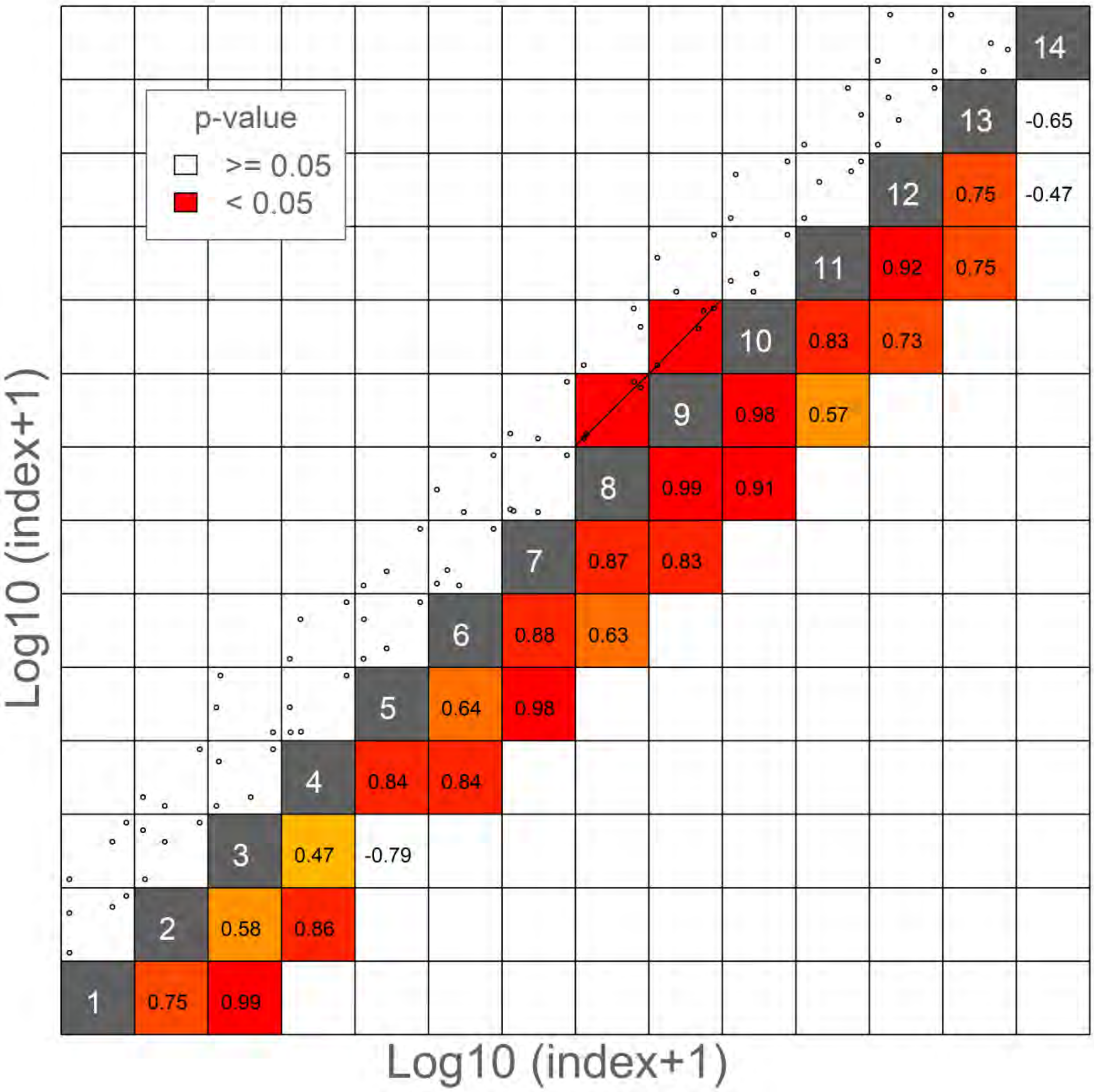

Figure 22. Internal consistency for Norwegian spring-spawning herring within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.

4.5 Blue whiting

Blue whiting was distributed in the central and eastern part of the survey area. The area around Iceland, influenced by the cold East Icelandic Current, southern Iceland and in the East Greenland area had very little blue whiting. The highest sA-values were observed in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope and around the Faroe Islands. The distribution in 2020 is somewhat changed compared to the 2019 distribution since the area to the west had less blue whiting. The main concentrations of older fish were observed in connection with the continental slopes, both in the eastern and the southern part of the Norwegian Sea (Figure 23). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during IESSNS 2020 was 1.8 million tons (Table 12), a decrease compared to 2019 (2.0 mill tons). The stock estimate in number for 2019 is 16.5 billion compared to 16.2 billion of age groups 1+ in 2019. Age group 1 is dominating the estimate in 2020 (22% and 35% of the biomass and by numbers, respectively, looking at age groups 1+). A good sign of recruiting year class (0-group) was also seen in the survey this year.

Number by age, with uncertainty estimates, for blue whiting during IESSNS 2020 is shown in Figure 24.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2020 IESSNS as in the previous survey years.

Bootstrap estimates of numbers by age of blue whiting are shown in table 13 and the baseline point estimates from 2016-2020 are shown in table 14. The internal consistency among year classes is shown in Figure 25.

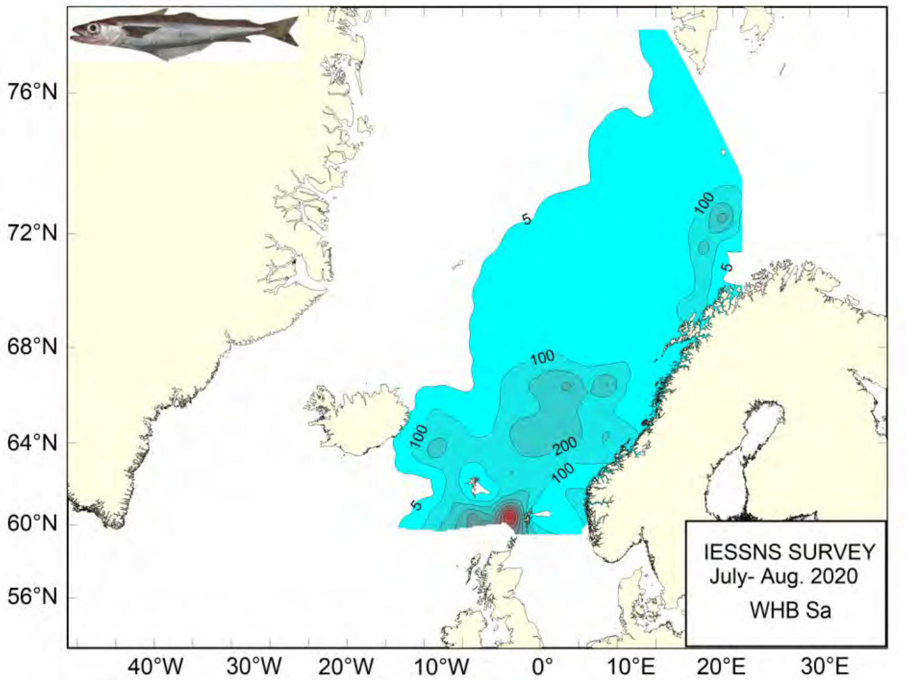

Figure 23a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2020. Presented as contour lines.

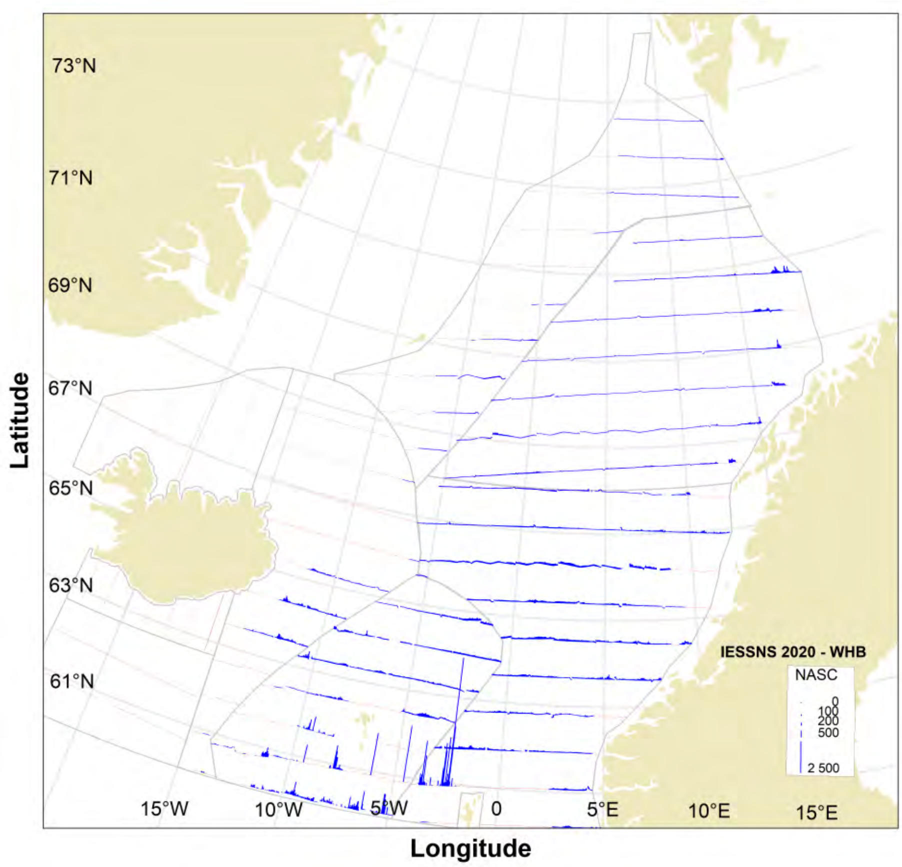

Figure 23b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2020. Presented as bar plot.

Table 12. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2020.

LenGrp	age 0	1	2	3	4	5	6	7	8	9	10	11	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
5-6	-	-	-	-	-	-	-	-	-	-	-	-	475244	475244	712.9	1.50
6-7	-	-	-	-	-	-	-	-	-	-	-	-	143824	143824	287.6	2.00
7-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-	8818	8818	-	-
11-12	563743	-	-	-	-	-	-	-	-	-	-	-	-	563743	5035.3	8.93
12-13	1397043	-	-	-	-	-	-	-	-	-	-	-	-	1397043	14951.9	10.70
13-14	1144766	-	-	-	-	-	-	-	-	-	-	-	-	1144766	15260.0	13.33
14-15	708720	-	-	-	-	-	-	-	-	-	-	-	-	708720	12718.3	17.95
15-16	204667	-	-	-	-	-	-	-	-	-	-	-	-	204667	4388.4	21.44
16-17	47482	-	-	-	-	-	-	-	-	-	-	-	-	47482	1288.3	27.13
17-18	-	3418	-	-	-	-	-	-	-	-	-	-	-	3418	88.9	26.00
18-19	-	64303	-	-	-	-	-	-	-	-	-	-	-	64303	1888.1	29.36
19-20	-	284101	-	-	-	-	-	-	-	-	-	-	-	284101	9739.1	34.28
20-21	-	587975	-	-	-	-	-	-	-	-	-	-	-	587975	24124.0	41.03
21-22	-	545134	47261	-	-	-	-	-	-	-	-	-	-	592395	32192.9	54.34
22-23	-	1398559	107462	37309	-	-	-	-	-	-	-	-	-	1543330	100316.9	65.00
23-24	-	1711675	308186	38983	-	-	-	-	-	-	-	-	-	2058844	153721.1	74.66
24-25	-	940084	647953	10125	10125	-	-	-	-	-	-	-	-	1608287	137805.7	85.68
25-26	-	236626	976587	187545	13539	-	-	-	-	-	-	-	-	1414296	139747.6	98.81
26-27	-	25266	630904	542256	117736	6493	12986	12986	-	-	-	-	-	1348629	144673.9	107.27
27-28	-	-	225161	499183	242781	286923	227906	82001	35726	-	-	-	-	1599680	184243.3	115.18
28-29	-	6671	29683	146062	307749	407455	442685	242832	46698	-	-	-	-	1629835	202332.8	124.14
29-30	-	-	3603	103964	357715	325435	424059	123417	17867	7132	-	-	-	1363192	185760.3	136.27
30-31	-	-	19072	-	35630	319960	432661	241792	51531	-	-	-	-	1100647	172701.0	156.91
31-32	-	-	-	42429	109970	230538	173418	61271	18805	-	7979	-	-	644410	115474.0	179.19
32-33	-	-	-	21413	10255	84793	163006	52500	5510	-	-	-	-	337476	66983.8	198.48
33-34	-	-	-	-	-	53440	76612	45387	-	3143	-	-	-	178582	37721.3	211.23
34-35	-	-	-	-	-	3265	17964	73978	4902	4902	-	3265	-	108277	24233.5	223.81
35-36	-	-	-	-	-	-	15450	2572	11583	6000	2572	-	-	38177	9852.7	258.08
36-37	-	-	-	-	-	-	3428	-	8719	-	-	15899	-	28047	7717.8	275.17
TSN(1000)	4066422	5803812	2995873	1629269	1205499	1718303	1990176	938736	201341	21177	10551	19165	627886	21228210	-	-
TSB(1000 kg)	53642.3	389957.9	286417.5	187223.1	156139.2	250393.4	297906.6	141121.8	30522.9	4034.1	2102.3	5499.9	1000.5	-	1805961.5	-
Mean length (cm)	12.93	22.54	25.10	26.86	28.42	29.36	29.60	29.92	29.86	32.51	32.35	36.07	5.55	-	-	-
Mean weight (g)	13.19	67.19	95.60	114.91	129.52	145.72	149.69	150.33	151.60	190.49	199.25	286.98	1.62	-	-	85.11

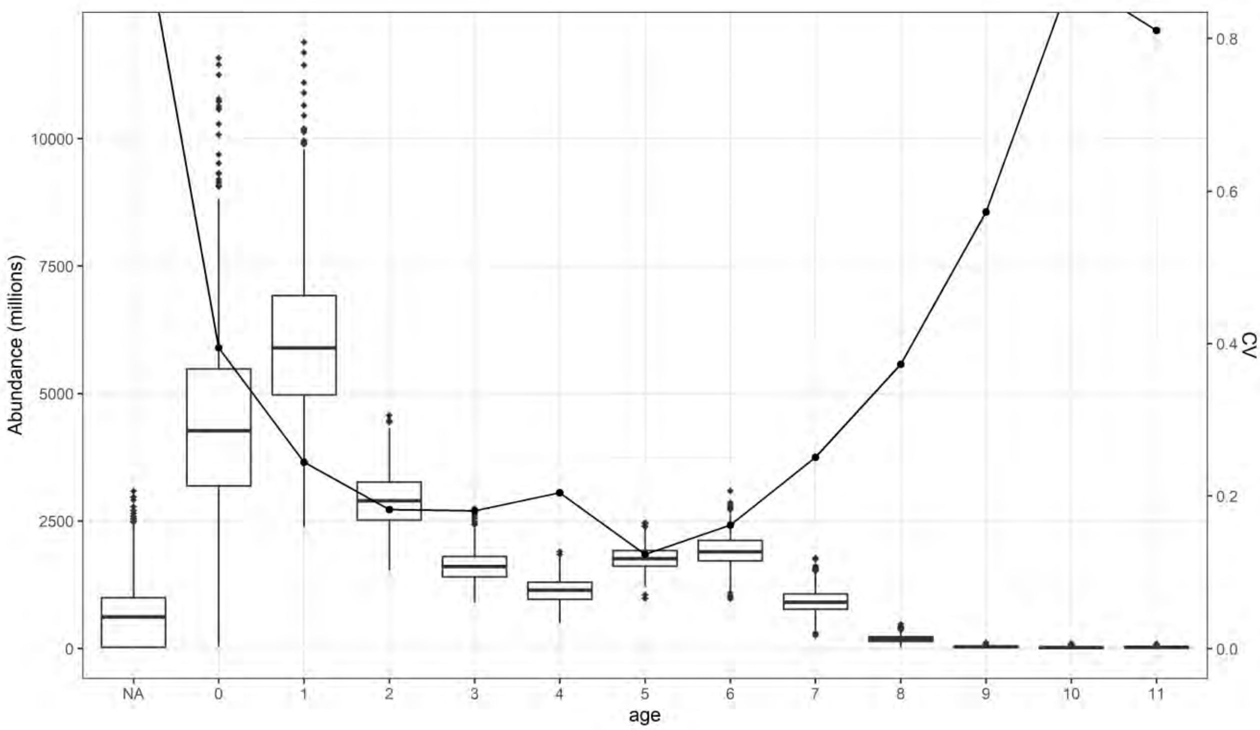

Figure 24. Number by age with uncertainty for blue whiting during IESSNS 2020. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 13. Bootstrap estimates of blue whiting in IESSNS 2020 from StoX based on 1000 replicates. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tonnes.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
0	2022.3	4267.3	7716.5	4460.7	1760.1	0.39
1	3897.4	5891.6	8780.3	6027.3	1473.2	0.24
2	2083.9	2896.4	3787.5	2903.3	529.4	0.18
3	1138.0	1602.8	2081.1	1607.7	290.3	0.18
4	755.5	1140.6	1502.4	1134.9	231.8	0.20
5	1411.6	1761.9	2114.7	1762.2	217.3	0.12
6	1431.1	1894.8	2453.9	1923.9	311.4	0.16
7	563.8	907.5	1350.8	928.6	232.9	0.25
8	73.5	184.5	305.9	186.0	69.3	0.37
9	9.1	30.9	68.8	33.4	19.2	0.57
10	0.0	14.9	42.1	16.3	14.4	0.88
TSN	17416.6	21333.9	26740.9	21611.2	2850.5	0.13
TSB	1524.4	1787.7	2102.1	1798.8	177.9	0.10

Table 14. IESSNS baseline time series from 2016 to 2020. StoX abundance estimates of blue whiting (millions).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
2016	3 869	5 609	11 367	4 373	2 554	1 132	323	178	177	8	233	2 283
2017	23 137	2 558	5 764	10 303	2 301	573	250	18	25	0	25	2 704
2018	0	915	1 165	3 252	6 350	3 151	900	385	100	52	41	2 039
2019	2 153	640	1 933	2 179	4 348	5 434	1 151	209	229	5	8	2 028
2020	4 066	5 804	2 996	1 629	1 205	1 718	1 990	939	201	21	30	1 806

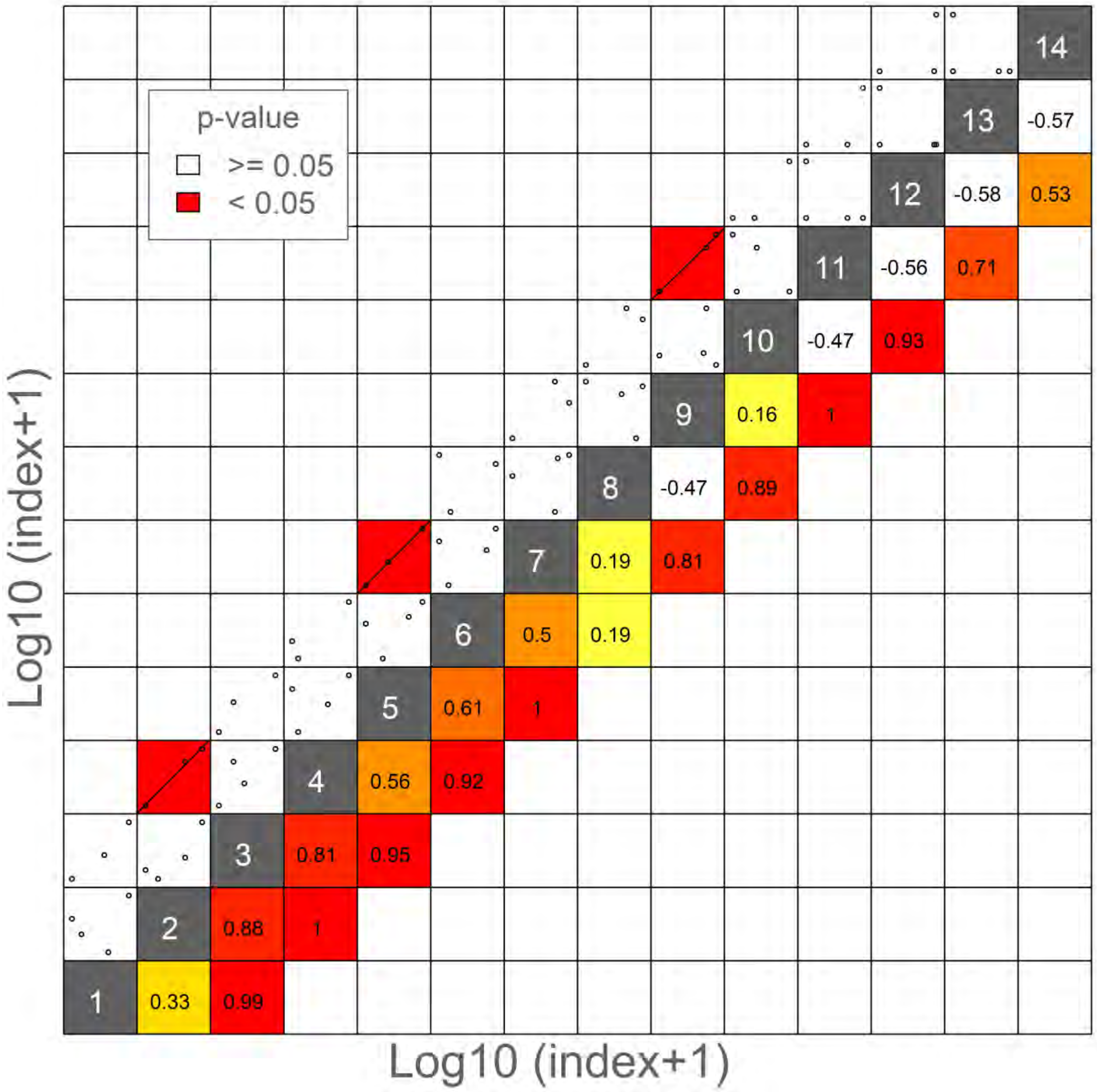

Figure 25. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 74% of trawl stations across the six vessels (Figure 26) and where lumpfish was caught, 72% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Of note, in previous years aboard the Faroese vessel, a subsample of 50 kg to 200 kg of the total catch was processed. Therefore, small catches (<10 kg) of lumpfish may have been missed, however in 2020, all lumpfish were sorted from the catch and weighed.

Abundance was greatest north of 66°N, and lowest directly south of Iceland, and western side of the North Sea. The zero line was not hit to the north, northwest and southwest of the survey so it is likely that the distribution of lumpfish extends beyond the survey coverage. The length of lumpfish caught varied from 2 to 50 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups (Figure 27). For fish ≥20 cm in which sex was determined, the males exhibited a unimodal distribution with a peak around 25-27 cm. The females also exhibited a unimodal distribution but with a peak around 27-30 cm which was positively skewed. Aboard the Norwegian vessels, of the fish which were sexed, the ratio of females to males was approximately 4.4:1. Generally, the mean length and mean weight of the lumpfish was highest in Faroese waters and the coastal waters and along the shelf edges of Norway and lowest in the central and northern Norwegian Sea.

A total of 715 fish (370 by R/V "Árni Friðriksson", 159 by M/V "Eros", 93 by M/V Vendla and 95 by M/V King's Bay) between 10 and 48 cm were tagged during the survey (Figure 28).

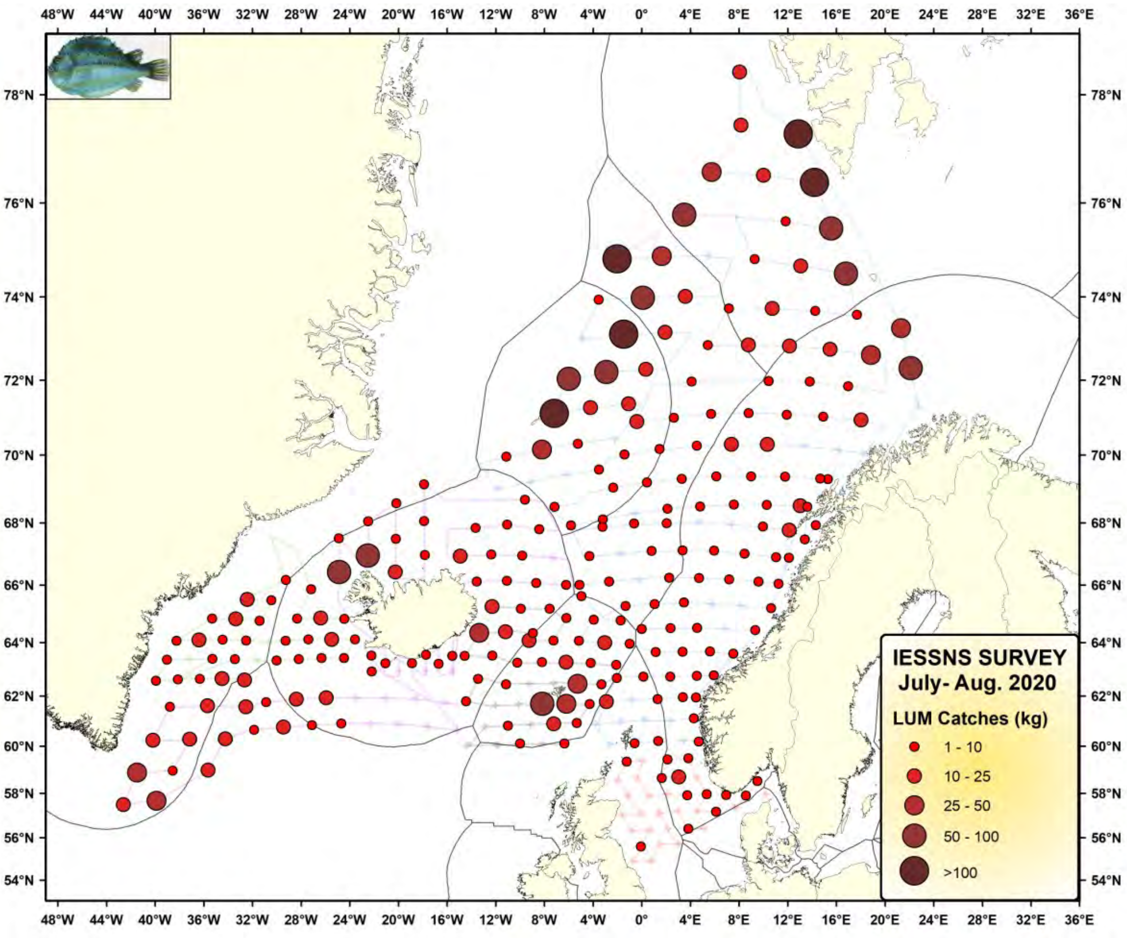

Figure 26. Lumpfish catches at surface trawl stations during IESSNS 2020.

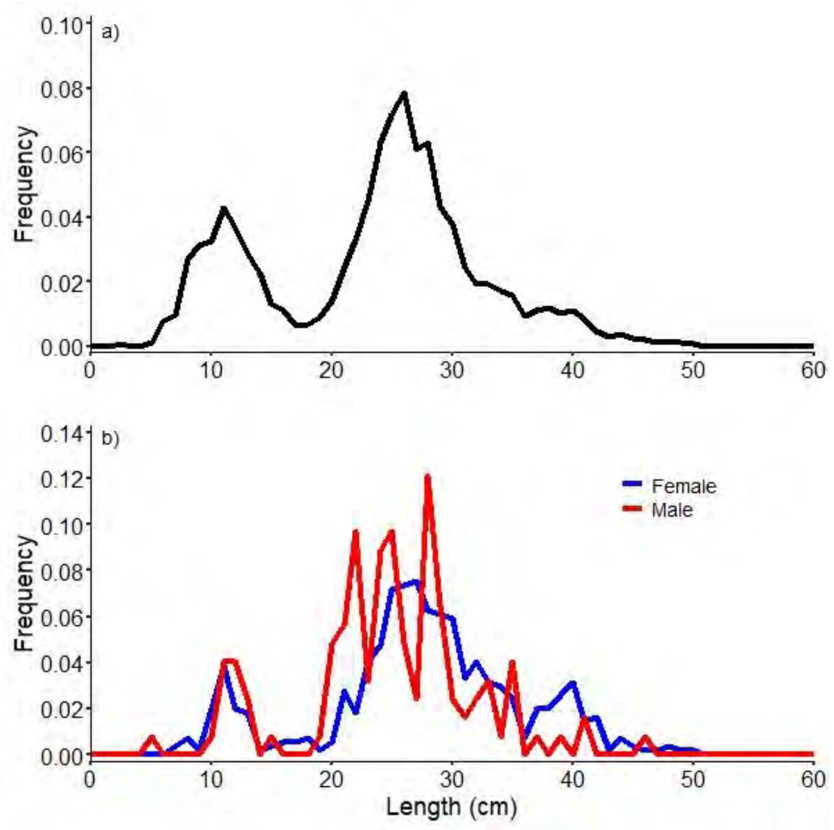

Figure 27. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

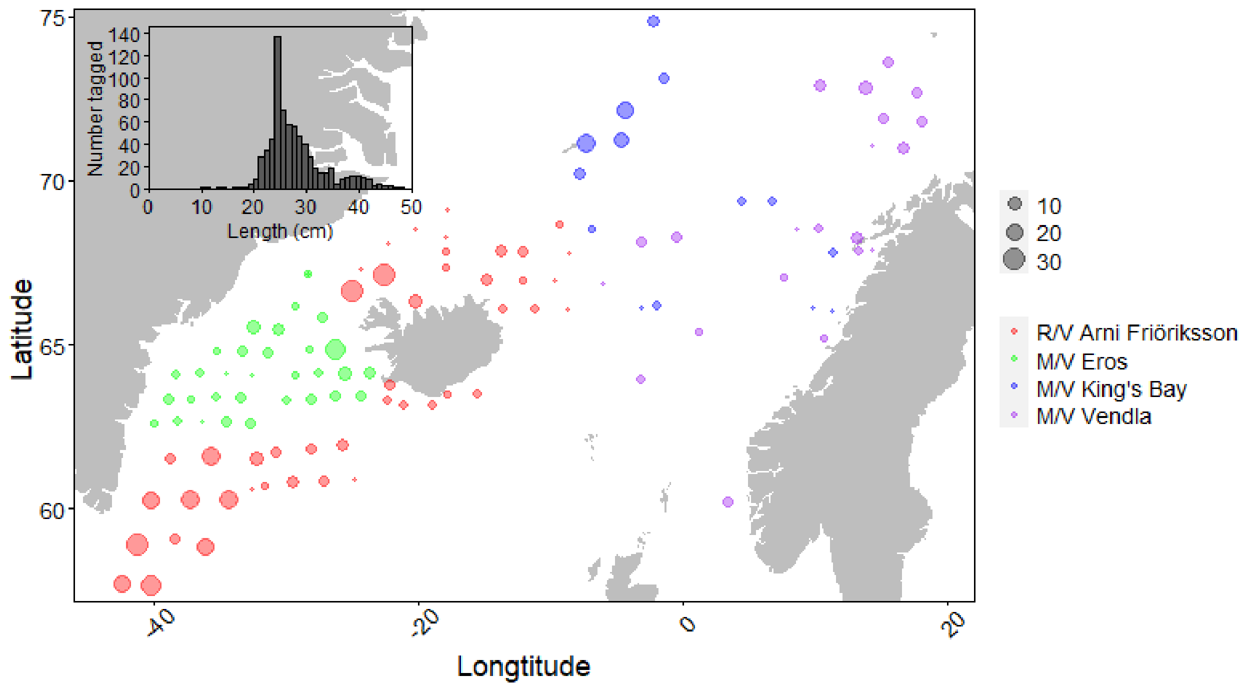

Figure 28. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish. Location of fish tagged aboard King's Bay was not available at time of writing.

Salmon (*Salmo salar*)

A total of 54 North Atlantic salmon were caught in 30 stations both in coastal and offshore areas from 60°N to >77°N in the upper 30 m of the water column during IESSNS 2020 (Figure 29). The salmon ranged from 0.084 kg to 2.73 kg in weight, dominated by postsmolt weighing 100-180 grams and individuals weighing 1-2 kg. We caught from 1 to 8 salmon (small shoals) during individual surface trawl hauls. The length of the salmon ranged from 20.5 cm to 61 cm, with a pronounced bimodal distribution of <30 cm and >45 cm long salmon.

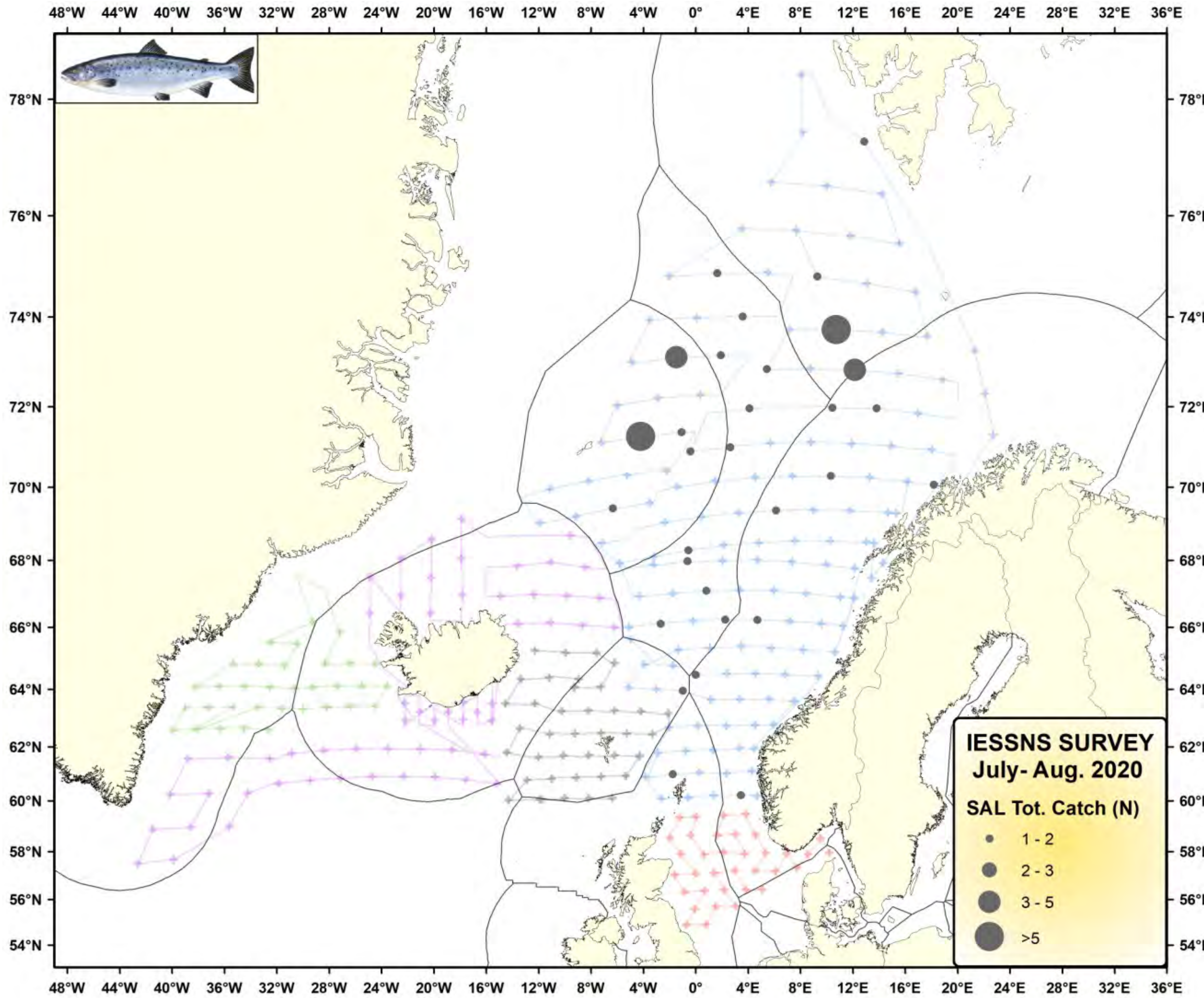

Figure 29. Catches of salmon at surface trawl stations during IESSNS 2020.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 42 stations primarily along the cold fronts: In East Greenland from Cape Farewell to Ittoqqertoormiit, Denmark Strait, North of Iceland, North-East of Jan Mayen and at the entrance to the Barents Sea (Figure 30).

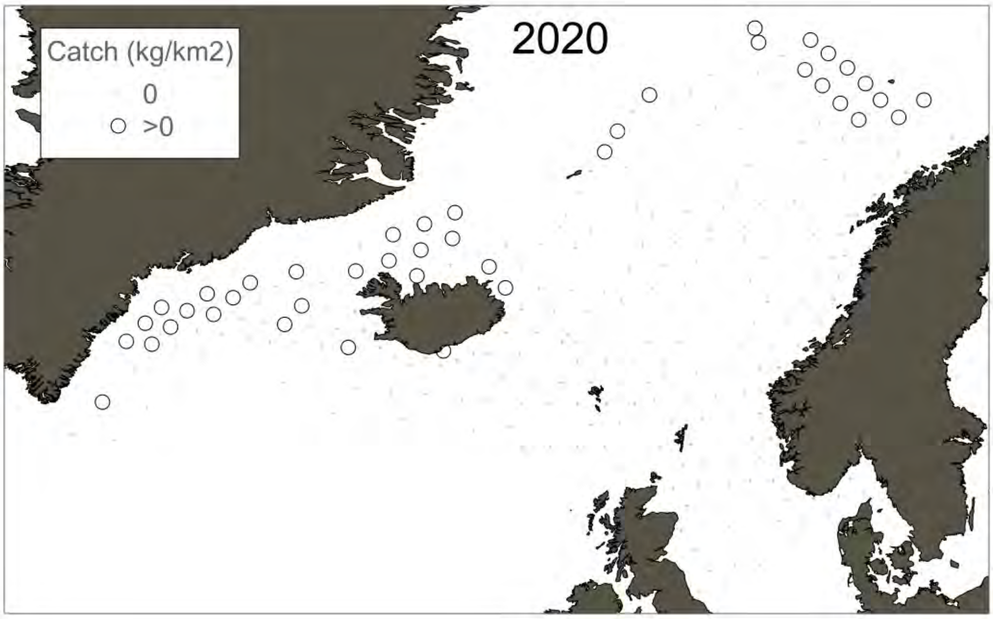

Figure 30. Presence of capelin in surface trawl stations.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Kings Bay" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland in 2020 (Figure 31). Overall, 802 marine mammals of 10 different species were observed, which was an increase from 521 marine mammals in 2019, 600+ in 2018 and 700+ in 2017 observed individuals. R/V "Árni Friðriksson" dedicated whale observers were onboard in 2017 and for the 1st leg in 2020, which was not the case from 2018-2019 and the 2nd leg in 2020. Kings Bay and Vendla conducted only opportunistic whale observations for all years including the years 2017-2020. The increase in number of marine mammals came even though both Kings Bay and Vendla had several days with fog and very reduced visibility in the north-western region (Jan Mayen area) and northernmost areas between Bear Island and Svalbard. This has possibly influenced the low number of marine mammals observed on these two vessels in the normally abundant marine mammal habitats within the northernmost parts of our surveyed areas during IESSNS 2020. R/V "Árni Friðriksson" had also occasional periods with fog north of Iceland.

The species that were observed included; blue whales (*Balaenoptera musculus),* fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), bottlenose whales (*Hyperoodon ampullatus)*, pilot whales (*Globicephala sp*.), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), white beaked dolphins (*Lagenorhynchus albirostris*) and harbour porpoise (*Phocoena phocoena*). The dominant number of marine mammal observations were found around Iceland, along the continental shelf between the north-eastern part of the Norwegian Sea and in a line between Finnmark to southwest of Svalbard. Fin whales (n = 117, group size = 1-20 (average groups size = 4.7)) and humpback whales (n = 89, group size = 1-60 (average groups size = 5.1)) dominated among the large whale species, and they were particularly abundant northwest of Iceland and from Norwegian coast outside Finnmark stretching north/northwest via Bear Island to southwest of Svalbard. Fin whales also appeared to be present in the northeastern part of the Norwegian Sea feeding on NSS herring. Killer whales (n = 71, group size = 1-12 (average groups size = 5.1)) dominated in the southern, northern and north-eastern part of the Norwegian Sea, mostly overlapping and feeding on NES mackerel in the upper water masses. Dolphins (n = 134, group size = 3-20 (average groups size = 8.9)) were present in the northern part of the Norwegian Sea. Minke whales (n = 37, group size = 1-4 (average groups size = 1.4)) dominated in the north-eastern part of the Norwegian Sea, primarily overlapping and feeding on NSS herring in the upper 40 m of the water column. Altogether 3 individual observations of blue whale were done north and northwest of Iceland, whereas 2 northern bottlenose whales were observed south of Iceland. There were generally low numbers of marine mammal observations made of marine mammals in the southern and central parts of the Norwegian Sea in 2020 compared to previous years.

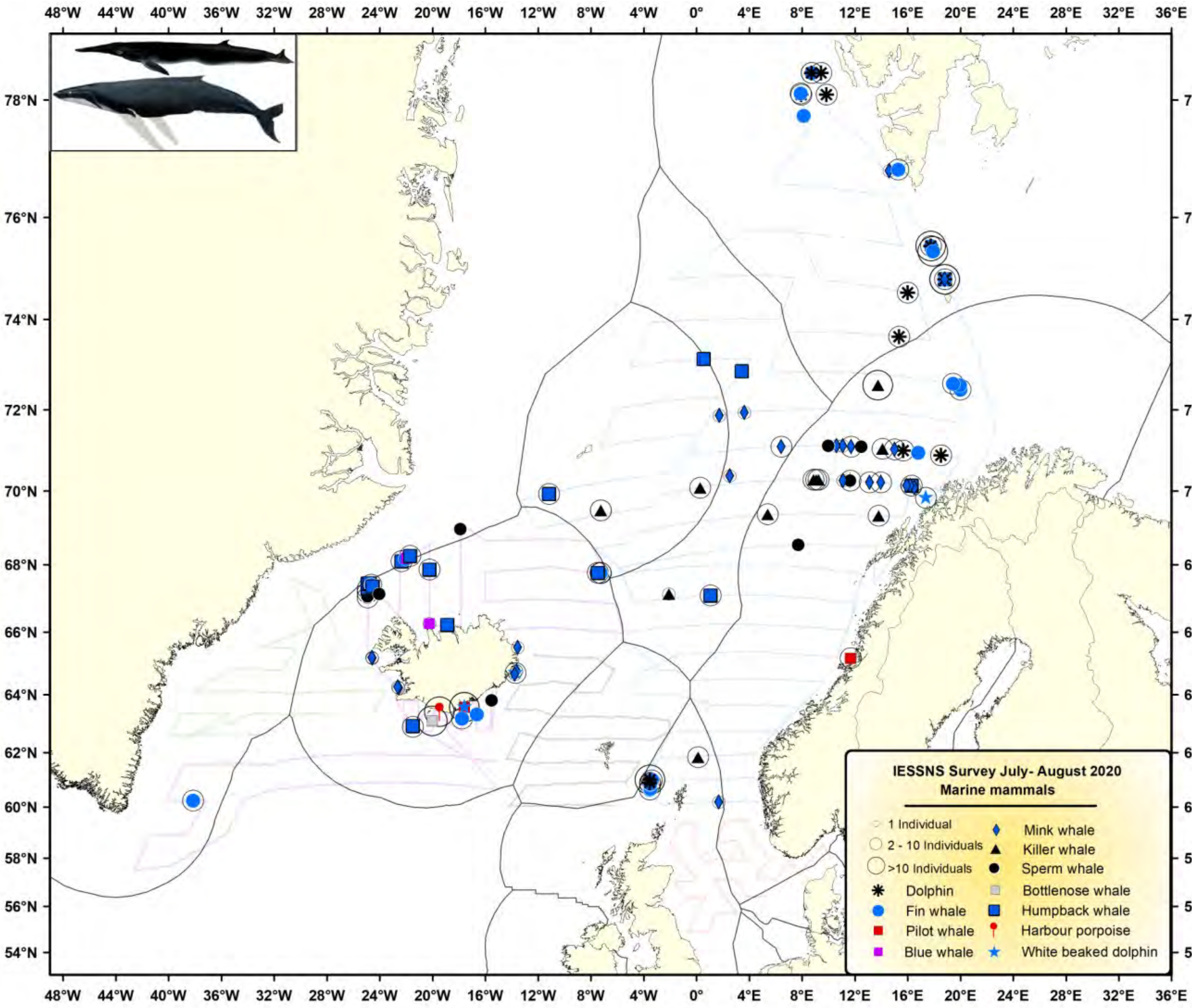

Figure 31. Overview of all marine mammals sighted during IESSNS 2020.

5 Recommendations

Recommendation	To whom
WGIPS recommends that the IESSNS extension to the North Sea should continue for establishing a time series suitable for assessing the part of the NE Atlantic Mackerel stock in the North Sea. The surveys conducted by Denmark in 2018, 2019 and 2020 have demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak for the area that is deeper than 50 m. The survey provides essential fishery-independent information on the stock during its feeding migration in summer and WGIPS recommends that the Danish survey should continue as a regular annual survey.	WGWIDE, RCG NANSEA

6 Action points for survey participants

Action points
The guidelines for trawl performance should be revised to reflect realistic manoeuvring of the Multpelt832 trawl.
Criteria and guidelines should be established for discarding substandard trawl stations using live monitoring of headline, footrope and trawl door vertical depth, and horizontal distance between trawl doors. For predetermined surface trawl station, discarded hauls should be repeated until performance is satisfactory. Explicit guideline for incomplete trawl hauls is to repeat the station or exclude it from future analysis. It is not acceptable to visually estimate mackerel catch, it must be hauled onboard and weighed. If predetermined trawl hauls are not satisfactory according to criteria the station will be excluded from mackerel index calculations, i.e. treated as it does not exist, but not as a zero mackerel catch station.
Tagging of lumpfish should be initiated or continue on all vessels.
We recommend that observers collect sighting information of marine mammals on all vessels.
Table 3 – biological sampling - needs to be changed to reflect what is sampled on the different vessels.
We should consider calculating the zooplankton index from annually gridded field polygons to extract area-mean time-series.
For next year's survey, the group should consider having the strata Greenland South and Iceland south offshore (Strata numbers 11 and 12) as dynamic Strata given the absence of mackerel in these strata the last two years.
For next year's survey, the group should consider distributing transects differently among vessels, such that synoptic coverage becomes better than this year and survey time is optimally used.

7 Survey participants

M/V "Vendla":
Arne Johannes Holmin (cruise leader), Institute of Marine Research, Bergen, Norway
Åge Høines (cruise leader), Institute of Marine Research, Bergen, Norway
Lage Drivenes, Institute of Marine Research, Bergen, Norway
Benjamin Marum, Institute of Marine Research, Bergen, Norway
Valantine Anthonypillai, Institute of Marine Research, Bergen, Norway
Thassya Christina dos Santos Schmidt, Institute of Marine Research, Bergen, Norway
Vilde Regine Bjørdal, Institute of Marine Research, Bergen, Norway
Lea Marie Hellenbrecht, , Institute of Marine Research, Bergen, Norway
Frøydis Tousgaard Rist Bogetveit, Institute of Marine Research, Bergen, Norway
Susanne Tonheim, Institute of Marine Research, Bergen, Norway

M/V "Kings Bay":
Leif Nøttestad (International coordinator and cruise leader), Institute of Marine Research, Bergen, Norway
Are Salthaug (cruise leader), Institute of Marine Research, Bergen, Norway
Jarle Kristiansen, Institute of Marine Research, Bergen, Norway
Olav j. Sørås, Institute of Marine Research, Bergen, Norway
Guosong Zhang, Institute of Marine Research, Bergen, Norway
Eilert Hermansen, Institute of Marine Research, Bergen, Norway
Ørjan Sørensen, Institute of Marine Research, Bergen, Norway
Erling Boge, Institute of Marine Research, Bergen, Norway
Astrid Fuglseth Rasmussen, Institute of Marine Research, Bergen, Norway
Herdis Langøy Mørk, Institute of Marine Research, Bergen, Norway
Inger Henriksen, Institute of Marine Research, Bergen, Norway
Adam Custer, Institute of Marine Research, Bergen, Norway
Christine Djønne, Institute of Marine Research, Bergen, Norway

R/V "Árni Friðriksson":
Anna Heiða Ólafsdóttir (cruise leader and coordinator), Marine and Freshwater Research Institute, Reykjavík, Iceland
Arnþór B. Kristjánsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Ása Hilmarsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Ástþór Gíslason, Marine and Freshwater Research Institute, Reykjavík, Iceland
Birkir Bárðarson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Enrique G. A. Garcia, DTU Aqua, Denmark
Freyr Arnaldsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Georg Haney, Marine and Freshwater Research Institute, Reykjavík, Iceland
Guðrún Finnbogadóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Halldór Tyrfingsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Jacek Sliwinski, Marine and Freshwater Research Institute, Reykjavík, Iceland
James Kennedy (cruise leader), Marine and Freshwater Research Institute, Reykjavík, Iceland
Klara Jakobsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Martina Blumel, Geomar, Germany
Ragnhildur Ólafsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Sigurlína Gunnarsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Sólrún Sigurgeirsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland

Svanhildur Egilsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Sverrir Daníel Halldórsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Teresa S. G. Silva, Marine and Freshwater Research Institute, Reykjavík, Iceland

M/V "Tróndur í Gøtu":
Eydna í Homrum, Faroe Marine Research Institute, Torshavn, Faroe
Ebba Mortensen, Faroe Marine Research Institute, Torshavn, Faroe
Poul Vestergaard, Faroe Marine Research Institute, Torshavn, Faroe
Ragnar Karlsson, Faroe Marine Research Institute, Torshavn, Faroe

M/V "Eros":
On-board cruise leader: Søren L. Post, Greenland Institute of Natural Resources, Nuuk, Greenland
Jørgen Sethsen, Greenland Institute of Natural Resources, Nuuk, Greenland
Alexander Damkjær, Greenland Institute of Natural Resources, Nuuk, Greenland
Frederik Fuda Bjare, Greenland Institute of Natural Resources, Nuuk, Greenland
Svandís Eva Aradóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Land based coordinator: Teunis Jansen, Greenland Institute of Natural Resources, Nuuk, Greenland

M/V "Ceton"
At sea:
Kai Wieland (cruise leader), National Institute of Aquatic Resources, Denmark
Per Christensen, National Institute of Aquatic Resources, Denmark
Dirk Tijssen, National Institute of Aquatic Resources, Denmark
Lab team:
Jesper Knudsen, National Institute of Aquatic Resources, Denmark
Søren Eskildsen, National Institute of Aquatic Resources, Denmark
Gert Holst, National Institute of Aquatic Resources, Denmark
Maria Jarnum, National Institute of Aquatic Resources, Denmark

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1 Appendix 1:

Denmark joined the IESSNS in 2018 for the first time extending the original survey area into the North Sea. The commercial fishing vessels “Ceton S205” was used, and in total 39 stations (CTD and fishing with the pelagic Multipelt 832 trawl) had successfully been conducted. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths larger 50 m. No plankton samples were taken and no acoustic data were recorded because this is covered by the HERAS survey in this area.

Denmark joined the IESSNS again in 2020 using the same vessel. 35 stations were taken (PT and CTD, no plankton and no appropriate acoustic equipment available). The locations of stations differed slightly from the previous year focussing on the area north and west of Doggerbank and extended into the eastern Skagerrak.

Average mackerel catch in 2020 was higher than in 2019 (1318 kg/km² compared to 1009 kg/km² in 2019 and 1743 kg/km² in 2018). The length and age composition indicate a relative high amount of small (< 25 cm) individuals (Tab. A.1) whereas the abundance of older (≥ age 6) mackerel was similar to the two previous years (Fig. A.1.).

StoX baseline estimate of mackerel abundance in the North Sea was 257 079 tonnes (Table A1-1.)

Table A1-1. StoX baseline estimate of age segregated and length segregated mackerel index for the North Sea in 2020. Also provided is average length and weight per age class.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290	16.2	56.00
20-21	658	-	-	-	-	-	-	-	-	-	-	-	-	-	-	658	46.0	69.86
21-22	14362	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14362	1095.1	76.25
22-23	89711	-	-	-	-	-	-	-	-	-	-	-	-	-	-	89711	7814.2	87.10
23-24	243191	-	-	-	-	-	-	-	-	-	-	-	-	-	-	243191	24255.8	99.74
24-25	221620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	221620	24426.8	110.22
25-26	70558	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70558	8987.5	127.38
26-27	20143	30	-	-	-	-	-	-	-	-	-	-	-	-	-	20173	3056.0	151.49
27-28	14250	755	-	-	-	-	-	-	-	-	-	-	-	-	-	15005	2587.2	172.43
28-29	16512	10895	30	-	-	-	-	-	-	-	-	-	-	-	-	27438	5589.7	203.72
29-30	41904	45292	-	118	-	-	-	-	-	-	-	-	-	-	-	87314	20048.0	229.61
30-31	12433	105414	10511	149	-	-	-	-	-	-	-	-	-	-	-	128506	32163.8	250.29
31-32	9337	87232	18023	8	56	-	-	-	-	-	-	-	-	-	-	114656	30945.2	269.90
32-33	-	44072	29681	2938	273	-	33	33	-	-	-	-	-	-	-	77031	23036.7	299.06
33-34	-	6172	33006	24828	3610	17	-	33	-	-	-	-	-	-	-	67667	21906.0	323.73
34-35	-	104	18866	8811	27909	2740	10	-	-	-	-	-	-	-	-	58440	19251.6	329.43
35-36	-	-	2525	2680	24833	8721	-	-	-	71	-	-	-	-	-	38830	14652.9	377.36
36-37	-	-	-	8	6446	14148	1943	271	-	-	-	-	-	-	-	22816	9291.2	407.22
37-38	-	-	-	-	420	4214	3603	1294	31	765	61	-	-	-	-	10388	4638.9	446.57
38-39	-	-	-	-	138	215	273	982	403	16	-	-	-	-	-	2026	966.3	476.93
39-40	-	-	-	-	-	-	891	194	800	-	-	-	-	-	-	1885	956.1	507.11
40-41	-	-	-	-	-	-	-	635	8	246	689	125	-	157	-	1860	963.2	517.87
41-42	-	-	-	-	-	-	-	-	-	48	224	-	-	-	-	272	170.5	626.65
42-43	-	-	-	-	-	-	-	-	-	212	-	-	18	-	61	291	207.7	714.65
43-44	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	8	6.3	807.00
44-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46-47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TSN(1000)	754967	299966	112643	39540	63685	30054	6754	3442	1242	1366	974	125	18	157	61	1314994	-	-
TSB(1000 kg)	91063.5	76959.2	34212.6	13320.1	22366.7	12552.2	2985.1	1575.9	592.4	711.0	542.8	68.5	11.4	81.0	36.4	-	257078.9	-
Mean length (cm)	24.13	30.42	32.35	33.26	34.55	35.68	36.99	37.79	38.63	38.40	40.04	40.00	42.00	40.00	42.00	-	-	-
Mean weight (g)	120.62	256.56	303.73	336.88	351.21	417.66	441.98	457.84	476.86	520.68	557.39	550.00	649.00	516.00	596.00	-	-	195.50

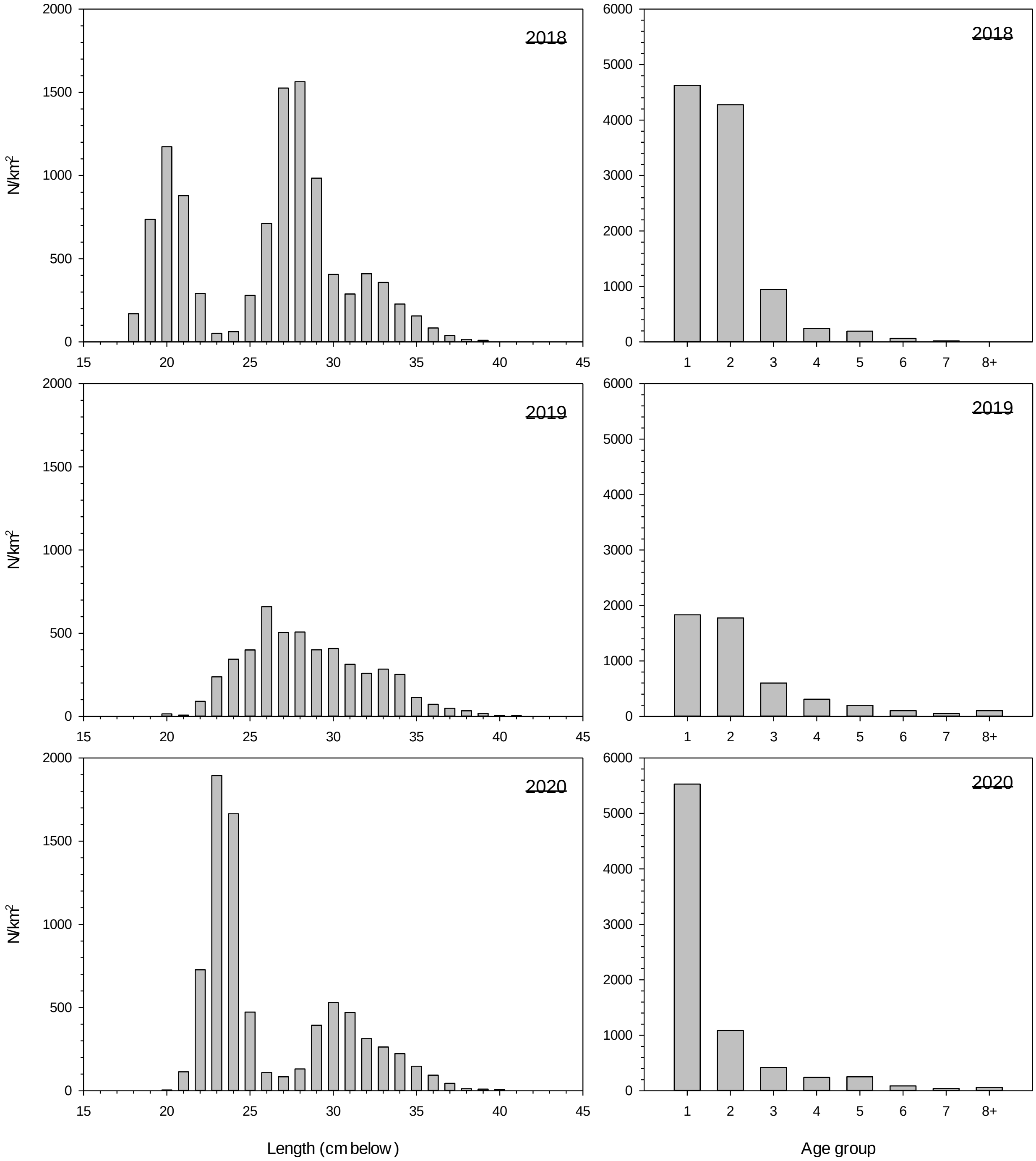

Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018, 2019 and 2020.

2 Annex 2:

The mackerel index is calculated on all valid surface stations. That means, that invalid and potential extra surface stations and deeper stations need to be excluded. Below is the exclusion list used when calculating the mackerel abundance index for IESSNS 2020.

Table A2-1: Trawl station exclusion list for IESSNS 2020 for calculating the mackerel abundance index.

Vessel	Country	Exclusion list	
		Cruise	Stations
Kings Bay	Norway	2020814	15,21,28,33,38,46,50,57,61,64,69,81,94
Vendla	Norway	2020813	41,46,54,61,71,77,85,88,89,91,96,99,101,104,125
Árni Friðriksson	Iceland	A7-2020	393,401,414,417,424,427,433
Tróndur í Gøtu	Faroe Islands	2052	7,14,25,42,49,70,73 *
Eros	Greenland	CH-2020-01	122,128
Ceton	EU (Denmark)	IESSNS2020	none

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceded by 2052 (e.g. ‘20520025’)

Working Group for the Working Group on Widely Distributed Stocks (WGWIDE)
26 August – 1 September 2020, Copenhagen (Denmark)

Update of striped red mullet abundance indices from professional fishing data (2016-2018)

Nathalie Caill-Milly[1], Muriel Lissardy[1], Noëlle Bru[2]

[1] Ifremer, LITTORAL, 1, allée du Parc Montaury, F-64600 Anglet, France

[2] Université de Pau et des Pays de l'Adour, E2S UPPA, CNRS, LMAP, Anglet, France

Context

The ROMELIGO project (2015-2018) aimed to contribute to the improvement of the knowledge on three stocks (mur-west, whg-89a and pol-89a – see Table 1) on the basis of the available data (landings data, sampling data for the French fleet, data from scientific campaigns...) or specific data collected during the project.

Table 1: Stocks considered by the ROMELIGO project for red mullet, whiting and pollack.

Species	**Stock name**	**Stock code**
Striped red mullet	Striped red mullet areas VI, VIII et sub-areas VIIa-c, e-k et IXa (West area)	mur-west
Whiting	Whiting area VIII et sub-area IXa	whg-89a
Pollack	Pollack area zone VIII et sub-area IXa	pol-89a

The project was organized in the same way in three parts and applied for each of the three stocks:

- Part 1 - Analyses of catches and activity of the French professional fishery (composition and evolution of catches, seasonality, spatial distribution, gear used and discards);
- Part 2 - Analyses of the size composition of the catches on professional and scientific vessels, analyses of the discards, proposition of abundance indicators using professional fishing data and analyses of CPUE from available scientific surveys;
- Part 3 - Collection of basic biological data relying on various samplings and calculation of biological parameters (length / weight relationships, growth curves, length at first maturity (L50) or maturity ogive...).

The contract report is available online (Léauté et al., 2018[1]). A paper on the methodology used to select the reference fleets for the calculation of red mullet LPUE was also published (Caill-Milly et al., 2019).

In relation to this work and regarding **striped red mullet**, two WDs were already sent and presented to the WGWIDE respectively in 2017 and 2018:

- One dedicated to part 1 integrating as a preamble a bibliographic review on the biology of the species (Caill-Milly et al., 2017);
- One dedicated to parts 2 and 3 (Caill-Milly et al., 2018).

This WD provides the update of striped red mullet abundance indices from professional fishing data (2016-2018).

[1] https://archimer.ifremer.fr/doc/00440/55126/

A reminder of the previous results (Caill-Milly et al., 2018)

For this species and for the Bay of Biscay, Table 2 describes the characteristics of the fleets selected to build abundance indices from professional fishing data. The selection was based on gears, technical characteristics of the vessels (defined by clusters), characteristics of the gears (mesh class) and time. No space specification within the Bay of Biscay were defined for this species. For red mullet, the retained gears and clusters are:

- "Bottom otter trawls" (OTB) and cluster 1. Cluster 1 corresponds to small vessels (7.9 to 15.8 m) with small tonnage (2.0 to 43.9 grt) and an engine power comprised between 44 and 256 kW. The full year was considered;
- "Set gillnets (anchored)" (GNS) and cluster 2. This second cluster corresponds to medium vessels (8.2 to 14.8) with medium tonnage (2.0 to 30.2 grt) and an engine power comprised between 70 and 331 kW. Depending of the mesh class, quarters 2 and/or 3 were selected because the activity is marked by a strong seasonality.

Table 2: Characteristics of the selected fleets regarding whiting.

Retained gear	Cluster	Gear mesh class	Period	Specific spatial delimitation
Bottom otter trawls (1 vessel) "OTB"	Cluster 1	70 to 79 mm	Annual	No (whole Bay of Biscay)
Set gillnets (anchored) "GNS"	Cluster 2	50 to 59 mm	Quarter 2	No (whole Bay of Biscay)
			Quarter 3	
		60 to 69 mm	Quarter 2	
		Sup to 90 mm	Quarter 2	

Gear "OTB"

For the selected mesh class (70 - 79 mm), the evolutions of the LPUE mean level and of its use over time were considered for the entire year and the whole Bay of Biscay.

The number of uses shows a decrease during the study period, however this decrease is not significant. Like uses, LPUE decreases over the period of study but significantly in this case (Figure 1).

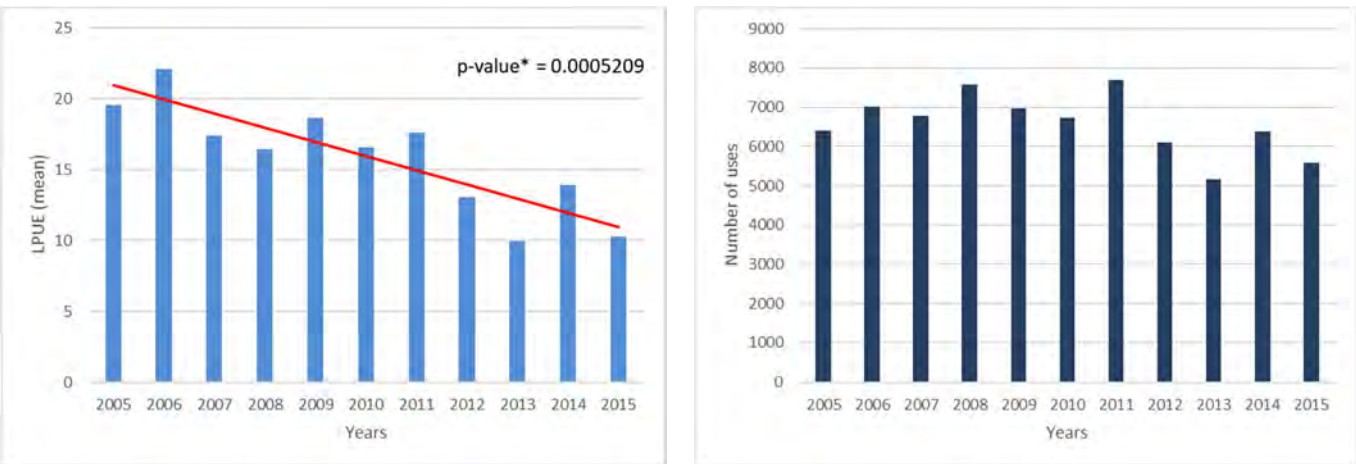

Figure 1: Levels of LPUE and number of uses - Bottom otter trawls - Cluster 1 - Mesh class 70 - 79 mm - Annual – Bay of Biscay

Gear “GNS”

For each of the combinations mesh / quarter of cluster 2 - GNS, the evolutions of their use over time and of their LPUEs for the entire Bay of Biscay were considered.

Gear meshes 50 - 59 mm and 60 - 69 mm have their use levels of gear that decrease significantly for the second quarter (Figures 2 and 4). For the gear mesh 60 - 69 mm, this decrease is in conjunction with a significant decrease of the LPUEs over the period. For the other couples of gear mesh classes / quarter, the number of uses and the LPUEs seem to decrease but it is not significant (Figures 3 and 5).

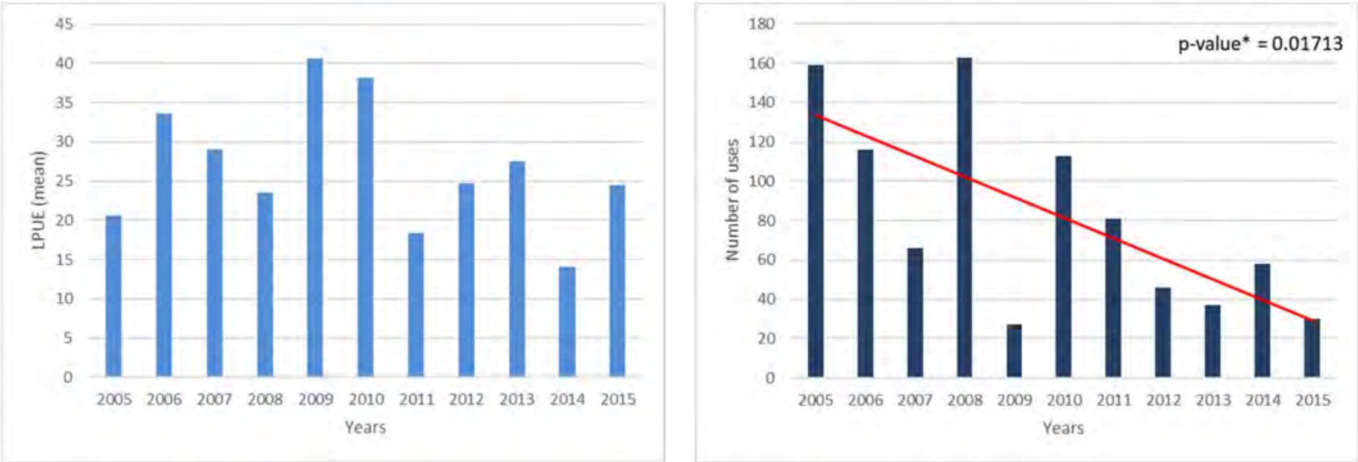

Figure 2: Levels of LPUE and number of uses - Set gillnets - Cluster 2 - Mesh class 50 - 59 mm - Quarter 2 – Bay of Biscay

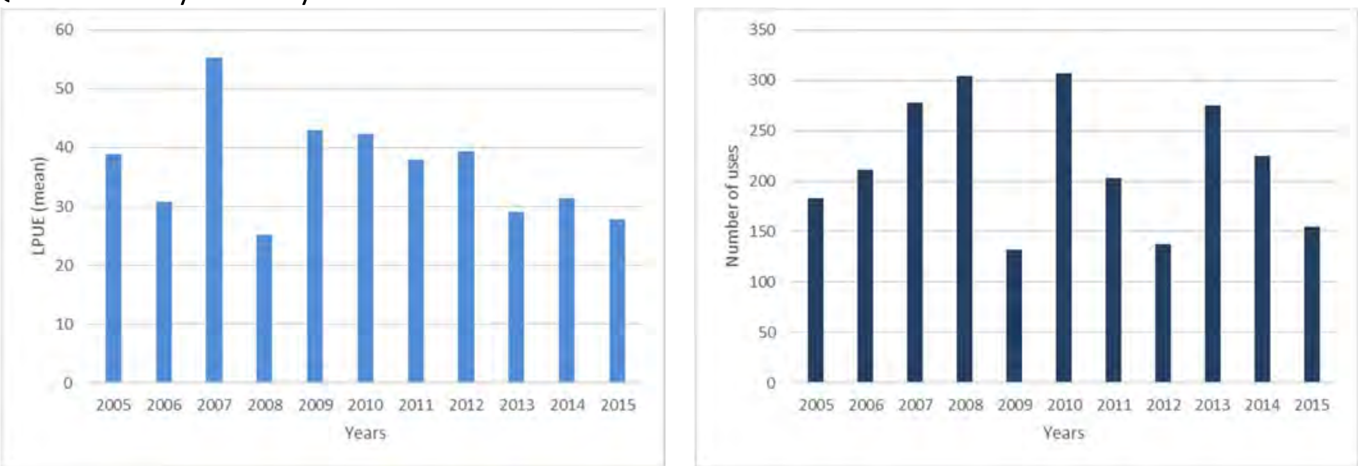

Figure 3: Levels of LPUE and number of uses - Set gillnets - Cluster 2 - Mesh class 50 - 59 mm - Quarter 3 – Bay of Biscay

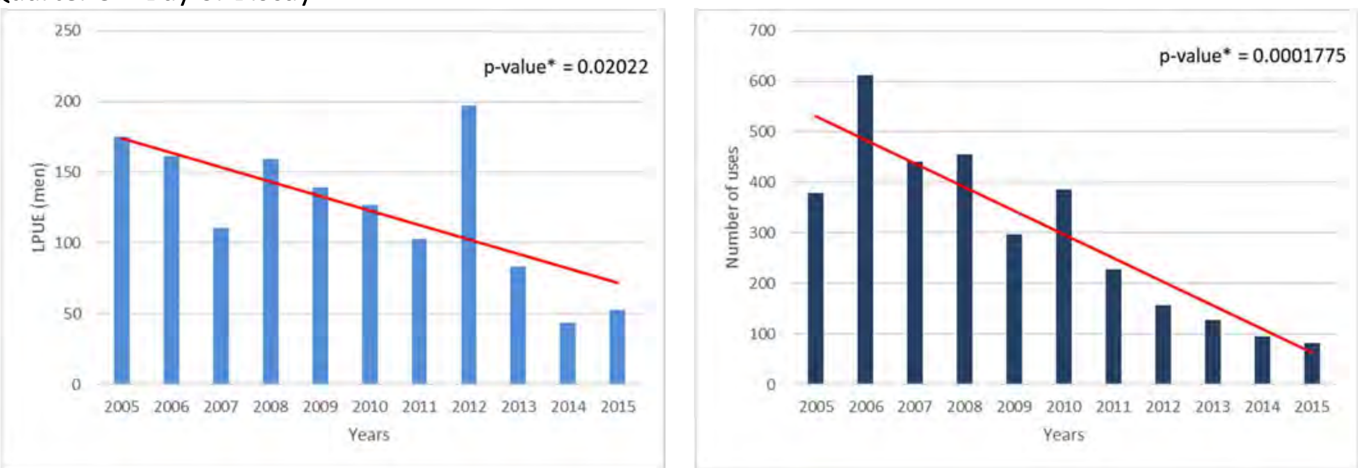

Figure 4: Levels of LPUE and number of uses - Set gillnets - Cluster 2 - Mesh class 60 - 69 mm - Quarter 2 – Bay of Biscay

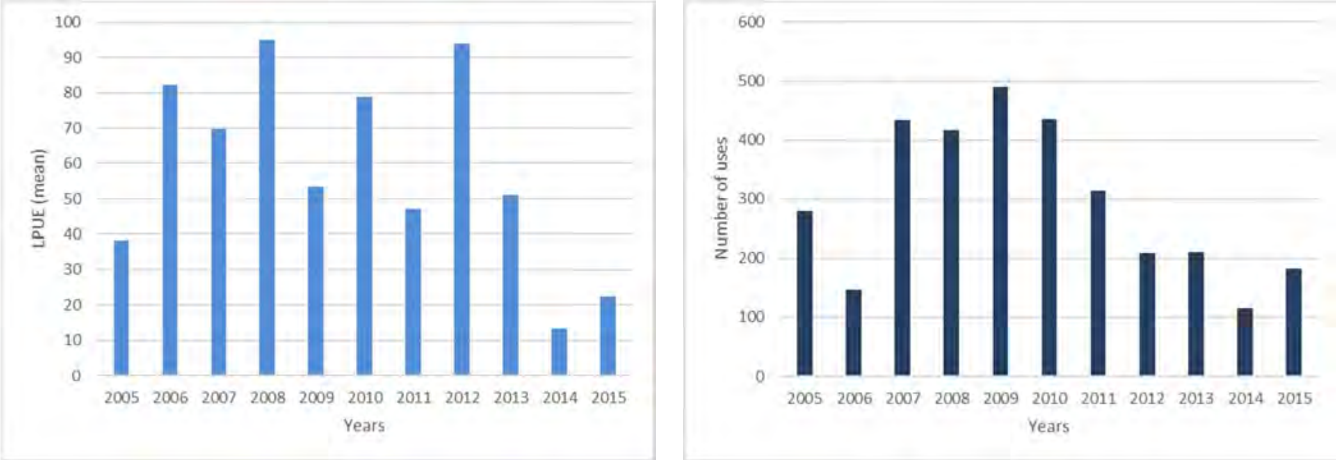

Figure 5: Levels of LPUE and number of uses - Set gillnets - Cluster 2 - Mesh class higher than 90 mm - Quarter 2 – Bay of Biscay

Method used to update the abundance indices from professional fishing data

The proposed method allows an update of the LPUEs of the selected fleets after 2015. It requires the assignment of new vessels in one of the clusters defined in the project beforehand. This is to be done at the level of the selected gear for the species (*i.e.* OTB and GNS for striped red mullet).

Clusters are the result of a hierarchical classification of vessels based on their technical characteristics (length, tonnage and engine power). The vessels were grouped according to their degree of similarity for these three variables using Hierarchical Aggregation Clustering (HAC) with Ward aggregation criterion and Euclidean distance.

When grouping with a clustering method such as the above one, it is difficult to identify clearly the bounds allowing to affect one vessel in a specified cluster (because of possible overlaps of some of the characteristics from one cluster to another). A method of assigning vessels was therefore developed for the selected gear.

To do this, conditional decision trees were built for each selected gear (OTB and GNS for striped red mullet). In each case, the targeted variable was the variable “cluster”. Based on the existing classification, each decision tree provides the rules fixing the values that must take the different technical variables for a vessel to belong to a given cluster for a given gear. The leaves (of the tree) not selected are either because they do not concern the targeted cluster or because the risk of classification error is considered too high.

Once this step has been completed, updating of the data (number of uses of the selected gears and average levels of LPUE) was carried out. It concerned the years 2016, 2017 and 2018. This update was sent to the professional structures involved in the former "CPUE Working Group" of the Romeligo project. The objective was to identify regulatory or other elements that could potentially disturb the LPUE index constructed for 2016, 2017 and 2018.

Results

Decision criteria for the assignment of new vessels appearing in 2016, 2017 or 2018

Regarding striped red mullet and for OTB, the retained tree (Fig. 6) is the one which setting minimizes the prediction error for cluster 1 and for all the data (cluster 1 prediction error: 0.4%; total prediction error: 1.1%).

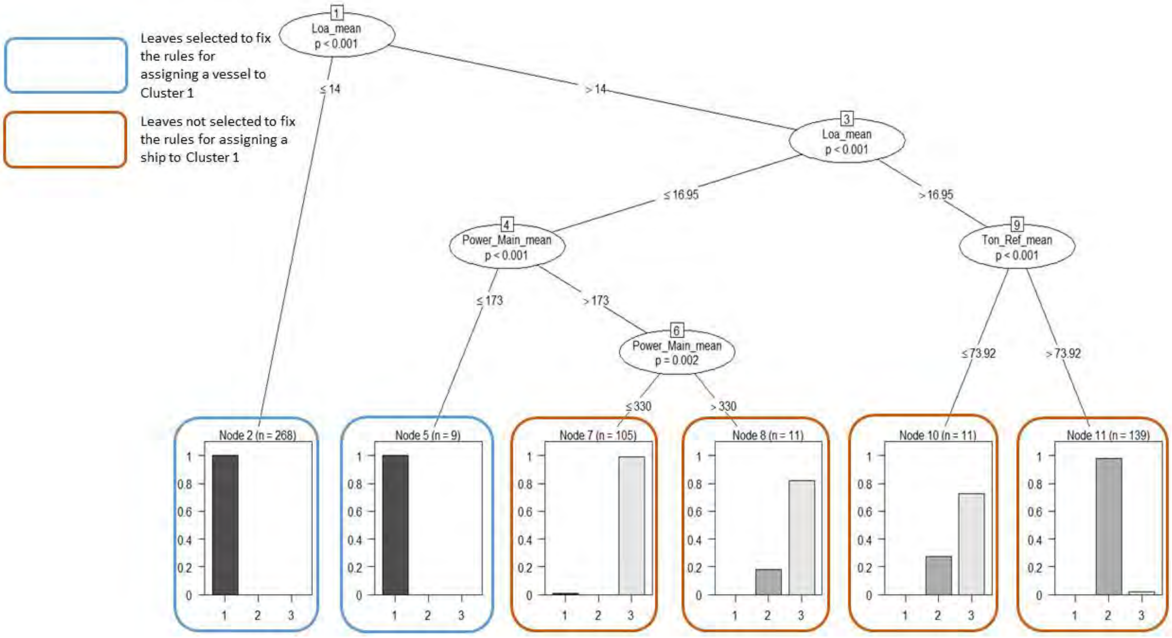

Figure 6: Conditional regression tree on cluster 1 variable (for striped red mullet / OTB) with technical characteristics [Loa: Length (m); Ton_Ref: tonnage (grt); Power_Main: engine power (kW)].

Consequently, a vessel falls into the cluster 1 if:

• Its length is less or equal to 14 m;

• Or if its length is greater than 14 m and less than 16.95 m with an engine power less or equal to 173 kW.

Regarding striped red mullet and for GNS, the retained tree (Fig. 7) is the one which setting minimizes the prediction error for cluster 2 and for all the data (cluster 2 prediction error: 0.8%; total prediction error: 1.3%).

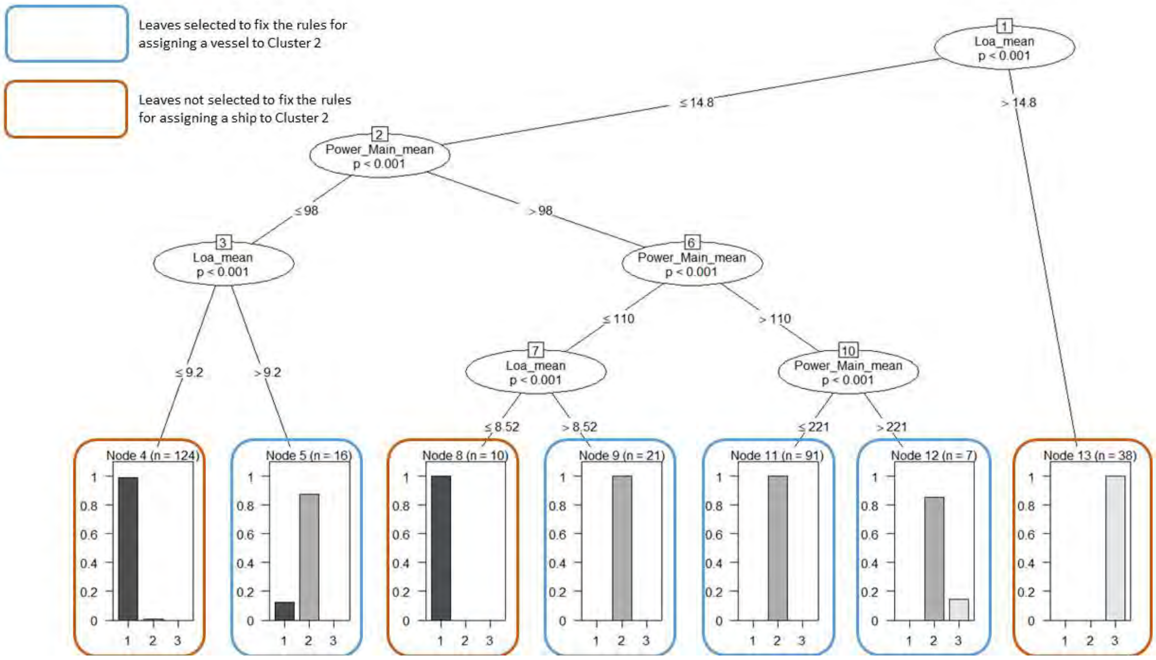

Figure 7: Conditional regression tree on cluster 2 variable (for striped red mullet / GNS) with technical characteristics [Loa: Length (m); Ton_Ref: tonnage (grt); Power_Main: engine power(kW)].

Consequently, a vessel falls into the cluster 2 if its length is less than 14.8 m and:

• If its engine power is less or equal to 98 kW and its length greater than 9.2 m;

• Or if its engine power is greater than 98 kW and lower than 100 kW with a length greater than 8.52 m;

• Or if its engine power is greater than 110 kW.

Update of data and evolution of the indices

For OTB

The evolution of the number of uses and of the mean level of LPUE are shown for the entire year and the whole Bay of Biscay (Figure 8).

Figure 8: Numbers of uses and levels of LPUE - Bottom otter trawls - Cluster 1 - Mesh class 70 - 79 mm – Annual – Bay of Biscay

The number of uses shows little variation during the period. In recent years, the LPUEs calculated for the Bay of Biscay show low levels which remain low compared to the whole series. The end of the series seems to be marked by an upward recovery which will remain to be confirmed in the following years.

For GNS

The evolution of the number of uses and of the mean level of LPUE for each couples of gear mesh classes / quarter are shown for the selected quarters and for the whole Bay of Biscay (Figures 9 to 12).

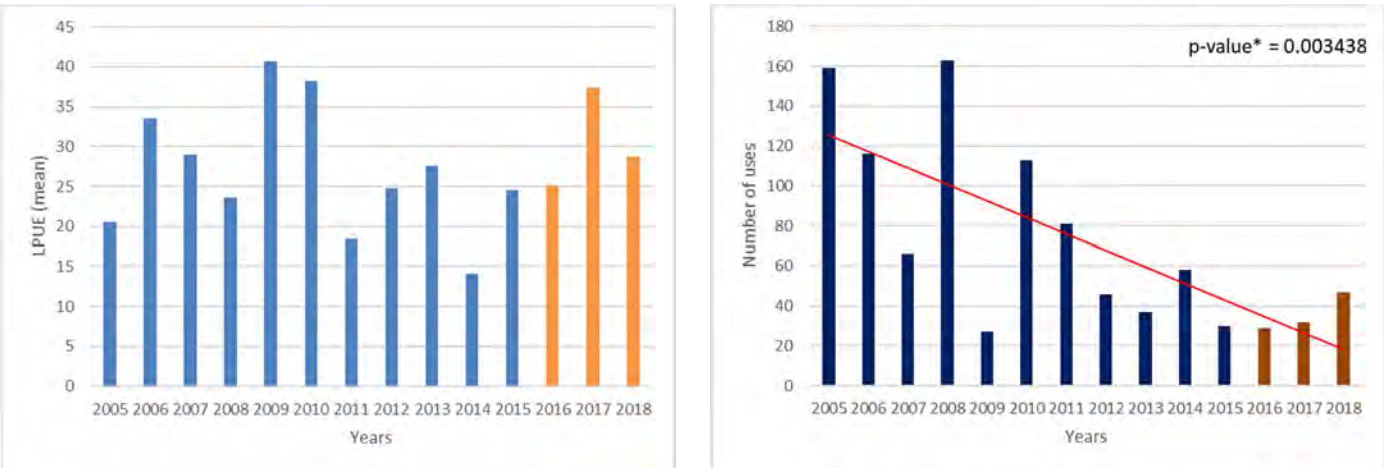

Figure 9: Numbers of uses and levels of LPUE - Set gillnets - Cluster 2 - Mesh class 50 - 59 mm – Quarter 2 – Bay of Biscay

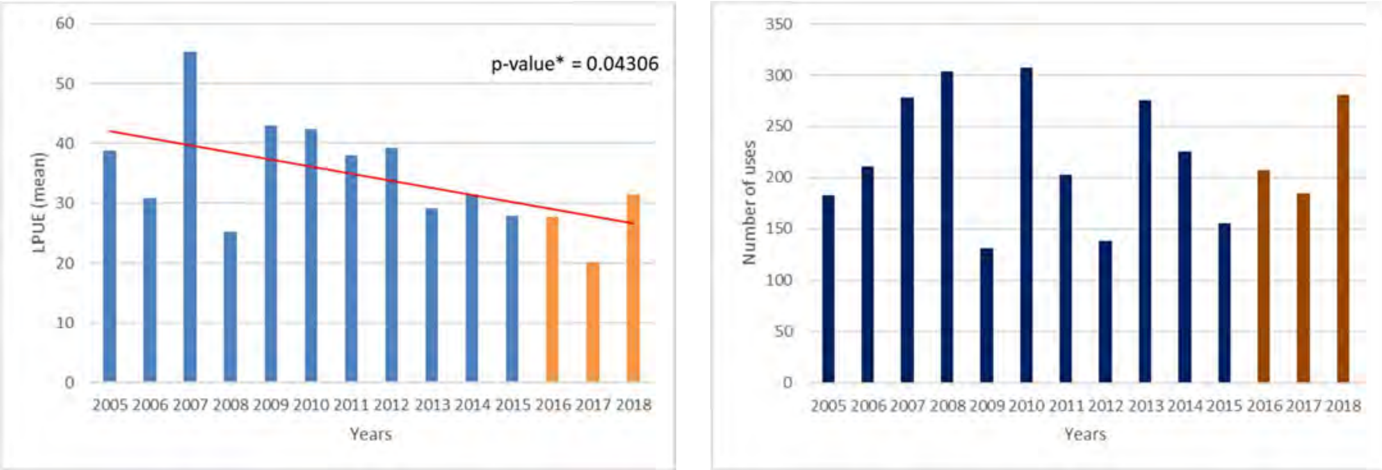

Figure 10: Numbers of uses and levels of LPUE - Set gillnets - Cluster 2 - Mesh class 50 - 59 mm – Quarter 3 – Bay of Biscay

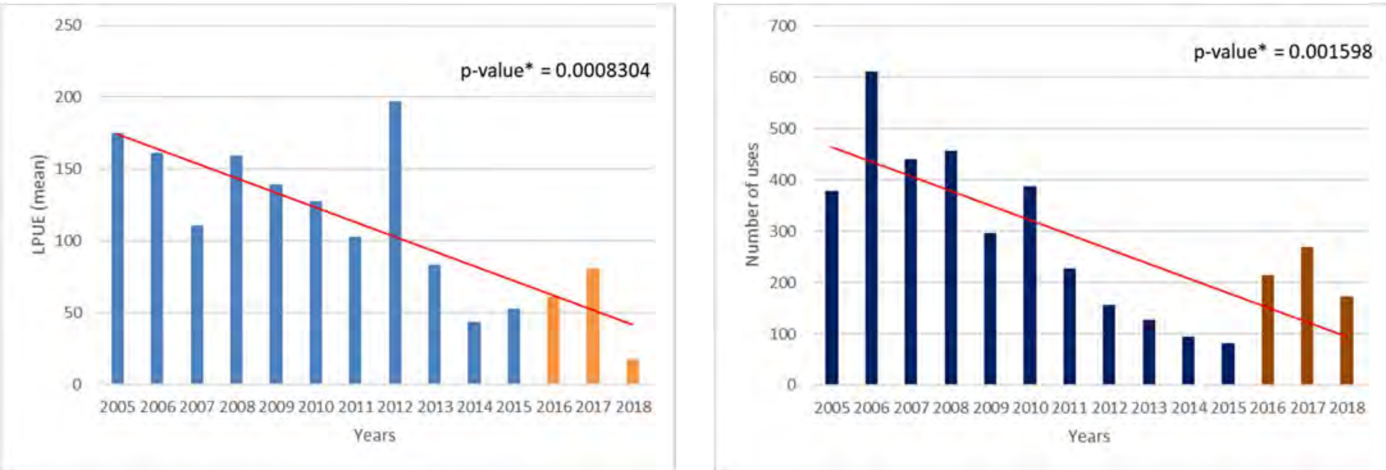

Figure 11: Numbers of uses and levels of LPUE - Set gillnets - Cluster 2 - Mesh class 60 - 69 mm – Quarter 2 – Bay of Biscay

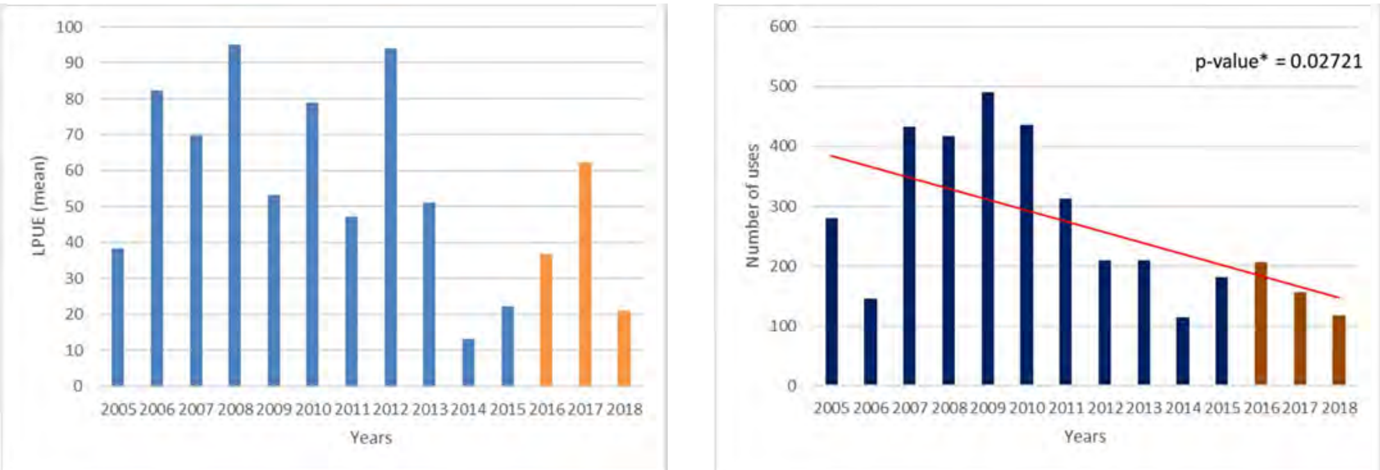

Figure 12: Numbers of uses and levels of LPUE - Set gillnets - Cluster 2 - Mesh class higher than 90 mm – Quarter 2 – Bay of Biscay

Over the whole period, a downward trend is observed in three out of four cases for the number of fishing sequences and in two out of four cases for the average LPUE.

In recent years, only LPUEs for the 50-59 mm class in the second quarter have shown high levels compared to the rest of the series, but for a low number of sequences. The LPUE level for the 60-69 mm mesh class in the second quarter was particularly low in 2018.

Information from the consultation of professional structures

For OTB

The consultation identified one regulatory element that could potentially have disturbed the LPUE indices built for 2016, 2017 and 2018: the decree concerning trawlers over 12 m which have a European Fishing Authorization (EFA) to fish common sole in the Bay of Biscay[2].

The list of these vessels was not recovered. We only looked at the evolution of the number of fishing sequences by vessels over 12 m and their associated LPUE. This number of sequences is marked by a sharp drop in 2016 and remained at a low level in 2017 and 2018. It was accompanied by a drop in the average LPUE for these vessels (longer than 12 m), a drop already recorded before.

⇨ Considering all the available data and assuming that all things are equal, it is estimated that the levels of LPUE between 2016 and 2018 could have been impacted by the measurement management, but without changing the trend of the indicator.

For GNS

The consultation did not identify regulatory element that could potentially have disturbed the LPUE / GNS indices built for 2016, 2017 and 2018.

Conclusion

Currently five fleets are selected for the Bay of Biscay:

- OTB - Cluster 1 - Mesh size 70 - 79 mm - Annual - Bay of Biscay;
- GNS - Cluster 2 - Class mesh 50 - 59 mm - Quarter 2 - Bay of Biscay;
- GNS - Cluster 2 - Class mesh 50 - 59 mm - Quarter 3 - Bay of Biscay;
- GNS - Cluster 2 - Class mesh 60 - 69 mm - Quarter 2 - Bay of Biscay;
- GNS - Cluster 2 - Class mesh greater than 90 mm - Quarter 2 - Bay of Biscay.

For the GNS indicators, the number of uses decreases in three out of four cases, that concerning the mesh class 50 - 59 mm in the 2nd quarter reaching a very low level (around 40 sequences in 2018). It is proposed to no longer use this last indicator because we consider that it is no longer representative. For the others, more in-depth work should be able to be carried out in the project ACOST (submitted to the FFP call). At the same time, the interest of considering the Danish seine gear could be posed because the length of the series is now sufficient.

[2] Since January 1st, 2016, this decree imposes a mandatory minimum mesh size of 80 mm for the vessels concerned (having this authorization), out of derogation period from June 1st to September 30th each year. This latter period makes it possible to practice specific metiers (for example bottom trawls targeting wedge sole). This decree was modified at the end of 2018, with the possibility of shifting the derogation period of 4 consecutive months.

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Sacrois versions used for the update: V.3.3.7 for the 2016 to 2017 data and V.3.3.8 for the 2018 data (extraction November 2019)

Working document 05, WGWIDE 2020

Overview of spatial distribution of catches of mackerel, horse mackerel, blue whiting and herring

Martin Pastoors, 31/08/2020

Abstract

An overview is presented of the catch per rectangle data that is available at WGWIDE 2020 for mackerel, horse mackerel, blue whiting and Atlanto-scandian herring.

Introduction

WGWIDE and its precursors WGMHSA and WGNPBW have been publishing catch per rectangle plots in their reports for many years already. Catch by rectangle has been compiled by WG members and generally provide a WG estimate of catch per rectangle. In most cases the information is availalble by quarter whereas most recently, the data has been requested by month. So far, the catch by rectangle has only been presented for one single year in the WG reports. Here, we collated all the catch by rectangle data that is available for herring, blue whiting, mackerel and horse mackerel for as many years as available.

Results

An overview of the available catches by rectangle, species and year is shown in the text table below. For horse mackerel and mackerel, a long time series is available, starting in 2001 (HOM) and 1998 (MAC). The time series for herring and blue whiting are shorter (starting in 2011) although additional information could be derived from earlier WG reports.

species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HOM	.	.	.	242971	220889	226642	204409	218002	182172	162691
MAC	634501	573960	614831	664986	648890	568184	579449	505956	447288	550033

species	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HER	.	.	.	993001	819755	684723	461383	328679	383081	715545
HOM	111071	261563	252455	211305	181505	220870	141685	108136	113592	122009
MAC	584410	713180	861394	936099	874986	920066	1374495	1166138	1083641	1151726
WHB	.	.	.	103861	377079	616511	1139737	1389447	1175687	1540077

species	2018	2019
HER	592555	776193
HOM	118276	144149
MAC	1016924	831564
WHB	1698078	1507471

For each species an overview table is presented of catch by country and year and a figure with catch by rectangle and year. Catches by rectangle have been grouped in logarithmic classes (1-10, 10-100 etc).

Discussion

While the aggregation and presentation of the catch per rectangle data for mackerel, horse mackerel, blue whiting and atlanto-scandian herring does not constitute rocket-science, it does provide us with meaningful insights into the changes of catching areas over time. This could be relevant also in understanding the impacts of climate change on fisheries and in relating changes in the distribution of prey or predator species (e.g. bluefin tuna). As such, these graphical representations of catching areas provide a useful addition to the WG report.

One important check that still needs to be carried out is the check on data availability by country and year that may not be consistent over the time series. Making the time-series complete would improve the useability of the information.

Mackerel

country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
DEU	21490	19956	22977	25323	26532	24059	23368	19123	16599	18221
DNK	28157	30208	32693	31133	32180	27198	25311	22921	24230	24877
ESP	44607	45914	38320	44143	31845	23858	34968	53192	54569	63235
FRA	.	.	.	.	.	.	.	.	15968	14997
FRO	11229	11620	21023	24004	19768	14014	13029	9769	12066	13393
GBR	179710	159321	164069	189809	191100	170575	174728	152702	95816	133686
IRL	69171	59578	71226	70443	72173	63588	58929	42530	38563	46675
ISL	.	.	.	.	.	.	.	.	4220	36496
NLD	46127	28070	32403	49815	42254	34263	35680	41432	24007	23912
NOR	158179	160728	174098	180595	184291	163404	157363	119680	121981	131697
POL	.	.	.	.	.	.	.	.	.	977
PRT	2846	1981	2253	3049	2934	2749	2143	1479	2591	2598
RUS	67837	51348	50772	41568	45811	40026	49489	39922	33462	35408
SWE	5146	5233	4995	5099	.	4447	4437	3202	3210	3858
(ALL)	634499	573957	614829	664981	648888	568181	579445	505952	447282	550030

country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BEL	.	.	.	.	38	60	.	51	142	128
BES	.	.	.	.	.	.	10509	.	8165	.
DEU	15503	22703	19055	24082	18974	20933	28451	28207	23411	24857
DNK	26726	23228	41045	29213	36503	33261	41903	45015	40655	37899
ESP	64785	114141	53350	23988	17735	13069	33734	33744	21426	34425
EST	.	.	.	.	.	1366	.	.	.	.
FRA	15454	9740	12108	12393	17859	14642	21695	.	20171	22920
FRO	11289	14061	70987	122049	107629	143001	150419	107993	93266	99499
GBR	113945	157012	160419	181629	169733	163303	287418	246962	216819	225404
GRL	.	.	.	162	5319	52796	78672	30410	36194	46498
GUY	.	.	.	.	.	8	8	4	.	.
IMN	.	.	.	11	.	7	3	4	7	.
IRL	44318	61086	57993	63188	63058	56611	103178	88738	76523	84914
ISL	112220	116157	122337	159008	149584	151326	172960	169257	170374	166601
JEY	7	7	.	6	.	.	6	2	2	.
LTU	.	.	.	.	.	.	.	553	2539	.
NLD	19933	23355	25062	34500	32554	21159	46665	39807	37752	43765
NOR	121470	121225	233941	208077	176031	164602	277724	242233	210569	222397
POL	.	.	.	.	.	.	.	.	0	0
PRT	2367	1742	2355	938	821	253	636	928	619	633
RUS	32728	41413	59310	73601	74578	80756	116086	128292	121336	138077
SWE	3660	7303	3428	3247	4563	2906	4421	3930	3662	3700
(ALL)	584405	713173	861390	936092	874979	920059	1374488	1166130	1083632	1151717

country	2018	2019
BEL	167	66
DEU	19882	16904
DNK	29865	30401
ESP	28196	21056
FRA	21370	17855
FRO	81078	62663
GBR	189999	151803
GRL	63024	30469
IMN	3	2
IRL	66743	53311
ISL	168328	128076
NLD	30392	22697
NOR	187030	159107

POL	4056	3706
PRT	4564	3941
RUS	118254	126543
SWE	3965	2957
(ALL)	1016916	831557

Table 1: Catch of mackerel (tonnes) included in the rectangle data by year and country

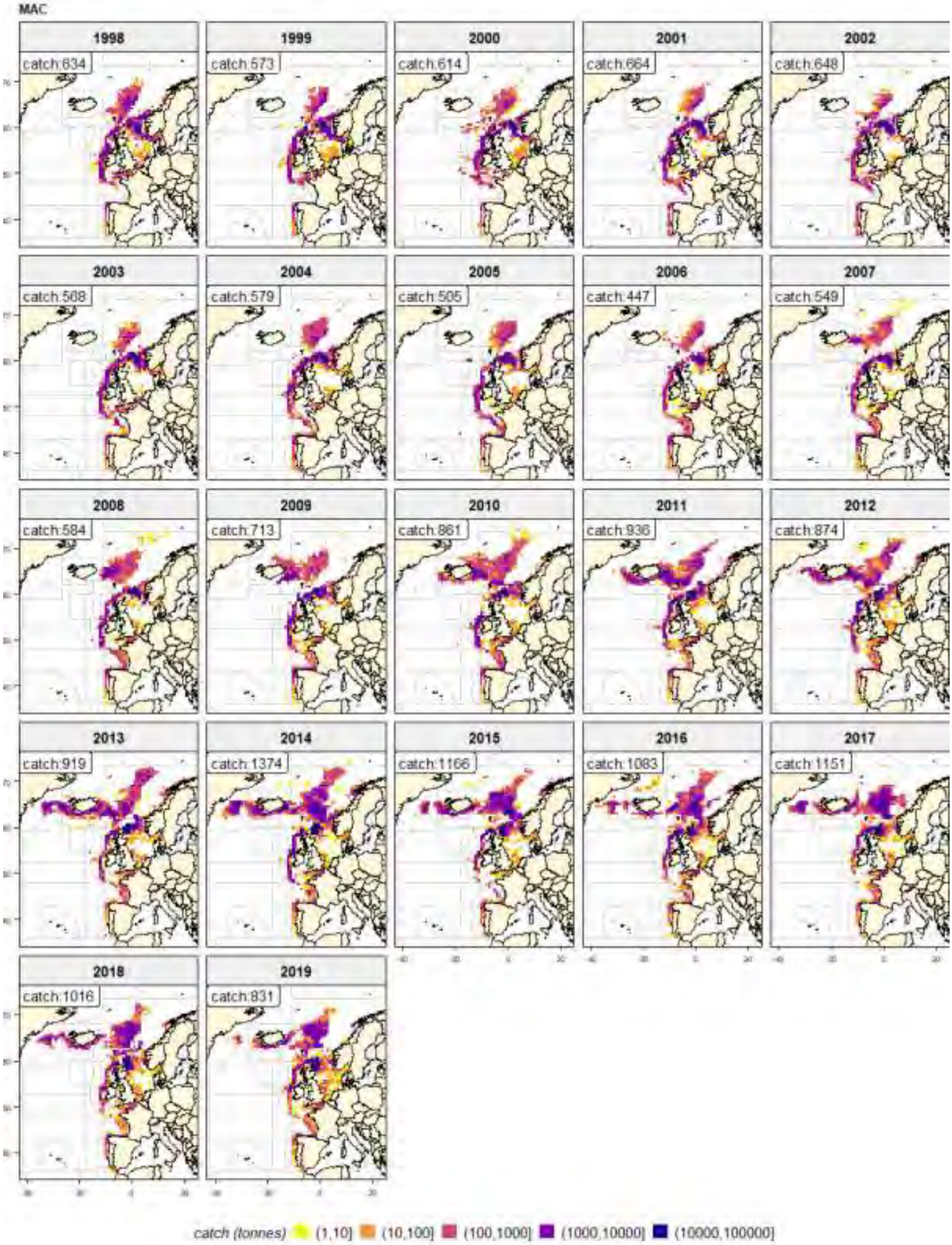
MAC
1998
catch:634
1999
catch:573
2000
catch:614
2001
catch:664
2002
catch:648
2003
catch:568
2004
catch:579
2005
catch:505
2006
catch:447
2007
catch:549
2008
catch:584
2009
catch:713
2010
catch:861
2011
catch:936
2012
catch:874
2013
catch:919
2014
catch:1374
2015
catch:1166
2016
catch:1083
2017
catch:1151
2018
catch:1016
2019
catch:831
catch (tonnes) (1,10] (10,100] (100,1000] (1000,10000] (10000,100000]

Figure 1.1: Catch of mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

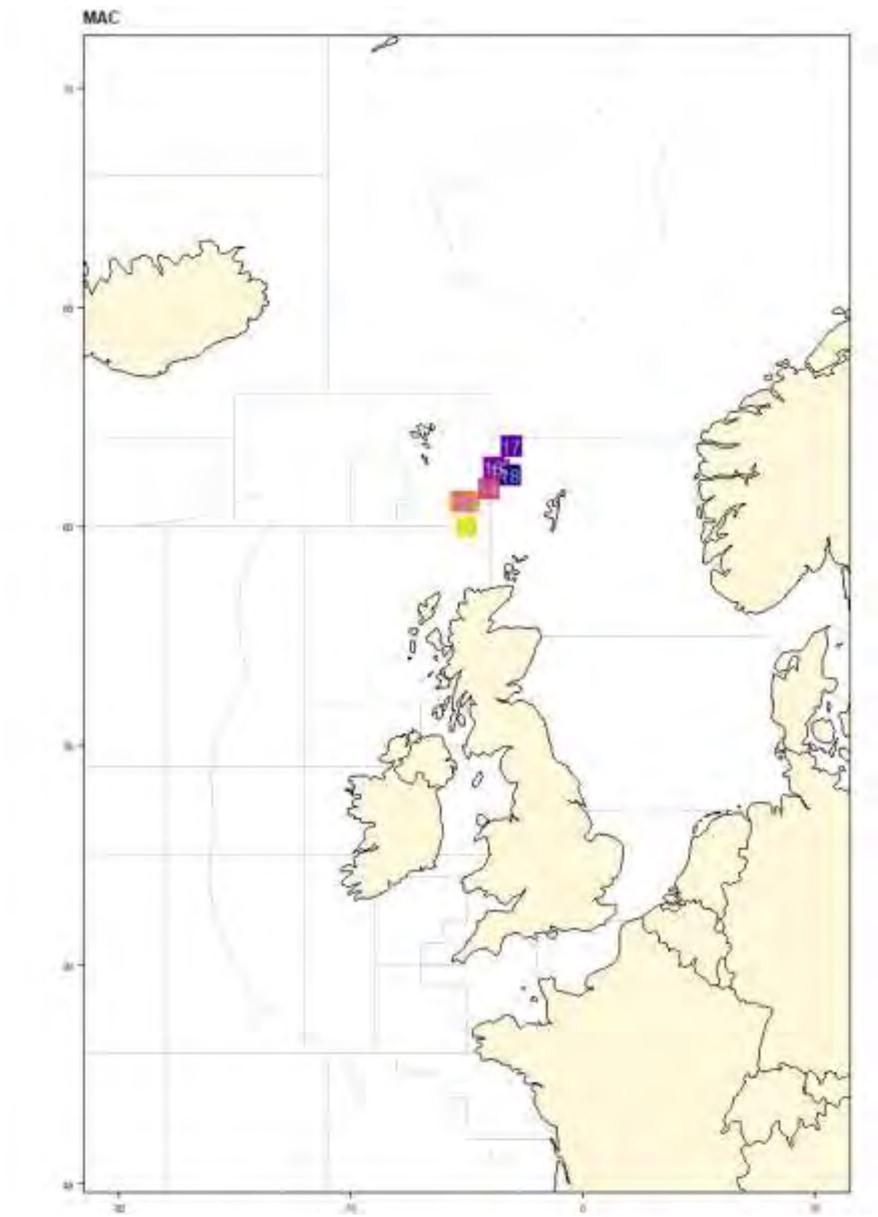

Figure 1.2: Centre of gravity of mackerel catches by year. Only latitudes between 46 and 70 have been used for the calculations.

Horse Mackerel

country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DEU	12510	15925	18762	22792	18978	12453	5871	12882	16420	21482
DNK	.	12478	14636	20256	14135	9794	7885	.	6097	5935
ESP	34688	34258	32926	27947	26435	23829	27319	34169	36722	54230
FRO	.	.	808	3846	3695	.	477	477	.	.
GBR	18459	11201	6405	11775	7845	993	13807	5508	17627	17063
IRL	52212	36482	35854	26432	35359	28856	30091	36508	40779	44475
NLD	103349	59585	86162	68733	73130	64413	61433	.	60459	85042
NOR	7992	36689	20515	10749	25115	27225	5425	12247	72615	12500
PRT	13759	14269	10571	11874	13307	14607	10380	9278	10840	11726
(ALL)	242969	220887	226639	204404	217999	182170	162688	111069	261559	252453

country	2011	2012	2013	2014	2015	2016	2017	2018	2019
BEL	.	.	.	.	63	.	67	44	.
DEU	21114	22588	27959	19056	10061	13293	8121	8121	8462
DNK	6100	4674	.	.	.	.	.	.	.
ESP	32942	12373	39507	32907	37896	32851	33860	37109	44473
FRA	.	.	.	.	.	.	5785	3443	1869
FRO	.	.	.	.	.	.	50	.	.
GBR	26932	14631	48307	12426	737	970	.	190	9666
IRL	38464	45306	35783	32660	21647	27606	23559	25347	28899
NLD	71981	78552	62519	29975	28150	27685	19906	19906	31862
NOR	13770	3378	6791	14658	9560	11184	11184	10742	11274
PRT	.	.	.	.	.	.	19473	13370	7641
SWE	.	.	1	1	18	.	.	.	.
(ALL)	211303	181502	220867	141683	108132	113589	122005	118272	144146

Table 2: Catch of horse mackerel (tonnes) included in the rectangle data by year and country

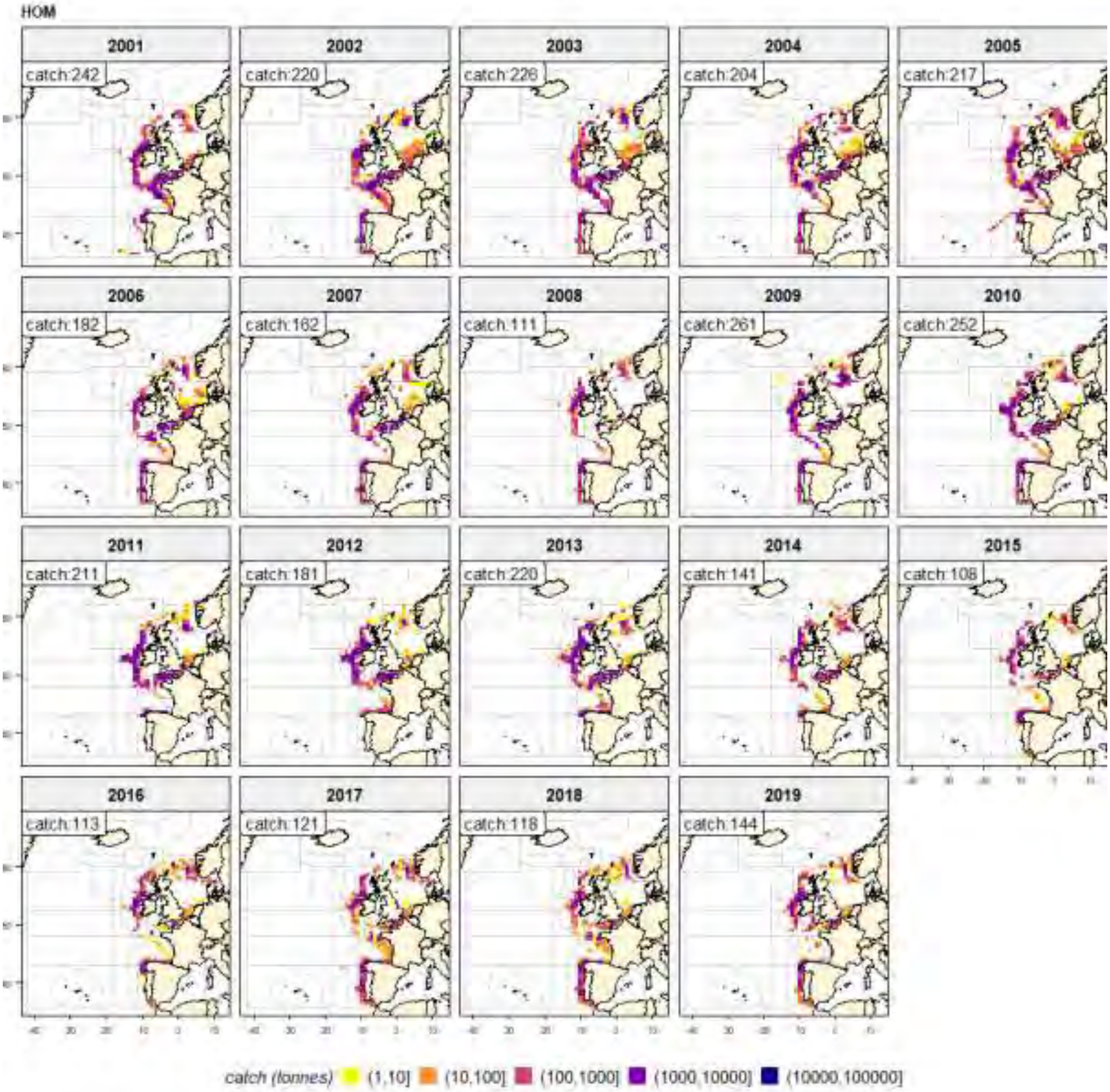
HOM
2001
catch:242
2002
catch:220
2003
catch:226
2004
catch:204
2005
catch:217
2006
catch:182
2007
catch:162
2008
catch:111
2009
catch:261
2010
catch:252
2011
catch:211
2012
catch:181
2013
catch:220
2014
catch:141
2015
catch:108
2016
catch:113
2017
catch:121
2018
catch:118
2019
catch:144
catch (tonnes) (1,10] (10,100] (100,1000] (1000,10000] (10000,100000]

Figure 2.1: Catch of horse mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

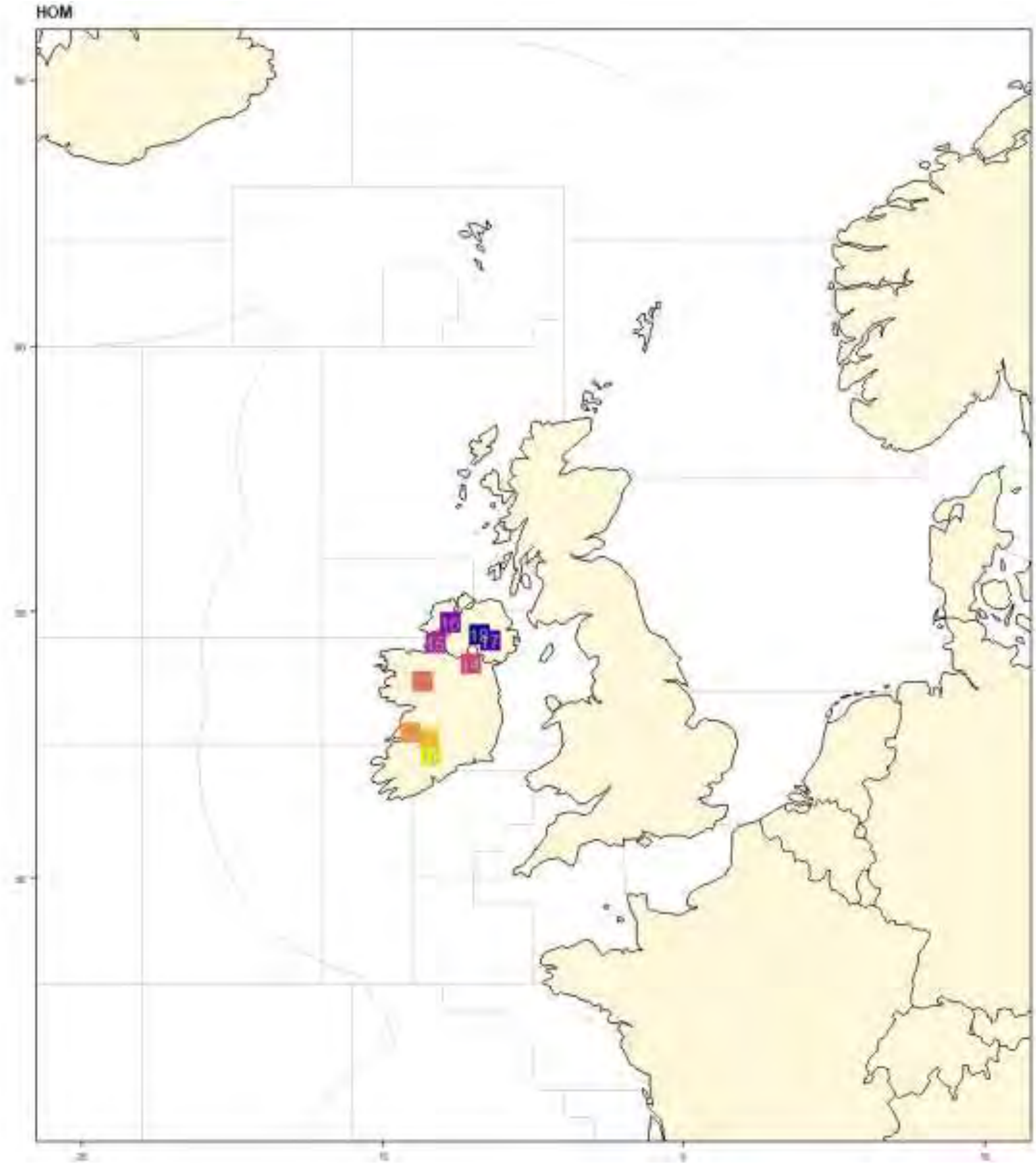

Figure 2.2: Centre of gravity of horse mackerel catches by year. Only latitudes between 46 and 65 have been used for the calculations.

Blue whiting

country	2011	2012	2013	2014	2015	2016	2017	2018	2019
ALL	.	377079	.	.	.	.	.	.	.
DEU	266	.	11528	24487	24106	20024	45555	47797	38243
DNK	.	.	.	27945	45047	39134	60866	83564	64169
ESP	2416	.	13388	25140	24967	27493	27433	21059	20621
FRA	4337	.	8978	10410	9657	10345	13221	16409	16095
FRO	16404	.	85767	224699	282477	282364	356501	349837	336568
GBR	1331	.	8166	26835	30508	38270	68132	68375	60757
GRL	.	.	.	.	.	.	20212	23333	19753
IRL	1194	.	13205	21467	24785	26329	43237	49902	38568
ISL	5887	.	104912	182873	214868	186907	228934	292951	268351
LTU	.	.	.	4718	.	1129	5299	.	.
NLD	4595	.	51634	38524	56397	58148	81155	121864	75020
NOR	20539	.	196246	399520	489438	310412	399363	438426	351428
POL	.	.	.	.	.	.	.	12152	27184
PRT	.	.	2014	1303	1429	1429	1625	1497	2659
RUS	46888	.	120669	151810	185763	173655	188449	170891	188006
SWE	.	.	.	1	.	42	89	15	43
(ALL)	103857	377079	616507	1139732	1389442	1175681	1540071	1698072	1507465

Table 3: Catch of blue whiting (tonnes) included in the rectangle data by year and country

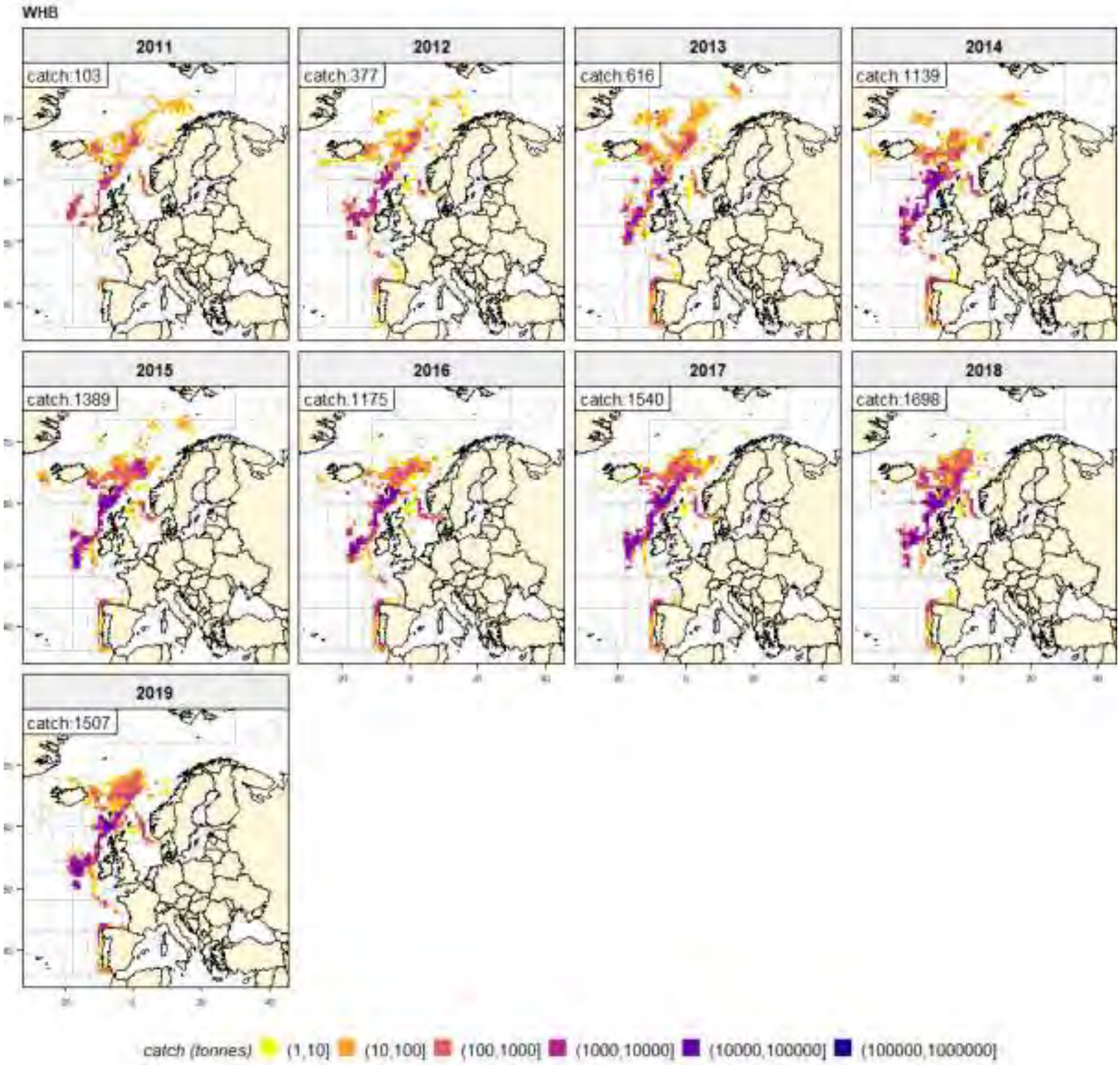

Figure 3.1: Catch of blue whiting (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

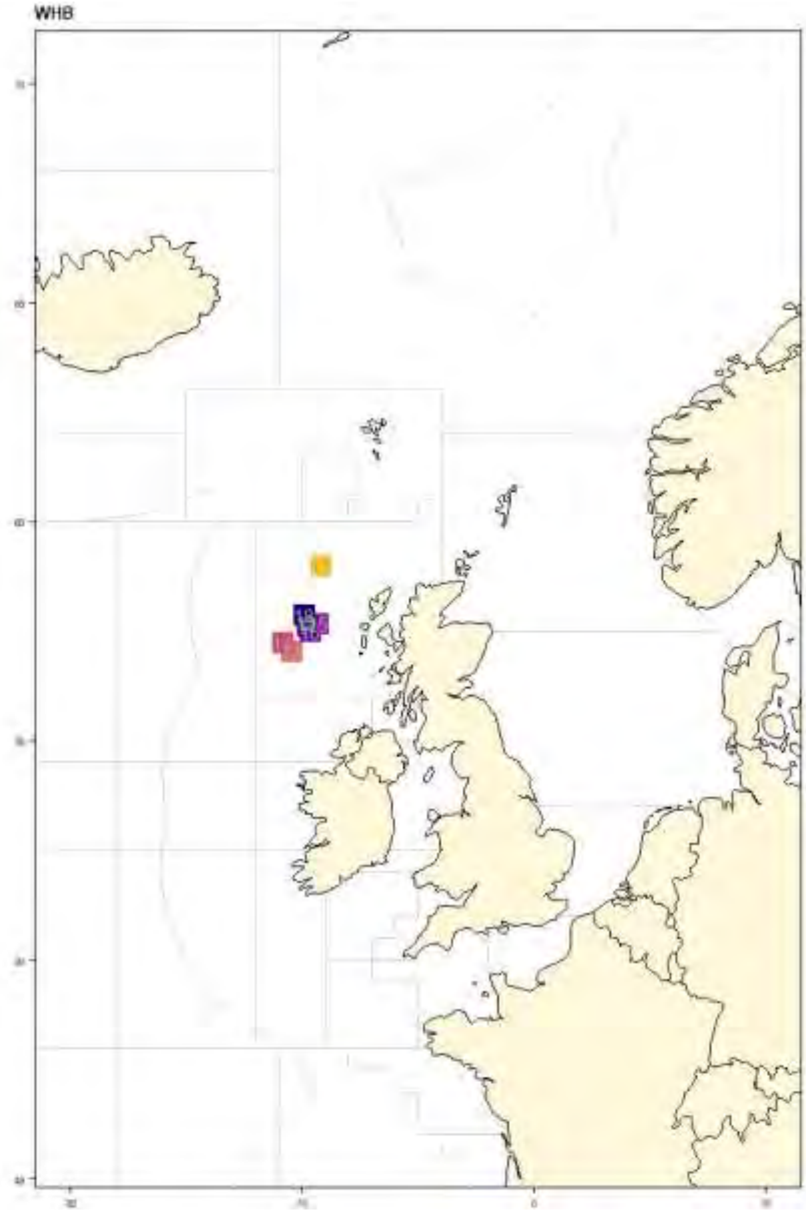

Figure 3.2: Centre of gravity of blue whiting catches by year. Only latitudes between 46 and 70 have been used for the calculations.

Atlanto-scandian herring

country	2011	2012	2013	2014	2015	2016	2017	2018	2019
ALL	.	819755	.	.	.	.	.	.	.
DEU	13295	.	4243	668	2660	2582	5201	1994	4188
DNK	26732	.	17159	12513	9105	10384	17373	17051	20247
FRO	53270	.	105037	38527	33030	44726	98170	82062	113940
GBR	14045	.	8342	4233	.	3899	.	2581	1800
GRL	3426	.	11787	13187	12434	17507	12569	2465	3190
IRL	5738	.	3814	705	1399	2048	3494	2428	2775
ISL	151078	.	90729	58827	42626	50457	90400	83392	108044
NLD	8348	.	5625	9175	5248	3519	6678	4289	5110
NOR	572637	.	359458	263252	176321	197500	389383	331717	430501
POL	.	.	.	.	.	.	.	.	1327
RUS	144429	.	78501	60291	45853	50454	91119	64147	84362
SWE	.	.	23	.	.	.	1155	425	705
(ALL)	992998	819755	684718	461378	328676	383076	715542	592551	776189

Table 4: Catch of Atlanto-scandian herring (tonnes) included in the rectangle data by year and country

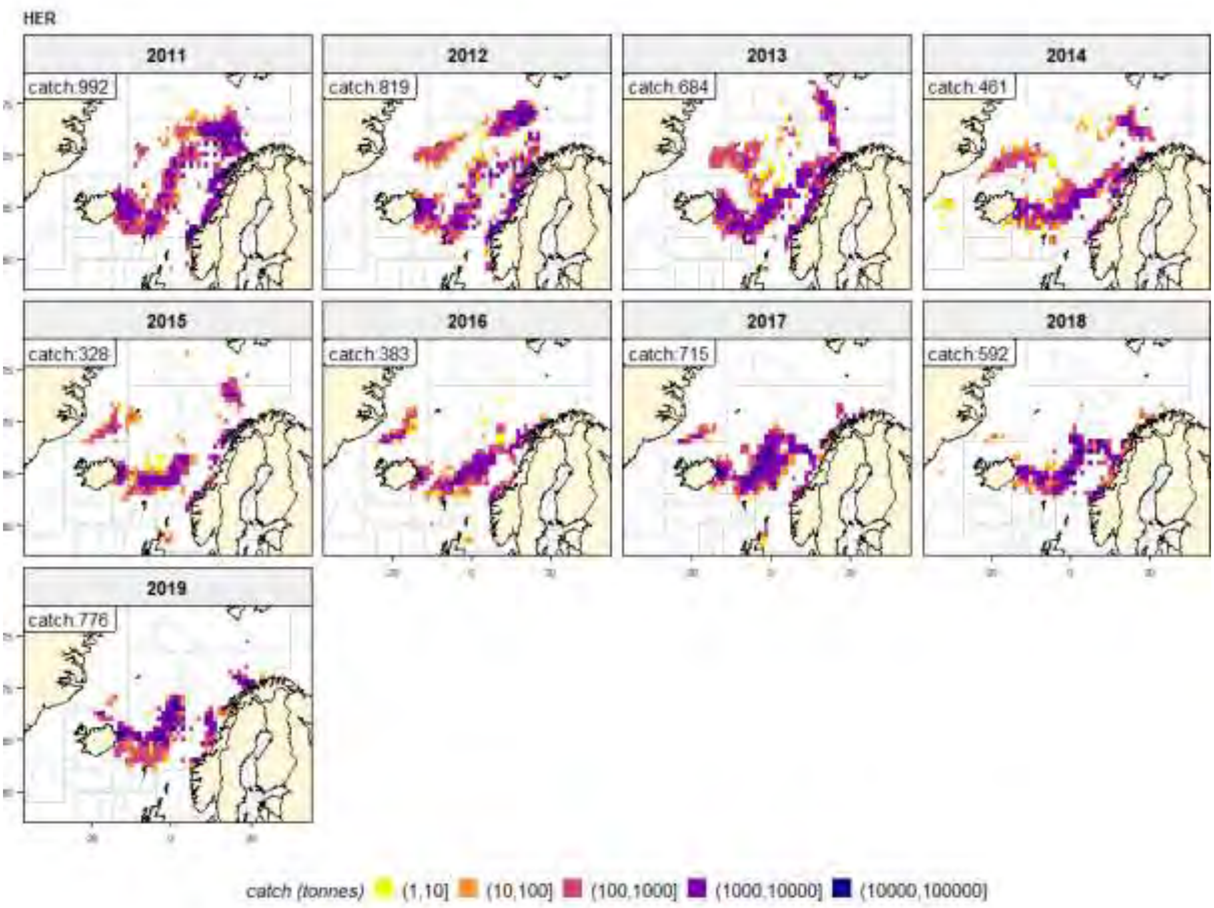

Figure 4.1: Catch of Atlanto-scandian herring (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

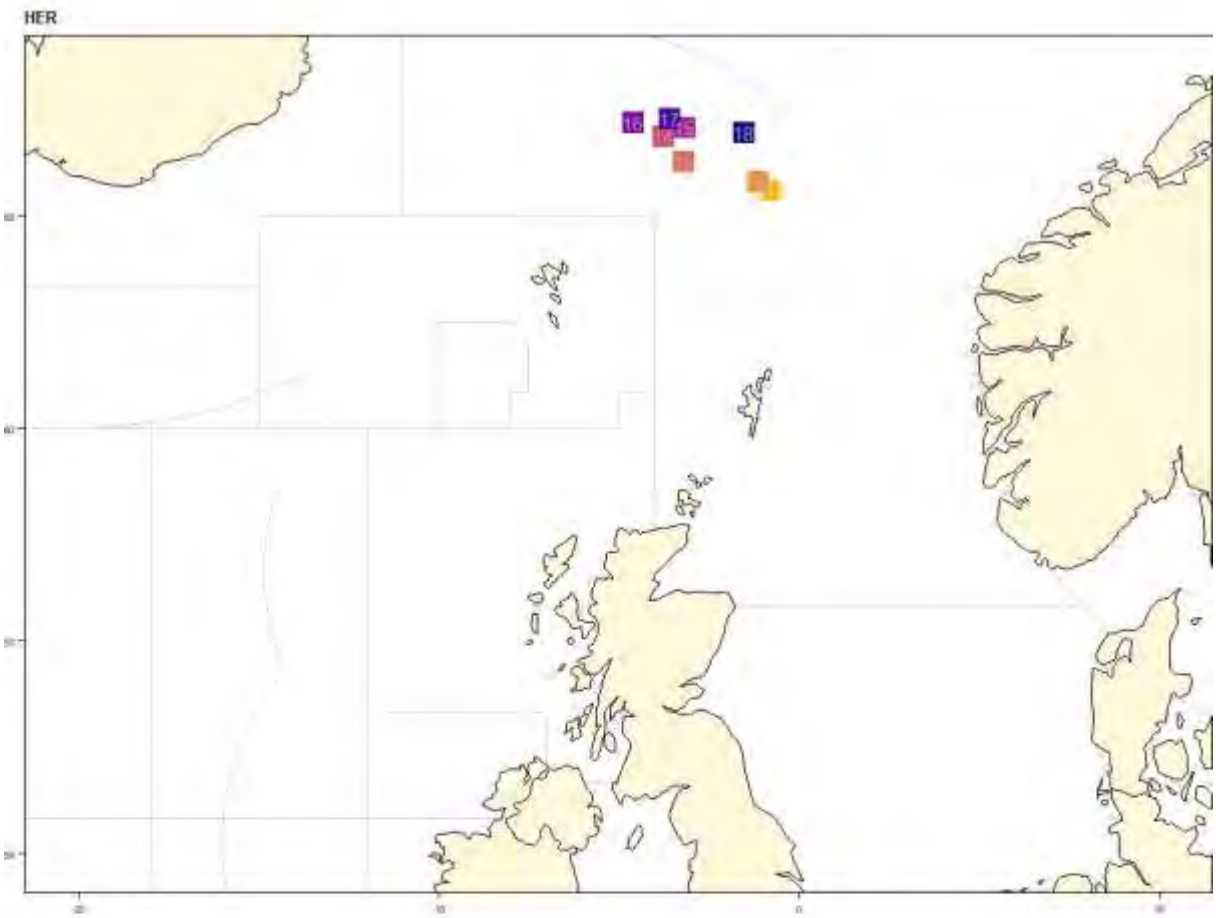

Figure 1.2: Centre of gravity of herring catches by year.

Survey report

MS *Eros*, MS *Kings Bay* MS *Vendla* 14.-26.02.2020

Distribution and abundance of Norwegian spring-spawning herring during the spawning season in 2020

By Are Salthaug, Erling Kåre Stenevik, Sindre Vatnehol, Valantine Anthonypillai, Egil Ona and Aril Slotte

Institute of Marine Research (IMR), P. O. Box 1870 Nordnes, N-5817 Bergen, Norway

Summary

During the period 14-26th of February 2020 the spawning grounds of Norwegian spring-spawning herring from Møre (62º20´N) to Nordvestbanken (70º40´N) were covered acoustically by the commercial vessels MS *Eros*, MS *Kings Bay* and MS *Vendla.* The survey was carried out under challenging weather conditions, however, the collected acoustic and biological data are considered to be of good quality. The estimated biomass was around 24 % lower and the estimated total number was about 10 % lower this year than in the 2019 survey. The uncertainty of the estimate in 2020 was estimated to be higher compared with 2019. The surveyed population was dominated by the 2013 and 2016 year classes. The 2016 year class is estimated to be around three times more abundant than the 2013 year class was as 4 year olds in 2017 (in this survey). The spatial distribution of the spawning stock was similar to earlier years; close to the coast south of Træna and on the slope around the banks outside Lofoten and Vesterålen, with the youngest and smallest herring in the north and older and larger herring in the south. The estimates of relative abundance from the survey in 2020 are recommended to be used in this year's ICES stock assessment of Norwegian spring-spawning herring.

Survey participants 14-26.02.2019:

MS *Eros*	
Erling Kåre Stenevik	Survey leader
Lage Drivenes	Instrument/Acoustics
Guosong Zhang	Instrument /Acoustics
Inger Henriksen	Biology
Jostein Røttingen	Biology
Egil Ona	Head of acoustics
MS *Kings Bay*	
Sindre Vatnehol	Survey leader
Reidar Johannesen	Instrument/Acoustics
Sture Vatnehol	Instrument/Acoustics
Adam Custer	Biology
Ørjan Sørensen	Biology
MS *Vendla*	
Are Salthaug	Survey coordinator
Benjamin Marum	Instrument/Acoustics
Magnar Polden	Instrument/Acoustics
Valantine Anthonypillai	Biology
Justine Diaz	Biology

Introduction

Acoustic surveys on Norwegian spring-spawning herring during the spawning season has been carried out regularly since 1988, with some breaks (in 1992-1993, 1997, 2001-2004 and 2009-2014). In 2015 the survey was initiated again partly based on the feedback from fishermen and fishermen's organizations that IMR should conduct more surveys on this commercially important stock. Since then this has continued with a survey design using three commercial vessels, and IMR has contracted the same vessels to run this survey during the period 2017-2020. The ICES WKPELA benchmark in 2016 decided to use the data from this time series as input to the stock assessment, together with the ecosystem survey in the Norwegian Sea in May and catch data, meaning that the results of the survey have significant influence on ICES catch advice.

Hence, the objective of the NSS spawning survey 2020 was to continue the relative abundance estimates for use in the ICES WGWIDE stock assessment, more specifically to estimate indices of abundance and biomass at age during the period of spawning migration from wintering areas at/off the northern Norwegian coast and in the Norwegian Sea towards the coastal spawning ground further south. Finally, it was also a purpose that the results of the survey should be compared with recent surveys with comparable effort and design during 2015-2019.

Material and methods

Survey design

During the period 14-26th of February 2020 (same period as in 2017-2019) the spawning grounds from Møre (62º20´N) to Troms (70º40´N) were covered acoustically by the commercial fishing vessels *MS Eros, MS Kings Bay* and MS *Vendla*.

The survey was planned based on information from the previous spawning cruises and the distribution of the herring fishery during the autumn 2019 up to the survey start February 14 2020 (Figure 1). The fishery prior to the survey start in 2020 indicated that the herring wintering in the Norwegian Sea were entering the coast in the Træna deep south of Røst and following the eastern shelf edge 200 m depth southwards from Træna as also observed in 2016-2019. This information also suggested that smaller and younger herring recruiting to the spawning stock initiated their spawning migration from wintering grounds further north of 70ºN west of Tromsøflaket and in the Kvænangen fjord area, which was the basis for the planned survey coverage this far north. As seen from Figure 1, the fishery had already started at Buagrunnen (63°N) at the onset of survey in 2020.

The survey design followed a standard stratified design (Jolly and Hampton 1990), where the survey area was stratified before the survey start according to the expected density and age structures of herring (Figure 2). With exception of stratum 13, all strata this year were covered with a zigzag design instead of parallel transects. The introduction of a zigzag design started in 2018. Compared with parallel transects, zigzag design is more efficient since a higher proportion of the sailed distance is used for coverage (Harbitz 2019). In 2015-2017, a significant part of the survey time was used as transport between transects, whereas in 2018-2020 insignificant time was used on transport. Each straight line in the zigzag design were considered as transects and primary sampling units (Simmonds and MacLennan 2008), with fairly uniform coverage of strata and a random starting position in the start of each stratum. In order to investigate potential herring aggregations west of Buagrunnen (it has previously been stated by some fishermen that herring arrives on the Buagrunnen directly from the Norwegian Sea, i.e. from west) two parallel transects were covered extending approximately 80 nautical miles west of Buagrunnen (63°N).

Biological sampling

Trawl sampling was carried out on a regular basis during the survey to confirm the acoustic observations and to be able to give estimates of abundance for different size and age groups. All three vessels used commercial herring trawls with small meshed (20 mm) inner net in the codend, and with a slit (so called “splitt”) close to the codend to avoid too large catches. The positions of the trawl hauls are shown in Figure 3. The following variables of individual herring were analysed for each station with herring catch: Total weight (W) in grams and total length (L_T) in cm (rounded down to the nearest 0.5 cm) of up to 100 individuals per sample. In addition, age from scales, sex, maturity stage, stomach fullness and gonad weight (W_G) in grams were measured in up to 50 individuals per sample. The maturation stages were determined by visual inspection of gonads as recommended by ICES: immature = 1 and 2, early maturing = 3, late maturing = 4, ripe = 5, spawning = 6, spent = 7 and resting/recovering = 8. Data from the subjective evaluation of maturation stages were used to split between immature and mature herring in the estimation of spawning stock biomass (SSB), as well as to demonstrate spatial differences in maturation. The gonadosomatic index (GSI=gonad weight/total weight x100) was also used to demonstrate spatial differences in maturation along the coast.

Environmental sampling

CTD casts (using Seabird 911 systems) were taken by Eros and Vendla, spread out in the survey area (Figure 3).

Echo sounder data

Multifrequency (18, 38, 70, 120, 200 kHz) acoustic data were recorded with a SIMRAD EK 60 echo sounder and echo integrator on board Eros and Vendla, and SIMRAD EK 80 on board Kings Bay. Continuous Wave (CW) pulse, i.e. single frequency, was transmitted from all sounders. All three vessels were calibrated at the tip of the fishing pier in Ålesund prior to the survey according to standard methods (Foote et al., 1987), adjusted for split beam methods as described in Ona (1999) and (Demer et al. 2015). The calibration reports of each vessel are shown in Annex 1. The low frequency sonars were not calibrated. The intention was only to use the sonar data for studies of potential issues with herring in the echo sounder blind zone close to the surface or avoidance, not for biomass estimations of schools. Hence, a new calibration of the sonars was not considered necessary.

LSSS, Large Scale Survey System (Korneliussen et al., 2006) was applied for the interpretation of the multi-frequency data. The recorded area echo abundance, i.e. the nautical area backscattering coefficient (NASC) (MacLennan et al. 2002), was interpreted and distributed to herring and 'other' species at 38 kHz. Various characteristics of the acoustic recordings like frequency response (Korneliussen and Ona 2002) and visual appearance were used to identify herring from other targets.

In 2020 the survey suffered from relatively bad weather condition, like last year. During conditions where the vessels had to survey against strong winds, acoustic registrations on some transects were significantly influenced by air bubble attenuation. This was corrected for during the scrutinization of the data in LSSS, and the problems and methods used to adjust is described in Annex 3 in last year's cruise report (Slotte et al. 2019). However, only a small fraction of the acoustic values had to be corrected in this year's survey.

Abundance estimation methods

The acoustic density values were stored by species category in nautical area scattering coefficient (NASC) [m^2 n.mi.$^{-2}$] units (MacLennan et al. 2002) in a database with a horizontal resolution of 0.1 nmi and a vertical resolution of 10 m, referenced to the sea surface. To estimate the mean and variance of NASC, we use the methods established by Jolly and Hampton (1990) and implemented in the software StoX (Johnsen et al. 2019). The primary sampling unit is the sum of all elementary NASC samples of herring along the transect multiplied with the resolution distance. The transect (*t*) has NASC value (*s)* and distance length *L*. The average NASC (S) in a stratum (*i*) is then:

$$\hat{S}_i = \frac{1}{n_i} \cdot \sum_{i=1}^{n_i} w_{it} s_{it} \tag{1}$$

where $w_{it} = L_{it} / \overline{L}_t$ (t= 1,2,.. n_i) are the lengths of the n_i sample transects, and

$$\overline{L}_i = \frac{1}{n_i} \sum_{t=1}^{n_i} L_{it} \tag{2}$$

The final mean NASC is given by weighting by stratum area, A;

$$\hat{S} = \frac{\sum_i A_i \hat{S}_i}{\sum_i A_i} \tag{3}$$

Variance by stratum is estimated as:

$$\hat{V}\left(\hat{S}_i\right) = \frac{n}{n_i - 1} \sum_{t=1}^{n} w_{it}^2 \left(s_t - \bar{s}\right)^2 \quad \text{with } \bar{s}_i = \frac{1}{n_i} \cdot \sum_{t=1}^{n_i} s_t \tag{4}$$

Where $w_{it} = L_{it} / \overline{L}_t$ (t= 1,2,.. n_i) are the lengths of the n_i sample transects.

The global variance is estimated as

$$\hat{V}(\hat{S}) = \frac{\sum_i A_{i=1}^2 \hat{V}(\hat{S})}{\left(\sum_i A\right)^2} \tag{5}$$

The global relative standard error of NASC

$$RSE = 100 \sqrt{\frac{\hat{V}(\hat{S})}{N}} \Big/ \hat{S} \tag{6}$$

where N is number of strata.

In order to verify acoustic observations and to analyse year class structure over the surveyed area, trawling was carried out regularly along the transects (Figure 3). All trawl stations with herring were used to derive a common length distribution for all transect within the respective strata. All stations had equal weight.

Relative standard error by number of individuals by age group was estimated by combining Monto Carlo selection from estimated NASC distributions by stratum with bootstrapping techniques of the assigned trawl stations.

The acoustic estimates presented in this report use the 38 kHz NASC, and the mean was calculated for data scrutinized as herring and collected along the transects (acoustic recordings taken during trawling, and for experimental activity are excluded). The number of herring (*N*) in each length group (*l*) within each stratum (*i*) is then computed as:

$$N_l = \frac{f_l \cdot \hat{S}_i \cdot A_i}{\langle \sigma \rangle}$$

Where

$$f_l = \frac{n_l L_i^2}{\sum_{l=1}^{m} n_l L_l}$$

is the "acoustic contribution" from the length group L_l to the total energy and $\langle s_i \rangle$is the mean nautical area scattering coefficient [m^2/nmi^2] (NASC) of the stratum. A is the area of the stratum [nmi^2] and σ is the mean backscattering cross section at length L_l. The conversion from number of fish by length group *(l)* to number by age is done by estimating an age ratio from the individuals of length group *(l)* with age measurements. Similar, the mean weight by length and age grouped is estimated.

The mean target strength (TS) is used for the conversion where $\sigma = 4\pi\ 10^{(TS/10)}$ is used for estimating the mean backscattering cross section. Traditionally, TS = 20logL – 71.9 (Foote 1987) has been used for mean target strength of herring during the spawning surveys, however, several papers question this mean target strength. Ona (2003) describes how the target strength of herring may change with changes with depth, due to swimbladder compression. He measured the mean target strength of herring to be TS = 20logL – 2.3 log(1 + z/10) – 65.4 where z is depth in meters. Given that previous surveys were estimated using Foote (1987), the estimation this year was also done with this TS, for direct comparison and possible inclusion in the stock assessment by ICES WGWIDE 2020 as another year in the time series.

The StoX software developed by IMR were used in the abundance estimation in 2020, just as in 2015-2019. StoX is an open source software developed at IMR, Norway (Johnsen et al. 2019) to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application build with Java for easy sharing and further development in cooperation with other institutes. The underlying high resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Accessing

StoX from external software may be an efficient way to process time series or to perform bootstrapping on one dataset, where for each run, the content of the parameter dataset is altered. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990) is implemented.

Sonar data and analyses

Data from Simrad low-frequency sonars were logged on board all vessels with the objective to measure the presence and magnitude of potential bias related to vertical distribution (fish in blind zone above the echo sounder transducer) and avoidance behaviour of the herring relative to the presence of the vessel. Data from fisheries sonars have been collected from all participating vessels since 2015. Methods to quantify or evaluate the extent of these biases are presently being developed.

Results and discussion

Estimates of abundance

The abundance estimates from this survey are viewed as relative, i.e. as indices of abundance, since there are highly uncertain scaling parameters like acoustic target strength and compensation for herring migrating in the opposite direction of the survey (the latter issue is discussed in Appendix 2). In StoX, there are two types of point estimates of (relative) abundance at age and total abundance: baseline estimate and mean or median based on 1000 bootstrap replications. The baseline estimates are shown in Table 1 and the bootstrap estimates are shown in Table 2. The baseline estimate of biomass from the survey is 3.24 million tonnes while the bootstrap mean estimate is 3.27 million tonnes. The decline in estimated biomass from the survey in 2019 is 24 % based on the baseline estimates and 23 % based on the bootstrap estimates. The relative standard error (CV) of the biomass estimate for 2020 based on the bootstrap replicates is 17 % which is higher than in 2019 (CV = 10 %). The survey time series of stock biomass based on bootstrap replicates from the period 2015 to 2020 is shown in Figure 4. The level of the biomass has not changed significantly during 2016-2020. The baseline estimate of total number of individuals from the survey is 12.57 billion while the bootstrap mean estimate is 12.75 billion. The decline in estimated total numbers from the survey in 2019 is 11 % based on the baseline estimates and 10 % based on the bootstrap estimates. The estimated relative standard error (CV) of the total number in 2020 based on the bootstrap replicates is 16 % which is higher than in 2019 (CV = 10 %). The survey time series of total number based on bootstrap replicates from the period 2015 to 2020 is shown in Figure 5. The level of total number has not changed significantly during 2016-2020. The estimated stock number is dominated by 4 and 7 year old herring, which is the 2016 and 2013 year classes (Table 1-2 and Figure 6). The uncertainty is high for the very young and old year classes and moderate for the most abundant ages in the survey (Table 2 and Figure 6), which is the normal pattern observed in surveys and samples from commercial catches. Estimated numbers per year class from the surveys in 2015-2020 are shown in Figure 7. The estimated numbers from the survey in 2020 seems to decline as excepted for the year classes that are fully recruited to the survey, and it now seems like the survey in 2019 slightly over-estimated numbers at age (Figure 7). The 2016 year class is estimated more than three times more abundant than the 2013 year class was as 4 year olds in 2017.

Spatial distribution of the stock

The distribution and densities of herring in the area covered in 2020 was quite similar to that observed in 2017-2019, relatively evenly distributed along the coast 63-70º39´N, yet with some high density areas close to the coast from Buagrunnen to Træna (63°-66°30´N) and around the continental slope outside Lofoten, the Vesterålen banks and further north (66°30´N-70º39´N) (Figure 8 and 9). The relative distribution of the estimated biomass per stratum is shown in Figure 10. Most of the biomass was found in stratum 4, 6, 7, 9 and 10, i.e. close to the coast south of Træna and on the slope around the banks outside Lofoten and Vesterålen. This distribution is fairly similar to the distribution in 2019 but a bit more uniform in 2020 with more of the biomass in the north due to the incoming 2016 year class. Age compositions per stratum are shown in Figure 11. The southernmost strata (1-4) were dominated by herring older than 6 years and the age distributions are fairly uniform. In the middle strata from Træna to Lofoten (strata 5-9) 7 year olds (2013 year class) was the most numerous while the 4 year olds (2016 year class) dominated in the northernmost strata (10-13). The 2016 year class also appears clearly in stratum 8 and 9 (outside Lofoten). Mean length and mean weight per trawl station are shown in Figure 12 and 13. These figures show that the largest herring is found in the southern part of the covered area while smaller fish dominates in the north. The observed size dependent distribution pattern in 2020 is similar to what was observed in 2015-2019 (Slotte et al 2015, 2016, 2017, 2018, 2019). It is also in accordance with the observations in earlier years, which has been thoroughly discussed in Slotte and Dommasnes, 1997, 1998, 1999, 2000; Slotte, 1998b; Slotte, 1999a, Slotte 2001, Slotte et al. 2000, Slotte & Tangen 2005, 2006).. The main hypothesis is that this could be due to the high energetic costs of migration, which is relatively higher in small compared to larger fish (Slotte, 1999b). Large fish and fish in better condition will have a higher migration potential and more energy to invest in gonad production and thus the optimal spawning grounds will be found farther south (Slotte and Fiksen, 2000), due to the higher temperatures of the hatched larvae drifting northwards and potentially better timing to the spring bloom (Vikebø et al. 2012).

Geographical variation in temperatures experienced by the herring

Temperatures experienced by herring from close to the surface and down to deeper waters than 200 m varied from 4°-8°C (Figure 14). At typical spawning depths of herring 100-200 m temperature varied more this year than in 2017-2019 (Slotte et al. 2017, 2018, 2019), with warm water in the southern part of the covered area (around 8°C), colder water west of Lofoten (4-5°C) and warmer water again furthest north (6-7°C).

Quality of the survey

In 2020 all vessels were equipped with multifrequency equipment on a drop keel. Even though the weather conditions were challenging with strong wind during most of the survey period, acoustic data with good quality was recorded and trawling on registrations could be carried out most of the time. There were some periods where the survey speed had to be reduced to ensure acceptable quality of the acoustic data. Correction for air bubble attenuation had to be done in only a few instances so most of the NASC values were not adjusted. As in earlier years, the young fish in the north was sometimes found close to the surface and it is therefore assumed that some herring was “lost” in the blind zone, especially during the night. Moreover, an unknown fraction of the 2016 year class was distributed outside the survey area (Norwegian Sea and Barents Sea). This is not unexpected as it is assumed in the ICES stock assessment that 4 year olds are not fully recruited in this survey (this information is contained in the catchability parameters). Regarding the older and larger herring in the southern part of the survey area there are no observations this year or earlier years which indicate that significant amounts of herring has been distributed outside the area covered by the survey. This issue has been extensively discussed and analysed in previous survey reports and this year it was also carried out two additional “oceanic” transect west of Buagrunnen where no herring was observed. Also, the distribution of the commercial fishery indicates that most of the spawning stock was contained in the area covered by the survey. To conclude, the acoustic and biological data recorded in 2020 were of satisfactory quality and the estimates from the survey are recommended to be used in the stock assessment of Norwegian spring-spawning herring.

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Tables

Table 1. Baseline estimates from StoX of Norwegian spring-spawning herring during the spawning season 14.-26. February 2020.

	age																			
Length (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number	Biomass	MeanW
21-22	4401	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4401	264	60
22-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5970	5970	501	83.9
24-25	-	-	24672	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24672	2143	86.8
25-26	-	3349	79838	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	83187	8304	99.8
26-27	-	6738	226706	8151	-	-	-	-	-	-	-	-	-	-	-	-	-	-	241595	28037	116.1
27-28	-	16462	560050	2246	-	-	-	-	-	-	-	-	-	-	-	-	-	-	578758	74175	128.2
28-29	-	4401	1042950	78583	15729	38580	-	-	-	-	-	-	-	-	-	-	-	-	1180245	172641	146.3
29-30	-	8803	851130	57312	23250	-	-	-	34397	-	-	-	-	-	-	-	-	-	974892	160763	164.9
30-31	-	-	412161	124936	62859	-	-	-	-	-	-	-	-	-	-	-	-	-	599956	113719	189.6
31-32	-	-	124488	136422	323548	272276	2332	2896	-	-	-	-	-	-	-	-	-	-	861962	194614	225.8
32-33	-	-	52436	51801	485479	947774	47440	3088	-	-	-	-	-	-	-	-	-	-	1588018	403094	253.8
33-34	-	-	20670	55790	283548	1221070	176018	76803	-	-	-	-	-	-	-	-	-	-	1833899	505588	275.7
34-35	-	-	-	24537	33764	607968	174940	202273	19902	23515	4666	9854	9903	-	20635	-	-	-	1131956	340265	300.6
35-36	-	-	33467	-	22277	207402	72637	191609	63650	193184	24543	35361	117013	58179	89862	-	2399	-	1111581	371008	333.8
36-37	-	-	-	-	-	20699	35799	57267	124742	350808	66818	143322	311285	51094	224322	39112	8180	-	1433447	510053	355.8
37-38	-	-	-	-	1714	10637	7449	31916	65666	99504	20180	50587	210310	21927	166959	36004	1253	-	724106	276079	381.3
38-39	-	-	-	-	-	-	-	6200	7978	3720	6628	30840	40734	9932	27522	1845	29247	-	164645	66541	404.2
39-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6586	-	10496	-	17081	7374	431.7
40-41	-	-	-	-	-	-	-	-	-	-	-	-	2079	-	5669	-	-	-	7748	3893	502.4
TSN (1000)	4401	39752	3428570	539777	1252169	3326407	516615	572050	316334	670730	122835	269964	691324	141131	541554	76960	51575	5970	12568119	-	-
TSB (t)	264	5428	532007	109415	304172	917088	153727	184640	106128	237339	44483	97099	249981	51076	197450	28077	20182	501	-	3239055	-
Mean L (cm)	21.5	27.4	28.6	30.7	32.2	33.1	34.1	34.9	35.4	36.0	36.2	36.4	36.5	36.1	36.5	36.8	38.0	23.5	-	-	-
Mean W (g)	60.0	136.5	155.2	202.7	242.9	275.7	297.6	322.8	335.5	353.9	362.1	359.7	361.6	361.9	364.6	364.8	391.3	83.9	-	-	257.7
% mature	0	72	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100	-	-	-	-
SSB (t)	0	3908	516047	109415	304172	917088	153727	184640	106128	237339	44483	97099	249980	51076	197450	28077	20182	-	-	3220811	-

Table 2. Bootstrap estimates from StoX (based on 1000 replicates) of Norwegian spring-spawning herring during the spawning season 14. -26. February 2020. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	0.0	4.0	19.3	5.7	6.7	1.17
3	9.7	38.6	104.5	44.4	29.7	0.67
4	2385.5	3427.1	4808.1	3502.4	741.0	0.21
5	354.9	552.4	840.6	571.1	152.8	0.27
6	847.4	1202.5	1602.0	1212.4	225.7	0.19
7	2363.1	3329.1	4307.9	3336.7	584.4	0.18
8	349.3	523.9	729.3	530.2	116.2	0.22
9	406.4	599.6	850.5	609.1	135.1	0.22
10	201.8	355.4	553.2	364.1	109.5	0.30
11	415.7	641.6	919.5	649.7	154.0	0.24
12	80.2	127.9	192.7	131.4	34.9	0.27
13	177.6	273.8	393.1	279.5	67.2	0.24
14	384.6	669.7	987.6	676.6	187.1	0.28
15	64.2	152.3	258.9	154.9	59.3	0.38
16	330.6	520.8	843.4	541.4	153.8	0.28
17	42.8	76.2	134.9	81.0	27.2	0.34
18	10.9	46.7	95.6	48.1	26.9	0.56
TSN	9375.3	12756.7	16221.0	12750.4	2068.2	0.16
TSB	2376.8	3269.2	4212.5	3273.7	543.9	0.17

Figures

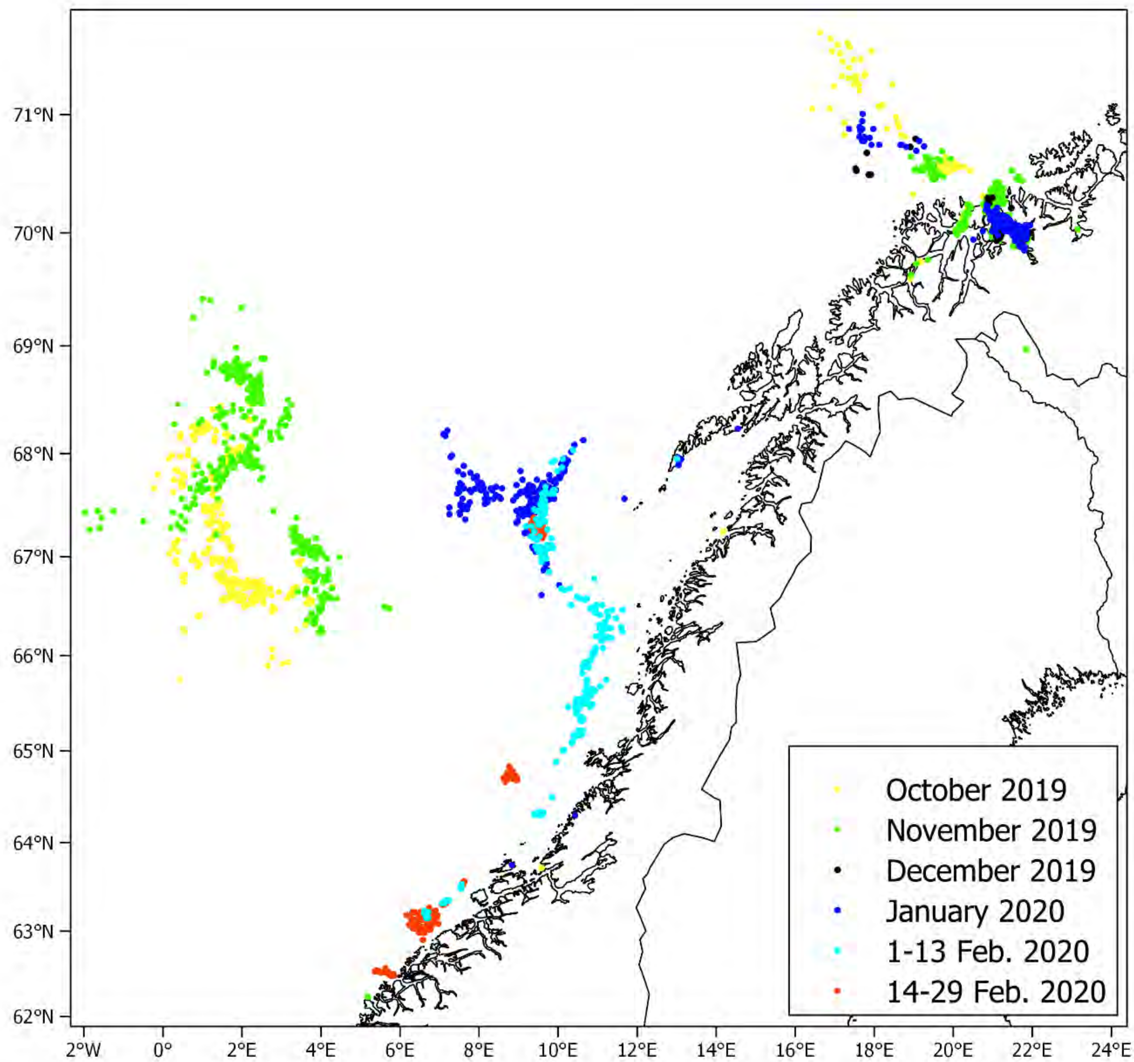


Figure 1. Distribution of commercial catches of Norwegian Spring-spawning herring from October 2019 until February 2020, based on electronic logbooks. Each point represent one catch, only catches larger than 10 tons are shown.

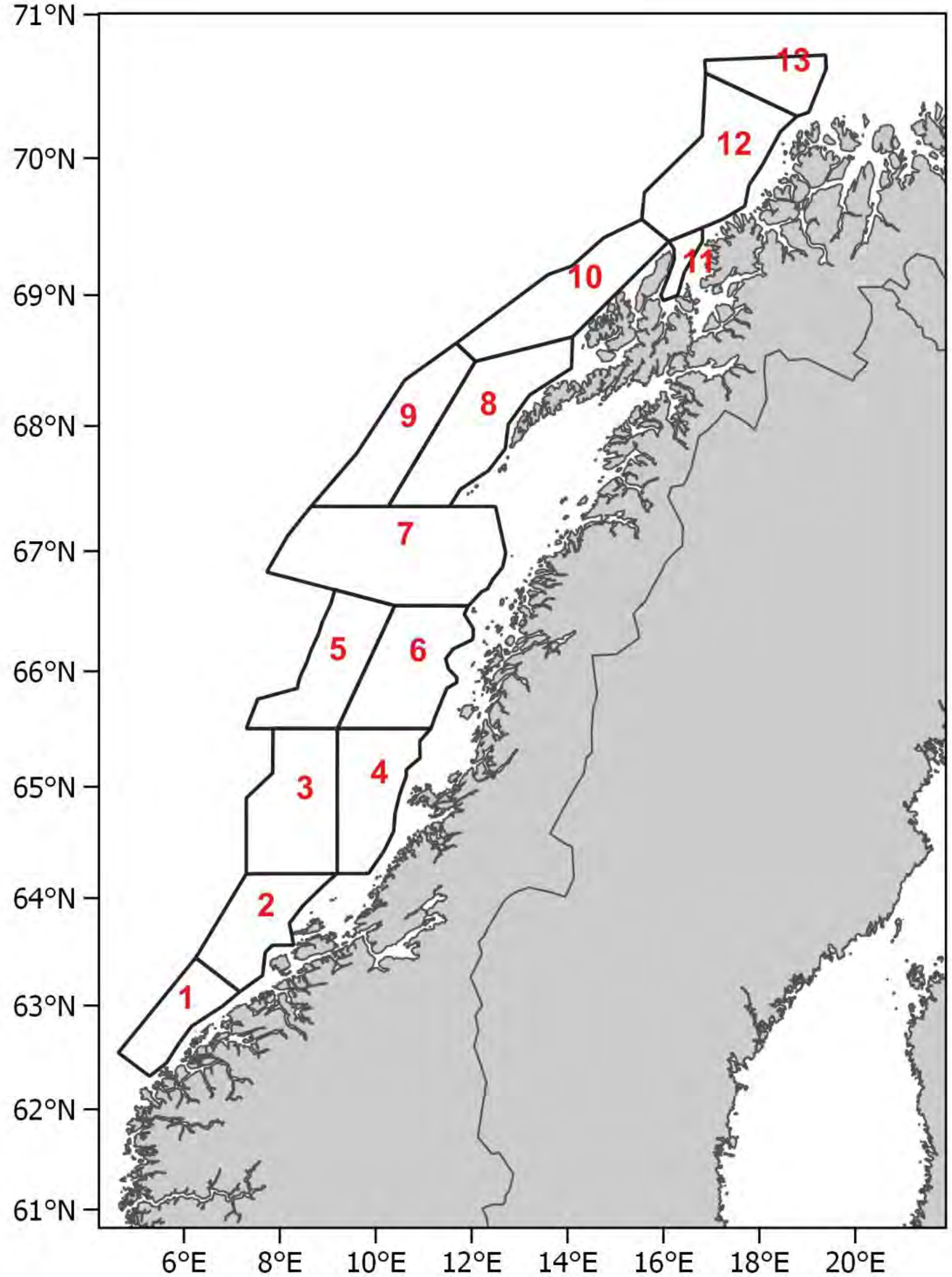


Figure 2. Strata covered during 14.-26. February 2020 with MS *Eros, Kings Bay* and *Vendla*

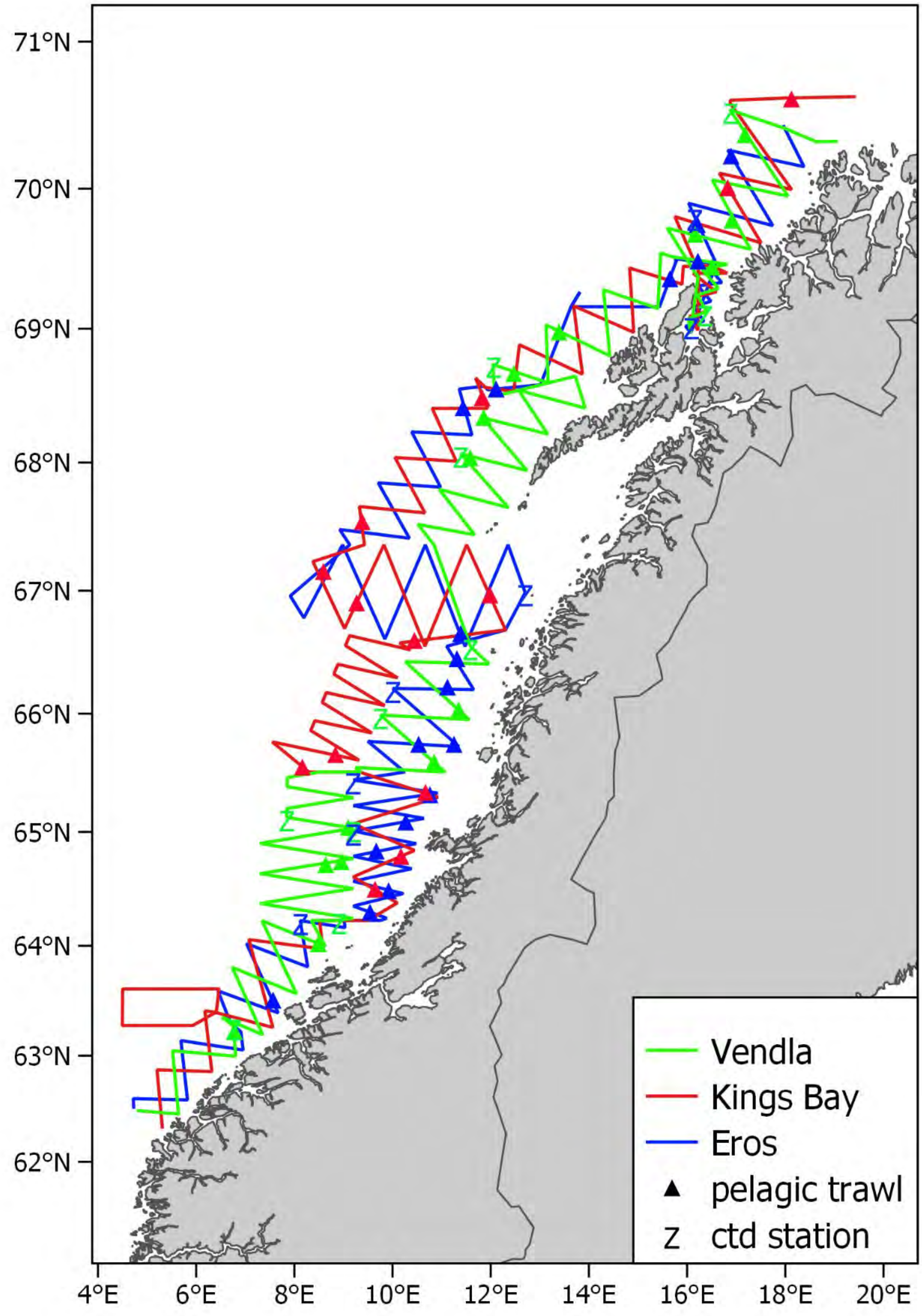


Figure. 3. Acoustic transects, pelagic trawl stations (triangles), and CTD stations (Z) covered with *Eros, Kings Bay* and *Vendla* 14.-26. February 2020.

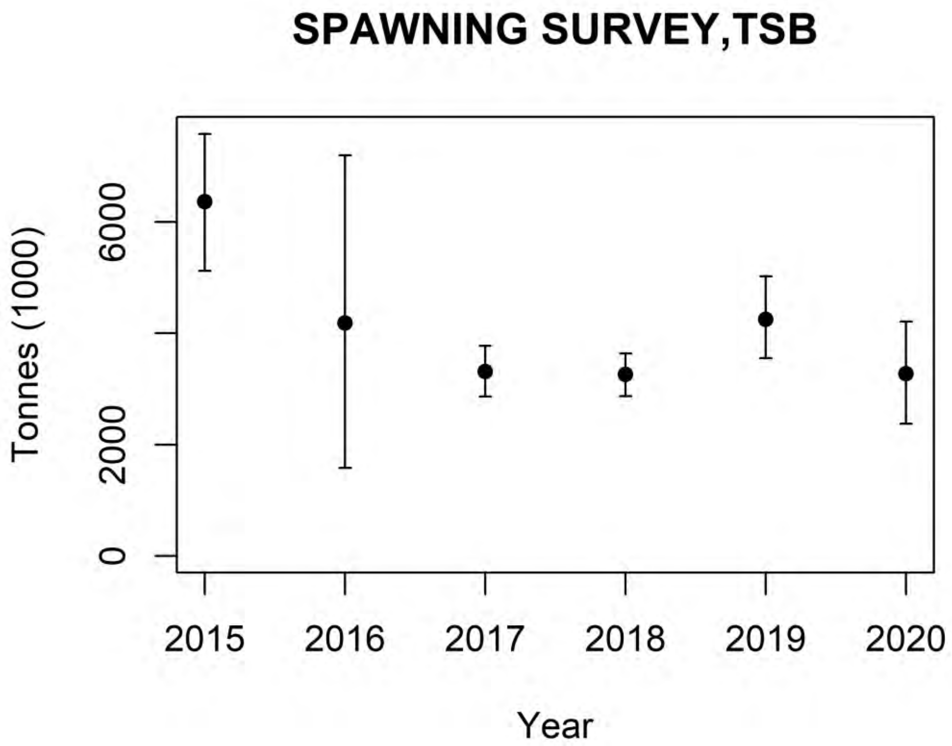


Figure 4. Estimates of total biomass from the Norwegian spring-spawning herring spawning surveys 2015-2020. The estimates are mean of 1000 bootstrap replicates in StoX and the error bars represent 90 % confidence intervals.

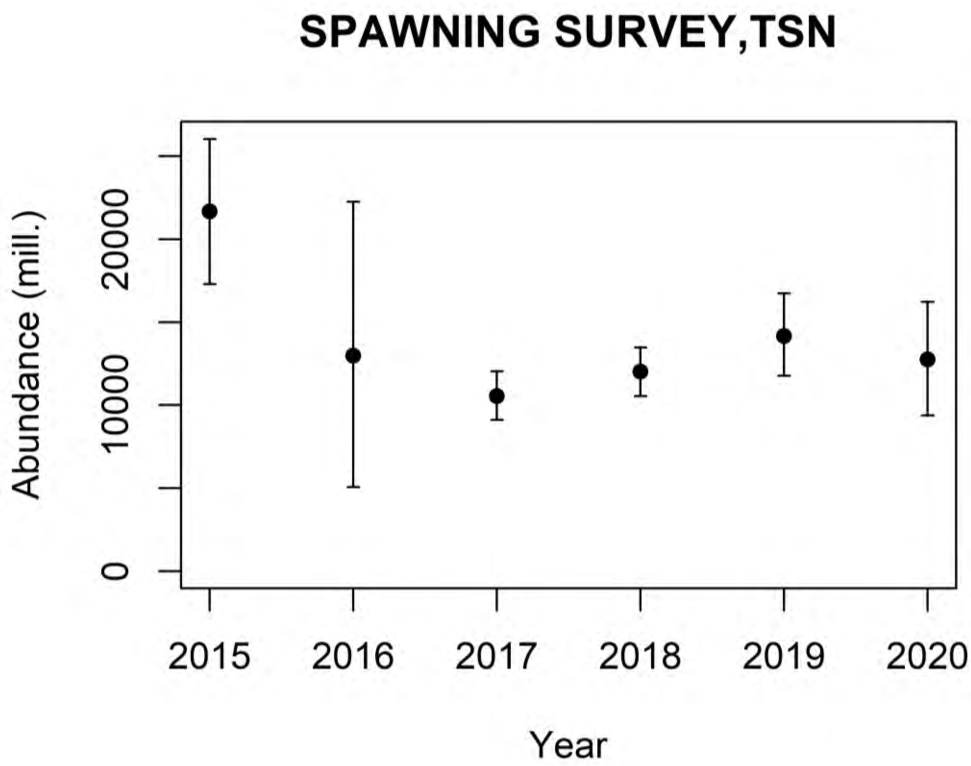


Figure 5. Estimates of total number from the Norwegian spring-spawning herring spawning surveys 2015-2020. The estimates are mean of 1000 bootstrap replicates in StoX and the error bars represent 90 % confidence intervals.

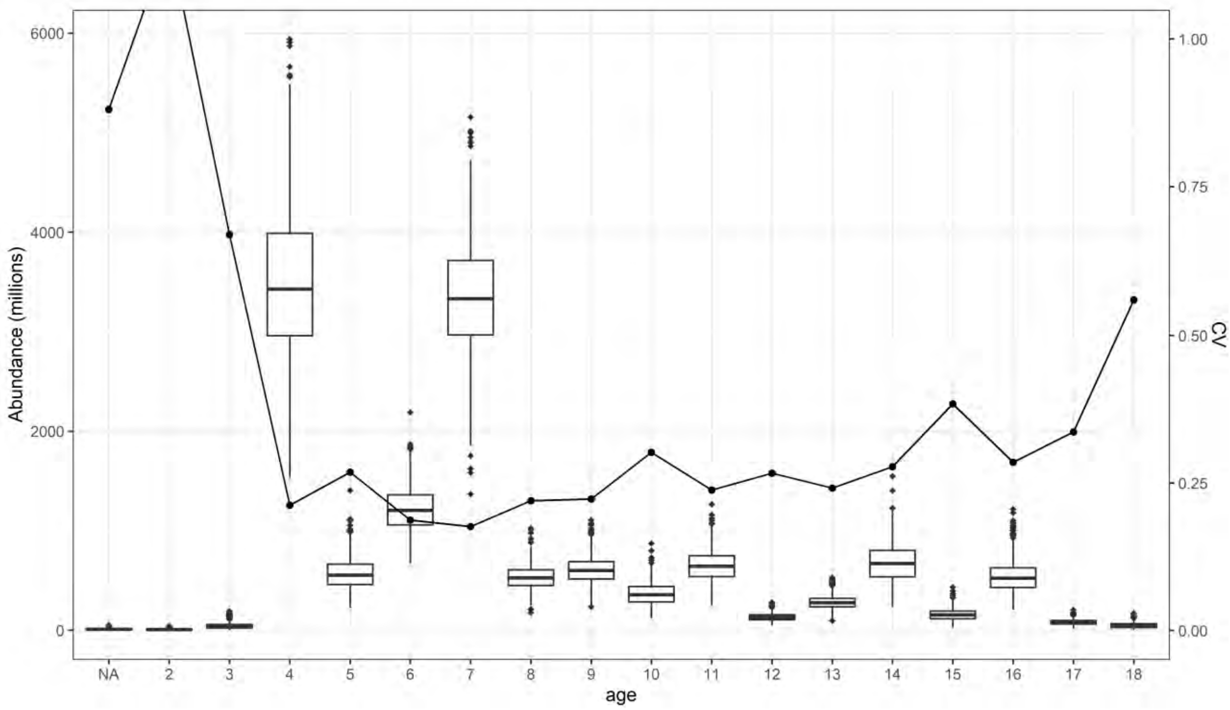


Figure 6. Standard box plot of abundance by age with uncertainty (CV) as estimated during 14.-26. February 2020. The Uncertainty estimates were based on 1000 bootstrap replicates in StoX.

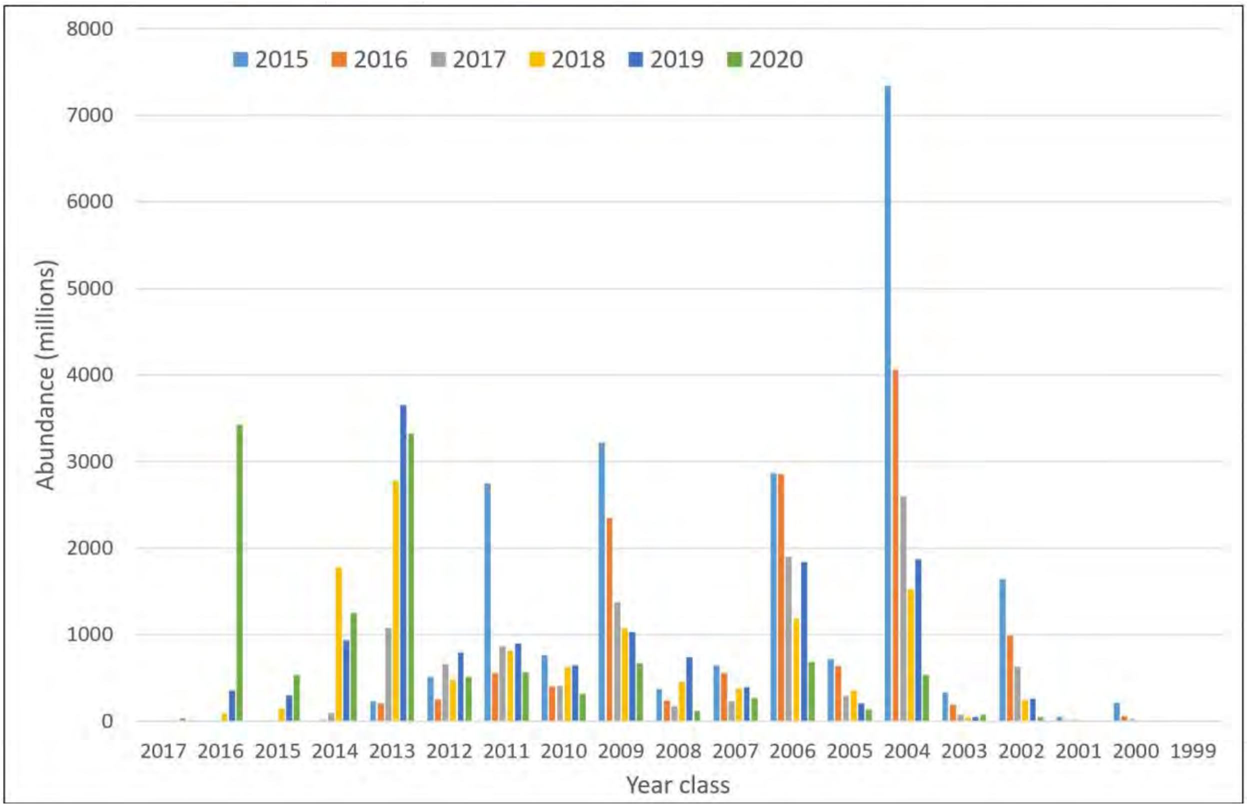


Figure 7. Abundance by year class estimated during the Norwegian spring-spawning herring surveys 2015-2020 (baseline estimates from StoX). Legend: Separate colour for each survey year.

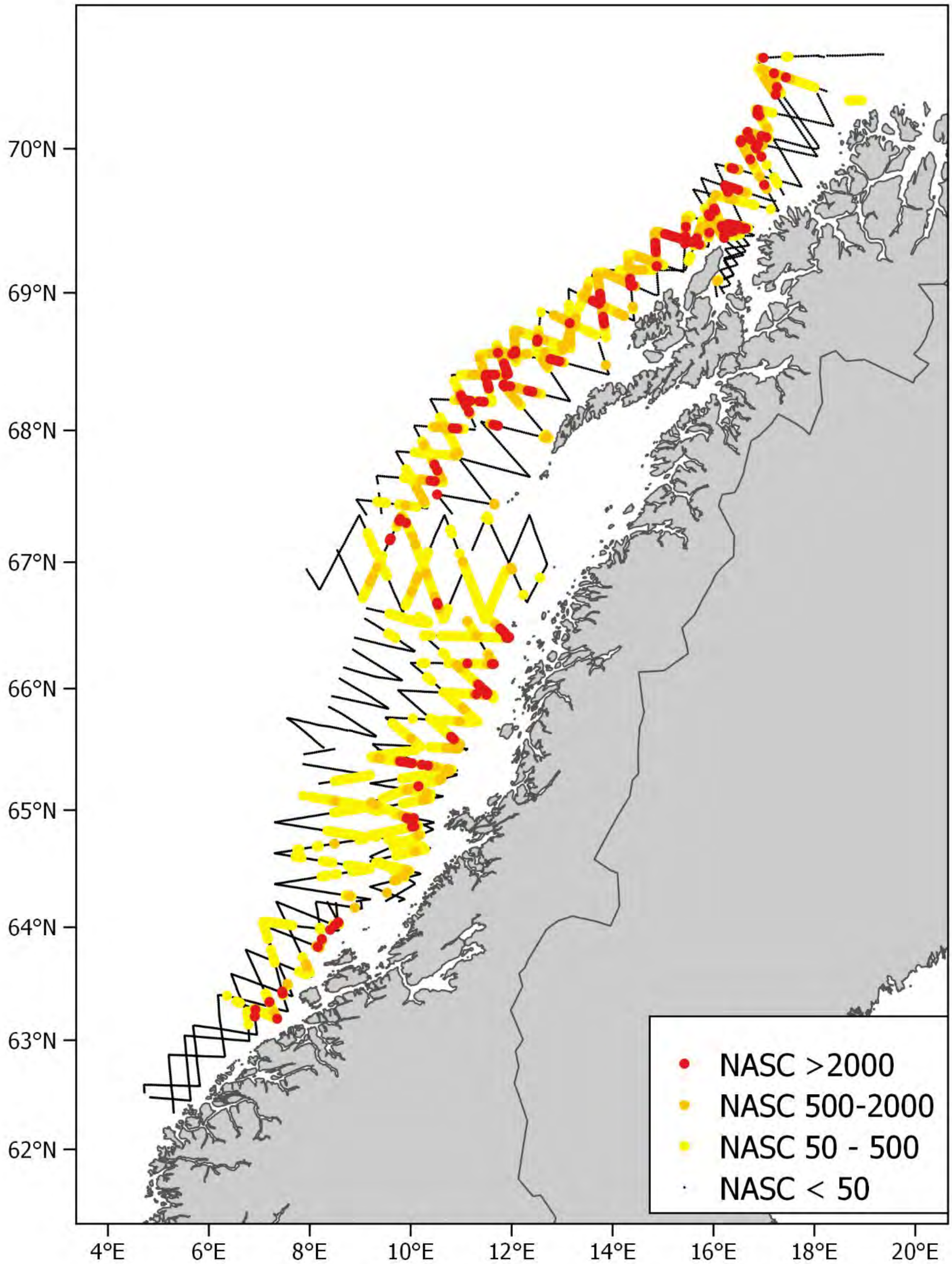


Figure 8. Acoustic density (NASC) of herring recorded during 14.-26. February 2020. Points represent NASC values per nautical mile.

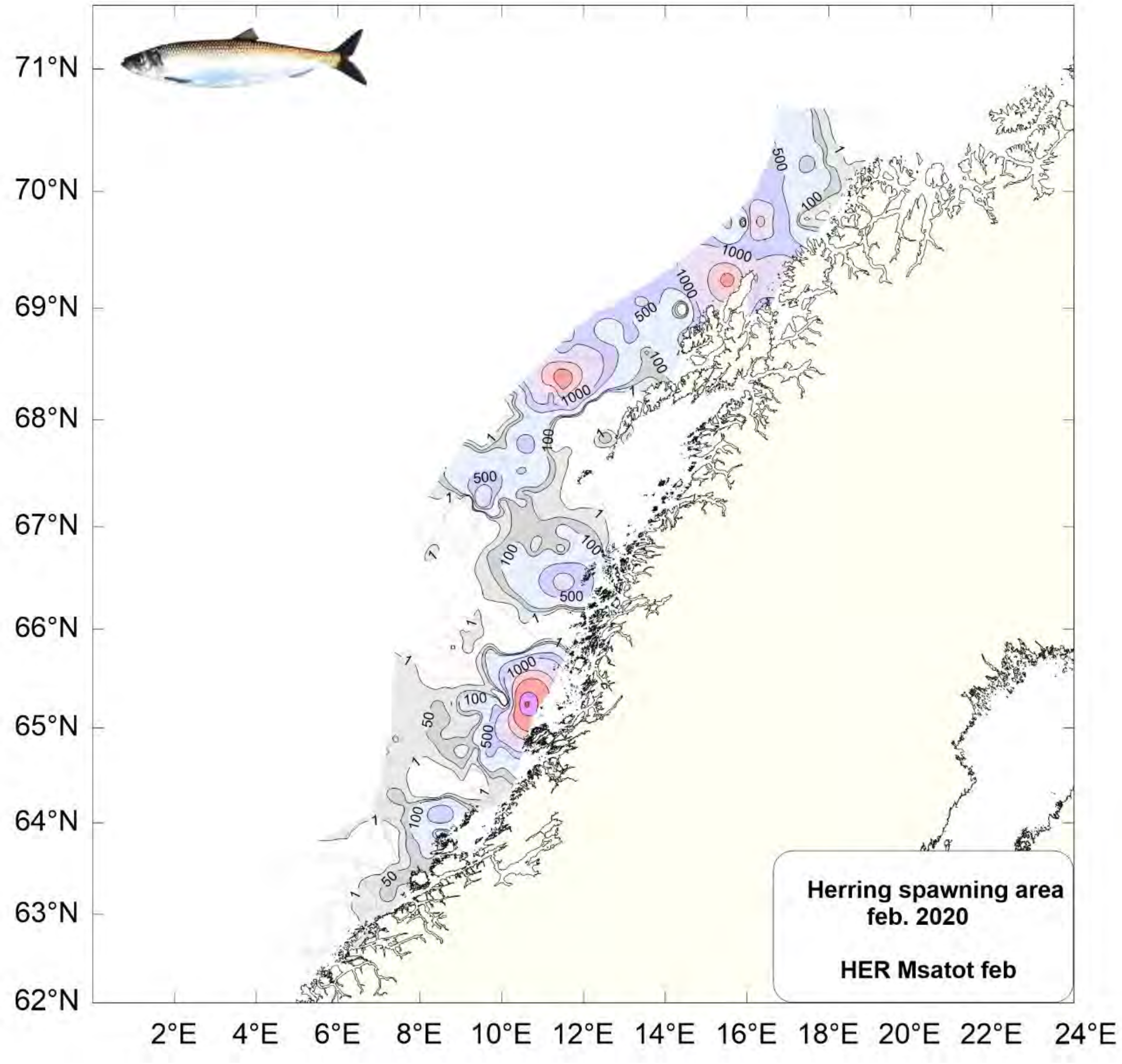


Figure 9. Contour plot of acoustic density (NASC) of herring recorded during 14.-26. February 2020.

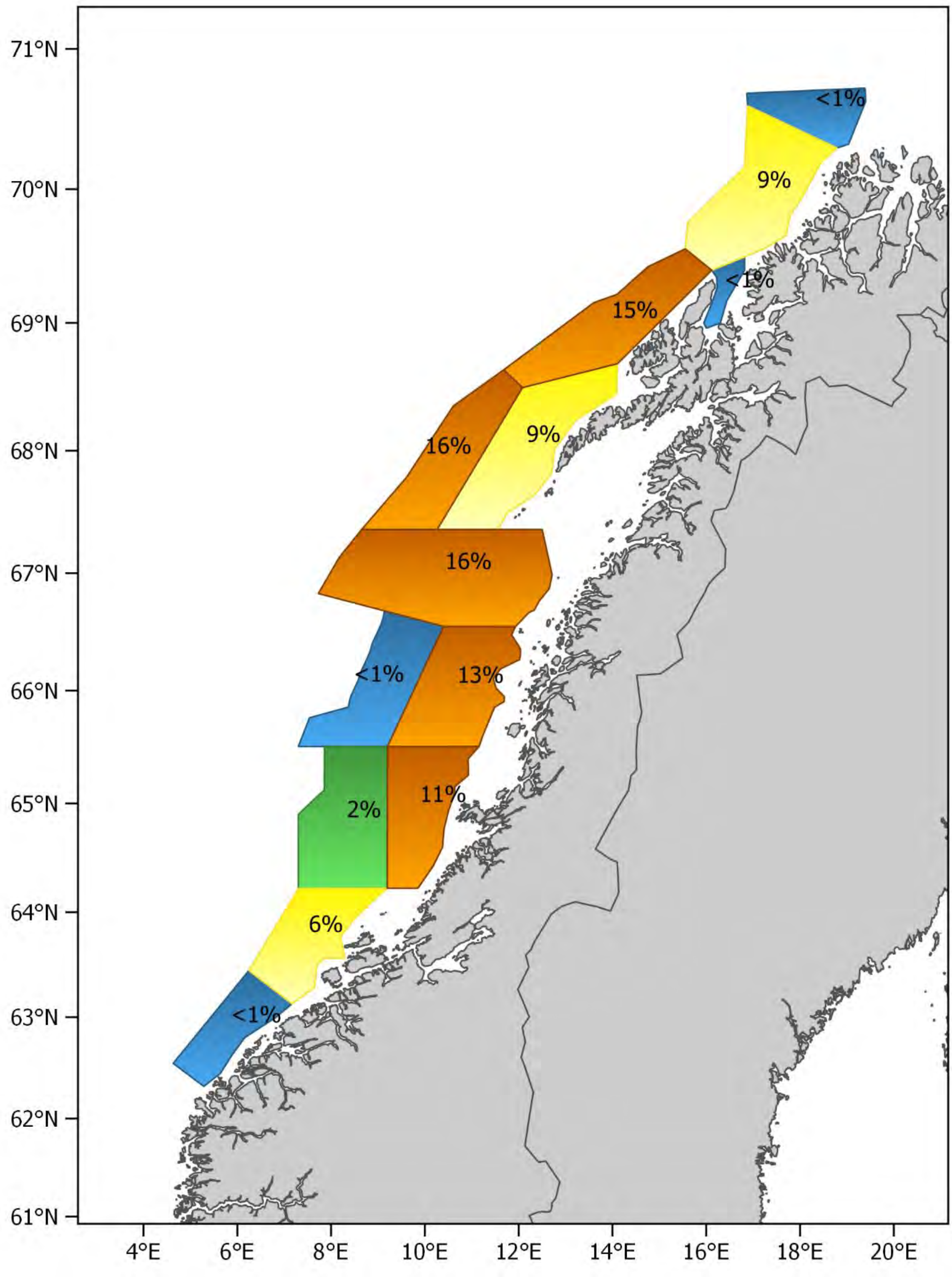


Figure. 10. Relative distribution by stratum of the biomass of herring (baseline estimates from StoX) 14.-26. February 2020. Strata numbers are given in Figure 2.

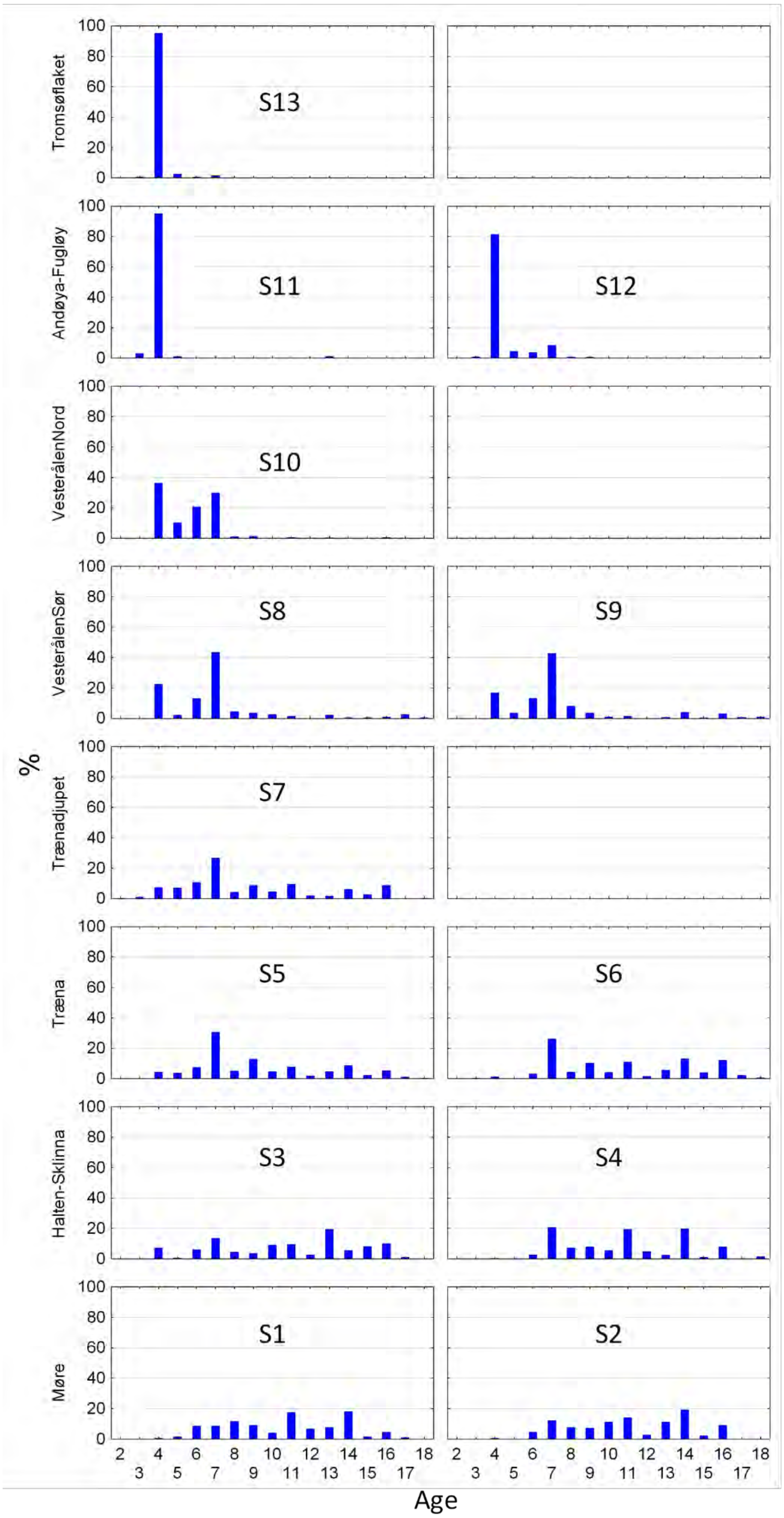


Figure 11. Comparison of age composition (%) estimated in different strata covered during 14.-26. February 2020. Strata numbers are given in Figure 2.

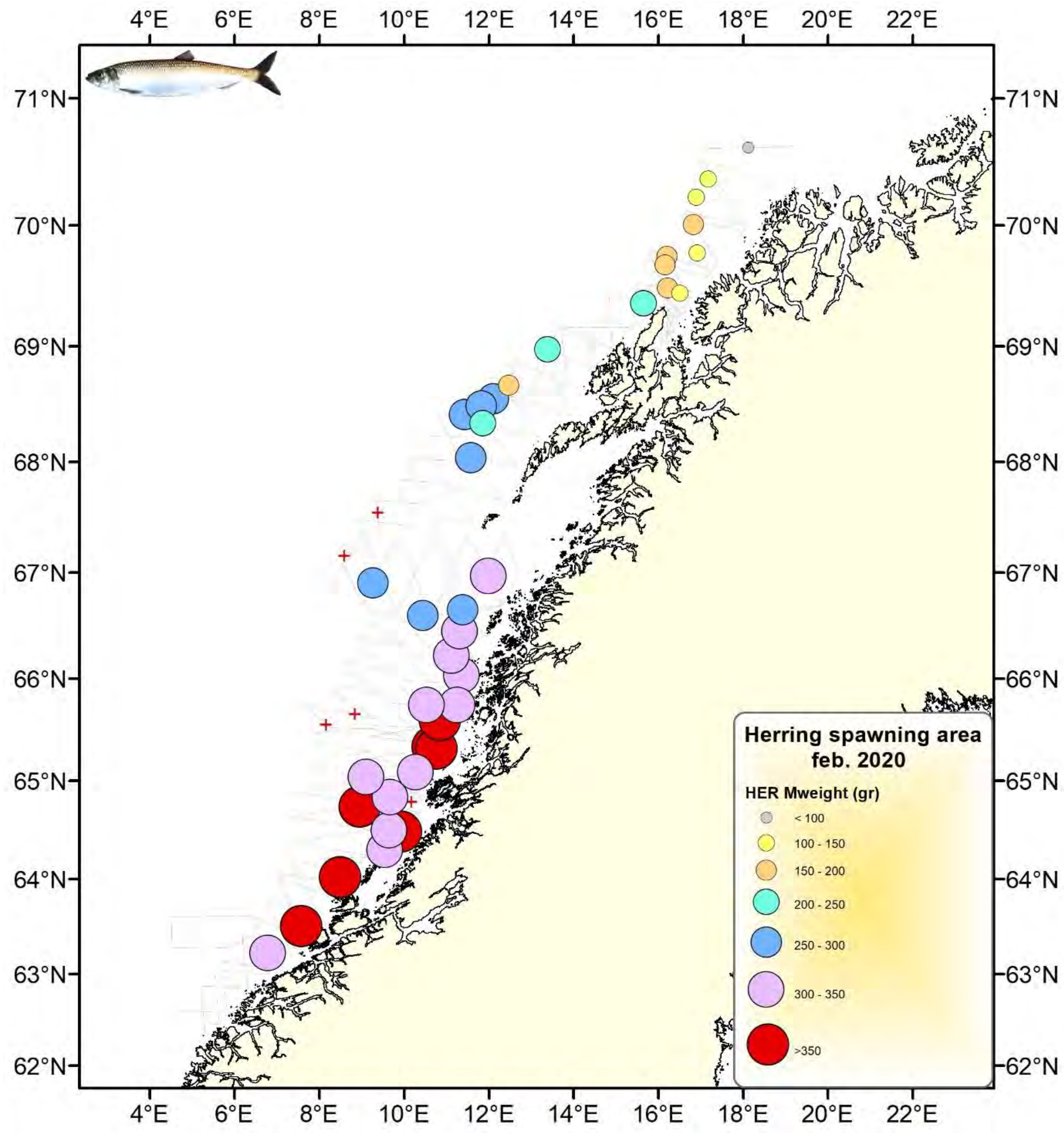


Figure 12. Mean weight (g) of herring by trawl station during the Norwegian spring-spawning herring survey 14.-26. February 2020.

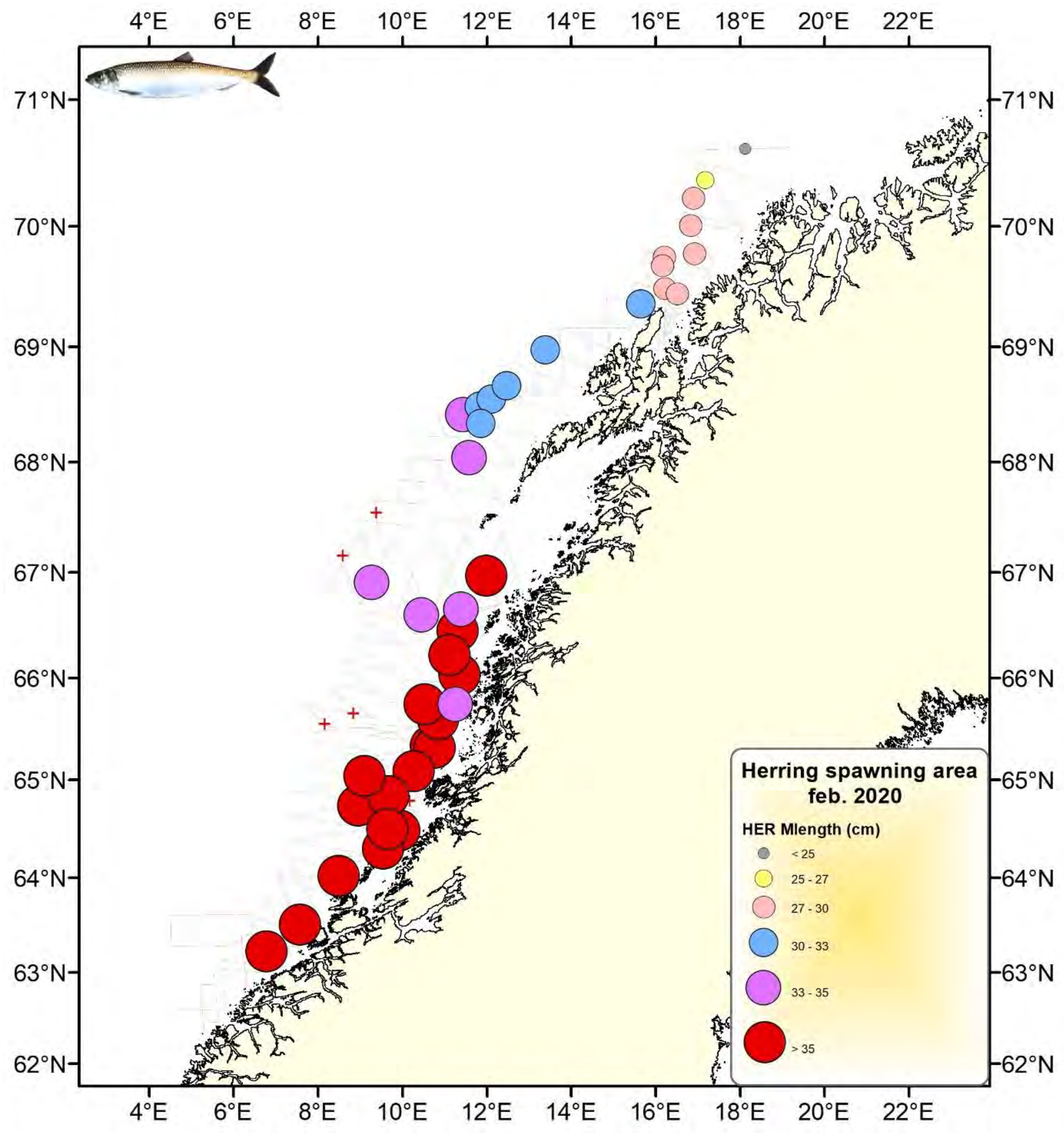


Figure 13. Mean length (cm) of herring by trawl station during the Norwegian spring-spawning herring survey14.-26. February 2020.

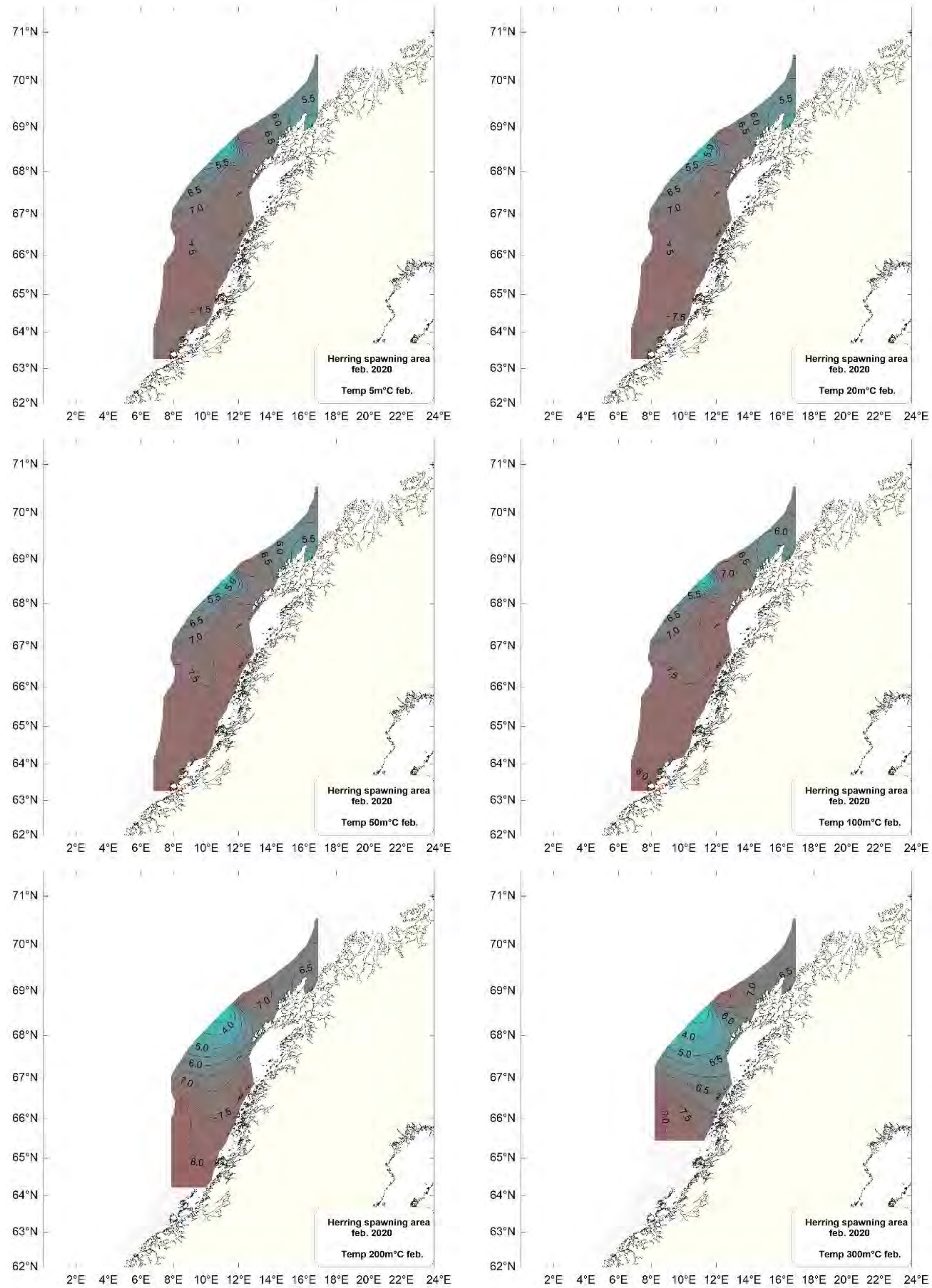


Figure 14. Temperature at 5, 20, 50, 100, 200, 300 m in the area covered during the Norwegian spring-spawning herring survey14.-26. February 2020.

Annex 1. Calibration results and settings

Table 1. Calibration data and parameter settings of the five echo sounders on each survey vessel in the survey, with the calibration done on February 14, 2020. Kings Bay has Simrad EK80 WBT's, while Vendla and EROS has Simrad EK60. EROS is running the EK80 software on the EK60 GPT's, while VENDLA runs the original EK60 software. The new WC57.2 calibration sphere was as target for all frequencies when calibrated at the tip of the fishery pier in Ålesund, with tabulated values for the sphere TS on EK60, and with the internally computed by the calibration program in EK80. After calibration was accepted, the new calibration parameters were entered into the echo sounders. The validity of the WC 57.2 calibration sphere against the original CU60 at 38 kHz was previously conducted on G.O.Sars in November 2018 with good results. The echo sounders calibration showed very good stability compared to 2017 and 2018. The 200 Khz echo sounder on Kings Bay was changed due to the failure discovered in 2018, and the 38 kHz system was changed due to a ripping of the old transducer cable. Otherwise, the systems are very stable, and as an example the calibration of the Vendla EK60 system gave values within 0.1 dB from previous February 2019 calibration except for 200 kHz, where the difference was 0.2 dB.

MS Kings Bay, Simrad EK80

Parameter					
	Survey data sample 2020818 1402: Simrad EK80, CW, 1 ms				
Transducer type	ES18	ES38-7	ES70-7C	ES120-7C	ES200-7C
Transmission frequency [kHz]	18	38	70	120	200
Transmission power [W]	2000	2000	750	250	150
Pulse duration [ms]	1.024	1.024	1.024	1.024	1.024
TS Transducer Gain [dB]	23.06	26.33	27.76	27.27	26.58
Sa Correction (dB)	0.009	0.000	0.16	-0.20	-0.33
Equivalent beam angle [dB]	-17.0	-20.7	-20.7	-20.7	-20.7
Absorption coefficient [dB km^{-1}]	2.9	10.1	20.9	31.8	52.15
Half power beam widths (along/athwart ship) [deg]	9.77/9.87	5.5/4.9	6.71/6.68	6.27/6.61	7.20/6.90
Transducer angle sensitivity (along ship and athwart ship)	15.5	23.0	23.0	23.0	23.0
Sound speed [m s^{-1}]	1473	1473	1473	1473	1473

M/S Vendla, Simrad EK60

Parameter					
	Calibration 20190218 Simrad EK60, CW narrow-band				
Transducer type	ES18	ES38B	ES70-7C	ES120-7C	ES200-7C
Transmission frequency [kHz]	18	38	70	120	200
Transmission power [W]	2000	2000	750	250	120
Pulse duration [ms]	1.024	1.024	1.024	1.024	1.024
TS Transducer Gain [dB]	22.84	25.46	26.53	27.09	27.25
Sa Correction (dB)	-0.57	-0.72	-0.35	-0.27	-0.27
Equivalent beam angle [dB]	-17.0	-20.6	-20.7	-21.0	-20.7
Absorption coefficient [dB km^{-1}]	2.8	9.6	20.3	31.3	44.5

Half power beam widths (along/athwart ship) [deg]	10.81/10.86	6.97/7.05	6.53/6.62	6.44/6.56	6.59/6.3|
Transducer angle sensitivity (along ship and athwart ship)	15.5	23.0	23.0	23.0	23.0
Sound speed [m s^{-1}]	1471	1471	1471	1471	1471

M/S EROS, Simrad EK60

Parameter					
	Calibration 20180218, Simrad EK60, CW narrow-band				
Transducer type	ES18	ES38B	ES70-7C	ES120-7C	ES200-7C
Transmission frequency [kHz]	18	38	70	120	200
Transmission power [W]	2000	2000	375	150	90
Pulse duration [ms]	1.024	1.024	1.024	1.024	1.024
TS Transducer Gain [dB]	22.25	25.84	26.52	26.67	26.53
SaCorrection (dB)	-0.23	0.00	-0.33	-0.36	-0.26
Equivalent beam angle [dB]	-17.0	-20.6	-20.7	-21.0	-20.7
Absorption coefficient [dB km^{-1}]	2.8	9.7	20.6	31.6	44.9
Half power beam widths (along/athwart ship) [deg]	10.15/10.32	6.99/6.80	6.86/6.92	6.97/6.70	6.03/5.79
Transducer angle sensitivity (along ship and athwart ship)	15.5	23.0	23.0	23.0	23.0
Sound speed [m s^{-1}]	1473	1473	1473	1473	1473

February 25. 2020, Egil Ona, M/S EROS, at Sea

Annex 2. Measuring the migration speed of herring

The spawning survey on NVG herring along the Norwegian coast is designed as a snap-shot survey over 12 days, covering a survey area of 30443 nmi^2. A zig zag survey design gives a higher mean progress speed than parallel transects (Harbiz, 2019). However, before spawning, the herring migrate against the prevailing current direction, and actively use the tidal variations in the current to adjust the migration speed. Vertical positioning therefore seems to be important. Simmonds and MacLennan (2005) writes: “The movements of fish can be conceived as having two components, random motion and migration. In the former case, the fish swim at a certain speed in directions that change randomly with time. In the latter case, the fish swim consistently in the same direction. Simmonds *et al*. (2002) used a fine-scale model of North Sea herring schools, based on a spatial grid covering 120 000 km^2 with a node spacing of 40 m, to study the effect of fish movements on the results of simulated surveys. They found that the random motion was unimportant, but the effect of systematic migration even at a modest speed could not be ignored. One factor in the survey design is the timing in relation to the migration cycle, which should ensure that the surveyed area includes the entire stock. But even if this condition is met, migration of the stock within the surveyed area can bias the abundance estimate. The extent of the bias depends on the direction of the migration in relation to the transects. Suppose the fish are migrating at speed vf , and vs is the speed at which the survey progresses in the direction of migration. If vs is positive, this means that the fish tend to follow the vessel as it travels along successive transects. If the cruise track were drawn on a map whose frame of reference moved with the fish, the transects would be closer together than those on the geostationary map. Thus the effective area applicable to the analysis is less than the actual area surveyed. The observed densities are unbiased, but since the abundance is the mean density multiplied by the effective area, the estimate ˆQ is biased. The expected value of ˆQ is:

$$E(\hat{Q}) = Q(1 + vf / vs)$$

Note that when the transects are long and perpendicular to the migration, vs is much smaller than the cruising speed of the vessel. For example, if the cruising speed is 5 ms−1, and the transect length is 10 times the spacing, then the survey progresses at vs = 0.5m s−1, a value which could well be comparable with vf . Harden Jones (1968) suggests that herring are capable of migration speeds up to 0.6m s−1. The swimming capability of fish depends on their size, but adult herring and mackerel can sustain speeds around 1.0m s−1 for long periods (He and Wardle 1988; Lockwood 1989). The bias is greatly reduced if the transects run alternately with and against the migration”.

A rough model can be plotted using the equation suggested by Simmonds and MacLennan (2005), with the suggested bias in the survey on the z axis. The start of the survey, the progress speed is about 1.17 m s-1 in the North - direction, indicating that the bias could be from 0 to 50% with a constant fish migration speed of 0.2 m s-1, well within the swimming capacity of adult herring. Using fishery sonar on distinct schools have been tried for direct measurement of the migration speed on earlier surveys, (Slotte et al, 2015,2016), but in this particular spawning survey, only a small fraction of the herring is moving in distinct schools. The more typical situation is layers, either in the water column, or closer to the bottom, as shown in Figure 1, and a better way to measure the migration speed is to use a Doppler system, as realized in a scientific ADCP.

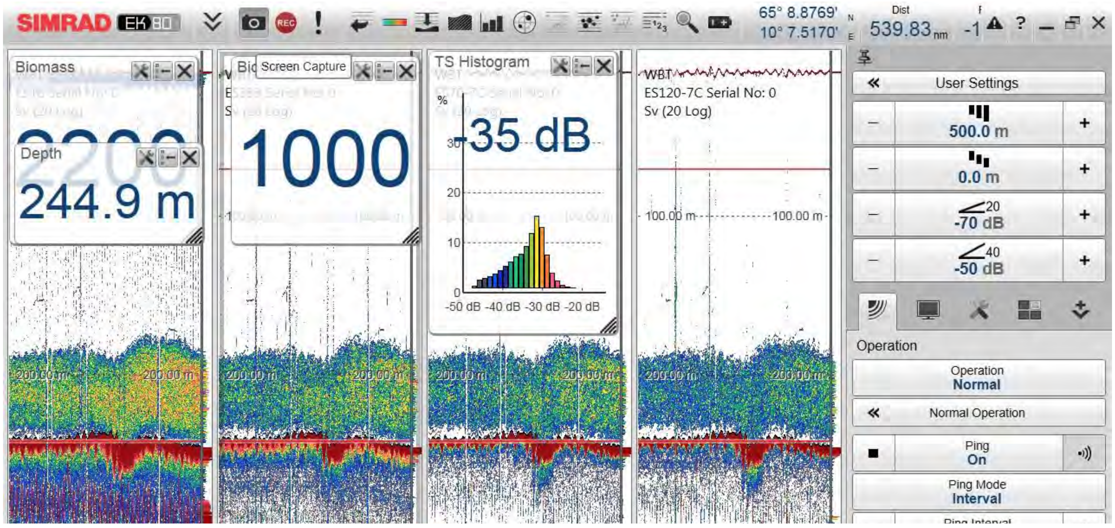
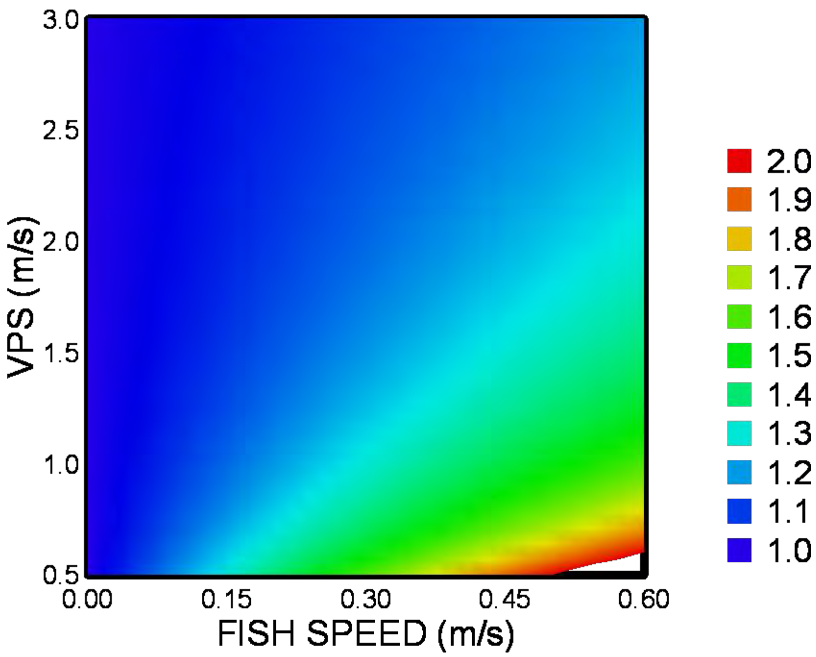


Fig 1. Typical herring layer in the NVG spawning survey (Slotte et al., 2019)



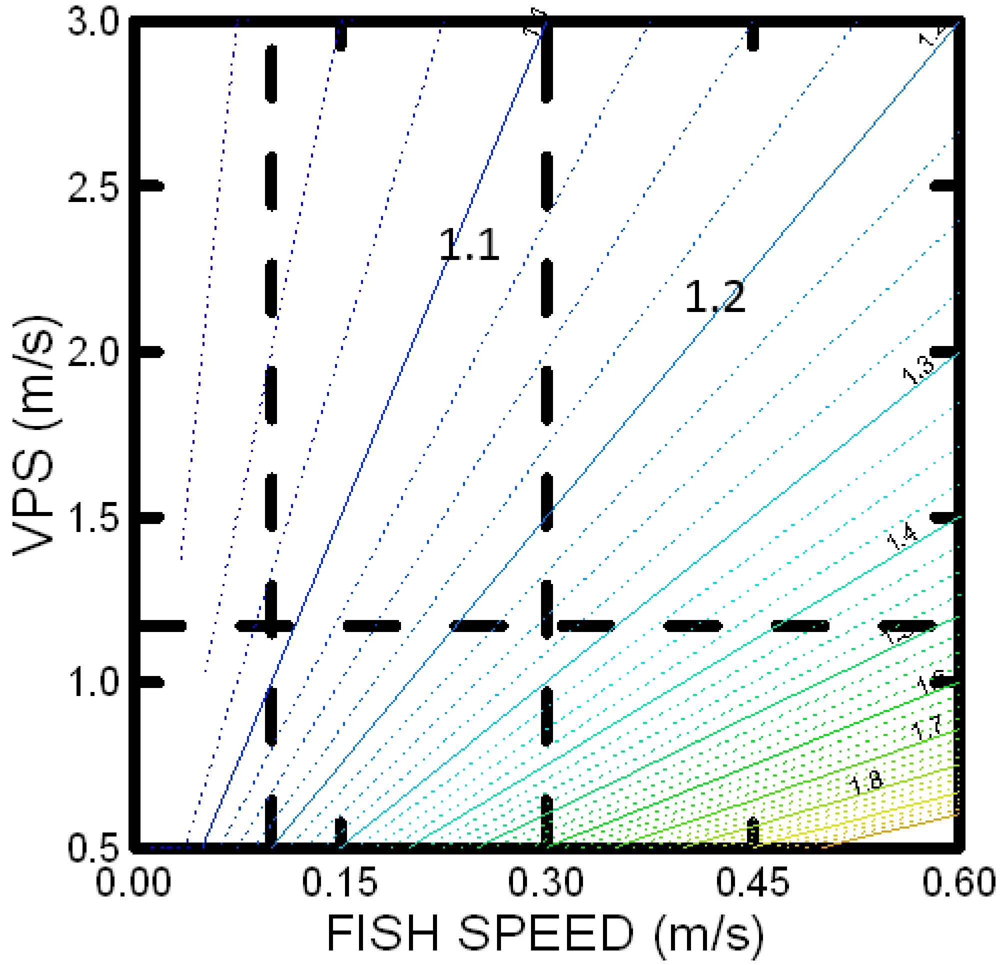


Fig 2. A, B, Overall figures for the migration error as a function of vessel progress speed, VPS (m s-1) and the herring migration speed. Error on Z axis, but with the mean vessel progress speed indicated for all strata 1.17 m s-1 as a vertical line. Observed migration speed for herring is between 0 and 0.3 m s-1, and the potential error can be evaluated to be maximum 1.2, or 20% in the worst case!

Material and methods

A Kongsberg Maritime ES150C EK80 ADCP system, with four acoustic beams transmitting a 150 kHz CW or FM signal installed on MS “EROS” in the dry dock at “Båtbygg”, Måløy, Norway, prior to the survey. The flat array transducer with the EK80 WBT installed in the transducer was transmitting a 12.1 ms CW pulse for the selected settings using phased array steering of the beams in ADCP mode, and a split beam transducer with 3° beam width in broad band echo sounder mode. The system was tested and tried calibrated in Ålesund February 14, 2020. Vessel GPS and KM motion Reference Unit (MRU) were coupled to the instrument, logging raw data to disk on the ADCP system PC.

Fig. 3. ADCP Simrad EC150-3C transducer (and WBT) mounted in box keel in front of the fishery sonars on EROS.

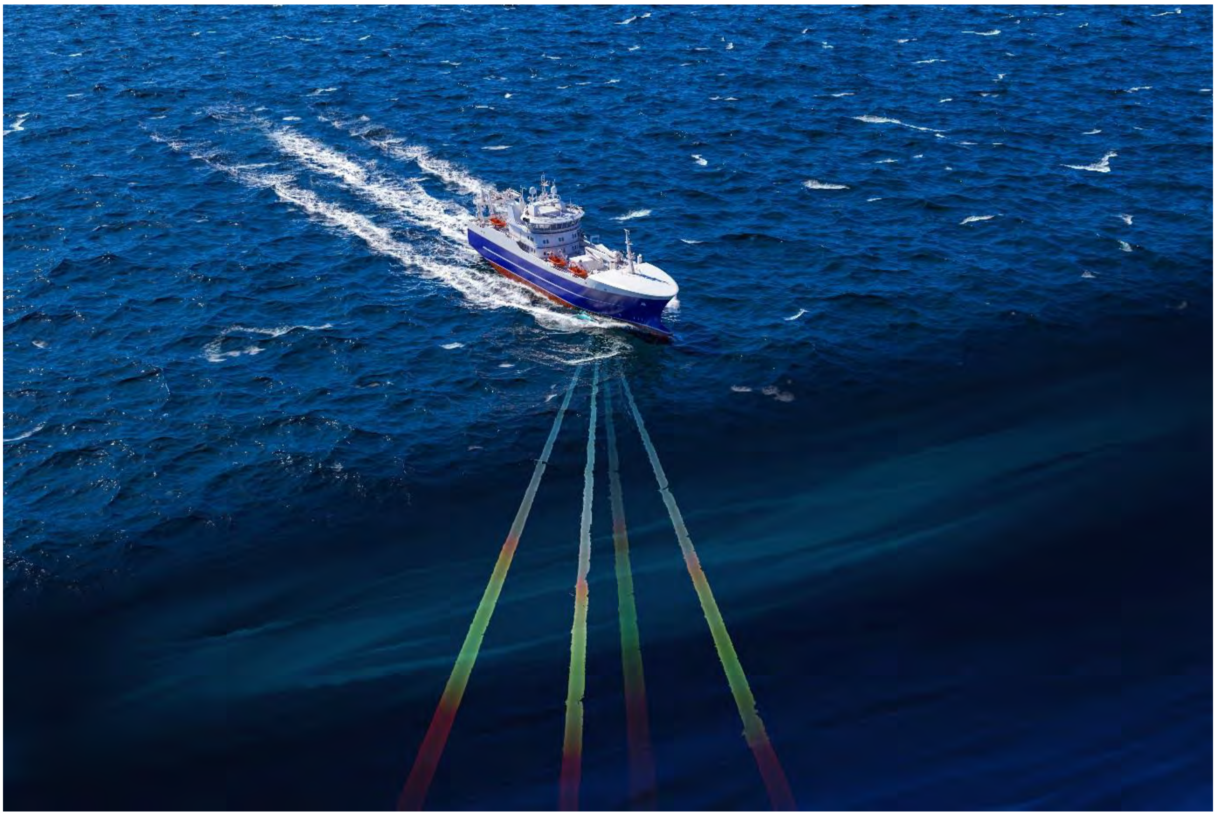


Fig 4. Principal sketch of the Simrad EC150-3C measuring system. (Figure: ®Tonny Algrøy, Kongsberg Maritime)

The ADCP system was run in parallel with the 5 EK60 GPT echo sounders and one SU90 sonar, as a stand-alone system, with no external triggering from the master echo sounder. Only weak interference was observed on the 120 kHz EK60 system, but not enough to disturb the abundance estimation of herring. GPS and a Kongsberg Motion Reference Unit, MRU 5 was connected to the ES150-C system.

The raw data was recorded, and the ADCP generated standard output current profile echograms on the screen, where both the movement of the water current and the herring movement could be monitored in real time.

For stability, averaging over 100 transmissions were used to generate preliminary real time current echograms, but could be re-run in echosounder replay using shorter averaging intervals needed for herring schools. Individual data sets were selected for further inspection and replayed locally on a secondary computer, based upon the scrutinizing results from the survey, using LSSS. During this process, the EK80 generated new processed data files, using standard output in NETCDF format. These were further read by a Phyton script, where further manipulation of the data could be done. Only preliminary analysis was done during the survey itself.

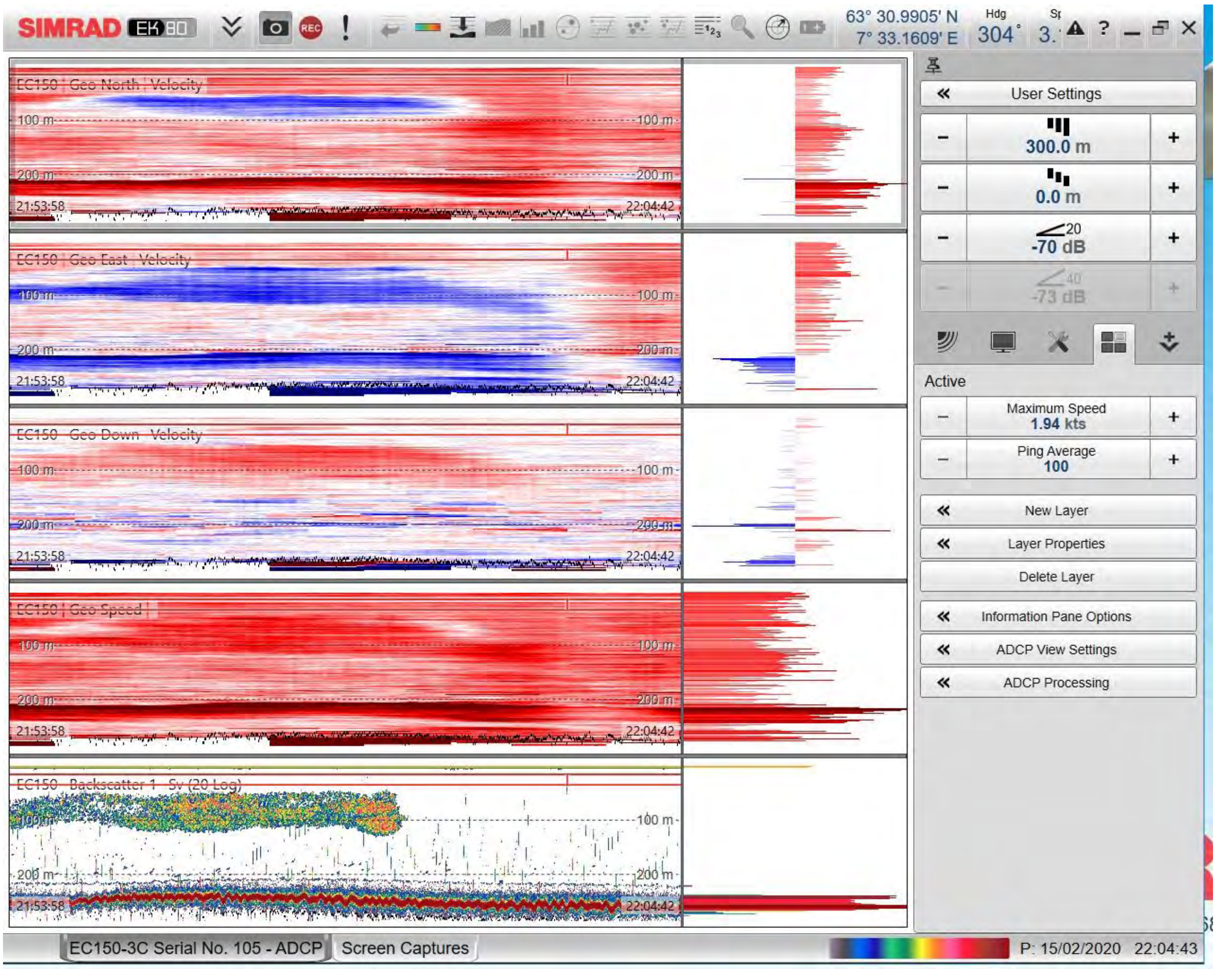


Fig 5. Example display of ADCP processed data. The screen is divided into 4 "echograms" horizontally, where the lower panel shows the backscattering in one of the ADCP beams. The upper panel shows the N/S component, here scaled to 0-2 knots, red is North, blue is South. The panel below the upper one is the E-W display, with similar settings, red is East, blue is West. Then, the third panel is the vertical speed measured, using the same scale, DOWN/ UP, with down as red, up as blue. Further, the last panel shows the sum of the vectors in the previous panels. All measurements here is geo-references, showing movement over ground. It is here clear that the herring swims against the relatively strong costal current.

Interpretation of example display:
First, the current in this transect is moving in a North direction at about 0.5 knots and slightly towards East. The current speed is similar across the entire whole water column.
The herring, however, is migrating in South direction at 0.5 knots, but also towards East with a similar swimming speed, 0.5 knots, i.e straight against the prevailing current. So, first the herring must compete and overcome the current, and exceeded the water speed with 0.5 knots. Relative to the surrounding water, it is actually swimming at 1 knot, 0.5 m s-1, or about 1.5 bl s-1, which according to Harden Jones (1968) is well within herring migration capacity.
During this first survey, there was no analyzing and processing tools available, and a manual selection of 10 values from the school and 10 values from the water column was selected and stored as separate variables.

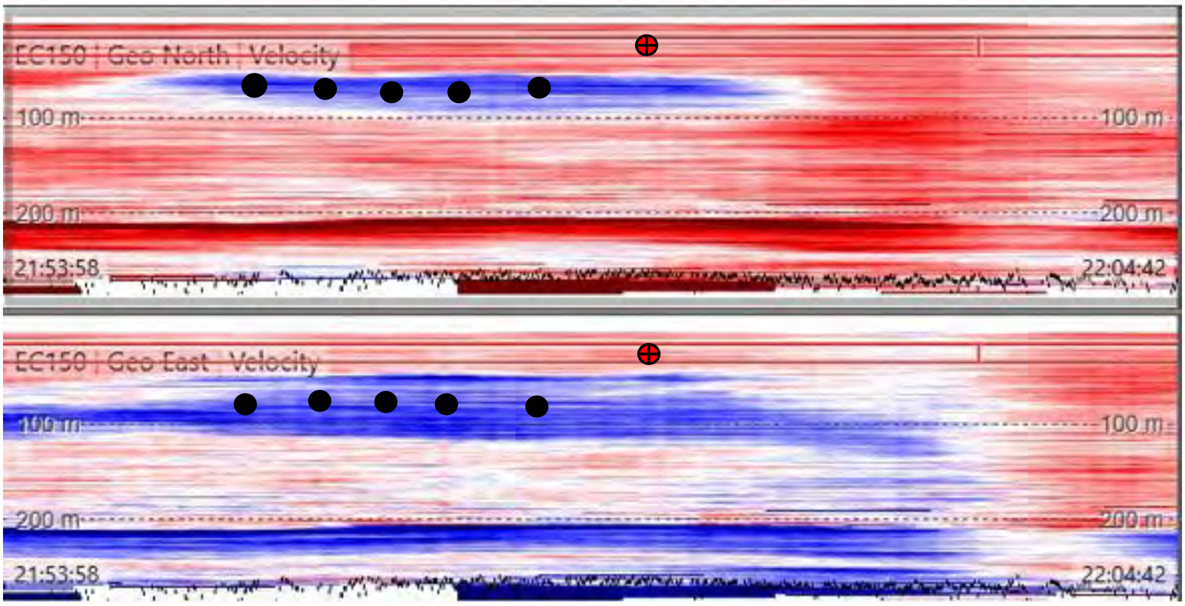


Fig 6. Manual selection of representative swimming speed and current speed, Version 1. In later versions of processing, a mask should be created using LSSS, and the mask transferred to the current echograms. Normal gridding output for both water and herring can then be computed and stored to normal user files.

About 39 data sets have been analyzed during the survey, where the herring swimming speed and current direction have been manually extracted. These data will be used to pair with the density data, either at transect level, or at stratum level.
One could either chose to weigh the speed with the acoustic density, either at transect level or at strata level:
Transect level:

$$h = \frac{\sum_n^i (v_i s_A)}{\sum_n^i s_A}$$

Then, compute the mean backscattered energy weighed speed to be used for the individual strata.
Or at strata level, h could be is the mean speed for all herring inside the strata, and the weight of migration could be the density inside the strata. (not yet decided).

The statistics of the mean survey progress (SPS) speed is shown in the Table 1.

stratum	Δt (H)	S (nmi)	VPS (knots)	VPS (m s-1)
1	14.39	67.65	4.70	2.42
2	24.64	65.67	2.67	1.37
3	55.74	77.42	1.39	0.71
4	50.55	77.10	1.53	0.78
5	38.02	70.56	1.86	0.95
6	37.32	62.56	1.68	0.86
7	38.45	48.70	1.27	0.65
8	36.66	79.48	2.17	1.12
9	30.21	76.62	2.54	1.30
10	25.53	63.60	2.49	1.28
11	11.01	32.40	2.94	1.51
12	45.78	72.00	1.57	0.81
13	9.01	25.54	2.84	1.46

Table 1. Vessel progress speed in North direction in the different strata of the survey. Delta h is the number of hours inside the strata, and the number of sailed nautical miles inside the strata is S 8nmi). Minimum 0.65 m s-1 and maximum 2.41 m s-1in strata 7 and 1 respectively. The overall mean progress speed is 1.17 m s-1 with a standard deviation of 0.47 m s-1.

We are now working on measuring the mean migration speed for each stratum, but already see that while the migration speed is high in the southern and middle strata, the migration is slower and less systematic further north.

Examples of processed data in Phyton, after replaying in local EK80 software, and generation of NETCDF output files, is shown below.

If we should make an educated guess at this point, correction for the migration effect on this survey would increase the biomass with 5 to 10%, which is still inside the uncertainty level of the survey estimate.

Egil Ona, At sea 26.2.2020, and home office 30.3.2020.

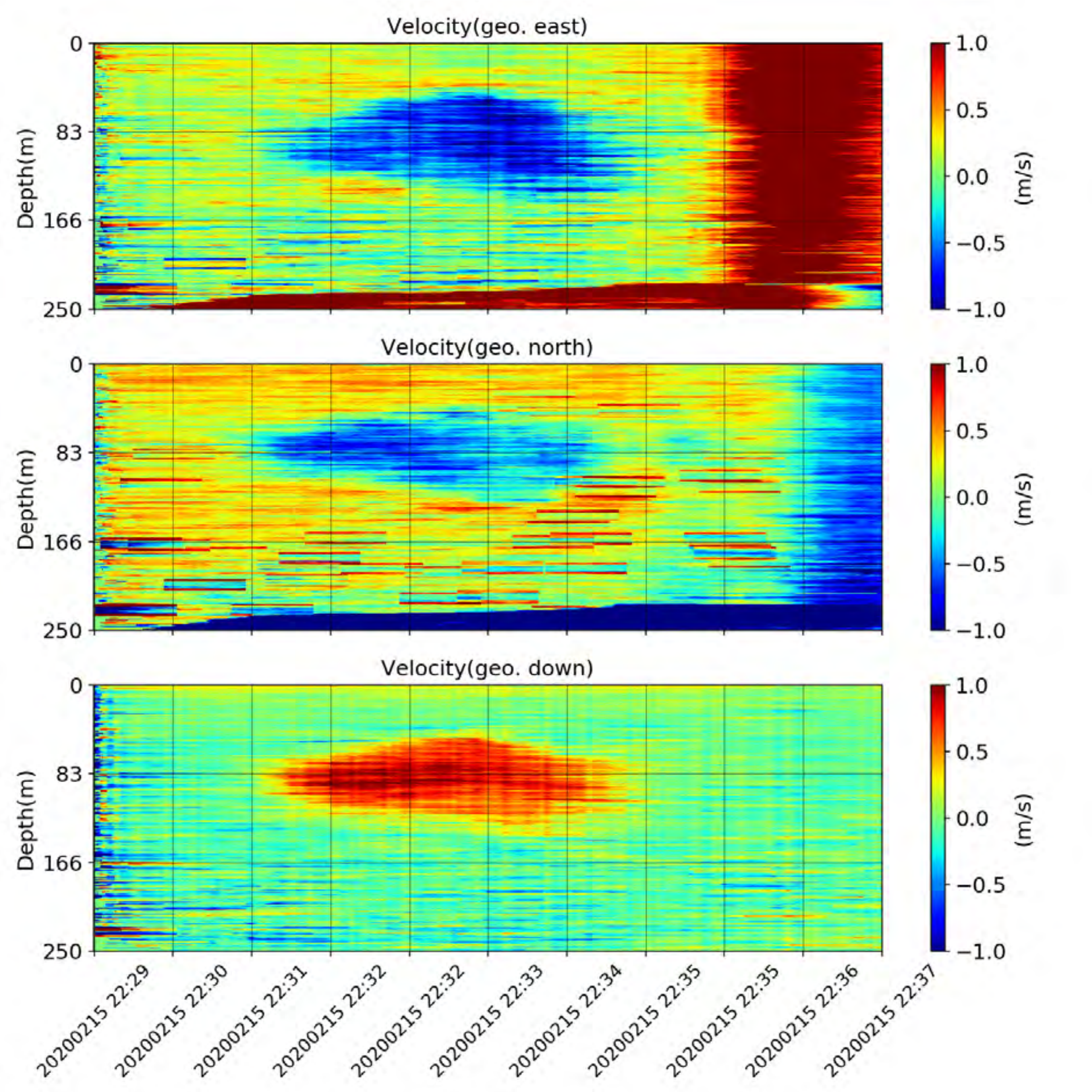


Figure 7. Phyton output of water and herring speed, georeferenced, i.e speed over ground, UPPER (East-West direction, MIDDLE (North-South direction) and LOWER : Vertical direction, Down-Up, with DOWN positive= Red. The dark red in the last part of the "echogram" is connected with a turning of the vessel, a movement which is not compensated for properly, the "sliding movement" of the ship while turning.

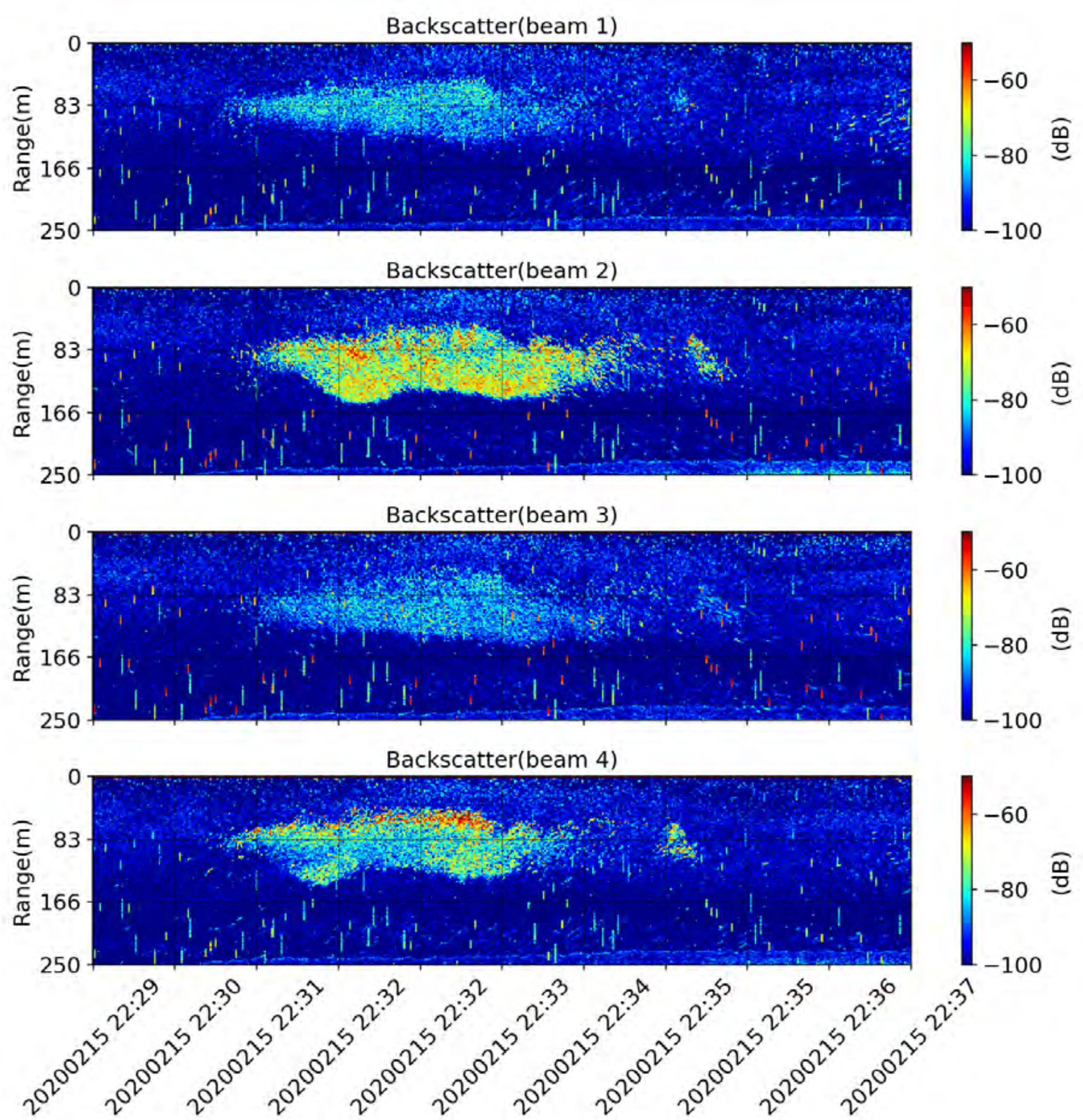


Figure 8. Echogram from the 4 ADCP beams where the Doppler is extracted.

Working document 07, WGWIDE 2020, 26 August-1 September 2020

Inventory of industry-acoustic data for potential application on blue whiting biomass estimates

Benoit Berges[1], Serdar Sakinan[1], Sytse Ybema[2], Gert-Jan Kooij[2], Martin Pastoors[3]

Abstract

Since 2012 the Dutch pelagic industry (PFA) has been engaged in the collection of acoustic data at a large scale. This working document presents an overview of the acoustic data with a focus on blue whiting. Further work will be carried out to (automatically) analyse the acoustic data and couple those results with the PFA self-sampling data. The ambition is to explore the development of an index of abundance from commercial acoustic data that could aid the blue whiting acoustic survey in case of missing surveys or bad weather conditions.

[1] Wageningen Marine Research, The Netherlands

[2] Sustainovate, Norway

[3] Pelagic Freezer-trawler Association, The Netherlands

1 Background

Since 2012 the Dutch pelagic industry (PFA) is engaged in the collection of acoustic data at a large scale. Through the years, this took the form of several projects serving abundance estimation [1]–[4] and species identification [5], [6] (SEAT project, unpublished[1],[2]). Through the course of the various projects, consistency in the type of data collected (using SIMRAD EK systems, EK60, ES70, EK80) and quality through regular calibration was ensured. Since, 2019, there is an effort to automate and standardize the data collection through the Ocean-Box system[3]. As a result, there is a wealth of quality acoustic data available that could be used to derive a range of indicators on various fish stocks in the North Sea. Since 2015, this is complemented by biological data collected through the self-sampling program put in place by PFA. This program expands the ongoing biological monitoring programs on board of pelagic freezer-trawlers by the specialized crew of the vessels [7], [8]. In the context of WGWIDE, the focus of the hereby report is on Blue Whiting and especially the inventory of data available to date for this fish species.

2 Overview of industry acoustic data available

Acoustic data on blue whiting collected by Dutch Freezer trawlers are composed of:

1. data collected and analysed through the course of two historical projects ([1], [2])
2. data collected systematically onboard specific vessels but not analysed to date.

2.1 Data from historical projects

Through the course of the two historical projects, acoustic data on blue whiting, herring and sprat has been collected. During both projects, substantial effort has been devoted to the calibration of the participating vessels.

Acoustic data collected during 2012 [1]

[1] https://sustainovate.com/portfolio/seat-phase-1/
[2] https://sustainovate.com/portfolio/seat-phase-2/
[3] https://sustainovate.com/portfolio/oceanbox/

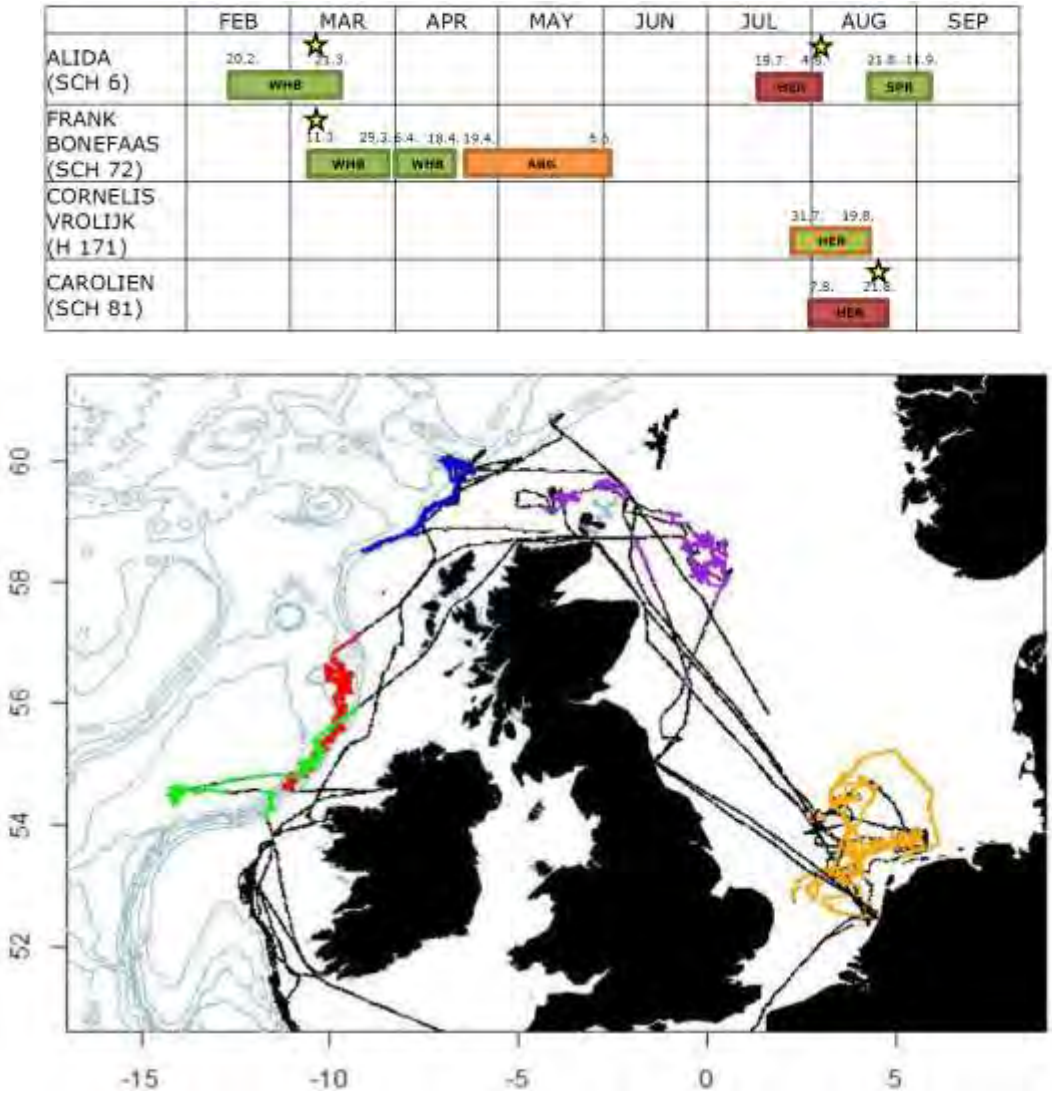


Figure 1 timing tracks of fishing trips on which acoustic data was collected during 2012. Coloured sections correspond to locations where acoustic density values of fish species were rec-orded: blue whiting (green, red and blue), herring (purple) and sprat (orange). Extracted from [1].

Acoustic data collected during 2013-2015 [2]

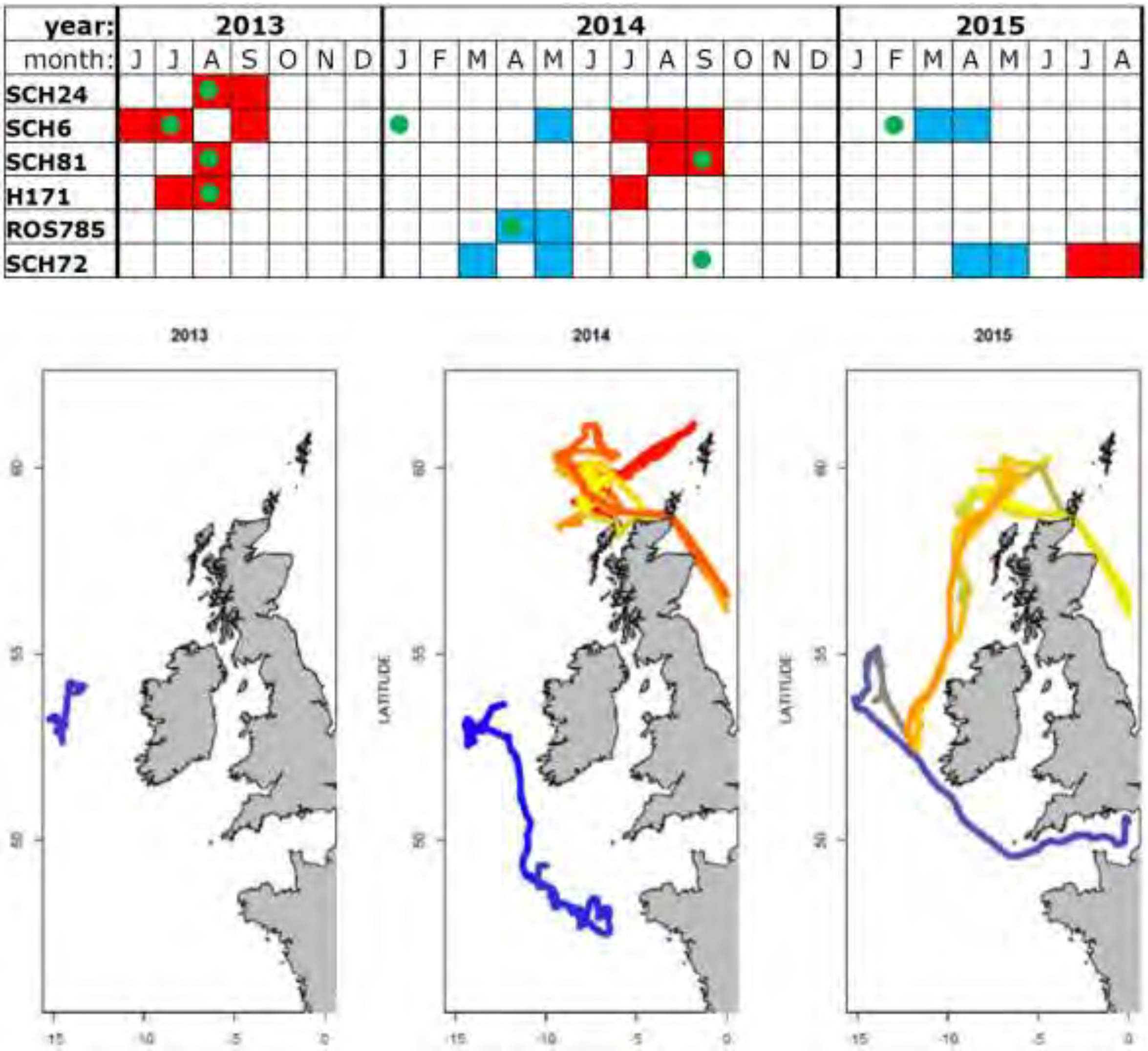


Figure 2 timing and tracks of the fishing trips during which the data was collected from 2012-2015 for blue whiting. Colouring represents the timeline of data collection (start in blue (3 March), end in red (28 May). Extracted from [2].

2.2 Data from other projects (not yet analysed)

During the course of several other projects, directed at acoustics species recognition or acoustic biomass estimation, acoustic data relevant to the blue whiting fisheries has been collected. An overview by year is presented in figure 3 and and overview by year and week in figure 4.

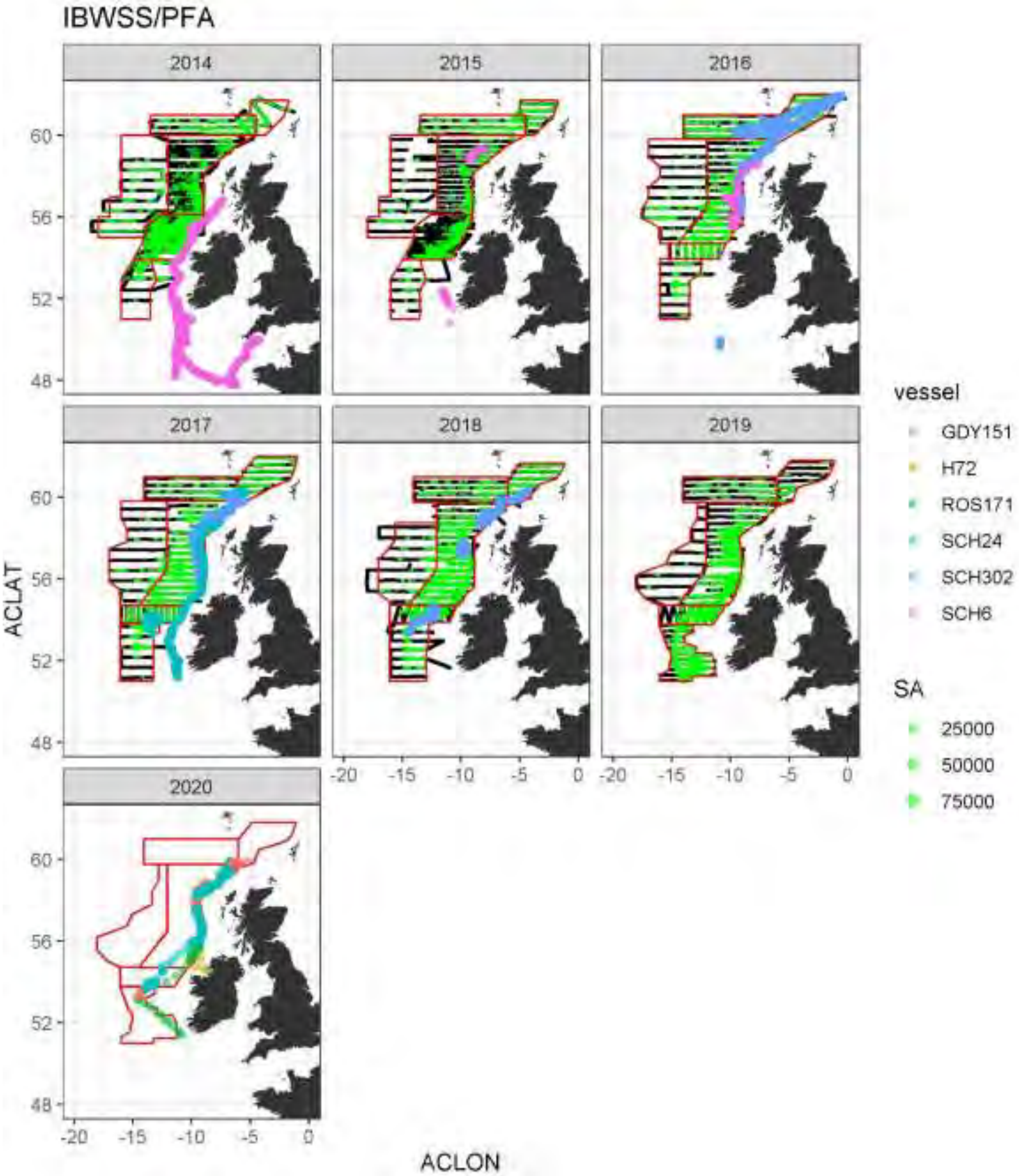


Figure 3 annual maps of acoustic data collected by PFA trawlers (associated to trips where WHB was caught) around the IBWSS surveys in the different years (March/April). Red boxes are the different strata used for the analysis of the IBWSS survey. The green circle markers are the WHB acoustic densities in 1 nmi intervals.

Figure 4 weekly maps of acoustic data collected by PFA trawlers (associated to trips where WHB was caught) around the IBWSS surveys in the different years (March/April). Red boxes are the different strata used for the analysis of the IBWSS survey. The green circle markers are the WHB acoustic densities in 1 nmi intervals.

3 Ambition and further work

In 2020, due to COVID-19 pandemics, the IBWSS survey was cancelled so that no survey index is available for 2020. Similarly, in 2010, the survey index was not used for the assessment because of disruptions in the survey. Our ambition is to explore whether data collected on board of commercial trawlers could potentially be used to derive an alternative index of abundance. The immediate ambition of this working document has been to present an overview of the data that has been collected on board of commercial trawlers since the start of the acoustic data collection projects. Currently, Wageningen Marine Research, Sustainovate and the Pelagic Freezer-trawler Association are working together to aggregate and analyse the acoustic data collected onboard freezer-trawlers in order to derive indicators blue whiting (and herring) stocks. This will be done in combination with the available self-sampling data [7].

The next steps in the project will be the analysis of the acoustic data (e.g. using automated processing) and the development of the methodology for deriving a relative abundance index over the 2012-2020 period. Of course these methods will need to deal with the biased data sampling that is implied by fishing operations. The intention is to present results of this work to WGWIDE 2021.

4 References

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[6] B. J. P. Berges et al., "Practical implementation of real-time fish classification from acoustic broadband echo sounder data," IJmuiden Wageningen Mar. Res. (Wageningen Mar. Res. Rep. C076/19), 2019.

[7] M. Pastoors, "PFA self-sampling report 2015-2018," PFA, vol. 03, 2019.

[8] M. Pastoors, "Self-sampling Manual v 2.12," PFA2, vol. 05, 2019.

Working document 08, WGWIDE 2020, 26 August - 1 September 2020

Progress report on industry gonad research in the context of the "Year of the mackerel and horse mackerel 2019-2020"

Cindy van Damme, Ewout Blom, Martin Pastoors, 30/08/2020 16:52:02

Abstract

This Working Document summarizes the status of the industry-science collaboration aimed at improving the knowledge on gonad development of mackerel and horse mackerel. The work is based on samples taken by the fishing industry (PFA) on targeted or bycatches of mackerel and/of horse mackerel. The overall aim of the Year of the Mackerel project is to gain insight in the gonad devel-opment of female and male mackerel throughout the year in order to better understand the spawning strategy. For horse mackerel, the aim is to investigate when western horse mackerel spawning occurred in 2020. To date, 1365 mackerel have been sampled and 197 horse mackerel (horse mackerel only started in 2020). Preliminary results of the analysis on mackerel are presented in the working document. Final results for mackerel are expected in October 2020 and for horse mackerel in the first half of 2021.

1 Introduction

Mackerel

The stock of Northeast Atlantic mackerel has raised a lot of attention over the last number of years. The expansion of the area of distribution of mackerel has been very conspicuous, with mackerel now being caught much more westerly and northerly compared to the past. In recent years also changes in spawning are apparent, with changes in timing and centre of gravity of spawning. Dealing with a stock with such a wide area of distribution from the west of Portugal all the way to the Norwegian Sea is providing a continuous challenge to attempt to monitor the development of this stock. Unfortunately we have also witnessed some hick-ups in the scientific assessment and advisory system in recent years that have resulted in substantial revisions of the perception of stock size. This is a highly valuable stock and it is beyond question that getting the best available understanding of stock development and stock behaviour is in the interest of everyone involved with this stock.

Currently there are five main information sources to inform the stock assessment of mackerel:

1. Commercial catches reported by each country
2. Recruitment index based on coordinated international scientific survey 'IBTS'
3. Tagging time-series – with tags recovered from X factories
4. Scientific swept-area survey in the northern feeding area
5. Egg survey in the spawning areas every 3 years.

The fishing industry has been getting involved in providing data on mackerel through different means, such as the mackerel tagging program and providing vessels to conduct the swept-area survey and the mackerel egg survey. In all cases, understanding the spatial-temporal patterns of mackerel is key to making these sources reliable indicators for stock assessment. There is a need to improve understanding of how mackerel gonads develop ane when and where mackerel spawn (or do not) because this information could affect the design of the mackerel egg survey and possibly also how spawning stock biomass is calculated from the stock in numbers within the stock assessment model.

In order to follow the gonad development, it is necessary to prepare histological sections of the gonads to follow the growth of oocytes and spermatozoa. Ideally, gonads would be fixed in formaldehyde before they are sectioned. On commercial vessels, were fish is caught for human consumption, it is not allowed to have formaldehyde on board. Thus, samples from commercial vessels will have to be frozen before being fixed in formaldehyde. During the spawning season tests have already been carried out with frozen samples to investigate the quality of the histological sections and the oocyte development. During a pilot project in 2018, it was tested if it is possible to prepare high quality histological sections from frozen mackerel gonads outside the spawning season.

The resulting photographs of these histological sections were discussed with international colleagues during the Workshop on egg staging, fecundity and atresia in horse mackerel and mackerel (WKFATHOM) in 2018. The report of the workshop is not yet available. The main conclusions of this discussion were:

1. The quality of the male and female gonad sections of the frozen fish is surprisingly good and enough to follow oocyte and spermatozoa development through time.
2. Staining of the male gonads needs to be improved at the start of the Year of the Mackerel project in order to be able to more easily see the development of the spermatozoa.
3. Working with fixed frozen mackerel gonads is possible.

Horse mackerel

Horse mackerel (Trachurus trachurus) is one of the most important pelagic species for the freezer-trawler fleet (https://www.pelagicfish.eu/species). At the moment the western horse mackerel spawning stock biomass (SSB) is low (ICES, 2019a). In 2017 SSB was estimated as the lowest in the time-series, below the limit reference point and just above in 2018 (ICES, 2019a). Currently there are four main information sources to inform the stock assessment of western horse mackerel:

1. Commercial catches reported by each country
2. Recruitment index based on coordinated international scientific survey 'IBTS'
3. Acoustic survey SSB estimate
4. Egg survey in the spawning areas every 3 years.

One of the indices used for the assessment is the annual egg production estimated from the mackerel and horse mackerel egg survey results. This survey is coordinated by the ICES Working Group for Mackerel and Horse mackerel Egg Surveys (WGMEGS). Once every three years this survey covers the spawning area of mackerel and horse mackerel during the spawning season (ICES, 2019b). To get an accurate estimate of the annual egg production of horse mackerel, the egg survey should sample the entire spawning area multiple times during the spawning season. Because horse mackerel is an indeterminate spawner the Daily Egg Production Method (DEPM; i.e. estimating batch fecundity and daily egg production) should be used for converting egg production to SSB (Damme et al. 2013). WGMEGS is currently investigating the possible collecting of batch fecundity samples for the DEPM survey (ICES, in prep.). Therefore, WGMEGS currently provides only an egg production estimate for the horse mackerel assessment and not a SSB estimate.

Western horse mackerel spawns in the northern Bay of Biscay, Celtic Sea and west of Ireland (ICES, 2019b). In the past, horse mackerel spawning occurred in May-July, with peak spawning in June. This was overlapping with mackerel (Scomber scombrus) spawning from February till July (See WGMEGS reports). In the last decade the mackerel stock has increased, and the horse mackerel stock has decreased. This has coincided with horse mackerel gradually spawning later in the year (ICES, 2014, 2017, 2019b).

At the moment there are doubts whether the current time window of the mackerel and horse mackerel survey still covers the horse mackerel spawning season. In 2013 the peak of spawning of horse mackerel occurred in July, the last month of the mackerel and horse mackerel egg survey (ICES, 2014). WGMEGS could therefore not be certain if the actual spawning peak had been sampled that year. In 2016 an extra survey was added at the end of July, to check for continued spawning of horse mackerel (ICES, 2017). This survey showed that the peak of horse mackerel spawning occurred earlier in July 2016. In 2019 the egg survey last sampling period was in beginning July (ICES, 2019b). The numbers of eggs found in June and July were very low compared to previous surveys, with a very small peak at the beginning of July (ICES, 2019b). Investigating gonad samples of horse mackerel showed that only few horse mackerel had started spawning and a high percentage were still developing oocytes and did not show signs of spawning (ICES, in prep.). This was contrary to 2016 and 2013 surveys when horse mackerel gonads did show signs of spawning. Based on this WGMEGS concluded that it was highly likely that the egg survey of 2019 missed the peak of western horse mackerel spawning and that the egg production estimate was not a reliable index as before (ICES, in prep.). The question is: has the western horse mackerel spawning shifted to later in the year and when is the actual horse mackerel spawning occurring?

2 Research questions

Mackerel

The overall aim of the Year of the Mackerel project is to gain insight in the gonad development of female and male mackerel throughout the year in order to better understand the spawning strategy. On a monthly basis male and female mackerel will be collected by the pelagic industry throughout the distribution area of mackerel. Histological sections will be prepared of the gonads. Each gonad will be analysed to identify which development stages of oocytes and spermatozoa are present in the gonad. This will allow to follow the gonadal development over time and determine the timing when mackerel is ready for spawning.

Horse mackerel

For annual egg production to be an accurate index of SSB, it is necessary that the entire spawning area is sampled multiple times for eggs during the spawning season. As western horse mackerel spawning has gradually shifted to later in the year (ICES, 2019b) and the sampling periods have not been extended, it is unlikely that the results of the mackerel and horse mackerel egg surveys provided an accurate estimate of western horse mackerel in 2019 (ICES, in prep.). In this project we will investigate when western horse mackerel spawning occurred in 2020. This information can be used to inform WGMEGS for the planning of the 2022 mackerel and horse mackerel egg survey and try to improve horse mackerel sampling.

By collecting western horse mackerel gonad samples from May till November it is possible to follow the development of oocytes in the ovaries and sperm cells in the testis and to check for spawning activity. Hydrated oocytes, eggs and post-ovulatory follicles (POFs) in an ovary are signs of recent spawning. Motile spermatozoa are sings of male spawning activity. Such sampling would provide evidence of the actual spawning period and of a possible shift of spawning to later in the year.

3 Approach

Fish were collected on board the vessels, aim was to collect 25 fish, both females and males during each fishing trip. During an egg survey gonad samples are directly fixed in 3.6% buffered formaldehyde, but on fishing vessels formaldehyde is not allowed. It was decided to use frozen samples, which are shock-frozen on board and will be fixed in the laboratory before being defrosted. In November 2018 a test was run with 50 gonads to test if this method would work. Although we saw deterioration of the samples compared to freshly fixed gonads the samples were of good enough quality to do the required analyses on to be able to investigated development within the gonads.

The first sampling started in February 2019 and continued until February 2020. Mackerel were collected from the fishing hauls. Immediately after catch the gonads and guts were taken from the fish. The gonad was put in a small plastic bag, the fish in another plastic bag. The gonad was than added to the bag with the fish. The large bag containing fish and gonad was labelled and shock frozen as soon as possible. The shock freezing is important in this aspect as that produces less damage to the tissue inside the gonads compared to regular freezing.

The frozen fish and gonads arrived in the laboratory in Ijmuiden (Fig 3.1). Fish and gonad was measured in the lab and maturity stage determined. Without defrosting the gonad was put in 3.6% buffered formaldehyde, to defrost and fix at the same time (Fig 3.1). The fish was than left to defrost and the next day otoliths were collected for age estimation. After two weeks in formaldehyde the gonads were properly fixed and could be cut for preparation of histological slides.

From the fixed gonad a slice of about 0.5 cm is cut (Fig 3.1). For the males it is important that this part is taken from the middle of the testis to ensure the spermatoduct is part of the 0.5 cm section. For the females it has been tested and oocyte stages are homogeneous distributed throughout the gonad, thus the exact position of the cutting is less important. However to ensure enough material a section from the middle part of the ovary was taken as well, unless the ovary was damaged. In case of damage a section of the non-damaged part was taken.

The 0.5 cm section was put in a fine mesh cassette (Fig 3.2). The cassettes were put in ethanol for dehydration (Fig 3.2). There are multiple steps of dehydrating the samples in different ethanol solutions. After the dehydration the samples are infiltrated with historesin (Fig 3.2). Again in multiple steps increasing the historesin concentration. After infiltration

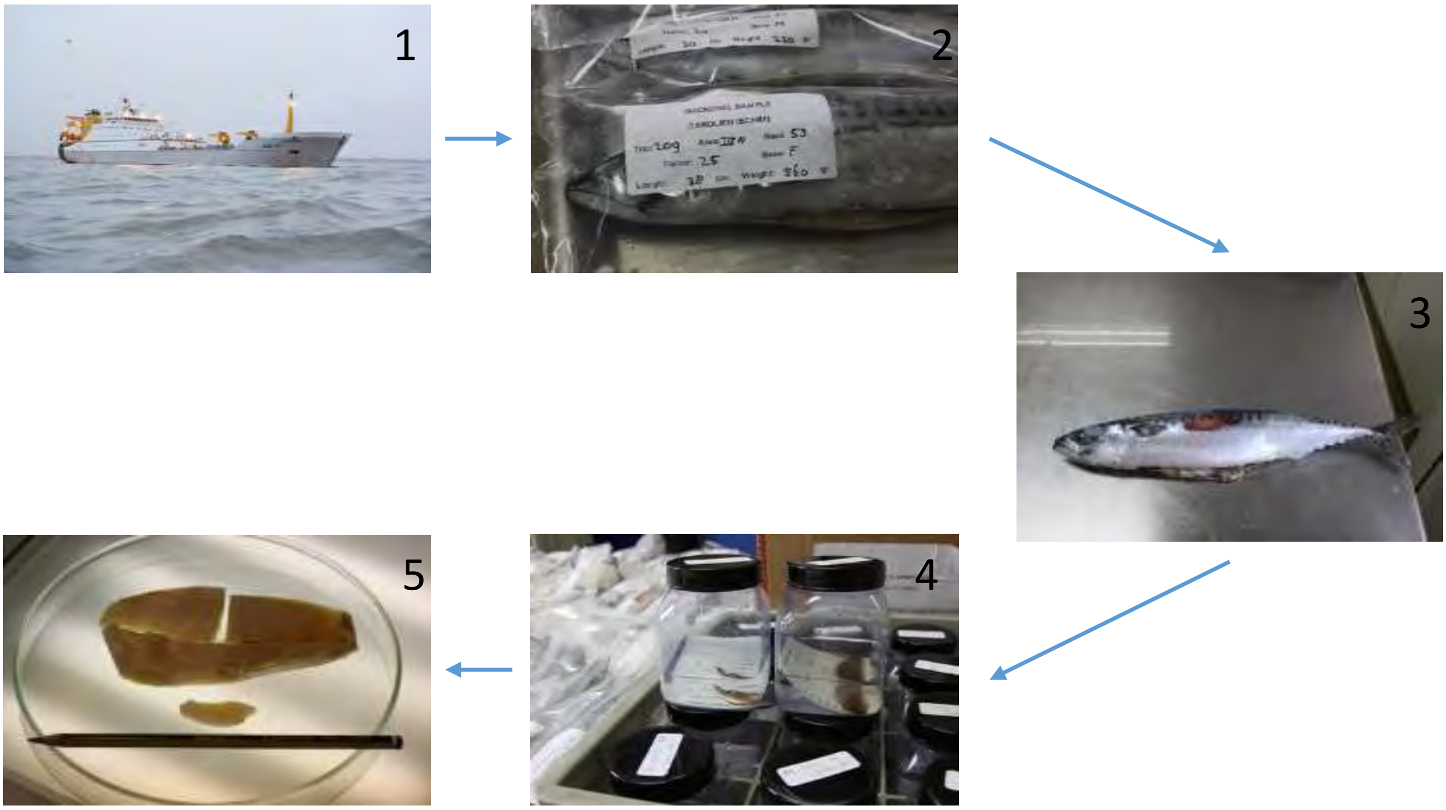

Figure 3.1. Fish was collected on board (1), gonads were dissected and frozen separately from the fish, and kept in the same large plastic bag with the fish (2). In the laboratory the frozen fish was measured and gonad weight taken (3) and the still frozen gonad was put in 3.6% buffered formaldehyde (4). After two weeks in formaldehyde the gonads are ready to be cut for the preparation of histological slides (5).

the samples are put in moulds and polymerised with clean historesin (Fig 3.2). The samples need to be cooled for a good polymerisation in the moulds. Afterwards the moulds are put in the fridge. The next day the samples are blocked up (Fig 3.2) and taken from the moulds. The blocks are kept in a box with high humidity to ensure the thin sections can be taken later on. This whole process takes about two weeks.

After some days in the humidity the samples are ready to be sectioned. Sections of 4 µm are cut and stained with haematoxylin and eosin. After mounting and covering the sections are ready for analyses (Fig 3.3).

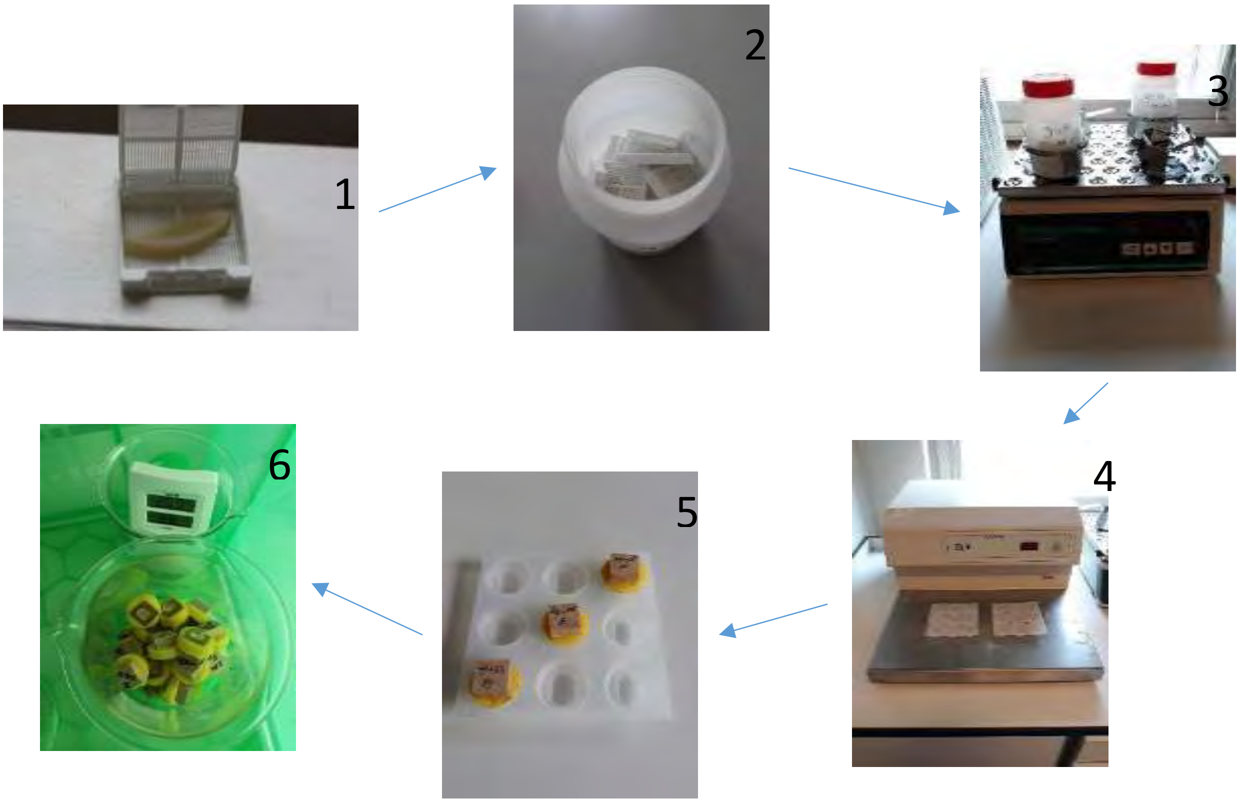

Figure 3.2. Preparation of the sample for sectioning. Gonad section of 0.5 cm is put in the cassette (1) and dehydrated in multiple ethanol steps (2). After dehydration samples are infiltrated with historesin (3) in multiple steps. Afterwards the samples are put in the moulds for polymerisation on a cooling plate (4). The samples are blocked up and marked (5) and kept in humid conditions (5) for later sectioning.

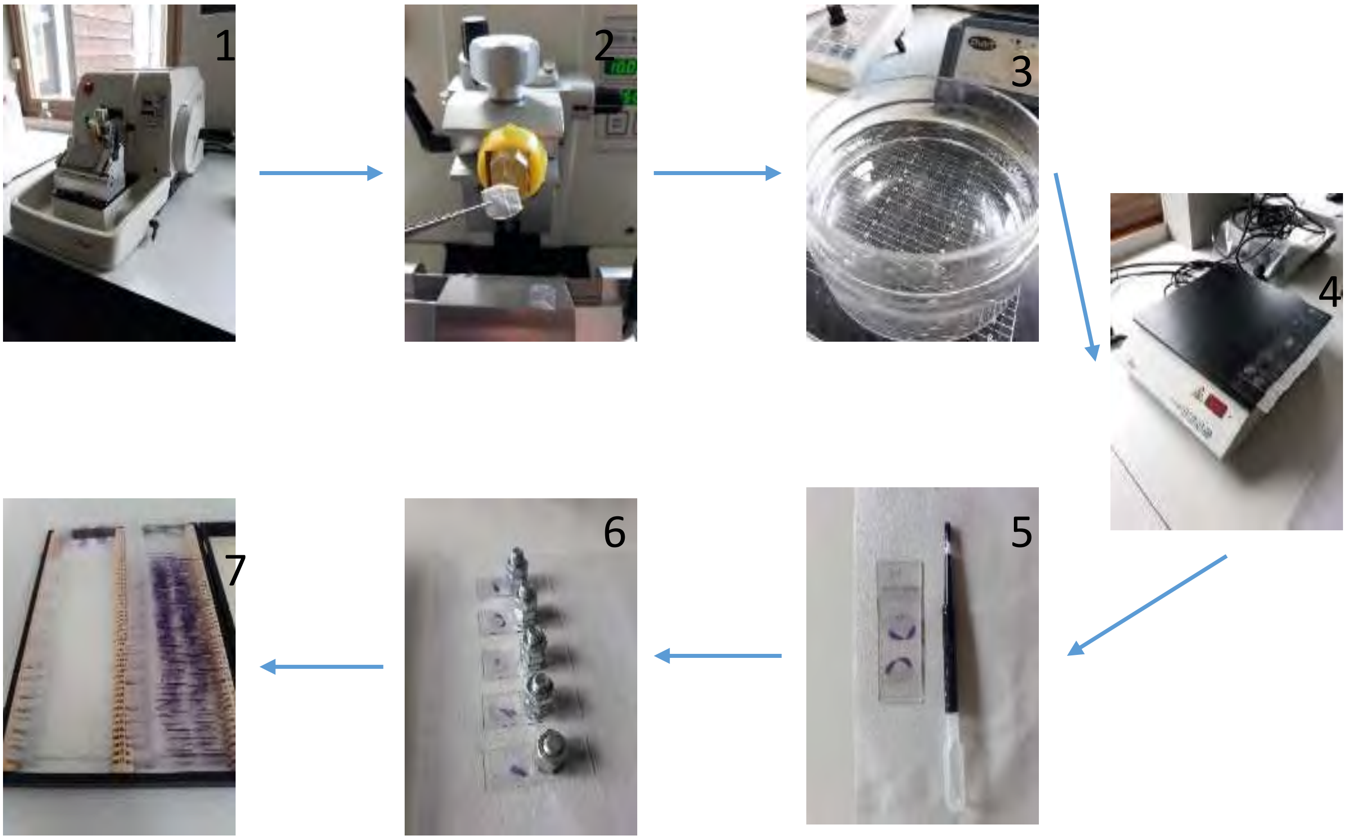

Figure 3.3. Preparation of the histological sections. On the microtome sections of 4 µm are cut (1 and 2). These are put in a water bath containing a few drops of ammonia (3). Samples are taking up on a glass slide and dried on a hot plate (4). The section is stained (5) and covered with a cover glass (6) and ready for analyses (7).

The female histological slides are scanned and images are examined in Hamamatsu NDP-viewer (Fig 3.4). Female ovaries sections are first screened for presence/absence of oocyte development stages. Afterwards two images at 5X magnification are selected. These images are analysed using a Weibel grid to estimate the area proportion of each of the oocyte development stages. On each image also the number of oocytes in each development stage is counted for an estimation of the oocytes in the gonad. The last step is the measurement of the oocyte diameter. In each 5X magnification image the 5 largest oocytes in each development stage are measured.

The male testis histological slides were only screened for presence/absence of the sperm cell development stages in the testis and in the spermatoduct.

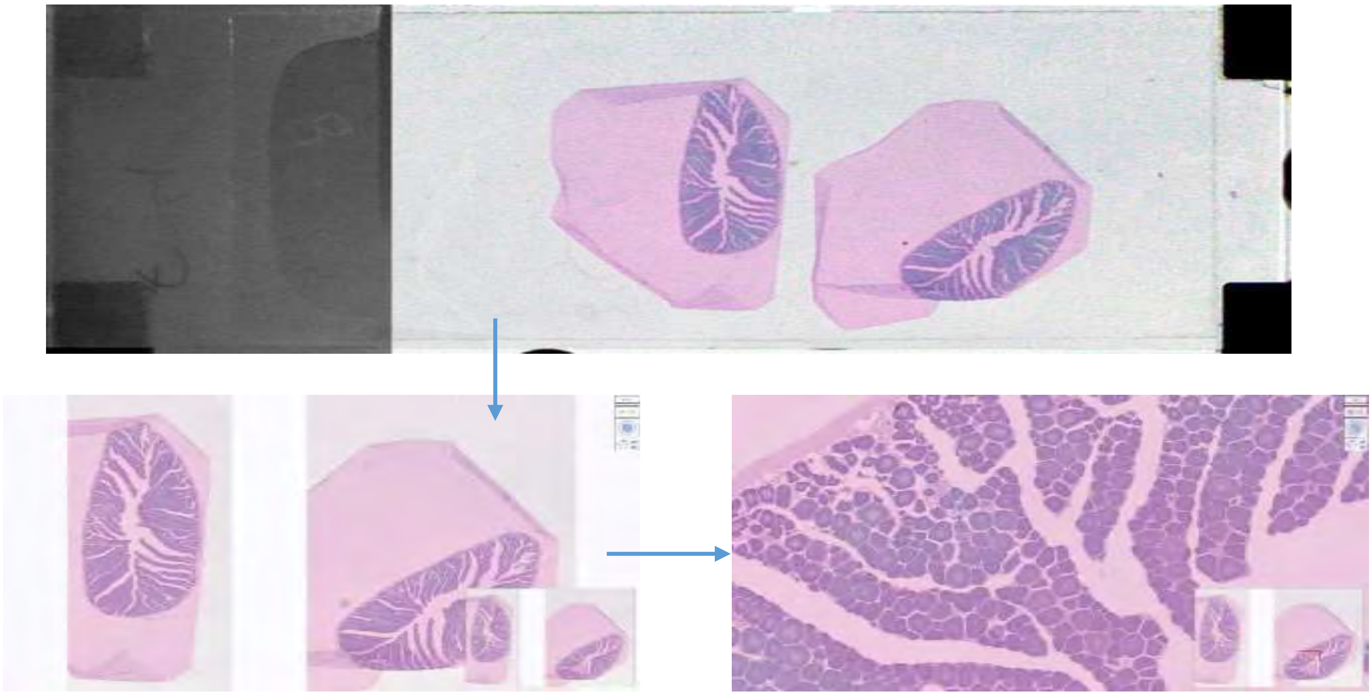

Figure 3.4. Histological section (top) zoomed in at 0.5X and 5X in NDP-viewer.

4 Samples collected

Overview of sampled hauls

year	month	nvessels	ntrips	nhauls	mac	hom
2019	2	3	3	30	51	0
2019	3	4	6	43	65	0
2019	4	4	5	24	40	0
2019	5	2	2	42	107	0
2019	6	1	1	8	28	0
2019	7	4	4	57	93	0
2019	8	4	7	93	131	0
2019	9	5	8	61	88	25
2019	10	5	6	49	73	0
2019	11	3	3	25	39	0
2019	12	4	4	39	66	0
2019	(all)		49	471	781	25
2020	1	5	7	52	132	0
2020	2	6	8	45	95	0
2020	3	6	8	86	169	0
2020	4	5	7	90	160	0
2020	5	3	5	40	28	21
2020	6	4	6	46	0	83
2020	7	2	2	21	0	66
2020	8	1	1	2	0	2
2020	(all)		44	382	584	172
(all)	(all)		93	853	1365	197

Table: Number of individuals

Haul positions

An overview of all self-sampled hauls in fisheries where mackerel or horse mackerel samples were taken.

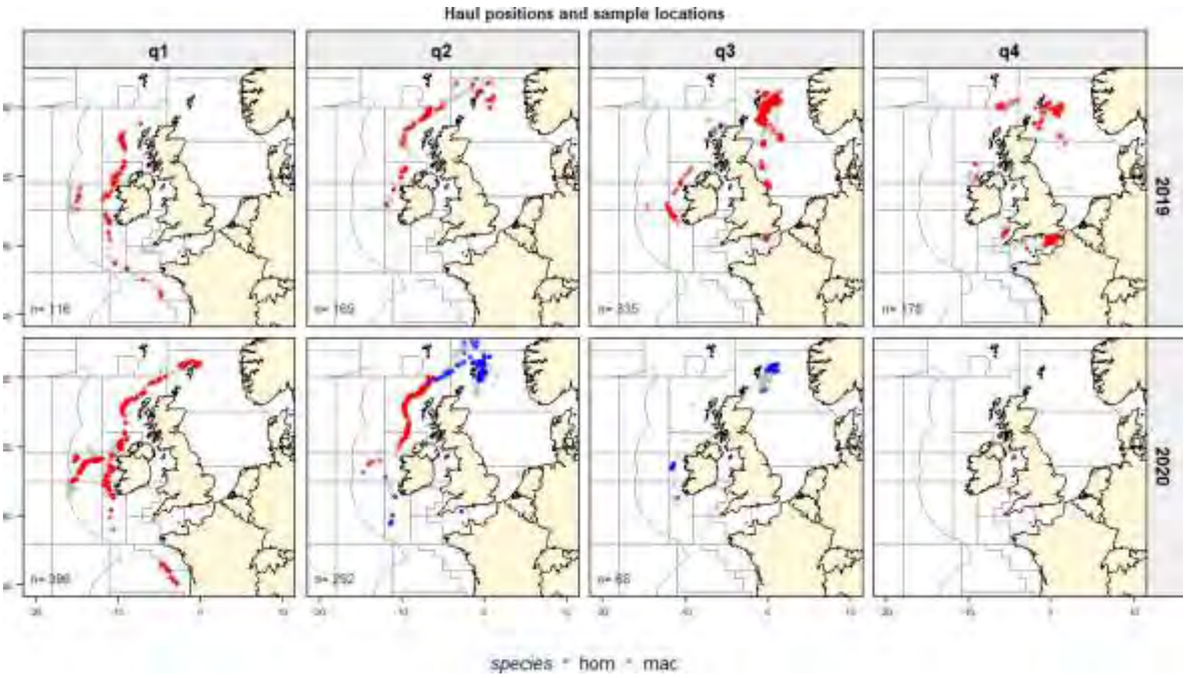

Figure 3.1: Haul positions in PFA self-sampled "Year of the Mackerel" (red). N indicates the number of sampled mackerel.

Length distributions by quarter

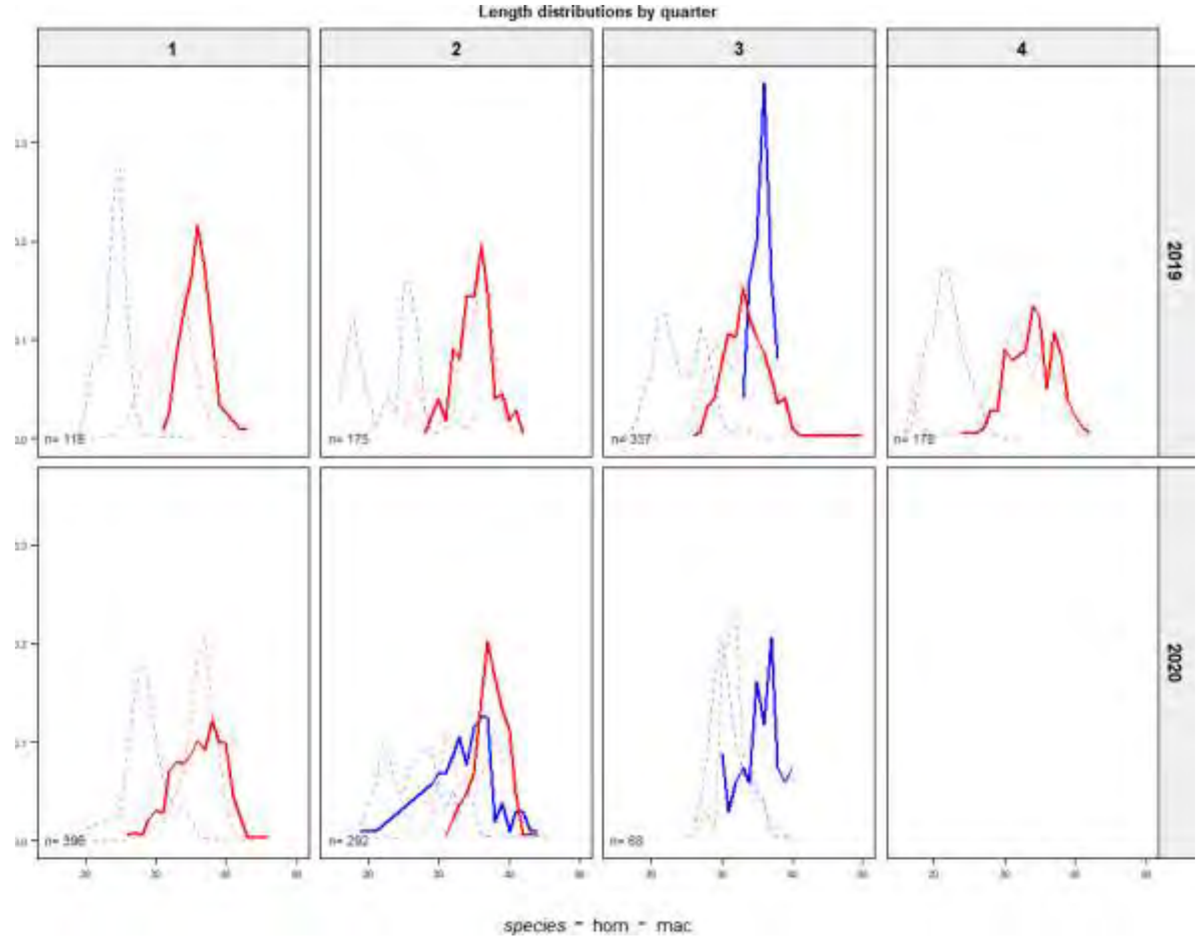

Figure 3.2: Comparing length compositions.

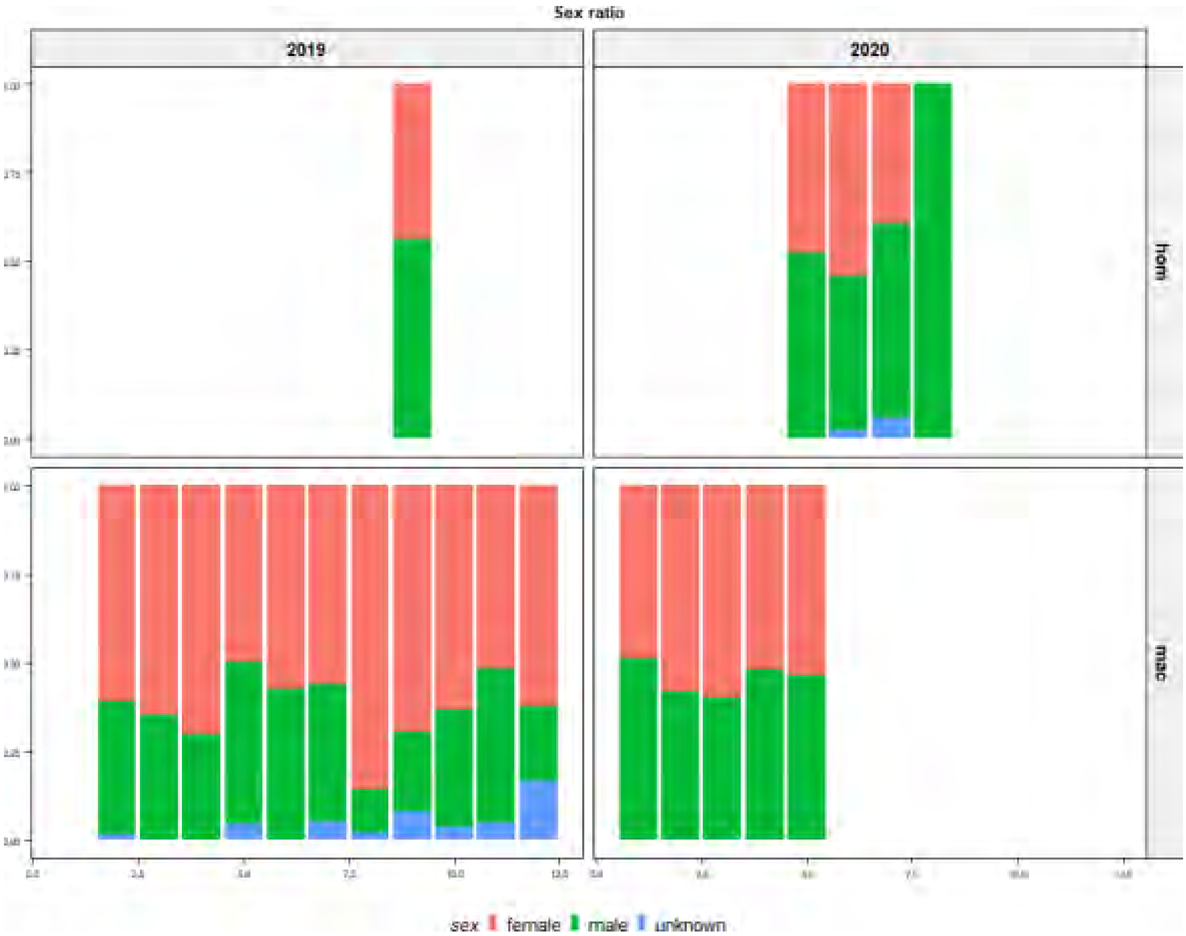

Figure 3.3: Sex ratio.

5 Results of analyses

[Ongoing]

Length of female mackerel analysed over the year did not vary much, although the mackerel in January to April are slightly larger compared to the other months (Fig 5.1). The variation in weight over the year is larger, with high weights in January to April, but also in September and October after the summer feeding period (Fig 5.1). Ovary weights were significantly higher in January to April compared to the other months (Fig 5.1). Highest ovary weights were found in February. The oldest fish were caught in the first four months of the year, which coincided with the slightly larger fish caught in this period (Fig. 5.1).

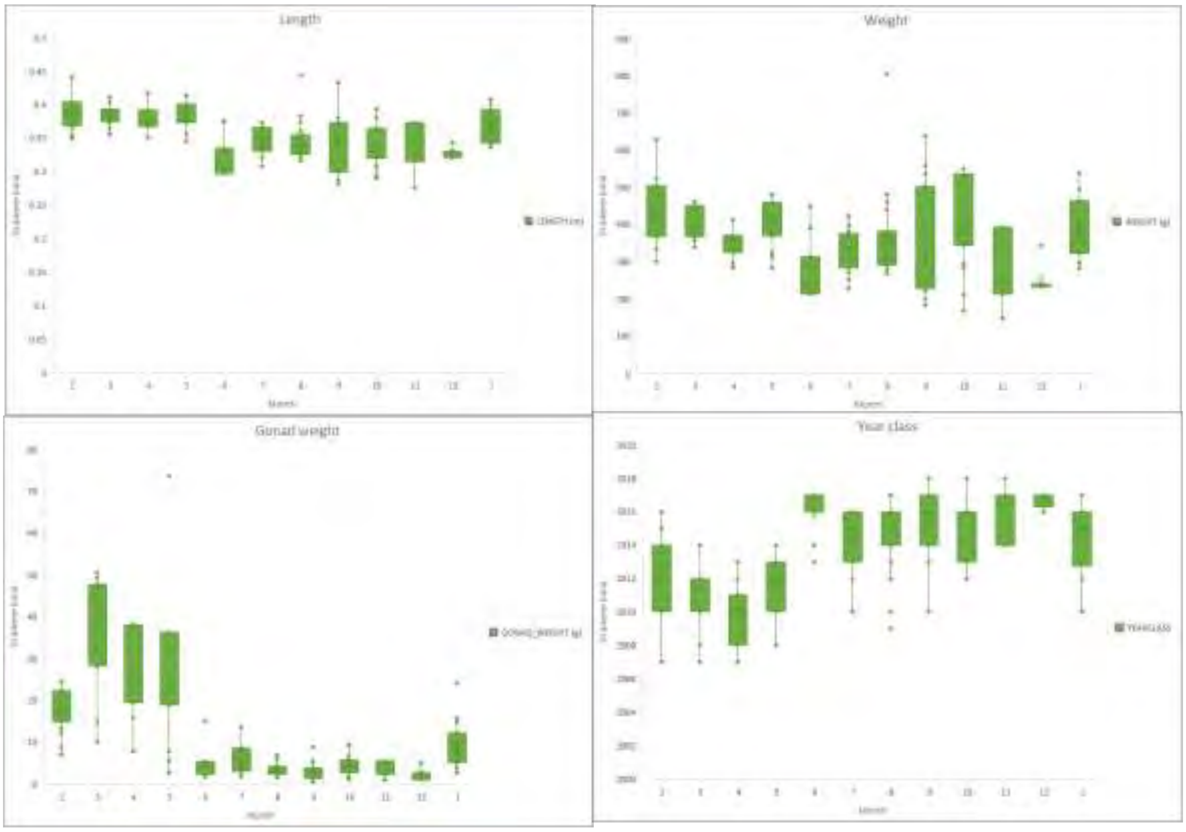

Figure 5.1. Length, weight, ovary weight and year class of the females analysed.

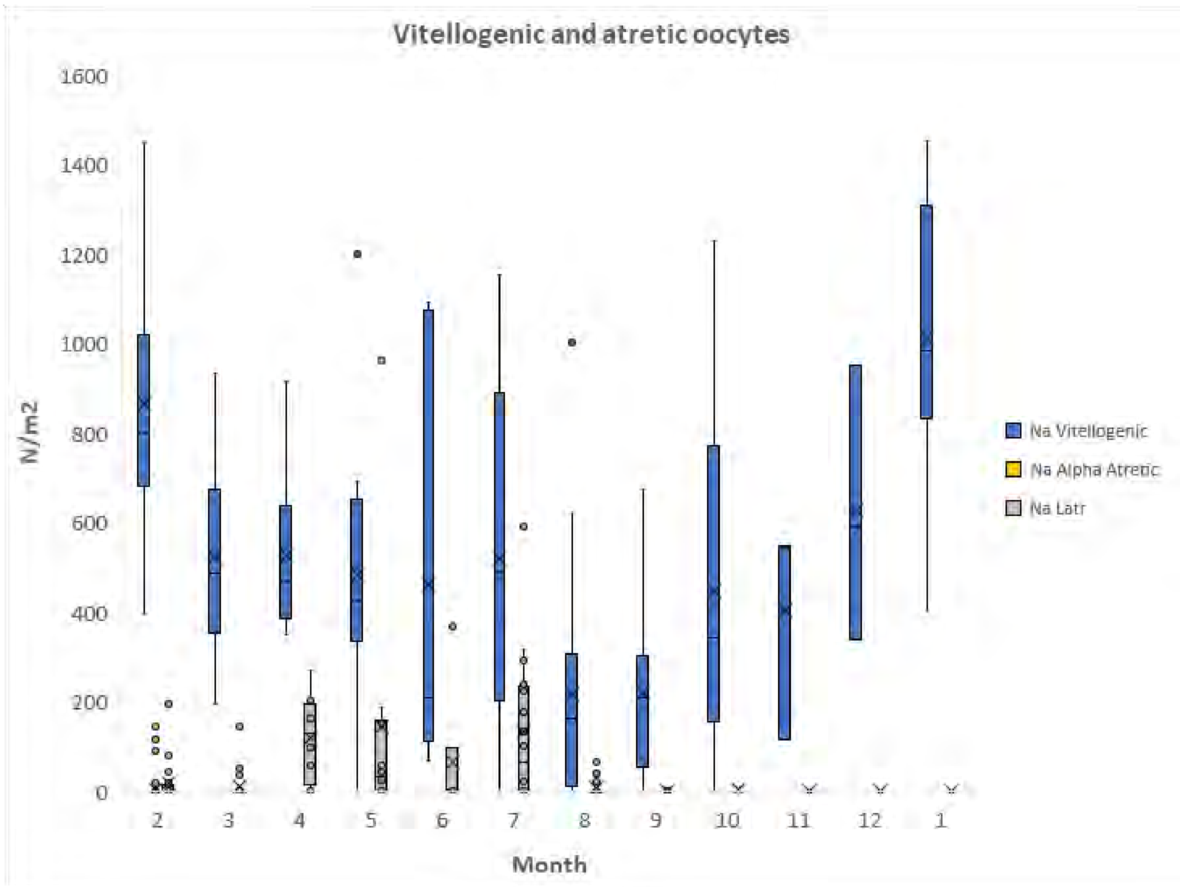

Figure 5.2. Number of vitellogenic and atretic oocytes in the ovaries per cm^2 over the year.

Vitellogenic oocytes were found in all months of the year, these are oocytes that are being developed. Higher numbers of vitellogenic oocytes were found in January-February, prior to spawning (Fig 5.2). Lower numbers of vitellogenic oocytes were found in July and August. This indicates that mackerel are always developing oocytes over the year and there is no resting period in the ovary between the actual spawning periods. Atretic oocytes are only found in February to July (Fig 5.2). This seems to suggest that from August to January the females are preparing oocytes for the next spawning season.

From August to January early vitellogenic oocytes dominate, while from February to July late vitellogenic oocytes are present (Fig 5.3). This supports the fact that the spawning season runs from February to July and females are only preparing oocytes for the next spawning season from August to January.

Few eggs were actually found in the samples (Fig 5.4), but post-ovulatory follicles (POFs) were present in higher numbers. POFs are the follicle that is left after the egg is spawned. POFs were also seen late in the year, indicating the long period it takes for POFs to be resorbed.

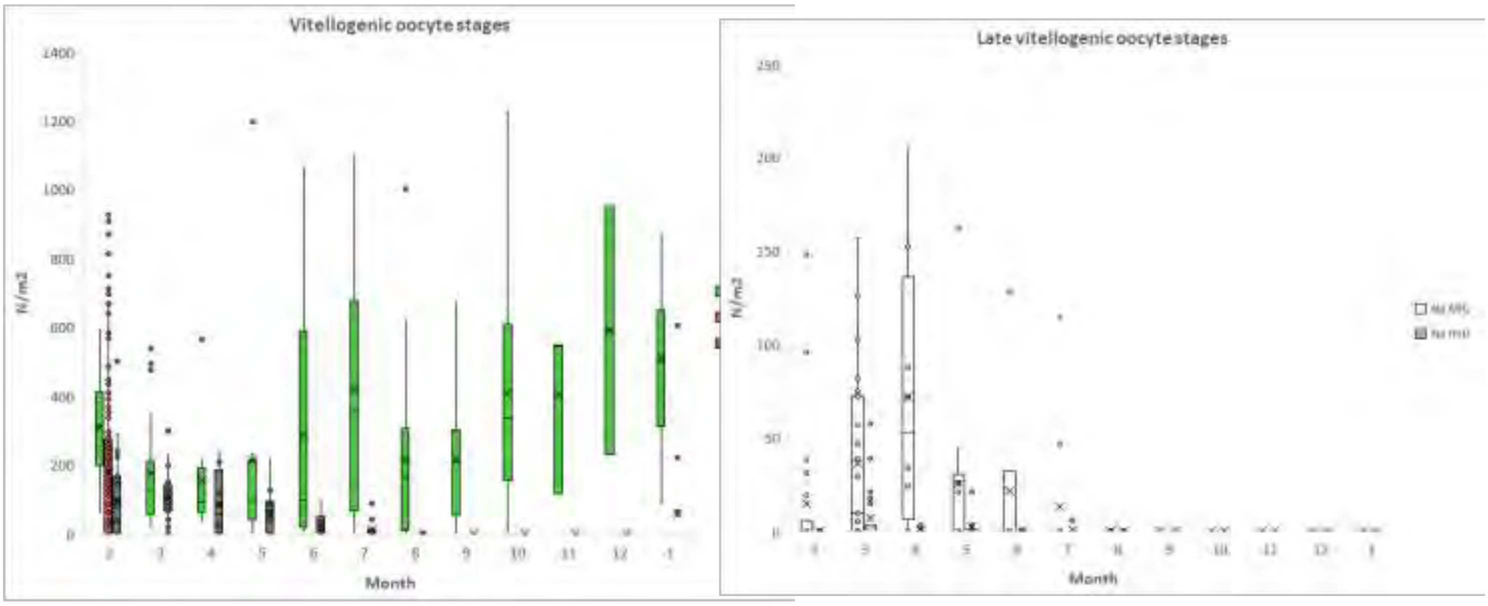

Figure 5.3. Early and late vitellogenic oocytes in the ovaries per cm² over the year.

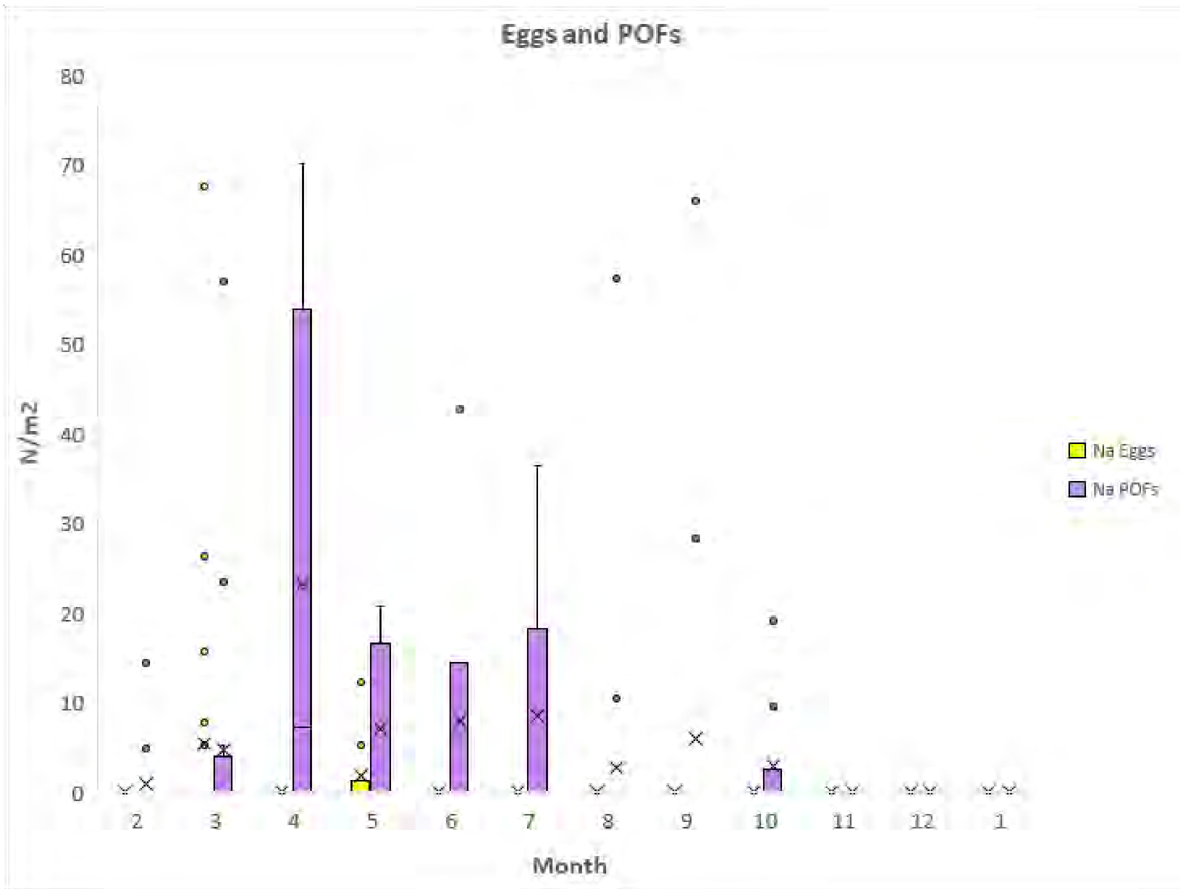

Figure 5.4. Number of eggs and POFs in the ovaries per cm² over the year.

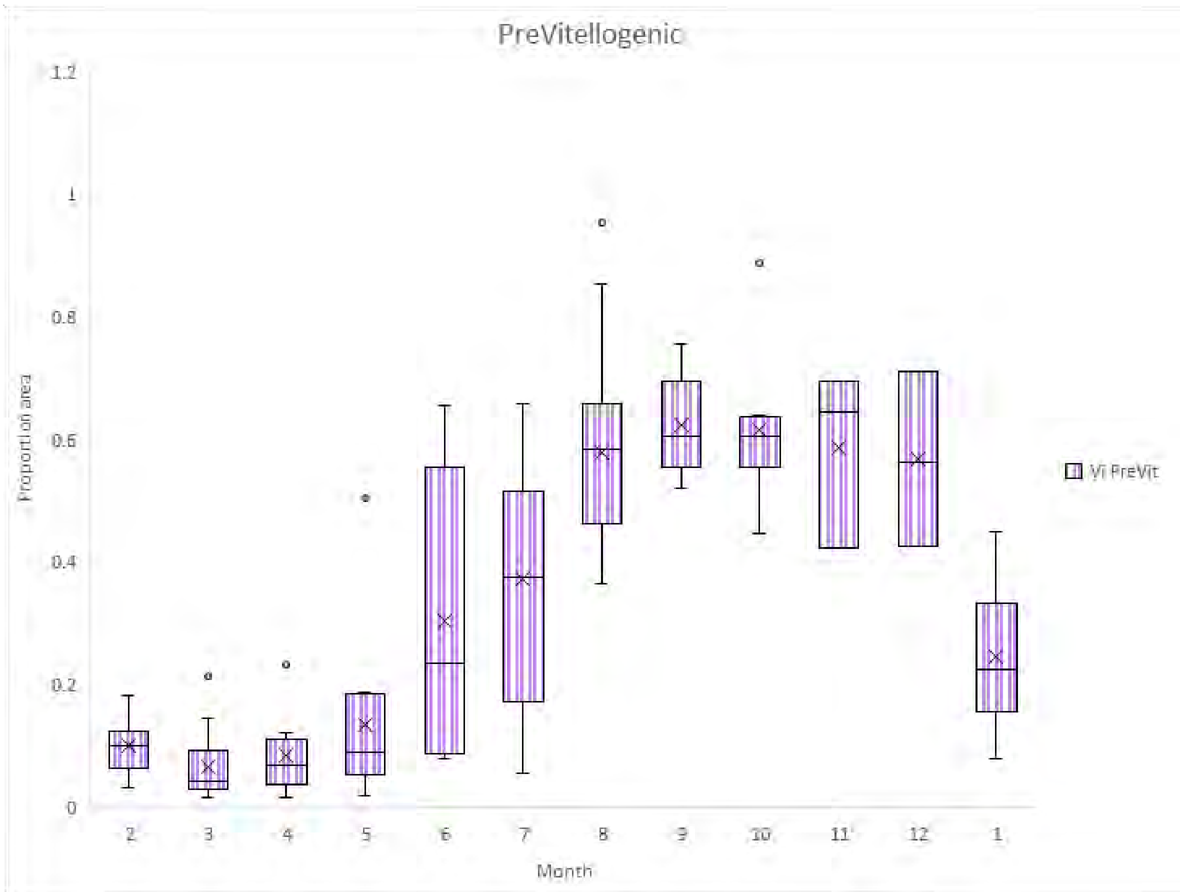

Figure 5.5. Proportion area of previtellogenic oocytes in the ovaries over the year.

Proportion area of previtellogenic oocytes (oocytes that are not being developed) was low January to May, increased June and July and was highest from August to December. This also shows that the spawning season runs from February till May, and June-July the spawning season is coming to an end (Fig 5.5).

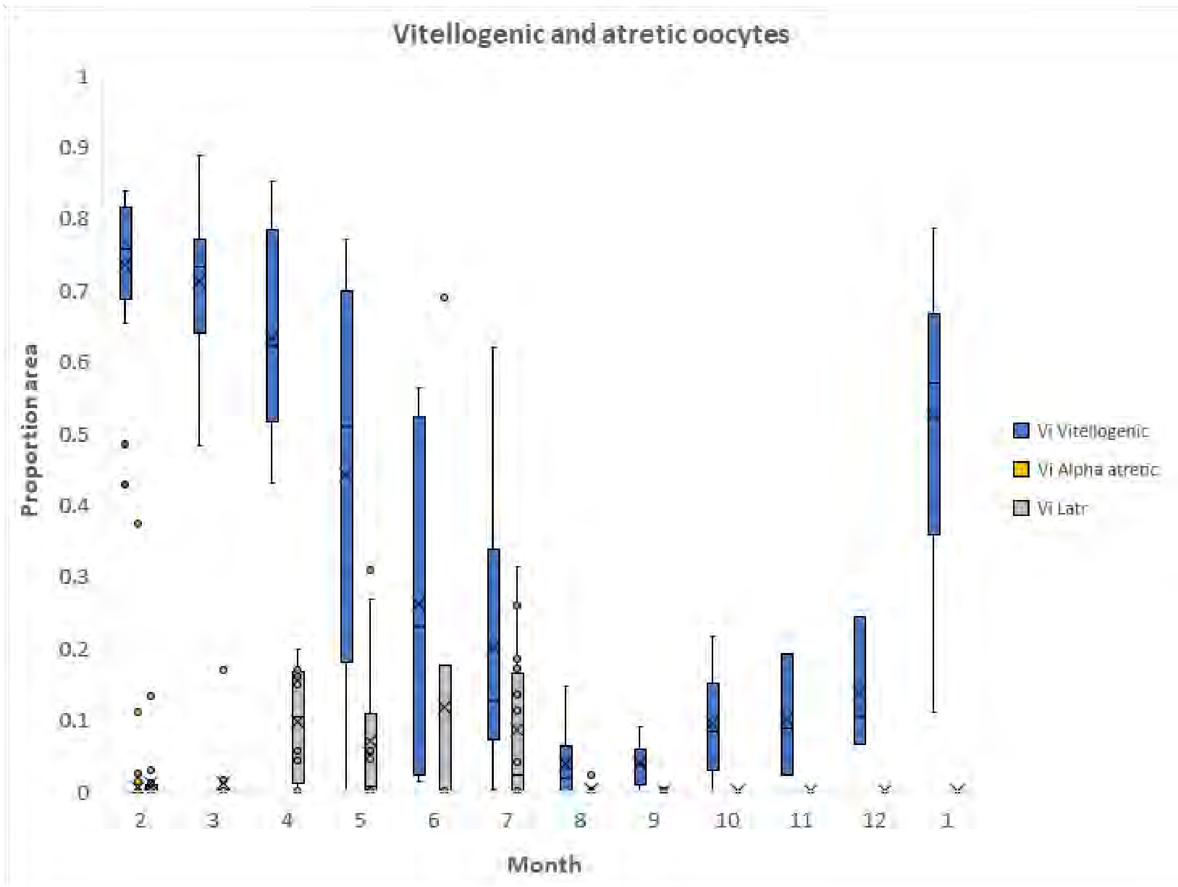

Figure 5.6. Proportion area of vitellogenic and atretic oocytes in the ovaries over the year.

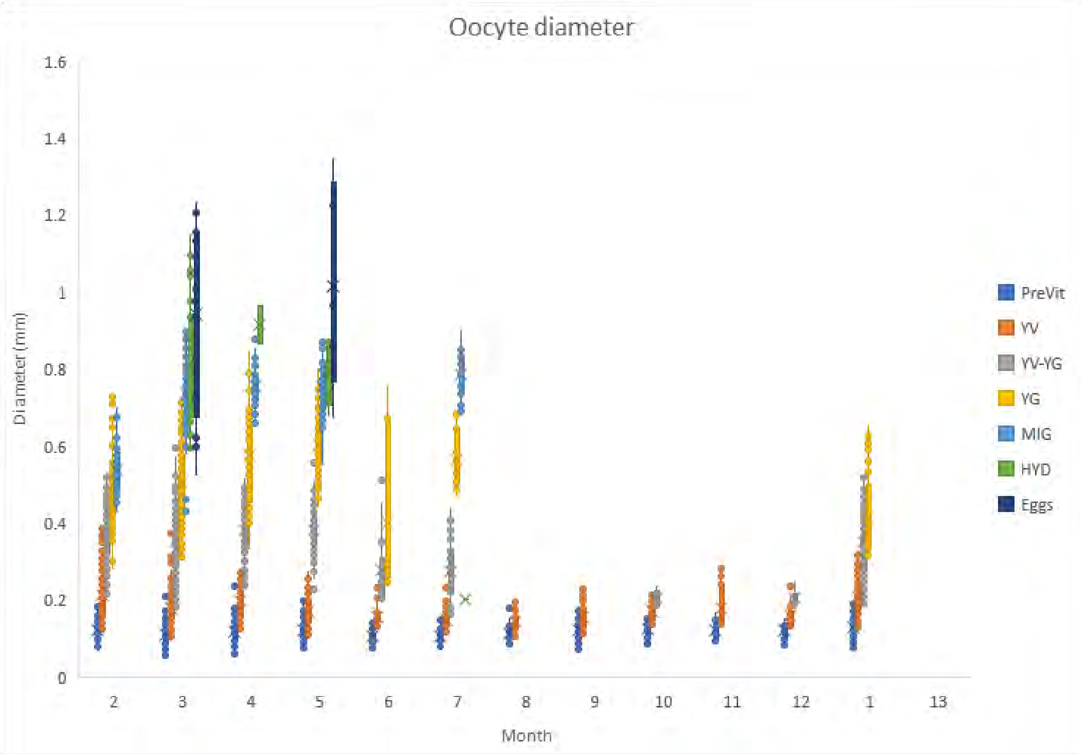

Figure 5.7. Diameters of vitellogenic oocytes and eggs in different development stage the ovaries over the year.

Oocyte diameters are small August to December, when oocytes are being prepared for the next spawning season (Fig 5.7). There is an increase in oocyte diameter in January just before spawning.

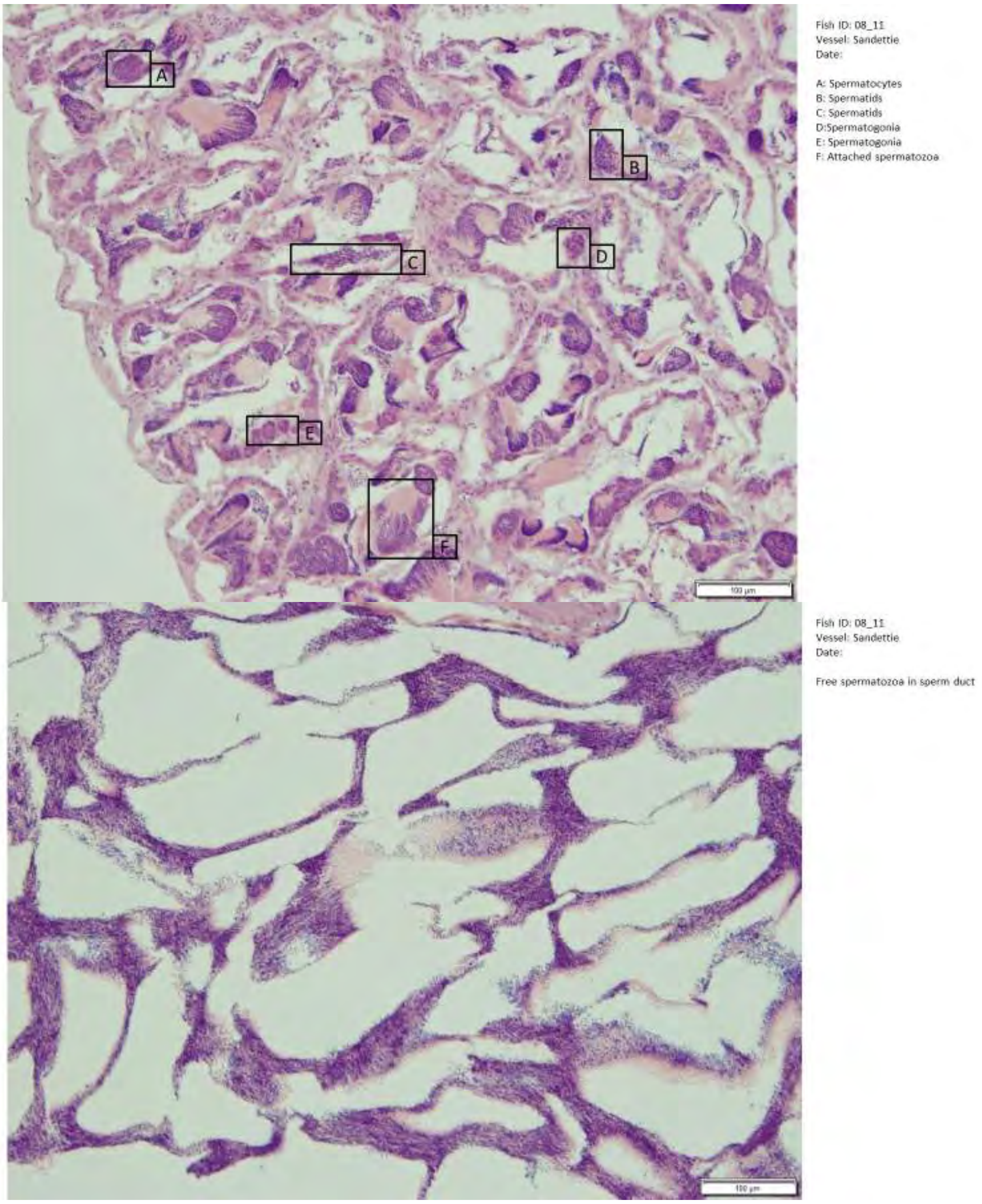

Figure 5.8. Evidence of spawning males. Top image shows various development stages of sperm cells. The bottom image shows the free spermatozoa in the spermatoduct, true sign of spawning.

Males were examined for the state of the testis, developing or actually spawning. Free spermatozoa can be present in the testis, but that is not a sign of actual spawning, because it was found that the spermatoduct was still empty. As soon as free spermatozoa were found in the spermatoduct these males were also running when the testis was pressed. Probably the movement from the testis to the spermatoduct takes a short time period and males keep developing sperm cells over the spawning season to be ready when they meet a spawning female. There are signs that males show indeterminancy like females, i.e. keep recruting new sperm cells during the spawning season. But this needs to be investigated further.

An interesting find is that some males showed evidence of encapsulated eggs. This has been found in other fish species that were found in highly polluted waters, where the pollution stimulates the development of eggs in males. This will be investigated further.

6 references

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[Needs further updating]

NEA mackerel

Alternative assessment

Working Document #9 for WGWIDE 2020.

Höskuldur Björnsson

August 30st 2019

1 Introduction

The Mackerel assessment this year is as before based on 5 data sets.

1. Catch in numbers
2. Triannual Egg survey 1992-2019
3. Recruitment index from bottom trawl surveys in the Northsea and west of Ireland and Scotland.
4. Pelagic trawl survey in the North Atlantic.
5. Tagging data

4 different Muppet assessments are shown, all based on estimating a multiplier on the catches before 1998 and using catch in numbers since 1980 for tuning. None of the Muppet assessments uses the steel tag data. All (except VPA) use a seperable model with 2 selection periods. Where tag data are used tagloss is estimated. The difference between the assessments is.

1. All RFID tags where $RecaptureY > ReleaseY$.
2. VPA based on assessment 1.

3. No Tagging data.

4. Same tagging data as in the SAM assessment.

As before, results of the assessment are relatively strange and do not seem to follow main trends in the data. The SAM model utilizes process error in some strange way that is most likely a reflection of inconsistences in the data. In the Muppet model varying M lead to the conclusion that low or even negative M gives the best fit, probably an indication that the data are not perfect.

New egg survey was included last year but not this year. With increasing number of years that the pelagic survey has been conducted increases the weight of that survey in the Muppet assessment and the same can probably be said about the SAM assessment.

The recruitment index has been at very high level 2016-2019 and high since 2003 compared to the time before that (figure 2). As data on younger agegroups are scarce this index can have effect on adviced TAC if it is considered reliable.

The tuning data and 2 assessments, VPA and SAM are summarized in figure 1. The VPA assessment is used, as sufficiently far back in time the results are independent of the tuning data. B3+ is used instead of SSB for comparison with SAM as the Muppet model does not use exactly the same settings regarding proportion of F and M before spawning.

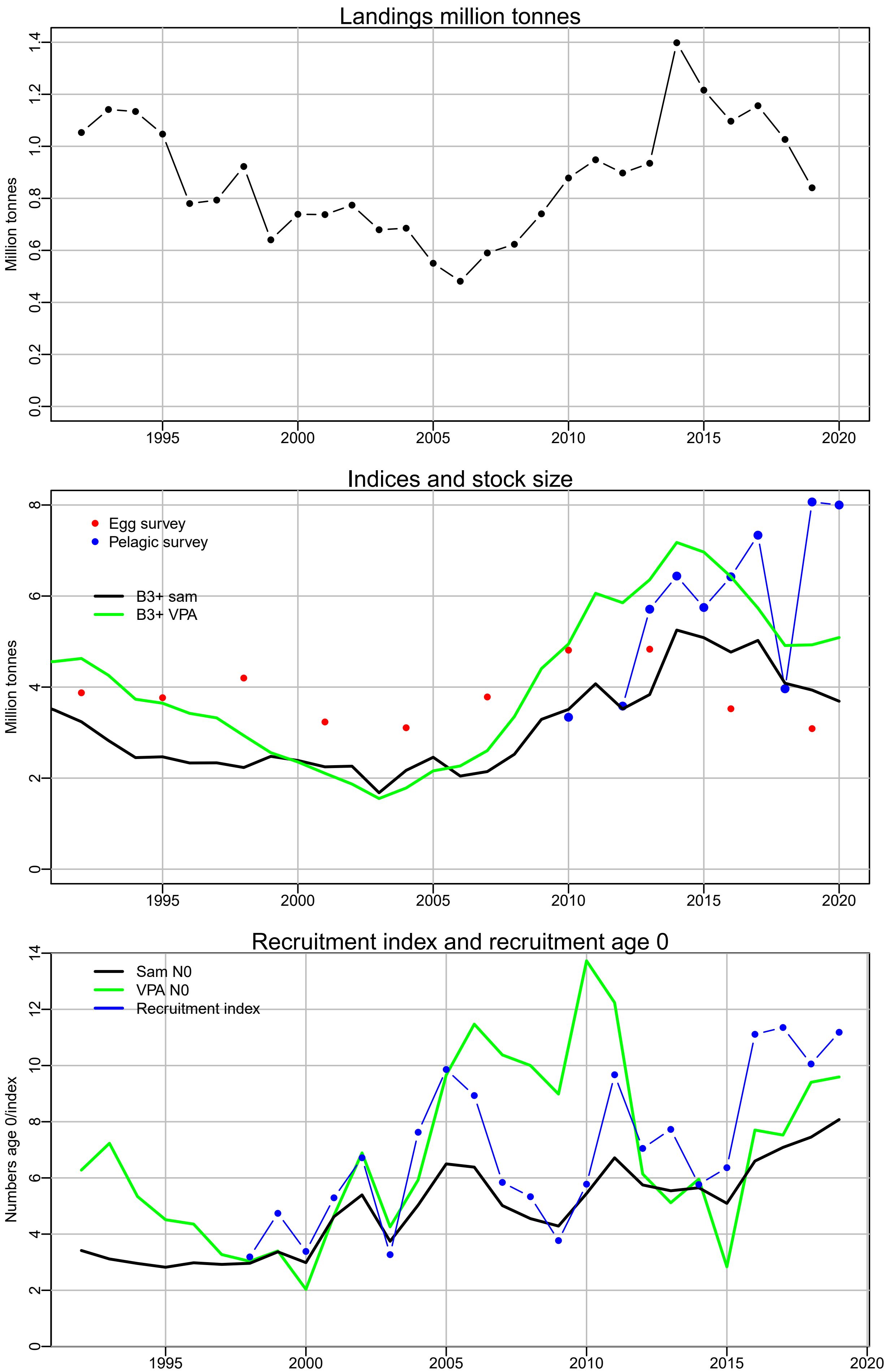


Figure 1: Summary of input data, SAM assessment and VPA assessment

The recruitment pattern from SAM is surpringly different from the VPA model. The development of the stock since 2014 is also somewhat in contrast with the pelagic survey thats indicate that the stock might be at very high level today (the egg survey 2019 is low). The variability in the pelagic survey in recent years will likely reduce the weight of this survey in the assessment.

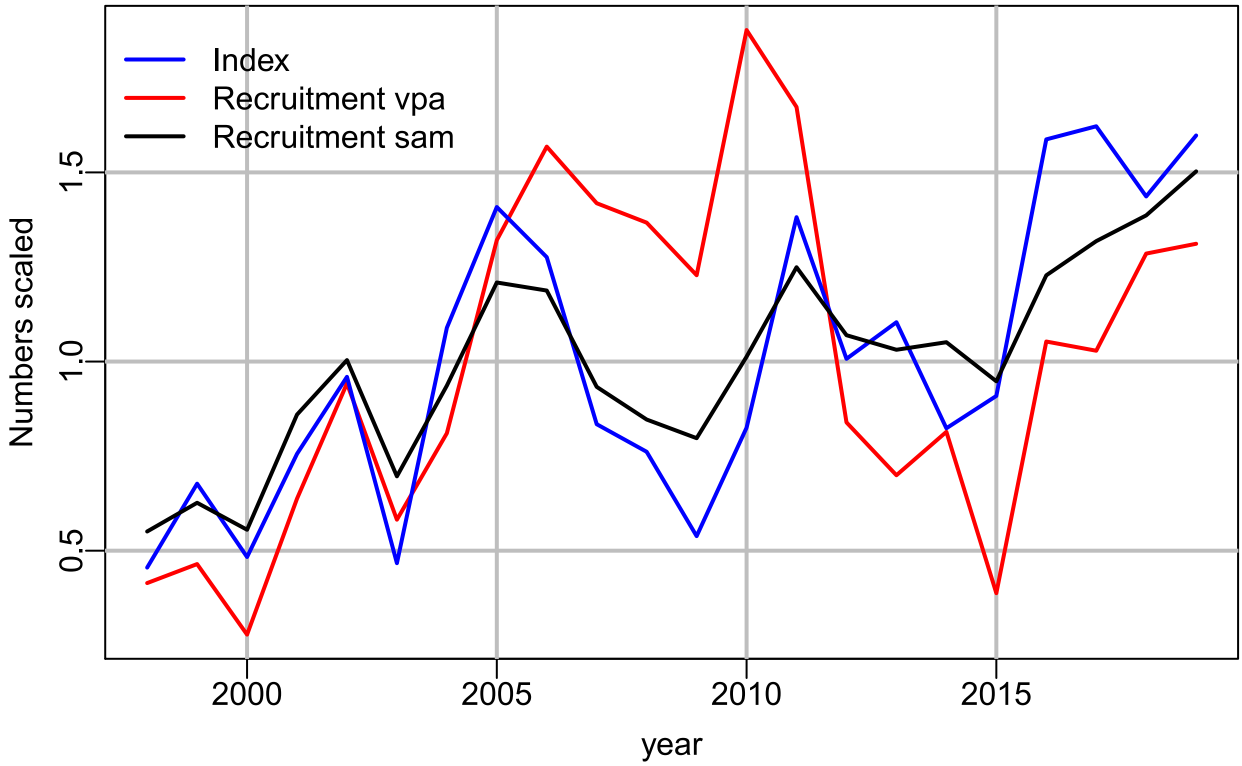


Figure 2: Recruitment index and recruitment (age 0) since 1998 , all values scaled to average of 1

Sam follows the recruitment much closer than muppet (figure 2). Estimated CV of this index in SAM is ≈ 0.2 but ≈ 0.4 in Muppet. The estimated CV in of the recruitment index in SAM is gradually increasing every new assessment year.

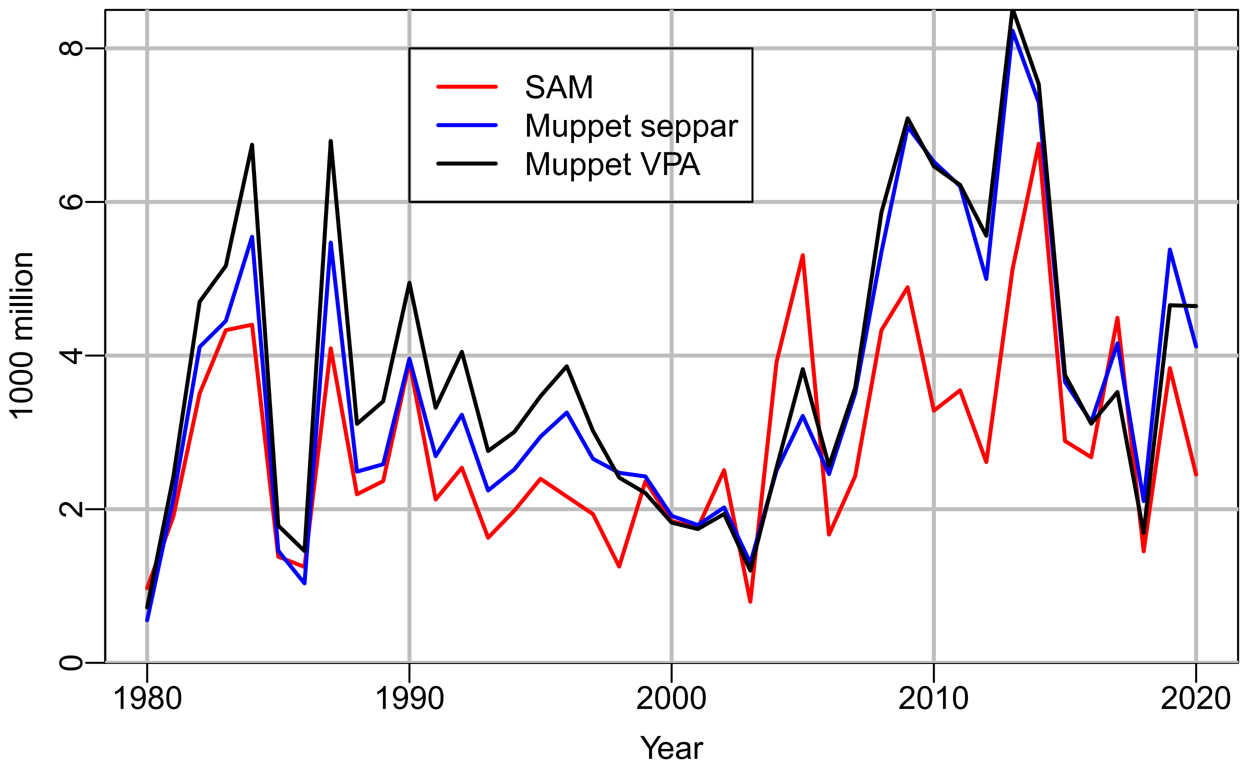


Figure 3: Number at age 3 from Muppet VPA and separable and Sam.

Looking at the comparison between age 3 from Muppet and SAM (figure 3) they are surprisingly similar before 2000 as the method and data used are very different in this period. After 2000 the number at age 3 are on the other hand surprisingly different. In the converged period VPA and Separable Muppet indicate similar numbers at age 3, the most notible difference is the 2002 yearclass. Before 1998 the estimated multplier in VPA is apparently a little higher than in the VPA model than the separable model.

Age 0 and age 3 from the Muppet model are very similar (figure 4). This is to be expected as fisheries on age 0-2 are limited.

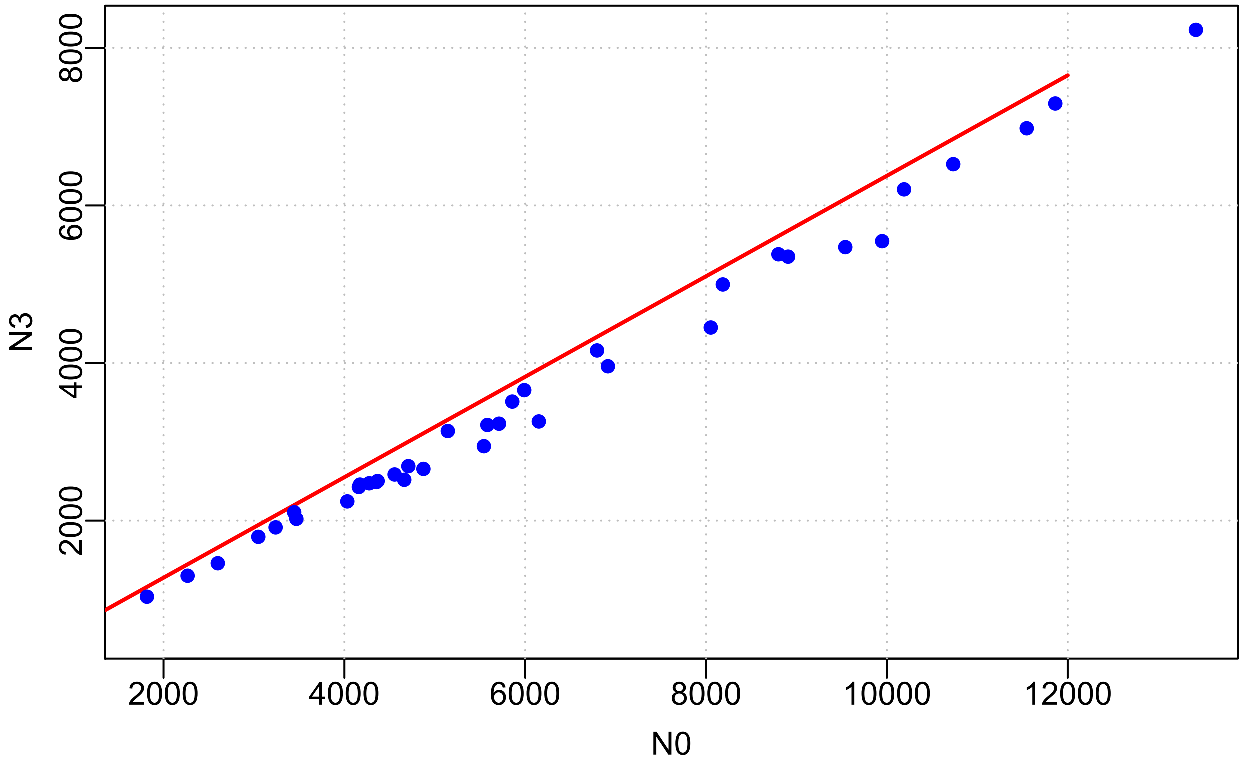


Figure 4: Muppet separable. Number at age 3 vs number at age 0. The red line has the slope $e^{-0.45}$

The relationship between n0 and n3 in SAM is on the other hand rather poor, $r^2 = 0.53$ on log scale (figure 5). The relationship between $n0$ and $n3$ is considerably worse than the relationship between $n0$ and the recruitment index (Important in HCR evaluations).

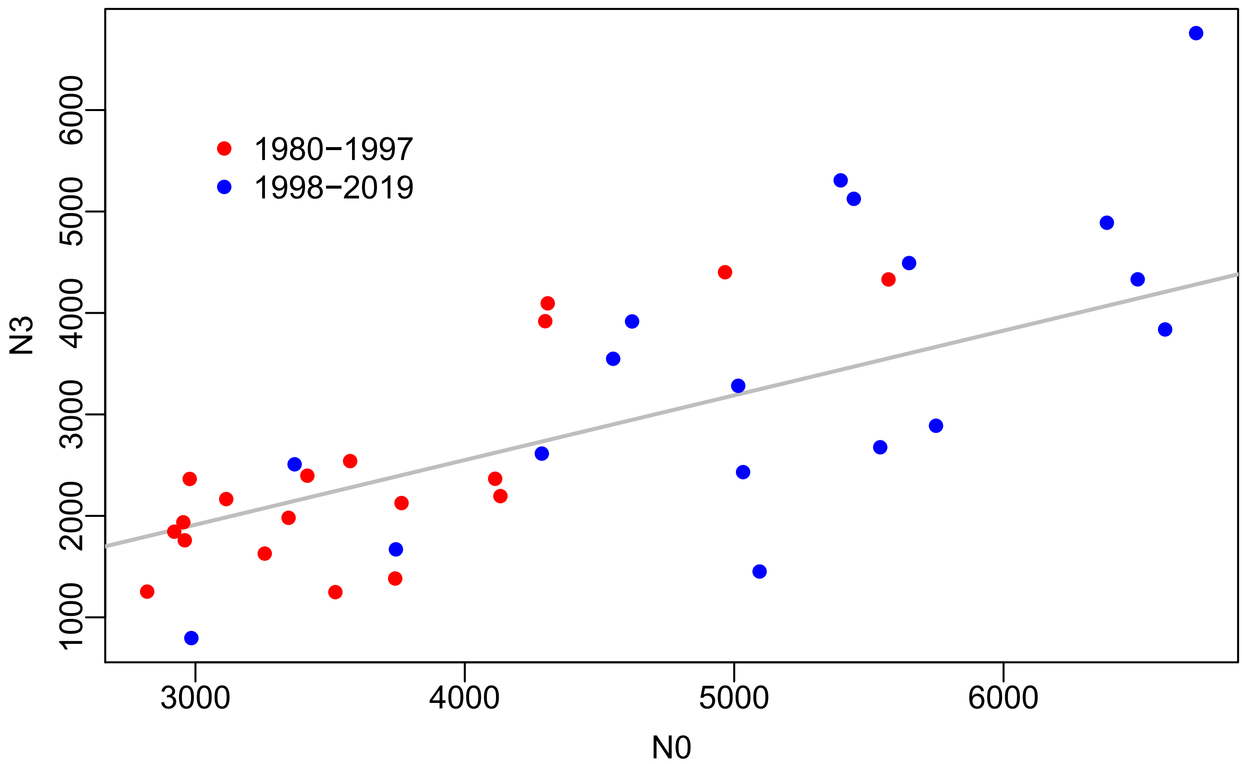


Figure 5: SAM. Number at age 3 vs number at age 0. The grey line has the slope $e^{-0.45}$

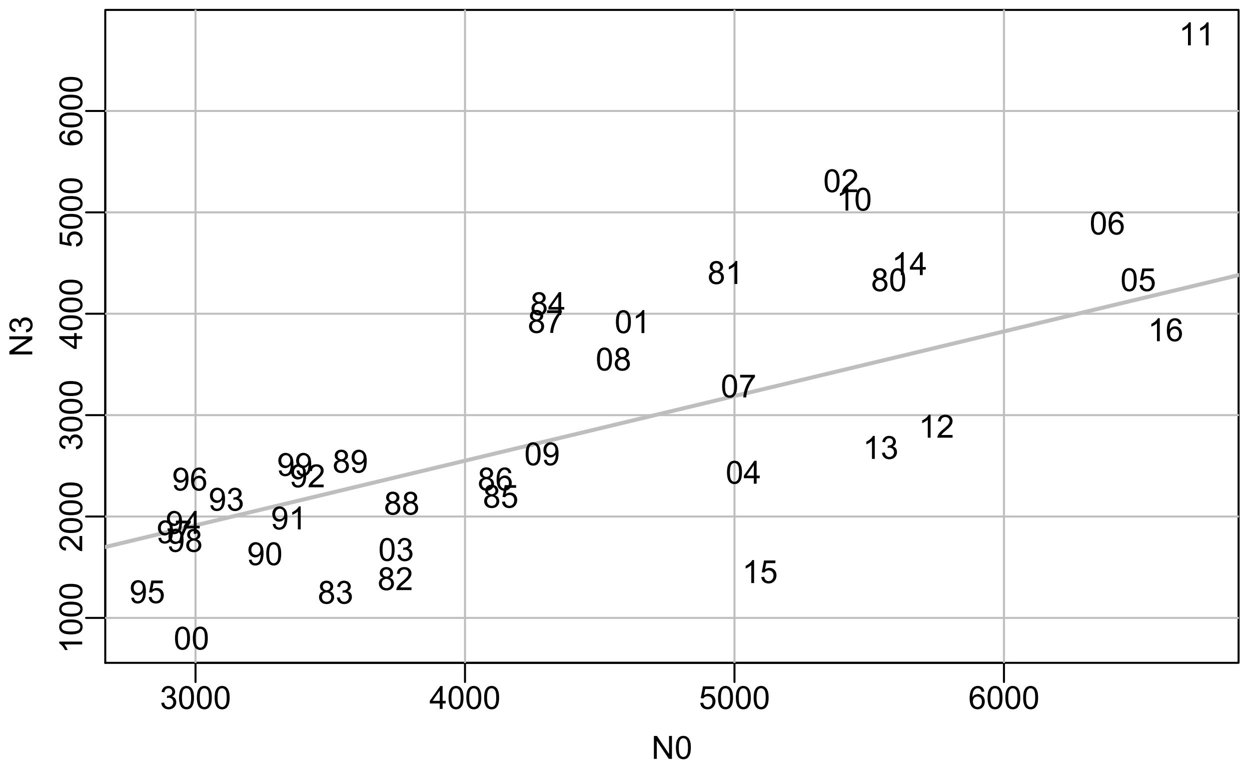
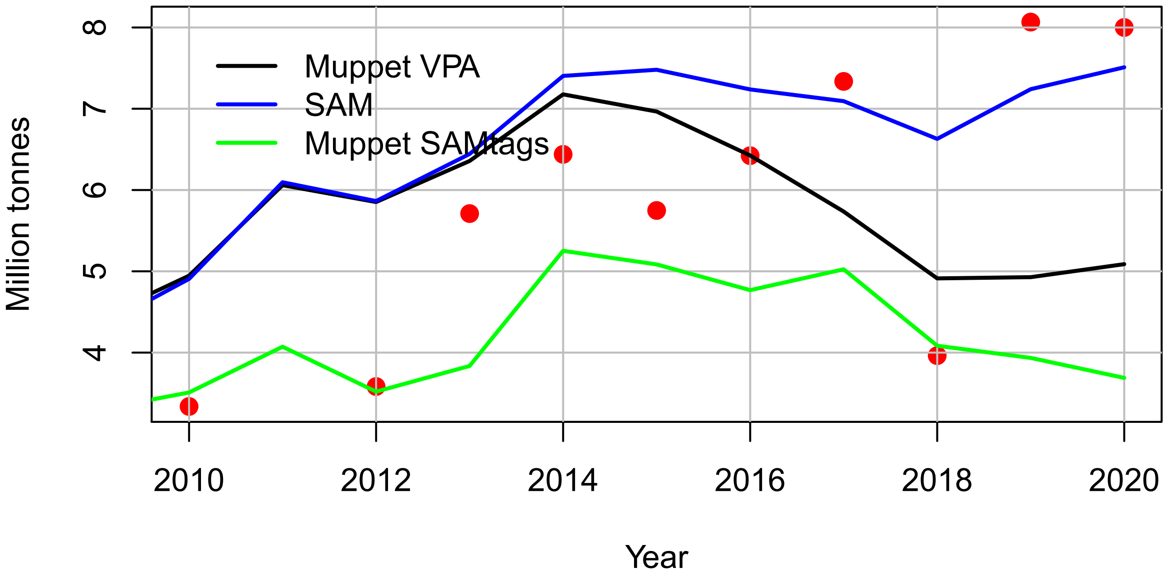


Figure 6: SAM. Number at age 3 vs number at age 0. The grey line has the slope $e^{-0.45}$. The text shows yearclass.

The pelagic survey might currently be the most important source of data in the assessment. The values from the pelagic survey are converted to biomass by multiplying the index by stock weights, summarizing over all the age groups. The stock weights are not the correct weights for this purpose but are probably sufficient for that is investigated here.

The pelagic index is at record high level in the years 2019 and 2020 while the stock assessment shows a downward trend since 2015 (figure 1). The Muppet and Sam assessments show somewhat different trends of biomass but do both have this "problem". In the figure predicted survey biomass and $B3+$ from Muppet are nearly identical ($q = 1$) but $B3+$ from SAM is lower but the trends are similar. The Muppet model limited to the same tags as the official assessment shows somewhat different trends (blue curve).



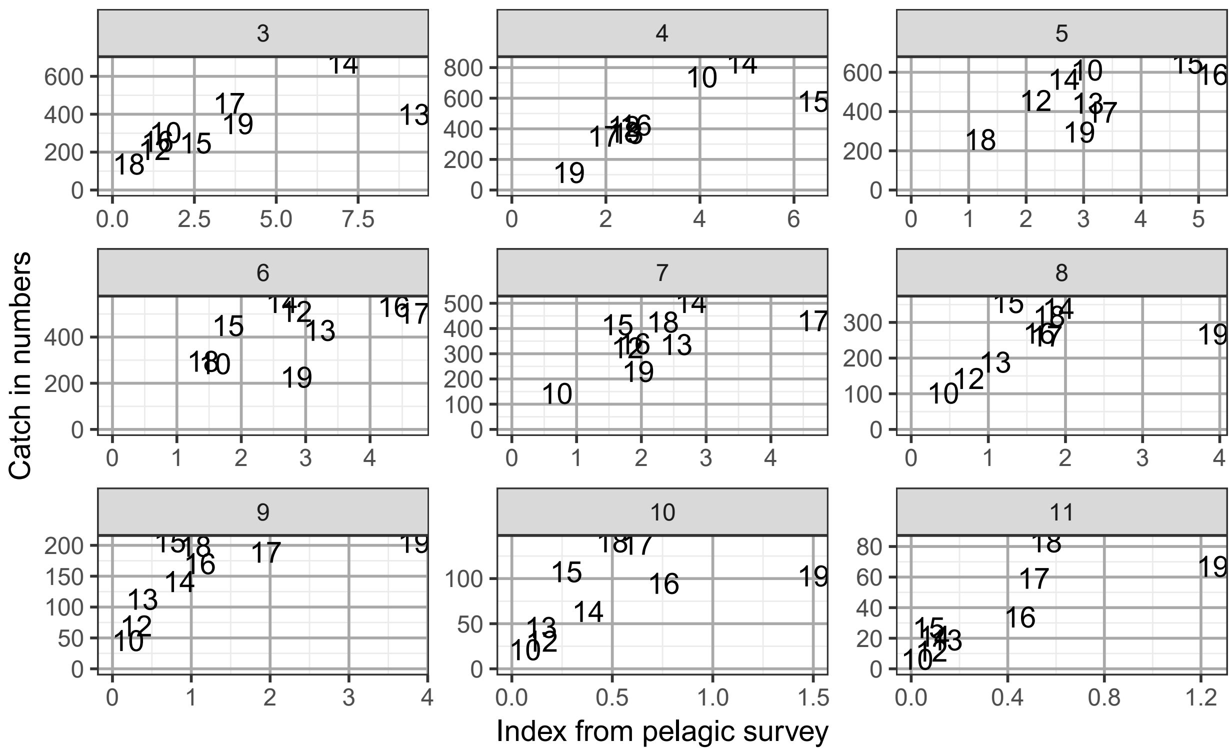


Figure 7: Catch in numbers by age vs indices from the Pelagic survey for the years 2010 and 2012:2019. The text indicate years.

Catch in numbers and index from the pelagic survey fit well for the older age groups but not as well for the younger age groups where contrast in data is less, especially in the catches. The plus group is missing in this plot but should be added.

Finally biomass 3+ and F_{4-8} from the 5 assessments listed above is shown (figure 8 and 9). The adopted assessment indicates the lowest biomass and highest fishing mortality. The range of results is probaly an indication of the uncertainty in the assessment that is probably even more than indicated by the range of results.

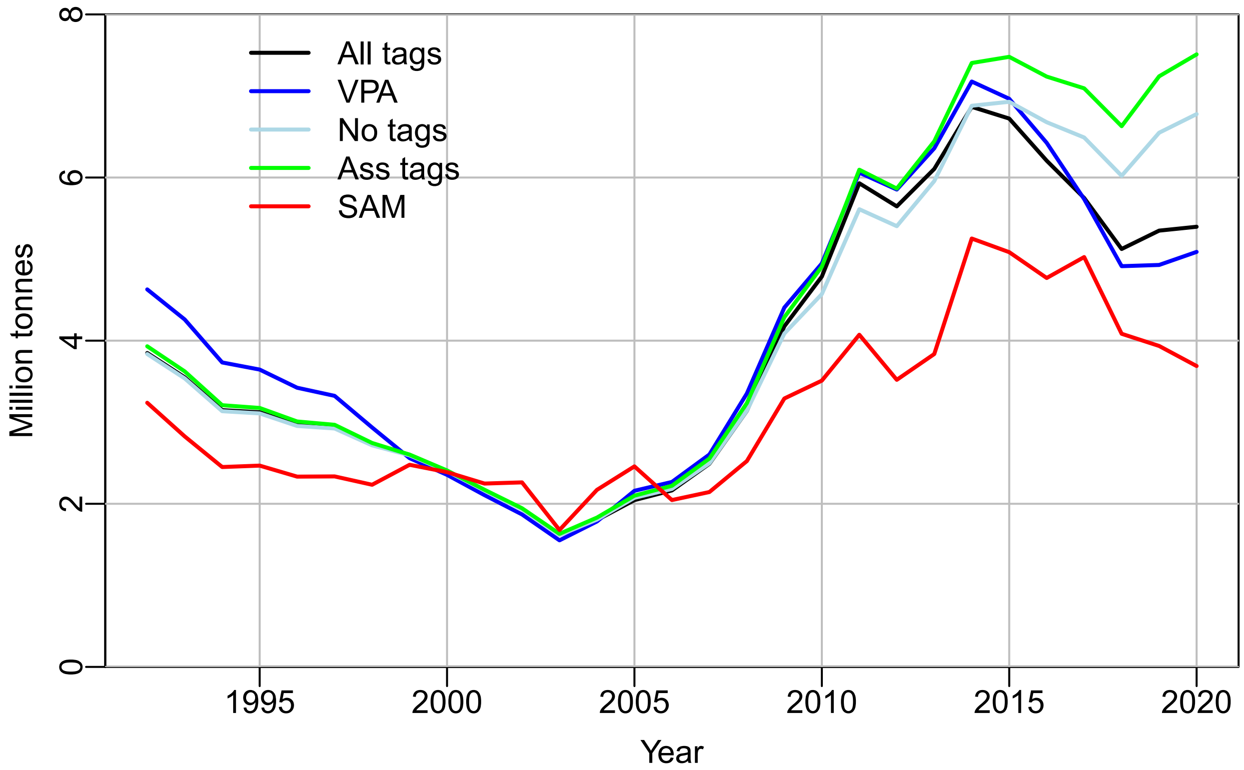


Figure 8: Development of B3+ from few diffent runs.

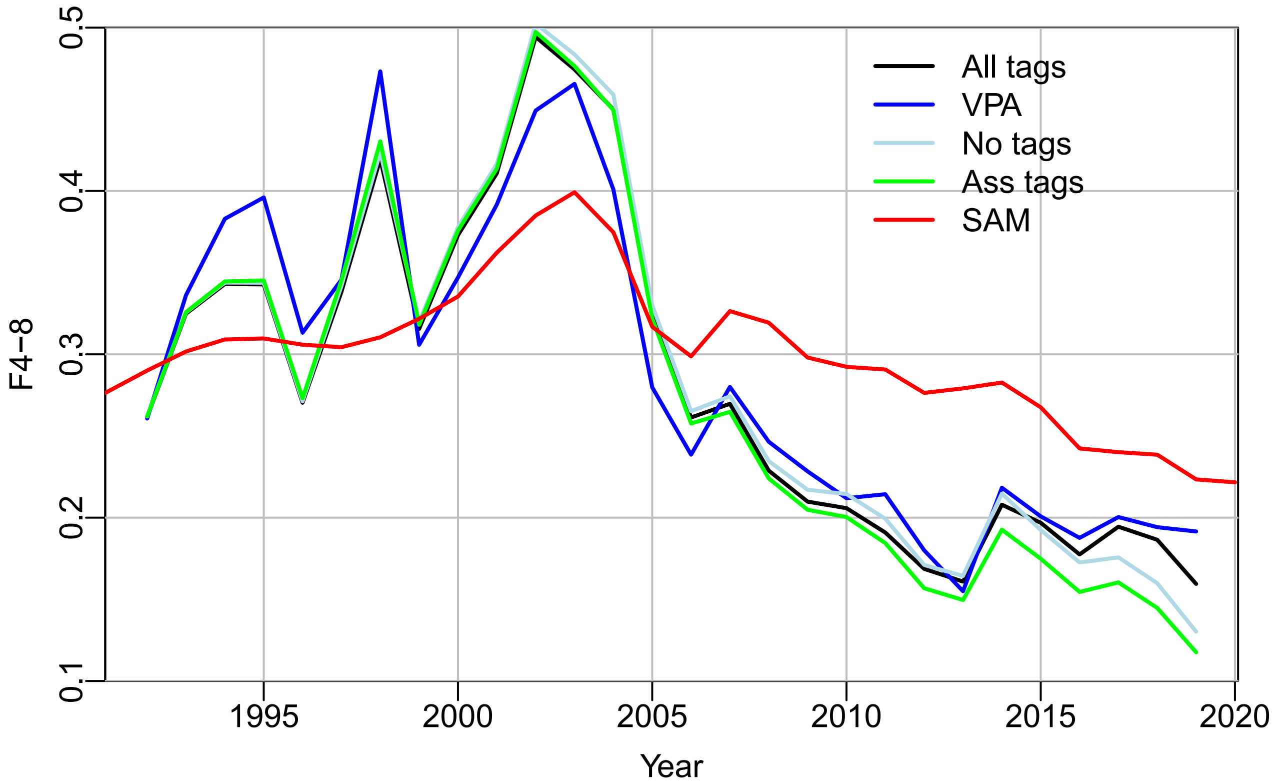


Figure 9: Development of F_{4-8} from few diffent runs.

Working Document to

Working Group on International Pelagic Surveys (WGIPS)
Belfast, 18 - 22 January 2021
and
Working Group on Widely Distributed Stocks (WGWIDE)
Copenhagen, 26 August - 1 September 2020

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2020

Post-cruise meeting on Teams, 16-18 June 2020

Are Salthaug[1], Erling Kåre Stenevik[1], Sindre Vatnehol[1], Åge Høines[1], Valantine Anthonypillai[1], Kjell Arne Mork[1], Cecilie Thorsen Broms[1], Øystein Skagseth[1]
RV G.O. Sars

Kai Wieland[2], Karl-Johan Stæhr[2], Susan Mærsk Lusseau[2], Benoit Berges[3]
RV Dana

Sigurvin Bjarnason[4], Anna Heiða Ólafsdóttir[4]
RV Árni Friðriksson

Sólvá Káradóttir Eliasen[5], Jan Arge Jacobsen[5], Leon Smith[5]
RV Magnus Heinason

[1] Institute of Marine Research, Bergen, Norway
[2] DTU-Aqua, Denmark
[3] Wageningen Marine Research, IJmuiden, The Netherlands
[4] Marine and Freshwater Research Institute, Hafnarfjordur, Iceland
[5] Faroese Marine Research Institute, Tórshavn, Faroe Islands

Introduction

In May-June 2020, four research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherlands, Sweden and UK. Due to the Covid19 situation in 2020 there was only participation from Denmark in the actual cruise), R/V Magnus Heinason, Faroe Islands, R/V Árni Friðriksson, Iceland and R/V G.O. Sars, Norway participated in the International ecosystem survey in the Nordic Seas (IESNS). The aim of the survey was to cover the whole distribution area of the Norwegian Spring-spawning herring with the objective of estimating the total biomass of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 also the EU participated (except 2002 and 2003) and from 2004 onwards it was more integrated into an ecosystem survey. This report represents analyses of data from this International survey in 2020 that are stored in the PGNAPES database and supported by national survey reports from each survey (Dana: Cruise Report R/V Dana Cruise 04/2020. International Ecosystem survey in the Nordic Seas (IESNS) in 2020, Magnus Heinason: IESNS Cruise Report Magnus Heinasen, Eliasen et al, FAMRI 2020, Árni Friðriksson: Óskarsson et al. 2019).

As previous years, it was planned that Russia would cover the Barents Sea. However, due to technical issues with the research vessel, Russia was not able to conduct the survey and thus no IESNS estimates from this area exist for 2020.

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2020 and by correspondence. Planning of the acoustic transects and hydrographic stations and plankton stations were carried out by using the recently developed survey planner function in the r-package Rstox version 1.11 (see www.imr.no/forskning/prosjekter/stox). The survey planner function generates the survey plan (transect lines) in a cartesian coordinate system, and transforms the positions to the geographical coordinate system (longitude, latitude) using the azimuthal equal distance projection, which ensures that distances, and also equal coverage, if the method used is designed with this prerequisite, are preserved in the transformation. Figure 1 shows the planned acoustic transects and hydrographic and plankton stations in each stratum. Only parallel transects were used this year, however, the transects now follow great circles instead of a constant latitude as before, so they appear bended in a Mercator projection. The participating vessels together with their effective survey periods are listed in the table below:

Vessel	Institute	Survey period
Dana	DTU Aqua - National Institute of Natural Resources, Denmark	01/5-25/5
G.O. Sars	Institute of Marine Research, Bergen, Norway	01/5-02/6
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	29/4- 11/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	10/5-28/5

Figure 2 shows the cruise tracks, Figure 3a the hydrographic and plankton stations and Figure 3b the pelagic trawl stations. Survey effort by each vessel is detailed in Table 1. Frequent contacts were maintained between the vessels during the course of the survey, primarily through electronic mail. The temporal progression of the survey is shown in Figure 4.

In general, the weather condition did not affect the survey even if there were some days that were not favourable and prevented for example WP2 and Multinet sampling at some stations. The survey was based on scientific echosounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote *et al*., 1987) prior to the survey. Salient acoustic settings are summarized in the text table below.

Acoustic instruments and settings for the primary frequency (boldface).

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason
Echo sounder	Simrad EK 60	Simrad EK 80	Simrad EK80	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 70, 120, 200	**38**,200
Primary transducer	ES38BP	ES 38B	ES38-7	ES38B
Transducer installation	Towed body	Drop keel	Drop keel	Hull
Transducer depth (m)	5 - 7	8.5	8	3
Upper integration limit (m)	7 - 9	15	15	7
Absorption coeff. (dB/km)	10.1	10.1	10	10.1
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	?	2.425
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	18	21.9
2-way beam angle (dB)	-20.5	-20.7	-20.3	-20.8
Sv Transducer gain (dB)				
Ts Transducer gain (dB)	25.17	26.05	26.9	25.57
s_A correction (dB)	-0.50	-0.66	-0.02	-0.68
3 dB beam width (dg)				
alongship:	6.96	6.48	6.53	7.17
athw. ship:	6.98	6.22	6.5	7.06
Maximum range (m)	500	500	500	500
Post processing software	LSSS	LSSS	LSSS	LSSS

All participants used the same post-processing software (LSSS) and scrutinization was carried out according to an agreement at a PGNAPES scrutinizing workshop in Bergen in February 2009 (ICES 2009), and "Notes from acoustic Scrutinizing workshop in relation to the IESNS", Reykjavík 3.-5. March 2015 (Annex 4 in ICES 2015). Generally, acoustic recordings were scrutinized on daily basis and species identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms. All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason
Circumference (m)		**496**	**832**	**640**
Vertical opening (m)	**25-35**	**25-30**	**20–35**	**45–55**
Mesh size in codend (mm)	**16**	**24**	**20**	**40**
Typical towing speed (kn)	**3.5-4.0**	**3.0–4.5**	**3.1–5.0**	**3.0–3.5**

Catches from trawl hauls were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. A subsample of herring, blue whiting and mackerel were sexed, aged, and measured for length and weight, and their maturity status was estimated using established methods. An additional sample of fish was measured for length. For the Norwegian, Icelandic and Faroese vessel, a smaller subsample of stomachs was sampled for further analyses on land. Salient biological sampling protocols for trawl catches are listed in the table below.

	Species	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason
Length measurements	Herring	200-300	100	300	100-200
	Blue whiting	200-300	100	50	100-200
	Mackerel	100-200	100	50	100-200
	Other fish sp.	100	30	30	30
Weighed, sexed and maturity determination	Herring	50	25-100	100	50-100
	Blue whiting	50	25-100	50	50-100
	Mackerel	0	25-100	50	50-100
	Other fish sp.	0	0	0	30*
Otoliths/scales collected	Herring	50	25-30	100	50-100
	Blue whiting	50	25-30	50	50-100
	Mackerel	0	25-30	50	50-100
	Other fish sp.	0	0	0	0
Stomach sampling	Herring	0	10	10	5-10
	Blue whiting	0	10	10	5-10
	Mackerel	0	10	10	5-10
	Other fish sp.	0	0	0	0

* Only weighed, not sexed or determination of maturity.

** Will be included in the final report

Acoustic data were analysed using the StoX software package which has been used for some years now for WGIPS coordinated surveys. A description of StoX can be found in Johnsen et al. (2019) and here: www.imr.no/forskning/prosjekter/stox. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). This method requires pre-defined strata, and the survey area was therefore split into 6 strata with pre-defined acoustic transects as agreed during the WGIPS in January 2019. Within each stratum, parallel transects with equal distances were used. The distance between transects was based on available survey time, and the starting point of the first transect in each stratum was randomized. This approach allows for robust statistical analyses of uncertainty of the acoustic estimates. The strata and transects used in StoX are shown in Figure 1. All trawl stations within a given stratum with catches of the target species (either blue whiting or herring) were assigned to all transects within the stratum, and the length distributions were weighted equally within the stratum. The following target strength (TS)-to-fish length (L) relationships were used:

Blue whiting: TS = 20 log(L) – 65.2 dB (ICES 2012)

Herring: TS = 20.0 log(L) – 71.9 dB

The target strength for herring is the traditionally one used while this target strength for blue whiting was first applied in 2012 (ICES 2012).

The hydrographical and plankton stations by survey are shown in Figure 3a. Most vessels collected hydrographical data using a SBE 911 CTD. Maximum sampling depth was 1000 m. Zooplankton was sampled by a WPII on all vessels, according to the standard procedure for the surveys. Mesh sizes were 180 or 200 µm. The net was hauled vertically from 200 m to the surface or from the bottom whenever bottom depth was less than 200 m. All samples were split in two and one half was preserved in formalin while the other half was dried and weighed. The samples for dry weight were size fractionated before drying by sieving the samples through 2000 µm and 1000 µm sieves, giving the size fractions 180/200 – 1000 µm, 1000 – 2000 µm, and > 2000 µm. Data are presented as g total dry weight per m^2. For the zooplankton distribution map, all stations are presented. For the time series, stations in the Norwegian Sea delimited to east of 14°W and west of 20°E have been included. The zooplankton data were interpolated using objective analysis utilizing a Gaussian correlation function to obtain a time-series for four different areas. The results are given as inter-annual indexes of zooplankton abundance in May. This method was introduced at WGINOR in 2015 (ICES, 2016) and the results match the former used average index.

Results and Discussion

Hydrography

The temperature distributions in the ocean, averaged over selected depth intervals; 0-50 m, 50-200 m, and 200-500 m, are shown in Figures 5-7. The temperatures in the surface layer (0-50 m) ranged from below 0°C in the Greenland Sea to 9°C in the southern part of the Norwegian Sea (Figure 5). The Arctic front was encountered below 65°N east of Iceland extending eastwards towards about 2° West where it turned northeastwards to 65°N and then almost straight northwards. This front was well-defined at 200-500 m depth while shallower it was unclear. Further to west at about 8° West another front runs northward to Jan Mayen, the Jan Mayen Front that was most distinct in the upper 200 m. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures >6 °C to the Bear Island at 74,5° N in the surface layer.

Relative to a 25 years long-term mean, from 1995 to 2019, the temperatures at 0-50 m were 0-1 °C below the mean for almost the whole Norwegian Sea (Figure 5). Warmest region is in the eastern Greenland Sea with temperatures 2 °C higher than the mean. This warming can be observed at all depths. At 50-200 m the temperatures were also, in most regions, 0-1 °C lower than the long-term mean. An exception is for the southwestern Norwegian Sea, west of the 0 meridian, where the temperatures were about 0-0,5 °C higher than the mean (Figure 6). At 200-500 m depth, the pattern is more fragmented but in the southwestern region the temperatures were near the long-term mean while in more eastern areas the temperatures were in general lower than the mean (Figure 7).

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in 26-28 April 2020 are shown in Figure 8. Atlantic water is lying over the colder and fresher intermediate layer and reach down to 500 m at the shelf edge and shallower westward. The warmest water, above 8 °C, is located near the shelf edge where the core of the inflowing Atlantic Water is located. Westward, temperature and salinity are reduced due to mixing with colder and less saline water. Compared to a 30 years long-term mean, from 1978 to 2007, the temperatures in 2020 were higher than the mean at the shelf edge but westward the temperatures were both lower and higher than the mean due to meandering or eddies. The salinity was however lower than the long-term mean for the whole section above 400 m with the exception in coastal water.

Two main features of the circulation in the Norwegian Sea, where the herring stock is grazing, are the Norwegian Atlantic Current (NWAC) and the East Icelandic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the southwestern Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is only in the last three decades that a similar layer has been observed all over the Norwegian Sea.

This circulation pattern creates a water mass structure with warm Atlantic Water in the eastern part of the area and more Arctic conditions in the western part. The NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward. The western branch of the NWAC reaches the area of Jan Mayen at about 71°N. Further northward in the Lofoten Basin the lateral extent of the Atlantic water gradually narrows again, apparently under topographic influence of the mid-ocean ridge. It has been shown that atmospheric forcing largely controls the distribution of the water masses in the Nordic Seas. Hence, the lateral extent of the NWAC, and consequently the position of the Arctic Front, that separates the warm North Atlantic waters from the cold Arctic waters, is correlated with the large-scale distribution of the atmospheric sea level pressure. The local air-sea heat flux in addition influence the upper layer and it is found that it can explain about half of the year to year variability of the ocean heat content in the Norwegian Sea.

Zooplankton

The zooplankton biomass (g dry weight m^{-2}) in the upper 200 m is shown in Figure 9. Sampling stations were evenly spread over the area, covering Atlantic water, Arctic water, and the Arctic frontal zone. The highest zooplankton biomasses were not concentrated in a specific area but spread over several locations in the northern part of the sampling area. High biomasses were found in northwestern parts of the central Norwegian Sea, northeast of Iceland and Jan Mayen, and in an area around Lofoten/Vesterålen and north of that area. Lower biomasses were found in the entire southern part of the sampling area, especially in southwest.

Figure 10 shows the zooplankton index given for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional difference in the biomass, the total area where divided into 4 subareas 1) Southern Norwegian Sea including the Norwegian Sea Basin, 2) The Northern Norwegian Sea including the Lofoten Basin, 3) Jan Mayen Arctic front, and 4) East of Iceland. The mean index of subarea 1 and 2 is also given. The zooplankton biomass index for the Norwegian Sea and nearby areas in 2020 was 8.3 g dry weight m^{-2}, which is a decrease from last year. A similar decrease was observed in all sub-areas, except from East of Iceland where an increase was observed.

The zooplankton biomass index for the Norwegian Sea in May has been estimated since 1995. For the period 1995-2002 the plankton index was relatively high (mean 11.5 g) even if varying between years. From 2003-2006, the index decreased continuously and has been at lower levels since then, with a mean of 7.9 g for the period 2003-2020. An increase can be noted in the last part of the low-biomass period. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea. The zooplankton biomass at the Jan Mayen Arctic front was high until 2007 but has since then been at the same level as the Norwegian Sea. The zooplankton biomass East of Iceland was in general higher compared with the other sub-areas until 2015.

The reason for this fluctuation in the zooplankton biomass is not obvious to us. The unusually high biomass of pelagic fish feeding on zooplankton has been suggested to be one of the main causes for the reduction in zooplankton biomass. However, carnivorous zooplankton and not pelagic fish are the main predators of zooplankton in the Norwegian Sea (Skjoldal *et al.,* 2004), and we do not have good data on the development of the carnivorous zooplankton stocks. Timing effects, as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. It is also worth noting that the period with lower zooplankton biomass coincides with lower-than-average heat contents in the Norwegian Sea (ICES 2018) and reduced inflow of Arctic water into the southwestern Norwegian Sea (Kristiansen et al., 2019). More ecological and environmental research to reveal inter-annual variations and long-term trends in zooplankton abundance are recommended.

Norwegian spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2020. The zero-line was believed to be reached for adult NSS herring in most of the areas. On some of the transects in stratum 2 and 4, however, aggregations of herring were recorded on the easternmost part indicating that the zero-line was not fully reached on those transect although some of the transect were extended. It is, however, recommended that the results from IESNS 2020 can be used for assessment purpose. The herring was primarily distributed in the south-western area where the 2013-year-class dominated, and in the eastern area where the 2016 year-class dominated (Figure 11). It is a commonly observed pattern that the older fish are distributed in the southwest while the younger fish are found closer to the nursery areas in the Barents Sea (Figure 12). The distribution of the recruiting 2016 year-class in the eastern part of the Norwegian Sea extends all the way from 70°N south to 64°N. This is different from earlier year-classes recruiting to the Norwegian Sea, which usually do not extend farther south than 69°N.

Four years old herring (year class 2016) dominated both in terms of number (57%) and biomass (41 %) on basis of the StoX baseline estimates for the Norwegian Sea (Tables 2-4). Its number at age 4 is higher than for the 2004 year class at same age (Figure 13), which puts the size of the 2016 year class into perspective. The large 2004 year class, which has dominated the stock together with the 2002 year class, has contributed significantly to the biomass of older age-groups (see paragraph on issues with age determination below). Herring aged 12-18 years old thus comprised 11% of the numbers and 19% of the biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 14 and Table 5. The relative standard error (CV) of the total biomass estimate is 15 % and 12 % for the total numbers estimate, and the relative standard error for the dominating age groups is around 30 % (Figure 14 and Table 5).

The total estimate of herring in the Norwegian Sea from the 2020 survey was 22.8 billion in number and the biomass was 4.25 million tonnes. The biomass estimate is 0.62 million tonnes (13 %) lower than the 2019 survey estimate while the estimated number is 15 % higher in 2020. The biomass estimate decreased significantly from 2009 to 2012, and has since then been rather stable at 4.2 to 5.9 million tonnes with similar confidence interval (Figure 15), with the lowest abundance occurring in 2017. Although there is only little change in total abundance and biomass, there is a gradual shift in age and size composition with the 2016 year class becoming more dominant than the older year classes.

In the last 5 years, there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences – particularly older specimens appear to have uncertain ages. A scale and otolith exchange has been ongoing for some period, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop was planned in the spring 2018 to discuss the results. This workshop was postponed indeterminately. The survey group emphasizes the necessity of having this workshop before next year's survey takes place.

With respect to age-reading concerns in the recent years, the comparison between the nations in this year's survey could not been done fully since restrictions on the cruise tracks due to COVID-19 prevented the Norwegian vessel to enter stratum 1 and 3. However, in stratum 2 and 4 there was overlap between the Norwegian vessel and the Danish vessel and the age distributions from those strata seems to be relatively similar between the two vessels (Figure 20).

In the IESNS survey in 2020 some differences regarding the acoustic scrutinizing between neighbouring vessels were observed and discussed. The data where re-scruitinized, and there was a better agreement between the vessel. Still, the difference between the original and the re-scrutinization where small, indicating that the difference where not caused by an scrutinization error. There is a need to further discuss the scrutinizing process before next year's survey. The survey group suggest to have a meeting before next year's survey to discuss the protocol for acoustic scrutinizing in the IESNS survey.

Recently concerns have been raised by the survey groups for the International ecosystem surveys in the Nordic Seas (IESNS and IESSNS) on mixing issues between Norwegian spring-spawning herring and other herring stocks (e.g. Icelandic summer-spawning, Faroese autumn-spawning, Norwegian summer-spawning and North Sea type autumn-spawning herring) occurring in some of the fringe regions in the Norwegian Sea. Until now, fixed cut lines have been used by the survey group to exclude herring of presumed other types than NSS herring, however this simple procedure is thought to introduce some contamination of the stock indices of the target NSS herring.

In the IESNS 2020 survey, all herring in the Stratum 1 was allocated to NSSH, although the southernmost transect east of the Faroes (Figure 11) contained mainly autumn-spawning type herring, probably local Faroese autumn-spawners or North Sea type autumn-spawners. WGIPS noted in their 2019 report that the separation of different herring stock components is an issue in several of the surveys coordinated in WGIPS and the needs for development of standardized stock splitting methods was also noted in the WKSIDAC (ICES 2017).

Blue whiting

The spatial distribution of blue whiting in 2020 was similar to the years before, with the highest abundance estimates in the southern and eastern part of the Norwegian Sea, along the Norwegian continental slope. The main concentrations were observed in connections with the continental slopes of Norway and along the Scotland – Iceland ridge (Figure 16). Blue whiting was distributed similar as last year. The largest fish were found in the western and middle part of the survey area (Figure 17). It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period.

The total biomass index of blue whiting registered during the IESNS survey in 2020 was 0.39 million tonnes, which is a 26 % decrease from the biomass estimate in 2019 (0.53). The abundance index for 2020 was 4.9 billion, which is 21 % lower than in 2019. Age 1 is dominating the acoustic estimate (32.5 % of the biomass and 57% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 18 and Table 6. The relative standard error (CV) of total biomass estimate is 16 % and 17 % for total numbers (Table 6).

In this year’s IESNS survey, one-year old blue whiting was at similar level as the estimate of one-year olds in 2019 and more numerous as compared to IESNS 2017 and 2018. The survey group compared age and length distributions by vessel and strata (Figure 20 and 21) and no clear differences were found compared to earlier years.

This year the blue whiting estimate was based on only three of the four vessels. Staffing constraints on Dana due to the Covid-19 situation meant that the survey data was scrutinised after the survey ended rather than during the cruise. This resulted in some discrepancy in the procedure used for scrutinization of blue whiting from Dana. Visual observation of significant inconsistencies between the neighbouring transects of Dana and G. O. Sars lead the survey group to decide to omit the acoustic data from Dana this year. This resulted in a higher total estimate of blue whiting (~21%) but also higher uncertainty. The biological information from Dana was still used.

Mackerel

Trawl catches of mackerel are shown in Figure 22 Mackerel was present in the southern and eastern part of the Norwegian Sea (up to 69°N) in the beginning of May. No further quantitative information can be drawn from these data as this survey is not designed to monitor mackerel.

General recommendations and comments

Recommendation	Adressed to
1. Continue the methodological research in distinguishing between Herring and blue whiting in the interpretation of echograms.	WGIPS
2. It is recommended that a workshop based on the ongoing otolith and scale exchange will take place before next year's IESNS survey.	WGBIOP, WGWIDE
3. It is recommended that the WGIPS meeting in 2021 includes a workshop on how to deal with stock components of herring in the IESNS-survey.	WGIPS
4. It is recommended that the WGIPS meeting in 2021 discusses the possible implementation of sonar observations in IESNS and other acoustic surveys.	WGIPS

Next year's post-cruise meeting

We will aim for next meeting in 15-17 June 2021. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2020 at 0-200 m depth was generally below the long-term mean (1995-2019) in the Norwegian Sea.
- The 2020 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters decreased a bit from last year.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 4.25 million tonnes, which is a 13 % decrease from the 2019 survey estimate. The estimate of total number of NSSH was 22.8 billion, which is a 15 % higher than in the 2019 survey. The survey followed the pre-planned protocol and the survey group recommends using the abundance estimates in the analytical assessment.

- The 2016 year class of NSSH dominated in the survey indices both in numbers (57%) and biomass (41%), and it is on the same level as the strong 2004 year class at the same age (in the 2008 survey).
- The biomass of blue whiting measured in the 2020 survey decreased by 26 % from last year's survey and 21 % in terms of numbers. Age 1 (2019 year class) is the dominating year class (32.5 % of the biomass and 57% by number)

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Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2020.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	01/05-25/05	1893	25	29	468	1866	34
Magnus Heinason	29/4-11/5	1319	15	22	394	775	22
Árni Fridriksson	12/5-26/5	3188	14	34	830	2758	30
G.O.Sars	01/5-02/6	3632	73	66	659	2065	60
Total		**10032**	**127**	**151**	**2351**	**7464**	**146**

Table 2. IESNS 2020 in the Norwegian Sea. Baseline estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
14-15	15775	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15775	276.1	17.50
15-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2379	2379	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8387	8387	385.8	46.00
20-21	20596	46719	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67315	3942.2	58.56
21-22	-	42542	23662	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66204	4583.0	69.23
22-23	-	124419	109173	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	233593	18657.3	79.87
23-24	-	63233	286786	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	350019	31906.0	91.16
24-25	-	63676	1122561	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1186237	118331.1	99.75
25-26	-	26921	2767160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2794080	313130.6	112.07
26-27	-	24267	2575099	7327	-	30359	-	-	-	-	-	-	-	-	-	-	-	-	2637052	323632.1	122.72
27-28	-	96829	1389284	-	3530	24990	14119	-	-	3586	-	-	-	-	-	-	-	-	1532337	213322.6	139.21
28-29	-	5884	1927200	78548	47422	153158	41188	-	-	-	-	-	-	-	-	-	-	-	2253401	357169.5	158.50
29-30	-	-	1929251	84784	114419	415279	144971	45132	13717	-	9145	-	-	-	-	-	-	-	2756696	484901.5	175.90
30-31	-	-	731038	211152	282243	388372	287591	71245	39794	9036	8689	-	-	-	-	-	-	-	2029160	402964.2	198.59
31-32	-	-	89081	163380	260560	238699	50907	90121	78299	101878	27584	11822	-	-	-	-	-	-	1112330	248182.8	223.12
32-33	-	-	11658	22823	165992	404084	14312	30234	42153	49547	-	-	-	-	-	-	-	-	740803	179908.2	242.86
33-34	-	-	18429	2096	63689	517652	52388	40442	19271	2096	12573	-	-	-	-	-	-	-	728636	184875.2	253.73
34-35	-	-	9607	11823	64531	293609	125357	92216	28374	33103	7094	7094	4729	2365	9458	-	-	-	689359	193224.9	280.30
35-36	-	-	-	-	32093	81692	70022	164132	113785	163384	64187	140044	72939	35011	11670	-	-	-	948959	293187.8	308.96
36-37	-	-	-	-	-	25001	25001	44233	58296	211548	92913	180777	278740	115390	38463	17308	-	-	1087672	351837.7	323.48
37-38	-	-	-	-	-	-	2778	25002	27780	104176	57361	141679	255578	230576	137512	25002	-	-	1007445	340918.5	338.40
38-39	-	-	-	-	-	-	-	-	14787	11375	6825	44362	85311	109198	101236	32987	11375	-	417455	148142.6	354.87
39-40	-	-	-	-	-	-	-	-	-	-	-	19266	23799	-	36266	20400	5667	-	105398	39859.4	378.18
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10205	10205	-	-
41-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1136	1136	-	-
TSN(1000)	36371	494488	12989989	581932	1034479	2572896	828633	602757	436258	689729	286370	545043	721097	492539	334605	95697	17041	22107	22782032	-	-
TSB(1000 kg)	1471.2	47893.6	1755258.9	112070.0	232978.9	593613.9	192408.4	159723.7	119478.0	210165.6	90037.0	177472.5	238730.4	165718.0	116523.5	33343.8	6065.9	385.8	-	4253339.0	-
Mean length (cm)	17.81	23.76	26.86	30.19	31.15	31.50	31.37	33.21	33.68	34.82	35.10	36.18	36.60	36.83	37.25	37.59	38.33	29.75	-	-	-
Mean weight (g)	40.45	96.85	135.12	192.58	225.21	230.72	232.20	264.99	273.87	304.71	314.41	325.61	331.07	336.46	348.24	348.43	355.95	46.00	-	-	186.81

Table 4. IESNS 2020 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	3175	-	-	-	-	-	-	-	-	3175	69.8	22.00
17-18	56465	-	-	-	-	-	-	-	-	56465	1442.4	25.54
18-19	260128	-	-	-	-	-	-	-	-	260128	7978.6	30.67
19-20	895640	-	-	-	-	-	-	-	-	895640	33357.1	37.24
20-21	708352	39471	-	-	-	-	-	-	-	747823	33457.2	44.74
21-22	510440	49345	26468	-	-	-	-	-	-	586253	31207.9	53.23
22-23	267390	91340	18972	-	-	-	-	-	-	377703	23374.3	61.89
23-24	95144	105467	56782	-	-	-	-	-	-	257393	18312.6	71.15
24-25	24788	82626	122028	-	-	-	-	-	-	229442	19304.4	84.14
25-26	-	47957	171008	17439	10899	-	-	-	-	247304	23504.4	95.04
26-27	-	57515	154081	22617	19547	-	-	-	-	253760	26919.0	106.08
27-28	-	6822	31835	6822	9096	2656	11629	-	-	68860	8684.8	126.12
28-29	-	-	51237	24091	44665	79472	10325	9822	-	219613	32134.2	146.32
29-30	-	-	17933	73231	103619	39343	19603	-	-	253729	42296.7	166.70
30-31	-	-	30704	98407	120707	50174	27940	10235	-	338168	59325.9	175.43
31-32	-	-	-	13533	26074	45444	20141	-	-	105191	20992.3	199.56
32-33	-	-	-	-	17544	9029	2567	4695	-	33836	7113.2	210.23
33-34	-	-	-	-	-	2109	-	-	-	2109	493.6	234.00
34-35	-	-	-	-	-	-	-	-	-	-	-	-
36-37	-	-	-	-	-	-	-	-	382	382	113.9	298.20
TSN(1000)	2821522	480543	681050	256141	352152	228228	92204	24752	382	4936973	-	-
TSB(1000 kg)	126992.5	36024.1	68641.8	40862.5	57978.5	39223.4	16101.6	4143.9	113.9	-	390082.3	-
Mean length (cm)	20.09	23.27	25.44	28.95	29.36	29.55	29.59	29.63	36.00	-	-	-
Mean weight (g)	45.01	74.97	100.79	159.53	164.64	171.86	174.63	167.42	298.20	-	-	79.01

Table 5. IESNS 2020. Bootstrap estimates from StoX (based on 1000 replicates) of Norwegian spring-spawning herring. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	9.0	40.0	85.4	42.7	24.0	0.563
3	245.8	466.7	714.2	471.9	144.8	0.307
4	10156.8	13067.0	16037.7	13064.5	1826.4	0.140
5	216.9	512.5	808.0	512.7	175.7	0.343
6	528.3	977.8	1585.3	1009.2	317.5	0.315
7	1543.8	2446.6	3602.0	2492.2	633.2	0.254
8	404.4	758.2	1262.3	786.4	263.5	0.335
9	340.3	615.7	965.8	629.4	196.7	0.313
10	219.4	418.0	684.5	433.8	144.0	0.332
11	357.6	678.3	1071.4	694.2	223.6	0.322
12	152.4	311.2	528.3	323.8	113.2	0.349
13	231.7	484.8	843.4	505.1	192.8	0.382
14	356.1	698.5	1166.3	725.6	257.6	0.355
15	228.9	466.9	777.6	483.0	177.6	0.368
16	118.5	292.8	543.5	307.8	133.3	0.433
17	30.7	92.0	175.7	96.6	46.1	0.477
18	0.0	12.7	34.3	14.4	11.1	0.768
Unknown	9.0	21.7	40.8	22.8	10.0	0.439
TSN	18020.8	22708.0	27299.3	22615.9	2795.2	0.124
TSB	3161.1	4206.4	5296.1	4209.9	638.3	0.152

Table 6. IESNS 2020. Bootstrap estimates from StoX (based on 1000 replicates) of blue whiting. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
1	1931.0	2777.9	3834.2	2817.2	597.2	0.21
2	319.1	486.1	701.5	492.9	119.6	0.24
3	448.1	667.5	955.3	680.6	156.6	0.23
4	123.3	245.7	398.3	251.6	82.9	0.33
5	174.2	339.8	539.6	345.1	113.0	0.33
6	133.6	235.2	349.8	237.8	68.1	0.29
7	46.4	88.1	151.7	92.3	32.1	0.35
8	7.0	23.0	42.0	23.4	10.5	0.45
10	0.0	0.4	1.3	0.4	0.3	0.81
TSN	3682.9	4928.6	6231.0	4942.5	777.7	0.16
TSB	283.6	391.1	497.5	388.8	64.3	0.17

Figures

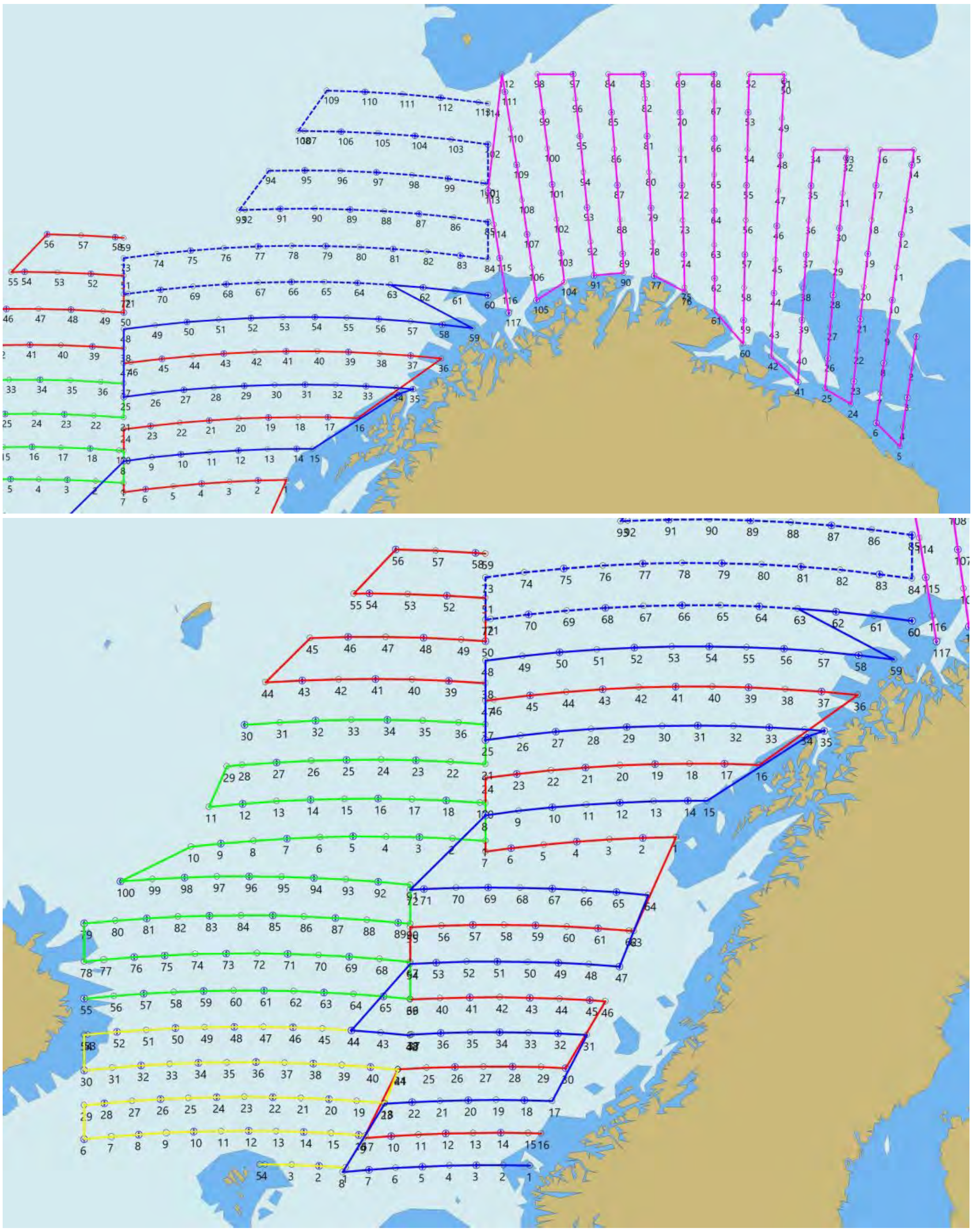


Figure 1. The pre-planned strata and transects for the IESNS survey in 2020 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends. **Note:** The Russian vessel was not able to conduct the survey planned in the Barents Sea.

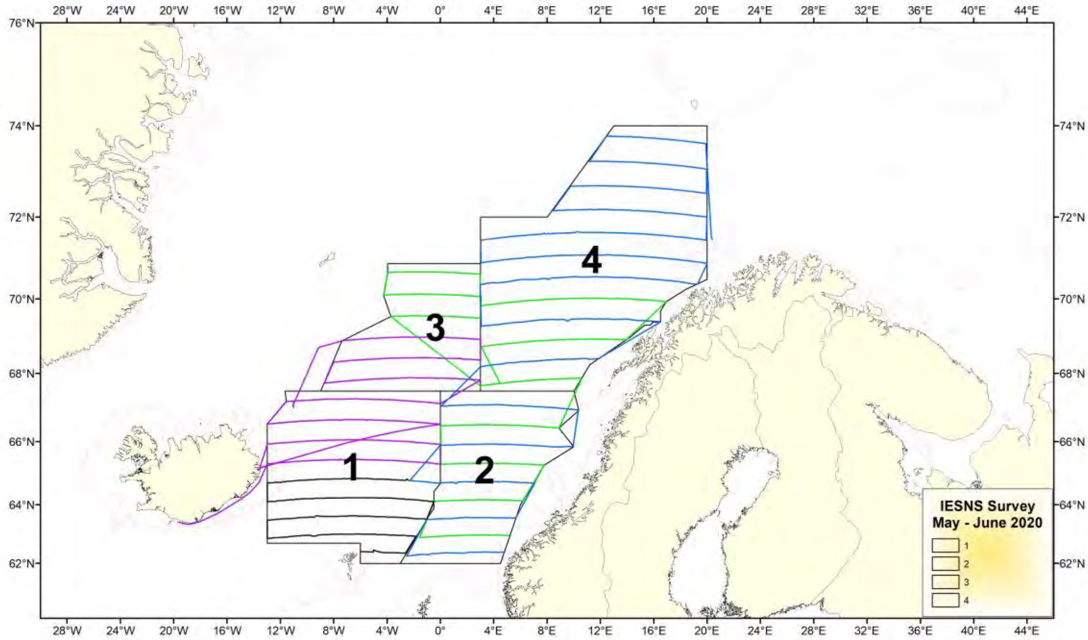


Figure 2. Cruise tracks and strata (with numbers) for the IESNS survey in May 2020.

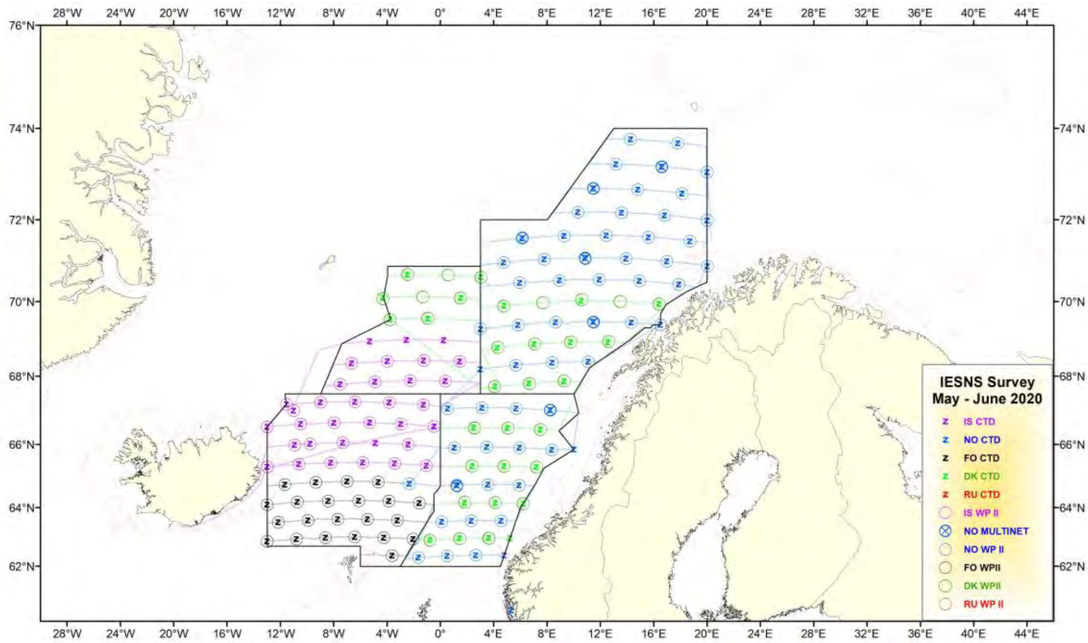


Figure 3a. IESNS survey in May 2020: location of hydrographic and plankton stations. The strata are shown.

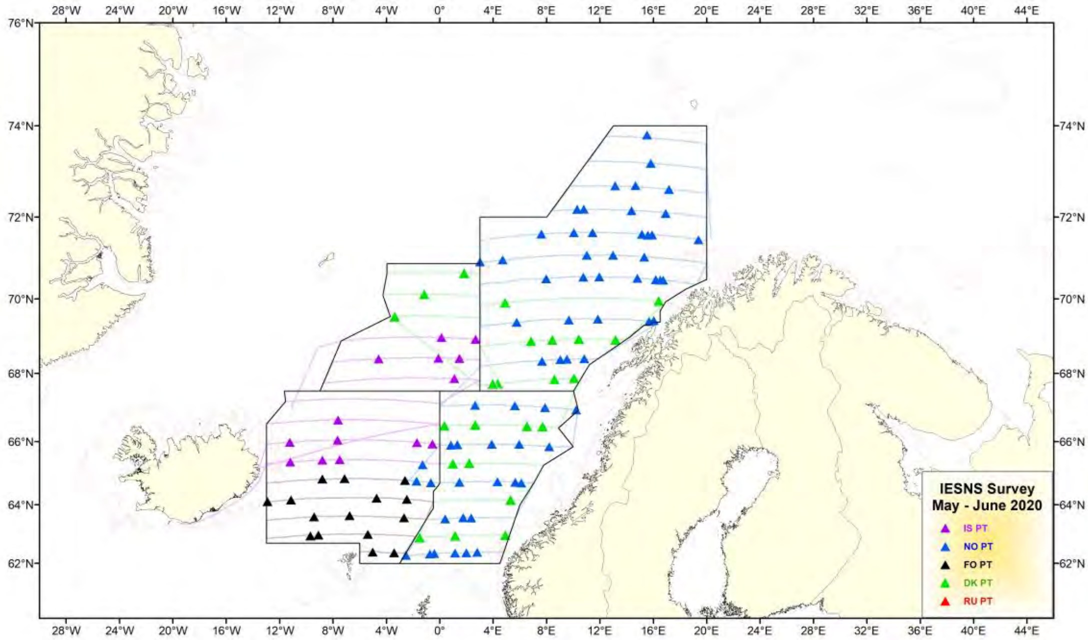


Figure 3b. IESNS survey in May 2020: location of pelagic trawl stations. The strata are shown.

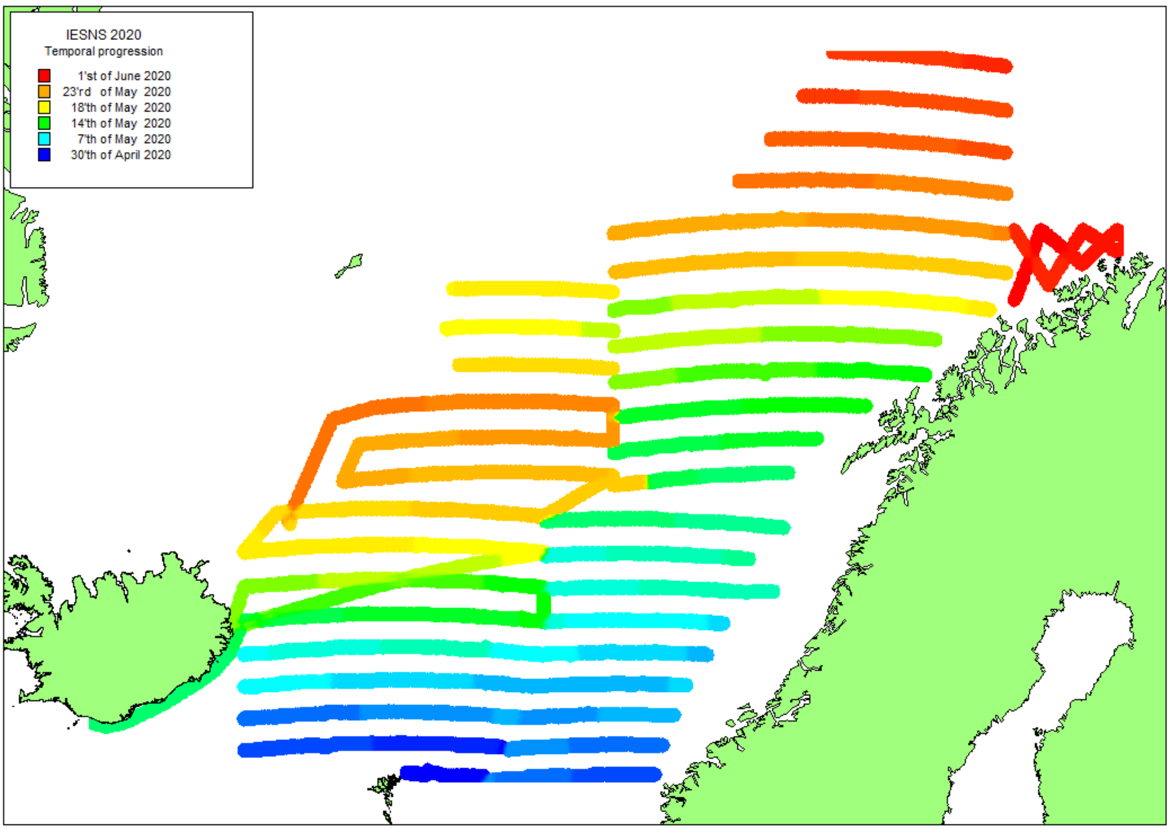


Figure 4. Temporal progression IESNS in May-June 2020.

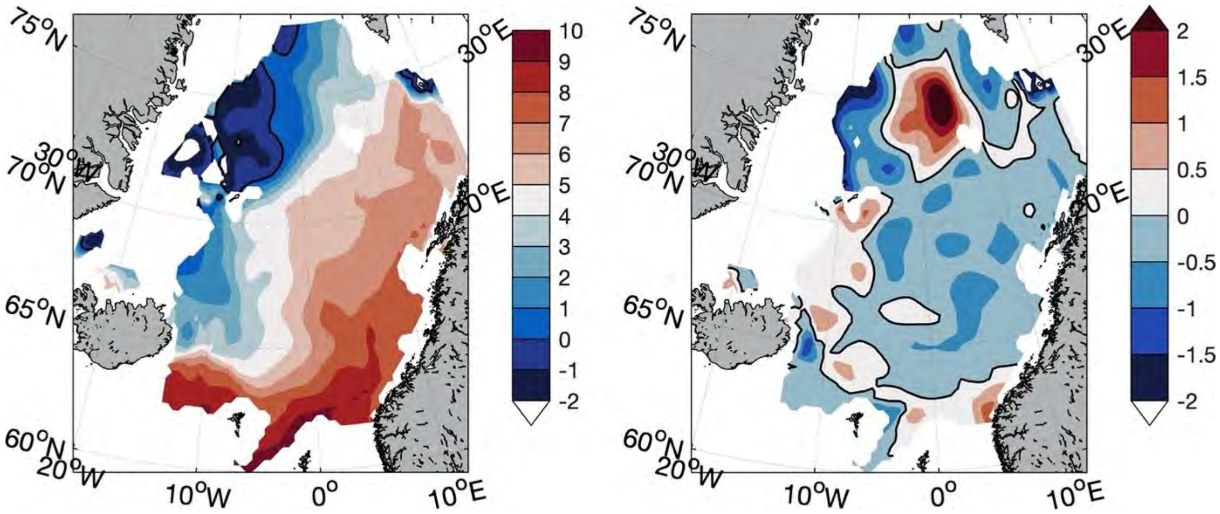


Figure 5. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2020. Anomaly is relative to the 1995-2019 mean.

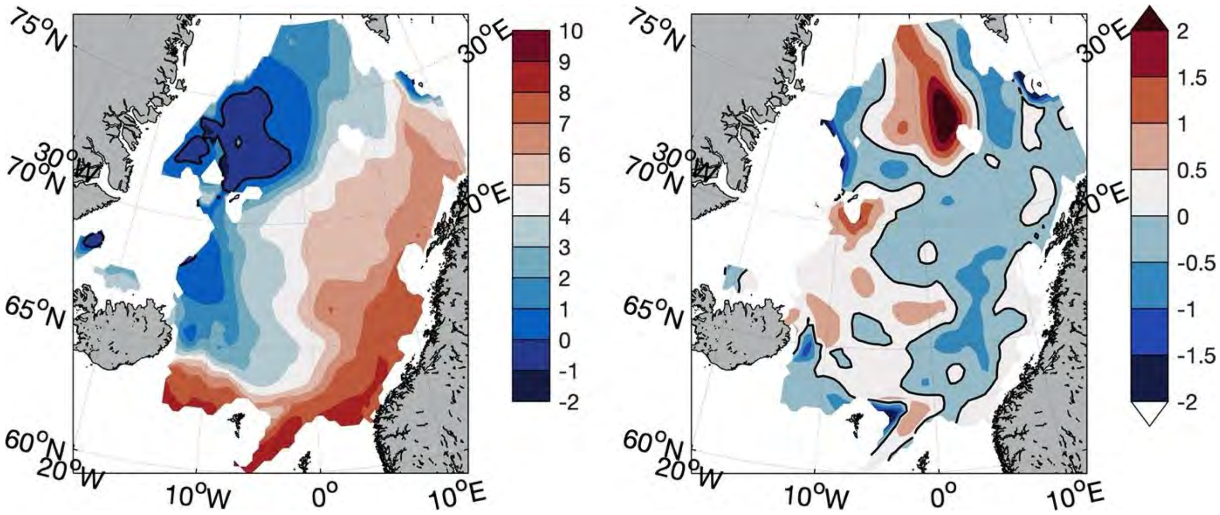


Figure 6. Same as above but averaged over 50-200 m depth.

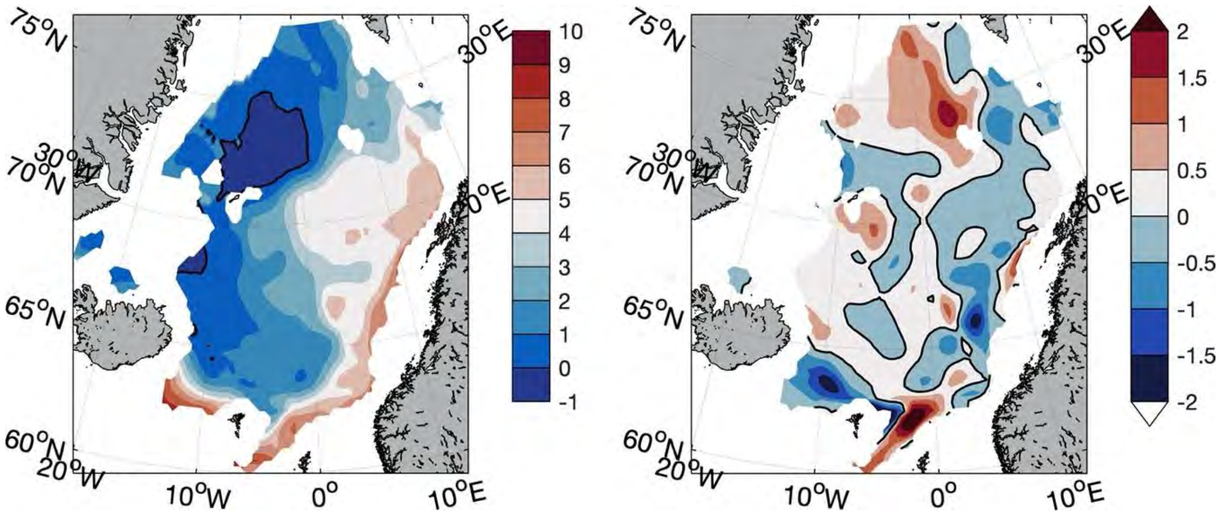


Figure 7. Same as above but averaged over 200-500 m depth.

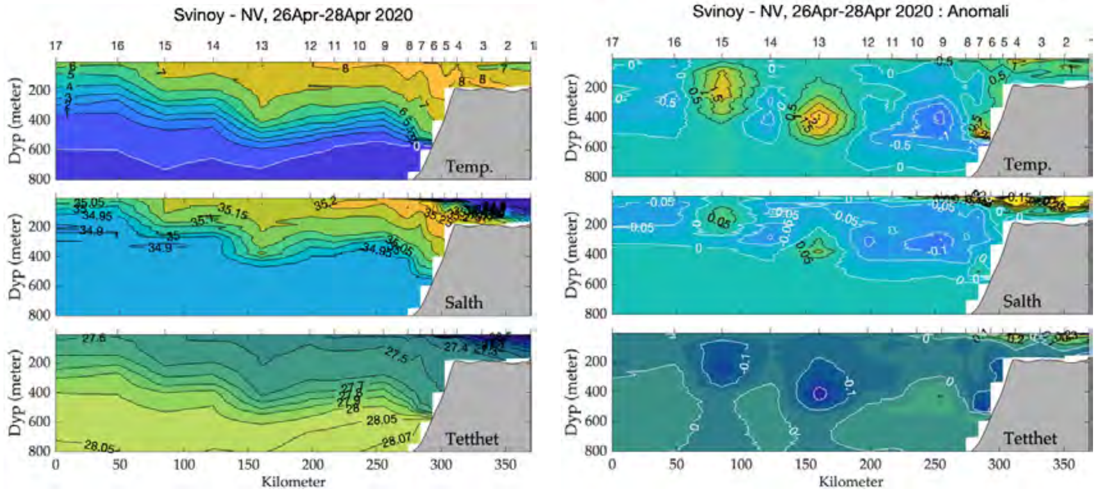


Figure 8. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinøy section, 26-28 April 2020. Anomalies are relative to a 30 years long-term mean (1978-2007).

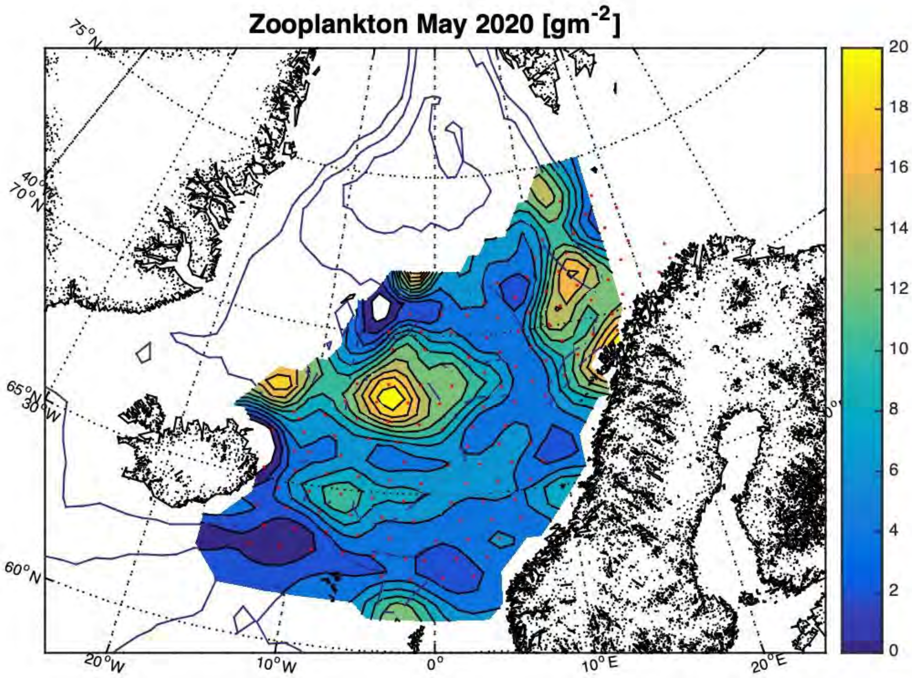


Figure 9. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May 2020.

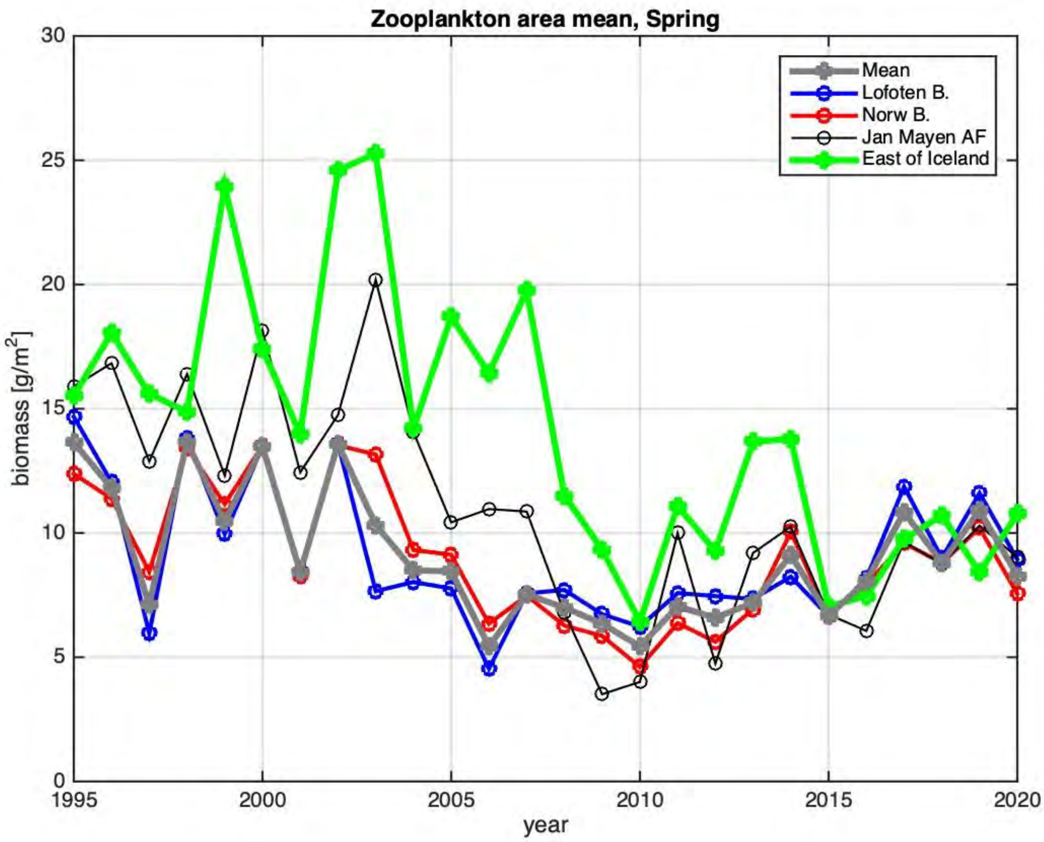
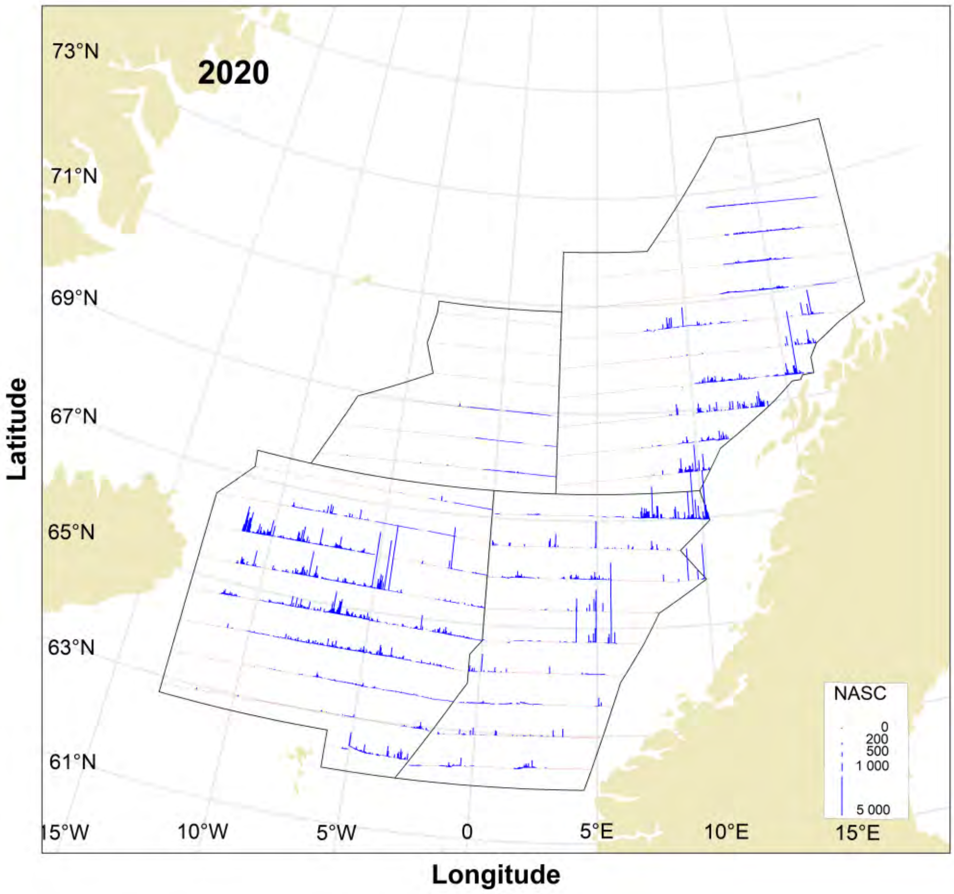


Figure 10. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1995 to 2020 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

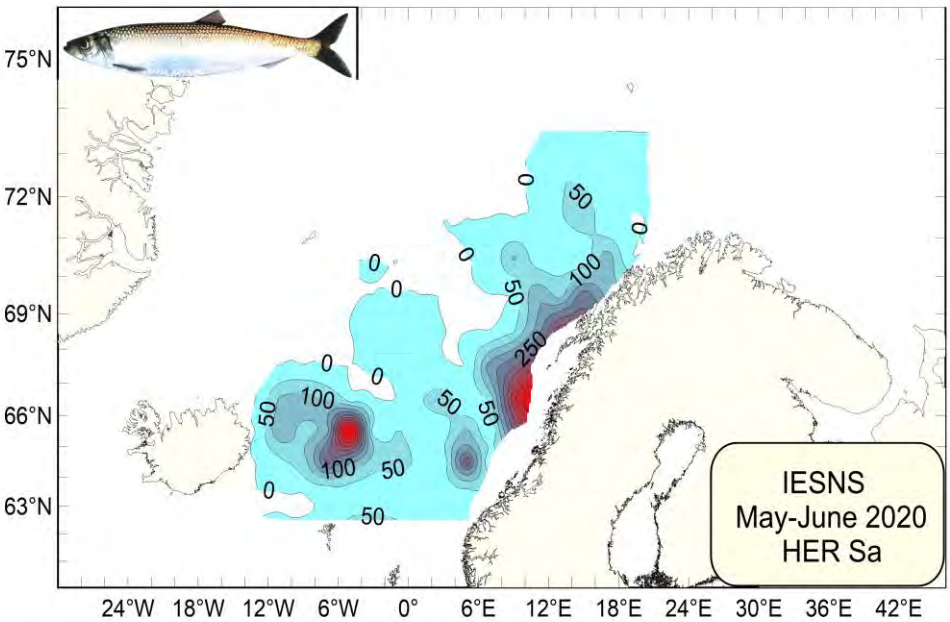


Figure 11. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2020 in terms of NASC values (m²/nm²) averaged for every 1 nautical mile and (b) represented by a contour plot.

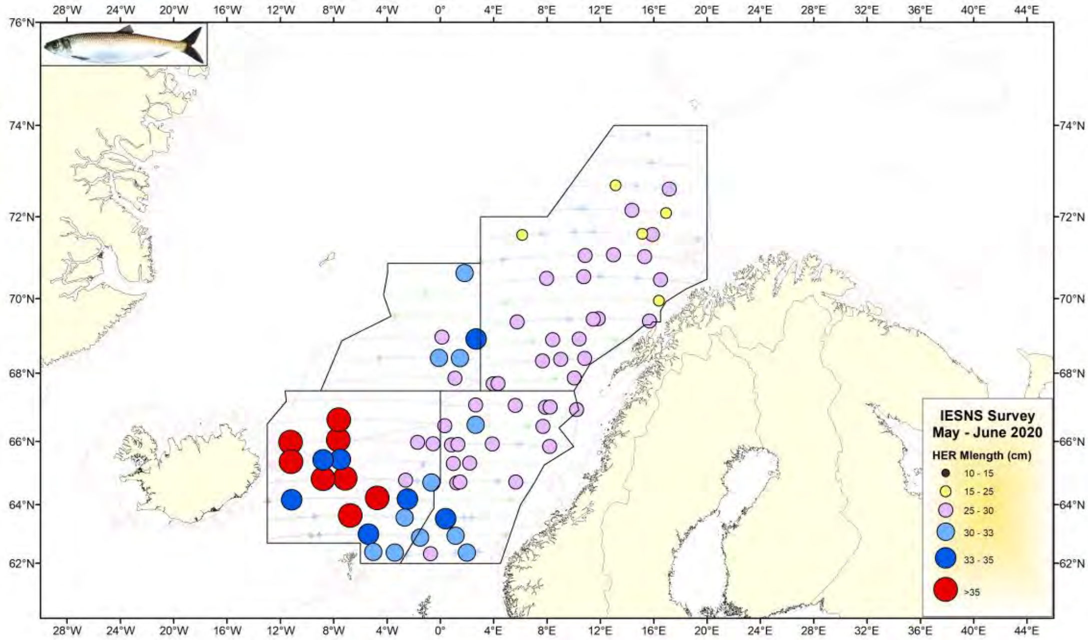


Figure 12. Mean length of Norwegian spring-spawning herring in all hauls in May 2020. The strata are shown.

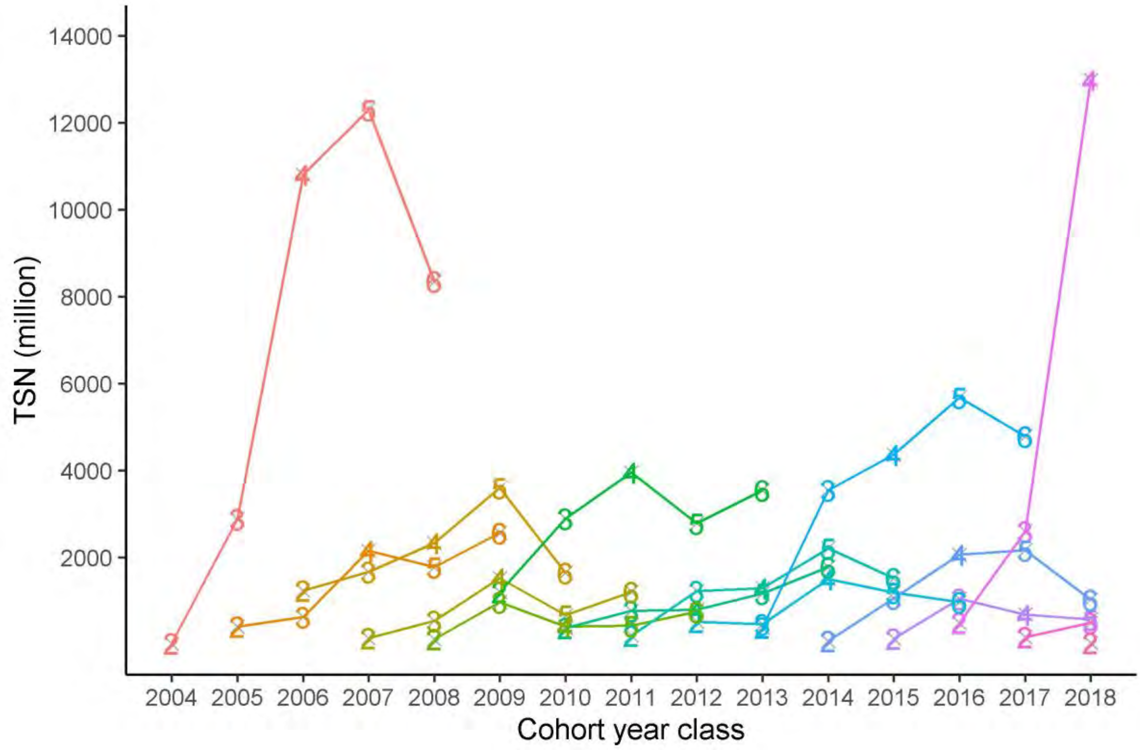


Figure 13. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

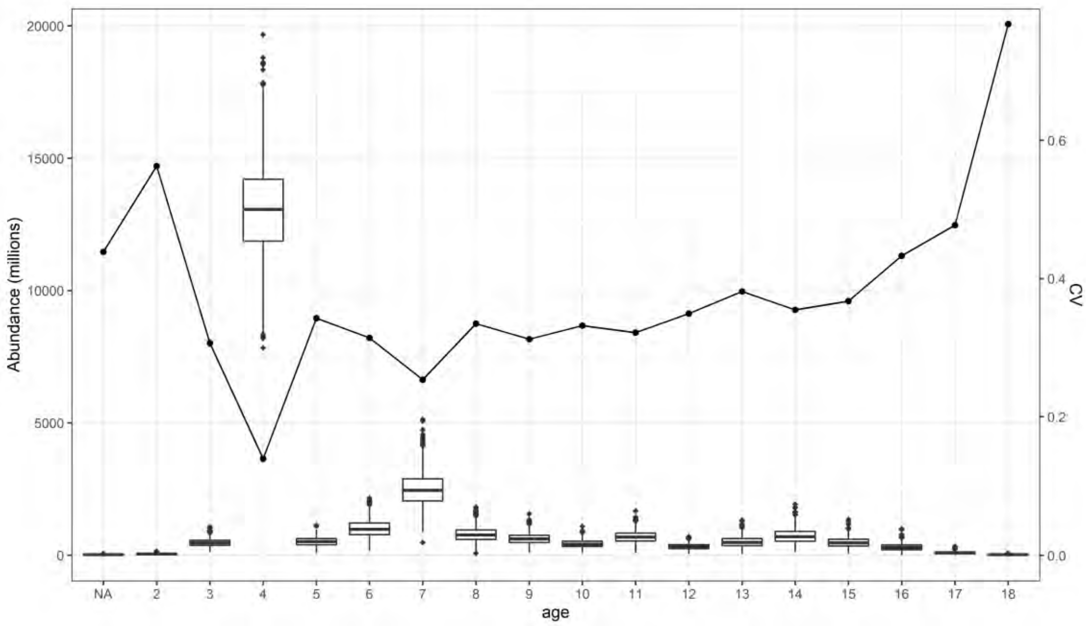


Figure 14. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

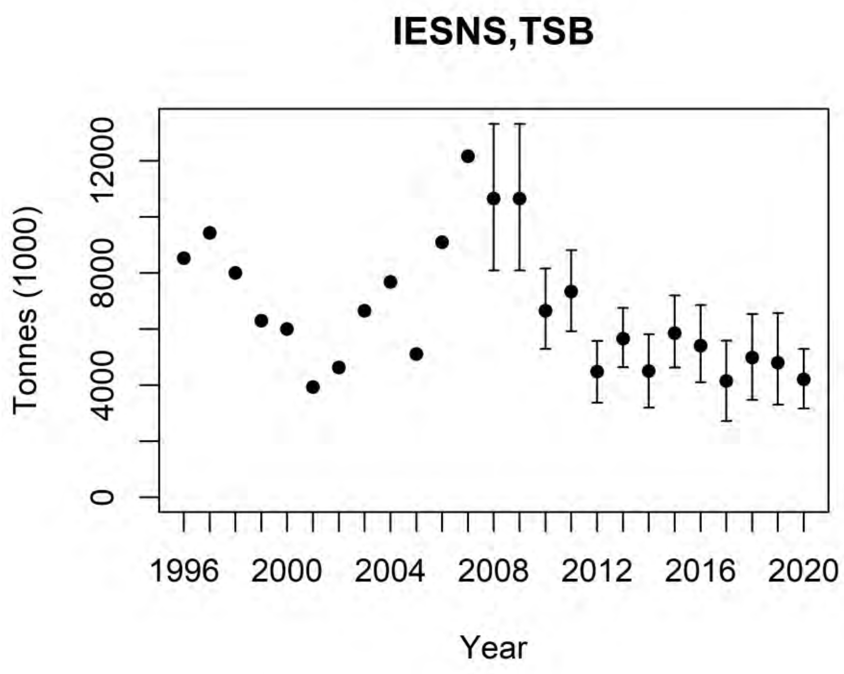
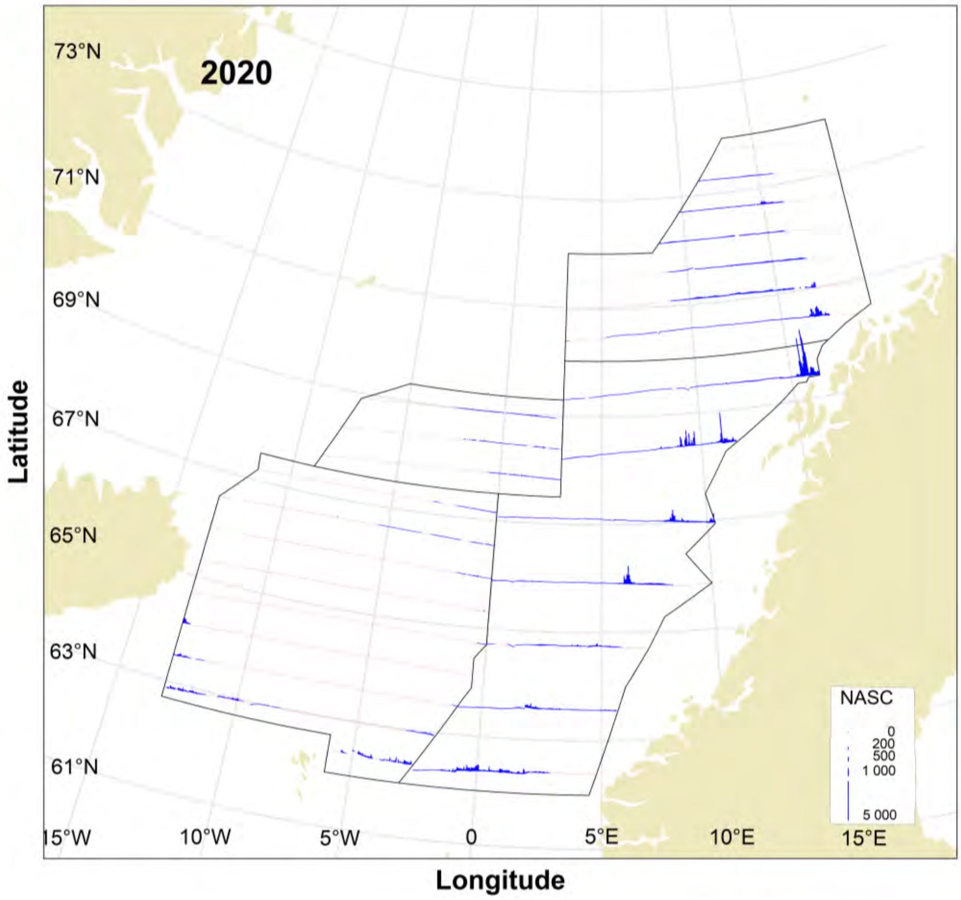


Figure 15. Biomass estimates of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2020 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2020; boostrap means with 90% confidence interval; calculated on basis of standard stratified transect design).

(a)



(b)

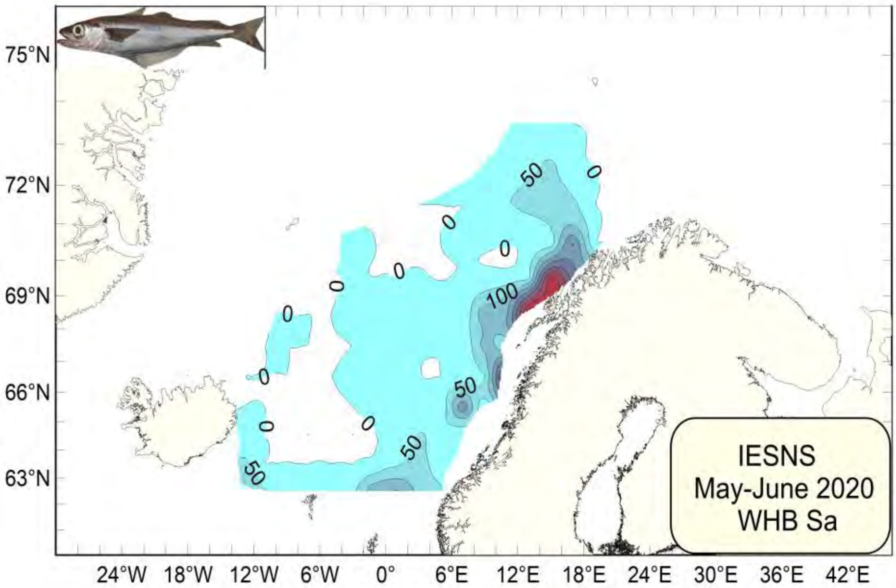


Figure 16. Distribution of blue whiting as measured during the IESNS survey in May 2020 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot.

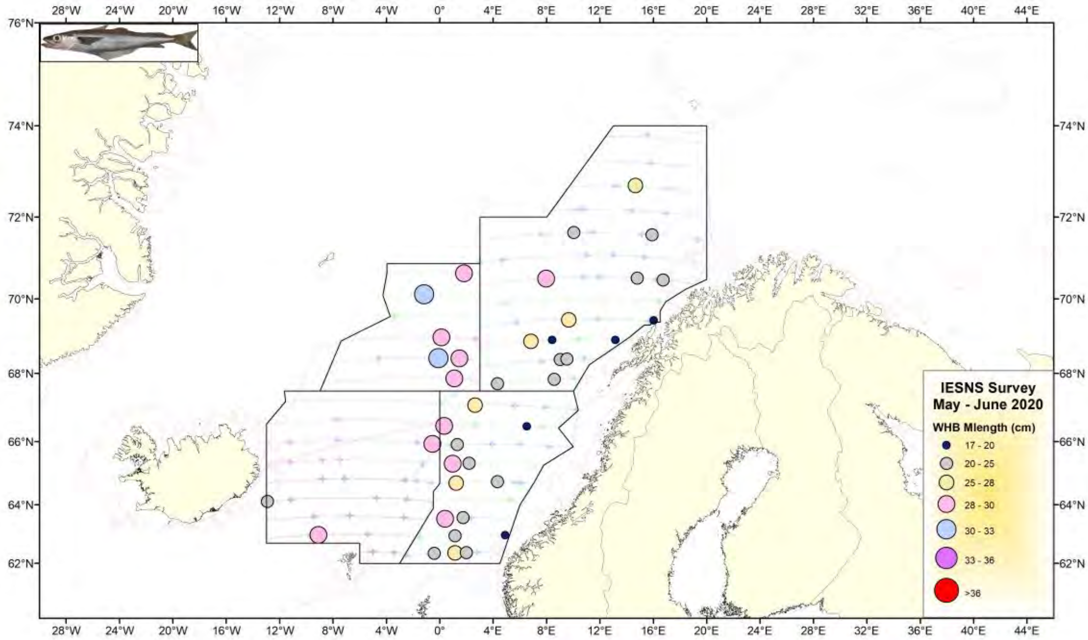


Figure 17. Mean length of blue whiting in all hauls in IESNS 2020. The strata are shown.

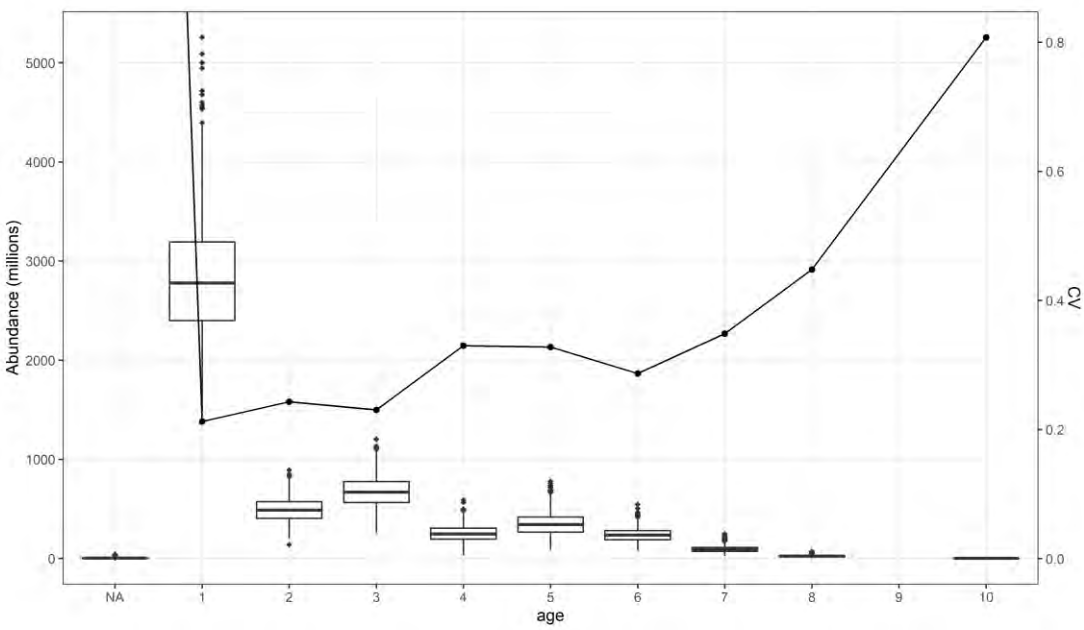


Figure 18. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

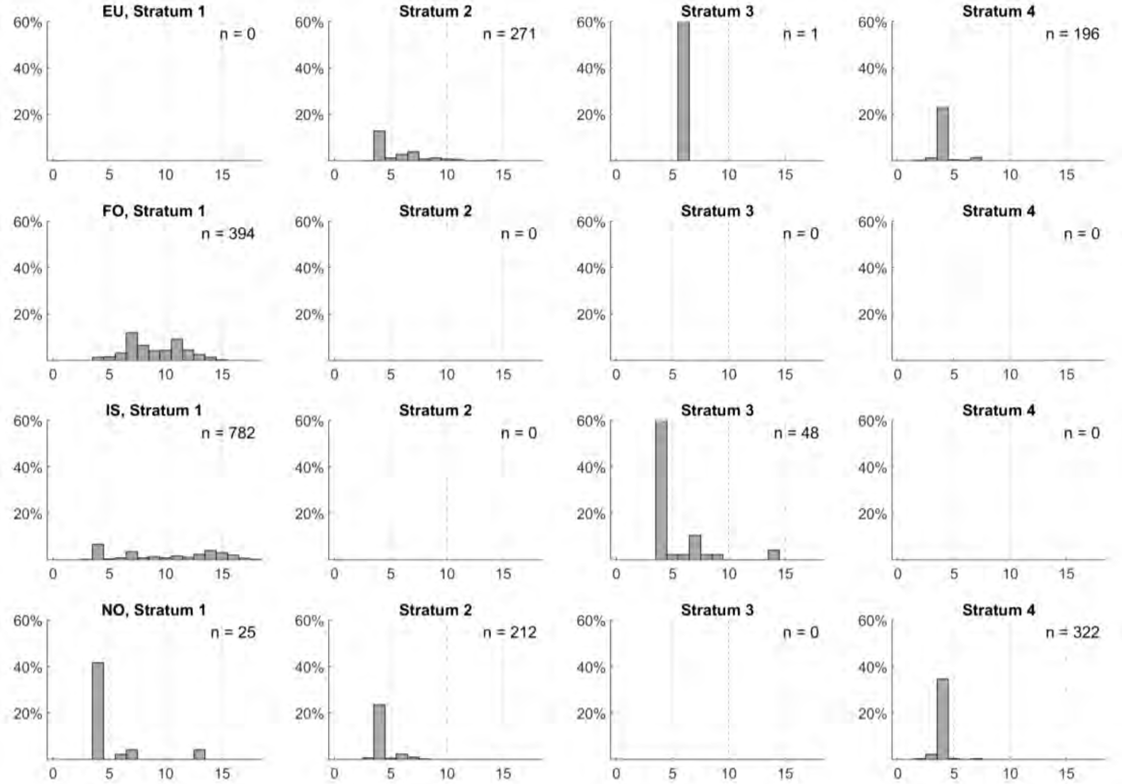


Figure 19. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2020. The strata are shown in Figure 3.

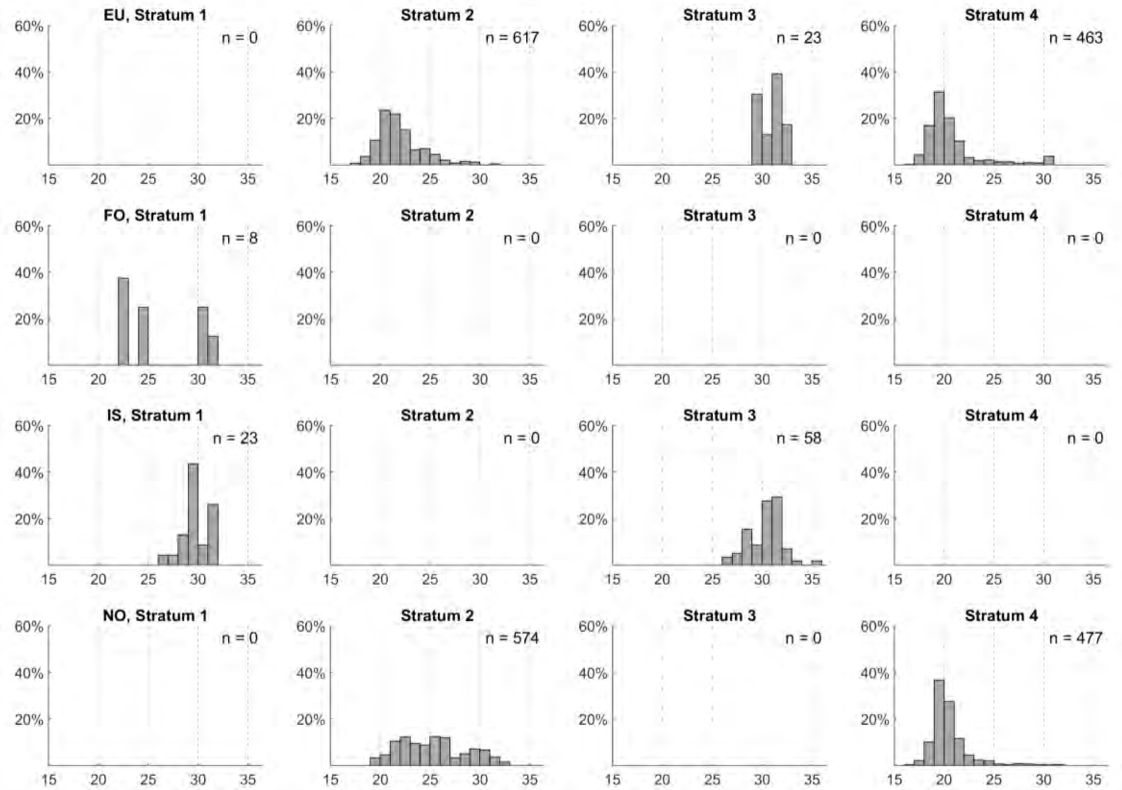


Figure 20. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2020. The strata are shown in Figure 3.

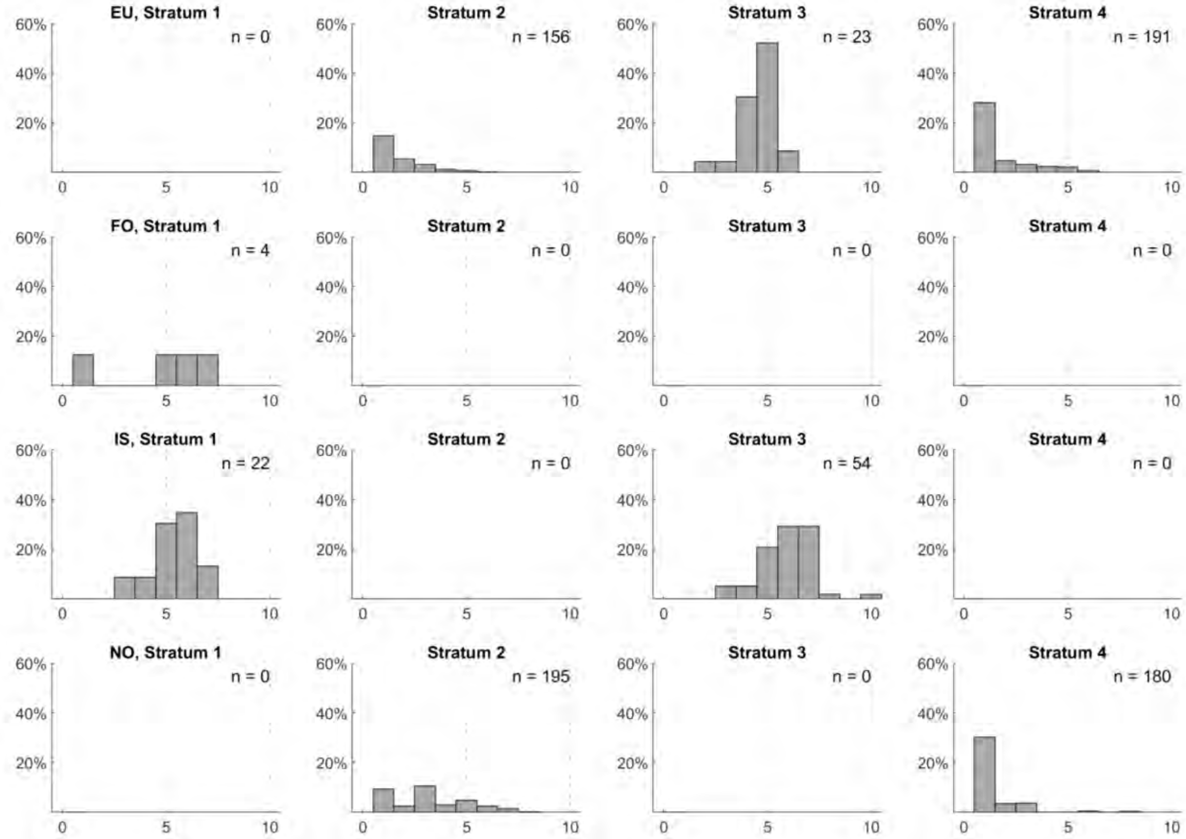


Figure 21. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2020. The strata are shown in Figure 3.

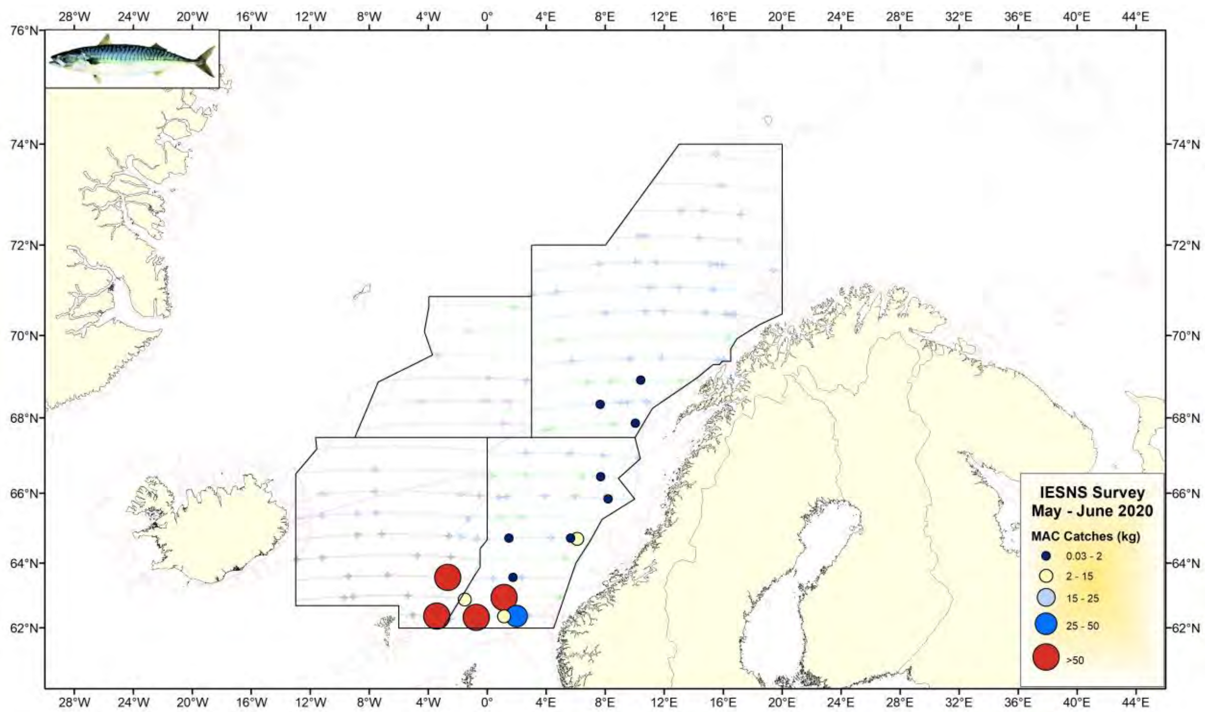


Figure 22. Pelagic trawl catches of mackerel in IESNS 2020. The strata are shown.

Appendix A

Distribution of NASC in the IESNS survey in the period 2014 – 2019.

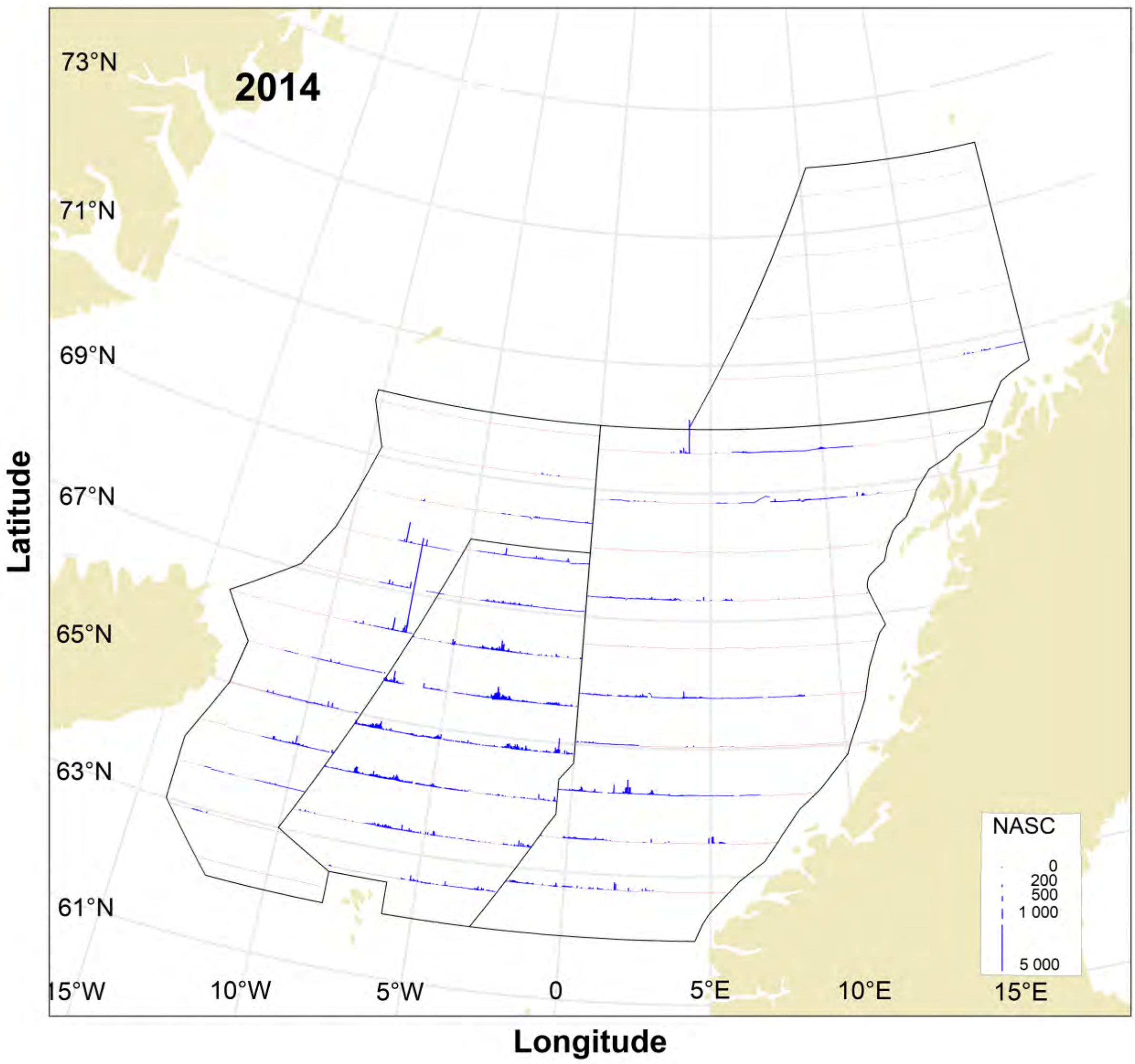


Figure A1. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2014 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

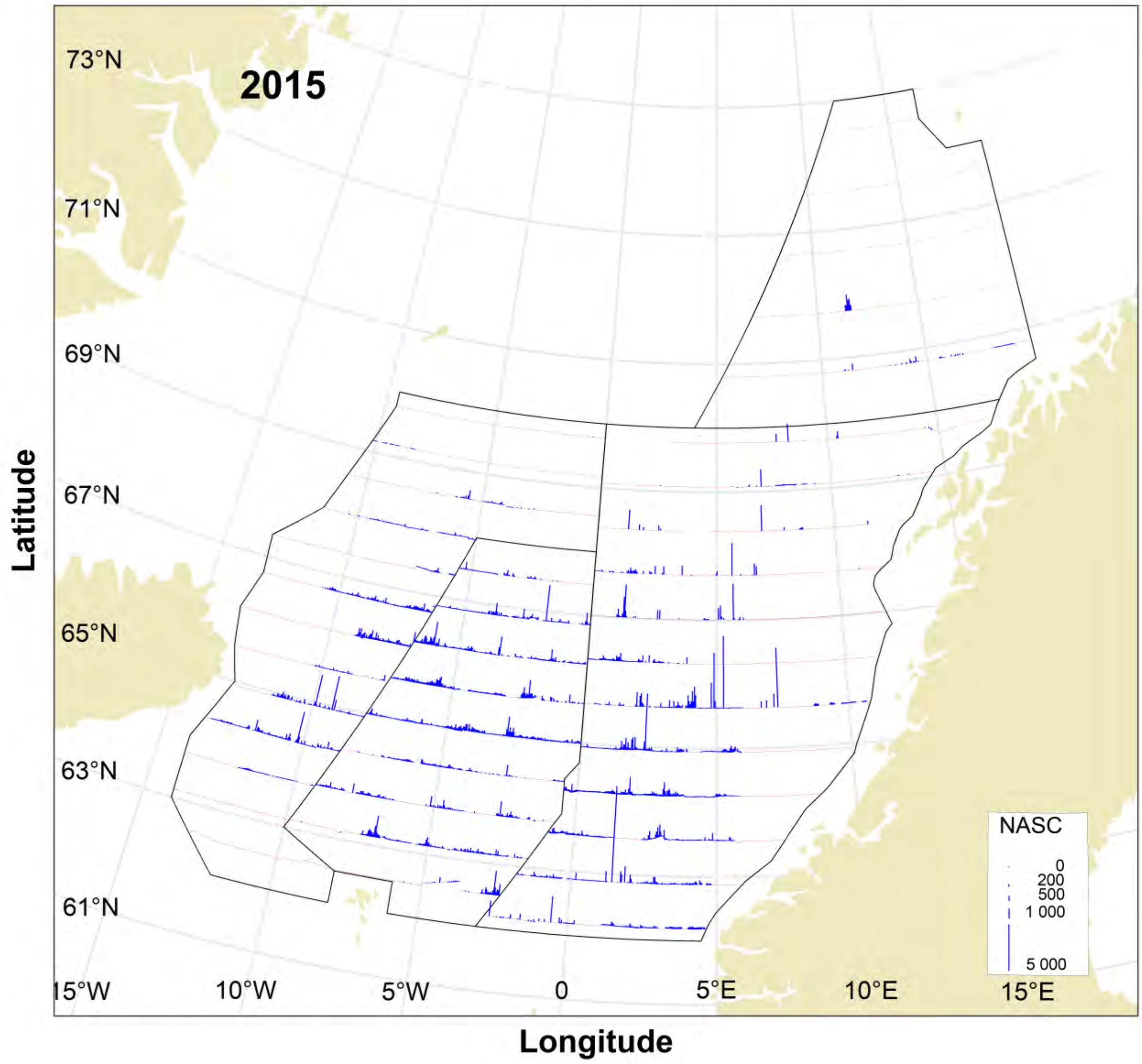


Figure A2. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2015 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

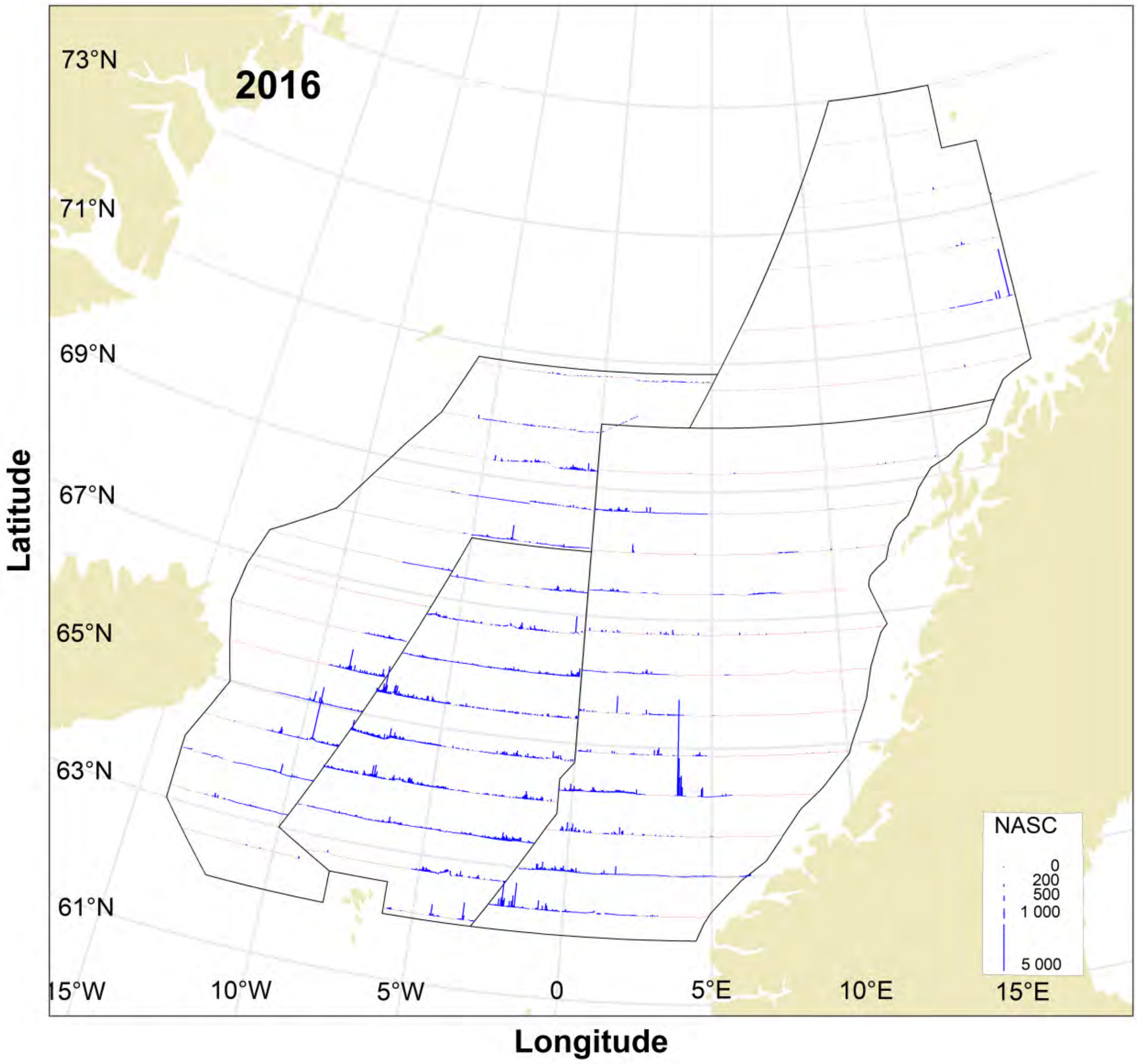


Figure A3. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2016 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

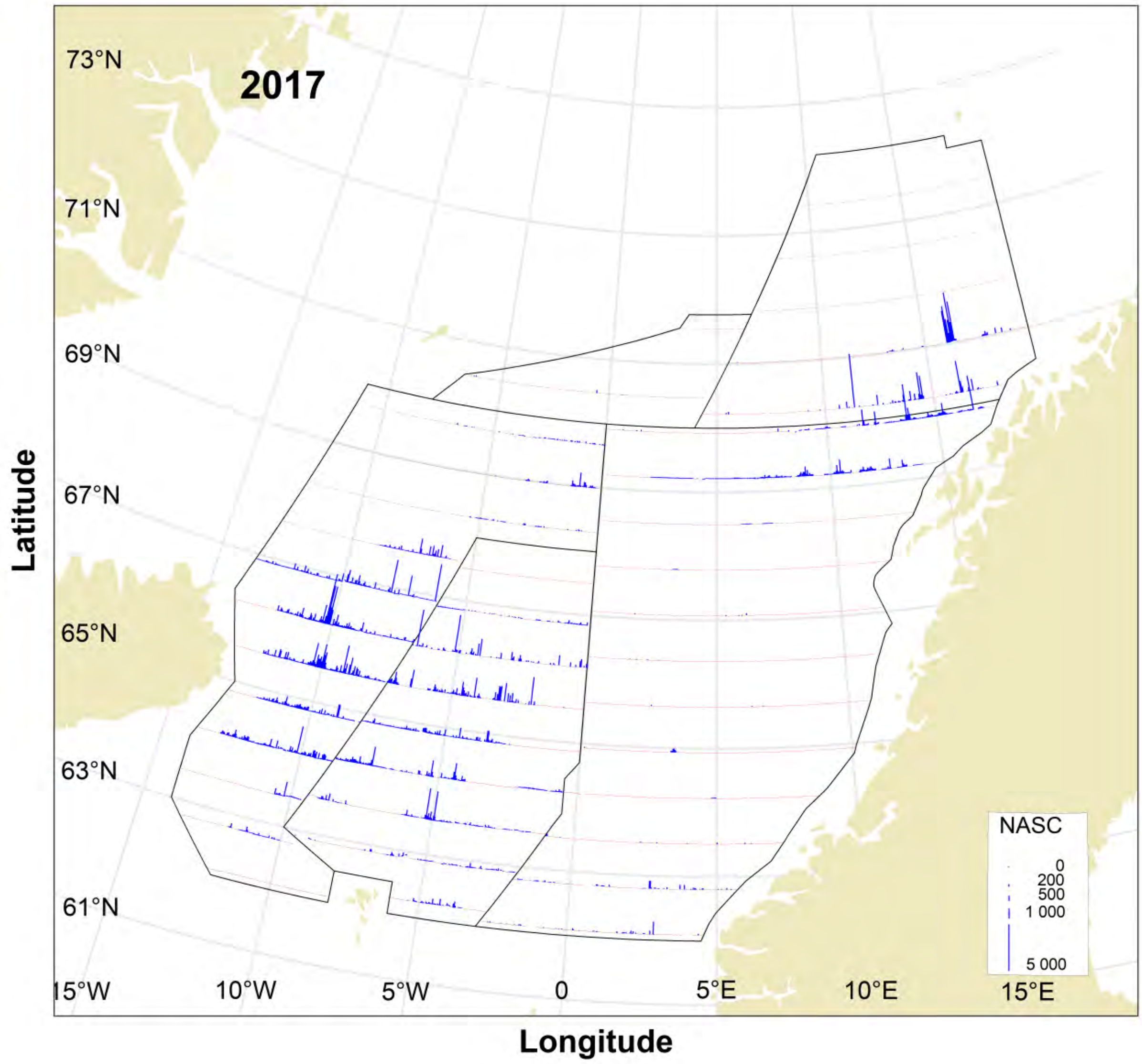


Figure A4. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2017 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

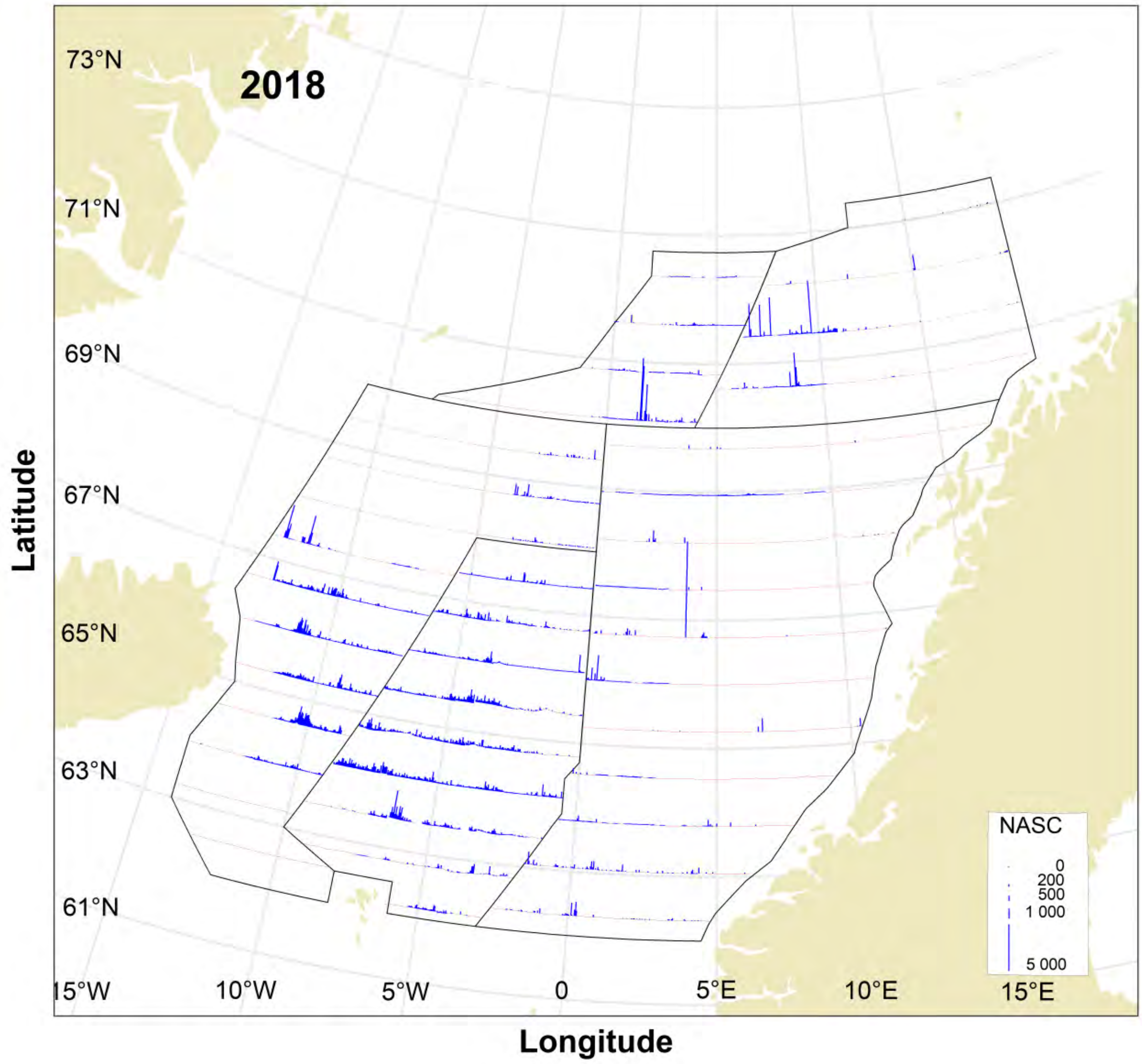


Figure A5. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2018 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

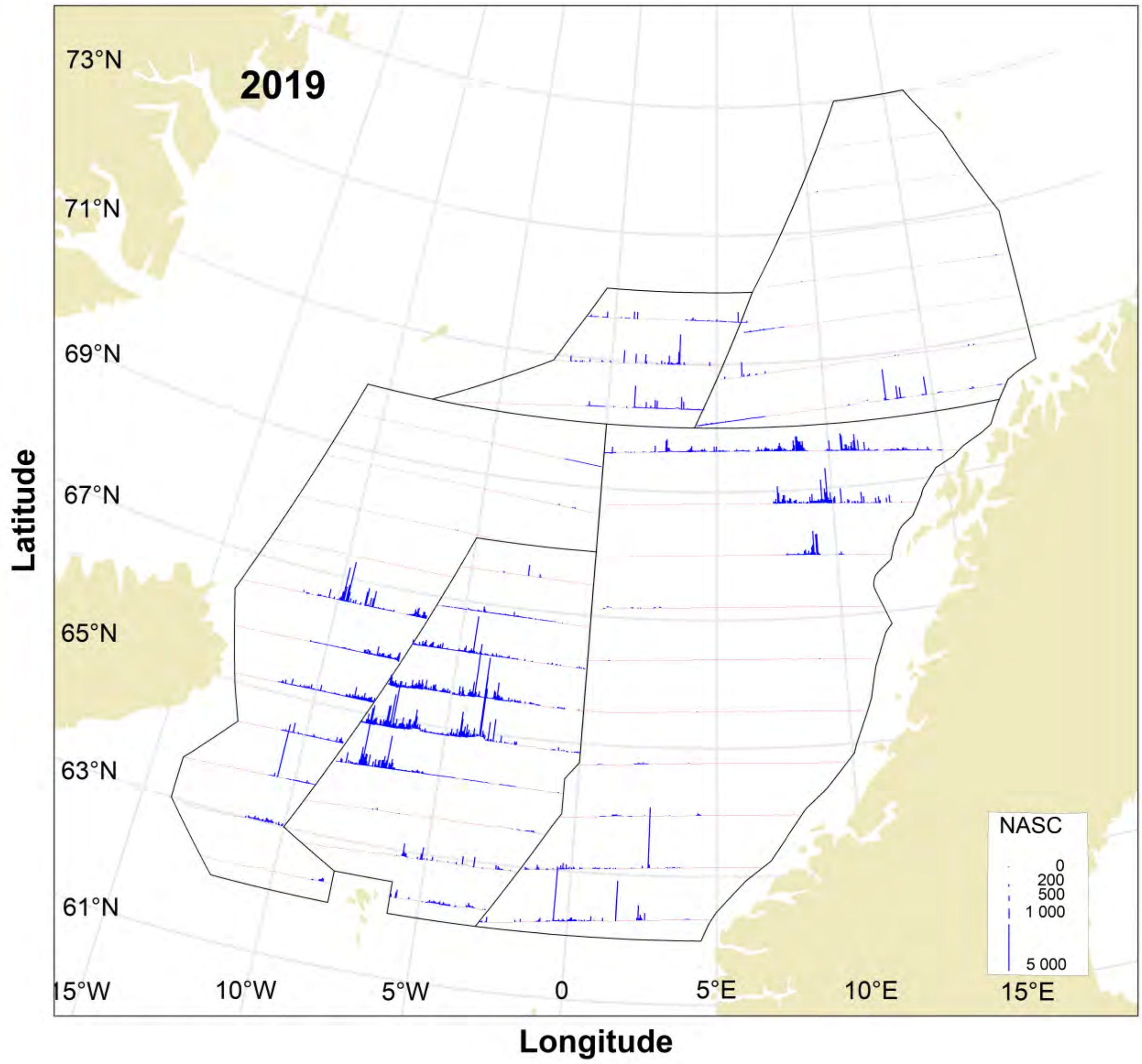


Figure A6. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2019 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile.

Appendix B

Vertical distribution of herring from omni directional fisheries sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2020

Héctor Peña
Marine ecosystem acoustic group
Institute of Marine Research, Bergen, Norway

Introduction

The biomass estimation method using hull mounted echo sounder has two sources of bias related to the collection of the acoustic backscattering of the target species: i) fish present in the echo sounder blind zone, and ii) fish avoidance to the surveying vessel. Omni directional fisheries sonars can potentially provide with data to investigate when these biases occur and its magnitude along an acoustic surveying.

Since 2017, the collection and scrutinizing of sonar data has been an additional activity in the IESNS survey carried out by the Institute of marine research. Experience gained will help to evaluate feasibility and benefits of using sonar in a routine basis during acoustic pelagic trawling surveys.

The main goal of the present study was to use the omni sonar SU90 onboard RV “G. O. Sars” to quantify the fraction of NSS herring in the upper 60 m during the IESNS survey in the Nordic sea. Sonar vertical distribution of fish abundance will be compared with the distribution from echo sounder.

Methods

Sonar set up

The horizontal beams from the sonar onboard RV “G. O. Sars” was previously calibrated prior to the survey on May 1st in Bergen bay. Calibration using a reference target was done at 26 kHz frequency, FM normal transmission mode and narrow beam. Attempt to calibrate vertical beams was unsuccessful because of high noise levels, which not allowed visualization the calibration sphere. Echoes from bottom may be the reason and in future is planned to perform calibration in deeper waters.

During the survey (1st May to 03rd June), the sonar was set up to achieve a high ping rate operating at a range of 600 m. The sonar was synchronized with the EK80 echo sounder and

MS70 scientific sonar to avoid interference, which resulted in a ping rate of the horizontal beams between 4 to 5 seconds.
A tilt of 5 deg was set for the horizontal beams with a theoretical upper depth of the beam of 8 m at 50 m range and lower depth of the beam of 90 m at the maximum operational range. Experienced showed that shallower tilt angles (i.e. 1 or 2 deg) can affect severely data acquisition, which is subject to noise produced by air bubbles swept down by waves, that in high winds (>25 knots) can reach up to 50 m below the surface. The vessel roll contained in the echo sounder data was used as an indicator of bad sonar conditions (high wind and high waves), not processing sonar data with absolute roll angles larger than 2.5 deg.
The 180° vertical beam fan was set perpendicular to the vessel track with a horizontal range of 600 m and a vertical range of 600 m.
All the sonar filters (AGC, RCG, Ping to ping) were set to the default values, except for the "Noise filter", which was disabled because it alters the values of exported raw data.

PROFOS settings
The Processing system for omni directional fisheries sonar (Profos) module of the LSSS software was used for the data replay and school segmentation. The automatic school detection functionality was used, with a posterior manual quality control of the segmented school. The segmentation settings most commonly used were: 12 dB above the background level, minimum surface of 300 m^2, maximum surface of 7000 m^2, two missing pings, at least 10 pings schools, and a ratio of 10 between length and school width. The output from LSSS contained school descriptors and vessel navigation information for each ping de the school was detected.

Vertical distribution of sonar and echo sounder
School descriptors from sonar data were used to compute the nautical area scattering coefficient (S_A, m^2 nmi^{-2}) by 1 nmi distance and depth channels of 10 m, from surface up to 60 m. Similar integration criteria was used with the echo sounder data resulted from the official survey scrutiny. Data was sorted by transects and vertical distributions of S_A were generated. A correlation analysis was done to compare the standardized NASC form sonar and echosounder by 10 m depth channels.
Because different ensonification angle of the two instruments used (vertical for echo sounder and horizontal for sonar) the S_A values are not directly comparable, and a conversion factor was used to upscale the lower sonar S_A values, and facilitate the visual comparison. The conversion factor used was 2.5. This value corresponds to the linear difference of 4 dB between the lower horizontal mean target strength compared with the mean vertical target strength.

Results

Predominant NSS herring from 2016-year class was found mostly as well defined small (ca. 10 m diameter) and medium size (ca. 100 m diameter) schools in the upper 100 m.

Conditions for sonar operation were optimal almost during the whole survey with few periods of bad weather which impeded good sonar data.

The sum of the herring NASC from 0 to 60 m depth by transects for sonar showed a similar spatial distribution as the NASC from the echo sounder from transect 1 to 8 (Figure 1). Only in the western part of transect 4, more schools were detected by the sonar. In the northern transects (9 to 12), herring was distributed disperse and not as schools or dense layers, and therefore only observed by the echo sounder. In transects with higher herring NASC values (i.e. transects 3 to 7), schools were observed in the eastern end towards the Norwegian coast.

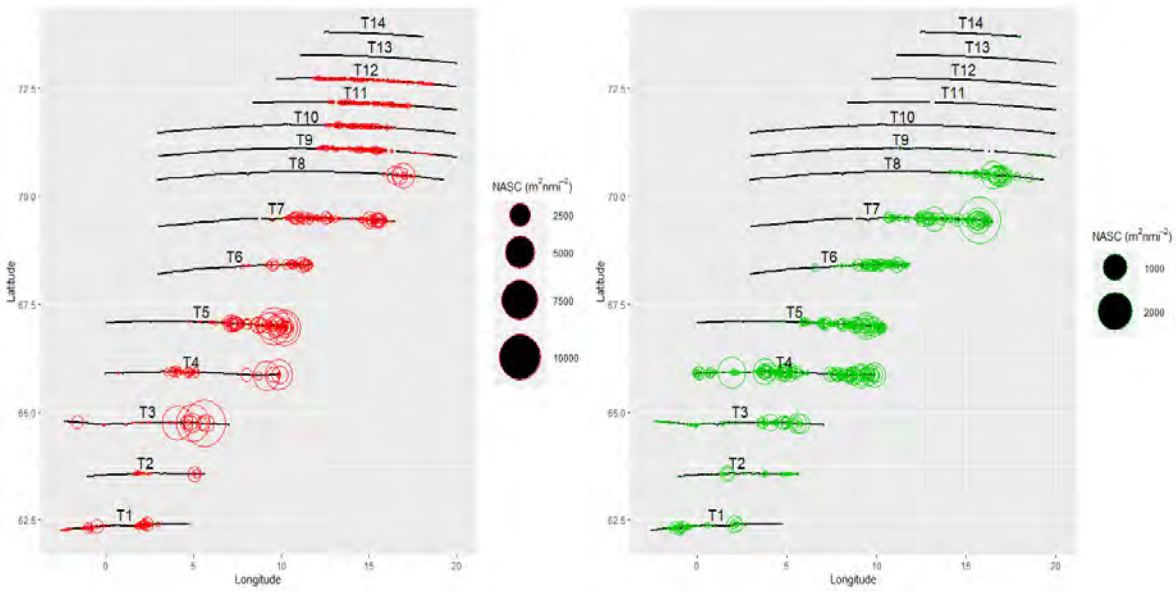


Figure 1. Herring NASC from 0 to 60 m by transects for echo sounder (left panel) and sonar (right panel).

In this region, presence of herring schools was found until the eastern border (end of transects 4 and 6, start of transect 5) of transects towards the coast, indicating that the zero line was not reached (Figure 2 and 3). Transects 4 and 5 were extended during the survey towards east from its original design, but not enough to reach areas with no herring. During surveying, sonar information was valuable to evaluate the presence of schools ahead of the vessel track, and the need to establish criteria to extend a transect (when zero line has not been reached), based in sonar observations, was suggested in the post-cruise meeting.

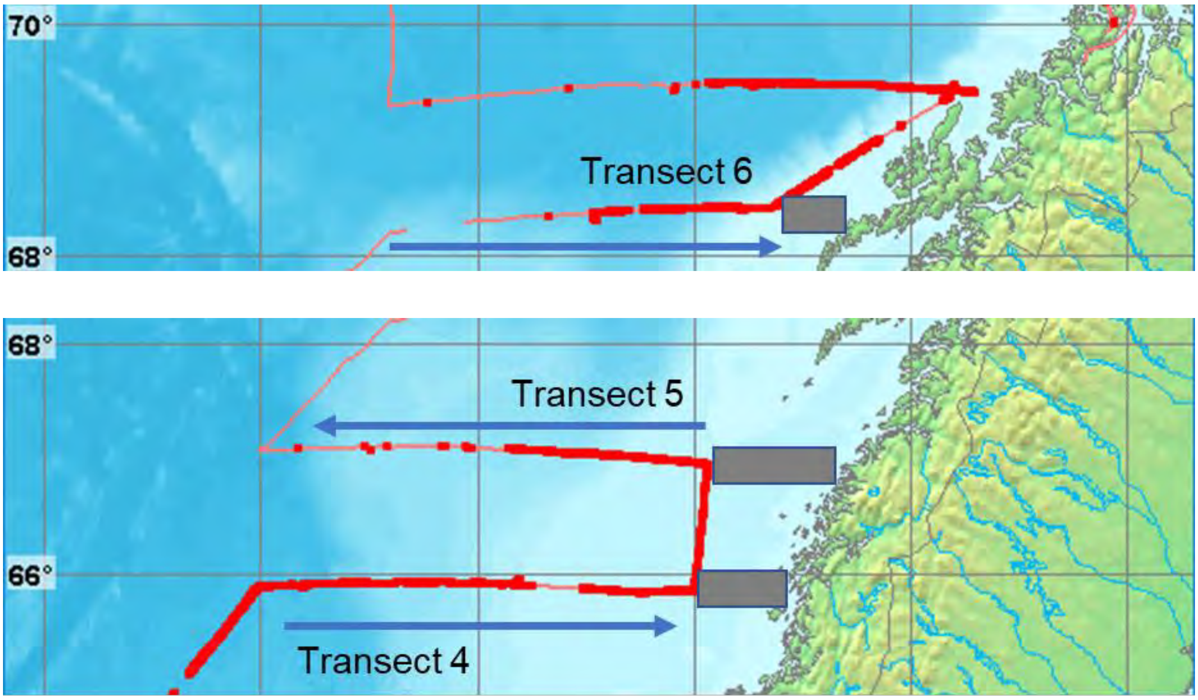


Figure 2. Detail of transects 4, 5 and 6 showing the schools detected by sonar as red dots along the survey pink line. Blue arrows indicate vessel direction and grey boxes regions towards the east that were not covered by the transects along the coast.

Examples of the different herring schools observed by echo sounder and sonar displayed in LSSS are shown in Figure 3. In general, larger schools were observed in transects 3 to 5, and smaller and denser in the region off Loffoten and Vesterålen (transects 6 to 8).

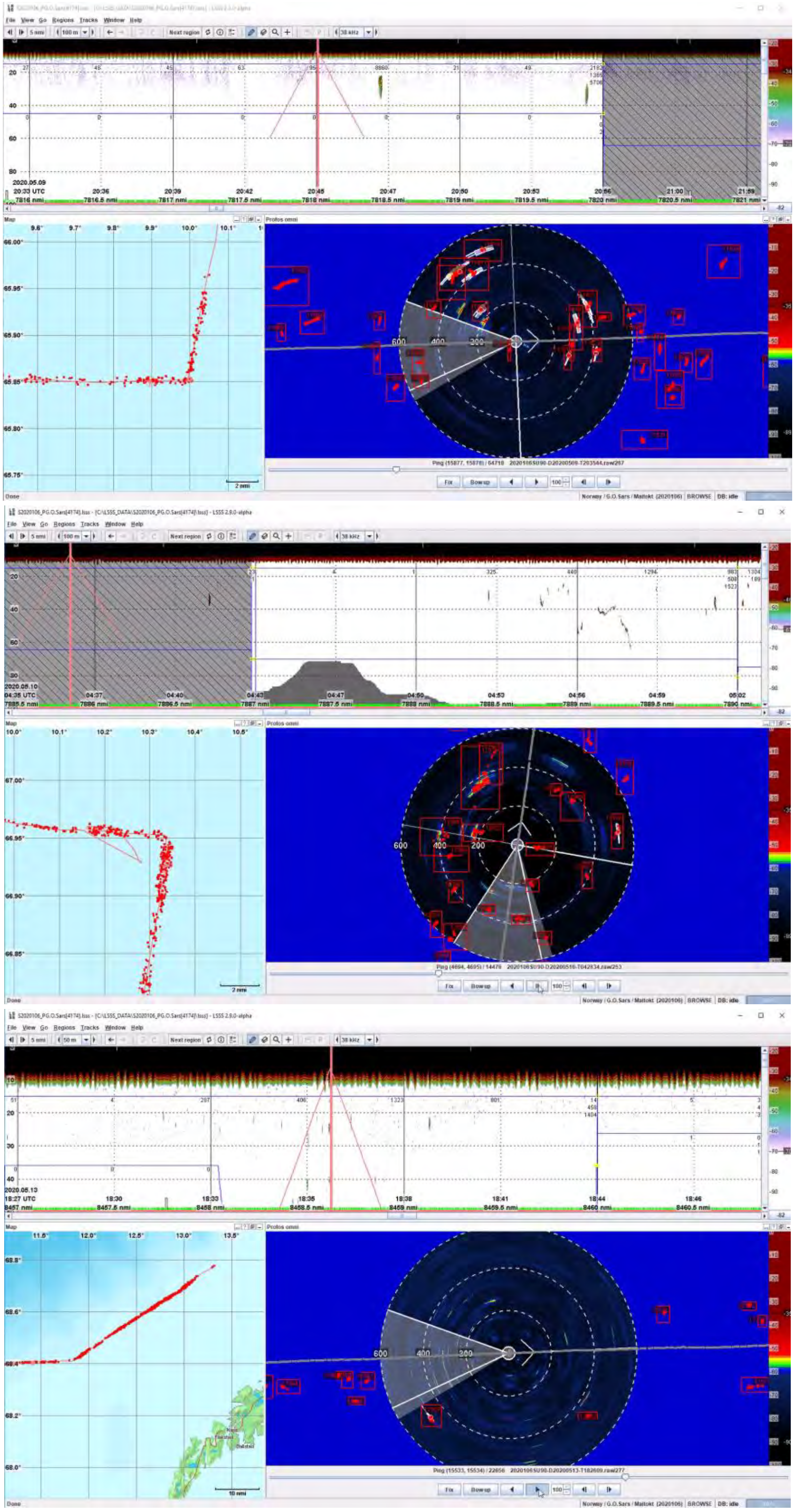


Figure 3. Image of LSSS display showing typical herring aggregations from echo sounder and sonar in transects 4 (Top), 5 (middle) and 6 (bottom). Larger and more distant schools in transect 4, smaller and more dense schools in transects 5 and 6.

No statistical differences were found between the standardized NASC by 10 m depth channels from echo sounder and sonar in any of the transects where herring was observed (*i.e.* transects 1 to 8) (Figure 4)

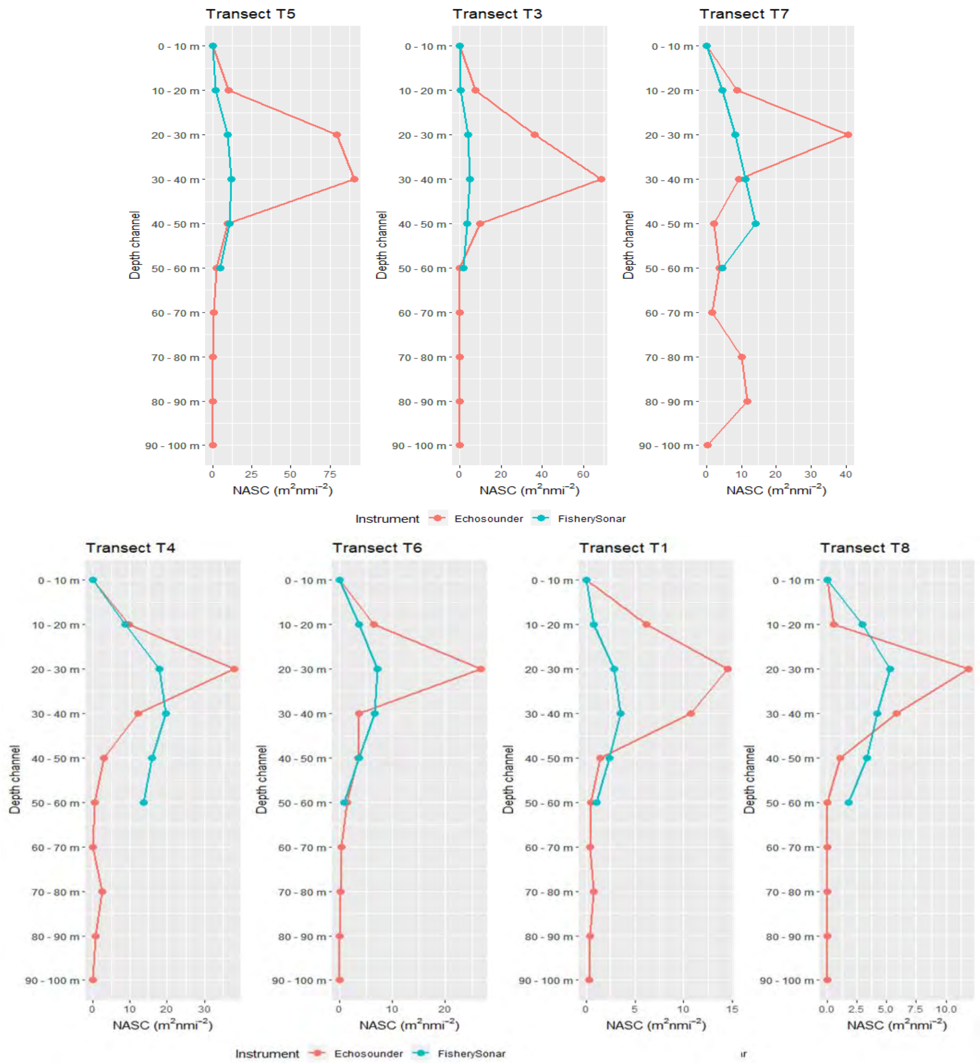


Figure 4. Vertical distribution of herring NASC values from echo sounder and sonar for transects in decreasing order of contribution of NASC from echo sounder measurements (top left to bottom right).

Discussion

NSS herring 2016-year class was predominant in the sonar measurements in the upper 60 m in the 2020 IESNS survey. Well defined schools and general good weather conditions conditioned good quality sonar data.
Abundant schools were measured with the sonar in the eastern end of transects 4 to 6, not reaching the zero line. Even though a reduced transect extension was implemented, it was not enough. The need to establish a criterion based in the sonar measurement, when these situations occurs, was indicated in the post-cruise meeting. For example, the absence of schools in the sonar for 10 nmi after the end of a transect could be a rule to decide stop surveying along that transect and continue with the next one.
The similar spatial distribution of herring from echo sounder and sonar is a good indicator that both acoustic systems are detecting the presence of herring in the layer up to 60 m depth, when herring was aggregated in schools (transect 1 to 8). In the northern area (transects 8 to 12), herring was present as disperse fish, and not detected by the sonar.
The analysis of the vertical distribution of herring between echo sounder and sonar indicate no statistical differences between distributions on depth and levels of NASC. The relative contribution of NASC by depth channels from the sonar data, don’t show higher levels in the 10 to 20 m depth, similar observed in echo sounder distribution, which indicate no bias of the echo sounder in this depth layer.
Current analysis of data series from 2017 to 2020 aim to evaluate if the current scaling factor between the sonar and echo sounder NASC is appropriate or need to be modified.
In summary, the vertical distribution of herring from sonar indicates no bias from the measurements of the echo sounder from depths from 10 to 60 m during the IESNS 2020 survey. In three transects the zero line was not reached, and a procedure to use the sonar information to avoid this problem is indicated.

Appendix C

Vertical distribution of herring from sonars during international ecosystem survey in Nordic seas (IESNS) in May 2020

Rolf Korneliussen and Arne Johannes Holmin
Research group Ecosystem acoustics
Institute of Marine Research, Norway

Introduction

The biomass estimation method using hull mounted echosounders only, have at least two sources of bias related to the collection of the acoustic backscattering of the pelagic target species: i) fish present in the echosounder blind zone close to the sea surface, and ii) fish avoidance to the surveying vessel. Horizontally oriented sonars can potentially provide data to investigate those biases.

During the last three years, the collection and scrutinizing of sonar data has been an additional activity in the IESNS survey carried out by the Institute of Marine Research (IMR). Experience gained will help to evaluate feasibility and benefits of using sonar in a routine basis during acoustic pelagic trawling surveys.

Two classes of sonars were used; an omnidirectional fisheries sonar (SU90), and a scientific matrix sonar (MS70). The SU90 sonar can be run in two modes: either by measuring in a 360 degrees dish, or in a vertical slice. The SU90 is similar to sonars common on many fishing vessels and has the advantage of being available on many fishing vessels, while MS70 is currently only available onboard RV "G.O. Sars". The MS70 points port and use a mesh containing 25 x 20 beams = 500 beams covering 60 degrees (horizontally) by 45 degrees (vertically) in. Thus, the MS70 sonar has a better spatial resolution, but a poorer horizontal coverage than SU90. MS70 provides data both at horizontal ranges from the ship and also vertically.

The main goal of the present study was to use the sonars onboard RV "G. O. Sars" to quantify the fraction of NSS herring in the upper depths of 60 m during the IESNS survey in the Nordic seas. SU90 can cover the upper 60 m, and MS70 was used to investigate the upper 200 m. The vertical distribution of fish abundance by means of SU90 and MS70 will be compared with the distribution from echo sounder. In this document we concentrate on the MS70 sonar, while the SU90 comparison is mainly covered in another document.

Methods

MS70 was calibrated at the survey operation mode with for the first time in 2019 with the highest frequency in the top fan. New integrated electronic cards were installed in MS70 in 2020, and MS70 sonar was calibrated prior to the 2020 survey.

The MS70 scientific matrix sonar

Setup

MS70 was set up to cover a horizontal distance of 250 m (i.e. range 410 m) and to ping at least every second EK80 ping (1 ping per 2 seconds). The highest frequency (112 kHz) closest to the surface with centre of beams parallel to the surface, and the lowest beams (75 kHz) was pointing 45 degrees down. The highest frequencies were used at the top to have the narrowest beams in the vertical direction in order to get as close to the surface as possible. The MS70 transducer were mounted on a protrudable instrument keel, with the centre of the transducer at 7.5 m below the sea surface.

Data preprocessing

The MS70 data were preprocessed by means of LSSS-PROMUS (Processing system for advanced multibeam sonar). A brief description of the preprocessing is as follows:

1) Spatial and temporal spikes were detected and replaced median of the surrounding data.
2) Ambient noise was estimated for each of the 500 beams and then each sample was corrected for ambient noise.
3) Data were collected to a range of 500 m. Data closer to the ship than 20 m were removed. Data at larger horizontal range from the ship than 250 m were removed.
4) Data closer to the surface than 2.5 m were removed. This implies that at least the two uppermost fans were cut at ranges where the upper edge of beam is closer to the surface than 2.5 m. The vertical extent of the fans is a source of uncertainty: we used the nominal vertical beamwidth multiplied by 1.65.
5) Data more than 200 m below the surface were removed. This implies that at least the two uppermost fans were cut at ranges where the upper edge of beam is closer to the surface than 2.5 m. The vertical extent of the fans is a source of uncertainty, but unlike the uppermost beams the lowermost beams were cut by using used the nominal vertical (i.e. the beamwidth multiplied by 1.0).
6) Data were thresholded, so that all S_v-samples weaker than -70 dB and stronger than -5 dB were removed (set to -120 dB).
7) Data were compressed by removing data where 20 samples in a row were weaker than -70 dB. This reduced the data volume by 85%.

Pre-scrutiny

School-candidates were automatically detected from preprocessed data according to specified criteria. The most important of those were:

1) The school seed-point needed to be between -30 and -60 dB.
2) The maximum grow-depth of the centre of the beam was 200 m (although the lower edge of the beam could be deeper). This means that at depths deeper than 200 m, the data are not trusthworthy.

3) The minimum grow-depth depended on the weather. It mostly varied between 2.5 and 15 m below the sea surface, but it could be as deep as 25 – 30 m.

Data interpretation (scrutiny)

The EK80 data were scrutinized by the cruise leader and the chief instrument engineer some hours after the data were collected. The MS70 data were scrutinized by a single scientist (Rolf Korneliussen). MS70-data collected after May 20 were scrutinized a few hours after the EK80 data. Data collected from May 1 were scrutinized after May 20. All scrutiny finished by the end of the survey.

No data with central axis deeper than 200 m was stored. Thus, the data deeper than 200 m is not representative

MS70 data were scrutinizing by first removing outliers of the school-candidates. Then the school-candidates were scrutinized in pretty much the same way as the EK80 data, i.e. by considering scattering strength, shape of school (in 4 dimensions), biological samples, and by conferring the results of the EK80-data scrutiny. Scrutinization of 24 hours of MS70 data took typically 20 minutes.

Data were stored in a database as volume backscattering data and were exported to files to be processed in external systems. The data were averaged to over the same distance (1 nmi) as the EK80 data, and in range-cells of 10 m, and at its native beam resolution. Thus, each database cell is an average of typically 4500 MS70-samples. Note that MS70-data and database storage cells are natively shaped as sphere-sectors, and that the data used here are converted to cartesian coordinates.

Scrutinization of the fishery sonar and MS70 sonar differ from that of the echosounder in that they consider schools of a minimum volume 250 m^3. This represents a potential source of bias in the comparison between the instruments, as a layer of small schools or individual fish can contribute significantly to the echosounder NASC while being excluded from the sonar NASC.

Results

Figure 1 shows the 2020106 survey. The cruise started in south. After the “official” cruise tracks shown, there was additional triangular shaped cruise-lines in north-west (not shown).

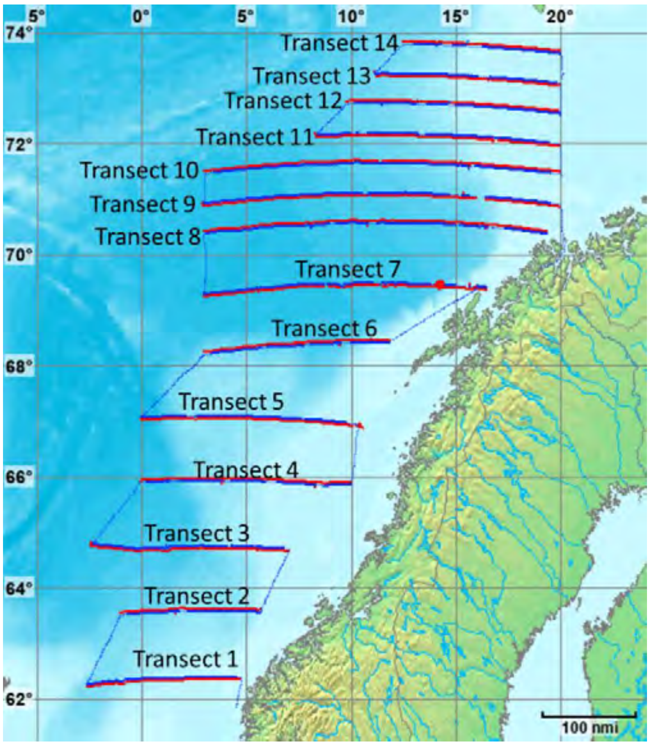


Figure 1. Cruise tracks of survey 2020106. Transects started in south and ended in north.

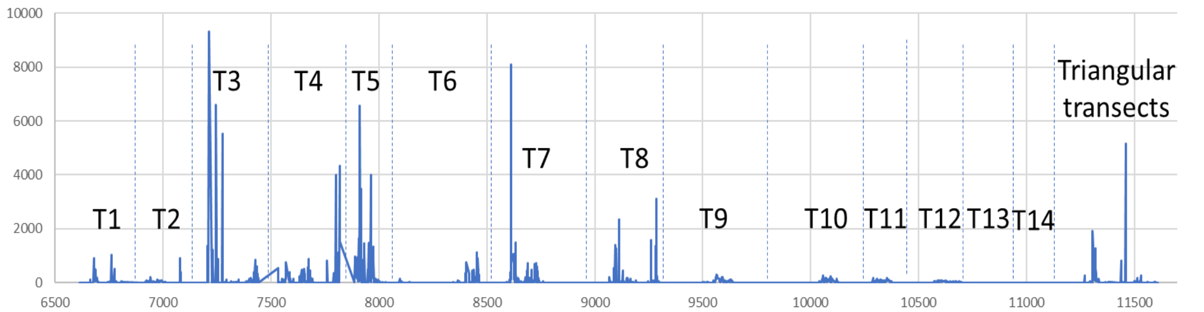


Figure 2. Herring scrutinized on survey 2020106, 38 kHz CW EK80 data. Transects are named "Transect N" or TN. After Transect 14, there were some triangular shaped cruise lines that was not a part of the official survey.

Comparison between echosounder and sonar cannot be done directly as the database contains NASC for the echosounder and s_V for the sonars. $s_V = 4\pi 1852^2 s_v$, so the difference between NASC = s_A and s_V is multiplication by the vertical extent of the depth channel, which in this case is 10 m for the EK80 data. Furthermore, the frequencies of the sonar MS70 is 75 – 112 kHz, i.e. approximately 90 kHz on average, while it is 38 kHz for EK80. For herring, measured frequency response measured by means of echosounder data indicate that NAASC is approximately 50% stronger at 38 kHz than at 90 kHz. In addition to this, dorsal tilt distribution is much smaller than the horizontal direction. Theoretical estimations indicate approximately 4.5 dB difference between herring measured dorsally and horizontally at the same frequency. Thus, the frequency and horizontal measurements is expected to be approximately a factor 4 ($2.8 \times 1.5 = 4.2 \approx 4$) weaker. In total, the s_V measured horizontally at 90 kHz by MS70 needs to be multiplied by (approximately) 10 (m) x 4 = 40. Figure 3 shows vertical distribution from the 2020 survey, and Figure 4 similar vertical distributions from three selected transects of the 2019 survey for comparison.

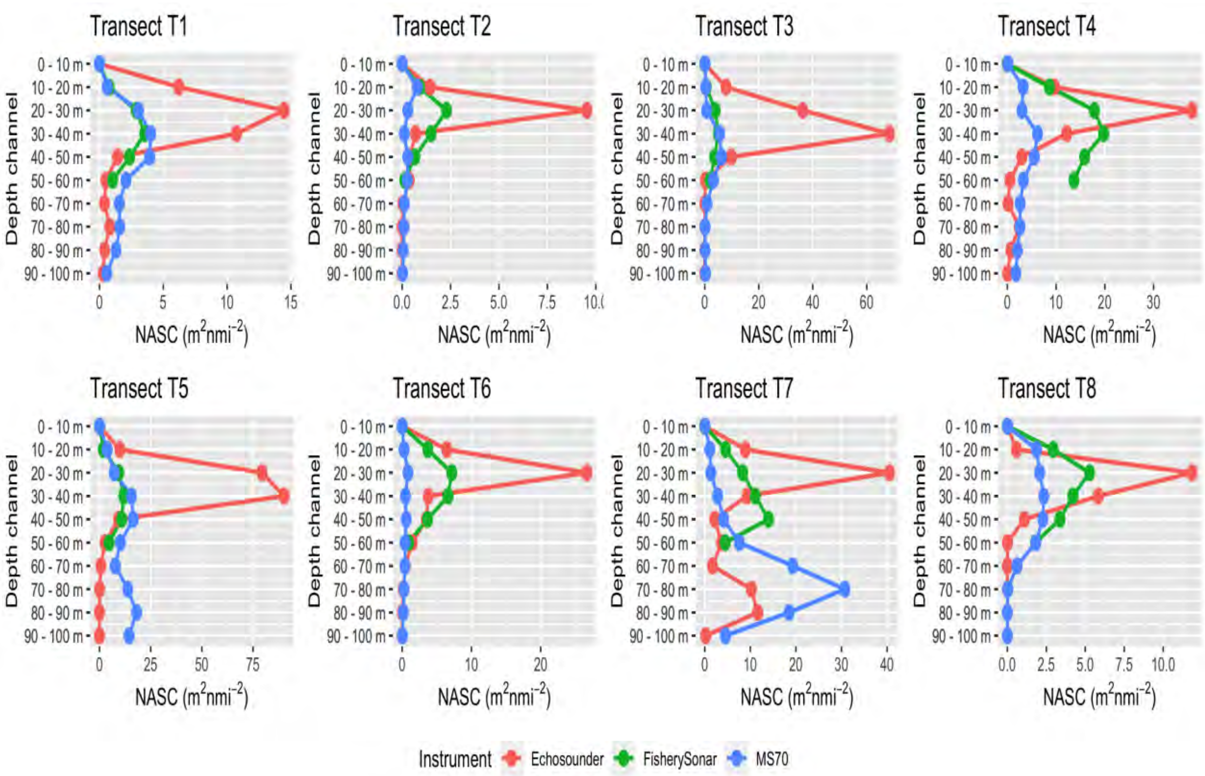


Figure 3. Vertical distribution of Transects T1 – T8 from the 2020106 Norwegian Sea ecosystem survey for echosounder (EK80 - red), fishery sonar (SU90 – green), matrix sonar (MS70 – blue).

Figure 2 was used to select transect with large herring abundance. Figure 4 shows the vertical distribution from surface down to 200 m depth. The horizontal distance from the ship is 50 – 200 m. The integrated acoustic abundance (integral under the curves) are not very different, but MS70 finds most of the abundance deeper than the EK80. This is somewhat surprising as the MS70 is designed to detect schools all the way up to the surface.

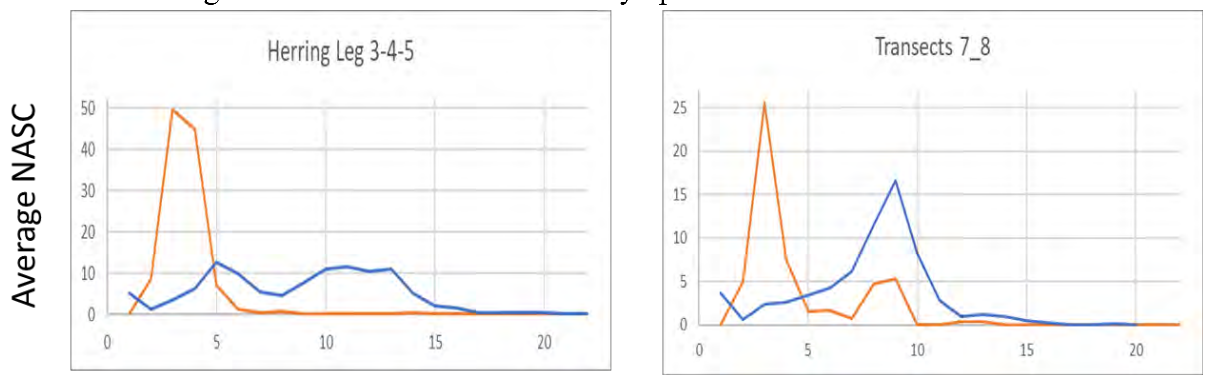


Figure 4. Survey 2020106. Vertical distribution of herring NASC values from echo sounder (red) and MS70 sonar (blue) for transects 3-5 (left panel), 7-8 (right panel). Depth channel 1 (horizontal axis) is 0 – 10 m below sea surface, depth channel 2 is 10 – 20 m (and so on). The MS70 data is based on data from 50 m – 200 m horizontally from the ship, and down to 200 m depth (centre beam).

As a reminder from previous Ecosystem surveys from the Norwegian Sea, Figure 5 shows the vertical distribution from 3 selected transects, and Figure 6 visualize an image from MS70. Figures 5 and 6 shows that MS70 should be able to see schools of fish close to the surface. As shown in Figure 5 (2019 survey), the surface noise on the MS70 sonar propagates below 20 m depth in transect S2019107-T10 (red layer in the lower panel, frame "MS70-Phantom"), intersecting with the large peak in the vertical distribution of the echosounder. In transect S2019107-T8 the surface noise is negligible.

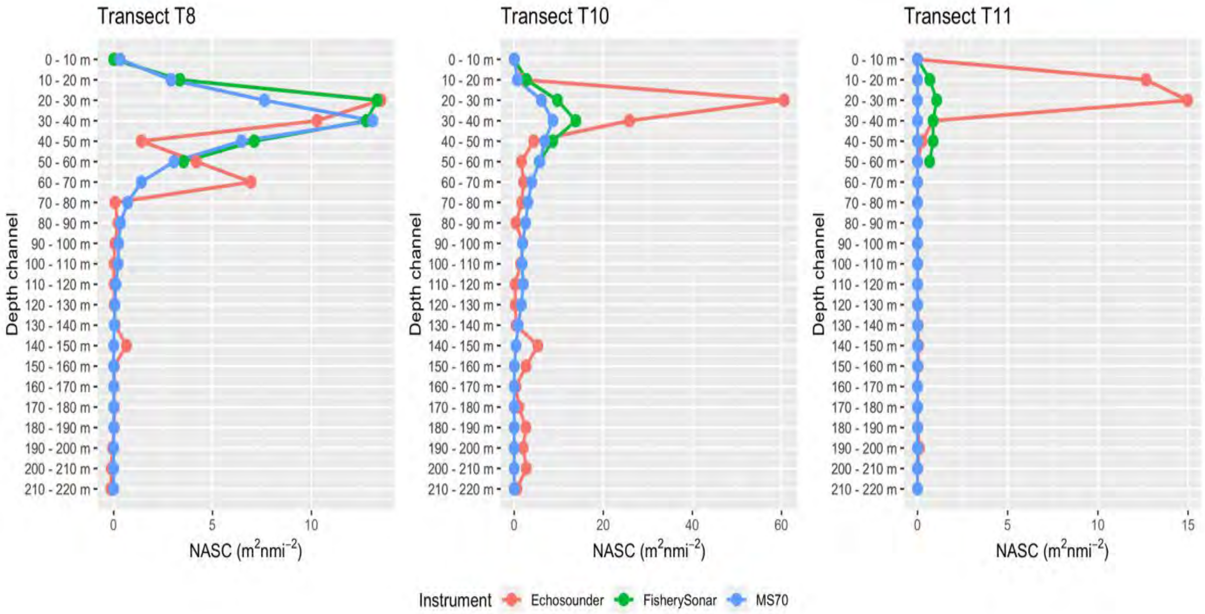
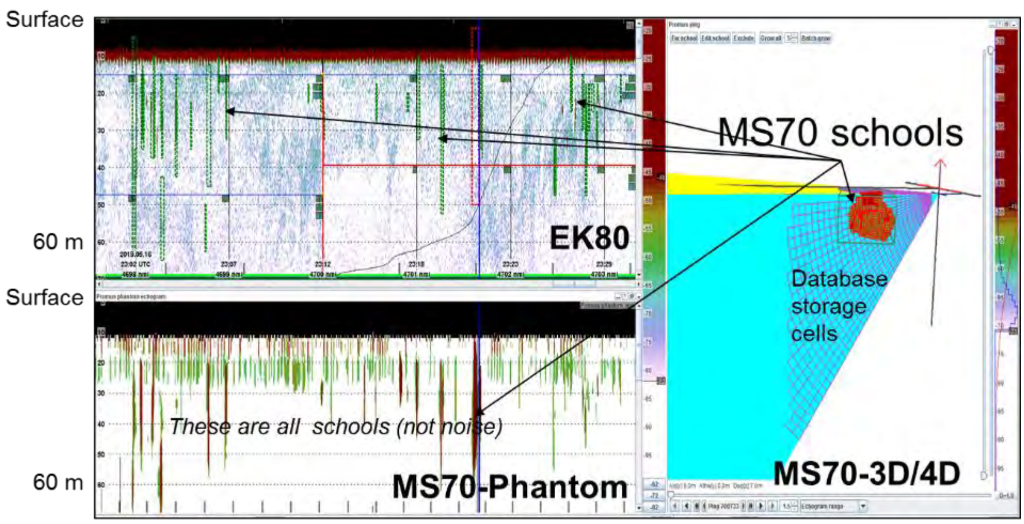


Figure 4. Survey 2019107. Vertical distribution of herring NASC values from echo sounder (red), fishery sonar (green) and MS70 sonar (blue) for transects 8 (left panel), 10 (middle panel), 11 (right panel).



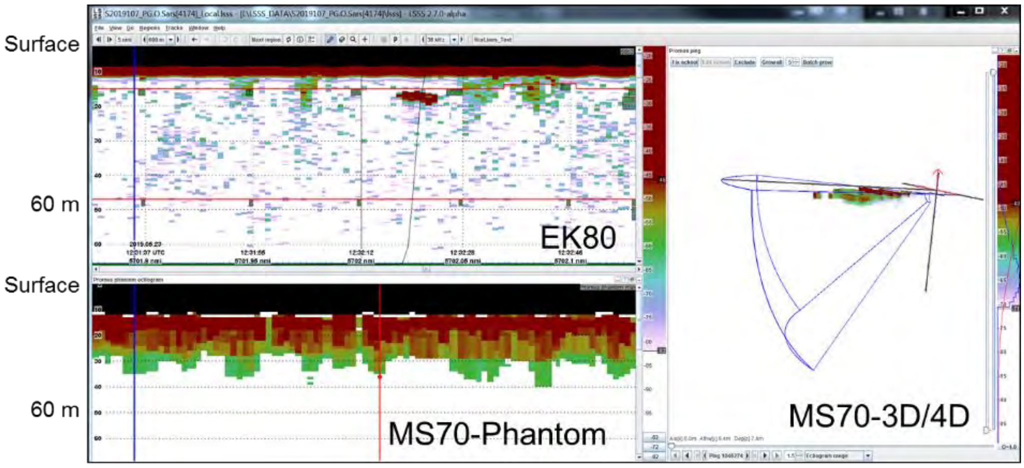


Figure 5. From survey S2019106. Screen dump from the Large Scale Survey System (LSSS), showing echosounder echogram (upper left frame), MS70 phantom echogram (lower left frame) and 3-D view of the MS70 sonar (right frame) of transect T8 (upper panel) and T10 (lower panel). In T8 there were some schools found in EK80, and many in MS70 (some "onto" the surface). In T10, the weather was bad, so the upper school detection depth was 20m. In T10, the weather was very bad, which explains very few detections of MS70.

Discussion

The vertical distribution from echosounder and the fishery sonar and MS70 sonar showed discrepancies in the level depending on the transects. On average the sonars fail to return a peak at the same level as the echosounder. This discrepancy illustrates a fundamental issue with sonar data, which is related to the width of the sonar beams. When observing a near surface school, separation of school and surface noise can be challenging, which could result in exclusion of these schools from the vertical distribution

The sonar data were scrutinized in terms of schools of a required size. The echosounder data can in contrast include all data down to single targets, as long as the data are categorized in acoustic categories representing species. If there are aggregations of individual fish and small schools at certain depths, this difference in post-processing can lead to bias in the vertical distribution from the sonars. This can in particular be a problem close to the surface, where small schools are more likely to be excluded from the sonar scrutinization than larger schools.

The vertical distribution from the echosounder did not show any strong signs of avoidance to the vessel in this survey, with a peak in the vertical distribution starting at 10 m depth and reaching a maximum in the interval 20 to 30 m depth. As such, these data serve as a useful example to comparing vertical distribution from the different instruments, as the avoidance, which is generally unknown, will not affect the comparison. Given that the echosounder performs equally well or better than the sonars as indicator of biomass in the upper 30 meters, there is no strong cause for using sonar to assist the survey estimation. Note, however, that the school depths found by the sonars are estimated from the centre of the beam. Although this is a good estimate of depth for most beams, it also prevents registering schools at the shallowest depths. For MS70, the two uppermost beams were cut at some range, so that a school on the surface 150 m from the transducer would be registered at 20 m depth. Results from calmer weather during this survey showed that MS70 could in fact measure schools onto the surface. Thus, methods to visualize shallow schools need to be developed.

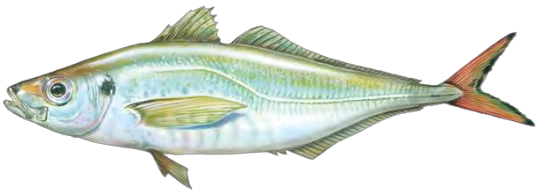
The methods presented in this study for estimating vertical distribution from sonars can be applied to other surveys where reactions to the research vessel may be stronger than in the IESNS survey from 2019 used in this study. In calm weather the sonars appear to compare well to the echosounder in terms of vertical distribution. In rough weather scrutinization of sonar can however be challenging, and further development should focus on improving separation of fish and noise in these conditions.

Difference in scrutiny of EK80 and MS70

Is the difference in depth distribution close to the surface measured with EK80 and MS70 be due to how data are scrutinized or the ability to measure, or is there maybe another reason? Is the difference in depth distribution at depths 50 – 100 m as measured with EK80 and MS70 due to how data are scrutinized or the ability to measure? These are not easy questions to answer.

1) The EK80 data were scrutinized by the cruise-leader and the instrument engineer close to the time of data collection, all in accordance with procedure for interpreting acoustic data.
2) The MS70 data were scrutinized by one scientist. From May 20, the data were scrutinized shortly after collection, while data prior to May 20 were scrutinized after May 20.
3) Candidates for schools measured by means of MS70 was automatic detected. There were a set of criteria for detection of schools, e.g. a minimum size of schools. The data were inspected by the scrutinizer. Herring was expected to dominate the abundance of schools at shallow depths, and down to 200 m. A criterium for allocating acoustic values to herring was scattering strength, but it turned out to be surprisingly difficult to identify which schools were herring, from what was thought to be likely zooplankton. The sonar does not measure relative frequency response.
4) The EK80 data close to the surface were to a large extent layers, i.e. not schools. They were not seen clearly on the echogram but were still interpreted to be herring due to catches.
5) Catches could be directed by EK80, but in practice not by MS70.

Population structure of the Atlantic horse mackerel (*Trachurus trachurus*) revealed by whole-genome sequencing



A report prepared for the members of the

Northern Pelagic Working Group

and

the Pelagic Advisory Council

by

Angela P. Fuentes-Pardo, Mats Pettersson, C. Grace Sprehn, Leif Andersson

Uppsala University, Sweden

&

Edward Farrell

EDF Scientific Limited, Ireland

July 2020

Executive Summary

The Atlantic horse mackerel, *Trachurus trachurus* (Linnaeus, 1758) is a species of jack mackerel distributed in the East Atlantic, from Norway to west Africa and the Mediterranean Sea. It is a pelagic shoaling species found on the continental shelf and it is one of the most widely distributed species in shelf waters in the northeast Atlantic, where it is targeted in pelagic fisheries. In the northeast Atlantic region, the species is assessed and managed as three stocks: the Western, the North Sea and the Southern. Despite the commercial importance of the horse mackerel, the accuracy of alignment of these stock divisions with biological units is still uncertain.

The aims of this study were to identify informative genetic markers for the stock identification of horse mackerel and to estimate the extent of genetic differentiation among populations distributed across the distribution range of the species. For this we used modern sequencing techniques that allowed us to assess genetic variants in the entire genome. We discovered that while the populations differ in a small fraction of their DNA (< 1.5%), such genetic differences are significant as they likely represent natural selection and might be involved in local adaptation. We validated a small fraction of these highly differentiated genetic variants by a SNP assay and demonstrated that they can be used as informative molecular markers for the genetic identification of the main stock divisions of the Atlantic horse mackerel.

The results, based on the analysed samples, indicated that the North Sea horse mackerel are a separate and distinct population. The samples from the Western stock, west of Ireland and the northern Spanish shelf, and the northern part of the Southern stock, northern Portugal, appear to form a genetically close group. There was significant genetic differentiation between the northern Portuguese samples and those collected in Southern Portuguese waters, with those in the south representing a separate population. The North African and Alboran Sea samples were distinct from each other and from all other samples.

These results indicate that a further large-scale analysis of samples, with a greater temporal and spatial coverage, with the newly identified molecular markers is required to test and reassess the current stock delineations.

Table of Contents

1. Background

1.1 Biology

The horse mackerel, *Trachurus trachurus* (Linnaeus, 1758) is a species of jack mackerel from the Carangidae family and is distributed in the East Atlantic from Norway to Western Africa and the Mediterranean Sea (Froese and Pauly, 2015). It is a pelagic shoaling species found on the continental shelf and is one of the most widely distributed species in shelf waters in the northeast Atlantic. The range of horse mackerel partially overlaps with four other *Trachurus* spp; *Trachurus picturatus* (Bowdich, 1825) and *Trachurus mediterraneus* (Steindachner, 1868) in Iberian, North African and Mediterranean waters, *Trachurus trecae* (Cadenat, 1949) in West African waters and the very closely related *Trachurus capensis* (Castelnau, 1861) in west and southwest African waters.

Horse mackerel are estimated to mature at c.20 cm total length and between 2 and 4 years of age (Abaunza et al., 2003). Waldron and Kerstan (2001) validated the age determination of horse mackerel otoliths, through marginal increment analysis of whole otoliths, up to age four. However, examination of subsequent growth zones indicated that false rings and annuli are often of a similar appearance and as such accurate ageing beyond four years of age year is difficult. Horse mackerel grow rapidly during the first years of life and more slowly after three years of age. The maximum estimated age is reported as 40 years (Abaunza et al., 2003). Both growth and age at maturity fluctuate, which is suggested to be a density-dependent response to the extremely large fluctuations in year-class strength (ICES, 1991).

Horse mackerel is considered to be an asynchronous batch spawner with an indeterminate fecundity (Gordo et al., 2008; Ndjaula et al., 2009). In the northeast Atlantic area, the horse mackerel population has an 8-month long spawning season (Abaunza et al., 2003; Dransfeld et al., 2005), although the duration of an individual's spawning period is unknown (Van Damme et al., 2014). Horse mackerel appear to undertake annual migrations to spawning, feeding and over-wintering area (Abaunza et al., 2003). The peak spawning in the northeast Atlantic west of Britain and Ireland is in June in shelf waters (ICES, 2017; van Damme et al., 2014). Peak spawning in the North Sea occurs in May and June (Macer, 1974), and spawning occurs in the coastal regions of the southern North Sea along the coasts of Belgium, the Netherlands, Germany, and Denmark. Peak spawning in Portuguese waters is earlier than the other regions being in February in shelf waters (Borges & Gordo, 1991), though it should be noted that there is significant overlap between these areas. In winter the North Sea spawning horse mackerel are believed to migrate to the Western English Channel, whilst those that spawn west of Ireland and Britain migrate from feeding grounds off Norway and the northern North Sea to the continental slope southwest of Ireland (Heessen et al., 2015).

1.2 Stock Identification

ICES has long considered horse mackerel in the northeast Atlantic to consist of three stocks (Figure 1). The southern stock was defined as that found in the Atlantic waters of the Iberian Peninsula (Division 9a), the North Sea stock in the eastern English Channel and southern North Sea area (Divisions 3a, 4b,c, and 7d), and the western stock on the northeast continental shelf of Europe, stretching from the Bay of Biscay in the south to Norway in the north (Subarea 8 and Divisions 2a, 4a, 5b, 6a, and 7a–c, e–k). This separation of horse mackerel was based on a variety of factors including the temporal and spatial distribution of the fishery, the observed egg and larval distributions, information from acoustic and trawl surveys and from parasite infestation rates (see ICES, 2015). A tagging programme was established in 1994 (ICES, 1995) and further studies based on genetic (allozyme) population structure and morphometric characteristics, were conducted in 1997 (ICES, 1998). Tagging studies failed to recover any tagged fish, and neither the genetic nor morphometric studies provided a basis for changing the stock separation as previously defined.

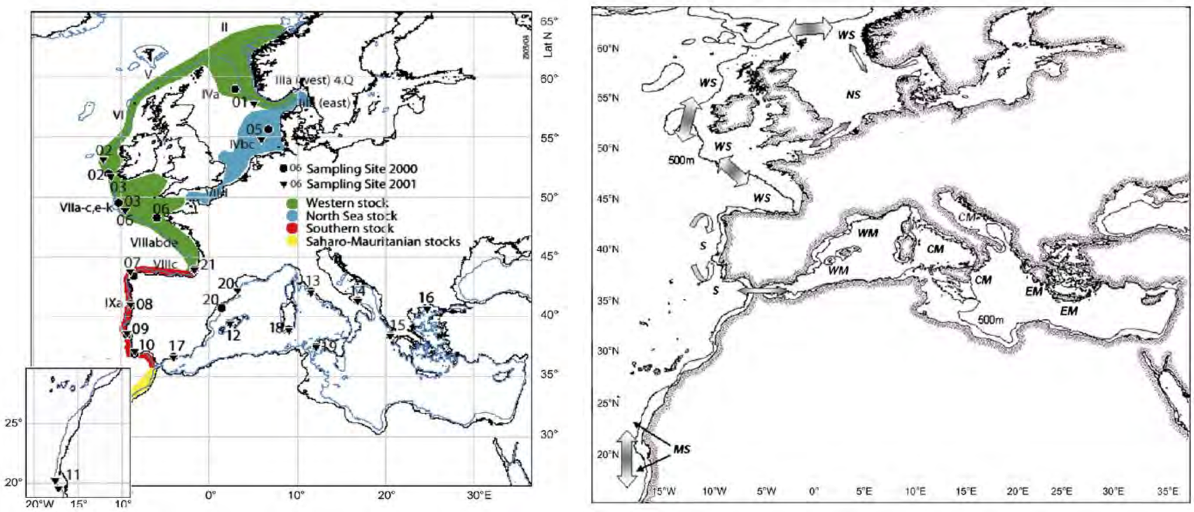


Figure 1. (Left panel) The suggested stocks of horse mackerel prior to the HOMSIR project. The sampling sites in the HOMSIR project in 2000 (circles) and 2001 (triangles). (Right panel) Proposed horse mackerel stocks according to the HOMSIR project. The arrows indicate possible migratory movements. WS: western stock; NS: North Sea stock; S: southern stock; MS: Saharo-Mauritanian stock; WM: western Mediterranean stock; CM: central Mediterranean stock; EM: eastern Mediterranean stock. From Abaunza *et al*. (2008).

Further refinements of the definitions of stock units were based on the results from the EU-funded HOMSIR project (2000-2003), which utilised a multidisciplinary approach including various genetic approaches (allozymes, mitochondrial DNA and microsatellites), the use of parasites as biological tags, body morphometrics, otolith shape analysis and the comparative study of life history traits (growth, reproduction and distribution) (Abaunza et al., 2008). The resulting stock structure was broadly similar to that previously considered by ICES (Figure 1). However, it was observed that the population structure in the western European coasts could be more complicated and that more research was needed to clarify the migration patterns within the Northeast Atlantic Ocean. This was especially relevant to the mixing areas between the North Sea stock and the Western stock (Northern North Sea and English Channel). The sampling in this region was relatively sparse whereas the southern regions had significantly better coverage (Figure 2). The genetic components of the project failed to resolve stock structure largely due to the low number (four microsatellites) and low power of the genetic markers employed (Kasapidis and Magoulas, 2008).

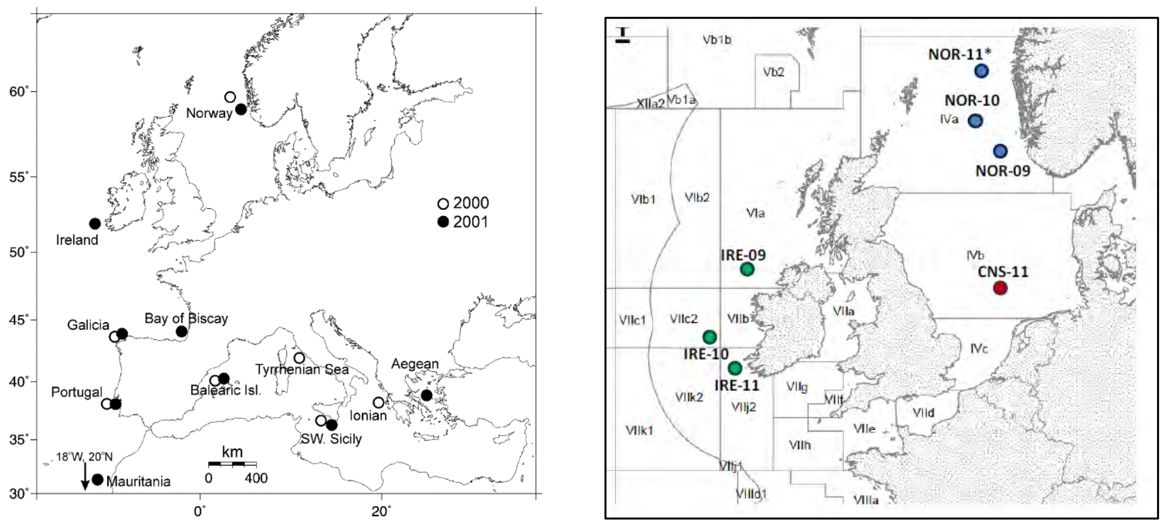


Figure 2. (Left Panel) The genetic samples collected and analysed in the Kasapidis and Magoulas (2008) study which was part of HOMSIR. (Right Panel) The genetic samples collected and analysed in the Mariani (2012) pilot study.

A recent preliminary study on western and North Sea horse mackerel employed 12 microsatellites (4 from horse mackerel, *Trachurus trachurus* and 8 from Chilean jack mackerel, *Trachurus murphyi* Nichols, 1920) to screen a small number of samples (n = 7 samples/339 individuals) from both putative stocks (Figure 2). The results indicated significant population structure within the samples from the western stock while no significant structure was observed between the samples collected west of Ireland and those collected in the central North Sea (Mariani, 2012). However, there were a number of issues related to the genetic markers employed being non species-specific and also the samples screened not being from spawning individuals.

The degree of separateness of the western and North Sea stocks is uncertain. It is known that the western stock spawns west of Ireland while the North Sea stock has a separate spawning ground in the North Sea. However, it is unclear if these spawning grounds are used interchangeably. Unlike herring (*Clupea harengus* Linnaeus, 1758), horse mackerel are not known to be faithful to their original spawning grounds. Therefore, without strong evidence to the contrary, it cannot be assumed that the two stocks are indeed separate. Treating these stocks as separate, if indeed they are not, is dangerous from a precautionary management perspective. Further research is needed to clarify the level of differentiation between the North Sea and Western stocks and also to define the boundary areas, if any, between them. The levels of mixing in the northern North Sea (area 4a) are also unclear and catches and survey data from this area are currently allocated to the North Sea stock in quarters 1 and 2 and to the western stock in quarters 3 and 4, highlighting the uncertainty in the assessments for these stocks.

1.3 Stage 1 - PFA/IMARES pilot study

In 2015 the Pelagic Freezer Trawler Association (PFA) contracted the Wageningen UR, Institute for Marine Resources and Ecosystem Studies, IJmuiden (IMARES) to undertake a study on North Sea Horse Mackerel (Brunel et al., 2016). The primary aim of the study was to improve the data quality used for an analytical stock assessment model of North Sea horse mackerel. The stock is currently classified by ICES as a data poor stock, for which the catch advice is based on the trend in an abundance index.

The management boundary between the western and North Sea stocks in the English Channel (corresponding to the separation between areas 7e, western Channel and 7d, eastern Channel) does not correspond to a real biological boundary, as mixing of the two stocks is known to occur in area 7d in autumn and winter (Brunel et al., 2016). The catches taken in 7d are officially considered as being North Sea horse mackerel and represent c.80% of the catches from this stock. An unknown proportion of this catch is likely from the western stock, which interferes with the cohort signal in the catch at age matrix, hampering the development of an age-structured assessment model for the North Sea stock. Developing methods to separate catches from the western stock from catches from the North Sea stock in area 7d are therefore necessary to improve the quality of the catch information for the North Sea stock. Within the project, two pilot studies, based on chemical fingerprint and genetics, were conducted to investigate new methods to determine stock structure and to develop techniques to identify the stock origin of the catches taken in the eastern English Channel.

The chemical fingerprint analysis was carried out by IMARES using two-dimensional gas chromatography (GCxGC-MS), in order to establish a full chemical fingerprint of the horse mackerel samples from both the western and North Sea stocks. Results were inconclusive but suggested that the chemical fingerprint approach was a potential tool to determine stock of origin, with a moderate risk of misclassification. However, more insight on the sources of variation of compound concentrations (seasonal changes, influence of sex, length, age, reproducibility of the results from year to year) is required before this method can be further developed.

IMARES, contracted University College Dublin (UCD) to undertake a pilot study to develop a method of genetic stock identification for discriminating North Sea and Western Horse mackerel (Brunel et al., 2016). The aims of the pilot study were to firstly develop and validate at least 24 polymorphic microsatellites markers in horse mackerel and secondly to screen spawning fish collected in 2015 from the Western and North Sea stocks to establish a genetic baseline of the spawning stocks and test the presence of population structure. Recently developed Next Generation Sequencing (NGS) and Genotyping by Sequencing (GBS) based approaches, which were developed on cod (*Gadus morhua* Linnaeus, 1758), boarfish (*Capros aper* Lacépède, 1802) and 6a/7bc herring were used for marker development and screening of spawning samples (Carlsson *et al.*, 2013; Farrell *et al.*, 2016; Vartia *et al.*, 2014 & 2016). The pilot study successfully identified a large number of novel microsatellites, however initial data analyses were confounded by a poor-quality sequencing run and as such the discrimination power between the western and North Sea sample was low. This resulted in the pilot study being unable to separate the two stocks conclusively and unequivocally.

1.4 Stage 2 – Northern Pelagic Working Group (NPWG) genetic baseline project

In an effort to resolve these uncertainties the Northern Pelagic Working Group contracted EDF Scientific Limited and Jens Carlsson to undertake a comprehensive genetic stock identification study on Atlantic horse mackerel (Farrell & Carlsson, 2018). Sampling was conducted over three consecutive years and three spawning seasons and covered a large area of the distribution of the species including the Western, North Sea and Southern stock areas and also West African waters. In total 33 population samples, comprising 2,295 individual fish were collected from 2015 to 2017 across the study area (Figure 3). Total genomic DNA was extracted from 2,208 of these specimens. Spawning samples were analysed with a panel of 37 novel, putatively neutral microsatellite markers and statistical analyses (F_{ST}, structure, assignment testing, mixed stock analyses and FCA analyses) indicated that horse mackerel in the northeast Atlantic region does not represent a single biological unit. A high level of species misidentification in the West African samples was also observed. On the highest level there are mixed species catches in African waters, a clear separation of the southern North Sea from other regions and further, less pronounced, structure along the northeast Atlantic continental shelf. Exploratory assignment testing and mixed stock analysis of the western and North Sea baselines indicated a success rate of c.60-65% for self- assignment. This was considered relatively low and is due to the relatively low genetic differentiation between the populations at putatively neutral loci. Despite this, further exploratory assignment testing and mixed stock analysis of the fish caught outside spawning time in the northern North Sea and western English Channel (Figure 3) indicated that a large component of these fish belonged to the Western stock. No samples from the eastern English Channel were available for testing.

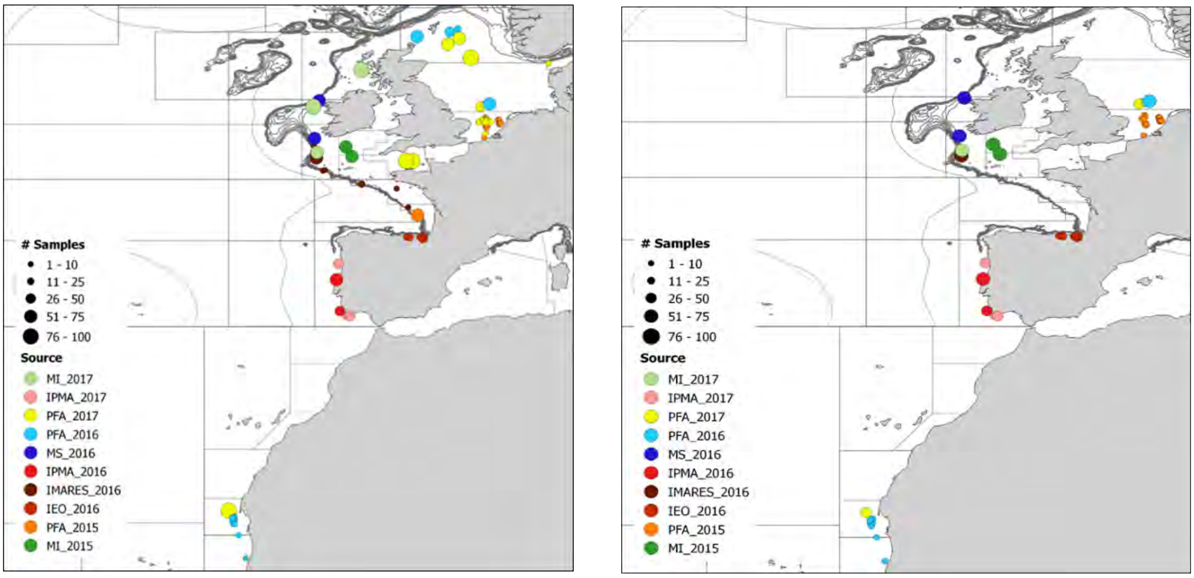


Figure 3. (Left Panel) The horse mackerel samples collected from 2015 to 2017 and (right panel) those included in the baseline dataset.

The results showed that the genetic information produced in the stage 2 study could be used for mixed stock analyses and that the information could be used to delineate the range of the North Sea stock – information that could be taken into account by fisheries management. However, it was suggested in the project report that further genetic analyses were warranted (full genome, RNA and RAD sequencing-based approaches) to increase the numbers and types of genetic markers available for this species. This would improve stock discrimination, mixed stock analyses and individual assignment capacity, similar to the approaches deployed for Baltic and Atlantic herring and other commercial fisheries species. This proposal by Dr Edward Farrell of EDF Scientific Limited, Ireland and Professor Leif Andersson, Uppsala University outlines one such approach.

1.5 Stage 3 & Stage 4 - Population genomics of horse mackerel and SNP validation

The current report presents the results of stages 3 and 4 of the horse mackerel project. To improve our ability to identify informative genetic markers, Dr Edward Farrell of EDF Scientific Limited, Ireland, and Professor Leif Andersson of Uppsala University, Sweden, proposed to undertake full genome sequencing of horse mackerel. This method provides the highest resolution of genetic variants with respect to the reference genome of the species', which was recently assembled by the Wellcome Sanger Institute, UK (website: https://vgp.github.io/genomeark/Trachurus_trachurus/). The Northern Pelagic Working Group funded stage 3, which involved the whole-genome pooled DNA sequencing of a subset of the populations sampled in stage 2 to identify population specific genetic markers. Further validation of potentially informative SNPs was undertaken as stage 4 and was funded by the Pelagic Advisory Council.

2. Materials and Methods

2.1 Sampling and DNA isolation

The samples included in the current study were a subset of the baseline samples analysed in stage 2 (Farrell and Carlsson, 2018). Sampling was organised by EDF Scientific and the Pelagic Freezer Trawler association (PFA). Samples were collected opportunistically, from 2015-2017, through existing fisheries surveys and from both target and non-target fisheries. One additional sample from the Alboran Sea in the Mediterranean Sea was provided by Dr Jens Carlsson from the ATLAS Project (https://www.eu-atlas.org/). The primary focus of sampling for the genetic analysis was collection of spawning fish, in order to ensure that samples could be considered to provide a valid baseline. However, due to the opportunistic nature of the sampling programme this was not always possible. Maturity stages were recorded by sample collectors using a number of different maturity keys. Therefore, these were standardised to the six-point international horse mackerel maturity scale (see Annex 1 Table S1; ICES, 2015). Each fish was measured for total length (TL) to the 0.5 cm below and total body weight (TW) to the nearest 1.0 g. Sex and maturity were also assessed and a 0.5 cm^3 piece of tissue was excised from the dorsal musculature of each specimen and stored at 4°C in absolute ethanol. Total genomic DNA (gDNA) was extracted from the majority of samples by Weatherbys Scientific Ltd, from c.30 mg of tissue from each fish using sbeadex™ magnetic bead-based extraction chemistry on the LGC Oktopure™ platform. The remaining samples were extracted using a Chelex and proteinase-K or CTAB based extraction protocol (Table 1). Extracted DNA was quantified on a NanoDrop® ND-1000 spectrophotometer (Nano-Drop Technologies, Wilmington, DE, USA) and laid out on 96-well PCR plates.

2.2 High-throughput sequencing, QC of raw reads, and read mapping

We performed whole-genome resequencing of pooled DNA (Pool-Seq) to assess the population-level genomic variation of the 12 fish aggregates sampled in this study. For this, individual DNA samples were combined into 12 pools by location and year in equal quantity to obtain at least 1.5 μg in 25-50 μL (Table 1). Between 30 and 96 individuals were included in each pool (Table 1). Pools were quantified in ng/μL using a Qubit Fluorometer (Thermo Fischer Scientific Inc) prior to submission to the SNP&SEQ Technology Platform in Uppsala, Sweden for library preparation and high-throughput sequencing. A PCR-free Illumina TruSeq library kit with a target insert size of 350 base pairs (bp) (Illumina Inc) was used for most pools, except for 6a and 6b, for which a Splinted Ligation Adapter Tagging (SPLAT) library preparation was used because their DNA was single-stranded (Raine et al., 2016). All libraries were paired-end sequenced on Illumina NovaSeq S4 flowcells with a read sequence length of 150 bp.

The quality of raw sequence reads for each pool was examined with *FastQC* v0.11.8 (Andrews, 2010), and jointly analysed in a single report with *MultiQC* v.1.7 (Ewels et al., 2016). Based on this initial sequence quality assessment, we removed low quality bases (Phred score < 15), Illumina adapters, and short reads (< 36 bp) with *Trimmomatic* v.0.36 (Bolger et al., 2014) (parameters: ILLUMINACLIP:adapters.fa:2:40:15:8:true SLIDINGWINDOW:4:15 LEADING:15 TRAILING:15 MINLEN:36). The quality of the resulting trimmed reads was assessed again with *FastQC* before further analysis.

Reads were mapped against the Atlantic horse mackerel (*Trachurus trachurus*) genome using *bwa-mem* 0.7.17 (Li, 2013) and default parameters. Read mapping quality statistics, including the number of aligned reads and the average read depth of coverage, were generated with *QualiMap* v.2.2.1 (Okonechnikov et al., 2015). Prior to variant calling, mapped reads were sorted using *SAMtools* v.1.10

(Li et al., 2009), duplicated reads were marked and read groups were added, both with *Picard* v2.20.4 (Broad Institute, 2018), and an index file was created with *SAMtools*.

2.3 Variant calling and filtering

Variant calling was performed with *GATK-UnifiedGenotyper* v3.8 (McKenna et al., 2010) because, in our experience, this algorithm works well and produces less false positives than the *GATK-HaplotypeCaller* when analysing pooled samples. The *GATK-UnifiedGenotyper* is a single-base caller that simultaneously identifies Single Nucleotide Polymorphisms (SNPs) and small indels (insertions and deletions). Since we aimed to characterize genome-wide variation based on biallelic SNPs, we extracted these genetic markers from the raw variant set using *GATK*.

To remove spurious markers and thus, retain the best quality ones for further analysis, we applied various filters to the raw SNP set. First, we performed hard-filtering by retaining SNPs that passed cut-off values that were set based on the genome-wide distribution of GATK variant quality annotations. The cut-off values used were: FisherStrand (FS) > 60.0, StrandOddsRatio (SOR) > 3.0, RMSMappingQuality (MQ) < 40.0, MappingQualityRankSumTest (MQRankSum) < -12.5, and ReadPosRankSumTest (ReadPosRankSum) < -8.0 (for more details on the GATK quality annotations, see *https://gatk.broadinstitute.org/hc/en-us/articles/360035890471-Hard-filtering-germline-short-variants*). Next, we retained SNPs with a genotype quality (GQ) greater than 20, allowed for a missing rate per locus of a maximum of 20%, kept loci with a minor allele count of at least 3 reads (MAC), and removed monomorphic loci with *BCFtools* v.1.10 (Li et al., 2009). Lastly, we applied a depth of coverage filter as follows. Based on the total read depth (DP) per locus and pool, we generated depth of coverage distributions for each pool with *R* (R Core Development Team, 2020) and the *R* package *ggplot2* (Wickham, 2016). We evaluated three different cut-off value ranges (listed from the most to the least stringent filter): mean $\pm$ 1 standard deviation, mode $\pm$ ½ the mode, and between 20x and 300x (300x corresponds to three times the mean coverage for all pools). We retained SNPs that fulfilled the depth of coverage requirement for all pools while excluding samples 6a, 6b and 7 (see results for details). The resulting high-quality SNP set was used in further analysis. A schematic summary of the data generation steps is illustrated in Figure S1.

2.4 Population genetic structure

The population-level allele frequencies computed from Pool-Seq data are derived from the read counts of a variant site. To control for potential technical artifacts inherent to Pool-Seq that could bias the allele frequency calculation, such random variation in read coverage and in chromosome representation across pools (Dohm et al., 2008; Kolaczkowski et al., 2011), we applied the n_{eff} allele count correction (Feder et al., 2012; Kolaczkowski et al., 2011) to the read counts of each SNP using a custom script implementing this formula $n_{\text{eff}} = \frac{(n*CT)-1}{n+CT}$ where *CT* corresponds to read depth and *n* to the number of chromosomes in a pool, being equal to 2*N* for diploid species like herring. Population allele frequencies were then calculated based on the n_{eff} corrected read counts and constituted the basis of subsequent population analysis.

To estimate the level of genetic differentiation among pools, we computed the unbiased pool-F_{ST} statistic ($\hat{F}_{\text{ST}}^{\text{pool}}$) for all possible paired comparisons with the R package *poolfstat* (Hivert et al., 2018). This statistic is equivalent to the (Weir & Cockerham, 1984) F_{ST} and accounts for random chromosome sampling characteristic of Pool-Seq experiments. The pool-F_{ST} statistic ranges between 0 and 1, where a value of 0 indicates no genetic differences exists between populations, while a value of 1 means complete genetic differentiation between populations. In addition, to assess clustering patterns of pool samples, we performed Principal Component Analysis (PCA) using the whole SNP set. In a pilot analysis samples 1b, 6a, and 6b appeared as outliers (Figure S4). Considering that technical biases might have affected these samples, they were excluded from subsequent analyses.

Table 1. Collection details of the Atlantic horse mackerel samples analysed in the current project.
Abbreviations: N: North, S: South, W: West, SW: Southwest, *N*: Number of individuals, Mag: Magnetic, Med: Mediterranean.

											Maturity Stage						
Stock	**Area**	**Sample**	**Year**	***N***	**Latitude**	**Longitude**	**Extraction method**	**Pool**	***N* per**	**Pool ID**	**1**	**2**	**3**	**4**	**5**	**6**	**NA**
Western	W Ireland	1a	2016	51	54.42	-10.62	Mag Bead	1a	51	1a-WIR-2016		31	19	1			
Western	SW Ireland	1b	2016	44	51.35	-10.98	Mag Bead	1b	44	1b-WIR-2016		32	12				
Western	SW Ireland	2a	2017	46	50.20	-10.79	Mag Bead	2	62	2-WIR-2017			44	2			
Western	W Ireland	2b	2017	16	53.93	-11.09	Mag Bead	2					16				
N Sea	S North Sea	3	2016	96	54.15	3.30	Mag Bead	3	96	3-SNS-2016		88		8			
N Sea	S North Sea	4a	2017	18	54.07	2.85	Mag Bead	4	70	4-SNS-2017				18			
N Sea	S North Sea	4b	2017	21	54.03	2.90	Mag Bead	4						21			
N Sea	S North Sea	4c	2017	31	53.93	2.55	Mag Bead	4						31			
Southern	N Portugal	5a	2016	64	39.83	-9.20	Mag Bead	5a	64	5a-NPT-2016		64					
Southern	S Portugal	5b	2016	30	37.26	-8.92	Mag Bead	5b	30	5b-SPT-2016	22	5	3				
Southern	N Portugal	6a	2017	48	41.14	-9.03	Chelex	6a	47	6a-NPT-2017		47	1				
Southern	S Portugal	6b	2017	23	36.84	-8.38	Chelex	6b	48	6b-SPT-2017		18	2	3			
Southern	S Portugal	6c	2017	25	36.84	-8.10	Chelex	6b				19	6				
N African	Mauritania	7a	2016	4	20.20	-17.50	Mag Bead	7	57	7-NAF-2016		1		3			
N African	Mauritania	7b	2016	4	19.00	-17.20	Mag Bead	7						4			
N African	Mauritania	7c	2016	8	19.90	-17.60	Mag Bead	7				1		7			
N African	Mauritania	7d	2016	1	17.10	-16.60	Mag Bead	7				1					
N African	Mauritania	7e	2016	7	20.10	-17.70	Mag Bead	7					1	6			
N African	Mauritania	7f	2016	4	20.40	-17.70	Mag Bead	7				1		3			
N African	Mauritania	7g	2016	8	20.50	-17.50	Mag Bead	7				1		7			
N African	Mauritania	7h	2016	9	20.50	-17.6	Mag Bead	7				4		5			
N African	Mauritania	7j	2016	7	20.30	-17.7	Mag Bead	7						7			
N African	Mauritania	7k	2016	5	20.40	-17.7	Mag Bead	7				1		4			
Western	N Spanish Shelf	8a	2016	22	43.31	-3.46	Mag Bead	8	96	8-NSP-2016		9	12				1
Western	N Spanish Shelf	8b	2016	23	43.27	-3.21	Mag Bead	8				5	18				
Western	N Spanish Shelf	8c	2016	3	43.27	-2.42	Mag Bead	8					3				
Western	N Spanish Shelf	8d	2016	44	43.22	-2.14	Mag Bead	8				15	28	1			
Western	N Spanish Shelf	8e	2016	4	43.20	-2.10	Mag Bead	8					4				
Med	Alboran Sea	9a	2018	10	36.36	-5.12	CTAB	9	49	9-MED-2018				10			
Med	Alboran Sea	9b	2018	10	36.56	-4.55	CTAB	9						10			
Med	Alboran Sea	P9c	2018	10	36.49	-4.42	CTAB	9						10			
Med	Alboran Sea	P9d	2018	10	36.6865	-4.28	CTAB	9						10			
Med	Alboran Sea	P9e	2018	10	36.70	-3.56	CTAB	9						10			

2.5 Detection of loci putatively under selection

To identify regions of the genome with elevated genetic differences, generally interpreted as candidate signatures of natural selection, we calculated the absolute delta allele frequency (dAF) of each SNP between paired contrasts of single or grouped pools. In specific, we first calculated the mean allele frequency per SNP within each proposed group, and after, the absolute difference between the two groups. The contrasts and groupings examined were established taking in consideration geographic closeness, PCA clustering patterns, and stock divisions. The paired contrasts evaluated were:

- Each pool against all other samples
- Southern North Sea (3 and 4) vs. others (1a, 8, 5a, 5b, 9)
- Western Ireland (1a) vs. other northern samples (2, 3, 4, 8, 5a)
- Western Ireland (1a, 2) vs. other northern samples (3, 4, 8, 5a)
- Northern Spanish shelf (8) vs. other northern samples (2, 3, 4, 8, 5a)
- Southern Portugal and Alboran Sea (5b, 9) vs. all others (1a, 3, 4, 8, 5a)
- Southern Portugal and northern Africa (5b, 7) vs. all others (1a, 3, 4, 8, 5a, 9)
- “North” (1a, 2, 3, 4, 8, 5a) vs. “South” (5b, 7) groupings
- Northern Africa (7) vs. others (1a, 3, 4, 8, 5a, 5b, 9)

To identify genomic regions with consistent differentiation across various markers, we also calculated the moving (or rolling) mean of dAF values in windows of 100 SNPs for each contrast. In this way, we ruled out single SNPs that could be influenced by random effects of Pool-Seq experiments. We further explored the allele frequency pattern of the most highly differentiated SNPs at each locus and contrast across the 12 pool samples. We included here samples 1b, 6a, and 6b as it was focused on loci that were well supported in other samples. All the analyses were performed using *R* and plotting was done with the *ggplot2* package.

2.6 Individual validation of informative markers for stock assessment

The primary aim of this study was to identify a reduced and highly informative set of SNP markers that could be used for genetic stock identification. For this purpose and to validate the main findings with the Pool-Seq data, we screened a subset of the 100 most differentiated SNPs in a total of 160 individuals. In addition to confirming the allele frequencies observed in the Pool-Seq data it was also possible to undertake a preliminary analyses of population structure between the main sampling areas.

The loci included in the SNP panel were selected as follows. We started from a list of candidate SNPs with the highest dAF values from the major genomic regions of divergence in each of the main contrasts. In most cases we selected SNPs with dAF ≥ 0.35, but when a large number of SNPs passed this threshold we set a higher cut-off value, so we could obtain a reduced number of SNPs representative of that locus. We required that SNPs had a coverage ≥ 20x, a base quality ≥ 20, a mapping quality ≥ 20; that they were at least 10 bp away from an indel, more than 100 bp far from repetitive sequences, and more than 1 kb from the closest informative SNP; that alleles were equally supported by forward and reverse reads (no strand bias); that several chromosomes would be represented when that was the case; and that enough flanking sequence of good quality was available for primer design (± 120 bp). The genomic context of target SNPs was further examined using the genome browser *IGV* (Robinson et al., 2011; Thorvaldsdóttir et al., 2013). We additionally chose a set of SNPs that were lowly undifferentiated (or “neutral”) and a few SNPs that were distinctive of sample 1b, to test whether this sample was actually unique as it behaved as an outlier in pilot analysis. The neutral SNPs were randomly selected from the chromosomes underrepresented in the paired contrasts. We required these SNPs had a depth of coverage between 40x and 200x; were at least 10 bp away from nearby SNPs and indels; had an average allele frequency between 0.4 and 0.7; and had enough flanking sequence (± 120 bp) of good quality for primer design, which was visually evaluated with *IGV*. The final split of loci per region in the 100-SNP panel was: southern North Sea (n = 28), neutral loci (n = 24), north-south break (n = 13), 1b-western Ireland (n = 10), Alboran Sea (n = 13), southern Portugal (n = 4), 1a-western Ireland (n = 4), northern Africa (n = 4) (Figure S6).

A subset of 20 individuals each was selected from 8 of the 12 samples included in the Pool-Seq analyses (Table 2) for the SNP validation. Three or four individuals per sample were genotyped twice in order to test for genotyping errors. DNA extraction and SNP genotyping was undertaken by IdentiGEN, Dublin, Ireland using their proprietary IdentiSNP genotyping assay chemistry. The protocol utilises target specific primers and universal hydrolysis probes. Following the endpoint PCR reaction different genotypes are detected using a fluorescence reader.

Only individuals with >80% genotyping success and SNPs with >80% genotyping success were retained in the analyses. Deviations from Hardy–Weinberg equilibrium and linkage disequilibrium were tested with *Genepop* 4.2 – default settings (Rousset, 2008). *Microsatellite Analyzer* (*MSA*) 4.05 was used, under default settings, to calculate pairwise F_{ST} estimates (Dieringer & Schlötterer, 2003). In all cases with multiple tests, significance levels were adjusted using the sequential Bonferroni technique (Rice 1989). Discriminant Analysis of Principal Components (DPCA) and clustering analyses were performed in *R* using the *adegenet* package for the multivariate analysis of genetic markers (Jombart, 2008). It should be noted that sample sizes were small and therefore the results of the analyses presented in section 3.6 should be viewed as preliminary until further large-scale screening is undertaken. To illustrate the potential of the markers for individual assignment for stock identification, an exploratory assignment was also conducted in *GeneClass2* (Piry et al., 2004) and the *R* package *geneplot* (McMIllan & Fewster, 2017) with the Bayesian method of Rannala and Mountain (1997).

Table 2. The horse mackerel samples included in the SNP validation analyses

Stock	Area	Sample	Pool	Year	#individuals	# repeated
Western	West of Ireland	1a	1a	2016	20	4
Western	Southwest of Ireland	1b	1b	2016	20	4
North Sea	Southern North Sea	3	3	2016	20	4
North Sea	Southern North Sea	4b	4	2017	20	4
Southern	Northern Portugal	5a	5a	2016	20	4
Southern	Southern Portugal	5b	5b	2016	20	4
North African	Mauritania	7a	7	2016	4	0
North African	Mauritania	7b	7	2016	4	1
North African	Mauritania	7c	7	2016	8	1
North African	Mauritania	7e	7	2016	4	1
Western	Northern Spanish Shelf	8d	8	2016	20	3

3. Results

3.1 Sampling and DNA Isolation

A total of 33 collections comprising 716 individual fish were included in this study (Figure 4 and Table 1). Samples were aggregated into 12 pools based on spatial and temporal proximity, thus broadly representing most of the geographical range of the species in the northeast Atlantic and the western part of the Mediterranean Sea.

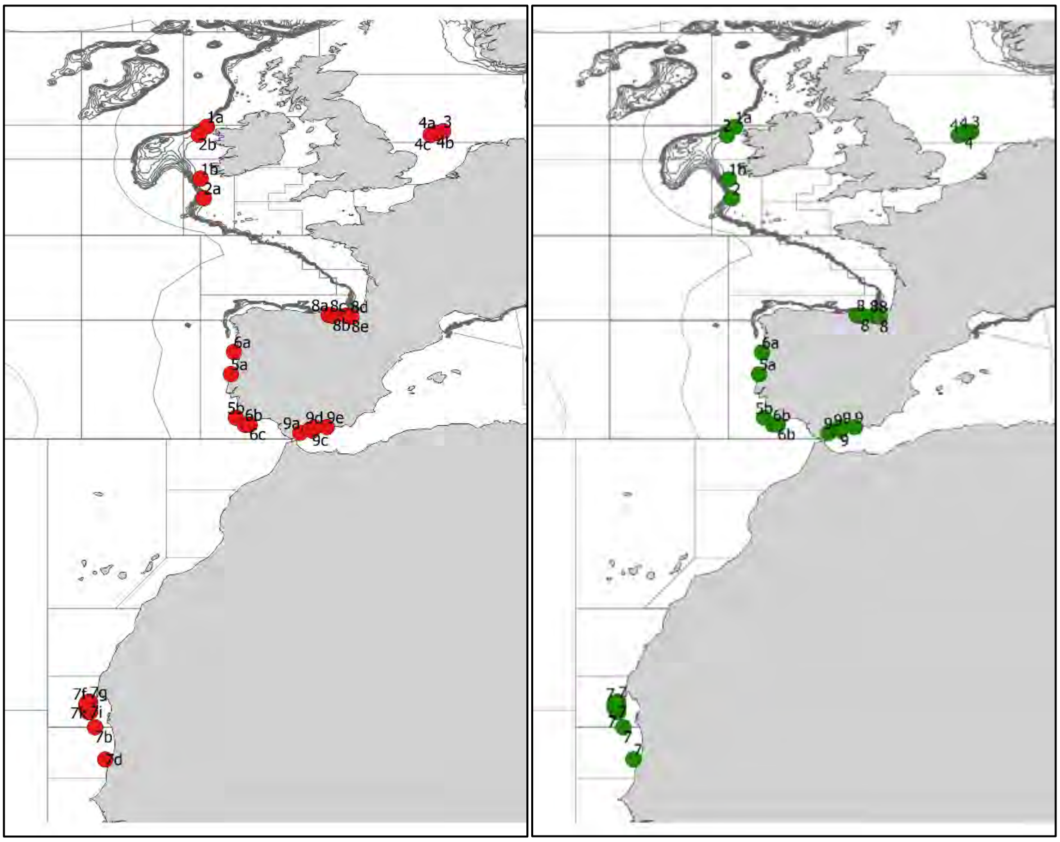


Figure 4. Sampling locations of the Atlantic horse mackerel included in this study. (Left) Sample batches collected at each location, (right) Pooled samples.

Four of the available samples corresponded to temporal replicates collected one year apart, which allowed us to examine the short-term stability of the genetic composition at these sites. Pool 2 was a mix of the replicates of the two samples collected in western Ireland (1a and 1b); pools 6a and 6b were temporal replicates of pools 5a and 5b from Northern and Southern Portugal, respectively; and pool 4 was the replicate of pool 3 from southern North Sea).

3.2 High-throughput sequencing, QC of raw reads, and read mapping

A total of 490-764 million high-quality reads were obtained for each pool. Mean read depth of coverage per pool ranged between 25.7x and 46.3x, mean mapping quality (MQ) was larger than 35 for all pools, and GC content was ~42% for most samples except for the African pool (46.6%) (Table S2).

A comparison of the mapping statistics of all pools showed that three of them (6a, 6b, 7) might be affected by technical artefacts. The two temporal replicates from Portugal (6a, 6b), which were extracted with Chelex and had a SPLAT library preparation, had a smaller mean coverage and shorter insert size (~245 bp vs. ~400-465 bp) than the other pools (Figure S2). The sample from Africa had a flatter and wider coverage distribution, higher GC content, and higher missing rate (Figure S2) with respect to the other pools, which could be the result of certain degradation of the starting genetic material that was noticeable during DNA quantification. Given the difficulty to rule out the effect of technical biases from biological variation in these samples, they were excluded from some analyses.

3.3 Variant calling and filtering

From the three depth of coverage thresholds tested (Figure S3), we chose the range of 20x-300x because in a pilot analysis it provided a large number of SNPs and similar genetic patterns as the more stringently filtered sets. A total of ~12.8 million polymorphic biallelic SNPs passed all the quality filters and were used in the population analysis.

3.4 Population genetic structure

The large set of genetic variants here analysed indicated that overall, there are low levels of genetic differentiation among Atlantic horse mackerel populations distributed across the broad geographic area here represented (Figure 5) (global mean pool-F_{ST} = 0.007, pairwise pool-F_{ST} values ranged between 0.001 and 0.015). The genetic differences among populations constituted less than 1.5% of their entire genome.

The pairwise pool-F_{ST} values revealed a north-south genetic break along mid Portugal, distinguishing a “north” group comprising southern North Sea (3, 4), western Ireland (1a, 2), northern Spanish shelf (8) and northern Portugal (5a), from a “south” group including southern Portugal (5b), northern Africa (7), and the Alboran Sea (9) samples (Figure 5). These statistics also showed that the sample from the Alboran Sea (pool 9) was the most genetically distinct of all (pool-F_{ST} 0.01-0.015), followed by Southern Portugal (5b) and northern Africa (7), respectively (pool-F_{ST} 0.005-0.007). In contrast, the two samples collected one year apart from southern North Sea (pools 3 and 4) were the most genetically similar of all (pool-F_{ST} 0.001).

For the PCA we excluded samples 1b, 6a and 6b, as in a pilot analysis they appeared as outliers. The PCA agreed with the previous observations of a north-south break and it additionally revealed sub-structuring within the “north” and “south” groupings. The first two PCs show that the genetic differences among the samples within the “north” group (1a, 2, 3, 4, 5a, 8) are very small (all cluster together near the centre) with respect to the differences between the three samples in the “south” group (5b, 7, 9). PC1 shows that within the “south” group, genetic differences exist between the Alboran Sea (9), southern Portugal (5b) and northern Africa (7). PC2 indicates that differences also occur between northern Africa (7) and the Alboran Sea (9) and southern Portugal (5b). PC3 separates the “north” and “south” groups, being southern Portugal (5b) closer to the “north” group than northern Africa (7) and the Alboran Sea (9). PC4 distinguishes western Ireland (1a) and northern Portugal (5a) and also shows the high genetic similarity (tight clustering) between the two samples from the southern North Sea (3, 4).

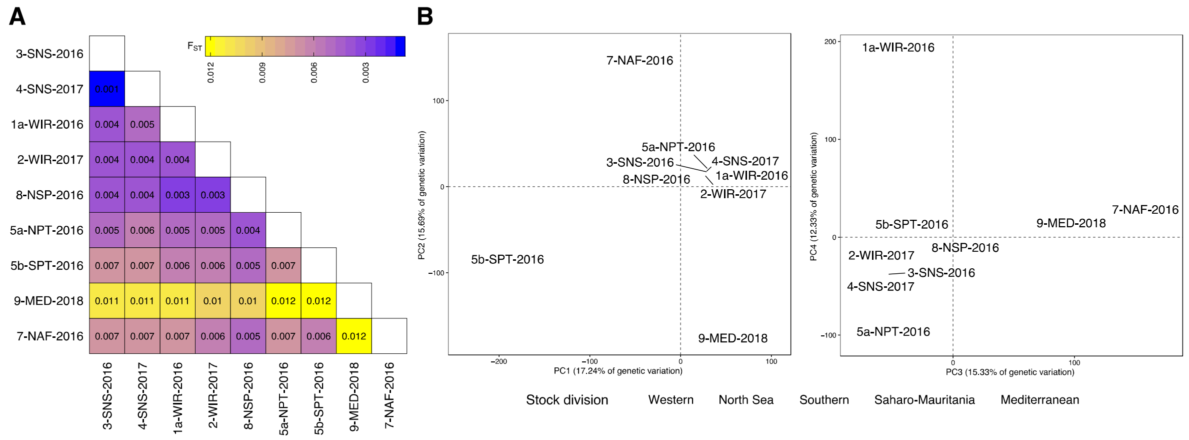


Figure 5. Population genetic structure of the 9 pool samples analysed. **A**. Pairwise pool-F_{ST} statistics, **B**. PCA of 9 pools; (left) PC1-2, (right) PC3-4.

3.5 Detection of loci putatively under selection

The genome-wide scans for the identification of candidate loci under selection revealed a number of genomic regions with elevated allele frequency differences for three contrasts: i) "north" vs. "south" groupings; ii) southern North Sea vs. others; and iii) Alboran Sea (9) vs. others.

The comparison between the "north" and "south" groups disclosed that a single large locus, likely corresponding to a chromosome structural variation (SV), underlies the north-south genetic break (Figure 6). This locus on chromosome 21 appears as a large block of SNPs with elevated allele frequency differences spanning 9.9 Mb. The large genomic size and abrupt change in allele frequencies (well-defined edges) at this locus are common characteristics of SVs with suppressed recombination (e.g. inversions). A further exploration of the allele frequency patterns of some of the most differentiated SNPs at this locus (dAF ≥ 0.72) showed that one allele occurs at high frequency among all northern samples and in the Alboran Sea; at intermediate frequencies in southern Portugal (Figure 6, inset box); and the alternative allele occurs at high frequency in northern Africa, the southernmost sample studied.

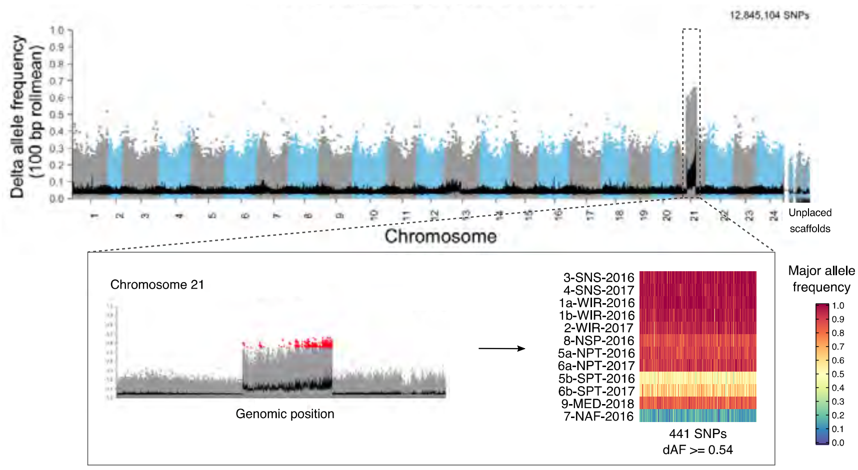


Figure 6. Manhattan plot representing the dAF of each SNPs along the genome for the north-south contrast. Each dot corresponds to a single SNP, the x-axis shows its genomic position, and the y-axis indicates its dAF frequency value for a given contrast. The line in black corresponds to the rolling mean of dAF calculated over 100 SNPs. The inset box shows a zoom-in of the putative chromosomal structural variant found in chromosome 21. The red dots correspond to the SNPs with a dAF ≥ 0.72. The heatmap plot at the right-hand side of the inset

shows the major allele frequencies of these top SNPs. In the heatmap plot, rows correspond to pool samples, and columns to SNP variants.

The comparison of the southern North Sea samples against all others disclosed that seven genomic regions distinguish this population. Two of these regions are located on chromosome 1, and the others are on chromosomes 4, 7, 11, 20, and 21 (Figure 7); they stand out as a "peak" or aggregate of SNPs with elevated differences in allele frequencies in respect to the neighbouring variants. Further examination of the allele frequencies of some of the most divergent SNPs at each locus show the large agreement in allele frequency patterns that exists between the two southern North Sea temporal replicates, and that they are distinctive of this population (Figure 7, inset boxes).

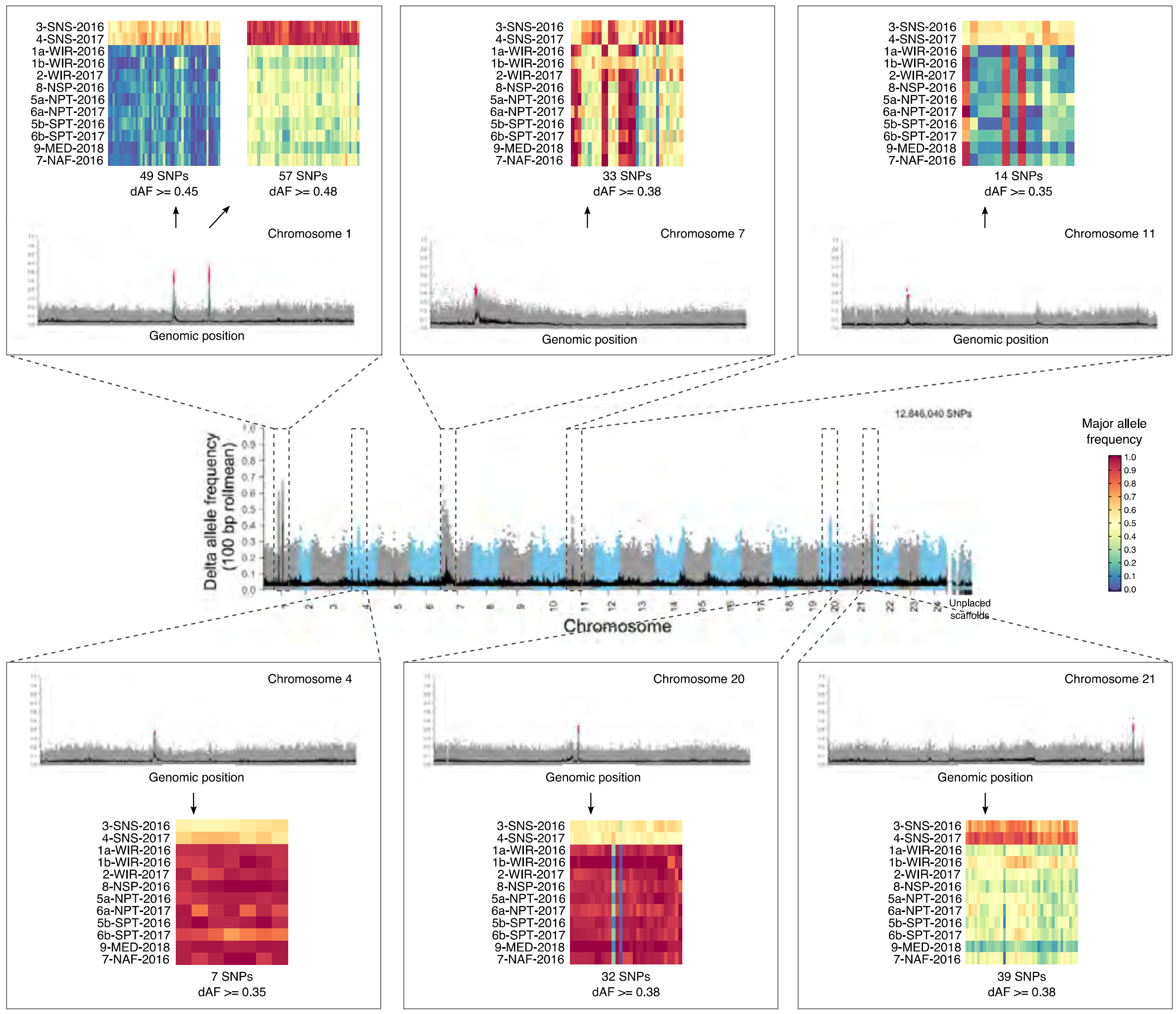


Figure 7. Manhattan plot of the dAF of each SNPs along the genome for the contrast distinguishing the southern North Sea samples. Each dot is a single SNP. The line in black corresponds to the rolling mean of dAF over 100 SNPs. The inset boxes show a zoom-in into the 7 genomic regions across chromosomes 1, 4, 7, 11, 20, and 21, characteristics of the North Sea samples. The red dots in the zoomed dAF profile of each chromosome correspond to the most highly differentiated SNPs per genomic region. The heatmap plot at the right-hand side of the inset shows the major allele frequencies of these top SNPs. In the heatmap plot, rows correspond to pool samples, and columns to SNP variants.

The contrast of the Alboran Sea sample against all others showed that two regions, one on chromosome 5 and another on chromosome 21, distinguish this sample from other samples (Figure 8). In this case the "peaks" of divergence were not as evident as in the other contrasts, for which it was necessary to focus more on the patterns shown by the rolling mean in dAF values. The examination of allele frequencies of the most differentiated SNPs showed that the Alboran Sea sample had a characteristic allele frequency pattern.

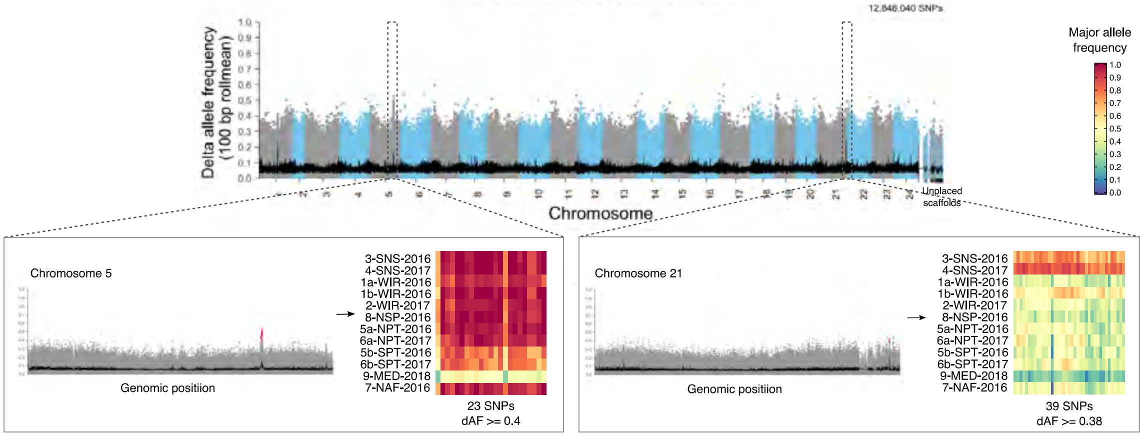


Figure 8. Manhattan plot of the dAF of each SNPs along the genome for the contrast distinguishing the Alboran Sea (from the western part of the Mediterranean Sea) sample. Each dot is a single SNP. The line in black corresponds to the rolling mean of dAF over 100 SNPs. The inset boxes show a zoom-in into the two genomic regions in chromosomes 5 and 21 showing high differentiation between the Alboran Sea sample and other samples. The red dots in the zoomed dAF profile of each chromosome correspond to the most highly differentiated SNPs per genomic region. The heatmap plot at the right-hand side of the inset shows the major allele frequencies of these top SNPs. In the heatmap plot, rows correspond to pool samples, and columns to SNP variants.

3.6 Individual validation of informative markers for stock assessment

The strong correlation between population allele frequencies obtained with individual genotyping and with Pool-Seq confirms the main genomic regions of divergence discovered with Pool-Seq (Figure S5). A total of 72 out of the 100 SNPs included in the panel had a genotyping success >80% (Table 3). Of these, six SNPs had indication of deviation from Hardy-Weinberg Equilibrium (HWE), two markers (12_3119866 and 17_972744) were not polymorphic and one had evident scoring errors (24_5252083). After removing these nine markers, the resulting dataset had 63 SNPs and 157 out of 160 individuals with a genotyping success >80%.

Table 3. Details of the 100 SNPs tested in the validation analyses. The SNPs highlighted in red did not reach the 80% genotyping success threshold or failed to amplify. The SNPs highlighted in orange deviated from HWE, were not polymorphic or had scoring errors and were removed from the analyses. '*LD*' indicates significant linkage disequilibrium between samples and '*Assumed*' indicates assumed LD based on chromosome position. * indicates SNPs that were included in the 17 SNP dataset.

SNP Name	>80% success	Chromosome	Position	Contrast	LD Group	Comment
1_17504018*	Yes	1	17504018	Southern North Sea	Assumed	
1_17506941	Yes	1	17506941	Southern North Sea	LD	
1_17510324	Yes	1	17510324	Southern North Sea	LD	
1_17517550	Yes	1	17517550	Southern North Sea	LD	
1_17521852	Yes	1	17521852	Southern North Sea	LD	
1_17523218	Yes	1	17523218	Southern North Sea	LD	
1_17525646	Yes	1	17525646	Southern North Sea	Assumed	
1_17558501	Yes	1	17558501	Southern North Sea	LD	
1_22046469	Yes	1	22046469	Southern North Sea	LD	
1_22046756	Yes	1	22046756	Southern North Sea	LD	
1_22047461	Yes	1	22047461	Southern North Sea	LD	
1_22049353	Yes	1	22049353	Southern North Sea	LD	
1_22053057*	Yes	1	22053057	Southern North Sea	LD	
1_22081696	No	1	22081696	Southern North Sea	Assumed	
3_2811572	No	3	2811572	Neutral markers		
3_18949602	No	3	18949602	Neutral markers		
3_18951336	Yes	3	18951336	Neutral markers		
3_33715024	No	3	33715024	Neutral markers		
4_13086614*	Yes	4	13086614	Southern North Sea	LD	
4_13088818	Yes	4	13088818	Southern North Sea	LD	
4_13098092	Yes	4	13098092	Southern North Sea	LD	
5_22983273	No	5	22983273	Western Ireland (1a)		
5_28197435	Yes	5	28197435	Med and/or S Portugal		
5_28205448	Yes	5	28205448	Med and/or S Portugal		
5_28240764	Yes	5	28240764	Med and/or S Portugal		
5_28240785	Yes	5	28240785	Med and/or S Portugal		
5_28241356*	Yes	5	28241356	Med and/or S Portugal		
5_28242757	No	5	28242757	Med and/or S Portugal		
5_28243095	Yes	5	28243095	Med and/or S Portugal		
5_28274875	No	5	28274875	Med and/or S Portugal		
6_18368752*	Yes	6	18368752	Neutral markers		
6_24275858	No	6	24275858	Neutral markers		
6_33295851*	Yes	6	33295851	Neutral markers		
7_5053296*	Yes	7	5053296	Southern North Sea		
7_5108289	Yes	7	5108289	Southern North Sea		
8_2410897	No	8	2410897	Neutral markers		
8_3426603*	Yes	8	3426603	Neutral markers		
11_6942036	Yes	11	6942036	Southern North Sea		Out of HWE in 2 pops
12_3119866	Yes	12	3119866	Neutral markers		Not polymorphic
12_10994158	No	12	10994158	Neutral markers		
12_27660258	Yes	12	27660258	Neutral markers		Out of HWE in 3 pops
13_4844455	No	13	4844455	Western Ireland (1b)		
13_4874422	Yes	13	4874422	Western Ireland (1b)	LD	
13_4874692	Yes	13	4874692	Western Ireland (1b)	LD	
13_4874725	Yes	13	4874725	Western Ireland (1b)	LD	
13_5015377*	Yes	13	5015377	Western Ireland (1b)		
13_5092546	Yes	13	5092546	Western Ireland (1b)		
16_22440492	No	16	22440492	Africa		
17_955542	No	17	955542	Western Ireland (1b)		
17_955717	Yes	17	955717	Western Ireland (1b)		Out of HWE in 1 pop
17_961283	No	17	961283	Western Ireland (1b)		
17_972744	Yes	17	972744	Western Ireland (1b)		Not polymorphic
18_4093892*	Yes	18	4093892	Africa		
19_4188265	No	19	4188265	Neutral markers		
19_4189387	No	19	4189387	Neutral markers		
19_4194438	No	19	4194438	Neutral markers		
19_13550308	No	19	13550308	Neutral markers		
20_11636865	Yes	20	11636865	Southern North Sea	LD	
20_11638825*	Yes	20	11638825	Southern North Sea	LD	
20_11640406	Yes	20	11640406	Southern North Sea	LD	
20_11643211	Yes	20	11643211	Southern North Sea	LD	
20_11644062	Yes	20	11644062	Southern North Sea	LD	
20_11647497	Yes	20	11647497	Southern North Sea	LD	
20_11647537	Yes	20	11647537	Southern North Sea	LD	
20_11649644	Yes	20	11649644	Southern North Sea	LD	
21_13901383	Yes	21	13901383	North-South pattern		
21_15195721	Yes	21	15195721	Southern Portugal		
21_15619806*	Yes	21	15619806	North-South pattern		
21_16093398	Yes	21	16093398	North-South pattern		
21_18106603	Yes	21	18106603	North-South pattern		
21_19507025	Yes	21	19507025	Southern Portugal		Out of HWE in 1 pop
21_20477335	Yes	21	20477335	North-South pattern		

Table 3. *Continuation.*

SNP Name	>80% success	Chromosome	Position	Contrast	LD Group	Comment
21_20646321	Yes	21	20646321	North-South pattern	LD	
21_20838721	Yes	21	20838721	North-South pattern	LD	
21_21340446	Yes	21	21340446	North-South pattern	LD	
21_21591928	Yes	21	21591928	North-South pattern		
21_21801450	Yes	21	21801450	North-South pattern		
21_22552517	Yes	21	22552517	North-South pattern		
21_23412586*	Yes	21	23412586	North-South pattern	LD	
21_23420067	Yes	21	23420067	North-South pattern	LD	
21_34276436	No	21	34276436	Southern Portugal		
21_34279224	No	21	34279224	Southern Portugal		
21_34570675	Yes	21	34570675	Med and/or S Portugal	LD	
21_34571601	No	21	34571601	Med and/or S Portugal		
21_34571721	Yes	21	34571721	Med and/or S Portugal	LD	
21_34573582*	Yes	21	34573582	Med and/or S Portugal	LD	
21_34578009	No	21	34578009	Med and/or S Portugal		
22_253248	No	22	253248	Africa		
22_29332559	Yes	22	29332559	Western Ireland (1a)		Out of HWE in 5 pops
22_29369048*	Yes	22	29369048	Western Ireland (1a)		
22_29400293	Yes	22	29400293	Western Ireland (1a)		
24_2630784	No	24	2630784	Neutral markers		
24_2631095	No	24	2631095	Neutral markers		
24_3769194	No	24	3769194	Neutral markers		
24_5252083	Yes	24	5252083	Africa		Scoring error
24_5255627	No	24	5255627	Neutral markers		
24_10305770*	Yes	24	10305770	Neutral markers		
24_10306442	Yes	24	10306442	Neutral markers		Out of HWE in 1 pop
24_14507474	No	24	14507474	Neutral markers		
24_19228299*	Yes	24	19228299	Neutral markers		

As expected, analyses of linkage disequilibrium (LD) indicated significant linkage between a number of SNPs located in close proximity on the same chromosomes (Table 3). Though LD was not statistically significant in some cases (e.g. SNPs on chromosome 5), these were considered to be linked due to the closeness of the SNPs. In order to identify the most informative SNPs for discriminating the samples, the F_{ST} per locus was analysed by marker and by population (Figure 9). The most informative SNP (highest average F_{ST}) per linkage group was retained, yielding a 17 SNP dataset comprising 155 out of 160 individuals with a genotyping success >80%. Further analyses were conducted with both the 63_SNP and the 17_SNP datasets (individual genotypes in each SNP set are shown in Figure S7).

There was no significant genetic differentiation between the North Sea temporal replicates or between the two west of Ireland samples (Table 4). There was also no significant genetic differentiation between the northern Spanish shelf sample, the northern Portugal sample and the two west of Ireland samples (Table 4). Discriminant Analysis of Principal Components (DAPC) and clustering analyses of the 63_SNP and 17_SNP datasets indicated the same pattern as the F_{ST} analyses with the North Sea temporal replicates clustering together, the west of Ireland, northern Spanish shelf and northern Portugal samples clustering together and the southern Portugal and northern African samples forming two separate clusters (Figure 10). Due to the lack of genetic differentiation, the two North Sea samples were combined into one sample and the two west of Ireland samples were combined into one sample for further analyses.

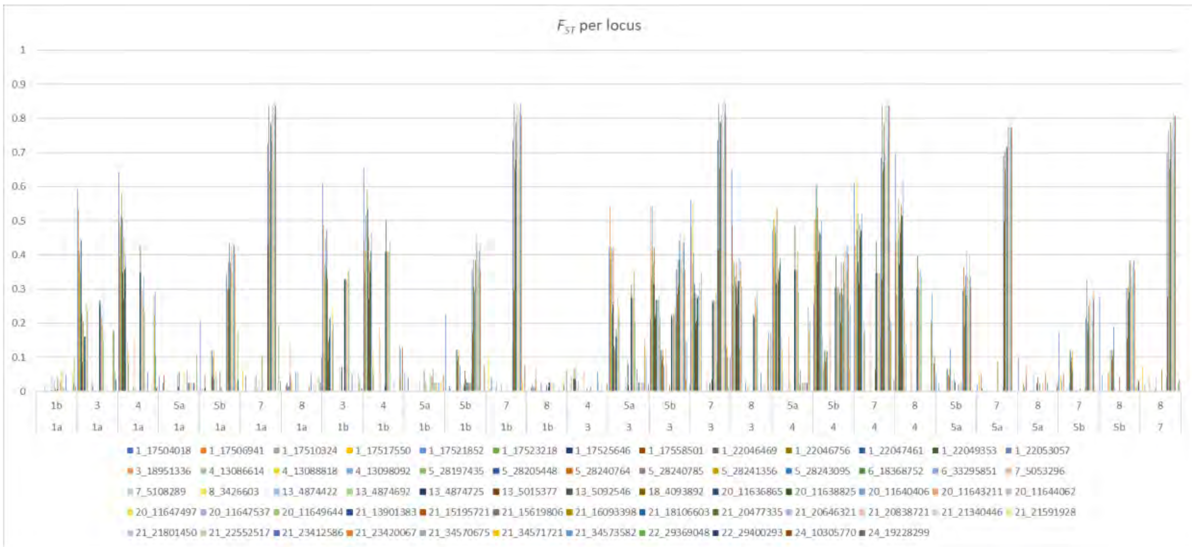


Figure 9. The pairwise F_{ST} per locus for the 63_SNP dataset

Table 4. Pairwise multi-locus F_{ST} (above the diagonal) and associated *P*-values (below the diagonal) for the 63_SNP dataset (top panel) 17_SNP dataset (bottom panel). *P*-values highlighted in red were still significant after sequential Bonferroni correction.

	1a	1b	3	4	5a	5b	7	8
1a		0.004	0.195	0.260	-0.004	0.135	0.361	0.004
1b	0.28		0.198	0.265	-0.006	0.124	0.352	-0.003
3	0.00	0.00		-0.006	0.180	0.243	0.417	0.218
4	0.00	0.00	0.60		0.241	0.287	0.446	0.286
5a	0.61	0.71	0.00	0.00		0.101	0.323	-0.002
5b	0.00	0.00	0.00	0.00	0.00		0.080	0.111
7	0.00	0.00	0.00	0.00	0.00	0.00		0.334
8	0.29	0.54	0.00	0.00	0.51	0.00	0.00	

	1a	1b	3	4	5a	5b	7	8
1a		0.016	0.138	0.196	0.004	0.088	0.241	0.009
1b	0.09		0.121	0.190	0.003	0.075	0.221	-0.002
3	0.00	0.00		-0.002	0.102	0.137	0.297	0.168
4	0.00	0.00	0.53		0.154	0.187	0.340	0.233
5a	0.32	0.35	0.00	0.00		0.033	0.183	0.006
5b	0.00	0.00	0.00	0.00	0.01		0.055	0.068
7	0.00	0.00	0.00	0.00	0.00	0.00		0.209
8	0.17	0.52	0.00	0.00	0.26	0.00	0.00	

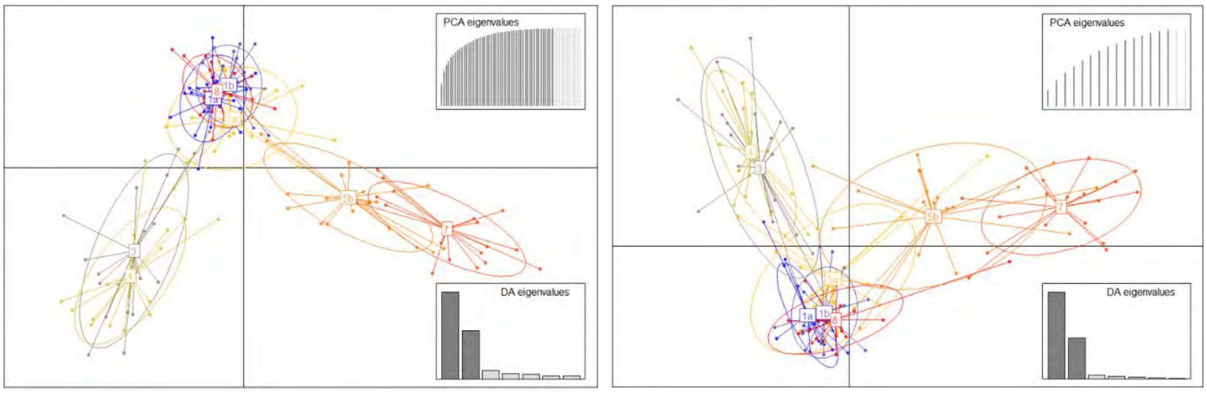


Figure 10. Discriminant Analysis of Principal Components of the 63_SNP dataset (left panel) and the 17_SNP dataset (right panel).

Membership probability plots of the two datasets also indicated the close affinity between the west of Ireland samples and the northern Spanish shelf and northern Portugal samples. A degree of mixing or admixture is evident in a small number of individuals (3-4) in the North Sea sample that have a high probability of originating from the western group. Similarly, the southern Portugal sample had a number of outliers which appear to originate from the western group (n=3) or from the African group (n=2).

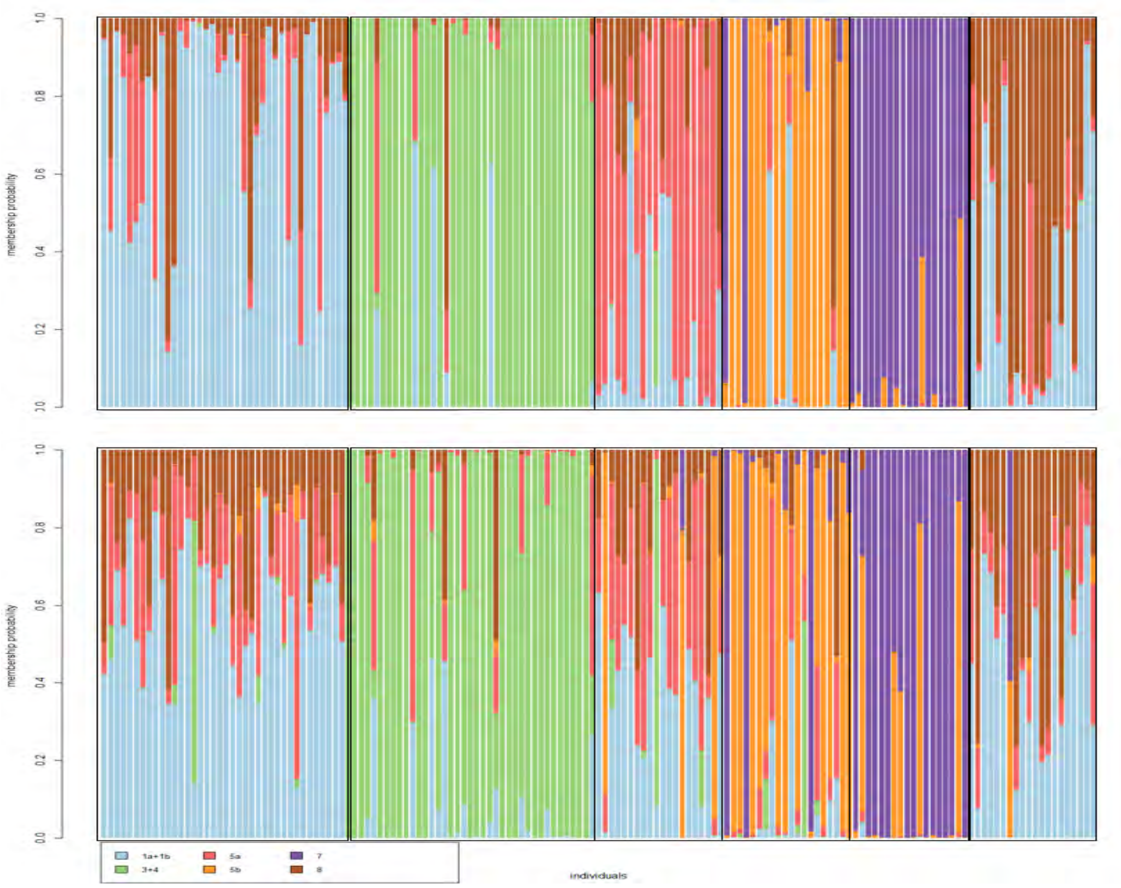


Figure 11. Membership probability plots the 63_SNP dataset (top panel) and the 17_SNP dataset (bottom panel). Samples 1a and 1b are combined into one sample and samples 3 and 4 are combined into one sample. Samples are delineated by the black boxes.

An exploratory assignment was conducted for illustration purposes using a combined 1a, 1b, 8 sample to represent what is currently considered to be the Western Stock and a combined 3, 4 sample to represent the North Sea. Only the 17_SNP dataset was used in order to avoid the violation of the assumption of independent markers, which is a prerequisite of the Rannala and Mountain approach. *Geneplot* indicated a self-assignment rate of 93% and *geneclass2* a self-assignment rate of 95%, indicating significant power to discriminate between mixed samples from these areas.

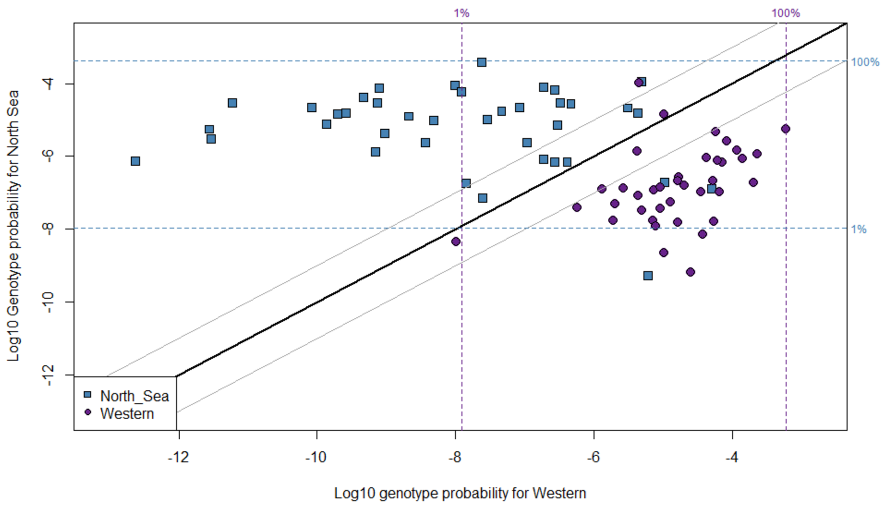


Figure 12. Plot generated with *genePlot* based on the 17_SNP dataset of the Western and North Sea stock samples. Each point represents an individual. The horizontal axis shows the posterior log-probability of obtaining each individual's genotype from the Western stock; the vertical axis shows the same, but with respect to the North Sea stock. The thick diagonal line shows equal probability with respect to Western and the North Sea. The vertical dashed lines shows the 0% and 100% percentile lines, that is, the minimum and maximum log-genotype probability, for the Western stock; the horizontal lines show the 0% and 100% percentile lines for the North Sea population.

4. Discussion

This study represents the largest and most comprehensive genetic assessment of the Atlantic horse mackerel to date. The combination of extensive geographic sampling and analysis of a large number of SNP markers derived from whole-genome sequencing, provided a powerful dataset that allowed us to discover, for the first time, genomic regions supporting population subdivision within the species. The genetic differences largely separate five groups: i) southern North Sea, ii) western Ireland - northern Spanish shelf - northern Portugal, iii) southern Portugal, iv) Alboran Sea/Mediterranean, and v) northern Africa. With the exception of the Southern stock, these genetic-based subdivisions are in agreement with the main horse mackerel stocks proposed by the HOMSIR project using morphometry, parasites, and life history traits (Abaunza et al., 2008). Our genetic data suggest that the samples from the southern stock in Portuguese waters do not come from a single biological population. The samples from northern Portugal appear to be genetically closer to the Western stock, while samples from southern Portugal form their own group. Further wide scale sampling is required to confirm these findings and assess the spatial and temporal trends in mixing between these areas. We additionally demonstrated that 63 of the most genetically differentiated SNP markers tag the genetic subdivisions and, thus, could be used as a genetic tool to inform the appropriate level of data collation for fisheries stock assessment. In fact, using a reduced panel of 17 markers, we demonstrated that it is possible to differentiate between individuals collected in the North Sea and Western stocks with a potential accuracy up to 95%.

Population structuring detected at loci putatively under selection

Genetic analysis of horse mackerel revealed that populations distributed across the broad geographic area spanning from the North Sea to northern Africa (Figure 5) differ by less than 1.5% of their DNA (Global mean pool-F_{ST} = 0.007, pairwise pool-F_{ST} values ranged between 0.001 and 0.015). This result indicates that gene flow occurs across the distribution range of the species. The observed genetic differences, despite representing a small fraction of the genome, are highly significant as they correspond to outlier SNPs putatively under selection and support population structuring within the species. A pattern of low genome-wide differentiation at neutral loci and high differentiation at adaptive loci is becoming a relatively common observation among various highly dispersive marine species inhabiting heterogeneous environments [e.g. Atlantic cod (Clucas et al., 2019); Atlantic herring (Lamichhaney et al., 2017)]. Many of these species, including the horse mackerel (Abaunza et al., 2008; Bozano et al., 2015; Cimmaruta et al., 2008; Farrell & Carlsson, 2018; Healey et al., 2020), were previously assumed to be panmictic, largely because prior genetic techniques did not provide enough genomic resolution. New genomic sequencing techniques enable the thorough examination of the genetic variation of non-model species and are revealing unprecedented levels of structuring, as we accomplished here for the horse mackerel. The large population sizes and high dispersal and gene flow presumed to be characteristic of numerous marine species may explain the low levels of genome-wide structuring observed, as the role of genetic drift in population structuring becomes negligible in these circumstances. The presence of well-defined parts of the genome showing high differentiation, so called “genomic islands of divergence or speciation” are generally associated with ecological adaptation or reproductive isolation (Seehausen et al., 2014; Turner et al., 2005). Theory predicts that when genetic variants are advantageous in a local environment, natural selection would favour their frequency in the local population (Yeaman & Whitlock, 2011). Thus, when different populations are locally adapted to heterogenous environments, it would be expected to see large differences in allele frequencies between them. This scenario goes in line with the fact that the horse mackerel exhibits a broad spatial distribution encompassing heterogeneous environments, for which, populations should be exposed to diverse selective pressures that can promote genetic differentiation, and thus, local adaptation.

Indeed, we hypothesize that the large chromosomal structural variant (9.9 Mb) underlying the cryptic north-south genetic break discovered here for the horse mackerel along mid Portugal, is associated with differential responses of populations to contrasting environmental conditions. Interestingly, a similar genetic pattern has also been observed in the boarfish (*Capros aper*) (Farrell et al., 2016), a pelagic fish with overlapping distribution and similar life-history characteristics in the northeast Atlantic. This suggests that a major biogeographic barrier may exist in Portugal waters, which could be leading to differentiation of biota inhabiting this area.

The structural variant exhibits high frequency of homozygotes for one allele among populations from the “north” (southern North Sea, west of Ireland, northern Spanish shelf, northern Portugal) and the Alboran Sea; heterozygotes are predominant in southern Portugal; and homozygotes for the alternative allele are in high frequency in the “south”, at coastal areas near Mauritania, northern Africa. These contrasting allele frequency patterns are in concordance with differences in sea water conditions at the local spawning peak in each area. For example, oceanographic data collected in previous horse mackerel egg surveys (ICES, 2019) suggest that reproduction along the west of Ireland and the northern Spanish shelf may occur at temperatures around 12.5-14°C. Similarly, reproduction at the northern coast of Portugal may occur at sea water temperatures around 12.5° and also at lower salinities associated with freshwater discharge from rivers. In contrast, reproduction at the southern coast of Portugal may happen at warmer sea water temperatures around 17° and higher salinity with to respect to the northern coast of Portugal (ICES, 2019).

Out of the 12 samples included in this study, the sample from the Alboran Sea, at the western part of the Mediterranean Sea, was the most genetically distinct of all. This result may be explained by the ecological (Coll et al., 2010; Emig & Geistdoerfer, 2004) and geological (Garcia-Castellanos et al., 2009) differences existing between the Mediterranean Sea and the Atlantic Ocean. Moreover, the genetic data supports the consideration of the Mediterranean Sea as a separate stock, as proposed by the HOMSIR project based on morphometry, otoliths, and life history traits (Abaunza et al., 2008). The genetic distinctiveness of the Alboran Sea sample suggests that it likely constitutes a separate population, although its genetic closeness with the sample from southern Portugal indicates that gene flow may occur between these two areas. This observation is also in agreement with data collected in the HOMSIR project, indicating the mixed nature of the Alboran Sea populations (Abaunza et al., 2008).

Our genetic analysis provides evidence that the North Sea stock represents a distinct population. As many as 7 specific genomic regions distinguished the southern North Sea samples. The allele frequency patterns at these genomic regions were nearly identical between the 1-year temporal replicates, which also showed the smallest genome-wide differentiation of the 12 samples analysed (pool-F_{ST} 0.001). The North Sea samples were the northeastern most samples included in this study. Thus, we hypothesize that the observed genetic differentiation may be associated with local adaptation to colder sea water conditions experienced during spawning or at early life-history stages. We expect that further gene annotation of the novel horse mackerel genome, will help understand the putative role of these genomic regions in the differentiation of the North Sea stock. Regardless, a subset of the top outlier SNPs distinguishing the North Sea samples could be used for conservation and management purposes, as these genetic markers could help elucidate the extent of mixing between the Western and North Sea stocks along the English Channel and in ICES area 4a in the northern North Sea.

The samples from the Western stock, west of Ireland and the northern Spanish shelf, and the northern part of the Southern stock, northern Portugal, appear to form a genetically close group. This result lends support to the inclusion of the Spanish shelf in the Western stock as proposed by the HOMSIR project, and also points to the need of an extended genetic study along the Spanish shelf and northern Portugal to determine whether the southern boundary of the Western stock should be extended.

Individual genotyping confirms Pool-Seq findings and constitute an informative SNP panel

The individual genotype data for the subset of samples corroborate the main results of the Pool-Seq analyses (Figure S4). The same pattern of sample clustering was observed with temporally stable samples in the North Sea that were distinct from all others. The two samples collected west of Ireland did not display any significant genetic differentiation between themselves or the northern Spanish Shelf sample. The northern Portuguese sample was also closely affiliated with these western samples and could not be robustly separated based on the reduced marker panels. The southern Portuguese samples formed a separate cluster, however there was evidence of mixing between this and the northern Portuguese group. As expected, the outlier group consisting of the African samples was significantly differentiated to all other samples but most closely related to the most geographically close sample in southern Portugal. Whilst these results should be treated with caution, as the sample sizes were small and temporal stability was not tested in all populations, they do prove the potential for using the reduced marker panels to investigate the population structure of horse mackerel on a larger scale.

Limitations and recommendations

While this study made important contributions to our understanding of the population structuring of the horse mackerel, we acknowledge there is room for improvement and emphasize the importance of follow-up studies. Firstly, the sampling, conducted over three consecutive years and three spawning seasons, while it covered a large area of the distribution of the species, is spatially and temporally limited. A more extensive spatial sampling within each stock area could, for instance, help identify the boundaries between the Western and Southern stocks, and between the Western and North Sea stocks. Repeated genetic monitoring (e.g. every one or two years) are necessary to assess the long-term stability of genetic sub-divisions. The Mediterranean Sea was a notable exclusion, as only a single sample from the Alboran Sea was studied. Whilst analysis of this sample indicates limited connectivity with the adjacent southern Portuguese samples, it does not enable any further conclusions the be drawn regarding population structure within the Mediterranean Sea. Secondly, whilst every effort was made to collect spawning fish from each putative stock this proved to be difficult in some areas and as such the best available alternative samples were included. Future sampling efforts should focus both on the collection of spawning baseline samples from each of the putative populations and also the collection of potentially mixed samples outside of the spawning season. Lastly, while the Pool-Seq approach is a powerful method to perform genome scans, it is sensitive to poor DNA sample quality, and variation in laboratory procedures such as pooling and library preparation. Thus, high quality DNA and standard laboratory procedures among samples are highly recommended to minimize technical biases.

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7. Annex

Table S1. The international maturity scale for horse mackerel, *Trachurus trachurus.*

Stage	Name	Female	Male
1	Immature	Ovaries small. Ovaries wine red and clear, torpedo shaped.	Testes small, when fresh pale flattened and transparent. When frozen it may be opaque.
2	Developing	Ovaries occupying 1/4 to almost filling body cavity. Opaque eggs visible in ovaries giving pale pink to yellow to orange coloration. Largest oocytes may have oil globules.	Gonads occupying 1/4 to to almost filing body cavity. Testes off-white to creamy white., milt not running. When frozen testes can be bleuish.
3	Spawning	Ovaries characterized by externally visible hyaline oocytes no matter how few or how early the stage of hydration. Ovary size variable from full to < 1/4 of body cavity. Ovaries can be bloodshot.	Testes from filling to < 1/4 of body cavity, milt freely running. Testes can be shrivelled (wrinkled and contracted) at anus. When frozen there might be a change of structure and the testes needs a little pushing before running.
4	Regressing Regenerating	Ovaries occupying 1/4 or less of body cavity. Ovaries reddish and often murky (dark and gloomy) in appearance, sometimes with a scattering or patch of opaque eggs. The empty ovaries will ripple when pushed together.	Ovaries occupying 1/4 or less of body cavity. Testes opaque with brownish tint and no trace of milt. When frozen testes can be bleuish ore purple.
5	Omitted spawning	No evidence of omitted spawning	No evidence of omitted spawning
6	Abnormal	No evidence of abnormal ovaries	No evidence of abnormal testes

Table S2. Read mapping summary statistics of the Pool-Seq data of 12 horse mackerel samples included in this study. Abbreviations: W: Western, SW: Southwestern, S: South, N: North, MQ: Mapping quality, cov.: coverage.

Area	Sample	Total reads	% reads aligned	%GC	Median insert size	Mean MQ	Median cov.	Mean cov.
W Ireland	1a-WIR-2016	496686692	99.0	42.4	405	39.05	83	30.7
SW Ireland	1b-WIR-2016	594538427	99.1	42.2	416	38.97	99	35.2
SW Ireland	2-WIR-2017	573044377	99.0	42.4	465	38.95	96	35.5
S North Sea	3-SNS-2016	724017069	99.1	42.3	416	39	122	45.1
S North Sea	4-SNS-2017	764658923	99.1	42.3	419	38.97	128	46.3
N Portugal	5a-NPT-2016	571274302	99.2	42.4	404	38.9	95	35.2
S Portugal	5b-SPT-2016	494209199	99.1	42.9	426	39.13	83	29.0
N Portugal	6a-NPT-2017	490808045	98.1	41.8	*248*	39.32	75	26.1
S Portugal	6b-SPT-2017	514732597	99.2	42.3	*245*	39.12	79	27.5
Africa Mauritania	7-NAF-2016	714009211	98.5	*46.6*	425	38.49	91	25.7
N Spanish Shelf	8-NSP-2016	720020789	98.9	43.3	438	38.96	122	41.0
Mediterranean - Alboran Sea	9-MED-2018	671149600	98.8	42.5	422	35.13	112	41.5

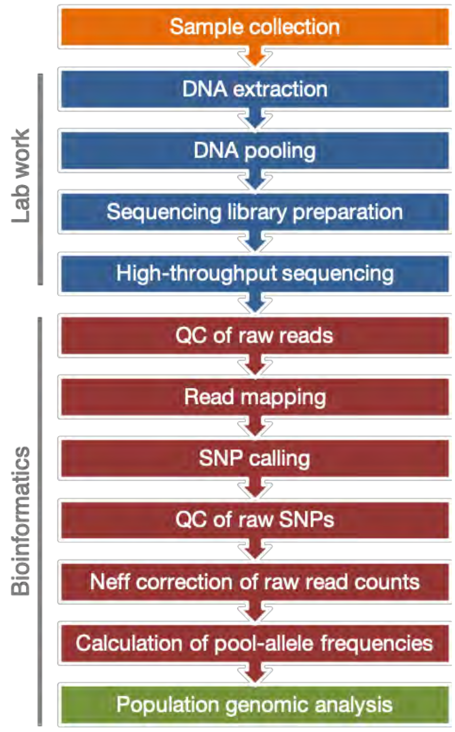

Figure S1. Schematic summary of steps followed for data generation.

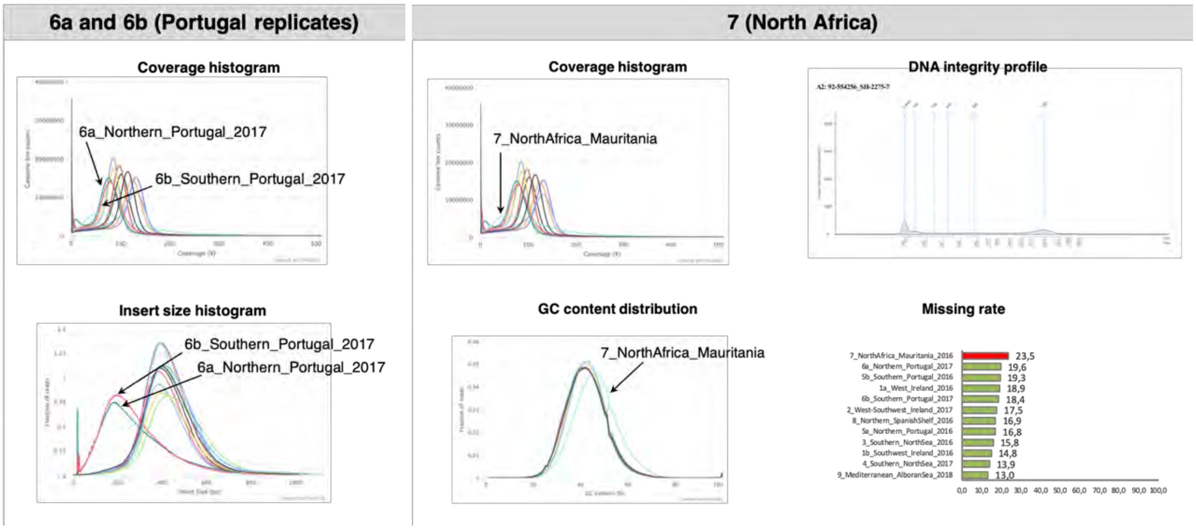

Figure S2. Read mapping statistics supporting that samples 6a, 6b, 7 were likely affected by technical artefacts. Plots obtained with *MultiQC*. (Left) Coverage and insert size distribution plots for the 12 samples, denoting the lines corresponding to samples 6a and 6b. (Right) Left, coverage and GC content distribution for all 12 samples, sample 7 is highlighted. Right, DNA integrity profile for the African sample and comparison of missing rate percentage for all 12 samples, the African sample is denoted in red.

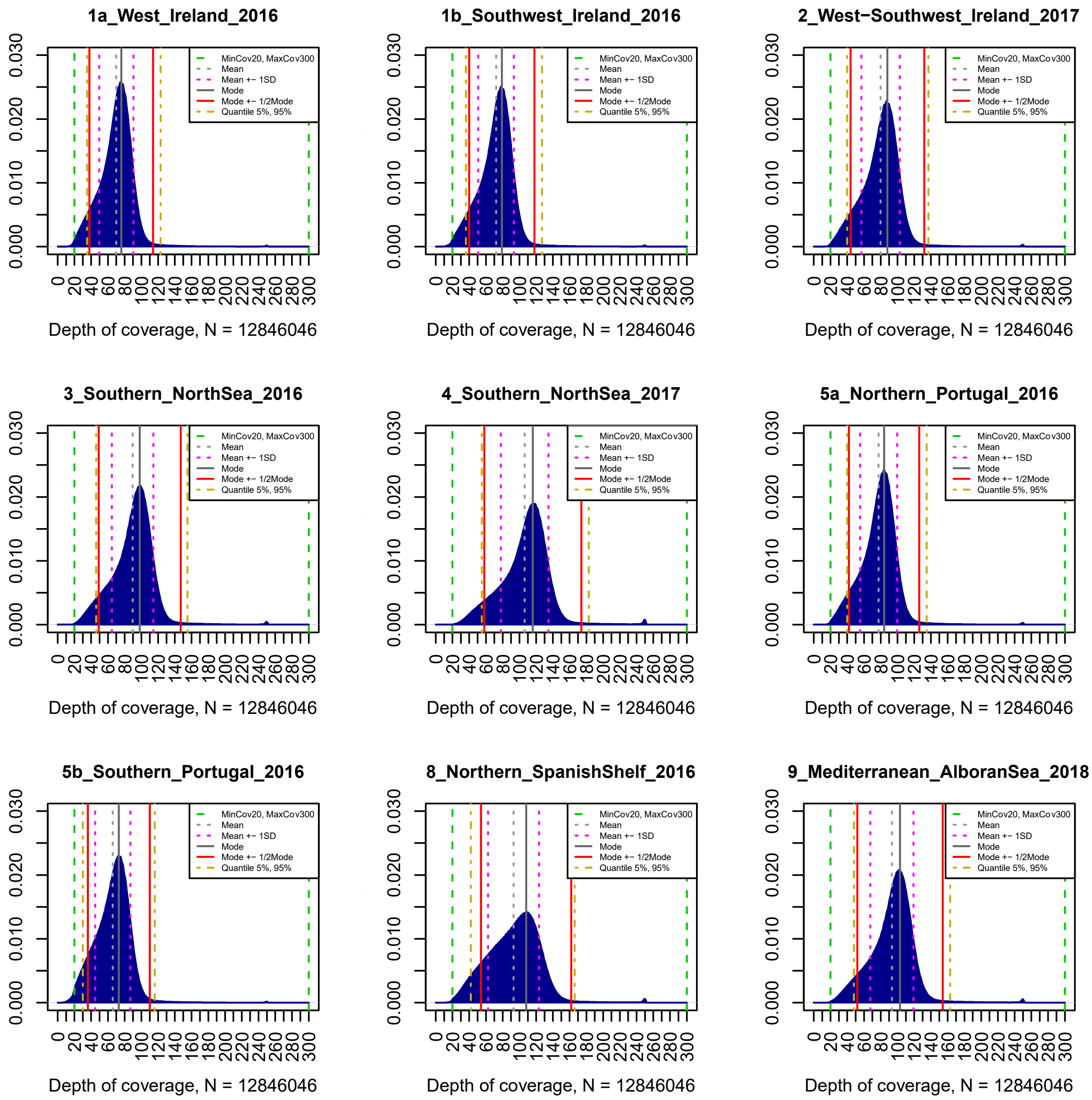

Figure S3. Depth of coverage distribution of 9 horse mackerel pools based on the SNPs that passed quality filters (~12 million). The different vertical lines correspond to the various lower and upper depth of coverage cut-off values examined.

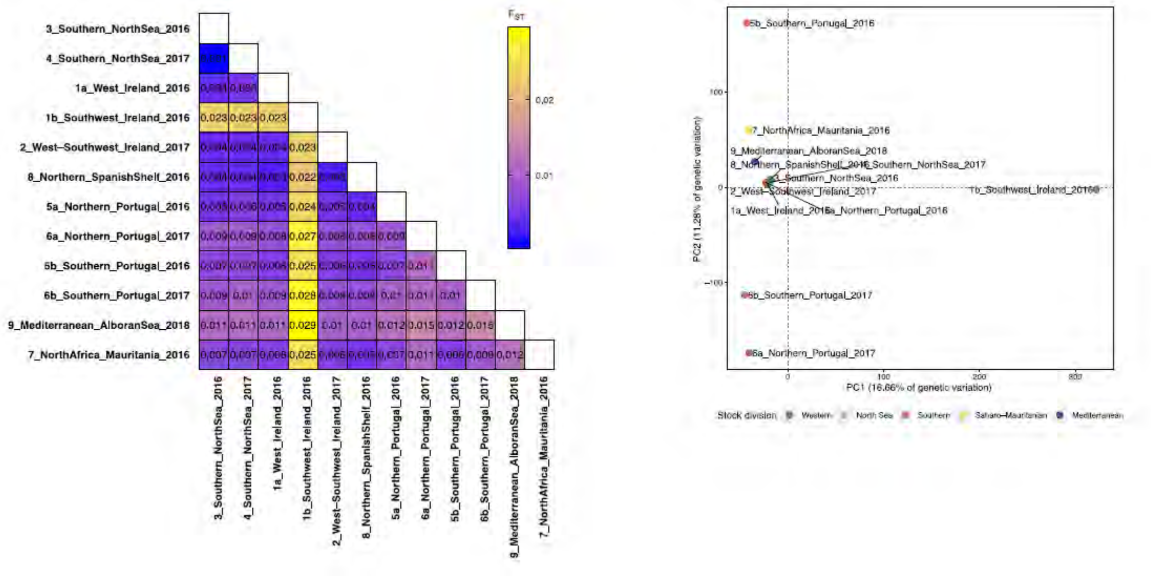

Figure S4. Exploratory population structure analysis for the 12 pools of the horse mackerel showing that samples 1b, 6a, and 6b correspond to outlier samples. (Left) Pairwise F_{ST}. (Right) PCA.

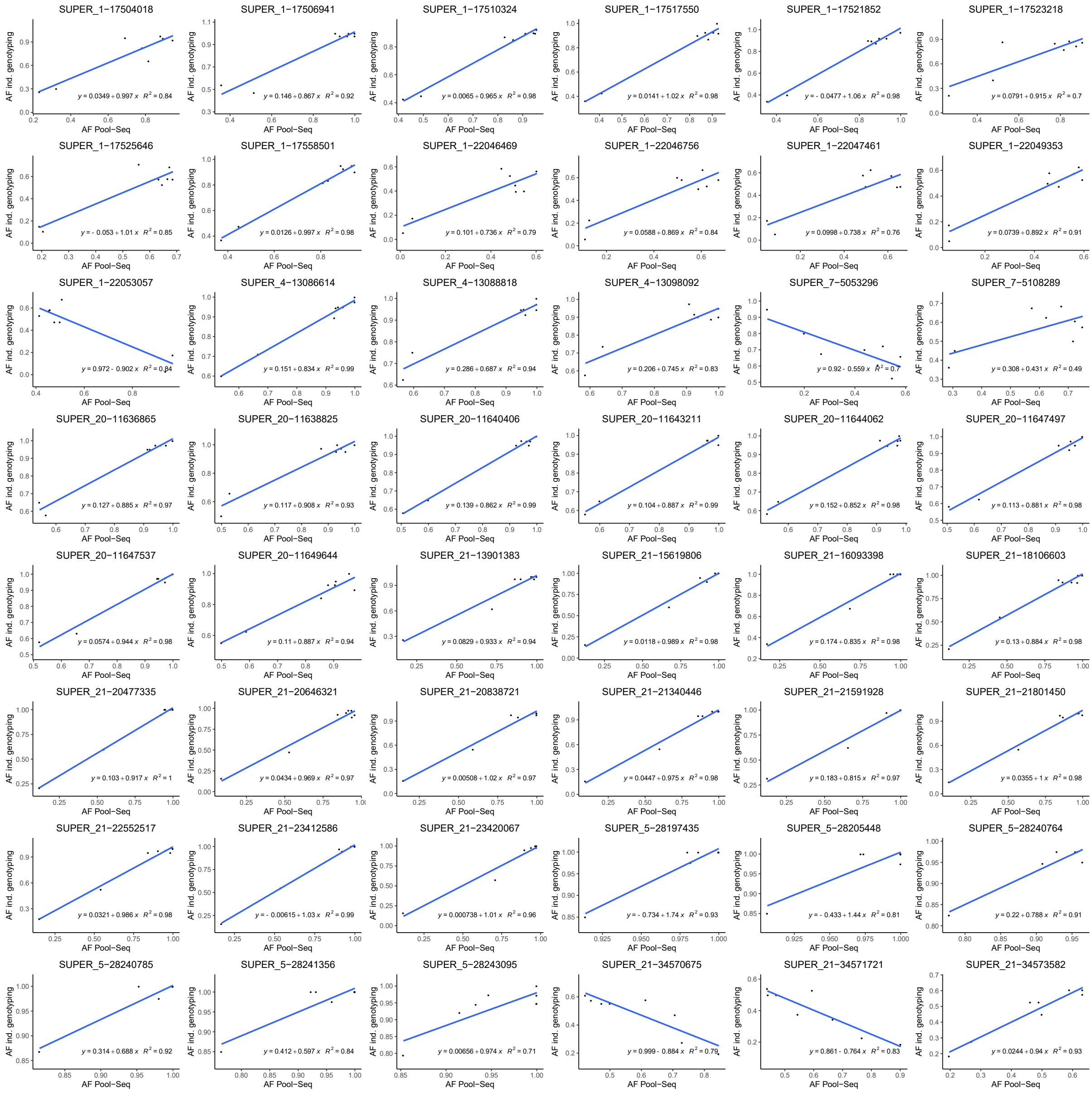

Figure S5. Comparison of population allele frequencies obtained with Pool-Seq and individual genotyping for the 48 SNPs putatively under selection.

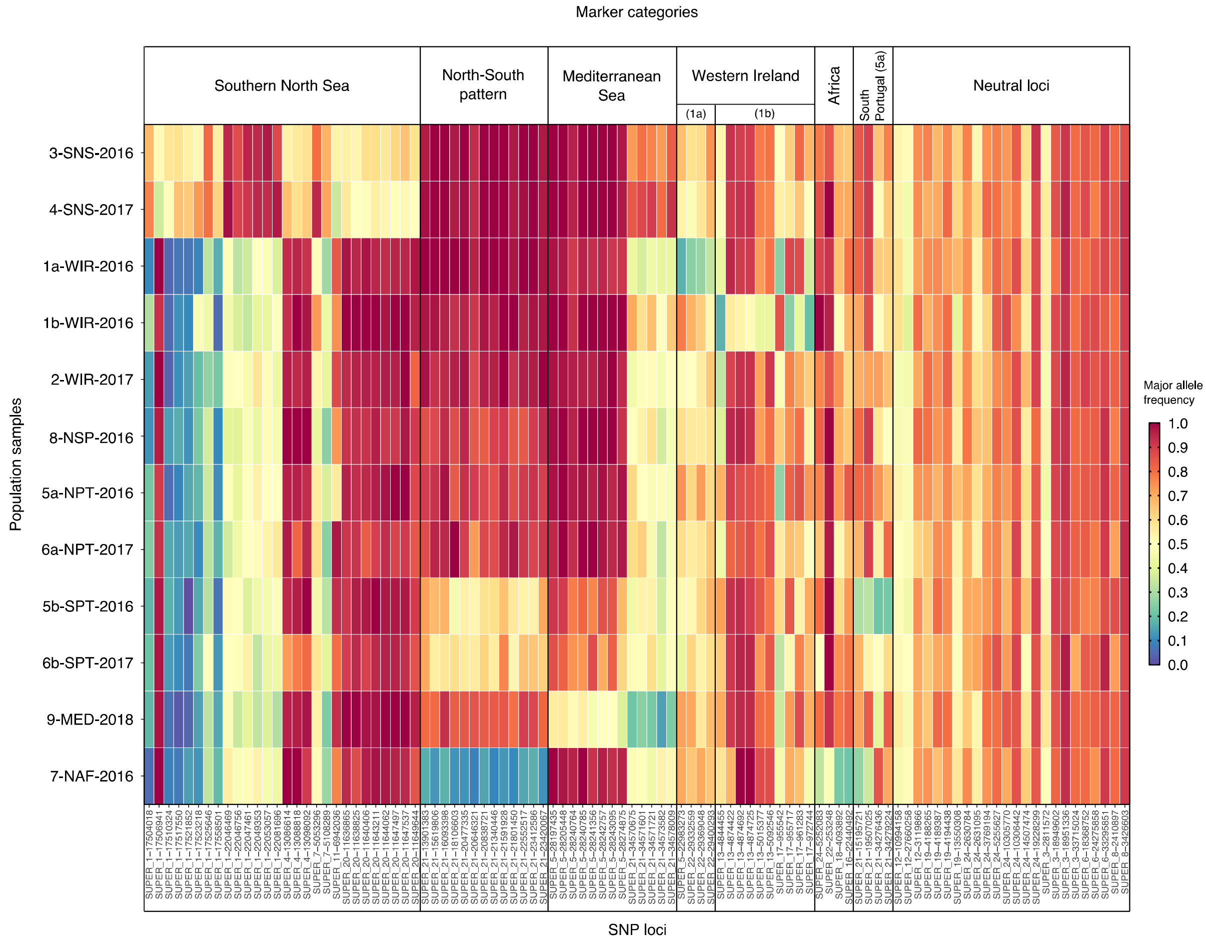

Figure S6. Heatmap plot representing the population allele frequencies of the 100 genetic markers included in the SNP panel. Rows correspond to samples and columns to SNP loci.

Figure S7. Heatmap plot representing the genotype of 157 individuals screened in 63 of the most informative SNPs for the horse mackerel. Squares in blue highlight the genotypes distinguishing the southern North Sea and the north-south genetic break.