WORKING GROUP ON WIDELY DISTRIBUTED STOCKS (WGWIDE)

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Contents

i Executive summary

WGWIDE reports on the status and considerations for management of the 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 Mackerel. This migratory stock is widely distributed throughout the Northeast Atlantic with significant fisheries in several ICES subareas. The assessment conducted in 2021 is an update assessment, based on the configuration agreed during the 2019 inter-benchmark with updates to include sampling of the commercial catch, a recruitment index and tagging time series updated to 2020 and data from the 2021 IESSNS swept area survey. No update to the egg survey based SSB index is available with the most recent survey carried out in 2019 and the next survey scheduled for 2022. 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 above MSY Btrigger. Fishing mortality has been below FMSY since 2015 but is rising and is just below FMSY in 2020.

Blue Whiting. This pelagic gadoid is widely distributed in the eastern part of the North Atlantic. The current assessment configuration (inter-benchmark in 2016) uses preliminary catch and sampling data along with the acoustic survey data from the current year. The 2021 update assessment indicates that SSB is continuing to decrease from a maximum reached in 2017, with below average recruitment from 2017-19, although it remains above MSY Btrigger in 2021. Fishing mortality has been above FMSY since 2014 and is rising since 2019. There are indications in the most recent data of a moderate increase in recruitment in 2020-21.

Norwegian Spring Spawning Herring. This stock is migratory, spawning along the Norwegian coast and feeding throughout much of the Norwegian Sea. The 2021 update assessment is based on an implementation of the XSAM assessment model introduced following a benchmark in 2016. This years' assessment is consistent with that from 2020 but indicates an increase in SSB in the most recent year due to the strong 2016 year-class, the size of which has been revised upwards by the assessment. However, stock size is forecast to resume declining with weak recruitment since 2016, although the stock is predicted to remain above MSY Btrigger.

Western Horse Mackerel. The western stock of horse mackerel is distributed throughout ICES subareas 4,6,7,8 and 9. 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. As in previous years the assessment, whilst indicating the same trend as previous assessments rescales the absolute levels of SSB and F over the time series and the working group proposes that a benchmark be scheduled to address this. SSB in 20201 is estimated to be just above Blim.

North Sea Horse Mackerel. Catch advice for this stock is issued biennially on the basis of an assessment based on a combined index from groundfish surveys in the North Sea and the Channel. Although no 2020 survey index is available due to restricted survey coverage, a reduction in the index value is observed in 2019 and a length based indicator continues to indicate F is above FMSY in both 2019 and 2020.

Northeast Atlantic Boarfish. Boarfish is a small, pelagic, planktivorous, shoaling species, found over much of the Northeast Atlantic shelf but primarily in ICES subareas 4,6,7 and 8. 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. The stock is assessed using an exploratory Bayesian surplus production model with catch and survey data from groundfish surveys and an acoustic survey. The current assessment indicates that, following a sharp decline after 2012, biomass has been increasing in recent years. The most recent acoustic surveys indicate a period of above average recruitment from 2018-2020.

Northeast-Atlantic Red Gurnard. This stock was first considered by WGWIDE in 2016 with advice issued biennially. The assessment was benchmarked in 2021 and a survey-based relative biomass indicator was developed. The 2021 update assessment continues to show the indicator fluctuating without trend since 2010. However, large uncertainties remain with regard to landings data due to poor resolution at the species level and reported discarding levels vary widely.

Striped Red Mullet in Bay of Biscay, Southern Celtic Seas, Atlantic Iberian Waters. No assessment is available for this stock and information on abundance and exploitation level is limited with advice given triennially on the basis of the precautionary approach. However, there are a number of research projects underway which will inform a future benchmark and potential up-grade of the assessment category.

ii Expert group information

Expert group name	Working Group on Widely Distributed Stocks (WGWIDE)
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair(s)	Andrew Campbell, Ireland
Meeting venue(s) and dates	25-31 August 2021, online, 46 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 25-31 August 2021. 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 were the generic ToRs for Regional and Species Working Groups:

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 on the following for the fisheries relevant to the working group:

   i) descriptions of ecosystem impacts on fisheries

   ii) descriptions of developments and recent changes to the fisheries

   iii) mixed fisheries considerations, and

   iv) emerging issues of relevance for management of the fisheries;

c) Conduct an assessment on the stock(s) to be addressed in 2021 using the method (assessment, forecast or trends indicators) as described in the stock annex and produce a **brief** report of the work carried out regarding the stock, providing summaries of the following where relevant:

   i) Input data and examination of data quality; in the event of missing or inconsistent survey or catch information refer to the ACOM document for dealing with COVID-19 pandemic disruption and the linked template that formulates how deviations from the stock annex are to be reported.

   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 2020.

   iv) Estimate MSY reference points or proxies for the category 3 and 4 stocks

   v) Evaluate spawning stock biomass, total stock biomass, fishing mortality, catches (projected landings and discards) using the method described in the stock annex;

      1) for category 1 and 2 stocks, in addition to the other relevant model diagnostics, the recommendations and decision tree formulated by WKFORBIAS (see Annex 2 of https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2020/WKFORBIAS_2019.pdf) should be considered as guidance to determine whether an assessment remains sufficiently robust for providing advice.

      2) b. If the assessment is deemed no longer suitable as basis for advice, consider whether it is possible and feasible to resolve the

issue through an InterBenchmark. If this is not possible, consider providing advice using an appropriate Category 2 to 5 approach.;

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

Consistent with ACOM's 2020 decision, the basis for Fpa should be Fp.05.

1) 1. Where Fp.05 for the current set of reference points is reported in the relevant benchmark report, replace the value and basis of Fpa with the information relevant for Fp.05

2) 2. Where Fp.05 for the current set of reference points is not reported in the relevant benchmark report, compute the Fp.05 that is consistent with the current set of reference points and use as Fpa. A review/audit of the computations will be organized.

3) 3. Where Fp.05 for the current set of reference points is not reported and cannot be computed, retain the existing basis for Fpa.

vii) Catch scenarios for the year(s) beyond the terminal year of the data 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 associated quality issues. For the analytical performance of category 1 and 2 age-structured assessments, report the mean Mohn's rho (assessment retrospective bias analysis) values for time series of recruitment, spawning stock biomass, and fishing mortality rate. 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.

a) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

   i. In the section 'Basis for the assessment' Table 3 under input data align the survey names with the ICES survey naming convention

b) Review progress on benchmark issues and processes of relevance to the Expert Group.
   i) update the benchmark issues lists for the individual stocks;
   ii) review progress on benchmark issues and identify potential benchmarks to be initiated in 2022 for conclusion in 2023;
   iii) determine the prioritization score for benchmarks proposed for 2022-2023;
   iv) as necessary, document generic issues to be addressed by the Benchmark Oversight Group (BOG)

c) Prepare the data calls for the next year's update assessment and for planned data evaluation workshops;

d) Identify research needs of relevance to the work of the Expert Group.

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

f) If not completed in 2020, complete the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity' for the new assessments and data used for the stocks. Also note in the benchmark report how productivity, species interactions, habitat and distributional changes, including those related to climate-change, could be considered in the advice.

1.1.1 The WG work 2021 in relation to the ToRs

The WG considered updates for all eight stocks within its remit. Based upon these assessments and associated short term forecasts, the group produced draft advice sheets for Northeast Atlantic mackerel, Blue Whiting, Norwegian spring spawning herring, Western horse mackerel, North Sea horse mackerel, boarfish and red gurnard. 2021-23 catch advice for striped red mullet was issued in 2020. 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, six stock annexes were updated and the productivity audit was completed for each stock.

A brief review of ecosystem and fisheries overviews was also carried out. Since WGWIDE stocks are relevant to a number of geographically based overviews, the quantity of material for review is substantial and the review was limited principally to the ecosystem overviews. It was felt that presenting summaries of stock trends for widely distributed stocks within overview documents covering only a small fraction of the overall stock distribution may not be meaningful. Additionally, it was suggested that a formalised method for providing feedback arising from such a review should be established.

1.2 Participants at the meeting

WGWIDE 2021 was attended by 46 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 prevented them from acting with scientific independence, integrity, and impartiality.

1.3 Overview of stocks within the WG

Eight stocks are assessed by WGWIDE. In 2021, the group drafted 2022 advice sheets for 7 stocks. 2022 advice for striped red mullet was issued in 2020 the relevant data series and stock assessments were updated and considered at WGWIDE 2021. 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
Boarfish	boc.27.6-8	3.2	Bayesian Schafer surplus production model	2	2019
Red gurnard	gur.27.3-8	3.2	Survey trends based	2	2019
Norwegian spring-sp. herring	her.27.1-24a514a	1	XSAM	1	2020
Western horse mackerel	hom.27.2a4a5b6a7a-ce-k8	1	Stock Synthesis	1	2020

Stock	ICES code	Data Category	Assessment method	Assessment Frequency	Last Assess-ment
North Sea horse mackerel	hom.27.3a4bc7d	3.2	Survey trends based	2	2019
NE-Atlantic macke-rel	mac.27.nea	1	SAM	1	2020
Striped red mullet	mur.27.67a-ce-k89a	5	No assessment	3	2020
Blue whiting	whb.27.1-91214	1	SAM	1	2020

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 and van Overzee 2009, 2010, van Overzee and van Helmond 2011, Ulleweit *et al.* 2016, van Overzee *et al.* 2013, 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 and the results are currently being analysed.

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.

The next workshop (virtual) and exchange is planned for October/November 2021 using the SmartDots platform.

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.

Last year, WGWIDE recommended to organise a scale/otolith exchange and workshop. This work appears to be in progress in WGIPS, WGBIOP and nationally at the institutes.

1.4.4.4 Blue Whiting

In 2021, between 31 May and 4 June, took place the last workshop on age reading of blue whiting (WKARBLUE3). The workshop was preceded by an inter-calibration age reading exchange, which was undertaken in 2020 using the SMARTDOTS platform. In the exchange, the otolith collection included 407 otoliths from the entire stock distribution area, from which 190 otoliths where from the northern areas and 217 where from the southern areas of distribution. The otolith dataset enables a good coverage of samples by area and sex and took into account the differences in growth patterns by areas (northern and southern), and by sex due to the sexual dimorphism in blue whiting (Gonçalves *et al.* 2017).

The overall agreement of the pre-workshop exercise was 66% considering all readers and 70% for the assessment readers (advanced readers). Considering only the otoliths samples from the northern areas and the readers from the northern that usually read the otoliths from those areas for the assessment, 69% of agreement was achieved. Otherwise, considering only the otoliths samples from the southern areas and the readers from the southern that usually read the otoliths from those areas for the assessment, 79% of agreement was achieved. During the workshop, a small exchange was also conducted with 55 otoliths in which 73% agreement between the advanced readers was achieved.

The main issues identified on blue whiting age reading are still: the fact that the otoliths from some areas revealed to be more difficult to read (*e.g.* 27.2.a, 27.5.b); the first ring identification; edge type interpretation and false or double rings identification (Gonçalves, 2021).

During the workshop some of the otoliths from the exercise were polished, to help readers in the cases were the first age ring 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 in cases here the visible first ring size presents a size higher than the expected and the readers have doubts if an inner first ring are there. The hypothesis of the existence of a non-visible first ring has been described in the otoliths from the adult fish as the otolith becomes thicker and wider.

Although, during the WKARBLUE3 progresses have been made and objective and more clear age reading guidelines had been constructed. The recurrent age reading issues still remain the same, e.g. the identification of the position of the first annual growth ring, false rings and interpretation of the edge. In order to overcome those problems and increase the accuracy on age classifications, age validation studies on blue whiting otoliths to solve growth rings interpretation, were further recommended and should be conducted.

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. Quality Control and Data Archiving

1.4.5 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

Official Catch	Catches as reported by the official statistics to ICES
WG Catch	The sum of the 6 categories above
Sampled Catch	The catch corresponding to the age distribution

1.4.6 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 (e.g. 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 the age and length distribution of catches	To ensure the sampling of age and length information from all catch fractions and all areas and within all quarters from all commercial fleets with a distribution of sampling effort over the year and areas in the North Sea	National institutes
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	Species level catch reporting and sampling	Red gurnard catches should be reported to species level and with the appropriate codification. Where reported as mixed gurnards, this should be accompanied by documented procedures for estimating the proportion of red gurnard.	National laboratories
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	National laboratories

Stock	Data Problem	How to be addressed in	By who
		and methods for estimation (e.g. CCTV systems) should be investigated.	
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

1.4.7 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.

1.4.8 Information from stakeholders

The procedure for the submission of inputs from stakeholders into the scientific advice changed in 2020. Instead of contributing information directly into the Advice Drafting Groups, information from stakeholders is now submitted directly to the expert group for consideration and inclusion into the draft advice, if applicable.

For WGWIDE stocks there are several instances of strong cooperation between research institutes and fishing industry stakeholder 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 2021, the following contributions from fishing industry research activities have been reported to the working group:

1. PFA self-sampling report 2015-2021
2. Gonad sampling for mackerel and horse mackerel 2019-2021

1.4.8.1 PFA self-sampling report 2016-2021 (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 from 2017 onwards is presented in the text table below.

Year	Number Vessels	Number Trips	Number Days	Number Hauls	Catch (t)	Catch per Day (t)	Number Length Measurements
2017	12	64	887	1 886	184 973	208	95 190
2018	16	88	1 330	2 901	272 344	204	176 432
2019	16	101	1 426	3 113	253 326	177	151 187
2020	18	117	1 576	3 373	324 943	206	259 099
2021*	19	64	829	1 876	173 412	209	144 952
All		434	6 048	13 149	1 208 998		826 860

***incomplete**

The Mackerel fishery takes place from October through to March of the subsequent year. Minor by-catches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 357 fishing trips with 4 940 hauls, a total catch of 287 836 t and 91 096 individual length measurements. The main fishing areas are ICES divisions 27.4.a and 27.6.a. Compared to the previous years, mackerel in the catch in 2021 has been relatively large with a median length of 36.4 cm compared to 33.6-36.2 in the preceding years. Median weight has been somewhat higher at 435 g compared to 385-422 g in the preceding years.

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 2017 - 2021 (up to 27/07/2021) covered 243 fishing trips with 3 446 hauls, a total catch of 141 548 t and 153 307 individual length measurements. The main fishing areas are ICES divisions 27.6.a, 27.7.b and 27.7.d. Horse mackerel have a wide range in the length distributions in the catch. Median lengths in divisions 27.6.a, 27.7.b and 27.7.j have fluctuated between 26.2 and 31.3 cm (with one low median length of 23.3 cm in 27.6.a in 2018). In ICES divisions 27.7.d and 27.7.h, median lengths in the catch are smaller and fluctuated between 21.3 and 24.6 cm.

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 2017 - 2021 (up to 27/07/2021) covered 240 fishing trips with 6 560 hauls, a total catch of 650 604 t and 507 481 individual length measurements. The main fishing areas are ICES divisions 27.6.a, 27.7.c and 27.7.k. Compared to the previous years, blue whiting in the catch in 2021 have been relatively large with a median length of 27.9 cm compared to 24.2-27.2 cm in the preceding years. Also, the median weight has been somewhat higher at 137 g compared to 85-120 g in the preceding years.

The Norwegian Spring Spawning Herring (NSSH or ASH) fishery is a relatively small fishery for the PFA and takes place mostly in October. Overall, the self-sampling activities during the years 2017 - 2021 (up to 27/07/2021) covered 27 fishing trips with 456 hauls, a total catch of 36 003 t and 10 327 individual length measurements. Only the herring fishery in ICES division 27.2.a is considered for ASH, although there are herring catches in other divisions within the selected trips e.g. trips where North Sea herring has been fished with some bycatches of mackerel. Atlanto-Scandian herring have a relatively narrow range in the length distributions in the catch. Median lengths have been between 31 and 36 cm.

1.4.8.2 Gonad sampling for mackerel and horse mackerel

Working Document 08 presented to WGWIDE 2020 summarized the status of the industry-science collaboration aimed at improving the knowledge on gonad development of mackerel and horse mackerel. The work was 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 was 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 was to investigate the period during which spawning occurred in 2020 for the Western horse mackerel. Unfortunately, the final report on the analyses was not available for WGWIDE 2021 although it is expected to be ready soon. Gonad sampling for mackerel has been restarted again from the beginning of 2021.

1.5 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 a benchmark that took place in January 2017 (ICES, 2017) 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. The Blue whiting SAM assessment was introduced following a benchmark in 2012. Since this time, an inter-benchmark in 2016 incorporated the use of preliminary in-year catch data with the stock weights in the assessment year estimated from catch sampling incorporated in 2019 (previously the average of the most recent three years was used). The acoustic survey time series was updated in 2020 following recalculation by the StoX platform with minor updates to the historic index. The red gurnard assessment conducted at WGWIDE 2021 followed a benchmark in February 2021 (WKWEST) during which an index of abundance based on a number of bottom trawl surveys was developed.

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

1.6 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 the Boarfish should be benchmarked. Ongoing sampling of the commercial catch, an expanded acoustic survey time series and advances in modelling techniques *e.g.* VAST should be explored with a view to improving the current assessment. A number of research projects are underway for Striped red mullet - findings will be presented to the working group when available and will inform any proposed future benchmark.

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

Stock	Benchmark History	WGWIDE 2021 Proposal
Boarfish	Never benchmarked	Full benchmark
Red gurnard	Full benchmark 2021	
Norwegian Spring Spawning herring	Full benchmark 2016	
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	
Blue whiting	Benchmarked 2012 Inter-benchmark 2016	

1.7 Scientific advice and management of widely distributed and migratory pelagic fish

1.7.1 General overview of management system

The North East Atlantic Fisheries Commission (NEAFC) is the Regional Fisheries Management Organisation (RFMO) for the North East Atlantic. NEAFC is an end user of ICES advice and provides a forum for its contracting parties (Coastal States) to manage the exploitation of straddling stocks that occur in several EEZs and international waters such as WGWIDE stocks North East Atlantic Mackerel, Blue Whiting and Norwegian Spring Spawning herring (also known as Atlanto-Scandian herring). There are 6 contracting parties to NEAFC: Denmark (in respect of the Faroe Islands and Greenland), European Union, Iceland, Norway, Russian Federation and the UK. The management of Western horse mackerel is not considered by NEAFC with sharing subject of separate agreements between EU, Norway and the UK.

1.7.2 Management plans

Catch advice for two stocks considered by WGWIDE is given on the basis of an agreed management plan:

- A long term management strategy for Norwegian spring spawning herring was agreed by the European Union, the Faroe Islands, Iceland, Norway and Russian Federation in 2018 following an evaluation by ICES (WKNSSHMSE, ICES, 2018c) which found it to be precautionary. The plan is based on a target fishing mortality of 0.14 when the stock is above B_{pa}. Should SSB fall below B_{pa}, the target fishing mortality is linearly reduced to 0.05 at and below B_{lim}. The plan incorporates TAC change limits of -20% and +25% which are suspended when below B_{pa} and 10% interannual transfer which is suspended when below B_{lim}. The plan is scheduled for review no later than 2023. Although the plan is agreed by the parties involved in the fishery and ICES advice is based on application of the management strategy, there has been no agreement on the relative catch share since 2013 with the total unilaterally declared quotas exceeding the management plan based catch advice since this time.

- A long term management strategy for Blue Whiting was agreed by the European Union, the Faroe Islands, Iceland and Norway in 2016 following an evaluation by ICES (WKBWMS, ICES, 2016c) in 2016 which found it to be precautionary. The plan is based on a target fishing mortality equivalent to F_{MSY} (0.32) when the stock is above B_{pa}. Should SSB fall below B_{pa}, the target fishing mortality is linearly reduced to 0.05 at and below B_{lim}. The plan incorporates TAC change limits of +/-20% which are suspended when below B_{pa} and 10% interannual transfer. No agreement on quota shares has been reached since 2015 and catches have exceeded advice since this time.

There is no currently agreed management strategy for either Northeast Atlantic Mackerel or Western horse mackerel. Strategies have been proposed and evaluated but agreement has not yet been reached on their implementation such that catch advice has been given on the basis of the MSY approach.

1.7.3 Comparison of advice, TAC and catches

This section presents an overview of the time-series (2010 to present) of ICES catch advice, TAC (either agreed between all fishing parties or a sum of unilaterally declared quotas) and ICES estimates of total catch for Norwegian spring spawning herring, Western horse mackerel, Northeast Atlantic mackerel and blue whiting. The overviews are based on the history of advice, management and catch as reported in the ICES single stock advice documents. The information is summarised in table 1.10.1 and figure 1.10.1. Figures 1.10.2-4 depict the percentage deviation of TAC from advice, catch from advice and catch from TAC respectively.

For Norwegian spring-spawning herring some deviations between TAC and advice occurred between 2010-2013, but from 2014 on the sum of unilateral quotas has been in excess of the scientific catch advice which was based on the agreed management plan. The realised catches are similar to the sum of unilateral quotas and thus also in excess of the advised catch.

Western horse mackerel: some deviations between TAC and advice have been occurring during the time-series presented, but there does not appear to be a clear trend. There is no agreed management plan for western horse mackerel and advice has been given on the basis of the MSY approach for the most recent decade. Catches have generally been at or below the agreed TAC.

The Northeast Atlantic mackerel fishery has not had an agreed TAC during the period presented with the total of declared unilateral quotas consistently in excess of the scientific catch advice and 81% greater in 2018, despite an agreement on sharing between some of the Coastal Stats for much of this period. Catches have likewise been in excess of the scientific advice and close to the sum of unilateral quotas.

Blue whiting: up to 2013, the agreed management plan had been followed. However, from 2014 onwards, no agreement has been reached and the sum of unilateral quotas and catches have been in excess of the scientific catch advice and the agreed management plan.

In summary, although agreed management plans exist for Norwegian spring-spawning herring, Northeast Atlantic mackerel and Blue whiting, they have not been instrumental in limiting the TACs to the plan-based values. While the fishing parties may have agreed on the overall TACs for these stocks, they have failed to agree on relative quota shares and have subsequently declared unilateral quotas. As a consequence, the catches have been in excess of the scientific advice and the management plans. For western horse mackerel (which is primarily exploited by the EU fleet), no agreed management plan is in place and, despite deviations, no systematic difference between scientific advice and TACs has been observed in the recent period.

Table 1.10.1. Overview of recommended F, scientific advice, agreed TAC (or sum of unilateral quotas) and catch

Norwegian Spring Spawning Herring					
Year	Advice Basis	Advised F	Advised Catch (t)	TAC or quotas	Catch (t)
2010	Do not exceed HCR	0.12	1 483 000	1 483 000	1 457 000
2011	Scenarios	0.12	1 170 000	988 000	993 000
2012	Follow management plan	0.12	833 000	833 000	826 000
2013	Follow management plan	0.12	619 000	692 000	685 000
2014	Follow management plan	0.10	418 000	436 000	461 000
2015	Follow management plan	0.08	283 000	328 000	329 000
2016	Follow management plan	0.08	317 000	377 000	383 174
2017	Follow management plan	0.12	646 075	805 142	721 566
2018	Follow management plan	0.09	384 197	546 448	592 899
2019	Follow management strategy (F_{mgt}=0.14, B_{mgt}=3.184Mt)	0.14	588 562	773 750	777 165
2020	Follow management strategy (F_{mgt}=0.14, B_{mgt}=3.184Mt)	0.14	525 594	693 915	720 937
2021	Follow management strategy (F_{mgt}=0.14, B_{mgt}=3.184Mt)	0.14	651 033	881 097	
2022	Follow management strategy (F_{mgt}=0.14, B_{mgt}=3.184Mt)	0.14	598 588		
Western Horse Mackerel					
Year	Advice Basis	Advised F	Advised Catch (t)	TAC or quotas	Catch (t)
2010	Follow proposed management plan		180 000	185 000	203 112
2011	Scenarios	0.13	229 000	184 000	193 698
2012	MSY framework	0.13	211 000	183 000	169 858
2013	MSY framework	0.13	126 000	183 000	165 258
2014	MSY approach	0.13	110 546	135 000	136 360
2015	MSY approach	0.12	99 304	99 300	98 419
2016	MSY approach	0.13	126 000	126 000	98 811
2017	MSY approach	0.11	69 186	95 500	82 961

2018	MSY approach	0.10	117 070	115 470	101 682
2019	MSY approach	0.11	145 237	136 376	124 947
2020	MSY approach	0.06	83 954	81 796	76 422
2021	MSY approach	0.06	81 376	81 375	
2022	MSY approach	0.06	71 138		
Northeast Atlantic Mackerel					
Year	Advice Basis	Advised F	Advised Catch (t)	TAC or Quotas	Catch (t)
2010	Harvest control rule	0.22	572 000	691 305	875 515
2011	Scenarios	0.22	672 000	929 943	946 661
2012	Follow the management plan	0.22	639 000	938 410	892 353
2013	Follow the management plan	0.22	542 000	857 319	931 732
2014	Follow the management plan	0.22	1 011 000	1 400 981	1 393 000
2015	Follow the management plan	0.22	906 000	1 208 719	1 208 990
2016	MSY approach	0.22	773 840	1 047 432	1 094 066
2017	MSY approach	0.22	857 000	1 191 970	1 155 944
2018	MSY approach	0.21	550 948	999 929	1 026 437
2019	MSY approach	0.23	770 358	864 000	840 021
2020	MSY approach	0.23	922 064	1 090 879	1 039 513
2021	MSY approach	0.26	852 284	1 119 103	
2022	MSY approach	0.26	794 920		
Blue Whiting					
Year	Advice Basis	Advised F	Advised Catch (t)	TAC or quotas	Catch (t)
2010	Follow the agreed management plan	0.18	540 000	548 000	540 000
2011	Scenarios	0.05	40 000	40 000	105 000
2012	Follow the agreed management plan	0.18	391 000	391 000	384 000
2013	Follow the agreed management plan	0.18	643 000	643 000	626 000
2014	Follow the agreed management plan	0.18	948 950	1 200 000	1 155 000
2015	Follow the agreed management plan	0.18	839 886	1 260 000	1 396 244
2016	MSY approach	0.30	776 000	1 147 000	1 183 187

2017	MSY approach	0.32	1 342 330	1 675 400	1 558 061
2018	Long-term management strategy	0.32	1 387 872	1 727 964	1 711 477
2019	Long-term management strategy	0.32	1 143 629	1 483 208	1 515 527
2020	Long-term management strategy	0.32	1 161 615	1 478 358	1 495 248
2021	Long-term management strategy	0.36	929 292	1 157 604	
2022	Long-term management strategy	0.32	752 736		

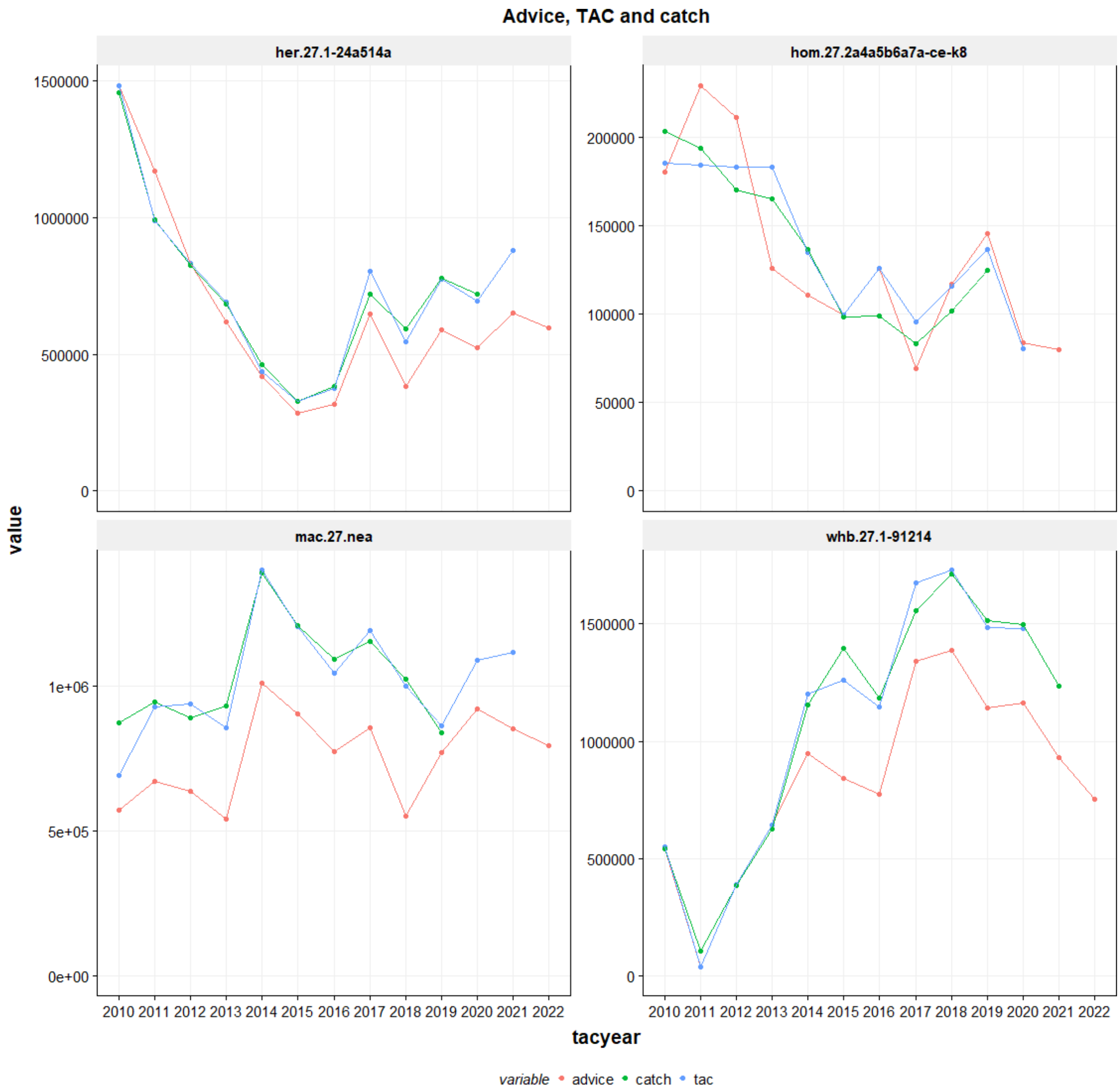


Figure 1.10.1.a: Overview of scientific advice, agreed TAC (or sum of unilateral quota) and catch

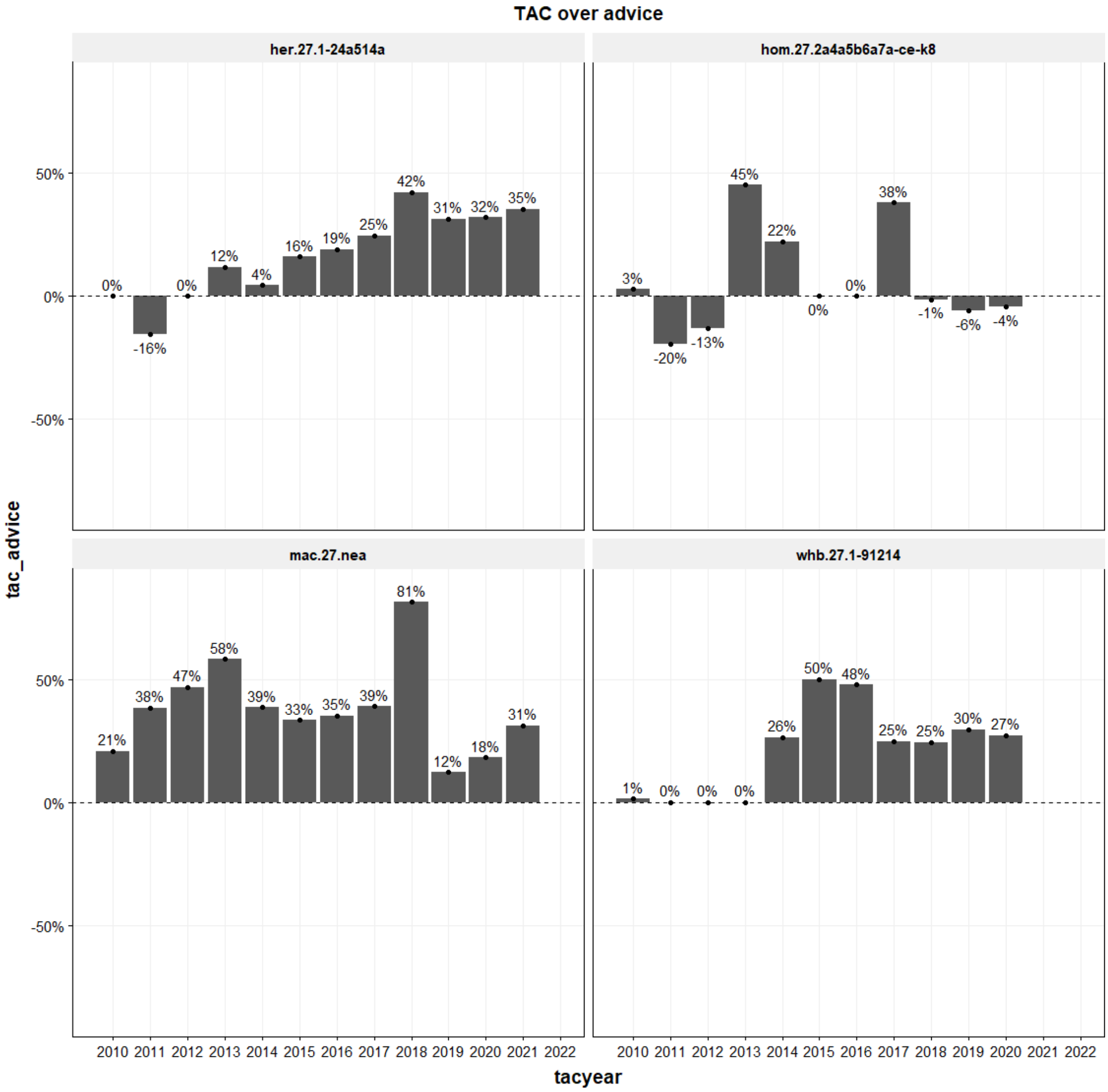


Figure 1.10.2: Overview of TAC (or sum of unilateral quota) over advice

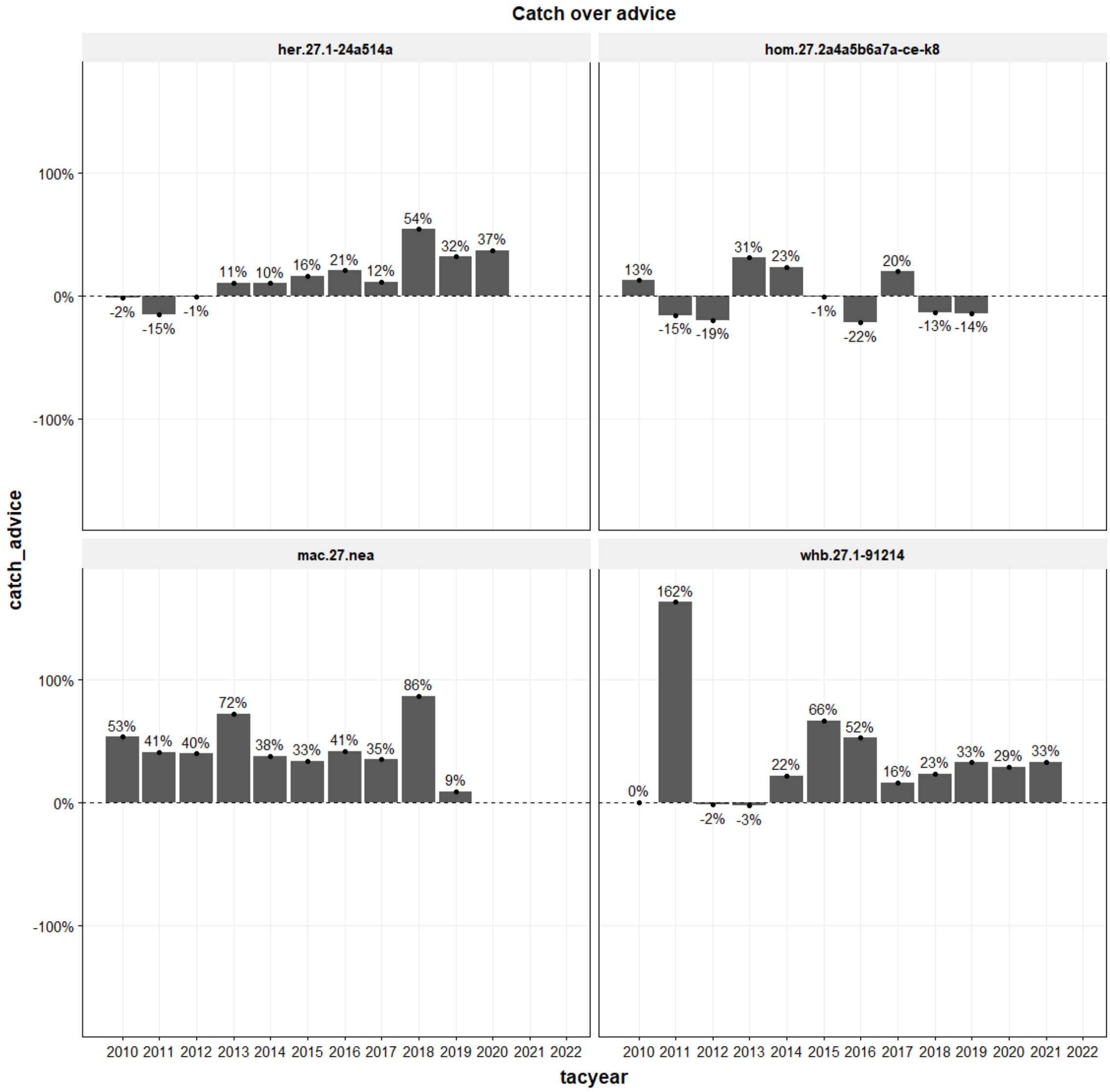


Figure 1.10.3: Overview of catch over advice

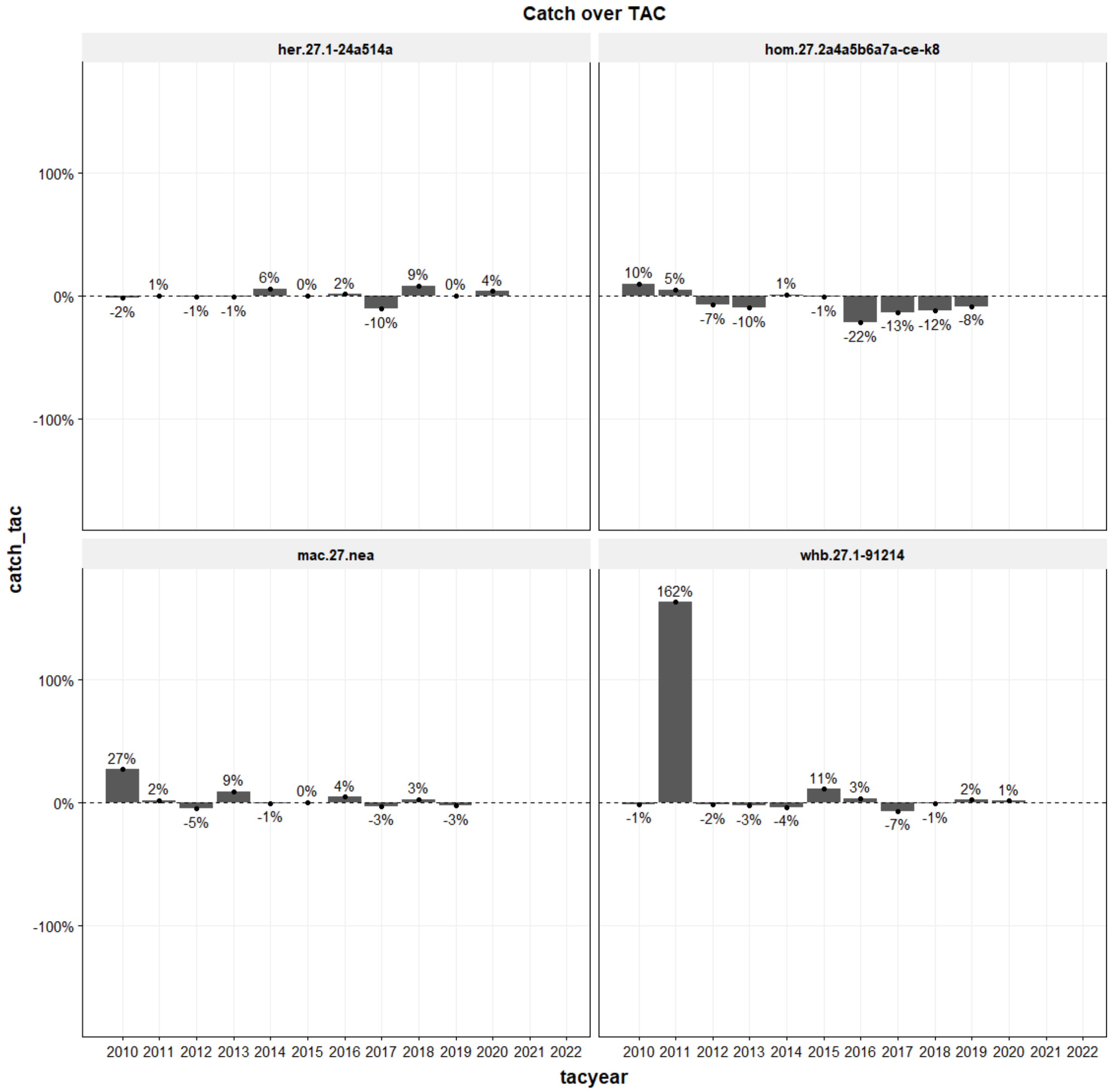


Figure 1.10.4: Overview of catch over TAC (or sum of unilateral quota)

1.8 General stock trends for widely distributed and migratory pelagic fish

WGWIDE 2021 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) 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 is shown in Figure 1.10.1. The highest combined catch (approx. 4 million tonnes) for these four species was been taken in

2004 and 2005. In the most recent 6 years the total catch has been composed of ~45% blue whiting, ~33% mackerel, ~18% herring and ~3% horse mackerel.

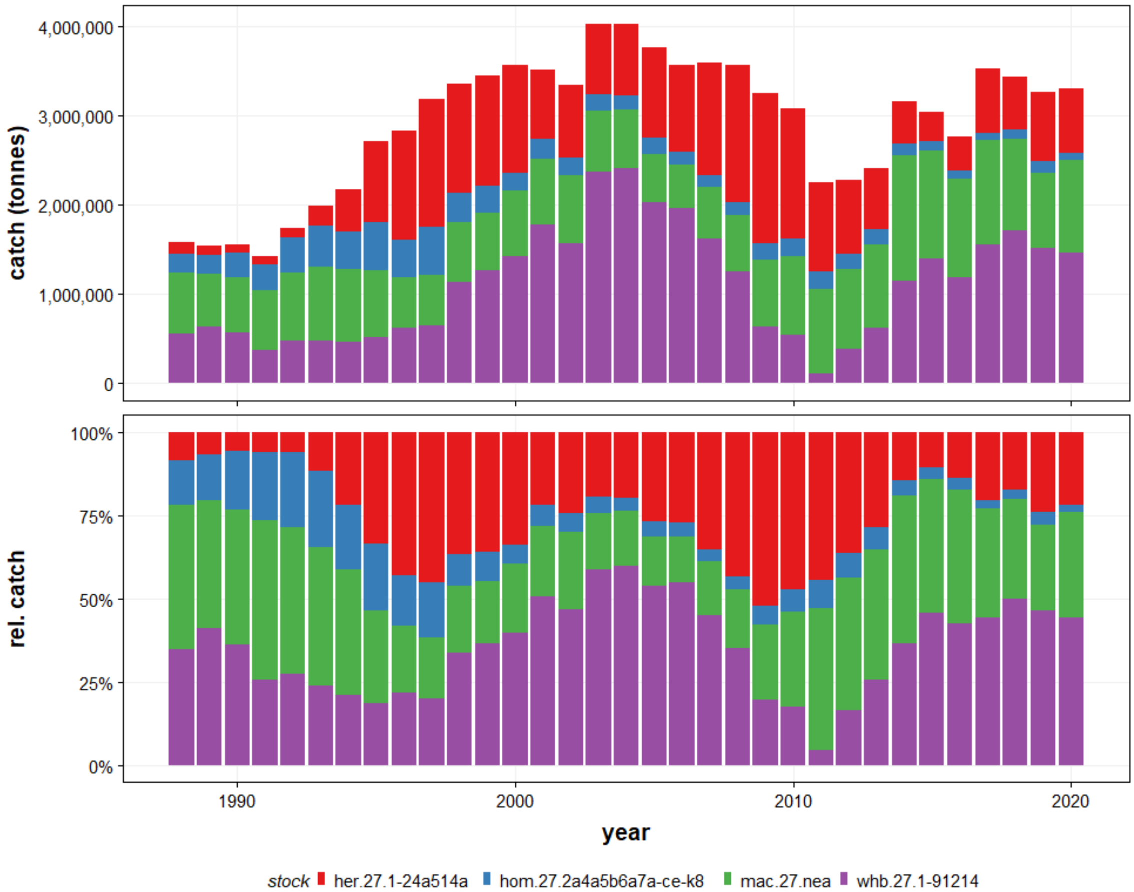


Figure 1.10.1: Catch of blue whiting, mackerel, western horse mackerel and Norwegian spring spawning herring

An overview of the key variables for each of the stocks (SSB, fishing mortality and recruitment), is shown in Figure 1.10.2. The stock sizes of herring, mackerel and blue whiting has been declining from historical highs in the recent years, although stock sizes are still above their respective MSY $B_{trigger}$ reference point values. The stock size of western horse mackerel has been around B_{lim} for much of the recent past although the stock size is increasing in the most recent period.

Recent fishing mortality for herring, horse mackerel and mackerel has been around F_{MSY} in the most recent period. Fishing mortality for blue whiting has been above F_{MSY} for much of the time series.

Absolute recruitment estimates for blue whiting and herring are on a comparable scale and substantially higher and more variable than horse mackerel (except for the 1982 year-class) and mackerel.

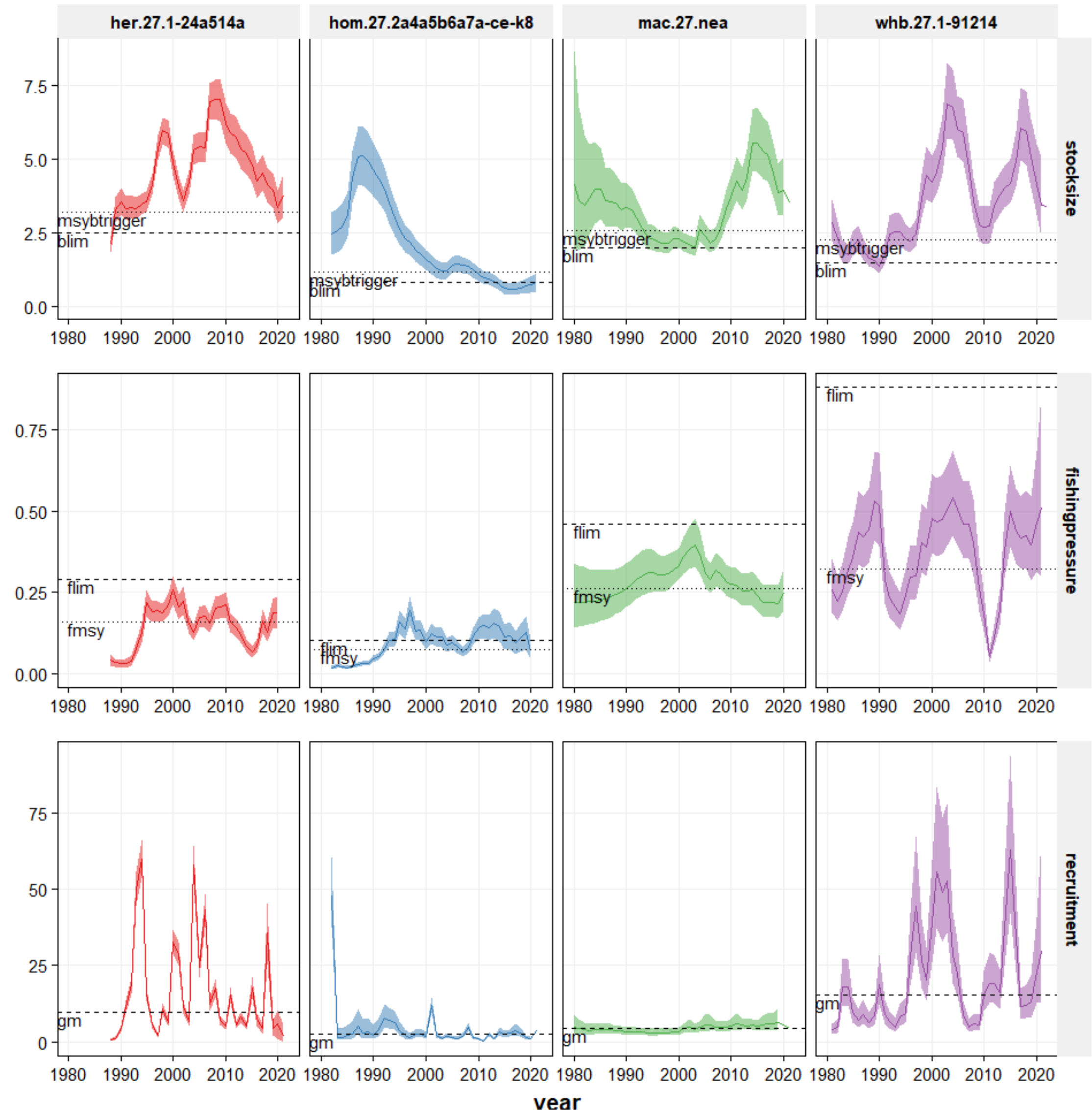


Figure 1.10.2: top - SSB (million tons), middle - fishing pressure and bottom - recruitment (billions) of Norwegian spring spawning herring, western horse mackerel, Northeast Atlantic mackerel and blue whiting.

An overview of stock weight-at-age for mackerel and blue whiting is shown in figures 1.10.3 and 1.10.4.

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 1.10.3: Stock weight-at-age of NEA mackerel

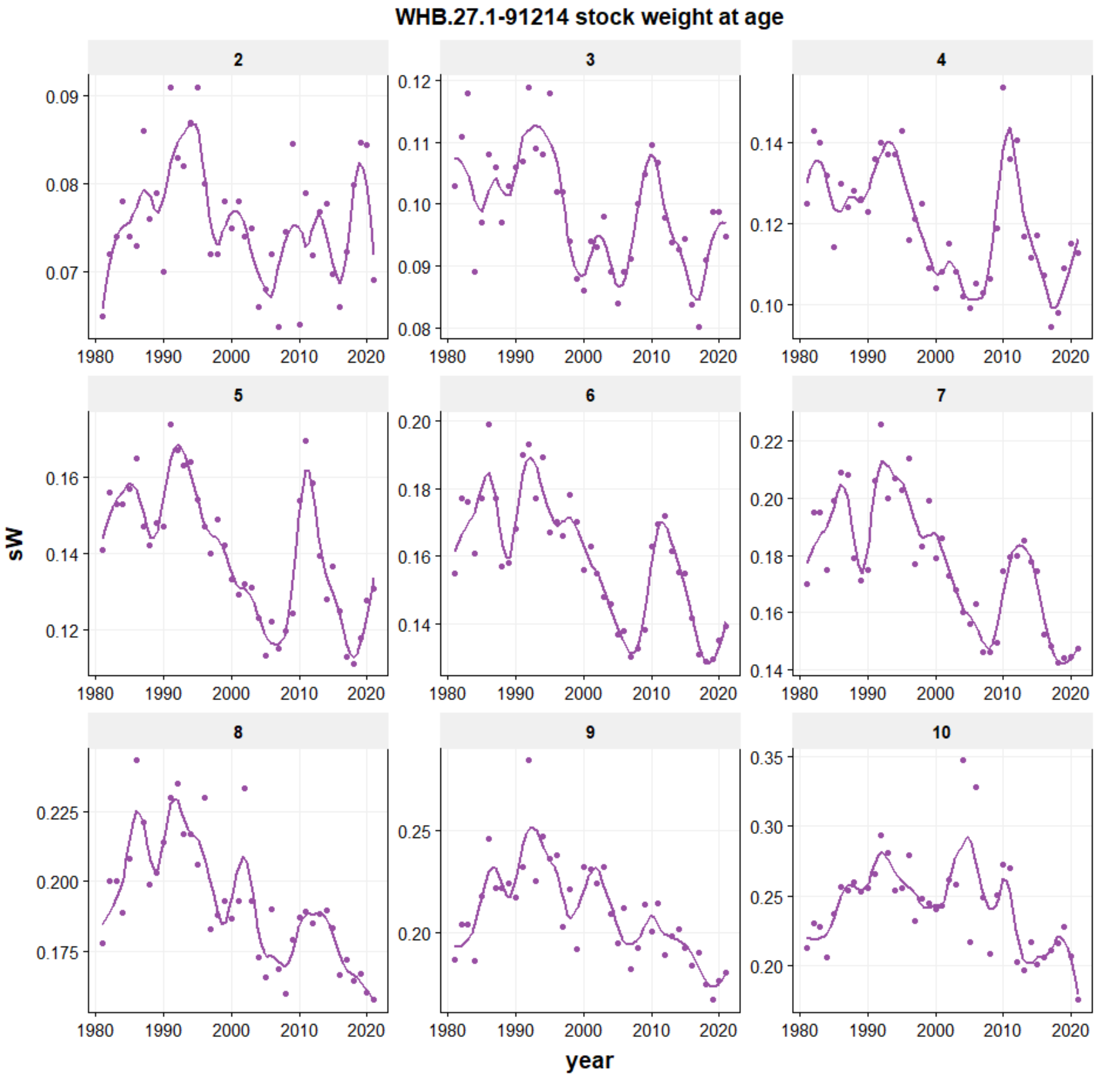


Figure 1.10.4: Stock weight at age of blue whiting

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 an estimate of total catch per rectangle (although 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 (horse mackerel) and 1998 (mackerel). The time series for herring and blue whiting are shorter (from 2011) although additional information could still be derived from earlier WG reports.

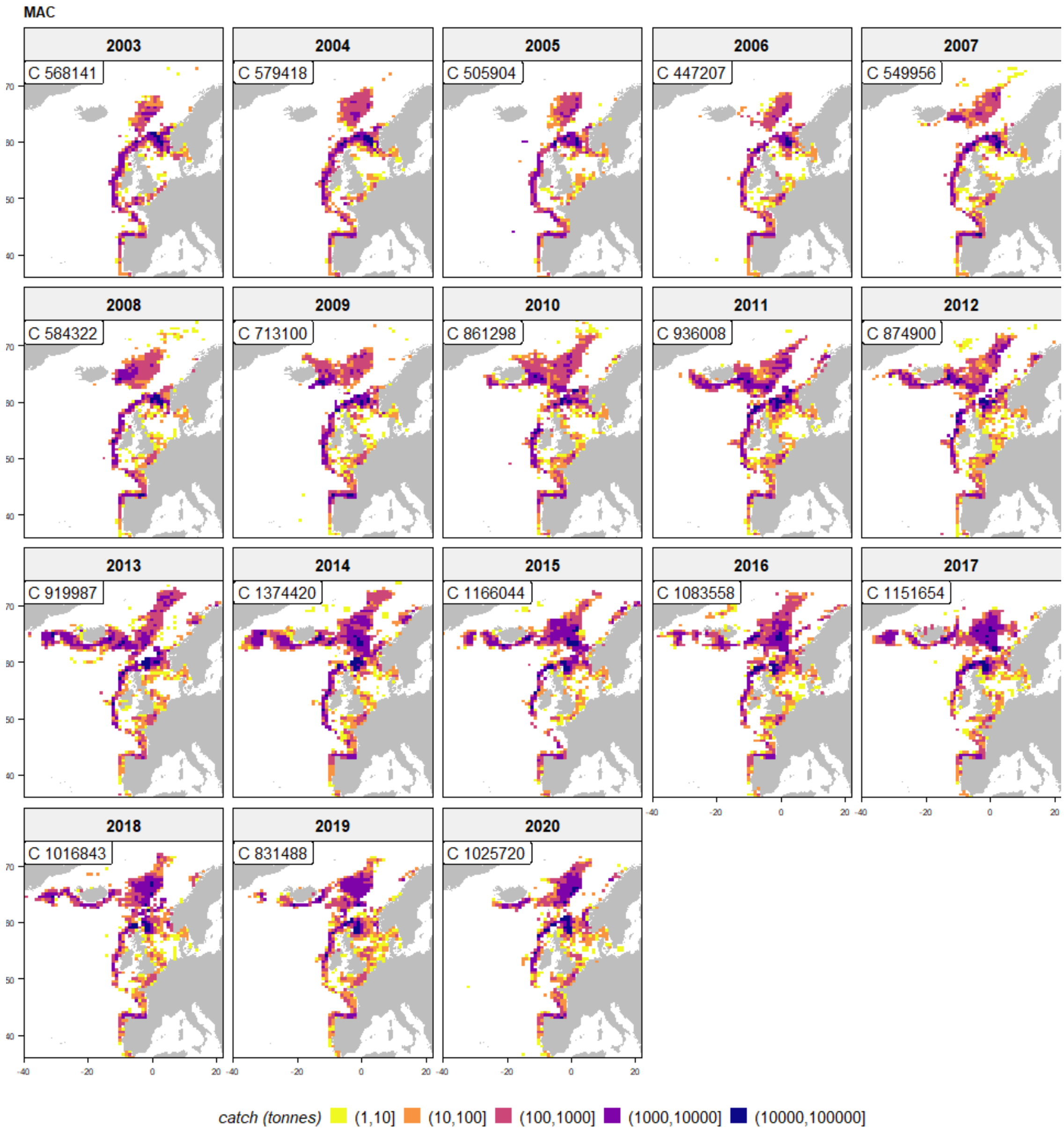


Figure 1.10.5: Catch of mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

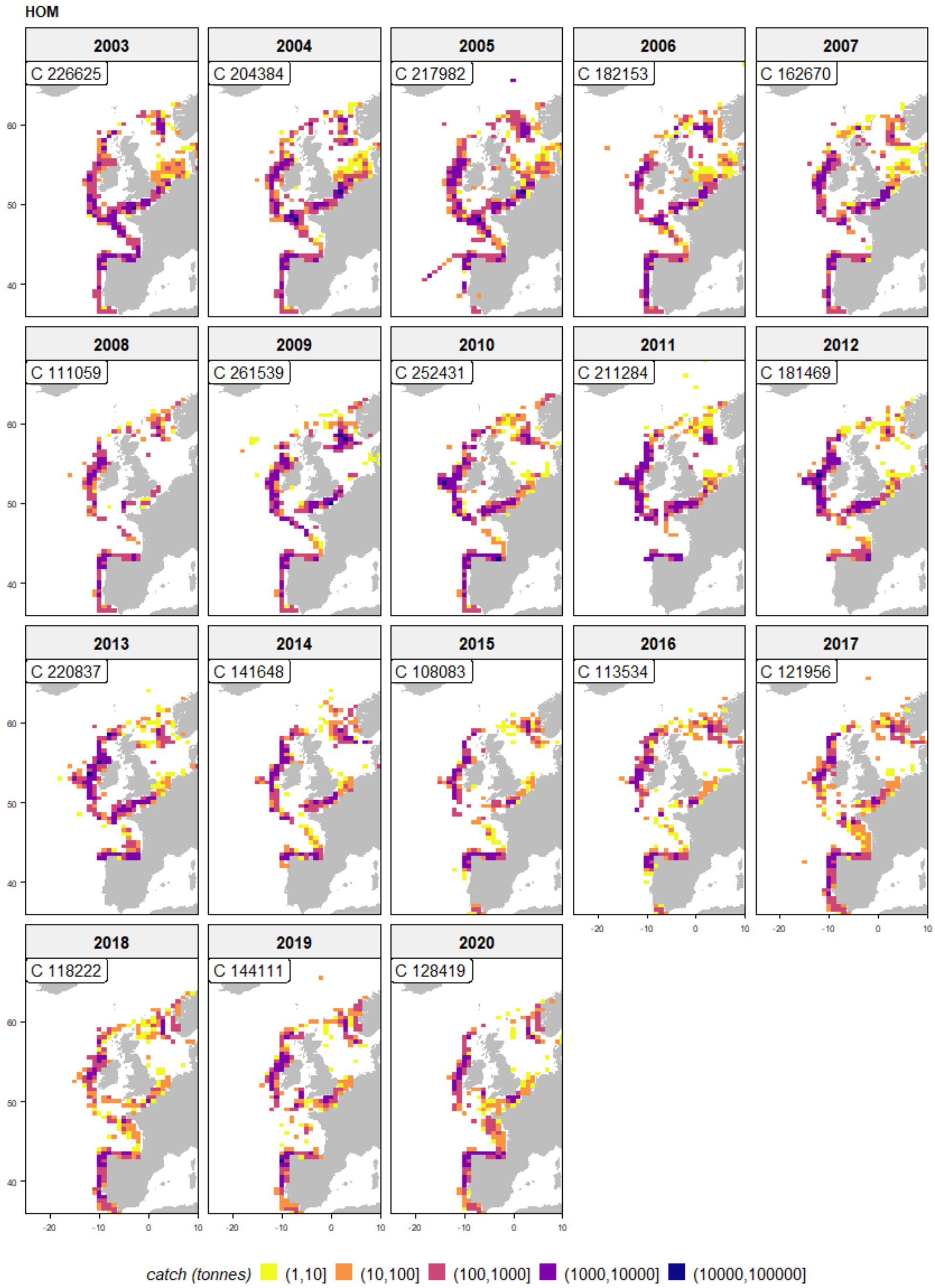


Figure 1.10.6: Catch of horse mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

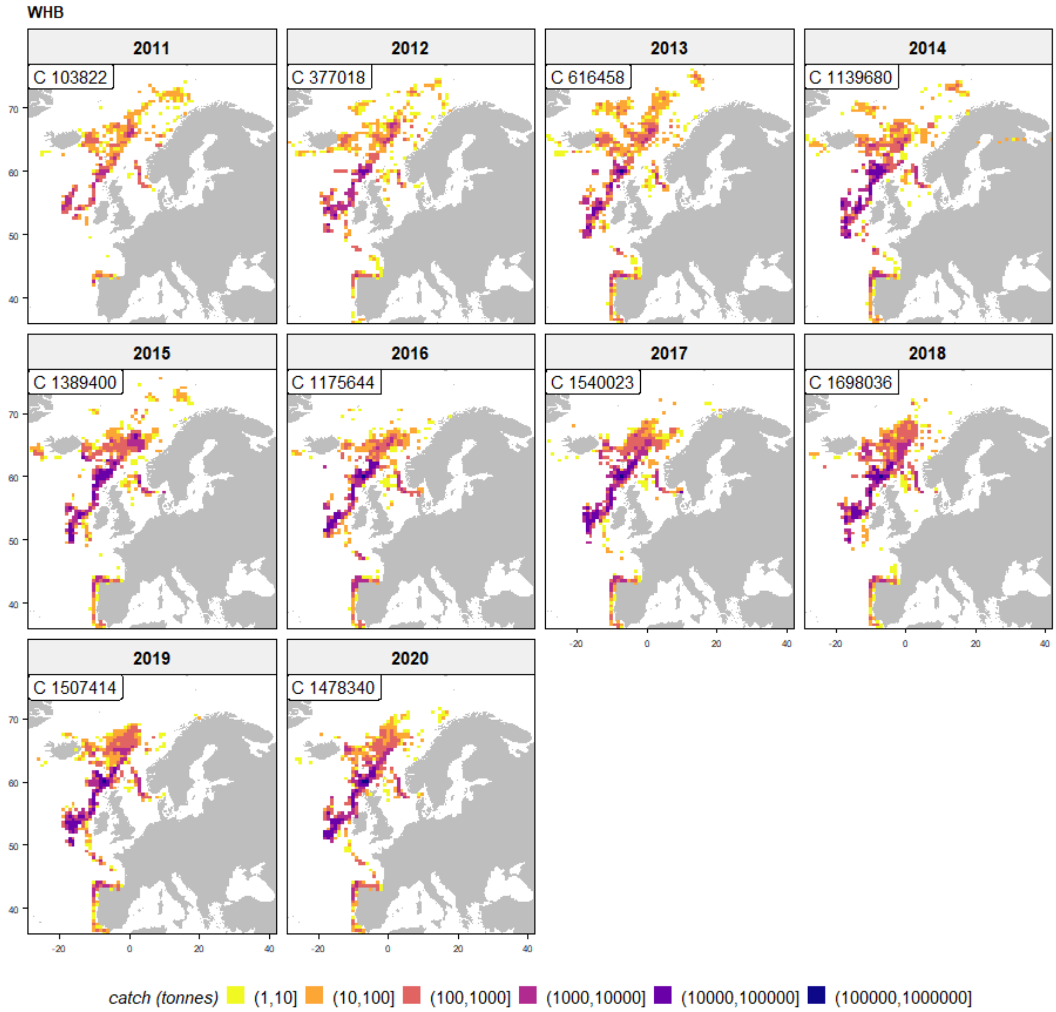


Figure 1.10.7: Catch of blue whiting (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

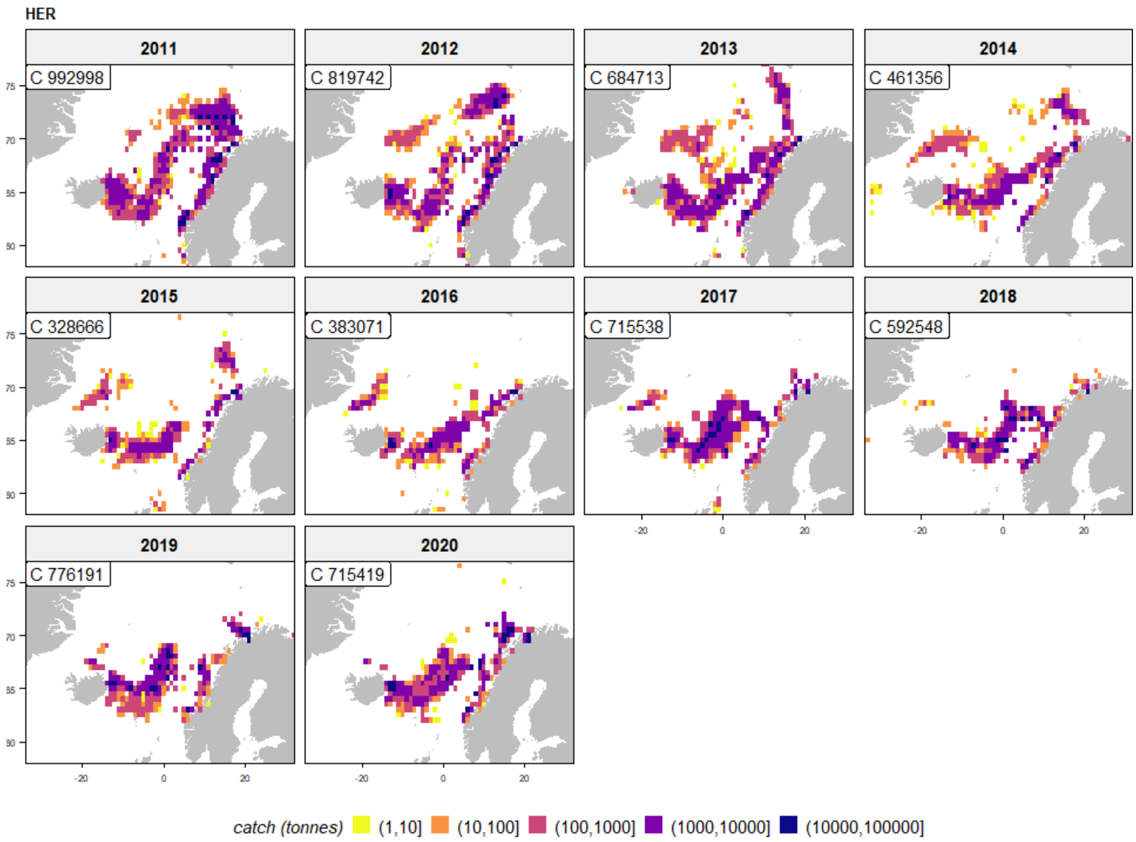


Figure 1.10.8: Catch of Norwegian spring-spawning (Atlanto-scandian) herring (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

1.9 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 2016b; 2018a; 2019a).

1.9.1 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 sea-water 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.

1.9.2 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.

1.9.3 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).

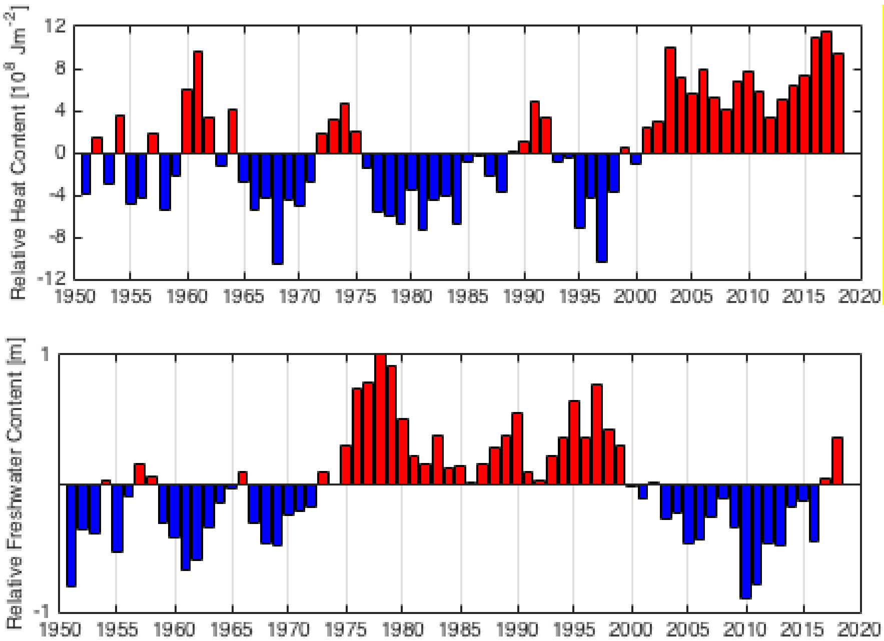


Figure 1.11.1. Time-series of anomalies of heat content (upper panel) and salinity (lower panel) of and the Atlantic waters in Norwegian Sea for the years 1951-2018(ICES 2019a).

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 mesozooplankton 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})

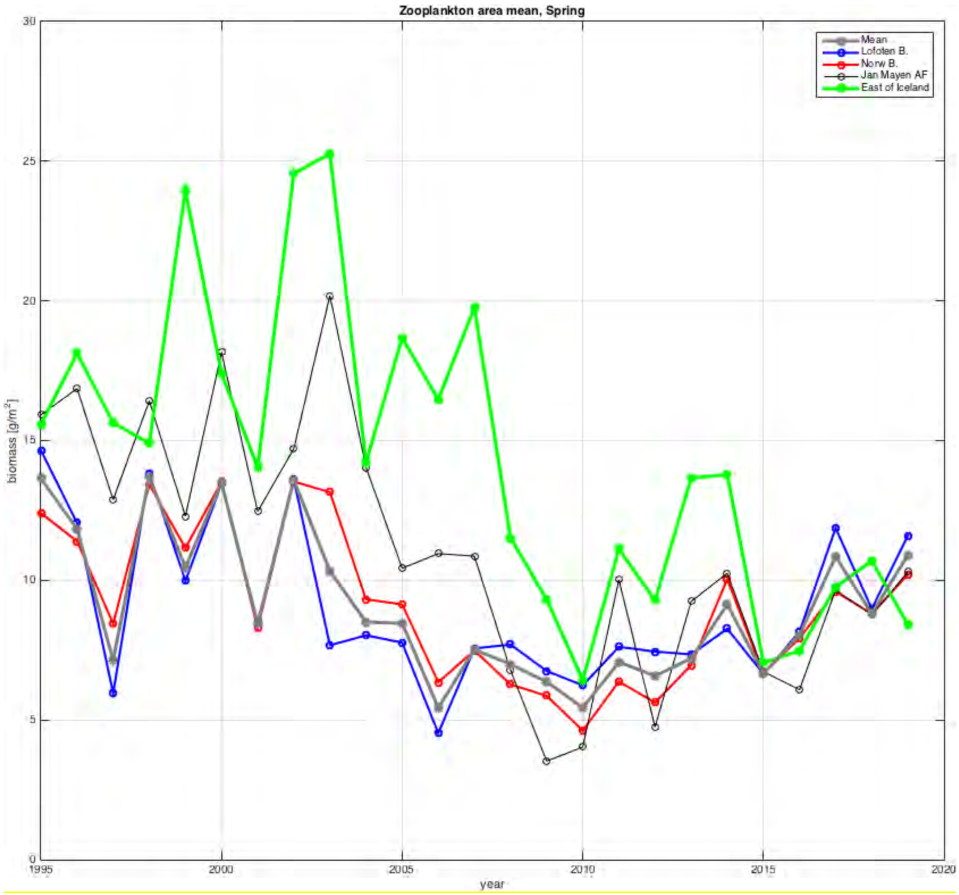


Figure 1.11.2. Indices of zooplankton dry weight (g m[-2]) sampled by WP2 in May in different areas in and near Norwegian Sea from 1995 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (ICES 2019b; see details on methods and areas in ICES 2016a).

1.9.4 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.

1.10 Future Research and Development Priorities (Stock Coordinators/ Assessors)

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.

1.10.1 NEA Mackerel

In 2019, the ICES Workshop on a Research Roadmap for Mackerel (WKRRMAC, (ICES, 2019d)) 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 (see report of WGWIDE 2019 (ICES, 2019) for details).

In 2020, 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 (WKEVALMAC) will review available information from appropriate methods to infer the stock structure of NEA Mackerel. WGWIDE 2021 agreed to proceed with identification of chairs and scheduling of the workshop at the earliest convenient opportunity..

1.10.2 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.

1.10.3 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, but it was later decided to postpone such exploration for the next benchmark. Some exploratory work was presented in WGWIDE 2021.

Consider the 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).

The maturity ogive for NSSH is back-calculated but with a delay of 6 years, i.e. the 5 last years uses one of two fixed maturity ogives scales (one for small cohort and the other for large cohort). The benchmark report has no objective criteria when to recognize a cohort as strong, and the current model is not optimal for medium-sized cohorts. This may result in deviation in SSB in intermediate year.

There is clear indication of a density dependent effect on maturity at age. A more proper estimate of the maturity for the last 5 years (and for the forecast) should be made using the estimated cohort strength directly, and this should be evaluated through a peer-review process.

1.10.4 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 that stage it was not yet possible to separate the two stocks when they occur in mixed samples. Subsequently, a full genome sequencing on horse mackerel has been carried out (Fuentes-Pardo et al 2020), which confirmed the earlier results on separating western, North Sea and southern horse mackerel (see also text below on North Sea horse mackerel). In addition, this study concluded that it would also be possible to distinguish horse mackerel from different spawning populations in mixed samples. Such samples have been collected during the winter of 2020 and will hopefully be analysed in the fall of 2021. Results may be expected for WGWIDE 2022.

The 2020 study also concluded that 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.

1.10.5 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 full genome of horse mackerel was sequenced and 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 are 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 have been be collected by the PFA on board of commercial vessels in the Autumn of 2020, while horse mackerel from Division 4.a have been 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. Additionally, the Institute of Marine Research in Norway sampled horse mackerel in coastal waters within 4.a during all quarters in 2019. Preliminary results presented at WGWIDE 2021 showed that the genetic profile of individuals caught in all quarters matched well with the genetic profile of the Western HOM stock, with just one or two individuals matching better with North Sea HOM profile (Florian Berg, pers. comm.). More samples and research is needed to confirm these results.

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, it was discovered that several hundred Dutch age readings coming from foreign vessels (mainly UK) have not been uploaded to InterCatch in the past. Efforts will be made to ensure this historic information will be uploaded in order to increase (the currently low) confidence in the estimates of catch-at-age. In 2021, it was the first time that Dutch age samples from 2020 were used in the raising procedure of UK and uploaded to InterCatch.

Future work on the exploitable biomass index will focus on including a spatial component when modelling the joint FR-CGFS and NS-IBTS survey index, and on the missing survey data in 2020. Additionally, application of the SPiCT model to the stock will be evaluated.

1.10.6 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.

1.11 References

Anker-Nilssen, T., and Lorentsen, S.-H. 2004. Seabirds in the Norwegian Sea. In: Skjoldal, H.R., Sætre, R., Færnö, A., Misund, O.A., and Røttingen, I. (eds.). The Norwegian Sea Ecosystem. Tapir Academic Press, Trondheim, pp 435-446.

Astthorsson OS, Valdimarsson H, Gudmundsdottir A, Óskarsson GJ. 2012. Climate related variations in distribution and abundance of mackerel (*Scomberscombrus*) in Icelandic waters. ICES Journal of Marine Science 69: 1289–1297.

Bachiller E., Irigoien X. 2015. Trophodynamics and diet overlap of small pelagic fish species in the Bay of Biscay. Marine Ecology Progress Series 534: 179-198.

Bachiller, E., Skaret, G., Nøttestad, L., and Slotte, A. 2016. Feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring and blue whiting in the Norwegian Sea. PloS one, 11: e0149238.

Bachiller E, Utne KR, Jansen T, Huse G., 2018. Bioenergetics modelingof the annual consumptionof zooplanktonby pelagic fish feeding in the Northeast Atlantic. PLoS ONE 13(1): e0190345.https://doi.org/10.1371/journal. pone.0190345

Borges, L., Rogan, E. and Officer, R. 2005. Discarding by the demersal fishery in the waters around Ireland. Fisheries Research, 76: 1–13.

Borges, L., van Keeken, O. A., van Helmond, A. T. M., Couperus, B., and Dickey-Collas, M. 2008. What do pelagic freezer-trawlers discard? ICES Journal of Marine Science, 65: 605– 611.

Dickey-Collas, M., van Helmond, E., 2007. Discards by Dutch flagged freezer trawlers. Working Document to the Working Group Mackerel, Horse Mackerel, Sardine and Anchovy (ICES CM 2007/ACFM: 31).

Farrell, E. D. and J. Carlsson (2019). Genetic stock identification of Northeast Atlantic Horse mackerel, Trachurus trachurus , EDF, December 2018.

Fuentes-Pardo, A.P., Petterson, M., Sprehn, C.G., Andersson, L., Farrell, E. 2020. Population structure of the Atlantic horse mackerel (*Trachurus trachurus*) revealed by whole-genome sequencing, July 2020.

Furness, R.W., 2002. Management implications of interactions between fisheries and sandeel dependent seabirds and seals in the North Sea. Ices Journal of Marine Science 59:261 – 269.

Gonçalves, P., Ávila de Melo, A., Murta, A. G. and Cabral, H. N. 2017. Blue whiting (*Micromesistius poutassou*) sex ratio, size distribution and condition patterns off Portugal', *Aquatic Living Resoyrces*, 30(24), pp. 1–8. doi: 10.1051/alr/2017019.

Gonçalves, P. 2021. Blue whiting age reading - data and issues. Working Document to ICES Third workshop on age reading of blue whiting (WKARBLUE3), 31 May-4 June.

Hátún, H., A. B. Sandø, H. Drange, B. Hansen and H. Valdimarsson, 2005. Influence of the Atlantic subpolar gyre on the thermohaline circulation. Science, 309, 1841 – 1844.

Hofstede, R. and Dickey-Collas, M. 2006. An investigation of seasonal and annual catches and discards of the Dutch pelagic freezer-trawlers in Mauritania, Northwest Africa. Fisheries Research, 77: 184–191.

ICES. 2013. Report of the Ad hoc Group on the Distribution and Migration of Northeast Atlantic Mackerel (AGDMM), 30-31 August 2011 and 29-31 May 2012, ICES Headquarters, Copenhagen. ICES CM 2013/ACOM:58. 211 pages.

ICES. 2014. First Interim Report of the Stock Identification Methods Working Group (SIMWG), by correspondence. ICES CM 2014/SSGSUE:02. 31 pp.

ICES. 2015. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V ”Brennholm”, M/V “Eros”, M/V “Christian í Grótinum” and R/V “Árni Friðriksson”, 1 July - 10 August 2015. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE), AZTI-Tecnalia, Pasaia, Spain, 25 – 31 August 2015. 47 pp

ICES. 2016a. Final Report of the Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR), 7-11 December 2015, Reykjavik, Iceland. ICES CM 2015/SSGIEA:10. 149 pp.

ICES. 2016b. Interim Report of the Working Group on Integrated Ecosystem Assessments for the Norwegian Sea (WGINOR), 28 November - 2 December 2016, Bergen, Norway. ICES CM 2016/SSGIEA:10. 28 pp.

ICES, 2016c. Report of the Workshop on Blue Whiting Long Term Management Strategy Evaluation (WKBWMS), 30 August 2016ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM:53

ICES. 2017. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January–3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

ICES. 2018a. Interim Report of the Working Group on InteICEgrated Ecosystem Assessments for the Norwegian Sea (WGINOR). ICES WGINOR REPORT 2017 27 November - 1 December 2017. Tórshavn, Faroe Islands. ICES CM 2018/SSGIEA:10. 38 pp.

ICES. 2018b. International ecosystem survey in the Nordic Sea (IESNS) in May to June 2018. WD No. 01 to Working Group on International Pelagic Surveys (WGIPS 2019) and Working Group on Widely distributed Stocks (WGWIDE), Tórshavn, Faroe Islands, 28 August - 3 September 2018. 26 pp.

ICES. 2018c. Report of the Workshop on a long-term management strategy for Norwegian Spring-spawning herring (WKNSSHMSE), 26–27 August 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM:53. 113 pp. https://doi.org/10.17895/ices.pub.5583. Annex 9 is available separately at the ICES website.

ICES. 2019a. Report of the Working Group on Integrated Ecosystem Assessments for the Norwegian Sea (WGINOR). ICES WGINOR REPORT 2018 26-30 November 2018. Reykjavik, Iceland. ICES CM 2018/IEASG:10. 123 pp.

ICES. 2019b. International ecosystem survey in the Nordic Sea (IESNS) in May to June 2019. WD No. 11 to Working Group on International Pelagic Surveys (WGIPS 2020) and Working Group on Widely distributed Stocks (WGWIDE), Santa Cruz, Tenerife, Spain, 28 August - 3 September 2019. 33 pp.

ICES. 2019c. Workshop on Age Estimation of Atlantic Mackerel (*Scomber scombrus*) (WKAR-MAC2), San Sebastian, Spain. 92 pp.

ICES. 2019d. Workshop on a Research Roadmap for Mackerel (WKRRMAC). ICES Scientific Reports. 1:48. 23 pp. http://doi.org/10.17895/ices.pub.5541

Jones, P. D., and Moberg, A., 2003. Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001. Journal of Climate 16: 206 – 223.

Langøy, H., Nøttestad, L., Skaret, G., Broms, C., and Fernö, A. 2012. Overlap in distribution and diets of Atlantic mackerel (Scomber scombrus), Norwegian spring-spawning herring (Clupea harengus) and blue whiting (Micromesistius poutassou) in the Norwegian Sea during late summer. Marine Biology Research, 8: 442–460. http://www.tandfonline.com/doi/abs/10.1080/17451000.2011.642803.

Nikolioudakis, N., Skaug, H. J., Olafsdottir, A. H., Jansen, T., Jacobsen, J. A., and Enberg, K. 2018 Drivers of the summer-distribution of Northeast Atlantic mackerel (*Scomberscombrus*) in the Nordic Seas from 2011 to 2017; a Bayesian hierarchical modelling approach. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsy085.

Nøttestad, L. Sivle, L.D., Krafft B.A., Langard, L., Anthonypillai, V., Bernasconi, M., Langøy, H., Axelsen, B.E. 2014. Ecological aspects of fin whale and humpback whale distribution during summer in the Norwegian Sea. Marine Ecology. ISSN 0173-9565.

Nøttestad, L., A. Fernö, O.A. Misund, R. Vabø, 2004. Understanding herring behaviour: linking individual decisions, school patterns and population distribution. In The Norwegian Sea Ecosystem, 1st edn, pp. 221 – 262. Eds. H. R. Skjoldal R. Sætre, A. Fernö, O.A. Misund and I. Røttingen.Tapir Academic Press, Trondheim, Norway. 559 pp.

Leif Nøttestad, Kjell R. Utne, Guðmundur J. Óskarsson, Sigurdur Þ. Jónsson, Jan Arge Jacobsen, Øyvind Tangen, Valantine Anthonypillai, Sondre Aanes, Jon Helge Vølstad, Matteo Bernasconi, Høgni Debes, Leon Smith, Sveinn Sveinbjörnsson, Jens C. Holst, Teunis Jansen, Aril Slotte, Quantifying changes in abundance, biomass, and spatial distribution of Northeast Atlantic mackerel (*Scomber scombrus*) in the Nordic seas from 2007 to 2014 , *ICES Journal of Marine Science*, Volume 73, Issue 2, January/February 2016, Pages 359–373, https://doi.org/10.1093/icesjms/fsv218

Olafsdóttir, A.H., Utne, K.R., Jacobsen, J.A., Jansen, T., Óskarsson, G.J., Nøttestad, L., Elvarsson, B.Þ., Broms, C., and Slotte, A. 2018. Geographical expansion of Northeast Atlantic mackerel (*Scomb-erscombrus*) in the Nordic Seas from 2007 to 2016 was primarily driven by stock size and constrained by low temperatures. Deep-Sea Research Part II. https://doi.org/10.1016/j.dsr2.2018.05.023.

Patterson, K.R. 1998: A programme for calculating total international catch-at-age and weight at-age. WD to Herring Assessment Working Group 1998.

Pierce, G. J., J. Dyson, E. Kelly, J. D. Eggleton, P. Whomersley, I. A. G. Young, M. B. Santos, J. J. Wang and N. J. Spencer (2002). Results of a short study on by-catches and discards in pelagic fisheries in Scotland (UK). Aquatic Living Resources 15(6): 327-334.

Rossby, T., 1999. On gyre interaction. Deep-Sea Research II, Vol. 46, No. 1 – 2, pp. 139–164.

Skaret G., Bachiller E., Langøy H., Stenevik, E.K. 2015. Mackerel predation on herring larvae during summer feeding in the Norwegian Sea. ICES JMS, doi:10.1093/icesjms/fsv087.

Skjoldal, H. R., Dalpadado, P., and Dommasnes, A., 2004. Food webs and trophic interactions.InTheNorwegian Sea Ecosystem, 1st edn, pp. 263 – 288. Eds. H. R. Skjoldal R. Sætre, A. Fernö, O.A. Misund and I. Røttingen. Tapir Academic Press, Trondheim, Norway. 559 pp.

Sherman, K., and Skjoldal, H.R., 2002. Large Marine Ecosystems of the North Atlantic. Changing states and sustainability. Sherman, K., and Skjoldal H.R. (Eds.)). Elsevier Science B.V. The Netherlands.

Ulleweit, J. and Panten, K., 2007. Observing the German Pelagic Freezer Trawler Fleet 2002 to 2006 – Catch and Discards of Mackerel and Horse Mackerel. Working Document to the Working Group Mackerel, Horse Mackerel, Sardine and Anchovy (ICES CM 2007/ACFM: 31).

Ulleweit, J., Overzee, H. M. J., van Helmond, A. T. M., van Panten, K. (2016): Discard sampling of the Dutch and German pelagic freezer fishery operating in European waters in 2013-2014 – Joint report of the Dutch and German national sampling programmes. Stichting DLO Centre for Fisheries Research (CVO), 62 pages, CVO Report 15.014

Utne, K. R., Hjøllo, S. S., Huse, G., and Skogen, M. D. 2012. Estimating the consumption of *Calanus finmarchicus* by planktivorous fish in the Norwegian Sea using a fully coupled 3D model system. Marine Biology Research, 8: 527–547.

van Helmond, A.T.M. and H.J.M. van Overzee 2009. Discard sampling of the Dutch pelagic freezer fishery in 2003-2007. CVO report 09.001

van Helmond, A.T.M. and H.J.M. van Overzee 2010. Discard sampling of the Dutch pelagic freezer fishery in 2008 and 2009. CVO report 10.008

van Overzee, H. M. J., & van Helmond, A. T. M. (2011). Discard sampling of the Dutch pelagic freezer fishery in 2010. (CVO report; No. 11.010). Centrum voor Visserijonderzoek. https://edepot.wur.nl/189414

van Overzee, H. M. J., ; Helmond, A. T. M. van; Ulleweit, J.; Panten, K. (2013): Discard sampling of the Dutch and German pelagic freezer fishery operating in European waters in 2011 and 2012. Stichting DLO Centre for Fisheries Research (CVO), 68 pages, CVO Report 13.013

van Overzee H.M.J., Ulleweit J, Helmond ATM van, Bangma T (2020) Catch sampling of the pelagic freezer trawler fishery operating in European waters in 2017-2018 - joint report of the Dutch and German national sampling programmes. Ijmuiden: Stichting Wageningen Research, Centre for Fisheries Research (CVO), 53 p, CVO Rep 20.004

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 between the feeding and 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 2020

ICES notes fishing mortality (F) is estimated to be above F_{MSY} since 2014. Spawning-stock biomass (SSB) has been decreasing since 2018; however, it is estimated to remain above MSY $B_{trigger}$. Recruitment (R) from 2017 to 2020 is estimated to be low, following a three-year period of high recruitment. ICES advises that when the long-term management strategy agreed by the European Union, the Faroe Islands, Iceland, and Norway is applied, catches in 2021 should be no more than 929 292 tonnes.

2.2 The fishery in 2020

The total catch in 2020 was 1.495 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 (85.5%) 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 southern part of the Norwegian Sea, in the Norwegian Trench and along the coast of Spain and Portugal. The fishery in the second half of the year was mainly east of the Faroes and in the central Norwegian Sea, with smaller amounts in the Norwegian Trench and along the coast of Portugal and Spain.

The multinational fleet targeting blue whiting in 2020 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 survey estimates. In recent years, between 85-90% of the annual catches of the age 3+ fish have been taken in the first half of the year, which makes it reasonable to estimate the total annual catch-at-age from reported first semester (Q1 & Q2) data and expected total catches for the remainder of the year. The catch data sections in this report contain a comprehensive description of the 2020 data as reported to ICES and a brief description of the 2021 preliminary catch data.

2.3.1 Officially reported catch data

Official catches in 2020 were estimated as 1 495 248 tonnes based on data provided by WGWIDE members (Table 2.3.1.1). Data provided as catch by rectangle represented 99% of the total WG catch in 2020.

In 2020, the majority of catches were caught on the spawning grounds with largest contribution from ICES area 27.7.c, 27.7.k, and 27.5.b, 27.6.a respectively (Figure 2.3.1.1; Tables 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 27.5.b, 27.6.a, 27.7.c and 27.7.k while later in the year catches are mainly taken further north in area 27.2.a and in the North Sea (27.4.a) (Figures 2.3.1.6 and 2.3.1.7 and Table 2.3.1.3).The spatial and temporal distribution of catches in 2020 are similar to previous years (Figures 2.3.1.2, 2.3.1.3, 2.3.1.4; Table 2.3.1.4). The majority of the blue whiting catch was caught by five 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 targeting 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 2020, discards were 28% 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 4% (in weight) in 2020 (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, Ireland, Portugal, Spain, Sweden, UK (England and Wales) and UK (Scotland) to the working group. The discards constituted 0.19% of the total catches, 2 828 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 8 tonnes in 2020. The largest fishing nations, Norway, Faroe Islands, Russia and Iceland do not provide discards information.

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 16% of the total catches of blue whiting in 2020.

2.3.1.1 Sampling intensity

In 2020, 81% of catches were covered by the sampling program. In 2020, 672 length samples, 580 age samples, were collected from the fisheries , and 89 110 fish were measured and 16 641 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 2020 is given in Table 2.3.1.1.1. Sampling intensity per country, quarter and ICES division for 2020 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, Lithuania, Poland, Sweden and the UK (Northern Ireland) which combined represent 5% 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 2020, 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 2021 catch data (Quarters 1 and 2)

The preliminary catches for 2021 as reported by the WGWIDE members are presented in Table 2.3.2.1.

The spatial distribution of these 2021 preliminary catches is similar to the distribution in 2020 with majority of catches taken in division 27.6.a, 27.5.b, 27.7.c and 27.7.k (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 2021 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 2020, preliminary and final catch estimates are similar with maximum deviation in 2020 when the final catch was 21 % higher than the preliminary catch (Table 2.3.2.4). Age compositions (Figure 2.3.2.2) are also similar between preliminary and final catch data. There is no clear pattern in the deviations; it is both the catch at age for young and older fish that change between preliminary and final data.

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

2.3.3 Catch-at-age

Catch-at-age numbers from 1981 to 2021 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. More recently, the propagation of the large 2014 year class is also evident.

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 2010-2014 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 ages to the fisheries. With an assumed natural mortality (M=0.2), the assessment F around 0.4-0.5 fits well to the Z values estimated from the catch curves.

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 1981-2021 used in the stock assessment. Mean weight at ages 3-9 has generally decreased in the period 2010-2018, followed by an increase in the most recent years, for the most abundant ages in the catches.

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, 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 full time series of IBWSS was recalculated in summer 2020, using the same software (StoX; Johnsen *et al.*, 2019) and method as previously applied. The values are presented in Table 2.3.7.1.1 and Figure 2.3.7.1.1A

The survey time-series (2004-2021) show variable internal consistency ranging from 0.26 to 0.86 (Figure 2.3.7.1.1B) The overall internal consistency plot for age-disaggregated year classes was slightly reduced compared to last year. There is a high internal consistency for the younger ages (1-5 years) and older ages (7-9 years) with correlation between 0.70 and 0.86, but poor (0.02 < r < 0.03) between ages 5 to 8. This may indicate age readings problems for this group of ages.

The distribution of acoustic backscattering densities for blue whiting for the period 2018-2021 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 2017 to 2021 are given in Figure 2.3.7.1.3.

Survey indices, (ages 1-8 years 2004-2021) 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 equal or 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. The survey was cancelled in 2020 due to the COVID-19 pandemic, but conducted as planned in 2021.

The presented assessment in this report follows the recommendations from the Inter-Benchmark Protocol of Blue (ICES, 2016a) to use the SAM model. The configuration of the SAM model was kept unchanged in this year’s assessment.

The time period for estimating recruitment for forecast, was changed from the full time series (minus terminal year) to the period since 1996 (minus terminal year).

2.4.1 2021 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 2.4.1.1) 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 2.4.1.1. There are no abrupt changes in the estimated parameters over the time-series presented. The lowest observation noises, and thereby the largest weight in the assessment model, have in all years been from catches at ages 3-8, which constitute the largest proportion of the catch.

The process error residuals (“Joint sample residuals”) (Figure 2.4.1.2) are reasonable randomly distributed. Process noise SAM is implemented as a “process mortality, Z”; these deviations in mortalities are shown in Figure 2.4.1.3. The deviations in mortality (plus or minus mortality) seems fairly randomly distributed without very pronounced clusters as also seen in Figure 2.4.1.2).

The correlation matrix between ages for the catches and survey indices (Figure 2.4.1.4) shows 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 2.4.1.5 presents exploitation pattern for the whole time-series. There are no abrupt changes in the exploitation pattern from 2010 to 2021, 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 since mid-2000s seems more realistic than the more linear selection estimated for the beginning of the time series. 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 = 0.93, Table 2.4.1.1).

The retrospective analysis (Figure 2.4.1.6) shows a 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 2.4.1.2). Even though the annual values might be high for recruitment (reflecting large changes from one year to the next) the average Mohn’s rho is low for both recruitment, F and SSB, indicating no bias.

Stock summary results with added 95% confidence limits (Figure 2.4.1.7 and Table 2.4.1.5) 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 0.45. Recruitment was historically high in 2015, followed by a lower recruitment in 2016 and much lower recruitments in 2017-2019. The recruitment in most recent years is estimated higher. SSB has increased in the period 2010-2018, followed by a large reduction.

Comparison of the assessment made in 2020 and 2021 (Figure 2.4.1.8) shows that the uncertainties on F and SSB in the terminal year are higher in the assessment from last year, where the IBWSS survey was cancelled due to Covid-19. The uncertainties on the recruitment estimates in the terminal seem however slightly higher this year. Last year, there were only one (the catch) observation for age 1 in the terminal year, while both catch and survey observations are present in 2021. For age 1, the lowest observation variance (Table 2.4.1.1) is estimated for catch observation, so the 2020 situation with only one age 1 observation, seems (statistically) to produce a more certain recruitment estimate in the terminal year.

2.4.2 Alternative model runs

The assessment XSA and TISVPA models were run for a better screening of potential errors in input and for comparison with the SAM results. The three models gave a similar result (Figure 2.4.2.1), however with some differences in F in the terminal years. even though the absolute values differ between models. XSA estimates the highest F, TISVPA the lowest F and SAM estimates a value in between.

The working document WD11 “Blue whiting, an alternative assessment including more surveys” (Hølleland *et al.*, 2021) was presented to the WGWIDE. The assessment is a SAM assessment, and made use of two (IESNS and IESSNS) additional survey data for blue whiting. The time series for IESSNS is still short (6 years). The alternative assessment gave similar results for SSB and F as estimated by the presently used SAM (Figure 2.4.3.2). The estimated recruitment in 2021 was however larger in the alternative assessment, due to high abundance of age 1 in 2021 in both additional surveys.

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.

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—2021, with catch data up to 2020 and preliminary catch data for the first semester (Q1 and Q2) of 2021 raised to expected annual catches, and survey data from March-April, 2004–2021. SSB 1st January in 2022 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 2.4.1.3–2.4.1.4 and summarized in Table 2.4.1.5 and Figure 2.4.1.7. Residuals of the model fit are shown in Figures 2.4.1.1 and 2.4.1.2.

2.6 State of the Stock

Fishing pressure (2021) on the stock is above F_{MSY} and between F_{pa} and F_{lim}; spawning-stock size (2022) is above MSY $B_{trigger}$, B_{pa} and B_{lim}.

F has increased from a historic low at 0.052 in 2011 to around 0.45 since 2014. F has been above F_{MSY} and Fpa 0.32) since 2015. SSB increased from 2010 (2.69 million tonnes) to 2017 (6.06 million tonnes), followed by a decline to 3.40 million tonnes in 2022.

Recruitment (age 1 fish) was high in 2014-2016 followed by recruitments in the low end of the historical recruitments in the years 2017-2019. This is followed by a moderate increase in recruitment in 2020 and 2021. 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}.

ICES made in 2021 the decision to use F_{p05} as the value for F_{pa}. F_{p05} was estimated by WKBWMSE (ICES 2016b), where it was concluded that the EQSIM simulations showed that $F_{p0.05}$ (0.32) is less than the F_{MSY} in the constant F simulations, so F_{MSY} was set to this lower value.

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}	0.32	Fp05; the F that leads to SSB ≥ Blim with 95% probability	ICES (2016b) and WGWIDE 2021

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 (2020 year class) and the 2–group (2019 year class) indices from the survey in 2021 were above the median and below the median of the historical range, respectively.

The 1-group (2020 year class) and the 2–group (2019 year class) indices from The International Blue Whiting Spawning Stock Survey (IBWSS) was above the median in the time series (Table 2.3.7.1.1).

The Norwegian bottom-trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March 2021, showed that 1-group blue whiting was the third highest in the time series (Table 2.3.7.2.2). 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 2021 (2020 year class) from the Icelandic bottom-trawl survey showed an increase compared to 2020 and was the highest in the time-series.

The 1-group estimate in 2021 (2020 year class) from the Faroese Plateau spring bottom-trawl survey showed an increase compared to 2020 and was below the median in the time-series.

In conclusion, the indices from available survey time-series indicate that the 2019 year class is above the median it corresponds to the SAM assessment results. The 2020 year classes estimated from surveys are also above the median, which also is the result of the SAM assessment. It was therefore decided not to change the SAM estimate of the 2019 and 2020 year classes.

No information is available for the 2022 and 2023 year classes and the geometric mean of the time-series from 1996-2020) was used for these year classes (20.98 billion at age 1 in 2022) (Table 2.8.1.1). WGWIDE decided to change from using the geometric mean of the full time-series (1981–2020) to use a shorter time-series for the calculations. The motivation for this change was to use a more recent period, which is assumed to better reflect the environmental changes and more variable recruitment in general since 1996. The reasons to shorten the time-series were two-fold. Firstly, prior to 1995 only one time-series, the Barents Sea demersal trawl index, was available as a proxy for blue whiting recruitment. After 1995 several indices became available, beginning with the Faroese and Icelandic spring demersal surveys and later other proxies were included (Figure 2.8.1.1). Secondly, hydrographic time series in the northeast North Atlantic and Nordic Seas show that the freshening trend of the 1960s–1990s completely reversed in the upper ocean in the mid-1990s (Holliday *et al.*, 2008). Since the weakening of the subpolar gyre in the mid-1990s temperature and salinity have rapidly increased in the Atlantic inflow to the Rockall/Hatton Plateau region, apparently leading to changes in the recruitment levels of blue whiting in the following decades (Hátún *et al.*, 2009b, Payne *et al.*, 2012). Recent hydrographic observations indicate again a freshening occurred in the area after 2015 (González-Pola *et al.*, 2020).

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 (2019—2021) 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 2020 and 2021 are assumed as estimated by the SAM model, as additional survey information was not conflicting this result. Recruitment in 2022 and 2023 are assumed as the long-term average from the period with both high and low recruitments (geometric mean of the time-series since 1996, minus the terminal year, 1996-2020).

As the assessment uses preliminary catches for 2021 an estimate of stock size exist for the 1st of January 2022. The normal use of an "intermediate year" calculation is not relevant in this case. F in the "intermediate year" (2021) is as calculated by the assessment model. Catches in 2021 is the (model input) preliminary catches. 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 2022 at 752 736 tonnes. This corresponds to a 19.0 % reduction compared to the ICES advice last year, and 39.4% reduction compared to the preliminary estimate of catches in 2021.

The LTMS specifies a TAC constraint at +25 / -20 %. With at maximum decrease at 19% in catches in relation to the ICES advice last year (LTMS advice), the TAC constraint is not applied.

SSB in 2023 is predicted to increase by 19.1 % to 4052163 tonnes, if the advised catches are taken. The higher recruitment estimated for 2020 and 2021 contributes to this increase in SSB.

2.9 Comparison with previous assessment and forecast

Comparison of the final assessment results from the last 5 years shows a consistent assessment (Figure 2.9.1). Historic fishing mortalities and recruitments are estimated higher this year, but the differences between this year's and last year's assessment results are small.

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 2.4.1.7). The retrospective analysis (Figure 2.4.1.6), 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 2017-2021 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 as also 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.

Exploratory assessments (XSA, TISVPA) using the same data as the default assessment gave similar results as the default run. Another SAM assessments with data from two additional surveys (IESNS and IESSNS) included, showed a higher recruitment in the terminal year, and estimates similar F and SSB.

The assessment uses data from one survey only, the International Blue Whiting Spawning Stock Survey, which was cancelled in 2020 due to the COVID-19 disruption, but continued in 2021. The lack of 2020 survey data seems not to increase the uncertainties of the assessment results this year, and the assessment results are consistent with the results from previous years.

2.11 Management considerations

The assessment estimates low 2016-2018 year classes and slightly higher 2019 and 2020 year classes. The large year 2014 and 2015 year classes have been reduced considerably through fishing and natural mortality and the will not contribute much to the catches in the coming years. The forecast predicts a 10-20% increase in SSB (compared to SSB in 2022) depending on the F in 2022. This increase is dependent on the year class strength of the 2019 and 2020 year classes, whereas the size of the 2021 and 2022 have a limited effect for SSB in 2023.

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*., 2015). 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). Where distribution of blue whiting and herring overlap (Utne *et al*., 2012) they appear to feed on different species, herring mainly feed on copepods and blue whiting mainly on euphausiids and amphipods, although juvenile blue whiting feed on copepods (Bachiller *et al.,* 2016; Pinnegar et al., 2015). Given the current knowledge, future benchmarks do not need to consider prey competition between blue whiting and herring/mackerel, and therefore 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 a 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. The catch advice does not take into account consistent deviations from the long-term management strategy as evident from the sum of unilateral quotas since 2018. During the evaluation of the management strategy (ICES, 2016b), the implementation error in the form of a consistent overshoot of the TAC was not included. Therefore, the current implementation of the long-term management strategy may no longer be precautionary. See section 1.8 for a comparison of historic advice, TAC and catch.

WGWIDE estimates the total expected catch for 2021 to be 1 242 727 tonnes, 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 2021 should be no more than 929 292 tonnes. This advice was followed by the Coastal States by setting a TAC at the ICES advice, however there was no agreement on the split of TAC between nations.

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.

The management strategy evaluation did not take into account consistent deviations from the long-term management strategy as evident from the sum of unilateral quotas in recent years. During the evaluation of the management strategy (ICES, 2016b), the implementation error in the form of a consistent overshoot of the TAC was not included. Therefore, the current implementation of the long-term management strategy may no longer be precautionary.

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 different areas. Although, is expected that on the next year data, those differences should be almost neglected, because an age reading workshop just took place in 2021 (WKARBLUE3) and an increase on age classification precision was achieved. The results from the age reading inter-calibration exercise, conducted previously to the WKARBLUE3, revealed an increase on the age classifications precision between participants, with an overall of 70% of agreement on advanced readers. Although, there are still issues on ageing this species, and the main assumptions to overcome those felt in the expertise of the readers. The main issues are: otoliths from some areas revealed to be more difficult to read (*e.g.* 27.2.a, 27.5.b); the first ring identification; edge type interpretation and false or double rings identification. During the WKARBLUE3 objective and more clear guidelines had been constructed. Thus, the main goal during the WKARBLUE3 has been to increase the ageing precision and that was achieved. Nonetheless, in order to increase the accuracy on age classifications, age validation studies to clarify growth rings pattern interpretation must be conducted.

The age-error matrixes, by quarter and area, resulting from the inter-calibration exercise are now available and can be used to correct the catch-at-age and survey data used for assessment. Furthermore, the impact of these uncertainties on age reading on the stock assessment results will be 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, but resumed in 2021. The stock assessment this year followed the approach outlined in the Stock Annex.

The uncertainties on F and SSB in the terminal year are estimated lower in this year's assessment compared to last year's assessment with no survey in the terminal year.

2.16 References

Bachiller, E., Skaret, G., Nøttestad, L., Slotte, A. 2016 Feeding ecology of northeast Atlantic mackerel, Norwegian spring- spawning herring and blue whiting in the Norwegian Sea. PLoS One, 11 (2016), 10.1371/journal.pone.0149238

Berg, C.W. and Nielsen, A. 2016. Accounting for correlated observations in an age-based state-space stock assessment model. ICES Journal of Marine Science, 73: 1788-1797. doi:10.1093/icesjms/fsw046

Dolgov, A. V., Johannesen, E., Heino, M., and Olsen, E. 2010. Trophic ecology of blue whiting in the Barents Sea. ICES Journal of MarineScience, 67: 483–493

González-Pola, C., Larsen, K. M. H., Fratantoni, P., and Beszczynska-Möller, A. (Eds.). 2020. ICES Report on Ocean Climate 2019. ICES Cooperative Research Reports No. 350. 136 pp. https://doi.org/10.17895/ices.pub.7537

Hatun H, Payne, M.R., Beaugrand, G., Reid, P.C., Sando, A.B., Drange, H., Hansen, B., Jacobson, J.A. and Bloch., D. 2009a. Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the Subpolar Gyre, via plankton, to blue whiting and pilot whales. Progress in Oceanography 80 (2009b) 149–162.

Hatun H, Payne, M.R., and Jacobson, J.A. 2009b. The North Atlantic Subpolar Gyre regulates the spawning distribution of blue whiting (Micromesistius poutassou). Canadian Journal of Fisheries and Aquatic Science 66: 759–770. doi:10.1139/F09-037441

Heino M., and Godø, O.R. 2002. Blue whiting – a key species in the mid-water ecosystems of the north-eastern Atlantic. ICES C.M. 2002/L:28.

Holliday, N. P., Hughes, S. L., Bacon, S., Beszczynska-Möller, A., Hansen, B., Lavín, A., Loeng, H., Mork, K. A., Østerhus, S., Sherwin, T. J., and Walczowski, W. 2008. Reversal of the 1960s to 1990s freshening trend in the northeast North Atlantic and Nordic Seas. Geophysical Research Letters

ICES. 2013a. NEAFC request to ICES to evaluate the harvest control rule element of the long-term management plan for blue whiting. Special request, Advice May 2013. *In* Report of the ICES Advisory Committee, 2013.ICES Advice 2013, Book 9, Section 9.3.3.1.

ICES. 2013b. NEAFC request on additional management plan evaluation for blue whiting. Special request, Advice October 2013.*In* Report of the ICES Advisory Committee, 2013.ICES Advice 2013, Book 9, Section 9.3.3.7.

ICES. 2016a. Report of the Inter-Benchmark Protocol for Blue Whiting (IBPBLW), 10 March–10 May 2016, By correspondence. ICES CM 2016/ACOM:36. 118 pp.

ICES. 2016b. Report of the Workshop on Blue Whiting Long Term Management Strategy Evaluation (WKBWMS), 30 August 2016ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM:53

ICES. 2016c. Report of the Stock Identification Methods Working Group (SIMWG), By correspondence. ICES CM 2016/SSGEPI:16. 47 pp.

ICES. 2020. Report of the Working Group on Widely Distributed Stocks (WGWIDE) ICES Scientific Reports. 2:XX. XXX pp. http://doi.org/10.17895/ices.pub.XXXX.

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019; 10:1523–1528.

Keating, J.P., Brophy, D., Officer, R.A., and Mullins, E. 2014.Otolith shape analysis of blue whiting suggests a complex stock structure at their spawning grounds in the Northeast Atlantic. Fish. Res. 157: 1–6. doi:10.1016/j.fishres.2014.03.009.

Miesner, A.K., Payne, M.R., 2018. Oceanographic variability shapes the spawning distribution of blue whiting (Micromesistius poutassou). Fish. Oceanogr. 623–638. doi:10.1111/fog.12382

Payne, M. R., Egan, A., Fässler, S. M. M., Hátún, H., Holst, J. C., Jacobsen, J. A., Loeng, H. (2012). The rise and fall of the NE Atlantic blue whiting (Micromesistius poutassou). Marine Biology Research, 8, 475–487. https://doi.org/10.1080/17451000.2011.639778

Pointin F. and Payne, M.R. 2014.A Resolution to the Blue Whiting (Micromesistius poutassou) Population Paradox?PLoSONE 9(9): e106237. doi:10.1371/journal.pone.0106237.

Pinnegar, J. K., Goñi, N., Trenkel, V. M., Arrizabalaga, H., Melle, W., Keating, J., and Óskarsson, G. 2015. A new compilation of stomach content data for commercially important pelagic fish species in the northeast Atlantic, Earth Syst. Sci. Data, 7, 19–28, https://doi.org/10.5194/essd-7-19-2015.

Trenkel, V., Huse,G., MacKenzie, B., Alvarez, P., Arrizabalaga, H.,Castonguay, M., Goñi, N., Grégoire, F., Hátún, H., and Jansen, T. Comparative ecology of widely distributed pelagic fish species in the North Atlantic: implications for modelling climate and fisheries impacts. Prog. Oceanogr., 129 (2014), pp. 219-243.

Utne, K. R., Huse, G., Ottersen, G., Holst, J. C., Zabavnikov, V., Jacobsen, J. A., Oskarsson, G. J., and Nøttestad, L. 2012. Horizontal distribution and overlap of planktivorous fish stocks in the Norwegian Sea during summers 1995–2006. Marine Biology Research (1745-1019) 2012-04, Vol. 8, N. 5–6, P. 420–441.

2.17 Tables

Table 2.3.1.1. Blue whiting. ICES estimated catches (tonnes) by country for the period 1988–2020.

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	
Faroe Islands	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 1988–2020.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Denmark	89500	41450	54663	48659	18134	248	140	165	340	2167	35256	45178	39395	60868	87348	68716	58997
Estonia	*															0	
Faroe Islands	322322	266799	321013	317859	225003	58354	49979	16405	43290	85768	224700	282502	282416	356501	349838	336569	343372
France		8046	18009	16638	11723	8831	7839	4337	9799	8978	10410	9659	10345	13369	16784	16095	13769
Germany	15293	22823	36437	34404	25259	5044	9108	278	6239	11418	24487	24107	20025	45555	47708	38244	42362
Iceland	379643	265516	309508	236538	159307	120202	87942	5887	63056	104918	182879	214870	186914	228934	292944	268356	243725
Ireland	75393	73488	54910	31132	22852	8776	8324	1195	7557	13205	21466	24785	27657	43238	49903	38836	40135
Lithuania			4635	9812	5338						4717		1129	5300			9543
Netherlands	95311	147783	102711	79875	78684	35686	33762	4595	26526	51635	38524	56397	58148	81156	121864	75020	62309
Norway	957684	738490	642451	539587	418289	225995	194317	20539	118832	196246	399520	489439	310412	399363	438426	351429	354033
Poland														15889	12152	27185	47616
Portugal	3937	5190	5323	3897	4220	2043	1482	603	1955	2056	2150	2547	2586	2046	2497	3481	2819
Spain	15612	17643	15173	13557	14342	20637	12891	2416	6726	15274	32065	29206	31952	28920	24718	22782	23676
Sweden	19083	2960	101	464	4	3	50	1	4	199	2	32	42	90	16**	54	25
UK (England + Wales)	2593	7356	10035	12926	14147	6176	2475	27	1590	4100	11	131	1374+	3447	1864	4062	7458
UK (Northern Ireland)										1232	2205	1119			4508	2899	2958
UK (Scotland)	57028	104539	72106	43540	38150	173	5496	1331	6305	8166	24630	30508	37173	64724	66682	54040	41344
Russia	346762	332226	329100	236369	225163	149650	112553	45841	88303	120674	152256	185763	173655	188449	170892	188006	181496
Greenland										2133				20212	23333	19753	19611
Unallocated									3499								
TOTAL	**2380161**	**2034309**	**1976176**	**1625255**	**1260615**	**641818**	**526357**	**103620**	**384021**	**628169**	**1155279**	**1396244**	**1181850**	**1558061**	**1711461**	**1515527**	**1495248**

*** 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 2020.

ICES Division	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	UK (England + Wales)	UK (Northern Ireland)	UK (Scotland)	Total
27.2.a	52	32692	14	5085	375	13463	4	441	109	988	41		28458		1	216		2	**81941**
27.3.a	107									6					16				**130**
27.4																		47	**47**
27.4.a	160	19338	267	1731	1241	9687		1539	1211	26467	1357		1126		8			0	**64132**
27.4.b	10									8						0			**18**
27.5.a		1692				8451													**10143**
27.5.b	731	169885	965		13450	135617		2487	533	469	5787		73645						**403570**
27.6.a	25611	51894	9236	19913	2695	31548	10089	5076	32414	56541	26767		21744	147		7241	30	11787	**312732**
27.6.b	422	495	0		690	5723	1192		1284	9252			9572	9				563	**29201**
27.7.b	148		733	1			544		141					28				2779	**4373**
27.7.c	18716	26191	1446	15162		177	22195		18034	174868	10951		1066	440				20074	**309320**
27.7.e	0		0						0							2			**2**
27.7.g									0					2					**2**
27.7.h	0		27						38					9					**74**
27.7.j			0	16			955		99		22			160		0			**1252**
27.7.k	13041	41185	60		1160	39059	5156		8444	85434	2691		45885	74			2929	6092	**251208**
27.8.a			476				0		1					0					**477**
27.8.b			5	20										89		0			**114**
27.8.c												229		13963					**14192**
27.8.d			540	434															**974**
27.9.a												2590		8756					**11346**
Total	**58997**	**343372**	**13769**	**42362**	**19611**	**243725**	**40135**	**9543**	**62309**	**354033**	**47616**	**2819**	**181496**	**23676**	**25**	**7458**	**2958**	**41344**	**1495248**

.

Table 2.3.1.3. Blue whiting. ICES estimated catches (tonnes) by quarter and ICES division for 2020

ICES Division	Quarter 1	Quarter 2	Quarter 3	Quarter 4	2020*	Total
27.2.a	526	37015	24430	19971		81941
27.3.a		1	128	1		130
27.4					47	47
27.4.a	529	33299	19688	10616		64132
27.4.b	0	9	9	0		18
27.5.a	5		1391	8747		10143
27.5.b	27120	271893	254	104303		403570
27.6.a	36486	255516	7	20679	44	312732
27.6.b	21940	7163	13	7	79	29201
27.7.b	3093	1203	63	16		4373
27.7.c	262985	46265	34	37		309320
27.7.e	2	0		0		2
27.7.g			2	0		2
27.7.h			7	67		74
27.7.j	1	997	144	110		1252
27.7.k	251139			70		251208
27.8.a	4	1	1	471		477
27.8.b	6	39	18	51		114
27.8.c	2901	4737	4087	2467		14192
27.8.d	365	69		540		974
27.9.a	1355	3623	3136	3231		11346
Total	**608455**	**661830**	**53411**	**171382**	**170**	**1495248**

***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 1988–2020 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;Divs.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
2020	**92084**	**1059197**	**64327**	**1215608**	**279640**	**1495248**

*** 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 2020.

Country	Catches	Landings	Discards	% discards
Denmark	58997	58983	14	0.02
Faroe Islands	343372	343372		0.00
France	13769	13769		0.00
Germany	42362	42362		0.00
Greenland	19611	19611		0.00
Iceland	243725	243725		0.00
Ireland	40135	39180	955	2.38
Lithuania	9543	9543		0.00
Netherlands	62309	62309	0	0.00
Norway	354033	354033		0.00
Poland	47616	47615	1	0.00
Portugal	2819	2026	793	28.13
Russia	181496	181496		0.00
Spain	23676	22789	887	3.75
Sweden	25	25		0.00
UK (England+Wales)	7458	7450	8	0.11
UK(Northern Ireland)	2958	2958		0.00
UK(Scotland)	41344	41174	170	0.41
Total	**1495248**	**1492420**	**2828**	**0.19**

Table 2.3.1.6. Blue whiting. ICES estimated catches (tonnes) inside and outside NEAFC regulatory area for 2020 by country.

Country	Catches inside NEAFC RA	Catches outside NEAFC RA	Total catches
Denmark	5103	53895	58997
Faroe Islands	39850	303522	343372
France*	512	13257	13769
Germany	508	41854	42362
Greenland*	15326	4285	19611
Iceland	45792	197933	243725
Ireland	559	39576	40135
Lithuania*	2753	6790	9543
Netherlands	69	62240	62309
Norway*	58583	295450	354033
Poland	10	47605	47616
Portugal	0	2819	2819
Russia	77348	104148	181496
Spain	0	23676	23676
Sweden	0	25	25
UK (England+Wales)	0	7458	7458
UK(Northern Ireland)	0	2958	2958
UK(Scotland)	0	41343	41344
Total in 2020	**246412**	**1248836**	**1495248**

*** the values of catches inside/outside NEAFC RA have been estimated 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 2000-2020.

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
2020	**1495248**	**81**	**672**	**89110**	**16641**

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 2020.

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	58997	90	18	18	655	590	10	11
Faroe Islands	343372	96	25	25	2447	1908	6	7
France	13769	0	24	0	1619	0	0	118
Germany	42362	7	8	8	1704	755	18	40
Greenland	19611	0	0	0	0	0	0	0
Iceland	243725	95	99	99	7663	2438	10	31
Ireland	40135	91	38	18	6425	1807	45	160
Lithuania	9543	0	0	0	0	0	0	0
Netherlands	62309	90	47	47	10826	1108	18	174
Norway	354033	92	86	86	2484	2484	7	7
Poland	47616	0	0	0	0	0	0	0
Portugal	2819	92	19	19	1493	756	268	530
Russia	181496	79	120	120	38166	1598	9	210
Spain	23676	61	133	133	9913	2848	120	419
Sweden	25	0	0	0	0	0	0	0
UK (England+Wales)	7458	0	3	0	30	0	0	4
UK(Northern Ireland)	2958	0	0	0	0	0	0	0
UK(Scotland)	41344	49	52	7	5685	349	8	138
Total	**1495248**	**81**	**672**	**580**	**89110**	**16641**	**11**	**60**

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 2020.

Country	Catches (ton)	No. of Length Samples	No. of Length Measured	No. Age Readings
Denmark				
Quarter 1	33047	14	512	448
Quarter 2	25674	4	143	142
Quarter 3	199	0	0	0
Quarter 4	77	0	0	0
Total	**58997**	**18**	**655**	**590**
Faroe Islands				
Quarter 1	97687	10	904	749
Quarter 2	174380	10	1001	899
Quarter 3	9685	0	0	0
Quarter 4	61620	5	542	260
Total	**343372**	**25**	**2447**	**1908**
France				
Quarter 1	2314	8	599	0
Quarter 2	9734	0	0	0
Quarter 3	1	0	0	0
Quarter 4	1721	16	1020	0
Total	**13769**	**24**	**1619**	**0**
Germany				
Quarter 1	9987	0	0	0
Quarter 2	28510	2	473	272
Quarter 3	2948	6	1231	483
Quarter 4	917	0	0	0
Total	**42362**	**8**	**1704**	**755**
Greenland				
Quarter 1	2400	0	0	0
Quarter 2	12064	0	0	0
Quarter 3	25	0	0	0
Quarter 4	5122	0	0	0
Total	**19611**	**0**	**0**	**0**
Iceland				
Quarter 1	51297	22	1918	546
Quarter 2	134167	51	3867	1246
Quarter 3	1956	1	45	25
Quarter 4	56305	25	1833	621
Total	**243725**	**99**	**7663**	**2438**

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 2020.

Ireland	Catches (ton)	No. of Length Samples	No. of Length Measured	No. Age Readings
Quarter 1	28117	13	2972	1307
Quarter 2	12007	25	3453	500
Quarter 4	11	0	0	0
Total	**40135**	**38**	**6425**	**1807**
Lithuania				
Quarter 4	9543	0	0	0
Netherlands				
Quarter 1	13038	22	5122	525
Quarter 2	44286	25	5704	583
Quarter 3	116	0	0	0
Quarter 4	4869	0	0	0
Total	**62309**	**47**	**10826**	**1108**
Norway				
Quarter 1	252430	71	2040	2040
Quarter 2	77987	15	444	444
Quarter 3	19509	0	0	0
Quarter 4	4108	0	0	0
Total	**354033**	**86**	**2484**	**2484**
Poland				
Quarter 1	10456	0	0	0
Quarter 2	25052	0	0	0
Quarter 3	22	0	0	0
Quarter 4	12087	0	0	0
Total	**47616**	**0**	**0**	**0**
Portugal				
Quarter 1	678	8	548	204
Quarter 2	585	4	255	194
Quarter 3	831	3	384	236
Quarter 4	725	4	306	122
Total	**2819**	**19**	**1493**	**756**
Russia				
Quarter 1	65293	68	17888	928
Quarter 2	95733	37	11227	227
Quarter 3	11345	10	4618	295
Quarter 4	9125	5	4433	148
Total	**181496**	**120**	**38166**	**1598**

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 2020.

Spain	Catches (ton)	No. of Length Samples	No. of Length Measured	No. Age Readings
Quarter 1	3986	14	1165	100
Quarter 2	8006	30	1693	100
Quarter 3	6535	28	2380	1408
Quarter 4	5150	61	4675	1240
Total	**23676**	**133**	**9913**	**2848**
Sweden				
Quarter 3	24	0	0	0
Quarter 4	1	0	0	0
Total	**25**	**0**	**0**	**0**
UK (England)				
Quarter 1	202	3	30	0
Quarter 2	7040	0	0	0
Quarter 3	216	0	0	0
Quarter 4	0	0	0	0
Total	**7458**	**3**	**30**	**0**
UK(Northern Ireland)				
Quarter 1	2958	0	0	0
UK(Scotland)				
Quarter 1	34565	7	1488	349
Quarter 2	6606	0	0	0
Quarter 3	0	0	0	0
Quarter 4	2	0	0	0
2020*	170	45	4197	0
Total	**41344**	**52**	**5685**	**349**
Total Geral	**1495248**	**672**	**89110**	**16641**

*** 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 2020.

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	81941	32	32	11107	1309	16	136
27.3.a	130	0	0	0	0	0	0
27.4	47	30	0	845	0	0	18155
27.4.a	64132	5	5	431	192	3	7
27.4.b	18	0	0	0	0	0	0
27.5.a	10143	8	8	397	200	20	39
27.5.b	403570	113	108	19625	2397	6	49
27.6.a	312732	78	61	10562	2342	7	34
27.6.b	29201	31	26	7011	441	15	240
27.7.b	4373	0	0	0	0	0	0
27.7.c	309320	91	88	10376	3279	11	34
27.7.e	2	3	0	30	0	0	16379
27.7.g	2	0	0	0	0	0	0
27.7.h	74	0	0	0	0	0	0
27.7.j	1252	20	0	2228	0	0	1780
27.7.k	251208	98	98	14079	2605	10	56
27.8.a	477	5	0	300	0	0	629
27.8.b	114	0	0	0	0	0	0
27.8.c	14192	110	110	7818	1474	104	551
27.8.d	974	6	2	713	272	279	732
27.9.a	11346	42	42	3588	2130	188	316
TOTAL	**1495248**	**672**	**580**	**89110**	**16641**	**11**	**60**

Table 2.3.2.1. Blue whiting. ICES estimated preliminary landings (tonnes) in 2021 by quarter and ICES division. Data submitted to InterCatch.

	Landings		
ICES div.	Quarter 1	Quarter 2	Total
27.2.a	1096	52924	54020
27.3.a		1	1
27.4.a	1104	13715	14819
27.4.b		5	5
27.5.a	1		1
27.5.b	52948	216436	269384
27.6.a	74121	152749	226870
27.6.b	8755		8755
27.7	9		9
27.7.b	6427	65	6492
27.7.c	154051		154051
27.7.f	1		1
27.7.g	0		0
27.7.j	109		109
27.7.k	144221		144221
27.8.b		27	27
27.8.c	5078	7423	12502
27.9.a	303	350	653
Total	**448223**	**443695**	**891918**

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 2021 preliminary data (quarters 1 and 2). Data submitted to InterCatch.

ICES Division	Catch (ton)	No. samples	No. Measured	No. Aged
27.2.a	54020	1	95	95
27.3.a	1	0	0	0
27.4.a	14819	0	0	0
27.4.b	5	0	0	0
27.5.a	1	0	0	0
27.5.b	269384	49	8961	709
27.6.a	226870	89	14754	2443
27.6.b	8755	4	832	226
27.7	9	0	0	0
27.7.b	6492	2	508	102
27.7.c	154051	97	22447	2679
27.7.f	1	0	0	0
27.7.g	0	0	0	0
27.7.j	109	1	281	102
27.7.k	144221	52	9292	1045
27.8.b	27	0	0	0
27.8.c	12502	0	0	0
27.9.a	653	8	834	398
Total	**891918**	**303**	**58004**	**7799**

Table 2.3.2.3. Blue whiting. ICES estimates of catches (tonnes) in 2021, based on (initial) declared quotas and expected uptake estimated by WGWIDE.

Country	Quarter 1	Quarter 2	Prelim Q1-Q2 catch	Expected remaining catch	Total catch
Denmark	27702	10317	38019	13	38032
Faroe Islands	64194	124641	188835	141323	330158
France	237	12109	12346	0	12346
Germany	21899	11979	33878	2800	36678
Greenland					20207
Iceland	23124	128931	152055	31634	183689
Ireland	22817	16091	38908	0	38908
Lithuania	8682	0	8682	0	8682
Netherlands	33684	20912	54596	10600	65196
Norway	174903	41179	216082	24000	240000
Poland	12445		12445	16000	28445
Portugal	291	313	604	1396	2000
Russia	61551	72054	133605	20017	153622
Spain	5099	7487	12586		12586
UK(Scotland)	34198	30703	64901	0	72107
Sweden	0.112	0.004	0.116	70	70
Total	490826	476716	967542	247853	
Best estimate of catch for 2021					1242727

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

Year	Preliminary	Final	Deviation %*
2016	1147000	1180786	2.9
2017	1559437	1555069	-0.3
2018	1712874	1709856	-0.2
2019	1444301	1515527	4.7
2020	1179029	1495248	21

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

Table 2.3.3.1. Blue whiting. Catch-at-age numbers (thousands) by year. Discards included since 2014. Values for 2021 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
2002	1821053	3232244	3291844	2242722	1824047	1647122	344403	168848	102576	142743

Year/Age	1	2	3	4	5	6	7	8	9	10+
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	1135859	834162	1106838	1797157	3072708	3041983	923392	235330	80440	64535
2021	1349673	1259314	1517653	1602500	1600311	1668786	1562070	388584	96018	86107

Table 2.3.4.1. Blue whiting. Individual mean weight (kg) at age in the catch. Preliminary values for 2021.

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	0.141	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	0.063	0.084	0.099	0.115	0.127	0.135	0.144	0.161	0.176	0.207
2021	0.048	0.069	0.095	0.113	0.131	0.139	0.147	0.158	0.181	0.176

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 2004-2021) 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
2020**											

Year	Age 1	2	3	4	5	6	7	8	9	10+	TSB
2021	1948	2095	2545	2275	3914	3197	3379	463	189	114	2357

*Survey discarded. **No survey

Table 2.3.7.2.1. Blue whiting. Estimated abundance of 1 and 2 year old blue whiting from the International Ecosystem Survey in Nordic Seas (IESNS), 2003–2021.

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
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	2822	481
2021	10264	1500

***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
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

Catch Rate		
Year	**All**	**< 19 cm**
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
2021	182.86	161.04

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
2021	79.6

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	1401
1995	1162
1996	4821
1997	2307
1998	463
1999	1717
2000	863
2001	4424
2002	4480
2003	1038
2004	15749
2005	35159
2006	23105
2007	11568
2008	1268
2009	4362
2010	855
2011	23323
2012	8366
2013	13254
2014	70139
2015	34806
2016	21316
2017	4446
2018	1890
2019	286
2020	141
2021	2224

Table 2.4.1.1. Blue whiting. Parameter estimates, from final assessment (2021) and retrospective analysis (2017-2020).

Parameter Year	2017	2018	2019	2020	2021
Random walk variance					
-F Age 1-10	0.38	0.38	0.37	0.37	0.36
Process error					
-log(N) Age 1	0.63	0.61	0.61	0.60	0.60
--- Age 2-10	0.18	0.18	0.18	0.18	0.18
Observation variance					
-Catch Age 1	0.44	0.43	0.43	0.44	0.43
--- Age 2	0.29	0.28	0.28	0.28	0.28
--- Age 3-8	0.20	0.19	0.19	0.19	0.19
--- Age 9-10	0.40	0.40	0.39	0.38	0.38
-IBWSS Age 1	0.73	0.73	0.75	0.72	0.71
--- Age 2	0.30	0.31	0.33	0.33	0.32
--- Age 3	0.42	0.43	0.41	0.40	0.39
--- Age 4-6	0.39	0.38	0.37	0.37	0.37
--- Age 7-8	0.47	0.51	0.54	0.53	0.53
Survey catchability					
-IBWSS Age 1	0.07	0.06	0.07	0.06	0.06
--- Age 2	0.12	0.11	0.11	0.11	0.11
--- Age 3	0.38	0.38	0.37	0.37	0.37
--- Age 4	0.70	0.68	0.68	0.68	0.67
--- Age 5-8	0.90	0.87	0.87	0.89	0.89
Rho					
--	0.93	0.93	0.93	0.93	0.93

Table 2.4.1.2. Blue whiting. Mohn's rho by year and average over the last five years (n=5).

Year	R(age 1)	SSB	Fbar(3-7)
2016	0.257	0.056	-0.100
2017	-0.062	-0.086	0.134
2018	-0.149	-0.075	0.056
2019	-0.224	0.044	-0.063
2020	-0.079	-0.002	-0.035
rho.mean	-0.051	-0.013	-0.002

Table 2.4.1.3. 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	0.244	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	0.117	0.171	0.211	0.240	0.314	0.337	0.419	0.445	0.445
1984	0.095	0.143	0.212	0.265	0.305	0.397	0.418	0.509	0.529	0.529
1985	0.101	0.150	0.230	0.295	0.346	0.448	0.465	0.561	0.576	0.576
1986	0.113	0.169	0.268	0.358	0.431	0.552	0.573	0.691	0.703	0.703
1987	0.100	0.150	0.248	0.338	0.415	0.538	0.560	0.673	0.675	0.675
1988	0.098	0.148	0.253	0.349	0.439	0.575	0.588	0.694	0.677	0.677
1989	0.113	0.171	0.304	0.420	0.526	0.686	0.712	0.841	0.805	0.805
1990	0.105	0.159	0.292	0.408	0.510	0.664	0.712	0.848	0.815	0.815
1991	0.059	0.089	0.167	0.235	0.290	0.367	0.395	0.465	0.450	0.450
1992	0.048	0.073	0.140	0.195	0.233	0.286	0.311	0.370	0.362	0.362
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	0.113	0.160	0.186	0.219	0.241	0.292	0.286	0.286
1995	0.046	0.070	0.149	0.215	0.243	0.284	0.313	0.382	0.368	0.368
1996	0.055	0.085	0.185	0.271	0.297	0.347	0.382	0.472	0.450	0.450
1997	0.054	0.084	0.188	0.279	0.300	0.349	0.382	0.474	0.452	0.452
1998	0.070	0.110	0.251	0.381	0.408	0.473	0.509	0.629	0.592	0.592
1999	0.064	0.101	0.237	0.370	0.398	0.459	0.483	0.593	0.558	0.558
2000	0.074	0.117	0.279	0.446	0.498	0.576	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	0.430	0.494	0.572	0.574	0.679	0.643	0.643
2002	0.065	0.104	0.251	0.418	0.504	0.595	0.597	0.701	0.665	0.665
2003	0.067	0.107	0.262	0.440	0.545	0.635	0.629	0.710	0.669	0.669
2004	0.068	0.109	0.269	0.462	0.592	0.691	0.689	0.754	0.710	0.710
2005	0.060	0.095	0.239	0.420	0.557	0.651	0.657	0.705	0.667	0.667
2006	0.051	0.082	0.209	0.373	0.509	0.597	0.607	0.641	0.606	0.606
2007	0.048	0.078	0.197	0.357	0.505	0.604	0.629	0.661	0.628	0.628
2008	0.042	0.068	0.171	0.308	0.443	0.529	0.563	0.590	0.568	0.568
2009	0.027	0.045	0.112	0.197	0.286	0.340	0.369	0.385	0.372	0.372
2010	0.019	0.032	0.080	0.137	0.199	0.235	0.258	0.263	0.256	0.256
2011	0.006	0.010	0.024	0.040	0.057	0.067	0.074	0.075	0.075	0.075
2012	0.012	0.021	0.052	0.086	0.121	0.141	0.160	0.167	0.165	0.165
2013	0.020	0.035	0.091	0.151	0.214	0.245	0.279	0.294	0.292	0.292
2014	0.037	0.067	0.177	0.297	0.414	0.473	0.538	0.570	0.564	0.564
2015	0.048	0.087	0.233	0.392	0.543	0.625	0.697	0.736	0.724	0.724
2016	0.042	0.075	0.201	0.344	0.476	0.556	0.617	0.648	0.636	0.636
2017	0.040	0.072	0.194	0.332	0.456	0.531	0.579	0.601	0.591	0.591
2018	0.040	0.072	0.196	0.339	0.464	0.542	0.591	0.608	0.599	0.599
2019	0.037	0.067	0.181	0.316	0.431	0.501	0.546	0.556	0.547	0.547
2020	0.043	0.078	0.212	0.372	0.505	0.586	0.641	0.653	0.638	0.638
2021	0.047	0.086	0.233	0.411	0.555	0.642	0.699	0.713	0.698	0.698

Table 2.4.1.4. Blue whiting. Estimated stock numbers-at-age (thousands). Preliminary catch data for 2021 have been used.

Year /Age	1	2	3	4	5	6	7	8	9	10+
1981	3946080	3488881	4858076	2075467	2616594	2143488	1646105	1741446	1221690	2961401
1982	4696923	2959384	2521927	3288270	1587238	1501436	1296370	1014308	889757	1937887
1983	18021467	3782040	1880233	1824547	1909739	1218909	1013368	854387	627623	1261812
1984	17927420	14381350	2440981	1235055	1264728	1394828	814494	550144	481759	928367
1985	9575365	13474205	9725627	1452648	750741	911346	746052	458313	265779	723204
1986	7251591	6399491	9402588	5526602	941898	452591	469648	375703	230561	497593
1987	9110901	5062609	4095247	6842718	2562332	395447	253537	237551	156389	293029
1988	6440989	6871604	3530169	2883688	3710117	1264149	199052	125606	99146	170848
1989	8544270	4636631	4990194	2429990	2128243	1682736	351574	102766	60487	115489
1990	18706545	6006263	3104831	2736494	1482317	1186471	560884	120929	33178	85010
1991	9030557	15592087	4278056	1796965	1491288	872112	562067	189376	32515	45368
1992	6712684	7420121	12475541	3308264	1264549	793022	487040	288012	101778	39265
1993	4997346	5135998	5290113	9703194	2260163	978270	517956	283011	157397	74552
1994	8107500	3423023	4074643	3409003	6915122	1439820	764662	328260	206786	116756
1995	9366200	5876598	3140124	2574833	2855583	3748486	1039795	543767	220424	185407
1996	27896658	7121356	4080055	2396819	1557094	1864865	2239686	644778	306620	248928
1997	44565707	21247721	5491471	2570938	1422353	1070470	1063302	1214840	289054	335056

Year /Age	1	2	3	4	5	6	7	8	9	10+
1998	26745578	37619991	16365576	3495404	1378636	927874	781552	604311	617341	293256
1999	20454274	20561707	27519932	10505249	1712468	775156	520777	410520	236969	427921
2000	39231005	15357190	16581016	15783843	4333439	1107303	471714	323498	153941	313533
2001	55702658	31542480	12087266	10727537	7448094	1696260	489467	227019	162370	178502
2002	48895878	45190583	20424747	8313086	5459108	3392787	689885	254824	102602	154135
2003	52676531	38992385	34898597	13541168	5062130	2966580	1206065	345959	88994	106649
2004	28616022	42041076	29939138	20814843	7229138	2458915	1311090	501127	151230	80317
2005	22242605	21717708	28462681	18093591	10702844	3216550	1105461	512185	191274	98226
2006	9091134	15514301	22144581	19234358	9447264	4441803	1351317	481054	216722	119469
2007	4952577	6036750	13145859	15891635	10270967	4678374	1828853	606023	227072	161760
2008	5842915	3500008	4369894	11056804	9144335	4900979	1853861	752867	234131	198052
2009	5763280	4034046	2433903	3727750	6943856	4709063	2193544	854440	323777	188236
2010	15334306	5043345	2375179	1866784	3375653	4341237	2838047	1201574	413724	266316
2011	19236335	13403215	3336216	1666726	1619700	2610523	2699455	1354322	813827	392473
2012	19175444	15434634	12543207	2305415	1193211	1614801	2331692	2112107	1077976	899109
2013	16039501	16001936	11658859	7392216	2225768	1091745	1376169	1633502	1344090	1377427
2014	37131235	12692933	13840809	8026599	4371632	1344042	932427	998166	1015186	1489049
2015	62818315	32746083	10794145	8486052	4202017	1734666	735296	517757	481589	1055653

Year /Age	1	2	3	4	5	6	7	8	9	10+
2016	34221938	56546333	21364733	7660431	4323342	1802708	704454	350670	220580	592519
2017	11565966	27889368	45064410	15023031	4538325	2150495	737486	282998	160395	373641
2018	12061390	8949817	22089472	29231257	8721742	2459198	943081	313308	142157	263927
2019	13079208	8976003	8450272	14735133	16294262	4545275	1122193	404091	138783	196561
2020	22788112	10675689	6577758	6442614	8554151	7877493	2164844	537652	196205	161396
2021	29805438	17686107	7861257	4594971	4050703	3999555	3592288	863904	217528	167554
2022		23273308	13288721	5098852	2493135	1903468	1724028	1462329	346655	156875

Table 2.4.1.5. 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 2021 are included.

Year	R(age 1)	Low	High	SSB	Low	High	Fbar(3-7)	Low	High	TSB	Low	High
1981	3946080	2551853	6102055	2843799	2239591	3611014	0.258	0.188	0.355	3342019	2681169	4165754
1982	4696923	3008509	7332898	2302366	1834150	2890108	0.221	0.163	0.298	2772773	2247559	3420720
1983	18021467	11775650	27580072	1856506	1510944	2281099	0.255	0.191	0.339	2877093	2345564	3529071
1984	17927420	11823410	27182717	1750611	1448333	2115976	0.319	0.243	0.419	3074915	2485224	3804526
1985	9575365	6344090	14452447	2086876	1723059	2527512	0.357	0.275	0.463	3222250	2633423	3942737
1986	7251591	4832635	10881347	2269479	1877212	2743714	0.436	0.337	0.564	3110695	2579468	3751324
1987	9110901	6058765	13700566	1930865	1599576	2330768	0.420	0.324	0.544	2816340	2338790	3391399
1988	6440989	4280013	9693041	1637715	1367908	1960738	0.441	0.340	0.571	2427518	2023738	2911861

Year	R(age 1)	Low	High	SSB	Low	High	Fbar(3-7)	Low	High	TSB	Low	High
1989	8544270	5656169	12907066	1547055	1296180	1846487	0.529	0.411	0.682	2395175	1987409	2886604
1990	18706545	12204475	28672664	1358764	1128574	1635905	0.517	0.394	0.678	2498157	2000107	3120228
1991	9030557	5832076	13983178	1778560	1429332	2213114	0.291	0.214	0.394	3221839	2527447	4107008
1992	6712684	4385689	10274357	2458361	1949402	3100202	0.233	0.172	0.316	3528675	2801747	4444208
1993	4997346	3228601	7735075	2540185	2023037	3189531	0.204	0.151	0.276	3419865	2742863	4263967
1994	8107500	5285973	12435091	2534082	2039662	3148352	0.184	0.135	0.249	3415911	2775418	4204212
1995	9366200	6166052	14227206	2311535	1902342	2808745	0.241	0.181	0.320	3361278	2768183	4081447
1996	27896658	18407554	42277400	2210376	1836492	2660377	0.296	0.225	0.391	3723606	3033596	4570564
1997	44565707	29460840	67414990	2464353	2044176	2970896	0.300	0.228	0.394	5419396	4268697	6880286
1998	26745578	17791745	40205497	3669862	3001545	4486986	0.404	0.311	0.525	6804090	5445360	8501850
1999	20454274	13544156	30889878	4432233	3610899	5440387	0.389	0.299	0.506	7167410	5831204	8809803
2000	39231005	25926555	59362755	4230752	3514368	5093167	0.477	0.371	0.615	7460737	6088676	9141986
2001	55702658	37101728	83629152	4568522	3811227	5476291	0.467	0.362	0.602	8993257	7264374	11133604
2002	48895878	32563927	73418876	5400006	4498373	6482357	0.473	0.366	0.611	10328562	8372831	12741113
2003	52676531	35556956	78038651	6849571	5686857	8250010	0.502	0.394	0.640	11807831	9692142	14385353
2004	28616022	19265060	42505797	6755492	5672809	8044810	0.540	0.426	0.685	10368413	8665497	12405980
2005	22242605	15018310	32942020	6018029	5061918	7154734	0.505	0.395	0.645	8492573	7131484	10113436
2006	9091134	6072432	13610481	5870609	4920034	7004839	0.459	0.357	0.590	7715302	6471565	9198066

Year	R(age 1)	Low	High	SSB	Low	High	Fbar(3-7)	Low	High	TSB	Low	High
2007	4952577	3298315	7436530	4666706	3899972	5584181	0.458	0.353	0.595	5706469	4780348	6812012
2008	5842915	3846303	8875965	3593810	2963508	4358168	0.403	0.302	0.538	4414939	3657374	5329421
2009	5763280	3675852	9036107	2758087	2218803	3428445	0.261	0.190	0.358	3476623	2816989	4290718
2010	15334306	10024968	23455530	2689104	2122772	3406527	0.182	0.130	0.255	3763510	2998591	4723555
2011	19236335	12696647	29144431	2713450	2156951	3413526	0.052	0.036	0.076	4444320	3535979	5586000
2012	19175444	12878334	28551649	3445804	2808274	4228064	0.112	0.084	0.150	5118998	4169337	6284965
2013	16039501	10807867	23803549	3768379	3131928	4534165	0.196	0.149	0.258	5587760	4626764	6748358
2014	37131235	24799212	55595662	4004460	3366398	4763460	0.380	0.292	0.495	6634143	5473331	8041146
2015	62818315	42154778	93610758	4177415	3506095	4977273	0.498	0.388	0.639	8134033	6575161	10062489
2016	34221938	22968425	50989175	4900689	4039993	5944752	0.439	0.339	0.568	9066287	7305713	11251136
2017	11565966	7599119	17603565	6058300	4940280	7429336	0.418	0.322	0.544	8753473	7119023	10763176
2018	12061390	7806099	18636342	5916510	4806789	7282428	0.426	0.323	0.564	7807196	6341420	9611776
2019	13079208	7890921	21678799	5061219	4030938	6354834	0.395	0.287	0.544	6885890	5441112	8714299
2020	22788112	12759097	40700221	4151143	3134696	5497181	0.463	0.314	0.684	6354193	4650674	8681701
2021	29805438	13152311	67544339	3444751	2332874	5086562	0.508	0.298	0.865	5747899	3681372	8974465
2022	20982149*			3403663*			0.508			6050174		

***assuming long term GM(1996-2020) recruitment (20982149) in 2022.**

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 2021 are included.

Year	Estimate	Low	High	Observed catch
1981	786026	563271	1096875	922980
1982	544001	413221	716170	550643
1983	511286	394907	661961	553344
1984	560913	432749	727035	615569
1985	637584	500137	812804	678214
1986	759594	596217	967739	847145
1987	638131	501148	812557	654718
1988	569422	447815	724051	552264
1989	619197	490191	782154	630316
1990	553363	435299	703448	558128
1991	407488	316557	524539	364008
1992	438354	345107	556796	474592
1993	439560	344372	561059	475198
1994	424293	330597	544543	457696
1995	507974	402262	641466	505176
1996	597227	473104	753915	621104
1997	640039	503037	814355	639681
1998	1076678	841112	1378217	1131955
1999	1245781	968337	1602717	1261033
2000	1502768	1176771	1919076	1412449
2001	1559029	1221058	1990546	1771805
2002	1713207	1342017	2187065	1556955
2003	2198166	1729901	2793186	2365319
2004	2315573	1829682	2930497	2400795
2005	1998062	1581349	2524587	2018344
2006	1850619	1464595	2338389	1956239
2007	1553869	1227788	1966552	1612269
2008	1165559	914098	1486193	1251851

Year	Estimate	Low	High	Observed catch
2009	654934	512561	836854	634978
2010	476283	367095	617948	539539
2011	136701	100757	185467	103771
2012	326445	258292	412581	375692
2013	590207	466426	746836	613863
2014	1108591	870497	1411808	1147650
2015	1348148	1068156	1701533	1390656
2016	1247107	984705	1579434	1180786
2017	1481534	1168794	1877956	1555069
2018	1703786	1337677	2170095	1709856
2019	1534129	1202155	1957778	1512026
2020	1470581	1159558	1865027	1460507
2021	1239847	977113	1573228	1242727

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 2021	Mean weight in the stock and catch (kg) in 2022+	Proportion mature	Natural mortality	Exploitation pattern	Stock number(2022) (thousands)
Age 1	0.048	0.060	0.11	0.20	0.093	20982149
Age 2	0.069	0.079	0.40	0.20	0.169	23273308
Age 3	0.095	0.097	0.82	0.20	0.459	13288721
Age 4	0.113	0.112	0.86	0.20	0.810	5098852
Age 5	0.131	0.125	0.91	0.20	1.093	2493135
Age 6	0.139	0.135	0.94	0.20	1.263	1903468
Age 7	0.147	0.145	1.00	0.20	1.376	1724028
Age 8	0.158	0.162	1.00	0.20	1.404	1462329
Age 9	0.181	0.175	1.00	0.20	1.374	346655
Age 10	0.176	0.204	1.00	0.20	1.374	156875

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

Variable	Value	Notes
F ages 3–7 (2021)	0.508	From the assessment (based on assumed 2021 catches)
SSB (2022)	3 403 663	From the forecast; in tonnes
$R_{age\ 1}$ (2021)	29 805 438	From the assessment; in thousands
$R_{age\ 1}$ (2022–2023)	20 982 149	GM (1996–2020); in thousands
Total catch (2021)	1 242 727	As estimated by ICES, based on declared national quotas and expected uptake; in tonnes

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

Basis	Total catch (2022)	F (2022)	SSB (2023)	% SSB change *	% catch change **	% advice change ***
ICES advice basis						
Long-term management strategy F = FMSY	752736	0.32	4052163	19.1	-39.4	-19.0
Other scenarios						
MSY approach: FMSY	752736	0.32	4052163	19.1	-39.4	-19.0
F = 0	0	0	4738902	39.2	-100	-100
Fpa	752736	0.32	4052163	19.1	-39.4	-19.0
Flim	1695700	0.88	3214818	-5.5	36.4	82.5
SSB2023 = Blim	3797974	3.929	1500000	-55.9	205.6	308.7
SSB2023 = Bpa	2838799	2.034	2250000	-33.9	128.4	205.5
SSB2023 = MSY Btrigger	2838799	2.034	2250000	-33.9	128.4	205.5
F = F2021	1113313	0.508	3728501	9.5	-10.4	19.8
SSB2023 = SSB2022	1479984	0.731	3403629	0	19.1	59.3
Catch2022 = Catch2021	1242727	0.583	3613292	6.2	0	33.7
Catch2022 = Catch2021 −20%	994181	0.443	3834987	12.7	-20	7.0
Catch2022 = Catch2021 +25%	1553409	0.780	3339158	-1.9	25	67.2
Catch2022 = Advice2021 −20%	743434	0.315	4060575	19.3	-40.2	-20

*** SSB 2023 relative to SSB 2022.**

**** Catch 2022 relative to expected catch in 2021 (1 242 727tonnes).**

***** Catch 2022 relative to advice for 2021 (929 292 tonnes).**

2.18 Figures

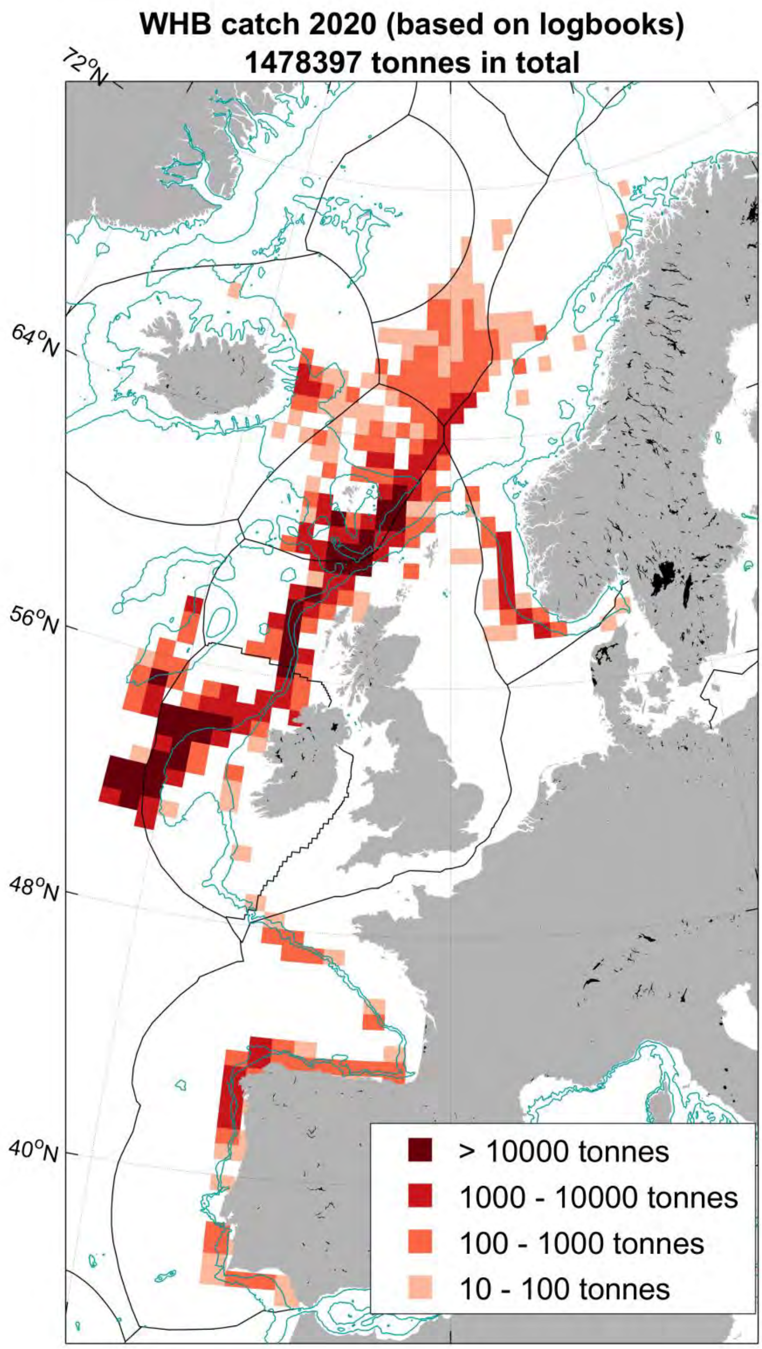


Figure 2.2.1. Blue whiting landings in 2020, based on logbook data. The catches on the map constitute 98.9 % of the ICES estimated catches. The 200 m and 1000 m depth contours are indicated in blue.

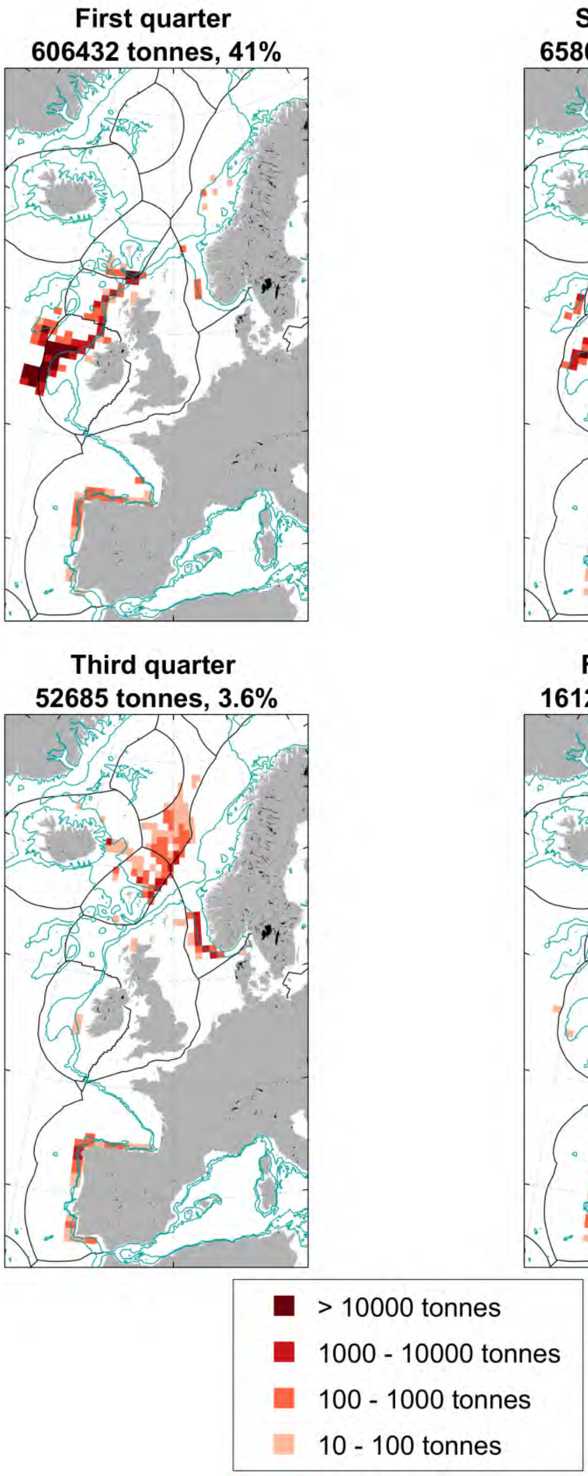


Figure 2.2.2. Blue whiting catches per quarter 2020. The catches on the map are based on logbook data and constitute 98.9 % of the ICES estimated catches. The total catches and percentages shown on each panel are also based on logbook data, and therefore deviate slightly from the ICES estimated catches pr. quarter. The 200 m and 1000 m depth contours are indicated in blue.

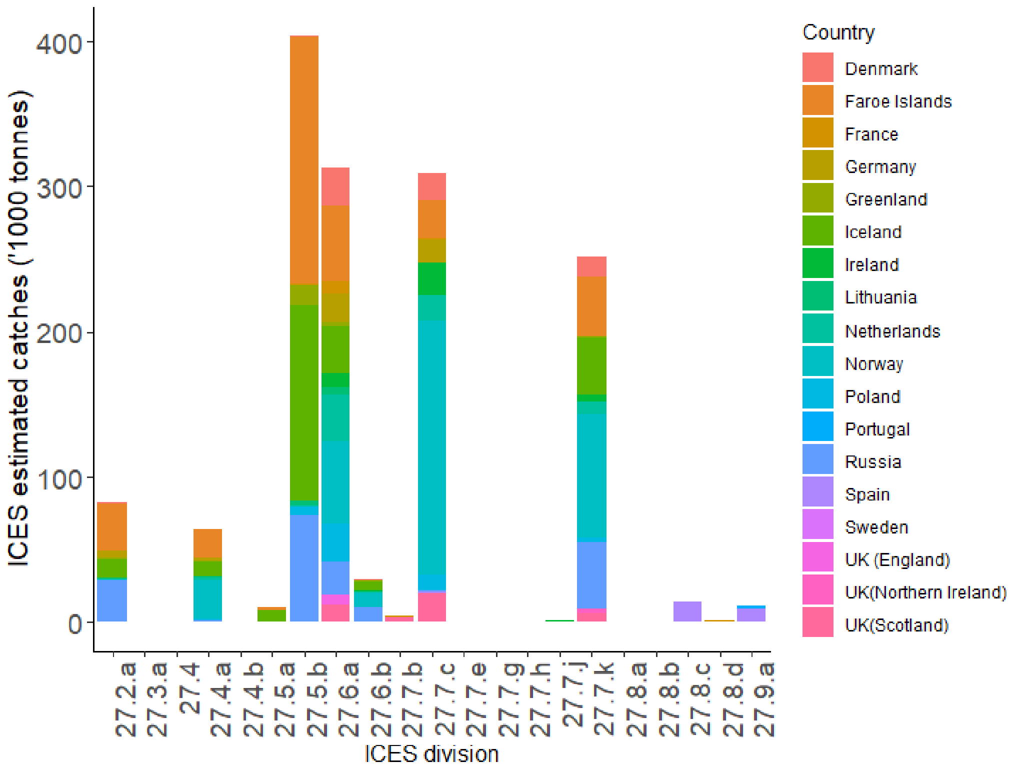
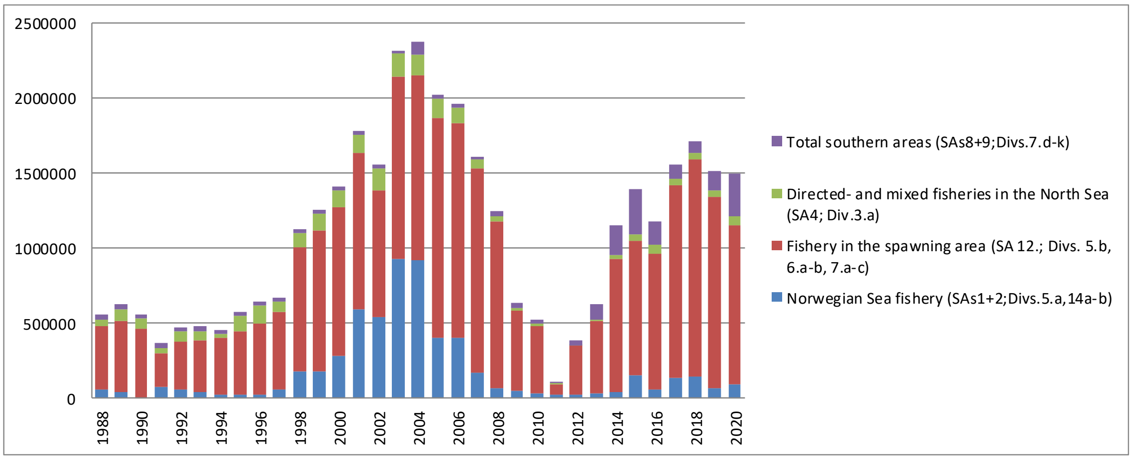


Figure 2.3.1.1. Blue whiting. ICES estimated catches ('1000 tonnes) in 2020 by ICES division and country.

A



B

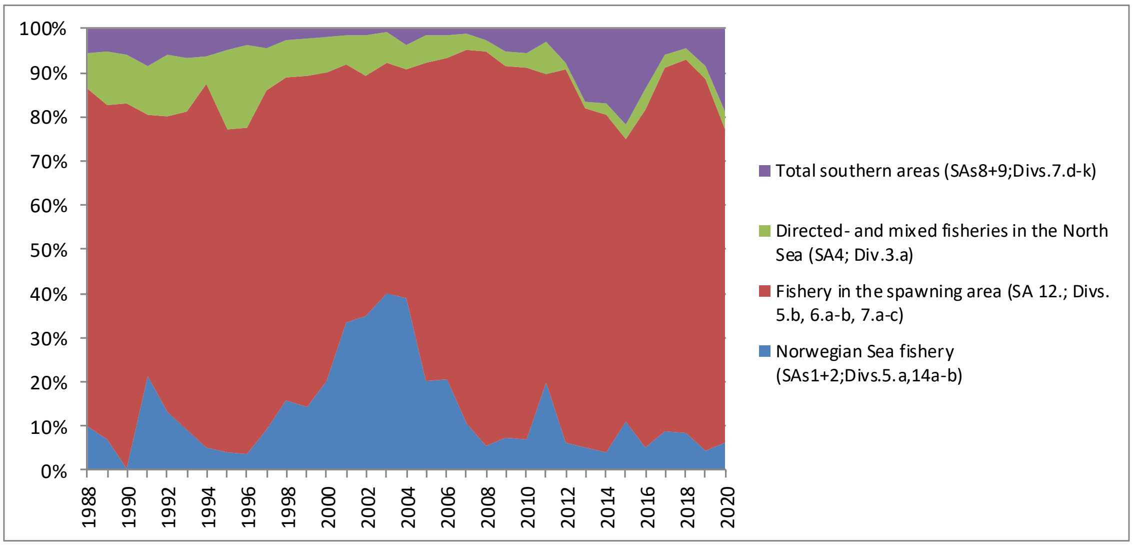


Figure 2.3.1.2. Blue whiting.(A) ICES estimated catches (tonnes) of blue whiting by fishery subareas from 1988-2020 and (B) the percentage contribution to the overall catch by fishery subarea over the same period.

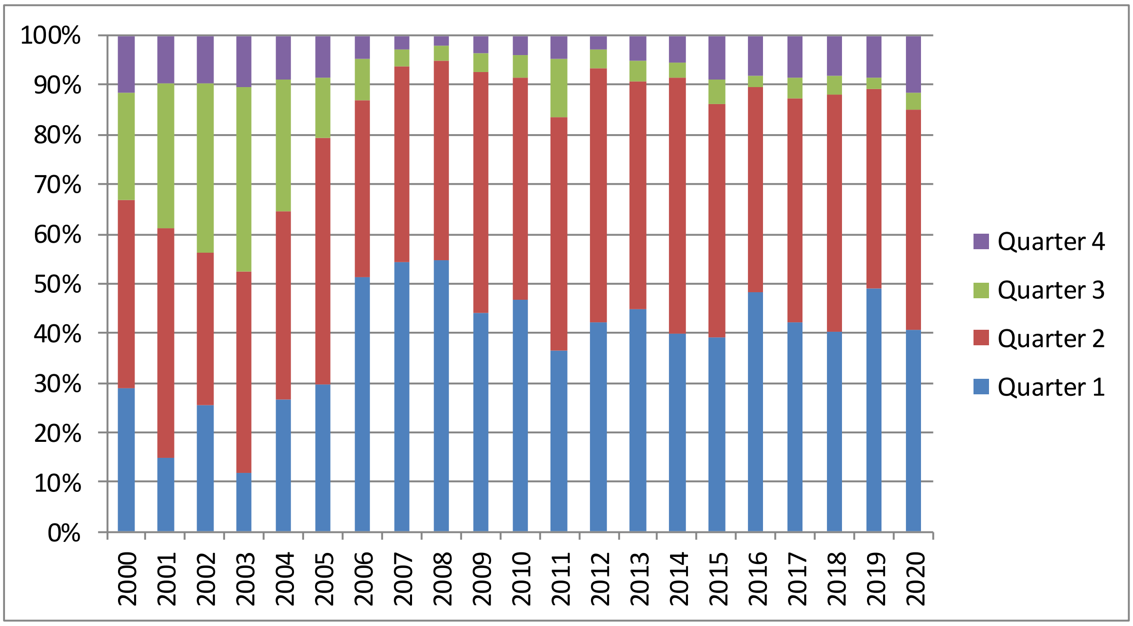


Figure 2.3.1.3. Blue whiting. Distribution of 2020 ICES estimated catches (in percentage) by quarter.

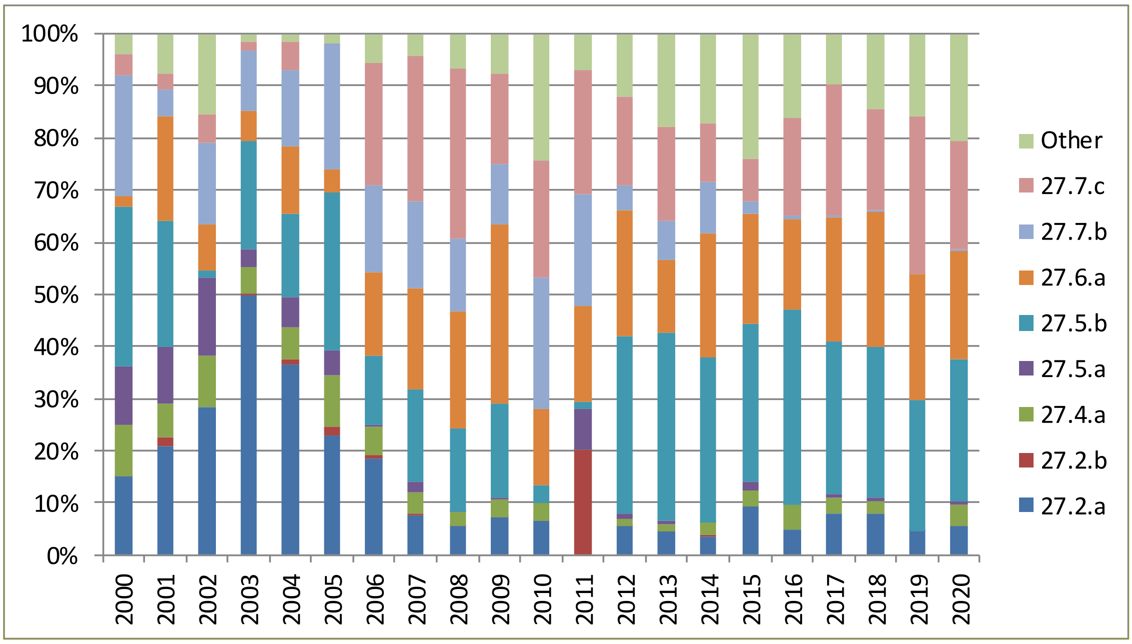


Figure 2.3.1.4. Blue whiting. Distribution of 2020 ICES estimated catches (in percentage) by ICES division area.

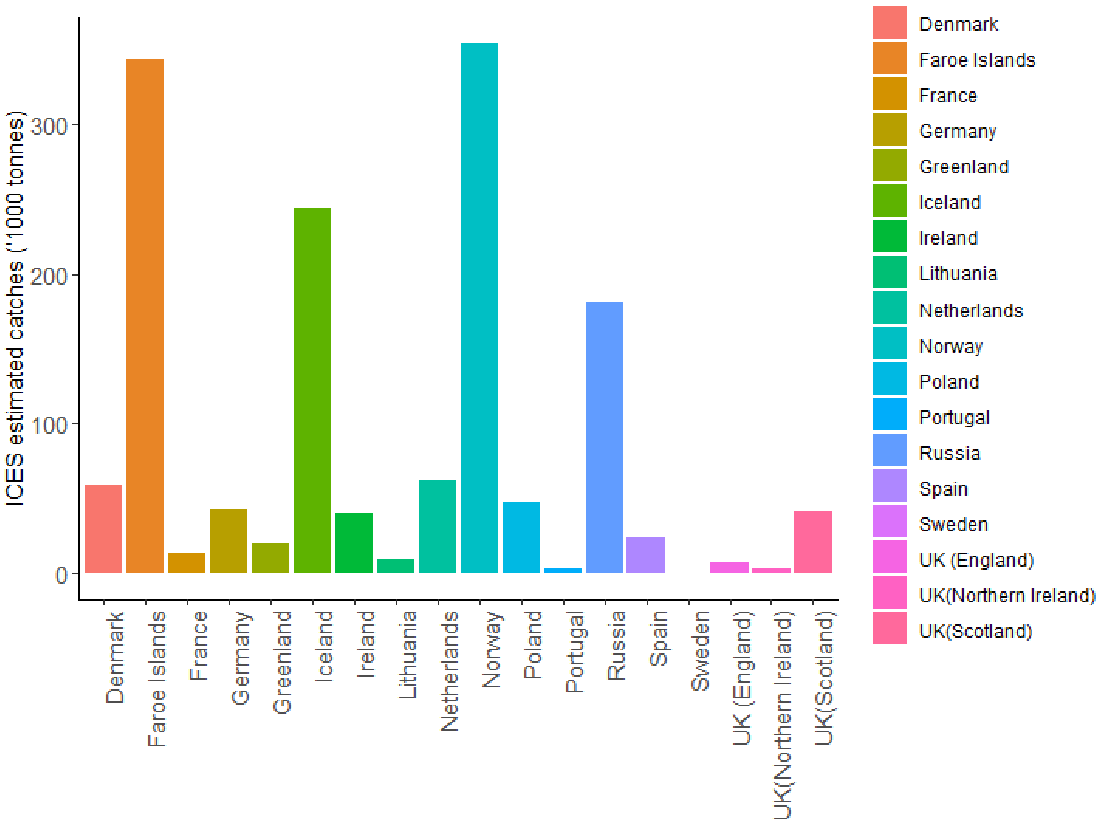


Figure 2.3.1.5. Blue whiting. ICES estimated catches ('1000 tonnes) in 2020 by country.

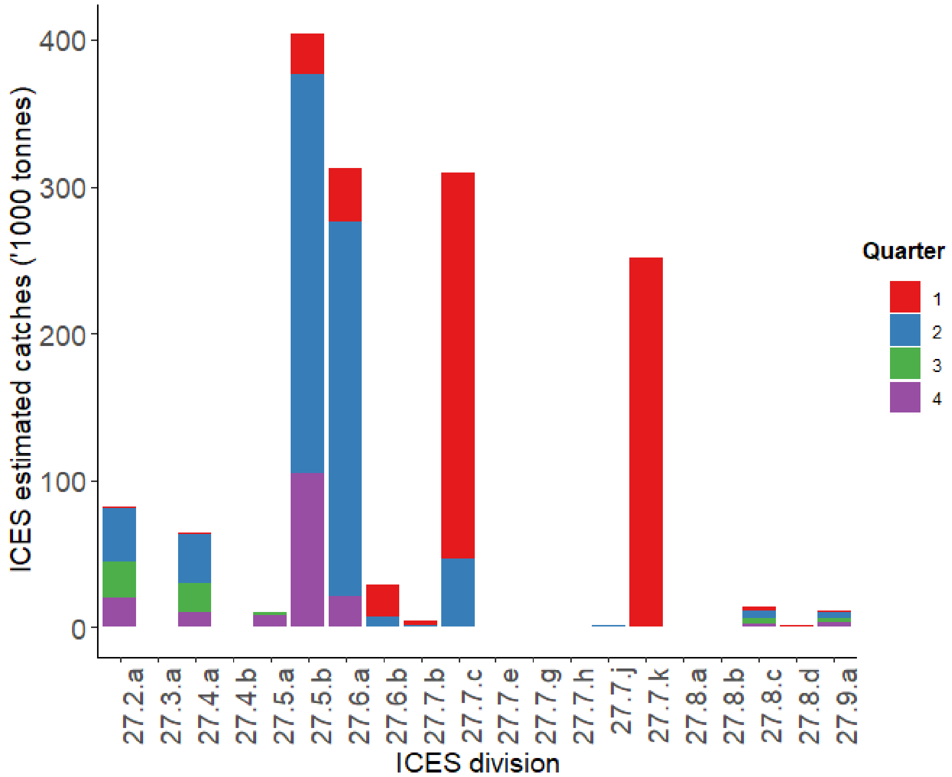


Figure 2.3.1.6. Blue whiting. Distribution of 2020 ICES estimated catches ('1000 tonnes) by ICES division and by quarter.

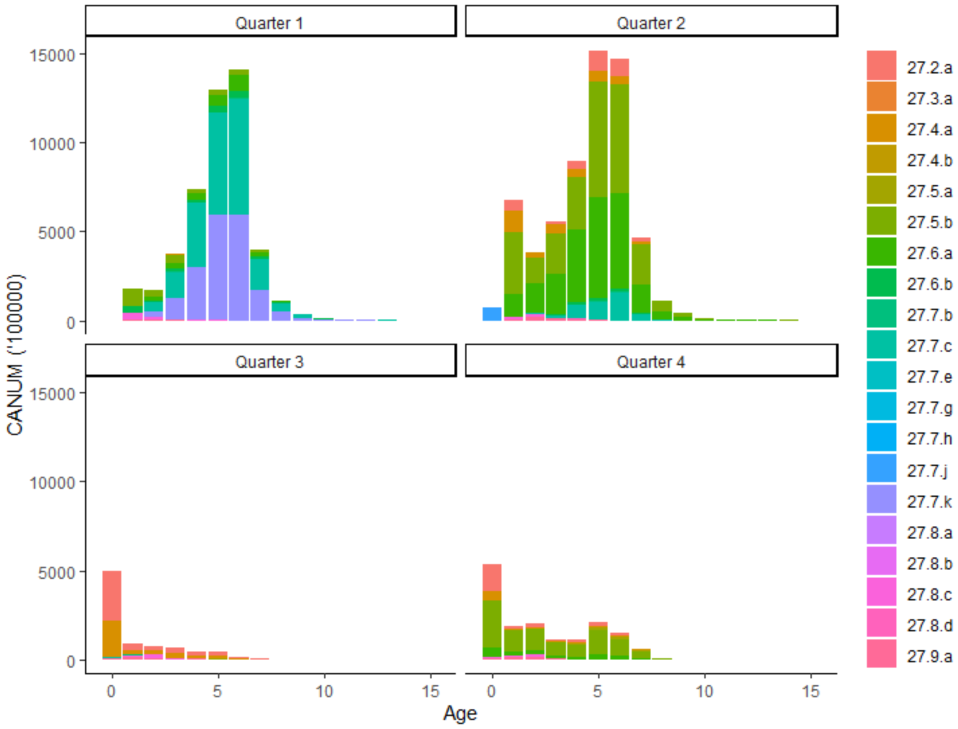


Figure 2.3.1.7. Blue whiting. Catch-at-age numbers (CANUM) distribution by quarter and ICES division for 2020.

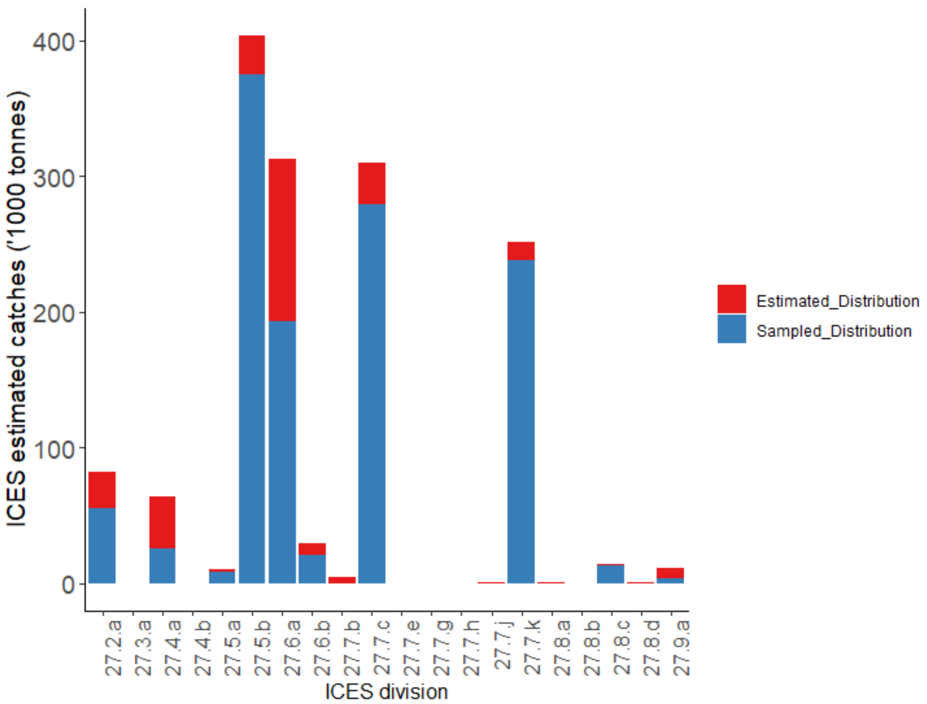


Figure 2.3.1.1.1. Blue whiting. 2020 ICES catches ('1000 tonnes) based on sampled or estimated distribution by ICES division.

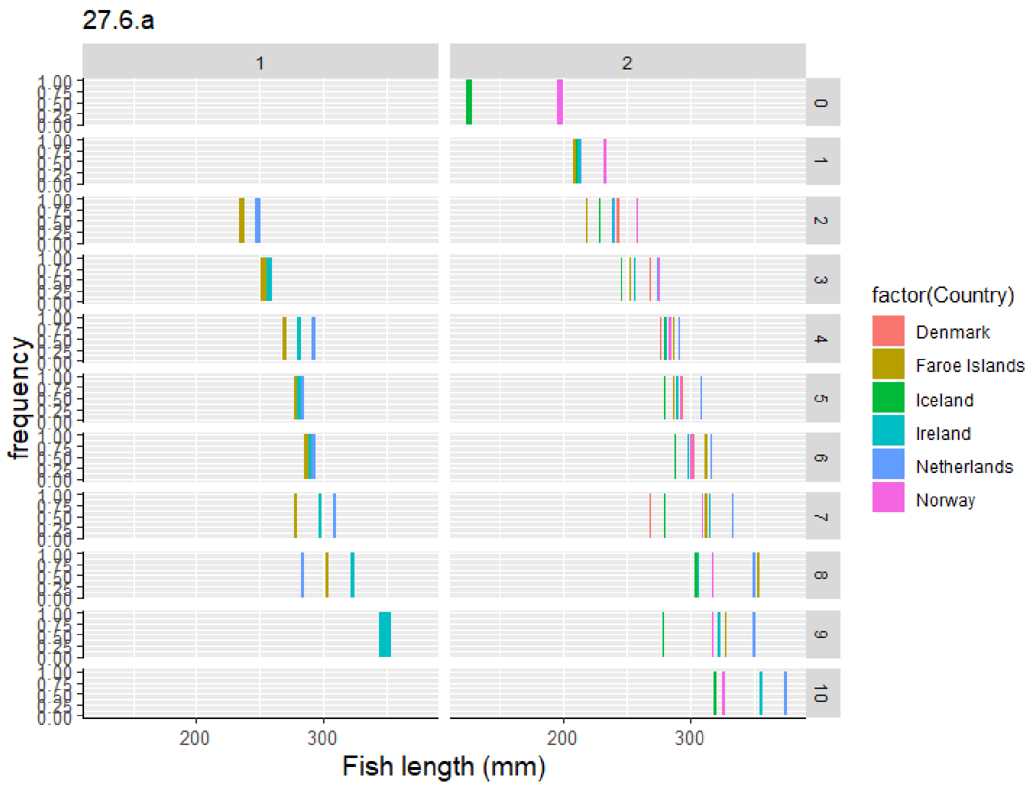


Figure 2.3.1.2.1. Blue whiting. Mean length (mm) by age (0-10 year), by quarter (1,2), by country for ICES division area 27.6.a. These data only comprises the 2020 ICES catch-at-age sampled estimates for ICES division 27.6.a.

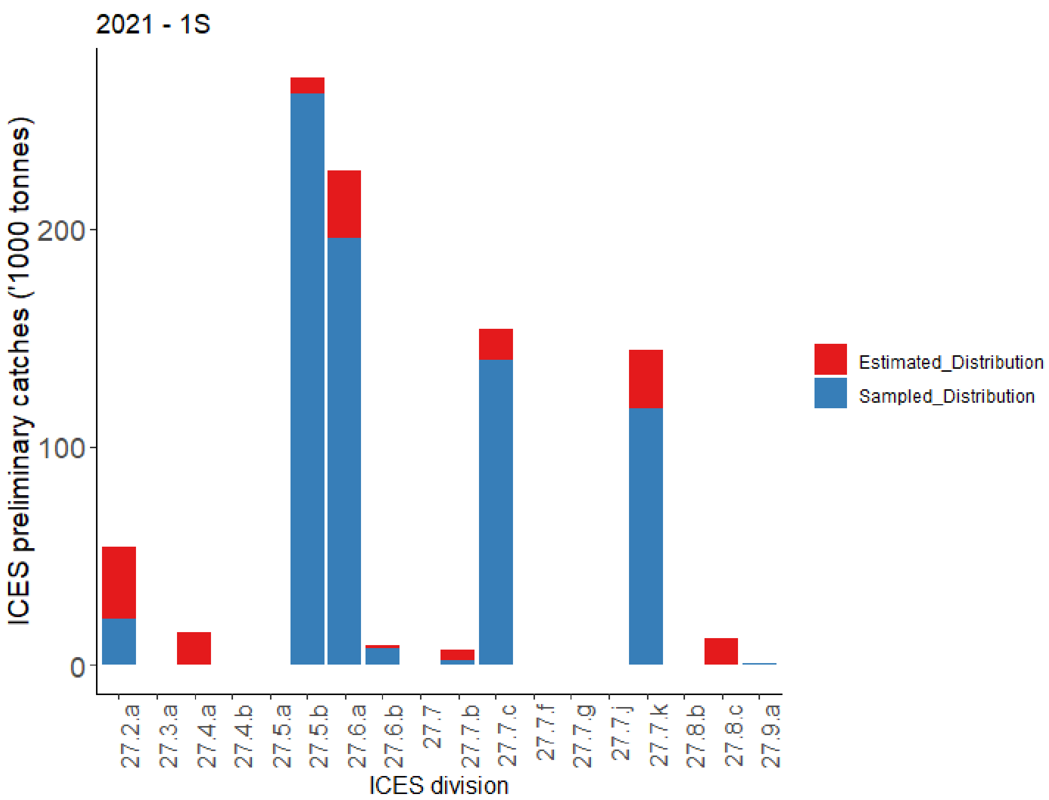


Figure 2.3.2.1. Blue whiting. 2021 ICES preliminary catches ('1000 tonnes) (Quarter 1 + Quarter 2) based on sampled or estimated distribution by ICES division.

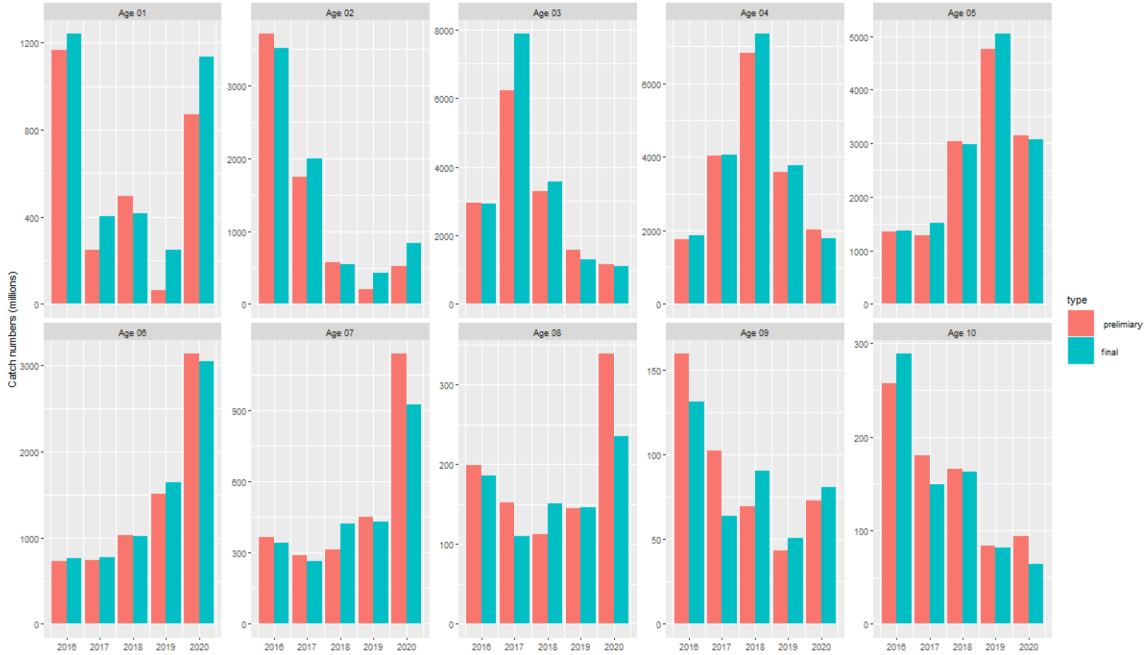


Figure 2.3.2.2 Preliminary and final estimates of catch at age number by age and year.

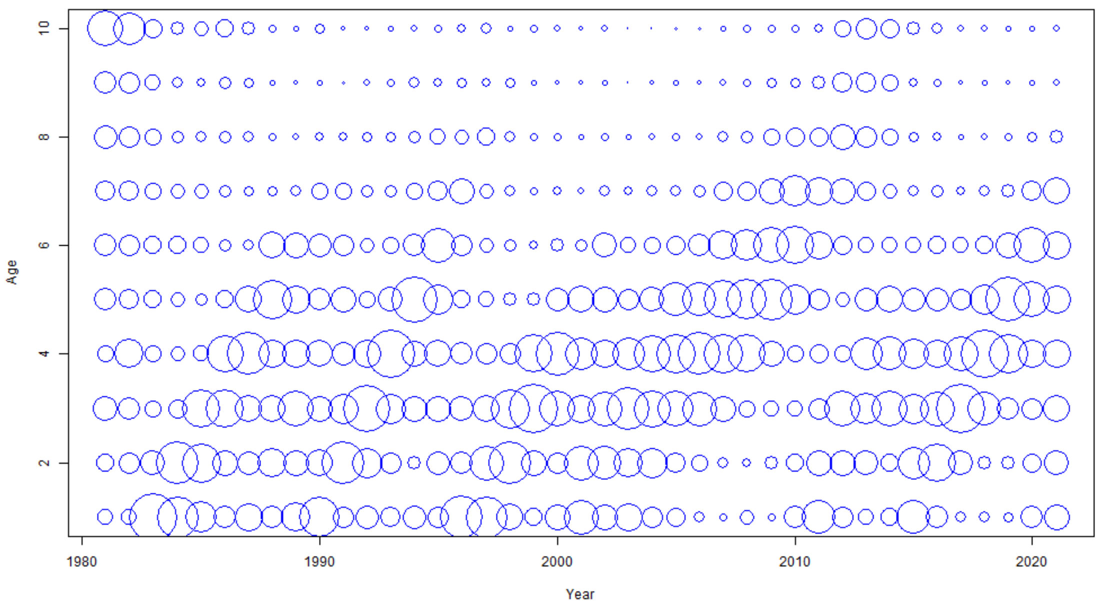


Figure 2.3.3.1. Blue whiting. Catch proportion at age, 1981-2021. Preliminary values for 2021 have been used.

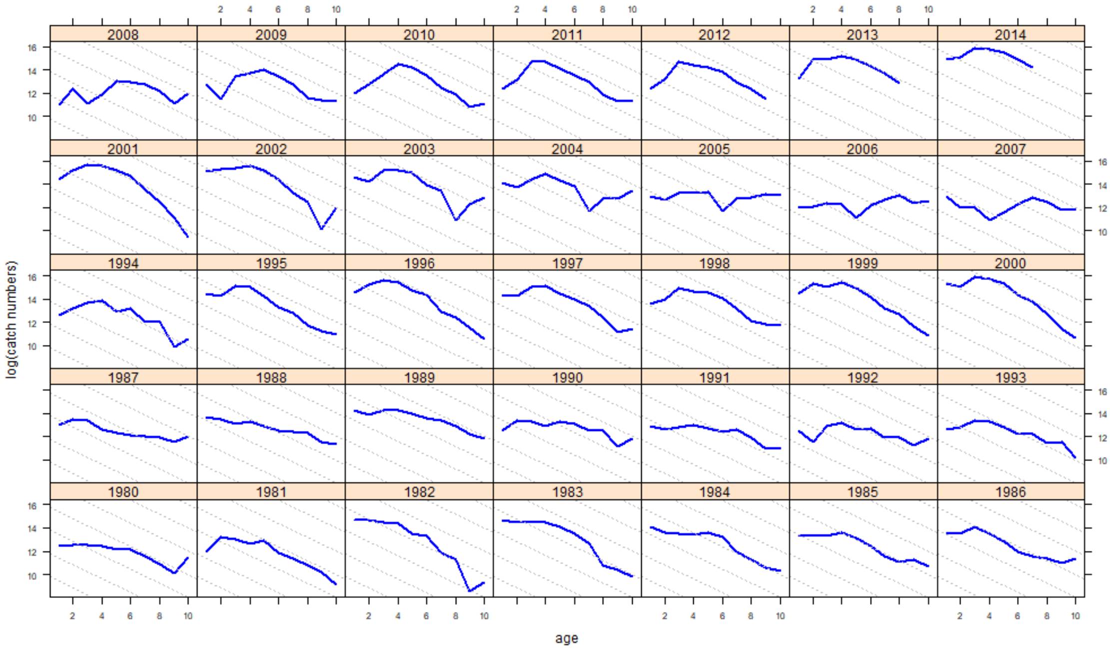


Figure 2.3.3.2. Blue whiting. Age disaggregated catch (numbers) plotted on log scale. The labels for each panel indicate year classes. The grey dotted lines correspond to *Z*=0.6. Preliminary catch-at-age data for 2021 have been used.

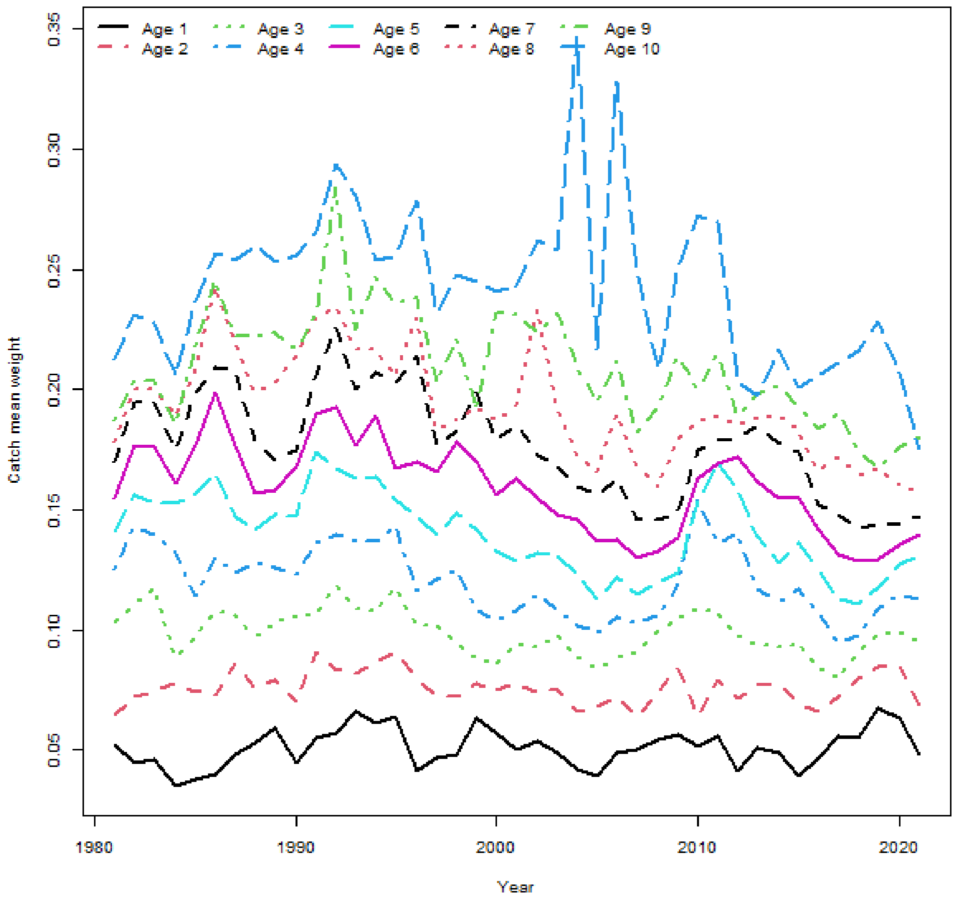


Figure 2.3.4.1. Blue whiting. Mean catch (and stock) weight (kg) at age by year. Preliminary values for 2021 have been used

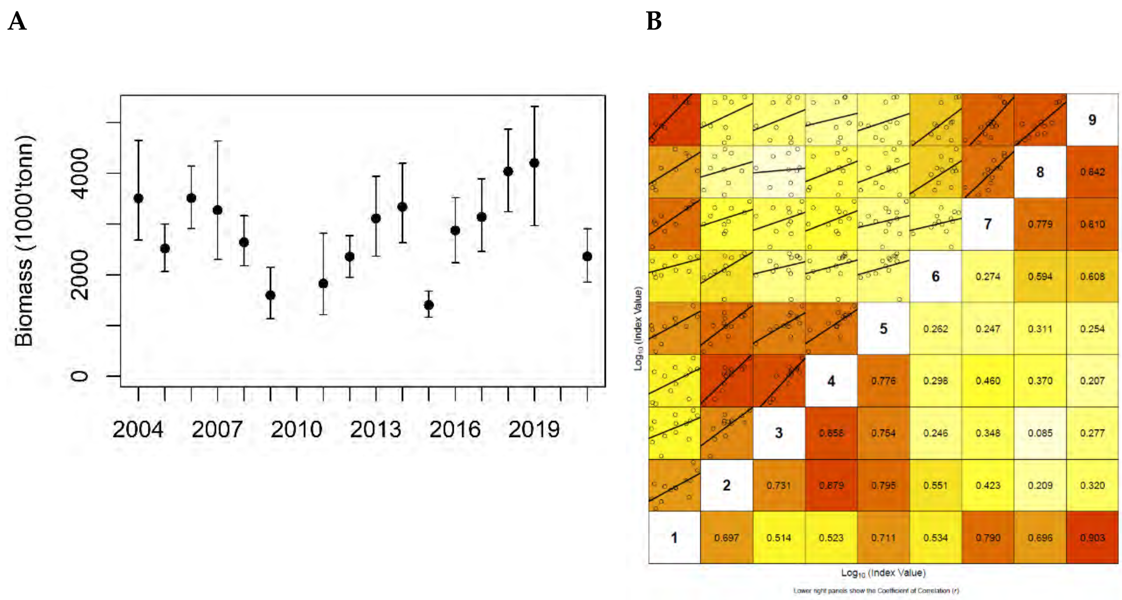
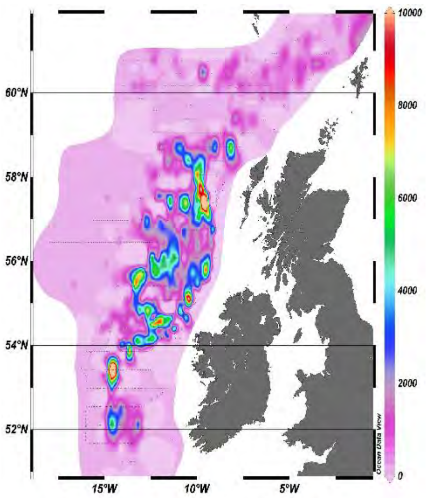
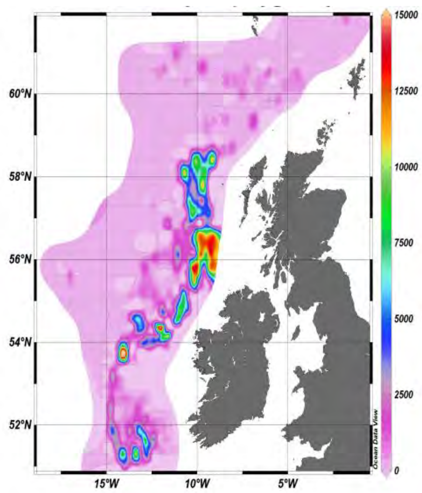


Figure 2.3.7.1.1. Blue whiting. (A) Estimate of total biomass from the International blue whiting spawning stock survey. The black dots and error bands are StoX estimates with 90 % confidence intervals. (B) Internal consistency within the International blue whiting spawning stock survey. The upper left 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.



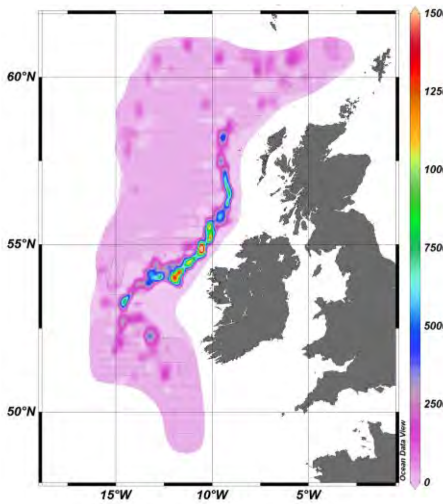
2018



2019

NO SURVEY

2020



2021

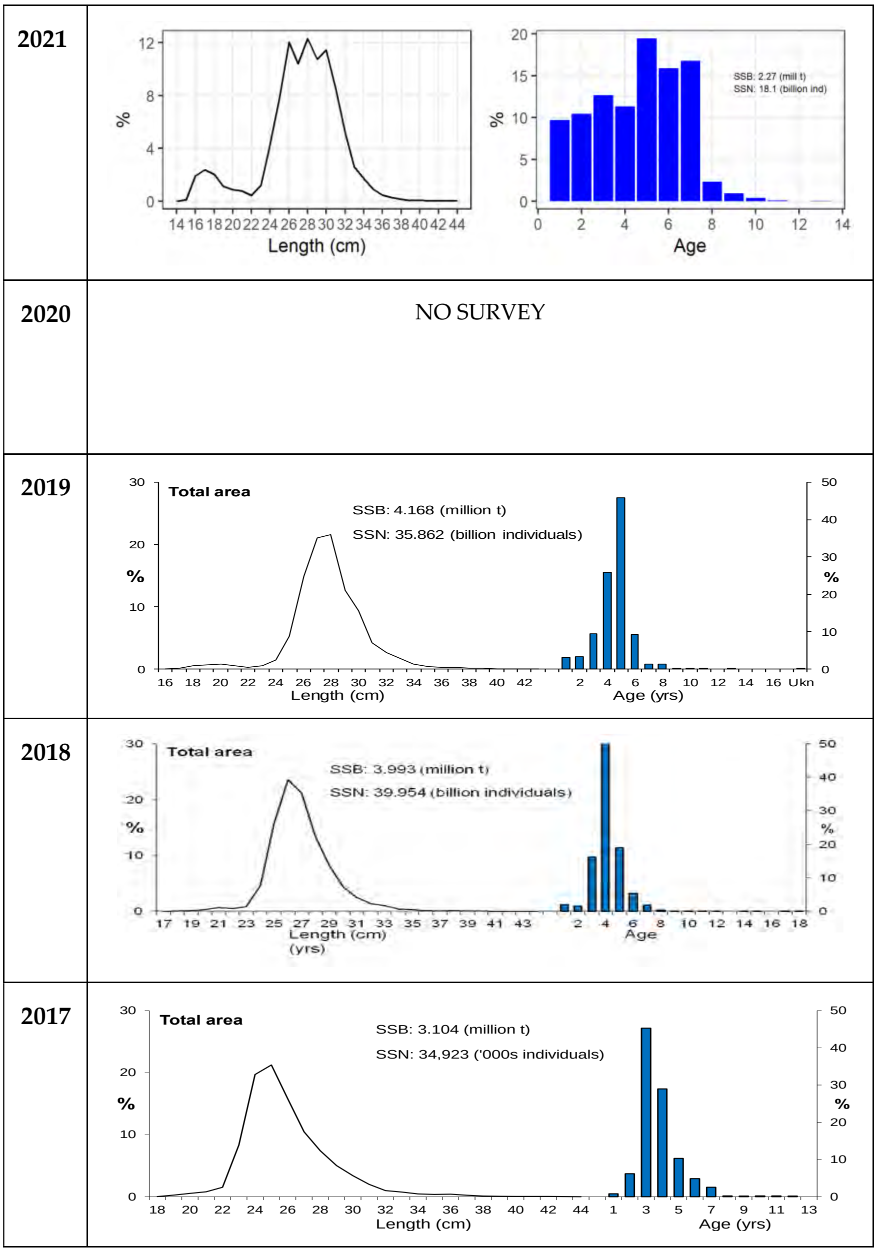


Figure 2.3.7.1.3. Blue whiting. Length (line) and age (bars) distribution of the blue whiting stock in the area to the west of the British Isles, spring 2017 (lower panel) to 2021 (upper panel). Spawning-stock biomass and numbers are given.

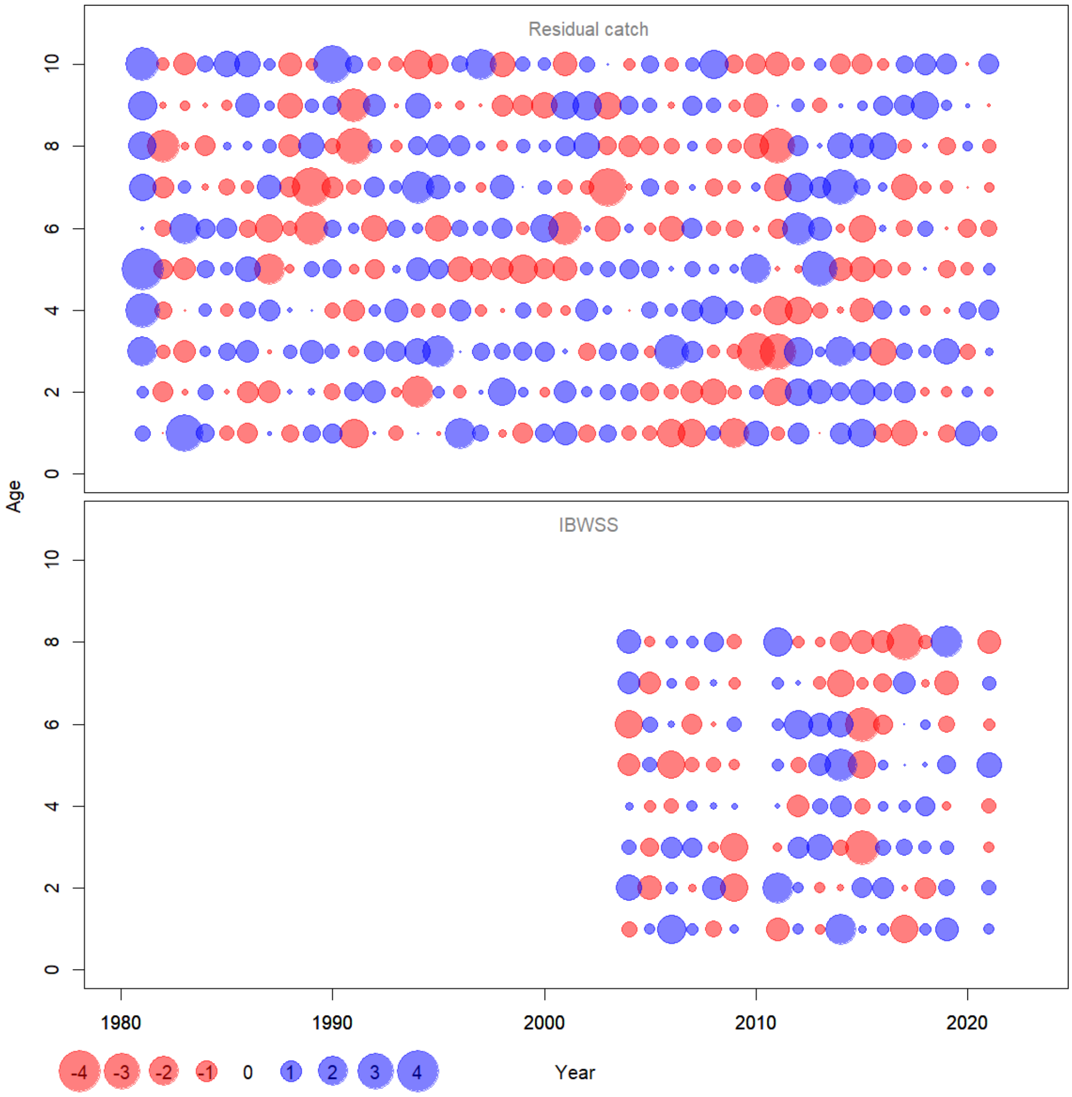


Figure 2.4.1.1. Blue Whiting. OSA (One Step Ahead) residuals (see Berg and Nielsen, 2016) from catch-at-age and the IBWSS survey 2004-2021 (no survey in 2020). Red (lighter) bubbles show that the observed value is less than the expected value. Preliminary catch data for 2021 have been used.

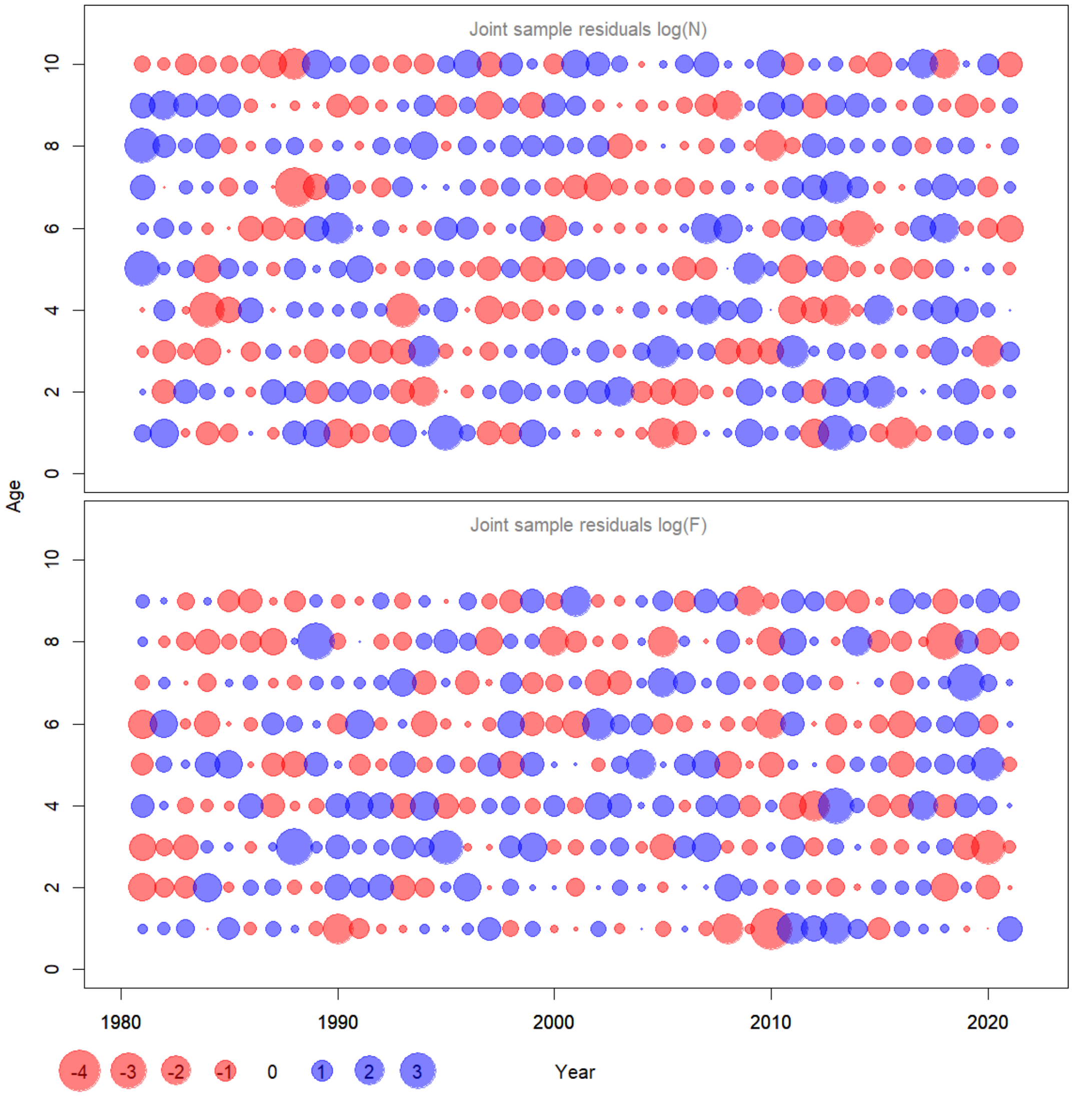


Figure 2.4.1.2 Blue whiting. Joint sample residuals (Process errors) for stock number and F at age. Red (lighter) bubbles show that the observed value is less than the expected value. Preliminary catch data for 2021 have been used.

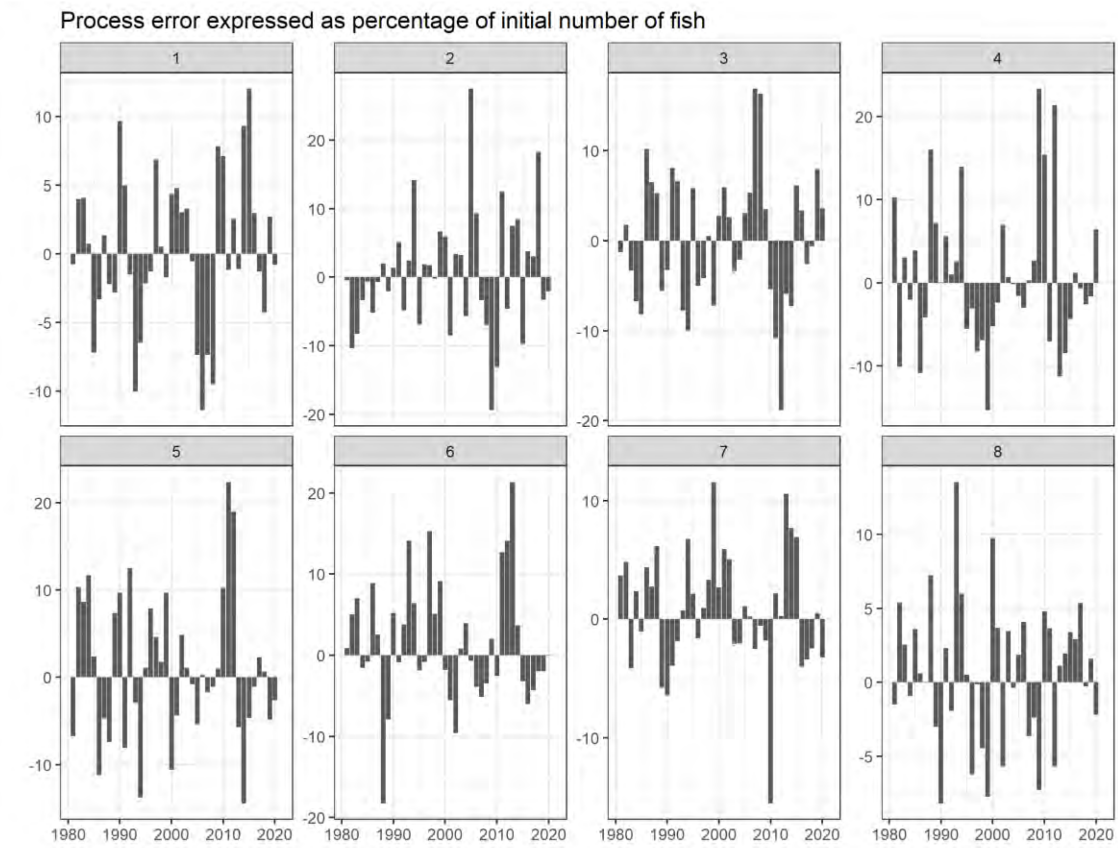


Figure 2.4.1.3. Blue whiting. Process errors expressed as deviation in instantaneous mortality at age by age and year.

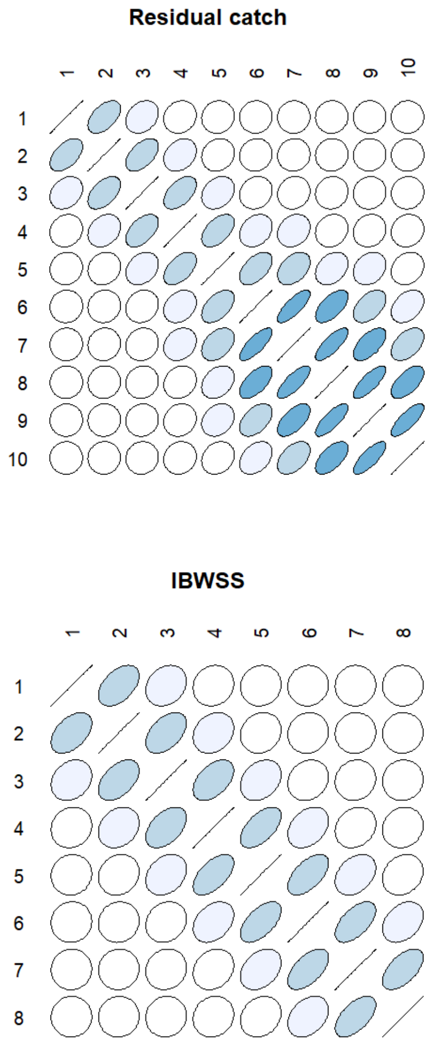


Figure 2.4.1.4. Blue whiting. The correlation matrix between ages for the catches and survey indices. Each ellipse represents the level curve of a bivariate normal distribution with the corresponding correlation. Hence, the sign of a correlation corresponds to the sign of the slope of the major ellipse axis. Increasingly darker shading is used for increasingly larger absolute correlations, while uncorrelated pairs of ages are depicted as circles with no shading. Preliminary catch data for 2021 have been used.

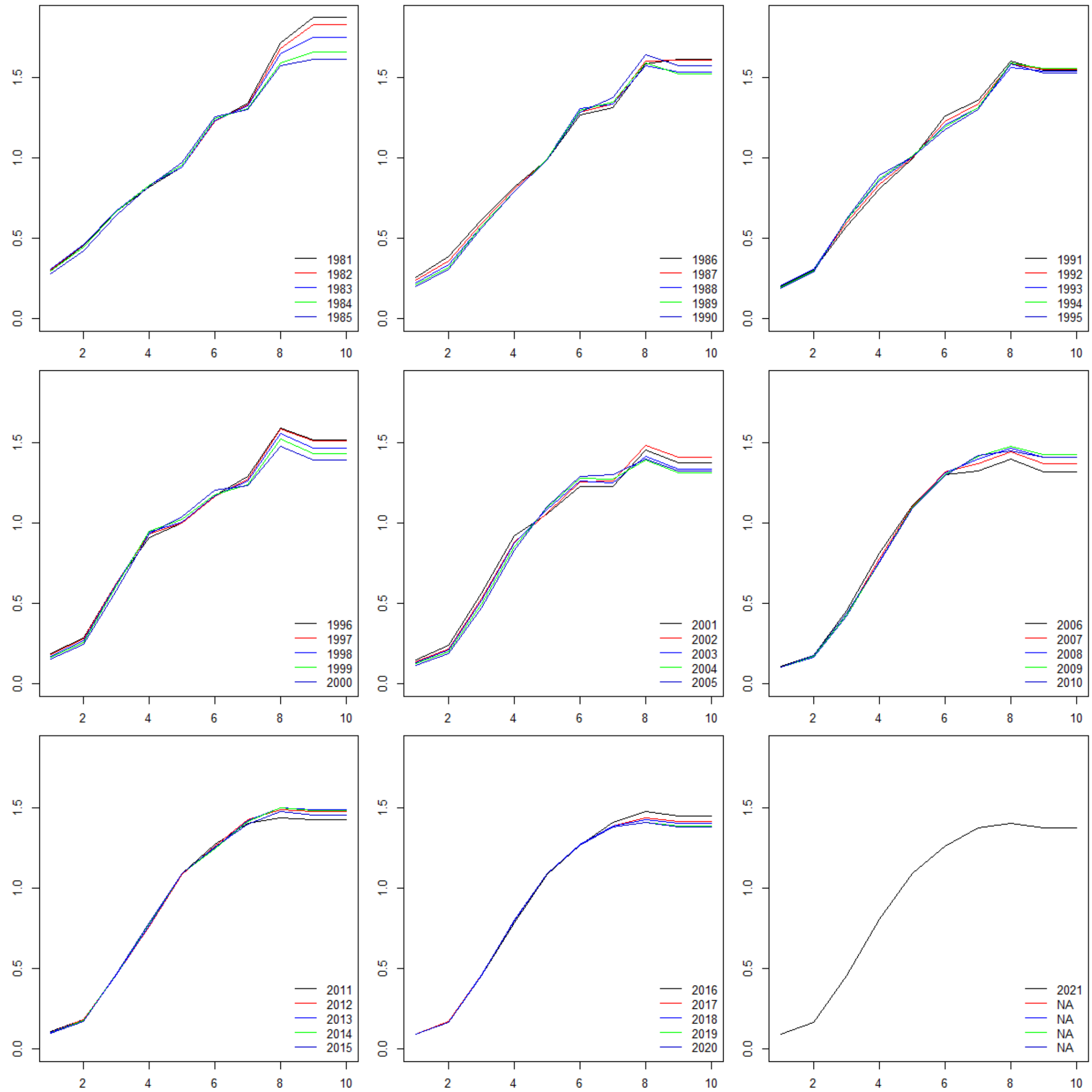


Figure 2.4.1.5. Blue whiting. Exploitation pattern by 5-years' time blocks. Preliminary catch data for 2021 have been used.

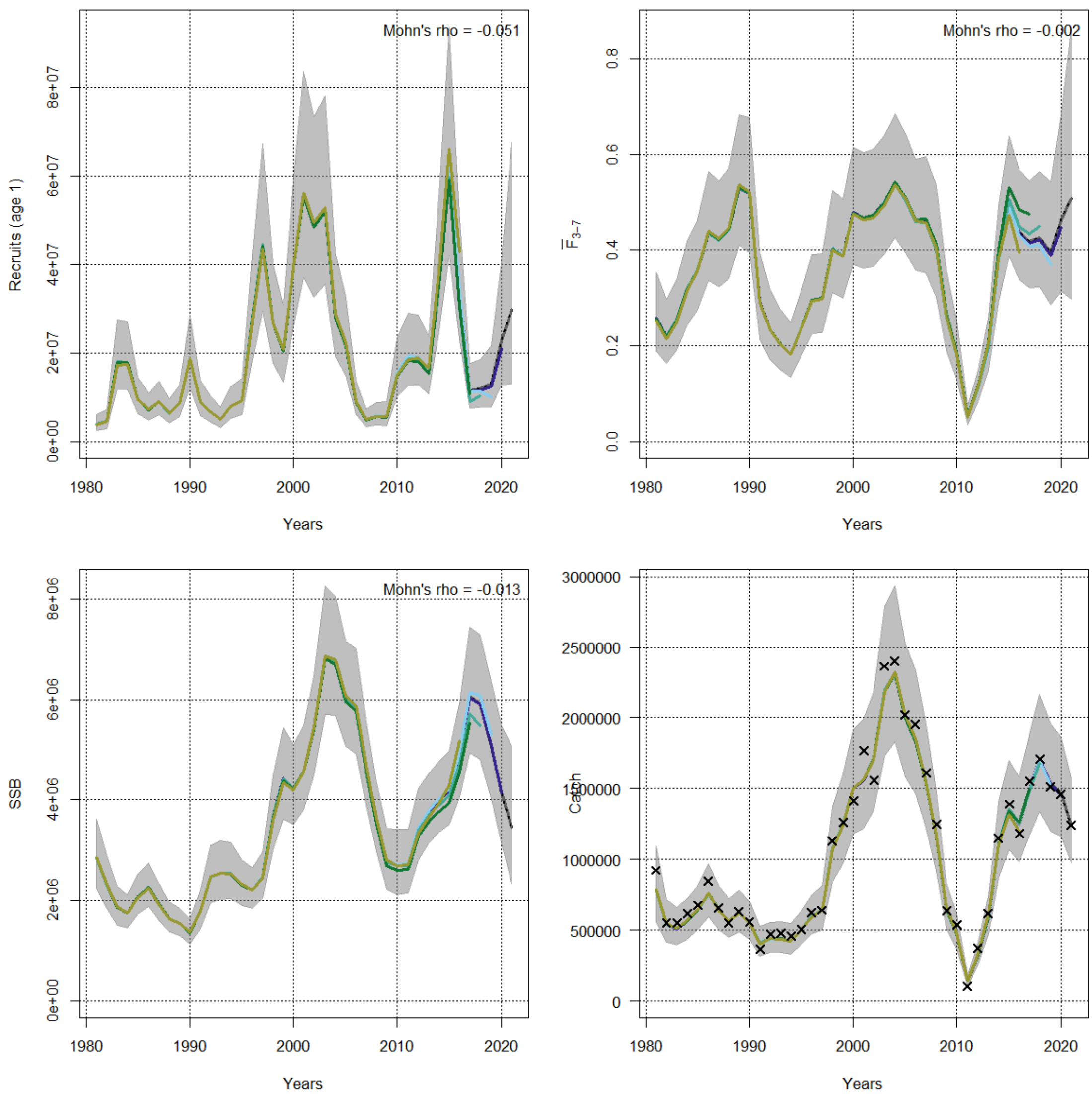


Figure 2.4.1.6. Blue whiting. Retrospective analysis of recruitment (age 1), SSB (tonnes), F and total catch using the SAM model. The 95% confidence interval is shown for the most recent assessment.

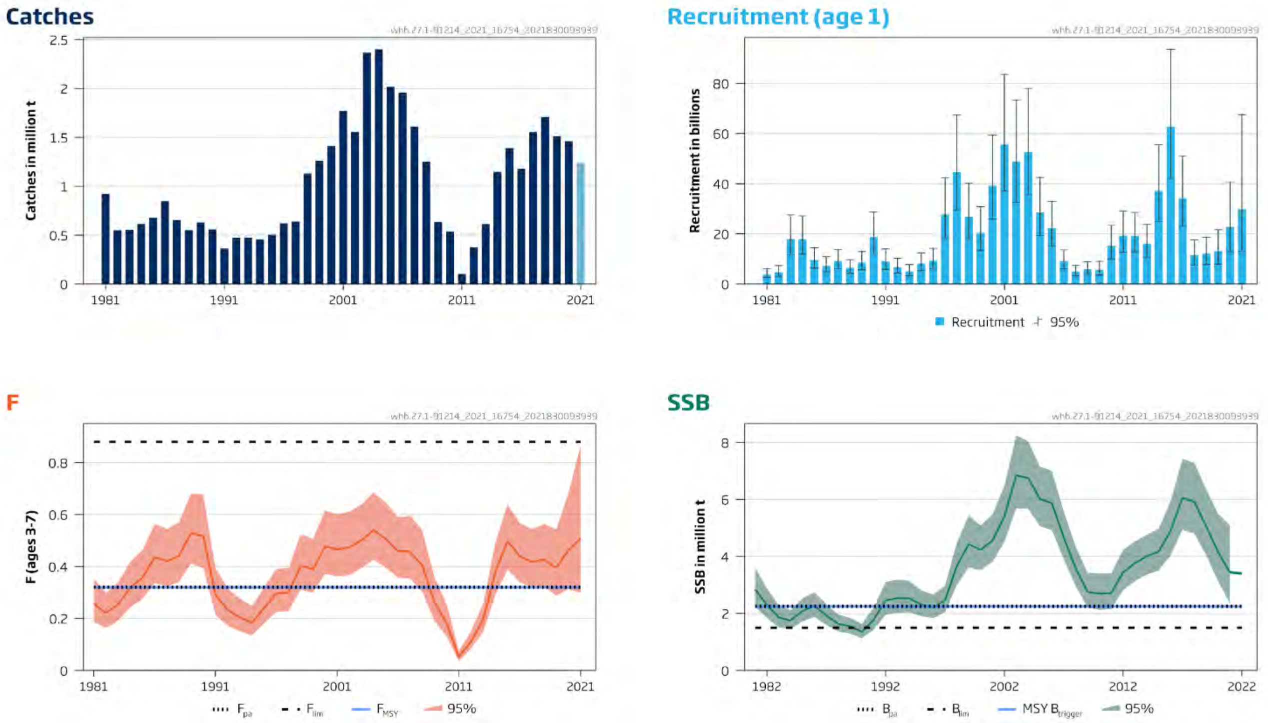
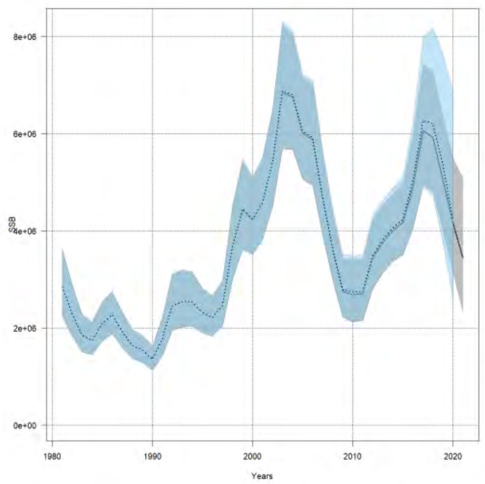
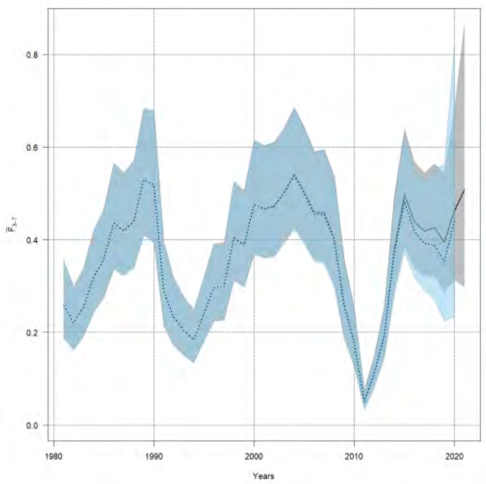


Figure 2.4.1.7. Blue whiting. SAM final run: Stock summary, total catches, recruitment (age 1), F and SSB. The graphs show the median value and the 95% confidence interval. Catches for 2021 are preliminary.

SSB



Fishing mortality



Recruits

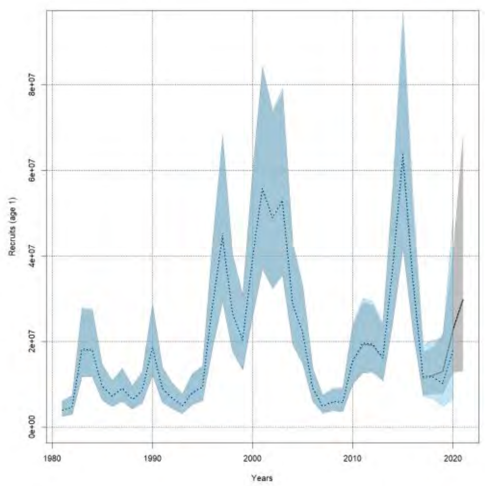


Figure 2.4.1.8. Blue whiting. SAM final run: Comparison of the 2020 and 2021 stock assessments, shown with 95% confidence intervals. Catches for 2021 are preliminary.

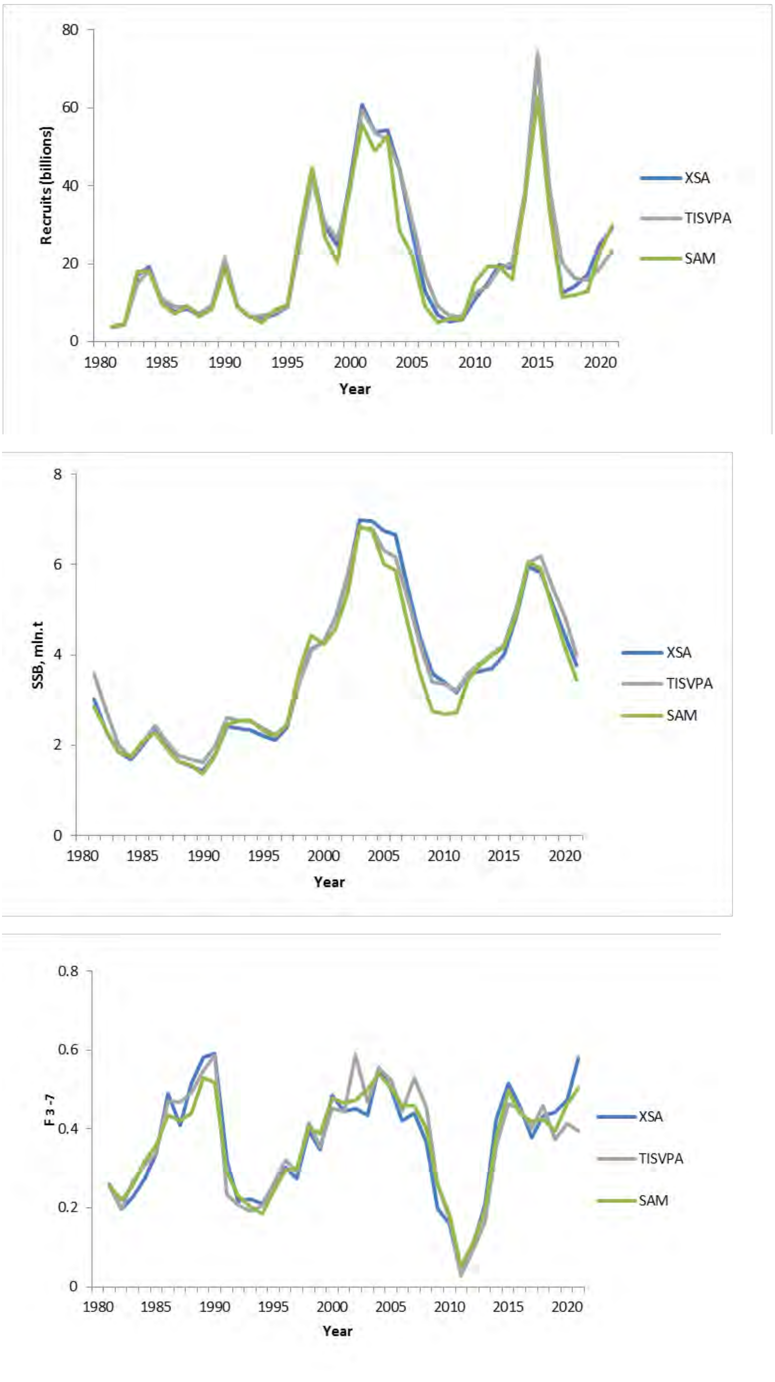


Figure 2.4.3.1. Blue whiting. Comparison of SSB, F and recruitment estimated by the assessment programs XSA, TISVPA and SAM. Catch values for 2021 are preliminary.

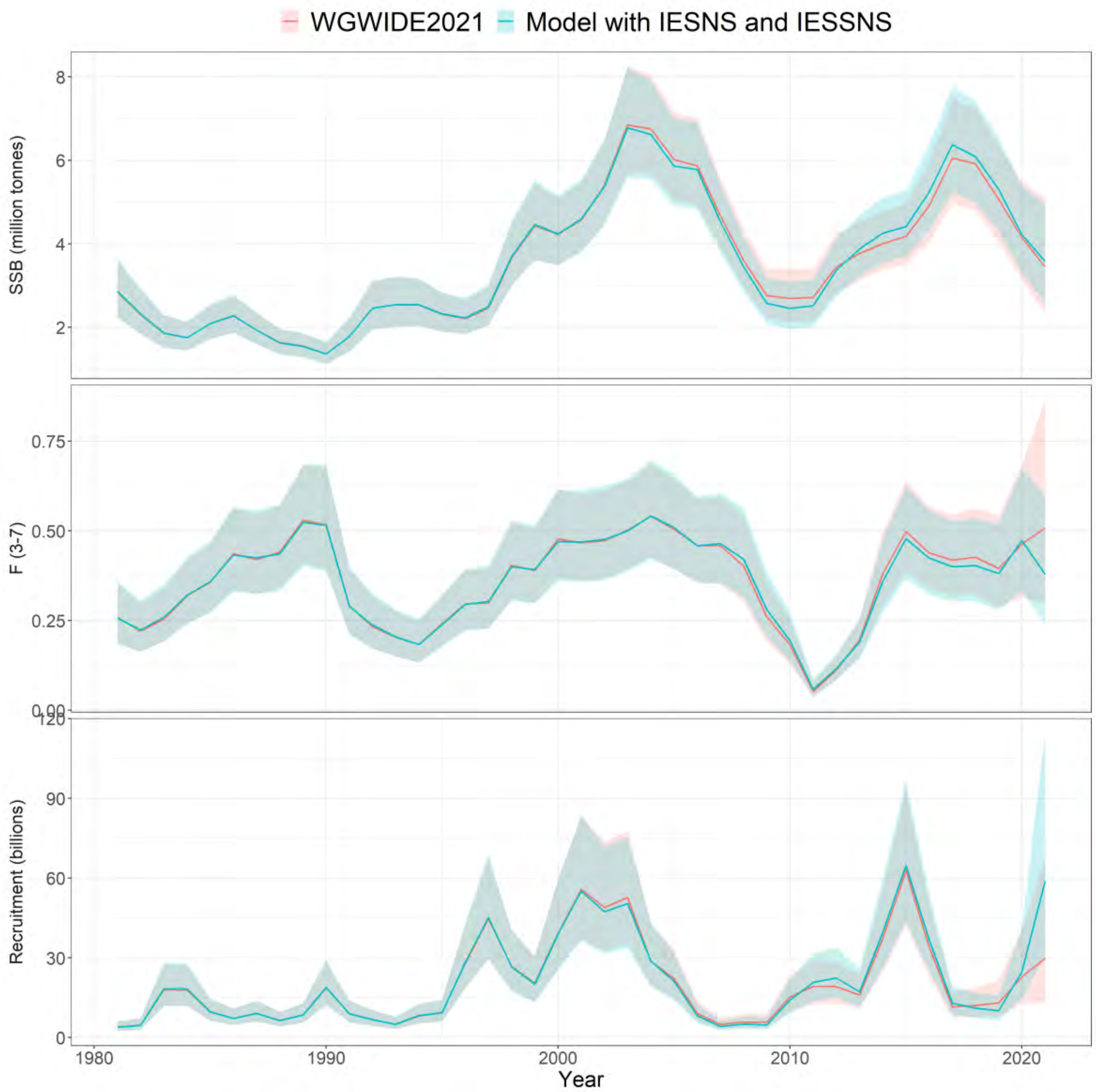


Figure 2.4.3.2. Blue whiting. Comparison of SSB, F and recruitment estimated by the official WGWIDE 2021 SAM model and an alternative version including the two surveys IESNS and IESSNS. Catch values for 2021 are preliminary.

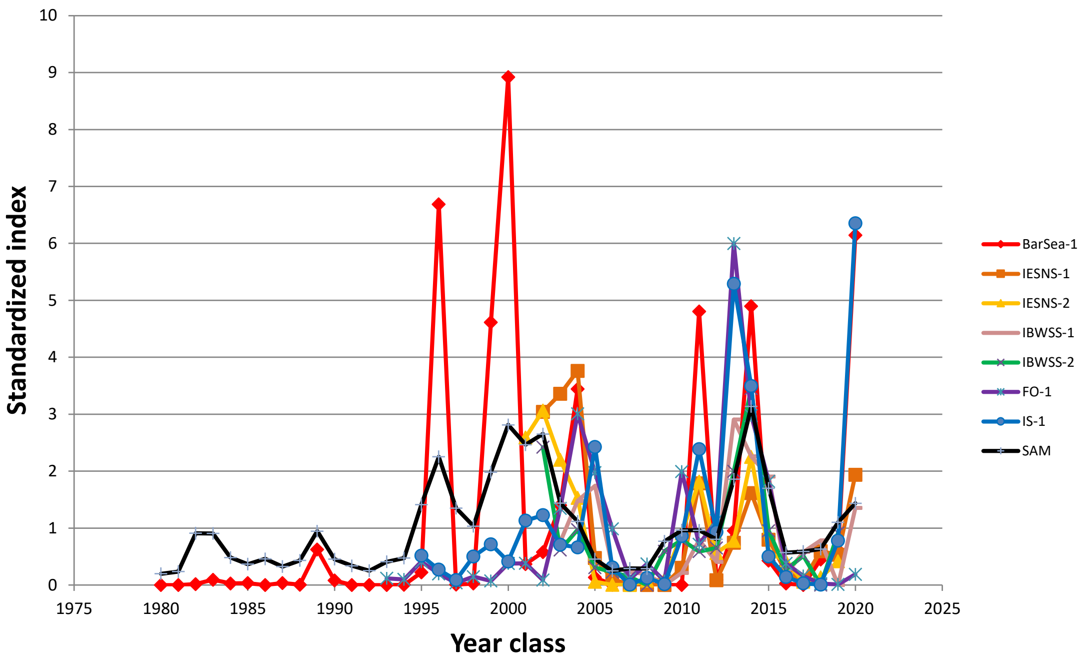


Figure 2.8.1.1. Blue whiting young fish indices from five different surveys and recruitment index from the assessment, standardized by dividing each series by their mean. BarSea - Norwegian bottom-trawl survey in the Barents Sea, IESNS: International Ecosystem Survey in the Nordic Seas in May (1 and 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.

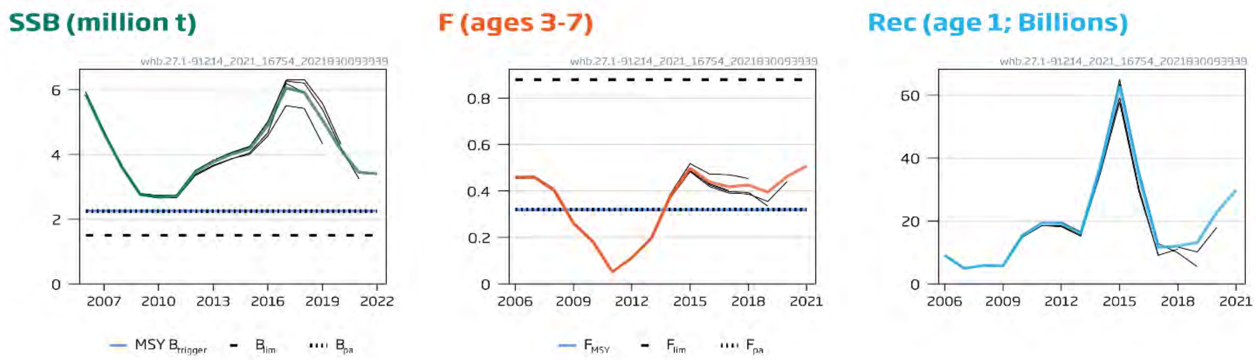


Figure 2.9.1. Blue whiting. Comparison of the 2017 - 2021 assessments.

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 south and southwest of Ireland and Northern Biscay. The boarfish fishery is conducted in shelf waters with the first landings reported in 2001. Landings were at very low levels from 2001-2005. The main expansion period of the fishery took place between 2006 and2010 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 catch advice for 2012 for the first time.

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 2021 only data from these areas were utilized.

3.1 The fishery

3.1.1 Advice and management applicable from 2011 to 2021

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 allowing the fishery to use 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 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 was 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 confirmed that the biomass was 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 table below. The effect of this is that a quantity not exceeding the value 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	759	5956
2020	688	3531
2021	701	3513

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. The management plan was not fully evaluated by ICES; however, in 2013 ICES advised that Tier 1 of the plan could be considered precautionary if a Category 1 assessment was available.

A revised draft management strategy was proposed by the Pelagic AC in July 2015. This management strategy aimed 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 it followed the rationale for TAC setting enshrined in the ICES advice, but with additional caution.

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

3.1.2 The fishery in recent years

Before the development of the fishery, boarfish was a discarded bycatch in the pelagic mackerel fishery 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 was also discarded in whitefish fisheries, particularly by Spanish demersal trawlers (Table 3.1.2.2).

The first landings of boarfish were reported in 2001. Landings fluctuated between 100 and 700 t per year up to 2005 (Table 3.1.2.1). In 2006, the landings began to increase considerably as a target fishery developed. Cumulative landings since 2001 exceed 600 000 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.

In 2014 and subsequent years, the full TAC has not been caught. This is thought to be partly due to a reduction in the availability of fishable aggregations, and partly due to economic and administrative reasons. 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 was 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. Tables 3.1.2.5 and 3.1.2.7 shows that two thirds of the Irish landings were taken in ICES divisions 7.h and 8.a respectively. Thirty-two Irish registered fishing vessels reported catches with the majority made in Q1 (7 143 t) and Q4 (8 711 t).

In 2017 a total of 17 388 t of boarfish were caught. Ireland continued to be the main participant landing 15 484 t but was 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 (Tables 3.1.2.5 and 3.1.2.7). 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. This represented 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 represented 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. Tables 3.1.2.5 and 3.1.2.7 shows that about 82% of the Irish landings were taken in ICES divisions 7.h and 8.a respectively.

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. Tables 3.1.2.5 and 3.1.2.7 shows that about 87% of Irish landings were taken in ICES divisions 7.h and 8.a respectively.

3.1.3 The fishery in 2020

In 2020, the total catch was 15 649 t which represented 82% of the quota (19 152 t). Ireland was the main partaker in the fishery (14 666 t) and landed more than its national quota (13 234 t) for the first time since TAC and quota regulations were established. The Irish landings accounted for 94% of the total catch. The other countries reporting catches are Denmark (196 t), the Netherlands (416 t), England (62 t), Poland (109 t) and Spain (1 t). The total discards for this year were 198 t. The majority of landings were taken in ICES divisions 7.b and 7.h (Tables 3.1.2.4 and 3.1.2.5).

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. 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

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.

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 but hasn't since 2018. 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 3.1.2.2 show the total annual discards and estimates from the demersal and non-target fisheries respectively.

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 numbers-at-age were prepared from Irish, Danish, Dutch, Spanish, Polish 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 2020, allocations to unsampled metiers were made according to Table 3.2.1.3. In total, 10 samples with the appropriate 0.5 cm length bin measurements were collected. (Table 3.2.1.4). These samples covered the most heavily fished areas (Table 3.2.1.5) and equated to one sample per 290 t landed. The samples comprised 534 fish measured for length frequency.

The results of the application of the ALK to commercial length-frequency data (available for the years 2007-2020) produced proxy catch numbers-at-age values which are available in Table 3.2.1.6. In the last couple of years, there has been the appearance of strong year classes in the catch numbers. A high number of 1-4 year olds were present in the 2020 data. 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 2020. 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. The 2021 survey was carried out by the RV *Celtic Explorer* and run in conjunction with 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 9 June in the south (47°30N) and working northwards to 59°30N ending on 20 July.

Calculation of acoustic abundance
The StoX software package (Johnsen et. al., 2019) was used to calculate acoustic abundance from survey data (StoX V2.7 and R-StoX V1.11) and aggregated survey data are available for download at the ICES acoustic database (https://www.ices.dk/data/data-portals/Pages/acoustic.aspx). Survey design and execution of the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (ICES, 2015).

Survey results 2021
The 2021 WESPAS survey provided continuous synoptic coverage from south to north over 42 days covering an area of over 50,552 nmi^2 (boarfish strata) and a transect mileage of over 4,986 nautical miles. In total, 65 trawl stations were undertaken during the survey. 35 hauls contained boarfish and provided 5,724 individual length measurements, 2,651 length and weight measurements and 1,474 otoliths.

Acoustic echotraces attributed to boarfish in 2021 are shown in Figure 3.3.1.1. Individual points represent the mean NASC over a 1nm transect distance. The 2021 estimate of total survey biomass of 444kt represents a slight increase over that observed in 2020 (399kt). The majority of the estimate (53%) is found in the Celtic Sea stratum with the Irish west coast contributing 33%, similar to the situation in 2020 (Figure 3.3.1.2.).

The Celtic Sea/Northern Biscay area was found to contained a high abundance of immature boarfish extending further northwards than observed in 2020 or previously. Mature fish were also present but in lower abundances than in previously. Immature boarfish represented 61% of the total abundance observed across the combined survey area, an increase from 59% observed in 2020.

The full time series of survey estimates of boarfish biomass is presented in Table 3.3.1.1.

The ALK developed in 2012 (during investigations to development the knowledgebase around boarfish) was used to estimate the survey abundance at age (otoliths are collected during the survey but are not currently aged), (Figure 3.3.1.3.). A plus group of 15+ is assumed and accounts for 23% of TSB and 6% of TSN. The contribution of 1-3 year olds represents over 33% of the TSB and 73% of TSN indicating strong recent recruitment. The previously observed strong year classes that are now 8-10-year-old fish are also present but in lower numbers than expected when compared to neighbouring year classes.

The 2021 stock estimate is dominated by the recently recruited year classes (2016-2020). The maturity ogive from the 2012 studies (see section 3.4) indicates that 79% of observed biomass in 2021 was mature (40% total abundance) compared to 90% biomass and 59% abundance in 2020. This year-on-year increase in the contribution of immature fish to the total stock estimate started in 2018 and has continued into 2021, indicating a continued positive trend of growth for the stock. Preliminary results from the PELGAS survey undertaken in the area south of the WESPAS grid during May indicates increased biomass of boarfish in northern Biscay, also with a significant contribution from immature ages in agreement with observations during WESPAS in the Celtic Sea (M. Doray, pers comm.). The current southern boundary of the WESPAS survey therefore does not ensure full containment of the stock such that the WESPAS estimate should be considered to be an underestimate.

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 shows the haul positions for each of the 6 surveys analysed.

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 main fishing grounds (Figure 3.1.2.1). Figures 3.3.2.3a and b shows the signal in abundance and biomass, increasing gradually in the 1990s, slowly declining in the early 2000s, before increasing again with a strong increase in the most recent period. Much of this increase which is stronger in terms of abundance is due to increased recruitment since 2017. The low estimates for the 2017 survey are partly explained by issues with the execution of the EVHOE survey. Due to mechanical breakdown, the majority of the survey stations could not be completed. The missed stations would have covered the area in North Biscay typically associated with the highest catch rates of boarfish.

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 the 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). The analyses were performed in WinBUGS from R with the R2WinBUGS package.

When the indices were recalculated in 2021, (following a refresh of the input data from DATRAS and national data submitters), the following issues were encountered

- An error with the coding of the EVHOE 2018 data in DATRAS was corrected, revising upwards the estimates from 2018 for this survey
- The truncated EVHOE 2017 dataset was removed from the analysis. In previous years, this data was retained but, because the available data only corresponds to a small fraction of the total survey area (where boarfish are not usually encountered in significant quantities) a very low survey estimate resulted. It was considered appropriate to remove this data from the analysis. In future, explicit modelling of spatial and temporal correlations may permit this data to be considered again.
- An error in the analysis was discovered whereby hauls with more than one catch category were underrepresented as only a single catch category was included during the model fitting. Multiple catch categories are usually the result of splitting the catch into adult and juvenile portions and using an appropriate subsampling strategy for each. This issue is particularly relevant for the IGFS which, over the most recent 4 years has 2 catch categories for boarfish recorded for approximately 20% of hauls. The outcome is an increase in CPUE for these hauls and a subsequent increase in the survey index for the IGFS in recent years (2016 onwards).

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 the small sample size and the 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 assumed that M was the mortality that would reduce a population to 1% of its initial size over the lifespan of the stock. Based on a maximum age of 31, M was calculated as follows

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

Following this procedure, M = 0.16 year^{-1}was considered a good estimate of natural mortality over the life span of the boarfish stock, as it was 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 was 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 was 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 will be 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 was considered appropriate.

3.5 Recruitment

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 (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).

The EVHOE, IGFS 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 in the EVHOE survey with 2010 and 2015 also indicating above average recruitment. Particularly strong recruitment has been noted in each of 2018-2020, especially for the EVHOE survey but also the IGFS in 2020.

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

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. 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 although the EVHOE data is excluded from the analysis for this year. 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. 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 updates described above with respect to data and analysis code corrections have resulted in increased correlation between the surveys most affected *i.e.* IGFS and EVHOE. 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 2011 in partnership with industry. The 2011 survey collected data over 24 hours. In 2012, the protocol was changed to exclude the hours between 00:00 and 04:00 as aggregations break up during the hours of darkness. The 2011 data was reworked in 2015 to exclude the data between 00:00 and 04:00. An acoustic target strength 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) with CV estimates ranging 0.11 to 0.31. Total biomass estimates declined sharply between 2012 and 2016 after which an increasing trend is seen. In the most recent surveys, the contribution of immature boarfish to the total estimate has been increasing such that the increase seen between 2020 and 2021 is largely due to juveniles. No substantial evidence exists for removing any of the survey points from the time series although 2016 may be considered an outlier (Table 3.3.1.1).

The PELACUS surveys is conducted annually in waters to the south of the boarfish (WESPAS) survey. In 2021 PELACUS recorded an increase in biomass on its most northerly transects (immediately south of the WESPAS southern limit) compared to 2019 (no survey was conducted in 2020), in broad agreement with increases noted on WESPAS. The PELACUS survey takes place approximately 1 month prior to the boarfish survey.

3.6.3 Biomass dynamic model

In 2012 an exploratory biomass dynamic model was developed for the assessment of boarfish. The model is a Bayesian state space surplus production model (Meyer & Millar 1999), incorporating the catch data, IBTS data, and acoustic biomass data. Following the initial development of the model, 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 has not changed with annual updates to the input data only.

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: 2011–2021

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 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 as it was 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 initial data year was set at 1991 when 3 groundfish survey indices are available (SPNGFS, ECSGFS and WCSGFS). The survey indices are weighted such that highly uncertain values receive lower weight in the fitting.

Catches

2003–2020 time series

Priors

The final run assumes a strong prior for the acoustic survey catchability with $ln(q_{acoustic}) \sim N(1, 1/4)$ (mean 1, standard deviation 0.25), which has 95% of the density between 0.5 and 2. Given the relatively short acoustic series 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 2021 model run converged with good mixing of the chains and Rhat values lower than 1.1 indicating convergence and acceptable autocorrelation (Figures 3.6.3.1-3).

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 towards the end of the available time series. This could be indicative of stock expansion into this area at higher stock sizes and suggests that this index is perhaps 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 result.

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 2021 is estimated to be 497 kt, continuing the increasing trend in stock size since 2016. The extremely low biomass estimate from the 2016 acoustic survey appears to be largely considered as an outlier by the model. This is also the case for the high survey estimate in 2012 although the drop in biomass between these points is seen in a number of the input data series. Retrospective plots of TSB and F, presented in Figure 3.6.3.7, show that the perception of the stock is stable over the most recent 5 years.

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 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, gradually reduced to 0.15 in 2015/16 before increasing in the recent period. The estimate for 2020 is low although the majority of the fishery was conducted on juveniles given the strong recent recruitment with less information available from the older ages.

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	11 313
2020	0.20	0.04	15649

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 increased although it remains below that from the previous high period. 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 likely an outlier and has little influence on stock abundance estimates. The 95% uncertainty bounds are relatively large reflecting 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.

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 production model assessment parameter values. In 2021, F_{MSY} (r/2) is estimated to be 0.17 and MSY $B_{trigger}$ (K/4) 160kt. Throughout the history of the fishery, estimates of total biomass have remained above MSY $B_{trigger}$. Fishing mortality (F) was briefly larger than the estimate of F_{MSY} between 2009 and 2010 and again in 2014, but has decreased since. In 2021, 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, all available data sources (catch, acoustic survey and IBTS surveys) indicate above average recruitment since 2017. The 2021 acoustic survey recorded the largest proportion of juvenile biomass (<10cm, 4yo) in the time series and is comprised of a number of recent year classes.

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 $F_{0.1}$ was estimated to be 0.13 whilst F_{MAX} was estimated in the range 0.23 to 0.33 (Figure 3.9.1.1). $F_{0.1}$ 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

No reference points have been defined for boarfish.

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 (*e.g.* WCSGFS for instance) may require revision.

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 assessment of megrim in Sub-divisions 4 and 6 with the model further developed by including acoustic survey biomass estimates. A drawback of the current assessment model is that it does not provide estimates of recruitment although estimates of recruitment strength are available from the Spanish and French bottom trawl surveys.

3.11 Management considerations

As this stock is placed in category 3, the 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 trends 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 not currently 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

Arrizabalaga, H., Pereira, J.G., Royer, F., Galuardi, B., Goñi, N., Artetxe, I., Arregi, I. & Lutcavage, M. 2008. Bigeye tuna (*thunnus obesus*) vertical movements in the Azores islands determined with pop-up satellite archival tags. *Fisheries Oceanography*, **17**, 74–83.

Barrett, R.T. & Furness, R.W. 1990. The prey and diving depths of seabirds on Hornøy, north Norway after a decrease in the Barents Sea capelin stocks. *Ornis Scandinavica (Scandinavian Journal of Ornithology)*, **21**, 179–186.

Beverton, R. & Holt, S. 1957. On the dynamics of exploited fish populations, fishery investigations series II volume XIX, ministry of agriculture. *Fisheries and Food*, **22**.

Blanchard, F. & Vandermeirsch, F. 2005. Warming and exponential abundance increase of the subtropical fish Capros aper in the Bay of Biscay (1973–2002). *Comptes Rendus Biologies*, **328**, 505–509.

Borges, L., Keeken, V., A, O., Helmond, V., M, A.T., Couperus, B. & Dickey-Collas, M. 2008. What do pelagic freezer-trawlers discard? *ICES Journal of Marine Science*, **65**, 605–611.

Brierley, A.S. & Fernandes, P.G. 2001. Diving depths of northern gannets: Acoustic observations of sula bassana from an autonomous underwater vehicle. *The Auk*, **118**, 529–534.

Cardador, F. & Chaves, C. 2010. Boarfish (*capros aper*) distribution and abundance in Portuguese continental waters (ICES div. IXa).

Clarke, M.R., Clarke, D.C., Martins, H.R. & Silva, H.M. 1995. The diet of swordfish (*xiphias gladius*) in Azorean waters. *ARQUIPÉLAGO. Life and Marine Sciences*, **13**, 53–69.

Coad, J.O., Hüssy, K., Farrell, E.D. & Clarke, M.W. 2014. The recent population expansion of boarfish, capros aper (linnaeus, 1758): Interactions of climate, growth and recruitment. *Journal of Applied Ichthyology*, **30**, 463–471.

Ellis, J.R., Pawson, M.G. & Shackley, S.E. 1996. The comparative feeding ecology of six species of shark and four species of ray (elasmobranchii) in the north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom*, **76**, 89–106.

Farrell, E.D., Carlsson, J.E.L. & Carlsson, J. 2016. Next gen pop gen: Implementing a high-throughput approach to population genetics in boarfish (*capros aper*). *Open Science*, **3**, 160651.

Farrell, E.D., Hüssy, K., Coad, J.O., Clausen, L.W. & Clarke, M.W. 2012. Oocyte development and maturity classification of boarfish (*capros aper*) in the northeast Atlantic. *ICES Journal of Marine Science*, **69**, 498–507.

Fässler, S.M.M., O'Donnell, C. & Jech, J.M. 2013. Boarfish (*capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. *ICES Journal of Marine Science*, **70**, 1451–1459.

Fock, H.O., Matthiessen, B., Zidowitz, H. & Westernhagen, H. v. 2002. Diel and habitat-dependent resource utilisation by deep-sea fishes at the great meteor seamount: Niche overlap and support for the sound scattering layer interception hypothesis. *Marine Ecology Progress Series*, **244**, 219–233.

Granadeiro, J.P., Monteiro, L.R. & Furness, R.W. 1998. Diet and feeding ecology of cory's shearwater calonectris diomedea in the Azores, north-east Atlantic. *Marine Ecology Progress Series*, **166**, 267–276

Granadeiro, J.P., Monteiro, L.R., Silva, M.C. & Furness, R.W. 2002. Diet of common terns in the Azores, northeast Atlantic. *Waterbirds: The International Journal of Waterbird Biology*, **25**, 149–155.

Holden, M.J. & Tucker, R.N. 1974. The food of raja clavata linnaeus 1758, raja montagui fowler 1910, raja naevus müller and henle 1841 and raja brachyura lafont 1873 in British waters. *ICES Journal of Marine Science*, **35**, 189–193.

Hüssy, K., Coad, J.O., Farrell, E.D., Clausen, L.A.W. & Clarke, M.W. 2012a. Age verification of boarfish (*capros aper*) in the northeast Atlantic. *ICES Journal of Marine Science*, **69**, 34–40.

Hüssy, K., Coad, J.O., Farrell, E.D., Clausen, L.W. & Clarke, M.W. 2012b. Sexual dimorphism in size, age, maturation, and growth characteristics of boarfish (*capros aper*) in the northeast Atlantic. *ICES Journal of Marine Science*, **69**, 1729–1735.

ICES. 2011. Report of the Working Group on Widely Distributed Stocks (WGWIDE). 23-29 August 2011, ICES HQ, Copenhagen, Denmark. ICES CM 2011/ACOM:15, 624 pp.

ICES. 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM 68. 42 pp.

ICES. 2015. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A., Dingsør, G., Fuglebakk, E. & Handegard, N. 2019. *StoX: An open source software for marine survey analyses*. *Methods in Ecology and Evolution*, **10**, 1523– 1528. https://doi .org/10.1111/2041-210X.13250

Kery, M. 2010. *Introduction to WinBUGS for ecologists: Bayesian approach to regression, ANOVA, mixed models and related analyses*, 1 edition. Academic Press, Amsterdam.

King, M. 1995. *Fisheries biology, assessment and management.* Oxford.

Lopes, M., Murta, A.G. & Cabral, H.N. 2006. The ecological significance of the zooplanktivores, snipefish macroramphosus spp. and boarfish capros aper, in the food web of the south-east north atlantic. *Journal of Fish Biology*, **69**, 363–378.

Macpherson, E. 1979. Estudio sobre el régimen alimentario de algunos peces en el mediterráneo occidental. *Miscellània Zoològica*, **5**, 93–107.

Mahe, K., Amara, R., Bryckaert, T., Kacher, M. & Brylinski, J.M. 2007. Ontogenetic and spatial variation in the diet of hake (*Merluccius merluccius*) in the Bay of Biscay and the Celtic Sea. *ICES Journal of Marine Science*, **64**, 1210–1219.

Meyer, R. & Millar, R.B. 1999. BUGS in Bayesian stock assessments. *Canadian Journal of Fisheries and Aquatic Sciences*, **56**, 1078–1087.

Minto, C., Clarke, M.W. & Farrell, E.D. 2011. Investigation of the yield- and biomass-per-recruit of the boarfish *capros aper*. Working document to WGWIDE 2011.

Morato, T., Santos, R.S. & Andrade, J.P. 2000. Feeding habits, seasonal and ontogenetic diet shift of blacktail comber, serranus atricauda (pisces: Serranidae), from the Azores, north-eastern Atlantic. *Fisheries Research*, **49**, 51–59.

Morato, T., Solà, E., Grós, M.P. & Menezes, G.M. 1999. Diets of forkbeard (phycis phycis) and conger eel (conger conger) off the Azores during spring of 1996 and 1997.

Morato, T., Solà, E., Grós, M.P. & Menezes, G. 2003. Diets of thornback ray (raja clavata) and tope shark (galeorhinus galeus) in the bottom longline fishery of the Azores, northeastern Atlantic. *Fishery Bulletin*, **101**, 590–602.

Morato, T., Solà, E., Grós, M.P. & Menezes, G. 2001. Feeding habits of two congener species of seabreams, pagellus bogaraveo and pagellus acarne, off the Azores (Northeastern Atlantic) during spring of 1996 and 1997. Bulletin of Marine Science, **69**, 1073–1087.

Oro, D. & Ruiz, X. 1997. Exploitation of trawler discards by breeding seabirds in the north-western Mediterranean: differences between the Ebro Delta and the Balearic Islands areas. *ICES Journal of Marine Science*, **54**, 695–707.

O'Sullivan, Moriarty, C. & Davenport, J. 2004. Analysis of the stomach contents of the European conger eel *Conger conger* in Irish waters. *Journal of the Marine Biological Association of the United Kingdom*, **84**, 823–826.

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. pp. 20–22.

Spiegelhalter, D., Thomas, A., Best, N. & Lunn, D. 2003. *WinBUGS user manual*. Version 1.4.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: Combining the GLM and delta approaches. *ICES Journal of Marine Science*, **53**, 577–588.

White, E., Minto, C., Nolan, C.P., King, E., Mullins, E. & Clarke, M. 2011. First estimates of age, growth, and maturity of boarfish (*Capros aper*): A species newly exploited in the Northeast Atlantic. *ICES Journal of Marine Science*, **68**, 61–66.

Xavier, J.C., Cherel, Y., Assis, C.A., Sendão, J. & Borges, T.C. 2010. Feeding ecology of conger eels (*Conger conger*) in north-east Atlantic waters. *Journal of the Marine Biological Association of the United Kingdom*, **90**, 493–501.

3.16 Tables

Table 3.1.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Landings by country, total discards and TAC by year (t), 2001–2020. (Data provided by Working Group members)

	Den-mark	Ger-many	Ire-land	Nether-lands	Eng-land	Po-land	Scot-land	Spain	Dis-cards	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		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				1173	17388	27288
2018	94		9513	172	0		0	148	1359	11286	21830
2019	757		9910	318	19			3	306	11313	21830
2020	196		14666	416	62	109		1	198	15649	19152

0 = <0.5t

Table 3.1.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Discards in demersal and non-target pelagic fisheries by year (data provided by Working Group members)

Year	Denmark	Germany	Ireland	Netherlands	Spain	UK	Lithuania	Total
2003			119	1998	8812			10929
2004			60	837	3579			4476
2005			55	733	5007			10271
2006			22	411	3933			4366
2007			549	23	2617			3189
2008			920	738	8410			10068
2009			377	1258	5047			16750
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	386		640	146			1	1173
2018	744		525	89			1	1359
2019			57		240	8		305

Year	Denmark	Germany	Ireland	Netherlands	Spain	UK	Lithuania	Total
2020			64		133	1		198
0 = <0.5t								

Table 3.1.2.3. Landings of boarfish in ICES Subareas 27.6

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Denmark															37	67	172	10
England													9				9	7
Ireland	65	292	10	21	99*	28	45	1356	26	125	538	182	116	377	907	269	568	1222**
Netherlands													128	45	34	78	79	108
Scotland								10			15	30						
*6t in 5b, 0=0-0.5t																		
** 8t in 4a																		

Table 3.1.2.4 Landings of boarfish in ICES Subareas 27.7bc

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Denmark											80	12	8	21				85
England													85	1			0	32
Germany													4	5				
Ireland	214	224	105	15	1259	3	74	2293	283	4609	10405	3262	2829	1198	124	163	241	6818

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Netherlands													33*	35	138	10	150	212
Scotland								4		1745	100							
*Division 7, 0=0-0.5t																		

Table 3.1.2.5 Landings of boarfish in ICES Divisions 7e-g

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Denmark								674							1		1	0
England															0		6	
Ireland				375	120	184	4912	3649	811	616	1808	135	547		1	2		1
Netherlands														0	0	3	7	1
Scotland											883							
0=0-0.5t																		

Table 3.1.2.6 Landings of boarfish in ICES Subareas 27.7h-k

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Denmark								39132	7779	18203	11828	8747	5	330	239	6	268	101
England													10	16	0	0	3	23
Ireland	179	122	12	2360	16131	21370	63597	81160	19565	50507	38358	30925	12152	8623	2994	3745	6222	6365
Netherlands														90	9	68	80	79

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Poland																		109
Scotland					772			9227	2813	3139	3381	8				0		
Spain																	0	0
0=0-0.5t																		

Table 3.1.2.7 Landings of boarfish in ICES Subarea 8

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Denmark									18		1354		6	7	271		315	
England														5				
Germany													1	1				
Ireland		38	38	1	5					93	1140	119	682	7297	11458	5336	2876	283**
Netherlands													2014			14	0	17
Spain																148*	2	1
*94t in 9a, 0=0-0.5t																		
**14t in 12b																		

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	Percent landings covered by sampling	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	8	371	0****
2020	15451	NA	10	534	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 Danish, Irish and Scottish commercial landings. This comprehensive ALK was used for all métiers to produce catch numbers-at-age for the pseudo-cohort analysis.**
Only aged fish measured to the 0.5cm were included in the ALK.
***** Only Irish collected samples were used for the length frequency, see stock annex.**
****** 2012 ALK was 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 2020

Country	Area	Quarter	Landed	ALK
DK	7.b	4	18.693	IE_7.b_Q4
DK	7.e	4	0.001	IE_7.h_Q4
DK	7.h	4	68.013	IE_7.h_Q4
DK	7.j	1	22.409	IE_8.a_Q1
DK	7.j	4	10.377	IE_7.j_Q4
ES	7.j	2	0.012	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
ES	7.j	3	0.028	IE_7.j_Q4
ES	8.c	4	1.021	IE_7.h_Q4 IE_7.j_Q4
IE	6.a	4	1,083.000	IE_6.a_Q4
IE	7.b	2	0.010	IE_7.b_Q4 IE_7.j_Q4
IE	7.b	4	6,676.000	IE_7.b_Q4
IE	7.c	4	2.364	IE_7.b_Q4
IE	7.g	2	0.311	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
IE	7.g	3	0.119	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
IE	7.g	4	0.162	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
IE	7.h	1	189.000	IE_8.a_Q1
IE	7.h	4	4,954.000	IE_7.h_Q4
IE	7.j	1	41.710	IE_8.a_Q1
IE	7.j	2	0.825	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
IE	7.j	3	56.670	IE_7.j_Q4
IE	7.j	4	1,123.000	IE_7.j_Q4
IE	8.a	1	268.600	IE_8.a_Q1
NL	6.a	3	1.690	IE_6.a_Q4
NL	6.a	4	73.440	IE_6.a_Q4
NL	7.b	2	2.240	IE_7.b_Q4 IE_7.j_Q4
NL	7.b	3	64.960	IE_7.b_Q4
NL	7.b	4	26.860	IE_7.b_Q4
NL	7.e	2	0.110	IE_8.a_Q1

Country	Area	Quarter	Landed	ALK
NL	7.f	4	0.390	IE_7.h_Q4 IE_7.j_Q4
NL	7.g	4	0.060	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
NL	7.h	1	0.700	IE_8.a_Q1
NL	7.h	3	12.920	IE_7.h_Q4
NL	7.j	1	17.630	IE_8.a_Q1
NL	7.j	2	34.240	IE_7.b_Q4 IE_7.h_Q4 IE_7.j_Q4
NL	7.j	3	13.020	IE_7.j_Q4
NL	8.a	2	2.960	IE_8.a_Q1
NL	8.a	3	13.660	IE_7.h_Q4
PL	7.j	3	109.460	IE_7.j_Q4
UKE	7.d	3	0.003	IE_7.h_Q4 IE_7.j_Q4
UKE	7.j	1	22.935	IE_8.a_Q1

Table 3.2.1.4. Boarfish in ICES Subareas 27.6, 7, 8. Catch (landings and discards) per country and corresponding number of samples collected in 2020

Official catch	Country	No. samples	No. measured	No. aged
196	DK	0	0	0
134	ES	0	0	0
14738	IE	10	534	0
416	NL	0	0	0
109	PL	0	0	0
63	UKE	0	0	0
1	UKS	0	0	0

Table 3.2.1.5. Boarfish in ICES Subareas 27.6, 7, 8. Catch per area and corresponding number of samples collected in 2020

Area	Official catch	No. samples	No. measured	No. measured per 1000t
27.3.a	0.00	0	0	0.00
27.3.b	0.00	0	0	0.00
27.3.c	0.00	0	0	0.00
27.3.d	0.00	0	0	0.00

Area	Official catch	No. samples	No. measured	No. measured per 1000t
27.4.a	7.50	0	0	0.00
27.4.b	0.00	0	0	0.00
27.6.a	1,340.11	2	85	63.43
27.6.b	3.25	0	0	0.00
27.7.b	7,156.11	3	169	23.62
27.7.c	15.16	0	0	0.00
27.7.d	0.00	0	0	0.00
27.7.e	0.34	0	0	0.00
27.7.f	0.39	0	0	0.00
27.7.g	0.99	0	0	0.00
27.7.h	5,291.11	2	88	16.63
27.8.a	285.22	2	151	529.42
27.8.b	5.46	0	0	0.00
27.8.c	27.58	0	0	0.00
27.7.j	1,523.14	1	41	26.92
27.7.k	0.00	0	0	0.00

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 2007-2020

Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	0	0	1575	2415	0	28	301	0	5556	218	1862	314	17427	40397
2	352	5488	15043	11229	2894	893	7148	695	116135	2385	4387	1736	37620	57719
3	2114	21140	65744	72709	41913	5467	156680	49503	32248	10737	8830	2628	9737	37192
4	40851	105575	338931	294382	28148	41278	58522	127520	16588	25114	34448	13610	9944	26433
5	48915	141300	475619	567689	30116	110272	59797	93705	24564	20263	27266	15570	12682	10162
6	62713	195339	543707	878363	175696	146582	68949	67275	26566	18025	21103	14731	12716	2583
7	26132	104031	307333	522703	143967	492078	302967	193061	74115	61229	55189	38686	29513	9113
8	29766	66570	172783	293719	107126	365840	250341	139124	52052	47573	38229	26821	18819	7487
9	56075	53159	155477	276672	77861	271916	212318	121042	44615	42478	32258	23670	15875	7897
10	44875	46893	130148	232122	60022	173486	160137	94225	34264	35150	25716	19395	11359	8164
11	14019	15289	42521	78588	46079	69396	63025	36078	12999	13297	9560	7148	4272	3049
12	32359	21178	61350	114600	40468	40968	41490	24895	9114	9132	7564	5846	2937	2786
13	4848	11854	39609	59932	24352	58888	59380	36309	13362	13774	10922	8183	4256	4152
14	16837	13570	31569	59060	19724	30277	30355	19064	7152	6682	5924	4554	2156	2333
15+	109481	112947	196967	349320	157707	217260	239366	150688	59139	49589	40797	32130	14864	17663

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 2007-2020

Length	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.5									14					
5.0									878					
5.5									515					2746
6.0				156					810		765		15868	37073
6.5				439					14		4607	203	70362	150810
7.0				1090	522	56	52		513	417	5250	405	80160	233347
7.5			1354	1574			551		10598	1684	12616	2635	85420	147915
8.0			677	375	1345	185	1419		80716	8685	11473	4703	115154	38949
8.5				1082		555	3592	1064	49508	6412	10115	3559	67471	43556
9.0			677	5382	851	555	7263	327	10219	7104	3874	6554	16504	101918
9.5		7473	17367	7883	7012	641	47509	4916	213	23065	14047	6196	3147	115103
10.0	9609	11209	54130	29410	33243	2791	94702	31649	1211	46010	32346	5559	9173	100550
10.5		52308	174796	130889	15848	6132	59833	71344	3865	39071	36242	4450	10144	55049
11.0	84555	63517	343283	361774	70615	24571	18359	108261	12226	14181	32445	17658	5796	9475
11.5		59781	321637	655875	93487	81928	20938	82470	28142	18249	31589	22826	22722	3172
12.0	44199	119561	297737	739025	189434	264888	98564	84288	41613	30975	33618	24070	22353	2396
12.5		70990	207739	564347	114904	398772	204868	112826	42461	51110	41650	24514	17521	3251

Length	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
13.0	82633	52308	147965	353484	133539	419060	315063	172416	59990	57000	46495	30665	28815	9494
13.5		29890	149314	246146	51235	307533	285688	153742	52625	58696	43121	38698	16688	13707
14.0	117224	22418	105782	224611	50857	176710	210137	138549	50139	76872	45353	34080	20053	16381
14.5		14945	71273	127711	25309	89726	105571	74059	28771	37755	39524	29908	13809	14913
15.0	65338	33627	47816	125463	25569	52791	62175	43347	16087	23137	21854	15561	5710	12563
15.5		11209	13082	81386	5473	25065	31122	22629	8572	7841	4932	5778	1513	4304
16.0	13452	11209	19397	24256	4181	13149	14990	7672	4331	625	1020	1948	143	1041
16.5		3736	4061	6209	2280	2738	4918	2134	2081	128		54	143	353
17.0		3736	677	1913	456	827	1109	1361	289					
17.5							407		23					353
18.0				283			296							
18.5									592					

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

Age	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
0										1084	259
1	5	22			199	5	111	77	782	897	9523
2	12	11	78		319	36	127	31	389	1157	3392
3	58	174	1843	15	17	46	345	115	97	967	2955
4	187	65	696	98	34	44	367	68	93	113	1315
5	437	95	382	102	80	6	156	107	88	157	463
6	1166	736	254	105	112	10	209	166	106	183	150
7	1184	974	1057	415	437	169	493	321	446	913	953
8	704	759	879	344	363	113	463	198	183	885	207
9	1095	849	801	342	354	118	397	293	288	721	378
10	1032	956	704	332	360	97	286	625	290	331	249
11	333	651	264	130	132	17	121	339	50	81	151
12	653	1100	203	105	113	32	82	264	192	195	188
13	336	857	297	166	174	49	74	198	79	299	81
14	385	656	170	89	108	18	220	117	57	267	327
15+	3519	6354	1464	855	1195	400	931	302	759	1641	1213
TSN	11104	14257	9091	3098	3996	1157	4387	3221	3899	9888	21805
TSB	670176	863446	439890	187779	232634	69690	230062	186252	179156	399872	443777
SSB	669392	861544	423158	187654	226659	69103	218810	184624	169213	357871	351955
CV	21.2	10.6	17.5	15.1	17.0	19	21.9	19.9	25.4	34.8	31.0

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	0	5	12	7	17	195	2645	5006	3691	3570	4422	12054	16633	7200	3472	503	18	1	0	0
1998	0	1	4	25	70	2083	18263	8566	6117	5961	7082	11828	14363	9600	5261	971	8	0	0	1
1999	0	0	13	52	33	245	10949	25911	23235	6484	2818	4632	7780	6151	1357	268	8	0	0	0
2000	0	17	79	120	8	1508	26901	17725	9864	22076	16424	29584	36849	16508	5399	988	76	0	0	0
2001	0	1	45	687	490	916	21328	37173	13322	28492	31640	18378	12315	6507	3193	1272	81	4	0	0
2002	0	2	18	23	11	547	9634	29844	17728	13175	9280	9513	9615	6185	2458	642	37	1	1	0
2003	0	0	17	47	17	57	426	1663	7155	20073	24977	21358	21939	15004	7355	1599	35	0	0	0
2004	0	0	33	534	397	123	1248	1420	1308	1083	3102	7308	7224	6353	7866	3630	241	5	0	0
2005	0	2	94	964	1264	146	1097	2302	1225	1551	3182	13394	15782	9879	6012	1658	117	70	0	0
2006	1	26	111	77	74	15506	37545	10729	3611	2128	1518	1960	4165	4024	2601	940	93	2	12	0
2007	0	7	188	473	234	1511	22812	127331	65589	6442	6823	5477	6110	6003	4268	1411	118	11	0	0
2008	0	3	432	2795	823	5487	54355	256210	169633	163128	69199	38406	18310	17213	9157	3486	745	6	1	0
2009	0	6	128	194	69	1482	19663	35649	5260	3906	9562	12271	9402	10835	6722	775	39	1	0	0
2010	0	21	529	116	154	5774	46490	74999	27177	12168	37971	59369	38501	37683	15699	1555	248	8	1	0
2011	0	61	95	214	5	536	2232	8210	14905	32671	29788	50316	56963	36588	11723	3058	572	159	47	0
2012	0	9	146	594	142	2913	28823	26800	6124	11739	13607	22370	37138	44084	19963	4893	127	1	0	0
2013	0	3	48	92	10	305	2187	2141	2558	13769	9938	15006	37563	40266	20130	6888	686	0	3	0
2014	0	2	693	1386	508	84	1440	885	3074	8732	28586	39397	74122	69736	26871	3908	59	433	0	0
2015	0	5	183	5898	4143	607	19075	179269	119004	15765	18014	61575	62024	59904	21525	5487	541	429	8	0

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2016	5	31	379	846	115	733	10284	14280	17251	42132	25304	68583	130633	131220	48538	11611	1358	26	0	0
2018	0	14	4957	193861	173779	210	10910	76288	48343	29096	45773	85164	132174	157883	48603	14951	592	18	0	0
2019	2	997	6467	589	10688	531908	561517	329850	59733	4505	3418	8451	32547	61582	30031	7468	962	204	0	0
2020	3	283	1280	657	21381	408706	595107	142947	218153	421028	220190	54726	70612	97364	74415	30606	4736	1	0	0

IGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2003	0	1	33	22	7	22	129	172	879	2942	2322	1325	3823	4629	2898	896	163	38	0	0
2004	0	23	63	34	8	117	628	1444	423	397	464	2276	4325	4709	3972	1019	90	5	1	0
2005	0	8	59	52	20	203	1024	585	288	636	341	3463	11457	11348	7955	1744	382	2	1	0
2006	5	60	68	48	35	212	969	621	2046	4190	8044	7946	24208	42119	32168	12296	2454	532	0	0
2007	1	6	44	18	31	501	923	1251	1638	1166	2510	3581	8275	10740	7093	1934	92	0	0	0
2008	0	0	26	18	23	127	672	531	2095	13780	17664	19268	16980	19484	15953	8789	1747	76	1	0
2009	0	3	80	76	25	94	228	486	1000	1139	9081	7749	5138	6921	5592	1084	68	1	0	0
2010	0	6	42	3	18	199	272	463	920	393	7914	34236	28611	16063	8161	1974	433	0	0	0
2011	0	7	17	5	4	189	772	592	556	669	2600	20246	22121	10851	5319	2218	269	9	6	0
2012	0	7	36	20	10	130	271	378	702	2143	1183	11104	34005	22731	10905	3901	525	4	0	0
2013	1	3	9	9	20	127	352	340	1320	2833	3971	15572	51637	52868	20485	6560	492	20	0	0
2014	0	10	68	54	4	18	13	25	60	130	1127	3251	19125	23016	10355	2988	284	18	0	0
2015	0	3	11	16	24	193	1008	3708	848	105	713	6315	29727	48220	33024	17350	1885	531	0	0
2016	4	31	121	63	7	67	187	1515	4057	2891	1349	4111	32753	57753	40907	15527	3670	85	0	0

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2017	0	0	37	131	48	132	460	652	11411	20321	5909	5520	16426	33117	29972	15815	3194	369	0	0
2018	4	51	247	139	32	45	286	585	1194	6107	17005	15168	48895	61833	36519	10722	2030	63	0	0
2019	4	19	117	47	52	262	583	173	106	487	2677	4967	6863	12080	10480	5125	772	71	4	0
2020	9	388	233	21	16	1772	2052	13941	65121	24505	7709	17859	12157	17223	9125	2499	110	2	0	0

SPNGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1990	0	0	8	0	16	317	1817	2496	260	141	154	314	632	613	689	97	0	0	0	0
1991	0	1	0	0	31	690	1311	313	49	9	6	7	7	4	0	0	0	6	0	0
1992	0	57	38	9	178	3290	2743	282	48	10	8	69	162	390	779	246	95	0	0	0
1993	0	57	1206	488	97	3730	3753	421	105	54	7	4	8	3	2	0	0	0	0	0
1994	1	40	33	0	342	4789	10162	8920	3195	53	106	20	9	12	1	0	0	0	0	0
1995	0	84	108	4	342	3063	2157	220	84	65	58	105	105	90	20	4	0	0	0	0
1996	0	218	537	143	245	4457	4449	267	820	722	82	145	126	219	96	39	2	0	0	0
1997	2	102	809	441	235	3458	6824	2189	1923	534	156	353	161	88	3	0	0	0	0	0
1998	3	2	7	4	49	1920	4685	2217	337	153	125	88	147	135	86	13	2	3	0	0
1999	0	6	59	13	134	2736	3010	193	106	83	109	143	390	645	402	69	0	0	0	0
2000	0	7	3729	2046	17	554	1947	489	277	486	756	1252	999	1021	199	34	13	0	0	0
2001	0	68	4	1	153	3241	5085	659	225	206	205	236	692	407	120	22	9	0	0	0
2002	0	4	20	0	133	2333	2013	284	50	58	54	60	231	314	72	9	0	0	0	0
2003	0	4	950	567	4	77	221	57	39	28	16	22	17	23	16	5	1	0	0	0

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2004	0	6	22	4	43	2289	3808	443	110	83	58	219	931	776	303	2	1	0	0	0
2005	0	16	451	25	9	754	1007	207	85	102	30	54	257	218	90	44	2	0	0	0
2006	0	14	156	160	50	2238	8913	4507	175	94	9	36	229	419	169	9	2	0	0	0
2007	0	49	40	1	111	3025	6620	1099	129	260	81	7	93	215	89	21	3	0	0	0
2008	7	4	92	247	1	936	1561	1326	234	1483	304	537	11	833	201	186	11	0	0	0
2009	1	17	62	119	11	2587	3893	4070	119	250	45	142	59	819	120	17	1	1	0	0
2010	0	55	102	5	232	13090	22032	3169	1160	1056	89	82	179	1007	1981	518	9	0	0	0
2011	0	29	260	105	46	2805	5511	1278	148	340	145	100	144	591	724	134	3	1	0	0
2012	0	29	132	35	556	7550	7844	1364	88	53	59	170	1051	2394	1553	432	21	0	0	0
2013	0	0	2	11	126	2163	4664	854	302	609	251	61	113	134	156	81	8	0	0	0
2014	0	75	117	6	12	263	465	79	1083	1175	1174	1266	998	2444	3623	817	31	1	0	0
2015	0	13	67	3	58	1889	4248	534	75	465	750	970	695	1173	1473	453	70	1	0	0
2016	0	17	99	5	41	922	2423	473	925	746	346	548	452	561	169	22	4	0	0	0
2017	1	23	20	1	16	641	1947	755	134	165	285	405	579	967	936	177	13	3	0	0
2018	0	0	2	0	45	708	1635	258	43	99	230	605	1370	3324	3865	949	3	0	0	2
2019	0	12	2	1	259	4128	3887	379	18	83	273	329	717	4200	8402	2215	202	0	0	0
2020	0	8	33	2	33	1218	2123	525	387	314	75	225	705	2518	4751	1603	10	0	0	0

SPPGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2001	0	1	0	1	1	2	0	44	5	52	133	162	667	1129	230	40	0	0	0	0
2002	0	0	0	0	0	0	0	0	1	4	90	212	791	843	313	60	0	0	0	0
2003	0	0	0	0	0	1	0	3	15	22	21	62	268	426	249	51	2	1	0	0
2004	0	1	0	0	0	6	3	0	5	6	23	124	385	592	390	52	1	0	0	0
2005	0	1	0	1	8	1	20	11	10	16	8	118	628	1118	833	272	23	0	0	0
2006	0	0	1	1	8	120	118	26	43	95	34	58	431	863	716	252	13	1	0	0
2007	0	0	0	0	4	5	12	20	16	12	37	34	96	202	191	34	5	0	0	0
2008	0	1	0	0	0	1	17	10	23	19	79	156	349	666	442	113	7	0	0	0
2009	0	8	7	0	3	10	11	1	0	2	220	457	1333	1746	1698	474	11	0	0	0
2010	2	0	0	1	6	17	4	1	6	3	43	390	710	976	620	164	13	0	0	0
2011	0	0	0	0	0	0	0	4	20	22	6	180	815	960	522	151	17	0	2	0
2012	0	0	0	1	1	0	0	2	2	1	10	87	456	570	267	79	4	0	0	0
2013	0	0	0	1	0	8	24	7	10	0	1	48	500	1032	564	163	15	1	0	0
2014	0	10	9	0	1	0	3	17	62	11	6	85	2453	6703	3168	2115	162	82	0	0
2015	0	0	0	2	1	0	0	1	1	0	0	32	300	471	316	151	43	0	0	0
2016	0	0	3	0	0	0	1	0	13	7	0	9	157	336	220	84	19	0	0	0
2017	0	67	19	0	0	0	10	0	0	1	18	26	148	498	529	268	17	0	0	0
2018	0	2	1	0	0	0	1	0	0	0	0	37	1159	3574	2449	1131	159	0	0	0
2019	5	36	4	0	0	0	0	0	3	4	0	15	426	952	796	192	15	0	0	0
2020	0	5	1	0	0	4	1	1	2	4	0	26	250	616	851	661	111	0	0	1

WCSGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	3	2	0	3	24	42	62	172	210	1286	856	450	52	17	0	0	0	0
1991	0	0	0	2	0	31	138	80	183	644	683	848	226	89	12	1	2	4	0	0
1992	0	0	0	1	0	8	12	14	44	478	1160	4028	1674	502	5	0	0	0	0	0
1993	0	0	0	0	0	1	109	2	670	2078	1074	4904	2753	2882	28	2	0	0	0	0
1994	0	0	2	0	0	0	15	30	30	205	283	312	454	388	147	0	0	0	0	0
1995	8	12	18	4	2	10	40	30	94	162	640	1485	1770	1139	318	14	2	4	6	0
1996	0	0	0	4	0	10	48	27	49	48	64	188	920	1888	416	18	1	0	0	0
1997	0	0	4	0	0	1	17	42	120	64	116	249	436	301	91	8	4	0	0	0
1998	0	0	0	1	0	1	7	6	7	16	47	69	105	171	78	8	2	0	0	0
1999	0	0	1	0	0	2	6	8	189	221	312	458	346	221	69	0	0	0	0	0
2000	0	0	0	0	0	0	3	3	42	118	230	303	206	108	54	8	0	0	0	0
2001	0	1	0	0	0	0	0	1	12	27	54	90	233	414	242	80	15	1	0	0
2002	0	0	0	0	0	1	8	2	1	82	759	3243	5711	5896	1558	189	1	0	0	0
2003	0	0	1	0	0	0	3	52	9	107	326	1536	3294	5409	3553	413	37	0	0	0
2004	0	0	0	1	0	0	6	2	45	83	744	4576	8611	9526	5698	954	84	0	0	0
2005	0	2	0	0	0	9	38	15	30	31	113	442	1115	1747	818	141	9	3	2	0

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2006	0	1	2	1	0	2	9	4	22	256	311	508	1524	2964	2104	449	73	2	0	0
2007	0	0	3	2	0	8	14	65	118	182	795	2938	5220	6953	5332	1538	116	0	0	0
2008	0	1	3	0	0	16	37	38	200	482	1406	3218	9904	22777	18407	6293	575	71	0	0
2009	0	0	1	0	1	1	4	6	64	2460	2246	694	505	416	338	136	12	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	530	1443	1384	1357	828	149	29	0	0	0

Table 3.6.1.1. Boarfish in ICES Subareas 27.6, 7, 8. IBTS length-frequency data converted to age-structured indices by application of the 2012 common ALK rounded down to 1cm length classes

EVHOE

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1997	1323	5891	4835	3829	3369	3053	9614	6955	5556	3779	1521	973	1456	828	6235
1998	9132	16881	8109	6147	4527	3452	9545	6632	5452	4058	1597	1312	1733	1022	8419
1999	5474	30494	25366	5015	2592	1427	4373	3215	2887	2276	855	564	888	491	3675
2000	13450	28555	16758	19454	12310	8420	23424	16159	12783	8538	3354	1885	3099	1722	12485
2001	10664	39887	26874	27998	16428	8946	15285	7816	5688	3538	1301	863	1271	750	6396
2002	4817	30622	24313	11299	6215	3393	7688	4838	3852	2716	1035	726	1060	611	4928
2003	213	3707	9293	20716	13365	8409	18107	11109	8937	6448	2467	1932	2635	1547	12700
2004	624	2006	1574	1777	1923	1842	5376	3816	3078	2541	1075	1423	1434	932	11369
2005	549	2492	1901	2205	2758	2983	9853	7261	5865	4310	1727	1437	1869	1110	9951
2006	18772	27129	6395	1838	1086	692	2217	1683	1593	1407	557	586	688	416	4256
2007	11406	118156	87434	6252	3796	2250	4968	3140	2686	2208	861	923	1067	657	6591
2008	27177	254528	229646	124210	54539	19047	30818	15021	10954	7348	2618	2251	2934	1795	16959

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2009	9832	35351	16200	5643	4832	3830	8969	5783	4721	3809	1459	1524	1806	1110	9216
2010	23245	82303	45710	20517	19648	16749	39369	25075	19324	14156	5280	4343	5906	3511	26732
2011	1116	11557	19043	30617	20479	14495	39161	26846	21792	15613	5980	3928	6016	3404	27139
2012	14412	34320	15329	11984	8843	6877	21882	16580	15805	14165	5382	5221	6581	3893	34397
2013	1093	3373	5082	11975	7436	5156	18526	14722	14572	13248	5121	5049	6254	3703	35819
2014	720	2334	4216	15081	14776	13252	40953	30549	28568	24182	9208	7776	10517	6071	49039
2015	9537	168718	142196	16589	15129	14025	43805	31952	26892	21239	8025	6461	8982	5218	43843
2016	5142	20412	24368	35467	23775	18507	68150	53795	50979	44038	16743	14289	19326	11149	95082
2018	5455	72428	63489	33998	28889	24760	79148	59901	56898	49999	18526	15688	21690	12453	106474
2019	280759	520569	150645	4035	3104	2844	14950	13581	15700	16891	6358	7404	8669	5219	49538
2020	297553	465569	273832	332726	148543	51435	79125	38909	36296	32676	12326	15407	16693	10460	118335

IGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2003	64	472	1214	2586	1401	743	2065	1523	1556	1484	578	653	750	456	4672
2004	314	1418	842	434	493	543	2252	1838	1732	1603	653	802	864	541	5422
2005	512	998	509	567	717	908	4790	4166	4162	3867	1557	1730	1973	1201	11568
2006	484	1580	2423	5269	4211	3388	12623	10487	11436	12263	4853	6606	6952	4368	50651
2007	462	1842	1748	1576	1408	1235	4362	3474	3496	3378	1326	1557	1754	1076	10509
2008	336	1388	4302	14466	9811	6581	15265	9859	8231	6912	2728	3247	3553	2238	28119
2009	114	772	1117	3682	3665	2967	5991	3553	2883	2398	928	1136	1233	783	7266

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2010	136	752	906	3336	6161	7220	21721	15262	11417	7656	3025	2151	3055	1795	14845
2011	386	966	715	1598	3198	4038	13856	10232	7932	5384	2159	1453	2121	1224	10962
2012	136	622	1006	1911	2306	2843	13844	11639	10956	8966	3576	2903	3900	2242	21003
2013	176	843	1557	3292	3917	4545	21801	18670	19029	17278	6613	5870	7777	4484	40599
2014	6	43	82	492	927	1262	7300	6613	7255	7083	2717	2714	3384	1986	18529
2015	504	3259	1827	403	1251	1945	12476	11625	13072	13999	5512	7082	7697	4765	58017
2016	93	2456	3763	2302	1775	1846	13082	12553	14753	16394	6464	8634	9226	5742	65723
2017	230	4468	11683	14642	6277	2402	9024	7578	8395	9474	3824	5785	5766	3703	49915
2018	143	930	2275	9391	8194	6861	23782	19030	19873	19320	7511	8412	9756	5903	59025
2019	292	442	242	1229	1449	1419	4664	3618	3540	3626	1453	2058	2107	1346	16899
2020	1026	32027	52719	18043	8761	4356	11714	8061	6664	5578	2105	2193	2649	1618	14790

SPNGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1990	909	2660	1033	142	110	93	335	263	243	224	95	128	129	83	770
1991	656	880	138	8	4	2	6	3	3	2	1	0	1	0	8
1992	1371	1575	128	10	13	16	97	89	92	122	57	124	102	71	965
1993	1877	2192	220	36	13	2	5	3	2	2	1	0	1	0	3
1994	5081	12093	5114	66	43	23	28	9	7	5	1	1	1	1	5
1995	1079	1254	142	61	41	29	78	54	44	33	12	8	13	7	53
1996	2225	2676	772	479	175	40	109	77	70	65	24	25	31	18	181

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1997	3412	5512	2113	389	183	84	198	123	82	47	17	6	14	8	43
1998	2343	3933	993	137	76	41	96	64	58	49	19	19	23	14	125
1999	1505	1669	151	88	66	53	202	168	181	188	73	89	100	61	556
2000	973	1392	445	562	447	351	877	582	475	359	130	88	138	78	577
2001	2542	3057	410	197	130	93	311	237	219	170	66	43	66	36	286
2002	1006	1212	139	54	35	26	103	87	95	92	33	28	40	22	172
2003	110	162	50	23	12	7	16	11	9	8	3	3	4	2	25
2004	1904	2236	237	74	66	71	359	310	313	273	106	88	120	68	508
2005	504	670	145	74	36	21	99	85	86	76	30	25	34	19	191
2006	4457	7519	1636	62	27	14	93	89	106	114	42	46	56	33	268
2007	3310	4086	502	187	74	19	50	39	50	56	20	24	28	17	155
2008	781	1743	878	1031	419	134	290	185	174	186	60	69	89	53	594
2009	1947	4700	1483	173	75	31	113	100	138	174	56	59	81	46	363
2010	11016	13516	2029	689	234	34	167	157	182	283	134	313	253	178	2099
2011	2756	3657	590	260	117	46	134	106	121	158	67	127	114	77	791
2012	3922	4860	523	54	58	68	465	450	551	640	247	337	361	225	2268
2013	2332	3002	602	460	194	59	100	54	51	48	19	28	28	18	238
2014	232	646	978	1123	697	431	1071	739	675	751	325	610	539	367	3971
2015	2124	2505	322	542	409	300	726	482	406	388	162	260	245	163	1874
2016	1211	1835	917	584	300	157	397	267	226	184	67	55	77	45	347
2017	974	1522	374	199	161	129	397	301	291	298	121	178	178	115	1130

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2018	817	1004	135	145	163	171	810	719	786	945	398	690	641	424	4531
2019	1943	2202	156	143	137	120	669	645	749	1182	560	1325	1065	752	9058
2020	1062	1540	492	224	113	68	460	447	505	731	341	759	623	436	5435

SPPGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2001	0	31	29	77	73	68	300	262	304	308	110	94	135	76	596
2002	0	0	2	34	58	71	330	283	294	270	103	92	122	70	584
2003	0	7	15	21	20	21	115	105	117	123	48	57	65	39	366
2004	1	3	5	13	25	34	177	158	169	175	69	85	94	58	515
2005	10	21	14	14	25	38	264	251	288	319	126	172	182	114	1218
2006	59	91	56	71	39	28	184	176	209	242	97	142	145	92	1021
2007	6	25	20	20	18	15	54	46	50	58	23	36	36	23	230
2008	8	23	23	40	47	48	193	163	176	188	73	95	104	64	636
2009	6	7	3	78	127	147	639	540	550	561	232	325	329	210	2203
2010	2	5	5	22	61	85	379	317	313	301	118	138	156	96	930
2011	0	9	19	19	35	52	320	290	310	301	118	125	149	89	861
2012	0	2	3	5	18	28	176	161	177	174	67	68	84	50	466
2013	12	20	9	1	12	22	197	197	244	277	105	132	148	90	899
2014	2	33	49	11	45	89	992	1044	1403	1685	624	783	898	543	6669
2015	0	1	1	1	7	14	112	109	126	137	54	68	75	46	564

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2016	1	5	10	5	4	6	61	62	78	91	35	48	51	32	360
2017	5	5	0	7	10	12	80	80	100	132	54	96	90	59	786
2018	0	0	0	1	19	41	501	534	718	906	349	516	536	337	4050
2019	0	1	3	3	8	15	167	172	215	260	104	157	158	101	1040
2020	0	2	2	3	7	11	113	115	136	177	77	146	129	87	1519

WCSGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	12	61	90	197	233	248	736	509	363	224	85	38	74	41	261
1991	69	184	275	631	405	256	482	257	153	72	25	8	19	12	63
1992	6	30	133	733	849	840	2097	1321	823	409	155	41	112	63	301
1993	54	279	846	1723	1227	981	2777	1908	1446	1017	359	177	351	191	1165
1994	8	38	71	222	157	112	292	202	179	143	54	43	60	35	250
1995	20	71	109	328	387	385	1141	811	665	480	184	116	183	102	718
1996	24	59	51	53	58	67	398	375	458	490	174	160	222	126	953
1997	8	76	107	81	76	71	233	174	154	119	46	31	47	26	197
1998	4	10	10	26	25	22	68	52	52	50	19	20	24	15	121
1999	3	71	173	244	182	134	315	199	150	100	38	24	37	21	141

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2000	2	18	53	151	122	93	205	125	90	56	22	14	21	12	92
2001	0	5	14	35	33	30	122	103	112	118	45	55	62	38	397
2002	4	6	23	347	634	778	3010	2402	2269	1942	725	559	813	459	3480
2003	2	39	46	196	311	380	1730	1482	1545	1585	619	774	853	528	4647
2004	3	19	52	367	802	1054	4442	3641	3470	3148	1237	1315	1553	939	8289
2005	19	39	32	63	97	118	547	472	504	506	191	207	250	149	1307
2006	4	15	67	266	208	177	781	680	760	834	326	442	470	294	2900
2007	7	90	141	415	626	727	2893	2356	2285	2205	881	1104	1195	746	7600
2008	18	110	248	798	948	1026	5180	4696	5396	6246	2479	3677	3739	2381	26466
2009	2	27	524	2249	1182	537	771	336	263	187	68	70	81	51	531
2010	0	0	4	191	315	347	1030	738	612	492	192	191	231	140	1236

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

Parameter	Mean	SD	2.5	25	50	75	97.5
r	0.35	0.17	0.06	0.22	0.34	0.46	0.71
K	639684	405965	302300	429500	531200	697700	1742000
F_{MSY}	0.17	0.09	0.03	0.11	0.17	0.23	0.36
B_{MSY}	159921	101491	75575	107375	132800	174425	435500
TSB	552960	253596	257500	390100	496700	646900	1176000

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	2020
1	0	0	1575	2415	0	28	301	0	5556	218	1862	314	17427	40397
2	352	5488	15043	11229	2894	893	7148	695	116135	2385	4387	1736	37620	57719
3	2114	21140	65744	72709	41913	5467	156680	49503	32248	10737	8830	2628	9737	37192
4	40851	105575	338931	294382	28148	41278	58522	127520	16588	25114	34448	13610	9944	26433
5	48915	141300	475619	567689	30116	110272	59797	93705	24564	20263	27266	15570	12682	10162
6	62713	195339	543707	878363	175696	146582	68949	67275	26566	18025	21103	14731	12716	2583
7	26132	104031	307333	522703	143967	492078	302967	193061	74115	61229	55189	38686	29513	9113
8	29766	66570	172783	293719	107126	365840	250341	139124	52052	47573	38229	26821	18819	7487
9	56075	53159	155477	276672	77861	271916	212318	121042	44615	42478	32258	23670	15875	7897
10	44875	46893	130148	232122	60022	173486	160137	94225	34264	35150	25716	19395	11359	8164
11	14019	15289	42521	78588	46079	69396	63025	36078	12999	13297	9560	7148	4272	3049
12	32359	21178	61350	114600	40468	40968	41490	24895	9114	9132	7564	5846	2937	2786
13	4848	11854	39609	59932	24352	58888	59380	36309	13362	13774	10922	8183	4256	4152
14	16837	13570	31569	59060	19724	30277	30355	19064	7152	6682	5924	4554	2164	2333
15+	109481	112947	196967	349320	157707	217260	239366	150688	59139	49589	40797	32130	14864	17663

Age	ln(Raised Numbers)													
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	0	0	7	8	0	3	6	0	9	5	8	6	10	11
2	6	9	10	9	8	7	9	7	12	8	8	7	11	11
3	8	10	11	11	11	9	12	11	10	9	9	8	9	11
4	11	12	13	13	10	11	11	12	10	10	10	10	9	10
5	11	12	13	13	10	12	11	11	10	10	10	10	9	9
6	11	12	13	14	12	12	11	11	10	10	10	10	9	8
7	10	12	13	13	12	13	13	12	11	11	11	11	10	9
8	10	11	12	13	12	13	12	12	11	11	11	10	10	9
9	11	11	12	13	11	13	12	12	11	11	10	10	10	9
10	11	11	12	12	11	12	12	11	10	10	10	10	9	9
11	10	10	11	11	11	11	11	10	9	9	9	9	8	8
12	10	10	11	12	11	11	11	10	9	9	9	9	8	8
13	8	9	11	11	10	11	11	10	10	10	9	9	8	8
14	10	10	10	11	10	10	10	10	9	9	9	8	8	8
15+	12	12	12	13	12	12	12	12	11	11	11	10	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	0.20
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	0.04

Age	ln(Raised Numbers)													
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Catches (t)	21576	34751	90370	144047	37096	87355	75409	45231	17766	19315	17388	11286	11313	15649
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	F2.5	F.50	F.97.5
1991	95660	183200	435600			
1992	156800	285100	659200			
1993	190900	346400	800495			
1994	225900	413300	961500			
1995	194000	355800	824795			
1996	196100	358200	836500			
1997	168900	302300	699895			
1998	224800	401000	925397			
1999	167200	299600	688992			
2000	144900	259700	599400			
2001	161300	283200	648600			
2002	138600	242600	555600			
2003	126500	220800	503195	0.02	0.05	0.09
2004	177600	309700	702097	0.01	0.02	0.03
2005	171100	298300	680895	0.01	0.02	0.03
2006	216200	371500	843897	0.01	0.02	0.03
2007	194200	337000	765000	0.03	0.06	0.11
2008	236600	407400	918500	0.04	0.09	0.15
2009	242000	411700	917397	0.10	0.22	0.37
2010	361700	613100	1377975	0.10	0.23	0.40
2011	317600	540000	1225000	0.03	0.07	0.12
2012	457100	753200	1678000	0.05	0.12	0.19
2013	308000	519600	1170000	0.06	0.15	0.24
2014	144500	243400	548897	0.08	0.19	0.31
2015	173000	292500	660195	0.03	0.06	0.10
2016	127200	217500	493600	0.04	0.09	0.15
2017	225300	384400	868895	0.02	0.05	0.08
2018	241900	410500	927200	0.01	0.03	0.05

Year	TSB.2.5	TSB.50	TSB.97.5	F2.5	F.50	F.97.5
2019	202502	345200	779700	0.01	0.03	0.06
2020	237100	408500	926100	0.02	0.04	0.07
2021	257500	496700	1176000			

3.17 Figures

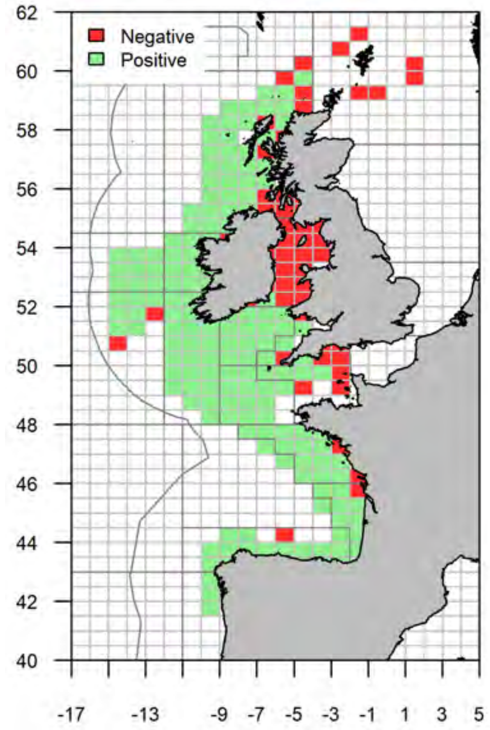


Figure 3.1. Boarfish in ICES Subareas 4, 27.6, 7, 8 and 9. Distribution of boarfish in the NE Atlantic area based on presence and absence in IBTS surveys (all years).

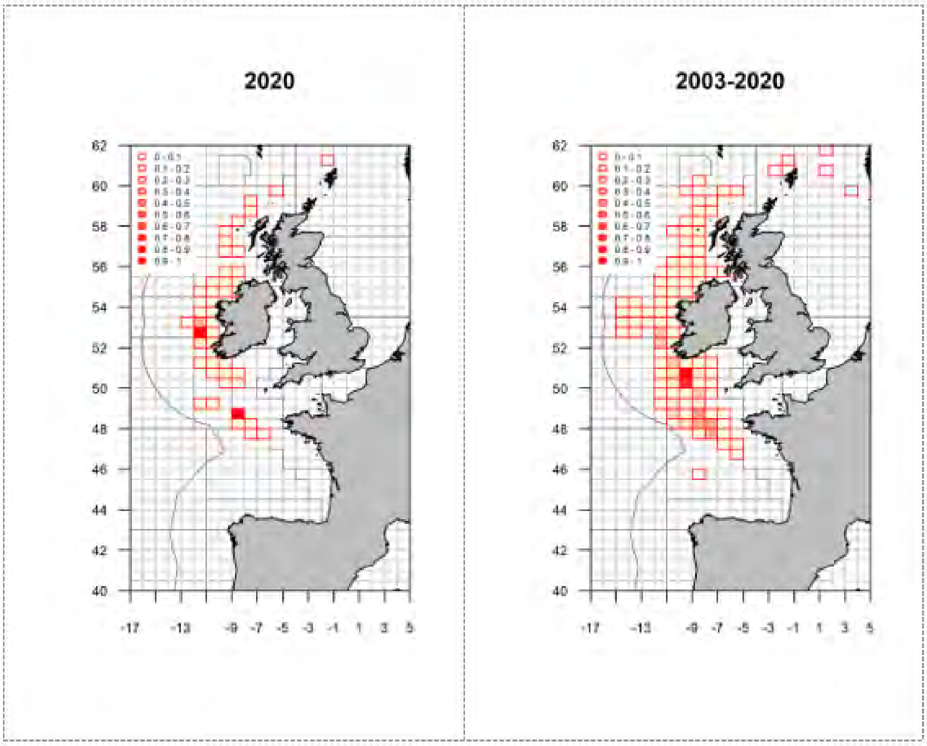


Figure 3.1.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Combined Irish boarfish landings 2003-2020 by ICES rectangle (Right). Irish boarfish landings 2020 by ICES rectangle (Left).

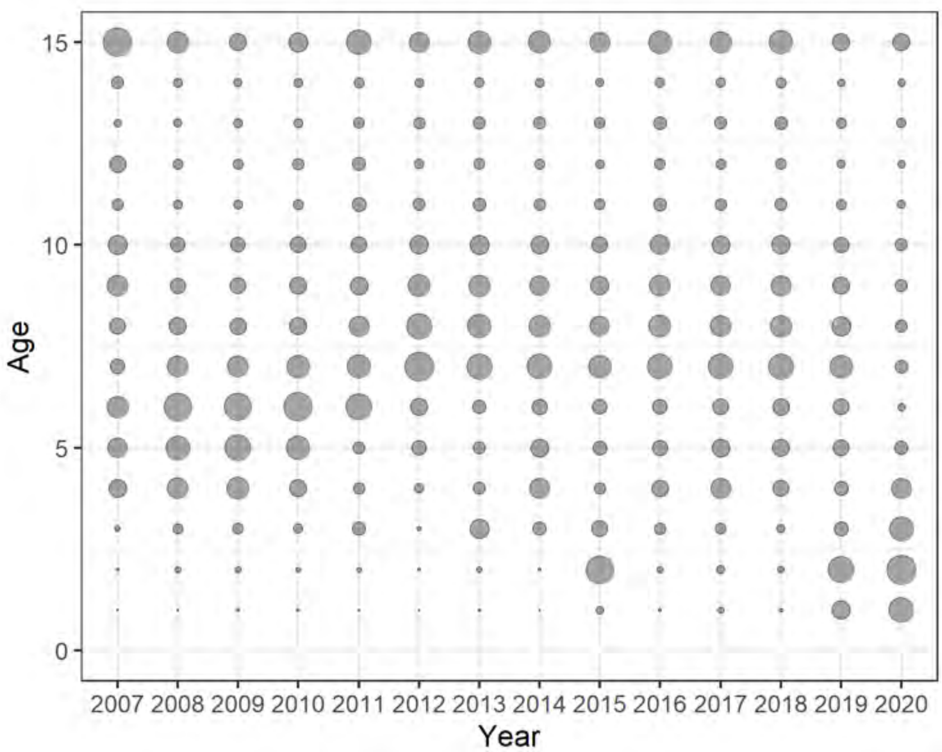


Figure 3.2.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Catch numbers-at-age standardised by yearly mean. 15+ is the plus group.

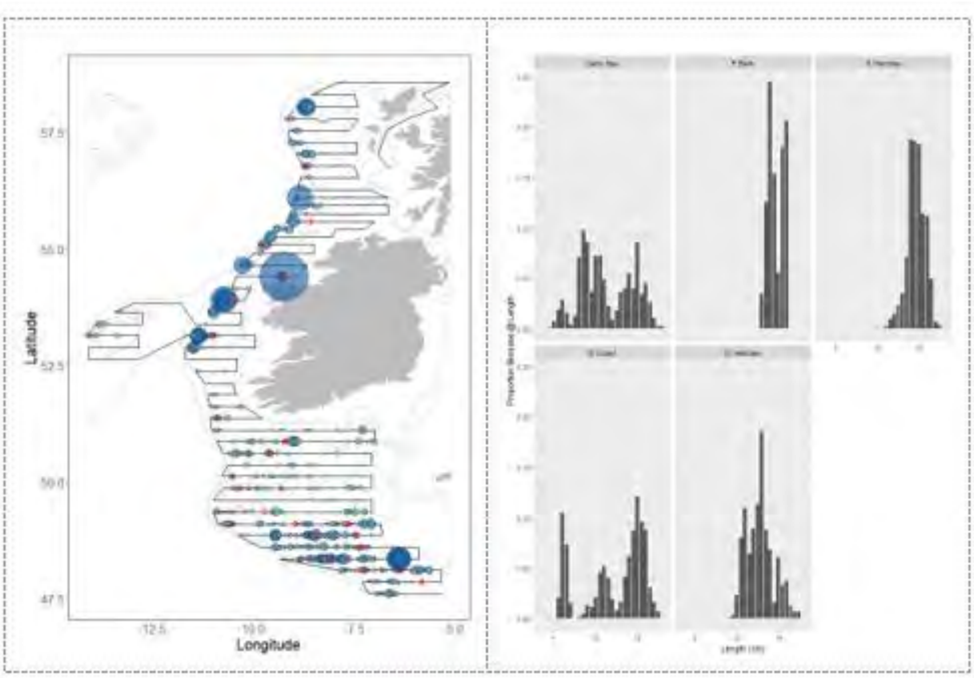


Figure 3.3.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey track and haul positions 2021 (left), estimates of biomass at length by stratum (right).

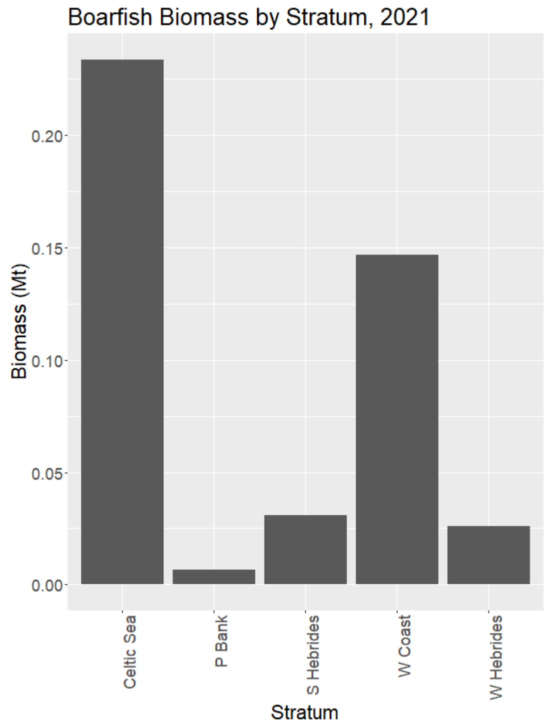


Figure 3.3.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey biomass estimate by stratum, 2021.

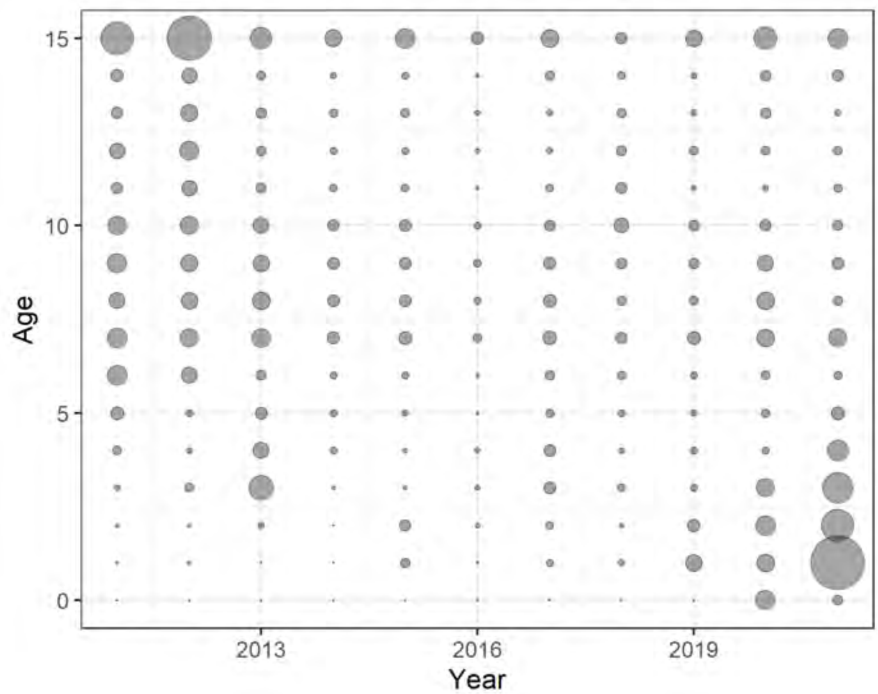


Figure 3.3.1.3. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey time series of acoustic estimates of abundance at age, 2011 - 2021.

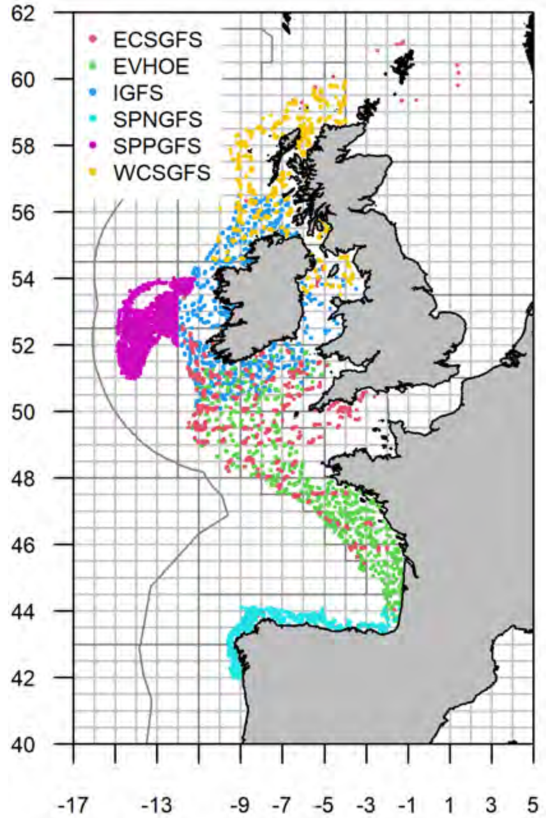


Figure 3.3.2.1. Boarfish in ICES Subareas 27.6, 7, 8. The haul positions of bottom trawl surveys analysed as an index for boarfish abundance.

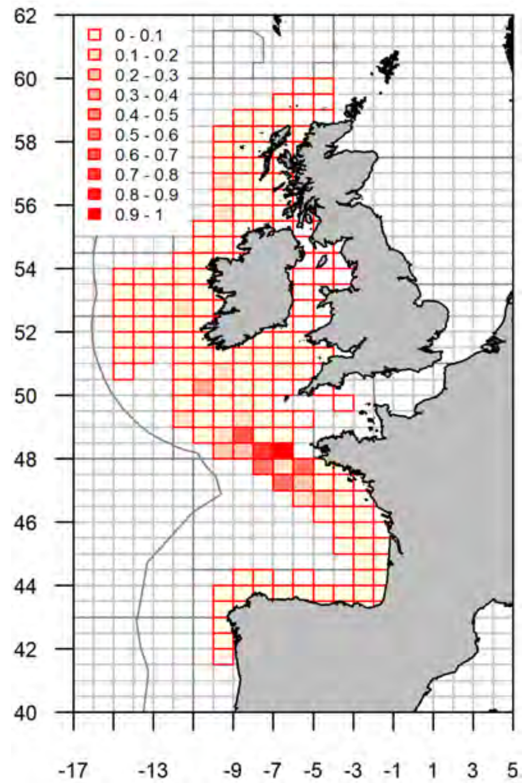


Figure 3.3.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Distribution of boarfish in the NE Atlantic from the 6 IBTS surveys.

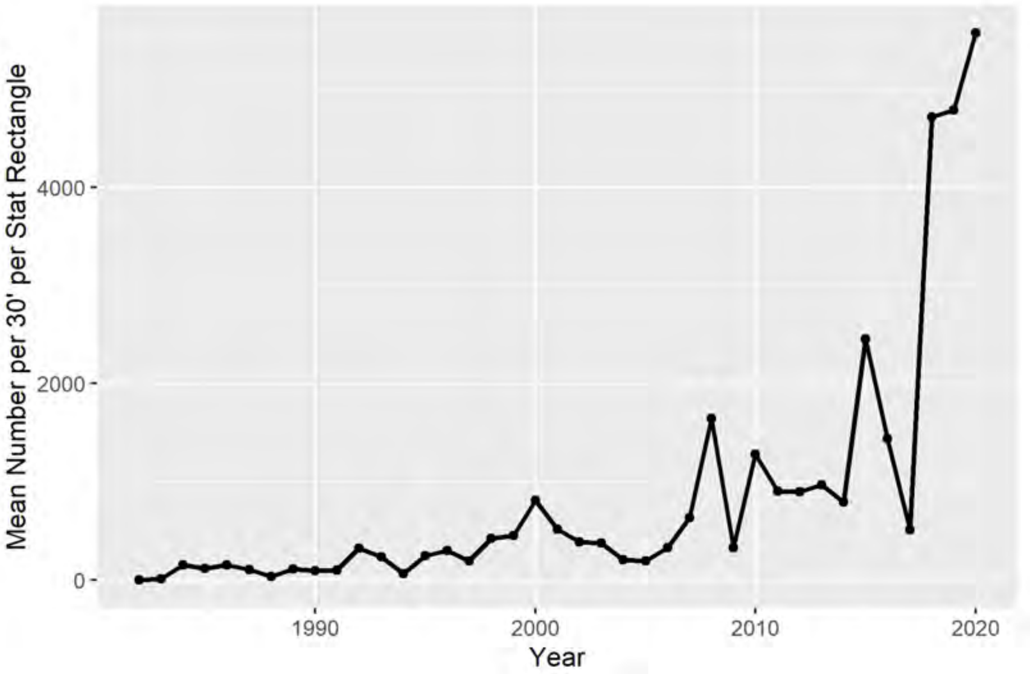


Figure 3.3.2.3a. Boarfish in ICES Subareas 27.6, 7, 8. CPUE in number per 30-minute haul of boarfish per rectangle in the western IBTS survey 1982 to 2020.

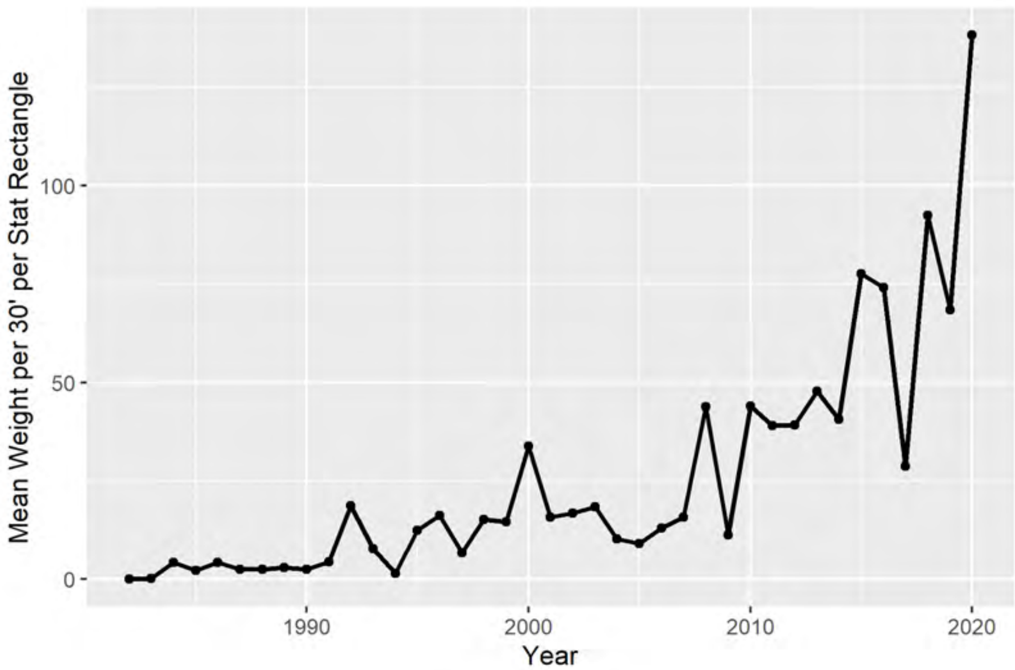


Figure 3.3.2.3b. Boarfish in ICES Subareas 27.6, 7, 8. CPUE in kg per 30-minute haul of boarfish per rectangle in the western IBTS survey 1982 to 2020.

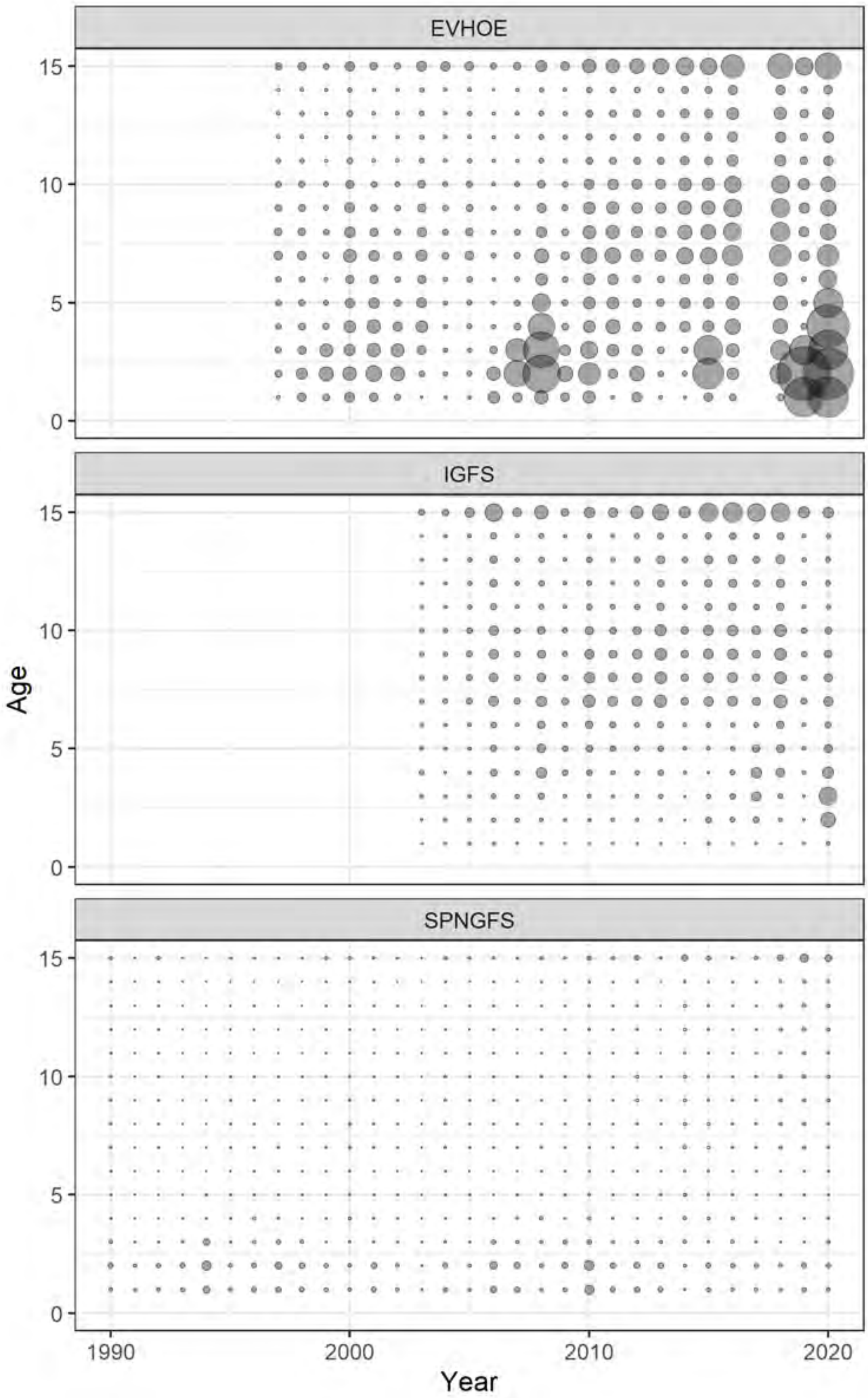


Figure 3.6.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Abundance-at-age in EVHOE, IGFS and SPNGFS surveys. Yearly mean standardised abundance –at-age.

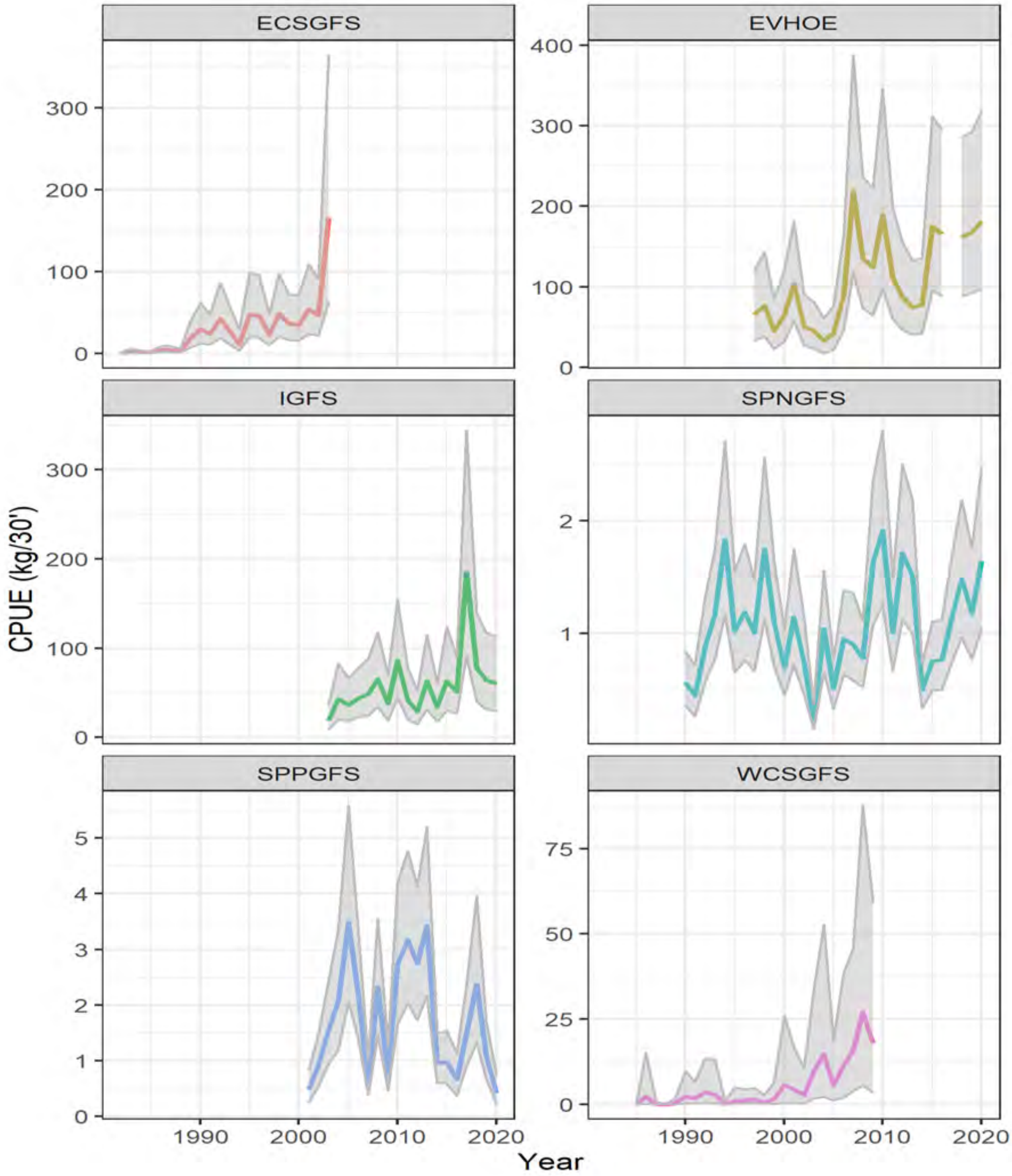


Figure 3.6.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish IBTS survey CPUE fitted delta-lognormal mean (solid line) and 95% credible intervals (grey region).

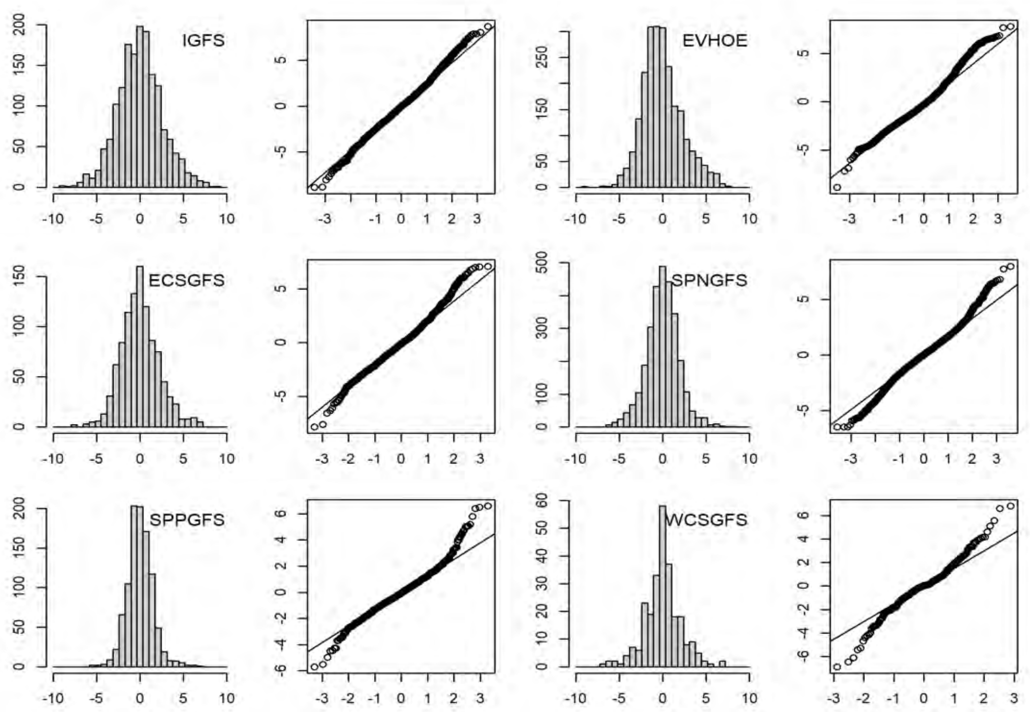


Figure 3.6.1.4. Boarfish in ICES Subareas 27.6, 7, 8. Diagnostics from the positive component of the delta-lognormal fits

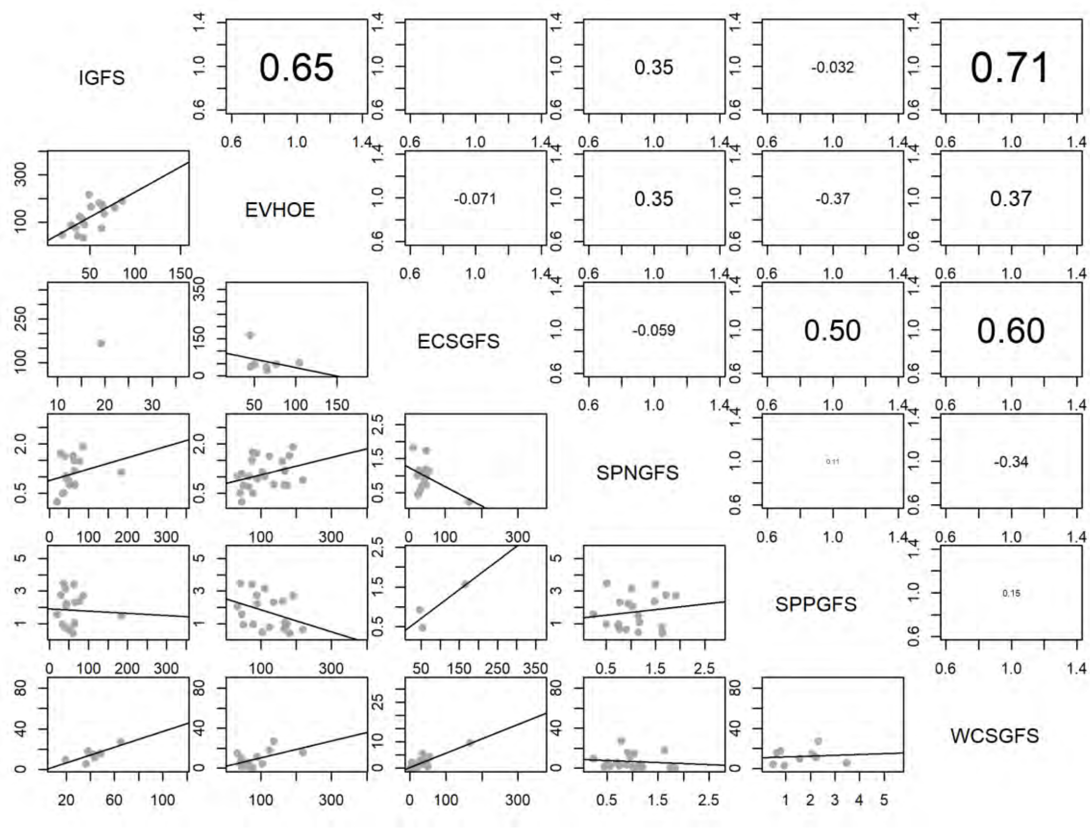


Figure 3.6.1.5. Boarfish in ICES Subareas 27.6, 7, 8. Pair-wise correlation between the annual mean survey indices.

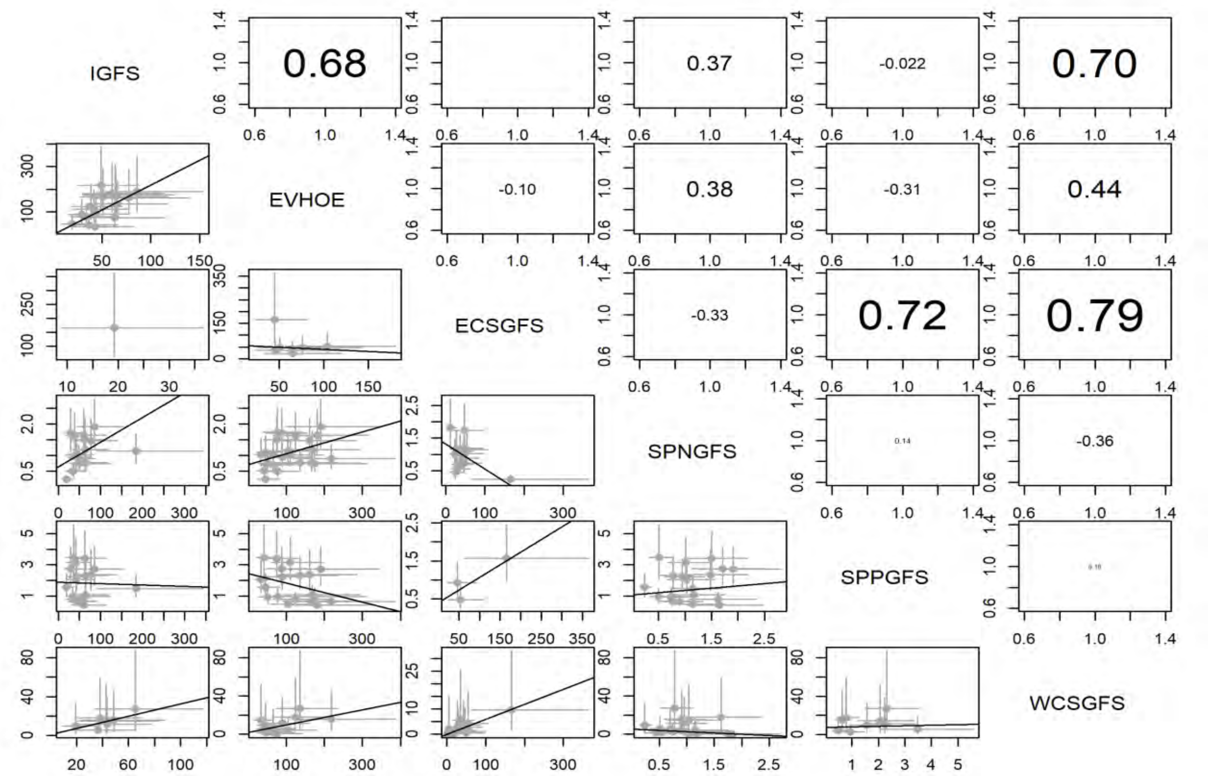


Figure 3.6.1.6. Boarfish in ICES Subareas 27.6, 7, 8. Weighted correlation between the annual mean survey indices. Correlations are weighted by the sum of the pair-wise variances.

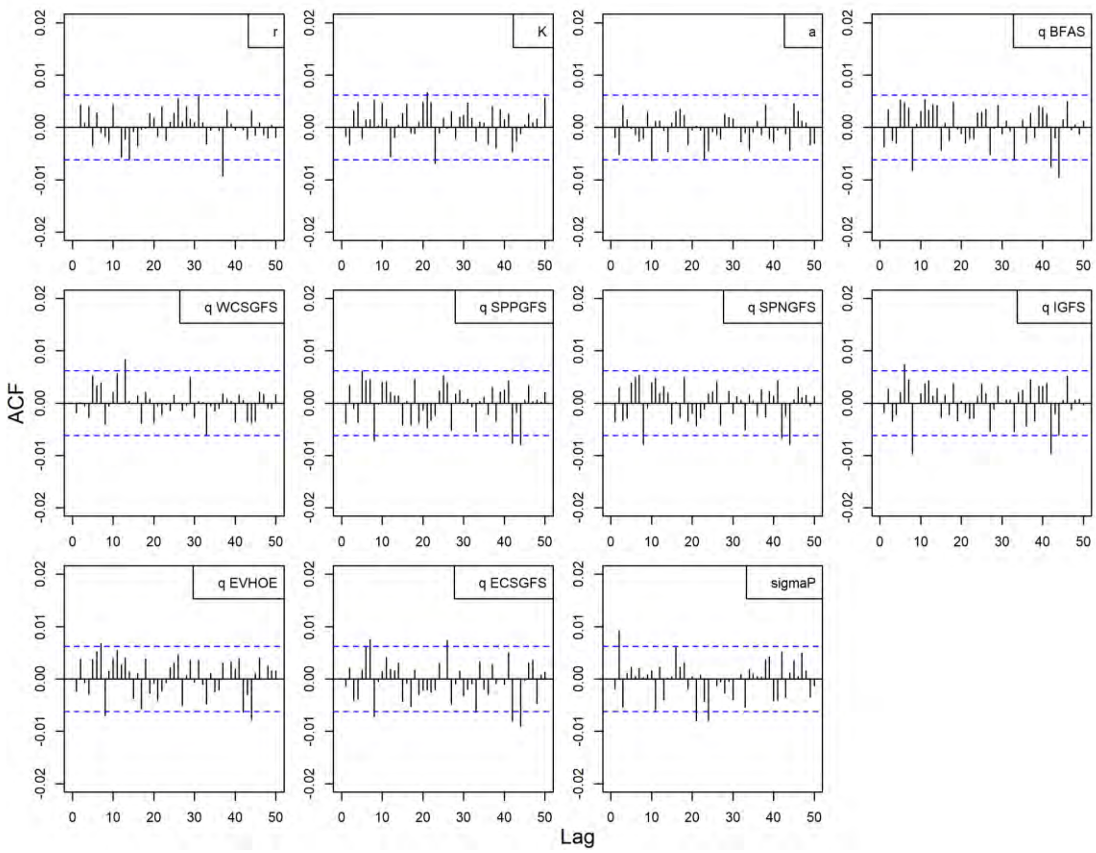


Figure 3.6.3.1. Boarfish in ICES Subareas 27.6, 7, 8. Parameters for final run converged with good mixing of the chains.

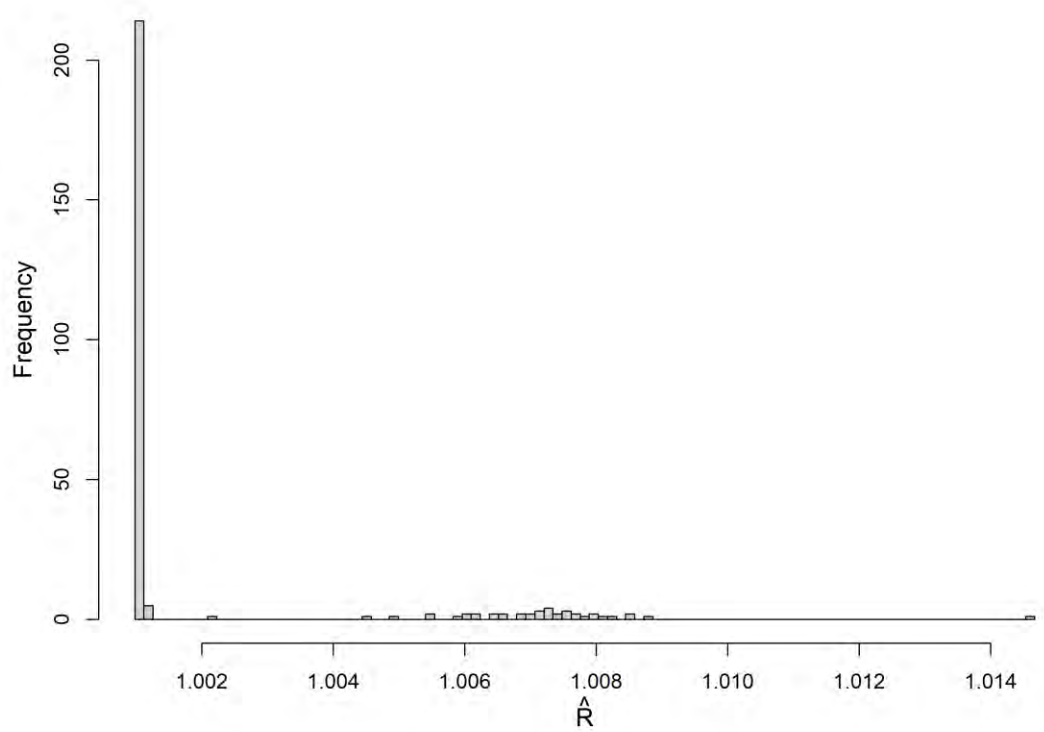


Figure 3.6.3.2. Boarfish in ICES Subareas 27.6, 7, 8. Rhat values lower than 1.01 indicating convergence.

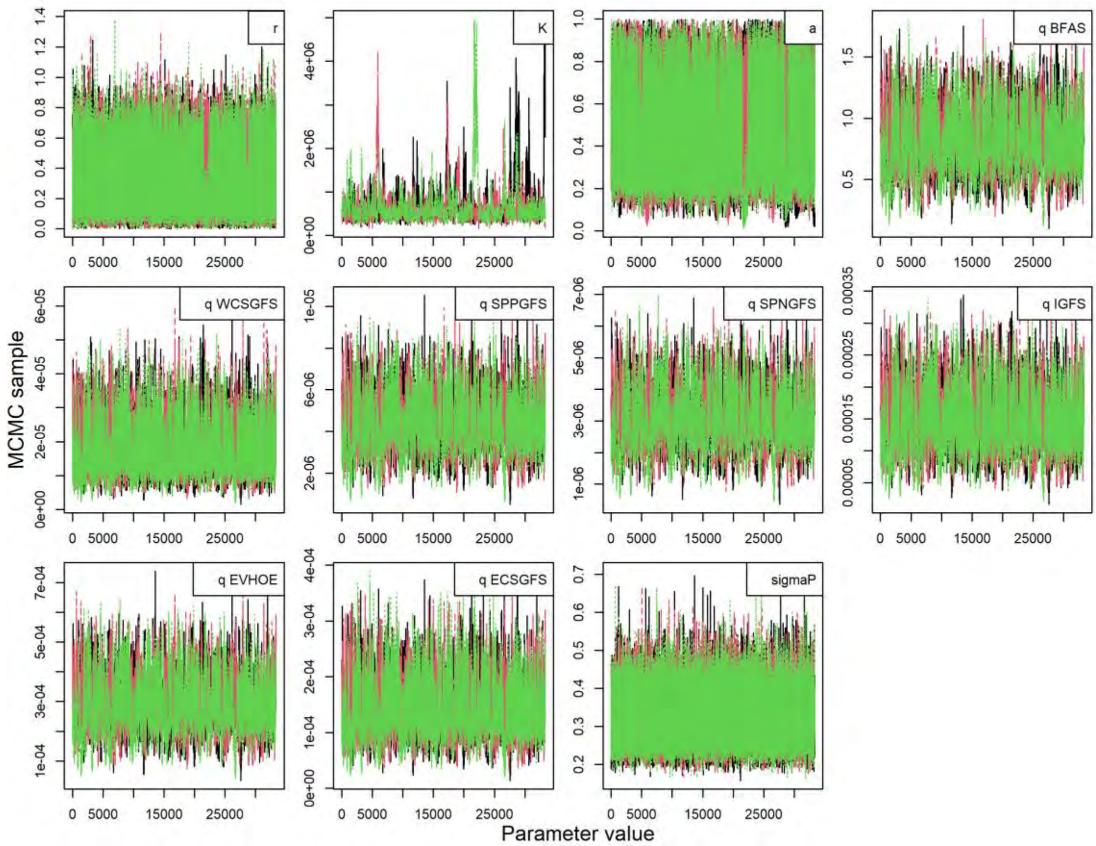


Figure 3.6.3.3. Boarfish in ICES Subareas 27.6, 7, 8. MCMC chain autocorrelation for final run.

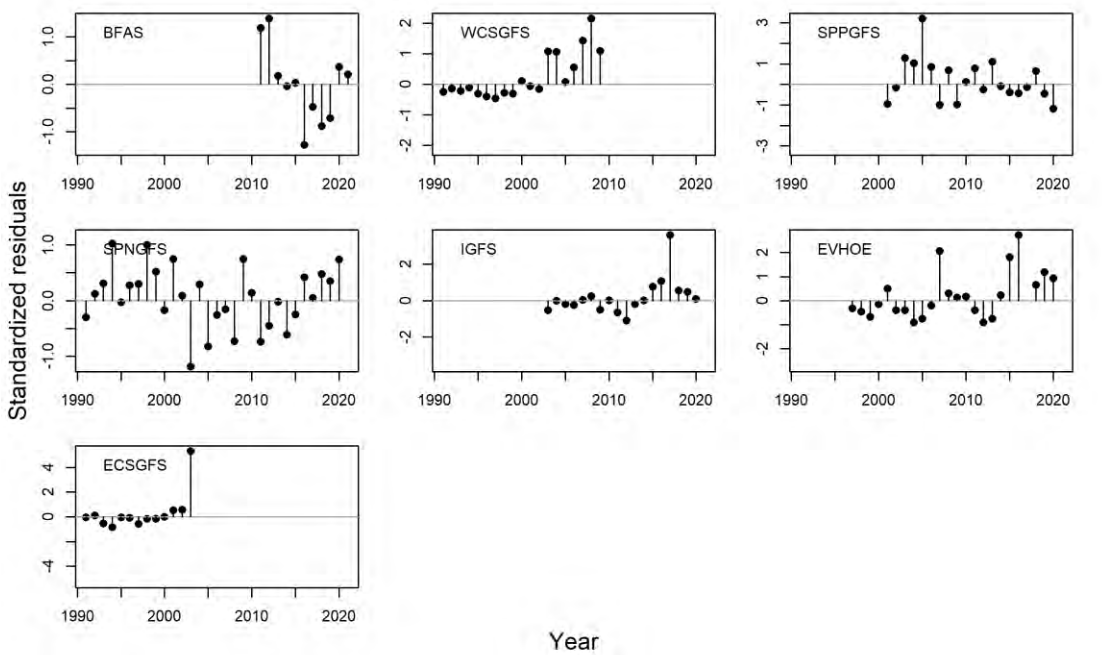


Figure 3.6.3.4. Boarfish in ICES Subareas 27.6, 7, 8. Residuals around the model fit for the final assessment run.

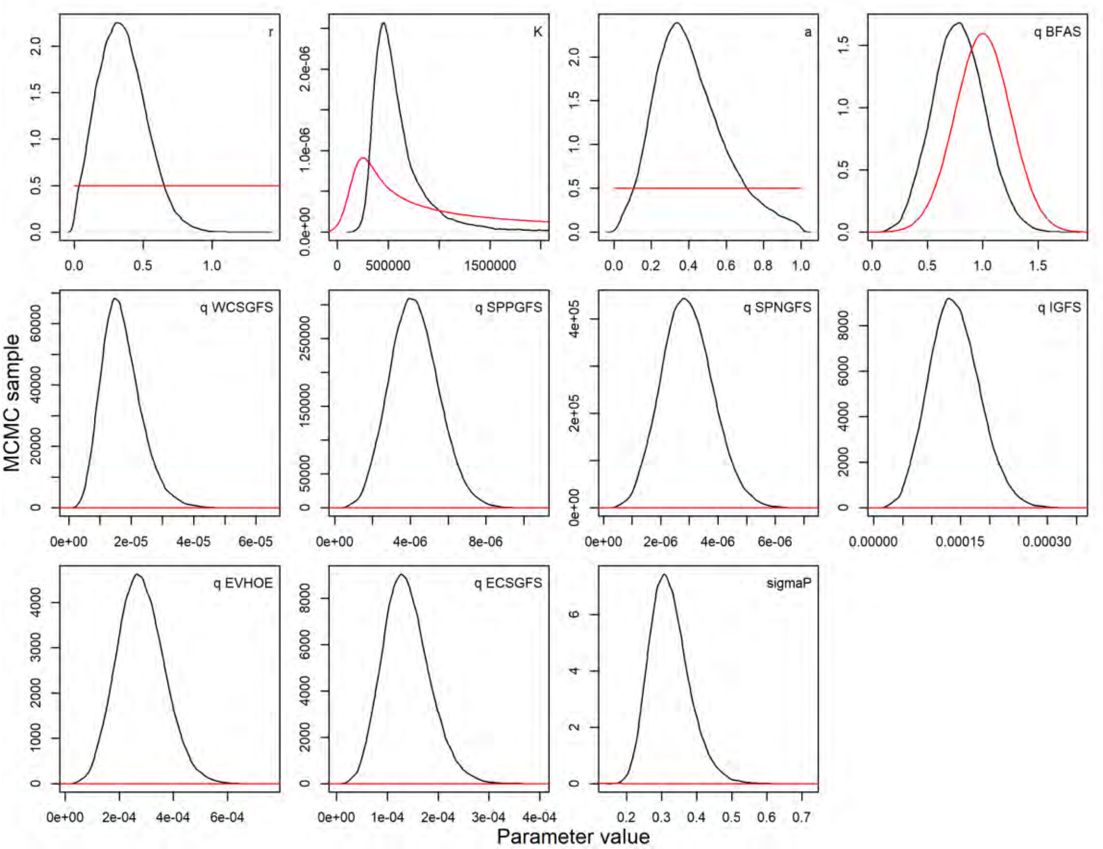


Figure 3.6.3.5. Boarfish in ICES Subareas 27.6, 7, 8. Prior (red) and posterior (black) distributions of the parameters of the biomass dynamic model.

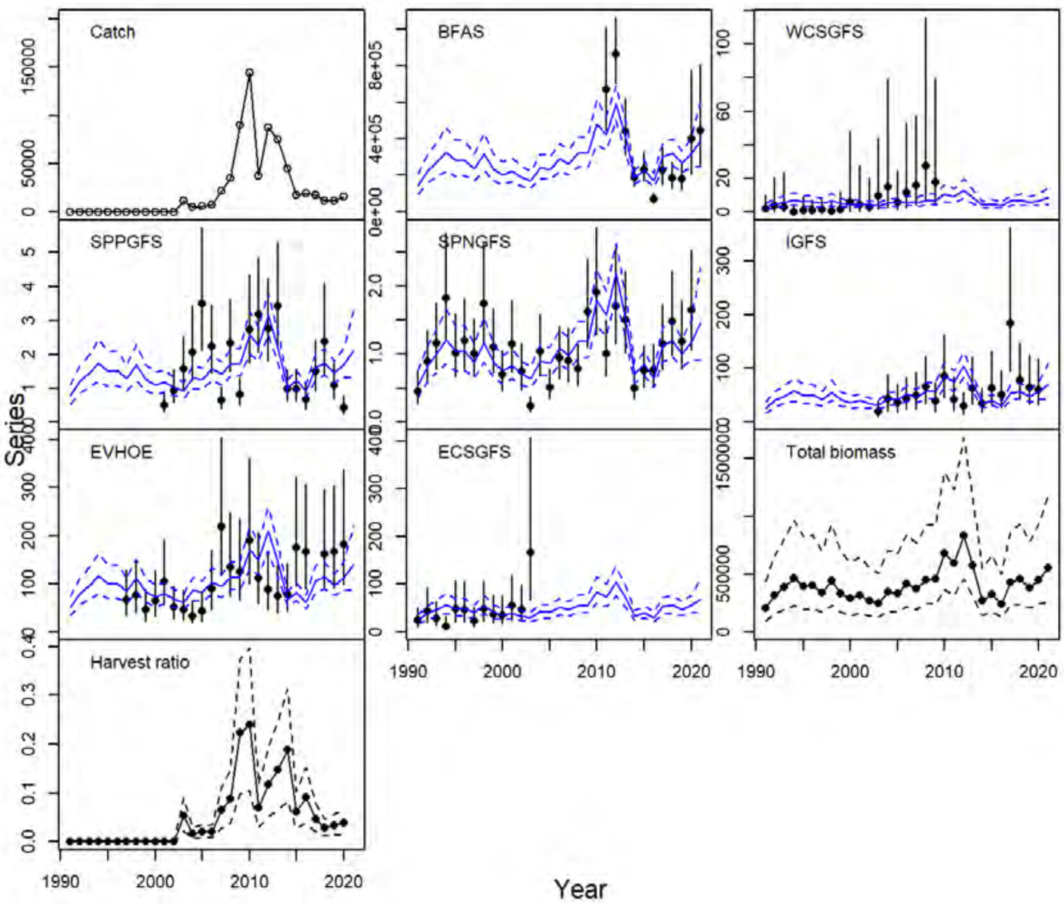


Figure 3.6.3.6. Boarfish in ICES Subareas 27.6, 7, 8. Trajectories of observed and expected indices for the final assessment run. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

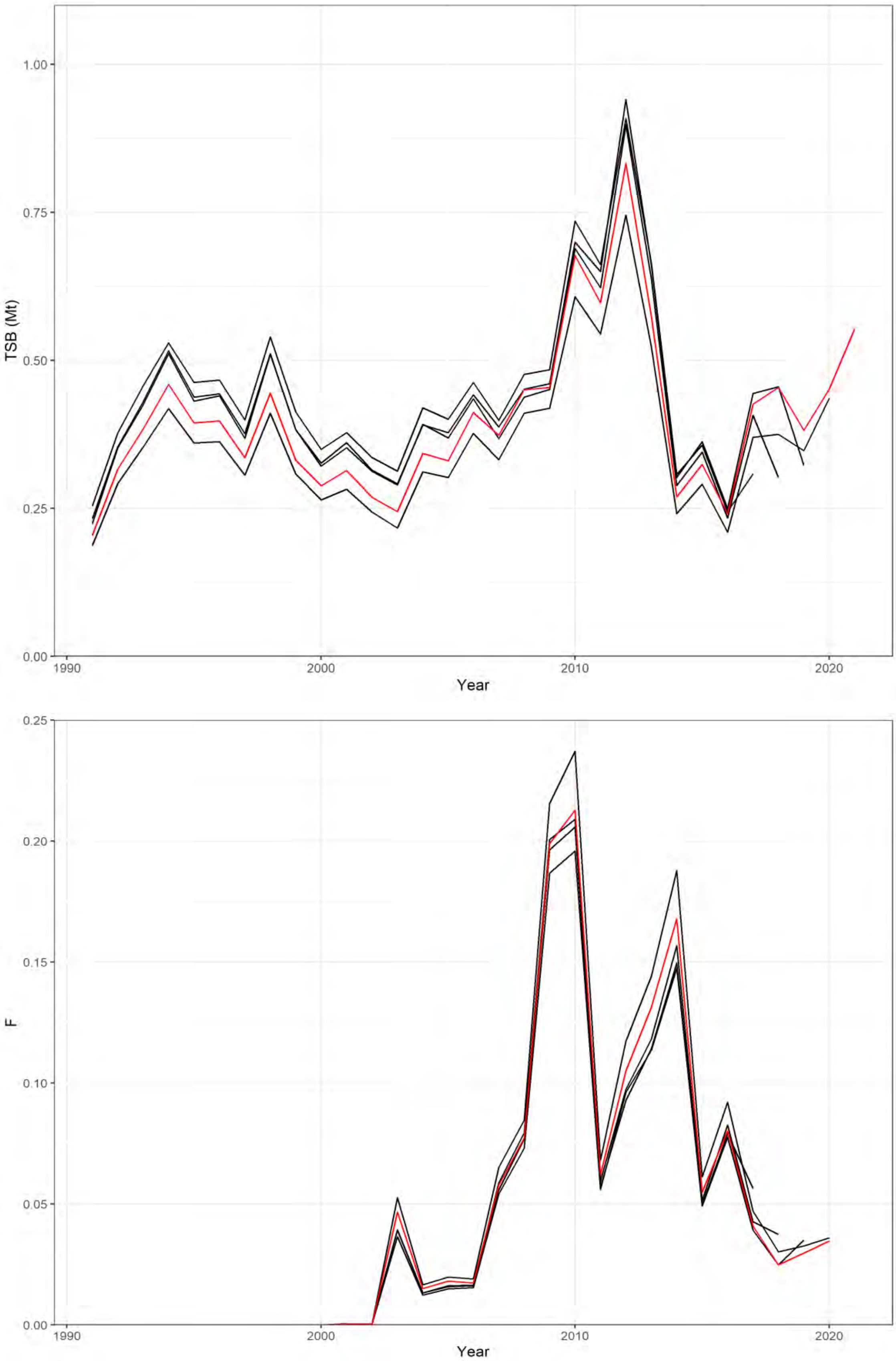


Figure 3.6.3.7. Boarfish in ICES Subareas 27.6, 7, 8. Retrospective plot of total stock biomass (above) and fishing mortality (below) from the surplus production model in 2013-2020.

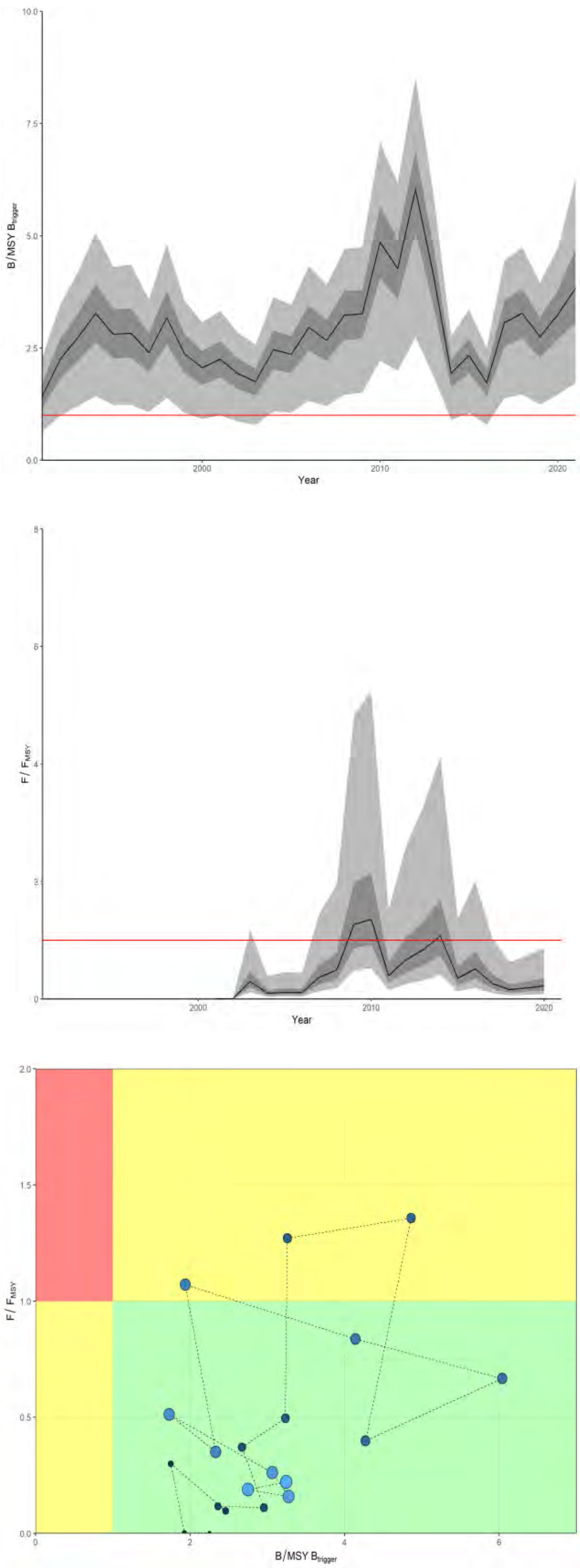


Figure 3.6.6.1. Boarfish in ICES Subareas 27.6, 7, 8. Ratios 'B / MSYBtrigger' and 'F / FMSY' through time and corresponding Kobe plot. Confidence intervals (50 and 95%) are given for the first two panels, the third displays median estimates only with the pink point representing the first point of the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

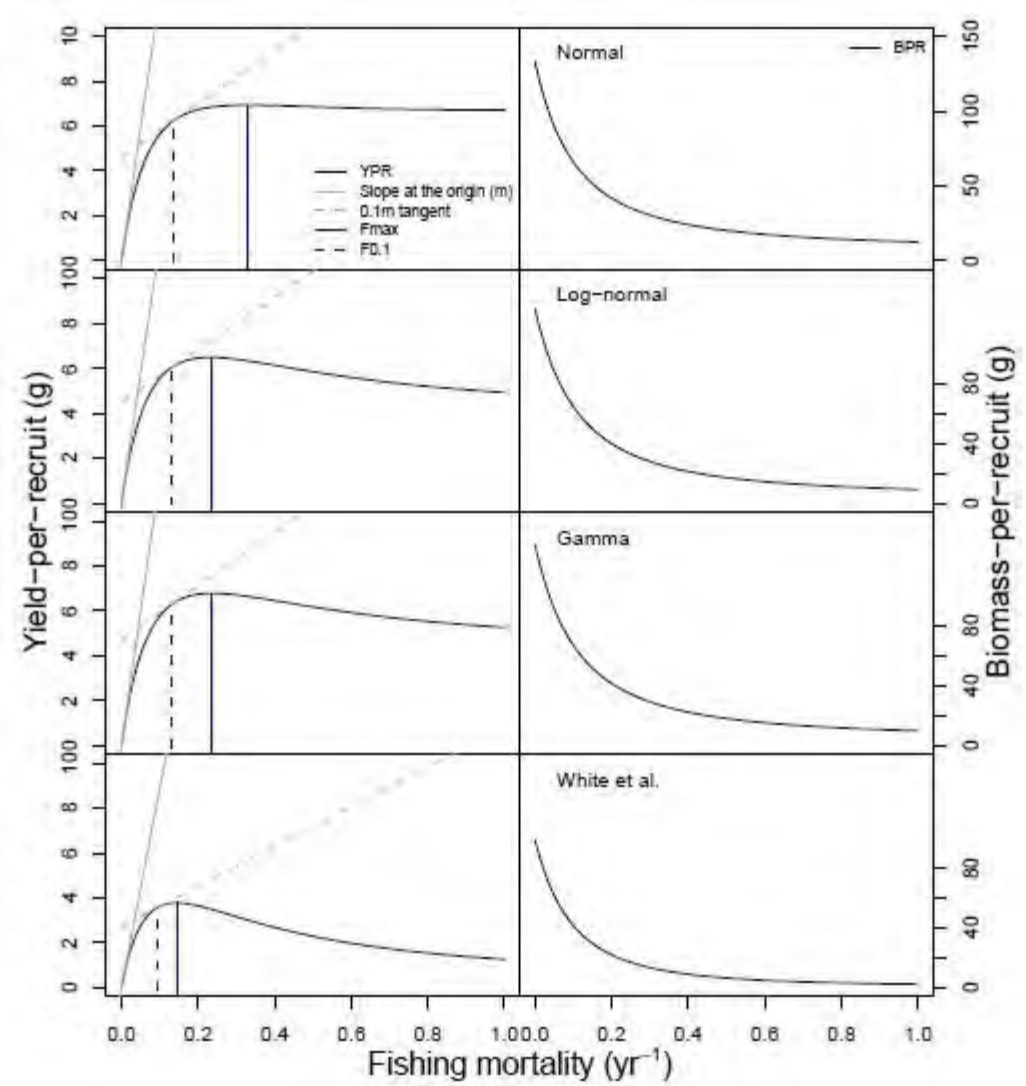


Figure 3.9.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White *et al*. 2011.

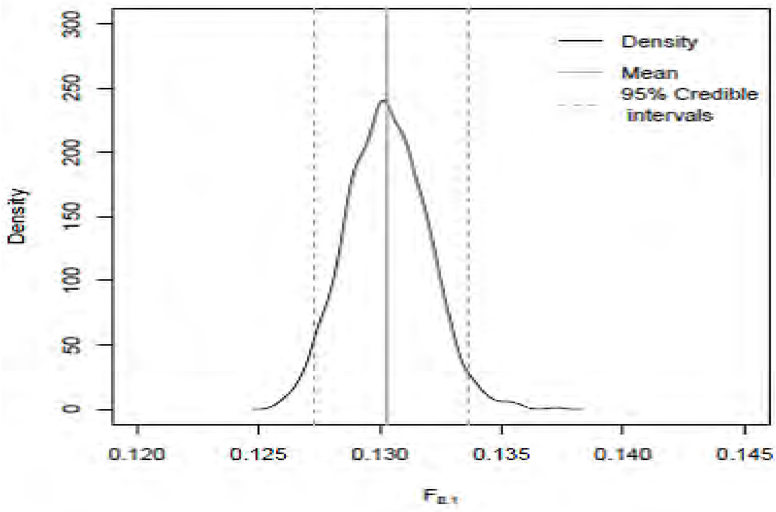


Figure 3.9.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Sensitivity of estimation of F0.1.

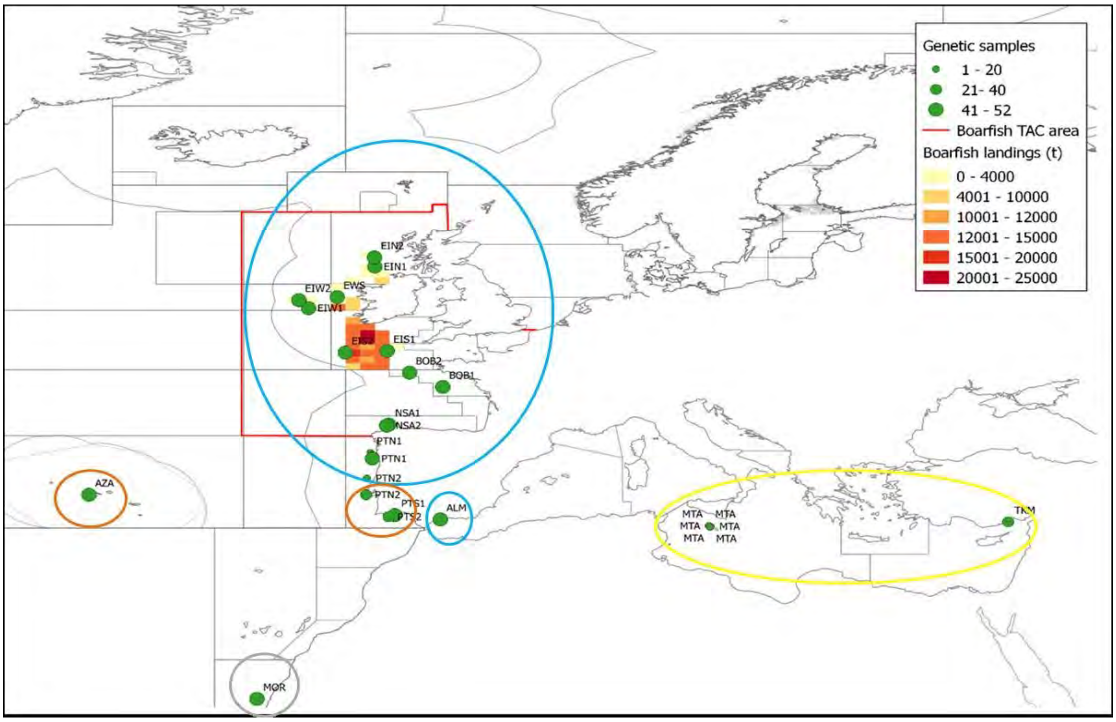


Figure 3.12.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish samples included in the genetic stock identification study are indicated in green. Population clusters identified by the STRUCTURE analyses are indicated by colour coded circles.

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

4.1 ICES advice in 2021

ICES advised that when the long-term management strategy agreed by the European Union, the Faroe Islands, Iceland, Norway, and the Russian Federation is applied, catches in 2021 should be no more than 651 033 tonnes. The advice for 2021 was 24% higher than that for 2020 due to an upward revision in the 2016 year class, which contributes more to the catches in 2021.

4.2 The fishery in 2021

4.2.1 Description and development of the fisheries

The distribution of the 2020 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 2020 herring fishing pattern was similar to recent years. The fishery began in January on the Norwegian shelf and focused on overwintering, prespawning, 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 moved into Faroese, Icelandic and International waters (Figure 4.2.1.2, quarter 3). In autumn and winter, the fishery continued in the central part of the Norwegian Sea but also commenced in the overwintering area in the fjords and oceanic areas off Lofoten. 59.5% of the catches were taken in the fourth quarter (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 95 322 tonnes in 2020, which represents 13% 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 of 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. The distribution in the feeding area in 2021 as observed in the ecosystem survey in May appeared to be similar to that of older year classes, although not quite as far west. 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. A similar pattern was observed during winter 2020/2021. The old fish wintered in the Norwegian Sea while part of the 2016 year class wintered in Kvænangen. From Norwegian catches during winter, it was, however observed that a large fraction of the 2016 year class wintered in the ocean further north (north of 70°N). The oldest and largest fish move farthest south and west during feeding, and the older year classes were in May through July 2021 concentrated in the southwestern 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 2020 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 2020 was 720 937 tonnes (Table 4.4.1.1) compared to the ICES-recommended catch of a maximum of 525 594 tonnes. The majority of the catches (82%) were taken in Division 2.a as in previous years. Samples were not provided by Greenland, The Netherlands, Poland, the UK or Sweden (less than 2% of the total catch were taken by these countries). Sampled catches accounted for 98% of the total catches, which is on a similar level as in previous years. The sampling levels of catches in 2020 in total, by country and by ICES Division are shown in Tables 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 herring. Although discarding may occur on this stock, it is considered to be low and a minor problem for the assessment. This is confirmed by estimates from sampling programmes carried out by some EU countries in the Data Collection Framework. Estimates of 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 year are shown in Table 4.4.3.1. The numbers are calculated using the SALLOC software. In 2020, catches (in numbers) were dominated by the 2013 (19%) and 2016 (24%) year classes.

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 2020 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 (ICES, 2010) decided to use average back-calculated maturity for “normal” and “big“ year classes 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 2021 the year 2016 was 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 assessment where several survey indices of this year class are included, and maturity-at-age 5 was set to 0.6 for this year class in the 2021 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:

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”). The Norwegian acous tic survey on the spawning grounds in February (“Fleet 1”)

The cruise reports from the IESNS (WD14) and spawning survey (WD08) in 2021 are available as working documents to this report. The spawning survey and IESNS in the Norwegian Sea and Barents Sea were both carried out successfully in 2021.

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 were 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 2010–2020 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 2015–2021, for Fleet 4 estimates of sampling errors are available for 2009–2019 and 2021, and for Fleet 5 for 2008–2021. Missing values for sampling variances are imputed using the Taylor function which provides good fits (R^2_{adj}'s are 0.95, 0.98 and 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 assessment took place in 2008 with the assessment tool TASACS selected as the standard assessment tool for the stock. A second benchmark took place in 2016 (WKPELA - 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 2021

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 2021 assessment, i.e. the catch prediction for

2021 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 of the fishery. It is important to note that this has marginal effect on the assessment, but larger effects on the prediction and short-term forecast.

The 2021 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), and a scaling constant common for all input data to allow additional variability of the input data that is not controlled by sampling is estimated. Additional details on the assessment 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 from ages 3–12+ with input data catch-at-age, Fleet 1 and Fleet 5, At WGWIDE 2016, it was decided to start the model at age 2 to allow short-term predictions with reasonable levels of variability. To achieve this, age 2 from Fleet 4, and age 2 in catch-at-age was 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.

The parameter estimates from the 2021 assessment 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 of the separable model for F) and σ_R^2 (variability of recruitment) are rather imprecise. The estimate of the scaling constant h is larger than 1, indicating 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 (variability of the separable model for F) and σ_2^2 (variability of the AR process for time varying selectivity) indicating little contrast in data for separating variability of 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 weaker 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. A 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 year 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 within the estimated levels of precision (Figure 4.5.1.7), and has a reasonably low Mohn's rho value of ~0.04 (Mohn, 1999; Brooks and Legault, 2016). Note that the retrospective patterns 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. A fairly good temporal match between the model estimate of SSB and the survey SSBs is seen, 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 2007 to 2009, then a decrease in 2020 before an increase in 2021. It is worth noting 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 2021 assessment results are shown in Figure 4.5.1.9. The estimate of fishing mortality for 2019 and 2020 is rather high, as a response to the high catch in both years with a point estimate of ~0.19. In 2018 the fishing mortality is estimated to be lower than in 2017 and 2019 (F=0.13). The spawning stock shows a declining trend since 2009 but an increase in 2021, and the 95% confidence interval of the stock level in 2021 ranges from ~3.060 to ~4.470 million tonnes with a point estimate of 3.765 which is 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 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 1988–2021. The model was run with catch data from 1988 to 2020, and projected forwards through 2021 assuming Fs in 2021 equal to those in 2020, to include survey data from 2021. 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 autumn survey in the Barents Sea) since this index was not updated by the survey group. This time-series (0-group) is currently being re-calculated.

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 and TISVPA in Figure 4.5.2.1.2. The time-series of SSB show similar trends for XSAM and TASACS, although SSB in recent years are higher in TASACS due to an upward revision in the 2021 TASACS assessment. For most of the years, the estimates from TASACS are within the confidence limits estimated by XSAM except for the assessment year 2021 where the SSB from TASACS is slightly above. The SSB on 1 January 2021 is estimated by TASACS to be 4.56 million tonnes.

4.5.2.2 TISVPA

The TISVPA model was applied using the catch-at-age data with age range from 0 to 15+ and data from three surveys (Surveys 1, 4 and 5). No data points were down-weighted. The two-parametric selection pattern used in the model in order to accommodate generation-dependent processes in entering the fishery revealed obvious peculiarities in the interaction between the stock and the fishery.

The results show the rise in SSB in 2021 to 5.1 million tonnes due to very abundant 2016 year class (see WD07) which this year at age 5 is better reveals in the catches than in younger ages.

The results from TISVPA are compared to those from XSAM and TASACS in Figure 4.5.2.1.2.

4.6 NSSH reference points

ICES last reviewed the reference points of Norwegian spring-spawning herring in April 2018 during WKNSSHREF (ICES, 2018a). ICES concluded that B_{lim} should remain unchanged at 2.5 million tonnes and MSY $B_{trigger} = B_{pa}$ was estimated at 3.184 million tonnes. F_{MSY} was estimated at the reference point workshop, but during the subsequent Management Strategy Evaluation WKNSSHMSE (ICES, 2018b) the fishing mortality reference points were revisited as issues were found with numerical instability and settings during the reference point workshop. F_{MSY} was re-estimated to be 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 and B_{pa} was estimated at 3.184 million tonnes. WKNSSHMSE estimated $F_{pa} = 0.227$. However, following recent ICES guidelines F_{pa} is now based on Fp05 which was estimated at 0.157 by WKNSSHMSE in 2018.

4.6.2 MSY reference points

The MSY reference points were evaluated by WKNSSHREF and WKNSSHMSE in 2018. In the ICES MSY framework B_{pa} 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 2021 is estimated by XSAM to be 3.765 million tonnes which is above B_{pa} (3.184 million t). The spawning stock has been declining since 2009 but increased in 2021. The SSB time-series from the 2021 assessment is consistent with the SSB time-series from the 2020 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 2021 assessment. Fishing mortality in 2020 is estimated to be 0.188 which is above the management strategy F (0.140) that was used to give advice for 2020. A new management strategy was implemented for the 2019 advisory year.

4.8 NSSH catch predictions for 2021

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. The catch weight-at-age, used in the forecast, is the average of the observed catch weights over the last 3 years (2018–2020).

For the weight-at-age in the stock, the values for 2021 were obtained from the commercial fisheries in the wintering areas in January. For the years 2022 and 2023 the average of the last 3 years (2019–2021) 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 (1988–2021) 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 2021. Therefore, to obtain an estimate of the total catch to be used as input for the catch-constraint projections for 2021, the sum of the unilateral quotas was used. In total, the expected outtake from the stock in 2021 amounts to 881 097 tonnes. F in 2021 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 881 097 tonnes is taken in 2021, it is expected that the SSB will increase from 3.765 million tonnes on 1 January in 2021 to 3.92 million tonnes in 2022. The weighted F over ages 5–12+ is 0.174. The model estimates the catch in 2022 to be dominated by three age groups, age 6 (44%), age 9 (13%), and age 12+ (13%).

4.9 Comparison with previous assessment

A comparison between the assessments 2008–2021 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 2020 and weighted F in 2019 as estimated in 2020 and 2021.

	ICES 2020	WG 2021	%difference
SSB (2020)	3315	3375	1.8%
Weighted F (2019)	0.191	0.186	−2.6%

4.10 Management plans and evaluations

The current management strategy for the Norwegian spring-spawning herring fishery was agreed 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 2020 is 1.8% higher in this year's assessment).

Historically, the size of the stock has shown large variations and dependence 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 2021 assessment and resulted in an increase in SSB from 2020 to 2021. SSB is, however, predicted to decrease in 2023 even if the management strategy (F=0.14) is applied in 2022.

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 strategy 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 in May 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, 2021a). 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, 2021b). 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.
- In general, the herring stock has had a more westerly feeding distribution (ICES, 2021a; 2021c) in the recent years than what was previously observed. The large 2016 year class included a more northeastern distribution than the older age classes in the stock in 2020, but in 2021 it was also widely distributed into the southwestern feeding area, although not as far west as the older herring. 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, 2021c).
- 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). There are studies showing mackerel being more effective feeder, which might indicate that the herring is forced to the southwestern and northeastern fringe of Norwegian Sea (ICES, 2021c). Alternatively, the higher zooplankton biomass in the southwest could also attract the herring in to this location, since zooplankton biomass is much lower in the northeast (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 (Allan *et al.*, 2021).
- The 2016 year class of herring was the strongest since the 2004 year class in the Norwegian Sea as 4 year old based on the IESNS survey 2020 but had decreased somewhat as 5 year olds in the IESNS survey 2021 (Table 4.4.7.3).
- In winter 2017/2018, the overwintering grounds shifted northward along the coast of Norway with older individuals occurring in oceanic areas. 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 5–8 years the annual progression of the fishery has changed into a pendular behaviour, starting in winter along the Norwegian coast, moving gradually to the west towards Iceland in summer, and then 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 increased again and have in the last four years been around 600 000–800 000 tonnes (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 north towards the Bear Island. Changes in migration have also resulted in late arrival at the Norwegian coast for this part of the stock (mostly older fish) during winter in recent years. In winter 2020/2021 the return migration was very late for parts of the adult migrating from the southwestern areas, as Faroese vessels fished on schools of prespawning herring in southern part of the international waters in mid-January 2021 and later in January Norwegian vessels targeted this herring further northeast. The Norwegian coastal fleet (smaller vessel that cannot go that far offshore) have therefore not been able to access this herring during winter fishery and targeted younger fish (mostly of the 2013 and in later years the 2016 year class) which overwintered in Norwegian fjords and close to the Norwegian coast in the north.

4.14 Recommendations

For some years there have been issues with age reading of herring. Last year, WGWIDE recommended to organize a scale/otolith exchange and workshop. This work appears to be in progress in WGIPS, WGBIOP and nationally at the institutes.

4.15 References

Aanes, S. 2016a. A statistical model for estimating fish stock parameters accounting for errors in data: Applications to data for Norwegian Spring-spawning herring. WD4 in ICES. 2016. Report of the Benchmark Workshop on Pelagic stocks (WKPELA), 29 February–4 March 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM 2016/ACOM:34. 106pp.

Aanes, S. 2016b. Diagnostics of models fits by XSAM to herring data. WD12 in ICES. 2016. Report of the Benchmark Workshop on Pelagic stocks (WKPELA), 29 February–4 March 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM 2016/ACOM:34. 106pp.

Aanes, S. 2016c. Forecasting stock parameters of Norwegian spring spawning herring using XSAM. WD at WGWIDE in 2016.

Allan, B.J.M., Ray, J.L., Tiedemann, M., Komyakova, V., Vikebø, F., Skaar, K.S. Stiasny, M.H., Folkvord, A., Nash, R.D.M., Stenevik, E.K. and Kjesbu, O.S. 2021. Quantitative molecular detection of larval Atlantic herring (Clupea harengus) in stomach contents of Atlantic mackerel (Scomber scombrus) marks regions of predation pressure. Scientific Reports, 11(1): 5095. https://doi.org/10.1038/s41598-021-84545-7

Bachiller E., Skaret G., Nøttestad L., and Slotte A. 2016. Feeding Ecology of Northeast Atlantic Mackerel, Norwegian Spring-Spawning Herring and Blue Whiting in the Norwegian Sea. PlosONE 11(2): e0149238. doi:10.1371/journal.pone.0149238.

Bachiller E., Utne K. R., Jansen T., and Huse G. 2018. Bioenergetics modeling of the annual consumption of zooplankton by pelagic fish feeding in the Northeast Atlantic. PlosONE 13(1): e0190345. https://doi.org/10.1371/journal.pone.0190345

Brooks, E.N. and Legault, C.M. 2016. Retrospective forecasting — evaluating performance of stock projections in New England groundfish stocks. Canadian Journal of Fisheries and Aquatic Sciences 73: 935–950.

Debes, H., Homrum, E., Jacobsen, J. A., Hátún, H., and Danielsen, J. 2012. The feeding ecology of pelagic fish in the southwestern Norwegian Sea – Inter species food competition between herring (Clupea harengus) and mackerel (Scomber scombrus). ICES CM 2012/M:07. 19 pp.

Engelhard, G.H., Dieckmann, U and Godø, O.R. 2003. Age at maturation predicted from routine scale measurements in Norwegian spring-spawning herring (Clupea harengus) using discriminant and neural network analyses. ICES Journal of Marine Science, 60: 304–313.

Engelhard, G.H. and Heino, M. 2004. Maturity changes in Norwegian spring-spawning herring before, during, and after a major population collapse. Fisheries Research, 66: 299-310.

Harvey, A.C. 1990. Forecasting, structural time-series models and the Kalman Filter. Cambridge University Press. ISBN 0 521 40573 4.

Hirst, D., Storvik, G., Rognebakke, H., Aldrin, M., Aanes, S., and Volstad, J.H. 2012. A Bayesian modelling framework for the estimation of catch-at-age of commercially harvested fish species. Can. J. Fish. Aquat. Sci. 69(12): 2064– 2076.

ICES 1998. Northern Pelagic and Blue Whiting Fisheries Working Group, ICES CM 1998/ACFM:18

ICES. 2008. Report of the Working Group on Widely Distributed Stocks (WGWIDE). 2-11 September 2008, ICES Headquarters Copenhagen. ICES CM 2008/ACOM:13: 691pp.

ICES. 2010a. Report of the Workshop on estimation of maturity ogive in Norwegian spring-spawning herring (WKHERMAT), 1–3 March 2010, Bergen, Norway. ICES CM 2010/ACOM:51. 47 pp

ICES. 2010b. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 28 August –3 September 2010, Vigo, Spain. ICES CM 2010/ACOM:12.

ICES. 2016, Report of the benchmark workshop on pelagic stocks (WKPELA). 29 February – 4 March 2016, ICES Headquarters Copenhagen. ICES CM 2016/ACOM:34.

ICES. 2017. Report of the Working Group on Inter-benchmark Protocol on Northeast Arctic Cod (2017), 4–6 April 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:29. 236 pp.

ICES. 2018a. Report of the Workshop on the determination of reference points for Norwegian Spring Spawning Herring (WKNSSHREF), 10–11 April 2018, ICES Headquarters, Copenhagen, Denmark. ICES CM 2018/ACOM:45. 83 pp.

ICES. 2018b. Report of the Workshop on a long-term management strategy for Norwegian Spring-spawning herring (WKNSSHMSE), 26-27 August 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM: 53. 108 pp.

ICES. 2021a. International ecosystem survey in the Nordic Sea (IESNS) in May to June 2021. WD14 to Working Group on International Pelagic Surveys (WGIPS) and Working Group on Widely distributed Stocks (WGWIDE) WebEx-meeting, 25.-31. August 2021. 30 pp.

ICES. 2021b. Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR; outputs from 2020 meeting). ICES Scientific Reports. 3:35. 114 pp. https://doi.org/10.17895/ices.pub.8021

ICES. 2021c. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS), 1 July – 4 August 2021. WD09 to ICES Working Group on Widely Distributed Stocks (WGWIDE), WebEx-meeting 25-31 August 2021. 60 pp.

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019, 10:1523–1528.

Langøy, H., Nøttestad, L., Skaret, G., Broms, C. and Fernö, A. 2012. Overlap in distribution and diets of Atlantic mackerel (Scomber scombrus), Norwegian spring- spawning herring (Clupea harengus) and blue whiting (Micromesistius poutassou) in the Norwegian Sea during late summer. Marine biology research, 8: 442—460.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES Journal of Marine Science 56: 473–488.

Óskarsson, G.J., A. Gudmundsdottir, S. Sveinbjörnsson and Þ. Sigurðsson 2016. Feeding ecology of mackerel and dietary overlap with herring in Icelandic Waters. Marine Biology Research, 12: 16-29.

Salthaug, A. and Aanes, S. 2015. Estimating the Norwegian catch-at-age of blue whiting, mackerel, North Sea herring and Norwegian spring-spawning herring with the ECA model. Working document in the Report of the working group on widely distributed stocks (WGWIDE). ICES CM 2015 / ACOM:15.

Skaret G., Bachiller E., Langøy H., Stenevik, E.K. 2015. Mackerel predation on herring larvae during summer feeding in the Norwegian Sea. ICES Journal of Marine Science 72(8), 2313-2321. doi:10.1093/icesjms/fsv087

4.16 Tables and figures

Table 4.4.1.1 Total landings (ICES estimate) of Norwegian spring-spawning herring (tonnes) 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	DEN-MARK	FAROES	ICELAND	IRELAND	NETHER-LANDS	GREEN-LAND	UK	GER-MANY	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	DEN-MARK	FAROES	ICELAND	IRELAND	NETHER-LANDS	GREEN-LAND	UK	GER-MANY	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**
2020	409436	74936	16523	103029	98173	2704	5060	3546	143	2969	0	1352	3065	**720937**

***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

YEAR	TOTAL CATCH	% CATCH COVERED BY SAMPLING PROGRAMME	NO. SAMPLES	NO. MEASURED	NO. AGED
2017	721566	95	335	31755	7241
2018	592899	97	253	22106	6047
2019	777165	97	361	29856	7421
2020	720937	98	232	34232	6742

Table 4.4.1.3 Norwegian spring-spawning herring. Sampling coverage by country in 2020.

COUNTRY	OFFICIAL CATCH	% CATCH COVERED BY SAMPLING PROGRAMME	NO. SAMPLES	NO. MEASURED	NO. AGED
Denmark	16523	100	13	1202	394
Faroe Islands	103029	100	14	791	715
Germany	2969	99	8	502	279
Greenland	3546	0	0	0	0
Iceland	98173	100	68	1880	1554
Ireland	2704	94	2	191	120
The Netherlands	5060	0	0	0	0
Norway	409436	100	103	2537	2537
Poland	1352	0	0	0	0
UK_Scotland	143	0	0	0	0
Sweden	3065	0	0	0	0

COUNTRY	OFFICIAL CATCH	% CATCH COVERED BY SAMPLING PROGRAMME	NO. SAMPLES	NO. MEASURED	NO. AGED
Russia	74936	99	24	27129	1143
Total for Stock	**720937**	**98**	**232**	**34232**	**6742**

Table 4.4.1.4 Norwegian spring-spawning herring. Sampling coverage by ICES Division in 2020.

AREA	OFFICIAL CATCH	NO SAMPLES	NO AGED	NO MEASURED	NO AGED/ 1000 TONNES	NO MEASURED/ 1000 TONNES
2.a	592854	174	5343	32776	9	55
4.a	88	0	0	0	0	0
5.a	127716	58	1399	1456	11	11
5.b	279	0	0	0	0	0
Total	**720937**	**232**	**6742**	**34232**	**9**	**47**

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	IIa	174202.4	
2	Norway	2	IIa	222.3	1
3	Norway	3	IIa	8294.6	
4	Norway	4	IIa	226628.8	
5	Norway	4	IVa	88.3	4
6	Iceland	3	IIa	5532	

Line	Country	Quarter	Div.	Catch (T)	Samples allocated (line)
7	Iceland	4	IIa	380	
8	Iceland	3	Va	62253	
9	Iceland	4	Va	30008	
10	Russia	1	IIa	529	1,22
11	Russia	2	IIa	80	
12	Russia	3	IIa	8590	
13	Russia	4	IIa	65682	
14	Russia	2	Vb	5	11
15	Russia	3	Vb	50	12
16	Faroe Islands	3	IIa	16030.946	
17	Faroe Islands	4	IIa	51321.124	
18	Faroe Islands	3	Va	4580.651	
19	Faroe Islands	4	Va	30874.658	
20	Faroe Islands	2	Vb	73.484	16,18
21	Faroe Islands	4	Vb	148.268	17,19
22	Denmark	1	IIa	8629.27	
23	Denmark	4	IIa	7894.151	
24	Netherlands	4	IIa	5059.77	4,7,13,17,23,32,34

Line	Country	Quarter	Div.	Catch (T)	Samples allocated (line)
25	Greenland	3	IIa	614	3,6,12,16,31
26	Greenland	4	IIa	2930	4,7,13,17,23,32,34
27	Greenland	2	Vb	2	11
28	Sweden	1	IIa	2865	1,22
29	Sweden	4	IIa	200	4,7,13,17,23,32,34
30	Germany	2	IIa	26.335	31
31	Germany	3	IIa	64.492	
32	Germany	4	IIa	2878.404	
33	Ireland	1	IIa	163.76	1,22
34	Ireland	4	IIa	2539.783	
35	Poland	4	IIa	1352.055	4,7,13,17,23,32,34
36	Scotland	1	IIa	143.357	1,22

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

	AGE															
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
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

	AGE														
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
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

	AGE															
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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
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

	AGE														
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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
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
2020	0	1299	8252	49455	544337	70633	150932	412498	118081	156696	94975	188852	100408	96557	132619	103350

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

	AGE														
YEAR	**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
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

	AGE															
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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						
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					

	AGE															
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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		
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

	AGE														
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
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

	AGE														
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
2020		0.131	0.170	0.204	0.236	0.274	0.306	0.317	0.342	0.358	0.374	0.395	0.402	0.408	0.415	0.444

Table 4.4.4.2. Norwegian spring spawning herring. Weight at age in the stock (kg).

	AGE															
YEAR	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
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

YEAR	AGE 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
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

	AGE															
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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
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

	AGE														
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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
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

	AGE															
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
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
2021	0.001	0.01	0.054	0.104	0.160	0.209	0.266	0.284	0.302	0.325	0.352	0.366	0.384	0.376	0.404	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

YEAR/AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
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

YEAR/AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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

YEAR/AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
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	0.1	0.5	0.9	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
2021	0	0	0	0	0.4	0.6	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**
2021	21	112	293	10210	733	738	1932	427	451	312	219	395	208	1153	**17250**	**4021**

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 2009–2021 are estimated with StoX (mean of bootstrap with 1000 iterations). "Fleet 4".

	AGE				
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

	AGE				
YEAR	**1**	**2**	**3**	**4**	**5**
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
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***					
2021	0.021	0.002	0.086	0.002	

***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 2008–2021 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**
2021	15	34	1109	1290	11906	698	1051	2039	501	551	476	462	442	615	1515	**22984**	**5096**

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	0.359	0.192	0.259	0.095	0.355	0.482	0.412	0.309	0.363	0.526	0.373
1989	0.259	0.521	0.484	0.420	0.113	0.491	0.790	0.833	0.499	0.663	0.682
1990	0.302	0.285	0.536	0.330	0.340	0.127	0.677	0.642	0.584	0.552	0.598
1991	0.498	0.368	0.528	0.658	0.308	0.363	0.128	0.546	0.944	1.620	0.632
1992	0.669	0.324	0.237	0.437	0.694	0.329	0.417	0.127	0.548	0.850	0.647
1993	0.387	0.249	0.162	0.173	0.366	0.483	0.245	0.285	0.105	NA	NA
1994	0.373	0.238	0.160	0.109	0.141	0.302	0.373	0.228	0.231	0.090	0.424
1995	0.706	0.198	0.111	0.092	0.091	0.126	0.303	0.300	0.186	0.175	0.081
1996	0.244	0.234	0.088	0.068	0.080	0.105	0.164	0.419	0.385	0.189	0.083
1997	0.271	0.152	0.120	0.065	0.063	0.086	0.113	0.194	0.279	0.238	0.100
1998	0.176	0.185	0.124	0.108	0.065	0.073	0.107	0.152	0.218	0.258	0.126
1999	0.436	0.149	0.231	0.150	0.103	0.067	0.075	0.117	0.162	0.309	0.132
2000	0.310	0.175	0.095	0.233	0.160	0.105	0.072	0.077	0.129	0.184	0.150
2001	0.580	0.164	0.142	0.103	0.225	0.168	0.116	0.083	0.098	0.183	0.204
2002	0.193	0.133	0.091	0.122	0.113	0.245	0.169	0.121	0.090	0.111	0.176
2003	0.451	0.181	0.113	0.087	0.138	0.140	0.267	0.182	0.129	0.094	0.120
2004	0.216	0.262	0.170	0.103	0.088	0.160	0.149	0.254	0.204	0.140	0.090
2005	0.277	0.102	0.169	0.139	0.091	0.080	0.155	0.155	0.226	0.190	0.091
2006	0.214	0.181	0.087	0.176	0.139	0.087	0.085	0.172	0.180	0.243	0.107
2007	0.368	0.127	0.109	0.065	0.144	0.124	0.087	0.098	0.211	0.258	0.141
2008	0.154	0.229	0.095	0.089	0.060	0.132	0.122	0.093	0.108	0.245	0.146
2009	0.159	0.134	0.145	0.074	0.081	0.063	0.147	0.121	0.104	0.125	0.150
2010	0.194	0.164	0.130	0.134	0.077	0.088	0.070	0.138	0.137	0.111	0.123
2011	0.123	0.193	0.163	0.126	0.130	0.086	0.096	0.091	0.171	0.157	0.132
2012	0.320	0.130	0.207	0.156	0.118	0.121	0.086	0.114	0.110	0.203	0.154
2013	0.275	0.195	0.119	0.185	0.159	0.118	0.124	0.093	0.139	0.147	0.210
2014	0.653	0.249	0.198	0.122	0.207	0.184	0.133	0.146	0.107	0.176	0.178
2015	0.502	0.299	0.200	0.204	0.144	0.235	0.190	0.143	0.164	0.132	0.175

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2016	0.557	0.214	0.217	0.159	0.174	0.141	0.204	0.183	0.138	0.167	0.122
2017	0.297	0.191	0.115	0.158	0.123	0.141	0.117	0.166	0.151	0.119	0.106
2018	0.269	0.257	0.195	0.121	0.145	0.137	0.161	0.137	0.174	0.166	0.098
2019	0.569	0.146	0.191	0.136	0.095	0.146	0.129	0.156	0.140	0.151	0.096
2020	0.371	0.208	0.096	0.185	0.145	0.105	0.157	0.143	0.168	0.135	0.103

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	0.317	0.334	0.162	0.449	0.548	0.685	0.537	0.599	0.512	NA
1989	0.643	0.327	0.438	0.190	0.428	0.685	0.874	0.489	NA	0.489
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	0.429	0.504	0.267	0.302	0.476	0.673	0.395	0.502	0.225	0.750
1995	0.307	0.183	0.199	0.222	0.336	0.612	NA	0.423	0.489	0.214
1996	0.374	0.221	0.163	0.214	0.265	0.336	NA	NA	0.400	0.227
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	0.334	0.259	0.202	0.146	0.162	0.225	0.289	0.385	0.517	0.228
1999	0.234	0.321	0.241	0.207	0.157	0.167	0.230	0.299	0.404	0.276
2000	0.279	0.208	0.421	0.303	0.250	0.187	0.204	0.301	0.500	0.354
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	0.354	0.282	0.218	0.174	0.161	0.287	0.300	0.388	0.437	0.214
2006	0.439	0.173	0.294	0.265	0.197	0.198	0.420	0.443	0.612	0.306
2007	0.321	0.231	0.147	0.269	0.283	0.203	0.199	0.397	0.357	0.258
2008	0.504	0.209	0.205	0.159	0.297	0.304	0.233	0.233	0.386	0.313
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Year/Age	3	4	5	6	7	8	9	10	11	12+
2010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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	0.296	0.206	0.275	0.198	0.318	0.279	0.206	0.272	0.166	0.214
2016	0.369	0.354	0.289	0.322	0.218	0.353	0.298	0.203	0.283	0.179
2017	0.420	0.253	0.284	0.265	0.311	0.242	0.376	0.365	0.220	0.193
2018	0.394	0.228	0.205	0.306	0.267	0.284	0.252	0.308	0.321	0.196
2019	0.320	0.334	0.261	0.192	0.274	0.265	0.282	0.254	0.276	0.184
2020	0.514	0.195	0.291	0.247	0.197	0.296	0.287	0.322	0.283	0.223
2021	0.418	0.338	0.154	0.276	0.275	0.223	0.311	0.307	0.333	0.221

Table 4.4.8.3 Norwegian spring-spawning herring. Relative standard error of Fleet 4 used by XSAM.

Year/Age	2
1991	0.462
1992	0.419
1993	0.395
1994	0.364
1995	0.444
1996	0.620
1997	0.741
1998	0.466
1999	0.464
2000	0.392
2001	0.445
2002	0.475
2003	NA
2004	NA
2005	0.468

Year/Age	2
2006	0.383
2007	0.477
2008	0.595
2009	0.609
2010	0.525
2011	0.474
2012	0.763
2013	0.502
2014	0.485
2015	0.426
2016	0.458
2017	0.486
2018	0.410
2019	0.498
2020	NA
2021	1.006

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	0.199	0.133	0.151	0.191	0.235	0.343	0.777	0.917	0.437	0.213
1997	0.269	0.206	0.138	0.150	0.225	0.244	0.423	0.516	0.377	0.216
1998	0.355	0.273	0.196	0.143	0.160	0.235	0.294	0.420	NA	0.326
1999	0.232	0.367	0.282	0.214	0.155	0.181	0.290	0.387	0.994	0.373
2000	0.260	0.219	0.495	0.351	0.262	0.174	0.187	0.246	0.382	0.417
2001	0.168	0.257	0.255	0.422	0.409	0.211	0.186	0.266	0.492	0.419
2002	0.180	0.162	0.257	0.297	0.353	0.291	0.238	0.224	0.257	0.429
2003	0.178	0.161	0.161	0.254	0.301	0.443	0.398	0.241	0.228	0.235
2004	0.252	0.188	0.152	0.158	0.275	0.318	0.518	0.369	0.356	0.224
2005	0.137	0.260	0.244	0.180	0.187	0.310	0.351	0.448	0.385	0.236
2006	0.371	0.147	0.258	0.236	0.178	0.175	0.307	0.303	0.425	0.232

Year/Age	3	4	5	6	7	8	9	10	11	12+
2007	0.217	0.183	0.136	0.264	0.237	0.177	0.185	0.310	0.332	0.218
2008	0.309	0.157	0.168	0.147	0.252	0.231	0.191	0.219	0.328	0.274
2009	0.242	0.229	0.154	0.167	0.162	0.235	0.256	0.222	0.259	0.295
2010	0.319	0.229	0.242	0.168	0.183	0.184	0.285	0.288	0.279	0.300
2011	0.285	0.247	0.206	0.222	0.164	0.196	0.198	0.297	0.282	0.275
2012	0.216	0.346	0.308	0.245	0.222	0.197	0.240	0.233	0.374	0.274
2013	0.303	0.206	0.343	0.270	0.241	0.216	0.195	0.219	0.241	0.243
2014	0.265	0.296	0.219	0.303	0.272	0.222	0.230	0.218	0.272	0.261
2015	0.342	0.262	0.271	0.207	0.262	0.268	0.212	0.224	0.195	0.237
2016	0.206	0.252	0.231	0.244	0.222	0.284	0.274	0.243	0.240	0.196
2017	0.283	0.197	0.268	0.252	0.293	0.257	0.368	0.301	0.279	0.193
2018	0.279	0.238	0.184	0.282	0.257	0.320	0.263	0.358	0.307	0.190
2019	0.222	0.307	0.232	0.193	0.270	0.266	0.283	0.266	0.293	0.203
2020	0.335	0.151	0.328	0.279	0.225	0.296	0.312	0.341	0.305	0.225
2021	0.273	0.263	0.154	0.305	0.276	0.236	0.330	0.322	0.334	0.214

Table 4.5.1.1. Norwegian spring-spawning herring. Parameter estimates of the final XSAM model fit. The estimates from the final 2020 assessment are also shown.

Parameter	Estimate	Std. Error	CV	Estimate 2020	Std. Error 2020
$\log(N_{3,1988})$	7.087	0.167	0.024	7.079	0.168
$\log(N_{4,1988})$	6.621	0.206	0.031	6.611	0.208
$\log(N_{5,1988})$	9.584	0.069	0.007	9.583	0.070
$\log(N_{6,1988})$	4.825	0.381	0.079	4.813	0.378
$\log(N_{7,1988})$	3.518	0.529	0.150	3.498	0.524
$\log(N_{8,1988})$	3.087	0.591	0.192	3.068	0.583
$\log(N_{9,1988})$	4.076	0.457	0.112	4.062	0.453
$\log(N_{10,1988})$	3.286	0.667	0.203	3.269	0.659
$\log(N_{11,1988})$	3.180	0.695	0.218	3.161	0.690
$\log(N_{12,1988})$	3.578	0.753	0.210	3.557	0.746
$\log(q_3^{F1})$	-9.669	0.179	0.019	-9.633	0.182

Parameter	Estimate	Std. Error	CV	Estimate 2020	Std. Error 2020
$\log(q_4^{F1})$	-8.108	0.128	0.016	-8.073	0.130
$\log(q_5^{F1})$	-7.474	0.115	0.015	-7.547	0.120
$\log(q_6^{F1})$	-7.296	0.117	0.016	-7.299	0.119
$\log(q_7^{F1})$	-7.152	0.128	0.018	-7.134	0.130
$\log(q_8^{F1})$	-6.939	0.091	0.013	-6.925	0.094
$\log(q_2^{F4})$	-14.515	0.193	0.013	-14.304	0.179
$\log(q_3^{F5})$	-7.653	0.107	0.014	-7.637	0.108
$\log(q_4^{F5})$	-7.123	0.095	0.013	-7.105	0.097
$\log(q_5^{F5})$	-6.904	0.093	0.013	-6.922	0.096
$\log(q_6^{F5})$	-6.805	0.097	0.014	-6.795	0.098
$\log(q_7^{F5})$	-6.734	0.103	0.015	-6.720	0.104
$\log(q_8^{F5})$	-6.557	0.109	0.017	-6.536	0.111
$\log(q_9^{F5})$	-6.543	0.121	0.019	-6.527	0.123
$\log(q_{10}^{F5})$	-6.490	0.135	0.021	-6.469	0.138
$\log(q_{11}^{F5})$	-6.433	0.131	0.020	-6.424	0.135
$\log(\sigma_1^2)$	-5.000	1.441	0.288	-5.000	1.420
$\log(\sigma_2^2)$	-2.769	0.256	0.092	-2.730	0.255
$\log(\sigma_4^2)$	-2.250	0.303	0.135	-2.204	0.308
$\log(\sigma_R^2)$	-0.008	0.275	36.114	-0.082	0.261
$\log(h)$	1.595	0.065	0.041	1.575	0.066
μ_R	9.275	0.180	0.019	9.329	0.176
α_Y	-0.513	0.300	0.584	-0.519	0.307
β_Y	0.810	0.108	0.134	0.808	0.111
α_{2U}	-1.242	0.167	0.135	-1.238	0.169
α_{3U}	-0.620	0.096	0.155	-0.625	0.098
α_{4U}	-0.214	0.060	0.279	-0.219	0.062
α_{5U}	0.043	0.051	1.188	0.045	0.053
α_{6U}	0.196	0.055	0.282	0.200	0.057
α_{7U}	0.264	0.060	0.226	0.264	0.061

Parameter	Estimate	Std. Error	CV	Estimate 2020	Std. Error 2020
α_{8U}	0.327	0.066	0.203	0.326	0.068
α_{9U}	0.368	0.072	0.195	0.365	0.074
α_{10U}	0.420	0.078	0.186	0.415	0.080
β_U	0.603	0.053	0.088	0.604	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	667	1196	751	14525	125	34	22	59	27	24	36
1989	1172	258	966	628	12010	103	28	16	40	16	43
1990	4341	471	217	817	526	10007	85	22	13	30	47
1991	11462	1759	401	184	687	439	8363	70	18	10	62
1992	18678	4654	1506	341	156	577	369	6970	57	14	59
1993	50069	7587	3991	1279	287	130	481	306	5763	47	59
1994	59966	20335	6500	3366	1044	232	106	389	246	4565	82
1995	15759	24344	17414	5474	2637	782	178	82	301	185	3435
1996	5713	6389	20795	14582	4178	1762	512	128	60	207	2241
1997	2152	2312	5423	17203	11156	2809	1133	336	89	40	1357
1998	10925	868	1916	4367	13112	7769	1753	666	209	54	756
1999	6479	4411	715	1480	3370	9600	5440	1124	414	123	459
2000	32832	2623	3675	558	1131	2503	6811	3648	703	246	301
2001	29100	13302	2195	2744	418	831	1788	4654	2250	411	271
2002	11426	11797	11281	1748	2013	312	616	1285	3229	1486	453
2003	6698	4626	9968	9110	1290	1414	227	432	873	2148	1293
2004	57944	2716	3919	8240	7155	951	1034	164	304	588	2251
2005	24530	23513	2308	3266	6664	5513	709	750	119	213	1759
2006	43221	9948	19881	1902	2611	5104	3904	483	509	79	1131
2007	12199	17529	8460	16452	1529	2044	3745	2676	335	352	705
2008	17776	4941	14869	6967	12623	1159	1497	2552	1776	225	718
2009	7147	7171	4180	12257	5391	8808	819	1030	1633	1122	627
2010	5104	2867	6004	3432	9479	3839	5737	549	642	977	1080

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2011	15456	2048	2390	4935	2735	7153	2678	3584	344	396	1122
2012	5525	6204	1711	1962	3980	2138	5395	1821	2398	224	964
2013	8202	2234	5194	1412	1580	3155	1636	3966	1286	1681	836
2014	5340	3322	1883	4259	1139	1253	2459	1223	2903	930	1968
2015	17817	2167	2827	1571	3461	923	1005	1936	938	2189	2318
2016	7282	7234	1850	2379	1299	2826	752	806	1531	727	3600
2017	4265	2956	6171	1551	1951	1043	2257	595	628	1168	3361
2018	35586	1729	2499	5058	1229	1460	769	1642	431	433	3241
2019	4567	14438	1468	2077	4085	937	1100	570	1219	312	2593
2020	5769	1852	12244	1206	1636	3035	682	770	398	856	1857
2021	1932	2338	1564	10046	956	1238	2218	478	528	270	1773

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	0.064	0.029	0.040	0.044	0.044	0.143	0.225	0.337	0.173	0.173
1989	0.011	0.021	0.017	0.027	0.032	0.036	0.077	0.110	0.151	0.091	0.091
1990	0.004	0.012	0.015	0.024	0.031	0.030	0.052	0.073	0.098	0.070	0.070
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	0.062	0.058	0.064	0.068	0.083	0.103	0.103
1994	0.001	0.005	0.022	0.094	0.139	0.115	0.100	0.107	0.135	0.152	0.152
1995	0.003	0.008	0.027	0.120	0.254	0.273	0.176	0.171	0.222	0.329	0.329
1996	0.005	0.014	0.040	0.118	0.247	0.292	0.271	0.212	0.244	0.440	0.440
1997	0.008	0.038	0.067	0.122	0.212	0.321	0.381	0.325	0.351	0.464	0.464
1998	0.007	0.044	0.108	0.109	0.162	0.206	0.295	0.326	0.377	0.419	0.419
1999	0.004	0.032	0.098	0.119	0.147	0.193	0.250	0.319	0.370	0.509	0.509
2000	0.004	0.028	0.142	0.140	0.158	0.187	0.231	0.333	0.387	0.552	0.552
2001	0.003	0.015	0.078	0.160	0.140	0.150	0.180	0.215	0.265	0.260	0.260
2002	0.004	0.018	0.064	0.154	0.203	0.171	0.205	0.237	0.258	0.255	0.255
2003	0.003	0.016	0.040	0.092	0.155	0.162	0.170	0.203	0.246	0.274	0.274

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2004	0.002	0.013	0.032	0.062	0.111	0.144	0.172	0.173	0.203	0.328	0.328
2005	0.002	0.018	0.044	0.074	0.117	0.195	0.232	0.238	0.264	0.406	0.406
2006	0.002	0.012	0.039	0.068	0.095	0.160	0.228	0.218	0.218	0.390	0.390
2007	0.004	0.015	0.044	0.115	0.127	0.161	0.234	0.260	0.246	0.238	0.238
2008	0.008	0.017	0.043	0.106	0.210	0.197	0.224	0.296	0.309	0.258	0.258
2009	0.013	0.028	0.047	0.107	0.190	0.279	0.251	0.324	0.364	0.332	0.332
2010	0.013	0.032	0.046	0.077	0.132	0.210	0.320	0.317	0.334	0.456	0.456
2011	0.013	0.030	0.048	0.065	0.096	0.132	0.235	0.252	0.278	0.304	0.304
2012	0.006	0.028	0.042	0.066	0.082	0.118	0.158	0.198	0.205	0.201	0.201
2013	0.004	0.021	0.048	0.065	0.082	0.099	0.141	0.162	0.174	0.096	0.096
2014	0.002	0.011	0.031	0.058	0.060	0.070	0.089	0.115	0.133	0.073	0.073
2015	0.001	0.008	0.022	0.040	0.053	0.055	0.072	0.084	0.105	0.075	0.075
2016	0.002	0.009	0.026	0.049	0.070	0.074	0.085	0.099	0.121	0.102	0.102
2017	0.003	0.018	0.049	0.083	0.140	0.154	0.168	0.172	0.222	0.185	0.185
2018	0.002	0.014	0.035	0.064	0.121	0.133	0.149	0.148	0.174	0.198	0.198
2019	0.003	0.015	0.046	0.089	0.147	0.168	0.207	0.209	0.203	0.297	0.297
2020	0.003	0.019	0.048	0.083	0.129	0.164	0.204	0.226	0.238	0.275	0.275
2021	0.003	0.017	0.046	0.083	0.128	0.157	0.191	0.210	0.229	0.229	0.229

Table 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 thousand tonnes	High	Low	Catches thousand tonnes	Fishing Pressure: F Ages 5–12	High	Low
1988	667	989	345	2124	2400	1849	135	0.042	0.059	0.025
1989	1172	1657	688	3285	3711	2859	104	0.033	0.047	0.019
1990	4341	5388	3294	3558	4009	3106	86	0.030	0.043	0.017
1991	11462	13409	9515	3335	3757	2913	85	0.031	0.045	0.018
1992	18678	21417	15939	3363	3767	2960	104	0.039	0.055	0.023
1993	50069	55571	44567	3336	3699	2973	232	0.076	0.100	0.052

Year	Recruit-ment (Age 2) millions	High	Low	Stock Size: SSB thou-sand tonnes	High	Low	Catches thou-sand tonnes	Fishing Pres-sure: F Ages 5–12	High	Low
1994	59966	66116	53816	3468	3830	3106	479	0.128	0.160	0.096
1995	15759	18170	13349	3537	3885	3190	906	0.218	0.259	0.176
1996	5713	6861	4565	4122	4471	3773	1220	0.191	0.223	0.159
1997	2152	2726	1578	5382	5795	4969	1427	0.193	0.221	0.164
1998	10925	12759	9091	5960	6413	5506	1223	0.187	0.216	0.157
1999	6479	7731	5227	5853	6329	5377	1235	0.213	0.248	0.178
2000	32832	36897	28767	4874	5311	4436	1207	0.257	0.301	0.213
2001	29100	32868	25332	4046	4440	3651	766	0.203	0.242	0.165
2002	11426	13371	9481	3572	3940	3205	808	0.223	0.267	0.180
2003	6698	8015	5381	4205	4612	3799	790	0.152	0.181	0.123
2004	57944	64360	51527	5299	5793	4805	794	0.128	0.152	0.103
2005	24530	28040	21020	5426	5947	4904	1003	0.172	0.204	0.140
2006	43221	48701	37741	5391	5905	4878	969	0.176	0.211	0.142
2007	12199	14435	9964	6936	7565	6306	1267	0.155	0.183	0.127
2008	17776	20753	14798	7024	7689	6360	1546	0.200	0.235	0.165
2009	7147	8631	5663	7001	7704	6297	1687	0.205	0.239	0.171
2010	5104	6244	3963	6214	6890	5539	1457	0.213	0.252	0.174
2011	15456	18154	12758	5883	6568	5197	993	0.158	0.188	0.127
2012	5525	6718	4332	5729	6432	5027	826	0.141	0.169	0.112
2013	8202	9902	6502	5363	6049	4678	685	0.120	0.147	0.094
2014	5340	6633	4046	5181	5867	4495	461	0.084	0.104	0.065
2015	17817	21498	14136	4818	5470	4166	329	0.067	0.085	0.050
2016	7282	9302	5262	4257	4845	3669	383	0.085	0.107	0.064
2017	4265	5780	2749	4536	5134	3938	722	0.161	0.198	0.124
2018	35586	45580	25592	4130	4714	3547	593	0.128	0.158	0.098
2019	4567	7072	2063	3947	4544	3349	777	0.186	0.230	0.142
2020	5769	10342	1196	3375	3948	2803	721	0.188	0.238	0.138

Year	Recruitment (Age 2) millions	High	Low	Stock Size: SSB thousand tonnes	High	Low	Catches thousand tonnes	Fishing Pressure: F Ages 5–12	High	Low
2021	1932	5617	0	3765	4470	3060				
Average	16091	18873	13360	4655	5173	4137	788	0.145	0.175	0.115

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 2021								
	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	1932	0.9	0	0	0	0.054	0.004	0.161
3	2338	0.15	0	0	0	0.104	0.023	0.207
4	1564	0.15	0.4	0	0	0.160	0.062	0.237
5	10046	0.15	0.6	0	0	0.209	0.111	0.273
6	956	0.15	1	0	0	0.266	0.172	0.308
7	1238	0.15	1	0	0	0.284	0.211	0.330
8	2218	0.15	1	0	0	0.302	0.258	0.353
9	478	0.15	1	0	0	0.325	0.283	0.371
10	528	0.15	1	0	0	0.352	0.308	0.387
11	270	0.15	1	0	0	0.366	0.308	0.400
12	1773	0.15	1	0	0	0.389	0.308	0.416

Input for 2022 and 2023								
	Stockno.	**Natural**	**Maturity**	**Proportion of M**	**Proportion of F**	**Weight**	**Exploitation**	**Weight**
age	**1-Jan.**	**mortality**	**ogive (2022/2023)**	**before spawning**	**before spawning**	**in stock**	**pattern**	**in catch**
2	10667	0.9	0/0	0	0	0.054	0.014	0.161
3		0.15	0/0	0	0	0.104	0.072	0.207
4		0.15	0.4/0.4	0	0	0.154	0.194	0.237
5		0.15	0.8/0.8	0	0	0.205	0.357	0.273

6	0.15	0.9/1	0	0	0.270	0.541	0.308
7	0.15	1/1	0	0	0.299	0.656	0.330
8	0.15	1/1	0	0	0.320	0.788	0.353
9	0.15	1/1	0	0	0.341	0.868	0.371
10	0.15	1/1	0	0	0.354	0.963	0.387
11	0.15	1/1	0	0	0.365	1	0.400
12	0.15	1/1	0	0	0.383	1	0.416

Table 4.8.2.1 Norwegian spring spawning herring. Short-term prediction.

Basis:	
SSB (2021):	3.765 million t
Landings(2021):	881 097 t (sum of national quotas)
SSB(2022):	3.92 million t
Fw5–12+(2021)	0.174
Recruitment(2021–2023):	1.932,10.667,10.667

The catch options:

Rationale	**Catches (2022)**	**Basis**	**FW (2022)**	**SSB (2023)**	**P(SSB2023 <Blim)**	**% SSB change**	**%TAC change**	**%CATCH change**
Management strategy	598588	F=0.14	0.14(0.109, 0.178)*	3607.952(2816.421, 4655.025) *	0.004	-7.951(-28,19) *	-8.1	-32
Fmsy	665436	F=0.157	0.157(0.124, 0.205) *	3549.887(2730.085, 4546.795) *	0.007	-9.432(-30,16) *	2.2	-24
Zero Catch	0	F=0.0	0(0, 0) *	4129.529(3298.271, 5124.868) *	0	5.356(-16,31) *	-100	-100
Fpa	665436	F=0.157	0.157(0.123, 0.205) *	3549.887(2694.812, 4623.457) *	0.008	-9.432(-31,18) *	2.2	-24
Flim	1152881	F=0.291	0.291(0.225, 0.4) *	3127.774(2254.705, 4230.593) *	0.073	-20.202(-42,8) *	77.1	31
$SSB_{2022}=B_{lim}$	1883778	F=0.534	0.534(0.411, 0.795) *	2500.041(1610.483, 3517.416) *	0.472	-36.217(-59,-10) *	189.4	114
$SSB_{2022}=B_{pa}$	1087697	F=0.272	0.272(0.215, 0.37) *	3184.08(2315.502, 4261.386) *	0.061	-18.765(-41,9) *	67.1	23
Status quo	729494	F=0.174	0.174(0.137, 0.229) *	3494.282(2652.31, 4516.433) *	0.01	-10.851(-32,15) *	12.1	-17

***95% confidence interval**

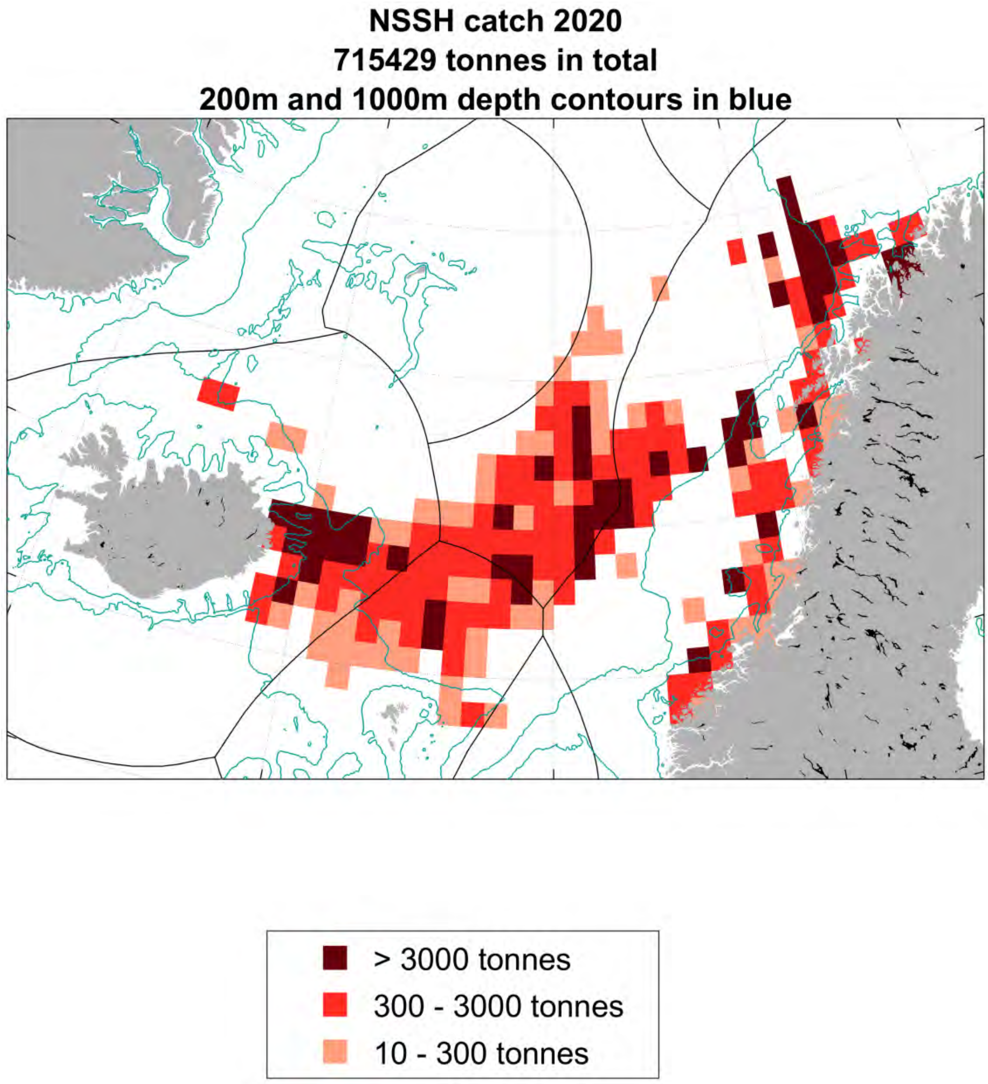


Figure 4.2.1.1. Total reported landings (ICES estimates) of Norwegian spring-spawning herring in 2020 by ICES rectangle. Landings below 10 tonnes per statistical rectangle are not included. The landings with information on statistical rectangle constitute 99.2% of the reported landings.

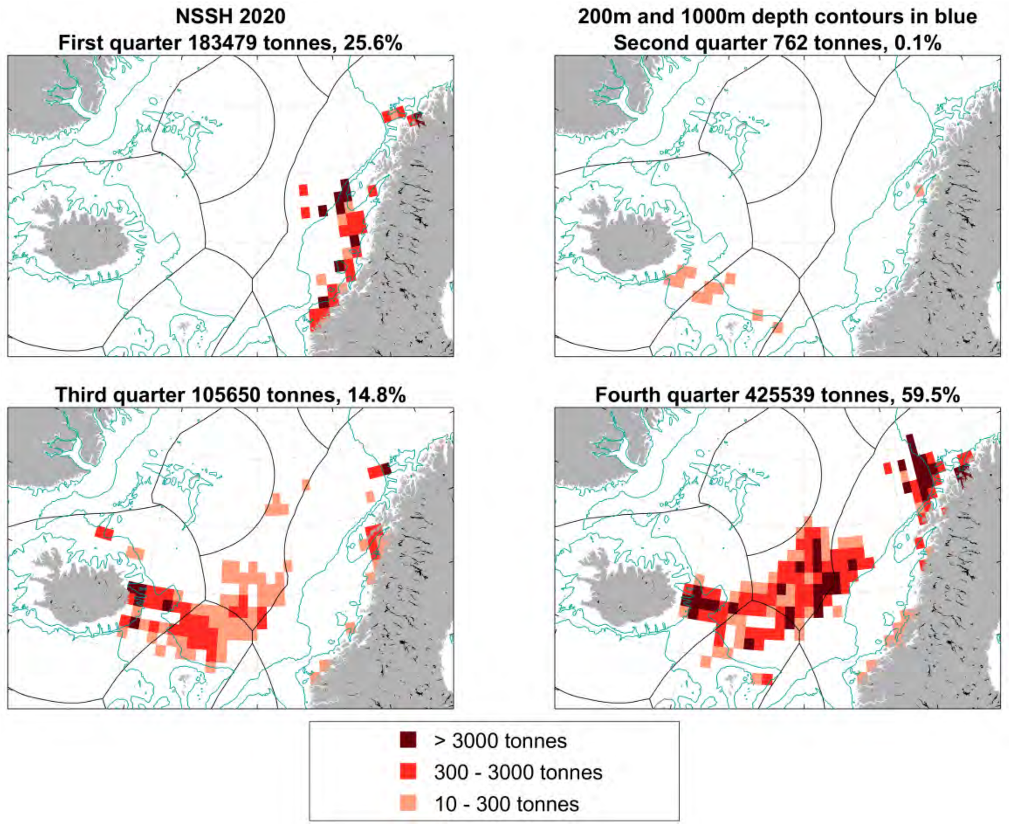


Figure 4.2.1.2. Total reported landings (ICES estimates) of Norwegian spring-spawning herring in 2020 by quarter and ICES rectangle. Landings below 10 tonnes per statistical rectangle are not included. The landings with information on statistical rectangle constitute 99.2% of the reported landings.

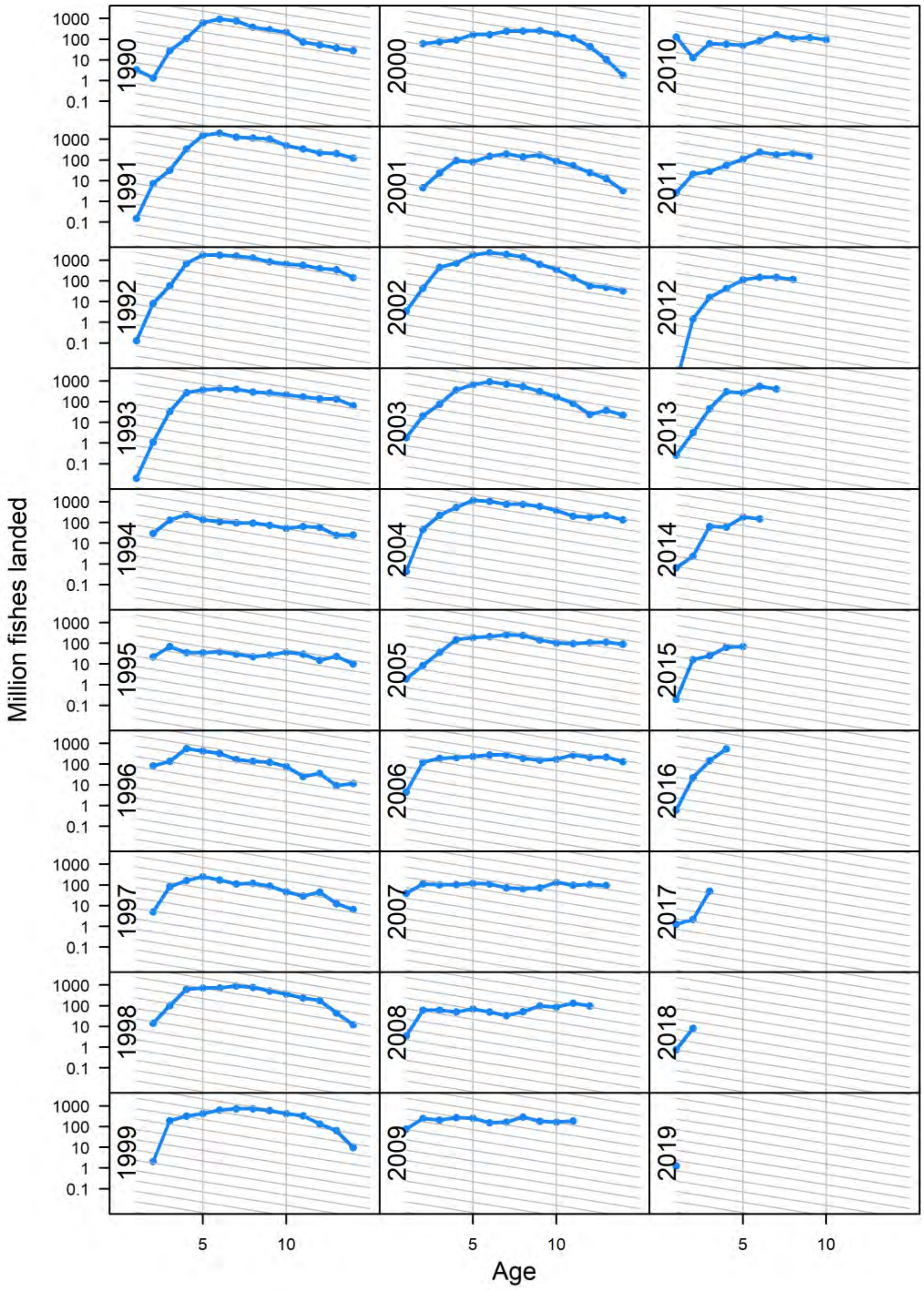


Figure 4.4.3.1. Norwegian spring spawning herring. Age disaggregated landings in numbers plotted on a log scale. Age is on x-axis. The labels indicate year classes and grey lines correspond to Z = 0.3.

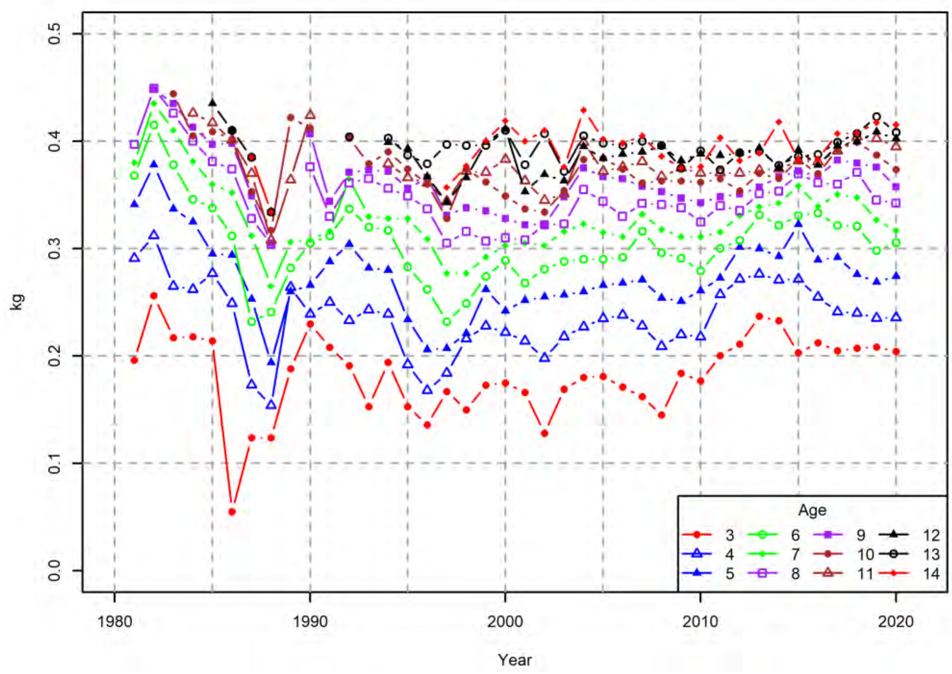


Figure 4.4.4.1. Norwegian spring spawning herring. Mean weight at age by age groups 3–14 in the years 1981–2020 in the landings.

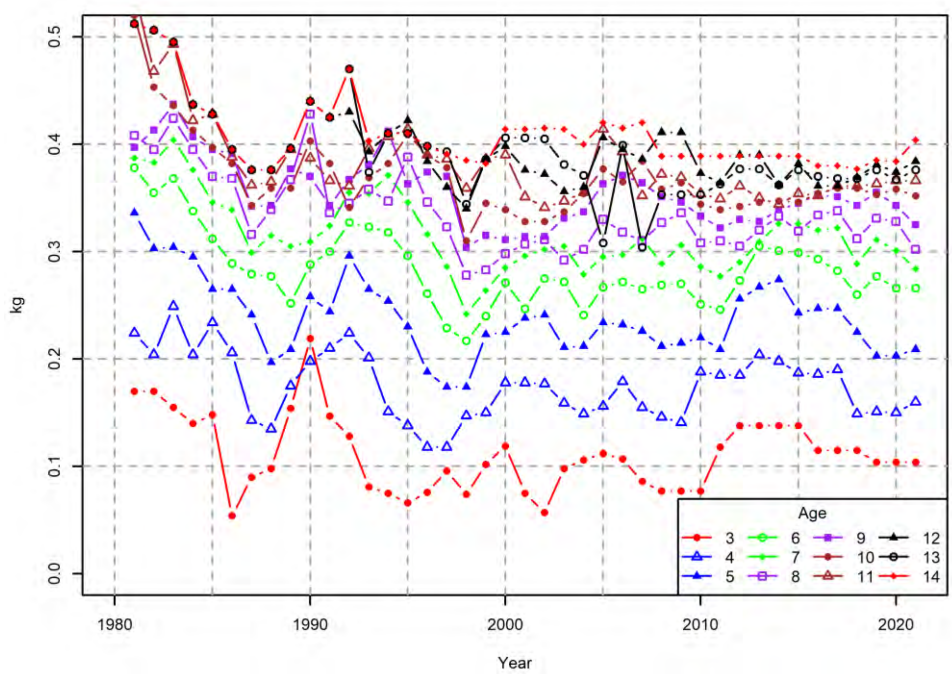


Figure 4.4.4.2. Norwegian spring-spawning herring. Mean weight at age in the stock by age groups 3–14 for the years 1981–2021.

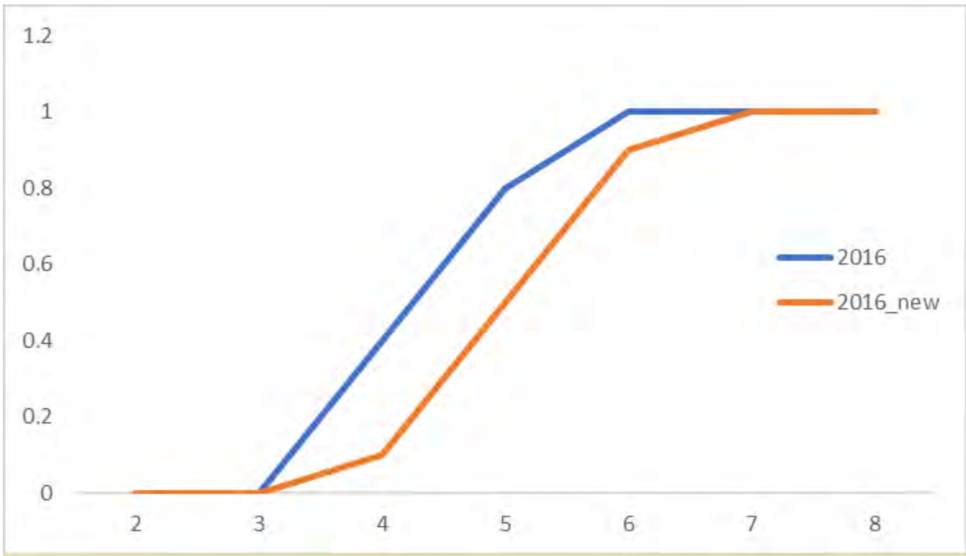


Figure 4.4.5.1. Assumed (blue line) and back-calculated (orange line) maturity-at-age for the year 2016.

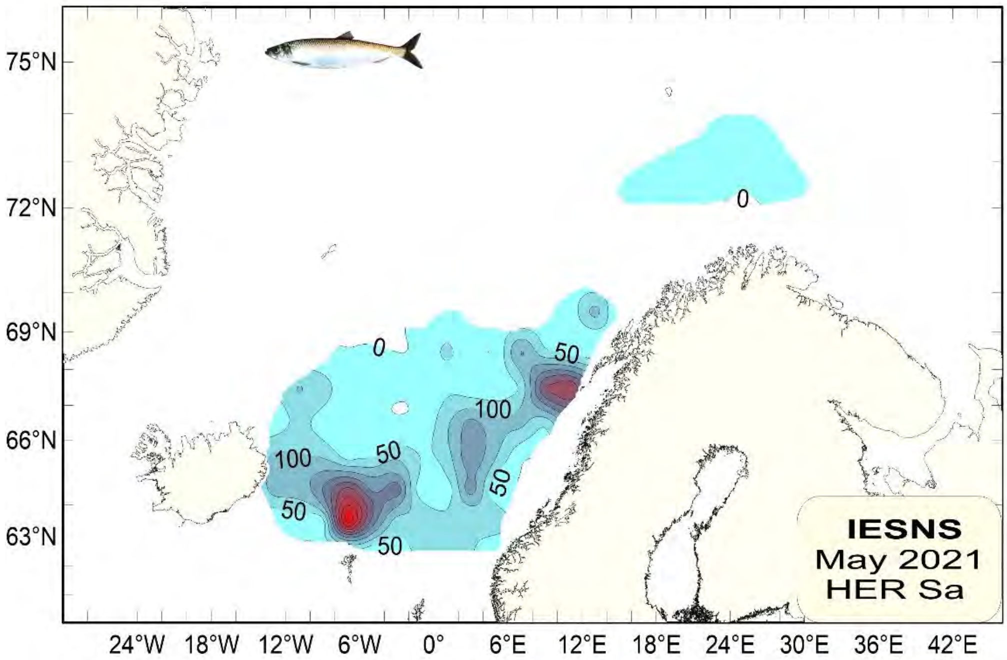


Figure 4.4.7.1. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2021 in terms of NASC values (m²/nm²).

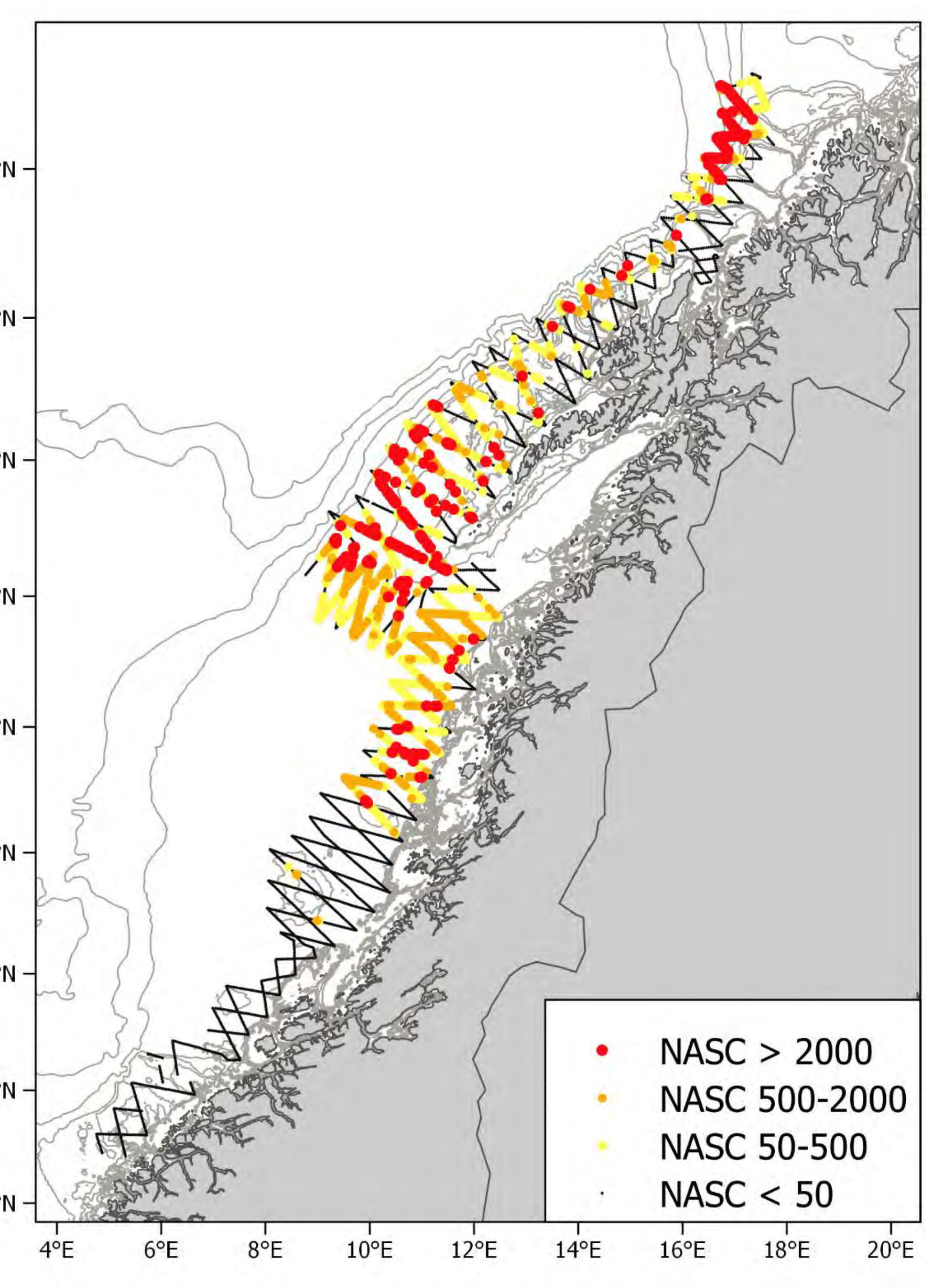


Figure 4.4.7.2. Norwegian acoustic survey on the NSSH spawning grounds. Distribution and acoustic density of herring recorded in 2021.

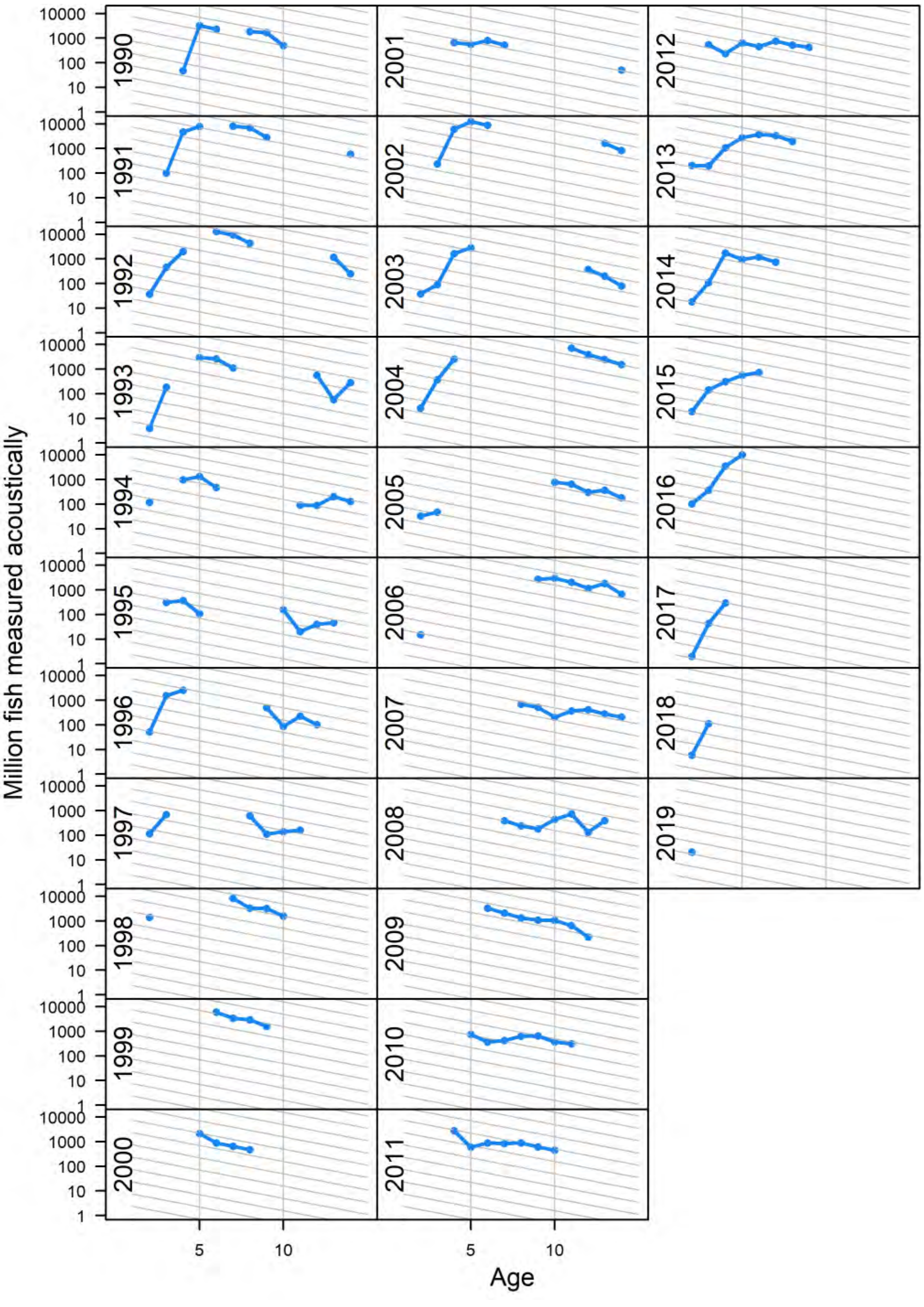


Figure 4.4.7.3. Norwegian spring spawning herring. Age disaggregated abundance indices (millions) from the acoustic survey on the spawning area in February-March (Fleet 1) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z = 0.3. Age is on x-axis.

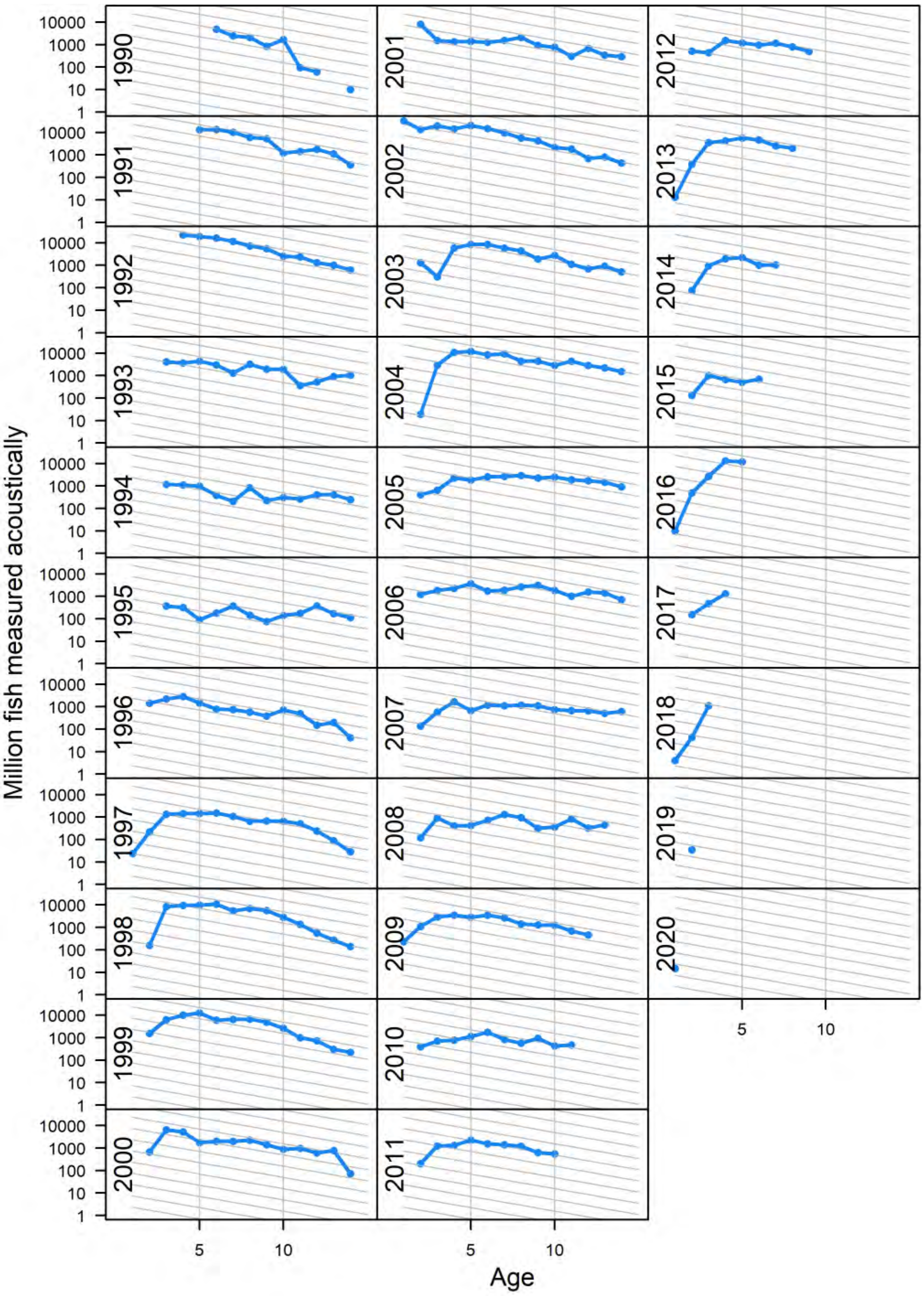


Figure 4.4.7.4. Norwegian spring spawning herring. Age disaggregated abundance indices (millions) from the acoustic survey in the feeding area in the Norwegian Sea in May (Fleet 5) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z = 0.3.

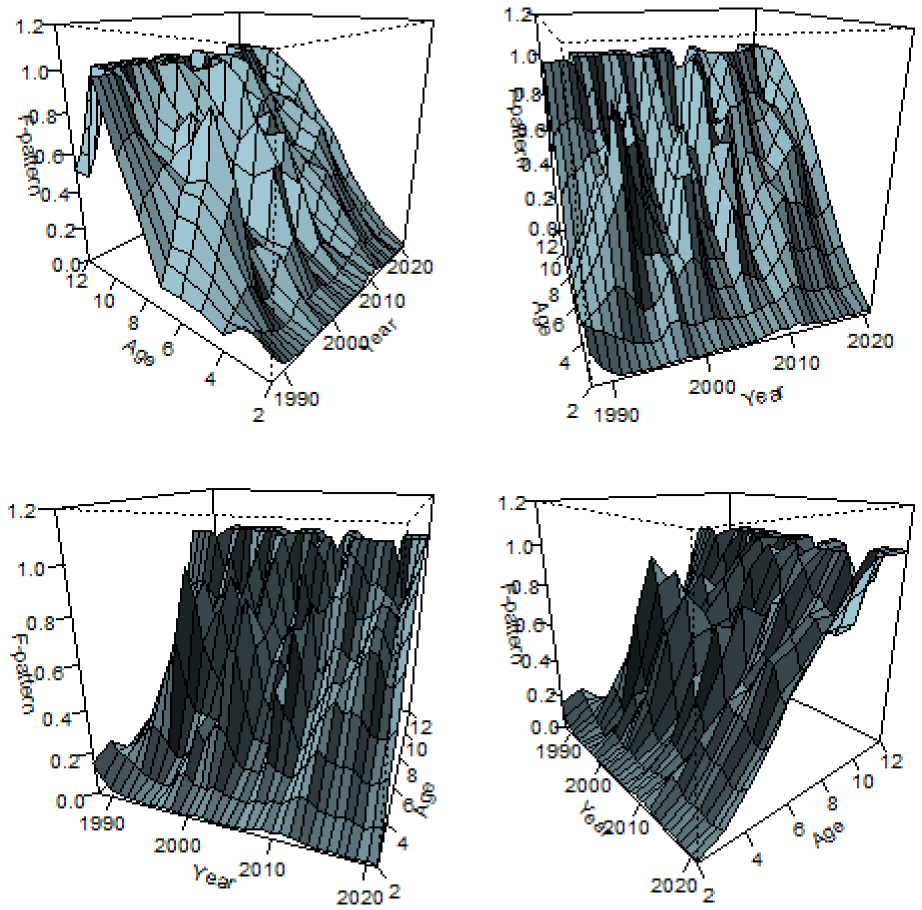


Figure 4.5.1.1. Estimated exploitation pattern for the years 1988–2021 by the XSAM model fit. All panels show the same data, but depicted at different angles to improve visibility at different time periods

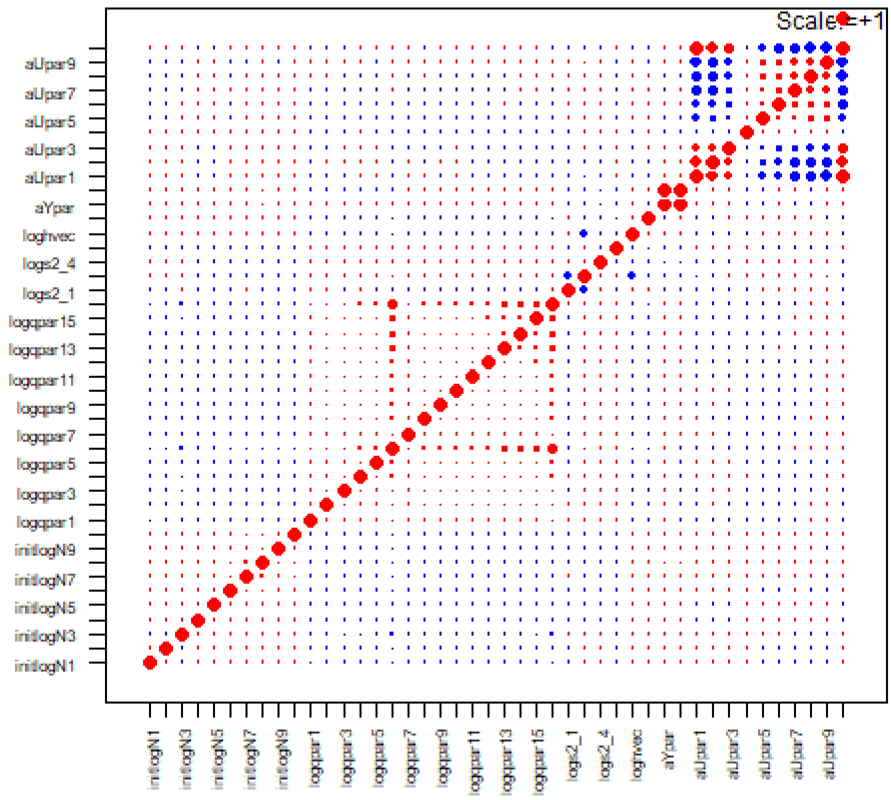


Figure 4.5.1.2. Norwegian spring spawning herring. Correlation between estimated parameters in the final XSAM model fit.

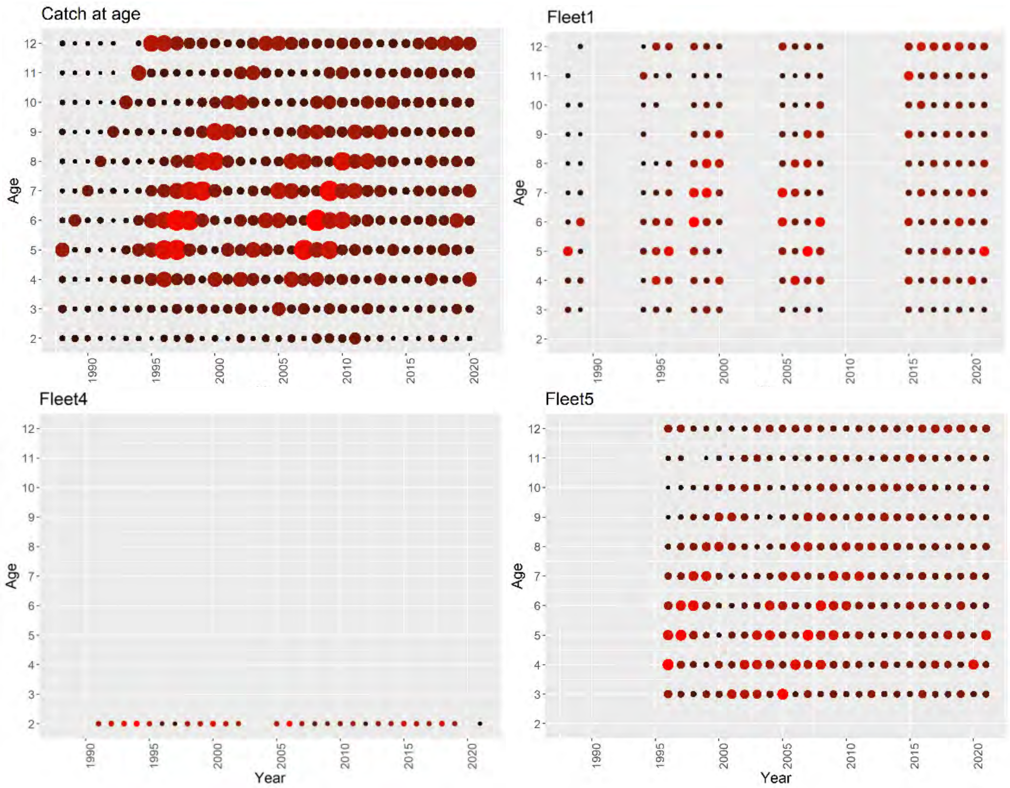


Figure 4.5.1.3. Norwegian spring spawning herring. Weights (inverse of variance) of data-input of the final XSAM model fit.

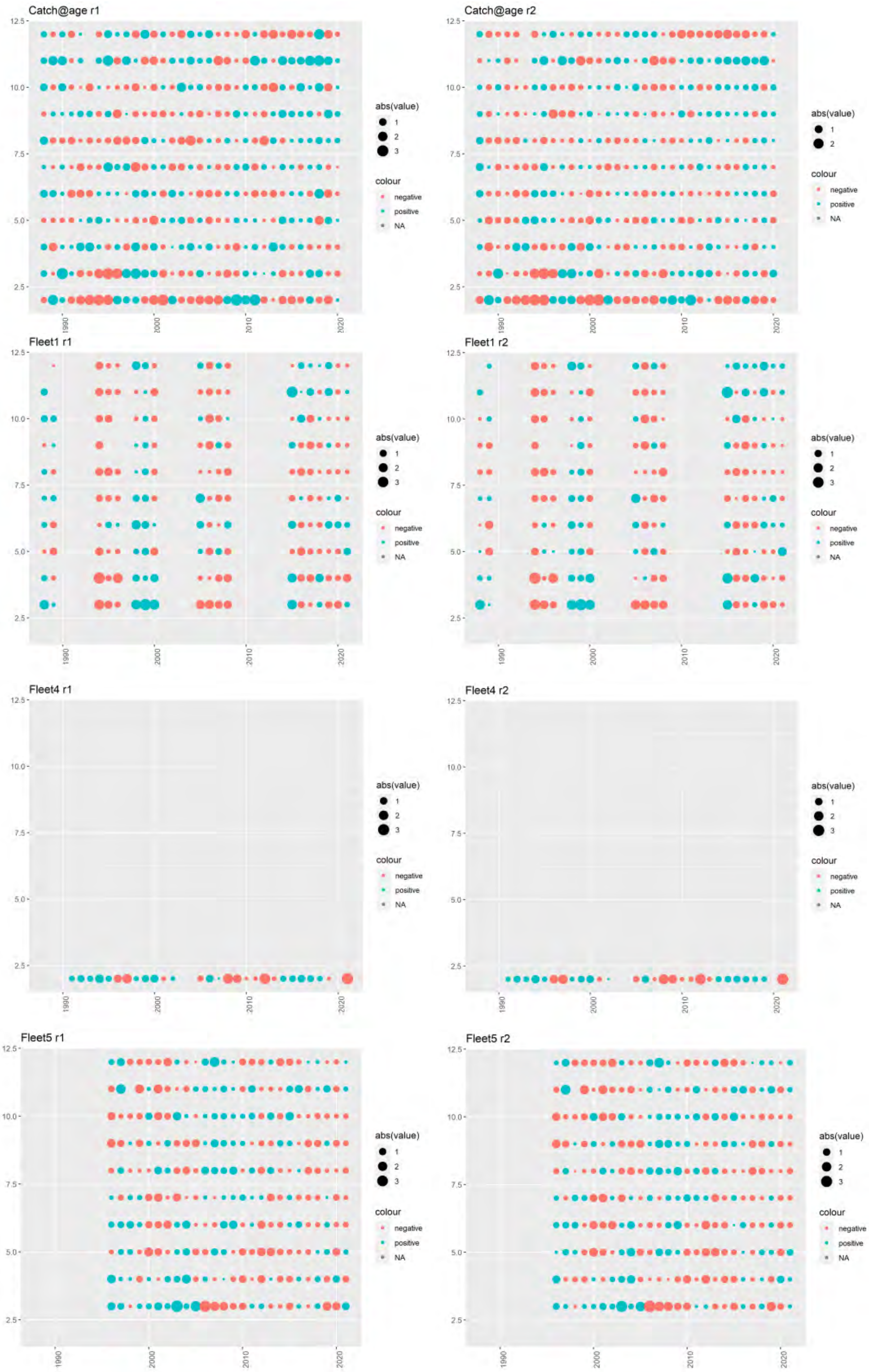


Figure 4.5.1.4. Norwegian spring spawning herring. Standardized residuals type 1 (left) and type 2 (right; see text) of data-input of the final XSAM model fit. Red is negative and blue is positive residuals.

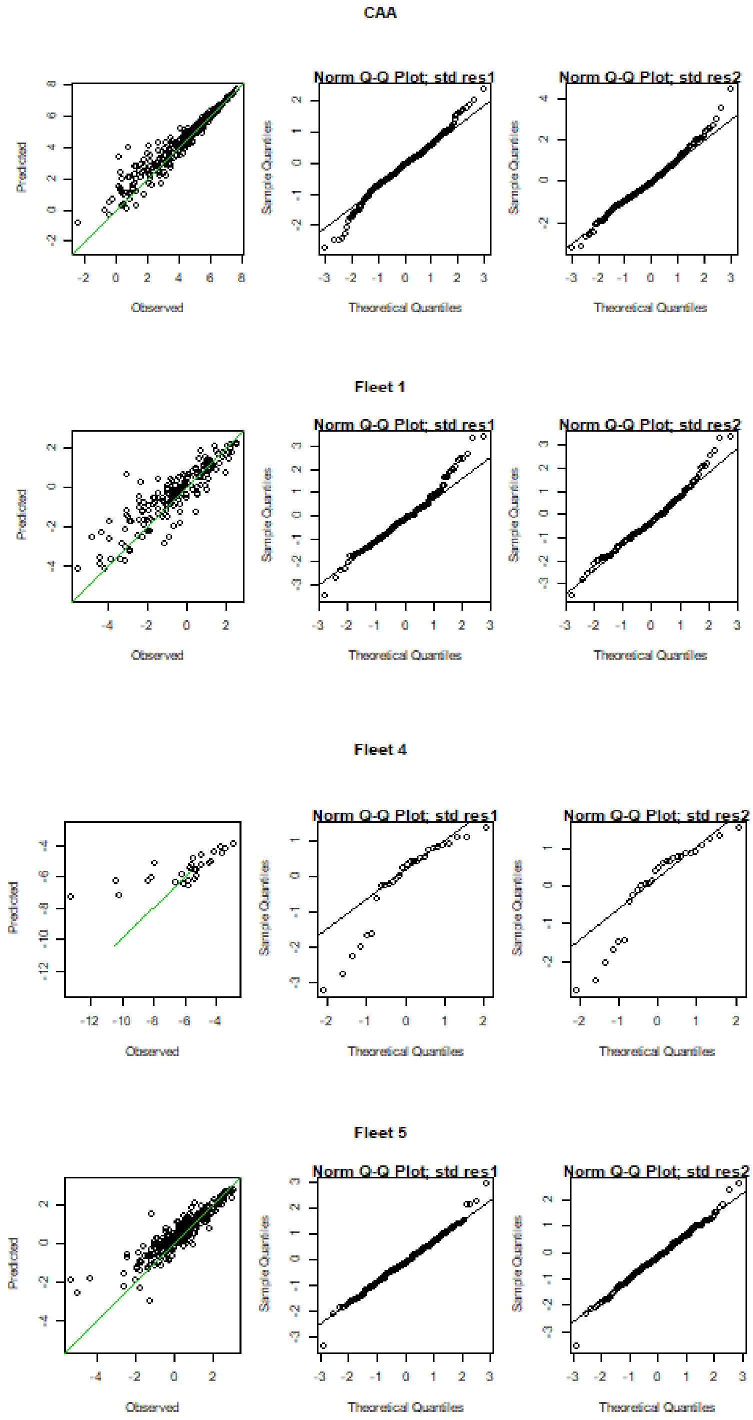


Figure 4.5.1.5. Norwegian spring spawning herring. Observed vs. predicted values (left column) and qq-plot based on type 1 (middle) and type 2 (right) residuals (see text) based on the final XSAM model fit.

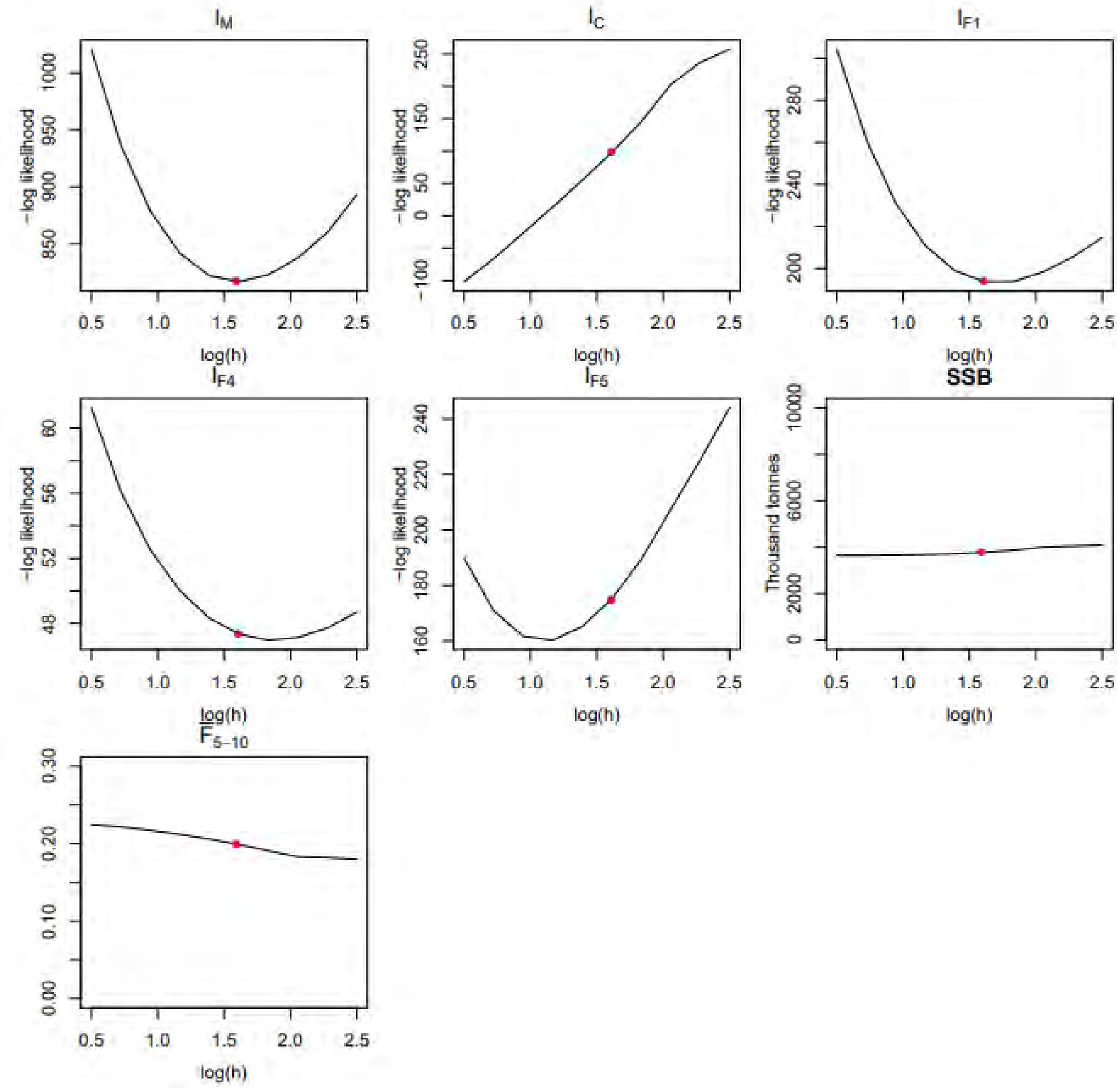


Figure 4.5.1.6. Norwegian spring spawning herring. Profiles of marginal log-likelihood l_M, the catch component l_C, Fleet 1 component l_{F1}, Fleet 4 component l_{F4}, Fleet 5 component l_{F5}, point estimate of SSB and average F (ages 5–12+) in 2020 over the common scaling factor for variance in data h for the final XSAM fit. The red dots indicate the value of the respective scaling factors for which the log-likelihood is maximized.

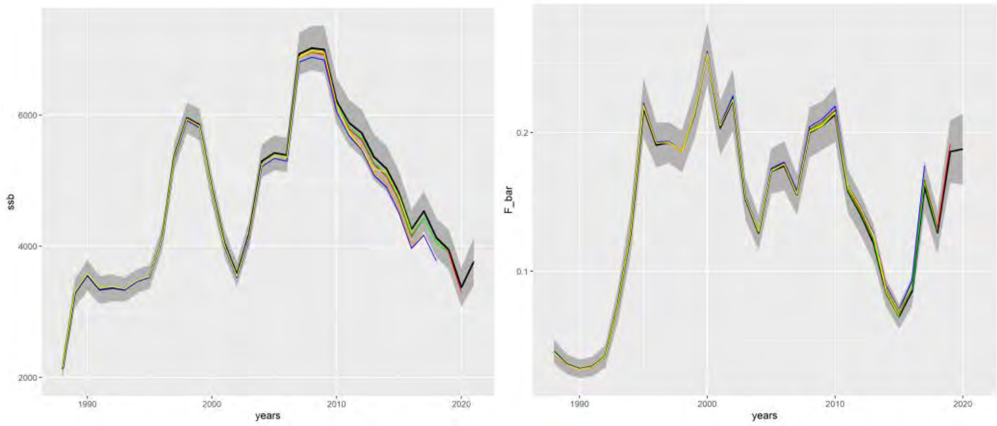


Figure 4.5.1.7. Norwegian spring spawning herring. Retrospective XSAM model fits of SSB and weighted average of fishing mortality ages 5–12 for the years 2015–2020. Mohn's rho computed to be -0.04 for SSB and -0.1 for F.

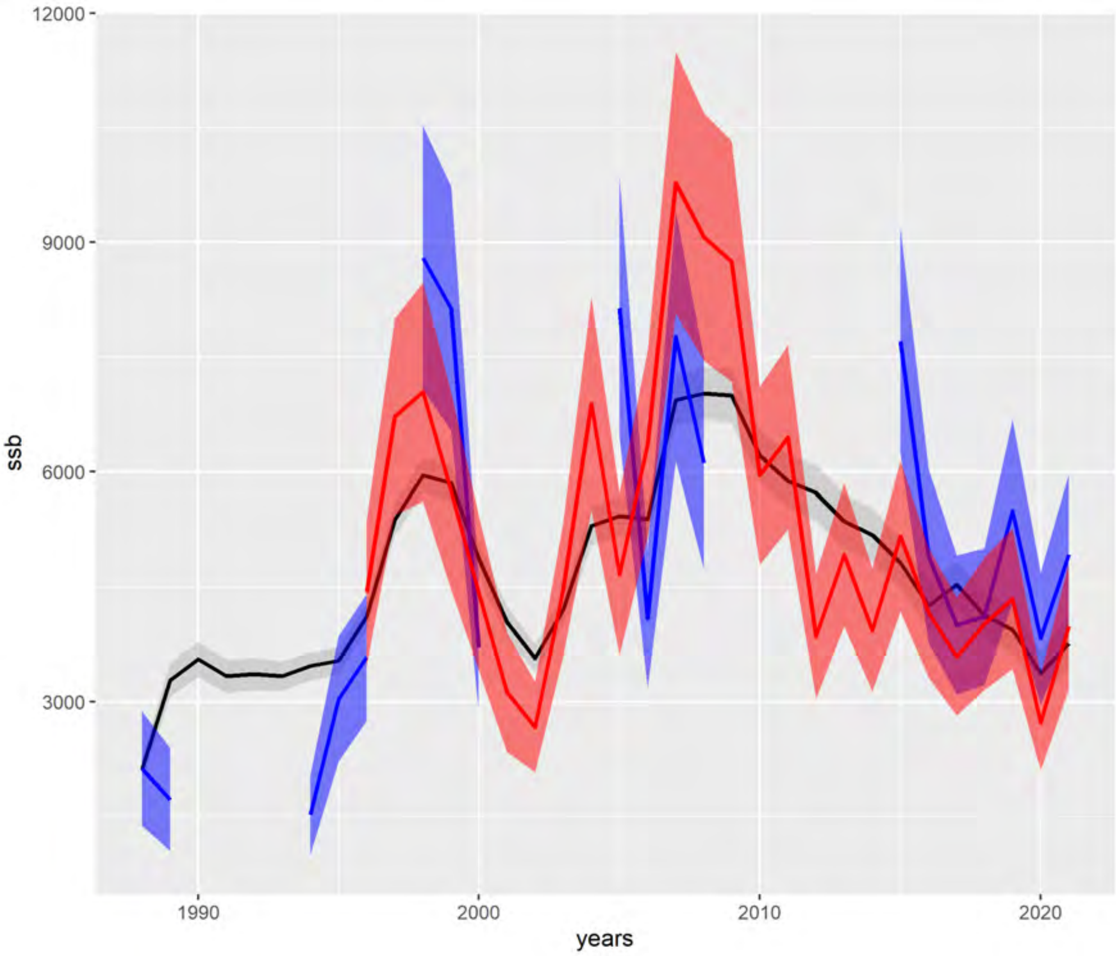


Figure 4.5.1.8. Norwegian spring spawning herring. Point estimates of Spawning-stock biomass by years 1988–2019 from model (black lines) and by survey indices from Fleet 1 (blue) and Fleet 5 (red). Shaded area is approximate to standard deviation.

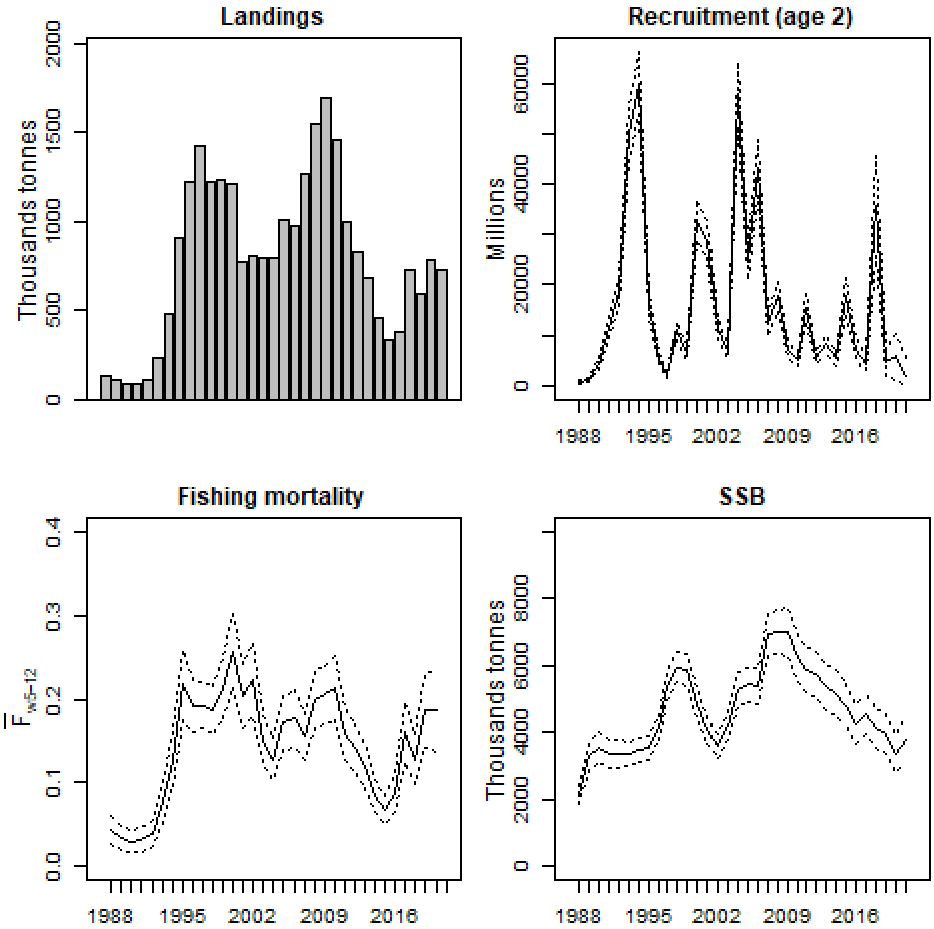


Figure 4.5.1.9. Total reported landings 1988–2020, estimated recruitment, weighted average of fishing mortality (ages 5–12) and spawning-stock biomass for the years 1988–2021 based on the final XSAM model fit.

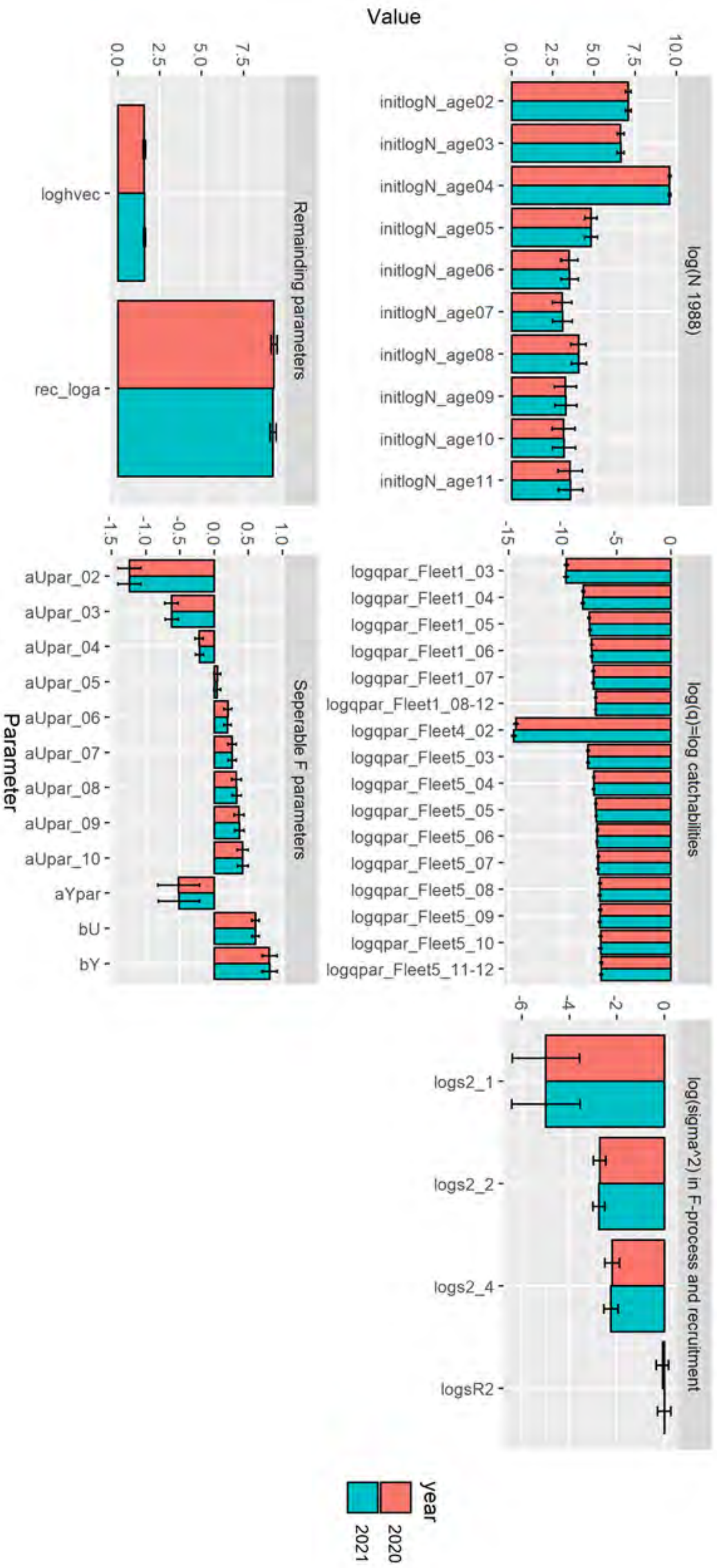


Figure 4.5.1.10. Norwegian spring-spawning herring. A visual representation of parameter estimates of the final XSAM model fit (see table 4.5.1.1). The estimates from the 2020 assessment are also shown (red).

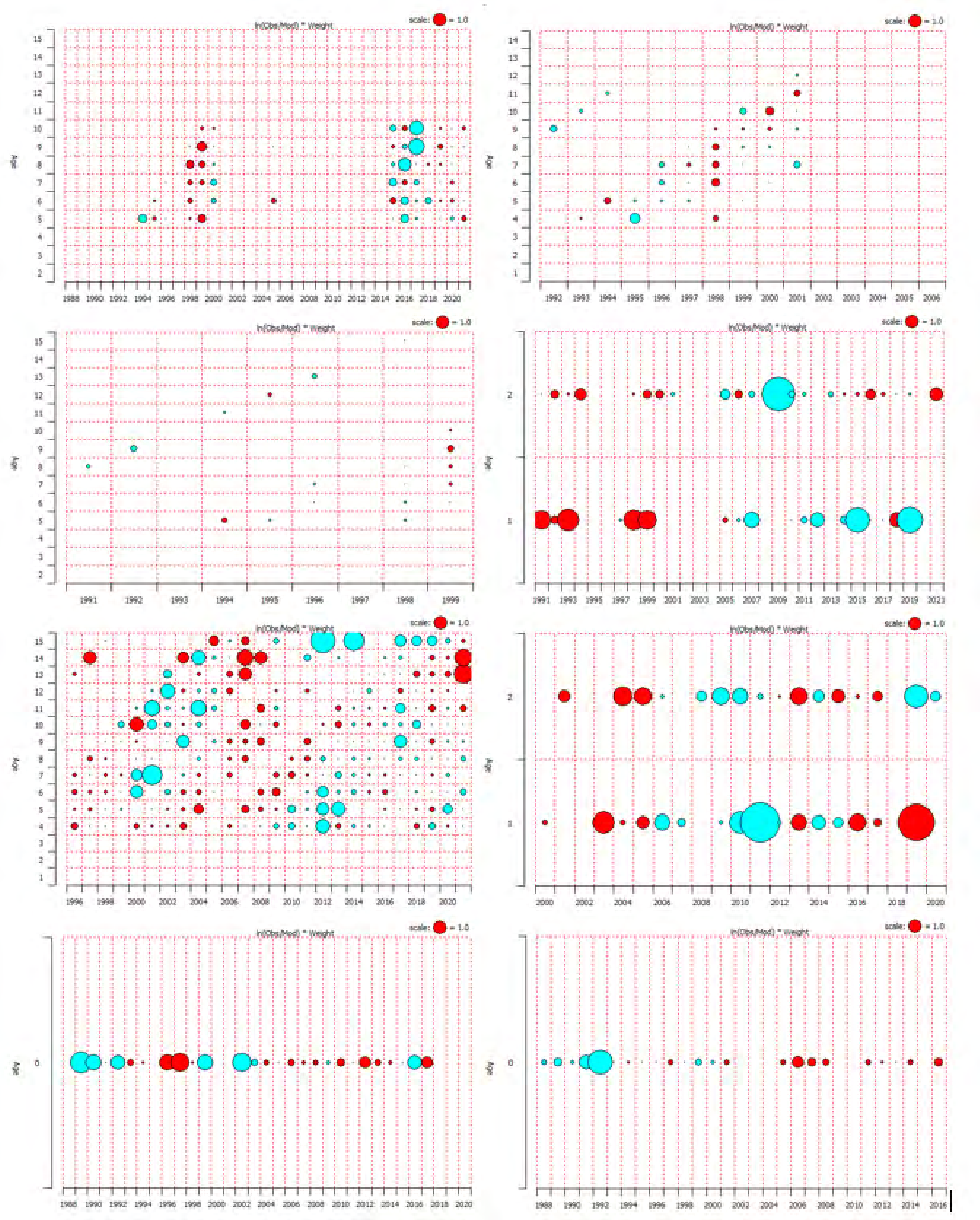


Figure 4.5.2.1.1. Norwegian spring-spawning herring. Residual sum of squares in the surveys separately from TASACS. First row starts with survey 1 and the last one in row four is larval survey.

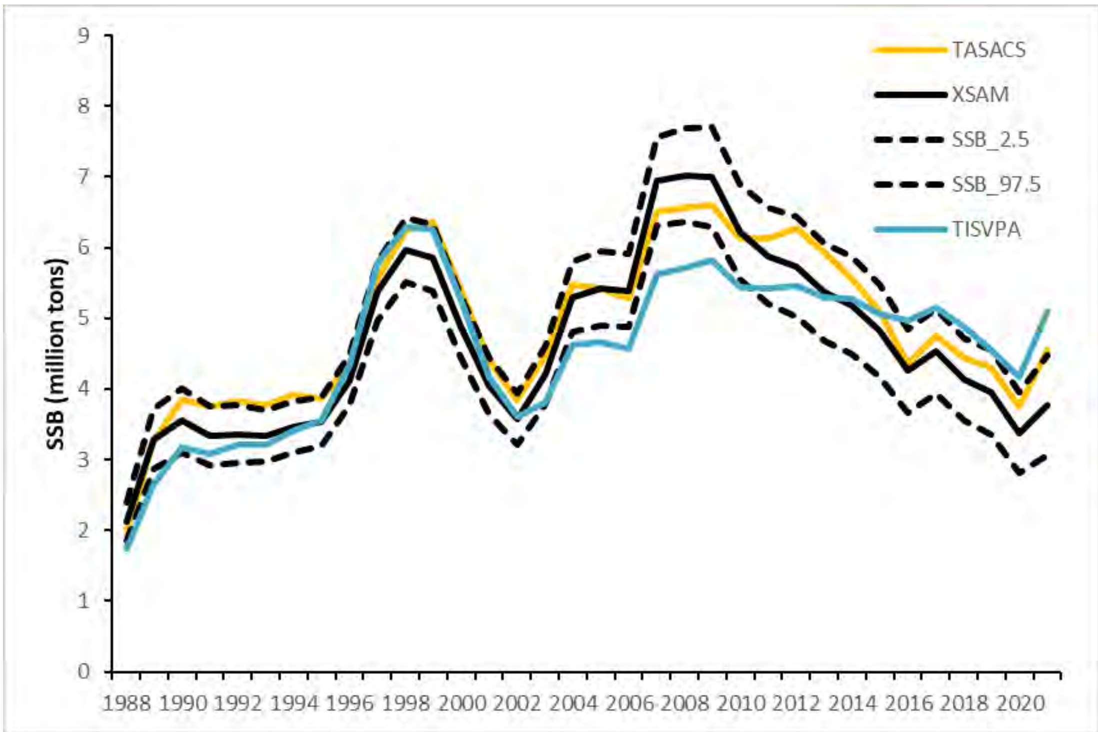


Figure 4.5.2.1.2. Comparison of SSB time-series from the final assessment from XSAM and exploratory runs from TASACS (following the 2008 benchmark procedure) and TISVPA. 95% confidence intervals from the XSAM final assessment are shown (dotted lines).

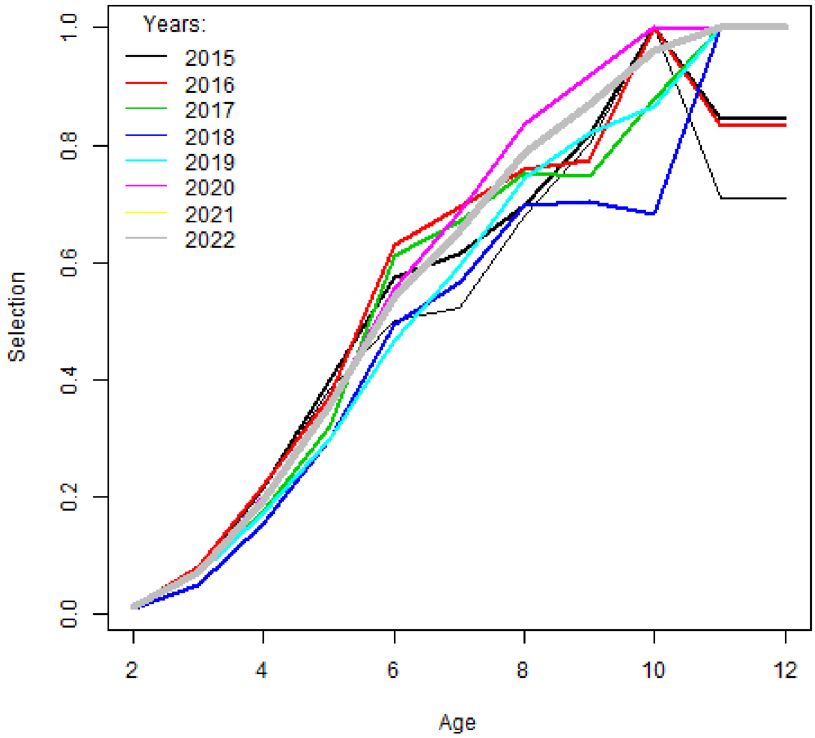


Figure 4.8.1.1. XSAM estimated selection pattern; selected years (estimates for 2015–2020 and predictions for 2021–2022) are shown in colours as indicated in the legend.

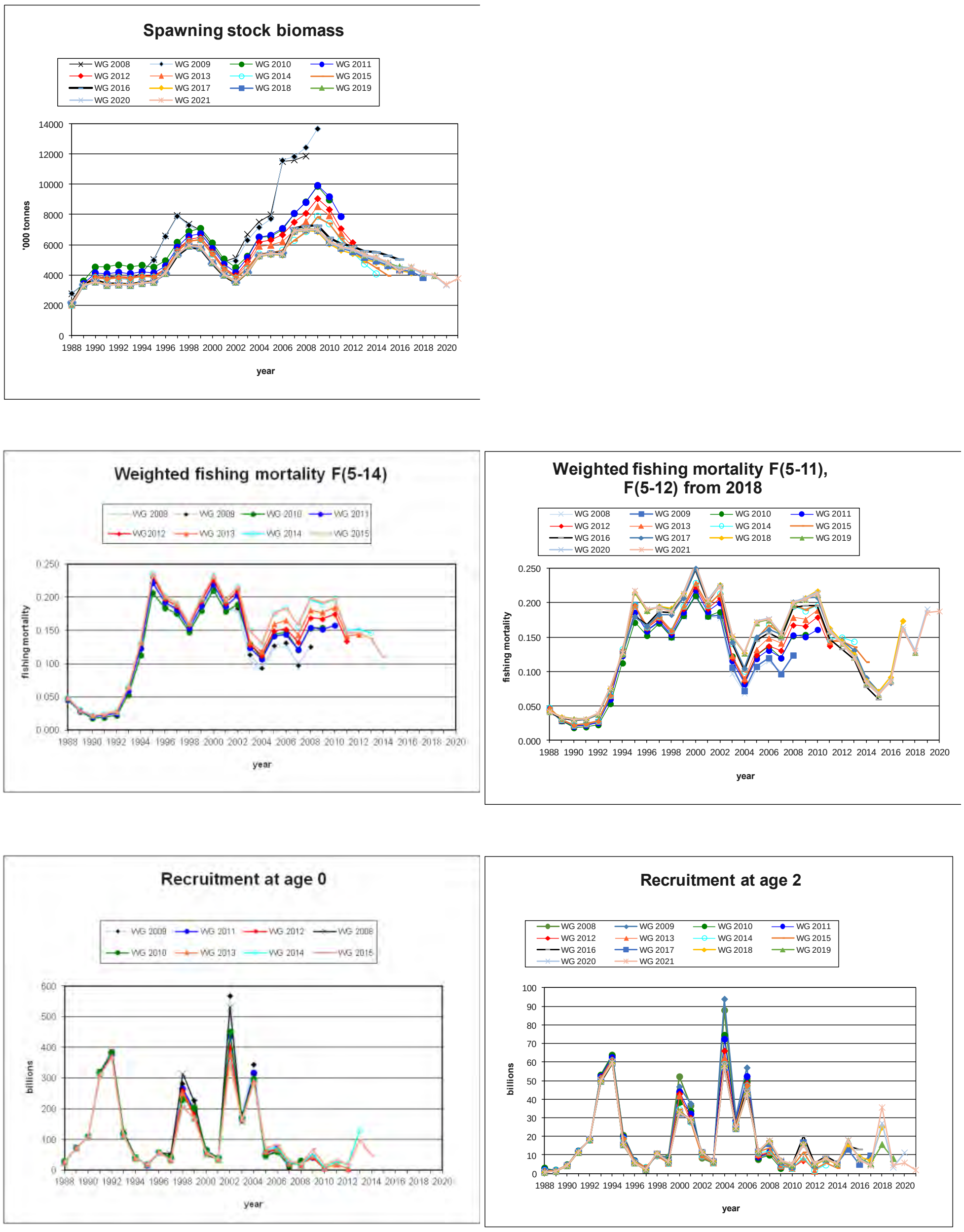


Figure 4.9.1. Norwegian spring spawning herring. Comparisons of spawning stock; weighted fishing mortality F(5–14) and F(5–11/5–12); and recruitment at age 0 and age 2 with previous assessments. In 2016 the proportion mature in the years 2006–2011 was changed; recruitment age changed from 0 to 2 and 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 (*Trachurus trachurus*)

5.1 Fisheries in 2021

The total international catches of horse mackerel in the Northeast 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 2020 for the Western and North Sea stocks was 89 009 t which is 47 741 t less than in 2019 and the second lowest in the time-series.

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 2020 are given in Table 5.1.2 and the distributions of the fisheries are given in Figures 5.1.1.a–5.1.1.d. Note that the figures also include catches of southern horse mackerel. The maps are based on data provided by Belgium, France, Germany, Ireland, Netherlands, Norway, Portugal, Spain and Scotland and represent 99% of the total catches. The distribution of the fishery is similar to recent years with the highest catches taken in the 1st and 4th quarter.

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 Northeastern 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 30 961 t (36% of the total catch of the combined 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: 7974 t. As usual, catches were significantly lower than in the first quarter as the second quarter is the main spawning period. Most of the catch were taken West of Ireland and along the Spanish coast. (Figure 5.1.1.b)

Third quarter: 19 789 t. Most of the catch were taken in Spanish waters, West of Ireland, in the Channel area and at the Norwegian coast (Figure 5.1.1.c).

Fourth quarter: Catches were 26 988 t (31% of the total catch). The catches were distributed in five main areas (Figure 5.1.1.d):

- Spanish waters,
- Western and Northern Irish waters and West of Scotland
- Norwegian coast
- Eastern part of the Channel
- Northeastern part of the Celtic Sea

5.2 Stock units

For many years the Working Group has considered the horse mackerel in the Northeast Atlantic as consisting of three separate 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. The main mismatches between the catch statistics in working group reports and these reviewed data were due to several reasons such as late availability of some data for the report or the availability of official catch data only.

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: 3rd and 4th quarters: Divisions 3.a and 4.a. Quarters 1–4: 2.a, 5.b, 6.a, 7.a–c, e–k and 8.a-e.

North Sea stock: 1st and 2nd quarters: Divisions 3.a and 4.a Quarters 1–4: 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 Subarea and Division for the Western and North Sea stocks for period 1982–2020 are shown in Figures 5.4.2–5.4.3. The catches by stock and countries for the period 1997–2020 are given in Table 5.4.2–5.4.3.

5.5 Estimates of discards

Only the Netherlands have provided data on discards over an extended period with occasional estimates from Germany and Spain. Since 2017 however, additional countries have provided estimates of discards with 7 countries reporting in 2020. 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 3.3 % 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 3.6% in 2020.

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 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 country

Ireland, Netherlands, France, UK (England), UK (Scotland) and Spain provided length distributions for their catches in 2020. The length distributions cover approximately 72% 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 between 2000 and 2020 are shown in figure 5.4.1 and indicate an overall decline in the catches of horse mackerel since 2009.

A detailed analysis on the development of the catch by age data were 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 fishers. However, it is also an alarming signal if a larger proportion of the catch consists of juveniles. These catches could be seen mostly in Division 7.d and to a lesser extent, 7.e.

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 years based on the InterCatch input. 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 2020, due to the Covid pandemic sampling activities in some countries were hampered which lead to an overall lower sampling coverage for 2020. However, due to the fact that for the first time it was possible to upload age samples taken from English vessels in the Netherlands for North Sea horse mackerel the proportion of sampling increased compared with last year for this stock.

Table 5.9.2 shows the sampling intensity for the Western stock in 2020 and table 5.9.3 shows the sampling intensity for the North Sea stock in 2020 by country.

In 2020, France, Ireland, the Netherlands, UK (England), UK Scotland, and Spain provided samples and length distributions and Ireland, the Netherlands, Norway, UK (England), 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 small number of fish which are aged.

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 the 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 lower in recent years (Figure 5.9.2) but due to the inclusion of samples of English vessels sampled in the Netherlands higher in 2020. 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.c and 7.d from the 3rd and 4th quarters. Therefore, these estimates can be biased, especially, since samples are usually less than the recommended 100 fish per sample. (Table 5.9.1)

The proportion of the sampled catches by region for the Western stock are shown in figure 5.9.3. No samples were available for the most Northern regions of the Western stock distribution and sampling for the West of Scotland/Western Irish waters and the Cantabrian Sea decreased substantially whereas the sampling in the Channel and Bay of Biscay regions slightly increased compared with 2019. The general index of sampling intensity is 51%. 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 do not reflect 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 and omit the horse mackerel target fleet. This lack of coverage may also affect the accuracy and reliability of the assessment and is a matter of concern for the Working Group.

5.10 References

Brunel, T., 2016. Revision of the Maturity Ogive for the Western Spawning Component of NEA Mackerel. Working document to WKWIDE, 6pp.

Costas, G. 2017a. Review of Horse Mackerel catch data. North Sea and Western Stocks. WD to WGWIDE 2017. 11 pp.

Costas, G. 2017b. Sampling coverage for Horse Mackerel Stocks. Presentation to WGWIDE 2017.

ICES, 1990. Report of the Working Group on the Assessment of the Stocks of Sardine, Horse Mackerel and Anchovy. ICES, C.M. 1990/Assess: 24.

ICES, 1991. Working group on the Assessment of the Stocks of Sardine, Horse Mackerel, and Anchovy. ICES CM 1991/Assess: 22. 138 pp.

Pastoors, M. (2017). A look at all the horse mackerel. WD to WGWIDE 2017.

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	2020
2	867	290
4 + 3.a	12 593	13 792
6	47 351	19 037
7	42 973	33 310
8	29 640	19 639
9[1]	34 080	31 344
Disc	3 326	2 942
Total	170 829	120 347

[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 2020.

Division	1Q	2Q	3Q	4Q	TOTAL
2.a+5.b	189	96	36	11	290
3	0	0	5	91	96
4.a	1450	761	7077	3310	12598
4.bc	13	290	352	442	1098
7.d	164	203	2598	6089	9077*
6.a b	12766	0	3	5939	19037**
7.a–c e–k	15568	958	1226	6481	24232***
8.a-e	811	5666	8528	4635	19639
Sum	30961	7974	19789	26988	86067****

*** for the total 24 t were added which were only declared as yearly catch**

**** for the total 329 t were added which were only declared as yearly catch**

***** for the total 3 t were added which were only declared as yearly catch**

****** for the total 356 t were added which were only declared as yearly catch**

Table 5.7.1 Horse mackerel general. Length distributions (%) by country and area in 2020.

	France	Ireland	Ireland	Ireland	Ireland	Ireland	Ireland	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands
cm	27.8.a	27.6.a	27.7.b	27.7.g	27.7.j	27.7.j.2	27.8.a	27.4.a	27.6.a	27.7.b	27.7.d	27.7.e	27.7.f	27.7.g	27.7.j.2
6			0.0	0.0	0.2										
7															
8															
9															
10															
11															
12	4.5														
13	4.5														
14	15.6														
15	17.8														
16	4.5														
17	11.1														
18	0.0			0.0	0.0									0.2	
19	6.7	0.0									2.5	8.0	2.0	0.2	
20		0.1									6.4	12.0	17.4	8.3	
21	2.2	0.2	0.1						3.9		17.6	12.0	31.7	27.3	
22	6.7	0.5		0.2	0.2				4.0		21.5	12.0	14.2	21.3	
23	2.2	2.5	0.1	0.4	0.8	0.1			0.1		9.4	24.0	14.9	18.7	0.3
24	2.3	4.5	0.0	1.9	5.7				11.3		19.0	16.0	10.8	14.7	0.5
25	0.1	2.5	0.3	4.4	12.6	0.1			4.3	0.0	14.6	8.0	4.8	5.7	0.3
26	0.4	6.8	2.3	8.5	22.1	1.8			8.3	3.7	5.2	8.0	2.4	2.0	1.6
27	0.4	15.3	10.7	11.2	14.9	8.7			21.7	7.8	1.9		0.6	1.3	8.9
28	0.5	21.5	24.0	19.0	12.7	20.0	1.8	2.2	22.8	40.3	1.6		1.2	0.5	16.9
29	1.0	15.5	25.0	23.1	11.0	19.5	1.8	14.5	8.6	17.1	0.2				18.0
30	1.9	8.6	14.9	15.2	3.6	21.5	1.8	29.0	9.6	12.3	0.2				16.1
31	1.6	5.2	9.3	6.2	1.3	13.6	1.8	31.2	3.1	4.5					7.8
32	1.6	3.8	5.3	4.6	2.2	7.7	5.2	16.9	1.0	0.4					7.0
33	1.5	3.2	3.6	1.5	1.0	3.5	9.5	4.2	1.0	3.9					5.4
34	1.6	4.1	2.1	0.7	1.3	1.9	7.7	2.0	0.1	3.9					7.4
35	1.3	3.3	1.3	1.4	2.6	1.1	16.3			1.9					4.2
36	1.0	1.5	0.7	0.6	2.3	0.6	12.1		0.2	4.0					3.1
37	1.2	0.6	0.1	0.1	0.7	0.1	13.7			0.0					1.6
38	5.1	0.2	0.3	0.3	1.6		13.7			0.0					0.6
39	1.3	0.0	0.0	0.2	0.8		9.5			0.1					0.5
40	0.7	0.0	0.0	0.3	1.7		3.4								
41	0.8		0.0	0.1	0.3		1.8								
42+	0.1		0.0	0.1	0.3		0.0								

Table 5.7.1 continued

	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain	UK (England)	UK (England)	UK (England)	UK (England)	UK (England)	UK (England)	UK (England)	UK(Scotland)
cm	27.6.a	27.7.b	27.7.c.2	27.7.g	27.7.h	27.7.j.2	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.4.c	27.6.a	27.7.b	27.7.d	27.7.e	27.7.g	27.7.j	27.6.a
6																		
7							0.0								7.8			
8							0.2								25.9			
9							0.6								18.8			
10							0.9		0.0						5.5			
11							1.0		0.0						0.4			
12							3.3		1.1						0.1			
13							4.9		10.6						2.6			
14							9.3		9.7						0.2			
15							6.5	1.0	1.9						3.1			
16							12.7	5.0	2.1						2.4			
17							16.9	1.0	5.8					0.3	6.8			
18							13.8	2.0	8.5		0.6			1.6	3.3			
19							8.3		10.5		2.3			3.1	3.2			
20							3.7	5.0	3.0	0.2	11.4			13.2	2.4			
21							1.7	11.6	2.3	1.7	25.1			24.9	2.4			
22							0.8	9.9	0.9	4.3	21.8			16.2	1.5			0.0
23							0.5	1.7	1.0	4.6	17.7			10.6	3.9			
24							0.5		1.3	7.6	9.9			12.5	1.2			0.1
25							0.3		1.1	5.8	5.0			5.6	1.1			0.2
26		0.1	0.5		0.4	0.6	0.5	20.8	1.9	14.2	4.3	3.3		5.1	1.1			1.8
27		0.3	0.9		0.8	1.1	0.5		2.9	7.4	1.2	18.9	4.1	2.0	1.5		2.2	1.0
28		1.9	4.5		4.3	5.5	0.7	41.2	4.6	3.4	0.7	28.2	12.2	1.6	1.0			5.1
29		5.1	10.0		9.4	12.2	0.9		3.1	3.1		18.6	20.3	0.4	1.8		4.4	8.7
30		8.9	14.2		13.4	17.4	1.1		2.9	3.1		9.7	32.5	0.5	0.5		4.4	8.9
31		5.3	7.0		6.6	8.6	1.5		3.7	2.9		9.8	12.2	1.1	0.5	25.8	2.2	10.1
32		5.7	6.3		5.9	7.7	1.6		3.4	4.6		4.9	8.1	0.5	0.3	22.6	17.0	7.1
33		5.1	4.6		4.4	5.7	1.6		3.1	4.0		5.6	3.6	0.4	0.2	9.7	10.1	10.8
34	6.9	6.7	5.1		4.8	6.3	1.8		3.5	3.1		0.9	7.1	0.2	0.1	22.6	14.2	14.4
35	13.2	7.0	6.0	9.4	6.2	5.3	1.6		3.8	7.3				0.2	0.1	12.9	9.7	15.8
36	32.0	19.8	17.3	37.6	18.5	12.8	1.0		3.0	8.9				0.1	0.1	3.2	17.6	9.8
37	18.8	13.0	13.6	41.2	15.1	7.4	0.6		2.2	5.9					0.0	3.2	6.3	3.5
38	22.9	11.9	6.9	11.9	7.2	5.8	0.4		0.9	4.8					0.2		6.2	1.5
39	6.2	7.8	2.6		2.5	3.2	0.2		0.4	1.1							3.8	0.4
40		1.4	0.4		0.4	0.5	0.1		0.3	0.7								0.3
41							0.0		0.2	0.5					0.0		1.9	0.3
42+							0.0	0.9	0.1	0.1								0.1

Table 5.9.1. Summary of the overall sampling intensity on horse mackerel catches in recent years in all areas 1992—2020

Year	Total Catch (ICES estimate)	% catch covered by sampling programme*	No. samples	No. Measured	No. Aged
1992	436500	45	1803	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

Year	Total Catch (ICES estimate)	% catch covered by sampling programme*	No. samples	No. Measured	No. Aged
2020	89009	52	516	41811	5662

*Percentage related to catch (catch-at-age) according to ICES estimation

Table 5.9.2. Horse mackerel sampling intensity for the Western stock in 2020.

Country	Catch	% Catch Sampled*	No. Samples	No. Measured	No. Aged
Denmark	6705	0	0	0	0
Faroe Islands	-	0	0	0	0
France**	2742	-*	35	808	0
Germany	955	0	0	0	0
Ireland	17507	98	268	10573	1833
Netherlands	14240	95	44	7515	1072
Norway	10666	0	0	0	0
Poland	1001	0	0	0	0
Spain	19349	35	478	24432	1143
Sweden	83	0	0	0	0
UK (England)***	4046	96	66	557	147
UK(Northern Ireland)	1503	0	0	0	0
UK(Scotland)**	439	-*	111	697	0
Total	76422	51	507	39777	4195

*Percentage based on ICES estimate with regards to age samples

**provided only length distributions

*** age samples processed by the Netherlands

Table 5.9.3. Horse mackerel sampling intensity for the North Sea stock in 2020.

Country	Catch	% Catch Sampled*	No. Samples	No. Measured	No. Aged
Belgium	39	0	0	0	0
Denmark	191	0	0	0	0
Faroe Islands	109	0	0	0	0
France**	945	0	0	0	0
Germany	3	0	0	0	0
Lithuania	0	0	0	0	0

Country	Catch	% Catch Sampled*	No. Samples	No. Measured	No. Aged
Netherlands	4803	60	9	2034	223
Norway	2090	0	0	0	0
Sweden	1	0	0	0	0
UK (England)****	4381	97	50	15847	1244
UK(Northern Ireland)	0	0	0	0	0
UK(Scotland)***	24	0	0	0	0
Total	12587	56	99	1902	475

***Percentage based on ICES estimate with regards to age samples.**

**** provided only length distributions**

*****provided length distributions not incl. in InterCatch**

****** age samples processed by the Netherlands**

5.12 Figures

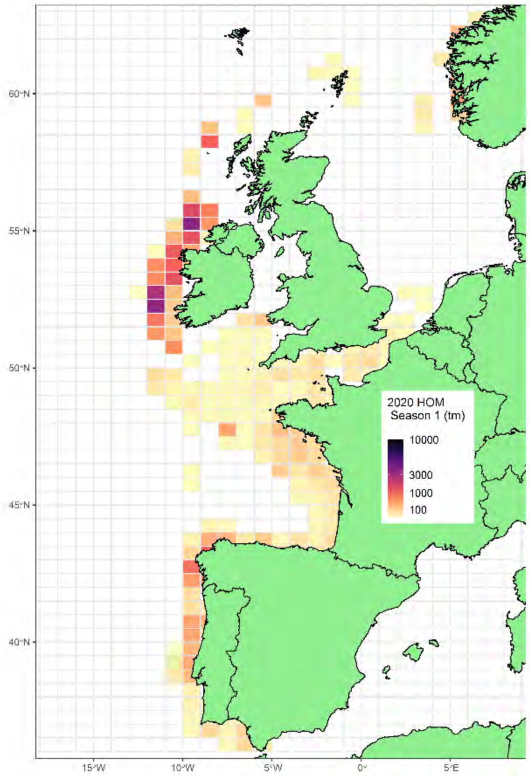


Figure 5.1.1a. Horse mackerel catches 1st quarter 2020

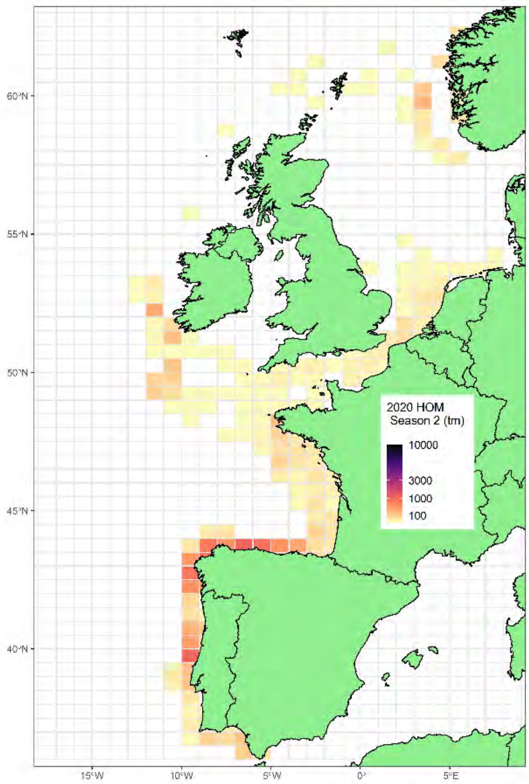


Figure 5.1.1b. Horse mackerel catches 2nd quarter 2020.

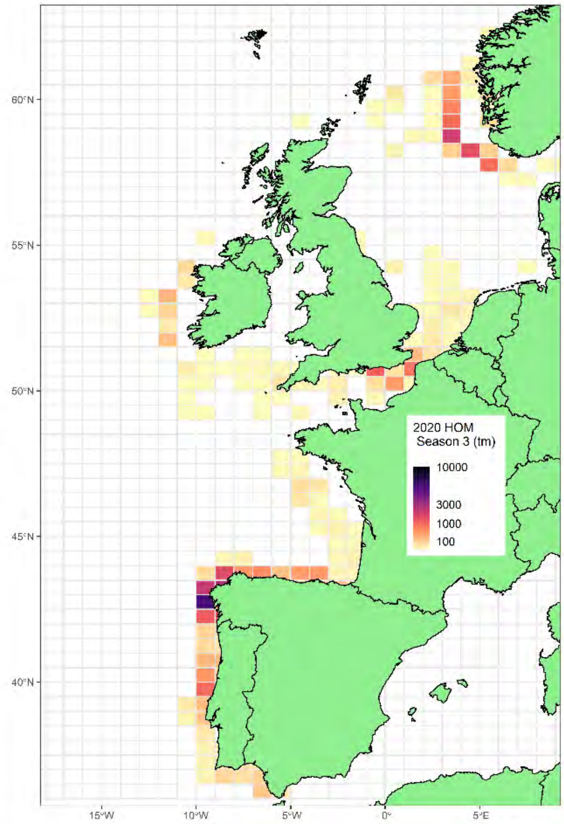


Figure 5.1.1c. Horse mackerel catches 3rd quarter 2020.

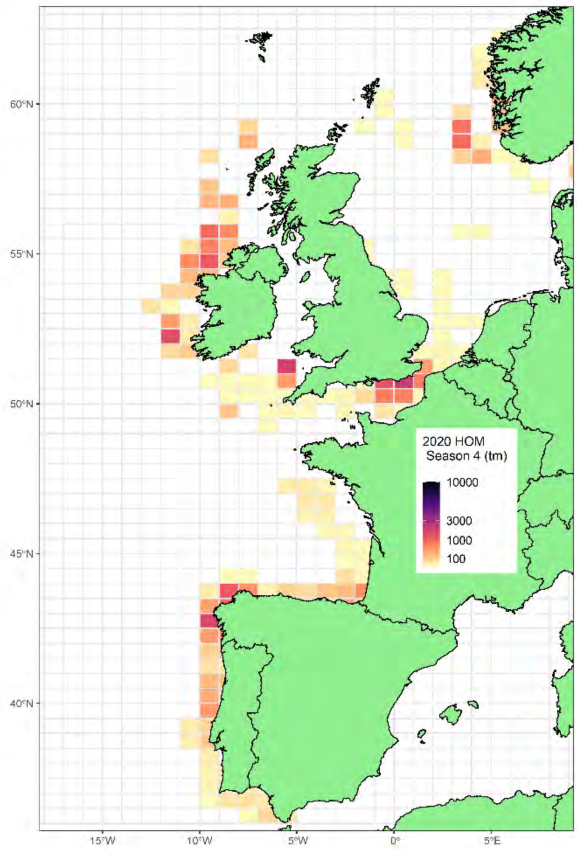


Figure 5.1.1d. Horse mackerel catches 4th quarter 2020.

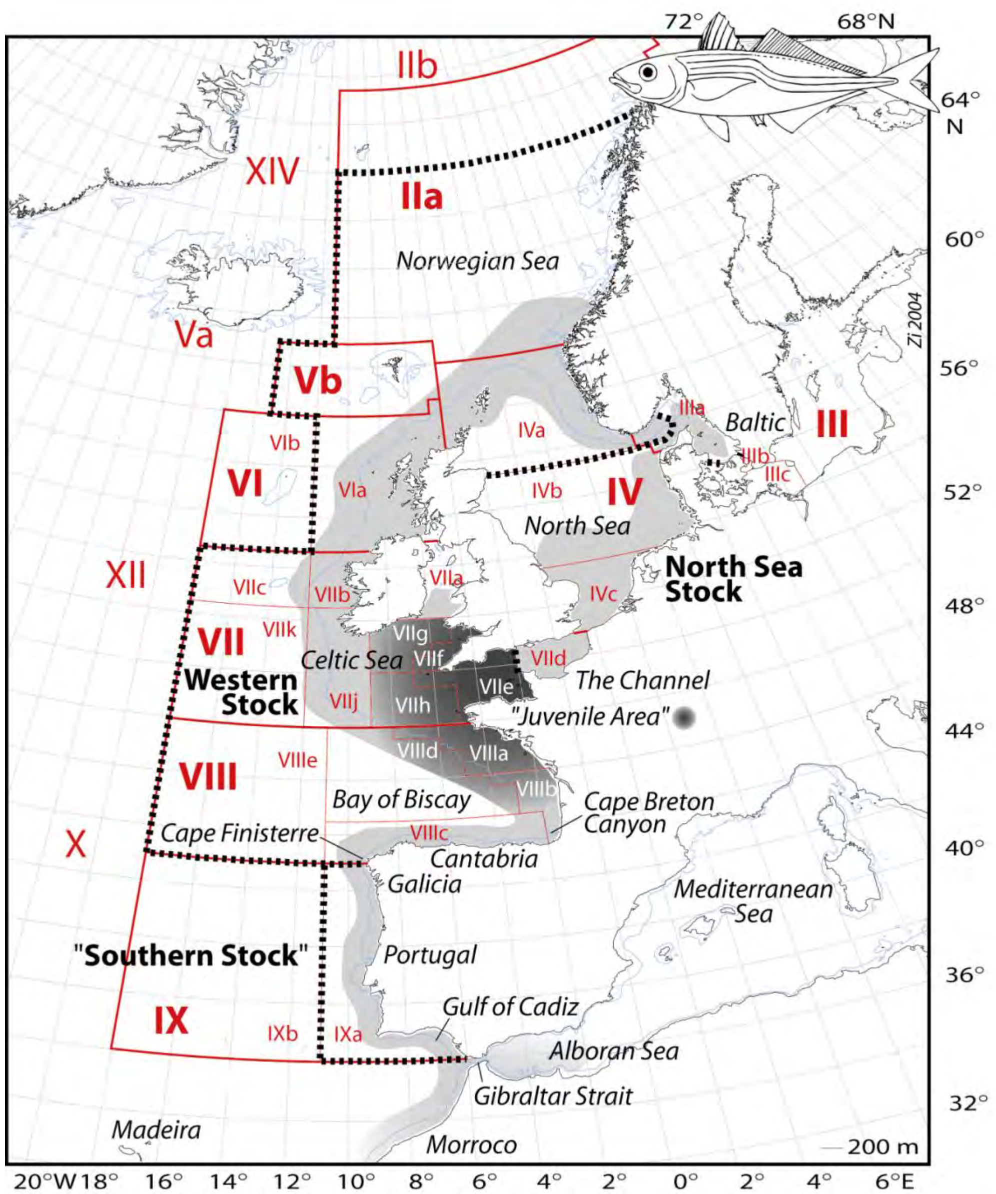


Figure 5.2.1: Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by the 2004 WG MHSA. Note that the "Juvenile Area" is currently only defined for the Western Stock distribution area – juveniles do also occur in other areas (like in Div. 7.d). Map source: GEBCO, polar projection, 200 m depth contour drawn.

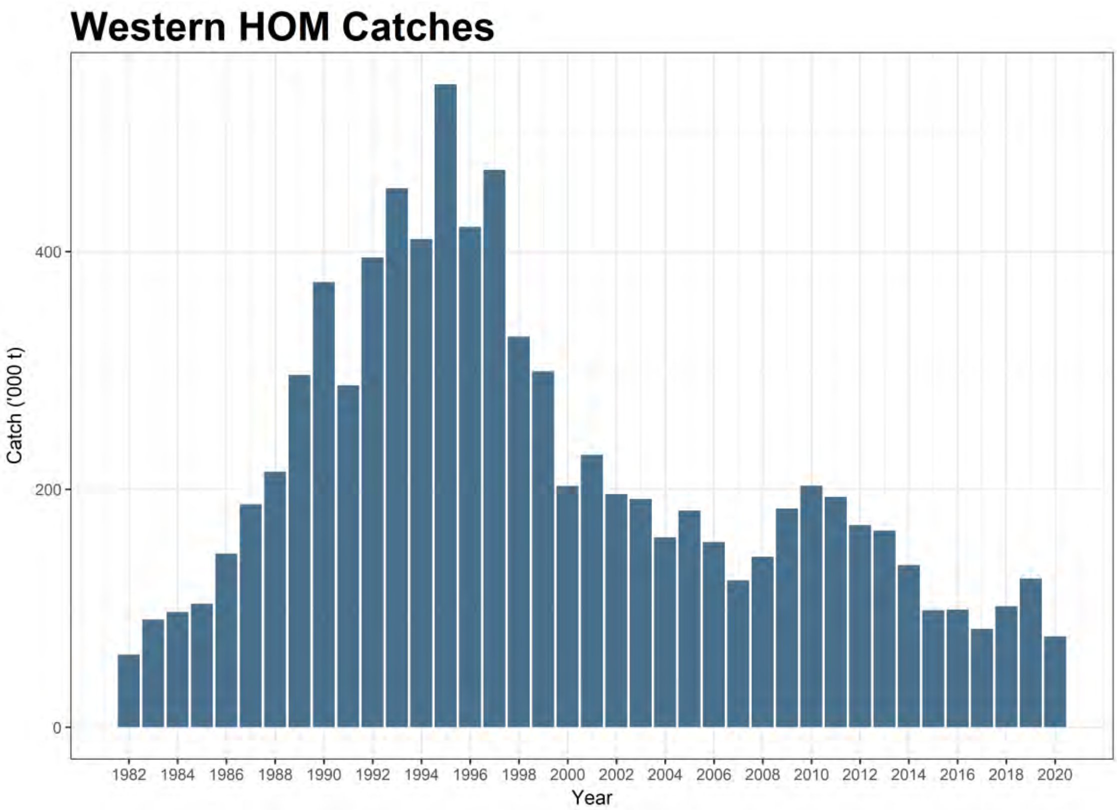


Figure 5.3.1. Total catch for Western Horse Mackerel stock, period 1982–2020.

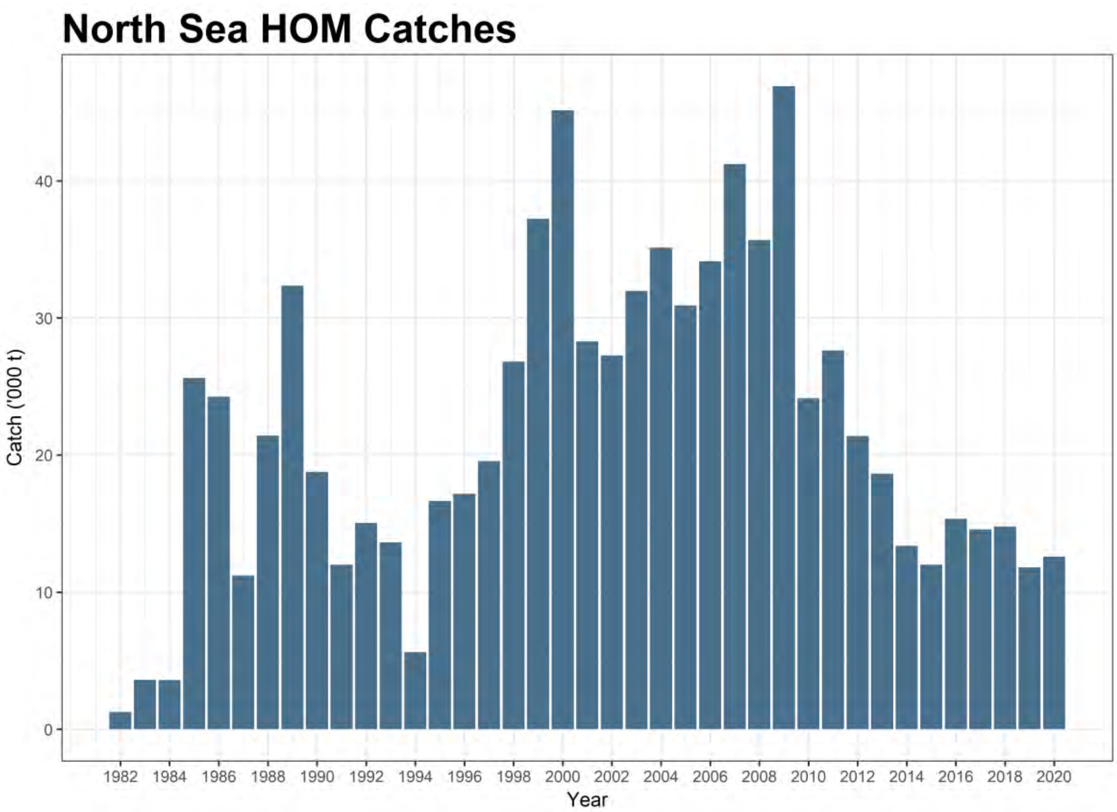


Figure 5.3.4. Total catch for North Sea Horse Mackerel stock, period 1982–2020

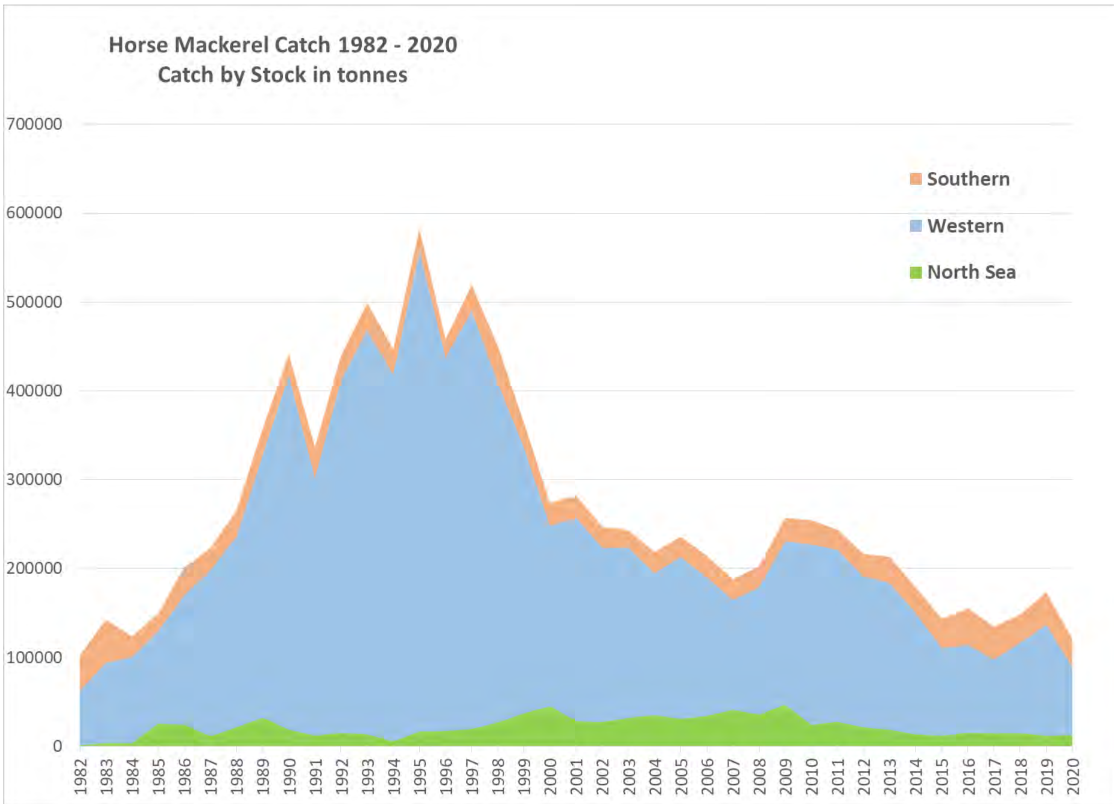


Figure 5.4.1 Horse mackerel general overview. Total catches in the Northeast Atlantic during the period 1982—2020. The catches taken from the southern, western and North Sea horse mackerel stocks are shown in relation to the total catches in the Northeast Atlantic. Catches from Div. 8.c were transferred from southern stock to Western stock from 1982 onwards. Southern horse mackerel is assessed by ICES WGHANSA since 2011.

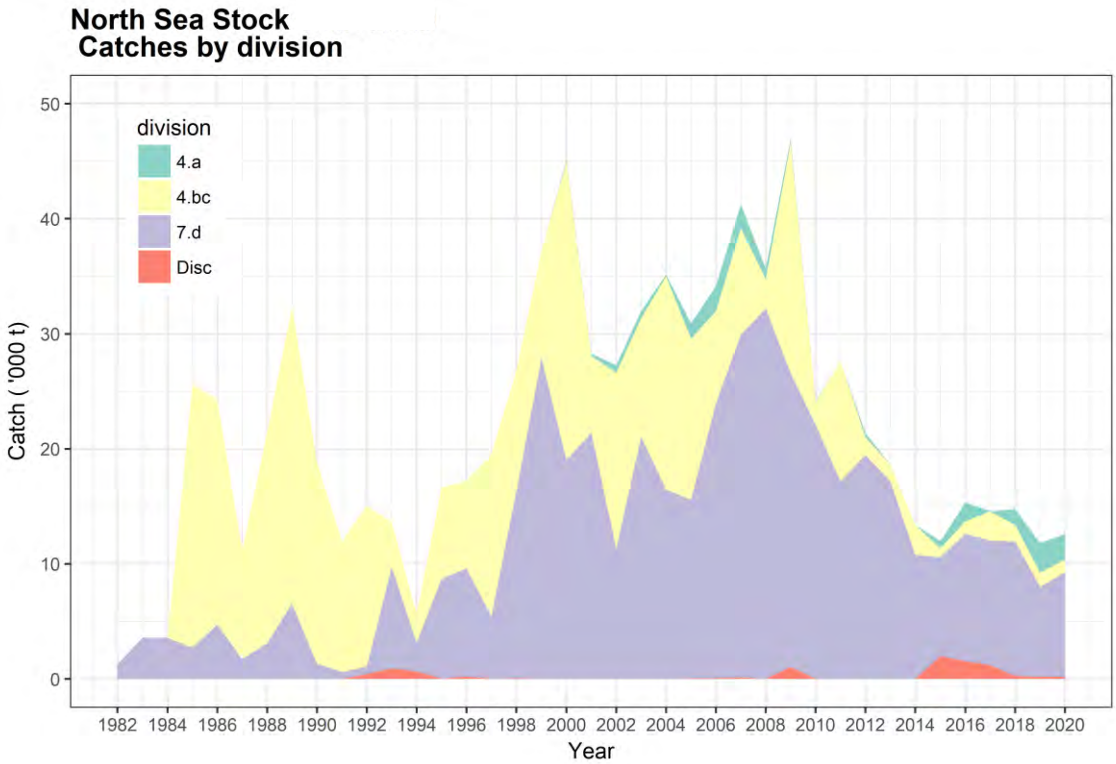


Figure 5.4.2. North Sea horse mackerel stock. Total catches by Division during the period 1982–2020.

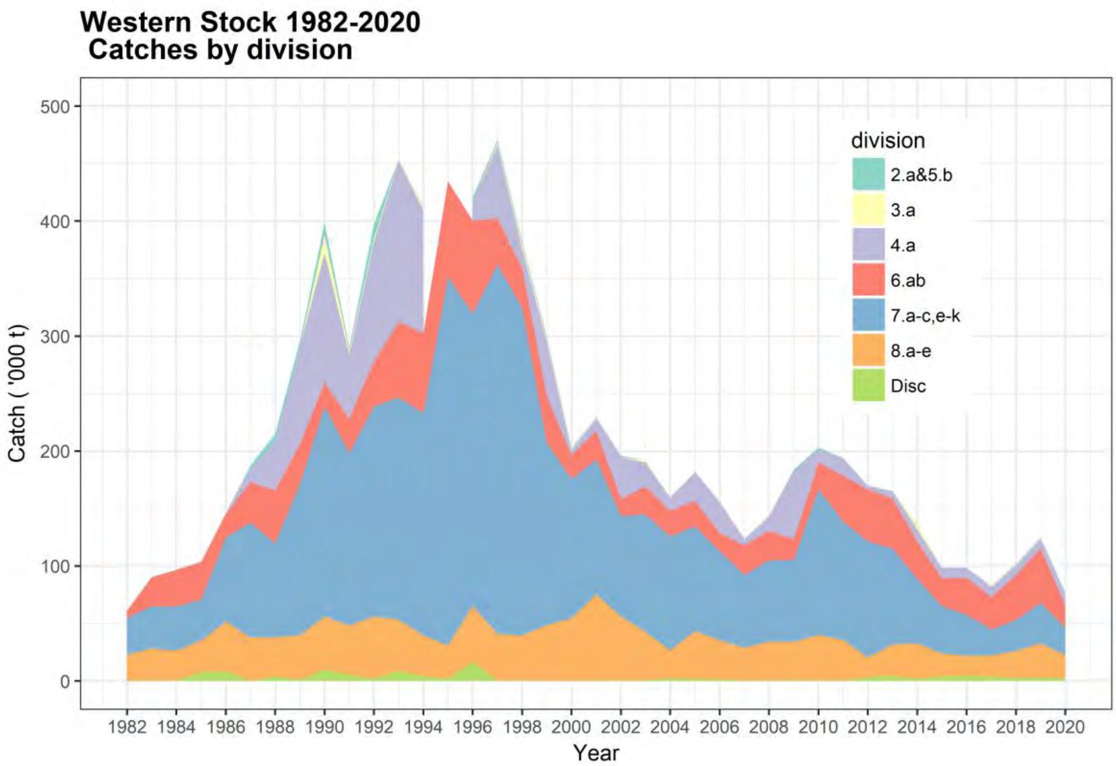


Figure 5.4.3. Western horse mackerel stock. Total catches by Sub-Area during the period 1982–2020.

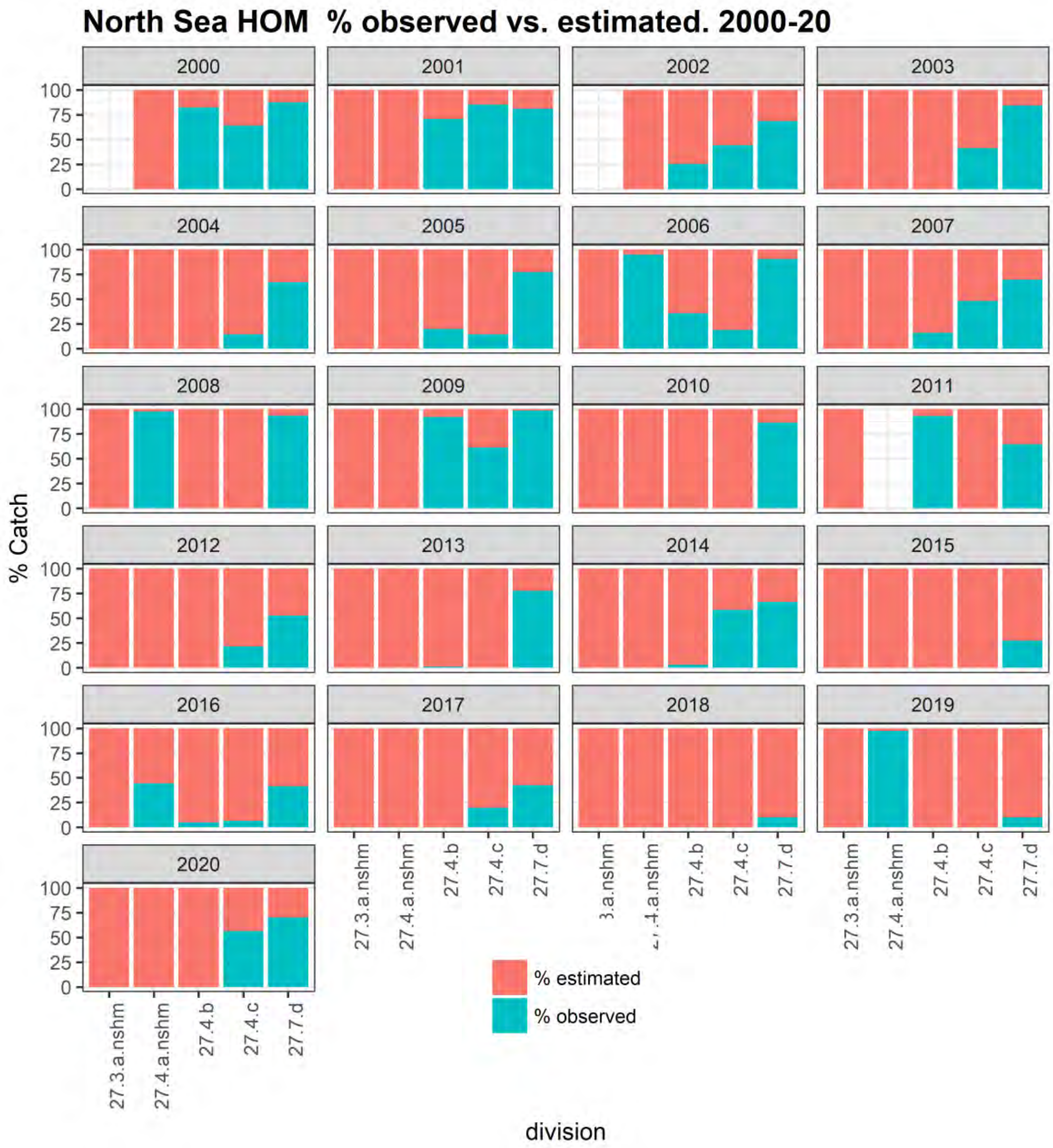


Figure 5.9.1 North Sea horse mackerel stock. Percentage sampled catch (blue) vs. unsampled catch (red) by Division and year. Period 2000–2020.

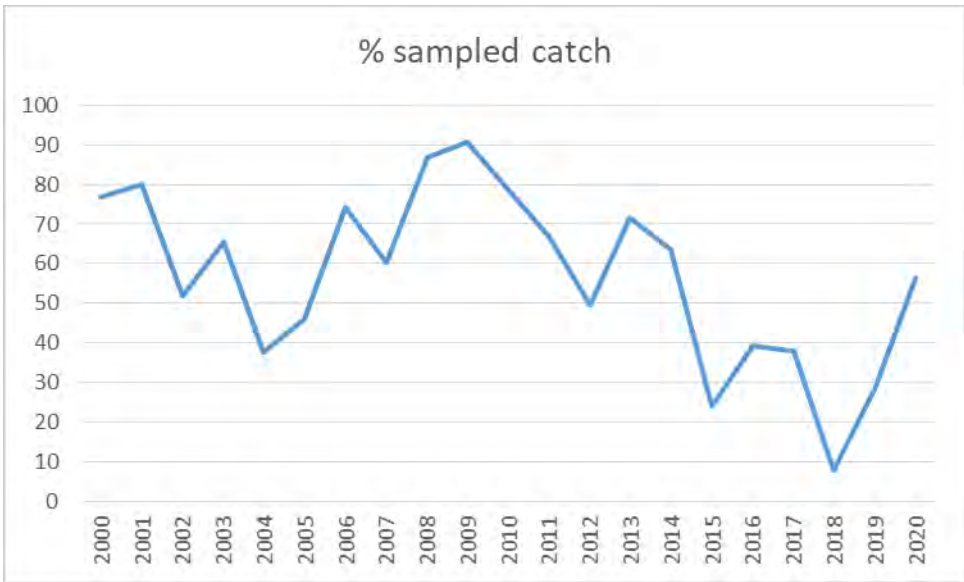


Figure 5.9.2. North Sea horse mackerel stock. Sampling intensity index as percentage sampled catch in total catch by year. Period 2000–2020

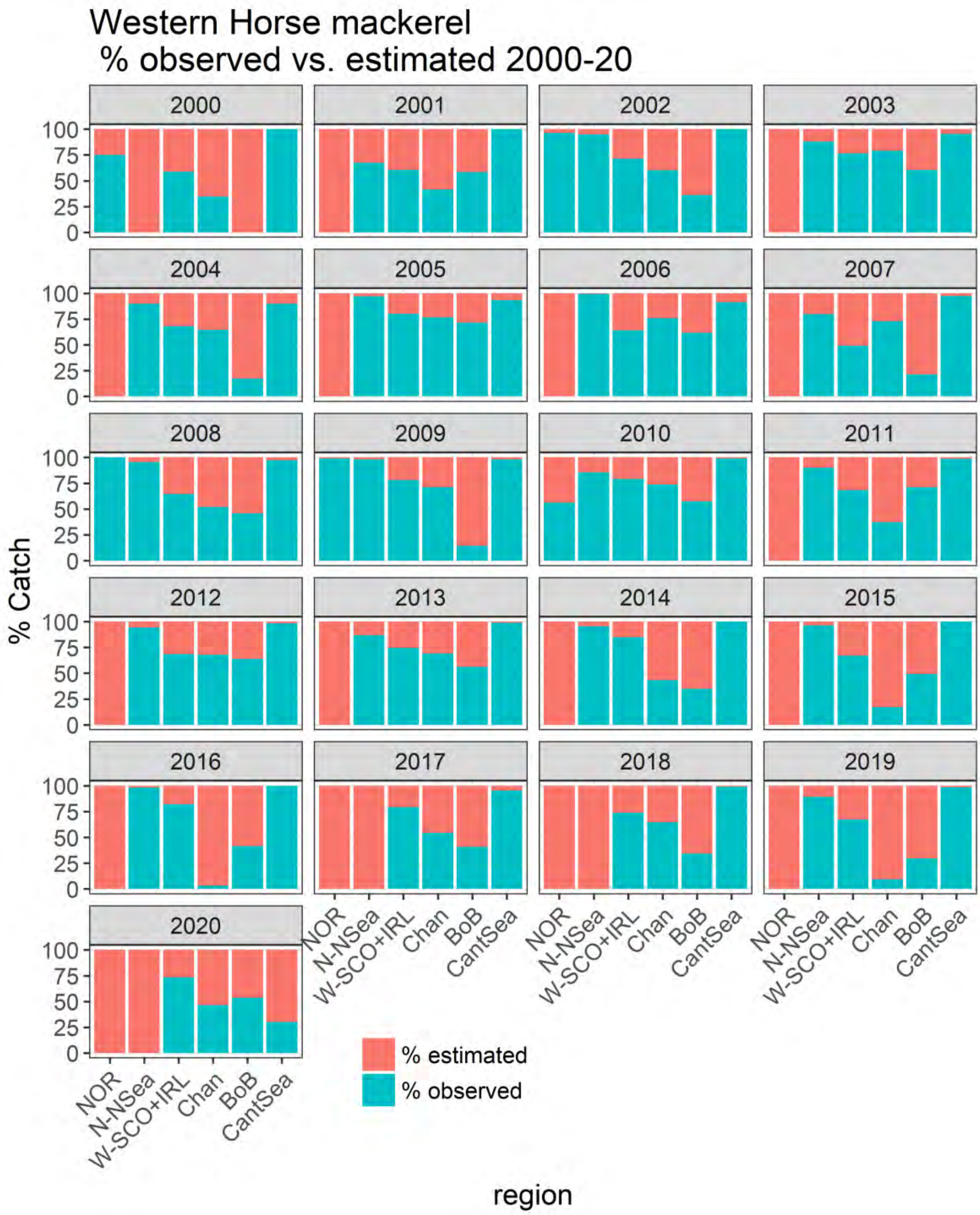


Figure 5.9.5. Western horse mackerel stock. Percentage sampled catch (blue) vs. unsampled catch (red) by Division and year. Period 2000–2020. Area of distribution of Western stock was divided into different regions. Chan: (7.e,f,h); W-SCO+IRL (7.a-c, 7.j-k and 6.a); BoB (8.a,b,d); CanSea(8.c); N-Nsea (3.a and 4.a); NOR (2.a and 5.a).

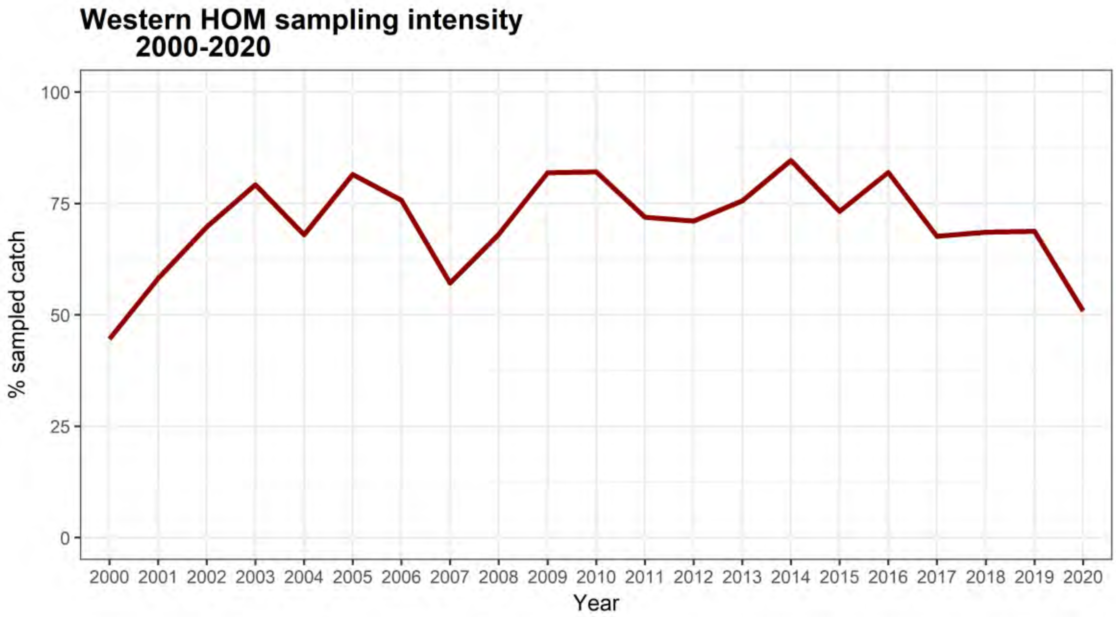


Figure 9.5.6. Western horse mackerel stock. Sampling intensity index as percentage sampled catch in total catch by year. Period 2000–2020.

6 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)

6.1 ICES advice in 2021

In 2012, the North Sea horse mackerel (NSHOM) 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 (FR-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, the stock was benchmarked and the NS-IBTS and FR-CGFS survey indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHOM stock was upgraded to category 3.

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 in 2019, leading to a catch advice for 2020 and 2021 of 14 014 tonnes. Considering the 5.05% discards rate (average of 2017 and 2018 rates), the corresponding wanted catches were advised to be 13 305 tonnes.

6.2 Fishery of North Sea horse mackerel stock

Based on historical catches taken by the Danish industrial fleet for reduction into fishmeal and fishoil 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 4.b and 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 led 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 1990s, a larger proportion of the catches have been taken in a directed horse mackerel fishery for human consumption by the Dutch-owned 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 underutilization 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 2020, 91% of the TAC was used, with the highest catches taken by the Netherlands, followed by UK, Norway and France (Figure 6.2.2).

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 t) and 2000 (45 130 t). From 2000 to 2010, the catches varied between 24 149 and 45 883 t. 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 2020 the catch was 12 587 t, with 72% of the total catch being caught in Area 27.7.d, which is a similar share of the overall catch as in 2019 (68%, 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 2020, the Netherlands accounted for most of the landings, followed by UK, Norway and France (Figure 6.2.5). The majority was still caught in quarter 4 in 27.7d, whereas the Norwegian catches were taken during quarters 1 and 2 in 27.4.a. Most of the discards reported were from 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%. 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. In 2017 and 2018 the discard rate was 8.3% and 1.8%, respectively, while it decreased to 1.6% in 2019. In 2020 the discard rate was again 1.6%.

6.3 Biological data

6.3.1 Catch in Numbers-at-age

In 2020 (as in recent years) the coverage of biological sampling remains on a very low level and in addition was also affected by the Covid-19 pandemic. However, due to the fact that, for the first time, it was possible to include samples taken from English vessels in the Netherlands the proportion of sampling increased to 56% compared with last year where just 1/3 of the landings was sampled. In the past higher sampling levels were achieved such as in 2013 and 2014 when 71% and 63% of the catch was sampled. Age samples were therefore available from two countries (the Netherland and UK/England) with regards to Q3 and Q4 in areas 27.4.c and 27.7.d. Although most landed catch was taken from 27.7.d in Q4, 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 1995–2020 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 compared with 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 is 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, 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.

The potential for mixing of fish from the Western and North Sea stock in areas 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 entire 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 is described in Section 6.7.

6.3.2 Mean weight at age and mean length-at-age

The mean annual weight and length over the period 2000–2020 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 1992–2009 period provide complete data for the 1992 to 2009 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 should 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 exploratory model fits were attempted with the JAXass model, 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. JAXass 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 carried out 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), additional 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 explored the Surplus Production model in Continuous Time (SPiCT) model for 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 biomass was estimated to be above B_{MSY} and fishing mortality 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, additional 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 and Horse Mackerel Egg Surveys in the North Sea do not cover the spawning area of the North Sea horse mackerel stock.

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 that 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 NS-IBTS is considered a reasonable alternative.

NS-IBTS data from quarter 3 were obtained from DATRAS and analysed. Based on a comparison of NS-IBTS data from all 4 quarters in the period 1991–1996, Rückert *et al.* (2002) showed that horse mackerel catches in the NS-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 of 20 cm and larger is the most appropriate to the purpose of interpreting trend in the stock.

To create indices, a subset of ICES statistical rectangles was identified. 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 (FR-CGFS) in 27.7.d in quarter 4. The FR-CGFS has been carried out since 1990 and has frequent captures of horse mackerel. Although this survey is conducted in a different quarter to the NS-IBTS, the observed seasonal migration patterns of horse mackerel indicate that fish move into the Channel following quarter 3, so the timing is considered appropriate.

In 2015, the RV Gwen Drez was replaced by the RV Thalassa to carry out the FR-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 RV Thalassa as measured by the MARPORT sensor were deemed erroneous, which may question the validity of estimated area swept by the net on the RV 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 affect in the estimated abundance.

For these reasons it was considered appropriate to continue using the FR-CGFS, standardizing the time-series of abundance for the period 1990–2015 with the estimated conversion factor 10.363.

6.4.3.4 Impact of Covid-19

Due to the Covid-19 pandemic and the lockdown in place in France at that time there was a delay in submitting the cruise application form for the FR-CGFS in 2020 to the French Foreign Ministry. The result was that no authorization was provided in time to allow the survey to trawl within UK waters in 2020. Therefore, only French waters were sampled, meaning that only 70% of the core survey stations were completed (ICES, 2021).

To assess the potential impact of missing UK stations in the FR-CGFS on the resulting abundance index for the exploitable stock, we tested the impact of

i. removing all UK sampling stations from the 1992–2019 time-series,
ii. removing UK sampling stations from 2016-2019, one year at the time, and
iii. removing the FR-CGFS in 2016–2019, one year at the time, when modelling the abundance and calculating the index.

Removing all UK sampling stations from all years did not change the overall trend of the abundance index, but there were quite some deviations for individual years (Figure 6.4.6). Removing UK stations from on year at the time for 2016–2019 resulted in virtually no change for 2017 and 2018, but more apparent changes for 2016 and 2019 (Figure 6.4.7). Both these exercises suggest that basing the abundance index on NS-IBTS and French stations from FR-CGFS only may lead to different index values compared to when UK stations are included. The French sampling stations in the FR-CGFS only are thus not representative for the abundance of adult horse mackerel in the entire eastern Channel. As a further exploration, the abundance index was modelled by leaving out the FR-CGFS entirely for 2019. However, the hurdle model was not able to run, and therefore a zero-inflated model was run instead. This 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). Removing the FR-CGFS from on year at the time for 2016–2019 resulted in minimal change for 2017 and 2018, but more apparent changes for 2016 and 2019 (Figure 6.4.8). Similar to (i) and (ii), leaving out the FR-CGFS may lead to different index values compared to when FR-CGFS is included.

As the investigations suggest that the missing UK stations from the FR-CGFS or leaving out the FR-CGFS entirely may lead to changes in the abundance index, it was decided that no reliable index value for 2020 could be produced.

6.4.4 Length distributions from the surveys

The largest proportion of fish caught in 2020 were around 16–17 cm and 20–21 cm in the NS-IBTS (Figure 6.4.9). The latter group could be the strong year class observed in 2018 (Figure 6.3.1, 6.4.9). In the FR-CGFS, the largest proportion of fish were between 9–12 cm, while in previous years, larger fish were dominating the catches (Figure 6.4.10). Note however that for 2020 these are only based on French sampling stations.

6.4.5 Length distributions from commercial catches

Currently, length distributions from catch data are available from 2016 to 2020. 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 national sampling programmes. For comparison, the analysis has also been run in the past with length data from the self-sampling programme of the Pelagic-Freezer-trawler Association (PFA), see for instance ICES (2019, 2020).

The length distributions based on the commercial catch data from 27.7.d show a consistent distribution in time with a mean length between 22.2 and 22.8 cm each year, although with the exception of 25.8 cm in 2019 (Figure 6.4.11). Lengths in 27.4.c were on average 21.7 cm in 2019 and 22.7 cm in 2020, and this similar to 27.7.d (Figure 6.4.12).

An error was found in the calculation of the length frequency distributions in the previous 2019 and 2020 assessments. Furthermore, the length frequency distribution calculated in 2019 included French data from only quarters 3 and 4, whereas data are also available for quarters 1 and 2. The length frequency distributions for 2018 and 2019 were re-calculated using all available data.

6.5 Stock assessment

6.5.1 Modelling the survey data

In January 2017, a benchmark of the North Sea horse mackerel assessment was conducted (ICES, 2017). Based on a capacity to model the overdispersion and the large proportion of zero values in the survey catch data, a hurdle model was considered the best option of all model alternatives tested. The log-likelihood ratio test, AIC and the evidence ratio statistic supported that the model that best represented the data were 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 synthesize the information from both the FR-CGFS and NS-IBTS and predict the average annual CPUE index as an indicator of trends in stock abundance. Separate models were fitted to the juvenile (<20cm) and adult exploitable (≥20cm) substocks. 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 NSHOM to a category 3 stock within the ICES classification.

Similar to the 2019 assessment (ICES, 2019) and 2020 assessment (ICES, 2020), the model for the adult substock 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 6.5.1). 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.

Due to the exclusion of the 2020 survey for modelling the abundance index, the same time period (1992–2019) was used as in the previous assessment (ICES, 2020). This updated abundance index resulted in a higher value for 2016 for the exploitable stock compared to last year (Figure. 6.5.2). For each assessment, survey data from all years are extracted so that any underlying changes in the raw data stored in DATRAS are taken account of. Changes in reported raw HOM catches in 2016 in the NS-IBTS led to a higher mean catch rate of HOM (Figure 6.5.3), resulting in a higher abundance index value for 2016.

6.5.2 Summary of index trends and survey length distributions

The survey index for both the juvenile and exploitable substock experienced a marked decline in the early 1990s and fluctuated at relatively low levels thereafter (Figures 6.5.4; Table 6.5.1). 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 substock (Figure 6.5.5). 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 6.5.4).

The index trend for the juvenile substock shows large fluctuations since 2015 (Figure 6.5.4). These are mainly attributed to the fluctuating trend of juveniles in the NS-IBTS (Figure 6.5.6), caused by some hauls with high catches of small horse mackerel in 2016 and 2018 (Figure 6.4.9). Fitted values for juveniles in the FR-CGFS show decreasing trend since 2014, but a slight increase again in 2019 (Figure 6.5.6). 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.

6.5.3 Length-based indicator 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 in area 27.7d, length distributions from this area were used to calculate the MSY proxy. In 2020, the F/F_{MSY} proxy based on the commercial catch samples indicated that fishing mortality was still slightly above F_{MSY}, with $L_{mean}/L_{F=M}$ = 23.2 cm / 25.0 cm = 0.927 (Figure 6.5.7).

The updated length distributions of 2018 and 2019 led to only small revisions in the F/F_{MSY} ratios in those years: from 0.954 to 0.927 for 2018, and 0.976 to 0.978 for 2019.

6.6 Basis for 2022 and 2023 advice

Stock advice for North Sea horse mackerel is biennial. The NS-IBTS and FR-CGFS were modelled together to produce a joint abundance index for the exploitable part of the stock (≥ 20 cm). No index value for 2020 could be produced. For this reason, the 2-over-3 rule applied to the index could only make use of index values from 2016 to 2019. The resulting index ratio (index value of 2019 over mean index value of 2016–2018) indicated that the adult substock declined by 21%. As the decline was more than 20%, the uncertainty cap of 0.8 was applied to the catch advice. The $L_{mean}/L_{F=M}$ ratio in 2020 was 0.927, indicating that the fishing mortality is above F_{MSY}. Because the precautionary buffer was last applied in 2017, and thus more than three years ago, the buffer was applied once again in 2021. Under these circumstances, and based on the last year's catch advice of 14 014 t, ICES advises that catches of North Sea horse mackerel in 2022 and 2023 should be no more than 8969 t.

There are some signs of improved recruitment in some years (e.g. 2016, 2018), but the trend of the abundance index for the juvenile substock is fluctuating and, when separated, the two surveys, NS-IBTS and FR-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 substock in 2019 suggests that this may be the case.

6.7 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 are able to reveal the stock identity of individual horse mackerel from potential mixing areas, namely Division 7.d, 7.e and 4.a. Following this, the Institute of Marine Research in Norway sampled horse mackerel in coastal waters within 4.a during all quarters in 2019. Preliminary results presented at WGWIDE 2021 showed that the genetic profile of individuals caught in all quarters matched well with the genetic profile of the Western HOM stock, with just one or two individuals matching better with North Sea HOM profile (Florian Berg, pers. comm.). More samples and research is needed to confirm these results. In another research project, horse mackerel from 7.d and 7.e have been collected by the PFA on board of commercial vessels in autumn 2020, while during the same period horse mackerel from 4.a have been be collected during the NS-IBTS in Q3. The stock identity of the sampled fish will be investigated, and results can be expected in 2022. The Norwegian research as well as the ongoing research described here may have large implications for stock delineation.

6.8 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. Recent work suggest that all horse mackerel caught in 27.4.a belong to the Western stock, and ongoing genetic research on samples from 27.4.a and 27.7.d will shed more light on the proportions of the two stocks in catches from these areas.

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

1. Stock: **hom.27.3a4bc7d**

2. Missing or deteriorated survey data:

The assessment is based on two surveys, NS-IBTS and FR-CGFS. Due to the pandemic, trawling authorization in UK EEZ was not delivered in time, consequently FR-CGFS survey was not allowed to sample stations within UK waters in 2020.

3. Missing or deteriorated catch data:

Related to age sampling coverage was 56% and was covering only Q3, Q4 in areas 27.4.c and 27.7.d. Although most landed catch is taken from 27.7.d in Q4, other areas and quarters remain uncovered. Length sampling were impacted by the pandemic as samples were only available by two countries.

4. Missing or deteriorated commercial LPUE/CPUE data:

Not applicable

5. Missing or deteriorated biological data:

Not applicable

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

Effects of having only UK stations in FR-CGFS in all years or a single year, and excluding FR-CGFS entirely for a single year on the combined survey index were investigated.

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

Exploration methods suggested that leaving out UK stations or FR-CGFS entirely may affect the survey index and would lead to a survey index value not representative of stock abundance. It was therefore decided to produce no survey index value for 2020.

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out?

The chosen solution affects the 2-over-3 rule by that only four instead of five index values can be used to assess the change in stock abundance. Like this year's assessment for 2022 and 2023, this will also affect the advice given in 2023 for 2024 and 2025.

6.10 References

Barange, M., Pillar, S. C., and Hampton, I. 1998. Distribution patterns, stock size and life-history strategies of Cape horse mackerel Trachurus trachurus capensis, based on bottom trawl and acoustic surveys. South African Journal of Marine Science, 19: 433–447.

Bolle, L.J., Abaunza, P., Albrecht, C., Dijkman-Dulkes, A., Dueñas, C., Gentschouw, G., Gill, H., Holst, G., Moreira, A., Mullins, E., Rico, I., Rijs, S., Smith, T., Thaarup, A., Ulleweit, J. 2011 . Report of the Horse Mackerel Exchange and Workshop 2006. CVO report: 11.007.Eaton, D. R. 1983. Scad in the North-East Atlantic. Laboratory Leaflet, Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Lowestoft, 56: 20 pp.

Eaton, D. R. 1983. Scad in the North-East Atlantic. Lab. Leafl., MAFF Direct. Fish. Res., Lowestoft (56): 20pp.

Fuentes-Pardo, A.P., Petterson, M., Sprehn, C.G., Andersson, L., Farrell, E. 2020. Population structure of the Atlantic horse mackerel (Trachurus trachurus) revealed by whole-genome sequencing, July 2020.

Farrell, E. D. and J. Carlsson (2019). Genetic stock identification of Northeast Atlantic Horse mackerel, Trachurus trachurs. , EDF, December 2018.

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M.N., Nielsen, A., Sibert, J. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software, 27: 233-249.

Gordo, L. S., Costa, A., Abaunza, P., Lucio, P., Eltink, A. T. G. W., and Figueiredo, I. (2008). Determinate versus indeterminate fecundity in horse mackerel. Fisheries Research, 89: 181-185.

ICES. 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM 68. 42 pp.

ICES. 2017. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January–3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

ICES. 2018. ICES reference points for stocks in categories 3 and 4. ICES Technical Guidelines. 13 February 2018. http://www.ices.dk/sites/pub/Publication%20Reports/Guidelines%20and%20Policies/16.04.03.02_Category_3-4_Reference_Points.pdf

ICES. 2019. Report of the Working Group on Widely Distributed Stock (WGWIDE. ICES Scientific Reports. 1:36. 948 pp.

ICES. 2020. Working Group on Widely Distributed Stocks (WGWIDE). ICES Scientific Reports. 2:82. 1019 pp. http://doi.org/10.17895/ices.pub.7475

ICES. 2021. International Bottom Trawl Survey Working Group (IBTSWG). ICES Scientific Reports. 3:69. 201 pp. https://doi.org/10.17895/ices.pub.8219

Macer, C.T. 1974. The reproductive biology of the horse mackerel Trachurus trachurus (L.) in the North Sea and English Channel. J. Fish Biol., 6(4): 415-438.

Macer, C.T. 1977. Some aspects of the biology of the horse mackerel [Trachurus trachurus (L.)] in waters around Britain. Journal of Fish Biology, 10: 51-62.

Pérez-Rodríguez, A. 2017. Use of Length Based Indicators to estimate reference points for the North Sea horse mackerel. Working Document to WGWIDE, 6pp.

Rückert, C., Floeter, Temming, J.A. 2002. An estimate of horse mackerel biomass in the North Sea, 1991-1997. ICES Journal of Marine Science, 59: 120-130.

6.11 Figures

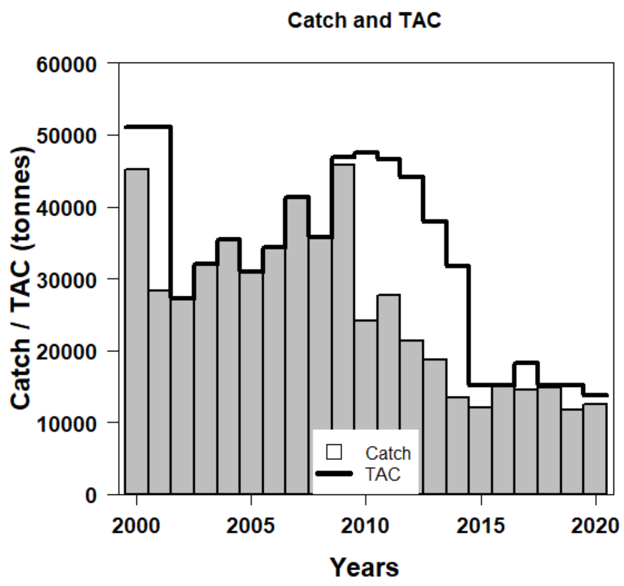


Figure 6.2.1. North Sea horse mackerel. Utilisation of quota from 2000 to 2020.

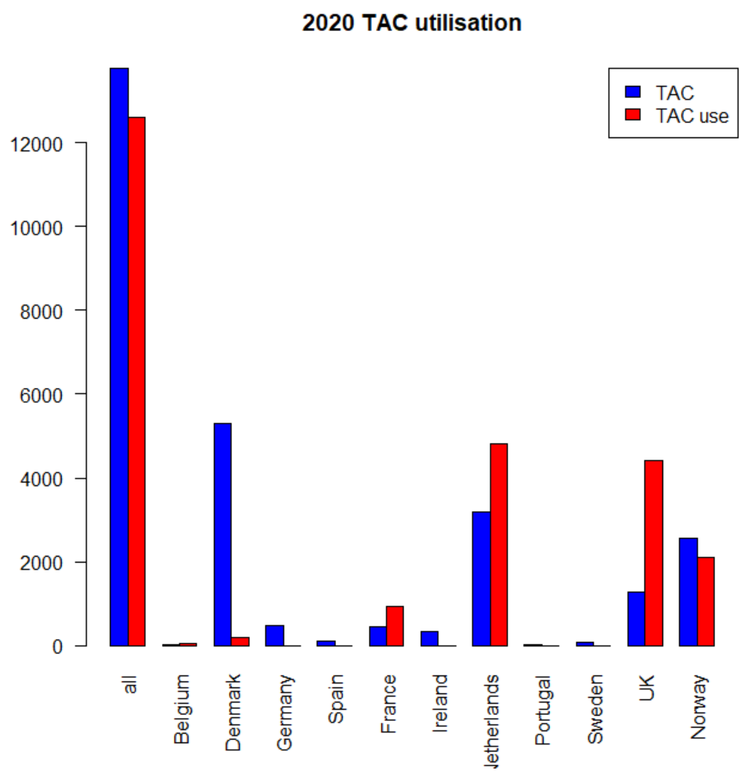


Figure 6.2.2. North Sea horse mackerel. Utilisation of quota by country in 2020.

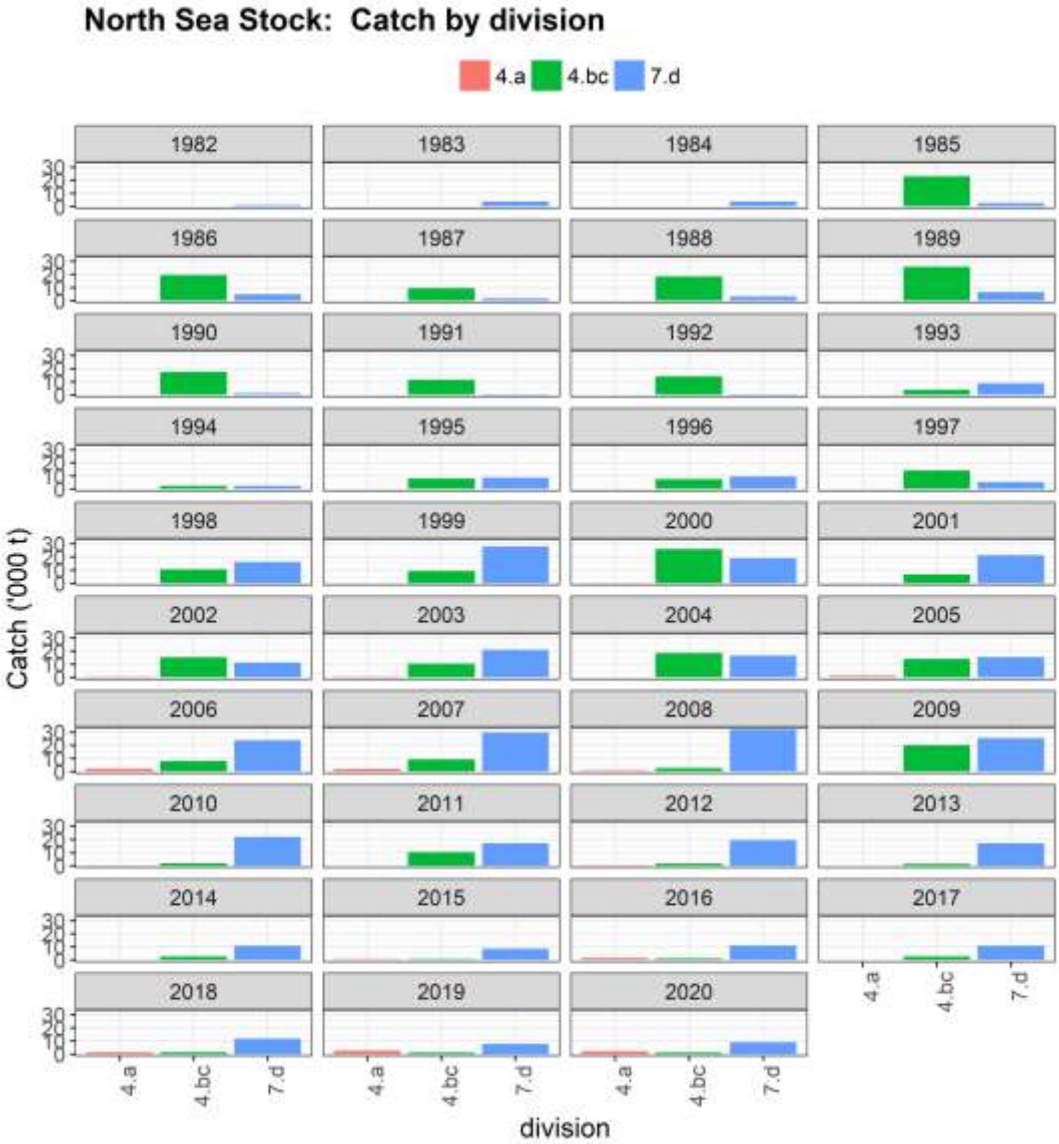


Figure 6.2.3. North Sea horse mackerel. Catch in (1000 t) by Division and year from 1982 to 2020.

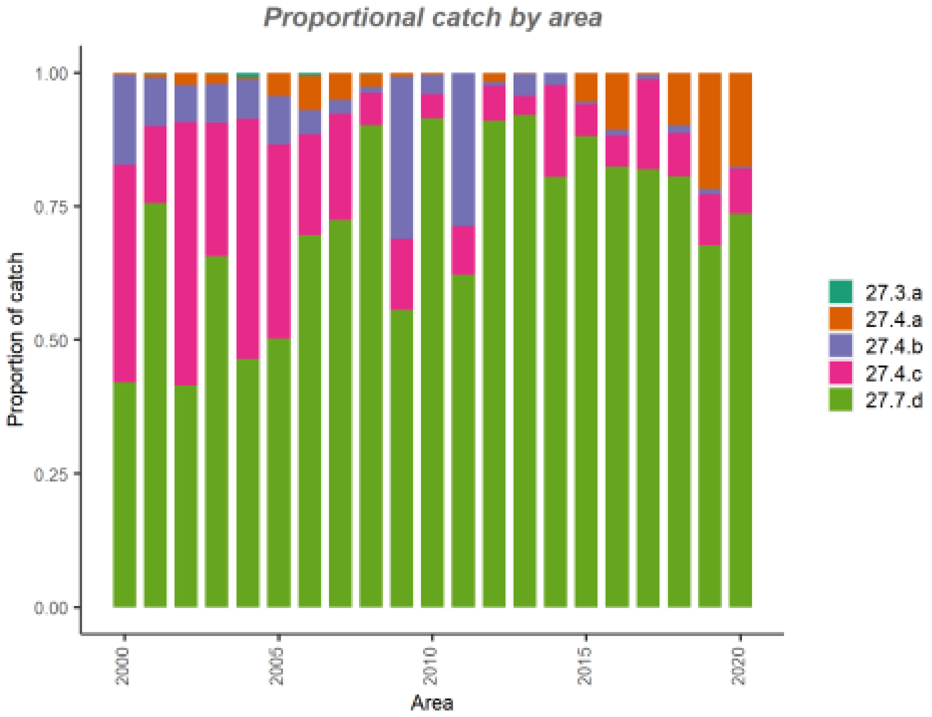
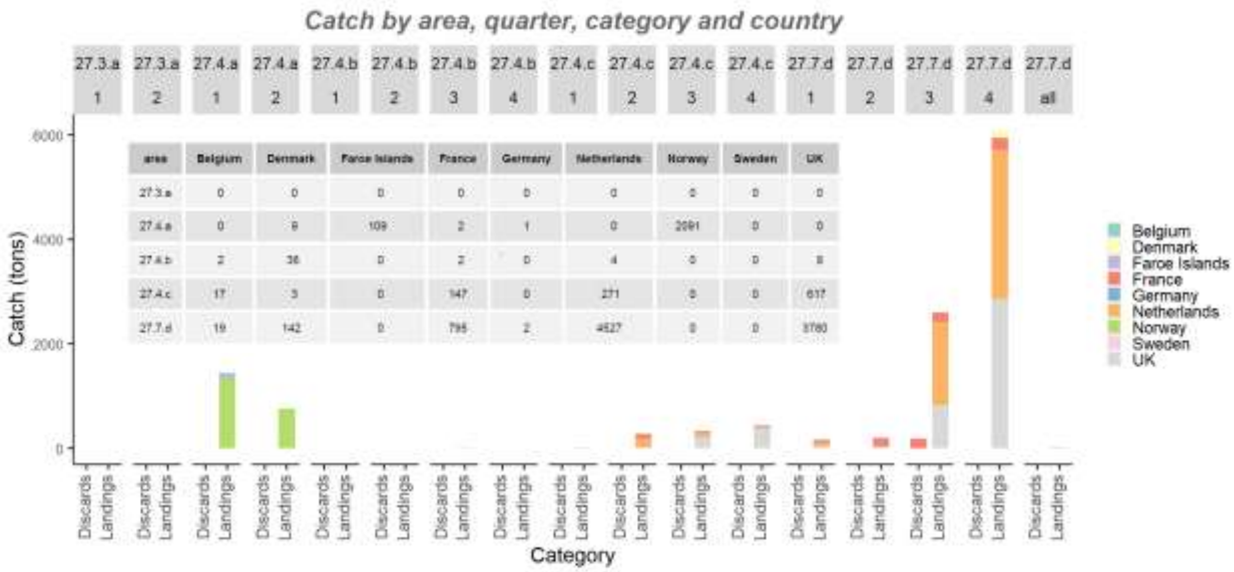


Figure 6.2.4. North Sea horse mackerel. Proportion of catches by ICES Division from 2000 to 2020.



area	Belgium	Denmark	Faroe Islands	France	Germany	Netherlands	Norway	Sweden	UK
27.3.a	0	0	0	0	0	0	0	0	0
27.4.a	0	9	109	2	1	0	2091	0	0
27.4.b	2	36	0	2	0	4	0	0	8
27.4.c	17	3	0	147	0	271	0	0	617
27.7.d	19	142	0	795	2	4527	0	0	3780

Figure 6.2.5. North Sea Horse Mackerel. Total catch (in tonnes) by ICES Division, quarter, catch category and country in 2020.

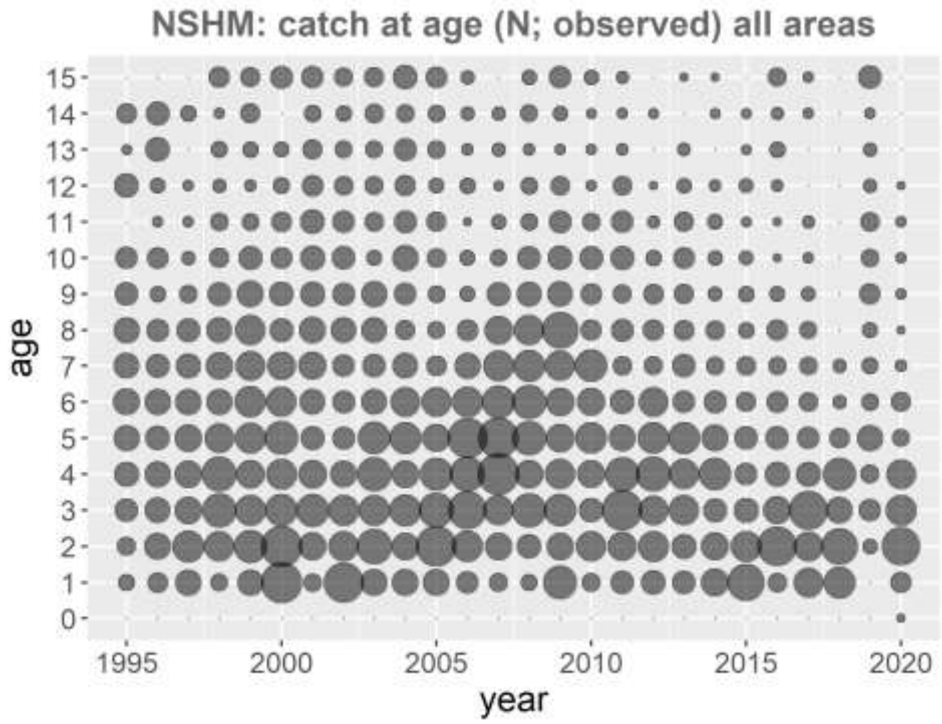
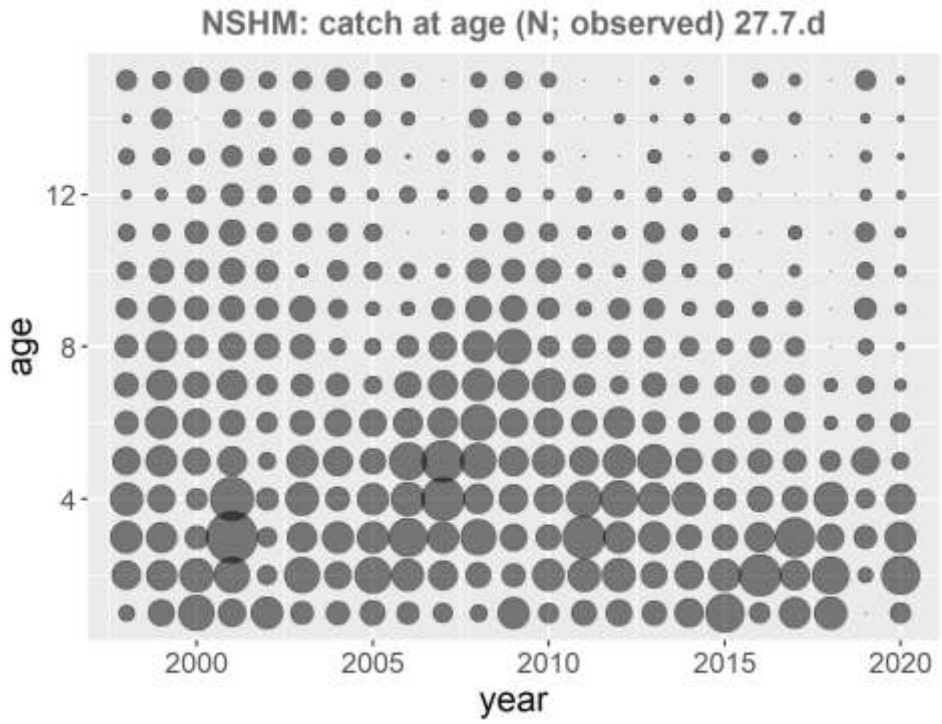


Figure 6.3.1. North Sea horse mackerel age distribution in the catch for 1995-2020. The size of bubbles is proportional to the catch number. Note that age 15 is a plus g



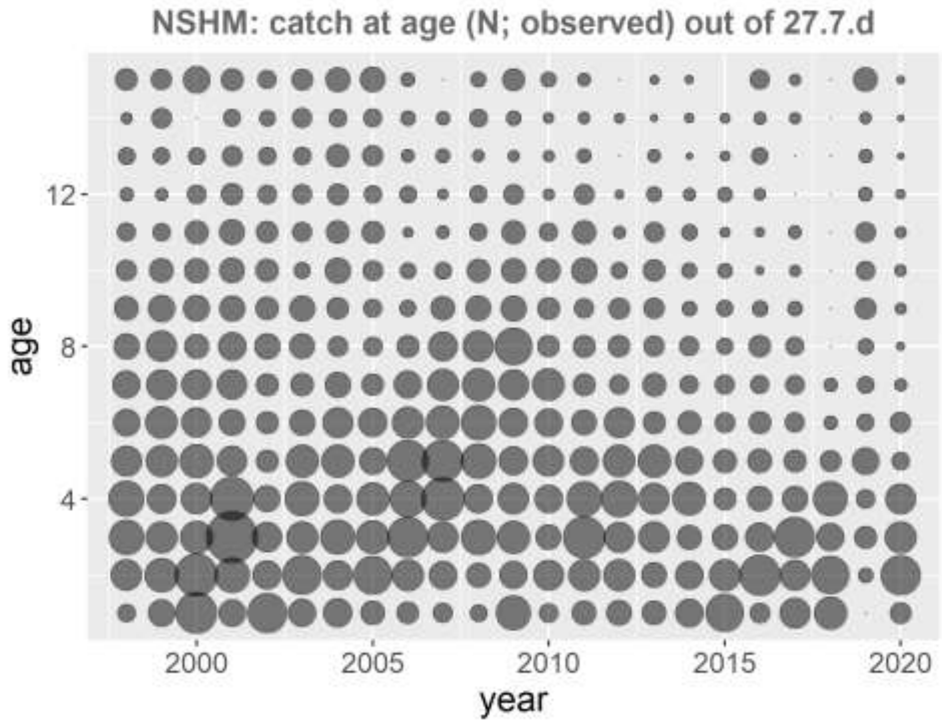


Figure 6.3.2. North Sea horse mackerel. Bubble plots of age distribution in the catch by area for 1998–2020 for area 7.d (upper panel) and out of 7.d (bottom panel). The size of bubbles is proportional to the catch numbers. Note that age 15 is a plus group.

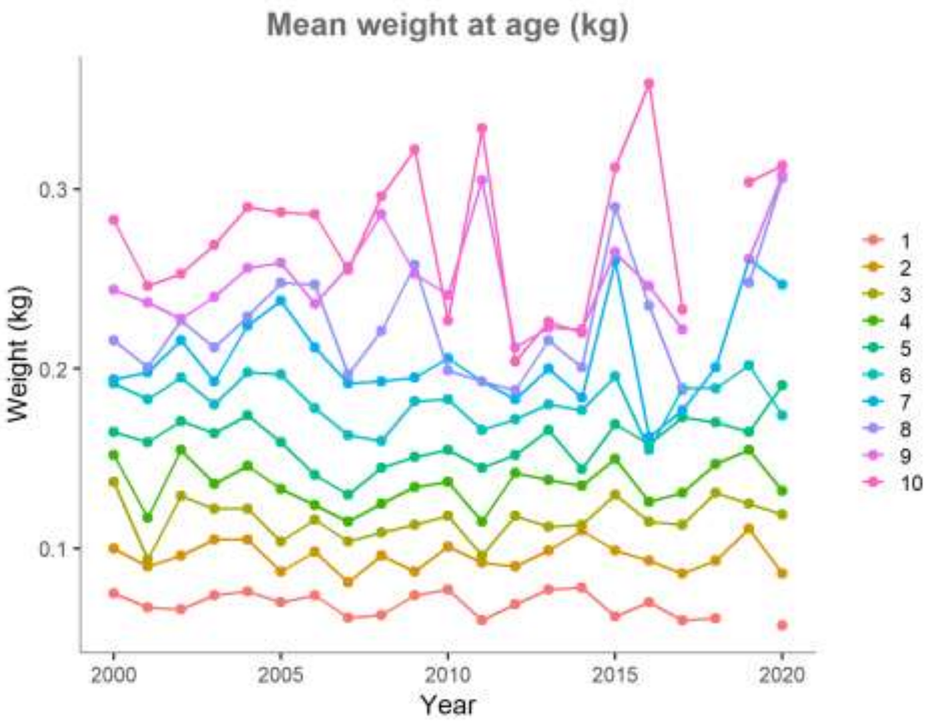


Figure 6.3.3. North Sea horse mackerel. Mean weight at age in commercial catches over the period 2000-2020. Note that only age 1–10 are presented and that 10 is not a plus group.

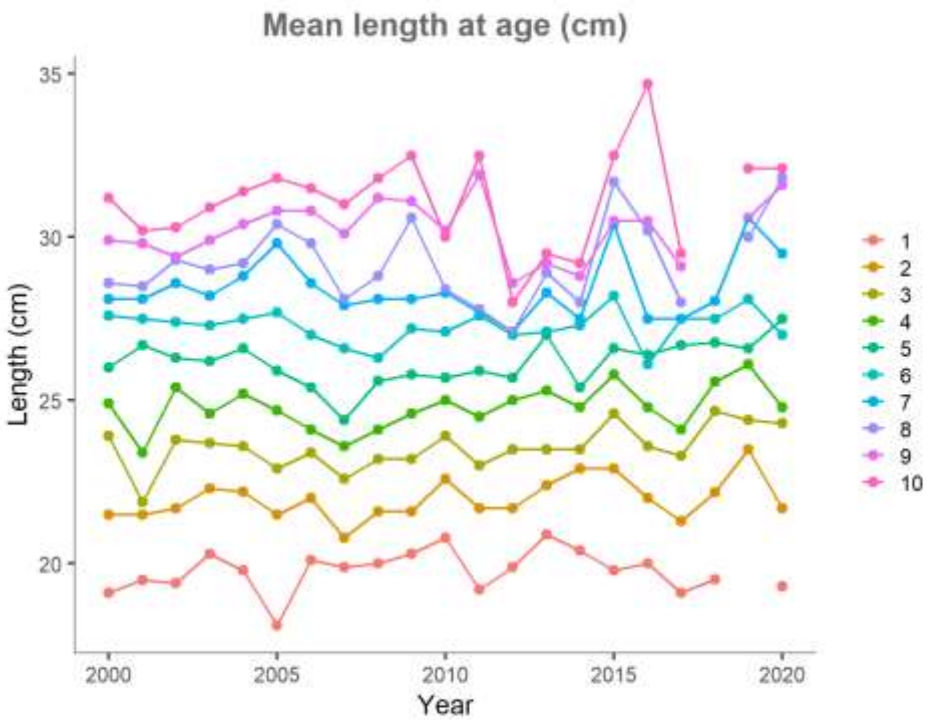


Figure 6.3.4. North Sea horse mackerel. Mean length at age in commercial catches over the period 2000-2020. Note that only age 1–10 are presented and that 10 is not a plus group.

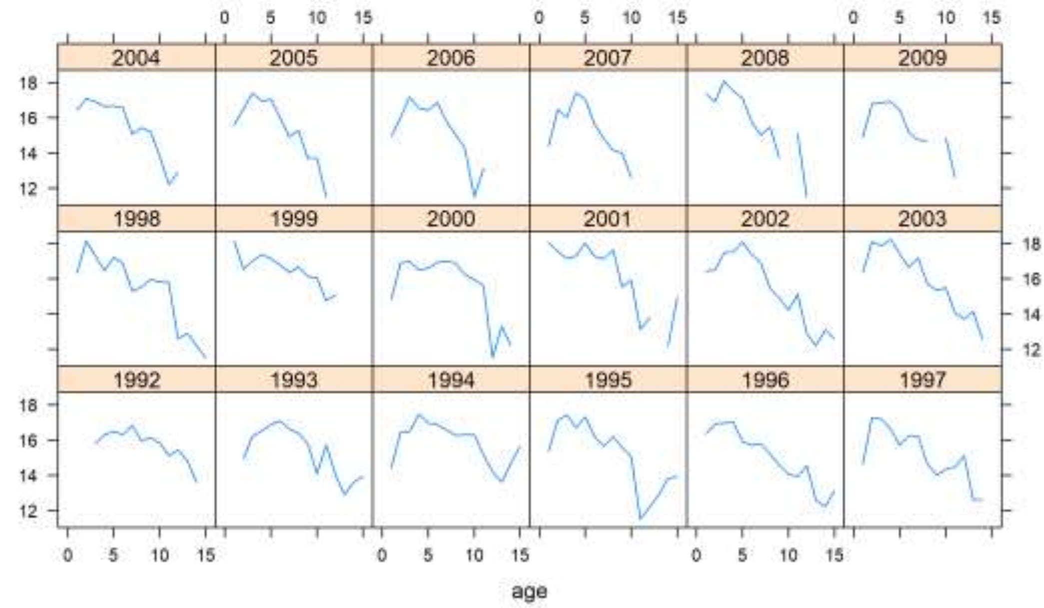


Figure 6.4.1. North Sea Horse Mackerel. Catch curves for the 1992 to 2009 cohorts, ages from 3 to 15+. Values plotted on the vertical axis are the log(catch) values for each cohort in each year. The negative slope of these curves estimates total mortality (Z) in the cohort.

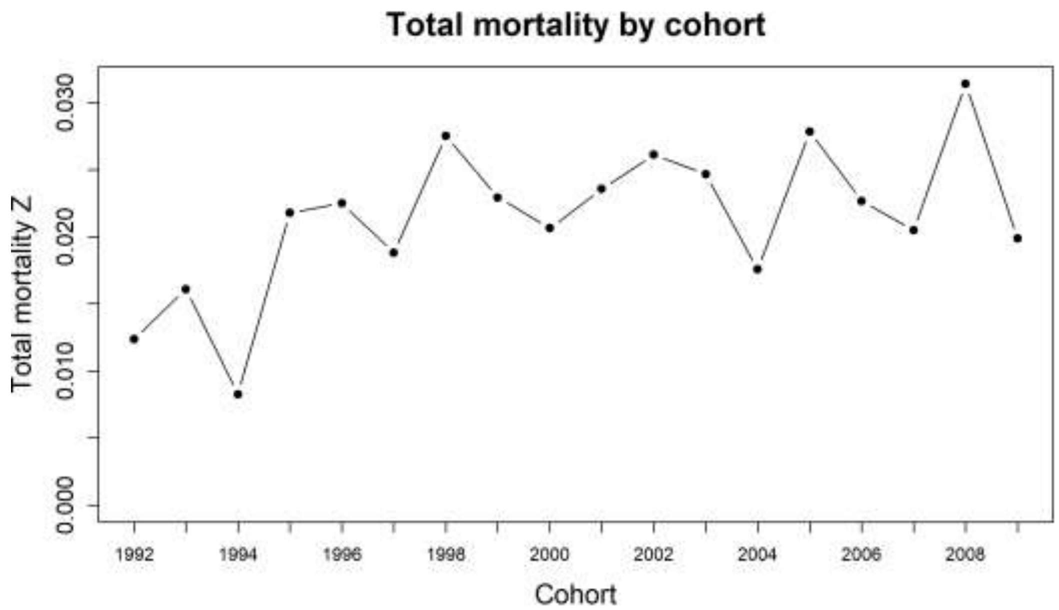


Figure 6.4.2. North Sea Horse Mackerel. Total mortality by cohort (Z) estimated from the negative gradients of the 1992—2009 cohort catch curves (Figure 6.4.1).

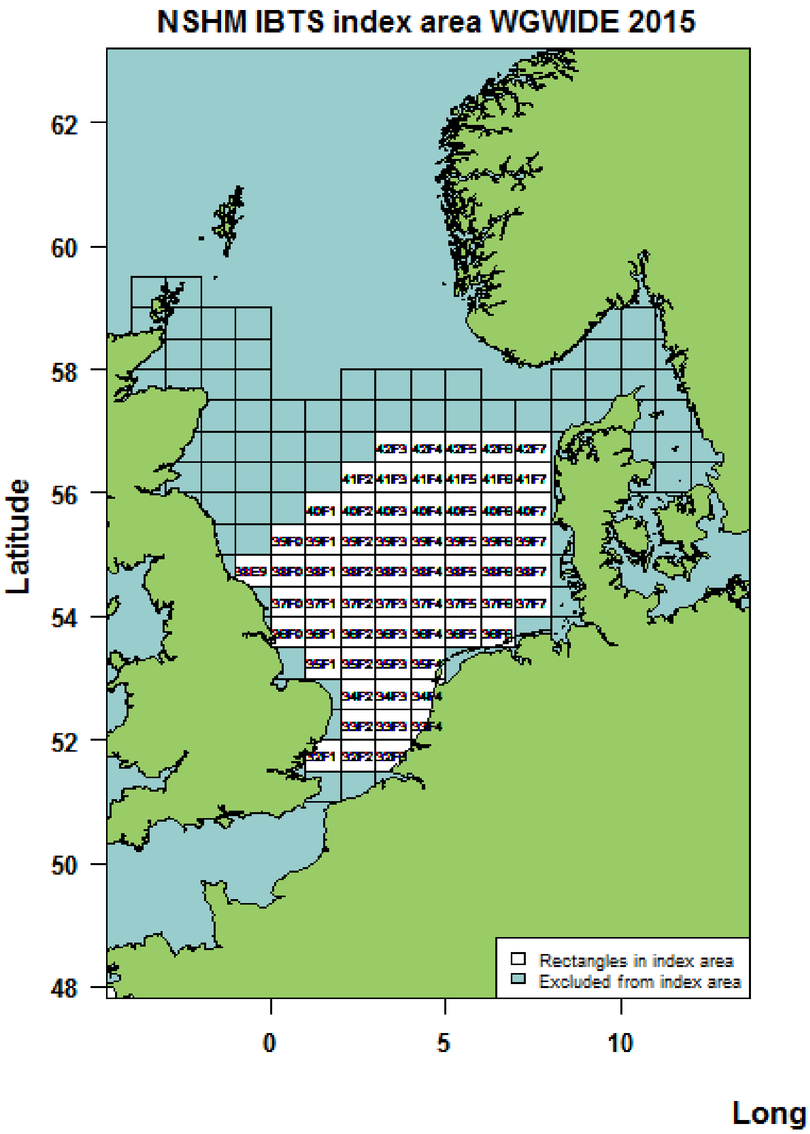


Figure 6.4.3. North Sea horse mackerel. ICES rectangles selected by WGWIDE in 2013 and currently used by the working group.

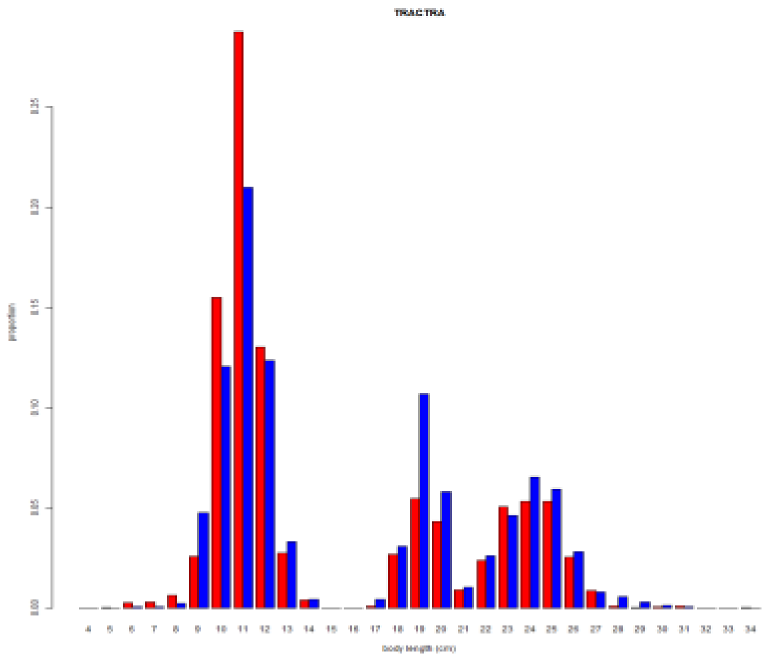


Figure 6.4.4. North Sea horse mackerel. Size distribution of North Sea horse mackerel catches during the inter-calibration exercise conducted in 2014 between the RV Gwen Drez (red bars) and Thalassa (blue bars).

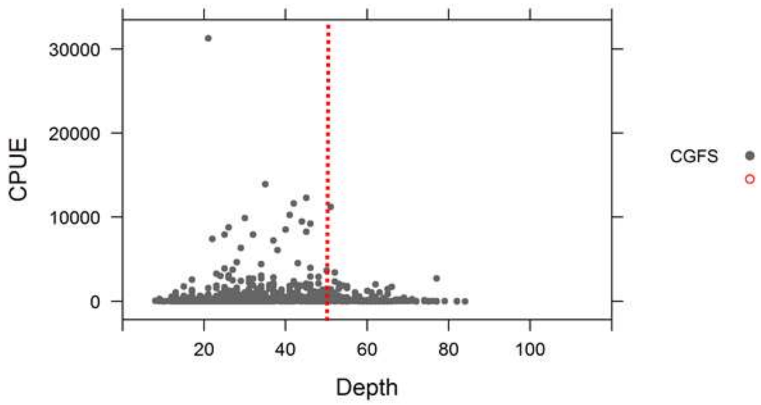


Figure 6.4.5. North Sea horse mackerel. CPUE by depth for the CGFS survey from 1992 to 2017.

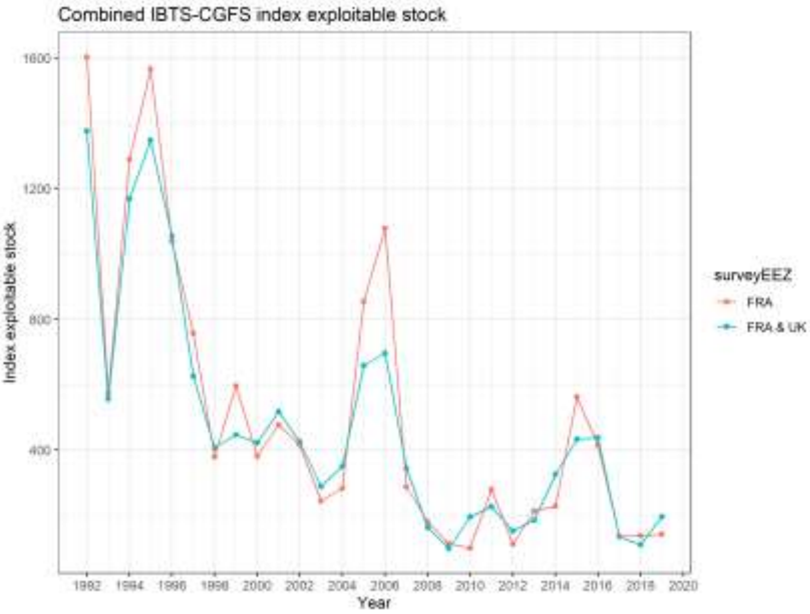


Figure 6.4.6. North Sea horse mackerel. Modelled abundance index from 1992–2019 including both UK and French stations in the FR-CGFS (blue) and excluding UK stations in the FR-CGFS (red) for the exploitable sub-stock (≥20 cm).

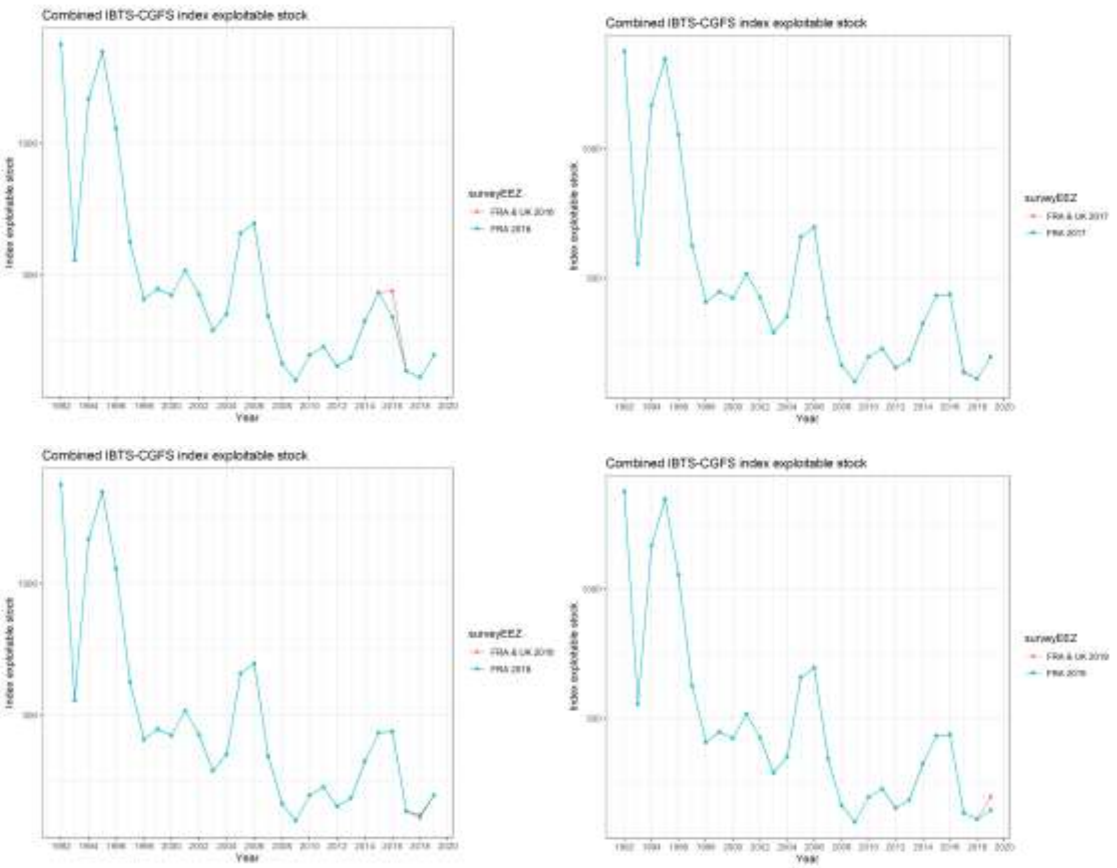


Figure 6.4.7. North Sea horse mackerel. Modelled abundance index from 1992–2019 for the exploitable sub-stock (≥20 cm) for when UK sampling stations from FR-CGFS have been excluded for 2016 (top left), 2017 (top right), 2018 (bottom left) and 2019 (bottom right).

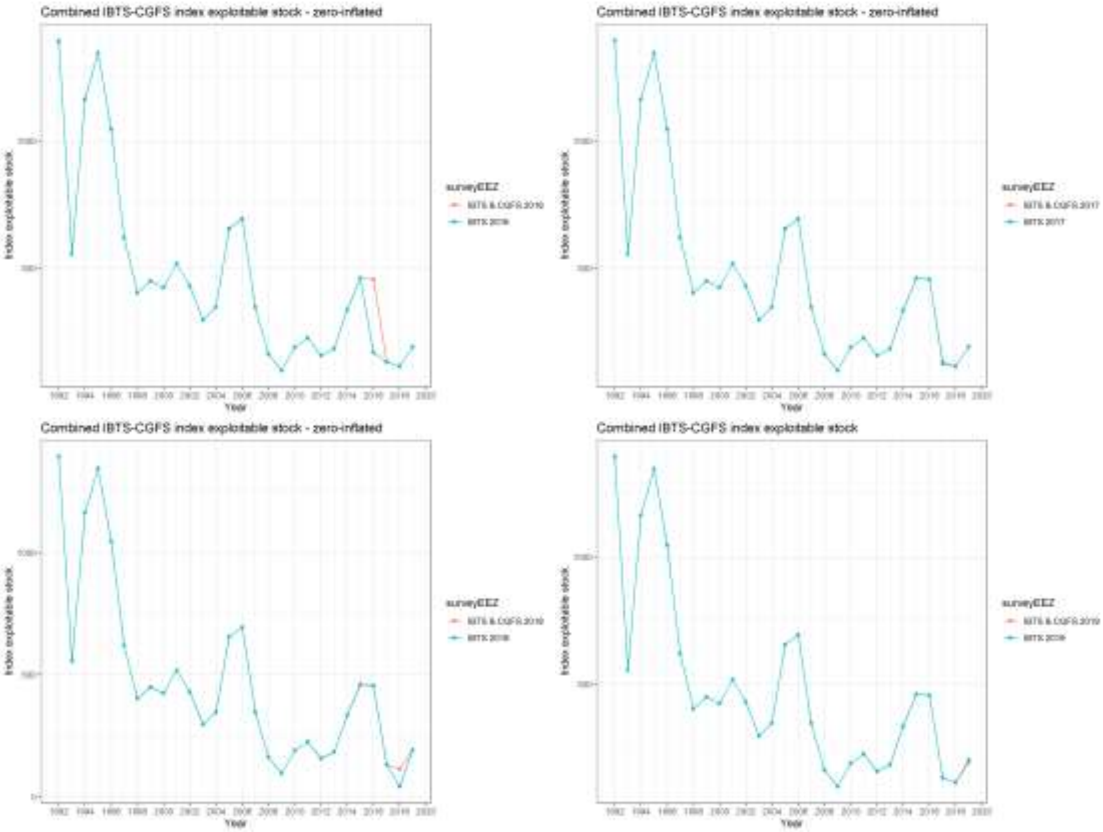


Figure 6.4.8. North Sea horse mackerel. Modelled abundance index from 1992–2019 for the exploitable sub-stock (≥20 cm) for when the FR-CGFS has been excluded for 2016 (top left), 2017 (top right), 2018 (bottom left) and 2019 (bottom right).

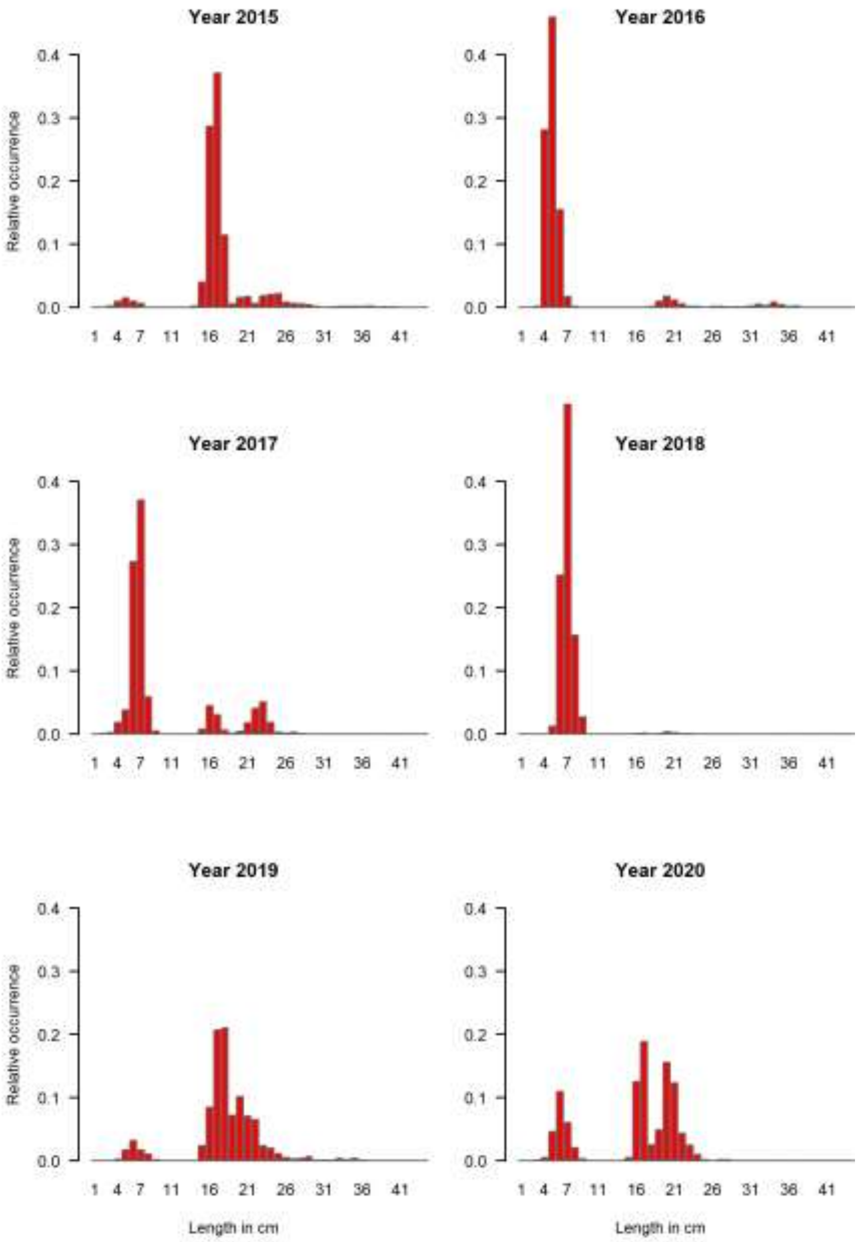


Figure 6.4.9. North Sea horse mackerel. Relative occurrence by length for the period 2014–2020 in the NS-IBTS.

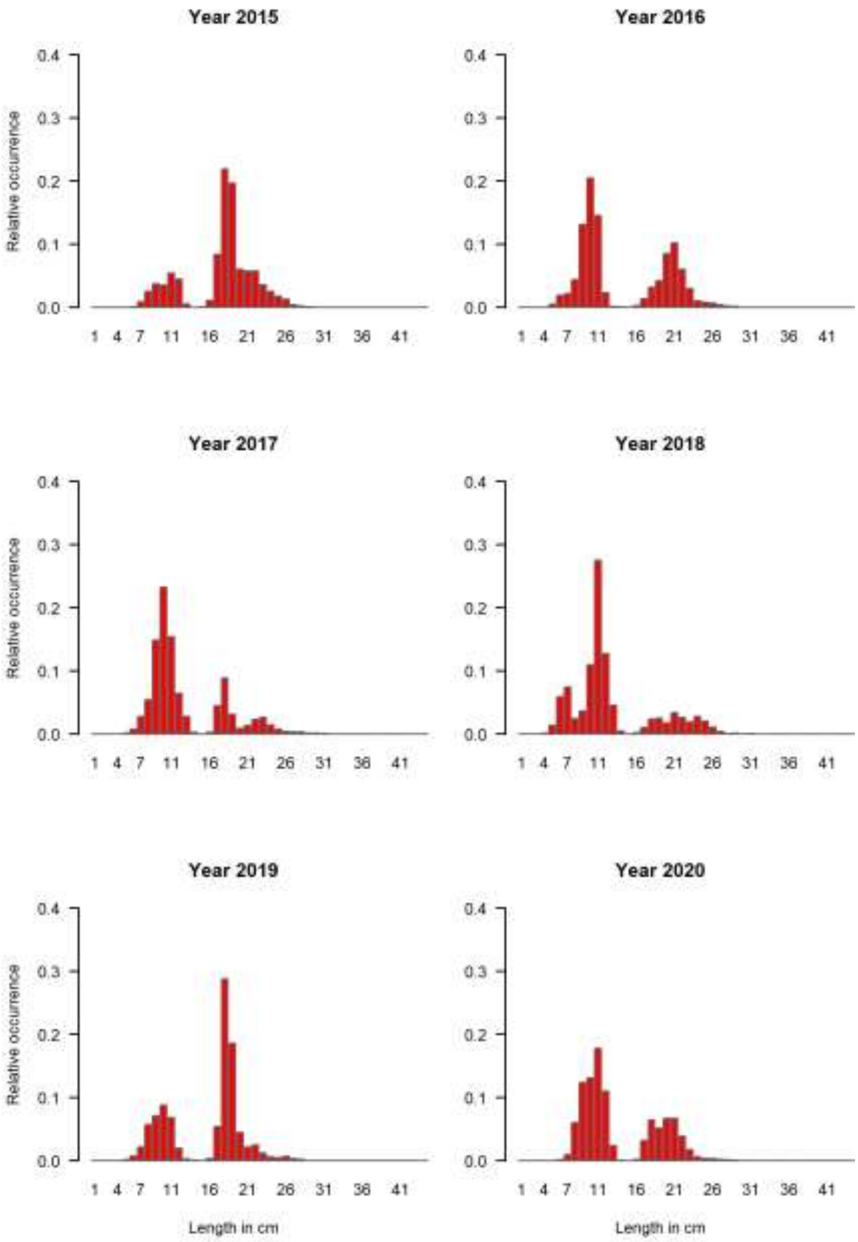


Figure 6.4.10. North Sea horse mackerel. Relative occurrence by length for the period 2015-2020 in the FR-CGFS. Note that stations in UK waters could not be visited in 2020.

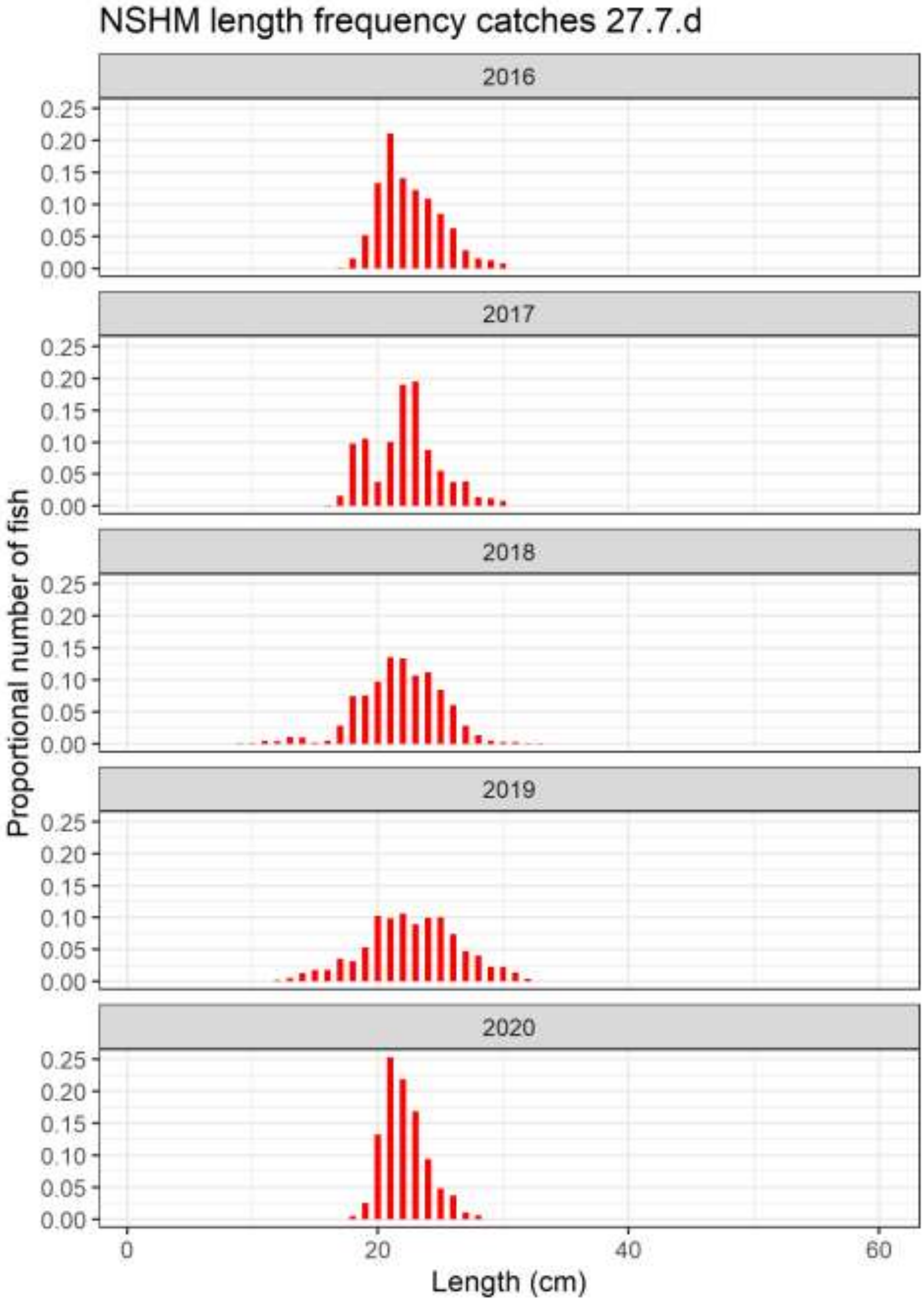


Figure 6.4.11. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.7.d for the period 2016-2020.

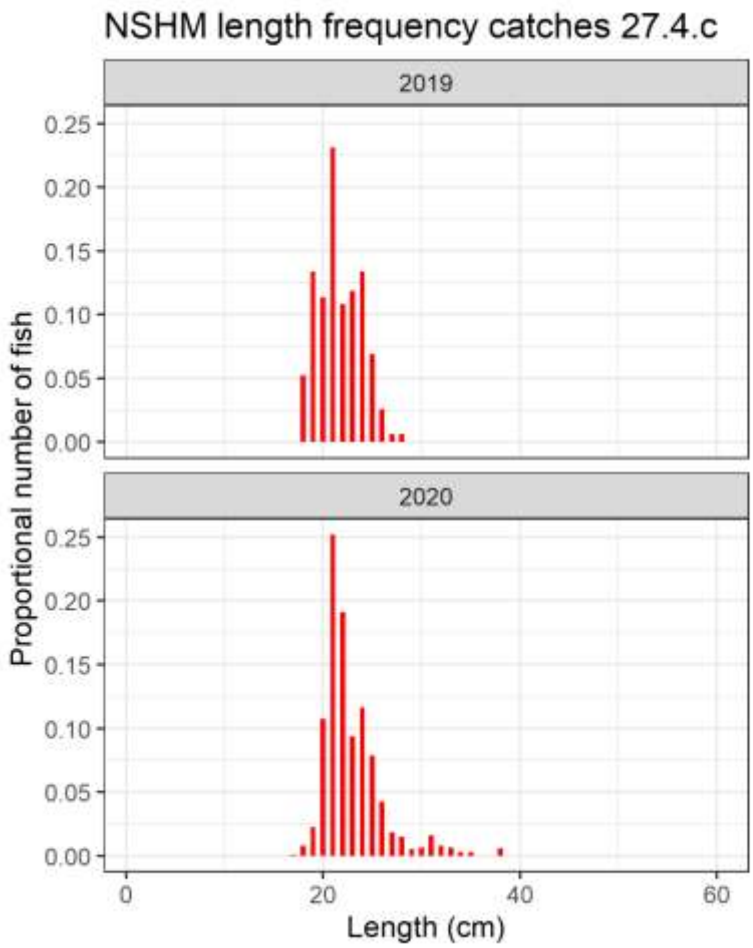


Figure 6.4.12. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.4.c in 2019 and 2020.

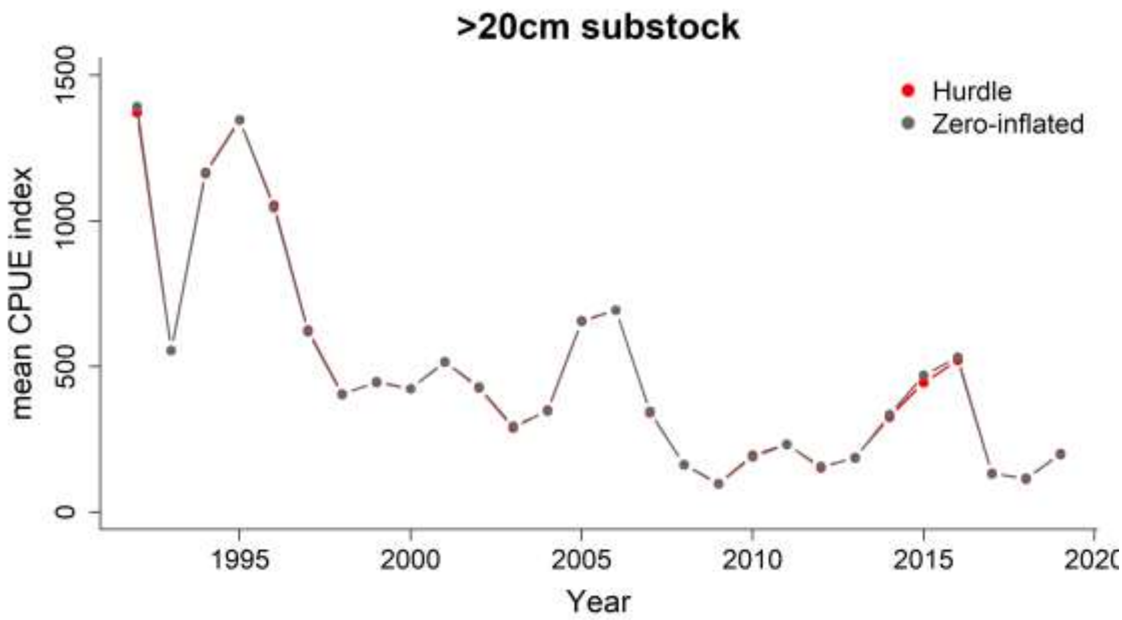


Figure 6.5.1. North Sea horse mackerel. CPUE per year of the exploitable sub-stock (≥20 cm) from 1992 to 2019 as modelled by the hurdle model (red) that returned a warning when ran, and the zero-inflated model (grey).

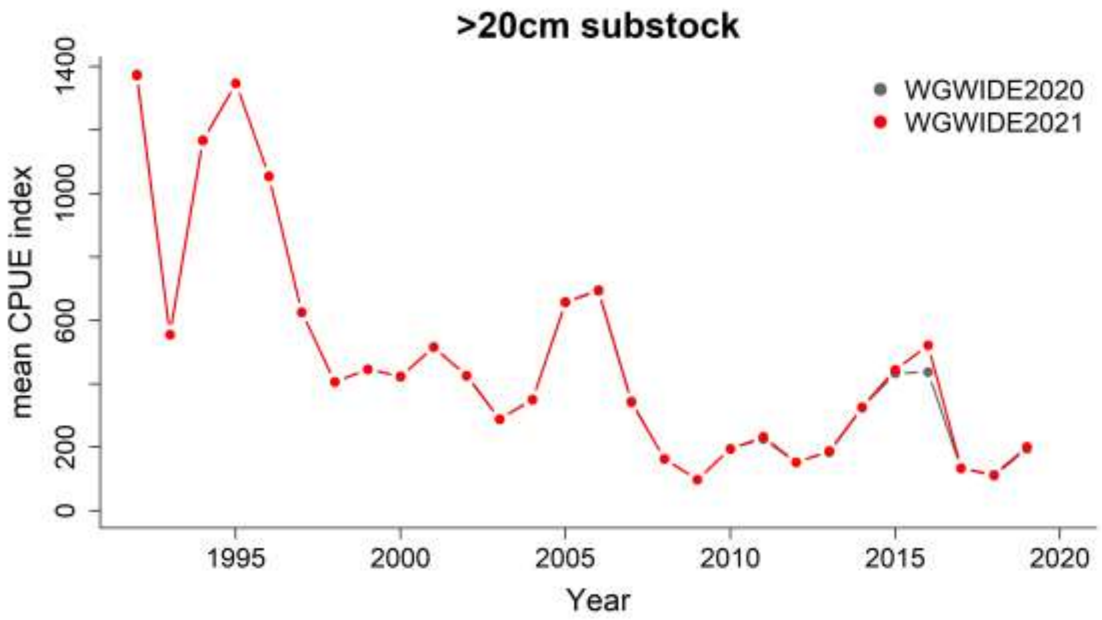


Figure 6.5.2. North Sea horse mackerel. CPUE per year of the exploitable sub-stock (≥20 cm) from 1992 to 2019 as modelled by the hurdle model at WGWIDE 2020 (grey) and WGWIDE 2021 (red).

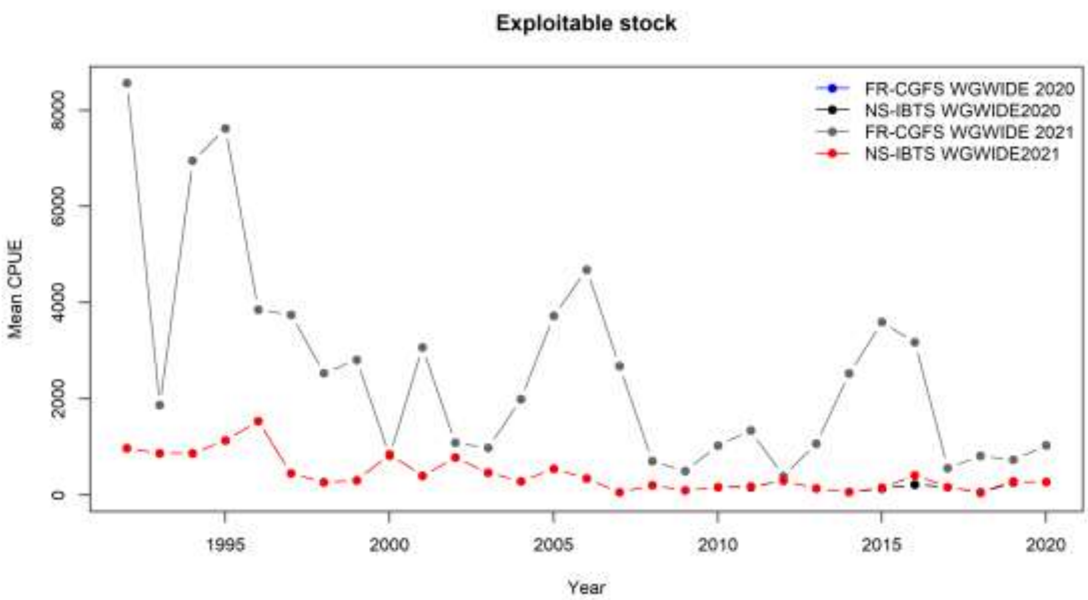


Figure 6.5.3. North Sea horse mackerel. Mean CPUE across hauls of the exploitable sub-stock (≥20 cm) from 1992 to 2019 for the FR-CGFS (blue WGWIDE 2020 (not visible), grey WGWIDE 2021) and the NS-IBTS (black WGWIDE 2020, red WGWIDE 2021).

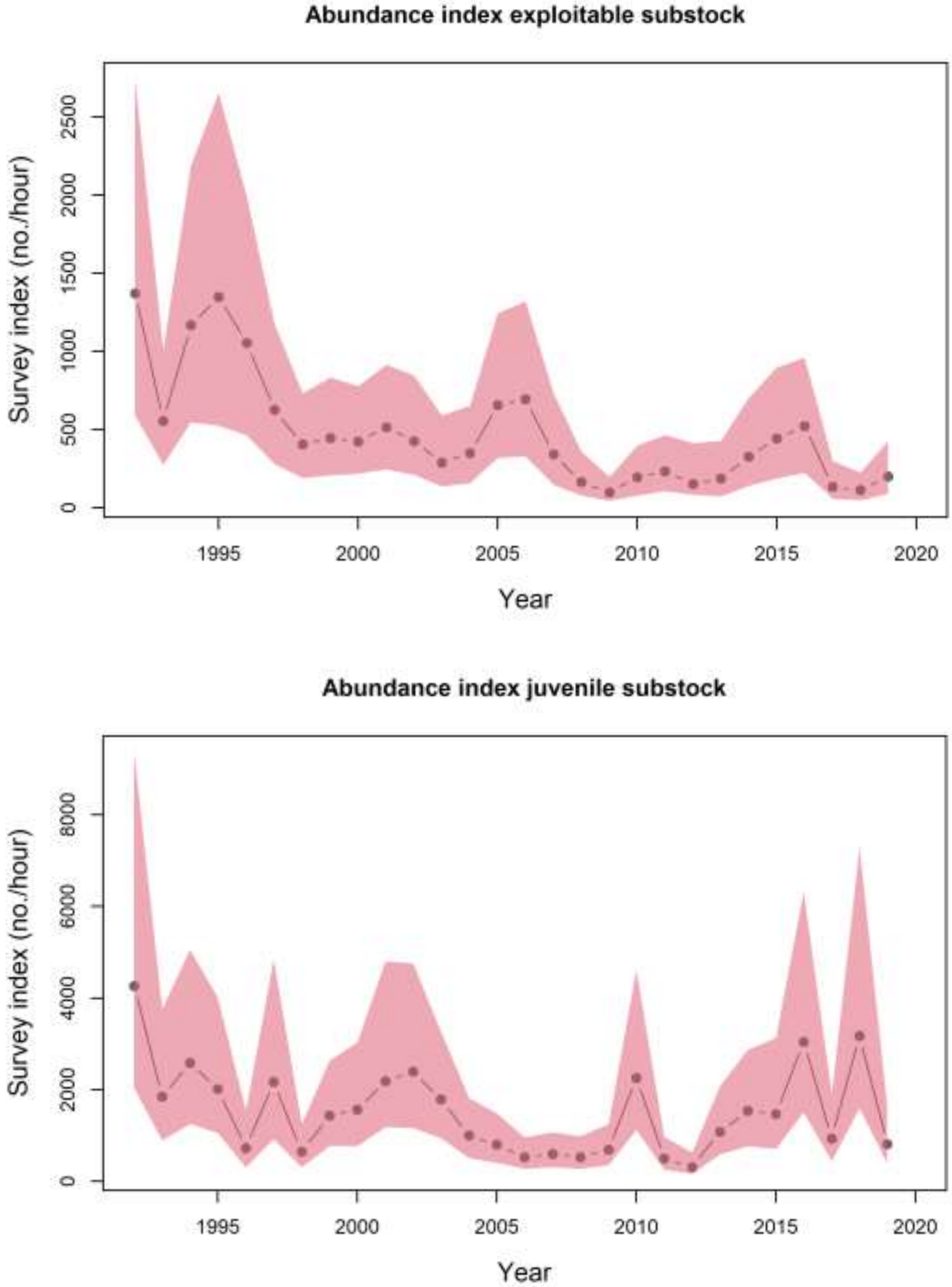


Figure 6.5.4. North Sea Horse Mackerel. Joint CPUE survey index (number/hour) derived from the hurdle model fit to the NS-IBTS survey in the North Sea and the FR-CGFS survey in the Eastern English channel for the period 1991–2020. No index value for 2020 could be produced due to sampling issues in the FR-CGFS. Top: exploitable sub-stock (≥20 cm), bottom: juvenile sub-stock (<20 cm). Red shaded area represent the 95% confidence interval, which is determined by bootstrap resampling of Pearson residuals with 999 iterations.

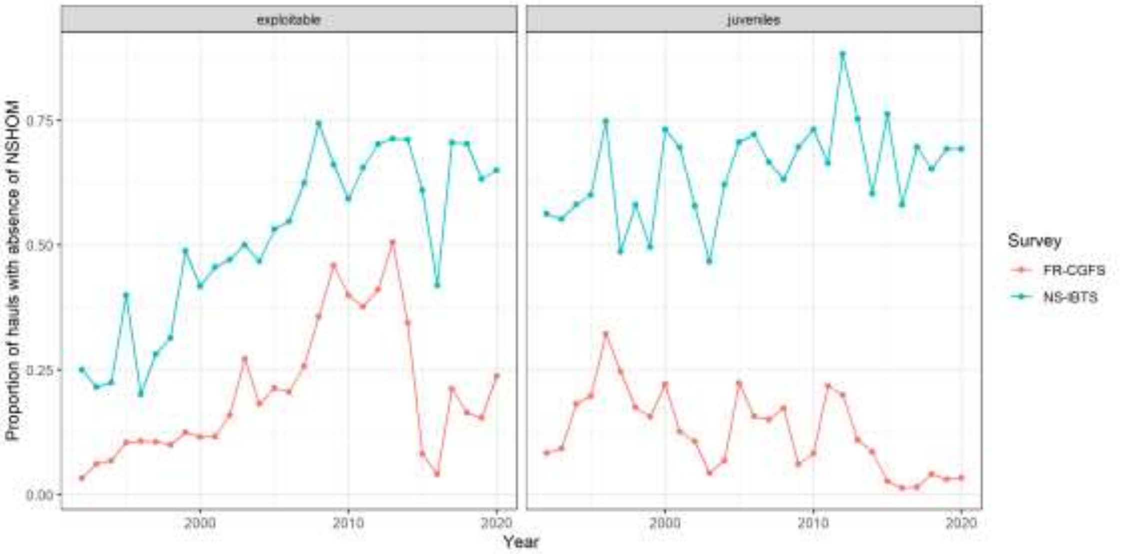
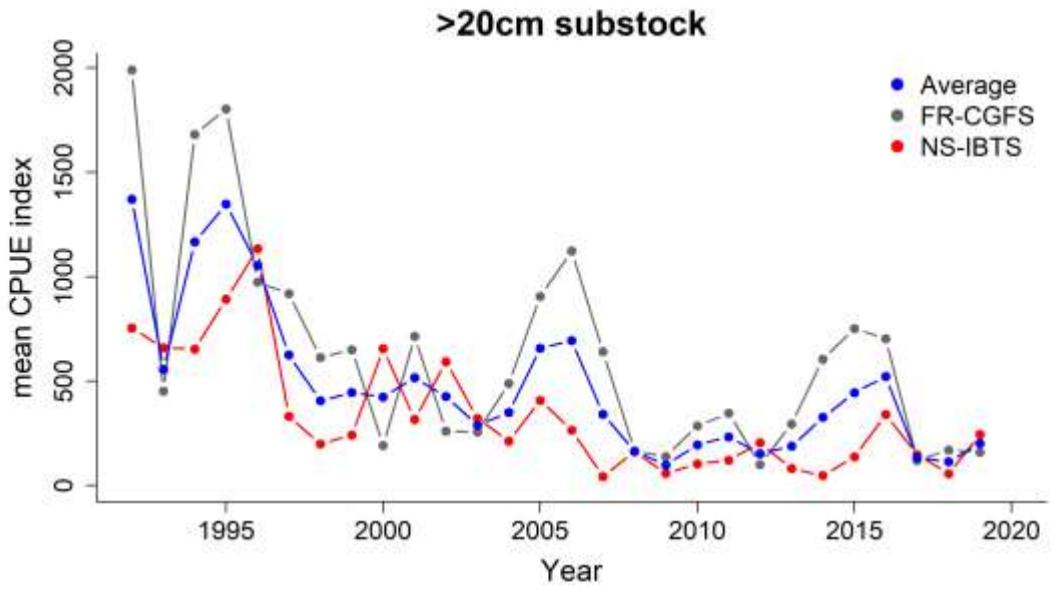


Figure 6.5.5. North Sea horse mackerel. Proportion of hauls with zero catch for the exploitable (≥20cm) and juvenile (<20 cm) sub-stocks in the NS-IBTS (blue) and the FR-CGFS (red) from 1992 to 2020. Note that the FR-CGFS 2020 values are based on French stations only, as UK stations could not be sampled.



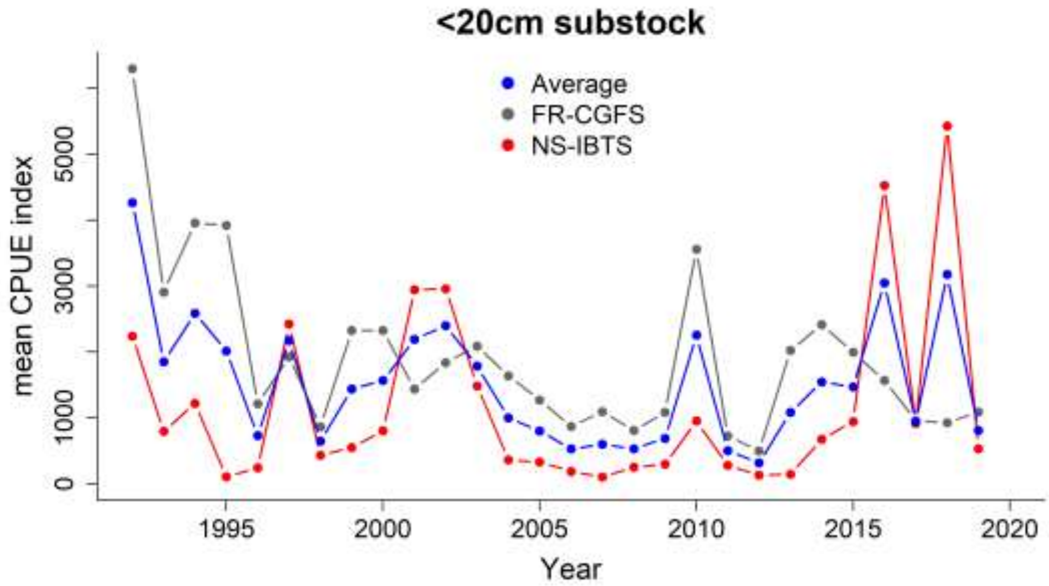


Figure 6.5.6. North Sea Horse Mackerel. Mean CPUE survey index (number/hour) obtained from the hurdle model fit to the NS-IBTS survey in the North Sea (in red), the FR-CGFS survey in the English channel (in grey) and the joint survey index (in blue). Top: exploitable sub-stock (≥20cm), bottom: juvenile sub-stock (<20 cm). No index values for 2020 could be produced due to COVID-19 pandemic impacting the FR-CGFS.

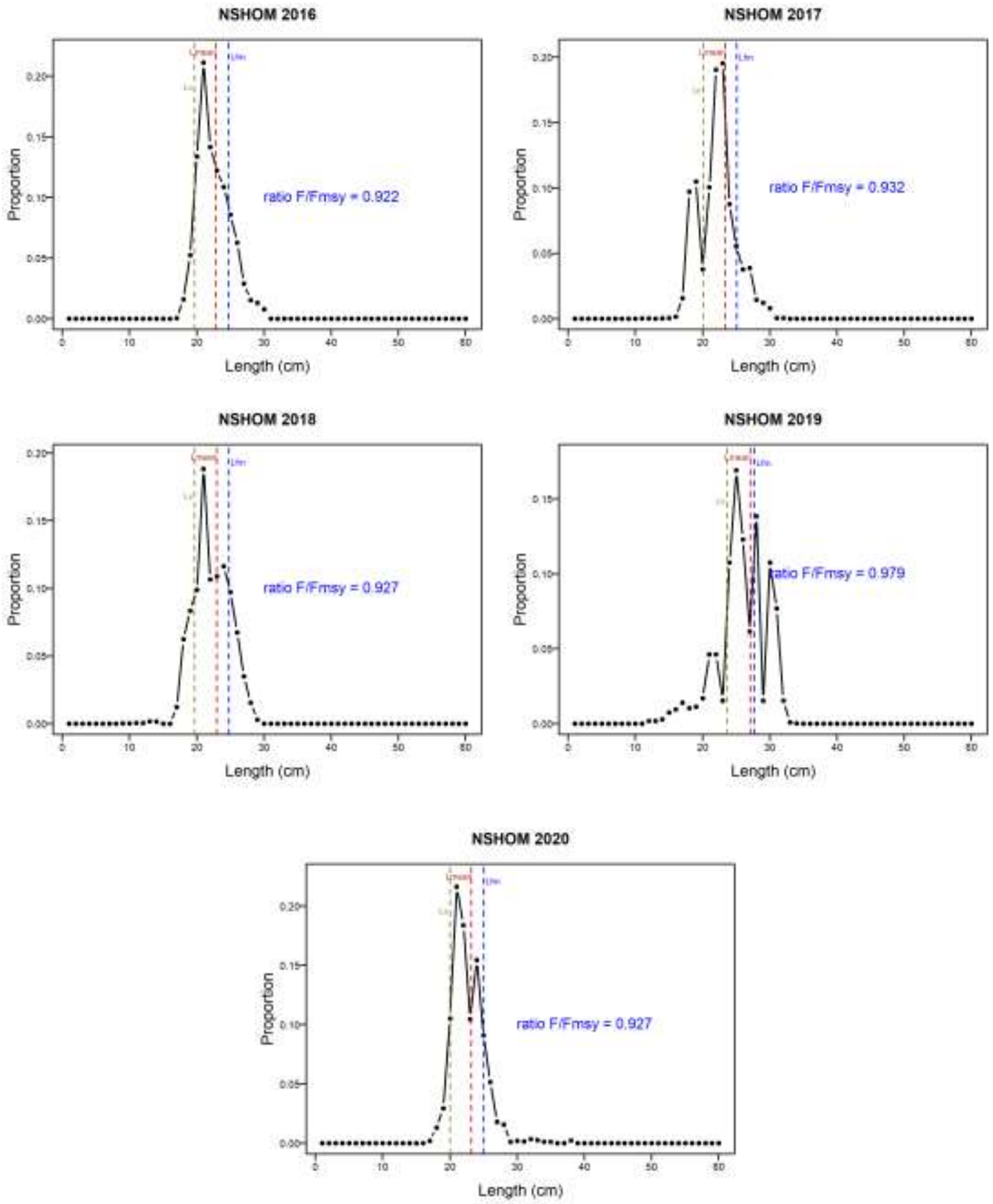


Figure 6.5.7. Length distribution (cm), estimated parameters L_c, L_{mean}, $L_{F=M}$ (cm) and F/F_{MSY} ratio for 2016–2020. Length samples from commercial catches in ICES Division 27.7.d.

7 Horse mackerel (*Trachurus trachurus*) in Subarea 8 and divisions 2.a, 4.a, 5.b, 6.a, 7.a–c,e–k (the North-east Atlantic)

7.1 TAC and ICES advice applicable to 2020 and 2021

Since 2011, the TACs cover areas in line with the distribution areas of the stock.

For 2020 the TAC was the following (EU 2020/123):

Areas	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 t	Western stock and North Sea stock in 4.a 1–2 quarters
4.b,c, 7.d	13 763 t	North Sea stocks
Division 8.c	11 179 t	Western stock

For 2021 the TAC was the following (EU 2021/1239):

Areas	TAC 2021	Stocks fished in this area
2.a, 4.a, 5.b, 6, 7.a–c, 7.e–k, 8.abde, 12, 14	70 254 t	Western stock and North Sea stock in 4.a 1–2 quarters
4.b,c, 7.d	14 014 t	North Sea stocks
Division 8.c	11 121 t	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 2020, ICES advised on the basis of MSY approach that Western horse mackerel catches in 2021 should be no more than 81 376 tonnes. The Western horse mackerel TAC for 2021 is 81 375 tonnes. The TAC should apply to the total distribution area of this stock. The horse mackerel catches in Division 3.a are taken outside the horse mackerel TACs.

7.1.1 The fishery in 2020

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–5.1.1.d. The total catch allocated to Western horse mackerel in 2020 was 76 422 tonnes which is 48 525 tonnes less than in 2019 and 4954 t less than ICES advice. The catches of horse mackerel by country and area are shown in Tables 7.1.1.1–7.1.1.5 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 some countries. Prior to 2013, the estimates available are considered to be an underestimate (Figure 7.1.2.1).

In 2020, most countries have submitted discard information. Countries that reported discard estimates for horse mackerel were Denmark, France, Ireland, Spain, UK (England and Wales) and UK (Scotland). 2020 discard estimates for Germany, the Netherlands and Norway are considered to be equal to zero. Total discards for Western horse mackerel were 2741 tonnes, equal to 3.6 % in weight of the total catches, a decrease compared with 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, Ireland 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 (and Figure 7.1.3.1). The Western stock is considered a management unit and advised accordingly. The stock is regulated by TAC, which is 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

The most recent mackerel and horse mackerel egg survey was carried out in 2019 and a presentation with the final results were given during the WGWIDE meeting by the survey coordinator in 2020 (O'Hea et al. 2019).

The time-series of egg production estimates for western horse mackerel is presented in Table 7.2.1.1 and Figure 7.2.1.1. Total Annual Egg Production (TAEP) estimated in 2019 was the lowest production in the historic time-series. Concern has been expressed as to whether the MEGS surveys are capturing the horse mackerel spawning sufficiently. WGMEGS has been considering if horse mackerel spawning had shifted to even later in the yea or if the reduction in egg numbers has been in response to the poor status of the stock resulting in a patchier distribution of eggs (ICES, 2021a).

The ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS; ICES, 2021a) met in April 2021 to plan the 2022 Mackerel and Horse Mackerel Egg Survey for the

Western horse mackerel stock. The provisional survey plan of the 2022 mackerel and horse mackerel egg survey, as agreed during last the WGMEGS meeting (ICES, 2021a), is presented in Table 8.6.1.1.1.

Fecundity parameters

Horse mackerel sampling will again be directed at the DEPM method and will be conducted in survey Periods 6 and 7, June and July. Sampling will be carried out as described in the survey protocols (ICES, 2019), but it should emphasize the need to collect enough samples for fecundity analyses.

With the current low stock size of Western horse mackerel, it is increasingly difficult to catch adult horse mackerel and WGMEGS therefore has put out specific requests to other survey groups asking them to collect adult horse mackerel samples from their surveys during May and June 2022 (ICES, 2021a).

7.2.2 Other surveys for Western horse mackerel

Bottom-trawl surveys

A bottom-trawl survey index for recruitment was available for 2020.The recruitment 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 2020. A Bayesian Delta-GLMM is used to calculate an index of juvenile abundance based on catch rates, and the index is updated every year when new data become available (ICES 2017b). The updated values are shown in Figure 7.2.2.1 (middle panel) and the indices estimated in 2018–2021 are given in Table 7.2.2.1. Annual revisions of the index are minor. 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 2016 levels in 2018. Recruitment in 2019 and 2020 decreased further and is close to the lowest values of the time-series.

Acoustic surveys

In the Bay of Biscay two coordinated acoustic surveys take place in spring, PELGAS (Ifremer-France) and PELACUS (IEO-Spain). Only the PELACUS survey, which cover the ICES Division 8c, is used in the assessment. There is no biomass estimate for 2020 because the survey was cancelled due to the Covid-19 pandemic. The estimate for 2021 is shown in this report (Figure 7.2.2.1, Table 7.2.2.2.), but it is not part of the assessment this year (no catches available yet for 2021).

The biomass estimated by the PELACUS survey was high in the 90s, reaching the maximum value in 1998 (139 395 t). Biomass values are lower in the 21st century, peaking in 2010 (53 417 t) and 2015 (67 068 t). Biomass has fluctuated around 10 000 t over the most recent 4 surveys.

7.2.3 Effort and catch per unit effort

No new information was presented on effort and catch per unit effort.

7.2.4 Catch in numbers

In 2020, the Netherlands (4.a, 6.a, 7.befgj), Ireland (6.a, 7.bgj, 8.a), Norway (4.a), Spain (8.bc) and UK (England; 6.a, 7.bj) provided catch in numbers-at-age (Figure 7.2.4.1). The catch sampled for age readings in 2020 covered 51% of the total reported catch. This reduction (from 69% in 2018 and 2019) is primarily due to the impact of the Covid pandemic on the national sampling programs. Spain had to reduce its sampling program and no sampling from Germany and Norway were available. Catch in number-at-length were available from the Netherlands (4.a, 6.a, 7.befgj), Ireland (6.a, 7.bgj, 8.a), Spain (6.a, 7.bcghj, 8.bc) and UK (England; 6.a, 7.bgj) as well as from France (8.a) and Scotland (6.a).

The total annual and quarterly catches in number for western horse mackerel in 2020 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.

Spain, Ireland, the Netherlands and UK (England) also provided the age length keys (ALK) for 2020.

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 202 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 1.5.4 of this report.

The Pelagic Freezer-trawler Association (PFA) provided an annual report on the self-sampling programme that started in 2015. Currently, all members (17 vessels in 2020) participate in the programme providing data during the main fishing season (October–March). Overall, the self-sampling activities for the horse mackerel fisheries during the years 2017–2021 (up to 27/07/2021) covered 243 fishing trips with 3446 hauls, a total catch of 141 548 tonnes and 153 307 individual length measurements. The main sampled areas were ICES divisions 6.a, 7.b and 7.d. The data analysis shows that horse mackerel has a wide range in the length distributions in the catch. Median lengths in divisions 6.a, 7.b and 7.j have fluctuated between 26.2 and 31.3 cm (with one low median length of 23.3 cm in 27.6.a in 2018). In ICES divisions 27.7.d and 27.7.h, median lengths in the catch are smaller and fluctuated between 21.3 and 24.6 cm.

There is also an industry-science collaboration aimed at improving the knowledge of gonad development of mackerel and horse mackerel. Samples were taken by the fishing industry (PFA vessels) on both targeted and bycatches of mackerel and/or horse mackerel. The overall aim for Western horse mackerel is to identify the spawning period in 2020 and investigate if the current egg survey (MEGS) is covering this period. Unfortunately, the final report on the analyses was not yet available for WGWIDE 2021 although it is expected to be ready soon.

Additionally, genetic samples have been also collected from 7.d and 7.e by the PFA on board of commercial vessels in autumn 2020, as well as from 4.a during the NS-IBTS in Q3. The goal of this study is to identify the stock identity in mixed areas, but the analyses have not been carried out yet (see section 1.12.4).

7.2.10 Data exploration

The length frequency distributions of the landings for the entire fleet included in the model are shown in Figures 7.2.10.1–7.2.10.2. The length distributions available for 2015–2020 show a considerable amount of very small fish, mostly from Spanish catches. The main mode of the distribution continuously increased since 2004 to 2017. It has decreased in recent years, probably due to the growth of the small individuals observed in recent years. The length distribution of discards has been provided by some countries since 2018. However, this information was not available at the last benchmark (2017) and therefore they are not included in the current assessment.

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. 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 presented is an update of the 2020 assessment, with the inclusion of the 2020 estimates for the IBTS recruitment index, the 2020 length frequency distribution of the landings, and the 2020 total catch and conditional ALKs. The biomass estimates and length distribution provided by the PELACUS survey were not available in 2020 because the survey was cancelled due to the Covid pandemic (see section 7.13). As in last year 's assessment, the length and age distributions were tuned using the Francis reweighting approach instead of using the McAllister and Ianelli approach, which did not perform well here in 2020.

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 and 2020 ALK, that was not evident in 2019. Recruitment estimates were unchanged from last year's assessment. The model does not fit well to the biomass estimates and length composition provided by the PELACUS survey. The fitting to the most recent length frequency distributions and the conditional ALKs remains suboptimal and it does not capture the small fish observed in recent years.

The 2021 assessment shows strong retrospective patterns, with a few peels falling outside the confidence intervals of SSB and recruitment estimates (Figure 7.2.11.3). The pattern is very consistent and has led to a rescaling of the SSB (downwards) and F (upwards) in the past years. Further investigation is needed to identify the reason of the pattern and resolve it. The Mohn's rho values are on the limit of the tolerance threshold with 0.24 for SSB and -0.189 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 2020 information from the IBTS index 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). SSB reached the minimum values of the time-series in 2017 (594 977 t), increasing slightly in recent years. In 2021, SSB is estimated to be just above B_{lim}.

The recruitment has been weak since 2001, reaching the lowest values in 2009–2011 and 2013. Recruitment estimates for 2014-2018 are the highest observed since 2008 and are higher than the geometric mean estimated over the years 1983–2020. Recruitment in 2019 and 2020 was low again.

Fishing mortality (ages 1–10) has oscillated over the time-series. It increased after 2007 as a result of increasing catches and decreasing biomass as the 2001 year class was reduced. The fishing mortality decreased between 2013 and 2017 due to a decrease in catches and a reduced proportion of the adult population in the exploited stock. The fishing mortality in 2020 (0.071) was the lowest value in the time-series since 2007 and it was just below F_{MSY} (0.074).

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 2020 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.

The WG had access to the landings from January-July 2021 for some of the main fleets participating in the fishery (the Netherlands, Ireland, UK, France, and Germany). Based on the high catch uptake from these fleets for the first half of the year (around 65%, whereas in 2018–2020 they only caught around 40% of their TAC for that time of the year), the expected landings for the intermediate year were set at 100% of the TAC (81 375 t). Note that although the plus group in the catch was set at 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 suffers from a retrospective pattern whenever a new year of data are 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: IBTS and MEGS. 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 PELACUS 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 addressed: for example, it is not clear whether the high presence of small specimens in the landings data are 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 model fixes the realized fecundity with a constant number of eggs/kg independently of the individual weight. However, Western horse mackerel is is an indeterminate spawner, which implies this relationship may not be appropriate when it comes to the use of an egg survey as index of spawning biomass. During the benchmark an attempt was made to estimate the parameters relative to fecundity, however, the information provided to the model 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 natural mortality should be investigated. However, there is no data available (such as tagging) that could assist in estimating natural mortality 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, also informed when occasional strong year classes are 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 very low weight in the model and is very noisy): a new index for the spawning biomass would therefore be beneficial for the future stability of this assessment. The development of a combined SSB index estimated from appropriate surveys in the area (e.g. PELACUS, PELGAS, WESPAS) 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 summarized 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, 2019a).

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. In 2021, F_{pa} was re-defined as F_{p05} (ICES, 2021b). These updated reference points were used in determining the MSY based 2022 catch advice.

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, 2019b) 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 have been reviewed by ICES (2021c). This rebuilding plan has not been currently approved by the European Commission and the UK.

7.8 Management considerations

The 2001 year class has now entered the plus group but no other detectable very strong year classes entering the fishery, although a higher amount of age 1–2 year old fish have been observed in the catches in the past 4–5 years.

Following the MSY approach, the advice for 2022 is catches in 2022 should be no more than 71 138 tonnes. This catch advice is 12.6% lower than in 2021 due to both the assumptions for the forecast (higher catches assumed for the interim year, which leads to lower biomass for the short-term forecast) and a downward revision in the perception of the stock biomass from the assessment.

A TAC has only been agreed for parts of the distribution and fishing areas (EU and UK waters). The Working Group advises that the TAC should apply to all areas and fleets catching Western horse mackerel. Note that Subarea 8.c is included in the ICES advice for Western horse mackerel.

7.9 Ecosystem considerations

Knowledge of 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 horse mackerel management agreements between EU and the UK, but not with Norway. The TAC set by EU and the UK therefore only applies to EU and UK waters and the EU and UK fleet in international waters. The minimum landing size of horse mackerel by the EU and UK 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 stock. Results of a recent genetic research project on stock structure of horse mackerel has been reported in sections 1.12.4 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 is modulated by temperature. Continued warming of the slope current is likely to affect the timing and spatial extent of this migration.

It has been reported 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 later in the year (October-November) since 1987 (Iversen *et al.* 2002, Iversen WD presented in ICES 2007/ACFM:31).

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

1. Stock: hom.27.2a4a5b6a7a–ce–k8

2. Missing or deteriorated survey data:

The length composition and the biomass index annually provided by the PELACUS survey were not available in 2020 because the survey was cancelled due to the Covid pandemic.

3. Missing or deteriorated catch data:

The samples for age readings in 2020 covered only 51% of the catch, whereas in previous years was 69%. This decrease is due to the impact of the Covid pandemic on the national sampling programs. Spain had to reduce its sampling program and no sampling from Germany and Norway were available.

4. Missing or deteriorated commercial LPUE/CPUE data:

Not applicable

5. Missing or deteriorated biological data:

Not applicable

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

Not applicable

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

The assessment was carried out without the 2020 data from PELACUS. No alternative options were found.

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out?

To test the sensitivity of the model to the PELACUS data, the assessment conducted last year was carried out without the PELACUS data for 2019 and the results were compared with the outputs of the actual assessment in 2020. The fishing mortality was slightly higher and the

spawning biomass slightly lower in recent years in the model without survey data, although the differences were inside of the confidence intervals of the parameters (Figure 7.13.1).

7.14 References

Abaunza, P., Gordo, L., Karlou-Riga, C., Murta, A., Eltink, A. T. G. W., García Santamaría, M. T., Zimmermann, C., Hammer, C., Lucio, P., Iversen, S. A., Molloy J., and Gallo, E. 2003. Growth and reproduction of horse mackerel, *Trachurus* (carangidae). Reviews in Fish Biology and Fisheries, 13: 27–61.

ICES 2017a. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 30 August–5 September 2017, ICES HQ, Copenhagen, Denmark. ICES CM 2017/ACOM:23.

ICES 2017b. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January–3 February 2017, ICES HQ, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

ICES. 2019a. Interbenchmark Protocol on Reference points for Western 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; IBPWHM). ICES Scientific Reports. 84 pp.

ICES. 2019b. Workshop on Guidelines for Management Strategy Evaluations (WKGMSE2). ICES Scientific Reports. 1:33. 162 pp. http://doi.org/10.17895/ices.pub.5331

ICES. 2020. Workshop on guidelines and methods for the evaluation of rebuilding plans (WKREBUILD). ICES Scientific Reports. 2:55. 79 pp. http://doi.org/10.17895/ices.pub.6085

ICES. 2021a. Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). ICES Scientific Reports. 3:82. 40pp. https://doi.org/10.17895/ices.pub.8249

ICES. 2021b. ICES. 2021. ICES fisheries management reference points for category 1 and 2 stocks; Technical Guidelines. In Report of the ICES Advisory Committee, 2021. ICES Advice 2021, Section 16.4.3.1. https://doi.org/10.17895/ices.advice.7891.

ICES. 2021c. EU request to ICES on the assessment of a new rebuilding plan for western horse mackerel (*Trachurus trachurus*) in ICES Subarea 8 and divisions 2.a, 4.a, 5.b, 6.a, 7.a–c, and 7.e–k. In Report of the ICES Advisory Committee, 2021. ICES Advice 2021, sr.2021.04. https://doi.org/ 10.17895/ices.advice.8039

Iversen, S., A., Skogen, M., D., and Svendsen, E. 2002. Availability of horse mackerel (*Trachurus trachurus*) in the northeastern North Sea, predicted by the transport of Atlantic water. Fish. Oceanogr., 11(4): 245-250.

O´Hea, B.,Burns, F.,Costas, G., Korta, M.,Thorsen, A. 2019. 2019 Mackerel and Horse Mackerel Egg Survey – Preliminary Results. Working Document to ICES WGWIDE, 28 Aug. - 3 Sept. 2019, No. 08

7.15 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	3272
USSR	-	-	-	-	-	-	-	-

Total	-	+	-	412	23	79	214	3311

	1988	1989	1990	1991	1992	1993	1994	1995
Faroe Islands	-	-	9643	1115	9157[3]	1068	-	950
Denmark	-	-	-	-	-	-	-	200
France	-[2]	-	-	-	-	-	55	-
Germany Fed. Rep.	64	12	+	-	-	-	-	-
Norway	6285	4770	9135	3200	4300	2100	4	11 300
USSR / Russia (1992 -)	469	27	1298	172	-	-	700	1633
UK (England + Wales)	-	-	17		-	-	-	-
Total	6818	4809	11 414	4487	13 457	3168	759	14 083

	1996	1997	1998	1999	2000	2001	2002	2003
Faroe Islands	1598	799[3]	188[3]	132[3]		-	-	-
Denmark	-	-	1755[3]	-		-	-	-
France	-	-	-	-		-	-	-
Germany	-	-	-	-		-	-	-
Norway	887	1170	234	2304	841	44	1321	22
Russia	881	554	345	121	78	16	3	2
UK (England + Wales)	-	-	-	-	-	-	-	-
Estonia	-	78	22	-	-	-	-	-
Total	3366	2601	2544	2557	919	60	1324	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	1847	1364	298

Russia	-	-	-	-	-	-	-	-
UK (England + Wales)	-	-	-	-	-	-	-	-
Estonia	-	-	-	-	-	-	-	-
Total	42	176	27	0	572	1847	1586	-

	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]
Faroe Islands	-	-	-	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	-	-	-
France	+	-	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-	-
Netherlands	-	-	107	-	-	-	-	-	-
Norway	66	30	302	10	45	5	718	867	290
Russia	-	-		-	-	-	-	-	-
UK (England + Wales)	-	-		-	-	-	-	-	-
Estonia	-	-		-	-	-	-	-	-
Total	66	30	409	10	45	5	718	867	290

[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	3576	1612	1590	23 730	22 495	18 652	7290	20 323
Faroe Islands	260	-	-	-	-	-	-	-	-
	292	421	567	366	827	298	2312	1891	7841
France	+	139	30	52	+	+	-	3	153
Germany Fed.Rep.	1161	412	-	-	-	-	-	-	-
Ireland	101	355	559	20292	824	1602	6002	8503	10 603
	119	2292	7	322	2	203	776	11 7283	344 253
Netherlands	-	-	-	2	94	-	-	-	-
Norway2	-	-	-	-	-	-	2	-	-
Poland	11	15	6	4	-	71	3	339	373
Sweden	-	-	-	-	3	998	531	487	5749

UK (Engl. + Wales)	-	-	-	-	489	-	-	-	-
UK (Scotland)									
USSR									
Total	**2151**	**7253**	**2788**	**4420**	**25987**	**24238**	**20808**	**20895**	**62877**

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belgium	10	13	-	+	74	57	51	28	-
Denmark	23329	20605	6982	7755	6120	3921	2432	1433	976
Estonia	-	-	-	293	-	-	17	-	-
Faroe Islands	-	942	340	-	360	275	-	-	296
France	248	220	174	162	302	-	-	-	-
Germany Fed.Rep.	506	2469[4]	5995	2801	1570	1014	1600	7	37
Ireland	-	687	2657	2600	4086	415	220	1100	8152
Netherlands	14172	1970	3852	3000	2470	1329	5285	6205	52
Norway	84161	117903	50000	96000	126800	94000	84747	14639	43888
Poland	-	-	-	-	-	-	-	-	-
Sweden	-	102	953	800	697	2087	-	95	1761
UK (Engl. + Wales)	10	10	132	4	115	389	478	40	10
UK (N. Ireland)	-	-	350	-	-	-	-	-	-
UK (Scotland)	2093	458	7309	996	1059	7582	3650	2442	10511
USSR / Russia (1992 -)	-	-	-	-	-	-	-	-	-
Unallocated+discards	12482[3]	-317[3]	-750[3]	-278[5]	-3270	1511	-28	136	-31615[6]
Total	**112047**	**145062**	**77904**	**114133**	**140383**	**112580**	**98452**	**26125**	**34068**

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	19	21	-	-	-	-	-	-	-
Denmark	2048	2026	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	4620	4072	0	0	4	534	0	44	1
Ireland	-	404	32	332	11	93	378	-	-
Lithuania	-	-	-	-	-	-	-	-	-
Netherlands	4548	3285	10	1	0	36	0	0	0
Norway	13129	44344	1141	7912	34843	20349	10687	24733	27087
Russia	-	-	2	-	-	-	-	-	-
Sweden	1761	1957	1009	68	561	1002	567	216	0
UK (Engl. + Wales)	1	12	-	-	-	-	0	-	-
UK (Scotland)	3041	1658	3054	3161	252	0	0	22	61
Unallocated+discards	737	-325	10	0	0	-36	0	0	0
Total	30311	58422	5338	11572	36395	23079	11756	25267	27210

[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 -4000 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	2020*
Denmark	37	7	21	289	183	22
Faroe Islands	0	0	67	0	6	-
France	12	4	1	2	98	0
Germany Fed.Rep.	6	28	1	1	5	0.5
Ireland	8	-	-	-	-	-
Netherlands	-	0	14	7	72	1
Lithuania	12	130	-	-	-	0
Norway	8887	8765	9880	8601	8154	10376
Sweden	10	0	41	23	323	83
UK (Engl. + Wales)	134	13	4	0	-	0
UK (Scotland)	36	14	-	-	50	-
Unallocated +discards	32	97	87	162**	339	1239
Total	9175	9057	10117	9085	9144	11700

[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	2785	7	-	-	-	769	1655
Faroe Islands	-	-	1248	-	-	4014	1992	4450[2]	4000[2]
France	45	454	4	10	14	13	12	20	10
Germany Fed. Rep.	5550	10212	2113	4146	130	191	354	174	615
Ireland	-	-	-	15086	13858	27102	28125	29743	27872
Netherlands	2385	100	50	94	17500	18450	3450	5750	3340
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	1427	138	1027	7834
USSR.	-	-	-	-	-	-	-	-	-
Unallocated + disc						-19168	-13897	-7255	-
Total	8724	11134	6283	19381	31716	33025	20455	35157	45842

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	973	615	-	42	-	294	106	114	780
Faroe Islands	3059	628	255	-	820	80	-	-	-
France	2	17	4	3	+	-	-	-	53
Germany Fed. Rep.	1162	2474	2500	6281	10023	1430	1368	943	229
Ireland	19493	15911	24766	32994	44802	65564	120124	87872	22474
Netherlands	1907	660	3369	2150	590	341	2326	572	1335
Norway	-	-	-	-	-	-	-	-	-
Spain	-[1]	-[1]	1	3	-	-	-	-	-
UK (Engl. + Wales)	44	145	1229	577	144	109	208	612	56
UK (N.Ireland)	-	-	1970	273	-	-	-	-	767
UK (Scotland)	1737	267	1640	86	4523	1760	789	2669	14452
USSR/Russia (1992-)	-	44	-	-	-	-	-	-	-
Unallocated + disc.	6493	143	-1278	-1940	-6960[3]	-51	-41326	-11523	837

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Total	34870	20904	34456	40469	53942	69527	83595	81259	40983

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	1131	433	856	3045
Faroe Islands		573		66					
France		73			246			195	65
Germany	1835	5097	635	773	6508	671	8616	4194	1980
Ireland	20010	18751	16596	19985	23556	29282	19979	15745	10894
Lithuania	80	641							
Netherlands	2177	3904	2332	1684	6353	12653	11078	8580	6211
Norway	2	20	27	18	48	2			
Spain	0								
UK (Engl. + Wales)	332			463			451	18	58
UK (N.Ireland)				59	198		2325	1579	1204
UK (Scotland)	38	588	243	89	2528	1231	385	1277	696
Unallocated+disc.	0	0	0	0	230	2	-	123	
Total	24474	29648	19833	23136	39726	44973	43266	32567	24153

Country	2016	2017	2018	2019	2020[1]
Denmark		3462	4982	6467	2267
Faroe Islands		113		20	
France	23	1025	197	550	3
Germany	4069	2884	2779	1418	0
Ireland	15381	15123	17959	21109	9187
Lithuania	2510				
Netherlands	9246	5497	11921	14421	5202
Norway					
Spain					
UK (Engl. + Wales)		66	32	830	817
UK (N.Ireland)	0		1026	1907	1229
UK (Scotland)	956			627	331**

Country	2016	2017	2018	2019	2020[1]
Unallocated+disc.		116	55	129	108
Total	32186	28286	38950	47480	19146

[1]Preliminary. ** 1.4t BMS included

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	5045	3099	877	993	732	1477	30408	27368	33202
France	1983	2800	2314	1834	2387	1881	3801	2197	1523
Germany Fed.Rep.	2289	1079	12	1977	228	-	5	374	4705
Ireland	-	16	-	-	65	100	703	15	481
Netherlands	23002	25000	27500	34350	38700	33550	40750	69400	43560
Norway	394	-	-	-	-	-	-	-	-
Spain	50	234	104	142	560	275	137	148	150
UK (Engl. + Wales)	12933	2520	2670	1230	279	1630	1824	1228	3759
UK (Scotland)	1	-	-	-	1	1	+	2	2873
USSR	-	-	-	-	-	120	-	-	-
Total	45697	34749	33478	40526	42952	39034	77628	100734	90253

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Faroe Islands	-	28	-	-	-	-	-	-	-
Belgium	-	+	-	-	-	1	-	-	18
Denmark	34474	30594	28888	18984	16978	41605	28300	43330	60412
France	4576	2538	1230	1198	1001	-	-	-	30571
Germany Fed.Rep.	7743	8109	12919	12951	15684	14828	17436	15949	28267
Ireland	12645	17887	19074	15568	16363	15281	58011	38455	43624
Netherlands	43582	111900	104107	109197	157110	92903	116126	114692	131701
Norway	-	-	-	-	-	-	-	-	-
Spain	14	16	113	106	54	29	25	33	6
UK (Engl. + Wales)	4488	13371	6436	7870	6090	12418	31641	28605	17464

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
UK (N.Ireland)	-	-	2026	1690	587	119	-	-	1093
UK (Scotland)	+	139	1992	5008	3123	9015	10522	11241	7902
Unallocated + discards	28368	7614	24541	15563	4010	14057	68644	26795	58718
Total	135890	192196	201326	188135	221000	200256	330705	279100	379776

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Faroe Islands	-	-		550	-	-	3750	3660	
Belgium	-	-	-	-		-			
Denmark	25492	19166	13794	20574	10094	10499	11619	9939	6838
France	22095	25007	20401	9401	5220	5010	5726	7108	6680
Germany	24012	13392	9045	7583	10212	13319	16259	9582	6511
Ireland	48860	25816	32869	29897	23366	13533	8469	20405	16841
Lithuania	-	-							3606
Netherlands	95753	63091	44806	37733	32123	38808	32130	26424	29165
Spain	-	58	50	7	11	1	27	12	3
UK (Engl. + Wales)	11925	7249	4391	5913	4393	3411	4097	2670	2754
UK (N.Ireland)	27	-	546	868	475	384	209		21
UK (Scotland)	5095	4994	5142	1757	1461	268	1146	59	365
Unallocated+discards	12706	31239	-9515	2888	434	17146	16553	11875	4679
Total	245965	190012	121530	117170	87788	102379	99985	91733	77463

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	2020[1]
Denmark	314	1057	1031	690	3198
France	551	595	1067	907	1486
Germany	7313	4077	1401	7673	952
Ireland	12193	7857	7169	7753	7870
Lithuania	86				
Netherlands	14415	8445	14009	15159	9036
Poland				127	1000
Spain	0		0	1	6
UK (Engl. + Wales)	820	478	2410	2862	679**
UK (Scotland)					3
UK (Northern Ireland)			52	0	2
Unallocated+discards	1692	830	548	918	311
Total	37384	23340	27687	36062	24544

[1]Preliminary. [2]French catches landed in the Netherlands **21t BMS landings included

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	3283	2793
France	3361	3711	3.073	2643	2489	4305	3534	3983	4502
Netherlands	-	-	-	-	-[2]	-[2]	-[2]	-[2]	-
Spain	34134	36362	19610	25580	23119	23292	40334	30098	26629
UK (Engl.+Wales)	-	+	1	-	1	143	392	339	253
USSR	-	-	-	-	20	-	656	-	-
Total	37495	40073	22684	28223	25629	27740	45362	37703	34177

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	6729	5726	1349	5778	1955	-	340	140	729
France	4719	5082	6164	6220	4010	28	-	7	8564
Germany Fed. Rep.	-	-	80	62	-		-	-	-
Netherlands	-	6000	12437	9339	19000	7272	-	14187	-
Spain	27170	25182	23733	27688	27921	25409	28349	29428	31082
UK (Engl.+Wales)	68	6	70	88	123	753	20	924	430
Unallocated+discards	-	1500	2563	5011	700	2038	-	3583	-2944
Total	38686	43496	46396	54186	53709	35500	28709	48269	37861

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark	1728	4769	2584	582					1513
France	1844	74	7	5316	13676	4908	2161	3540	3944
Germany	3268	3197	3760	3645	2293	504	72	4776	3326
Ireland	-	-	6485	1483	704	1314	1882	1808	158
Lithuania	-	-							401
Netherlands	8123	13821	11769	35106	12538	6620	1047	6372	6073
Spain	23599	24461	24154	23531	24752	24598	16245	16624	13874
UK (Engl. + Wales)	9	28	121	1092	1578	982	516	838	821
UK (Scotland)	-	-	249						
Unallocated+discards	1884	-8658	5093	4365	1705	2785	2202	7302	4013

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	40455	37692	54222	75120	57246	41711	24125	41260	34122

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Denmark	2687	3289	3109	632	200	581	14			
France	10741	2848			326	1218	2849	2277	1618	2219
Germany		918	281	64	61		417	19	49	4
Ireland	694					39			0	32
Netherlands	211	6269	1848	98	49	7	1057	526	635	1
Spain	14265	19840	21071	38742	34581	13502	22542	19443	13072	14235
UK (Engl. + Wales)		120	224	112	28		104	35	72	9
Unallocated+discards		67	913	7412	417	431	2055	182	9314	6643
Total	28598	33352	27447	47060	35662	15777	29039	22483	24760	23143

Country	2017	2018	2019	2020[1]
Denmark	1		422	
France	2303	2176	2914	728
Germany	210	554	144	2
Ireland	580	219	36	332
Netherlands	313	6	3	0.5
Spain	14901	20362	25775	19163
UK (Engl. + Wales)		2	344	
Unallocated+discards	2907	1921	1755	1104
Total	21213	25240	31396	20742

[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
1992	2094
1995	1344
1998	1242
2001	864
2004	884
2007	1486
2010	1033
2013	366
2016	311
2019	178

Table 7.2.2.1. Western horse mackerel. Time series of recruitment index estimated from the IBTS Surveys (2003–2020) in 2019–2021.

Year	Index 2021		Index 2020	Index 2019
	Mean	CV		
2003	732297	0.30	724708	684217
2004	2453310	0.31	2439512	2295299
2005	2151351	0.33	2148828	2027050
2006	1499811	0.33	1482969	1397314
2007	3121579	0.29	3088715	2886675
2008	7481365	0.30	7272792	6888222
2009	1148964	0.27	1135301	1061126
2010	864772	0.30	860652	808159
2011	178188	0.35	180361	169028
2012	4339882	0.31	4356450	4102691
2013	1111210	0.24	1092849	1034260
2014	2931963	0.24	2922237	2688011
2015	4060794	0.27	4030569	3789317
2016	5280009	0.29	5216531	4913923
2017	9460399	0.47	9450737	8855563

Year	Index 2021		Index 2020	Index 2019
	Mean	CV		
2018	5657414	0.29	4000271	3750158
2019	1637102	0.29	1636554	
2020	878485	0.27		

Table 7.2.2.2. Western horse mackerel. Time series of biomass from 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

Year	Biomass	CV
2017	13845	0.32
2018	9270	0.32
2019	13075	0.32
2020	NA	NA
2021	10233	0.32

Table 7.2.4.1. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2020 (15 = 15+ group)

Q1																		
Age	27.2.a	27.6.a	27.7.b	27.7.c	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.8.a	27.8.b	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0												245	21	22	101	1	0	390
1												921	2064	114	378	3	0	3482
2	5	80	1140	0	75	0	66	4	625	1258	0	398	1934	196	163	1	0	5946
3	126	7301	1579	0	133	0	866	6	858	1759	0	75	69	43	31	0	0	12846
4	57	3817	381	0	125	0	339	1	109	548	0	50	8	16	20	0	0	5472
5	85	4399	3398	0	28	0	54	3	372	2730	0	70	7	11	28	0	0	11185
6	585	40042	27346	0	128	0	120	17	2522	14430	0	118	11	14	27	0	0	85358
7	40	2510	3167	0	13	0	54	2	323	2161	0	85	9	11	26	0	0	8399
8	23	1825	1977	0	9	0	0	1	257	1484	0	188	12	14	33	0	0	5826
9	5	457	507	0	2	0	0	0	100	303		75	9	8	24	0	0	1491
10	8	584	448	0	2	0	0	0	73	380		117	5	5	19	0	0	1641
11	7	614	355	0	2	0	0	0	97	189		172	17	17	40	0	0	1511
12	38	3502	2389	0	9	0	0	2	312	1490	0	369	15	14	45	0	0	8186
13	4	355	245	0	1	0	0	0	28	73		134	16	13	46	0	0	915
14	2	161	7		0		0	0	14	42		94	9	8	26	0	0	362
15	31	2820	975	0	5	0	0	1	229	1137	0	292	14	12	49	0	0	5566
sum	1017	68467	43915	0	530	0	1499	38	5918	27983	0	3402	4221	518	1057	9	1	158576

Q2															
Age	27.2.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	27.8.d	Total
0										183	28	0	300	1995	2	2507
1										708	989	0	6047	7733	6	15484
2			0	0	0	0	0	0	2	266	997	0	743	2902	2	4912
3	52	1	1	3	0	0	0	0	14	35	35	0	94	386	0	622
4	29	1	6	3	0	0	0	0	13	48	21	0	136	520	0	777
5	30	1	3	14	0	2	2	2	487	74	31	0	192	814	1	1653
6	302	6	63	88	2	11	10	15	1288	52	44	0	233	573	0	2690
7	18	0	5	11	0	1	1	2	163	43	33	0	175	468	0	924
8	14	0	7	8	0	1	1	1	248	43	42	0	305	470	0	1141
9	4	0	1	2	0	0	0	0	115	21	9	0	243	228	0	624
10	4	0	0	2	0	0	0	0	9	11	3	0	70	115	0	215
11	5	0	0	2	0	0	0	0	217	49	26	0	937	530	0	1767
12	28	1	2	9	0	1	1	1	254	62	36	0	1114	679	1	2190
13	3	0	0	1	0	0	0	0	4	65	59	0	1419	715	1	2267
14	1	0	3	0	0	0	0	0	1	37	28	0	789	404	0	1264
15	23	0	7	6	0	1	1	1	446	70	106	0	1331	767	1	2758
sum	513	10	99	147	4	19	17	25	3262	1766	2487	0	14130	19299	16	41794

Table 7.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2020 (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.2	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	27.8.d	Total
0														519	945	2	3067	6838	0	11372
1														1265	923	3	6750	16673	0	25615
2	0	6	543	0	2	684	12	163	49	34	4	10	1399	398	195	11	2143	5364	0	11016
3	3	71	6372	3	2	884	15	210	63	44	5	13	1808	107	36	2	515	1469	0	11621
4	1	25	2215	1	0	58	1	14	4	3	0	1	120	115	24	2	892	1548	0	5024
5	3	56	5007	2	0	107	2	25	8	5	1	2	219	173	39	2	1436	2337	0	9423
6	11	237	21252	10	1	602	10	143	43	30	3	9	1232	120	35	0	809	1643	0	26192
7	1	19	1710	1	0	62	1	15	4	3	0	1	128	112	27	0	681	1551	0	4317
8	0	6	560	0	0	52	1	12	4	3	0	1	107	107	23	0	460	1487	0	2824
9	0	1	83	0	0	9	0	2	1	0	0	0	18	69	18	0	133	984	0	1319
10	0	3	236	0	0	2	0	1	0	0	0	0	5	46	15	0	26	669	0	1002
11	0	1	127	0	0	21	0	5	2	1	0	0	43	89	8	0	15	1245	0	1559
12	0	3	244	0	0	38	1	9	3	2	0	1	78	85	5	0	8	1154	0	1631
13	0	0	18	0	0	1	0	0	0	0	0	0	3	105	6	0	8	1404	0	1545
14	0	0	9	0	0	1	0	0	0	0	0	0	3	58	3	0	4	780	0	860
15	0	2	188	0	0	29	0	7	2	1	0	0	60	101	6	0	7	1356	0	1761
sum	20	431	38564	18	6	2552	44	607	183	126	13	37	5221	3471	2308	22	16954	46505	0	117081

Q4																					
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	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	Total
0															495	3119	0	52	4322	0	7987
1															944	3206	0	834	8238	0	13221
2	0	33	90	427	1	303	0	29	73	2704	8095	102	40	557	435	745	0	1003	3838	0	18473
3	1	804	2216	5202	1	428	0	39	100	2212	11684	139	55	810	104	123	4	542	1046	0	25511
4	0	364	1004	1847	0	102	0	5	13	127	576	18	7	267	105	87	8	363	1017	0	5910
5	0	543	1497	4045	0	483	0	16	41	52	101	56	22	1138	160	194	9	519	1445	0	10321
6	3	3720	10258	17827	3	4743	0	109	278	184	243	386	153	6907	107	240	1	324	949	0	46436
7	0	252	695	1412	0	446	0	14	35	19	168	48	19	675	100	308	1	322	887	0	5402
8	0	149	411	493	0	184	0	9	23	12	44	31	12	650	92	336	0	313	812	0	3570
9	0	34	95	79	0	20	0	2	5	3	1	7	3	74	53	275	0	235	467	0	1352
10	0	51	139	202	0	20	0	2	5	3	1	7	3	72	45	255	0	210	399	0	1415
11	0	47	130	118	0	90	0	1	4	2	1	5	2	78	30	133	0	122	271	0	1035
12	0	244	673	297	0	172	0	9	24	13	13	33	13	495	27	41	0	44	241	0	2341
13	0	24	67	25	0	8	0	1	2	1	1	3	1	34	7	20	0	22	60		275
14	0	11	31	12	0	2		0	0	0	0	1	0	20	5	14	0	13	48		158
15	0	196	541	233	0	49	0	5	12	7	10	17	7	120	17	12	0	21	147	0	1393
sum	6	6473	17847	32219	6	7051	0	240	614	5338	20939	852	337	11898	2725	9108	23	4939	24186	0	144800

Table 7.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2020 (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	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0																1441	4112	2	3442	13256	3	0	22256
1																3838	7182	3	13745	33023	10	0	57801
2	5	39	633	520	2	2127	0	40	311	2753	8195	110	675	3215	0	1497	3871	11	4084	12266	4	0	40360
3	182	875	8588	12800	3	2891	0	54	448	2275	12594	150	926	4390	0	322	264	6	1194	2931	1	0	50895
4	87	389	3219	5801	0	547	0	6	155	131	919	19	117	948	0	317	140	10	1408	3106	1	0	17318
5	118	599	6503	8643	1	3992	0	18	109	60	162	61	398	4575	0	477	270	11	2159	4624	1	0	32781
6	901	3958	31510	59231	4	32755	0	119	645	230	404	417	2698	23857	0	397	331	1	1380	3192	1	0	162029
7	59	271	2405	4015	0	3682	0	15	74	24	226	52	345	3127	0	340	377	1	1189	2931	1	0	19134
8	38	155	971	2373	0	2221	0	10	52	16	47	34	272	2489	0	430	412	0	1092	2802	1	0	13415
9	9	35	178	548	0	536	0	2	11	3	2	7	103	510		218	311	0	619	1704	0	0	4799
10	13	53	375	804	0	471	0	2	9	3	2	7	77	466		218	277	0	312	1203	0	0	4292
11	12	48	256	749	0	467	0	2	12	4	2	6	99	528		340	184	0	1090	2086	1	0	5888
12	67	247	917	3888	0	2602	0	10	52	16	16	36	328	2317	0	543	98	0	1180	2119	1	0	14437
13	7	25	85	389	0	254	0	1	4	1	1	3	29	113		311	102	0	1462	2226	1	0	5012
14	3	11	39	177	0	12	0	0	1	0	0	1	14	66		194	54	0	815	1258	1	0	2647
15	54	198	729	3125	0	1060	0	5	30	9	12	18	237	1763	0	480	138	0	1371	2319	1	0	11550
sum	1556	6904	56411	103062	12	53617	0	284	1912	5525	22583	920	6317	48364	0	11364	18124	45	36541	91047	25	1	464614

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
2020	22256	57801	40360	50895	17318	32781	162029	19134	13415	4799	4292	5888	14437	5012	2647	11550

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

year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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
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	2020
Timing	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
Sex	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
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	5.1
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	0.048
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	0.124

year	2003*	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	0.087
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	0.110
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	0.037
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	0.071
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	0.349
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	0.041
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	0.029
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	0.010
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	0.009
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	0.013
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	0.031
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	0.011
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	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	0.025

***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
2003	0	0	13	15	3	1	0	0	0	0	0	0	0	0	0	0
2003	0	1	24	63	32	7	2	2	0	1	1	0	0	0	0	0
2003	0	0	8	72	88	22	8	2	1	4	5	0	0	0	0	0
2003	0	0	2	41	111	57	11	14	18	12	1	0	0	0	1	0
2003	0	0	0	9	72	81	33	29	29	32	5	1	1	0	0	0
2003	0	0	0	1	34	54	43	33	25	47	11	3	1	1	1	3
2003	0	0	0	0	14	30	28	29	49	50	23	11	3	2	0	3
2003	0	0	0	0	1	8	22	23	33	52	19	5	7	2	2	5
2003	0	0	0	0	1	3	4	4	15	29	29	13	2	3	2	17
2003	0	0	0	0	0	2	3	2	7	15	10	8	6	2	3	5
2003	0	0	0	0	0	0	0	1	0	7	8	5	7	2	2	8
2003	0	0	0	0	0	1	0	2	1	3	6	2	2	0	4	4

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2003	0	0	0	0	0	0	0	0	1	0	3	3	1	2	2	5
2003	0	0	0	0	0	0	0	0	1	1	1	2	1	0	0	8
2003	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	10
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2003	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
2004	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	17	18	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	52	126	2	1	0	0	0	0	0	0	0	0	0	0
2004	0	0	51	186	14	5	0	0	0	0	0	0	0	0	0	0
2004	0	0	29	164	44	27	6	3	2	2	2	0	0	0	0	0
2004	0	0	4	95	71	64	21	5	2	13	3	4	1	0	0	1
2004	0	0	2	28	65	108	35	9	6	10	11	4	0	0	0	1
2004	0	0	1	2	36	73	50	9	9	21	5	7	0	1	0	2
2004	0	0	0	1	10	32	20	7	13	16	4	6	2	0	0	1
2004	0	0	0	0	2	4	11	5	8	8	12	3	4	0	1	2
2004	0	0	0	0	0	2	2	0	3	4	3	3	2	0	0	3
2004	0	0	0	0	0	1	1	0	3	1	1	3	1	1	1	6

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2004	0	0	0	0	0	0	1	0	0	3	0	2	0	1	0	3
2004	0	0	0	0	0	0	0	0	0	3	1	1	2	1	0	7
2004	0	0	0	0	0	0	0	1	0	3	1	2	1	0	2	3
2004	0	0	0	0	0	0	0	0	1	0	3	0	2	1	1	5
2004	0	0	0	0	0	0	0	0	0	0	1	1	3	0	0	3
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2004	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
2004	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2005	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	1	42	54	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	75	151	2	2	0	0	0	0	0	0	0	0	0
2005	0	0	0	61	230	4	4	2	0	0	0	0	0	0	0	0
2005	0	0	0	30	248	22	17	7	4	3	2	3	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2005	0	0	0	18	160	40	35	7	8	7	7	6	2	0	2	1
2005	0	0	0	3	37	45	51	18	8	12	9	6	2	1	0	0
2005	0	0	0	0	3	21	39	26	8	19	20	10	3	0	0	3
2005	0	0	0	0	1	4	22	24	11	15	19	13	7	0	1	2
2005	0	0	0	0	0	1	10	12	6	6	15	14	2	0	2	3
2005	0	0	0	0	0	2	13	11	7	8	8	8	3	2	0	4
2005	0	0	0	0	0	1	0	3	0	2	9	5	3	2	0	9
2005	0	0	0	0	0	0	1	2	3	3	3	8	6	2	3	7
2005	0	0	0	0	0	0	0	1	2	0	1	5	6	5	1	11
2005	0	0	0	0	0	0	0	0	1	0	4	2	5	4	2	16
2005	0	0	0	0	0	0	0	1	0	1	1	2	3	0	1	15
2005	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	14
2005	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	3
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2006	0	0	0	3	4	18	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	4	20	201	3	2	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2006	0	0	0	2	15	308	11	2	0	0	0	0	0	0	0	0
2006	0	0	0	0	7	303	24	12	3	3	0	0	0	0	0	0
2006	0	0	0	0	2	290	30	20	5	2	0	3	4	2	0	0
2006	0	0	0	0	1	129	67	34	31	5	1	6	8	7	0	0
2006	0	0	0	0	0	54	46	36	24	6	7	6	9	6	5	1
2006	0	0	0	0	0	14	22	21	27	8	6	6	8	5	3	2
2006	0	0	0	0	0	6	9	10	9	6	5	2	4	10	2	7
2006	0	0	0	0	0	2	4	9	6	4	2	2	8	3	4	7
2006	0	0	0	0	0	0	0	0	4	4	0	3	5	3	3	6
2006	0	0	0	0	0	0	1	0	0	2	2	3	4	3	3	6
2006	0	0	0	0	0	0	0	0	1	0	0	1	2	5	1	2
2006	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	5
2006	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	4
2006	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2007	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
2007	0	0	0	1	12	2	39	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
2007	0	0	0	0	27	9	234	2	0	0	0	0	0	0	0	0
2007	0	0	0	0	7	7	334	9	2	0	0	0	1	0	0	0
2007	0	0	0	0	1	3	360	7	5	3	1	1	0	0	0	0
2007	0	0	0	0	0	0	280	25	23	9	0	3	3	4	1	1
2007	0	0	0	0	0	2	213	27	27	19	10	2	1	9	4	2
2007	0	0	0	0	0	1	126	32	43	34	7	5	11	9	7	7
2007	0	0	0	0	0	0	54	22	34	28	15	13	9	16	6	14
2007	0	0	0	0	0	0	22	9	18	25	9	7	6	6	8	15
2007	0	0	0	0	0	0	8	7	8	17	2	3	1	8	6	24
2007	0	0	0	0	0	0	1	1	9	10	6	2	3	11	5	19
2007	0	0	0	0	0	0	0	0	6	2	2	5	4	5	5	18
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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
2020	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	4	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
2020	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	38	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	56	29	3	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	24	107	16	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	4	203	40	0	1	0	0	0	0	0	0	0	0	0	0
2020	0	4	136	75	6	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	97	111	10	1	0	0	0	0	0	0	0	0	0	0
2020	0	0	21	109	16	2	1	0	0	0	0	0	0	0	0	0
2020	0	0	12	89	66	23	14	0	0	0	0	0	0	0	0	0
2020	0	0	0	58	76	35	83	3	0	0	0	0	0	0	0	0
2020	0	0	1	24	69	60	185	11	0	0	0	0	0	0	0	0
2020	0	0	0	1	40	101	333	25	3	0	1	0	0	0	0	0
2020	0	0	0	3	6	121	321	31	17	0	0	0	0	0	0	0
2020	0	0	0	0	5	58	322	68	24	2	4	0	4	0	0	0
2020	0	0	0	0	4	23	197	102	49	15	8	10	12	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2020	1	0	0	0	0	4	74	62	113	18	10	19	41	5	0	6
2020	0	0	0	0	0	1	21	29	72	99	15	18	54	2	3	16
2020	0	0	0	0	0	0	6	21	39	35	77	24	56	8	4	28
2020	0	0	0	0	0	0	7	9	24	16	40	25	36	11	3	33
2020	0	0	0	0	0	0	6	15	9	19	8	27	24	15	4	39
2020	0	0	0	0	0	0	4	8	9	5	8	15	31	8	1	28
2020	0	0	0	0	0	0	2	0	2	6	3	6	6	13	10	16
2020	0	0	0	0	0	0	0	1	0	2	5	6	0	0	8	12
2020	0	0	0	0	0	0	0	0	0	2	2	4	4	0	0	10
2020	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	5
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

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	2020
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 number		34	42	50	40	47	53	57	37	46	87	68	49	48	66	63	82	101	108	104	96	51
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	0.002	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	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	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	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	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	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	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	0.002
	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	0.016
	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	0.015
	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	0.003
	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	0.004

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	0.011
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	0.016
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	0.019
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	0.019
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	0.046
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	0.034
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	0.030
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	0.047
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	0.021
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	0.041
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	0.103
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	0.171
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	0.117
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	0.091
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	0.052
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	0.033
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	0.029
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	0.028

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	0.021
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	0.016
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	0.007
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	0.004
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	0.002
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	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	0.001
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	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	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 7.2.4.6. 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	2021
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	5.08
Fleet		5	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	0
catch		0	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	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	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	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	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	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	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	0.002
	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	0.058
	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	0.110
	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	0.073
	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	0.029
	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	0.039
	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	0.052
	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	0.062

year	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018	2019	2021
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	0.069
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	0.055
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	0.030
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	0.039
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	0.026
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	0.027
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	0.058
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	0.056
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	0.033
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	0.026
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	0.026
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	0.025
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	0.032
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	0.032
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	0.014
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	0.004
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	0.002
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	0.000

year	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018	2019	2021
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	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	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	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	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	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	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	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	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	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	0.006
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	0.005
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	0.004
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	0.003
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	0.002
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	0.001
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	0.000

Table 7.2.5.1. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2020 (15 = 15+ group) Jens

Q1 Weight	27.2.a	27.6.a	27.7.b	27.7.c	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.8.a	27.8.b	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0												0.026	0.026	0.026	0.026	0.026	0.026	0.026
1												0.036	0.034	0.039	0.036	0.036	0.036	0.035
2	0.131	0.131	0.074	0.074	0.065	0.074	0.051	0.074	0.074	0.074	0.074	0.065	0.054	0.070	0.065	0.065	0.065	0.067
3	0.102	0.089	0.096	0.096	0.083	0.096	0.079	0.096	0.096	0.096	0.096	0.133	0.103	0.106	0.133	0.133	0.133	0.091
4	0.134	0.117	0.179	0.153	0.111	0.153	0.123	0.153	0.153	0.149	0.153	0.167	0.154	0.152	0.167	0.167	0.167	0.127
5	0.176	0.166	0.169	0.182	0.143	0.182	0.164	0.182	0.182	0.177	0.182	0.197	0.193	0.185	0.195	0.195	0.195	0.170
6	0.183	0.177	0.185	0.193	0.185	0.193	0.166	0.193	0.194	0.191	0.193	0.257	0.223	0.216	0.246	0.246	0.246	0.182
7	0.220	0.229	0.239	0.234	0.234	0.234	0.179	0.234	0.239	0.228	0.234	0.286	0.254	0.244	0.282	0.282	0.282	0.233
8	0.268	0.275	0.240	0.253	0.253	0.253	0.253	0.253	0.265	0.250	0.253	0.322	0.270	0.265	0.296	0.296	0.296	0.258
9	0.287	0.287	0.284	0.294	0.294	0.294	0.294	0.294	0.307	0.278	0.294	0.320	0.302	0.306	0.323	0.323	0.323	0.288
10	0.273	0.295	0.262	0.278	0.278	0.278	0.278	0.278	0.295	0.292	0.278	0.441	0.361	0.360	0.375	0.375	0.375	0.297
11	0.310	0.316	0.293	0.305	0.305	0.305	0.305	0.305	0.319	0.288	0.305	0.390	0.315	0.317	0.335	0.335	0.335	0.316
12	0.315	0.316	0.306	0.298	0.298	0.298	0.298	0.298	0.312	0.284	0.298	0.385	0.360	0.358	0.368	0.368	0.368	0.311
13	0.338	0.339	0.318	0.314	0.314	0.314	0.314	0.314	0.303	0.301	0.314	0.395	0.394	0.393	0.394	0.394	0.394	0.342
14	0.365	0.367	0.338	0.338	0.338	0.338	0.338	0.338	0.364	0.344	0.338	0.405	0.374	0.372	0.378	0.378	0.378	0.375
15	0.346	0.349	0.342	0.360	0.360	0.360	0.360	0.360	0.378	0.370	0.360	0.458	0.479	0.481	0.483	0.483	0.483	0.361

Q2 Weight	27.2.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	27.8.d	Total
0										0.026	0.026	0.026	0.026	0.026	0.026	0.026
1										0.041	0.043	0.041	0.026	0.041	0.041	0.035
2			0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.062	0.048	0.062	0.051	0.062	0.062	0.057
3	0.084	0.084	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.132	0.118	0.132	0.132	0.132	0.132	0.126
4	0.112	0.112	0.152	0.146	0.146	0.146	0.146	0.146	0.146	0.179	0.164	0.179	0.168	0.179	0.179	0.173
5	0.162	0.162	0.175	0.175	0.175	0.175	0.175	0.175	0.237	0.205	0.188	0.205	0.195	0.205	0.205	0.212
6	0.175	0.175	0.197	0.186	0.186	0.186	0.186	0.186	0.222	0.238	0.203	0.238	0.212	0.238	0.238	0.217
7	0.232	0.232	0.245	0.236	0.236	0.236	0.236	0.236	0.292	0.258	0.214	0.258	0.226	0.258	0.258	0.255
8	0.277	0.277	0.294	0.251	0.251	0.251	0.251	0.251	0.330	0.282	0.239	0.282	0.246	0.282	0.282	0.281
9	0.288	0.288	0.292	0.292	0.292	0.292	0.292	0.292	0.357	0.303	0.283	0.303	0.277	0.303	0.303	0.302
10	0.301	0.301	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.393	0.347	0.393	0.317	0.393	0.393	0.359
11	0.318	0.318	0.311	0.311	0.311	0.311	0.311	0.311	0.351	0.324	0.307	0.324	0.307	0.324	0.324	0.318
12	0.316	0.316	0.301	0.301	0.301	0.301	0.301	0.301	0.322	0.366	0.362	0.366	0.358	0.366	0.366	0.356
13	0.339	0.339	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.393	0.397	0.393	0.392	0.393	0.393	0.392
14	0.368	0.368	0.426	0.355	0.355	0.355	0.355	0.355	0.355	0.375	0.381	0.375	0.370	0.375	0.375	0.372
15	0.350	0.350	0.340	0.360	0.360	0.360	0.360	0.360	0.364	0.483	0.495	0.483	0.486	0.483	0.483	0.464

Table 7.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2020 (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.2	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	27.8.d	Total
0														0.026	0.026	0.036	0.026	0.026	0.026	0.026
1														0.044	0.050	0.055	0.055	0.044	0.044	0.047
2	0.131	0.131	0.131	0.131	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.073	0.079	0.088	0.074	0.074	0.073	0.077
3	0.121	0.121	0.121	0.121	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.137	0.124	0.129	0.140	0.137	0.137	0.118
4	0.171	0.171	0.171	0.171	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.176	0.171	0.176	0.182	0.176	0.176	0.174
5	0.188	0.188	0.188	0.188	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.202	0.203	0.195	0.207	0.202	0.202	0.196
6	0.199	0.199	0.199	0.199	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.245	0.243	0.207	0.242	0.247	0.245	0.205
7	0.202	0.202	0.202	0.202	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.275	0.272	0.205	0.260	0.278	0.275	0.242
8	0.238	0.238	0.238	0.238	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.293	0.303	0.293	0.287	0.295	0.293	0.282
9	0.280	0.280	0.280	0.280	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.326	0.328	0.326	0.311	0.330	0.326	0.325
10	0.201	0.201	0.201	0.201	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.364	0.355	0.364	0.357	0.368	0.364	0.327
11	0.268	0.268	0.268	0.268	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.333	0.345	0.333	0.362	0.338	0.333	0.332
12	0.286	0.286	0.286	0.286	0.289	0.289	0.289	0.289	0.289	0.289	0.289	0.289	0.289	0.365	0.366	0.365	0.371	0.367	0.365	0.349
13	0.313	0.313	0.313	0.313	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.395	0.395	0.395	0.398	0.396	0.395	0.395
14	0.313	0.313	0.313	0.313	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.376	0.376	0.376	0.381	0.378	0.376	0.377
15	0.292	0.292	0.292	0.292	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.490	0.490	0.490	0.491	0.493	0.490	0.463

Q4 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	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	Total
0															0.026	0.026	0.026	0.028	0.026	0.026	0.026
1															0.051	0.051	0.051	0.056	0.051	0.051	0.051
2	0.131	0.131	0.131	0.131	0.074	0.074	0.074	0.074	0.074	0.070	0.076	0.074	0.074	0.074	0.073	0.078	0.073	0.096	0.074	0.073	0.077
3	0.102	0.102	0.102	0.120	0.096	0.097	0.096	0.096	0.096	0.097	0.098	0.096	0.096	0.099	0.135	0.124	0.158	0.137	0.138	0.135	0.105
4	0.134	0.134	0.134	0.168	0.153	0.165	0.153	0.153	0.153	0.159	0.150	0.153	0.153	0.177	0.176	0.173	0.183	0.169	0.175	0.176	0.160
5	0.176	0.176	0.176	0.187	0.178	0.197	0.178	0.178	0.178	0.146	0.200	0.178	0.178	0.205	0.203	0.211	0.194	0.195	0.202	0.203	0.190
6	0.183	0.183	0.183	0.197	0.192	0.211	0.192	0.192	0.192	0.187	0.211	0.192	0.192	0.215	0.251	0.272	0.198	0.252	0.251	0.251	0.199
7	0.220	0.220	0.220	0.203	0.232	0.221	0.232	0.232	0.232	0.232	0.169	0.232	0.232	0.245	0.281	0.302	0.197	0.295	0.281	0.281	0.238
8	0.268	0.268	0.268	0.242	0.247	0.266	0.247	0.247	0.247	0.247	0.233	0.247	0.247	0.257	0.309	0.317	0.309	0.314	0.309	0.309	0.280
9	0.287	0.287	0.287	0.281	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.284	0.305	0.341	0.343	0.341	0.346	0.341	0.341	0.330
10	0.273	0.273	0.273	0.210	0.278	0.278	0.278	0.278	0.278	0.278	0.278	0.278	0.278	0.285	0.384	0.367	0.384	0.370	0.384	0.384	0.331
11	0.310	0.310	0.310	0.276	0.287	0.270	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.290	0.412	0.402	0.412	0.407	0.412	0.412	0.354
12	0.315	0.315	0.315	0.297	0.296	0.298	0.296	0.296	0.296	0.296	0.288	0.296	0.296	0.274	0.404	0.426	0.404	0.434	0.404	0.404	0.316
13	0.338	0.338	0.338	0.325	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.323	0.444	0.464	0.444	0.462	0.444	0.444	0.378
14	0.365	0.365	0.365	0.336	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.335	0.299	0.476	0.503	0.476	0.502	0.477	0.476	0.415
15	0.346	0.346	0.346	0.313	0.358	0.358	0.358	0.358	0.358	0.358	0.320	0.358	0.358	0.352	0.476	0.512	0.702	0.567	0.476	0.476	0.362

Table 7.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2020 (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	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0																0.026	0.026	0.035	0.026	0.026	0.026	0.026	0.026
1																0.043	0.045	0.054	0.042	0.045	0.039	0.036	0.044
2	0.131	0.131	0.131	0.131	0.075	0.075	0.074	0.075	0.072	0.070	0.076	0.074	0.074	0.075	0.074	0.069	0.058	0.088	0.075	0.071	0.063	0.065	0.073
3	0.097	0.103	0.116	0.102	0.097	0.097	0.096	0.097	0.093	0.097	0.096	0.096	0.096	0.097	0.096	0.135	0.118	0.150	0.137	0.137	0.133	0.133	0.105
4	0.127	0.136	0.160	0.134	0.157	0.174	0.153	0.154	0.120	0.159	0.140	0.153	0.153	0.159	0.153	0.175	0.170	0.182	0.177	0.176	0.175	0.167	0.154
5	0.173	0.177	0.185	0.176	0.194	0.174	0.181	0.182	0.178	0.155	0.188	0.178	0.182	0.192	0.182	0.202	0.207	0.194	0.203	0.203	0.202	0.195	0.186
6	0.181	0.184	0.193	0.183	0.203	0.189	0.193	0.195	0.197	0.194	0.198	0.192	0.194	0.201	0.193	0.249	0.258	0.200	0.239	0.247	0.241	0.246	0.191
7	0.223	0.219	0.207	0.220	0.233	0.236	0.234	0.233	0.234	0.233	0.173	0.233	0.239	0.235	0.234	0.277	0.291	0.199	0.264	0.276	0.267	0.282	0.238
8	0.271	0.267	0.251	0.268	0.261	0.243	0.251	0.250	0.257	0.255	0.236	0.247	0.264	0.262	0.253	0.308	0.307	0.293	0.283	0.297	0.288	0.296	0.271
9	0.287	0.286	0.283	0.287	0.306	0.285	0.290	0.289	0.301	0.297	0.299	0.285	0.306	0.302	0.294	0.326	0.340	0.325	0.311	0.330	0.314	0.323	0.312
10	0.282	0.269	0.228	0.273	0.279	0.263	0.278	0.278	0.279	0.279	0.279	0.278	0.295	0.290	0.278	0.411	0.366	0.372	0.357	0.376	0.381	0.375	0.318
11	0.313	0.309	0.289	0.310	0.309	0.290	0.300	0.295	0.308	0.303	0.306	0.290	0.318	0.317	0.305	0.368	0.378	0.336	0.319	0.344	0.329	0.335	0.327
12	0.315	0.314	0.307	0.315	0.294	0.305	0.297	0.295	0.296	0.295	0.289	0.296	0.312	0.286	0.298	0.381	0.389	0.368	0.361	0.371	0.367	0.368	0.323
13	0.339	0.338	0.333	0.338	0.316	0.317	0.314	0.314	0.315	0.315	0.315	0.314	0.303	0.309	0.314	0.396	0.410	0.395	0.393	0.397	0.394	0.394	0.383
14	0.366	0.365	0.353	0.365	0.324	0.354	0.337	0.332	0.331	0.328	0.329	0.335	0.363	0.329	0.338	0.393	0.410	0.378	0.372	0.381	0.376	0.378	0.377
15	0.348	0.346	0.332	0.346	0.360	0.343	0.359	0.359	0.359	0.359	0.327	0.359	0.377	0.367	0.360	0.469	0.495	0.682	0.487	0.488	0.483	0.483	0.401

Table 7.2.5.2. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2020 (15 = 15+ group)

Q1 cm	27.2.a	27.6.a	27.7.b	27.7.c	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.8.a	27.8.b	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0												14.3	14.3	14.3	14.3	14.3	14.3	14.3
1												15.9	15.6	16.4	15.9	15.9	15.9	15.7
2	25.4	25.4	21.6	21.6	20.7	21.6	19.0	21.6	21.6	21.6	21.6	19.3	18.4	20.0	19.3	19.3	19.3	20.3
3	24.0	23.4	23.3	23.4	22.4	23.4	22.0	23.4	23.4	23.4	23.4	24.9	22.9	23.1	24.9	24.9	24.9	23.3
4	26.2	25.4	28.7	26.9	24.3	26.9	25.1	26.9	26.9	27.1	26.9	26.9	26.2	26.1	26.9	26.9	26.9	25.8
5	28.5	28.1	28.7	28.9	26.6	28.9	28.0	28.9	28.9	28.7	28.9	28.4	28.2	27.8	28.3	28.3	28.3	28.4
6	28.9	28.7	29.0	29.3	28.8	29.3	27.8	29.3	29.4	29.2	29.3	31.2	29.6	29.3	30.5	30.5	30.5	28.9
7	30.5	30.8	31.1	30.9	30.9	30.9	28.0	30.9	31.1	30.7	30.9	32.2	30.8	30.4	32.0	32.0	32.0	30.9
8	32.4	32.6	31.6	31.8	31.8	31.8	31.8	31.8	32.3	31.7	31.8	33.7	31.6	31.4	32.6	32.6	32.6	32.0
9	33.1	33.1	33.2	33.6	33.6	33.6	33.6	33.6	34.5	33.1	33.6	33.5	32.8	32.9	33.5	33.5	33.5	33.2
10	32.3	33.2	32.0	32.7	32.7	32.7	32.7	32.7	33.1	33.3	32.7	37.6	34.8	34.8	35.3	35.3	35.3	33.2
11	33.9	34.1	33.7	33.7	33.7	33.7	33.7	33.7	34.6	33.1	33.7	35.8	33.3	33.3	34.0	34.0	34.0	34.1
12	34.1	34.2	34.3	33.7	33.7	33.7	33.7	33.7	34.4	33.1	33.7	35.9	34.9	34.8	35.2	35.2	35.2	34.1
13	34.9	34.9	34.4	34.4	34.4	34.4	34.4	34.4	33.6	34.6	34.4	36.0	35.9	35.9	35.9	35.9	35.9	34.9
14	36.0	36.1	35.4	35.4	35.4	35.4	35.4	35.4	36.9	35.5	35.4	36.4	35.2	35.2	35.4	35.4	35.4	36.0
15	35.2	35.3	35.7	35.9	35.9	35.9	35.9	35.9	36.4	36.0	35.9	38.0	38.3	38.4	38.4	38.4	38.4	35.7

Q2 cm	27.2.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	27.8.d	Total
0										14.5	14.5	14.5	14.5	14.5	14.5	14.5
1										16.6	17.1	16.6	14.4	16.6	16.6	15.8
2			19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.2	17.7	19.2	17.9	19.2	19.2	18.7
3	23.2	23.2	22.0	22.0	22.0	22.0	22.0	22.0	22.0	24.7	24.0	24.7	24.8	24.7	24.7	24.5
4	25.2	25.2	26.1	26.8	26.8	26.8	26.8	26.8	26.8	27.6	26.8	27.6	27.0	27.6	27.6	27.3
5	27.9	27.9	28.7	28.7	28.7	28.7	28.7	28.7	29.8	28.9	28.0	28.9	28.4	28.9	28.9	29.0
6	28.6	28.6	28.8	29.0	29.0	29.0	29.0	29.0	29.7	30.3	28.8	30.3	29.1	30.3	30.3	29.6
7	30.9	30.9	31.2	31.0	31.0	31.0	31.0	31.0	32.0	31.1	29.2	31.1	29.7	31.1	31.1	30.9
8	32.6	32.6	31.9	31.8	31.8	31.8	31.8	31.8	33.2	32.1	30.4	32.1	30.7	32.1	32.1	31.9
9	33.1	33.1	33.5	33.5	33.5	33.5	33.5	33.5	35.3	32.9	32.1	32.9	31.9	32.9	32.9	32.9
10	33.4	33.4	32.6	32.6	32.6	32.6	32.6	32.6	32.6	35.9	34.4	35.9	33.3	35.9	35.9	34.8
11	34.1	34.1	33.9	33.9	33.9	33.9	33.9	33.9	34.5	33.6	33.0	33.6	33.0	33.6	33.6	33.4
12	34.2	34.2	33.9	33.9	33.9	33.9	33.9	33.9	34.0	35.1	34.9	35.1	34.8	35.1	35.1	34.8
13	34.9	34.9	34.4	34.4	34.4	34.4	34.4	34.4	34.4	35.9	36.0	35.9	35.8	35.9	35.9	35.8
14	36.1	36.1	38.5	36.1	36.1	36.1	36.1	36.1	36.1	35.3	35.5	35.3	35.1	35.3	35.3	35.2
15	35.3	35.3	35.6	35.9	35.9	35.9	35.9	35.9	35.8	38.4	38.7	38.4	38.4	38.4	38.4	38.0

Table 7.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2020 (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.2	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	27.8.d	Total
0														14.4	14.4	16.2	14.5	14.4	14.4	14.4
1														17.1	18.0	18.4	18.6	17.1	17.1	17.5
2	25.4	25.4	25.4	25.4	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	20.3	20.9	21.8	20.6	20.3	20.3	20.9
3	24.9	24.9	24.9	24.9	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4	25.1	24.2	24.6	25.1	25.1	25.1	24.5
4	27.9	27.9	27.9	27.9	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.4	27.1	27.4	27.8	27.4	27.4	27.7
5	29.0	29.0	29.0	29.0	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	28.7	28.7	28.4	28.9	28.7	28.7	29.0
6	29.5	29.5	29.5	29.5	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.5	30.5	28.9	30.5	30.6	30.5	29.7
7	29.9	29.9	29.9	29.9	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	31.7	31.6	28.9	31.2	31.8	31.7	30.9
8	31.5	31.5	31.5	31.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.8	32.5	32.3	32.5	32.5	32.3
9	33.2	33.2	33.2	33.2	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	33.6	33.7	33.6	33.2	33.8	33.6	33.7
10	29.5	29.5	29.5	29.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.9	34.7	34.9	34.7	35.0	34.9	33.7
11	32.7	32.7	32.7	32.7	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	34.3	33.9	34.8	34.0	33.9	33.9
12	33.4	33.4	33.4	33.4	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	35.0	35.0	35.0	35.2	35.0	35.0	34.6
13	34.5	34.5	34.5	34.5	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.9	35.9	35.9	36.0	36.0	35.9	35.9
14	34.5	34.5	34.5	34.5	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	35.3	35.3	35.3	35.4	35.4	35.3	35.3
15	33.8	33.8	33.8	33.8	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.7	38.6	38.6	38.6	38.6	38.6	38.6	37.9

Q4																				
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	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	Total
0															14.4	14.3	14.4	14.8	14.4	14.4	14.4
1															18.0	18.2	18.0	18.7	18.0	18.0	18.1
2	25.4	25.4	25.4	25.4	21.6	21.6	21.6	21.6	21.6	21.3	21.7	21.6	21.6	21.6	20.3	20.9	20.3	22.3	20.3	20.3	21.4
3	24.0	24.0	24.0	24.8	23.4	23.4	23.4	23.4	23.4	23.5	23.4	23.4	23.4	23.5	25.0	24.2	26.5	25.2	25.1	25.0	23.9
4	26.2	26.2	26.2	27.8	26.9	27.6	26.9	26.9	26.9	27.0	26.5	26.9	26.9	28.1	27.5	27.2	27.8	27.0	27.4	27.5	27.1
5	28.5	28.5	28.5	29.0	28.8	29.5	28.8	28.8	28.8	28.1	29.2	28.8	28.8	29.7	28.8	29.1	28.4	28.3	28.7	28.8	28.9
6	28.9	28.9	28.9	29.5	29.3	30.0	29.3	29.3	29.3	28.8	29.9	29.3	29.3	30.1	30.8	31.6	28.5	30.8	30.8	30.8	29.5
7	30.5	30.5	30.5	30.0	30.8	30.4	30.8	30.8	30.8	30.8	26.8	30.8	30.8	31.4	32.0	32.8	28.5	32.5	32.0	32.0	30.9
8	32.4	32.4	32.4	31.6	31.7	32.5	31.7	31.7	31.7	31.7	30.9	31.7	31.7	32.0	33.1	33.3	33.1	33.2	33.1	33.1	32.5
9	33.1	33.1	33.1	33.2	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	34.0	34.2	34.2	34.2	34.3	34.2	34.2	34.0
10	32.3	32.3	32.3	29.8	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	33.1	35.6	35.0	35.6	35.1	35.6	35.6	33.9
11	33.9	33.9	33.9	32.9	33.4	32.7	33.4	33.4	33.4	33.4	33.4	33.4	33.4	33.5	36.5	36.1	36.5	36.3	36.5	36.5	34.9
12	34.1	34.1	34.1	33.7	33.7	33.8	33.7	33.7	33.7	33.7	33.4	33.7	33.7	32.7	36.5	36.8	36.5	37.0	36.5	36.5	34.1
13	34.9	34.9	34.9	34.7	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.7	37.4	37.9	37.4	37.9	37.4	37.4	35.9
14	36.0	36.0	36.0	35.2	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	33.8	38.4	38.9	38.4	38.9	38.4	38.4	37.0
15	35.2	35.2	35.2	34.4	35.9	35.9	35.9	35.9	35.9	35.9	34.7	35.9	35.9	35.7	38.5	39.2	43.5	40.4	38.5	38.5	35.6

Table 7.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2020 (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	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.e	Total
0																14.4	14.3	16.1	14.5	14.4	14.4	14.3	14.4
1																16.9	17.3	18.3	16.7	17.2	16.4	15.9	17.1
2	25.4	25.4	25.4	25.4	21.6	21.6	21.6	21.6	21.4	21.3	21.7	21.6	21.6	21.6	21.6	19.8	18.8	21.8	20.5	20.1	19.3	19.3	20.8
3	23.8	24.1	24.7	24.0	23.4	23.4	23.4	23.4	23.1	23.5	23.3	23.4	23.4	23.4	23.4	25.0	23.8	25.9	25.1	25.1	24.8	24.9	23.9
4	25.9	26.3	27.4	26.2	27.0	28.3	26.9	26.9	24.8	27.0	26.0	26.9	26.9	27.4	26.9	27.4	27.1	27.7	27.5	27.4	27.4	26.9	26.9
5	28.4	28.6	28.9	28.5	29.3	28.8	28.9	28.9	28.5	28.3	28.8	28.8	28.9	29.1	28.9	28.7	28.9	28.4	28.7	28.7	28.7	28.3	28.8
6	28.8	28.9	29.3	28.9	29.7	29.2	29.3	29.4	29.4	29.1	29.3	29.3	29.4	29.6	29.3	30.8	31.0	28.7	30.3	30.6	30.4	30.5	29.2
7	30.6	30.5	30.1	30.5	30.7	31.0	30.9	30.8	30.8	30.8	27.1	30.8	31.1	30.9	30.9	31.8	32.3	28.6	31.3	31.8	31.4	32.0	30.9
8	32.5	32.3	31.9	32.4	32.0	31.7	31.8	31.8	32.0	31.9	31.0	31.8	32.3	32.0	31.8	33.1	32.9	32.5	32.1	32.6	32.3	32.6	32.2
9	33.1	33.1	33.2	33.1	33.9	33.2	33.5	33.4	33.8	33.7	33.7	33.3	34.4	33.8	33.6	33.6	34.1	33.6	33.1	33.8	33.2	33.5	33.5
10	32.7	32.2	30.5	32.3	32.7	32.0	32.7	32.7	32.7	32.7	32.7	32.7	33.1	33.2	32.7	36.5	35.0	35.2	34.7	35.3	35.5	35.3	33.6
11	33.9	33.8	33.3	33.9	33.7	33.5	33.7	33.5	33.7	33.6	33.7	33.5	34.6	33.8	33.7	35.1	35.3	34.0	33.4	34.2	33.8	34.0	34.0
12	34.1	34.1	33.9	34.1	33.5	34.2	33.7	33.7	33.6	33.6	33.4	33.7	34.3	33.1	33.7	35.7	35.7	35.1	34.9	35.2	35.1	35.2	34.3
13	34.9	34.9	34.8	34.9	34.5	34.4	34.4	34.4	34.5	34.5	34.5	34.4	33.7	34.7	34.4	36.0	36.3	35.9	35.8	36.0	35.9	35.9	35.7
14	36.0	36.0	35.7	36.0	34.8	35.9	35.3	35.1	35.1	35.0	35.0	35.3	36.9	34.9	35.4	35.9	36.3	35.4	35.2	35.5	35.3	35.4	35.5
15	35.2	35.2	34.8	35.2	35.8	35.8	35.9	35.9	35.8	35.9	34.9	35.9	36.3	35.9	35.9	38.2	38.7	43.0	38.5	38.5	38.4	38.4	36.6

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
2020	0.026	0.028	0.051	0.083	0.121	0.170	0.181	0.235	0.259	0.288	0.297	0.315	0.318	0.373	0.371	0.386

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

	0	1	2	3	4	5	6	7	8	9	10	11+
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

	0	1	2	3	4	5	6	7	8	9	10	11+
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
2020	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.

	1987		1992		1995		1998		2000		2001		2001 (cont)	
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

	1987		1992		1995		1998		2000		2001		2001 (cont)	
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
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

	1987		1992		1995		1998		2000		2001		2001 (cont)	
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	47836900	1224800	2508310	5767780	1065790	1377590	1251940	752509	489208	437032	407175	470482	564493	707171	403839	258724	229811	203001	178882	157708	1174820

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1983	1506360	41138300	1050670	2142280	4901320	901783	1162120	1054260	633103	411396	367440	342303	395503	474520	594447	339464	217481	193176	170640	150365	1120100
1984	1618940	1295010	35245400	894754	1811780	4120630	755036	970653	879452	527798	342867	306190	285222	329540	395370	495288	282836	181201	160950	142173	1058520
1985	2127570	1391930	1109950	30043000	757875	1526320	3458410	632296	811919	735217	441117	286521	255855	238326	275352	330354	413838	236323	151401	134481	1003230
1986	2659390	1829580	1193880	947683	25516700	640806	1286540	2909760	531476	682139	617558	370485	240630	214869	200146	231238	277426	347534	198459	127144	955422
1987	5227420	2286430	1567970	1017420	802401	21485400	537501	1076700	2432270	444004	569712	515708	309362	200924	179411	167115	193075	231640	290176	165705	903891
1988	2828290	4492990	1957240	1332670	857669	671669	17897500	446460	892982	2015780	367846	471913	427144	256224	166407	148588	138404	159902	191841	240319	885819
1989	3172420	2430540	3843680	1661100	1120710	715617	557387	14804800	368692	736831	1662640	303347	389131	352198	211262	137204	122511	114113	131839	158171	928487
1990	2213230	2726170	2079000	3261050	1396150	934424	593360	460650	12214400	303926	607154	1369770	249889	320540	290109	174016	113014	100910	93993	108592	895053
1991	3917750	1900710	2326150	1753880	2715350	1149580	763457	482586	373756	9898750	246170	491643	1109020	202307	259495	234855	140871	91487	81689	76089	812460
1992	7659570	3363580	1620000	1957330	1454190	2223110	932988	616429	388597	300565	7955340	197780	394942	890818	162496	208425	188631	113144	73480	65610	713647
1993	6961380	6567500	2852190	1347130	1591500	1159880	1749720	728580	479399	301606	233059	6165760	153254	305993	690143	125885	161463	146127	87648	56922	603652
1994	6385880	5961650	5542790	2346090	1075830	1239210	887447	1325000	548746	360116	226277	174744	4621630	114856	229306	517156	94329	120986	109493	65674	494957
1995	3836720	5467840	5028040	4552080	1868720	834775	944280	669045	993332	410263	268886	168848	130354	3447040	85658	171004	385655	70342	90219	81648	418053
1996	2155970	3276980	4566950	4037690	3493900	1379850	600088	668167	469507	694263	286191	187397	117623	90786	2400390	59644	119067	268516	48975	62814	347903
1997	1497210	1843270	2747700	3700430	3145290	2631450	1015270	435502	481423	337096	497632	204971	134161	84191	64974	1717820	42682	85204	192146	35046	293894
1998	2574170	1276540	1529040	2171820	2766860	2242550	1815420	686963	291691	320850	224131	330496	136052	89025	55858	43104	1139550	28313	56518	127454	218185
1999	2711470	2201370	1071410	1241750	1698190	2094400	1659810	1326010	498296	210865	231571	161640	238257	98062	64159	40253	31061	821152	20402	40725	249056
2000	1999390	2318580	1847000	869408	969665	1283180	1546940	1209610	959566	359355	151821	166598	116243	171307	70499	46123	28936	22328	590261	14665	208295
2001	11846100	1712520	1957970	1521330	695878	757304	985274	1175960	914706	723765	270718	114306	125396	87481	128911	53049	34705	21773	16800	444126	167758

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2002	2179360	10134800	1439700	1596120	1197020	531176	566053	727393	862551	668803	528397	197499	83361	91432	63780	93979	38673	25299	15872	12247	446038
2003	1064110	1865450	8536920	1178950	1265280	922884	401720	423267	540682	639288	495005	390827	146032	61627	67587	47144	69464	28584	18699	11731	338718
2004	1949000	910936	1571990	6997360	936037	977550	699678	301190	315498	401870	474517	367184	289813	108270	45687	50103	34947	51492	21188	13861	259767
2005	1481480	1670320	770991	1301550	5648980	739481	760790	539744	231269	241708	307549	362958	280787	221592	82778	34929	38303	26717	39364	16198	209178
2006	1231430	1269120	1411440	635985	1044310	4426210	569975	580750	409927	175211	182904	232595	274423	212265	167502	62569	26401	28951	20193	29752	170341
2007	1956800	1055620	1075230	1171330	515397	829243	3465500	442570	448977	316241	135031	140891	179125	211311	163437	128966	48173	20326	22289	15547	154049
2008	4945330	1678710	897001	898450	960040	415500	660907	2743430	349120	353562	248830	106205	110793	140845	166144	128499	101395	37874	15980	17524	133333
2009	1277190	4239420	1422400	744600	728405	762764	325533	513549	2122550	269538	272694	191824	81855	85380	108532	128021	99011	78126	29182	12313	116234
2010	938294	1093160	3570050	1164040	589646	560805	575922	242984	381021	1570170	199114	201310	141563	60397	62992	80069	94444	73041	57633	21527	94826
2011	344757	802108	916174	2889600	905176	443052	411492	416708	174525	272692	1121840	142145	143654	100998	43085	44933	57112	67364	52097	41107	82987
2012	2417070	294622	671386	739362	2236040	675707	322604	295259	296710	123802	193092	793689	100523	101569	71400	30457	31762	40370	47615	36824	87712
2013	1053240	2066080	246842	543011	574223	1677340	494832	232924	211602	211872	88251	137530	565074	71553	72289	50814	21675	22603	28728	33884	88619
2014	3375470	899701	1726570	198463	417618	425139	1209580	351342	164041	148433	148342	61733	96161	395008	50012	50523	35512	15147	15796	20076	85606
2015	2396120	2884780	753259	1394150	153720	312140	310017	869306	250586	116563	105286	105132	43733	68107	279736	35415	35775	25145	10725	11184	74828
2016	2777670	2050940	2429710	616682	1104730	118452	235918	231657	645708	185589	86209	77817	77678	32307	50308	206619	26157	26423	18572	7921	63524
2017	3633800	2377160	1726350	1986380	487532	848642	89202	175591	171363	476216	136678	63446	57250	57138	23762	37000	151956	19237	19432	13658	52541
2018	2968230	3113140	2009260	1424950	1595430	382530	655178	68213	133605	130069	361042	103565	48061	43362	43273	17995	28020	115073	14568	14715	50129
2019	1356420	2541200	2624340	1648280	1132900	1234880	290637	492372	50969	99551	96788	268490	76992	35724	32228	32160	13373	20823	85515	10826	48187
2020	1083960	1160330	2135440	2137200	1294770	862859	920631	213963	360089	37155	72459	70397	195208	55967	25966	23423	23373	9719	15133	62148	42886

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	0.022	0.023	0.023	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1983	0.001	0.005	0.011	0.018	0.023	0.028	0.030	0.031	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.033	0.033	0.033	0.033	0.033	0.033
1984	0.001	0.004	0.010	0.016	0.021	0.025	0.027	0.029	0.029	0.029	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
1985	0.001	0.003	0.008	0.013	0.018	0.021	0.023	0.024	0.024	0.024	0.024	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
1986	0.001	0.004	0.010	0.016	0.022	0.026	0.028	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
1987	0.001	0.005	0.013	0.021	0.028	0.033	0.036	0.037	0.038	0.038	0.038	0.038	0.038	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1988	0.002	0.006	0.014	0.023	0.031	0.037	0.040	0.041	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1989	0.002	0.006	0.014	0.024	0.032	0.037	0.041	0.042	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1990	0.002	0.009	0.020	0.033	0.044	0.052	0.057	0.059	0.060	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
1991	0.003	0.010	0.023	0.037	0.050	0.059	0.064	0.067	0.068	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
1992	0.004	0.015	0.034	0.057	0.076	0.089	0.097	0.101	0.103	0.104	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
1993	0.005	0.020	0.045	0.075	0.100	0.118	0.128	0.133	0.136	0.137	0.138	0.138	0.138	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139
1994	0.005	0.020	0.047	0.077	0.104	0.122	0.132	0.138	0.141	0.142	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
1995	0.008	0.030	0.069	0.115	0.153	0.180	0.196	0.204	0.208	0.210	0.211	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
1996	0.007	0.026	0.060	0.100	0.133	0.157	0.171	0.178	0.181	0.183	0.184	0.184	0.184	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185
1997	0.009	0.037	0.085	0.141	0.188	0.221	0.241	0.251	0.256	0.258	0.259	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.261	0.261	0.261
1998	0.006	0.025	0.058	0.096	0.128	0.151	0.164	0.171	0.174	0.176	0.177	0.177	0.177	0.178	0.178	0.178	0.178	0.178	0.178	0.178	0.178
1999	0.007	0.026	0.059	0.097	0.130	0.153	0.166	0.173	0.177	0.179	0.179	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2000	0.005	0.019	0.044	0.073	0.097	0.114	0.124	0.129	0.132	0.133	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
2001	0.006	0.024	0.054	0.090	0.120	0.141	0.153	0.160	0.163	0.165	0.165	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166
2002	0.006	0.022	0.050	0.082	0.110	0.129	0.141	0.147	0.150	0.151	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152
2003	0.005	0.021	0.049	0.081	0.108	0.127	0.138	0.144	0.147	0.148	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149
2004	0.004	0.017	0.039	0.064	0.086	0.101	0.110	0.114	0.116	0.117	0.118	0.118	0.118	0.118	0.119	0.119	0.119	0.119	0.119	0.119	0.119
2005	0.005	0.018	0.043	0.070	0.094	0.110	0.120	0.125	0.128	0.129	0.129	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
2006	0.004	0.016	0.036	0.060	0.081	0.095	0.103	0.107	0.109	0.110	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.112	0.112	0.112
2007	0.003	0.013	0.030	0.049	0.065	0.077	0.084	0.087	0.089	0.090	0.090	0.090	0.090	0.090	0.091	0.091	0.091	0.091	0.091	0.091	0.091
2008	0.004	0.016	0.036	0.060	0.080	0.094	0.102	0.107	0.109	0.110	0.110	0.110	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
2009	0.006	0.022	0.050	0.083	0.111	0.131	0.142	0.148	0.151	0.153	0.154	0.154	0.154	0.154	0.154	0.154	0.154	0.154	0.154	0.154	0.154
2010	0.007	0.027	0.061	0.102	0.136	0.160	0.174	0.181	0.185	0.186	0.187	0.187	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
2011	0.007	0.028	0.064	0.106	0.142	0.167	0.182	0.190	0.193	0.195	0.196	0.196	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197
2012	0.007	0.027	0.062	0.103	0.137	0.162	0.176	0.183	0.187	0.188	0.189	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190
2013	0.008	0.030	0.068	0.113	0.151	0.177	0.192	0.201	0.205	0.206	0.207	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208
2014	0.007	0.028	0.064	0.105	0.141	0.166	0.180	0.188	0.192	0.193	0.194	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195
2015	0.006	0.022	0.050	0.083	0.111	0.130	0.141	0.147	0.150	0.152	0.152	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
2016	0.006	0.022	0.051	0.085	0.114	0.134	0.145	0.151	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
2017	0.005	0.018	0.042	0.069	0.093	0.109	0.118	0.123	0.126	0.127	0.127	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2018	0.005	0.021	0.048	0.079	0.106	0.125	0.136	0.141	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
2019	0.006	0.024	0.055	0.091	0.122	0.144	0.156	0.163	0.166	0.168	0.168	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169
2020	0.003	0.014	0.031	0.052	0.069	0.081	0.088	0.092	0.094	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095

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	47836900	3144430	2469210	61197	0.0248	0.008	0.021	0.018
1983	1506360	3644310	2587600	90442	0.0350	0.011	0.029	0.024
1984	1618940	4270810	2702620	96244	0.0356	0.010	0.026	0.022
1985	2127570	4843100	3134920	96343	0.0307	0.008	0.022	0.018
1986	2659390	5250280	4372860	137499	0.0314	0.010	0.027	0.023
1987	5227420	5434110	5087090	187338	0.0368	0.013	0.034	0.029
1988	2828290	5414920	5122550	210989	0.0412	0.014	0.038	0.032
1989	3172420	5256650	4916890	209583	0.0426	0.015	0.039	0.033
1990	2213230	5016550	4654220	275968	0.0593	0.021	0.054	0.046
1991	3917750	4662660	4339050	287438	0.0662	0.023	0.061	0.051
1992	7659570	4301480	3981390	393631	0.0989	0.035	0.094	0.078
1993	6961380	3893680	3503640	453246	0.1294	0.047	0.123	0.103
1994	6385880	3514220	2992100	412291	0.1378	0.048	0.127	0.107

Year	Recruit (thousands)	Total Biomass	Spawning biomass	Catch	Yield/SSB	Fbar(1-3)	Fbar(4-8)	Fbar(1-10)
1995	3836720	3248070	2629550	538950	0.2050	0.071	0.188	0.158
1996	2155970	2890570	2315190	422396	0.1824	0.062	0.164	0.137
1997	1497210	2633790	2179160	534673	0.2454	0.088	0.231	0.194
1998	2574170	2234260	1927560	325340	0.1688	0.060	0.158	0.132
1999	2711470	2009570	1784670	298992	0.1675	0.061	0.160	0.134
2000	1999390	1794360	1585430	202732	0.1279	0.045	0.119	0.100
2001	11846100	1707190	1439890	229081	0.1591	0.056	0.148	0.124
2002	2179360	1661210	1287020	196120	0.1524	0.051	0.135	0.113
2003	1064110	1682780	1197440	191856	0.1602	0.050	0.133	0.111
2004	1949000	1697580	1204550	159742	0.1326	0.040	0.105	0.088
2005	1481480	1704380	1400640	182001	0.1299	0.044	0.115	0.097
2006	1231430	1643210	1464720	155827	0.1064	0.037	0.099	0.083
2007	1956800	1568880	1411860	123356	0.0874	0.030	0.080	0.067
2008	4945330	1516110	1349390	143349	0.1062	0.037	0.098	0.082
2009	1277190	1453060	1247790	183782	0.1473	0.052	0.137	0.115
2010	938294	1355040	1105300	203112	0.1838	0.063	0.167	0.140
2011	344757	1227270	991969	193698	0.1953	0.066	0.175	0.146
2012	2417070	1094660	944091	169859	0.1799	0.064	0.169	0.141

Year	Recruit (thousands)	Total Biomass	Spawning biomass	Catch	Yield/SSB	Fbar(1-3)	Fbar(4-8)	Fbar(1-10)
2013	1053240	977448	868583	165258	0.1903	0.070	0.185	0.155
2014	3375470	871492	744841	136360	0.1831	0.066	0.173	0.145
2015	2396120	814045	640294	98419	0.1537	0.051	0.136	0.114
2016	2777670	818210	606453	98810	0.1629	0.053	0.140	0.117
2017	3633800	847879	594977	82961	0.1394	0.043	0.114	0.095
2018	2968230	916541	642427	101682	0.1583	0.049	0.130	0.109
2019	1356420	976690	691329	124947	0.1807	0.057	0.150	0.126
2020	1083960	1002650	734333	76422	0.1041	0.032	0.085	0.071

Table 7.4.1. Western Horse Mackerel. Short term prediction: INPUT DATA. *geometric mean of the recruitment time series from 1983 to 2020. ** from assessment output

Age	N	Mat	M	PF	PM	Stock weight at age**
0	1083960	0.000	0.150	0	0	0.0043
1	1160330	0.000	0.150	0	0	0.0182
2	2135440	0.047	0.150	0	0	0.0420
3	2137200	0.269	0.150	0	0	0.0726
4	1294770	0.731	0.150	0	0	0.1062
5	862859	0.953	0.150	0	0	0.1399
6	920631	0.993	0.150	0	0	0.1718
7	213963	0.999	0.150	0	0	0.2008

Age	N	Mat	M	PF	PM	Stock weight at age**
8	360089	1.000	0.150	0	0	0.2264
9	37155.4	1.000	0.150	0	0	0.2485
10	72459.4	1.000	0.150	0	0	0.2673
11	70396.5	1.000	0.150	0	0	0.2831
12	195208	1.000	0.150	0	0	0.2962
13	55967.1	1.000	0.150	0	0	0.3070
14	25965.7	1.000	0.150	0	0	0.3159
15	23423.3	1.000	0.150	0	0	0.3232
16	23373.3	1.000	0.150	0	0	0.3292
17	9719.2	1.000	0.150	0	0	0.3340
18	15133.1	1.000	0.150	0	0	0.3379
19	62147.7	1.000	0.150	0	0	0.3410
20	42886.4	1.000	0.150	0	0	0.3458

Table 7.4.2. Western Horse Mackerel. Short term prediction; single area management option table. Assumption: Catch 2021: 81 375 t (100% of 2021 TOTAL TAC).

Scenarios	F_{factor}	F_{bar}	Catch_2021	Catch_2022	SSB_2022	SSB_2023	Change_SSB_2022-2023(%)	Change_Catch_2021-2022(%)
B2023=B_{pa}	cannot be reached even by setting F to 0							
F=0	0.000	0.000	81375	0	912868	1008671	10.49	-100.00
	0.100	0.007	81375	8987	912868	1000341	9.58	-88.96

Scenarios	F_{factor}	F_{bar}	Catch_2021	Catch_2022	SSB_2022	SSB_2023	Change_SSB_2022-2023(%)	Change_Catch_2021-2022(%)
	0.200	0.014	81375	17902	912868	992081	8.68	-78.00
	0.300	0.021	81375	26744	912868	983892	7.78	-67.13
	0.400	0.028	81375	35515	912868	975772	6.89	-56.36
PELAC HCR	0.404	0.029	81375	36423	912868	974909	6.80	-55.24
	0.500	0.035	81375	44215	912868	967721	6.01	-45.67
	0.600	0.043	81375	52844	912868	959738	5.13	-35.06
	0.700	0.050	81375	61404	912868	951823	4.27	-24.54
	0.800	0.057	81375	69895	912868	943975	3.41	-14.11
$FmsyXSSB22byMSYB_{trig}$	0.815	0.058	81375	71138	912868	942827	3.28	-12.58
	0.900	0.064	81375	78317	912868	936194	2.56	-3.76
F_{stq}	0.981	0.070	81375	85078	912868	929950	1.87	4.55
	1.000	0.071	81375	86672	912868	928478	1.71	6.51
FMSY	1.043	0.074	81375	90214	912868	925208	1.35	10.86
	1.100	0.078	81375	94959	912868	920828	0.87	16.69
Fp05	1.113	0.079	81375	96038	912868	919832	0.76	18.02
	1.200	0.085	81375	103179	912868	913243	0.04	26.79
	1.300	0.092	81375	111333	912868	905722	-0.78	36.81
	1.400	0.099	81375	119421	912868	898265	-1.60	46.75

Scenarios	F_{factor}	F_{bar}	Catch_2021	Catch_2022	SSB_2022	SSB_2023	Change_SSB_2022-2023(%)	Change_Catch_2021-2022(%)
F_{lim}	1.451	0.103	81375	123540	912868	894468	-2.02	51.82
	1.500	0.106	81375	127444	912868	890871	-2.41	56.61
	1.600	0.114	81375	135402	912868	883540	-3.21	66.39
	1.700	0.121	81375	143297	912868	876271	-4.01	76.09
	1.800	0.128	81375	151128	912868	869063	-4.80	85.72
	1.900	0.135	81375	158896	912868	861916	-5.58	95.26
	2.000	0.142	81375	166601	912868	854830	-6.36	104.73
B2023=B_{lim}	2.292	0.163	81375	188749	912868	834480	-8.59	131.95

7.16 Figures

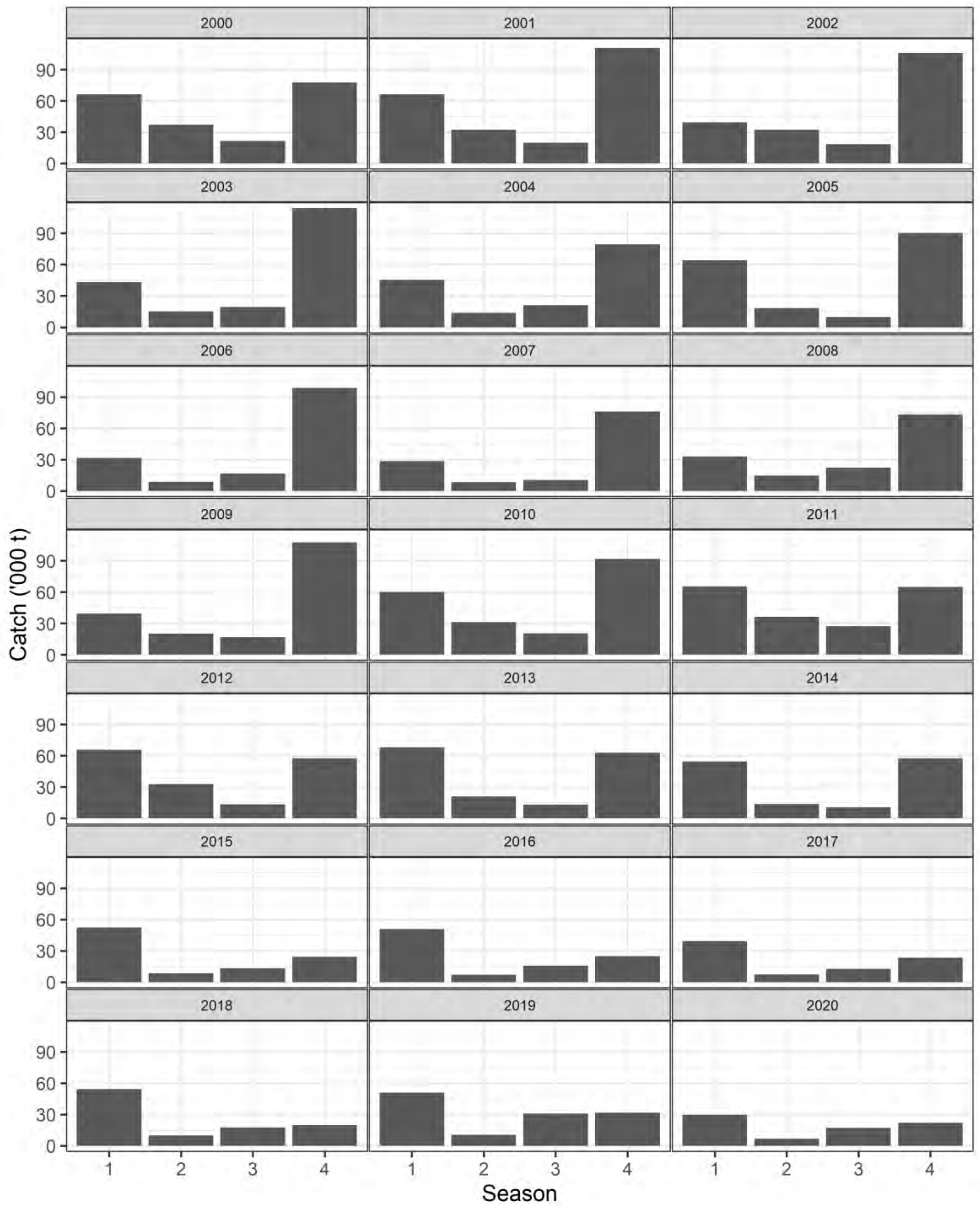


Figure 7.1.1.1: Western horse mackerel. Catch by quarter and year for 2000–2020.

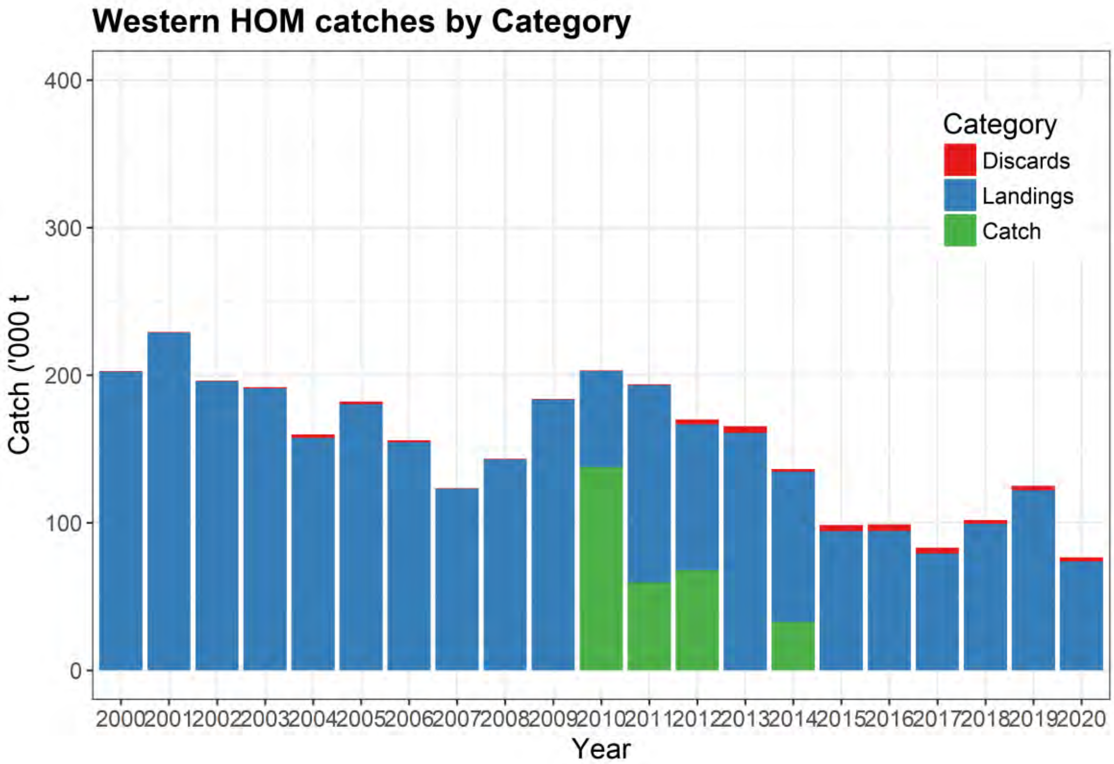


Figure 7.1.2.1. Western horse mackerel. Catch categories since 2000.

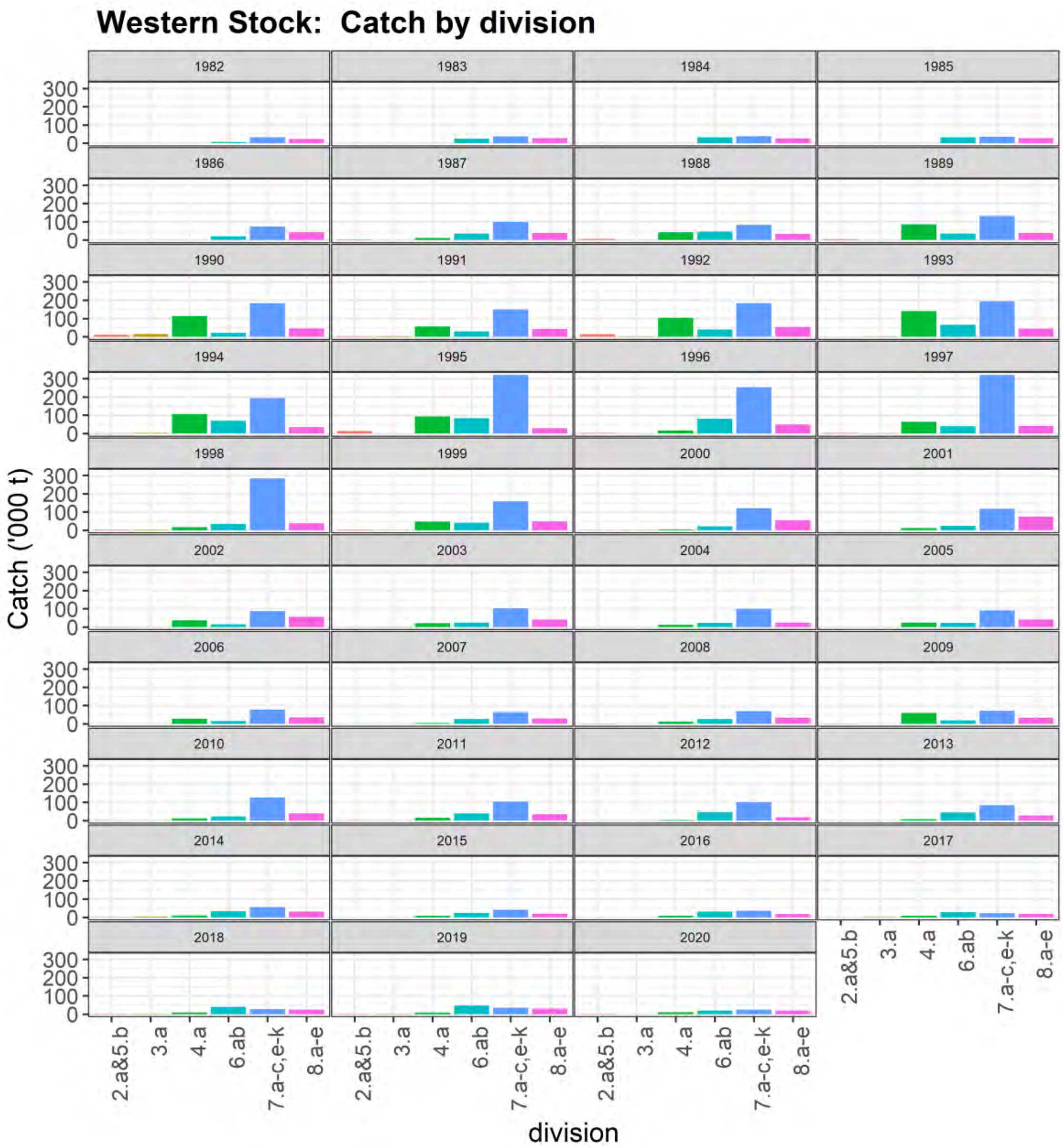


Figure 7.1.3.1: Western horse mackerel. Catch by ICES Division and year for 1982-2020.

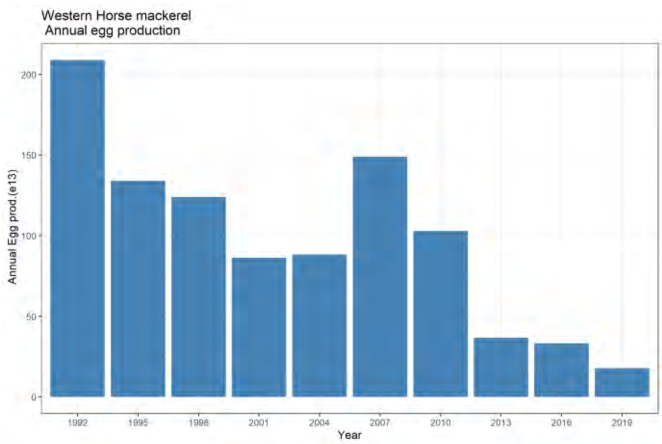


Figure 7.2.1.1. Total Annual Egg Production estimates for western horse mackerel stock. 1992–2019.

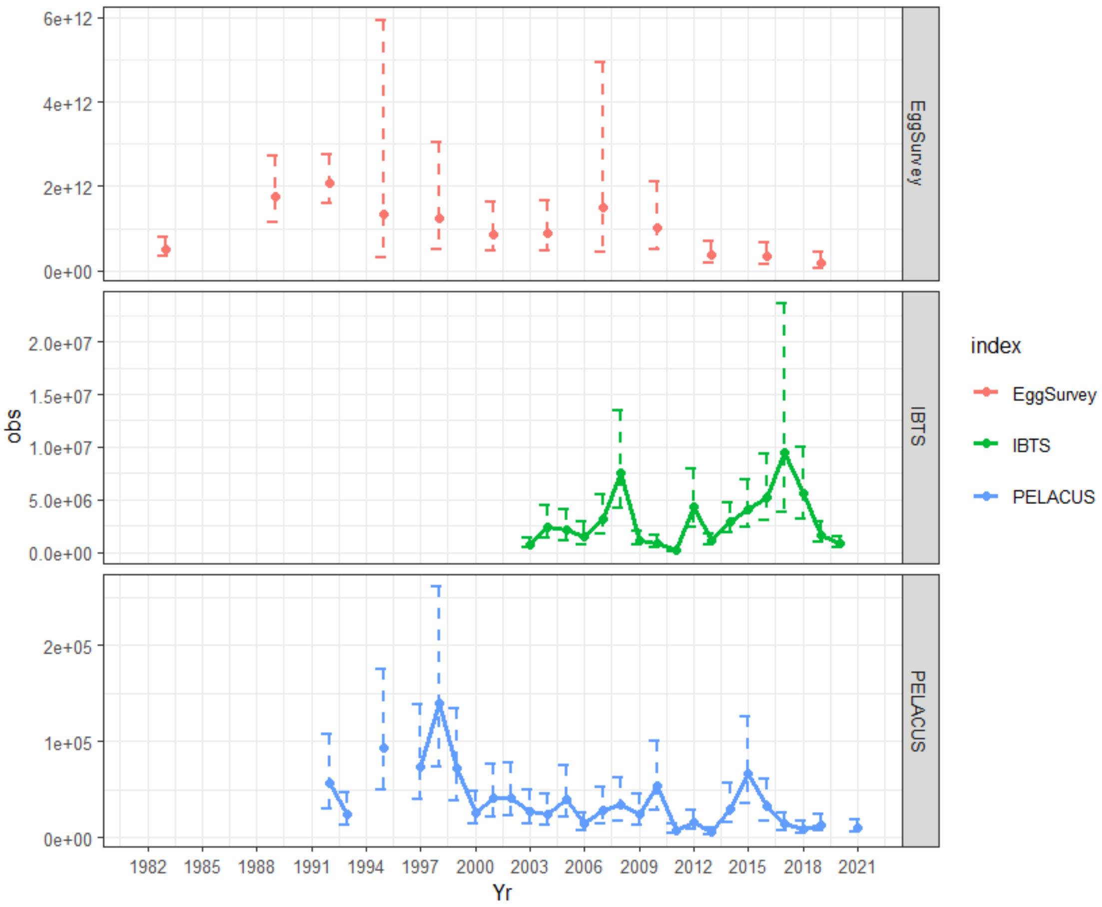


Figure 7.2.2.1: Western horse mackerel. Trend of the fisheries independent indices of abundance used in the assessment of Western Horse mackerel. Top: Spawning index from egg survey; middle: recruitment index from IBTS survey; bottom: biomass estimates from PELACUS acoustic survey. Confidence intervals are shown as well.

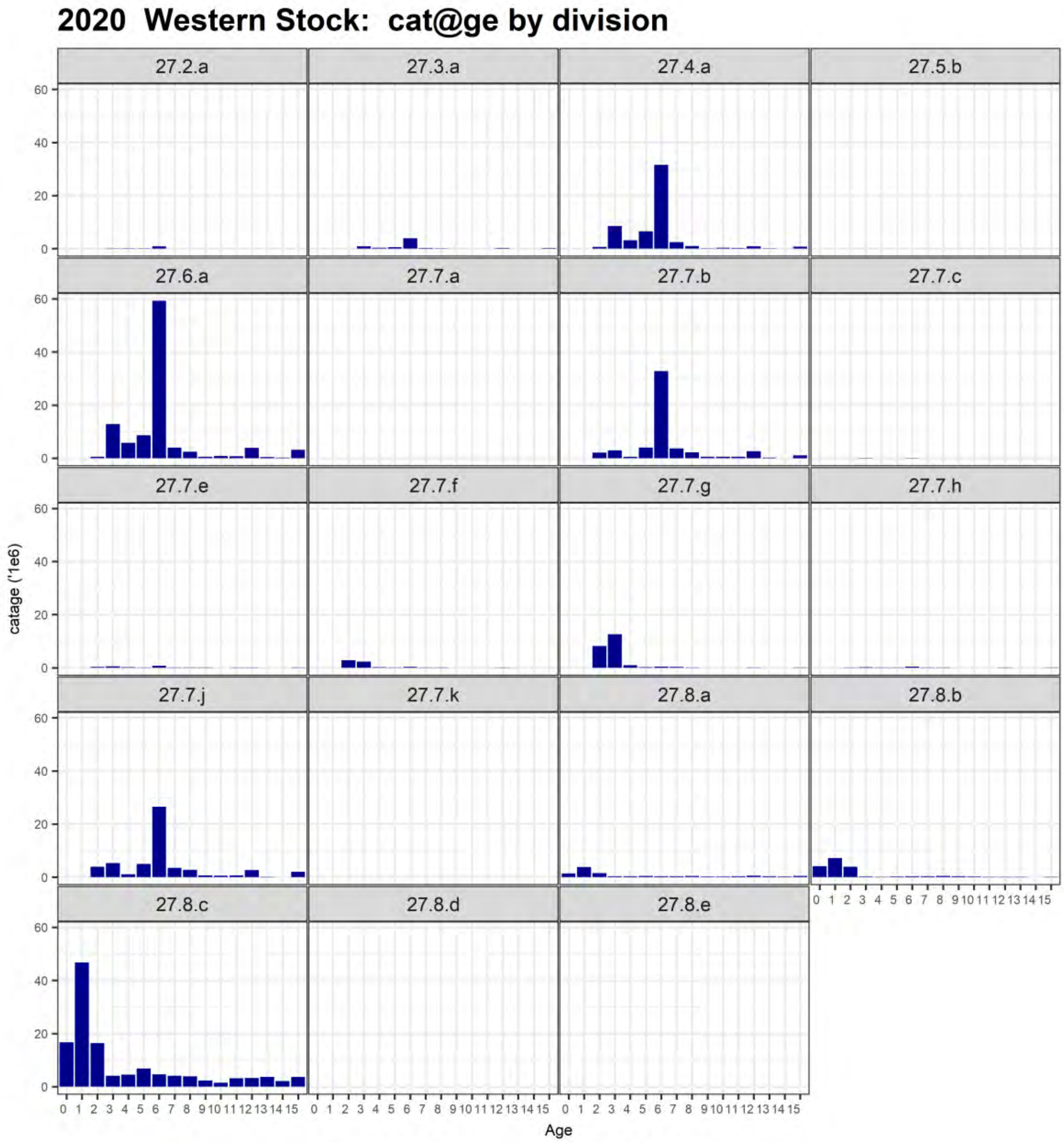


Figure 7.2.4.1: Western horse mackerel. Catch-at-age (millions) by ICES division in 2020.

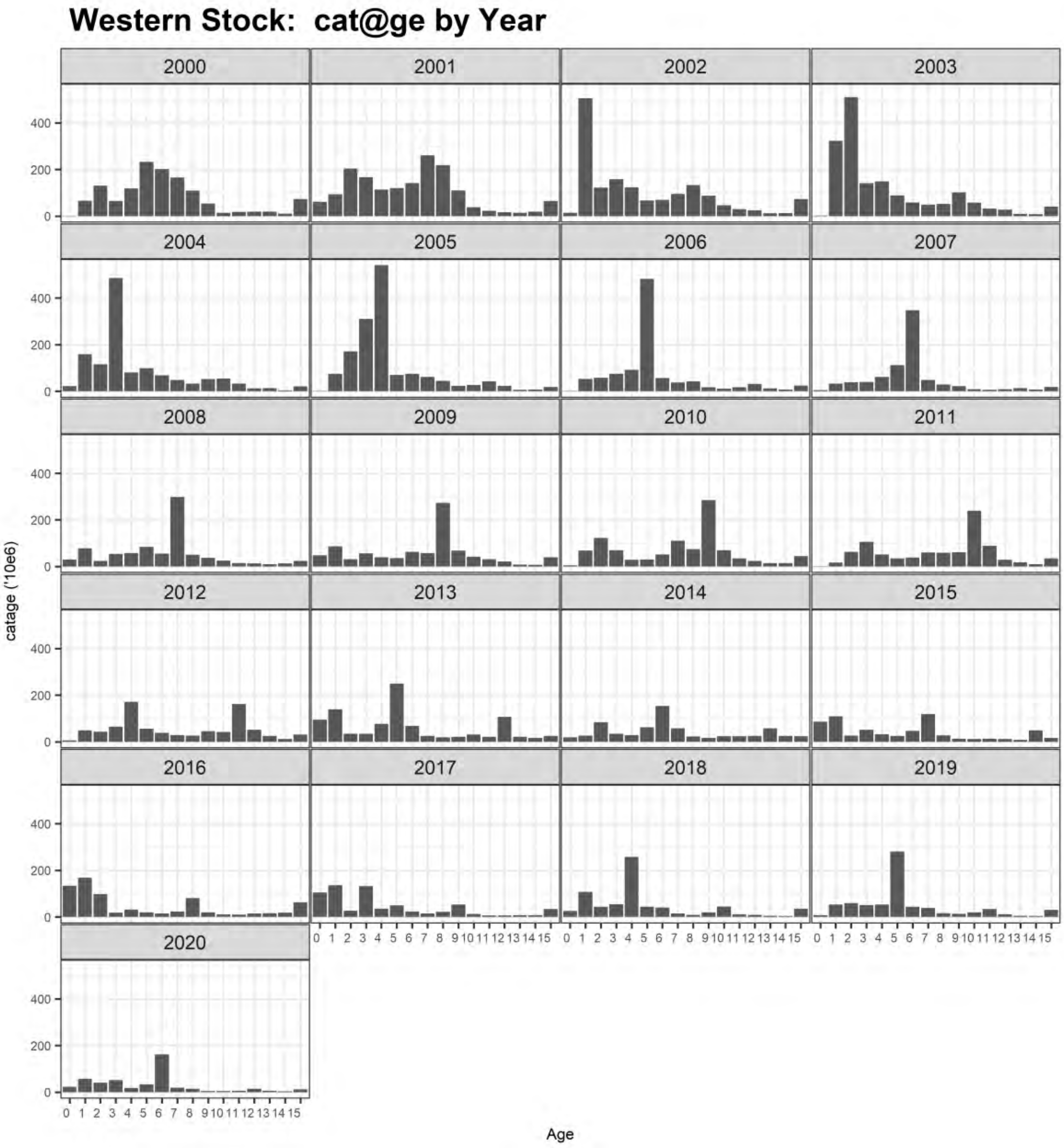


Figure 7.2.4.2: Western horse mackerel. Catch-at-age (millions) by Year.

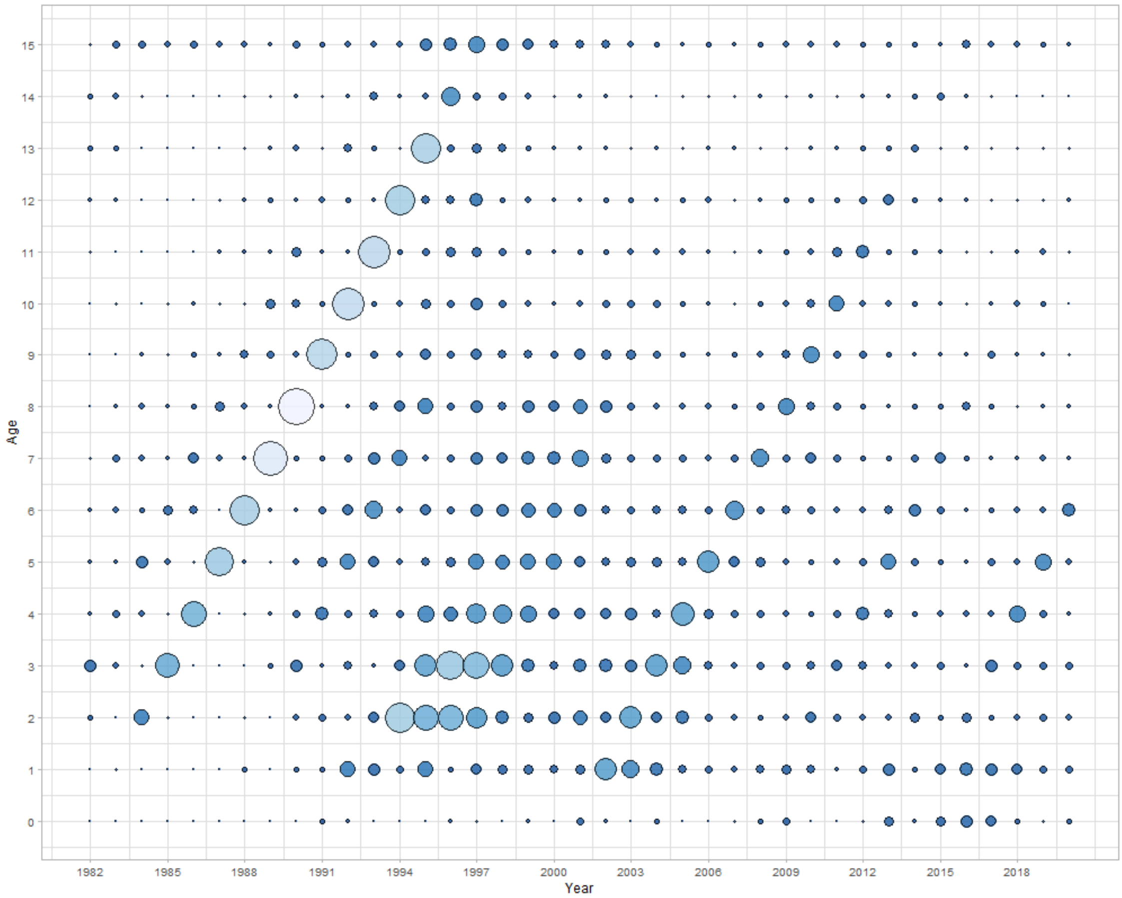


Figure 7.2.4.3: Western horse mackerel. Catch-at-age - the area of bubbles is proportional to the catch number. Age 15 is a plus group.

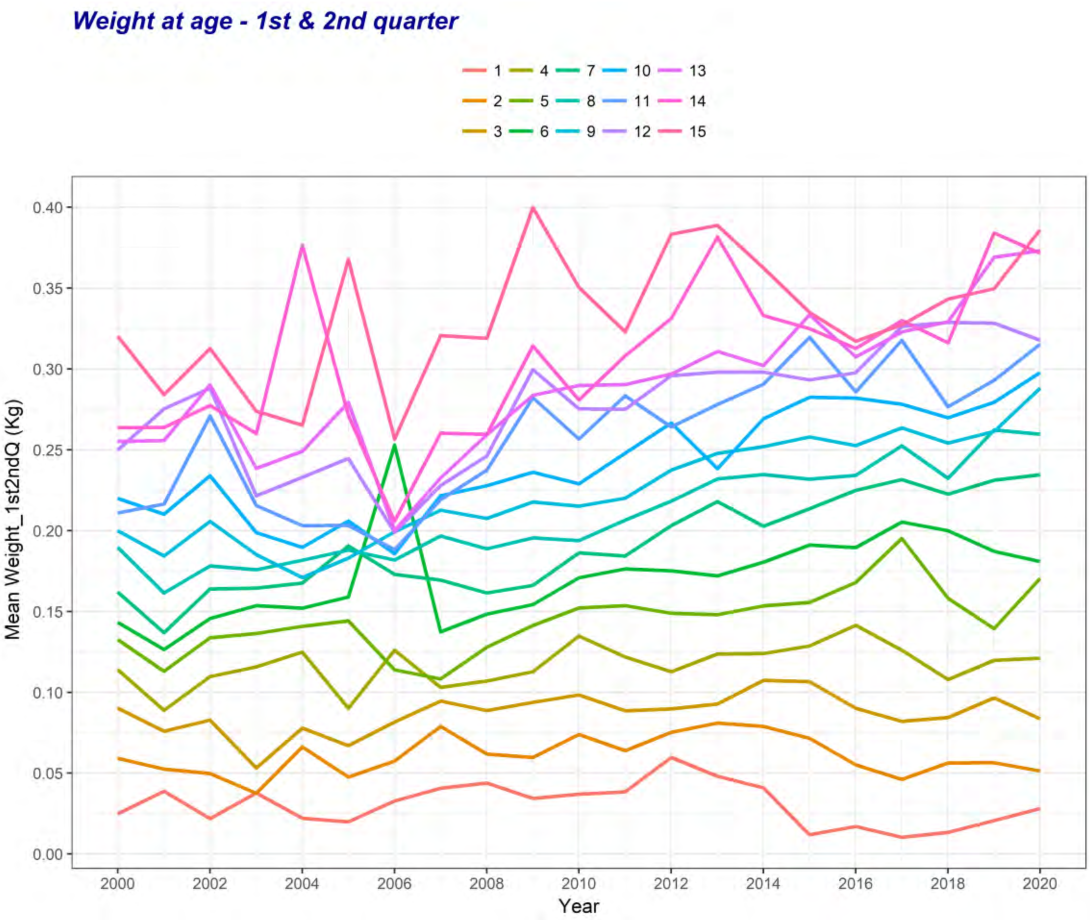


Figure 7.2.5.1: Western horse mackerel. Weight at age in the catch (kg) by year.

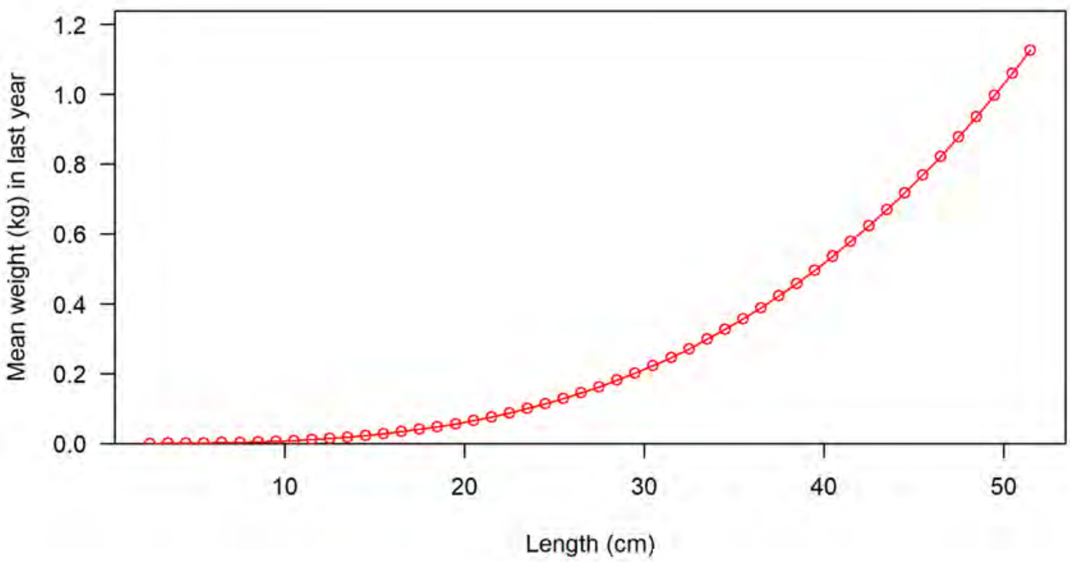


Figure 7.2.5.2: Western horse mackerel. Weight at length in the stock (kg) as estimated by the stock assessment.

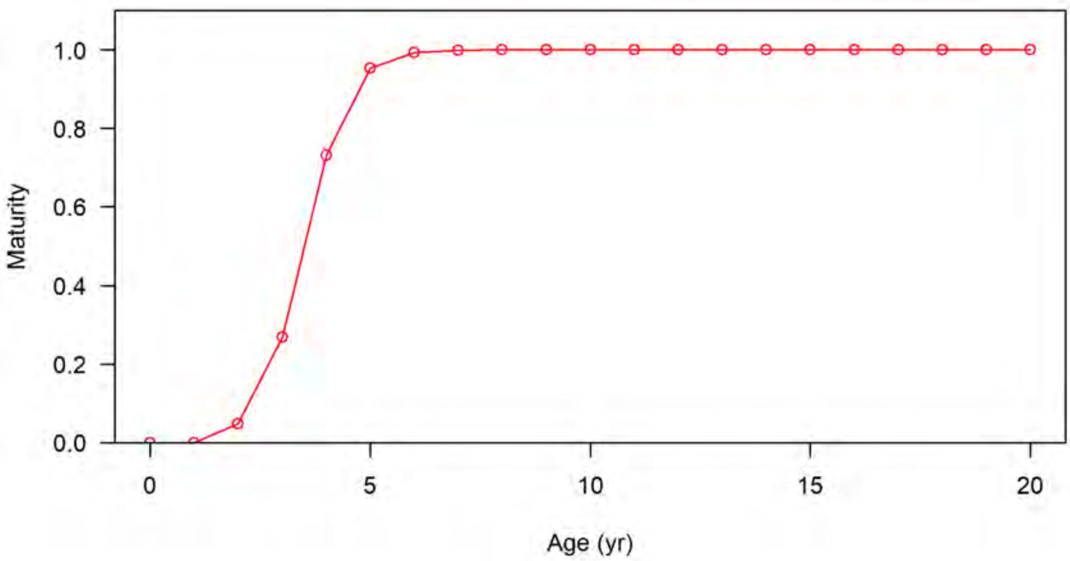


Figure 7.2.6.1: Western horse mackerel. Maturity at age as used in the assessment model.

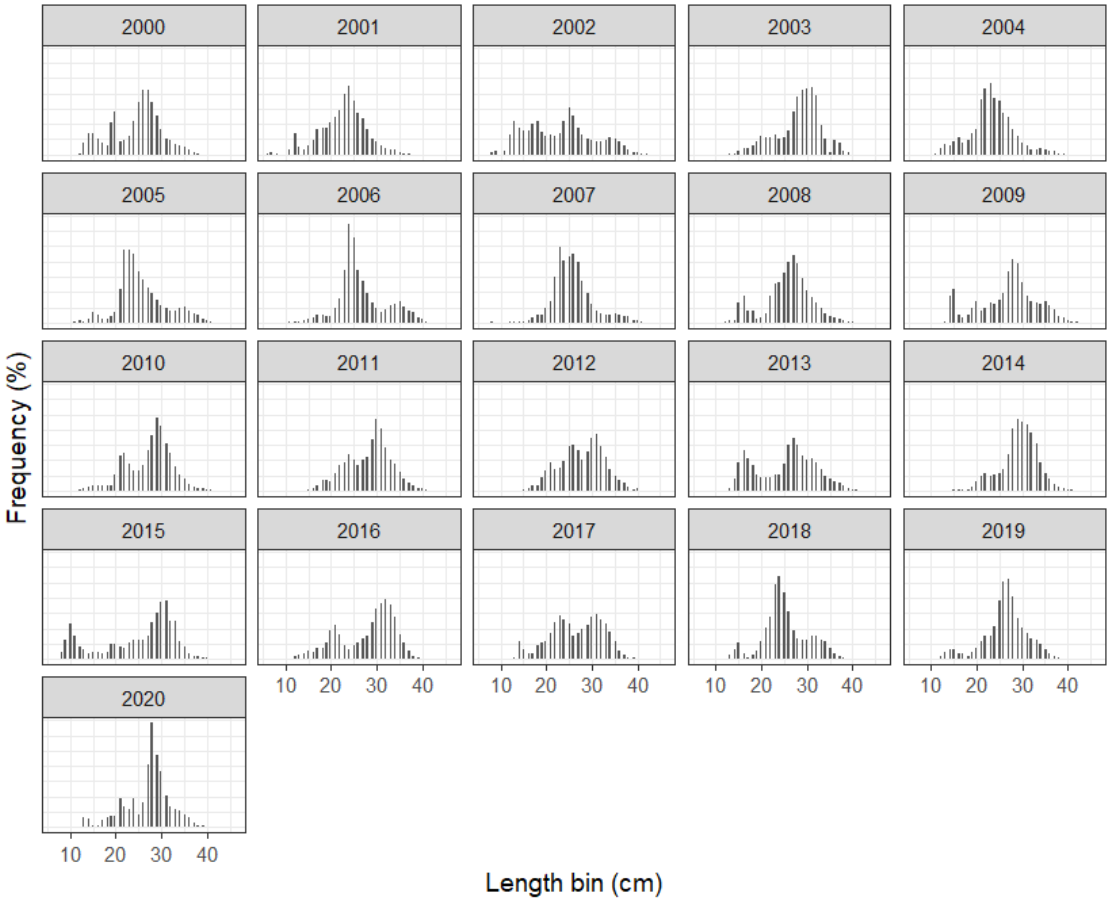


Figure 7.2.10.1: Western horse mackerel. Length frequency distribution of the landing data as used in the assessment model.

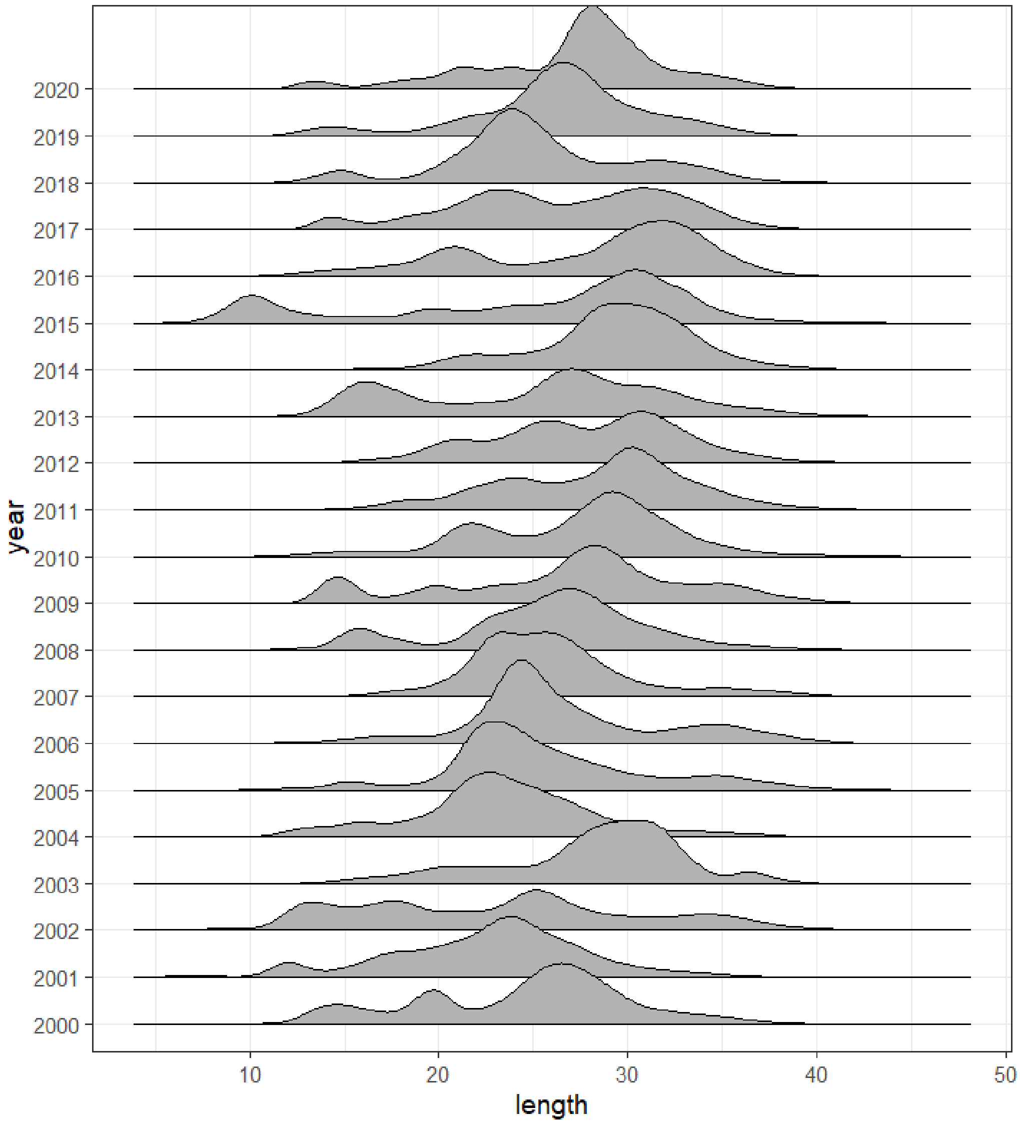


Figure 7.2.10.2: Western horse mackerel. Stacked length frequency distribution of the landing data as used in the assessment model.

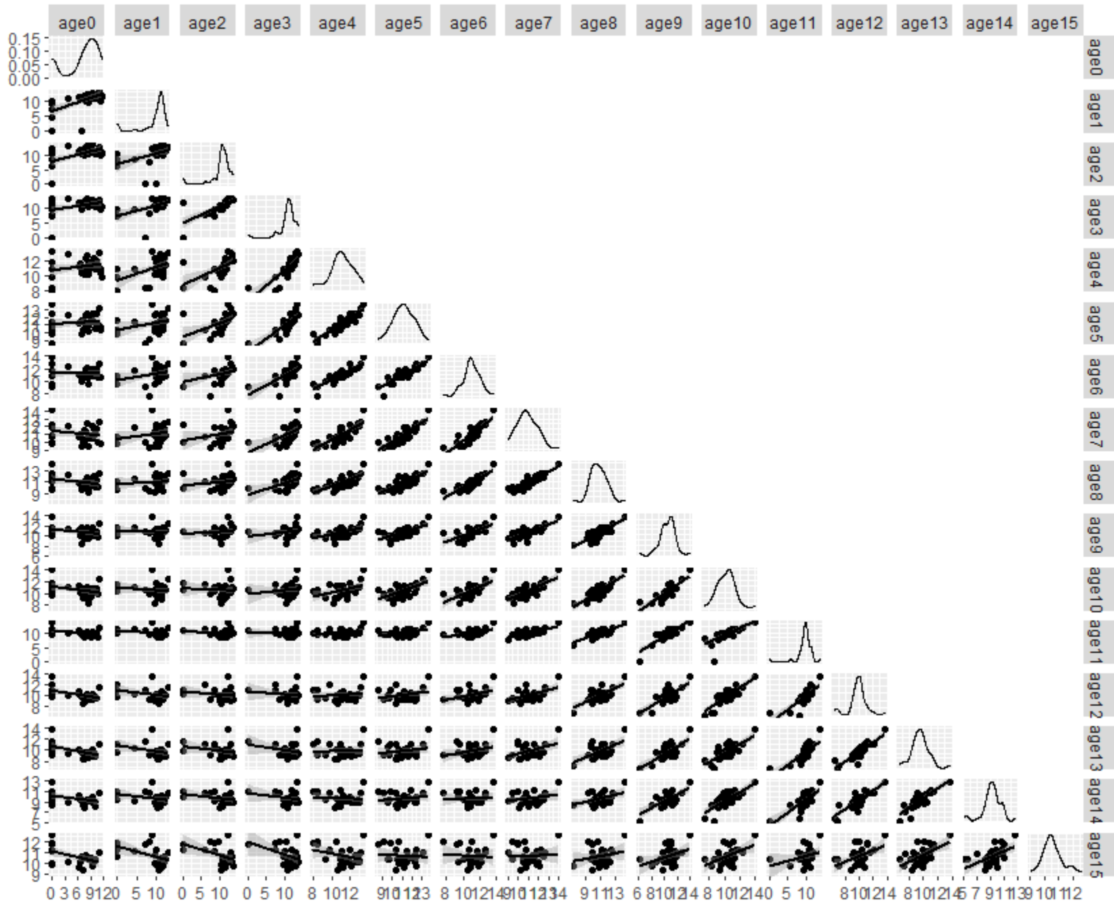


Figure 7.2.10.3: Western horse mackerel. Within-cohort consistency in the catch-at-age matrix, shown by plotting the log-catch of a cohort at a particular age against the log-catch of the same cohort at subsequent ages.

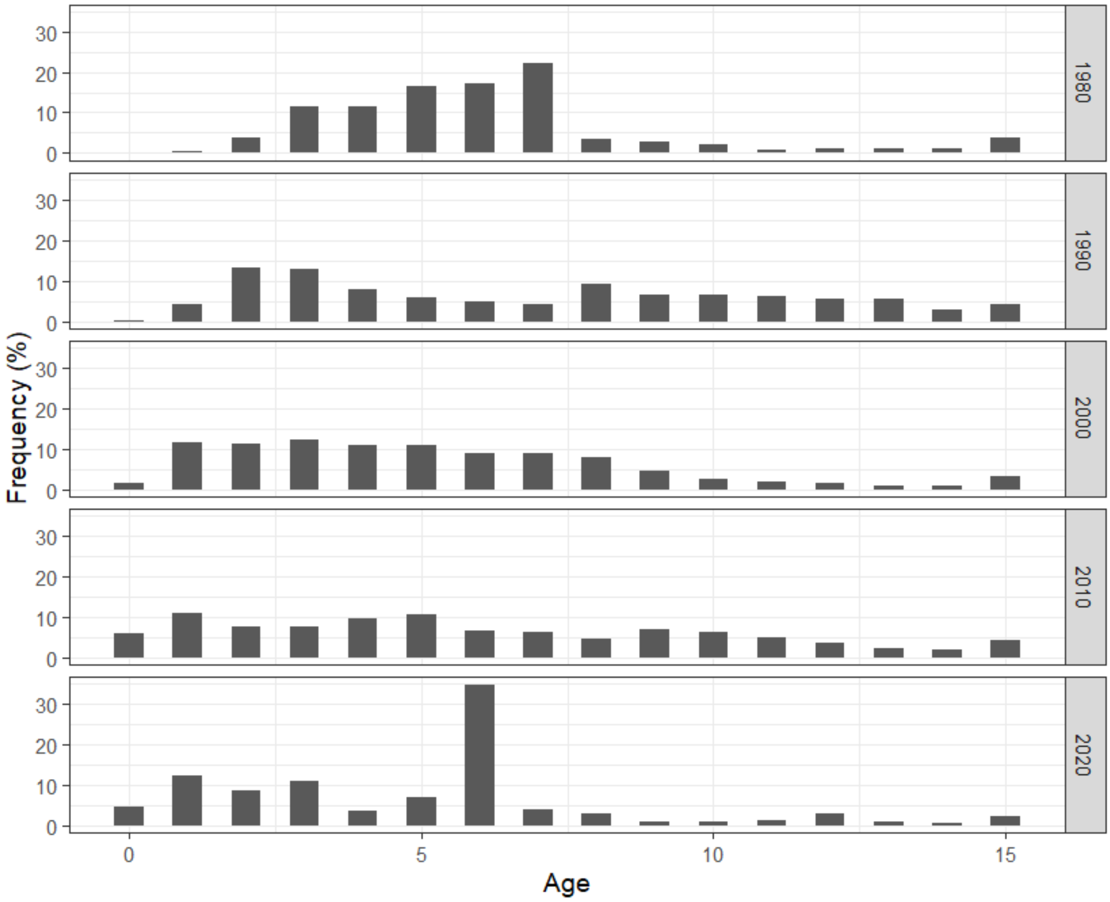
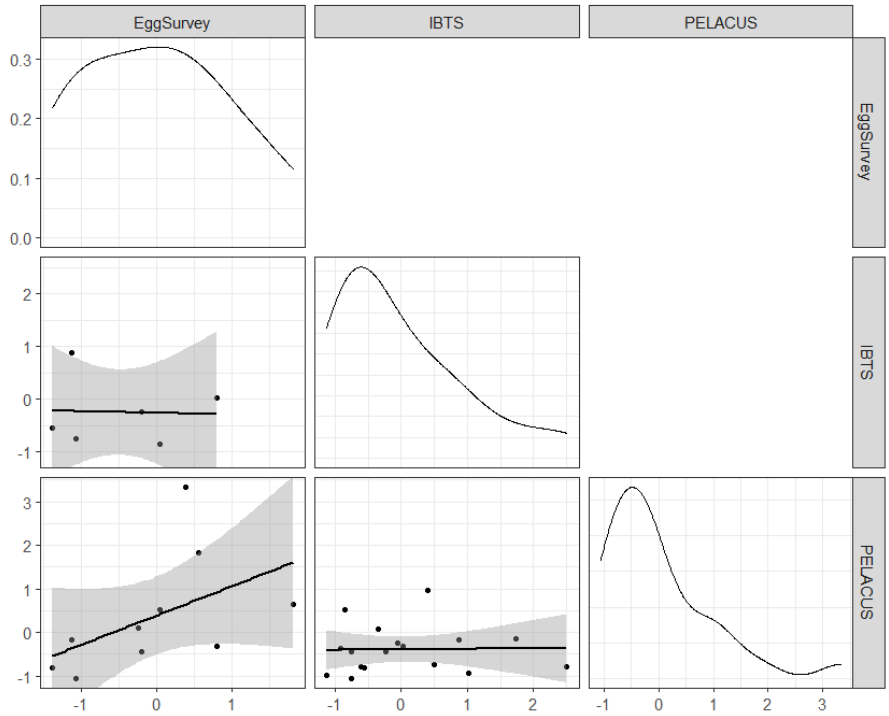


Figure 7.2.10.4: Western horse mackerel. Catch numbers at age composition by decade.



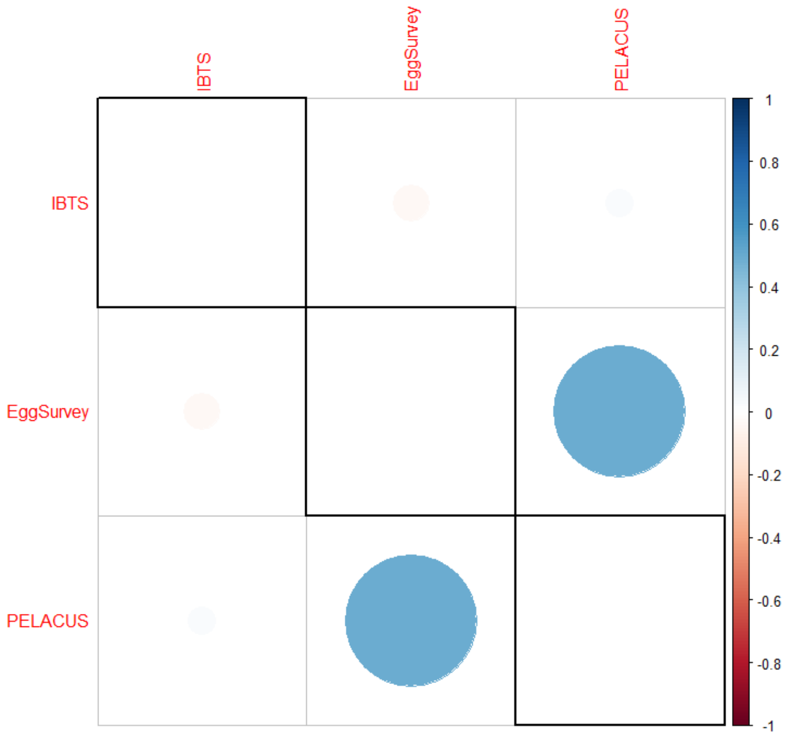


Figure 7.2.10.5: Western horse mackerel. Data exploration. Correlation plots between indices of abundance (including 2020 data points).

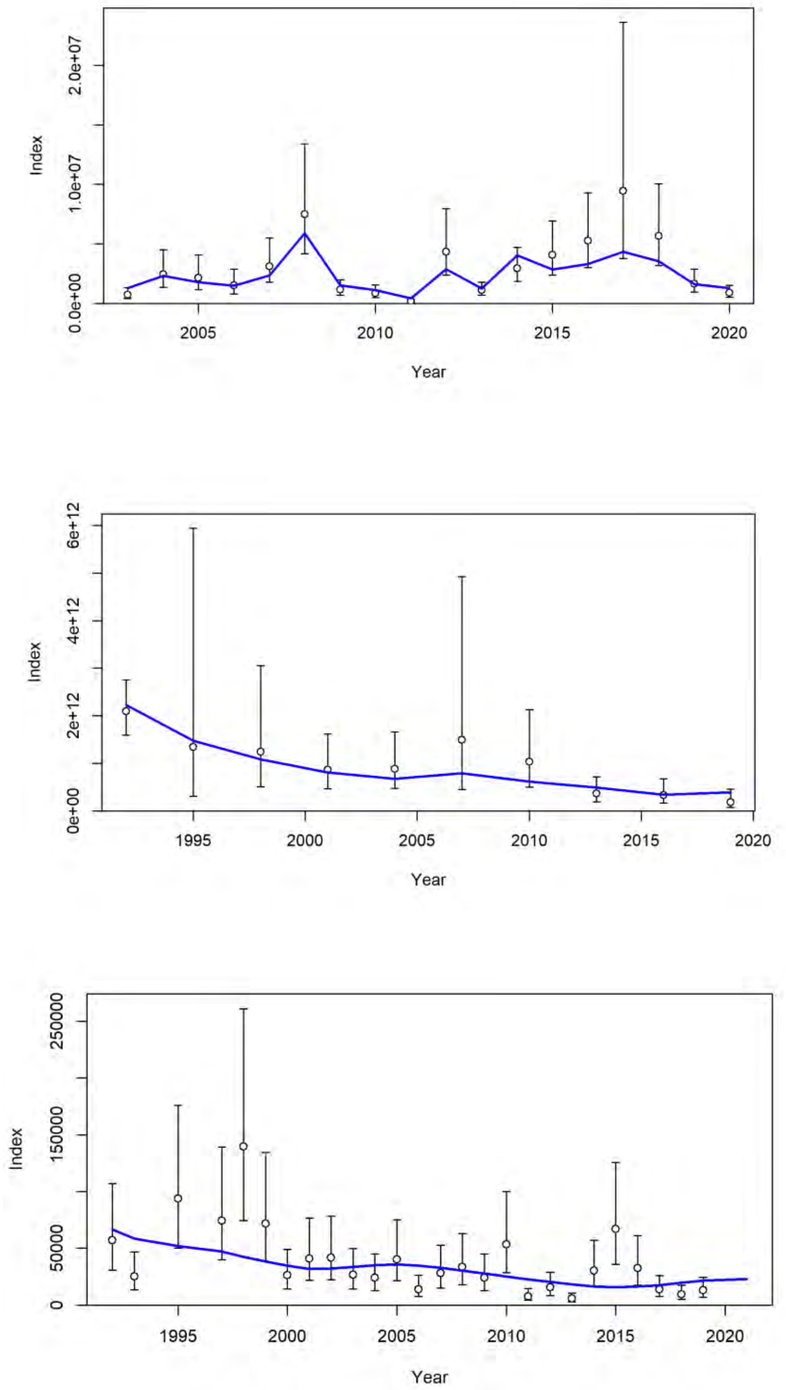


Figure 7.2.11.1: Western horse mackerel. Model fitting. Fitting of the model to the fisheries-independent indices. From top to bottom: IBTS, egg survey, PELACUS.

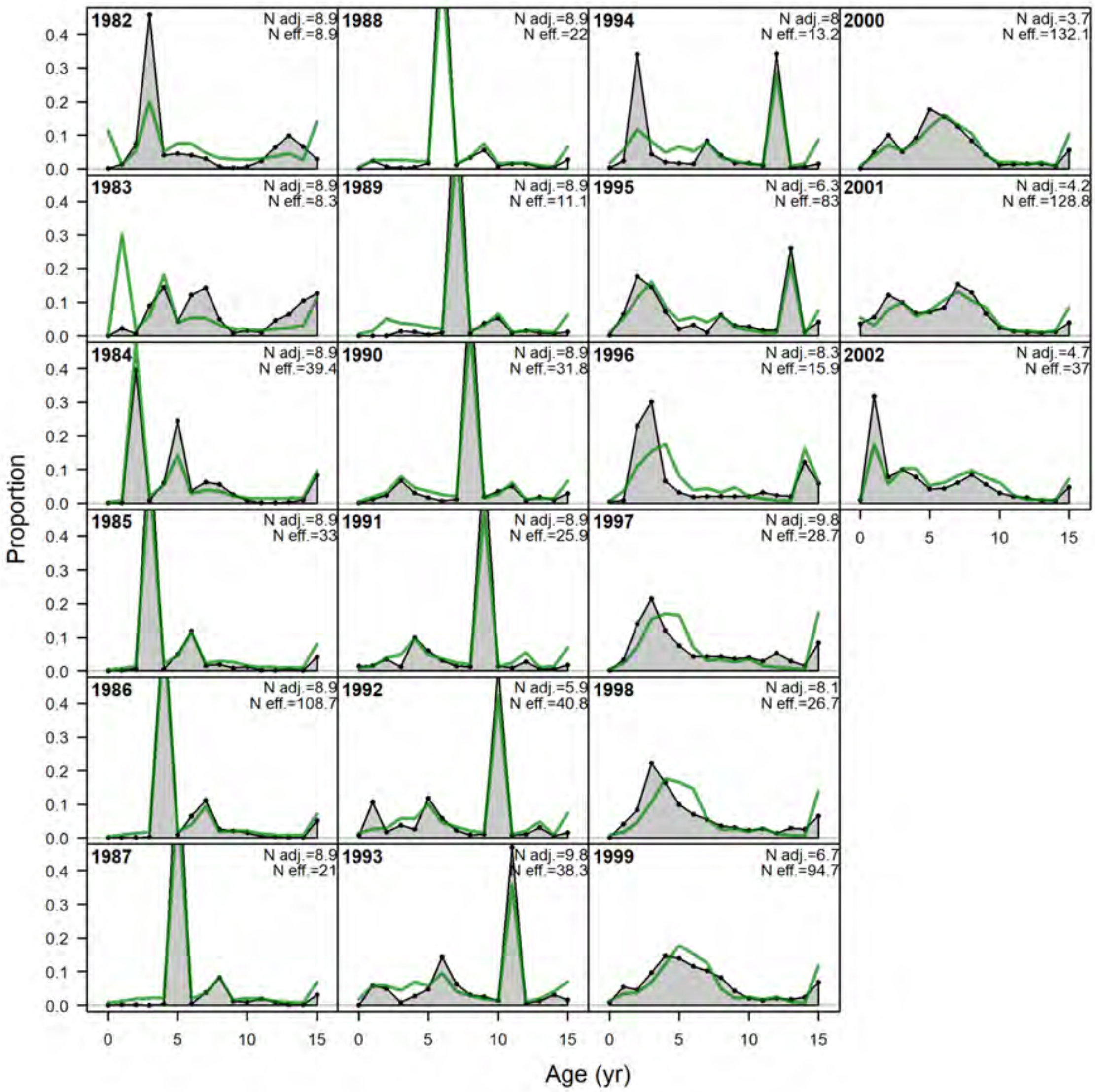


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the catch at age matrix from 1982 to 2002.

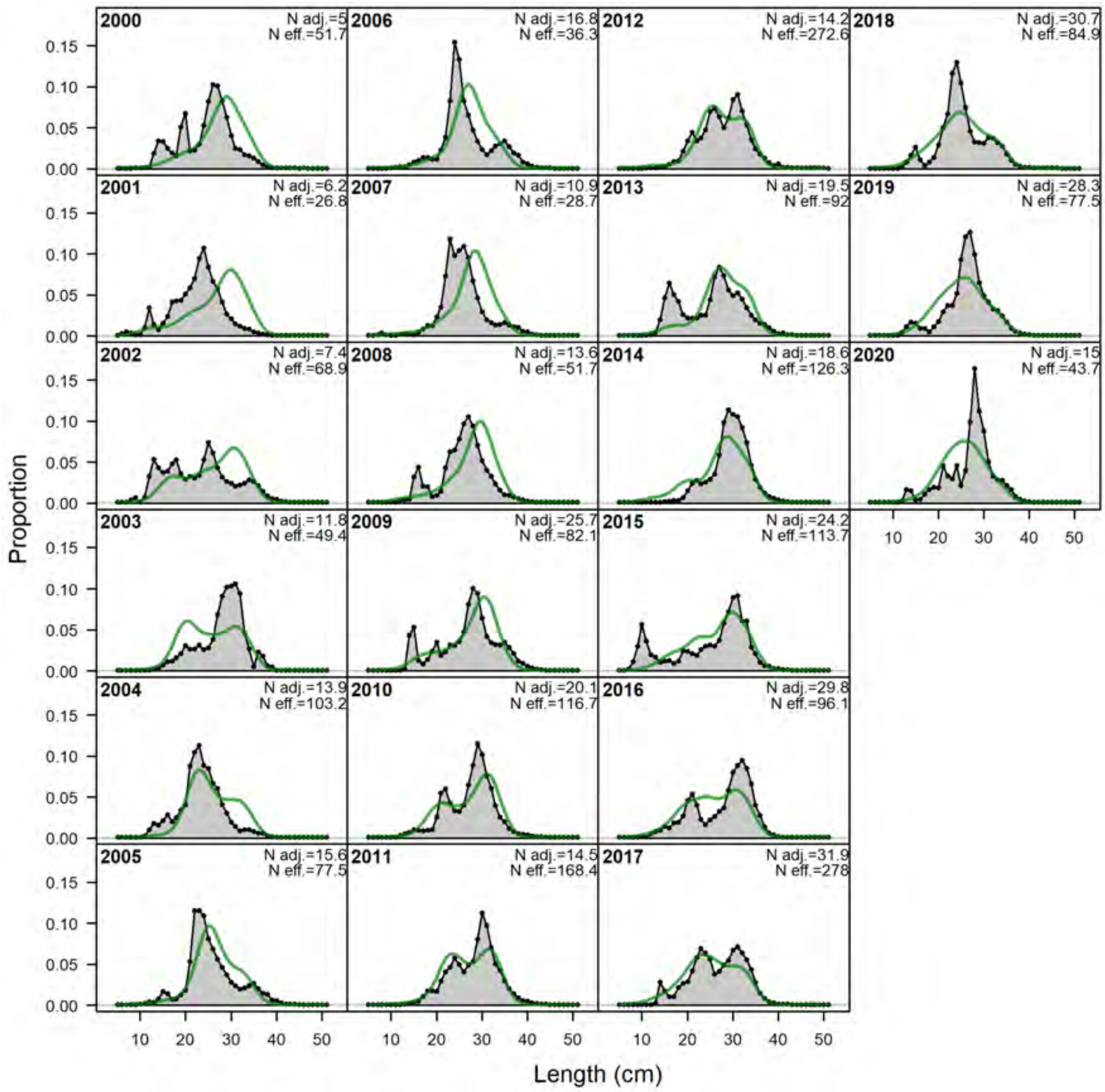


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the length composition of the landing data from 2002 to 2020.

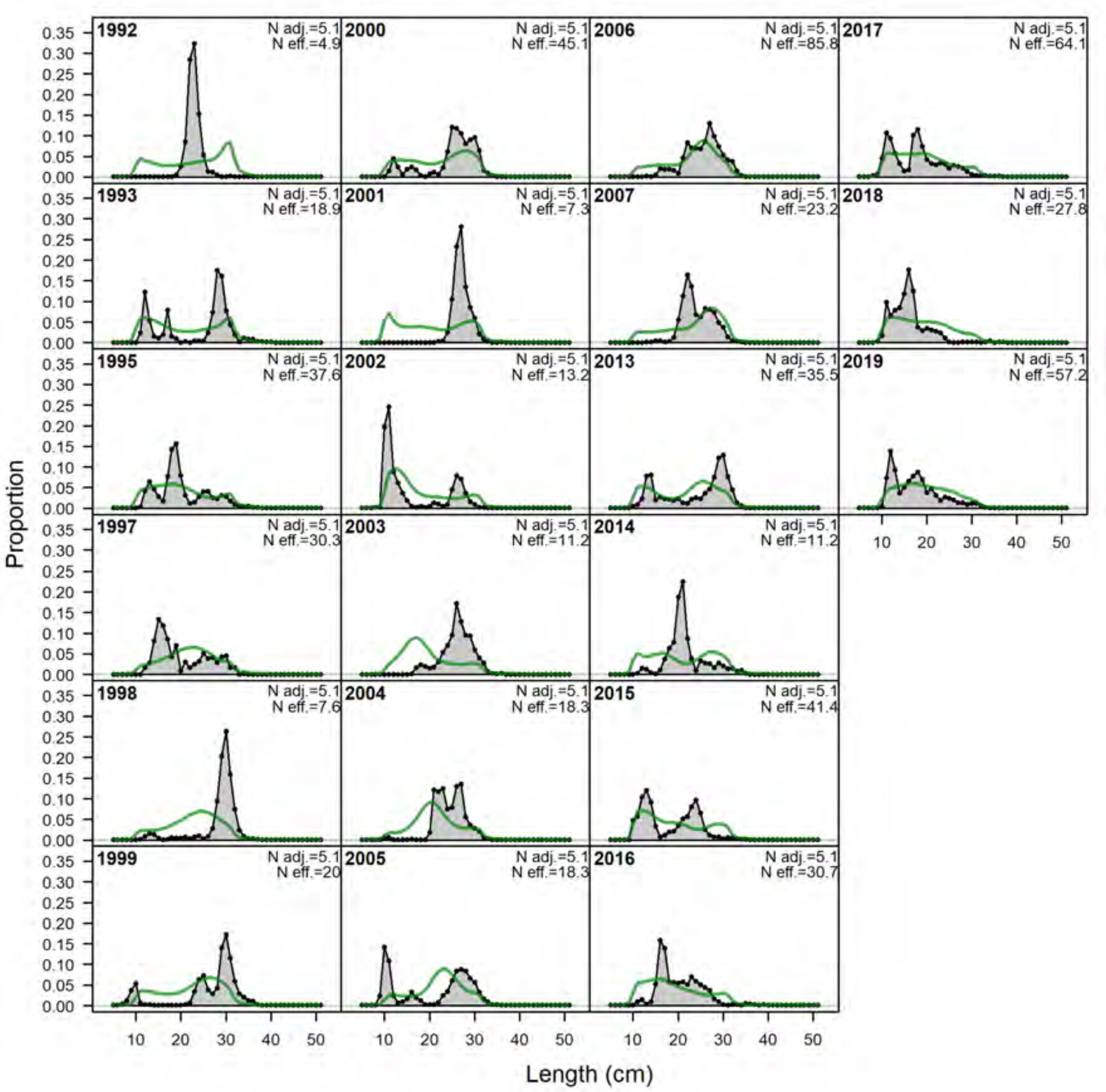
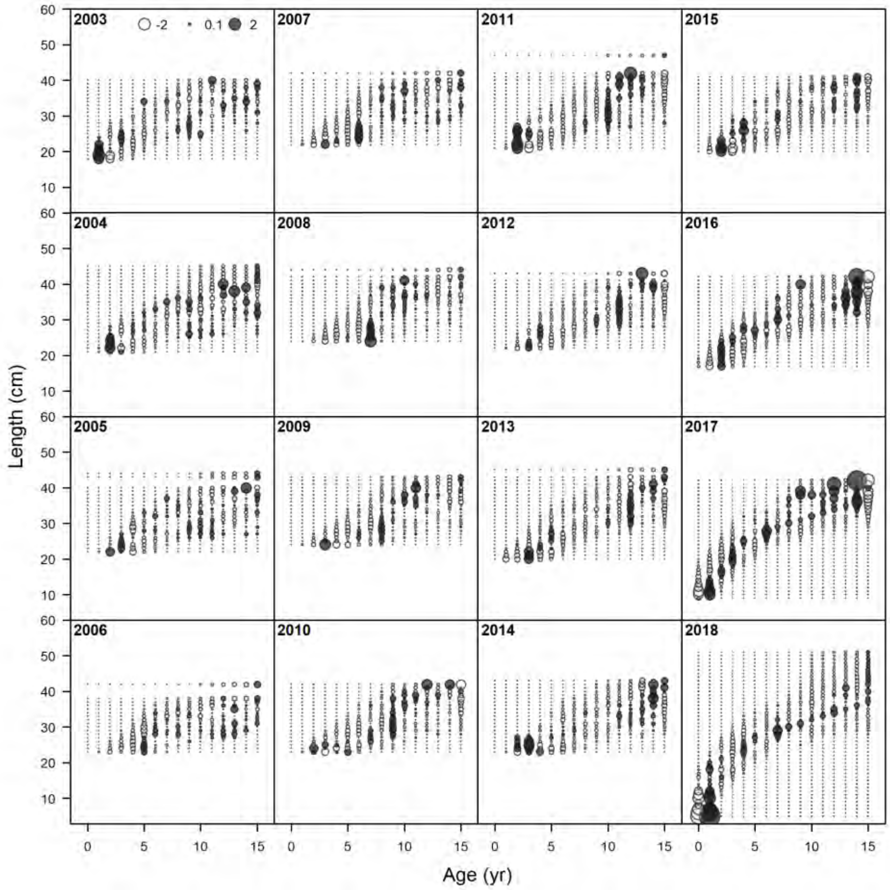


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the length composition of the acoustic survey.



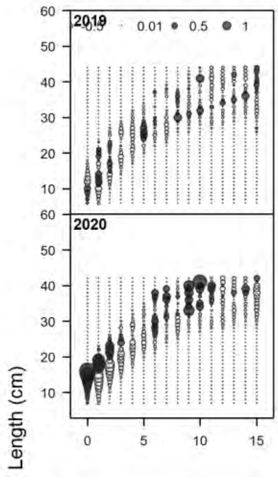


Figure 7.2.11.1 cont.: Western horse mackerel. Model fitting. Fitting of the model to the Age length comp of the catch.

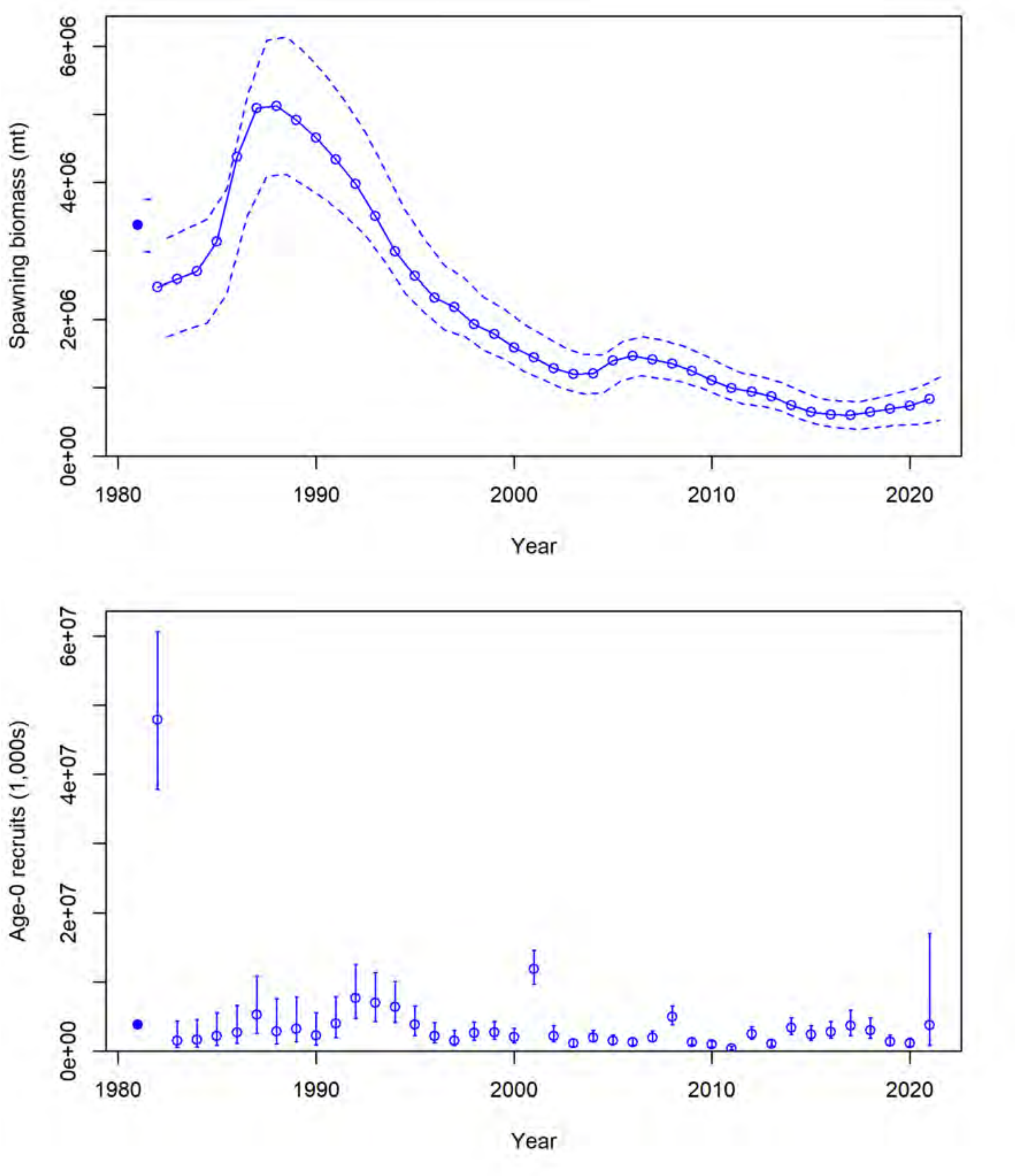


Figure 7.2.11.2: Western horse mackerel. Model results. Spawning stock biomass (0.5 of the overall SSB only is shown; plot on the top) and recruitment estimates (plot on the bottom) from the assessment model from 1982 to 2021. 95% CI are shown.

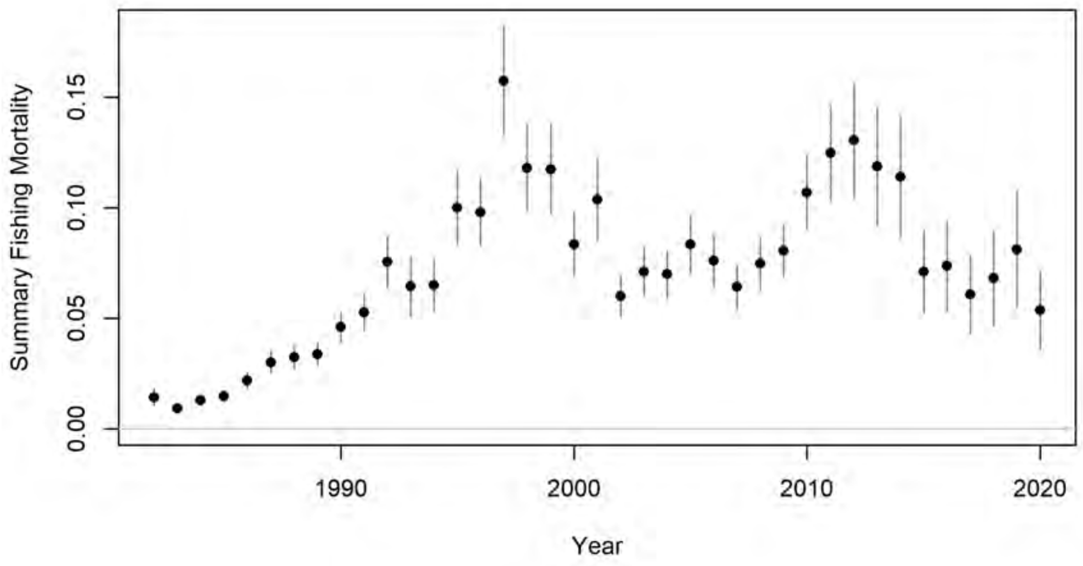


Figure 7.2.11.2 cont.: Western horse mackerel. Model results. Fishing mortality estimates (Fbar ages 1–10) from the assessment model from 1982 to 2020. 95% CI are shown.

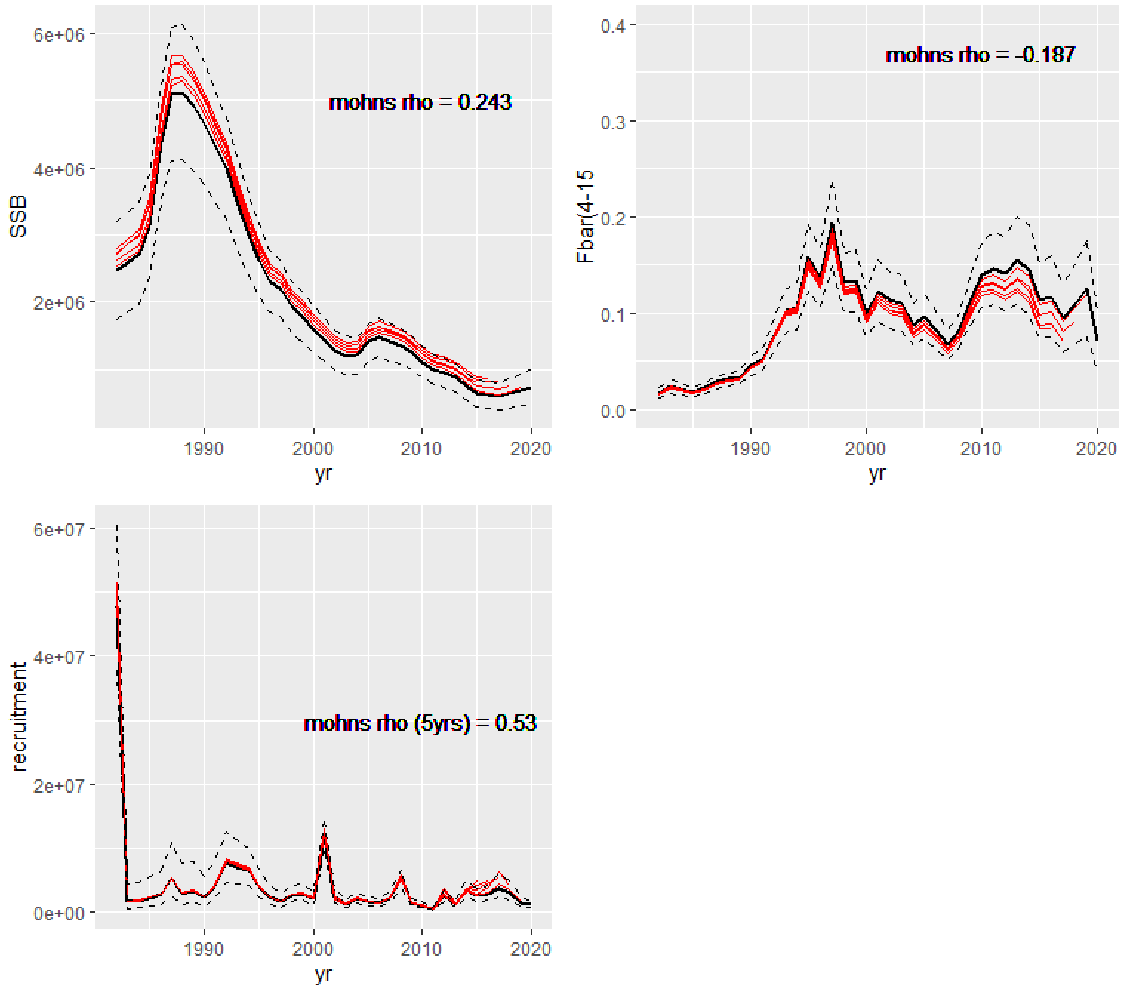


Figure 7.2.11.3: Western horse mackerel. Retrospective analysis. 5 years of retrospective analysis for SSB, F and Recruitment, and F. Dash lines are the 2021 assessment confidence intervals.

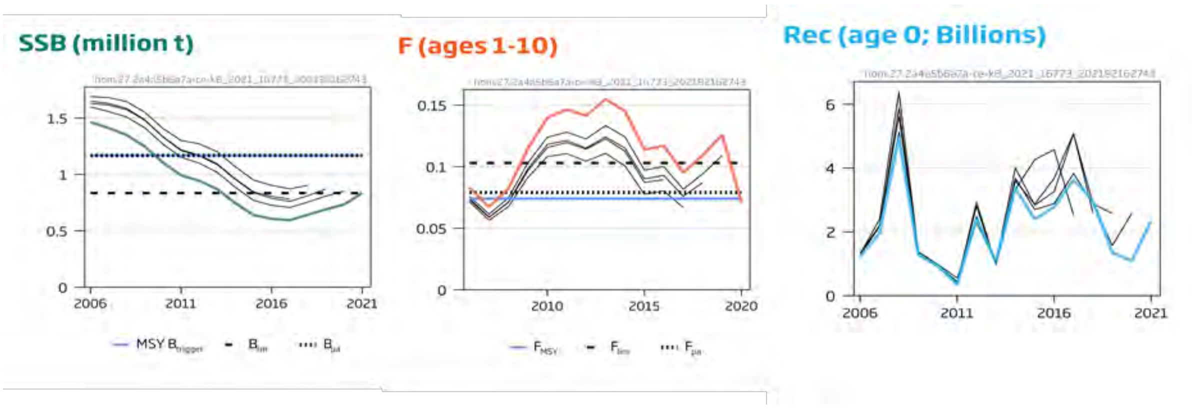


Figure 7.2.11.4: Western horse mackerel. Model results. Historical assessment results. Note: since the 2017 assessment, SSB is estimated on 1st of January. Prior to 2017 SSB has been estimated in May (spawning time).

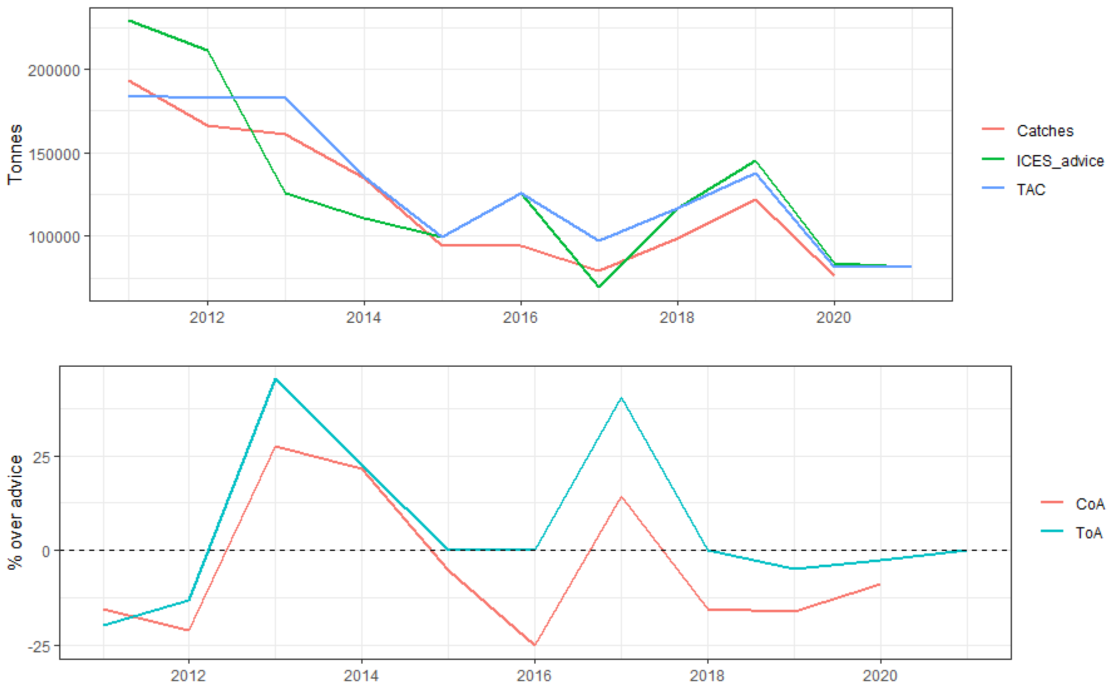


Figure 7.10.1. Western horse mackerel. Top: comparison of (max) scientific advice, TAC (or sum of unilateral quota) and Total Catch. Bottom: percentage deviation from ICES advice, CoA is Catch over Advice, ToA is TAC over Advice.

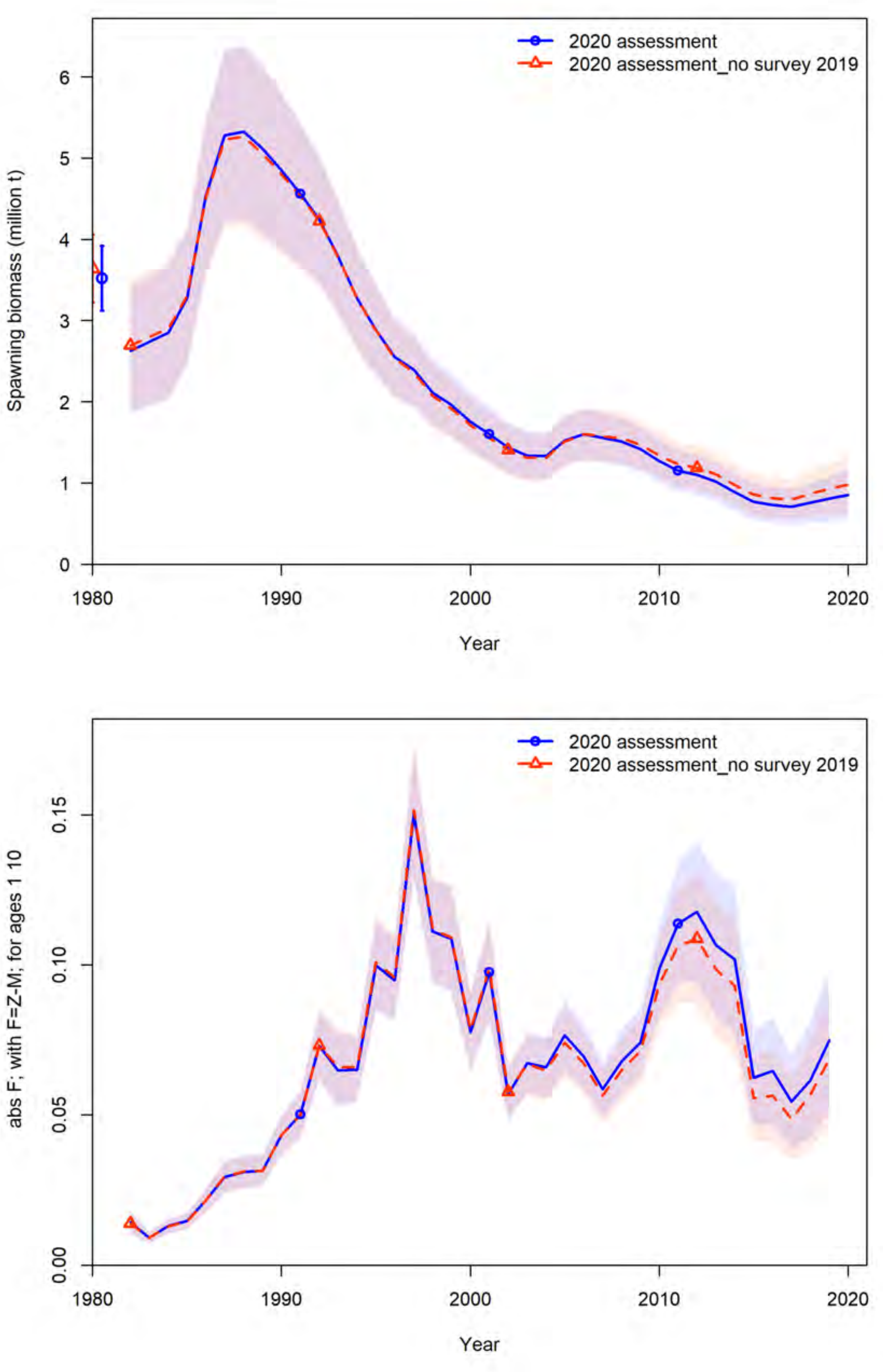


Figure 7.13.1. Sensitivity of the model to the PELACUS data. Spawning biomass and fishing mortality (ages 1–10) as estimated in the model conducted in 2020 (in blue) and in a model with the same setup but excluding the PELACUS data for 2019 (in red).

8 Northeast Atlantic Mackerel

8.1 ICES Advice and International Management Applicable to 2020

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. No agreement on the share of the stock has been reached after Brexit for 2021. Despite various agreements, the total declared quotas in each of the years 2015 to 2020 all exceeded the TAC advised by ICES. An overview of the declared quotas and transfers for 2021, as available to WGWIDE, is given in the text table below. Total removals of mackerel are expected to be approximately 1.2 million tonnes in 2021, exceeding the ICES advice for 2021 by about 347 000 t (41%).

Estimation of 2021 catch	Tonnes	Reference
EU quota	200 179	NEAFC HOD 21/22
UK quota	222 288	Department for Environment Food & Rural Affairs (UK). April 2021
Norwegian quota	298 299	NEAFC HOD 21/22
Inter-annual quota transfer 2020->2021 (NO)	-10 210	NEAFC HOD 21/22
Russian quota	120 423	NEAFC HOD 21/22
Discards	9 280	Previous years estimate
Icelandic expected catch	120 000	WGWIDE
Faroese quota	167 048	Faroese Fisheries Ministry regulations No. 85 and 115/2021
Inter-annual quota transfer 2020->2021 (FO)	33 796	Faroese Fisheries Ministry regulations No. 85 and 115/2021
Greenland expected catch	38 000	Ministry of Fisheries, Hunting and Agriculture in Greenland
Total expected catch (incl. discards) [1,2]	1 199 103	

[1] No estimates of banking from 2020 to 2021.

[2] Quotas refer to claims by each party for 2021 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 2020

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. Russian freezer trawlers fish for mackerel during the summer (June-September) in the Norwegian Sea in Division 2.a, mainly inside the NEAFC regulatory area. Part of the Icelandic fishery is 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 2020

The northern summer fishery in Subareas 2 and 5 continued in 2020. There was no fishery in Subarea 14. 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 2020 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 quarter 3 of 2020, with catch also taken in 5.a in waters to the south, east and west of Iceland. In 2020 Greenland targeted mackerel in Division 2.a with no catch taken from 14.b. In 2019 Greenland fished in 14.b and in 2018 both Greenland and Iceland reported landings from this area. Catches from Greenland have decreased again in 2020 to 27 kt, down from 30 kt in 2019 and almost 63 kt in 2018. The Faroese fleet targeted mackerel during late summer and early autumn with nearly half of the catches taken in 2.a and 4.a. The remaining catch was taken in quarter 1 mainly in 4.a and some in 6.a.

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 majority of the Irish mackerel fishery took place in quarter 1 along the west coast of Scotland and Ireland, with the Scottish fleet operating in the same area at this time. The Scottish fishery in quarter 4 was more concentrated in the North Sea.

In 2020 the Spanish fishery 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. In 2020 the northern summer fishery did not extend as far west as in previous years.

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 159 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 2020 the catch reported from Greenland was mainly from Division 2.a.

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 2020 no overarching Coastal States Agreement/NEAFC Agreement was in place and no overall international regulation on catch limitation was in force. 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). Currently there is no agreement on a management strategy covering all parties fishing mackerel.

Management aimed at a fishing mortality in the range of 0.15—0.20 in the period 1998—2008. In 2008 the Coastal states agreed a long term management plan which aimed 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. The last agreed management plan was in 2017 (ICES, 2017a). During the Coastal States' negotiations in 2019 for 2020, it was recognised that the F and B were outdated after the recent MSE on mackerel (ICES, 2019). Therefore, the Coastal States used F_{MSY} as reference F in setting their TAC for 2020. At the same time, they requested ICES to evaluate a new management plan for mackerel, which was finally evaluated by ICES in 2020. However, the Coastal States have not considered the response from ICES yet. 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, 2017) 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

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
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	877272	91	1241	124695	29462
2011	948963	88	923	97818	22817
2012	899551	89	1216	135610	38365
2013	938299	89	1092	115870	25178
2014	1401788	90	1506	117250	43475
2015	1215827	88	2132	137871	24283
2016	1100135	89	2200	149216	21456
2017	1159641	87	2183	151548	24104
2018	1023144	83	1858	139590	20703
2019	839727	88	1835	141561	17646
2020	1039513	87	1430	142991	15685

Overall sampling effort in 2020 was similar to previous years with 87 % 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 2020 sampling levels by country are shown below.

Country	Official catch	% WG catch covered by sampling programme	No. Samples	No. Measured	No. Aged
Belgium	124	0 %			
Denmark	38589	90 %	14	1515	967
Faroe Islands	69064	98 %	12	726	625
France	21936	0 %			
Germany	25030	65 %	88	15351	716
Greenland	26577	100 %	42	1998	88
Iceland	151534	99 %	112	4895	2755
Ireland	74232	99 %	47	8937	2061
Lithuania	815	0 %			
Netherlands	30321	62 %	35	2633	861
Norway	211672	96 %	65	2280	1776
Poland	5302	0 %			
Portugal	4799	12 %	101	2525	988
Russia	128817	100 %	201	64339	1349
Spain	34613	99 %	622	30510	2223
Sweden	3672	0 %			
UK (England & Wales)	30430	1 %	54	3165	227
UK (Northern Ireland)	14855	34 %	1	166	49
UK (Scotland)	167131	89 %	36	3951	1000

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, Lithuania and Poland did not supply sampling information in 2020. 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 65 % and 62 % 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
1	11	11	0	0	0
2.a	310223	310223	318	69611	3424
3.a	567	567	0	0	0
3.b	16	16	0	0	0
3.c	4	4	0	0	0
3.d	19	19	0	0	0
4.a	450720	450720	228	26072	5480
4.b	5024	5024	0	0	0
4.c	861	861	0	0	0
5.a	44867	44867	44	1979	1074
5.b	1879	1879	0	0	0
6.a	130903	130903	40	6206	1355
6.b	15	15	0	0	0
7.a	5	5	0	0	0
7.b	20281	20281	15	2261	622
7.c	191	191	1	51	25
7.d	5637	5637	0	0	0
7.e	8652	8652	55	3278	252
7.f	260	260	0	0	0
7.g	37	37	0	0	0
7.h	7	7	0	0	0
7.j	13629	13629	5	383	135
7.k	1	1	0	0	0
8.a	2688	2688	0	0	0
8.b	4727	4727	185	5150	389
8.c	24128	24128	47	428	639
8.c.E	11328	11328	316	24466	704

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
8.d	754	754	0	0	0
9.a	2070	2070	176	3106	1586
9.b	2	2	0	0	0
12.c	6	6	0	0	0

In general, areas with insufficient sampling have relatively low levels of catch.

8.4 Catch Data

8.4.1 ICES Catch Estimates

In 2021 the catch data time series was revised due to additional catch data reported from Division 8.c and the removal of logbook discard data from the working group catch. The led to new working group catch figures as well as a revised catch numbers at age and mean weights at age time series from 2010-2019.

The additional catch in Division 8.c was unsampled. Division 8.c was well sampled by other countries and these samples were allocated to the unsampled catch. For most years and ages, the differences between the previous and the revised catch numbers at age is less than 1 %. For the years and ages when the difference is higher this is due to the proportions at age in the sampled catch.

The logbook discard data reported in 2018 and 2019 were submitted from countries that also submitted discard data from observer programmes. It is not known if logbook registered discards are consistently recorded because the reporting of this data is not mandatory and there is a possibility of double counting. It was therefore decided to remove the logbook registered discards and only use the estimates from observer programme. Again, the differences in the previous estimates and the revised estimates was very small. The highest difference was for ages 0 and 1 in 2018 and this was because of the proportions at age in the discard samples that were used in allocations.

The total ICES estimated catch for 2020 was 1 039 513 an increase of 199 786 t on the estimated catch in 2019. Catches increased substantially from 2006—2010 and have averaged 1 040 kt since 2011.

The combined 2020 TAC, arising from agreements and autonomous quotas, amounts to 1 090 879 t. The ICES catch estimate (1 039 513 t) represents an undershoot of this but is still above the ICES advice of 992 064 t. The combined fishable TAC for 2021, as best ascertained by the Working Group (see Section 8.1), amounts to 1 199 103 t.

Catches reported for 2020 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 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.

- 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 2020, discard data for mackerel were provided by France, Ireland, Spain, Portugal, Denmark, England, Scotland and Sweden. Total discards amounted to 9 280 t which is an increase from 2019. Higher discards were reported by UK England and Wales mainly from one fleet. 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 in 2020 due to reduced sampling opportunities as a result of COVID but data available indicates that, in Division 8.b the majority of discarded fish were aged 0 to 3. In Divisions 8.c and 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 2020, Norway accounted for the greatest proportion (20 %) followed by Scotland (16 %), Iceland (15 %), Russia (12 %), Ireland (7 %) and Faroes (7 %). In the absence of an international agreement, Greenland, Iceland and Russia declared unilateral quotas in 2020. Russia and Iceland both had catches over 100 kt with Faroes catching 69 kt. Greenlandic catches decreased again from 30 kt to 27 kt. Scotland had catch in excess of 100 kt and Ireland caught 74 kt. Denmark had catches of around 35 kt. The Netherlands and Spain caught around 30 and 34 kt, respectively while UK England had increased catches in 2020 to 30 kt. German catch also increased to 25 kt. France had catches of the order of 22 kt.

In 2020, catches in the northern areas (Subareas 1, 2, 5, 14) amounted to 356 985 t (see Table 8.4.2.1), an increase of 11 966 t on the 2019 catch. Icelandic, Norwegian and Russian catches were all over 100 kt. Catches from Division 2.a accounted for 30 % of the total catch in 2020, similar to 2019. Almost all the Russian catch in 2020 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 2020 amounted to 457 211 t and represents a significant increase of 149 164 t from the 2019 catch figure (308 047 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) increased in 2020 to 187 788 t. This is an increase of around 26 000 t from 2019. 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 37 529 t represents an increase of almost 13 000 t from 2019. The catch is above the long-term average.

The distribution of catches by quarter (%) is described in the text table below:

Year	Q1	Q2	Q3	Q4
1990	28	6	26	40
1991	38	5	25	32
1992	34	5	24	37
1993	29	7	25	39
1994	32	6	28	34
1995	37	8	27	28
1996	37	8	32	23
1997	34	11	33	22
1998	38	12	24	27
1999	36	9	28	27
2000	41	4	21	33
2001	40	6	23	30
2002	37	5	29	28
2003	36	5	22	37
2004	37	6	28	29
2005	46	6	25	23
2006	41	5	18	36
2007	34	5	21	40
2008	34	4	35	27
2009	38	11	31	20

Year	Q1	Q2	Q3	Q4
2010	26	5	54	15
2011	22	7	54	17
2012	22	6	48	24
2013	19	5	52	24
2014	20	4	46	30
2015	20	5	44	31
2016	23	4	44	29
2017	24	3	45	28
2018	20	3	40	37
2019	28	5	42	26
2020	31	4	34	31

The quarterly distribution of catch from 2010- 2019 is similar to recent years with the northern summer fishery in Q3 accounting for the greatest proportion of the total catch. In 2020 the proportion in quarter 3 is still the highest at 34 % but is similar to the quarter 1 and quarter 4 catches which both account for 31 % of the total.

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 2020 (322 419 t – 31 %)

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 2020 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 again in 2020. The Spanish fisheries also take significant catches along the north coast of Spain during the first quarter.

- Second quarter 2020 (43 011 t – 4 %)

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 2020. 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 in Division 2.a.

- Third quarter 2020 (356 006 t – 34 %)

Figure 8.4.2.3 shows the distribution of the quarter 3 catches. Large catches were taken throughout Divisions 2.a (Russian, Norwegian and Faroese vessels), 4.a (Norwegian, Scottish vessels), 5.a (Icelandic vessels).

- Fourth quarter 2020 (318 077 t – 31 %)

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 increased from 26 % in 2019 to 31 % in 2020. 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.

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

This catch in numbers relates to a total ICES estimated catch of 1 039 513 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, Lithuania 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 catch numbers at age show a number of strong year classes in this fishery. Over 80 % of the catch in numbers in 2020 consists of 3 to 10-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 2020 and accounts for 11 % of the catch numbers at age. The 2015 year-class does not look as strong as the other year and represents 5 % of the total. In 2020 there is an increase in the proportion of fish in the plus group. Fish at 12+ represent 7 % of the total which is an increase from 3 % in 2019.

There is a small presence of juvenile (age 0) fish within the 2020 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 for 2020 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 2020 for 0 group mackerel (177 mm – 266 mm) is similar to 2019 (172 mm-267 mm) and 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 between northern and southern areas 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).

8.5.2 Weights at Age in the Catch and Stock

The mean weight-at-age in the catch for 2020 are given in Table 8.7.1.3. 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 2020 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 2020 were calculated from samples of the commercial catches collected from Divisions 4.a and 4.b in the second quarter of 2020. 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 2020 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 7 years do not show any specific trend (except for weights of ages 2 to 5 which have been increasing, Figure 8.5.2.2).

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel 2020 Weighted mean*
0				0.000
1	0.128			0.068
2	0.248	0.204	0.213	0.210
3	0.284	0.230	0.306	0.252
4	0.353	0.266	0.334	0.289
5	0.346	0.347	0.352	0.348
6	0.380	0.360	0.365	0.363
7	0.365	0.376	0.377	0.375
8	0.424	0.389	0.400	0.394
9	0.431	0.394	0.406	0.400

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel 2020 Weighted mean*
10	0.454	0.416	0.433	0.423
11	0.468	0.454	0.412	0.445
12+	0.482	0.481		0.486
Component Weighting	8.5 %	67.9 %	23.6 %	
Number of fish sampled	206	856	1897	

*** Missing value of mean weight-at-age per component are replaced by component mean value in the calculation of the stock weights**

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 2020 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 2020 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	0.000
1	0	0.129	0.02	0.092
2	0.37	0.385	0.54	0.420
3	1	0.971	0.70	0.909
4	1	0.997	1	0.998
5	1	1	1	1.000
6	1	0.999	1	0.999
7	1	0.999	1	0.999
8	1	1	1	1.000
9	1	1	1	1.000
10	1	1	1	1.000
11	1	1	1	1.000

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel
12+	1	1	1	1.000
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 2020 are now markedly lower than in the previous years and 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 Survey Planning for the 2022 Northeast Atlantic survey

The last mackerel egg survey (MEGS, I4189) was carried out in the NEA mackerel spawning areas in 2019 and a presentation with the final results were given during the WGWIDE meeting by the survey coordinator in 2020 (ICES, 2020a).

The ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) met in an online meeting in April 2021 to plan the international mackerel and horse mackerel egg survey in 2022. The nations participating in the 2022 MEGS survey will be Portugal, Spain, Scotland, Ireland, The Netherlands, Germany, Norway and the Faroe Islands.

In 2022, the MEGS survey in the western and southern areas for mackerel will continue as an Annual Egg Production Method (AEPM) survey; however, as with the surveys in 2013, 2016 and 2019, the intention will be to also carry out intensive Daily Egg Production Method (DEPM) adults sampling during the expected peak spawning period, in an attempt to calculate a DEPM SSB estimate.

WGMEGS considered a proposal to move the timing of the North Sea survey to the same year as the western surveys. If approved this survey would now be conducted by Denmark and England in 2022. Their participation would not lead to any reduction of available effort for the western surveys in 2022. This North Sea survey will be conducted as a DEPM survey (ICES, 2021).

The provisional survey plan of the 2022 mackerel and horse mackerel egg survey in the western and southern areas, as agreed during last the WGMEGS meeting (ICES, 2021), is presented in Table 8.6.1.1.1.

In preparation for the 2022 survey a workshop on Mackerel, Horse Mackerel and Hake Egg Identification and Staging (WKMACHIS) will take place during October 2021 and a Workshop on Adult Egg Production Methods Parameters estimation in mackerel and horse mackerel (WKAEPM) will be held in November 2021.

8.6.1.2 Changing from the Annual to Daily Egg Production Method.

From the start in 1977, WGMEGS has used the AEPM for estimation of NEA mackerel SSB (Lockwood *et al*. 1981; Lockwood, 1988) under the assumption that mackerel has a determinate fecundity. These surveys are carried out triennially.

The key concept for egg production method is very simple; if we know how many eggs have been spawned over a period of time (e.g., daily or annually) in the spawning area (egg production), and we know how many eggs an average individual mature female can produce over the same period (fecundity), then we can estimate the size of the spawning population (Bernal *et al.*, 2012).

There are two primary egg production methods (Gunderson, 1993; Hunter and Lo, 1993), namely the AEPM and the DEPM. The first method is designed for species with a determinate fecundity, i.e., those in which all the eggs to be spawned during the year are present and identifiable in the ovary immediately prior to spawning. With the AEPM, estimated total egg production is integrated over the whole annual spawning season and how many eggs are produced on average by female in the year (Costas *et al.*, WD04 in Annex 05). Whereas the application of AEPM is suitable for determinate annual spawners, the DEPM can in principle be applied to indeterminate and determinate spawners.

The AEPM requires several ichthyoplankton surveys covering the whole spawning season and spawning area to estimate total annual egg production and sampling of pre-spawning adults to estimate annual potential fecundity. (Armstrong *et al.*, 2012). Species with determinate fecundity have as an assumption that the fecundity is fixed before the onset of spawning (Hunter *et al.*, 1992).

The DEPM can be used for species with an indeterminate fecundity, in which the potential fecundity is not fixed before the onset of spawning (Stratoudakis *et al.*, 2006) and oocytes are recruited over the spawning season. The DEPM requires a single ichthyoplankton survey covering the entire spawning area during a brief period at or near the annual peak of spawning to estimate the mean daily egg production and to have representative samples of spawning adults during this survey period to estimate the mean daily fecundity (Parker, 1980; Stratoudakis *et al.*, 2006). Accordingly, the DEPM provides a snapshot rather than an integrated view of the spawning season as the AEPM (Stratoudakis *et al.*, 2006).

The main difference of the DEPM in relation to the AEPM method resides on the appropriate measure of fecundity, (Stratoudakis *et al.*, 2006, Bernal *et al.*, 2012).

In 2012, WGMEGS coordinated the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (ICES, 2012) as there are some indications that mackerel would be rather an indeterminate spawner and the DEPM might be more appropriate (Armstrong and Witthames, 2012). This workshop recommended that extra adult samples should be collected on surveys to investigate the estimation of DEPM adult parameters, and to attempt a contrast between AEPM and DEPM results.

During its 2018 WGMEGS meeting, after assessing the quality of the 2017 North Sea survey results, it was decided to consider utilizing DEPM for this survey, starting in 2020 (Costas *et al.*, WD04 in Annex 05). Utilizing DEPM for the North Sea mackerel egg survey would have the advantage of requiring only one full coverage of the spawning area over a shorter time period (ICES, 2018b).

For the western and southern areas WGMEGS continues the use of the AEPM for mackerel.

8.6.1.3 2021 North Sea mackerel egg survey

The North Sea Mackerel Egg Survey (NSMEGS, I1582) is designed to estimate the spawning stock biomass (SSB) of mackerel of the North Sea spawning component of the Northeast-Atlantic stock on a triennial basis. Prior to 2017 this survey was done utilizing the AEPM. In the 2018 WGMEGS meeting, it was agreed to switch to the DEPM for the NSMEGS in 2020 (ICES, 2018b). However, due to the pandemic and the implementation of Covid-19 measures, the survey has to be postponed to 2021 (van Damme *et al.*, WD01).The NSMEGS was carried out from 25th May to 12th June by The Netherlands, Denmark and Scotland. During this period the spawning area between 53ºN and 62ºN in the North Sea was covered by a total of 294 plankton stations and 22 pelagic trawl hauls were performed for the collection of mackerel adult and ichthyoplankton samples (Figure 8.6.1.3.1).

The spatial egg production distribution is shown in Figure 8.6.1.3.2. The mean Daily egg production was calculated for the total investigated area (Table 8.6.1.3.1).

The Netherlands sampled 524 mackerel during the survey and collected ovary samples of 164 females. Denmark sampled 817 mackerel during the survey and collected ovary samples of 119 females. The adult parameters are still very preliminary and without adult parameters the SSB cannot be estimated. When final fecundity parameter estimates are available and agreed by WGMEGS, an estimate of SSB will be provided to WGWIDE.

8.6.1.4 Results of the 2021 Exploratory Egg Survey in the Norwegian Sea.

Since 2007 WGMEGS has been observing and reporting on the offshore westwards and northwards expansion of NEA mackerel spawning. Initially spawning densities within these expanded areas were low, however the results from the most recent MEGS surveys in 2016 and 2019 provided clear evidence of a significant and unprecedented shift north and also westwards with some of the highest spawning densities observed being very close to the northern and north-western survey boundaries. During the last NEA mackerel benchmark in 2017 (ICES, 2017b) WGMEGS committed to undertake exploratory ichthyoplankton surveys within these remote boundary regions in the North and Northwest.

In 2017 and 2018 exploratory surveys undertaken by Ireland and Scotland as well as additional samples collected using existing Nordic surveys successfully mapped and delineated a mackerel spawning boundary within the North and northwest areas of Hatton Bank/South Iceland Basin and the Scotland-Faroe-Iceland Ridge (ICES, 2018b). The results and knowledge gleaned, informed the survey planning process ahead of the 2019 MEGS triennial survey but left the Norwegian Sea as an area that still provided a level of uncertainty and with the 2019 MEGS survey results providing evidence that mackerel appeared to be taking the North-eastern route towards their summer feeding grounds (Figure 8.6.1.4.1). A third and final exploratory survey was completed between the 7th – 22nd June 2021, (Burns and O' Hea, WD 15 in Annex 05) using the charter vessel Altaire. This would conclude the exploratory objective by surveying mackerel spawning activity up and along the Norwegian Sea and during the month when the highest mackerel spawning densities were likely to be encountered within this region. Additionally, 3 survey transects were also undertaken within the Northern North Sea area extending the survey's geographical footprint up to nearly 62N.

78 plankton deployments were completed with the Gulf VII sampler during the survey, which due to the relatively calm conditions experienced throughout was able to survey as far North as Lofoten at 68.25N. 5123 mackerel eggs of all stages were recorded during the survey, of which 1671 were recently spawned stage 1 eggs. Mackerel eggs were recorded from every deployment with stage 1 eggs being recorded on all but 2 of the stations completed. The numbers of mackerel eggs extracted from the Gulf VII samples were standardised and the stage 1 data presented as numbers /m^2/day (Figure 8.6.1.4.2). Egg counts recorded during the survey area were generally low with the highest egg counts generally being reported within the southern half (south of 66N) of the survey area. Densities reduced gradually with increasing latitude until down to single figures on transects West of Lofoten as even surface temperatures approached the temperature threshold for spawning mackerel at between 8 – 9 degrees Celsius. 2 successful deployments were completed with the vessels own midwater trawl providing 123 adult mackerel which were sampled for biological parameters and in addition 60 ovaries were also collected to progress ongoing research for IMR, Bergen.

Additional complementary plankton samples were collected by the Faeroe Islands during the IESNS survey during May 2021 and within the region extending from the east side of Iceland across to the north of Faroe and Shetland. These samples were collected using a vertically deployed WP2 net that is lowered to a depth of 50m. These samples have yet to be analysed but the results will be available prior to WGMEGS in 2022 and incorporated into the WG report.

The exploratory survey was unable to find a hard spawning boundary at its Northern extent albeit the numbers being encountered were very low at those high latitudes. This survey contrasted markedly with the previous exploratory surveys undertaken during 2017 and 2018 where the results reaffirmed the existence of the cold water barrier stretching from the East coast of Iceland across to the Faroe/Shetland channel and above which virtually no mackerel spawning takes place in June. The situation up and along the Norwegian Sea is very different with the influence of the Norwegian Current keeping sea surface temperatures (even at those high latitudes) well within a range that is tolerable for spawning mackerel. Nevertheless, the spawning levels observed in the sampled stations North of 62 degrees are overall very low with an estimated contribution to the overall total annual egg production (TAEP) of around 2-3%. Looking ahead to the 2022 survey, WGMEGS therefore does not identify any immediate requirement to significantly extend the survey coverage in this region much beyond what was undertaken in 2019. All the information gathered from these exploratory egg surveys as well as the additional samples received from the various Nordic surveys since 2017 have proved to be invaluable and provide an opportunity not available during the triennial survey year to map the distribution of spawning mackerel within these remote northern boundary regions ahead of the triennial survey in 2022.

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—2021 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 2020 Q4 and 2021 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 2020 Q4 and 2021 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, 2019), but with the same interannual pattern ($p < 0.001$, $r > 0.99$). 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 2020 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 International Ecosystem Summer Survey in Nordic Seas (IESSNS, A7806)

IESSNS is the only annual survey providing data used in the assessment and covers summer feeding distribution of mackerel age 3+ in Nordic Seas. In 2021, survey coverage in the western area was reduced as Greenlandic waters, Iceland basin (south of latitude 62°45′) and the Reykjanes ridge (south of latitude 62°45′) were not surveyed. Coverage reduction did no impact quality of the survey as zero mackerel boundary was established north, west, and south of Iceland. The survey was successfully conducted in 2021. IESSNS cruise report is available as a working document to this report and a detailed survey description is available in the mackerel Stock Annex.

Abundance estimates by age are displayed in input data for the assessment (Table 8.7.1.9), survey estimates of total stock abundance and stock biomass with confidence intervals in Figures 8.6.3.1-2, internal consistency of mackerel abundance from 2012 to 2021 is displayed in Figure 8.6.3.3 and catch curves abundance at age from 2010 to 2021 in Figure 8.6.3.4. Estimated total stock abundance and total biomass declined 53 % and 58 % respectively compared to 2020. Abundance declined for all cohorts age 3+ but the decline was greater for age 5+. Internal consistency declined compared to 2020, particularly for ages 5 – 8 years. This is a sudden and unexpected decline in mackerel abundance compared to 2019-2020 but when compared to 2018 it is 28 % lower. Further analysis of the IESSNS time series is needed to evaluate if the survey index is an overestimate in 2019-2020 or an underestimate in 2018 and 2021. The sudden drop in abundance is reflected in declining internal consistency and drop in catch curves. Bootstrap estimation of abundance by age displayed in Figure 8.6.3.5. Swept area trawl catch and mean catch rate for 2021 is displayed in Figure 8.6.3.6 and mean mackerel catch rate per rectangle for years 2010 and from 2012 to 2021 in Figure 8.6.3.7.

8.6.4 Tag Recapture data

The following is a summary of the most important information on tag recapture data, more detailed info can be found in a working document attached to this report (Slotte and Hølleland, WD06 in Annex 05). Information from steel tagging experiments conducted by Institute of Marine Research in Bergen (IMR) on mackerel at spawning grounds west of Ireland and British Isles in May-June and the respective recaptures at Norwegian factories with metal detectors (Tenningen *et al.*, 2011) was introduced to the mackerel assessment during ICES WKPELA 2014 (ICES, 2014). Data from release years 1980-2004, and recapture years 1986-2006 have been used in the update assessments following this benchmark. From 2011 onwards IMR changed tagging methodology to radio-frequency identification (RFID), more specifically passive integrated transponder tags (PIT-tags). This allowed for more automatic data processes with recaptures from scanned landings at factories in Norway, Scotland and Iceland now being updated real time in an IMR data base over internet.

The data format is the same for both tag types; a table showing numbers of 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 RFID data were considered to be a new time series with a different scaling factor (survival) than the steel tags, and it has been used in update assessments following the ICES WKWIDE2017 benchmark (ICES, 2017). For steel tags data from ages 2-11 and all recapture years are used in the assessment. During the 2017 benchmark it was decided to use the same filtering for the RFID data from release year 2011 onwards. However, following decisions made during ICES IBPNEAMac 2019 (ICES, 2019) update assessments are now only using RFID data from release years 2013 onwards, ages 5-11 and recapture year 1 and 2 after release.

An overview of all RFID tagging data in terms of numbers tagged, biomass scanned, and numbers recaptured per year, and geographical distributions of data are shown in Figures 8.6.4.1-3. The exclusion of recapture years 3 and longer after release is due to potential tag loss over time, which seem evident in the RFID data (Slotte and Hølleland, WD06 in Annex 05). The exclusion of release years 2011-2012 is mainly based in lack of distributional coverage of scanned fishery, which changed significantly when more countries joined the program from 2014 onwards (Figure 8.6.4.2). The exclusion of ages 1-4, was mainly based on the fact that early in the time series these age groups were relatively few compared with the scanned fish year 1 and 2 after release, leading to some noise in the data. However, the age structure of tagged and scanned fish year 1-2 after release has developed over time series to be more overlapping, and high proportions of tagged mackerel are now at ages 2-4 (Figure 8.6.4.4).

Trends in year class abundance indices from RFID data based on recaptures year 1 and 2 after release now seem consistent and informative for assessment from ages 2-12 (Figure 8.6.4.5). Note that an alternative assessment at WGWIDE2021 using these indices for the selected ages 5-11 instead of the regular data table resulted in negligible differences in SSB trend and same leave out RFID data effects; i.e., higher SSB in most recent years when excluding RFID data. Translating these abundance indices into different age-aggregated biomass indices also show comparable time trend with SSB from WGWIDE2021 from release years 2013 onwards (Figure 8.6.4.5). Especially the marked decrease in SSB from 2017-2019 seem to follow the decline in the RFID biomass estimates, which may explain why leave out RFID runs from WGWIDE2021 tends to lift the SSB upwards. The signals of total mortality rate (Z) in fully mature fish aged 4-12 for year classes 2003-2014 tends to be higher in the RFID data than in the catch data tightly overlapping with Z signals in the final WGWIDE2021 assessment, whereas for the international trawl survey IESSNS the estimated Z is even lower (Figure 8.6.4.6).

The overall conclusion is that the RFID time series is slowly developing, but still is a very short time series. Nevertheless, the data seem quite informative for stock assessment, although showing higher total mortality rate signals than the other input data. Such conflicting trends suggest that year to year variations in assessment and leave out effects may frequently occur in coming years when time series are short. Finally, the new development of the time series suggests that the current filtering of RFID data for use in stock assessment should be revised in near future. This especially counts for the inclusion of younger ages 2-4 that may be informative for incoming year classes to the stock.

8.6.5 Other surveys

8.6.5.1 International Ecosystem survey in the Norwegian Sea (IESNS, A3675)

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). Mackerel was present in the southern and eastern part of the Norwegian Sea (as far north as 68°N) in the beginning of May 2021.

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, WD14 in Annex 05). Therefore, no further quantitative information can be drawn from these data as this survey is not designed to monitor mackerel.

8.6.5.2 Acoustic estimates of mackerel in the Iberian Peninsula and Bay of Biscay (PELACUS, A2548)

PELACUS survey data have not been processed on time for WGWIDE and 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 2021

The update assessment was carried out by fitting the state-space assessment model SAM (Nielsen and Berg, 2014) using the R library stockassessment (downloadable at *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 2020 (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 (1998-2020); and 3) the abundance estimates for ages 3 to 11 from the IESSNS survey (2010, 2012-2021). 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 2020 (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 2020.
- Addition of the 2021 survey data in the IESSNS indices.
- Addition of the 2020 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.
- Update of the catch-at-age and mean-weight-at-age in the catch for the period 2010-2019 (see Section 8.4.3).
- The inclusion of the tag recaptures from 2020.

Input parameters and configurations are summarized in Table 8.7.1.1. The input data are given in Tables 8.7.1.2 to 8.7.1.9. 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).

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 1.22, 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 0.81 for age 3 to 1.95 for age 7 and 9. 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 (around 15 %).

The process error standard deviation (ages 1-11) is moderate as well as the standard deviation of the F and recruitment 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. The uncertainty on the observation variance estimates is not particularly high, especially for the data sources with the lowest observation variances, which are the most influential on the assessment (Figure 8.7.2.2). 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 uncertainty on the random walk variance for recruitment is very large, indicating that the parameter was poorly estimated.

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=0.77), then decreasing exponentially with age difference (Figure 8.7.2.3.). This high error correlation implies that the weight of this survey in the assessment is 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 8.7.2.4):

- 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 recruitment index is inversely correlated to the variance of the random walk of the recruitment. This implies that when the model relies less on the recruitment index, the estimated recruitment time series becomes smoother.

Residuals

The “one step ahead” (uncorrelated) residuals for the catches did not show any temporal pattern (Figure 8.7.2.5) 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. Residuals for the 2020 catches-at-age show that the model was not able to fully reproduce the strong increase in the catches of fish of age 9 and older although the estimated fishing mortality on the older fish has increased substantially 2020 (see results in section below).

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 2019 and 2020 index, where residuals tend to be mainly positive. Despite the strong drop in the abundances at age in 2021, the residuals for this year do not indicate any year effect (e.g., no large residuals of the same sign observed across ages) . Residuals to the recruitment index show no particular pattern, and appear to be relatively randomly distributed in the earlier years, but positive residuals are consistently observed over the last 5 years, indicating that the model has difficulties agreeing with this sustain period of high values in the index.

Finally, inspection of the residuals for the tag recaptures (Figure 8.7.2.6) 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 8.7.2.7).

All leave one out runs showed parallel trajectories in SSB and Fbar, except the one leaving out the RFID tag information, which shows a less steep decline in SSB since 2014, and continued decline in Fbar in the most recent years. For recruitment, all runs also resulted in similar trajectories, expect the run without the recruitment index, which recruitment decreased from high levels in the mid-2010s to historical low levels currently.

Removing the IESSNS resulted in lower SSB estimates and higher Fbar estimates for the period covered by the survey. Removing the recruitment index had a similar effect on SSB and Fbar. 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. As in previous years, the update 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 also resulted in a higher SSB than in the assessment using all data, and a slightly higher fishing mortality between 2007 and 2014, but higher after 2016. The magnitude of the effect of removing the RFID data is similar to removing other surveys. This is a contrasting situation compared to the 2020 WGWIDE assessment, in which the RFID had a very small influence on the assessment (no effect on estimated stock trajectory, slightly reduced uncertainty when RFID data are included). This indicates that the influence of the RFID data compared to other data sources has increased this year. This point is further discussed below in a section presenting additional exploratory runs (Section 8.7.5.2.).

Additional sensitivity runs

A series of additional sensitivity runs were done to identify the cause of the change in stock trajectories in the 2021 WGWIDE assessment compared to previous years assessment (see Section 8.10 for a description of this revision).

First, the influence of revisions in the historical data (catch-at-age and mean weight-at-age in the catch for the years 2010-2019) was tested by running the assessment using last year's data for 2010-2019, but keeping the new 2020. This run was almost identical to the WGWIDE 2021 update assessment (not presented here).

Then, the influence of the data added in 2021 was tested by running the model removing separately each of the new data added in 2021 (2020 catch-at-age, 2020 recruitment index, 2020 RFID recaptures and 2021 IESSNS index). The two model runs excluding the 2020 recruitment index and the 2021 IESSNS are very similar to the current assessment and are not shown on Figure 8.7.2.8.

The exclusion of the 2020 RFID data leads to larger SSB and lower Fbar estimates over the most recent years (2019-2020). The information from the 2020 recaptures indicate that abundance has declined in 2019 for the third year in a raw. Adding this information to the assessment therefore leads to the reduction of stock abundances, and hence SSB.

The 2020 catch-at-age also seem to have a strong influence on the assessment. Excluding this information leads to stock trajectories very similar to those from the WGWIDE2020 assessment. The stock trajectories are revised over almost a decade (since about 2009), with lower SSB and higher Fbar estimated when the 2020 catches are not used. The data for 2020 are characterised by a sharp increase in the catches for the older fish (age 9 and older, including the plus group) compared to 2019. No particular changes in fishing patterns for the fleets have been reported and the reason for this increase is not fully understood. Given the low observation variance for the catch-at-age 2 and older, the SAM model follows tightly this increase in the catches of 9+ fish in 2020. The fit to these higher catches can be achieved partly by increasing the fishing mortality on the older age. However, the extend by which fishing mortality-at-age can increase in a year is limited by the amplitude of the random walk, and the variance of these processes is rather low for the mackerel assessment (Table 8.7.2.1). In addition, to be able to fit these higher catches, the model estimated relatively large abundances for old fish in 2020, which seems to have caused an upward revision of the abundance of these cohorts as far back in time as 2014 (based on the comparison of abundance-at-age from last year’s and this year’s assessment, no shown). This upward revision for abundance-at-age explains the downwards revision of fishing mortality at age. Last year’s assessment (WGWIDE 2020; ICES, 2020a) was also quite sensitive to addition of a latest year of catch data (analysis done this year and hence not presented in the previous report) but the sensitivity is larger this year, probably due to the unexpected catches of old fish.

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 5.55 million tonnes in 2014 and 2015 and subsequently declined to reach a level just above 3.87 million tonnes in 2019 and increase slightly in 2020 to 3.94 million tonnes. The fishing mortality has declined from levels between F_{pa} (0.36) and F_{lim} (0.46) in the mid-2000s to levels well below F_{MSY} (0.26) since 2015 and increased to just under F_{MSY} in 2020. The recruitment time series from the assessment is not considered a reliable indicator of year-class strength (see Section 8.7.5.1).

There is some indication of changes in the selectivity of the fishery over the last 30 years (Figure 8.7.3.2.). In the years 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 the ages2-5). 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 8.7.4.1 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 2020 is estimated with a precision of +/- 24 % (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 2020 has a precision of +/- 25 %.

Model instability

The retrospective analysis was carried out for 7 retro years, (or peels) by fitting the assessment using the 2021 data, removing successively 1 year of data (Figure 8.7.4.2.). There was a systematic retrospective pattern found in Fbar for the older retrospective peels (current year -3 to current year -7) with a systematic downwards revision. However, this pattern is not apparent in the most recent peels, and the Mohn’s rho value of the last 5 years is of 0.16. There is no retrospective pattern in the SSB and the value of the Mohn’s rho on SSB for the last 5 peels if low (-0.03). Recruitment appears to be quite consistently estimated for the 6 older retrospective peels, but over the last 2 peels, recruitment has been revised downwards. This is related to the increase in the observation variance for the recruitment index, and corresponding decrease in recruitment random walk variance. Recruitment estimates have progressively become less influenced by the recruitment index (which displays high value in the recent years and revised recent estimates upwards).

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 8.7.4.3) 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 8.7.4.4). 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 2017, the biomass cumulated process error remains positive, and large (reaching in 2013 almost the weight of the catches). The reason for this misbehaviour of the model could not be identified.

8.7.5 Exploratory runs

8.7.5.1 Assessment starting at age 2

The age 0 estimates in the current assessment mainly rely on the recruitment index; the catch-at-age 0 information is considered by the mode as uninformative (large observation variance). Catch-at-age information becomes influential at age 2 (very low observation variance). The recruitment signal provided by abundances estimated at age 2 or 3 (when the fish enters the fishery), is different from the signal in the age 0 abundance (Figure 8.7.5.1). Age 0 abundances are less variable than abundances at age 2 and 3. For the period before 2012, there is a broad agreement in the perception of year class strength, although some year classes that do not appear particularly large at age 0 are perceived as very large at age 2 and 3 (e.g., 2002 year-class). For the more recent period, there is a greater discrepancy between recruitment at age 0 and at older ages. While the age 0 abundances indicate very high recruitment for the year-classes 2012 to 2018, number of those year-classes appear as particularly poor based on age 2 and 3 abundances (2015, 2017 and 2018). As very little fishing occurs between age 0 and 2 and 3, exploitation is not likely to explain these changes in perception of cohort strength. Such variations could be possibly due to variations in natural mortality (e.g., the strength of a cohort may not be fully determined at age 0 and processes occurring during the first years of life may still be determining year-class strength). However, processes occurring at the juvenile stage are more likely to dampen the variations in cohorts' size (e.g., density dependent mechanisms) than increasing it. In addition, some cohorts increase in size as they become older (e.g., 2001 and 2002), which clearly indicates that this is more likely a model artefact. The cohort strength at age 0, based on the recruitment index, is progressively revised, thanks to the process error occurring on annual survival, so that cohort strength at age 2 corresponds to the information coming from the catches.

This discrepancy between the recruitment estimates at age 0 and the actual size of the cohort when entering the fishery implies that the age 0 recruitment does not give an accurate indication on year-class strength, and should not be used to make assumption on stock development in the near future. This has implications for the short term forecast done to compute the catch advice, in which last estimated recruitment value (R2020 this year) contributes to around 10 % of the catch and SSB in the advice year.

As very little fishing occurs on 0 and 1 year olds, and catch-at-age data is considered very noisy, and since there appears to be a disagreement between the recruitment index at age 0 and at older ages in the recent years, it does not seem relevant to start the assessment at age 0 or 1. An exploratory run was conducted starting the assessment at age 2 (and hence removing catch-at-age information for age 0 and 1 and the recruitment index, while leave the rest of the data and model configuration unchanged).

The estimated parameters had in general similar values in the 2 models (Table 8.7.5.1) with a largest difference of 6 % for the IESSNS catchability at age 3, except for the process variances where large differences are observed. Recruitment variability increases by 246 %, and this is associated to an 80 % decrease on the standard deviation (uncertainty) on this parameter. F random walk variance increase by 24 % (with a 24 % reduction on the standard deviation) and the process error variance is reduced by 16 % (but this a larger standard deviation). The model starting at age 2 therefore gives a similar weight to the different data sources as the current model (same observation variances) but estimates a much more variable recruitment, and slightly more variable fishing mortality.

Both assessments give a very similar perception of the SSB and Fbar trajectories (Figure 8.7.5.2). There is a small different in SSB in the years 2010 and 2011, and in the last year with catch information (2020). Fbar trajectories are very consistent, with slightly larger variations for the assessment starting at age 2. The recruitment at age 2 (in blue on Figure 8.7.5.2, note that the curve should be shifted backwards by 2 years to compare year-class strength with the recruitment at age 0, red curve) shows a much variable year-class strength signal, with the same perception of year class strength as the age 0 recruitment for some years (broadly between year-classes 2000 and 2012), but a much lower estimated year-class strength since 2012.

In conclusion, both models broadly agree both in terms of fit to the data and in terms of stock trajectories, and the model starting at age 2 could be considered as potential alternative to the current model at the next benchmark for this stock. The two models however have very different implications regarding advice. While the current model assumes a high 2020 year-class, that will contribute to 10 % in the SSB and catch and advice year (age 2), the alternative model suggests a low 2018 year-class (age 4 in advice year) and average recruitments (geometric mean assumption) for the 2019 and 2020 year classes (age 3 and 2 in advice year).

8.7.5.2 Assessment using tag data as abundance indices

The last inter-benchmark (ICES, 2019) showed that the RFID tagging data had a very high influence on the previous assessment, simply due to the fact that it was a much larger dataset than other survey data (and growing much faster as well). The changes made during this IBP involved filtering out a large part of the RFID dataset (tags recovered after more than 2 years at liberty were excluded due to the suspicion of tag loss). At the time of the IBP, this decreased considerably the weight of the RFID data on the assessment (as measured then by the leave one out run). This year, with 2 additional years of data, the RFID dataset has grown by 28 data points, while the second largest index, the IESSNS, has grown by 18 data point. At the same time, the leave one out run (Figure 8.7.2.7) shows that the influence of the RFID dataset has increased markedly compared to last year. It is unclear whether this increasing influence is due to the RFID data being very informative, and therefore receiving a higher weight, or if it is due to the increase in the number of observations.

In order to investigate this, the SAM model was fitted using the RFID tag data expressed as abundance-at-age indices for the ages 5 to 11 (see Figure 8.6.4.5). In this configuration, the RFID data has a similar number of observations as for the IESSNS survey. The assessment using RFID as indices gives a perception of the stock very similar to the WGWIDE 2021 assessment (Figure 8.7.5.3). There is hardly any difference in the estimated SSB, and Fbar and recruitment are slightly higher. This strong similarity between the assessments using the RFID data as recaptures or as abundance indices indicates that the stronger influence of the RFID seen for the WGWIDE2021 is not likely to be due to the larger increase in number of data points compared to other data sources, but rather to the information contained in the dataset.

8.8 Short term forecast

The short-term forecast provides estimates of SSB and catch in 2022 and 2023, given assumption of the current year's (also called intermediate year) catch and a range of management options for the catch in 2022.

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 (2021) 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 (2020) 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 76 % (recruitment index) and 24 % (time tapered geometric mean), which leads to an expected recruitment of 5 743 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 2022.

Assuming catches for 2021 of 1 199 kt, F was estimated at 0.35 (above F_{MSY}) and SSB at 3.51 Mt (above B_{pa}) in spring 2021. If catches in 2022 equal the catch in 2021, F is expected to increase to 0.42 (above F_{pa}) in 2022 with a corresponding decrease in SSB to 3.21 Mt in spring 2022. Assuming an F of 0.42 again in 2023, the SSB will further decrease to 2.89 Mt in spring 2023.

Following the MSY approach, exploitation in 2022 shall be at F_{MSY} (0.26). This is equivalent to catches of 795 kt and a decrease in SSB to 3.31 Mt in spring 2022 (6 % decrease). During the subsequent year, SSB will remain at a similar level (3.27 Mt) in spring 2022.

8.9 Biological Reference Points

A management strategy evaluation Workshop on northeast Atlantic mackerel (MKMSEMAC) was conducted during 2020 (ICES, 2020b) which resulted in the adoption of new reference points for NEA mackerel stock by ICES.

The table below summarises the currently used reference points.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	2.58 million tonnes	B_{pa}	ICES (2020b)
	F_{MSY}	0.26	Stochastic simulations	ICES (2020b)
Precautionary approach	B_{lim}	2.00 million tonnes	B_{loss} in 2003 from the 2019 WGWIDE assessment (ICES, 2019)	ICES (2020b)
	B_{pa}	2.58 million tonnes	B_{lim} x exp(1.645 × σ), with σ_{SSB} = 0.15	ICES (2020b)
	F_{lim}	0.46	F that, on average, leads to B_{lim}	ICES (2020b)
	F_{pa}	0.36	F_{p05} (the F that leads to SSB ≥ Blim with 95 % probability)	ICES (2020b)

8.10 Comparison with previous assessment and forecast

Stock assessment output

The last available assessment used for providing advice was carried out in 2020 during the WGWIDE. The new 2021 WGWIDE assessment gives a slightly different perception of the development of the stock, with a higher SSB estimated for the period 2014-2017 and a lower Fbar estimated over the period 2009 2018 (Figure 8.10.1). For the latest year, the differences in the 2019 TSB, SSB and Fbar estimates between the previous and the present assessments are small, of -0.7 %, 3.9 % and -3.6 %, respectively. The 2018 fishing mortality is unchanged (0.2 % difference).

	TSB 2019	SSB 2019	Fbar4-8 2019
Values			
2020 WGWIDE	4 966 328 tonnes	3 731 510 tonnes	0.223
2021 WGWIDE	4 933 409 tonnes	3 876 306 tonnes	0.215
% difference	-0.7 %	3.9 %	-3.6 %

The addition of a new year of data has slightly modified model parameters compared to last year (Figure 8.10.2). The observation standard deviation has decreased for the IESSNS survey, and increased for the egg survey (although changes are very minimal in both cases). The observation standard deviation for the recruitment index increased by a larger proportion. This increase comes with a substantial decrease of the random walk variance for recruitment, and a larger uncertainty on this parameter. The 2021 model fit follows less the recruitment index and, in absence of other source of information on age 0, produces a smoother recruitment time series.

Although the parameters corresponding to the weight of the different data sources on the assessment (observation standard deviations) have not changed, the analyses presented in Section 8.7 indicated that the influence of the RFID time series has increased. In addition, Section 8.7 also showed that the revision observed this year is mainly due to the influence of the inclusion of the 2020 catch at age, which effect propagated backward in time.

The uncertainty on the parameter estimates has decreased for some parameters (observation standard deviation on the IESSNS survey, standard deviations of the F random walk for age 0 and 1, figure 8.10.2), but increased markedly for recruitment variance. The uncertainty on SSB and F_{bar4-8} in this year's assessment is higher for the earlier years (before 2015), but has reduced for the most recent estimates (Figure 8.10.3).

Short term forecast

The intermediate year catch assumption for 2020 used for the short-term forecast in the advice given last year (sum of 2020 TAC of 1 090 879 tonnes) was slightly lower than the actual 2020 catch reported for WGIWIDE 2021 and used in the present assessment (text table below). The new assessment produced an estimate of the SSB in 2020 which was 7 % higher than the 2020 WGWIDE forecast prediction. This discrepancy in the SSB is explained by the revision of the perception of the abundance at age 6 to 12+ (Figure 8.10.4) and possibly also by the actual 2020 catch being lower than the value assumed last year. The fishing mortality F_{bar4-8} for 2020 estimated at the WGWIDE 2020 is 21.9 % lower than the value estimated by the short-term forecast in the previous assessment also due to the combination of the stock being actually larger than forecasted, and the stock being revised upwards in 2020 (Figure 8.10.1).

	Catch (2020)	SSB (2020)	F_{bar4-8} (2020)
2020 WGWIDE forecast	1 090 879 t	3 681 413 t	0.32
2021 WGWIDE assessment	1 039 863 t	3 938 555t	0.25
% difference	-4.7 %	7.0 %	-21.9 %

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. No agreement on the share of the stock has been reached after Brexit for 2021. Despite various agreements, the total declared quotas in each of the years 2015 to 2020 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, 2017) 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 to the fishery (~ age 3) was high from year-class 2001, but recently have appeared to be reverting towards a low level. The recruitment index indicates high recruitment at age 0 up to 2020, however, since 2012 the recruitment index has been estimating substantially larger year-classes than what is later estimated at age 3 when they enter the fishery and the other surveys. It is not known if this is a sampling bias or altered mortality of the juveniles between age 0 and 3.

The 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 spawning in the Norwegian Sea was shown to be of little quantitative significance in 2021 (Burns and O' Hea, WD 15 in Annex 05).

From about 2005 to 2015 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 1 to 6 years of age (ICES, 2019; 2020).

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 km² in 2007 to at least 2.9 million km² 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 km² in 2019 (Nøttestad *et al*., 2019). However, we witnessed a substantial shift in mackerel concentrations and distribution during summers of 2020 and 2021, 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), followed by a decrease in 2021 (Nøttestad et al., WD09 in Annex 05). 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 2021 compared to 2014-2017 (ICES, 2018a; Nøttestad *et al*., 2019; 2020b).

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; WD09 in Annex 05). 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 spatiotemporal 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 2019-2021 where we had some increasing overlap between mackerel and herring (mainly 2013- and 2016- year classes) (Nøttestad *et al*., 2019; 2020; WD09 in Annex 05). 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 these areas (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 were found along the coast in Norway during the IESSNS 2019 (Nøttestad *et al*., 2019) and to some extent in 2020 (Nøttestad *et al*., 2020b) and 2021 (*Nøttestad et al*., 2021), 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).

8.13 References

Armstrong, M.J. and Witthames, P.R. 2012. Developments in understanding of fecundity of fish stocks in relation to egg production methods for estimating spawning stock biomass. Fisheries Research 117-118: 35–47.

Bachiller, E., Skaret, G., Nøttestad, L. and Slotte, A. 2016. Feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring and blue whiting in the Norwegian Sea. PLoS ONE 11(2): e0149238. doi:10.1371/journal.pone.0149238

Bachiller E, Utne KR, Jansen T, Huse G. 2018. Bioenergetics modeling of the annual consumption of zooplankton by pelagic fish feeding in the Northeast Atlantic. PLOS ONE 13(1): e0190345. https://doi.org/10.1371/journal.pone.0190345

Bernal, M., Somarakis, S., Witthames, P.R., van Damme, C.J.G., Uriarte, A., Lo, N.C.H., and Dickey-Collas, M. 2012. Egg production methods in marine fisheries: an introduction. Fisheries Research 117–118: 1–5.

Boge, E. 2019. The return of the Atlantic bluefin tuna to Norwegian waters. Master thesis in Fisheries Biology and Management, Department of Biological Sciences, University of Bergen, Norway. 84 p.

Bjørdal, V.R. 2019. Juvenile mackerel (*Scomber scombrus*) along the Norwegian Coast: distribution, condition and feeding ecology. Master thesis in Fisheries Biology and Management, Department of Biological Sciences, University of Bergen, Norway. 73 p.

Debes, H., Homrum, E., Jacobsen, J.A., Hátún, H. and Danielsen, J. 2012. The feeding ecology of pelagic fish in the southwestern Norwegian Sea –Inter species food competition between Herring (*Clupea harengus*) and mackerel (*Scomber scombrus*). ICES CM 2012/M:07. 19 pp.

Gunderson, D.R. (1993) Surveys of Fisheries Resources. Wiley, New York. 248 pp.

Hunter, J.R., Macewicz, B.J., Lo, N.C.H., Kimbrell, C.A. 1992. Fecundity, spawning and maturity of female Dover sole *Microstomus pacificus*, with an evaluation of assumptions and precision. Fishery Bullettin US 90, 101–128.

Hunter, J.R. and Lo, N.C.H. (1993) Ichthyoplankton methods for estimating fish biomass: introduction and terminology. Bulletin of Marine Science 53, 723–727.

Huse, G., Holst, J.C, Utne, K.R., Nøttestad, L., Melle, W., Slotte, A., Ottersen, G., Fenchel, T. and Uiblein, F. 2012. Effects of interactions between fish populations on ecosystem dynamics in the Norwegian Sea – results of the INFERNO project. Marine Biology Research 8(5-6): 415-419.

ICCAT. 2019. Report of the Standing Committee on Research and Statistics (SCRS). Spain, Madrid, 30. September to 4 October 2019, ICCAT Collective Volume of Scientific Papers. PLE-104, 459 pp.

ICES. 1974. Report of the Mackerel Working Group, 30 January - 1 February 1974. Charlottenlund, Denmark. ICES C.M. 1974/H:2. 20pp.

ICES. 1981. Report of the ICES Advisory Committee on Fishery Management, 1980, ICES. Cooperative Research Report no. 102.

ICES. 1990. Report of the ICES Advisory Committee on Fishery Management, 1989, ICES. Cooperative Research Report no. 168.

ICES. 1991. Report of the Mackerel Working Group. 29 April – 8 May 1991. Copenhagen, Denmark. ICES C.M. 1991/Asess: 19. 90 pp.

ICES 2012. Report of the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA), 16-17 April 2012, Galway, Ireland. ICES CM 2012/SSGESST:05. 28 pp.

ICES. 2013. Report of the Workshop to consider reference points for all stocks (WKMSYREF). 23 - 25 January 2013. Copenhagen, Denmark. ICES CM 2013/ACOM:37. 17 pp.

ICES. 2014. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA). 17–21 February 2014. Copenhagen, Denmark. ICES CM 2014/ACOM:43. 344 pp.

ICES. 2016. Second Interim Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). By correspondence. ICES CM 2016/SSGIEOM:09.

ICES. 2017a. EU, Norway, and the Faroe Islands request concerning long-term management strategy for mackerel in the Northeast Atlantic. *In* Report of the ICES Advisory Committee, 2017. ICES Advice 2017, sr.2017.19. 14 pp. https://doi.org/10.17895/ices.pub.3031.

ICES. 2017b. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January–3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

ICES. 2018a. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 30th of June – 6th of August 2018. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE), Havstovan, Tórshavn, Faroe Islands, 28. August – 3. September 2018, 39 pp.

ICES. 2018b. Report of the Working Group on Widely Distributed Stocks (WGWIDE). 28 August – 3 September 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM: 23. 488 pp.

ICES. 2019. Interbenchmark Workshop on the assessment of northeast Atlantic mackerel (IBPNEAMac). ICES Scientific Reports. 1:5. 71 pp.

ICES. 2020. Working Group on Widely Distributed Stocks (WGWIDE). ICES Scientific Reports. 2:82. 1019 pp.

ICES, 2020b. Workshop on Management Strategy Evaluation of mackerel (WKMSEMAC). ICES Scientific Reports 2(74), 175.

ICES. 2021. Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). ICES Scientific Reports. 3:82. 40pp. https://doi.org/10.17895/ices.pub.8249

Jansen, T. 2014. Pseudocollapse and rebuilding of North Sea mackerel (Scomber scombrus). ICES Journal of Marine Science, 71:2: 299–307. https://doi.org/10.1093/icesjms/fst148

Jansen, T. 2016. First-year survival of North East Atlantic mackerel (*Scomber scombrus*) from 1998 to 2012 appears to be driven by availability of Calanus, a preferred copepod prey. Fisheries Oceanography 25: 457–469. doi:10.1111/fog.12165

Jansen, T. and Burns F. 2015. Density dependent growth changes through juvenile and early adult life of North East Atlantic Mackerel (*Scomber scombrus*). Fisheries Research 169: 37-44.

Jansen, T. and Gislason, H. 2013. Population Structure of Atlantic Mackerel (*Scomber scombrus*). PLoS ONE 8(5): e64744. doi:10.1371/journal.pone.0064744

Jansen, T., Campbell, A., Brunel, T. and Clausen, L.A.W. 2013. Spatial segregation within the spawning migration of North Eastern Atlantic Mackerel (*Scomber scombrus*) as indicated by juvenile growth patterns. PLoS ONE 8(2): e58114. doi:10.1371/journal.pone.0058114

Jansen, T., Campbell, A., Kelly, C.J., Hátún, H. and Payne, M.R. 2012. Migration and Fisheries of North East Atlantic Mackerel (*Scomber scombrus*) in Autumn and Winter. PLoS ONE 7(12): e51541. doi:10.1371/journal.pone.0051541

Jansen, T., Kristensen, K., van der Kooij, J., Post, S., Campbell, A., Utne, K.R., Carrera, P., Jacobsen, J.A., Gudmundsdottir, A., Roel, B.A. and Hatfield, E.M.C. 2015. Nursery areas and recruitment variation of North East Atlantic mackerel (*Scomber scombrus*). ICES Journal of Marine Science 72(6): 1779-1789.

Kraus et al., 2012 G. Kraus, H.-H. Hinrichsen, R. Voss, E. Teschner, J. Tomkiewicz, F.W. Köster. Robustness of egg production methods as a fishery independent alternative to assess the Eastern Baltic cod stock (Gadus morhua callarias L.). Fisheries Research, 117–118 (2012), pp. 75-85

Langøy, H., Nøttestad, L., Skaret, G., Broms, C., and Fernö, A. 2012. Overlap in distribution and diets of Atlantic mackerel (*Scomber scombrus*), Norwegian spring- spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) in the Norwegian Sea during late summer. Marine biology research 8(5-6): 442-460.

Lockwood, S.J., Nichols, J.H., Dawson, W.A., 1981. The estimation of a mackerel (Scomber scomber L.) spawning stock size by plankton survey. J. Plankton Res. 3, 217–233.

Lockwood, S.J. – 1988. The mackerel. Its biology, assessment and the management of a fishery. Fishing Book News Ltd. Farn-ham, Surrey England. 181 pp.

Løviknes, S. 2019. Distribution and feeding ecology of fin (Balaenoptera physalus) and humpback whales (Megaptera novaeangliae) in the Norwegian Sea during the summers of 2013 to 2018. Master thesis in Biodiversity, Evolution and Ecology, Department of Biological Sciences, University of Bergen, Norway. 59 p.

Nielsen, A. and Berg, C.W. 2014. Estimation of time-varying selectivity in stock assessment using state–space models. Fisheries Research 158: 96-101.

Nøttestad L., Sivle, L. D., Krafft, B. A., Langård, L., Anthonypillai, V., Bernasconi, M., Langøy, H., and Fernø, A. 2014: Prey selection of offshore killer whales *Orcinus orca* in the Northeast Atlantic in late summer: spatial associations with mackerel. Marine Ecology Progress Series 499:275-283. DOI:10.3354/meps10638.

Nøttestad, L., Anthonypillai, V., Tangen, Ø., Utne, K.R., Óskarsson, G.J., Jónsson S., Homrum, E., Smith, L., Jacobsen, J.A. and Jansen, T. 2016. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V "M. Ytterstad", M/V "Vendla", M/V "Tróndur í Gøtu", M/V "Finnur Fríði" and R/V "Árni Friðriksson", 1 – 31 July 2016. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE). ICES HQ, Copenhagen, Denmark, 31 August – 6 September 2016. 41 pp.

Nøttestad, L., Ólafsdóttir, A.H., Anthonypillai, V. Homrum, E., Jansen, T. *et al*. 2017. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V "Kings Bay", M/V

“Vendla”, M/V “Tróndur í Gøtu”, M/V “Finnur Fríði” and R/V “Árni Friðriksson”, 3rd of July – 4th of August 2017. ICES Working Group on Widely Distributed Stocks (WGWIDE), ICES HQ, Copenhagen, Denmark, 30. August – 5. September 2017. 45 p.

Nøttestad, L. Utne, K.R., Sandvik, A., Skålevik, A., Slotte, A. and Huse, G. 2018. Historical distribution of juvenile mackerel northwards along the Norwegian coast and offshore following the 2016 mackerel spawning. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE), Havstovan, Tórshavn, Faroe Islands, 28. August – 3. September 2018, 25 pp.

Nøttestad, L., Ólafsdóttir, A.H., Anthonypillai, V. Homrum, E., Jansen, T.; Wieland K. *et al*. 2019. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 28th June – 5th August 2019. Working Group Document to ICES Working group on Widely Distributed Stocks (WGWIDE, No. 5). Spanish Institute of Oceanography (IEO), Santa Cruz, Tenerife, Canary Islands 28. August – 3 September 2019. 51 pp.

Nøttestad, L., Ólafsdóttir, A.H., Anthonypillai, V. Homrum, E., Jansen, T.; Wieland K. et al. 2020a. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 1st July – 4th August 2020. Working Group Document to ICES Working group on Widely Distributed Stocks (WGWIDE, No. 3), ICES HQ, Copenhagen, Denmark, (digital meeting) 26. August – 1. September 2020. 55 pp.

Nøttestad, L., Boge, E. and Ferter, K. 2020b. The comeback of Atlantic bluefin tuna (*Thunnus thynnus*) to Norwegian waters. Fisheries Research 231, November 2020.

Ólafsdóttir, A.H., Slotte, A., Jacobsen, J.A., Oskarsson, G.J., Utne, K.R. and Nøttestad, L. 2015. Changes in weight-at-length and size at-age of mature Northeast Atlantic mackerel (*Scomber scombrus*) from 1984 to 2013: effects of mackerel stock size and herring (*Clupea harengus*) stock size. ICES Journal of Marine Science 73(4): 1255-1265. doi:10.1093/icesjms/fsv142

Ólafsdóttir, A.H., Utne, K.R., Nøttestad, L., Jacobsen, J.A., Jansen, T., Óskarsson, G.J., Jónsson, S. Þ., Smith, L., Salthaug, A., Hömrum, E. and Slotte, A. 2017. Preparation of data from the International Ecosystem Summer Survey in Nordic Seas (IESSNS) for use as an annual tuning series in the assessment of the Northeast Atlantic mackerel (*Scomber scombrus L.*) stock. Working Document to the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), Copenhagen, Denmark, 30 January–3 February 2017. 36 pp.

Ólafsdóttir, A., Utne, K.R., Jansen, T., Jacobsen, J.A., Nøttestad, L., Óskarsson, G.J., Slotte, A., Melle, W. 2019. Geographical expansion of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2007 - 2014 was primarily driven by stock size and constrained by temperature. Deep-Sea Research Part II. 159, 152-168.

Óskarsson, G.J., Guðmundsdóttir, A., Sveinbjörnsson, S. and Sigurðsson, T. 2015. Feeding ecology of mackerel and dietary overlap with herring in Icelandic waters Ecological impacts of recent extension of feeding migration of NE-Atlantic mackerel into the ecosystem around Iceland. Marine Biology Research 12: 16–29. doi:10.1080/17451000.2015.1073327

Parker, K. 1980. A direct method for estimating northern anchovy, *Engraulis mordax*, spawning biomass. Fishery Bulletin 78: 541–544.

Pastoors, M., Brunel, T., Skagen, D., Utne, K.R., Enberg, K. and Sparrevohn, C.R. 2015. Mackerel growth, the density dependent hypothesis and implications for the configuration of MSE simulations: Results of an ad-hoc workshop in Bergen, 13-14 August 2015. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE), Pasaia, Spain, 25 – 31 August 2015. 20 pp.

Salthaug, A., Stæhr, K.J., Óskarsson, G.J., Homrum, E. Krevoshey, P. *et al*. 2019. International ecosystem survey in the Nordic Sea (IESNS) in May-June 2019. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE No. 11). Spanish Institute of Oceanography (IEO), Santa Cruz, Tenerife, Canary Islands 28. August – 3 September 2019. 33 pp.

Salthaug, A., Wieland, K., Olafsdottir, A.H.., Jacobsen, J.A.. *et al*. 2020. International ecosystem survey in the Nordic Sea (IESNS) in May-June 2020. Working Document to ICES Working Group on Widely Distributed Stocks (WGWIDE No. 4). Copenhagen 26. August – 1. September 2020. 38 pp.

Simmonds, E.J., Portilla, E., Skagen, D., Beare, D. and Reid, D.G. 2010. Investigating agreement between different data sources using Bayesian state-space models: an application to estimating NE Atlantic mackerel catch and stock abundance. ICES Journal of Marine Science 67: 1138–1153.

Skjoldal, H.R., Sætre, R., Fernö, A., Misund, O.A. and Røttingen, I. 2004. The Norwegian Sea ecosystem. Trondheim, Norway. Tapir Academic Press.

Shepherd, J.G. 1997. Prediction of year-class strength by calibration regression analysis of multiple recruit index series. ICES Journal of Marine Science 54: 741–752.

Stratoudakis, Y., Bernal, M., Ganias, K., and Uriarte, A. 2006. The daily egg production method: recent advances, current applications and future challenges. Fish and Fisheries 7: 35–57.

STECF. 2015. Expert Working Group on Technical measures part III (EWG 15-05), 2-6 March 2016, Dublin. N. Graham and H. Doerner. Brussels.

Tenningen, M., Slotte, A. and Skagen, D. 2011. Abundance estimation of Northeast Atlantic mackerel based on tag–recapture data – A useful tool for stock assessment? Fisheries Research 107: 68–74.

Utne, K.R., Hjøllo S.S., Huse G. and Skogen M. 2012. Estimating the consumption of Calanus finmarchicus by planktivorous fish in the Norwegian Sea using a fully coupled 3D model system. Marine Biology Research 8: 527–547. doi:10.1080/17451000.2011.642804

8.14 Tables

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	2010-2020	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	50826	4640	55466	864229	13045	877272
2011	160756	1836	162592	51098	5317	56415	301746	1906	303652	398132	28	398160	26337	1807	28144	938070	10894	948963
2012	121115	952	122067	65728	9701	75429	218400	1089	219489	449325	1	449326	29809	3431	33240	884377	15174	899551
2013	132062	273	132335	49871	1652	51523	260921	337	261258	465846	15	465861	24867	2455	27322	933567	4732	938299
2014	180068	340	180408	93709	1402	95111	383887	334	384221	684082	91	684173	53591	4284	57875	1395337	6451	1401788
2015	134728	30	134757	98563	3155	101718	295877	34	295911	632493	78	632571	43735	7133	50869	1205396	10431	1215827
2016	206326	200	206526	37300	1927	39227	248041	570	248611	563440	54	563494	39056	3220	42276	1094163	5971	1100135
2017	225959	151	226110	21128	1992	23119	269404	400	269804	603806	62	603869	36512	227	36739	1156809	2832	1159641
2018	157239	90	157329	32037	1611	33649	341527	620	342147	455689	51	455740	33761	518	34279	1020254	2890	1023144
2019	122995	144	123139	32840	5902	38742	307235	812	308047	345019	18	345037	23832	931	24763	831920	7807	839727
2020	130577	341	130918	48806	8065	56871	456479	732	457211	356985		356985	37386	143	37529	1030232	9280	1039513

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Subareas 1, 2, 5 and 14, 2000 – 2020 (Data submitted by Working Group members).

Year	Denmark	Estonia	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported	Unallocated	Discards	Total
2000	1375	2673	5546						2085		31778				491001				92557
2001	7	219	3272								21971		8	54	41566				67097
2002	1		4730				53			569	22670			665	45811	-570			73929
2003							122	495		44	125481			692	40026		-44		53883
2004			650	2				471		34	10295			2493	49489	-553	32	9	62922
2005			30	1			363			2393	13244				40491		-2393		54129
2006							4222				8914				33580				46716
2007			278		7		36706			10	493				35408		-10		72891
2008			123				112286			72	3474			4	32728		-18	112	148781
2009			2992				116160				3038				414141				163604
2010	4845		66312				121008			90	104858				58613			5	355729
2011	269		121499	2		621	159263	90		178	43168				73601			28	398160
2012			107198		107	74021	149282			5	110741		4		74587			1	449326
2013	391	13671	142976	197	74	541481	151103			1	33817		825	2	80812			151	465729
2014	2345		103896	8		875811	172960	1725	1082	5887	192322		3310	5534	116433			911	684173
2015	4321		76889	36	2963	30351	169333	6		6996	204574		740	7851	128433			78	632571
2016	1		61901		3499	36142	170374	2	1931	8599	153228		730	5240	121614			54	563315

Year	Denmark	Estonia	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported	Unallocated	Discards	Total
2017	2		66194		4064	46388	167366			7671	167739		1720	4601	138061			62	603869
2018	289		52061	733	577	62973	168330			2697	46853	2	910	2009	118255			51	455740
2019			37418		190	30241	128008			13	22605				126543			18	345036
2020			33291	8	206	26555	151534		2	0.73	15937	0.044	220	426	128805			0.05	356985

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), 2000-2020 (Data submitted by Working Group members).

Year	Belgium	Denmark	Faroe Islands	France	Germany.	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported (Area 6.a)	Unallocated	Discards	Total
2000	146	27720	10614	1588	78	9956		2262	142320		49941	58282	1672	8591	34761	1912	304896
2001	97	21680	18751	1981	4514	10284		2441	158401		5090	52988	1	39024	24873	24	339970
2002	22	343751	12548	2152	3902	20715		11044	161621		52321	61781		49918	22985	8583	394878
2003	2	275081	11754	1467	4859	17145		6784	150858		4450	67083		62928	-730	11785	365894
2004	4	25665	11705	1538	4515	18901		6366	147068		4437	62932		23692	-783	11329	317369
2005	1	232121	9739	1004	4442	15605		3915	106434	109	3204	37118	4	37911	7043	4633	254374
2006	3	242191	12008	285	2389	4125		4093	113079		3209	28628		8719	171	8263	209192
2007	1	252171	11818	7549	5383	13337		5973	131191		38581	46264			2421	4195	257208
2008	2	26716	7627	490	4668	11628		1980	114102		36641	37055		17280	2039	8862	236111
2009	3	23491	6648	1493	5158	12901		2039	118070		73031	47863		1959	-629	8120	235049

Year	Belgium	Denmark	Faroe Islands	France	Germany.	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported (Area 6.a)	Unallocated	Discards	Total
2010	27	36552	4639	686	25621	14639		1300	129064		34291	52563	696		660	883	247700
2011	21	32800	543	1416	52911	15810		9881	162878		32481	69858				1906	303652
2012	39	36492	432	5736	4560	20422		6018	64181		4560	75959				1089	219489
2013	62	31924	25	1788	5755	13523		4863	130056		2081	70840	4			337	261258
2014	56	21340	42919	4912	4979	45167	8340	24536	85409		1112	145119				334	384221
2015	38	35809	25672	7827	6056	34167		17547	36344	24	3190	129203				34	295911
2016	99	21696	18193	3448	10172	24437	596	11434	55089		2933	99945				559	248611
2017	107	27457	12915	5942	11185	35957		17401	51960	0.721	1981	104499				400	269804
2018	110	22207	15475	6714	12091	24567		13844	135715	4041	3056	103707				620	342147
2019	13	25374	17460	5455	7778	1678		8957	135083	1394	2152	101890	0.12			812	308047
2020	75	34375	32860	8959	15946	15395	813	18425	195515	16	3451	130650				732	457211

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), 2000–2020 (Data submitted by Working Group members).

Year	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	United Kingdom	Misreported	Unallocated	Discards	Total
2000		82	4863	17857	22901			61277		30123					4500		126620	-3775	31564	1920	297932
2001		835	2161	18975	20793			60168		33654					4063		139589	-39024	37952	1164	280553

Year	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	United Kingdom	Misreported	Unallocated	Discards	Total
2002			2490	19726	22630			51457		21831					3483		131599	-43339	27558	15191	252620
2003		113	2260	21213	19200			49715		23640							167246	-62928	5587	7111	233157
2004	1		674	18549	18730			41730		21132							149346	-23139	9714	7696	244432
2005				15182	14598			30082		18819		461			4795		115595	-37911	13412	20359	190597
2006			59	14625	14219			36539	95	20064		1368			4048		67205	-8719	4783	14723	169009
2007		6	1333	12434	12831			35923	7	18261	7	978			2772		87430		10042	10177	192201
2008		10	3539	14944	10834			33132		17920	3948				7327		768828	-17280	-952	27351	177662
2009	1		4421	16464	17545			48155		20900	121				8462		109155	-1959	490	6848	230603
2010	2	48	36	10301	16493			43355		21699	30			1	6532		107860		4503	7518	218377
2011		2889	8	11304	18792	10	45696	11	18336	2019					1257		111133		399	7153	219007
2012		8		14448	14277	5	42627	11	19794	1101					773		93783		16	10654	197496
2013		903		12438	15102	9	42988	8	16295	734					635		92965		-144	2105	183857
2014		18538	3421	16627	23478	9	56286	3	16242						1796		137378			1742	275519
2015	14	6741	5851	17820	19238	4	54571		15264	1313					951		111489		34	3185	236475
2016	44	19443	13173	16634	9740		52087	8	17896	1035				30	1253		112284			2126	245754

Year	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	United Kingdom	Misreported	Unallocated	Discards	Total
2017	21	12569	20559	16925	9608		48957	2	18694	2657					786		116308			2142	249229
2018	58	8194	13543	13974	7214			42181		13851	4639	14			1269		84327		13	1701	190978
2019	53	5189	7787	12371	8936		69	51635		13727	1420	2312	46	1	1217	805	50267			6046	161879
2020	49	4110	2913	12816	8878	22		58720		11895	221	5286	35	10	1784		72645			8405	187788

Table 8.4.2.4. NE Atlantic Mackerel. ICES estimated catch (t) in Divisions 8.c and 9.a, 2000 – 2020 (Data submitted by Working Group members). 9.b is included in 2020.

Country	France 8.c	Portugal 9.a	Portugal 8.c	Russia 9.b	Spain 8.c	Spain 9.a	Discards 8.c	Discards 9.a	Unallocated 8.c	Unallocated 9.a	Total 9.a	Total 8c and 9a
2000		2253			30061	3760		6013			12026	42087
2001		3119			38205	1874					4993	43198
2002		2934			38703	7938					10873	49575
2003	226	2749			17384	5464	531				8213	26354
2004	177		2289				928		28429	3946	6234	35768
2005	151		1509				391	405	42851	5107	7021	50414
2006	43		2620		43063	7025	3606	1			9646	56358
2007	55		2605		53401	6773	156	916			10293	63906
2008	168		2381		50455	6855	73	677			9913	60609
2009	383		1753		91043	14569	725	241			16562	108713
2010	392	1758	2363		38858	7347	4408	232		108	10049	55466
2011	44	2302	962		14709	2759	563	1245	4691	871	5836	28146
2012	283	4868	824		17768	845	2187	1244	4144	1076	3989	33239
2013	220	5134	254		14617	1162	1428	1027	-573	4053	6497	27322
2014	171	7334	618		33783	2227	2821	1463	8795	662	4308	57874
2015	21	6836	1456		29726	3853	4724	2409	11	1831	9550	50867
2016	106	6069	619		26553	2229	2469	751	1357	2123	5722	42276
2017	83	3697	634		30893	1206	84	143			1983	36740

Country	France 8.c	Portugal 9.a	Portugal 8.c	Russia 9.b	Spain 8.c	Spain 9.a	Discards 8.c	Discards 9.a	Unallocated 8.c	Unallocated 9.a	Total 9.a	Total 8c and 9a
2018	50	3709	855		27190	1656	324	194	300		2736	34279
2019	43	3188	706		19148	747	760	172			1625	24764
2020	96	4189	575	3	31143	1379	28	115			2069	37529

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2020 (Q1-Q4).

Age	1	2.a	2.a1	2.a2	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0					249				244	217	197	
1		280	263	263	292	289	292	292	296	295	295	
2	335	327	329	329	321	324	317	323	320	321	322	
3	348	331	331	331	330	336	327	320	332	323	326	353
4	358	341	343	343	343	348	340	329	344	338	341	351
5	353	345	357	357	354	360	355	348	356	350	354	367
6	371	360	368	368	363	368	363	366	364	351	357	369
7	373	364	365	366	372	375	372	381	371	365	370	373
8	379	369	371	371	376	378	376	384	375	366	376	376
9	385	374	377	377	378	380	379	389	378	372	374	377
10	390	373	374	374	384	389	386	386	383	382	383	379
11		377	376	376	384	391	389	397	388	383	384	384
12		382	389	389	391	396	399	390	391	389	380	390
13		385	380	381	395	399	399	403	393	390	391	392
14		390	392	392	396	402	415	393	397	390	392	394
15+		398	395	395	403	406	406	402	397	396	402	390

Age	5.b	5.b.1	6.a	6.b	7.a	7.b	7.c	7.d	7.g	7.h	7.j	7.k
0								173				
1			174	248		295		283				
2			296	314		304	306	318				
3	353	353	328	325		328	325	330	113	174	335	345
4	352	351	342	344	131	341	339	343	268	287	336	358
5	359	364	359	357	306	361	347	359	361	361	365	365
6	367	368	365	365	353	367	365	371	313	306	369	369
7	369	371	372	372	362	373	376	372	352	361	370	380
8	371	374	376	375	350	375	397	383	362	369	380	381
9	372	375	377	378	381	376	382	379	379	379	379	379

Age	5.b	5.b.1	6.a	6.b	7.a	7.b	7.c	7.d	7.g	7.h	7.j	7.k
10	374	377	383	385	388	382	393	385	387	385	384	398
11	374	380	391	393	402	387	403	424	409	433	423	399
12	385	388	394	396	373	387	387	405	399	403	402	395
13	389	391	397	399		389	392	393	395	395		
14	391	393	404	413		388	388	396	425	425	425	425
15+	380	388	409	412		401	401	416				

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2020 (Q1-Q4) continued.

Age	8.a	8.b	8.c	8.c.E	8.c.W	8.d	8.e	9.a	9.a.N	12.c	All
0	177	177	202	186	0			266	194		192
1	287	246	252	297	322	322	307	288	251		125
2	305	295	290	308	323	322	295	294	280		291
3	331	335	321	338	335	337	316	325	306	335	320
4	357	353	343	353	353	339	351	354	350	333	342
5	361	351	354	364	370	357	369	371	357	365	351
6	362	361	368	366	380	363	378	377	361	368	363
7	358	362	374	374	384	366	381	385	373	369	369
8	379	377	377	378	384	379	382	377	377	380	374
9	374	379	382	379	385	375	385	395	379	378	377
10	374	375	391	387	390	376	389	405	389	382	380
11	372	374	394	392	415	386	415	405	399	455	384
12	384	390	403	397	411	391	415		401	405	388
13	382	382	400	425		382		420			390
14	396	396	410	435		396					393
15+	405	405	432	432		405			420		398

Table 8.6.1.1.1. International mackerel and horse mackerel egg survey in the western and southern areas: Periods and area assignments for countries/institutes by week for the 2022 survey. Area assignments and dates are provisional.

Week	Starts	Area 9a	Cantabrian Sea	Biscay	Celtic sea	West of Ire-land	West of Scotland	Northern area	Period
3	09-Jan-22								1
4	16-Jan-22	PO1							2
5	23-Jan-22	PO1							2
6	30-Jan-22	PO1							2
7	06-Feb-22	PO1							2
8	13-Feb-22	PO1							2
9	20-Feb -22	PO1				SCO (IBTS)	SCO (IBTS)		2
10	27-Feb-22					SCO (IBTS)	SCO (IBTS)		2
11	06-Mar-22			IEO1	IRL 1	IRL 1	IRL 1		3
12	13-Mar-22			IEO1	IRL 1	IRL 1	IRL 1		3
13	20-Mar-22		IEO1	AZTI1	GER1	IRL 1	IRL 1		3
14	27-Mar -22		IEO1	AZTI1	GER1	GER1			3
15	03-Apr-22			AZTI1	GER1	GER1			3
16	10-Apr-22		IEO2	IEO2	GER2	GER 2 /SCO1	SCO1		4
17	17-Apr-22		IEO2	IEO2	GER2	GER 2 /SCO1	SCO1		4
18	24-Apr -22		IEO2	IEO2	GER2	GER 2 /SCO1	SCO1		4
19	1-May-22		IEO2/AZTI2 (DEPM)	IEO2					4
20	8-May-22		AZTI2 (DEPM)	AZTI2 (DEPM)/ NED1	NED1	NED1 / SCO2	SCO2	NOR	5
21	15-May-22			AZTI2 (DEPM)/ NED1	NED1	NED1 / SCO2	SCO2	NOR	5
22	22-May -22			AZTI2 (DEPM)/ NED1	NED1	NED1 / SCO2	SCO2	NOR	5
23	29-May-22							FAR	6
24	5-Jun-22			NED2	NED2	IRL2	IRL2	FAR	6
25	12-Jun-22			NED2	NED2	IRL2	IRL2	FAR	6
26	19-Jun -22			NED2	NED2	IRL2	IRL2		6
27	26-Jun -22								6
28	3-Jul-22				SCO3	SCO3	SCO3		7

Week	Starts	Area 9a	Cantabrian Sea	Biscay	Celtic sea	West of Ireland	West of Scotland	Northern area	Period
29	10 –Jul-22				SCO3	SCO3	SCO3		7
30	17-Jul-22				SCO3	SCO3	SCO3		7
31	24-Jul-22				SCO3	SCO3	SCO3		6

Table 8.6.1.3.1. Daily egg production estimate (stage 1A) for mackerel in the North Sea using the DEPM.

Year	DEP $*10^{13}$	CV DEP
2021	1.28	16%

Table 8.6.2.1. Model parameter estimates and standard errors.

Symbol	Description	Unit	Estimate	Std.Error
T	Decorrelation time	year	1,9	0.3
H	Spatial decorrelation distance	km	455	82
WS	Log Wing spread	nmi	-1.0	0.6
σ_N^2	Variance of the nugget effect	1	3.7	
σ_{xy}^2	Spatial variance parameter (year specific surfaces)	1	5.3	
σ_x^2	Spatial variance parameter (intercept surface)	1	5.4	

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 -2020		Yes
Catch-at-age in numbers	1980 -2020	0-12+	Yes
Weight-at-age in the commercial catch	1980 –2020	0-12+	Yes
Weight-at-age of the spawning stock at spawning time.	1980 –2020	0-12+	Yes
Proportion of natural mortality before spawning	1980 -2021	0-12+	Yes
Proportion of fishing mortality before spawning	1980 -2021	0-12+	Yes
Proportion mature-at-age	1980 -2021	0-12+	Yes
Natural mortality	1980 -2021	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)	1998-2020	Age 0
Survey (abundance index)	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)	2010, 2012-2021	Ages 3-11
Tagging/recapture	Norwegian tagging program	Steal tags : 1980 (release year)-2006 (recapture years) RFID tags : 2013 (release year) 2020 (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	1/2/3/3/3/3/3/3/3/3/3/3/3	Separate F random walk variances for age 0, age 1 and a same variance for older ages
Coupling of log abundance random walk variances	1/2/2/2/2/2/2/2/2/2/2/2/2	Same variance used for the log abundance random walk of all ages except for the recruits (age 0)
Coupling of the observation variances	1/2/3/3/3/3/3/3/3/3/3/3/3 0/0/0/0/0/0/0/0/0/0/0/0/0 4/0/0/0/0/0/0/0/0/0/0/0/0 0/0/0/5/6/6/6/6/6/6/6/6/0	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

year

age	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	23877	11325	62142	6732	716	28306	6995	6236
1	78636	62748	66370	47077	44558	104282	57466	43763	40332	41921
2	137351	115701	204121	235494	138880	127940	205840	89101	236207	126073
3	304647	323847	216711	400036	672022	250575	258176	461621	136779	350611
4	740816	471564	417953	371713	832975	583694	427212	353230	376312	114606
5	613418	656507	458718	445515	568835	651786	593046	398273	257069	295731
6	285438	490219	514489	433533	554367	453084	534943	505073	294539	226640
7	143537	244725	325982	340686	506804	416897	341408	432242	424715	229725
8	102446	113277	143643	190660	341618	356936	270586	262799	316779	267491
9	45963	53512	69962	113220	142398	206045	170574	189449	197761	204818
10	21268	25081	30761	46269	63871	107830	94849	138347	140403	102991
11	6272	12322	11657	19025	21501	26978	33910	59278	82812	66976
12	8529	10792	11720	17890	14123	22741	24427	51139	60485	74918

year

age	2020
0	6443
1	52637
2	107302
3	182163
4	266760
5	166627
6	270154
7	246268
8	274182
9	311215
10	241775
11	128294
12	179703

Table 8.7.1.3. NE Atlantic Mackerel. WEIGHTS AT AGE IN THE CATCH

Units : Kg

year

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

year

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

	year											
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	0.126	0.154
2	0.263	0.268	0.197	0.215	0.222	0.213	0.221	0.231	0.186	0.234	0.231	0.242
3	0.323	0.306	0.307	0.292	0.292	0.283	0.291	0.282	0.284	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	0.374	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	0.394	0.392
7	0.519	0.496	0.494	0.512	0.497	0.450	0.470	0.451	0.431	0.405	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	0.443	0.443
9	0.573	0.556	0.584	0.573	0.571	0.538	0.515	0.540	0.503	0.454	0.467	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	0.603	0.611	0.537	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	0.589	0.561

	year				
age	2016	2017	2018	2019	2020
0	0.035	0.018	0.066	0.057	0.057
1	0.154	0.178	0.147	0.112	0.174
2	0.240	0.266	0.247	0.260	0.285
3	0.297	0.311	0.320	0.297	0.322
4	0.329	0.356	0.355	0.360	0.360
5	0.356	0.377	0.397	0.388	0.389
6	0.383	0.397	0.410	0.429	0.417
7	0.411	0.415	0.426	0.441	0.444
8	0.438	0.444	0.446	0.453	0.459
9	0.453	0.465	0.469	0.472	0.471
10	0.479	0.484	0.492	0.497	0.495
11	0.499	0.497	0.507	0.514	0.519
12	0.520	0.531	0.537	0.537	0.554

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	2020
0	0.000	0.000	0.000	0.000	0.000
1	0.059	0.058	0.064	0.070	0.068
2	0.182	0.204	0.190	0.191	0.210
3	0.238	0.237	0.266	0.250	0.252

4	0.282	0.278	0.283	0.293	0.289
5	0.298	0.308	0.314	0.311	0.348
6	0.340	0.308	0.327	0.346	0.363
7	0.368	0.338	0.346	0.365	0.375
8	0.385	0.377	0.364	0.371	0.394
9	0.404	0.394	0.389	0.397	0.400
10	0.424	0.426	0.419	0.428	0.423
11	0.440	0.430	0.437	0.431	0.445
12	0.473	0.499	0.491	0.481	0.486

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	1994
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	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	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	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	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	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	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	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	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	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	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	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	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	0.15

year

age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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	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	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	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	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	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	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	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	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	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	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	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	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	0.15

year

age	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	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
2	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
4	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
6	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

8	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
10	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
12	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

ear

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
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	2016	2017	2018	2019	2020
0	0.000	0.000	0.000	0.000	0.000
1	0.111	0.109	0.092	0.092	0.092
2	0.632	0.604	0.469	0.440	0.420
3	0.937	0.945	0.902	0.902	0.909
4	0.997	0.998	0.999	0.998	0.998
5	0.999	1.000	1.000	1.000	1.000
6	1.000	1.000	1.000	1.000	0.999
7	0.999	0.999	0.999	1.000	0.999
8	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000

Table 8.7.1.7. NE Atlantic Mackerel. FRACTION OF HARVEST BEFORE SPAWNING

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	0.166	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	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	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

age												
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

	year				
age	2016	2017	2018	2019	2020
0	0.000	0.000	0.000	0.000	0.000
1	0.143	0.232	0.393	0.581	0.532
2	0.224	0.153	0.180	0.183	0.184
3	0.224	0.153	0.180	0.183	0.184
4	0.224	0.153	0.180	0.183	0.184
5	0.176	0.291	0.193	0.299	0.321
6	0.176	0.291	0.193	0.299	0.321
7	0.176	0.291	0.193	0.299	0.321
8	0.176	0.291	0.193	0.299	0.321
9	0.176	0.291	0.193	0.299	0.321
10	0.176	0.291	0.193	0.299	0.321
11	0.176	0.291	0.193	0.299	0.321
12	0.176	0.291	0.193	0.299	0.321

Table 8.7.1.8. NE Atlantic Mackerel. FRACTION OF NATURAL MORTALITY BEFORE SPAWNING

	year											
age	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

	year											
age	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
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  2020
  0  0.343 0.327 0.312 0.296 0.296
  1  0.343 0.327 0.312 0.296 0.296
  2  0.343 0.327 0.312 0.296 0.296
  3  0.343 0.327 0.312 0.296 0.296
  4  0.343 0.327 0.312 0.296 0.296
  5  0.343 0.327 0.312 0.296 0.296
  6  0.343 0.327 0.312 0.296 0.296
  7  0.343 0.327 0.312 0.296 0.296
  8  0.343 0.327 0.312 0.296 0.296
  9  0.343 0.327 0.312 0.296 0.296
  10 0.343 0.327 0.312 0.296 0.296
  11 0.343 0.327 0.312 0.296 0.296
  12 0.343 0.327 0.312 0.296 0.296
```

Table 8.7.1.9. NE Atlantic Mackerel. SURVEY INDICES

Some random text			
103			
SSB-egg-based-survey			
1992	2020		
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		
1	-1		
R-idx			
1998	2020		
1	1	0	0
0	0		
1	0.012476066		
1	0.01862673		
1	0.013289745		
1	0.020583855		
1	0.026244937		
1	0.012684229		
1	0.029582367		
1	0.038157763		
1	0.034722557		
1	0.022670008		
1	0.02064922		
1	0.014607073		
1	0.02237237		
1	0.037563703		
1	0.02733911		
1	0.029964112		
1	0.022348323		
1	0.024720467		
1	0.0432534		
1	0.043849281		
1	0.039094593		
1	0.04381569		
1	0.036397234		
Swept-idx			
2010	2021		
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
1	709444	1220543	1527964	367017	1291607	811226	1051955	969868	927410

Table 8.7.1.10. NE Atlantic Mackerel. RFID recapture data for the year 2020.

Release Yr	Recapture Yr	Year-class	age at re-lease	Numbers scanned in recapture Yr	Numbers Released in Release Year	Numbers re-captured
2018	2020	2007	19391477	1670.4499	7	2
2018	2020	2008	29244736	4092.9627	20	2
2018	2020	2009	39505301	3273.9251	17	2
2018	2020	2010	99081840	6506.48	40	2
2018	2020	2011	110470858	7923.5647	50	2
2018	2020	2012	61620787	2290.2767	15	2
2018	2020	2013	53083627	3049.499	20	2
2019	2020	2008	29244736	2556.359	28	2
2019	2020	2009	39505301	2871.3265	30	2
2019	2020	2010	99081840	4727.5524	49	2
2019	2020	2011	110470858	9482.5831	101	2
2019	2020	2012	61620787	6784.5181	72	2
2019	2020	2013	53083627	8039.9448	82	2
2019	2020	2014	73636345	5824.132	59	2

Table 8.7.2.1. NE Atlantic Mackerel. SAM parameter estimates for the 2021 update.

	esti-mate	std.dev	confidence interval lower bound	confidence interval upper bound
observation standard deviations				
Catches age 0	0.91	0.18	0.63	1.29
Catches age 1	0.36	0.23	0.23	0.58
Catches age 2-12	0.11	0.16	0.08	0.15
Egg survey	0.31	0.26	0.19	0.53
Recruitment index	0.28	0.30	0.15	0.50
IESSNS age 3	0.65	0.24	0.40	1.05
IESSNS ages 4-11	0.39	0.14	0.29	0.51
Recapture overdispersion tags	1.23	0.25	1.38	1.14

	esti-mate	std.dev	confidence interval lower bound	confidence interval upper bound
random walk standard deviation				
F age 0	0.25	0.49	0.09	0.66
F age 1	0.15	0.49	0.06	0.40
F age 2+	0.13	0.19	0.09	0.18
N@age0	0.16	0.74	0.04	0.70
process error standard deviation				
N@age1-12+	0.21	0.09	0.18	0.26
catchabilities				
egg survey	1.22	0.11	0.98	1.53
recruitment index	5.13E-09	1.25E-01	3.99E-09	6.59E-09
IESSNS age 3	0.82	0.23	0.52	1.30
IESSNS age 4	1.25	0.16	0.91	1.74
IESSNS age 5	1.71	0.16	1.24	2.37
IESSNS age 6	1.83	0.16	1.32	2.53
IESSNS age 7	1.95	0.16	1.41	2.70
IESSNS age 8	1.85	0.16	1.34	2.56
IESSNS age 9	1.95	0.16	1.41	2.69
IESSNS ages 10-11	1.76	0.16	1.28	2.42
post tagging survival steal tags	0.40	0.11	0.35	0.46
post tagging survival RFID tags	0.15	0.11	0.12	0.18

Table 8.7.3.1. NE Atlantic Mackerel. STOCK SUMMARY.

Year	Recruitment			SSB			Total	F		
	Age 0	97.5%	2.5%		97.5%	2.5%	Catch	Ages 4-8	97.5%	2.5%
	thousands			tonnes			tonnes			
1980	4811944	9103354	2543547	4119074	8671627	1956585	734950	0.22	0.34	0.142
1981	4534674	7611843	2701483	3605227	6741744	1927937	754045	0.22	0.33	0.145
1982	3958511	6325237	2477347	3447225	5801256	2048412	716987	0.22	0.33	0.148
1983	3818369	6144951	2372671	3653848	5503280	2425937	672283	0.22	0.32	0.152
1984	4135091	6275612	2724671	3961825	5566850	2819557	641928	0.22	0.32	0.156
1985	4044346	6012357	2720520	3991611	5369066	2967548	614371	0.23	0.32	0.161
1986	4002878	5882364	2723910	3583027	4725155	2716966	602201	0.23	0.32	0.167
1987	4028611	5995185	2707124	3546607	4679351	2688070	654992	0.24	0.32	0.174
1988	3736555	5367336	2601261	3495772	4501128	2714969	680491	0.24	0.32	0.182
1989	3575256	5131339	2491056	3278812	4158628	2585134	585920	0.25	0.33	0.192
1990	3369803	4917469	2309231	3365579	4194884	2700222	626107	0.26	0.34	0.20
1991	3351837	4800953	2340121	3266335	4031197	2646595	675665	0.28	0.35	0.22
1992	3326467	4738555	2335182	3003550	3672340	2456556	760690	0.29	0.37	0.23
1993	3138516	4505113	2186467	2673128	3248102	2199935	824568	0.30	0.38	0.24
1994	3023339	4400830	2077012	2337129	2819585	1937226	819087	0.31	0.39	0.25
1995	2938787	4375909	1973640	2304484	2756672	1926471	756277	0.31	0.38	0.25
1996	3002031	4359860	2067082	2190841	2612949	1836922	563472	0.30	0.37	0.25

Year	Recruitment			SSB			Total	F		
1997	2993152	4357776	2055857	2158199	2542155	1832234	573029	0.30	0.36	0.25
1998	3048761	4319517	2151848	2130817	2517107	1803809	666316	0.31	0.37	0.26
1999	3293974	4450358	2438065	2320394	2739168	1965643	640309	0.32	0.38	0.27
2000	3271449	4951287	2161535	2295030	2650345	1987350	738606	0.33	0.38	0.29
2001	4292777	6126570	3007872	2179261	2512207	1890440	737463	0.36	0.42	0.31
2002	4815423	7417020	3126363	2090999	2438985	1792662	771422	0.38	0.45	0.32
2003	4130904	6090027	2802018	2008630	2340992	1723455	679287	0.39	0.48	0.33
2004	4802786	6583472	3503736	2633091	3115008	2225730	660491	0.37	0.44	0.31
2005	5625640	9180956	3447116	2382116	2826649	2007492	549514	0.31	0.36	0.26
2006	5667557	8983000	3575776	2166834	2566138	1829664	481181	0.29	0.34	0.25
2007	4995749	6845907	3645610	2288905	2690795	1947040	586206	0.32	0.37	0.27
2008	4707792	6651030	3332312	2662883	3174335	2233837	623165	0.31	0.36	0.26
2009	4664141	6892403	3156260	3312494	3959391	2771290	737969	0.28	0.34	0.24
2010	5334499	7424733	3832715	3704409	4398473	3119866	877272	0.28	0.33	0.23
2011	5942633	9273284	3808240	4259835	5076085	3574841	948963	0.27	0.32	0.23
2012	5531582	7705525	3970969	3946707	4738821	3286997	899551	0.25	0.31	0.21
2013	5385707	7419743	3909279	4381909	5289301	3630182	938299	0.25	0.31	0.21
2014	5476329	7597921	3947156	5554870	6686129	4615013	1401788	0.26	0.31	0.21
2015	5171170	7228917	3699172	5554841	6735571	4581090	1215827	0.24	0.30	0.194
2016	5760094	8655929	3833059	5278481	6432921	4331214	1100135	0.22	0.27	0.174

Year	Recruitment			SSB			Total	F		
2017	5990287	9301147	3857969	5161638	6292364	4234102	1159641	0.22	0.27	0.175
2018	6041636	9229645	3954797	4521691	5529480	3697579	1023144	0.22	0.27	0.175
2019	6511865	10937279	3877051	3876306	4840328	3104283	839727	0.22	0.27	0.170
2020	5743130*			3938555	5014229	3093639	1039513	0.25	0.32	0.193
2021	4367513**			3510849†						
Average	4437228	6589293	2961178	3336758	4296605	2630110	770070	0.28	0.35	0.22

*** RCT3 estimate.**

**** Geometric mean 1990–2019.**

† 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	4811944	4534674	3958511	3818369	4135091	4044346	4002878	4028611	3736555	3575256
1	4906985	4565117	4423099	2843973	2671751	4185674	3365317	3309721	3999914	3008842
2	2352319	4073393	4218329	4206696	2001915	1834723	4127487	2744499	2686413	3878239
3	946215	1895555	3410854	4050384	4288850	1366283	1274935	4071426	2175748	2352879
4	1634417	727096	1423284	2873361	3706346	4055632	1011884	860882	3774327	1688475
5	3502369	1211575	522286	974609	2188505	3047018	3179966	793384	539031	3020884
6	2698169	2450353	867262	383786	666298	1626455	2228626	2173505	604829	346712
7	802869	1805822	1637759	584461	268795	462096	1081089	1497106	1410459	465834
8	298539	550334	1240000	1121849	396720	192990	309071	762959	1032937	1062503
9	825062	204624	376826	851091	766625	274128	135828	205838	536597	717372
10	222856	565887	140182	257707	583219	522820	191155	92645	136364	364659
11	326164	152766	387492	95996	176141	398065	354576	129493	62794	87873
12	674935	686985	574941	656675	512830	469173	586231	631401	508358	379329

age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	3369803	3351837	3326467	3138516	3023339	2938787	3002031	2993152	3048761	3293974
1	3122075	2615669	2885102	3098425	2585116	2539144	2302095	2669526	2455580	2667233
2	2372219	2660273	1987271	2427002	2816896	2075235	2080200	1758428	2314624	1963068
3	3940417	2140088	2559852	1644365	1987870	2401889	2173801	1941637	1231726	2379204
4	1842341	3069095	1526566	2037733	1095936	1426580	1816052	1786099	1641456	1259088
5	1079949	1252621	1937084	988781	1386293	677896	971840	1209516	1522591	1270361
6	1990828	775860	949151	1158070	584868	973641	492322	730339	861227	903114
7	214963	1227778	471291	569476	649669	343127	574871	321440	481979	618348
8	352590	137127	733390	310132	339398	281855	214493	347588	264687	311353
9	722972	249253	88658	412282	183807	178892	136670	152721	212067	181519
10	464602	490373	160056	53134	216892	111103	94119	86468	103085	131703

```
  11  242415  291894  307588   97913   30040  133054   64441   49787   53266   63649
  12  307504  356962  413037  448912  334155  220092  214507  173790  142603  125449
    year
age  2000    2001    2002    2003    2004    2005    2006    2007    2008    2009
  0  3271449 4292777 4815423 4130904 4802786 5625640 5667557 4995749 4707792 4664141
  1  3069524 1905634 5055227 6085740 2853647 3788048 5562698 5232261 4119724 3991675
  2  2282784 2595111 1160261 4805824 6767442 2348077 3340129 4693422 4700668 3396575
  3  1842612 1751779 2524613  792439 3971769 5359865 1678094 2442601 4353419 4927061
  4  1844107 1308343 1555153 1568371  753796 1863630 3158145 1454237 1944926 3896436
  5  1037294 1251170  994749  921241 1008506  536915 1021782 2077797 1227021 1588070
  6   862156  678869  813023  582841  479413  477746  372778  748714 1106484  907378
  7   619208  607205  414817  383143  268963  231907  280874  254789  421706  693813
  8   375071  412556  349520  245409  186923  135367  131299  185038  178773  265207
  9   190676  240199  230717  197698  118090   87514   73349   95048  102537  109904
  10  113401  128306  128642  119191   93961   62992   52736   47701   59082   53007
  11   69909   68730   63614   67505   47920   31275   31986   34478   22178   28775
  12  122154  127574  113255   82479   57594   40348   38469   39885   31447   20450
    year
age  2010    2011    2012    2013    2014    2015    2016    2017    2018    2019
  0  5334499 5942633 5531582 5385707 5476329 5171170 5760094 5990287 6041636 6511865
  1  4157195 5347146 6063029 4400260 4140907 5638931 3535950 5147012 4157675 4085909
  2  3868325 3287650 5496980 6407927 3633802 3302939 5043805 2171821 5012797 2968396
  3  3337197 3625580 2687931 5237881 6886128 2894679 2655306 4399675 1391233 3595444
  4  4653138 3033068 2956488 2402430 5041550 4608605 2702920 2090078 2795349  944287
  5  2934771 3375706 2376216 2458937 2391391 3592391 3380966 2094232 1343719 1457244
  6  1266128 2128897 2415490 2204974 2341222 1947569 2822270 2867086 1439873 1044754
  7   567224  916877 1361364 1608738 2009982 1829486 1558096 2537033 2178762 1045851
  8   379544  415737  602998  861848 1342799 1506580 1335250 1254062 1787575 1533512
  9   170567  207787  269303  409522  600520  959816  891519 1058229  978854 1263562
  10   74593   94860  125480  167550  268317  457779  524716  655479  664292  585991
  11   25440   46199   52475   81814   91627  135696  224733  358678  461162  405285
  12   32038   39467   49456   69104   65793  100889  133922  260203  331065  441157
    year
age  2020
  0  6597436
  1  5442333
  2  2773562
  3  2031825
  4  2325558
  5   815955
  6  1175515
  7   987483
  8  1021186
  9  1197961
  10 1075322
  11  509948
  12  715077
```

Table 8.7.3.3. NE Atlantic Mackerel. ESTIMATED FISHING MORTALITY

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	0.031	0.031	0.031	0.031	0.031	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	0.059	0.059	0.060	0.061	0.061
3	0.112	0.112	0.112	0.112	0.113	0.115	0.117	0.119	0.121	0.124	0.127	0.130	0.132	0.136
4	0.182	0.183	0.183	0.184	0.185	0.187	0.191	0.197	0.201	0.208	0.213	0.218	0.222	0.225
5	0.207	0.207	0.208	0.210	0.211	0.214	0.218	0.222	0.227	0.232	0.237	0.242	0.251	0.257
6	0.253	0.254	0.255	0.256	0.259	0.263	0.267	0.273	0.278	0.289	0.299	0.308	0.316	0.324
7	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
8	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
9	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
10	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
11	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
12	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352

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	0.008	0.007	0.007	0.007	0.006	0.005	0.005	0.005	0.005
1	0.030	0.030	0.030	0.030	0.030	0.030	0.029	0.028	0.027	0.024	0.021	0.019	0.019	0.018
2	0.062	0.063	0.063	0.065	0.066	0.067	0.068	0.068	0.067	0.066	0.068	0.063	0.055	0.046
3	0.138	0.140	0.143	0.146	0.149	0.156	0.164	0.158	0.158	0.144	0.146	0.135	0.115	0.107
4	0.228	0.229	0.230	0.230	0.235	0.242	0.254	0.263	0.259	0.235	0.222	0.196	0.182	0.176
5	0.261	0.266	0.273	0.285	0.300	0.314	0.331	0.321	0.325	0.320	0.309	0.278	0.254	0.261
6	0.327	0.329	0.329	0.331	0.336	0.348	0.366	0.401	0.396	0.399	0.381	0.343	0.331	0.327
7	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
8	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
9	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
10	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
11	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
12	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411

year

age	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
1	0.016	0.015	0.015	0.014	0.014	0.013	0.013	0.014	0.013	0.012	0.012	0.012	0.011
2	0.041	0.039	0.039	0.039	0.040	0.041	0.042	0.043	0.045	0.046	0.049	0.047	0.044
3	0.104	0.103	0.102	0.099	0.094	0.093	0.102	0.102	0.109	0.114	0.112	0.110	0.105
4	0.176	0.182	0.183	0.179	0.173	0.178	0.180	0.165	0.177	0.180	0.160	0.145	0.138
5	0.254	0.247	0.246	0.237	0.232	0.230	0.248	0.226	0.218	0.225	0.231	0.239	0.244
6	0.303	0.298	0.282	0.276	0.262	0.253	0.269	0.263	0.236	0.228	0.243	0.254	0.270
7	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
8	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
9	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
10	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
11	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
12	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296

Table 8.7.5.1. NE Atlantic Mackerel. Comparison of estimated SAM parameters (and uncertainty) between the 2021 WGIWDE assessment and an assessment starting at age 2.

	parameters values			parameter standard deviation		
	current	Age 2	% difference	current	Age 2	% difference
observation standard deviations						
Catches age 0	0.91	X		0.18	X	
Catches age 1	0.36	X		0.23	X	
Catches age 2-12	0.11	0.11	3%	0.16	0.15	-9%
Egg survey	0.31	0.32	1%	0.26	0.26	0%
Recruitment index	0.28	X		0.30	X	
IESSNS age 3	0.65	0.61	-5%	0.24	0.24	-1%
IESSNS ages 4-11	0.39	0.39	2%	0.14	0.14	3%
Recapture overdispersion tags	4.33	4.25	-2%	0.25	0.24	-2%
process variances						
F age 0	0.25	X		0.49	X	
F age 1	0.15	X		0.49	X	
F age 2+	0.13	0.16	24%	0.19	0.14	-24%
Rec Var	0.16	0.55	246%	0.74	0.15	-80%
Proc Err Var	0.21	0.18	-16%	0.09	0.10	14%
catchabilities						
egg survey	1.22	1.23	1%	0.11	0.11	-1%
recruitment index	0.00	X		0.13	X	
IESSNS age 3	0.82	0.87	6%	0.23	0.22	-5%
IESSNS age 4	1.25	1.26	1%	0.16	0.16	-2%
IESSNS age 5	1.71	1.68	-2%	0.16	0.16	-1%
IESSNS age 6	1.83	1.79	-2%	0.16	0.16	-1%
IESSNS age 7	1.95	1.96	0%	0.16	0.16	0%
IESSNS age 8	1.85	1.86	1%	0.16	0.16	0%
IESSNS age 9	1.95	1.96	1%	0.16	0.16	0%
IESSNS ages 10-11	1.76	1.77	0%	0.16	0.16	0%

	parameters values			parameter standard deviation		
	current	Age 2	% difference	current	Age 2	% difference
logitReleaseSurvival_0	0.67	0.64	-4%	0.11	0.10	-10%
logitReleaseSurvival_1	0.17	0.17	2%	0.11	0.11	-4%

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
2021								
0	4367513	0.15	0.000	0.000	0.301	0.000	0.002	0.060
1	4935722	0.15	0.092	0.502	0.301	0.067	0.012	0.144
2	4631377	0.15	0.443	0.182	0.301	0.197	0.047	0.264
3	2123273	0.15	0.905	0.182	0.301	0.256	0.110	0.313
4	1673559	0.15	0.998	0.182	0.301	0.289	0.149	0.358
5	1724965	0.15	1.000	0.271	0.301	0.324	0.239	0.391
6	418933	0.15	1.000	0.271	0.301	0.345	0.256	0.419
7	948935	0.15	1.000	0.271	0.301	0.362	0.247	0.437
8	612978	0.15	1.000	0.271	0.301	0.377	0.247	0.453
9	700155	0.15	1.000	0.271	0.301	0.395	0.247	0.471
10	741590	0.15	1.000	0.271	0.301	0.423	0.247	0.495
11	696832	0.15	1.000	0.271	0.301	0.438	0.247	0.513
12+	784248	0.15	1.000	0.271	0.301	0.486	0.247	0.543
2022								
0	4367513	0.15	0.000	0.000	0.301	0.000	0.002	0.060
1	-	0.15	0.092	0.502	0.301	0.067	0.012	0.144
2	-	0.15	0.443	0.182	0.301	0.197	0.047	0.264
3	-	0.15	0.905	0.182	0.301	0.256	0.110	0.313
4	-	0.15	0.998	0.182	0.301	0.289	0.149	0.358
5	-	0.15	1.000	0.271	0.301	0.324	0.239	0.391
6	-	0.15	1.000	0.271	0.301	0.345	0.256	0.419

	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
7	-	0.15	1.000	0.271	0.301	0.362	0.247	0.437
8	-	0.15	1.000	0.271	0.301	0.377	0.247	0.453
9	-	0.15	1.000	0.271	0.301	0.395	0.247	0.471
10	-	0.15	1.000	0.271	0.301	0.423	0.247	0.495
11	-	0.15	1.000	0.271	0.301	0.438	0.247	0.513
12+	-	0.15	1.000	0.271	0.301	0.486	0.247	0.543
2023								
0	4367513	0.15	0.000	0.000	0.301	0.000	0.002	0.060
1	-	0.15	0.092	0.502	0.301	0.067	0.012	0.144
2	-	0.15	0.443	0.182	0.301	0.197	0.047	0.264
3	-	0.15	0.905	0.182	0.301	0.256	0.110	0.313
4	-	0.15	0.998	0.182	0.301	0.289	0.149	0.358
5	-	0.15	1.000	0.271	0.301	0.324	0.239	0.391
6	-	0.15	1.000	0.271	0.301	0.345	0.256	0.419
7	-	0.15	1.000	0.271	0.301	0.362	0.247	0.437
8	-	0.15	1.000	0.271	0.301	0.377	0.247	0.453
9	-	0.15	1.000	0.271	0.301	0.395	0.247	0.471
10	-	0.15	1.000	0.271	0.301	0.423	0.247	0.495
11	-	0.15	1.000	0.271	0.301	0.438	0.247	0.513
12+	-	0.15	1.000	0.271	0.301	0.486	0.247	0.543

Table 8.8.3.2. NE Atlantic Mackerel. Short-term prediction: Multi-option table for 1 199 103 t catch in 2021 and a range of F-values in 2022.

2021			
TSB	SSB	F_{bar}	Catch
4 828 401	3 510 849	0.354	1 199 103

2022				2023		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
4419995	3479949	0.00	0	4918697	4056937	-100.0%
-	3473113	0.01	33966	4890260	4022211	-97.2%
-	3466295	0.02	67639	4862072	3987876	-94.4%
-	3459494	0.03	101023	4834131	3953927	-91.6%
-	3452710	0.04	134118	4806433	3920358	-88.8%
-	3445943	0.05	166930	4778976	3887167	-86.1%
-	3439194	0.06	199460	4751758	3854347	-83.4%
-	3432461	0.07	231710	4724778	3821894	-80.7%
-	3425746	0.08	263685	4698031	3789803	-78.0%
-	3419048	0.09	295386	4671516	3758070	-75.4%
-	3412366	0.10	326816	4645232	3726691	-72.7%
-	3405702	0.11	357978	4619174	3695661	-70.1%
-	3399055	0.12	388874	4593342	3664975	-67.6%
-	3392424	0.13	419507	4567733	3634630	-65.0%
-	3385810	0.14	449879	4542345	3604621	-62.5%
-	3379213	0.15	479994	4517176	3574945	-60.0%
-	3372633	0.16	509853	4492223	3545596	-57.5%
-	3366070	0.17	539459	4467485	3516571	-55.0%
-	3359522	0.18	568814	4442959	3487866	-52.6%
-	3352992	0.19	597921	4418643	3459476	-50.1%
-	3346478	0.20	626783	4394536	3431399	-47.7%
-	3339981	0.21	655400	4370635	3403630	-45.3%
-	3333500	0.22	683777	4346938	3376165	-43.0%

2022				2023		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	3327035	0.23	711915	4323443	3349000	-40.6%
-	3320587	0.24	739817	4300148	3322132	-38.3%
-	3314155	0.25	767485	4277052	3295558	-36.0%
-	3307739	0.26	794920	4254153	3269273	-33.7%
-	3301339	0.27	822126	4231447	3243274	-31.4%
-	3294956	0.28	849105	4208935	3217558	-29.2%
-	3288588	0.29	875858	4186613	3192120	-27.0%
-	3282237	0.30	902388	4164480	3166958	-24.7%
-	3275902	0.31	928697	4142534	3142068	-22.6%
-	3269583	0.32	954787	4120773	3117447	-20.4%
-	3263279	0.33	980661	4099195	3093092	-18.2%
-	3256992	0.34	1006320	4077800	3068999	-16.1%
-	3250720	0.35	1031766	4056584	3045165	-14.0%
-	3244464	0.36	1057002	4035546	3021586	-11.9%
-	3238224	0.37	1082029	4014685	2998261	-9.8%
-	3232000	0.38	1106849	3993998	2975185	-7.7%
-	3225791	0.39	1131465	3973485	2952356	-5.6%
-	3219598	0.40	1155878	3953143	2929770	-3.6%
-	3213421	0.41	1180091	3932971	2907425	-1.6%
-	3207259	0.42	1204104	3912966	2885318	0.4%
-	3201112	0.43	1227921	3893129	2863446	2.4%
-	3194981	0.44	1251543	3873456	2841805	4.4%
-	3188866	0.45	1274971	3853946	2820394	6.3%
-	3182766	0.46	1298209	3834598	2799209	8.3%
-	3176681	0.47	1321256	3815410	2778247	10.2%
-	3170611	0.48	1344116	3796381	2757507	12.1%
-	3164557	0.49	1366790	3777509	2736984	14.0%
-	3158517	0.50	1389280	3758793	2716677	15.9%

2022				2023		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	3152493	0.51	1411587	3740231	2696584	17.7%
-	3146484	0.52	1433714	3721821	2676700	19.6%
-	3140491	0.53	1455662	3703563	2657024	21.4%
-	3134512	0.54	1477432	3685454	2637554	23.2%
-	3128548	0.55	1499027	3667494	2618287	25.0%
-	3122599	0.56	1520448	3649680	2599219	26.8%
-	3116665	0.57	1541696	3632012	2580350	28.6%
-	3110746	0.58	1562774	3614488	2561677	30.3%
-	3104841	0.59	1583682	3597107	2543196	32.1%
-	3098952	0.60	1604424	3579867	2524907	33.8%
-	3093077	0.61	1624999	3562767	2506806	35.5%
-	3087217	0.62	1645410	3545806	2488892	37.2%
-	3081371	0.63	1665658	3528982	2471162	38.9%
-	3075540	0.64	1685745	3512294	2453613	40.6%
-	3069724	0.65	1705672	3495741	2436245	42.2%
-	3063922	0.66	1725441	3479322	2419054	43.9%
-	3058135	0.67	1745053	3463035	2402038	45.5%
-	3052362	0.68	1764509	3446878	2385196	47.2%
-	3046603	0.69	1783812	3430852	2368525	48.8%
-	3040859	0.70	1802963	3414954	2352024	50.4%
-	3035130	0.71	1821962	3399183	2335689	51.9%
-	3029414	0.72	1840812	3383538	2319520	53.5%
-	3023713	0.73	1859513	3368018	2303514	55.1%
-	3018026	0.74	1878068	3352622	2287670	56.6%
-	3012353	0.75	1896478	3337349	2271985	58.2%
-	3006694	0.76	1914743	3322196	2256458	59.7%
-	3001050	0.77	1932866	3307164	2241086	61.2%
-	2995419	0.78	1950847	3292252	2225868	62.7%

2022				2023		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	2989803	0.79	1968688	3277457	2210802	64.2%
-	2984200	0.80	1986391	3262779	2195887	65.7%
-	2978611	0.81	2003955	3248217	2181120	67.1%
-	2973037	0.82	2021384	3233769	2166499	68.6%
-	2967476	0.83	2038678	3219436	2152024	70.0%
-	2961929	0.84	2055838	3205214	2137692	71.4%
-	2956395	0.85	2072865	3191105	2123501	72.9%
-	2950876	0.86	2089761	3177105	2109450	74.3%
-	2945370	0.87	2106528	3163215	2095538	75.7%
-	2939878	0.88	2123165	3149434	2081762	77.1%
-	2934399	0.89	2139675	3135760	2068122	78.4%
-	2928934	0.90	2156058	3122192	2054615	79.8%
-	2923483	0.91	2172316	3108730	2041239	81.2%
-	2918045	0.92	2188450	3095372	2027994	82.5%
-	2912621	0.93	2204460	3082118	2014878	83.8%
-	2907210	0.94	2220349	3068966	2001890	85.2%
-	2901812	0.95	2236118	3055916	1989027	86.5%
-	2896428	0.96	2251766	3042966	1976289	87.8%
-	2891057	0.97	2267296	3030116	1963673	89.1%
-	2885700	0.98	2282709	3017364	1951180	90.4%
-	2880355	0.99	2298005	3004711	1938806	91.6%
-	2875024	1.00	2313186	2992154	1926551	92.9%
-	2869706	1.01	2328252	2979694	1914413	94.2%
-	2864402	1.02	2343205	2967328	1902392	95.4%
-	2859110	1.03	2358047	2955057	1890485	96.7%
-	2853831	1.04	2372777	2942879	1878691	97.9%
-	2848566	1.05	2387396	2930793	1867010	99.1%
-	2843313	1.06	2401907	2918800	1855439	100.3%

2022				2023		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
-	2838074	1.07	2416310	2906897	1843978	101.5%
-	2832847	1.08	2430605	2895084	1832624	102.7%
-	2827634	1.09	2444794	2883360	1821378	103.9%

Table 8.8.3.3. NE Atlantic Mackerel. Short-term prediction: Management option table for 1 199 103 t catch in 2021 and a range of catch options in 2022.

Rationale	Catch (2022)	F_{bar} (2022)	SSB (2022)	SSB (2023)	% SSB change	% catch change	% advice change
MSY approach: F = FMSY	794920	0.26	3307739	3269273	-1.2	-33.7	-6.7
Catch (2022) = Zero	0	0	3479949	4056937	16.6	-100.0	-100.0
Catch (2022) = 2021 catch −20%	959282	0.32	3268490	3113212	-4.8	-20.0	12.6
Catch (2022) = 2021 catch	1199103	0.42	3208545	2889918	-9.9	0.0	40.7
Catch (2022) = 2021 catch +25%	1498879	0.55	3128589	2618418	-16.3	25.0	75.9
Fbar (2022) = Fbar (2021)	1041030	0.35	3248428	3036502	-6.5	-13.2	22.1
Fbar (2022) = 0.36 (Fpa)	1057002	0.36	3244464	3021586	-6.9	-11.9	24.0
Fbar (2022) = 0.46 (Flim)	1298209	0.46	3182766	2799209	-12.1	8.3	52.3
SSB (2023) = Blim	2220349	0.94	2907210	2001890	-31.2	85.4	160.8
SSB (2023) = Bpa	1541696	0.57	3116665	2580350	-17.3	28.8	81.2

*** SSB 2023 relative to SSB 2022.**

**** Catch in 2022 relative to estimated catches in 2021 (1 199 103 t). There is no internationally agreed TAC for 2021.**

***** Advice value for 2022 relative to the advice value for 2021 (852 284 t).**

8.15 Figures

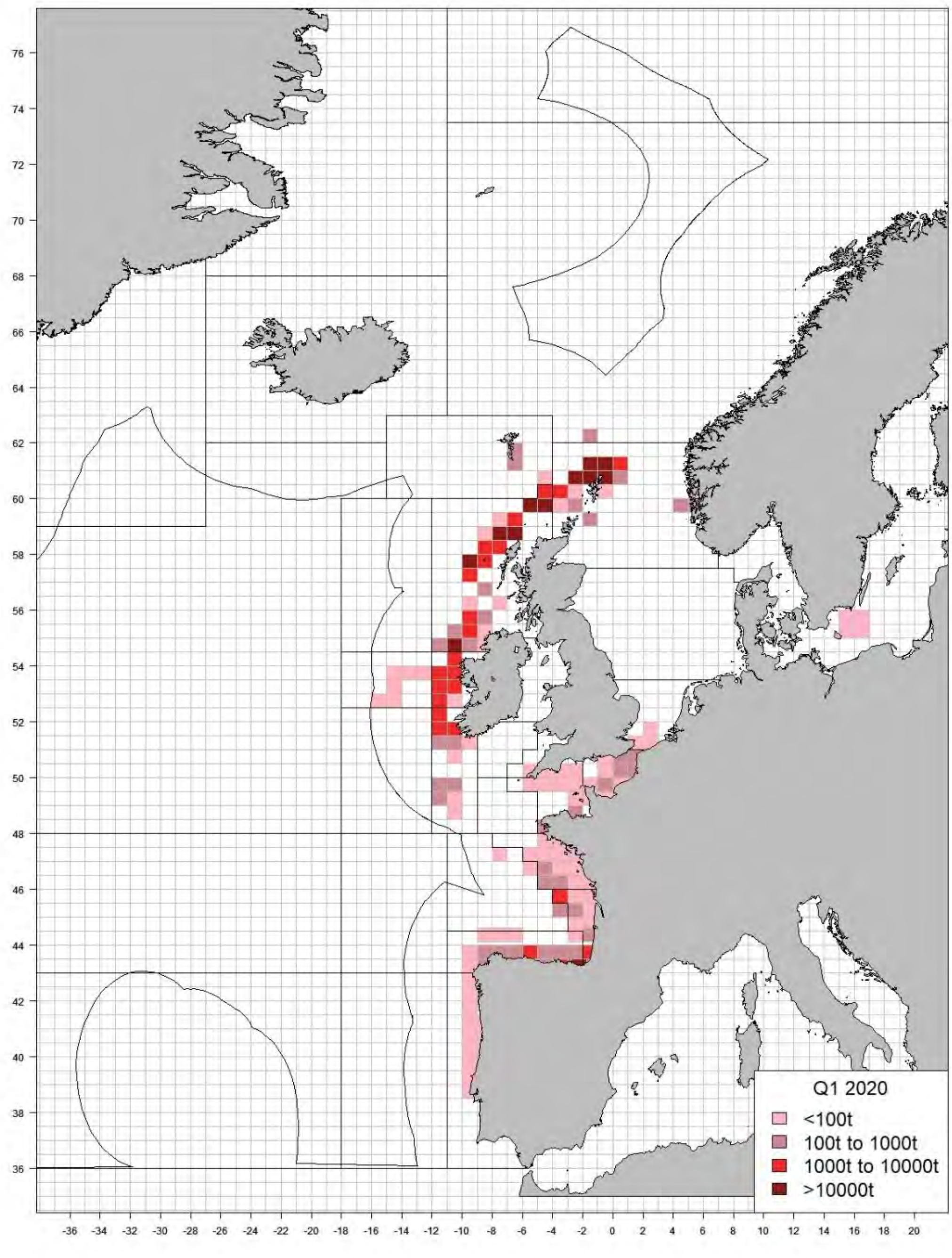


Figure 8.4.2.1. NE Atlantic Mackerel. Commercial catches in 2020, quarter 1.

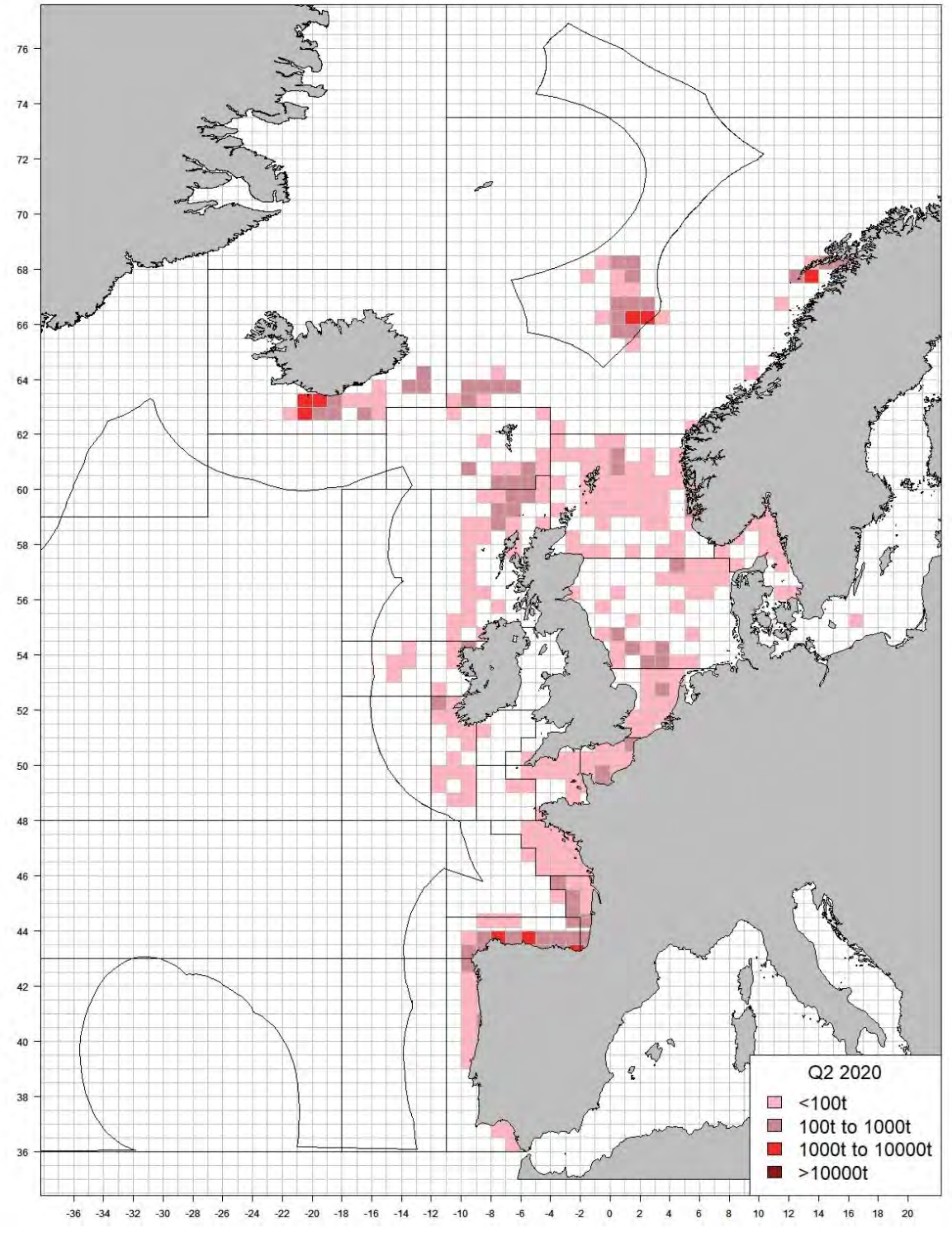


Figure 8.4.2.2. NE Atlantic Mackerel. Commercial catches in 2020, quarter 2.

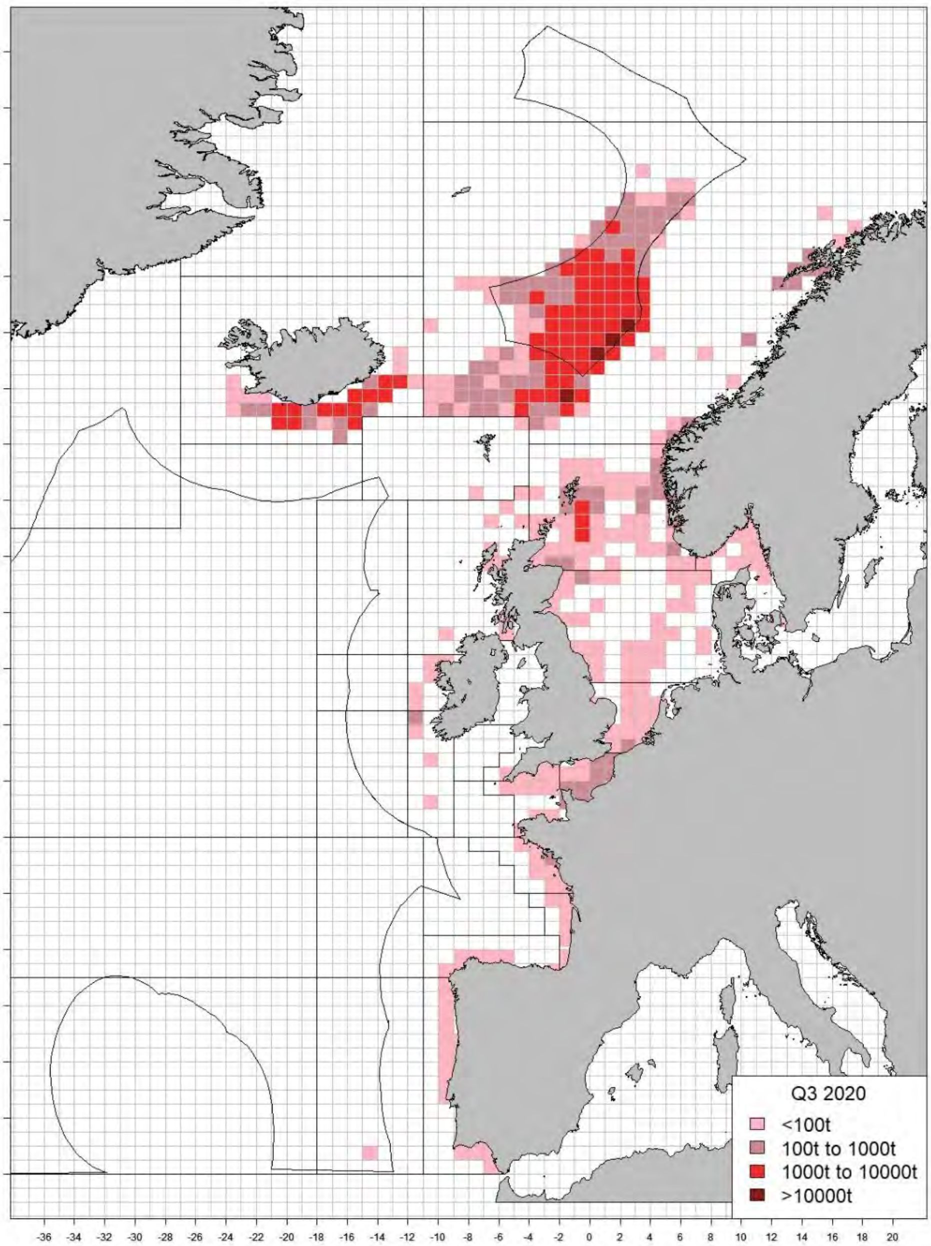


Figure 8.4.2.3. NE Atlantic Mackerel. Commercial catches in 2020, quarter 3.

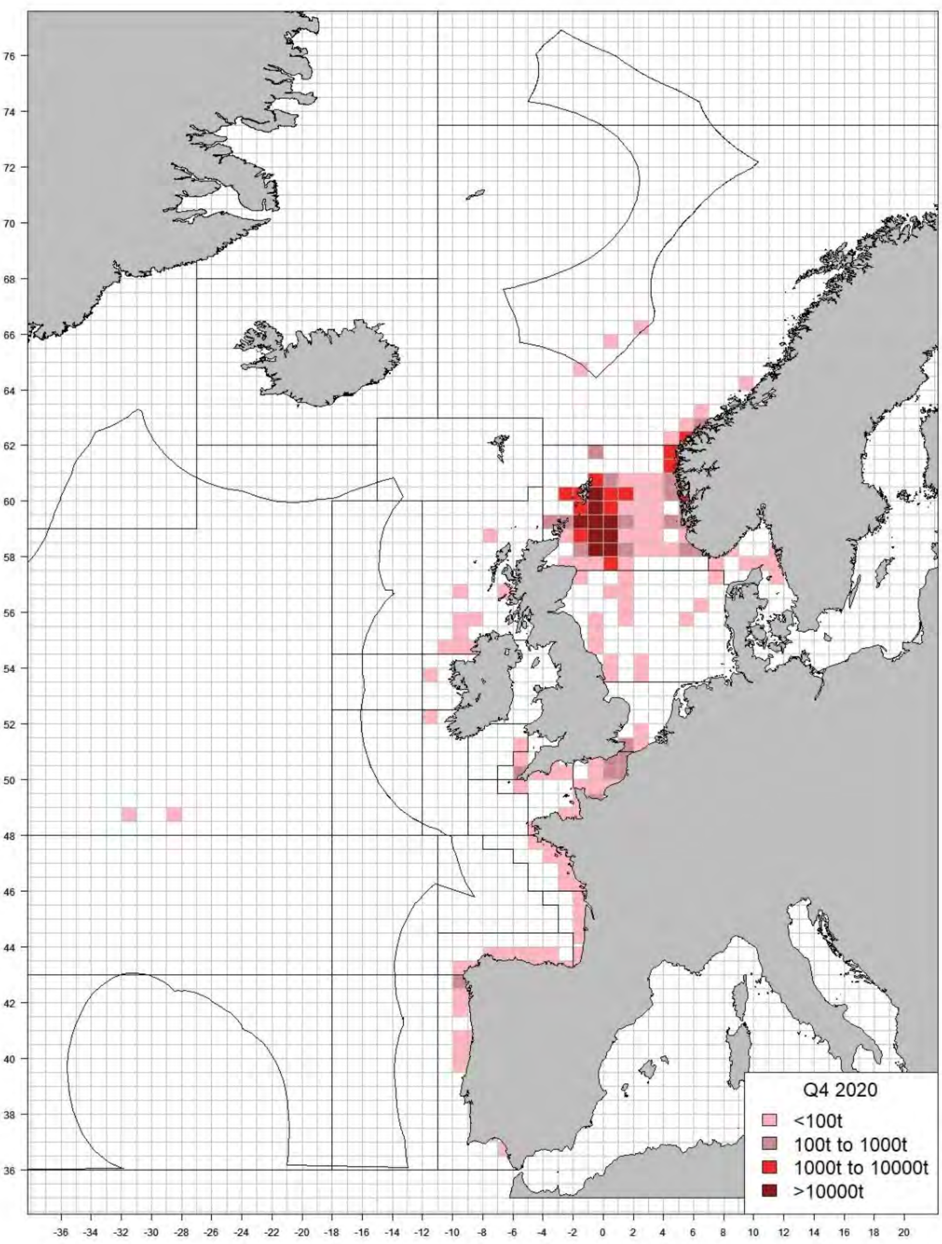


Figure 8.4.2.4. NE Atlantic Mackerel. Commercial catches in 2020, quarter 4.

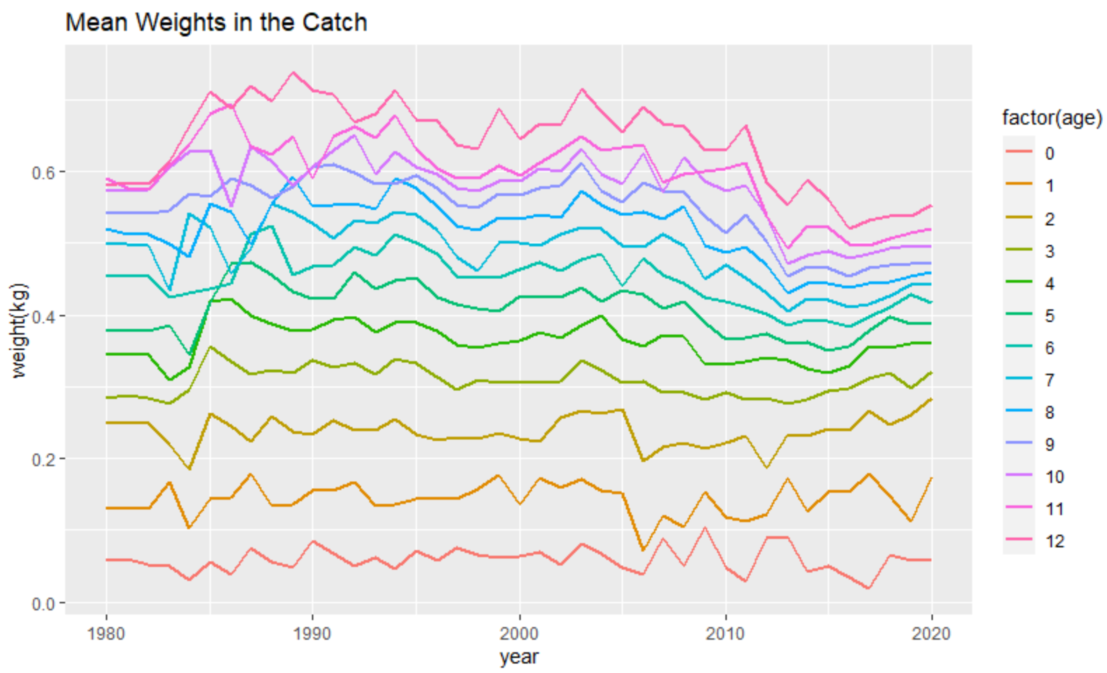


Figure 8.5.2.1. NE Atlantic mackerel. Weights-at-age in the catch.

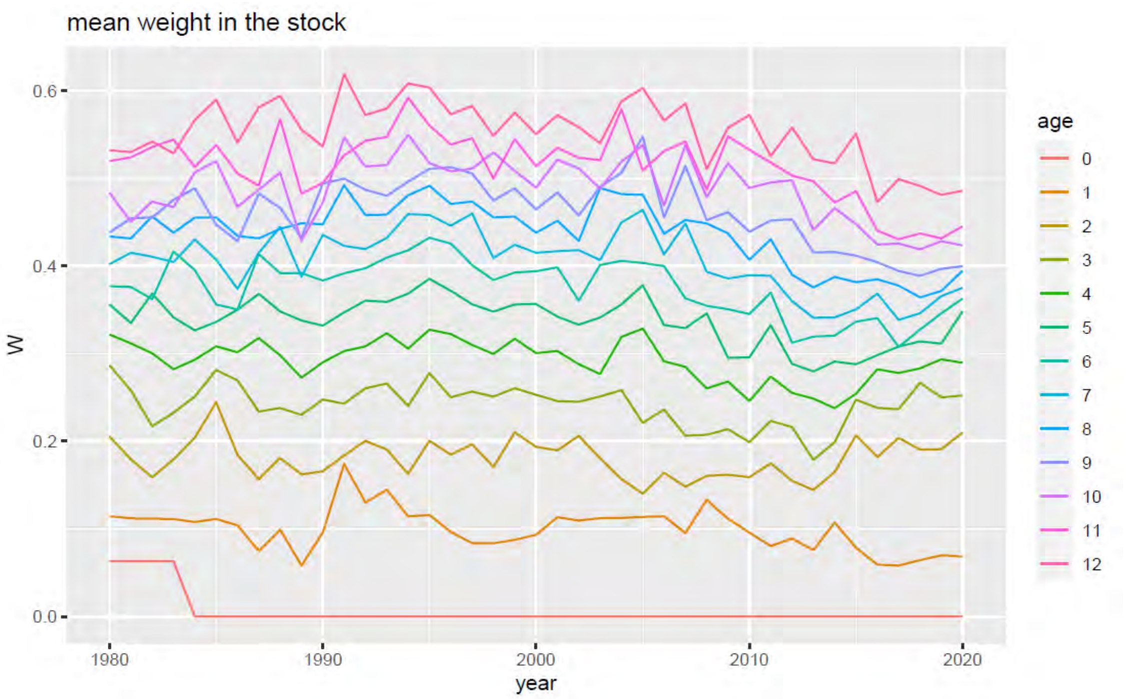


Figure 8.5.2.2. NE Atlantic mackerel. Weights-at-age in the stock.

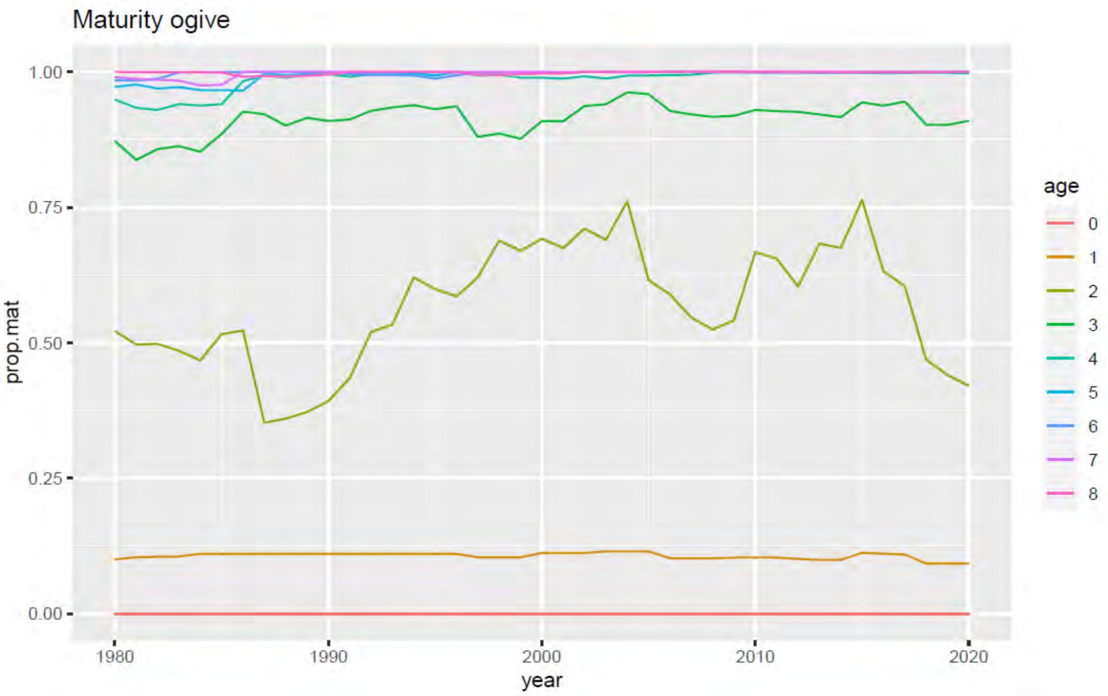


Figure 8.5.3.1. NE Atlantic mackerel. Proportion of mature fish at age.

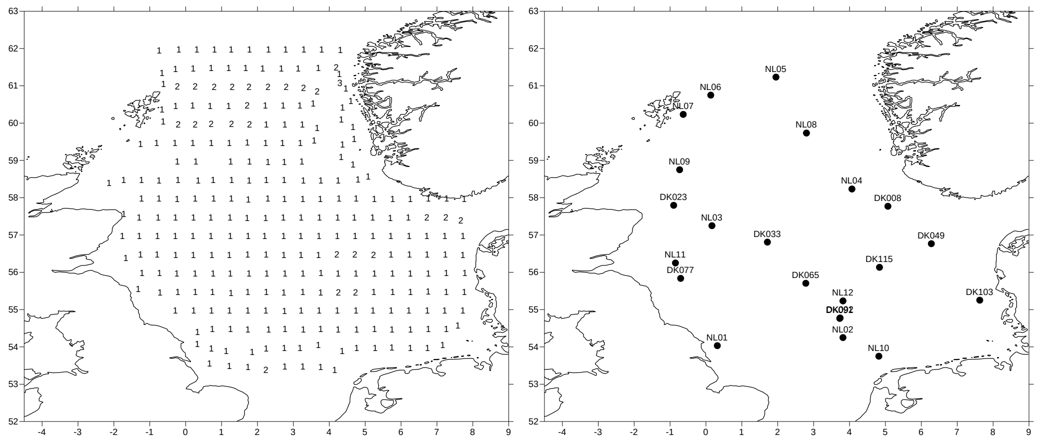


Figure 8.6.1.3.1. Number of samples for NSMEGS 2021; plankton samples per half ICES rectangle (left) and pelagic trawl hauls for mackerel adult samples (right).

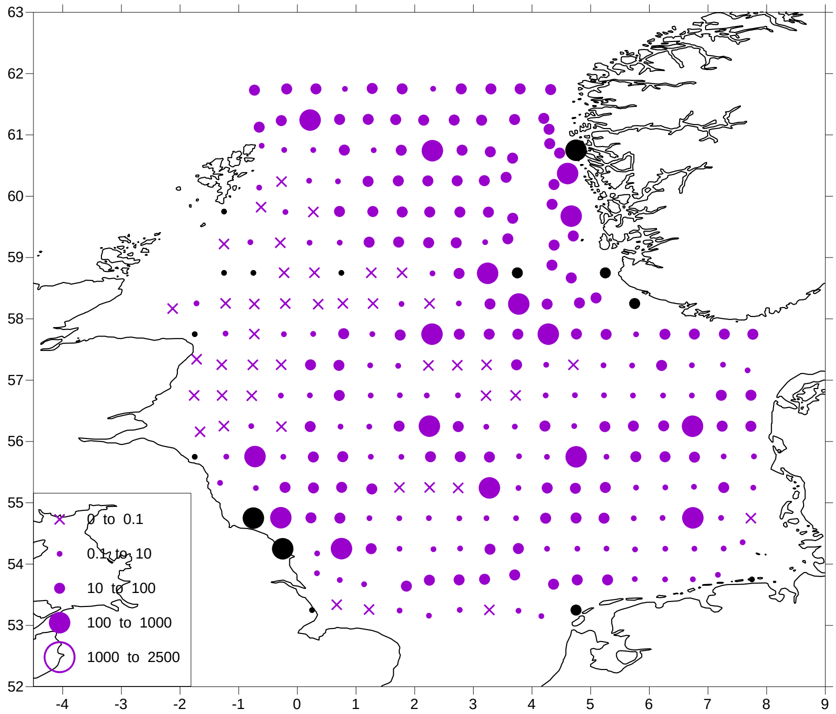


Figure 8.6.1.3.2. Stage 1A mackerel egg production (eggs/m²/day) by half rectangle for NSMEGS 2021. Purple circles represent observed values, black circles represent interpolated values, and crosses represent observed zeros.

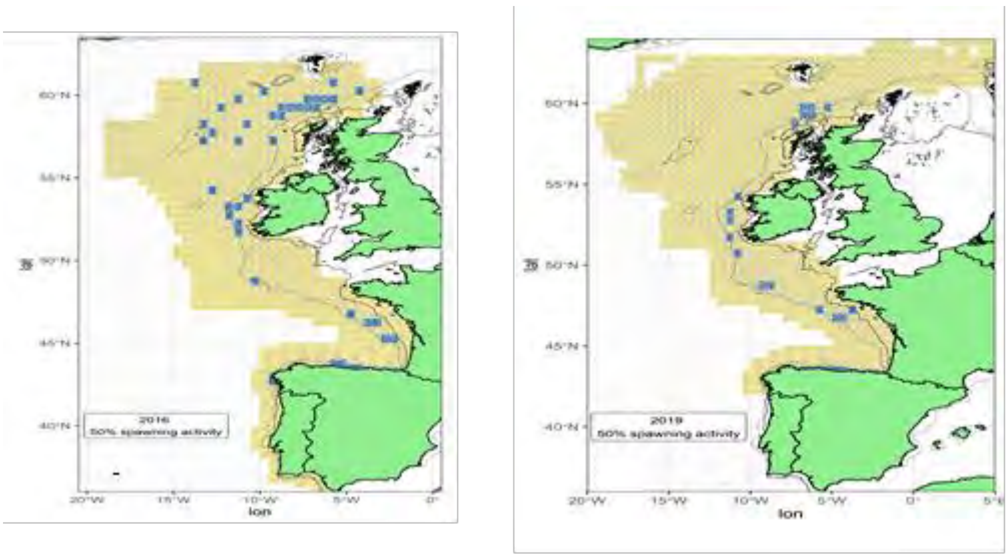


Figure 8.6.1.4.1.: Aggregated daily egg production values (stage 1 eggs/m2 /day) by half ICES rectangle for all MEGS stations sampled in 2016 and 2019 for all periods. Egg production values are square root transformed. Crosses denote locations where sampling was undertaken but where no spawning was recorded. Area in yellow denotes the maximum geographical survey extent for the western and southern survey area. Stations ranked in descending order and half ICES rectangles capturing 50% of total spawning activity overlaid in blue.

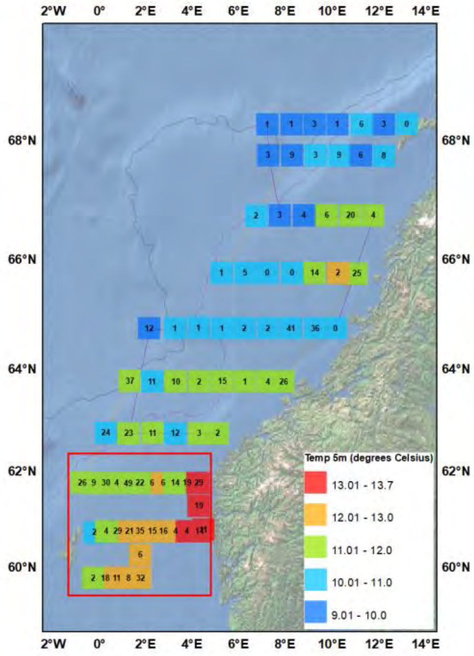


Figure 8.6.1.4.2.: Mackerel stage 1 egg counts/m²/day survey 0321H, for all stations sampled. The coloured squares represent the surface temperature in degrees Celsius at 5m depth during the ichthyoplankton deployments. Red outlined area denotes stations completed as part of North Sea MEGS.

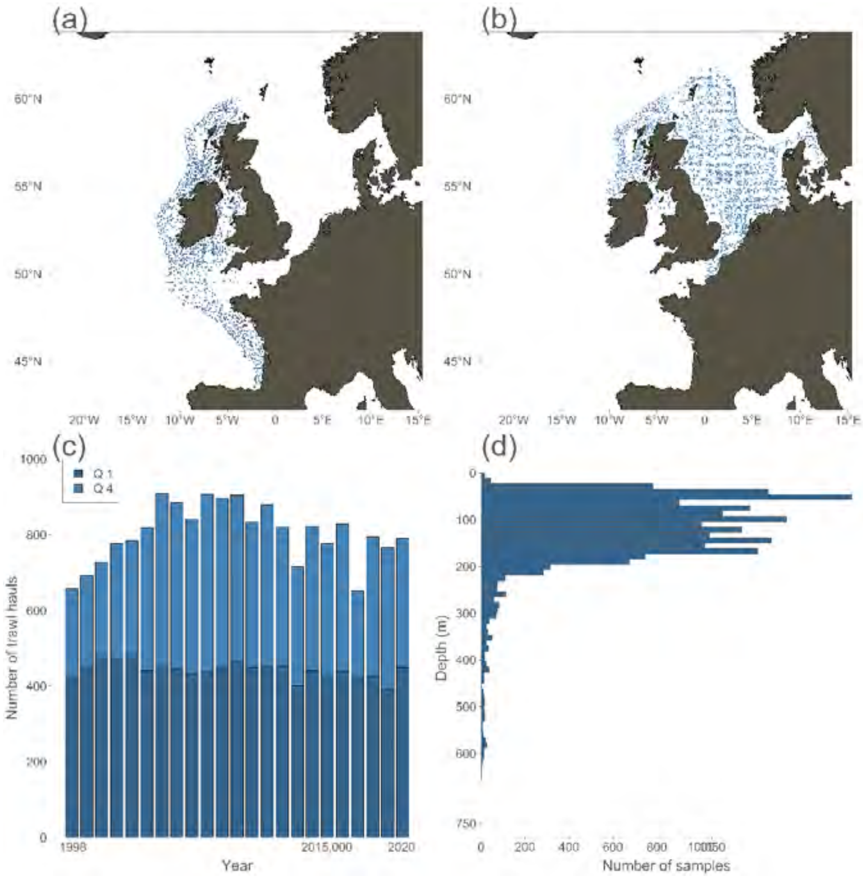


Figure 8.6.2.1. Demersal trawl survey data used to derive the abundance index of age-0 mackerel. (a) Trawl sample locations in the fourth quarter (Q4, October - November, blue dots); (b) trawl sample locations in the first quarter (Q1, January - March, light blue dots); (c) number of samples by year and quarter; and (d) depth.

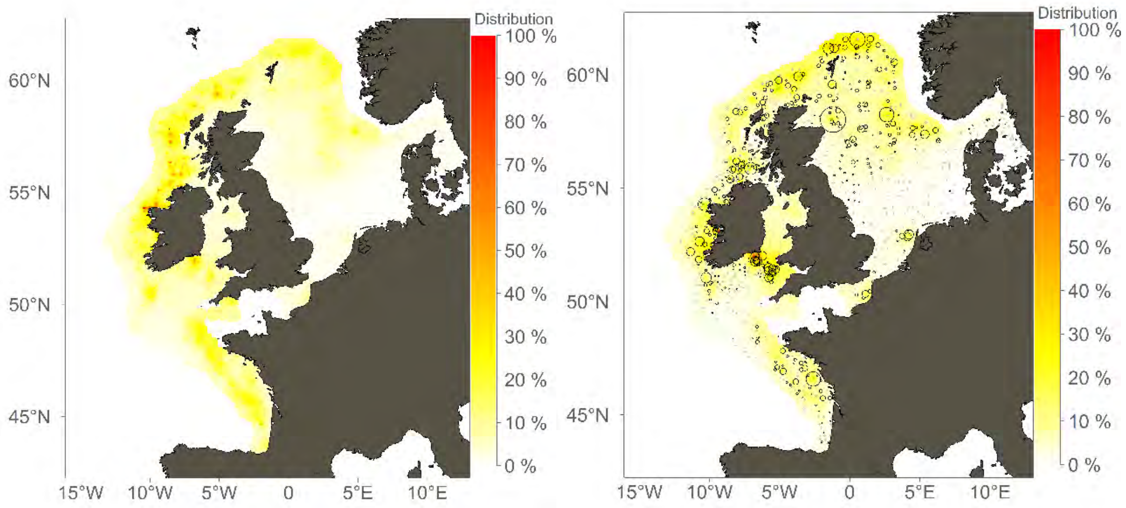


Figure 8.6.2.2. Spatial distribution of mackerel juveniles at age 0 in October to March. On the left, average for cohorts from 1998-2020; and on the right, 2020 cohort. Mackerel squared catch rates by trawl haul (circle areas represent catch rates in kg/km2) overlaid on modelled squared catch rates per 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.

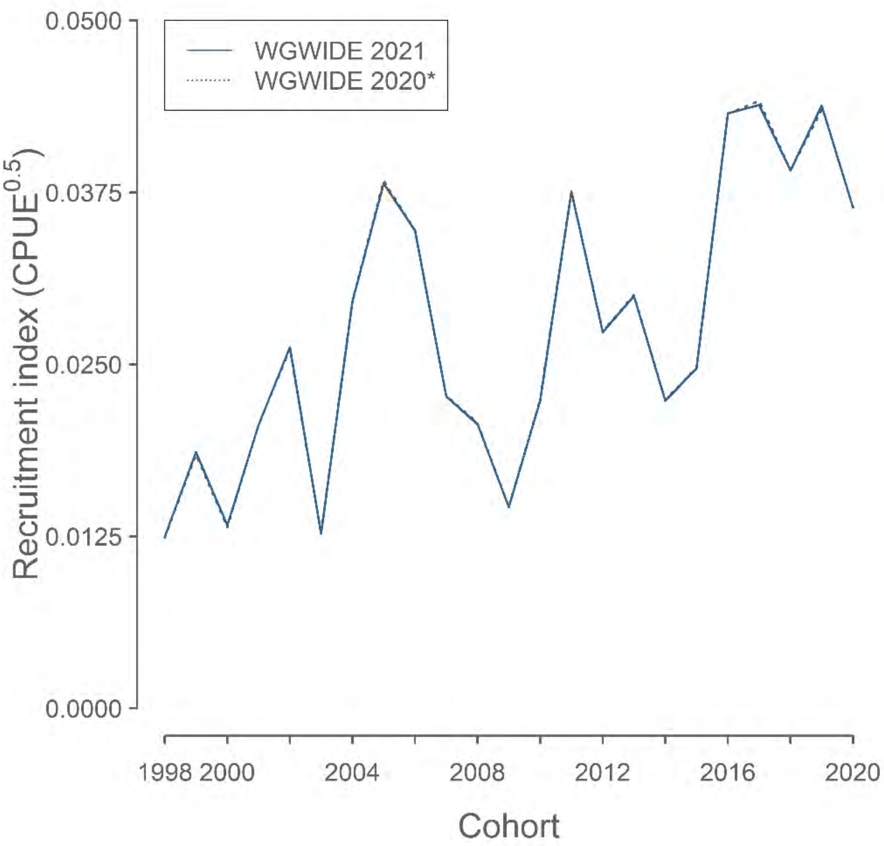


Figure 8.6.2.3. Index of mackerel juveniles at age 0 in October to March proxied by annual integration of square root of expected catch in demersal trawl surveys (Blue lines). See Jansen *et al.* (2015) for details. * Rescaled

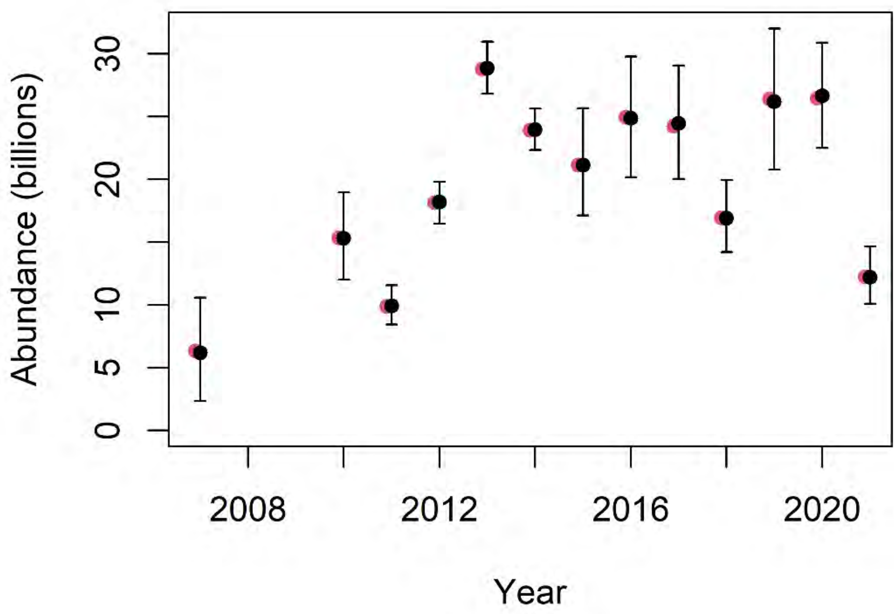


Figure 8.6.3.1. Estimated total stock numbers (TSN) of mackerel from IESSNS calculated using StoX for the years 2007 and from 2010 to 2021. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea and survey coverage was incomplete in 2007 and 2011.

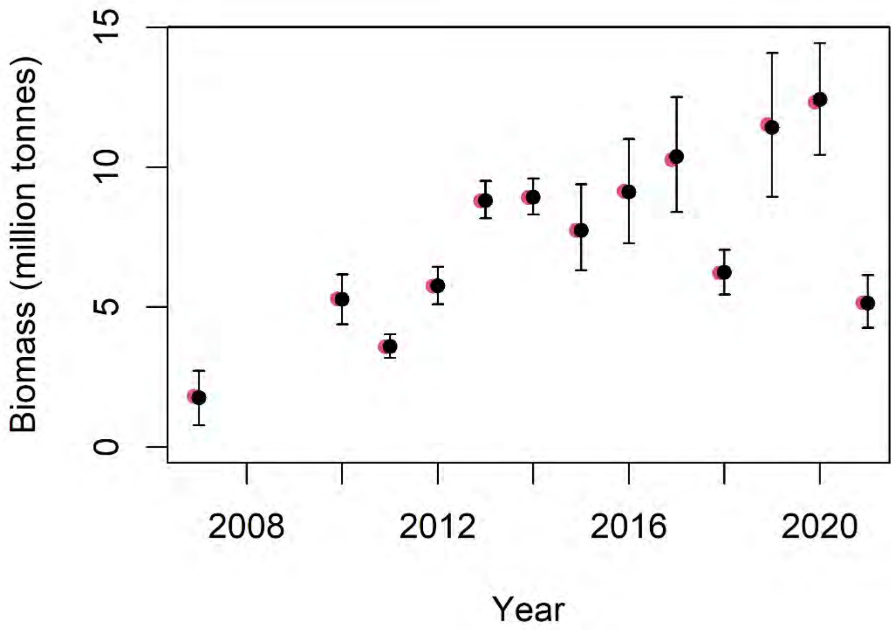


Figure 8.6.3.2. Estimated total stock biomass of mackerel from IESSNS calculated using StoX for the years 2007 and from 2010 to 2021. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea and survey coverage was incomplete in 2007 and 2011.

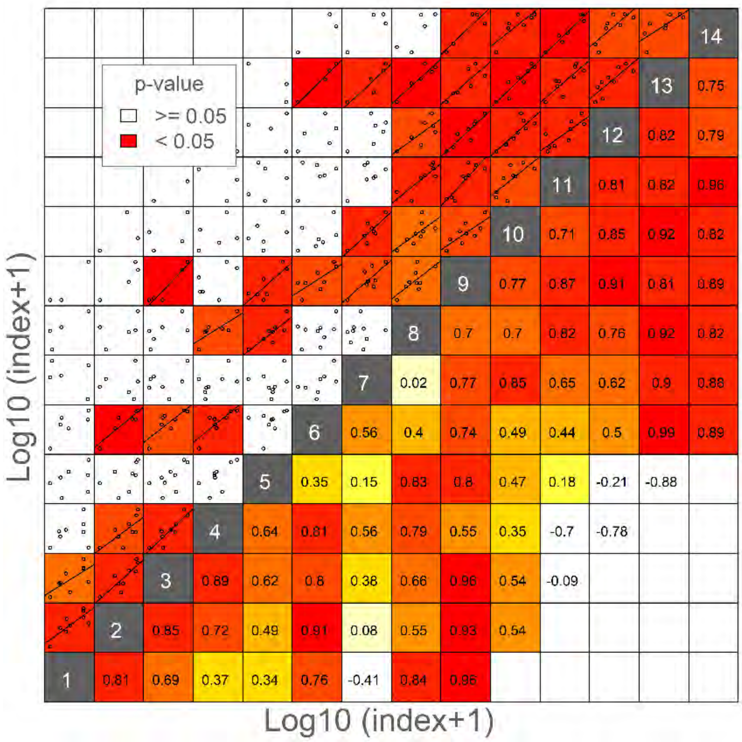


Figure 8.6.3.3. Internal consistency of the mackerel abundance index from the IESSNS surveys including data from 2012 to 2021, excluding North Sea. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

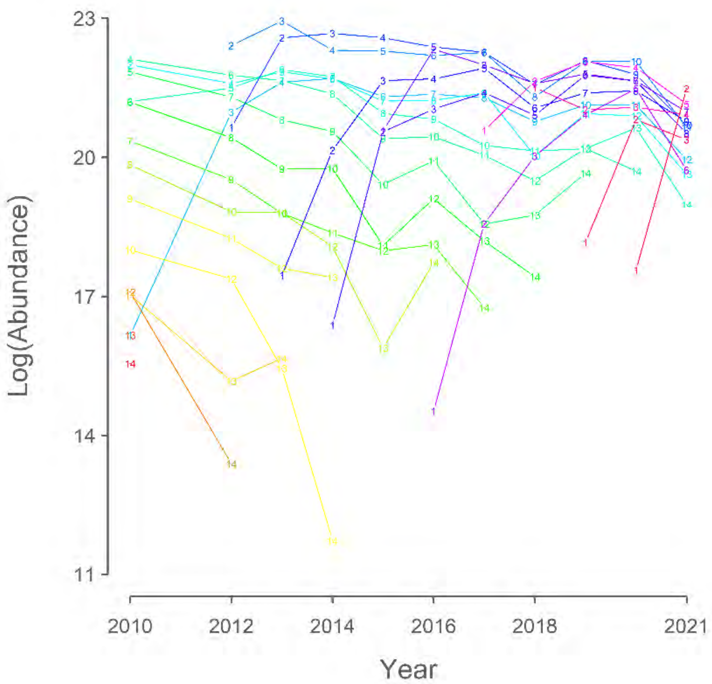


Figure 8.6.3.4. Mackerel catch curves from the estimate stock size at age from the IESSNS in 2010 and from 2012 to 2021, excluding the North Sea. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

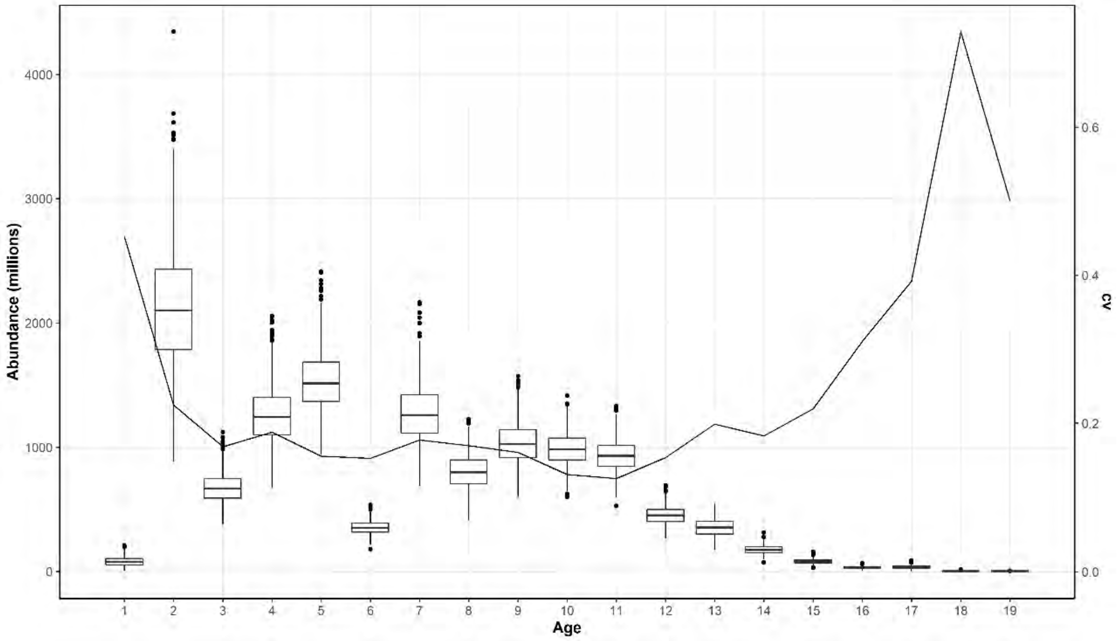


Figure 8.6.3.5. Mackerel numbers by age from the IESSNS survey in 2021, excluding North Sea. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using StoX version 3.10.

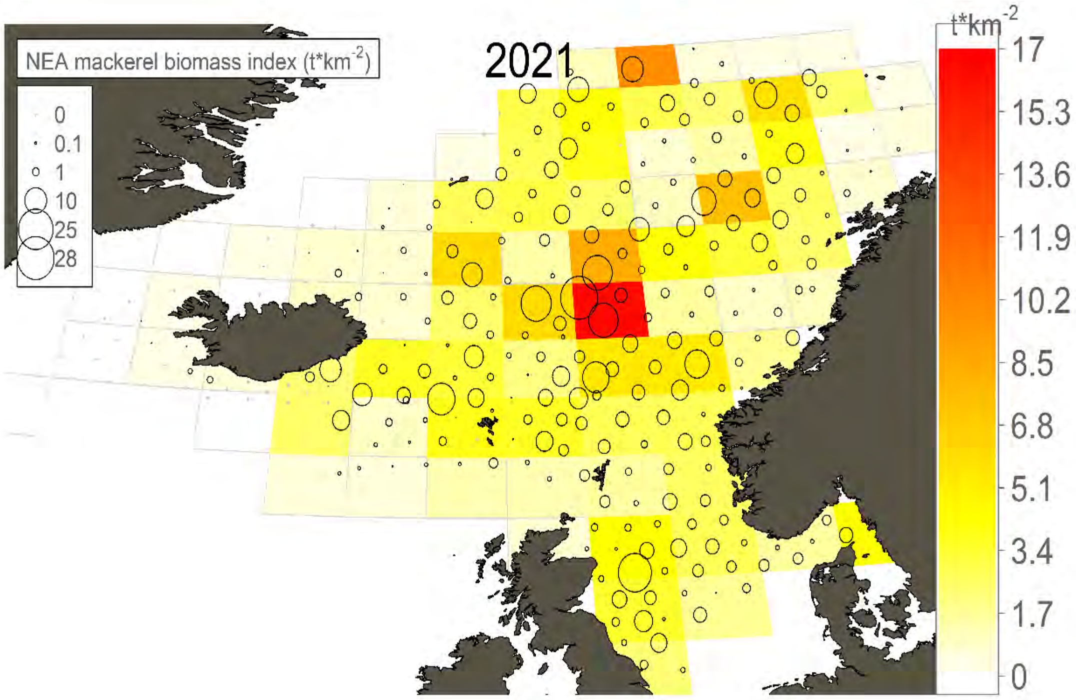


Figure 8.6.3.6. Mackerel catch rates from predetermined surface trawl stations (circle size represents catch rate in kg/km2) overlaid on mean catch rate per standardized rectangle (2° lat. x 4° lon.) from the 2021 IESSNS, including North Sea. Zero mackerel catches are displayed as grey crosses.

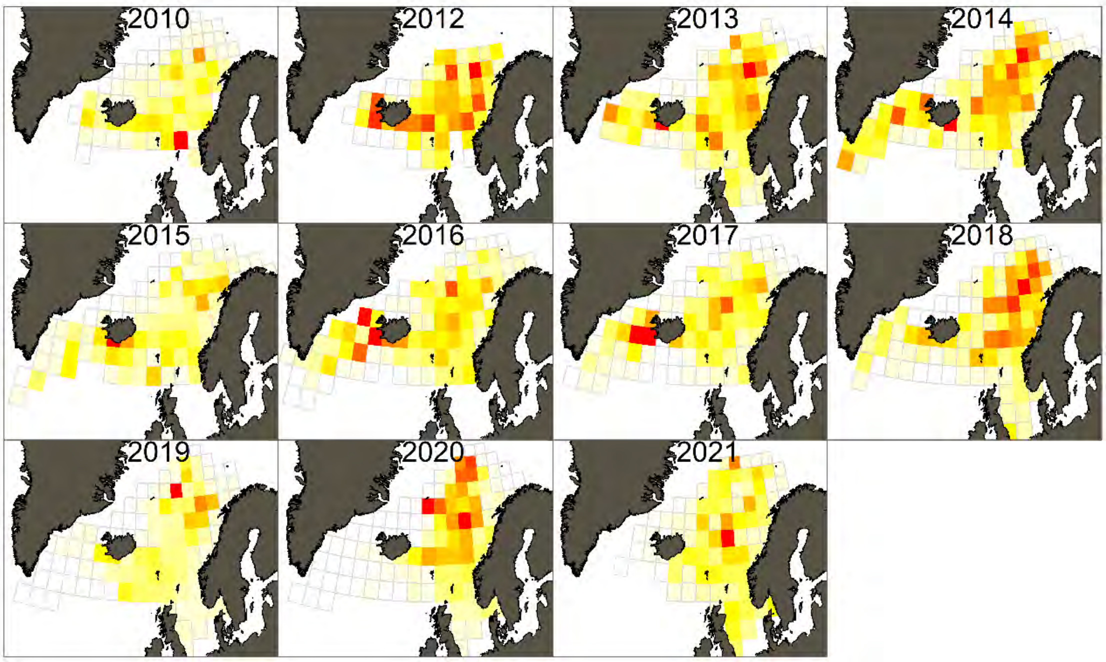


Figure 8.6.3.7. Mackerel annual distribution proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from predetermined surface trawl stations from IESSNS in 2010 to 2021, including North Sea. Colour scale goes from white (= 0) to red (= maximum value for the given year).

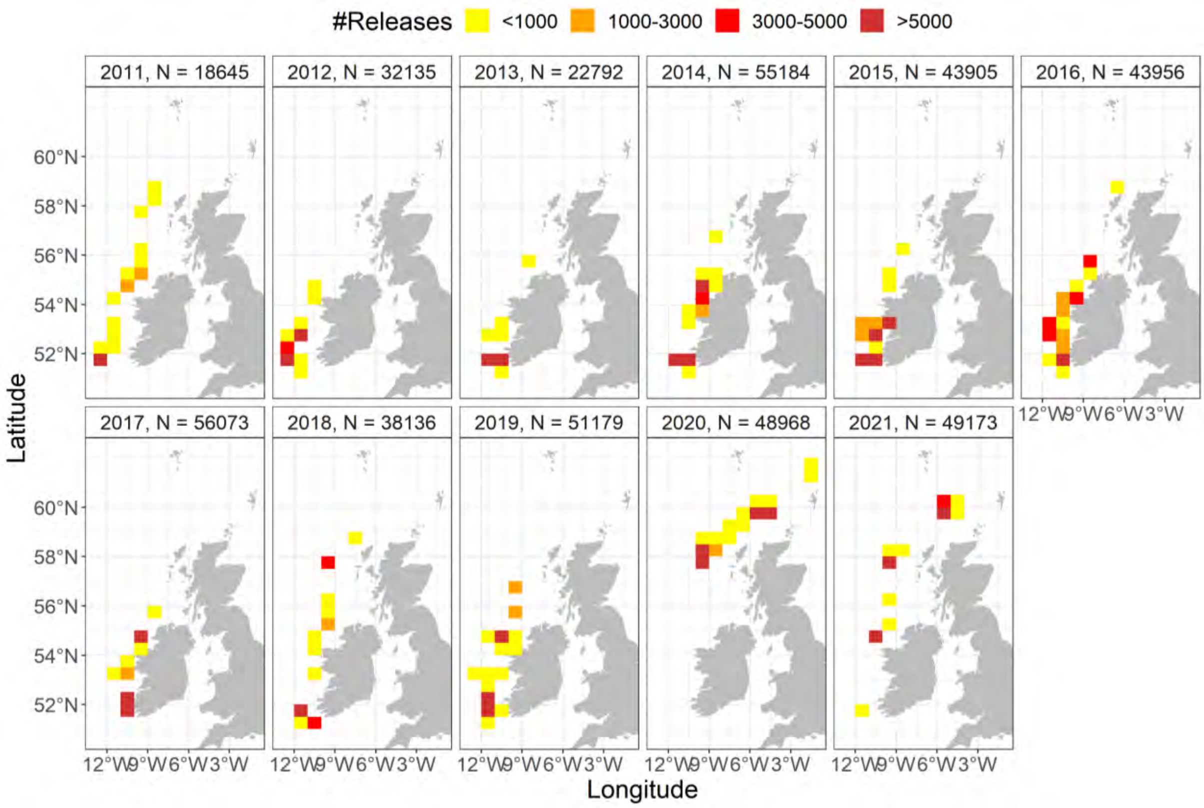


Figure 8.6.4.1. Number and distribution of RFID tagged mackerel from experiments west of Ireland and British Isles during 2011-2021. Note that data from releases 2011-2012 are not used in the stock assessment, based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019), and data from experiments in 2020-2021 are not included as there are no full years with recaptures yet.

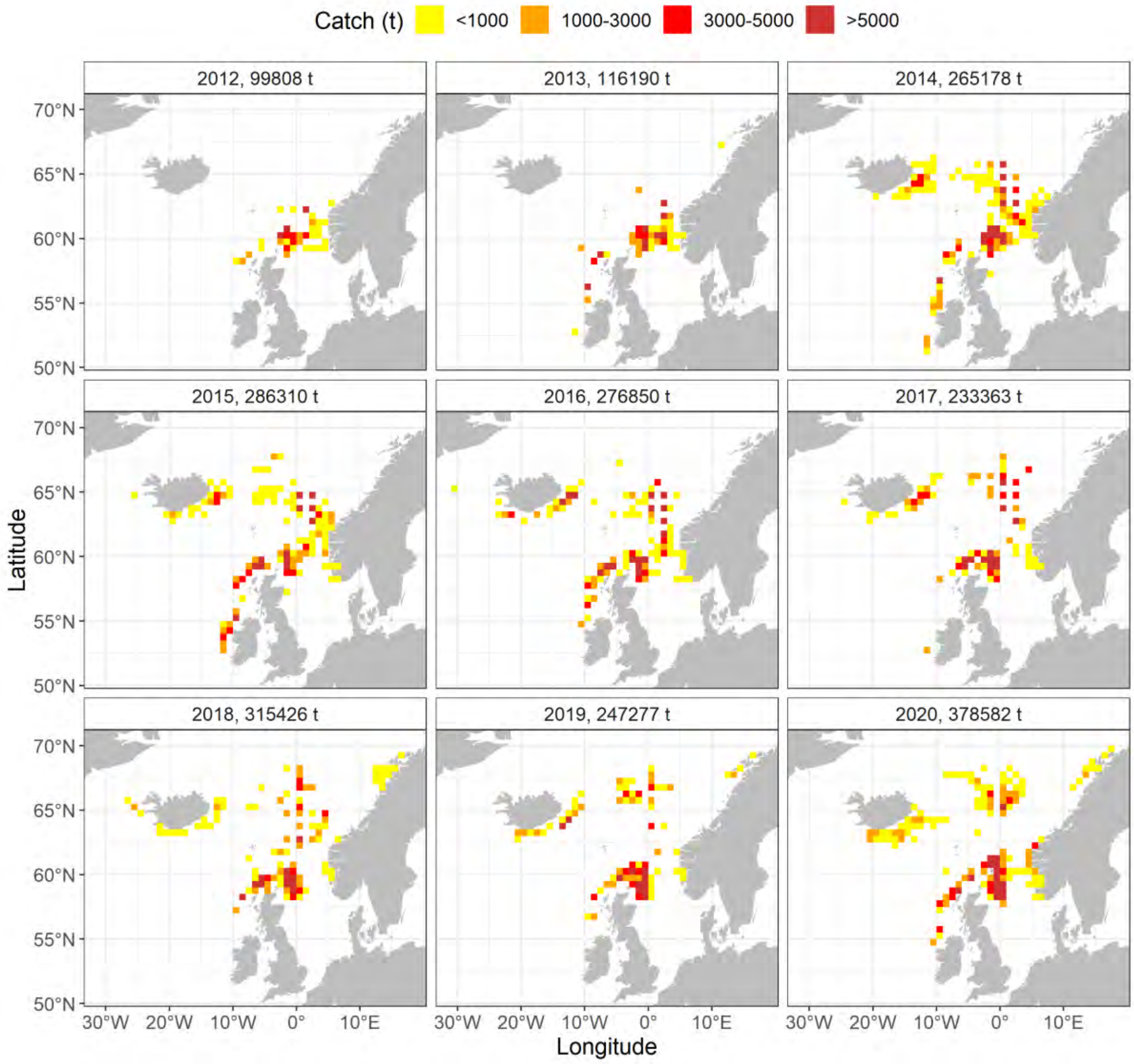


Figure 8.6.4.2. Biomass and distribution of catches scanned for RFID tagged mackerel during 2012-2020. Note that data from scanned catches in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019).

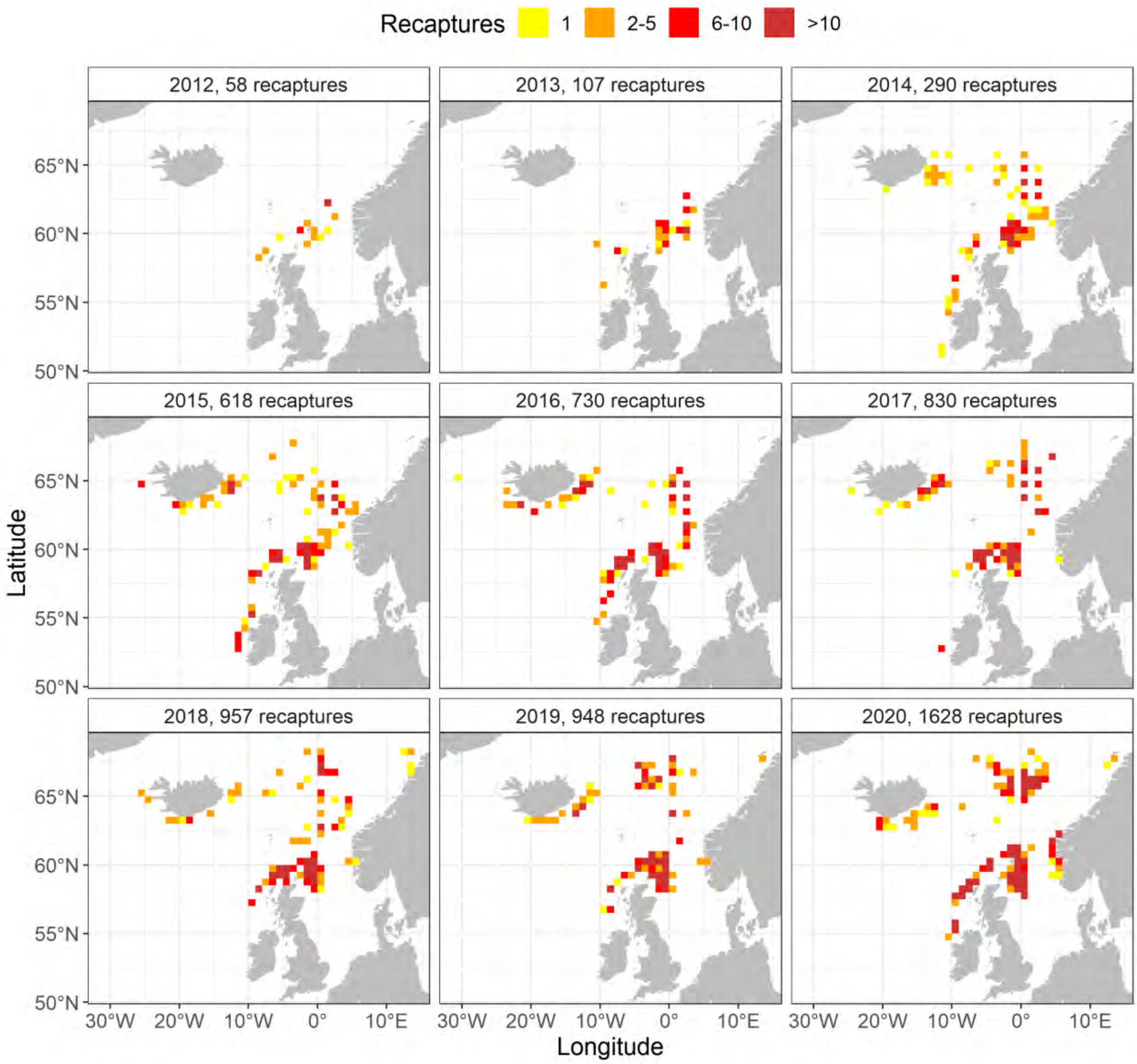
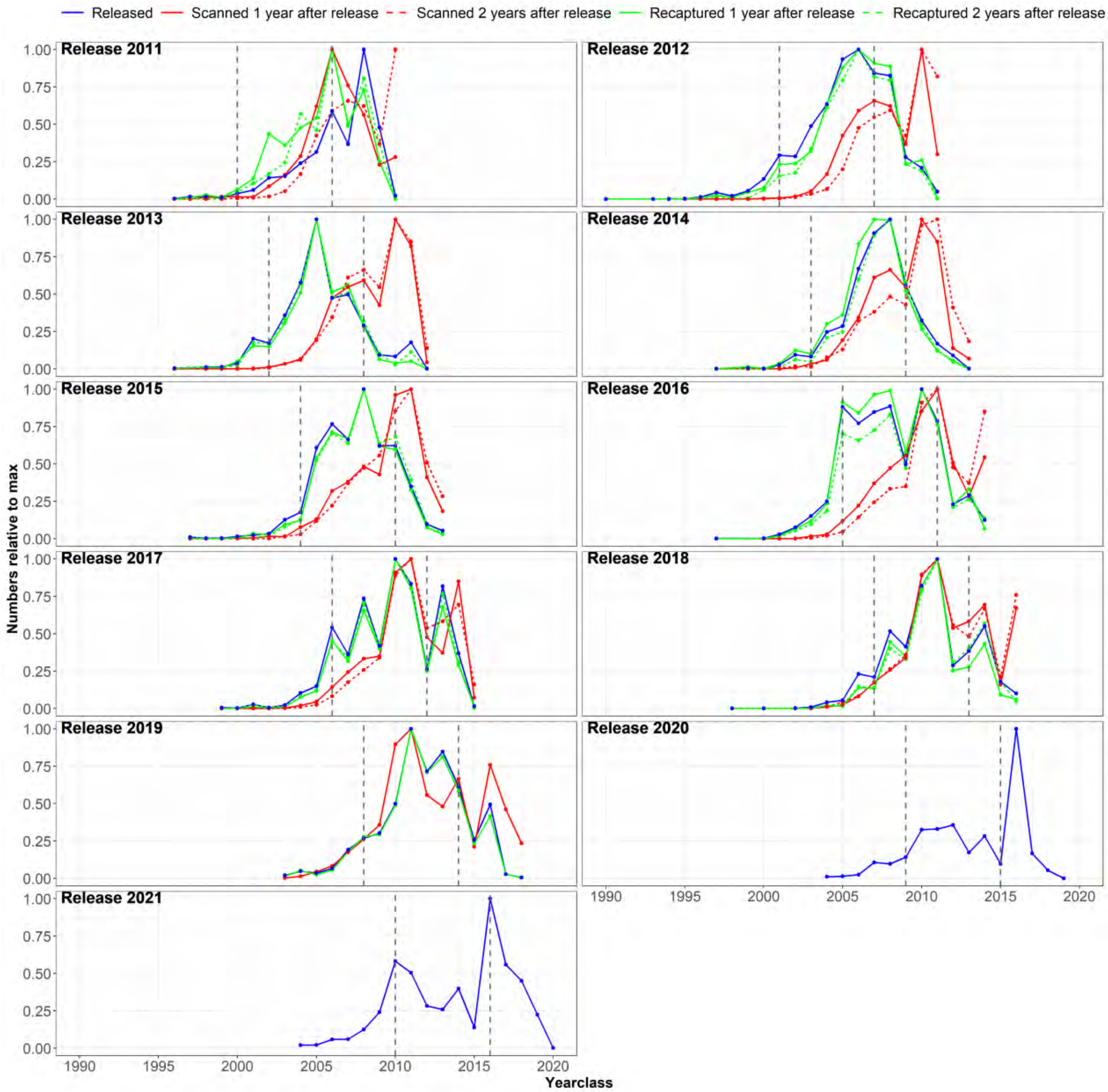


Figure 8.6.4.3. Distribution of recaptures of RFID tagged mackerel during 2012-2020. Note that data on recaptures in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019).



8.6.4.4. Overview of the relative year class distribution among RFID tagged mackerel per release year from experiments west of Ireland and British Isles in May-June, compared with the number scanned and recaptured in year 1 and 2 after release of the same year classes. 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 2019). 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.

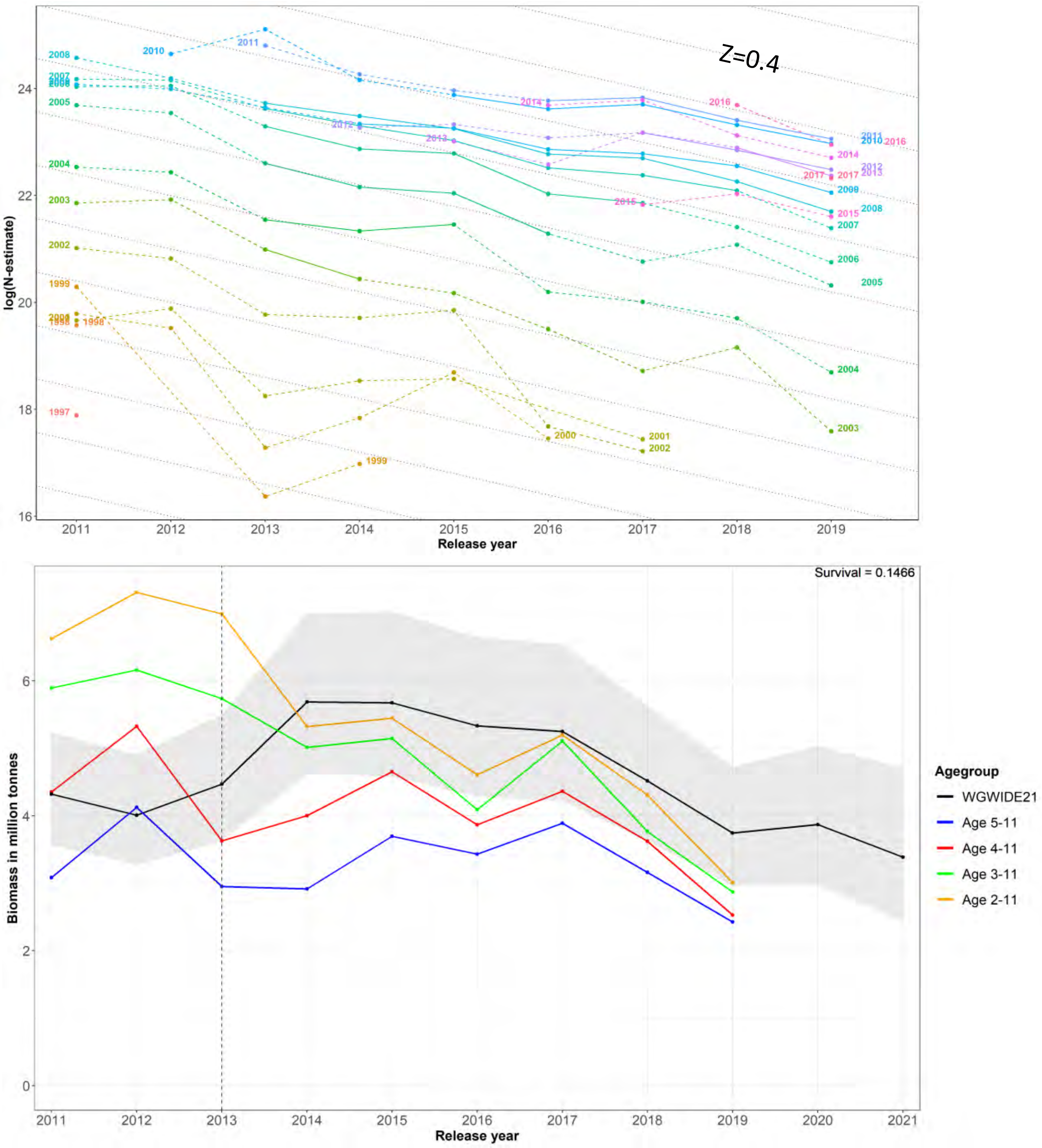


Figure 8.6.4.5. Upper panel: Trends in year class abundance (N=numbers released/numbers recaptured*numbers scanned) from RFID tag-recapture data based on aggregated data on recaptures and scanned numbers in year 1 and 2 after each release year. Data excluded in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019), release years 2011-2012 and ages 2-4 and 12+, are marked with dotted lines in year class trends. Bottom panel: Trends in various age aggregated biomass indices from RFID tag-recapture data compared with the SSB (±95 confidence intervals) from the WGWIDE2021 stock assessment. Data are based on a combination of estimated numbers by year class showed in upper panel scaled by survival parameter (0.1466) and weight at age in stock from WGWIDE2021. Vertical dotted line marks the starting year where RFID tagging experiments are used in the stock assessment. Note that final year with RFID biomass estimates in 2019 is only based on recapture year 2020 and will likely change when adding recapture year 2021 in WGWIDE2022.

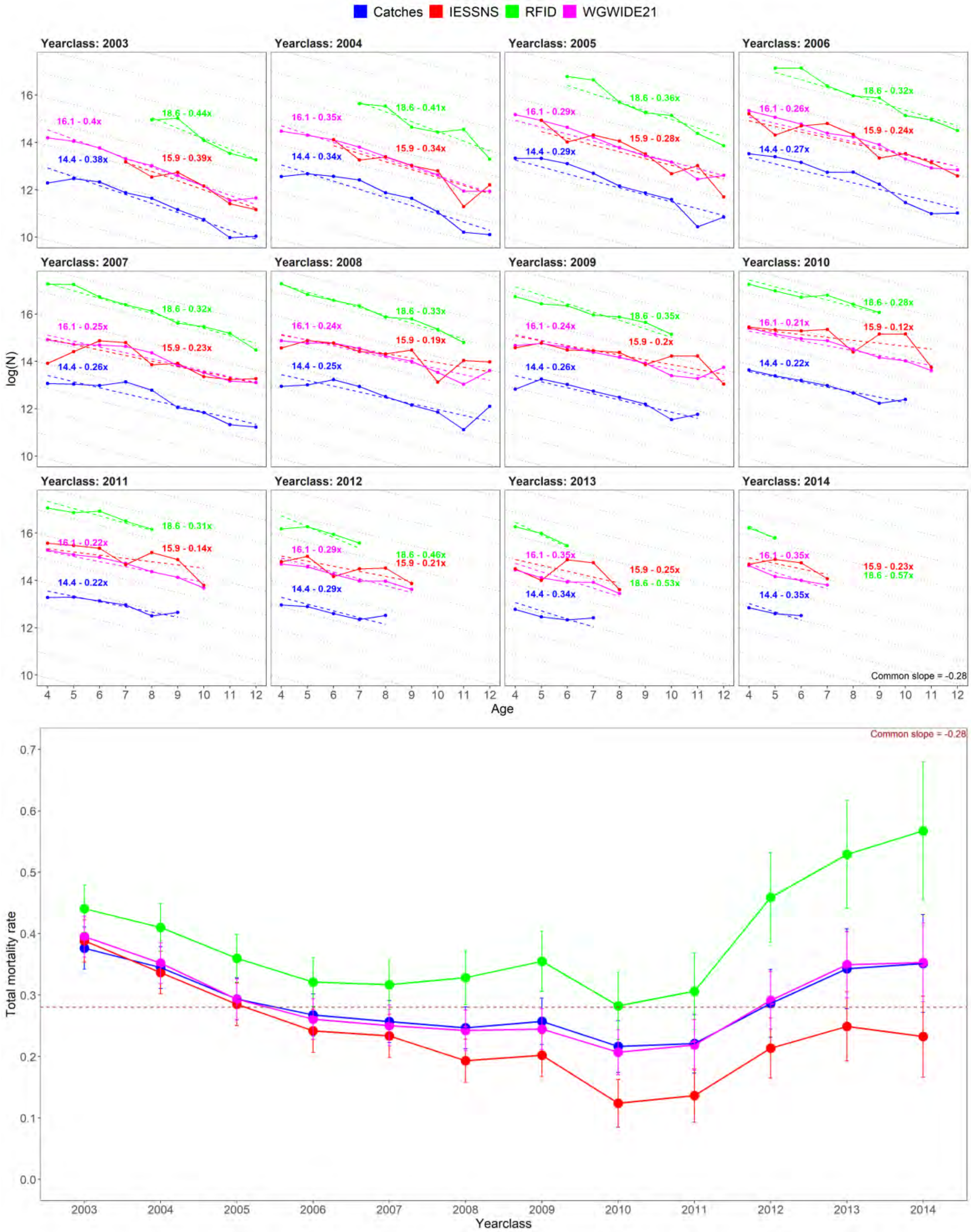


Figure 8.6.4.6. Signals of total mortality rate (Z). Upper panels show the trends in abundance of year classes 2003-2014 from unscaled input data (RFID, IESSNS and catches) and the WGWIDE2021 stock assessment. The estimated slope of decrease from the age 4 when it is fully recruited to the spawning stock until age 12 is interpreted as signal Z, grey dotted lines is Z=0.4. Bottom panels summarize the year class differences in estimated total mortality rate (with 95% confidence intervals), and differences between the various data sources.

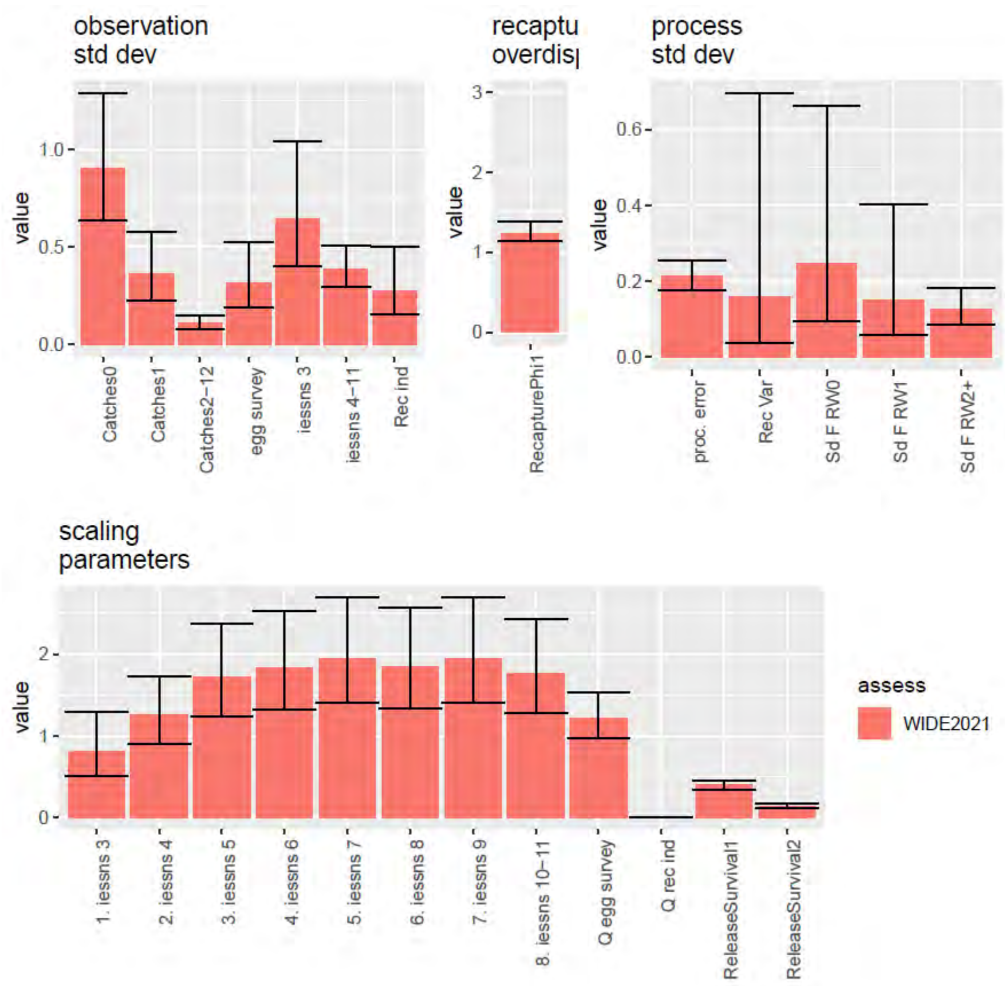


Figure 8.7.2.1. NE Atlantic mackerel. Parameter estimates from the SAM model (and associated confidence intervals) for the WGWIDE 2021 update assessment. top left : estimated standard deviation for the observation errors, top centre : estimated overdispersion for the errors on the tag recaptures, top right : standard deviation for the processes, bottom : survey catchabilities and post-release survival of tagged fish.

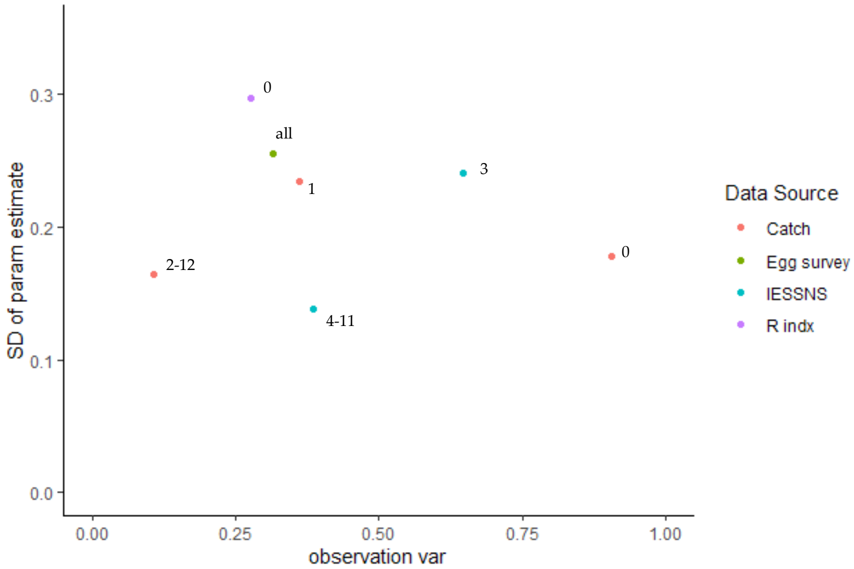


Figure 8.7.2.2. NE Atlantic mackerel. Parameter uncertainty (standard deviation of estimate) versus parameter value for the observation variances. The colours correspond to the different data sources and the number next to the dots indicate the age range to which each parameter apply.

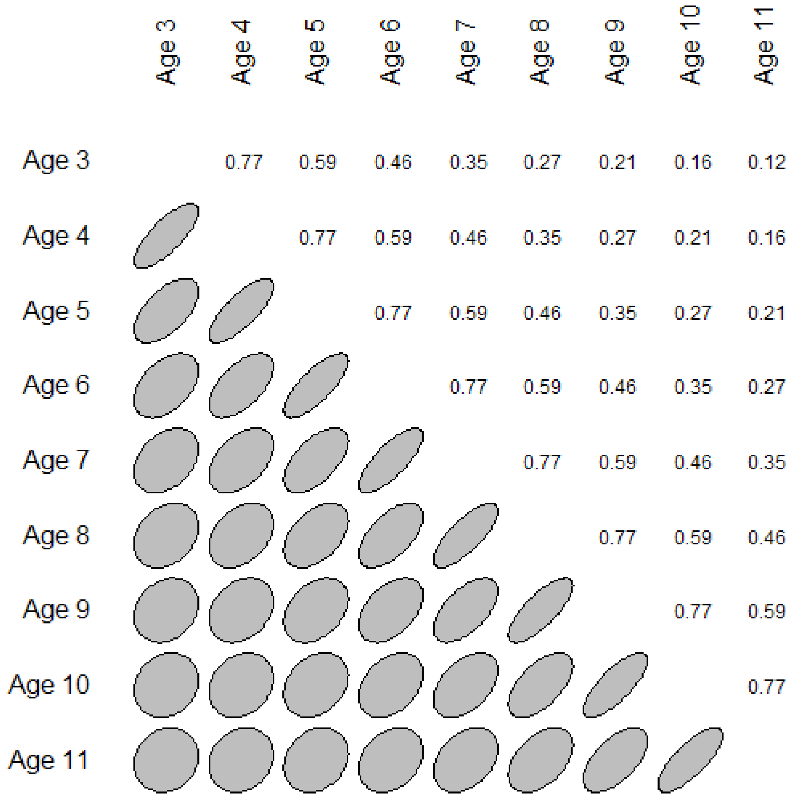


Figure 8.7.2.3. NE Atlantic mackerel. Estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11.

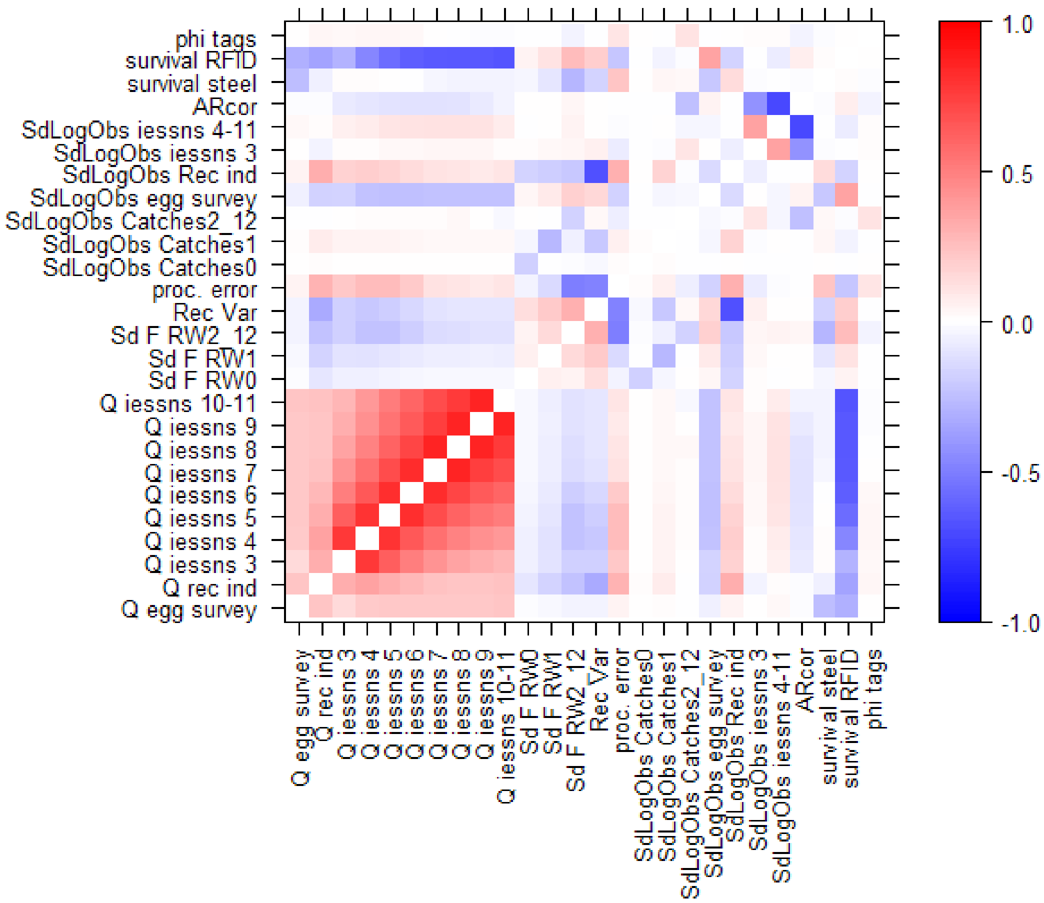


Figure 8.7.2.4. NE Atlantic mackerel. Correlation between parameter estimates from the SAM model for the WGWIDE 2021 update assessment

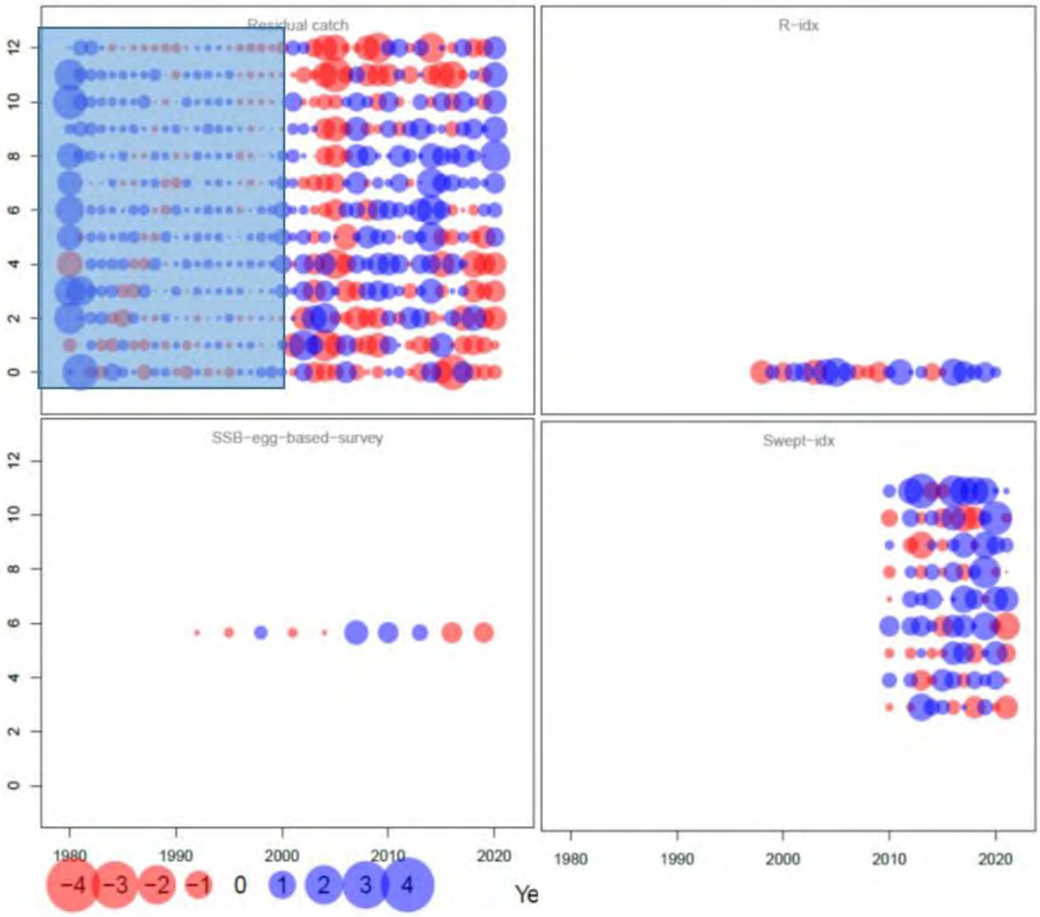


Figure 8.7.2.5. NE Atlantic mackerel. One Step Ahead Normalized residuals for the fit to the catch data (catch data prior to 2000 in blue rectangle were not used to fit the model). Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

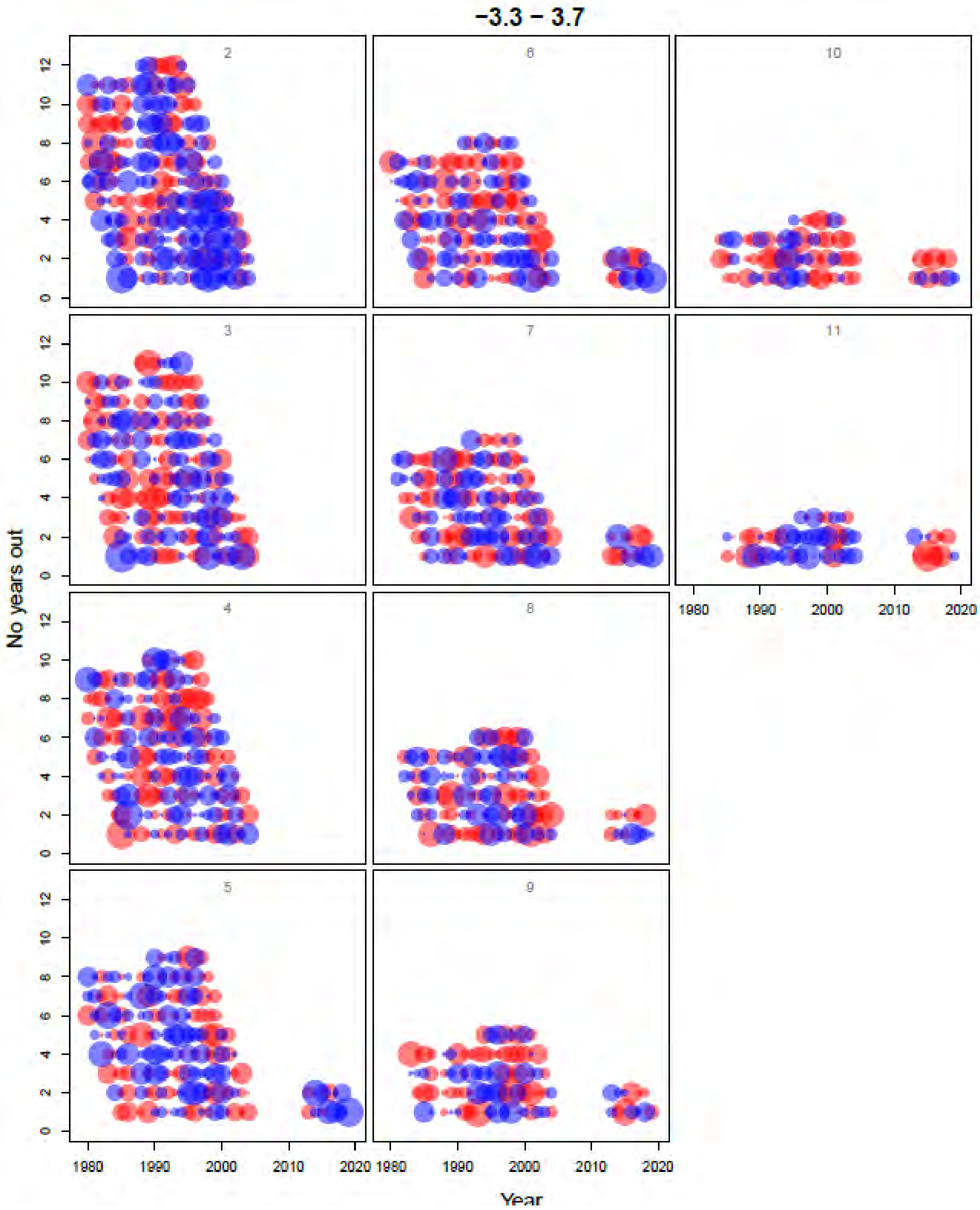


Figure 8.7.2.6. NE Atlantic mackerel. One step ahead residuals for the fit to the recaptures of tags in the final assessment. The x-axis represents the release year, and the y-axis is the number of years between tagging and recapture. Each panel correspond to a given age at release. Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

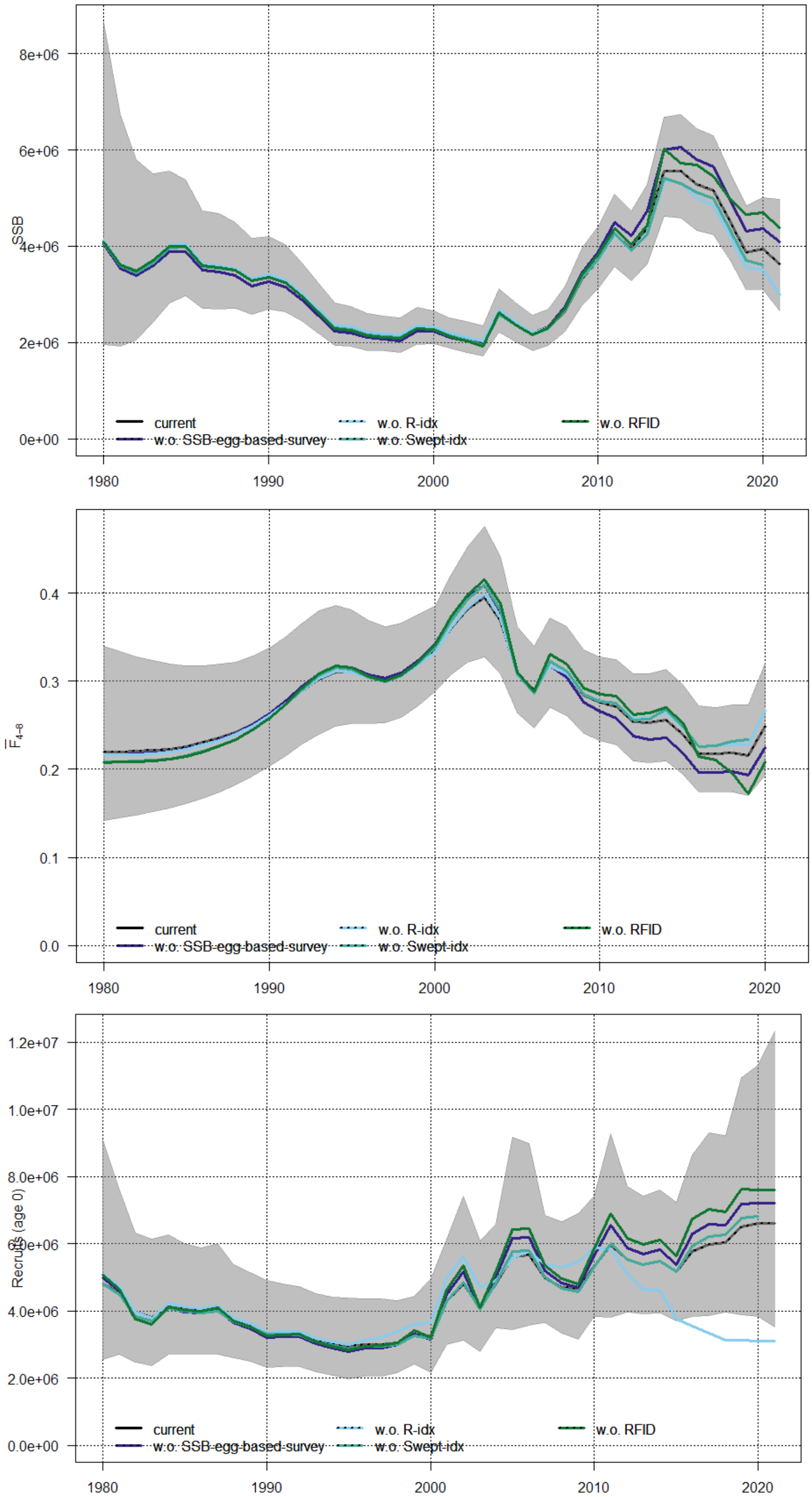
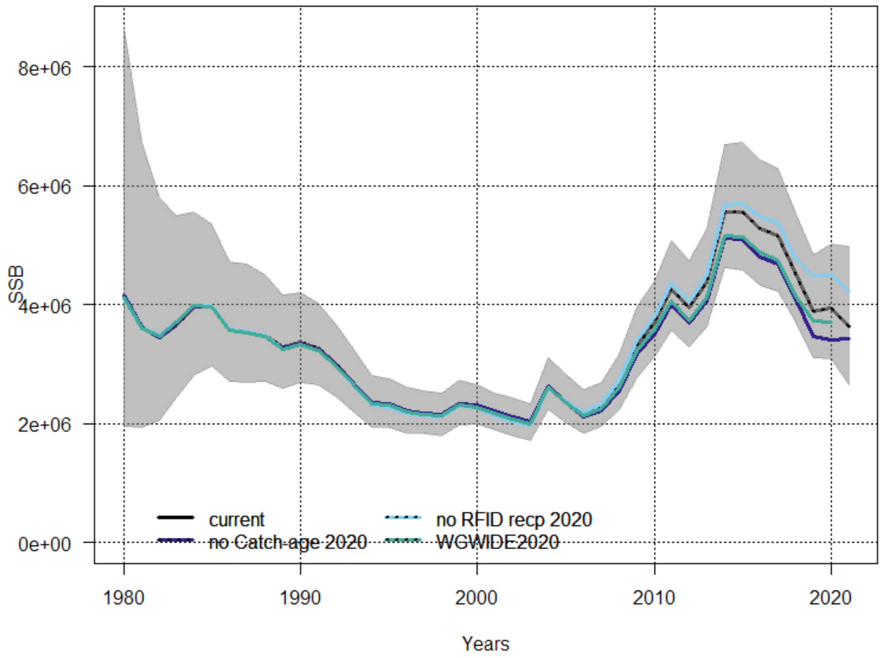


Figure 8.7.2.7. NE Atlantic mackerel. Leave one out assessment runs. SAM estimates of SSB, Fbar and recruitment, for assessments runs leaving out one of the observation data sets.



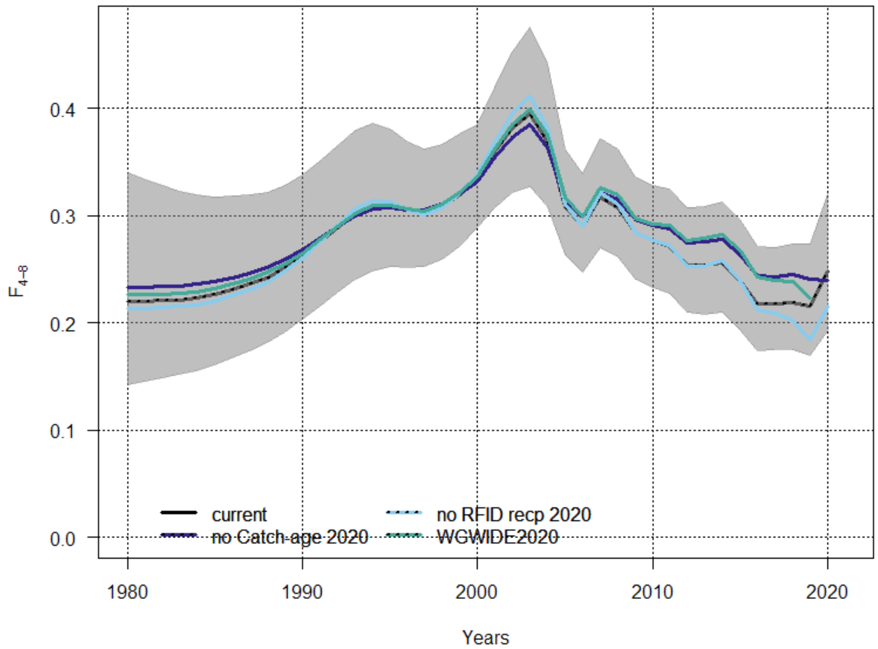


Figure 8.7.2.8. NE Atlantic mackerel. Estimated. Sensitivity of the estimated stock trajectories to the latest year of catch-at-age data and RFID data, and comparison with WGWIDE 2020 assessment.

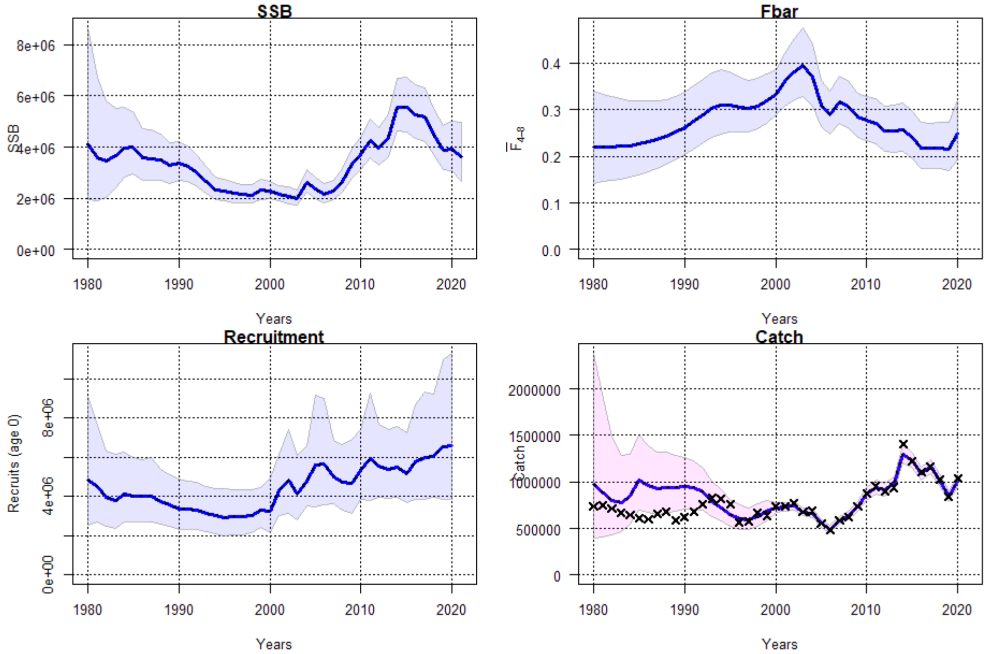


Figure 8.7.3.1. NE Atlantic mackerel. Perception of the NEA mackerel stock, showing the SSB, F_{bar}4-8 and recruitment (with 95% confidence intervals) from the SAM assessment.

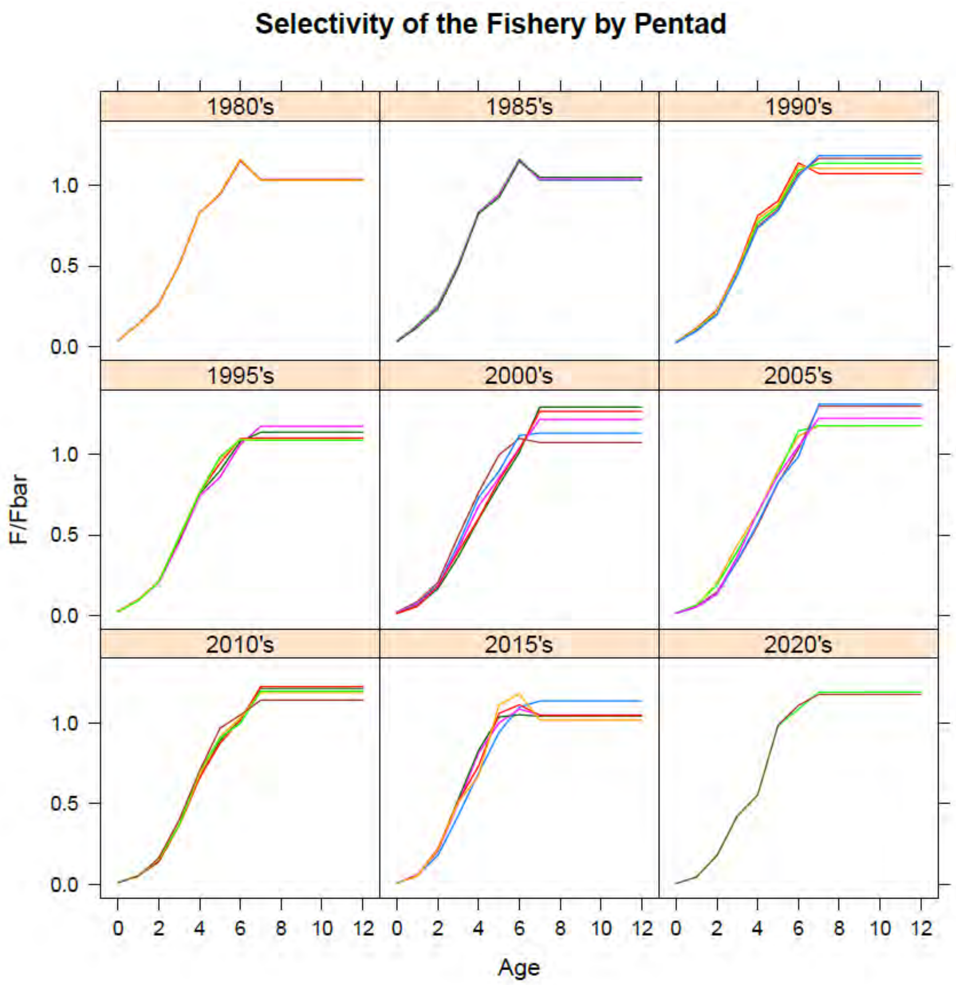


Figure 8.7.3.2. NE Atlantic mackerel. Estimated selectivity for the period 1990 to 2021, calculated as the ratio of the estimated fishing mortality-at-age and the Fbar4-8 value in the corresponding year.

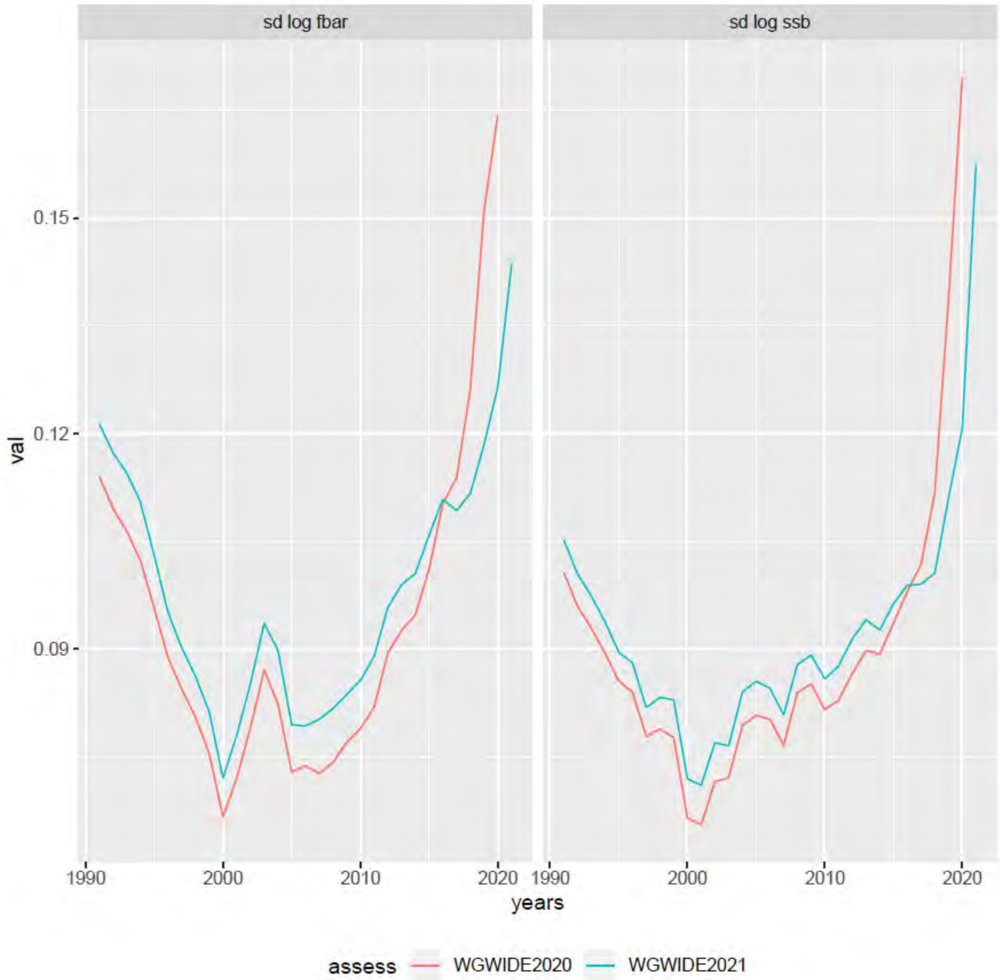


Figure 8.7.4.1. NE Atlantic mackerel. Uncertainty (standard deviation of the log values) of the estimates of SSB and Fbar from the SAM for the 2020 and 2021 WGWIDE assessments.

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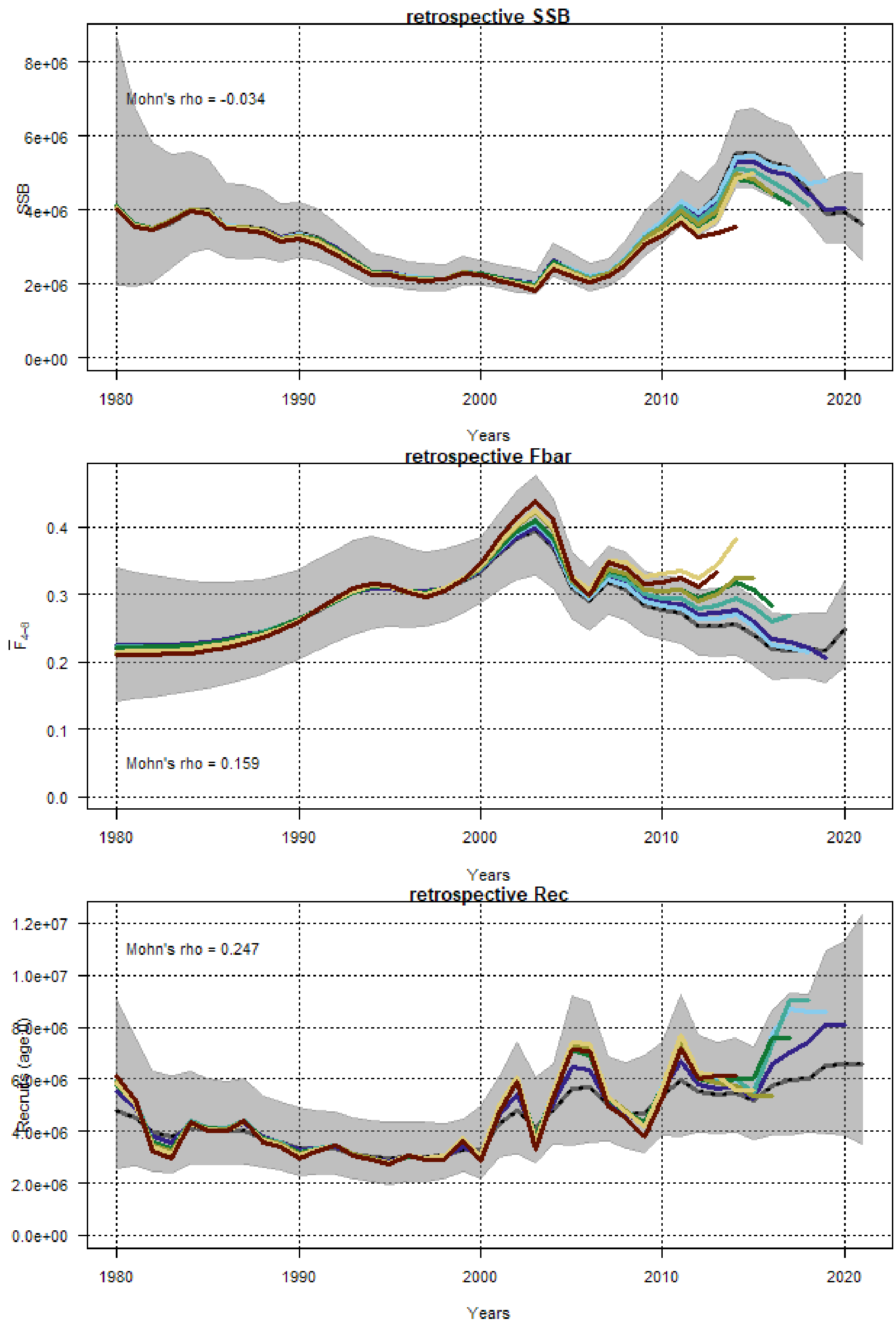

Figure 8.7.4.2. NE Atlantic mackerel. Analytical retrospective patterns (7 years back) of SSB, F_{bar}4-8 and recruitment from the WGWIDE 2021 update assessment. the Mohn's rho values are calculated based on 5 retro years
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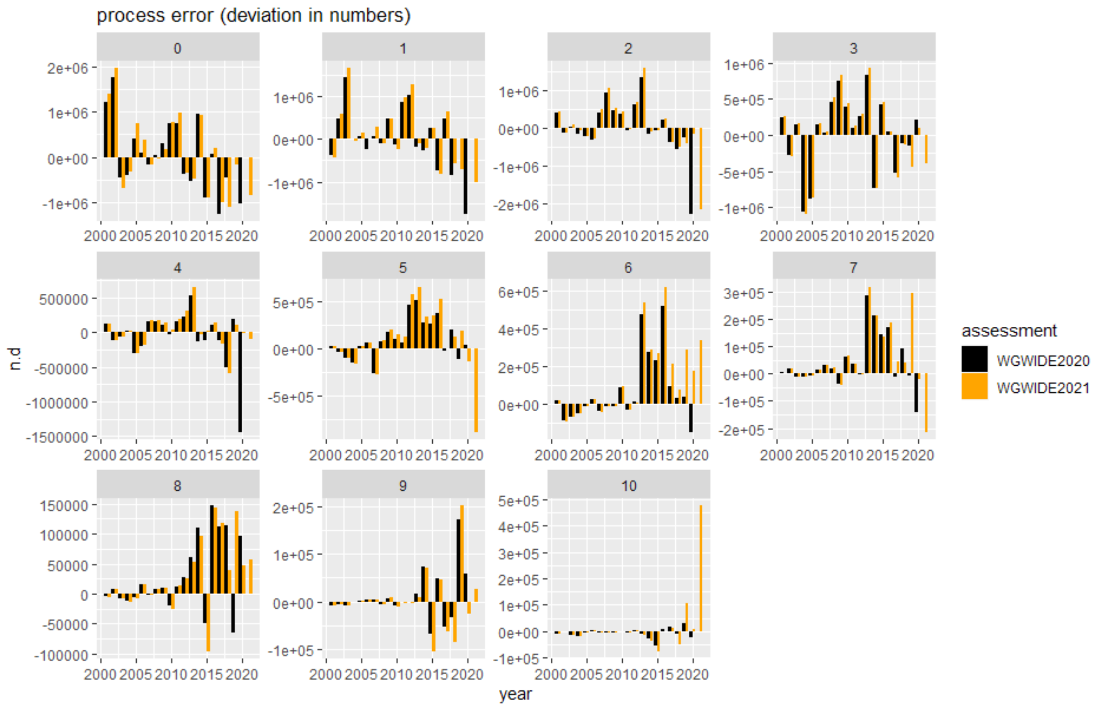

Figure 8.7.4.3. NE Atlantic mackerel. Process error expressed as annual deviations of abundances at age, for the 2021 WGWIDE assessment and from the 2020 WGWIDE assessment.

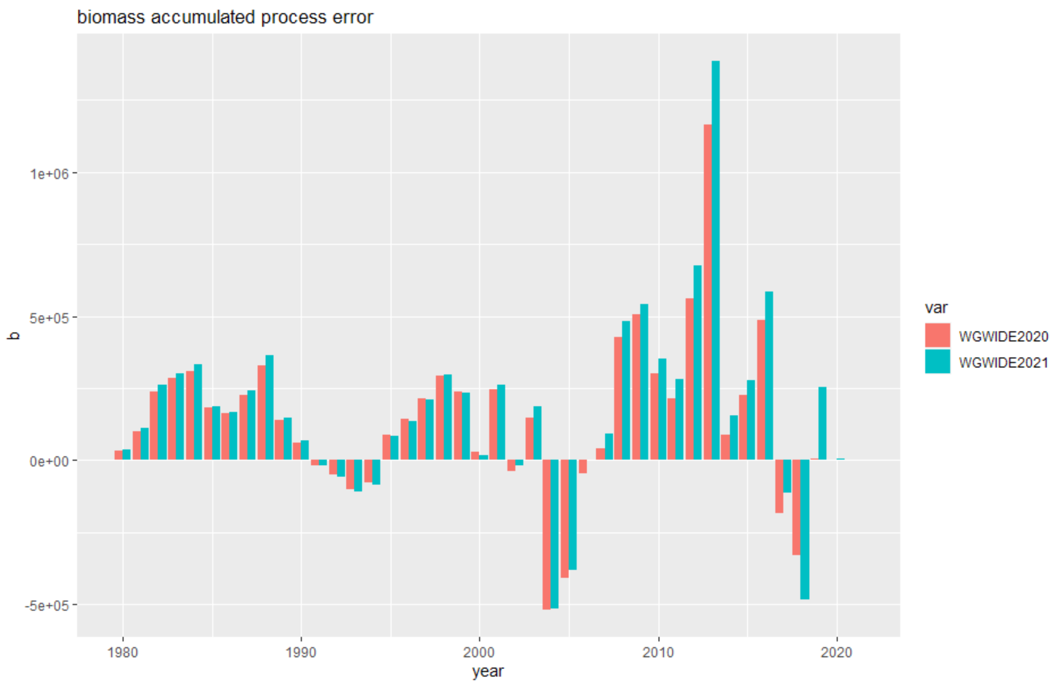

Figure 8.7.4.4. NE Atlantic mackerel. Model process error expressed in biomass cumulated across age-group for the 2021 WGWIDE assessment and for the 2020 WGWIDE assessment.

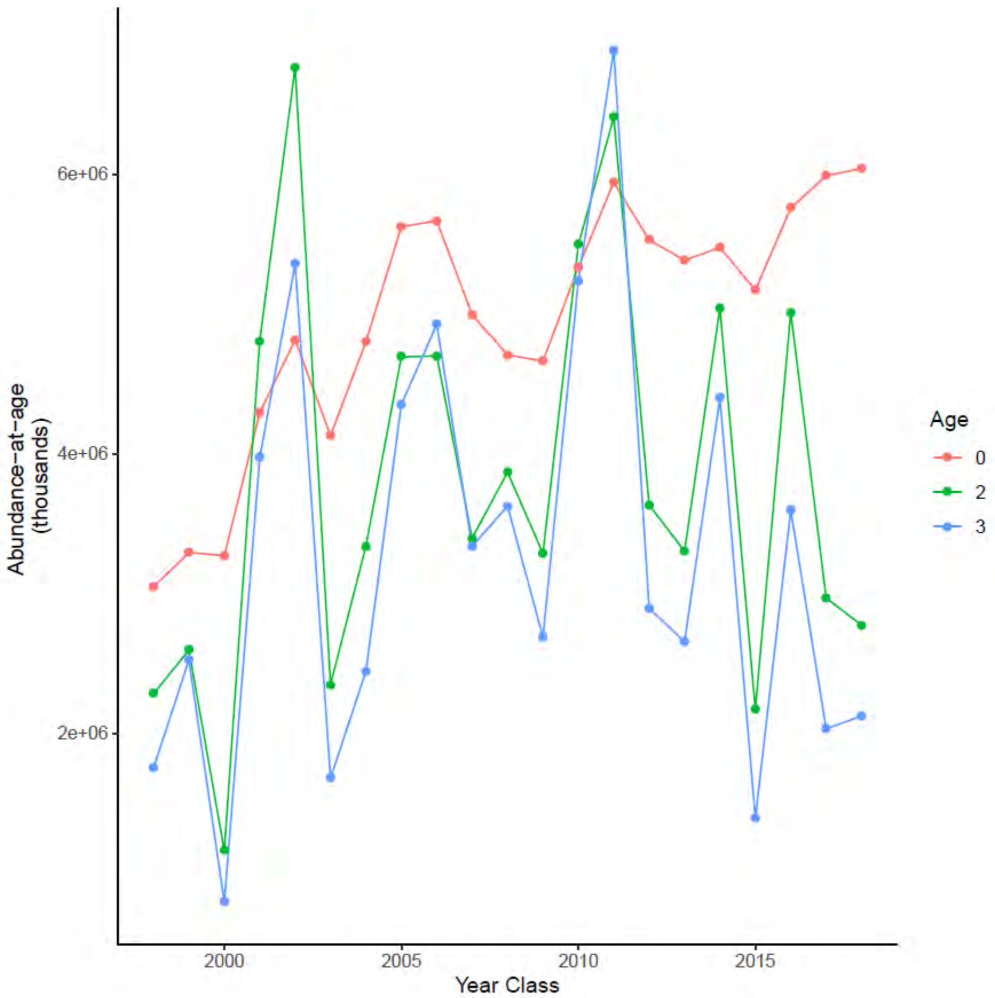

Figure 8.7.5.1. NE Atlantic mackerel. Model. comparison of the cohort signal based on SAM estimates at age 0, 2 and 3.

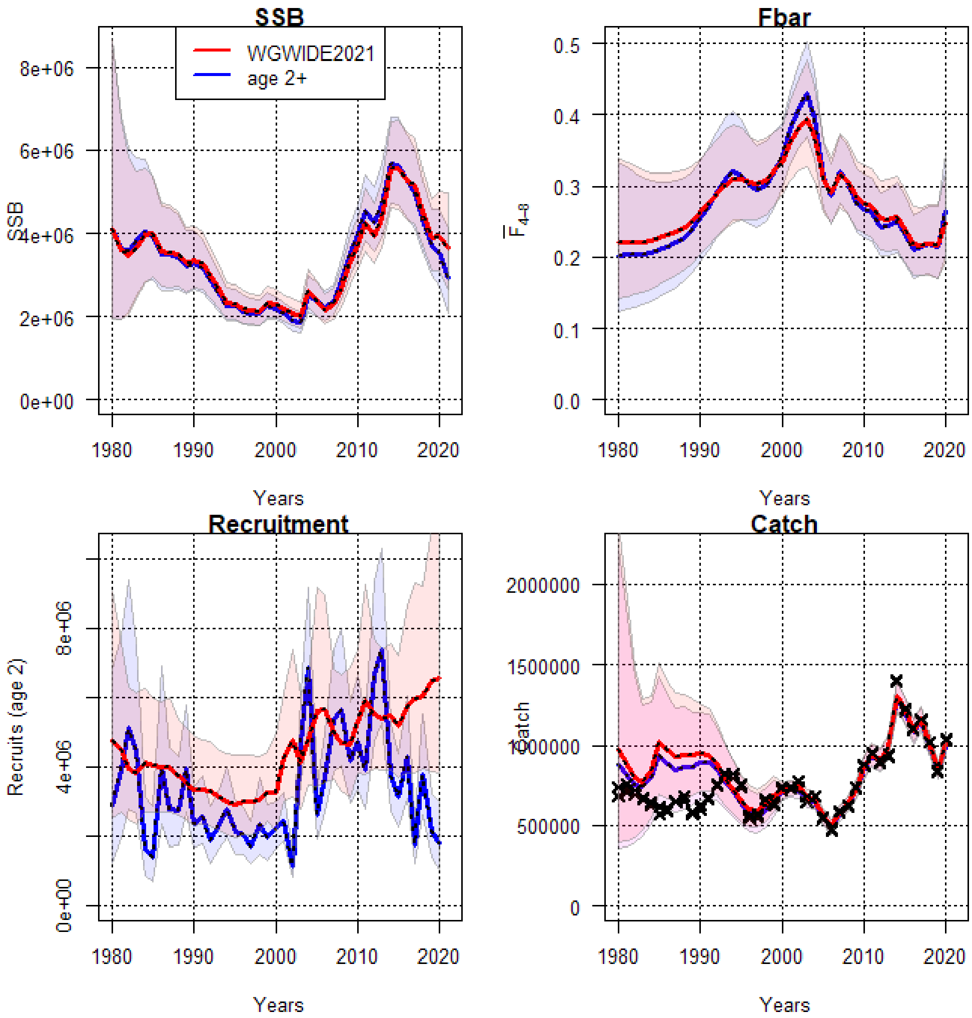

Figure 8.7.5.2. NE Atlantic mackerel. Model. comparison of the perception of the stocks from the WGWIDE 2021 assessment, and the assessment starting at age2.

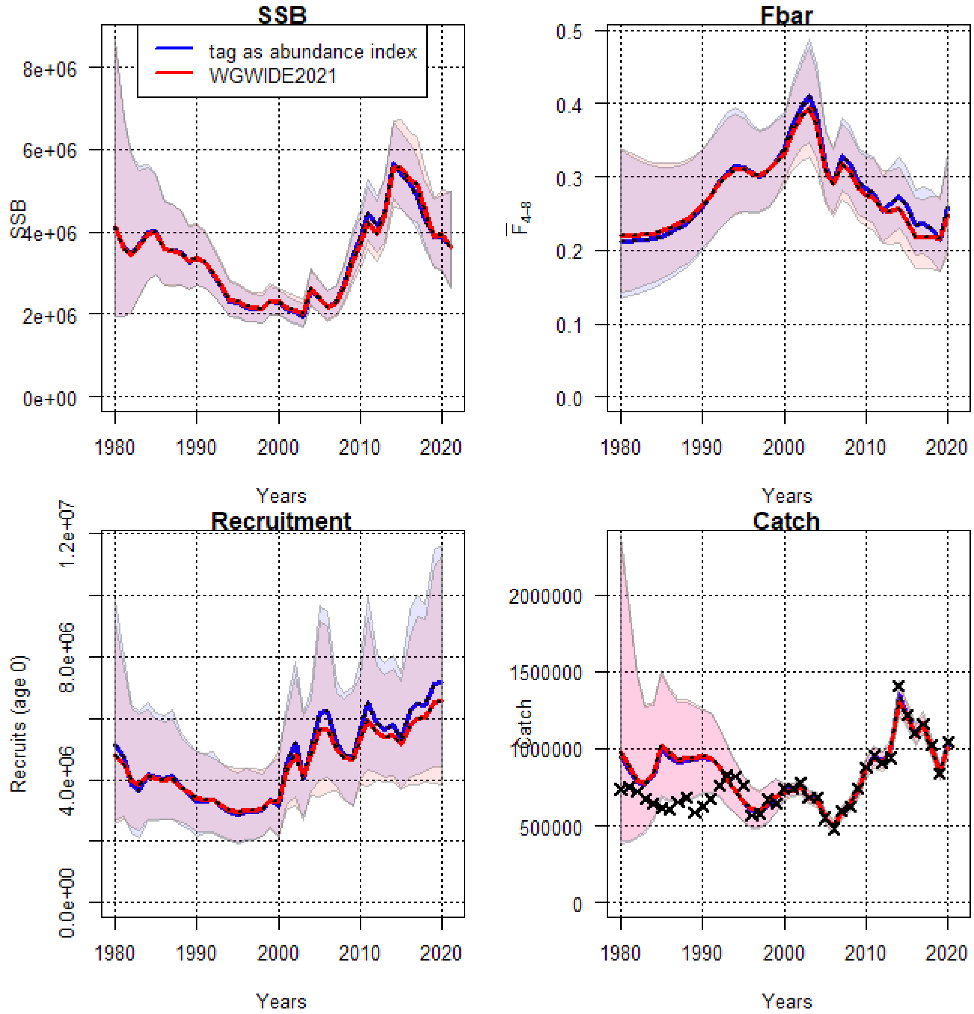

Figure 8.7.5.3 NE Atlantic mackerel. Model. comparison of the perception of the stocks from the WGWIDE 2021 assessment, and the assessment using the RFID data in the form of abundance index for ages 5 to 11.

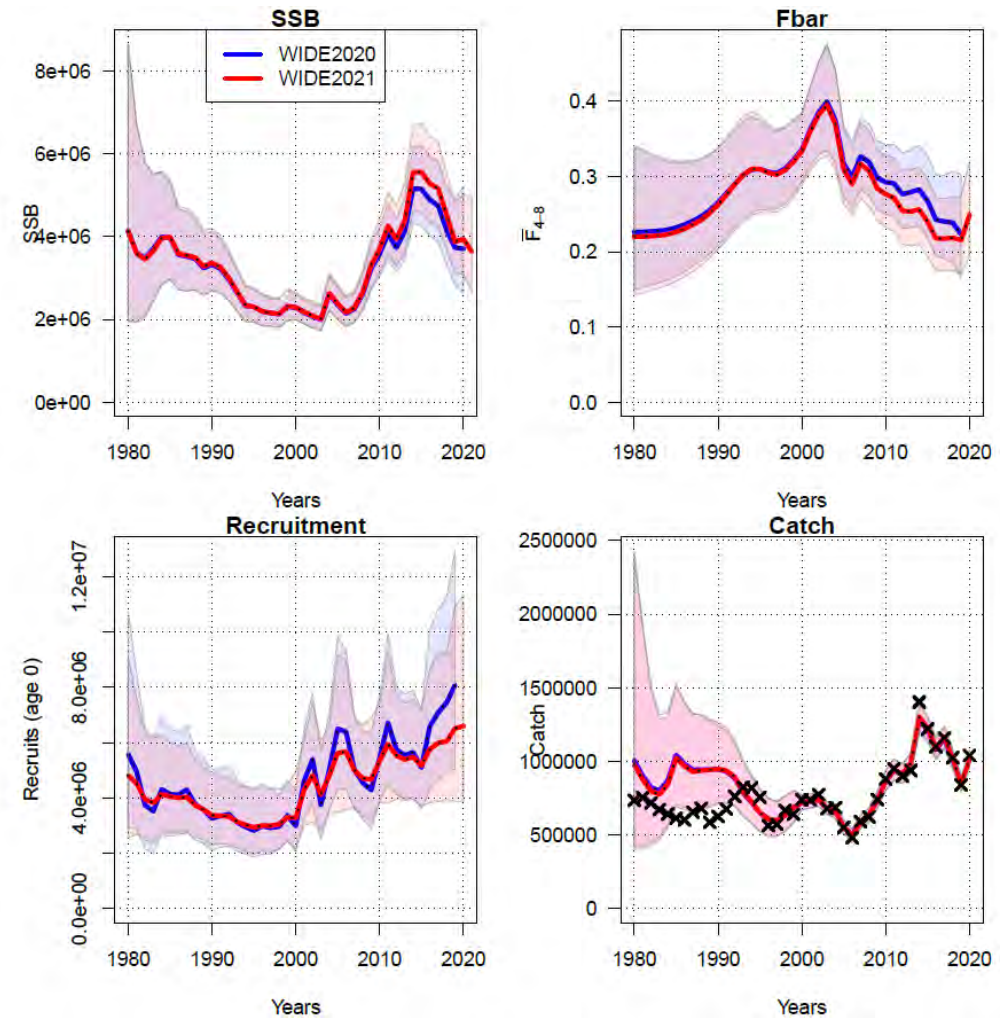

Figure 8.10.1. NE Atlantic mackerel. Comparison of the stock trajectories between the 2021 WGWIDE assessment and the 2020 WGWIDE assessment.

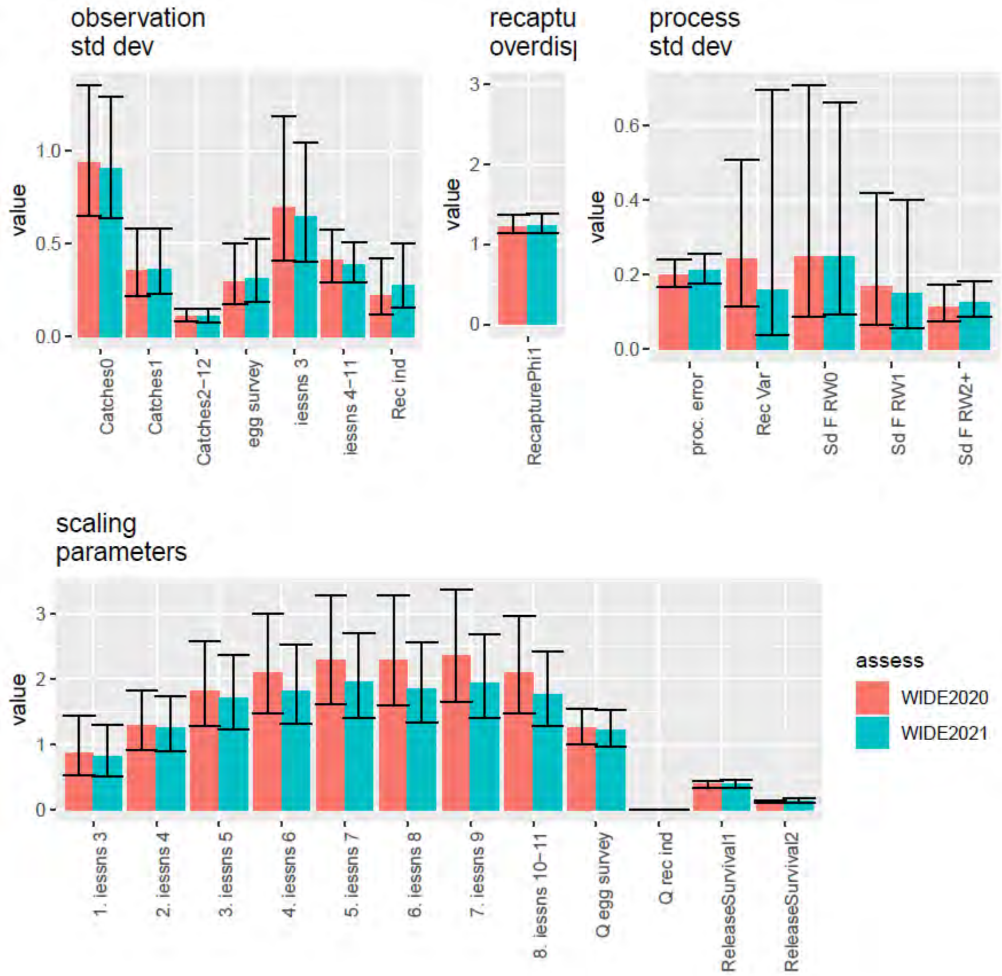

Figure 8.10.2. NE Atlantic mackerel. Comparison of model parameters and their uncertainty for the 2021 WGWIDE and the 2020 WGWIDE assessment

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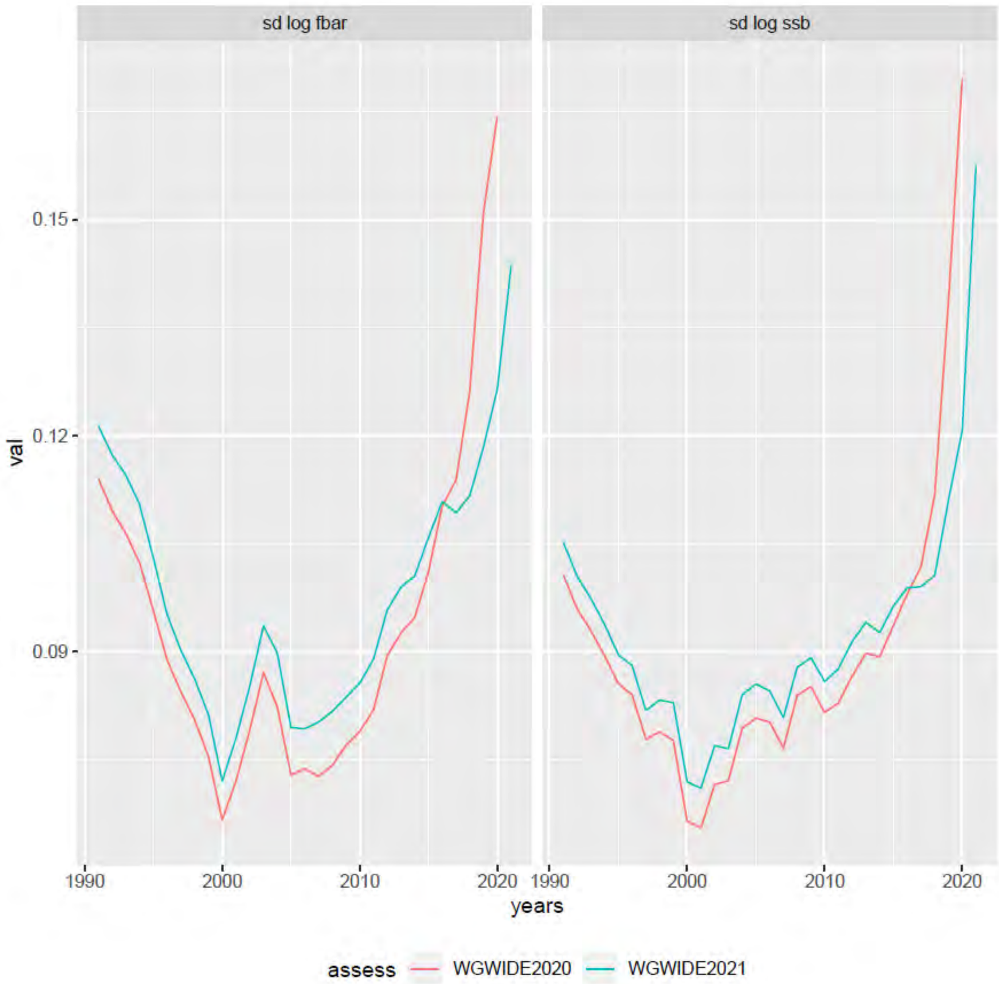

Figure 8.10.3. NE Atlantic mackerel. Comparison of the uncertainty on estimates of SSB and Fbar for the WGWIDE 2021 update assessment and the 2020 WGWIDE.

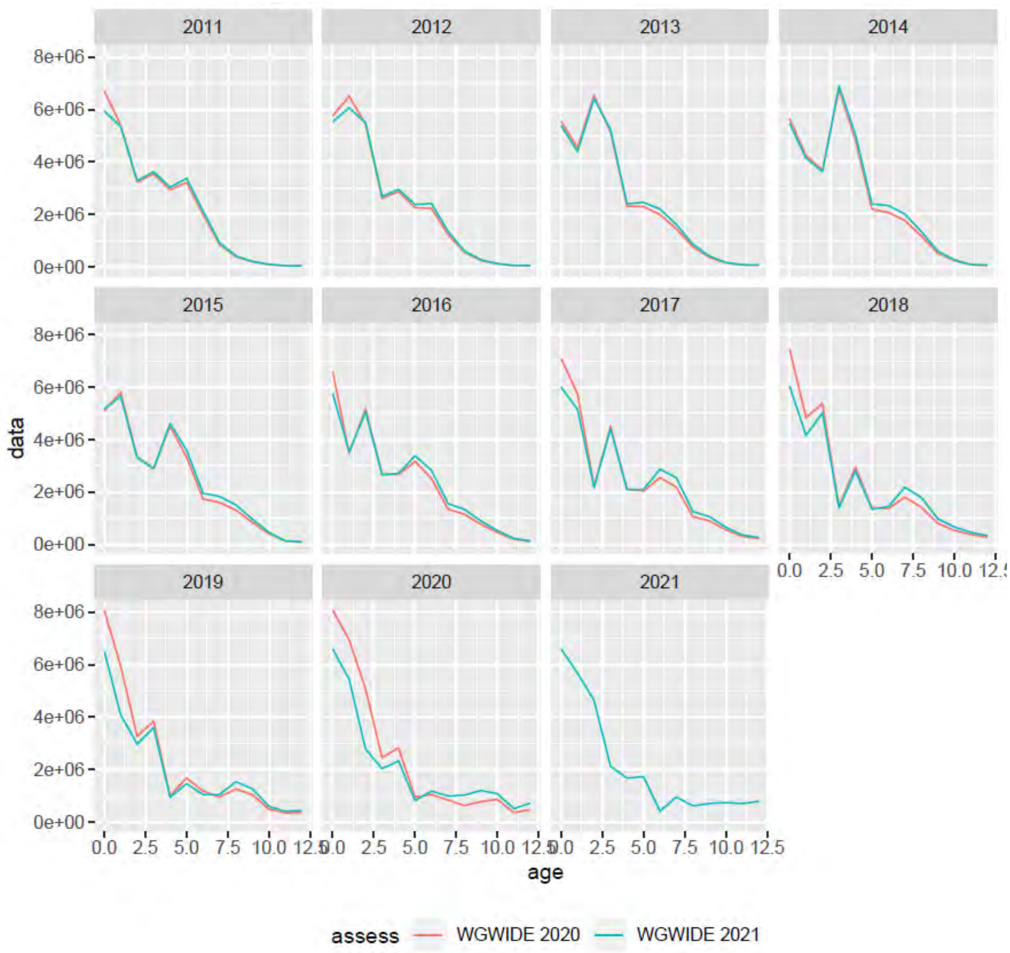

Figure 8.10.4. NE Atlantic mackerel. Comparison of the abundances at age from 2011 to 2021 estimated from the 2020 and 2021 assessments.

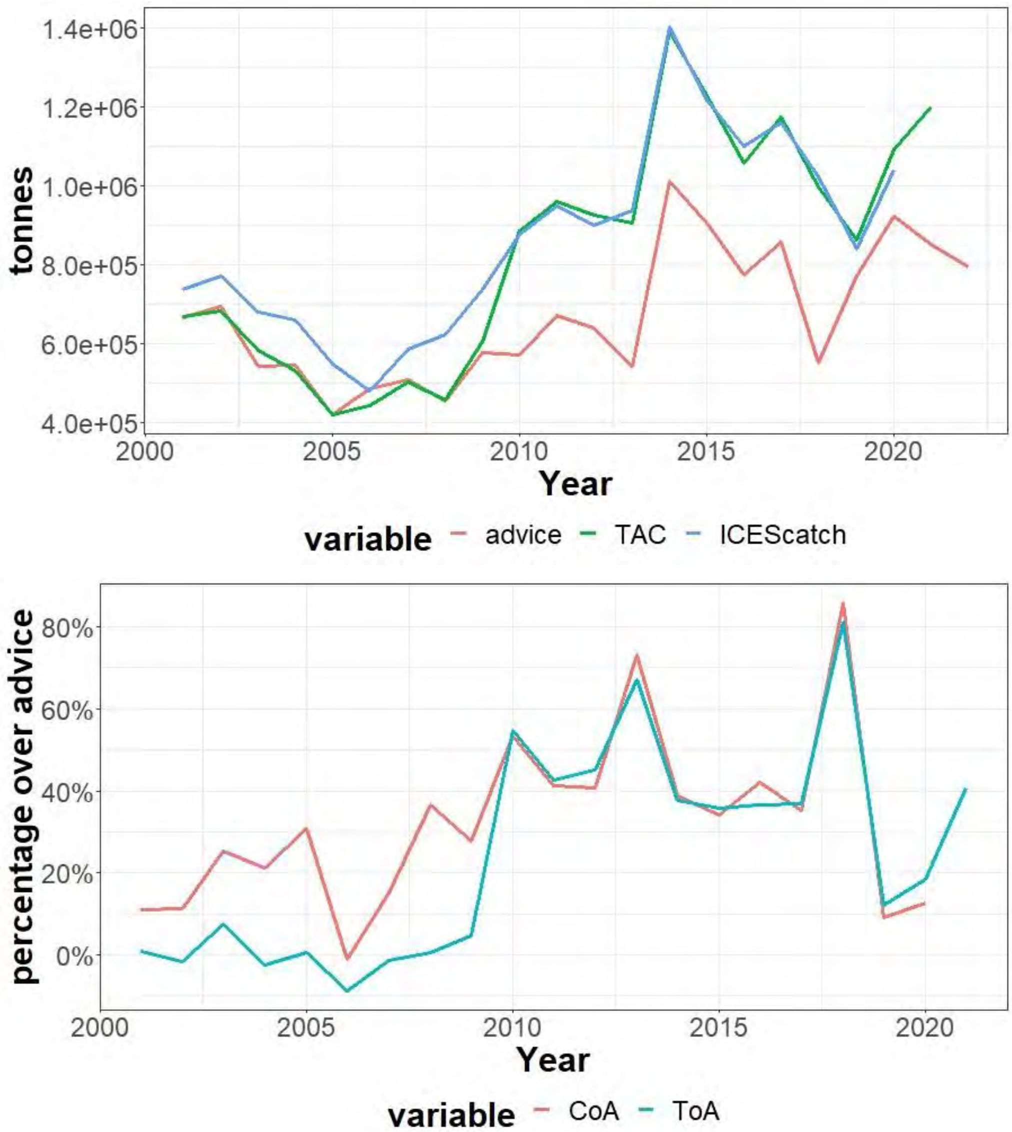

Figure 8.11.1. NE Atlantic mackerel. Top: comparison of the ICES advice, the agreed TAC (or the sum of the unilateral quota) and total catch. Bottom: calculated percentage of Catch over Advice (CoA) and TAC over Advice (ToA).

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), the shelf West of Brittany (7h, 8a), and west of Scotland (6a), 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 these Ecoregions does not seem appropriate. Divergent trends in survey abundances have been observed within the assessment area, with a sustained spike in abundance in Div. 6a in the early 2010's which is not seen in surveys covering SA 7-8. Further investigations, such as morphometric studies, tagging and genetic population studies, would be needed to progress on stocks boundaries, however SIMWG has advised that for now, there is not sufficient evidence to carry out assessments on smaller spatial units.

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 (Table 9.2). 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 of red gurnard reported to ICES are presented 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 (GUX). A questionnaire was circulated to WGCATCH to gather information on how landings of gurnards are assigned to species. For those countries who responded, only Portugal has presented information on how the reporting of landings at a species level is achieved. Other countries accept the species code as declared at the point of landing, without further validation. There is further complication as the species code for tub gurnards (GUU) seems to be used incorrectly by some countries. This makes interpretation of the records of official landings difficult. Landings of gurnards (red, grey, tub and mixed) are shown in Figure 9.1.

International landings have fluctuated between 3452 - 5171 tonnes between 2006-2019. Landings in 2020 were 3273 tonnes – the lowest on record. 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.

9.4.2 Discards

Discard data for red gurnard has been provided for 2015 - 2020 through InterCatch (Table 9.3). For those countries which provided data, discard rates are variable but high (Table 9.3). Given uncertainty over landings, these figures should be treated with caution.

9.5 Survey data

Information on gurnard abundance are available in DATRAS for a number of surveys. Those covering the core area of the stock as determined by WKWEST (ICES, 2021) are the Scottish West Coast Groundfish Survey (SCOWCGFS and SC-IBTS), Irish Groundfish Survey (IEGFS), English Channel Beam Trawl Survey (BTS), 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; however no survey covers the entire stock area. Lengths at age are available from CGFS-Q4 in and for some years from IE-GFS-Q4.

SCO-WCGFS and SC-IBTS series. Before 1996, red gurnard was also scarce on the west of Scotland. The CPUE trended strongly upwards after 1997, reaching a peak in 2013, before declining to around the series average in recent years. The point value for 2020 was sharply up on 2019 (Figure 9.2, Figure 9.3).

CGFS-Q4 series. Over the time-series 1988—2011, CPUE has fluctuated, peaked in 1994, reached a low in 2011, but is above long term mean since 2016 (Figure 9.4).

EVHOE-WIBTS-Q4 series. Over the period 1997—2020, the CPUE has fluctuated over time. It has been on an increasing trend since 2017, and 2020 is the second highest value in the series. 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 (Figure 9.4).

IE-GFS series. The CPUE of red gurnard in the IE-GFS series has varied around the series mean without trend between 2002 and 2020 (Figure 9.5).

EN-BTS Q4 series. CPUE in this relatively short series has fluctuated without apparent trend since 2006 (Figure 9.5).

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. Accurate estimates of landings are still lacking for this species.

9.8 Assessment

Having explored the trends in available survey data, the delta-lognormal assessment method developed during WKWEST (ICES, 2021) was applied. This approach extracts the estimates of year effect from the log-normal part of the model (there is no temporal term in the binomial part), together with their associated standard error, and standardises the series relative to its mean value, to provide an index of biomass across the multiple surveys. Goodness of fit metrics of the model remain high (Figure 9.6Figure 9.7) and the log-normal part of the model has an adjusted r^2 value of 0.32.

After a period of relative stability, the biomass indicator declined in 2019, before recovering strongly in 2020 (Figure 9.8). The indicator remains above the biomass limit reference level of 0.81.

The influence of covid-19 related disruption to surveys in the Channel during 2020 has not been investigated for this stock.

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 are undocumented, other than for Portuguese landings. This makes interpretations of the records of official landings difficult. An international approach to collection of data on species composition of gurnard landings is required to support the provision of advice for this stock.

9.10 References

Dorel, D. 1986. Poissons de l'Atlantique nord-est relations taille-poids. Institut Francais de Recherche pour l'Exploitation de la Mer. Nantes, France. 165 p.

ICES. 2021. Benchmark Workshop on selected stocks in the Western Waters in 2021 (WKWEST). ICES Scientific Reports. 3:31. 504 pp. https://doi.org/10.17895/ices.pub.8137

Table 9.1. Red gurnard in the Northeast Atlantic. Official landings by country in tonnes.

Year	Belgium	Spain	France	Jersey	Guernsey	Ireland	IM	Netherlands	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
2020*	211	105	2335	0	0	10	1	235	123	254	3273
2020**	210	16	2335		0	10	1	234		249	3055

***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	12c	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	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	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	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	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	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	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	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	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	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	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	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	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	0	4131
2019*	128	19	73	0	84	0	13	1	0	952	1499	74	28	477	0	5	74	37	65	0	121	0	0	0	0	0	3653
2020*	58	13	65	2	65	4	10	1	4	680	1504	90	19	425	4	0	69	51	87	1	128	0	0	8	0	0	3273

*Preliminary Data

Table 9.2. Red gurnard in the Northeast Atlantic. Discards (t) by country, 2015 – 2020.

Country	2015	2016	2017	2018	2019	2020
France	1323	2249	2232	770	3132	292
Ireland	10	147	93	251	180	76
Spain		286	272	189	122	161
UK (ENG)	74	30		207	506	110
UK (SCO)	649	411	198	512	331	117
Total	2056	3123	2795	1929	4270	757

Table 9.3. Red gurnard in the Northeast Atlantic. Discarding of Red gurnard in the Northeast Atlantic, as a percentage of catch, by country, 2017-2020.

Country	Discard rate (%)			
	2017	2018	2019	2020
France	48	21	56	11
Ireland	91	95	95	88
Spain	72	68	78	91
UK (England)			67	51
UK (Scotland)	68	92	60	45

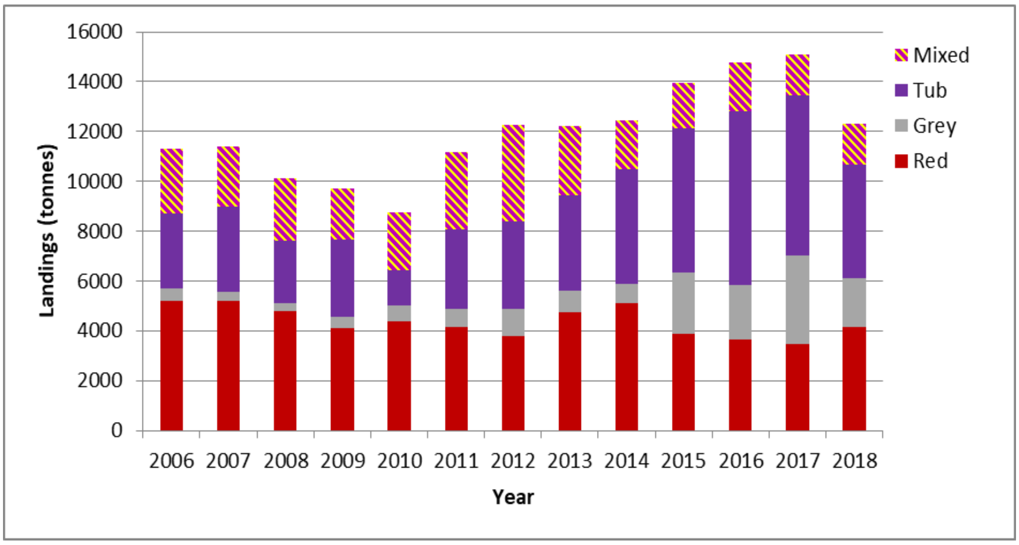

Figure 9.1. Red gurnard in the Northeast Atlantic. Official landings of red, grey, tub and mixed gurnards from SA3-8, 2006-2018.

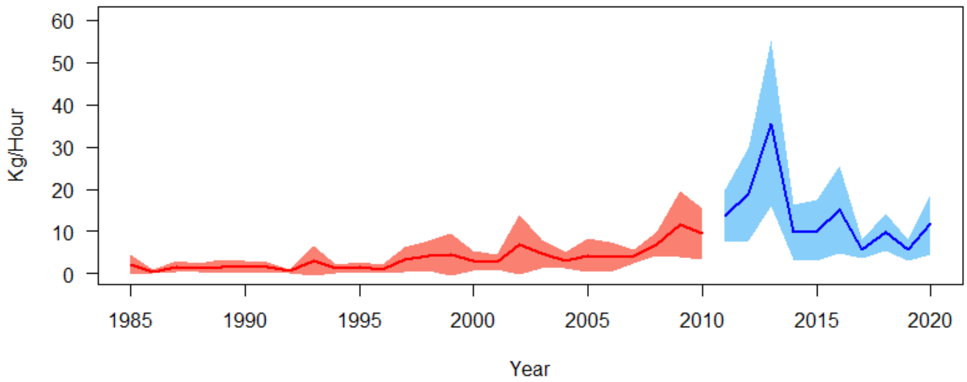

Figure 9.2. Red Gurnard in the northeast Atlantic. Trends in mean abundance (kg/hr) in the Q1 Scottish IBTS (1985 - 2010) and Q1 Scottish West Coast Groundfish Survey (2011 - 2020)

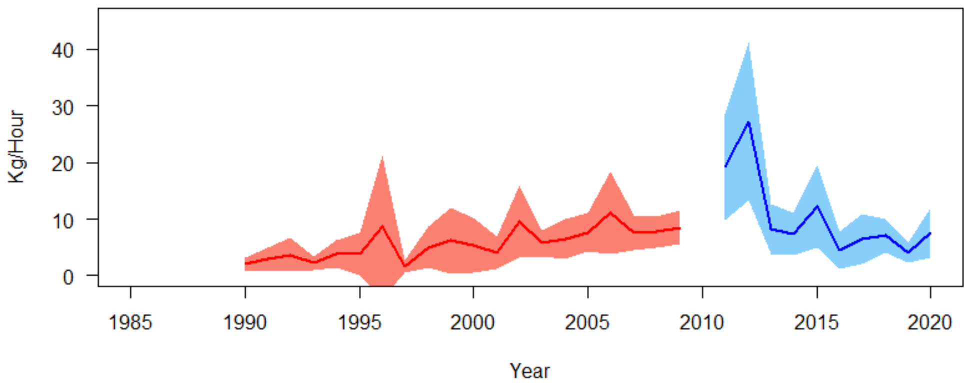

Figure 9.3. Red Gurnard in the northeast Atlantic. Trends in mean abundance (kg/hr) in the Q4 Scottish IBTS (1990 - 2009) and Q4 Scottish West Coast Groundfish Survey (2011 - 2020)

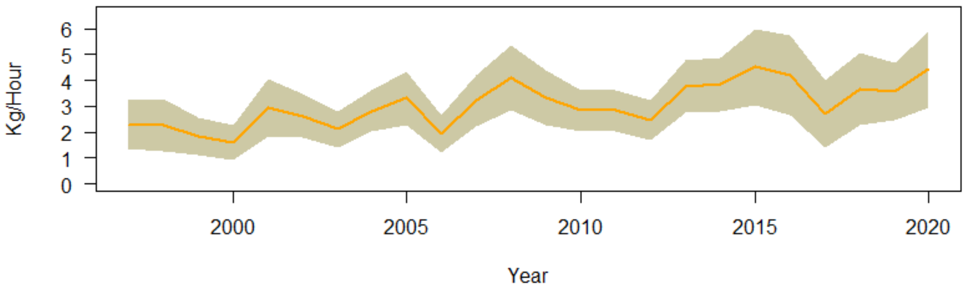

Figure 9.4. Red Gurnard in the northeast Atlantic. Trends in mean abundance (kg/hr) in the EVHOE (top) and French Channel Groundfish Survey (bottom)

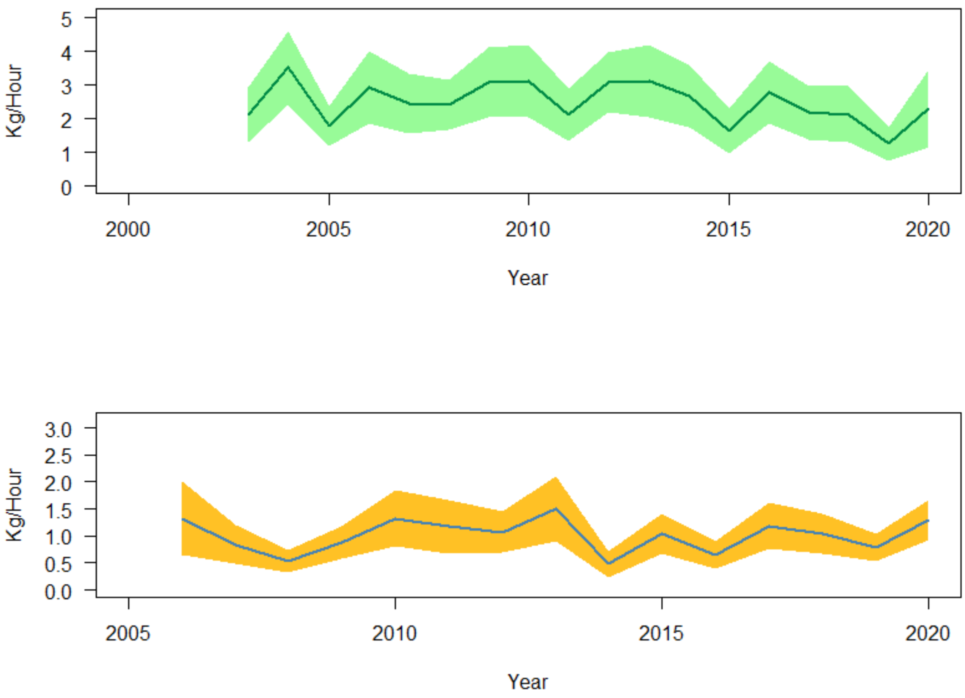

Figure 9.5. Red Gurnard in the northeast Atlantic. Trends in mean abundance (kg/hr) in the Irish Groundfish Survey (top) and English Channel Beam Trawl Survey (bottom)

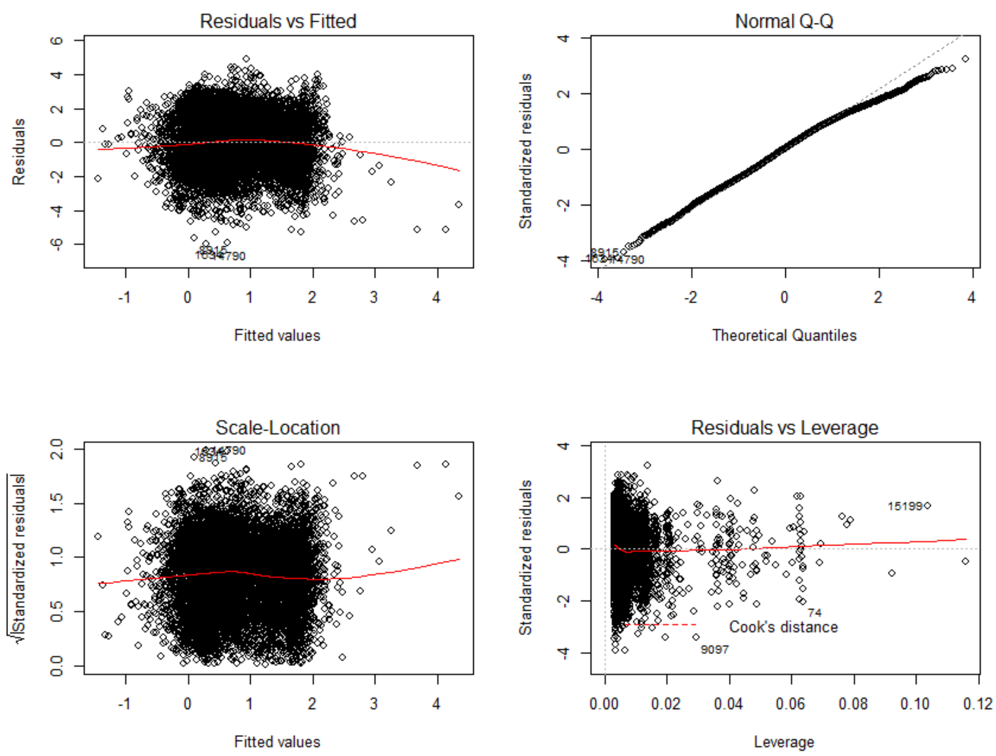

Figure 9.6. Red Gurnard in the northeast Atlantic. Measures of goodness of fit of the lognormal part of the assessment model.

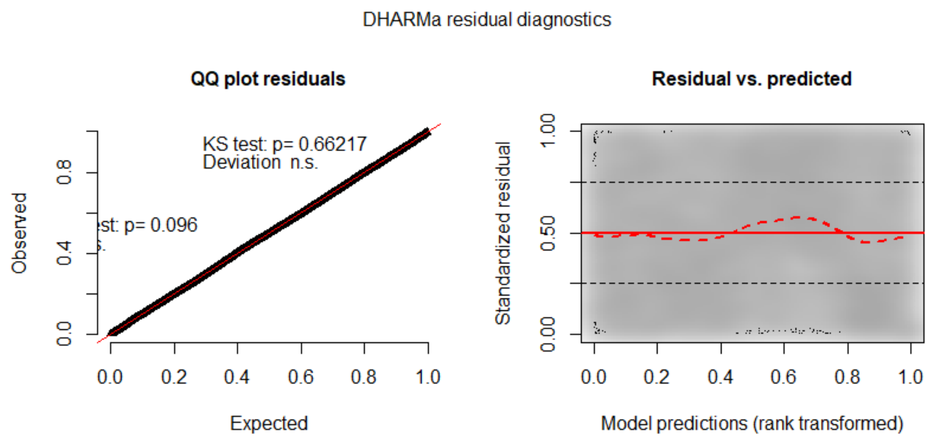

Figure 9.7. Red gurnard in the northeast Atlantic. Measures of goodness of fit of the binomial part of the assessment model.

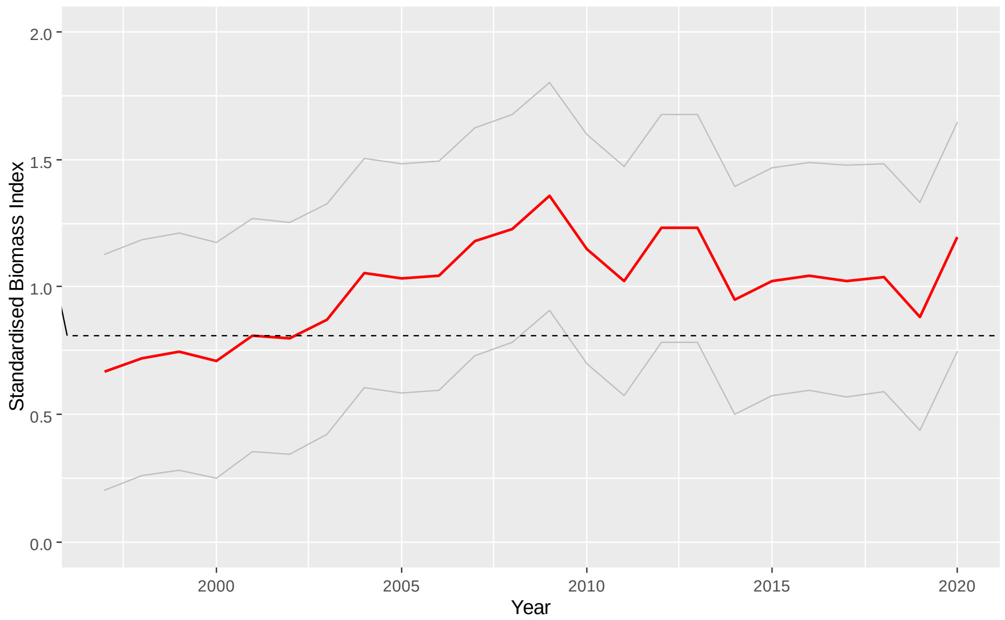

Figure 9.8. Red gurnard in the Northeast Atlantic. Results of the assessment model. Error ribbon is 2 standard errors. The dashed line represents MSY $B_{trigger}$ (0.81).

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 (Mahe *et al.*, 2005). Young fish are distributed in lower salinity coastal areas, while adults have a more offshore distribution.

Adult red mullets feed on small crustaceans, annelid worms, and mollusks, using their chin barbels to detect prey and search the mud. As a consequence, striped red mullets 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 (Mahe *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 22 cm.

Spawning occurs in the spring and early summer (May to June) according to Desbrosses (1933)- with a spawning peak in June in the northern Bay of Biscay (N'Da and Déniel, 1993). Eggs and larvae average 2.8mm and are pelagic (Sabatés *et al.*, 2015). The hatching takes place after three days at 18°C and after eight days at a temperature of 9°C (Quéro and 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 and 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 *et al.*, 2006).

The maximum reported age of the striped red mullet is 11 years (Quéro and Vayne, 1997; ICES, 2012), while the maximum length given is 44.5cm in the Bay of Biscay (Dorel, 1986) and 40cm elsewhere (Whitehead *et al.*, 1984; Fischer *et al.*, 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 16 cm. Since 2013 minimal size requirement has been established to 15 cm (France, 2013). 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 (Mahe *et al.*, 2014). 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 (Figure 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.

Discarding represented between 3% and 18% of the total catches in 2014–20 (Table 10.2). Since 2018, the discard rates are reported below 5%. However, there are concerns about how these discards have been estimated due to the lack of discards data for some countries. From the data provided to InterCatch in 2020, discards are essentially composed of individuals measuring less than 18 cm (Figure 10.2).

10.5 Survey data, recruit series

Exchange data is available in DATRAS during 1997-2020 for the French EVHOE survey, covering the Bay of Biscay and Celtic Sea, during 2001 – 2016 for the northern Spanish groundfish survey (SP-NSGFS), and from 2002 onwards for the Portuguese groundfish survey (PT-IBTS), covering the Portuguese coast. Relative total biomass 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 (Figure 10.3). The mean stratified abundance from Spain NSGFS follows a similar trend: high variability around the mean before 2017, then low level since 2017. (Figure 10.4) 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. 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 (Mahe *et al.*, 2012).

10.6 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. 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.

10.7 References

Benzinou, A., Carbini, S., Nasreddine, K., Elleboode, R., and Mahé, K. 2013. Discriminating stocks of striped red mullet (Mullus surmuletus) in the Northwest European seas using three automatic shape classification methods. Fisheries Research, 143: 153–160. https://www.sciencedirect.com/science/article/pii/S0165783613000192 (Accessed 30 August 2021).

Caill-Milly, N., Lissardy, M., and Leaute, J.-P. 2017. Improvement of the fishery knowledge of striped red mullet of the Bay of Biscay. Ifremer. https://archimer.ifremer.fr/doc/00399/51057/.

Desbrosses, P. 1933. Contribution à la connaissance de la biologie du rouget-barbet en atlantique nord, mullus barbatus (rond) surmuletus fage mode septentrional fage. Revue des Travaux de l'Institut des Pêches Maritimes, 6: 249–270. ISTPM. https://archimer.ifremer.fr/doc/00000/5822/.

Déniel, C. 1991. Biologie et élevage dudesbrosse rouget barbet Mullus surmuletus en Bretagne. Contrat Anvar-UBO A 8911096 E 00.

Dorel, D. 1986. Poissons de l'Atlantique Nord-Est : Relations Taille-Poids. https://archimer.ifremer.fr/doc/00000/1289/.

Fischer, W., Schneider, D., and Bauchot, L. 1987. Guide Fao d'Identification des Espèces pour les Besoins de la Pêche Méditerranée et Mer Noire - Zone de Pêche 37 Volume 2: Vertébrés. http://www.fao.org/3/x0170f/x0170f00.htm.

France. 2013, January. Arrêté du 29 janvier 2013 modifiant l'arrêté du 26 octobre 2012 déterminant la taille minimale ou le poids minimal de capture des poissons et autres organismes marins (pour une espèce donnée ou pour une zone géographique donnée) effectuée dans le cadre de la pêche maritime de loisir. https://www.legifrance.gouv.fr/loda/id/JORFTEXT000027093867/.

ICES. 2012. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). ICES, ICES Headquarters, Copenhagen. https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2012/WGNSSK/WGNSSK%202012.pdf.

Mahe, K., Destombe, A., Coppin, F., Koubbi, P., Vaz, S., Le Roy, D., and Carpentier, A. 2005. Le rouget barbet de roche Mullus surmuletus (L. 1758) en Manche orientale et mer du Nord. https://archimer.ifremer.fr/doc/00000/2351/.

Mahe, K., Elleboode, R., Charilaou, C., Ligas, A., Carbonara, P., and Intini, S. 2012. Red mullet (Mullus surmuletus) and striped red mullet (M. Barbatus) otolith and scale exchange 2011. https://archimer.ifremer.fr/doc/00063/17435/.

Mahe, K., Villanueva, M. C., Vaz, S., Coppin, F., Koubbi, P., and Carpentier, A. 2014. Morphological variability of the shape of striped red mullet Mullus surmuletus in relation to stock discrimination between the Bay of Biscay and the eastern English Channel. Journal of Fish Biology, 84: 1063–1073. https://onlinelibrary.wiley.com/doi/abs/10.1111/jfb.12345

Muus, B. J. 1.-2., and Nielsen, J. G. 1. 1999. Sea fish. Scandinavian Fishing Year Book, Hedehusene [Denmark].

N'Da, K., and Déniel, C. 1993. Sexual cycle and seasonal changes in the ovary of the red mullet, Mullus surmuletus, from the southern coast of Brittany. Journal of Fish Biology, 43: 229–244. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1095-8649.1993.tb00425.x

N'Da, K., and Déniel, C. 2005. Croissance des juvéniles du rouget de roche (Mullus surmuletus) dans le nord du golfe de Gascogne. Cybium, 29.

N'Da, K., Déniel, C., and Yao, K. 2006. Croissance du rouget de roche Mullus surmuletus dans le nord du golfe de Gascogne. Cybium, 30.

Quéro, J. C., and Vayne, J. J. 1997. LES POISSONS DE MER DES PECHES FRANCAISES. Identification, inventaire et répartition de 209 espèces.

Sabatés, A., Zaragoza, N., and Raya, V. 2015. Distribution and feeding dynamics of larval red mullet (Mullus barbatus) in the NW Mediterranean: The important role of cladocera. Journal of Plankton Research, 37: 820–833.

Whitehead, P. J. P., Bauchot, M.-L., and Hureau, J.-C. (Eds). 1984. Fishes of the North-eastern Atlantic and the Mediterranean. Unesco, Paris, France.

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	France	Guernsey	Ireland	Jersey	Netherlands	Portugal	Spain	UK	Total
2006	33	1947	8	16	1	115	10	387	170	2688
2007	43	1941	9	23	1	148	222	398	194	2978
2008	26	1394	9	22	0	165	169	394	165	2345
2009	20	1562	5	16	0	110	199	520	134	2567
2010	20	1743	5	8	0	128	276	479	133	2793
2011	21	1740	0	8	0	130	245	508	155	2806
2012	37	1342	0	7	1	125	217	332	122	2183
2013	28	932	5	4	0	50	187	246	71	1522
2014	12	926	5	2	0	2	221	265	53	1487
2015	23	1215	5	3	0	111	282	248	102	1989
2016	28	1179	0	4	0	69	204	194	83	1761
2017	36	997	0	10	0	13	154	327	64	1601
2018	37	896	0	0	0	95	122	321	67	1538
2019	30	1358	0	12	0	91	159	267	55	1973
2020	50	965	0	6	0	82	109	261	89	1562

Table 10.2: Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Official discards by country in tonnes. Total is presented with the total discards rates in %

Year	UK	France	Belgium	Portugal	Spain	Ireland	Netherlands	Total
2013	0							0 (0%)
2014		98						98 (6.2%)
2015	77	115						192 (8.8%)
2016	171	213	1	0	8			394 (18.3%)
2017	11	74	2	0	0	0		87 (5.1%)
2018	14	35	3	0	2	0		53 (3.3%)
2019	29	67	3		1	0		100 (4.8%)

Year	UK	France	Belgium	Portugal	Spain	Ireland	Netherlands	Total
2020	39	28	4		1	9	0	82 (5%)

Table 10.3: Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Official landings by area in tonnes

Year	6.a	7.a	7.b	7.c	7.e	7.f	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.d	9.a	8.e	6.b	Total
2006	0	1	1	0	869	50	24	103	11	0	1023	468	71	28	39	0	0	2688
2007	1	1	1	1	1047	54	22	104	24	0	861	473	90	32	267	0	0	2978
2008	0	1	1	0	880	46	16	72	26	0	639	246	86	35	296	0	0	2345
2009	2	1	2	2	592	25	9	74	35	0	879	460	156	88	243	0	0	2567
2010	2	1	3	2	642	26	10	59	32	1	1033	467	146	38	331	0	0	2793
2011	1	1	0	0	665	20	10	55	11	0	970	513	214	35	310	0	1	2806
2012	0	0	0	0	493	23	7	34	9	0	696	387	200	53	280	0	0	2183
2013	0	0	1	0	232	23	7	36	4	0	473	328	166	12	241	0	0	1522
2014	1	0	0	0	192	15	3	40	3	0	523	240	151	23	297	0	0	1487
2015	0	0	1	0	595	10	2	36	2	0	506	327	126	15	369	0	0	1989
2016	0	0	2	0	417	21	7	35	5	0	548	311	117	21	277	0	0	1761
2017	0	0	1	0	277	27	21	37	3	0	514	324	160	5	231	0	0	1601
2018	0	0	0	0	361	26	7	39	1	0	453	276	144	2	226	0	0	1538
2019	0	1	1	0	377	23	20	35	1	0	770	388	123	4	229	0	0	1973
2020	0	2	1	0	386	43	18	40	4	0	502	265	128	3	170	0	0	1562

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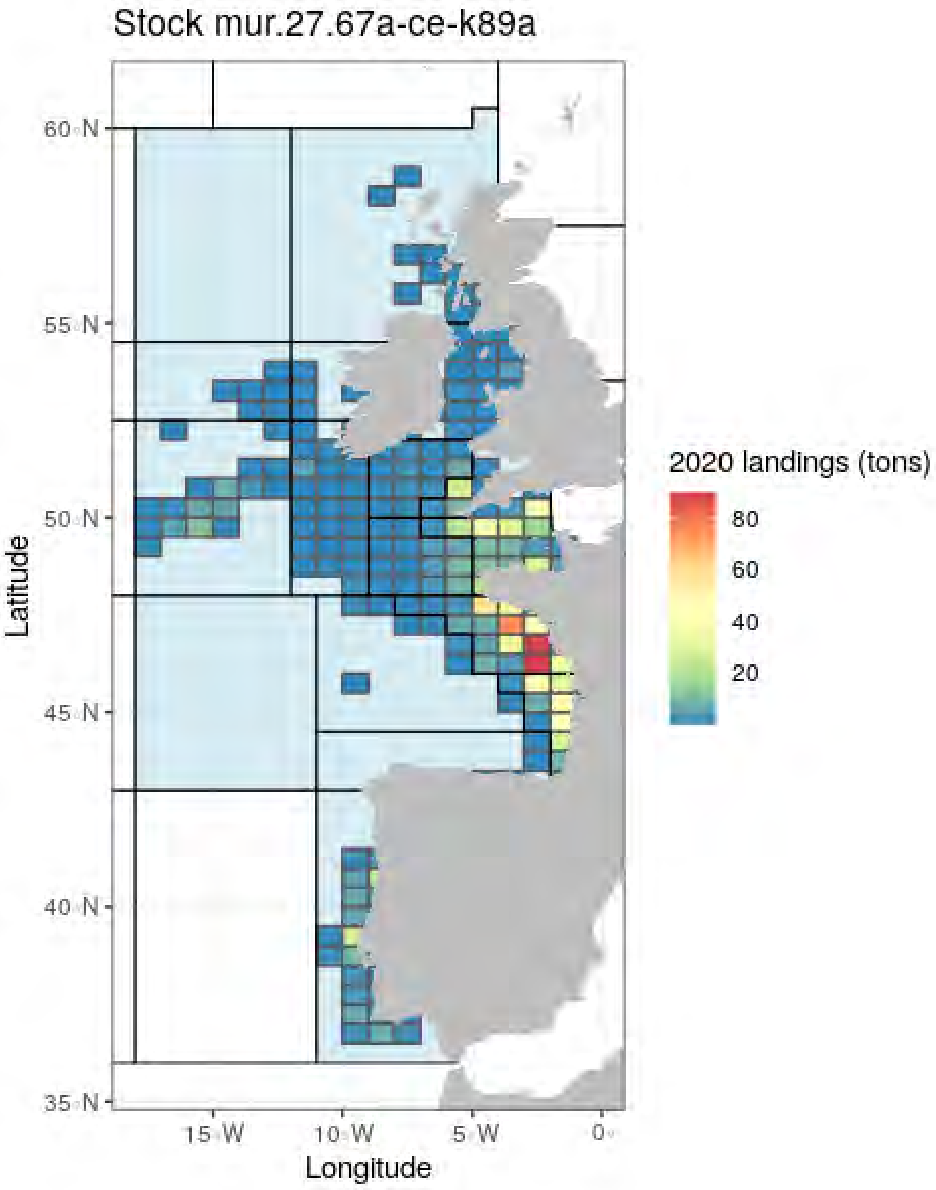

Figure 10.1: Striped red mullet in Subareas and Divisions 6, 7a-c, e-f, 8 and 9a. Landings by statistical rectangle for BEL, FRA, IRE, PT, UK (E&W), UK (SCO) in 2020.

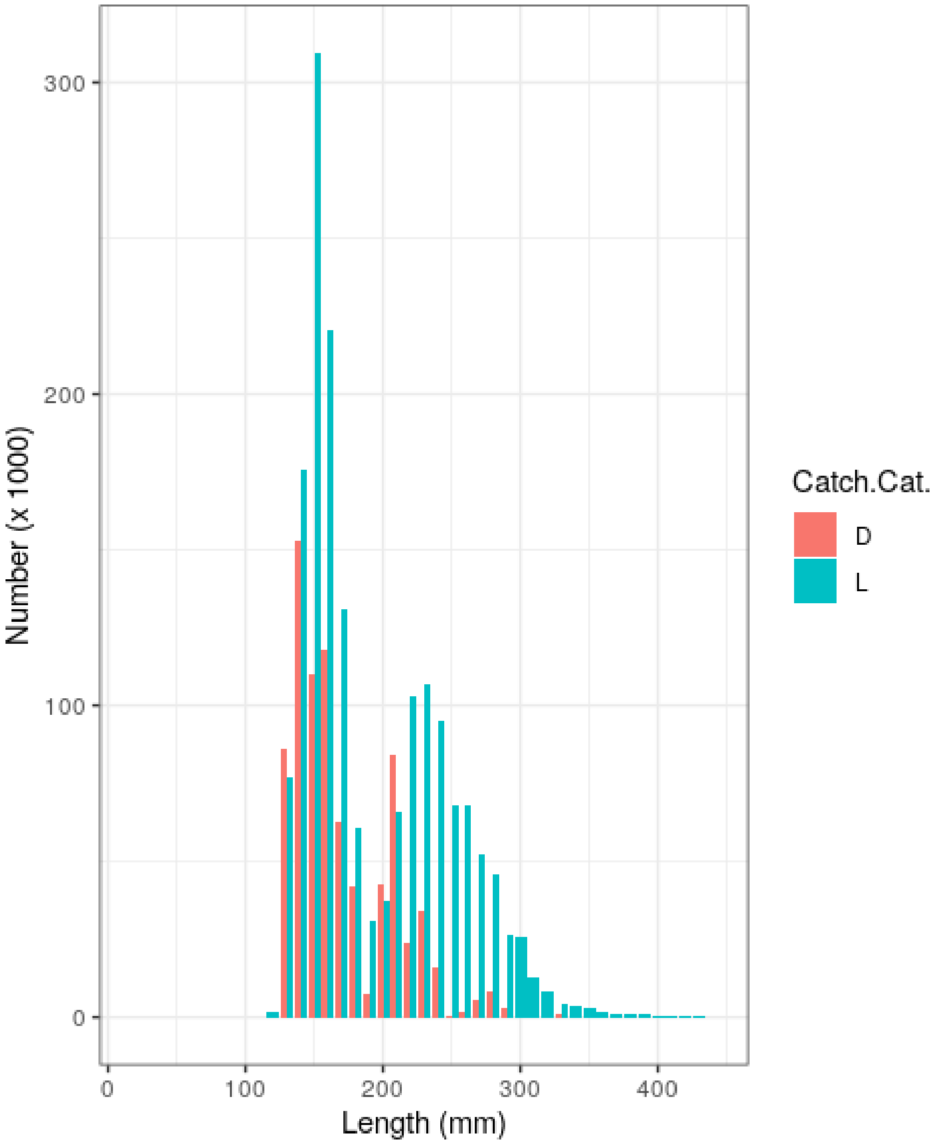

Figure 10.2: Striped red mullet in Subareas and Divisions 6, 7a-c, e-f, 8 and 9a. Length distribution in 2020 from Intercatch (D: Discards, L: Landings)

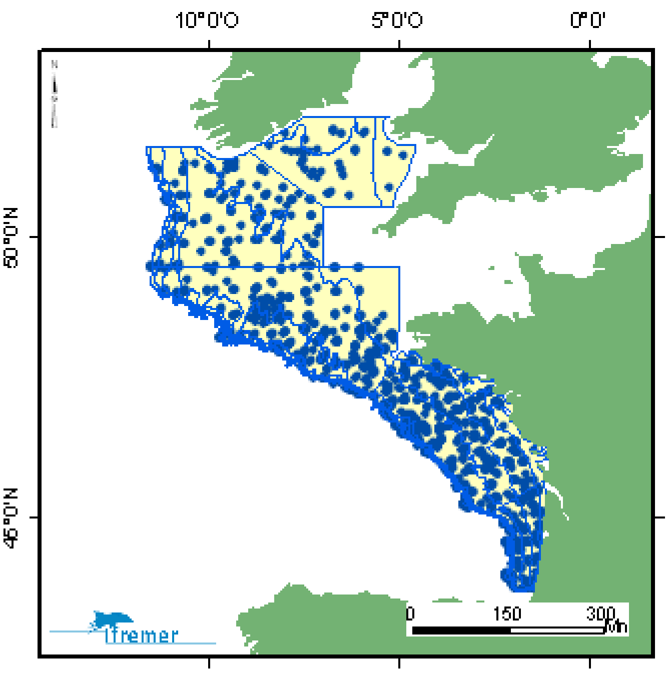

Figure 10.3: EVHOE survey station map

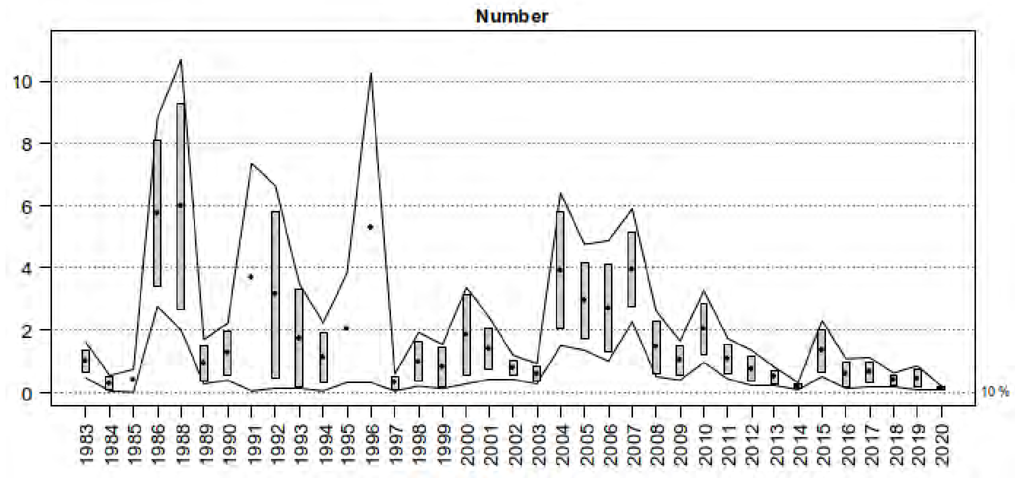

Figure 10.4: Striped red mullet in Subareas and Divisions 6, 7a-c, e-f, 8 and 9a. Spain NSGFS mean stratified abundance in northern Spanish Shelf 1983-2020

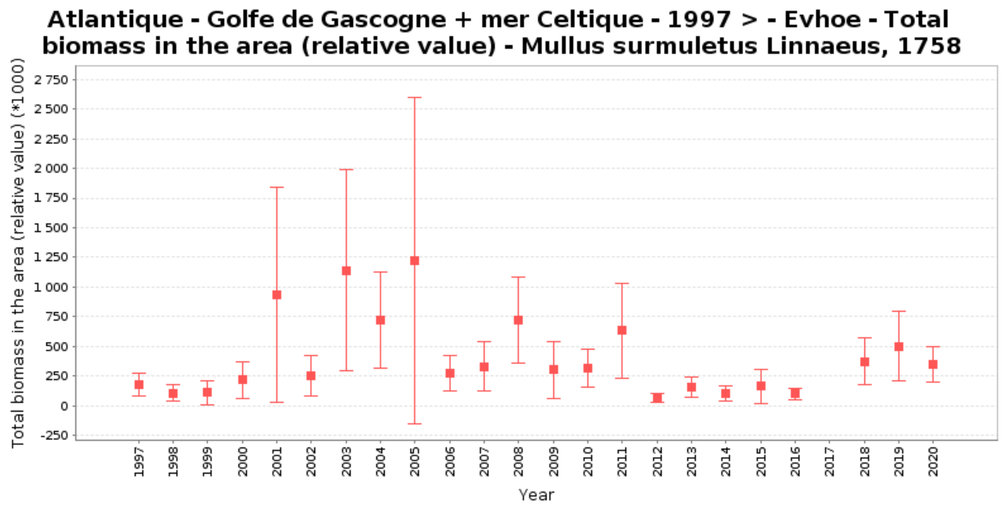

Figure 10.5: Striped red mullet in Subareas and Divisions 6, 7a-c, e-f, 8 and 9a. EVHOE total biomass in the area (relative value) 19972020

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Annex 2: Terms of Reference

WGWIDE– Working Group on Widely Distributed Stocks

This resolution was approved 3 November 2020

2020/2/FRSG20 The **Working Group on Widely Distributed Stocks** (WGWIDE), chaired by Andrew Campbell, Ireland, will meet 25–31 August 2021 online 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)	September 2021	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 Northeast Atlantic and Arctic Ocean)	September 2021	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 2021	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 2021	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 2021	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 2021	whb.27.1-91214_SA

Annex 4: Audits

Audit of (Northeast Atlantic mackerel (mac.27.nea))

Date: 8th September, 2021

Auditor: Sólvá Eliasen, Ole Henriksen, Richard Nash

- *Audience to write for: ADG, ACOM, benchmark groups and EG next year.*
- *Aim is to audit (check if correct):*
    - *the stock assessment– concentrate on the input data, settings and output data from the assessment*
    - *the correct use of the assessment output in the forecast, and check if forecast settings are applied correctly*
- *Any deviations from the stock annex should be described sufficiently.*
- *By the conclusion of the working group, all update assessments should be audited successfully.*
- *Store all audits on SharePoint for future reference.*

General

This audit focuses on the advice sheet and the WGWIDE report section on NEA Mackerel. The advice sheet and the stock annex are consistent with the report section. The assessment model performance was good, and a systematic downward revision in the retrospective pattern for F in recent years seems to be improved, although the causality of this change are not discussed and seems unresolved.

For single stock summary sheet advice:

1) **Assessment type:** updated assessment (inter-benchmarked in 2019)
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: A modified state-space Assessment Model (SAM) that is able to incorporate tag/recapture data – both historical steel tags (1980-2006) and recent RFID tags (2014-2020) together with three additional survey indices.
5) **Data issues:** All data are available as described in stock annex and in the report text.
6) **Consistency**: The retrospective bias, where the F has consistently been overestimated and SSB underestimated, has decreased for the 2021 assessment.
7) **Stock status**: SSB is above all reference points (MSY Bt_{rigger}, B_{pa}, and B_{lim}) and F is below F_{MSY}.
8) **Management Plan**: There is no management strategy agreed for the stock, therefore ICES based its advice on the MSY approach. No agreement on the share of the stock has been reached for 2021. Despite the acceptance of ICES advice, the total declared quotas in each of the years 2015 to 2020, all exceed the maximum catch advised by ICES.

General comments

The report section is readable and all information is there. Whilst the report is still rather long, the removal of numerous surplus tables was appreciated. The advice sheet is well documented.

Technical comments

The code and input data for the analysis (assessment, and short-term forecast) are all available on SharePoint. An auditor reran the assessment and short-term forecast, however, the documentation in the code was lacking. This must be added so that anyone who is interested in utilising/rerunning/changing the code can do so (a similar comment was also made in the 2020 audit).

To the best of our knowledge, the assessment has been performed correctly according to the stock annex.

Table and figure numbers and references to them in the text have been checked.

Conclusions

The assessment has been performed correctly according to the stock annex.

Audit of Northeast Atlantic Boarfish (Boc.27.6-8)

Date: 02/09/21
Auditor: Afra Egan

General

This is an update assessment with advice provided in 2021 for 2022 and 2023.

For single stock summary sheet advice:

9) **Assessment type: update/SALY**
10) **Assessment**: trends - Category 3 with biennial advice
11) **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". There are no issues with the new input data.
3) **Consistency**: This updated assessment is consistent with the assessment carried out in 2020.
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 proposed by the Pelagic AC was evaluated and found to be precautionary (ICES, 2015). ICES provides advice for this stock following the standard procedures, which in this case corresponds to the management 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 highlighted.

Technical comments

- Minor corrections applied to the numbering of tables.
- IBTS text section 3.6.1 needs figure numbers added
- Add a total column to table 3.1.2.2 to make checking easier
- Table 3.6.4.1 - 2020 - is missing from this table
- Check Irish catch and landings figures: Tables 3.1.2.1, Tables-3.1.2.3-3.1.2.7 and Table 3.2.1.4
- Specify that the figures in Tables 3.1.2.3-3.1.2.7 are landings

Conclusions

The assessment was rerun following the stock annex and all outputs generated were checked against the report and no errors found. The assessment has been performed correctly

Audit of Northeast Atlantic Boarfish (Boc.27.6-8)

Date: 10 september 2021
Auditor: Claus R. Sparrevohn

General

Update advice for the years 2022 and 2023

For single stock summary sheet advice:

6) **Assessment type:** update similar to the assessment in 2019
7) **Assessment**: Category 3 using the trend of a surplus production model as index of the TSB in the 2 over 3 calculation
8) **Forecast**: NA
9) **Assessment model**: State space surplus production model with catch data, IBTS survey indices, and one acoustic survey.
10) **Data issues:** No issues with data in this year's assessment
11) **Consistency**: Consistent with the 2019 assessment
12) **Stock status**: Reference points are not defined,
13) **Management Plan:** No agreed management plan.

General comments

Procedure is well described in the rapport.

Technical comments

None

Conclusions

The assessment has been performed according to the procedure and is suitable for advice.

Audit of Red Gurnard stock assessment

Date: 14.092021
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, 6 survey abundances index for the species area presented from around 1990 to 2020, with a combined biomass index built on these series.

For single stock summary sheet advice:

1) **Assessment type:** delta-lognormal assessment (from WKWEST)
2) **Assessment**: trend analyses
3) **Forecast**: not presented
4) **Assessment model**: surveys indices combined using a delta-lognormal model in an index of biomass to evaluate stock trend
5) **Data issues:** general lack of data
6) **Consistency:** undefined
7) **Stock status**: undefined.
8) **Management Plan**: there is no management plan.

General comments

Well structured and documented section pointing out the lack of data regarding this stock and showing the computation of a biomass index for this stock.

Technical comments

Conclusions

A combined biomass index has been computed correctly. There is no assessment for this stock.

Audit of North Seas Horse mackerel stock (hom.27.3a4bc7d)

Date: 02/09/2021
Auditor: Rosana Ourens

General

General remarks:

- In 2017 the stock was benchmarked and upgraded to category 3. A combined CPUE index is used to evaluate trends in abundance over time. This index is used to estimate the 2-over-3 rule and provide catch advice.
- FMSY proxy is the length based indicator ($L_{mean}/L_{F=M}$) =1. A biomass safeguard is not defined for this stock.
- The 2020 abundance index was not used in the assessment because it was biased (one of the surveys was incomplete).
- Uncertainty cap (downwards) and precautionary buffer were applied this year. It resulted in a catch advice 36% lower than last year.

For single stock summary sheet advice:

Assessment type: SALY Catch advice provided for 2022 and 2023
Assessment: Survey trend-based assessment
Forecast: not presented
Assessment model: NS-IBTS and FR-CGFS survey indices are used in a hurdle model to estimate an average annual CPUE index. This model, selected because the survey data show overdispersion and high proportion of zero values, has two components:

1) count model (GLM-negative binomial) with year and survey as explanatory factors, including their interaction; and
2) zero model (GLM-binomial), with year and survey as explanatory factors (without interaction).

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 (0.76 for NS-IBTS, and 0.24 fir FR-CGFS). Separate models were fitted to the juvenile (<20cm) and adult exploitable (≥20cm) sub-stocks. The index for the adult exploitable sub-stock is used to estimate the 2- over-3 rule.

Additionally, the length-based indicator $L_{mean}/L_{F=M}$ is used to evaluate the status of the stock against a F_{MSY} proxy ($L_{mean}/L_{F=M}$ =1). The length-based indicator is estimated from samples from the commercial catch in 27.7d, the main fishing area.
Data issues: FR-CGFS survey could not complete the stations located in the UK waters because of administrative and pandemic related issues. A sensitivity test was conducted to identify the best approach to deal with this missing data. The test suggested that missing the UK stations from the FR-CGFS or leaving out the FR-CGFS entirely may lead to changes in the abundance index. Therefore, it was decided that no reliable index value for 2020 could be produced. For this reason, the 2-over-3 ratio used in the advice catch was estimated as the 2019 index divided by the mean index value of 2016-2018.

A mistake was also found in the calculation of the length frequency distributions in the 2019 and 2020 assessments, and they were recalculated.

Consistency: The index survey is considered robust, but the hurdle model could not estimate the standard error for the intercept and the parameter θ of the count model for the adult sub-stock model. This issue has happened in the last three assessments, and it might require further exploration in the future. To test the robustness of the model, a zero-inflated model was run with the same setup as the hurdle model and produced very similar outputs.
Although the biomass indicator was estimated for the same time period (2016-2019) as last year given the lack of 2020 survey data, the results are slightly different. This was caused by updates on the data reported in DATRAS, which resulted in a higher biomass estimate for 2016 than in the 2020 assessment.

Stock status

14) The CPUE index for the adult sub-stock declined by 74% in 2017. It has remained low since then, although it slightly increased in 2019.
15) 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 FR-CGFS, do not show the same trend.
16) The fishing pressure has been slightly above F_{MSY} proxy since the beginning of the time series (2016). In 2020 the length-based indicator $L_{mean}/L_{F=M}$ was 0.927.

Management Plan: There is not a management plan for horse mackerel in this area

General comments

The report is well written, well documented, and easy to follow.

Technical comments

- Table 6.4.1 of the draft report has not been updated yet. The stock assessor has been notified.
- The stock annex has been updated since the last benchmark and details how the biomass index and the F_{MSY} proxy are calculated. However, it does not state what the basis for the advice is (2-over-3 rule).

Conclusions

The assessment has been performed correctly

Audit of North Seas Horse mackerel stock (hom.27.3a4bc7d)

Date: September 2nd, 2021
Auditor: Chetyrkin Anatoly

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 in TAC was advised by ICES.
In 2017, the stock was benchmarked and the NS-IBTS and FR-CGFS survey indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHOM stock was upgraded to category 3.
Due to the COVID pandemic impacting the FR-CGFS, no index value for 2020 was produced. The application of the HCR 3.1 (ICES, 2012) resulted in an index ratio of the 2019 index value (with 2020 is missing) over the mean index value of 2016-2018 of 0.79, meaning that an 20% uncertainty cap was applied to the catch advice.
This stock has a biennial advice for 2022 and 2023 therefore this is an update assessment. The advice sheet was provided in 2021 and report was well written and well documented, however the Stock Annex is rather incomplete and poorly documented.

For single stock summary sheet advice:

1) **Assessment type: SALY** Catch advice provided for 2022 - 2023
2) **Assessment**: category 3 (survey based method)
3) **Forecast**: not presented
4) **Assessment model**: Hurdle model and zero-inflated model

Together with the main model was launched a zero-inflated model 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. The fitted values of the zero-inflated model were very similar to that of the hurdle model with warning.

5) **Data issues:**

No data for UK waters due pandemic issues. The problem was solved and part of the catch was calculated with 2019 index divided by the mean index value of 2016-2018

6) **Consistency**: it is consistent with the assessment carried out last year.
The hurdle model could not estimate some parameters of the count model for the adult sub-stock model. Need to continue research in this direction or look for a new model.

7) **Stock status**: There are signs of improved recruitment in some years, but the trend in the abundance index for juveniles fluctuates and, when split into two surveys, does not show the same trend.
The $L_{mean}/L_{F=M}$ ratio in 2020 was 0.927, indicating that the fishing mortality is above F_{MSY}.

8) **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 stock annex has been updated with new details about FMSY proxy and biomass index calculation. But still not completely filled.

Conclusions

The assessment has been performed correctly. Stock advice for NSHOM is biennial (2022 and 2023).

Audit of Norwegian spring spawning herring (her.27.1-24a514a)

Date: 01.09.2021

Auditor: Are Salthaug, Anna Olafsdottir, Sigurvin Bjarnason

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:

17) **Assessment type: update/SALY**
18) **Assessment**: analytical
19) **Forecast**: presented
20) **Assessment model**: XSAM with 3 survey fleets
21) **Data issues:** Input data are available as described in the stock annex. Input data to the assessment were compared between assessment 2020 and 2021, and between the 2021 assessment and the input data tables in the 2021 report. 2021 assessment input data were fetched from the "06.Data" folder on sharepoint and all input data were available: https://community.ices.dk/ExpertGroups/WGWIDE/SitePages/HomePage.aspx?RootFolder=%2FExpertGroups%2FWGWIDE%2F2021%20Meeting%20Docs%2F06%2E%20Data%2Fher%2E27%2E1%2D24a514a&FolderCTID=0x012000FC5A3EF0E554B246B7BDD1920914AB7F&View=%7B1658FCBE%2DAA9C%2D4F82%2DBEC4%2D49E934FCB976%7D

    2020 assessment input data were also fetched from the sharepoint in folder "06.Data – HER – data". Input files were available for catch-at-age, spawning survey, Barents Sea age 1-2years, IESNS survey: https://community.ices.dk/ExpertGroups/WGWIDE/_layouts/15/start.aspx#/2020%20Meeting%20Docs/Forms/AllItems.aspx?RootFolder=%2FExpertGroups%2FWGWIDE%2F2020%20Meeting%20Docs%2F06%2E%20Data%2Fher%2E27%2E1%2D24a514a%2Fdata&FolderCTID=0x01200001CB4C8137392A41ADA4E2F0E296C61D&View=%7B1A2D5296%2D68F0%2D44ED%2DB3E8%2D334756DAC39B%7D

    Data were the same in tables except for 3 instances:

    a) Table 4.4.7.2 in 2021 report does not report values for age 1-2 in year 2008, however there are values in the input data tables both in 2020 and 2021.

    b) Table 4.4.3.1. Catch-at-age numbers. For age 0 in year 1976 the value in the report is wrong compared to the assessment input data. Appears to be a decimal issue.

    c) Table 4.4.4.1. Weight-at-age in the catch. In the assessment input file weight for age 15+ in years 1969-70, 1985-86, 1999, and 2001-2 is listed as zero but in report table values are listed.
22) **Consistency**: This years' assessment is consistent with last years' assessment and the WG accepted the assessment.
23) **Stock status**: The fishing pressure on the stock is above FMSY, FMGT and Fpa (but below Flim). Spawning-stock size is above MSY Btrigger, Bpa, and Blim.
24) **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.

General comments

The input data and assessment are documented as described in the stock annex and the report sections are well ordered.

Technical comments

The stock annex has been updated with the latest survey information. There is an upward revision of the 2016 year class in this years' assessment compared to last year's assessment.

Conclusions

The assessment has been performed correctly

Audit of Western Horse Mackerel data and assessment

Date: 02/09/2021
Auditor: Alessandro Orio, Sondre Hølleland and Gersom Costas

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:

25) **Assessment type:** update
26) **Assessment**: analytical.
27) **Forecast**: presented
28) **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.
29) **Data issues:** No data issues.
30) **Consistency**: The view of the WG was that the assessment should be accepted. The Stock annex needs to be updated for the F and M before spawning used in the forecast (assumed at the beginning of the year in the current forecast) and for the new Fpa value due the changed basis.
31) **Stock status**: Fishing pressure on the stock is at F_{MSY}. Spawning stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.
32) **Management Plan**: No management plan

General comments

The assessment and forecast have been available for review. Input and output data were correct. A few inconsistencies were found in the advice sheet but these have been already corrected.

Technical comments

Few inconsistencies are present in the stock annex. F and M before spawning in the forecast needs to be updated in the stock annex since in the forecast the spawning time is assumed to happen at the beginning of the year. The section on reference points needs to be updated with the new Fpa due to the change of basis.
A thorough revision of the number of samples used for the different age and length frequency distributions in the assessment is suggested for the next benchmark iteration. 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. 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.

Audit of WHB
Date: 03 September 2021
Auditor: Alexander Pronyuk

General

In this year IBWSS have been conducted. Application of IBWSS indexes for the main age groups is a proven way to fit the cohort programs. The WG used best estimate preliminary catches in 2021 1,242,727 tons. In complex the assessment is satisfactorily provided by the input data.
The WG accepted the update assessment as a basis for advice for 2022.

For single stock summary sheet advice:

1) **Assessment type:** Update assessment. Last interbenchmark protocol was conducted in 2016.
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: SAM, (in addition TISVPA and XSA as optional models for checking purposes; assessments with data from two additional surveys IESNS and IESSNS for checking purposes).
5) **Data issues:** The data for 2020 presented completely in the report. Data for 2021 are preliminary, but applied in the models. Data described in the stock annex, source code for the SAM model and model configuration are available https://www.stockassessment.org.
6) **Consistency**: The view of the WG was this year's assess should be accepted.
7) **Stock status**: SSB is more than Bpa. Fpa < F< Flim. R in 2020-2021 much higher than 2017-2019.
8) **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 not applied when calculating TAC for 2022.

General comments

The report is well documented, contains relevant data and references. Assessment provides a valid basis for advice. The contents of the report correspond to the agenda. Tables of input data (n at age / catch mean weight / survey abundance estimates) agree with data in stockassessment.org. The data have been used as specified in the stock annex. Prediction of overall catch level is done successfully. There is no reason to deviate from the standard procedure for this stock. Reliable recruitment forecast remains to be as the main task. Changing the time-series of geometric mean of a recruitment for the short forecast seems to enough argumented.

Technical comments

Technical comments are provided in the advice sheet and the report text using track changes.

Conclusions

The assessment has been performed correctly according to the stock Annex.

Annex 5: WGWIDE 2021 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	1	0	0	0	0
WGWIDE	her.27.1-24a514a	3	3	3	0	0
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	0	0	0	0	0
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	0	0	0	0	0
WGWIDE	her.27.1-24a514a	0	0	3	3	0
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	0	0	0	0	0
WGWIDE	whb.27.1-91214	1	1	1	0	0

Expert group	Stock code	MSE (management/rebuilding 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	0	0	0	0	0
WGWIDE	her.27.1-24a514a	0	3	1	1	0
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	0	0	0	0	0
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	0	0	1	1
WGWIDE	her.27.1-24a514a	0	1	1	1
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	0	0	0	0
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	0	0	0	0
WGWIDE	her.27.1-24a514a	1	0	0	1
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	0	0	0	0
WGWIDE	whb.27.1-91214	1	1	0	1

North Sea mackerel daily egg production and spawning stock biomass estimation in 2021

C.J.G. van Damme[1], E. Blom[1], B. Huwer[2], F. Burns[3] & G.Costas[4]

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[2] DTU Aqua, Copenhagen, Denmark

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[4] IEO, Vigo, Spain

Introduction

The North Sea Mackerel Egg Survey (NSMEGS) is designed to estimate the spawning stock biomass (SSB) of mackerel of the North Sea spawning component of the Northeast-Atlantic stock on a triennial basis. Prior to 2017 this was done utilizing the annual egg production method (AEPM). This method estimates and combines total annual egg production (TAEP), realized fecundity per gram female, and sex (male to female) ratio to calculate SSB.

Spatial and temporal coverage in the North Sea was impaired when Norway withdrew from the survey in 2014 and Netherlands was left as the sole survey participant in 2015 and 2017. In 2021 Denmark was recruited as a new participant for the NSMEGS. However, the planned coverage in 2021 of the mackerel spawning in the North Sea, both temporally and spatially, was far from ideal for the Annual Egg Production Method (AEPM; ICES 2018).

Another issue for the NSMEGS is that since 1982 it has been impossible to collect and sample pre-spawning mackerel, which are necessary in order to estimate the potential fecundity. For SSB estimation using the AEPM, the realized fecundity value used was from the 1982 estimate (Iversen and Adoff, 1983).

Consequently, WGMEGS discussed utilizing the Daily Egg Production Method (DEPM) for the NSMEGS. The DEPM only requires one full sweep, in a short time period, of the entire mackerel spawning area, preferably at peak spawning time, in order to estimate the Daily Egg Production (DEP). A disadvantage of the DEPM is that it requires many more mackerel ovary samples to be collected to estimate batch fecundity and spawning fraction. Considering the pros and cons of the AEPM and DEPM for the NSMEGS, in 2018 WGMEGS decided to switch to the DEPM for the NSMEGS in 2021 (ICES 2018).

Originally the NSMEGS was planned for 2020, however, due to the pandemic and the implementation of Covid-19 measures it was not possible to complete the survey in 2020. After consultation with WGMEGS chairs and the mackerel assessor it was agreed to postpone the survey to 2021.

Survey

In 2021 Netherlands and Denmark conducted the North Sea mackerel egg survey (NSMEGS). Whilst completing an exploratory egg survey, similar to those in 2017 and 2018, along the Norwegian Sea, Scotland was also able to contribute several additional survey transects within the Northern North Sea that were then incorporated into the 2021 NSMEGS dataset.

During 2021 Covid 19 measures continued to pose significant challenges that impeded the execution of the survey plan. The Dutch vessel was not permitted to enter foreign harbours during survey breaks, instead being required to undertake the long steam back to a Dutch harbour. As a consequence the Netherlands was unable to sample the most northerly transect. However Scotland was able to complete this transect during their exploratory survey.

The samples were collected and analysed according to the WGMEGS manuals (ICES 2019a, 2019b). The Netherlands and Scotland sampled eggs with a Gulf VII plankton sampler while Denmark used a Nackthai sampler. The Netherlands and Denmark utilised a 500 µm plankton net whereas Scotland used a 250 µm plankton net. At each station a double oblique haul was performed from the surface to 5 m above the bottom, a maximum depth of 200 m, or 20 m below the thermocline in case of stratification of the water column. Temperature and salinity were measured during the haul with a CTD mounted on top of the plankton sampler. Electronic flowmeters were mounted on the plankton sampler to monitor flow.

The NSMEGS was carried out from 25th May to 12th June (Table 1). During this period the spawning area between 53ºN and 62ºN was surveyed once, receiving a single coverage (Fig. 1). The survey is designed to cover the entire spawning area with samples collected every half ICES statistical rectangle (ICES, 2014). In total 294 plankton stations were sampled. In 26 of the half rectangles more than one plankton sample was collected (Fig. 1a). These rectangles were used to estimate the CV and variance of the DEP. On each transect at least one pelagic trawl haul was performed for the collection of mackerel adult samples (Fig. 1b).

Following the WGMEGS manual temperature at 5m depth was used to estimate egg development (ICES 2019a). For the DEPM only the mackerel eggs in development stage 1A are used to estimate daily egg production.

Results

Mackerel daily egg production

During the survey the weather was fine. Denmark and Scotland managed to sample all their planned plankton stations. The Netherlands missed 4 plankton stations due to technical issues and limited sampling time.

The spatial egg distribution is shown in Fig. 2. The standard interpolation rules (ICES, 2019a) were applied where needed (see interpolated stations in Fig. 2). The interpolated egg production accounted for 7.3% of the DEP. The egg distribution is comparable to previous surveys in the same area and period, with the highest numbers of eggs found in the south western area. Previous surveys did not sample above 59ºN and no comparison with previous years is available for this area.

The DEP was calculated for the total investigated area (Table 2). For comparison with the previous survey, the DEP was also calculated for the area between 53.5 and 59ºN which was the area sampled in 2017 in the same period of the year (extended period 2 of 2017). DEP of 2021 was 11% higher compared to 2017 (Table 3), but the sampled area was also a bit larger in 2021 (11%).

Adult parameters

Denmark was unable to analyse their ovary samples before the WGWIDE 2021 meeting. The Netherlands screened all samples and analysed part of the ovary samples for batch fecundity and spawning fraction estimation. Denmark had finished the screening of the samples. The Dutch and Danish results will be combined for the final estimations in 2022.

The Netherlands sampled 524 mackerel during the survey and collected ovary samples of 164 females. Of these 164 ovaries 73 can be analysed for batch fecundity estimation, and 108 for POF analyses for spawning fraction estimation. For this working document 40 batch fecundity and 51 POF samples were analysed. Denmark sampled 817 mackerel during the survey and collected ovary samples of 119 females.

The adult parameters are still very preliminary, and are therefore not provided in this document. Without adult parameters the SSB cannot be estimated. When final adult parameter estimates are available and agreed by WGMEGS an estimate of SSB will be provided to WGWIDE.

References

ICES, 2018. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). ICES CM 2018/EOSG:17, 70 pp.

ICES, 2019a. Manual for mackerel and horse mackerel egg surveys, sampling at sea. Series of ICES Survey Protocols SISP 6. 82 pp. http://doi.org/10.17895/ices.pub.5140

ICES, 2019b. Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel. Series of ICES Survey Protocols SISP 5. 89 pp. http://doi.org/10.17895/ices.pub.5139

Iversen, S.A. and Adoff, G.R. 1983. Fecundity observations on mackerel from the Norwegian coast. ICES C.M.1983, H:45, 6pp.

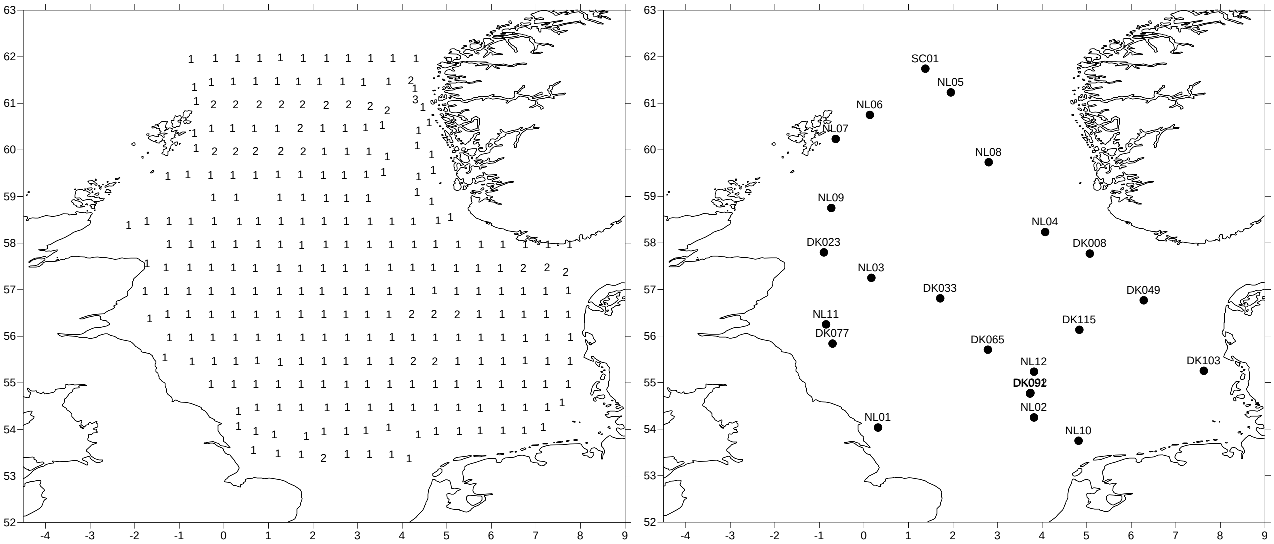

Figure 1. Number of samples for NSMEGS 2021; plankton samples per half ICES rectangle (left) and pelagic trawl hauls for mackerel adult samples (right; all hauls included).

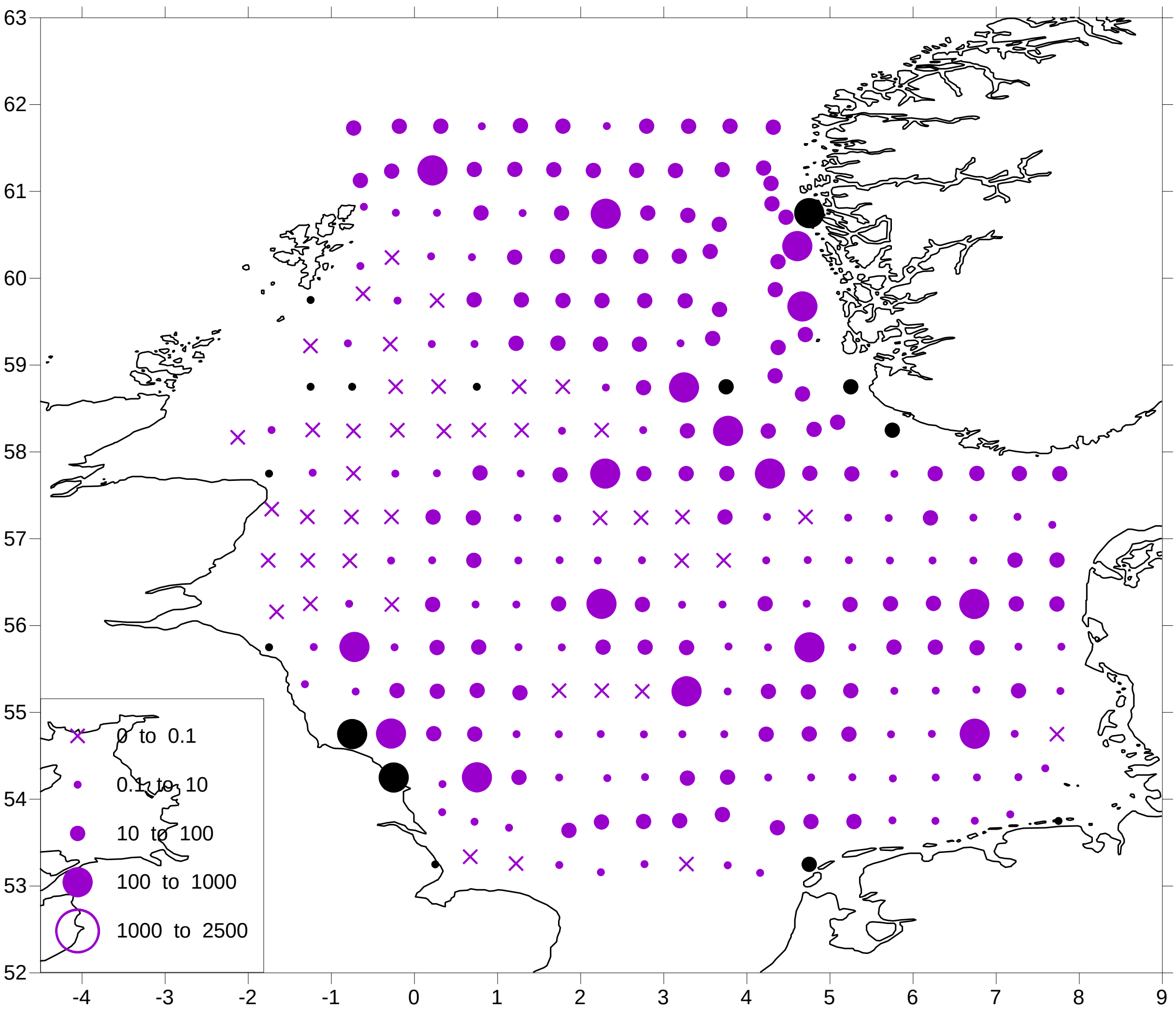

Figure 2. Stage 1A mackerel egg production (eggs/m^2/day) by half rectangle for NSMEGS 2021. Purple circles represent observed values, black circles represent interpolated values, and crosses represent observed zeros.

Table 1. NSMEGS surveys cruise dates in 2021 (For Scotland only stations used in the NSMEGS DEP calculation are shown.)

Country	NL	DK	SCO
Period	1	1	1
Dates	25.05-12.06	31.05-9.06	8.06-11.06
Plankton stations sampled	174	91	29
Pelagic trawl hauls	12	10	1

Table 2. Daily egg production estimate (stage 1A) in the North Sea.

Year	DEP $*10^{13}$	CV DEP
2021	1.28	16%

Table 3. Comparison of Daily Egg production (stage 1) between 2021 and 2017, in the area between 53.5 and 59ºN.

Year	2021	2017 Extended period 2
DEP $*10^{12}$	4.92	4.43
Area sampled ($* 10^{11}$ m^2)	2.24	1.97

PFA
PELAGIC FREEZER-TRAWLER ASSOCIATION

REPORT

PFA self-sampling report for WGWIDE 2021

M.A. Pastoors, F.J. Quirijns

WGWIDE 2021 WD02; PFA report 2021/08
24/8/2021

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Front cover: measuring oxygen content in RSW tank with horse mackerel, December 2020

WGWIDE 2021 WD02, PFA report 2021_08

PFA self-sampling report for WGWIDE 2021

M.A. Pastoors, F.J. Quirijns

Executive summary

The Pelagic Freezer-trawler Association (PFA) is an association that has nine member companies that together operate 15 (in 2021) freezer trawlers in six European countries (www.pelagicfish.eu). In 2015, the PFA has initiated a self-sampling program that expands the ongoing monitoring programs on board of pelagic freezer-trawlers aimed at assessing the quality of fish. The expansion in the self-sampling program 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 scientific coordination of the self-sampling program is carried out by Martin Pastoors (PFA chief science officer) with support of Floor Quirijns (contractor). The self-sampling program has been incrementally implemented in the fishery and by 2018 all vessels in the PFA fleet participated in the self-sampling.

This report for WGWIDE 2021 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%, weekly catch > 10 tonnes
- for mackerel : latitude > 45, proportion in the catch > 10%, weekly catch > 10 tonnes
- for blue whiting : latitude > 50, proportion in the catch > 10%, weekly catch > 10 tonnes
- for herring : division = 27.2.a, proportion in the catch > 10%, weekly catch > 10 tonnes

Trips from 2017 up to 27/07/2021 have been processed for this overview. Pelagic fisheries within the Pelagic Freezer-trawler Association are carried out by vessels from different countries. Overall, around 48% of the catch volume of trips in this overview were taken by Dutch trawlers, 22% German trawlers, 14% UK trawlers and 16% other countries. Blue whiting constitutes the majority of the catch in those trips (54%), followed by mackerel (23%) and horse mackerel (12%). Atlanto-Scandian herring only constitutes around 3% of the volume in the PFA widely distributed fishery. Note that the North Sea herring fishery is not included in this overview.

The **Mackerel fishery** takes place from October through to March of the subsequent year. Minor by-catches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 357 fishing trips with 4940 hauls, a total catch of 287836 tonnes and 91096 individual length measurements. The main fishing areas are ICES division 27.4.a and division 27.6.a. Compared to the previous years, mackerel in the catch in 2021 have been relatively large with a median length of 36.4 cm compared to 33.6-36.2 in the preceding years. Also, the median weight has been somewhat higher with median weight of 435 gram compared to 385-422 gram in the preceding years.

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 2017 - 2021 (up to 27/07/2021) covered 243 fishing trips with 3446 hauls, a total catch of 141548 tonnes and 153307 individual length measurements. The main fishing areas are ICES division 27.6.a, division 27.7.b and division 27.7.d. Horse mackerel have a wide range in the length distributions in the catch. Median lengths in divisions 27.6.a, 27.7.b and 27.7.j have fluctuated between 26.2 and 31.3 cm (with one low median length of 23.3 cm in 27.6.a in 2018). In ICES divisions 27.7.d and 27.7.h, median lengths in the catch are smaller and fluctuated between 21.3 and 24.6 cm.

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 horse mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 240 fishing trips with 6560 hauls, a total catch of 650604 tonnes and 507481 individual length measurements. The main fishing areas are ICES division 27.6.a, division 27.7.c and division 27.7.k. Compared to the previous years, blue whiting in the catch in 2021 have been relatively large with a median length of 27.9 cm compared to 24.2-27.2 in the preceding years. Also, the median weight has been somewhat higher with median weight of 137 gram compared to 85-120 gram in the preceding years.

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 horse mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 27 fishing trips with 456 hauls, a total catch of 36003 tonnes and 10327 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 relatively narrow range in the length distributions in the catch. Median lengths have been between 31 and 36 cm.

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 program that expands the ongoing monitoring programs on board of pelagic freezer-trawlers by the specialized crew of the vessels. The primary objective of that monitoring program is to assess the quality of fish. The expansion in the self-sampling program 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 program is carried out by Martin Pastoors (PFA chief science officer) with support of Floor Quirijns (contractor).

2 Material and methods

The PFA self-sampling program has been implemented incrementally on many vessels that belong to the members of the PFA. The self-sampling program 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 program.

A major feature of the PFA self-sampling program 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 program 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.

In order to supply relevant information to WGWIDE, 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

For this report, data have been processed for 2017 - 2021 (up to 27/07/2021).

3 Results

3.1 General

An overview of all the selected self-sampling hauls is shown in Table 3.1.1.

year	nvessels	ntrips	ndays	nhauls	catch	catch/day	nlength
2017	12	64	887	1,886	184,973	208	95,190
2018	16	88	1,330	2,901	272,344	204	176,432
2019	16	101	1,426	3,113	253,326	177	151,187
2020	18	117	1,576	3,373	324,943	206	259,099
2021*	19	64	829	1,876	173,412	209	144,952
(all)		434	6,048	13,149	1,208,998		826,860

*Table 3.1.1: PFA fisheries for widely distributed species Self-sampling Summary of number of vessels, trips, days, hauls, catch (tonnes), catch per day and number of fish measured. * denotes incomplete year*

Catch and number of self-sampled hauls by year and division

division	2017	2018	2019	2020	2021*	all	perc
27.6.a	75,513	126,079	116,955	126,406	89,565	534,518	43.94959%
27.4.a	23,979	36,282	39,949	64,054	7,018	171,282	14.08329%
27.7.c	29,652	30,523	26,905	44,548	27,329	158,957	13.06990%
27.2.a	23,597	22,134	13,921	16,116	59	75,827	6.23471%
27.7.b	8,607	5,323	10,623	11,827	9,682	46,062	3.78735%
27.7.d	8,765	10,595	11,855	12,800	1,859	45,874	3.77189%
27.7.k	95	7,645	2,036	11,338	19,293	40,407	3.32238%
27.7.j	664	3,703	8,727	16,656	3,143	32,893	2.70456%
27.5.b	8,061	7,932	3,924	10,277	1,457	31,651	2.60244%
27.7.h	1,329	6,570	1,235	130	6,168	15,432	1.26886%
27.4.b	1,524	1,974	3,935	4,909	0	12,342	1.01479%
27.7.e	1,472	1,011	4,127	40	4,262	10,912	0.89722%
27.6.b	158	7,742	604	1,119	0	9,623	0.79123%
27.4.c	1,558	1,385	1,666	2,136	563	7,308	0.60088%
27.8.a	30	2,296	3,821	145	922	7,214	0.59316%
27.7.f	0	283	2,146	765	2,004	5,198	0.42739%
27.7.g	0	436	1,839	2,088	833	5,196	0.42723%
27.8.b	0	366	98	1,767	0	2,231	0.18344%
27.8.d	275	237	182	1,161	15	1,870	0.15376%
27.7.a	0	328	1,064	0	0	1,392	0.11445%
27.3.a	0	0	18	0	0	18	0.00148%
27.8.c	0	0	0	0	0	0	0.00000%
(all)	185,279	272,844	255,630	328,282	174,172	1,216,207	100.00000%

Table: catch

division	2017	2018	2019	2020	2021*	all	perc
27.6.a	668	1,268	1,281	1,210	792	5,219	39.691%
27.4.a	191	376	439	549	82	1,637	12.450%
27.7.c	256	243	252	328	241	1,320	10.039%
27.2.a	264	249	174	237	1	925	7.035%
27.7.d	157	190	206	213	35	801	6.092%
27.7.b	140	88	175	207	188	798	6.069%
27.7.j	20	60	138	209	112	539	4.099%
27.7.k	3	59	17	95	153	327	2.487%
27.5.b	66	82	38	87	11	284	2.160%
27.7.h	30	96	24	7	102	259	1.970%
27.7.e	45	32	79	11	73	240	1.825%
27.4.b	19	24	53	75	0	171	1.300%
27.8.a	1	41	101	9	14	166	1.262%
27.7.g	0	9	39	37	23	108	0.821%
27.4.c	22	16	25	30	12	105	0.799%
27.7.f	0	4	31	22	36	93	0.707%
27.6.b	2	50	10	7	0	69	0.525%
27.8.b	0	6	4	24	0	34	0.259%
27.8.d	2	2	13	16	1	34	0.259%
27.7.a	0	6	12	0	0	18	0.137%
27.3.a	0	0	1	0	0	1	0.008%
27.8.c	0	0	1	0	0	1	0.008%
(all)	1,886	2,901	3,113	3,373	1,876	13,149	100.000%

Table: nhauls

*Table 3.1.2: PFA fisheries for widely distributed species Self-sampling Summary of catch (top) and number of hauls (bottom) per year and division. * denotes incomplete year*

Catch and number of self-sampled hauls by year and month

month	2017	2018	2019	2020	2021*	all	perc
Jan	28,838	25,647	36,173	38,991	49,257	178,906	14.71%
Feb	19,420	32,985	34,946	28,442	39,045	154,838	12.73%
Mar	30,164	43,158	33,089	51,917	36,868	195,196	16.05%
Apr	28,506	58,665	28,857	66,444	29,582	212,054	17.44%
May	12,368	30,230	22,450	29,189	13,580	107,817	8.86%
Jun	0	6,866	1,498	4,241	2,271	14,876	1.22%
Jul	773	790	6,192	1,704	3,572	13,031	1.07%
Aug	6,762	4,551	3,960	5,083	0	20,356	1.67%
Sep	11,505	10,529	12,586	15,511	0	50,131	4.12%
Oct	21,362	28,098	34,110	35,940	0	119,510	9.83%
Nov	21,916	21,809	29,240	29,799	0	102,764	8.45%
Dec	3,666	9,521	12,535	21,024	0	46,746	3.84%
(all)	185,280	272,849	255,636	328,285	174,175	1,216,225	100.00%

Table: catch

month	2017	2018	2019	2020	2021*	all	perc
Jan	315	309	470	374	569	2,037	15.49%
Feb	208	333	413	290	465	1,709	13.00%
Mar	232	391	413	455	347	1,838	13.98%
Apr	201	494	289	580	248	1,812	13.78%
May	145	372	251	312	142	1,222	9.29%
Jun	0	77	23	103	32	235	1.79%
Jul	15	10	75	26	73	199	1.51%
Aug	68	39	42	70	0	219	1.67%
Sep	153	170	207	211	0	741	5.64%
Oct	247	301	410	424	0	1,382	10.51%
Nov	271	319	416	361	0	1,367	10.40%
Dec	31	86	104	167	0	388	2.95%
(all)	1,886	2,901	3,113	3,373	1,876	13,149	100.00%

Table: nhauls

*Table 3.1.3: PFA fisheries for widely distributed species Self-sampling summary of catch (top) and number of hauls (bottom) per year and month. * denotes incomplete year*

Catch and number of self-sampled hauls by year and country (flag)

flag	2017	2018	2019	2020	2021*	all	perc
NL	118,291	104,338	118,576	132,034	80,617	553,856	47.5%
DEU	29,214	57,340	49,764	72,173	42,113	250,604	21.5%
UK	37,780	32,276	32,124	39,468	21,572	163,220	14.0%
POL	0	17,042	31,602	55,192	12,421	116,257	10.0%
FR	0	13,483	22,157	15,216	6,325	57,181	4.9%
LIT	0	0	1,413	13,744	8,681	23,838	2.0%
(all)	185,285	224,479	255,636	327,827	171,729	1,164,956	100.0%

Table: catch

flag	2017	2018	2019	2020	2021*	all	perc
NL	1,243	1,138	1,491	1,591	969	6,432	50.6%
DEU	291	680	588	672	345	2,576	20.3%
UK	352	315	354	366	222	1,609	12.7%
FR	0	264	424	250	123	1,061	8.4%
POL	0	125	222	341	101	789	6.2%
LIT	0	0	34	142	62	238	1.9%
(all)	1,886	2,522	3,113	3,362	1,822	12,705	100.0%

Table: nhauls

*Table 3.1.4: PFA fisheries for widely distributed species Self-sampling summary of catch (top) and number of hauls (bottom) per year and month. * denotes incomplete year*

Catches by species and year (in tonnes).

species	english_name	scientific_name	2017	2018	2019	2020	2021*	all	perc
whb	blue whiting	Micromesistius poutassou	79,304	162,542	116,129	175,315	117,315	650,605	53.8%
mac	mackerel	Scomber scombrus	63,654	57,931	55,036	86,419	24,796	287,836	23.8%
hom	horse mackerel	Trachurus trachurus	21,278	30,250	40,822	27,987	21,211	141,549	11.7%
her	herring	Clupea harengus	8,621	11,135	23,540	14,834	4,450	62,580	5.2%
her_ash	herring	Clupea harengus	7,950	5,278	12,249	10,526	0	36,004	3.0%
arg	argentines	Argentina spp	2,596	4,097	4,566	7,036	4,646	22,940	1.9%
boc	boarfish	Capros aper	247	161	351	626	515	1,900	0.2%
pil	pilchard	Sardina pilchardus	818	514	170	232	40	1,773	0.1%
spr	sprat	Sprattus	257	7	32	1,271	0	1,567	0.1%
hke	hake	Merluccius merluccius	107	274	208	182	162	933	0.1%
oth	NA	NA	141	156	224	516	278	1,314	0.1%
(all)	(all)	(all)	184,974	272,344	253,326	324,944	173,412	1,209,000	100.0%

*Table 3.1.5: PFA fisheries for widely distributed species Self-sampling Summary of total catch (tonnes) by species. 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 fisheries for widely distributed species.

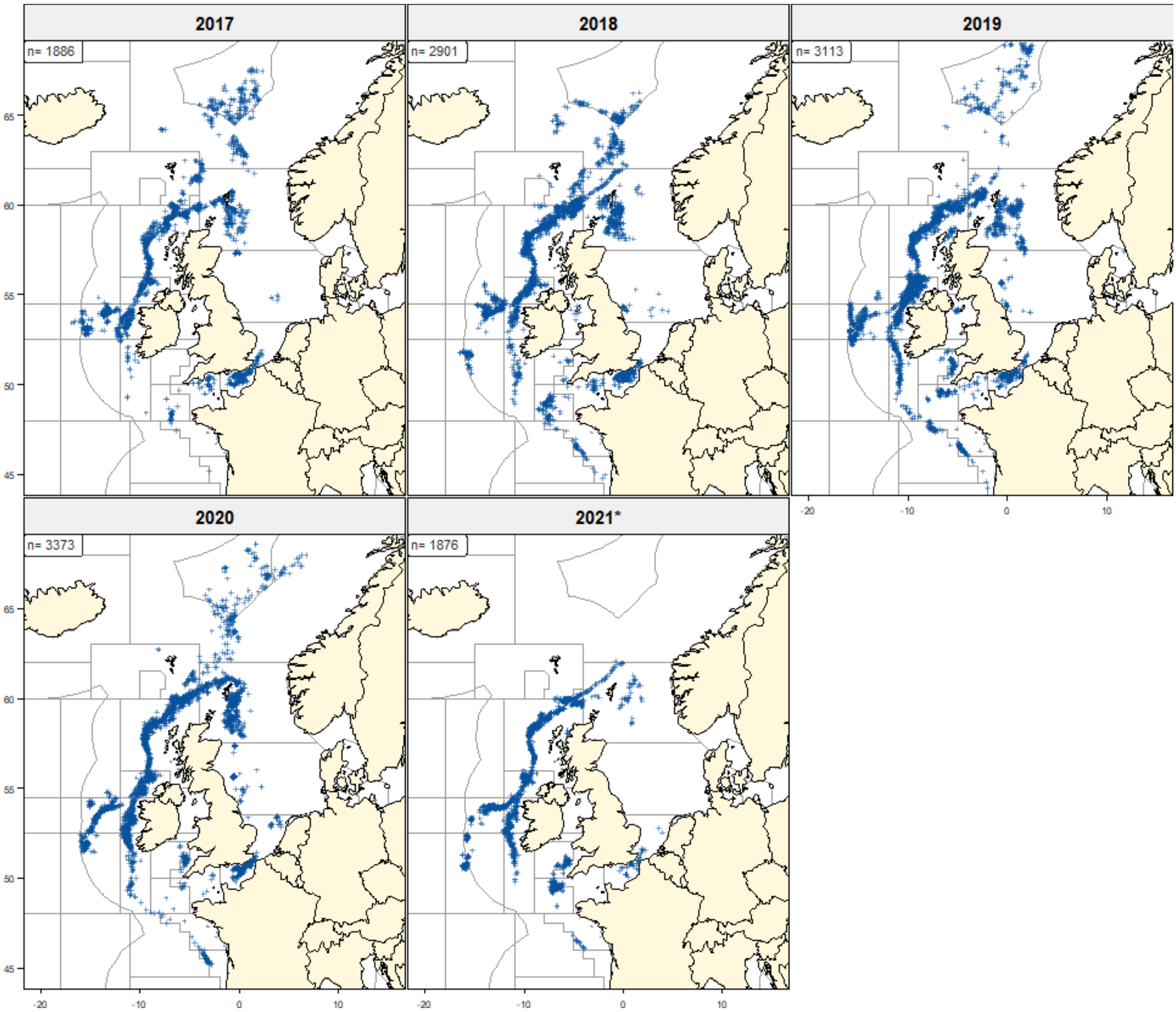

*Figure 3.1.1: PFA fisheries for widely distributed species Self-sampling haul positions. N indicates the number of hauls. * denotes incomplete year*

Catch of the main target species

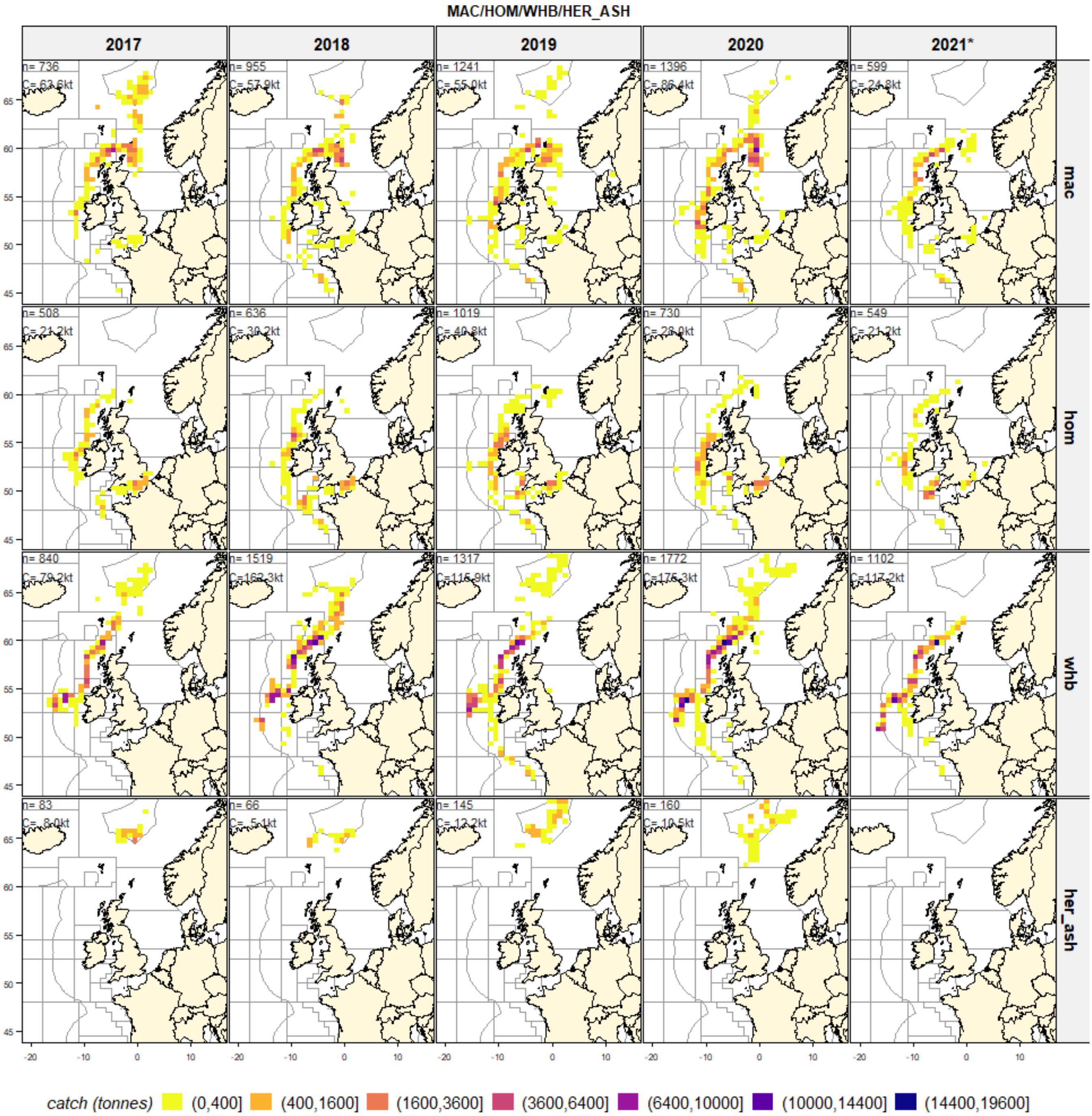

*Figure 3.1.2: PFA fisheries for widely distributed species Self-sampling catch per species and per rectangle. N indicates the number of hauls. Catch refers to the total catch per year. * denotes incomplete year*

Catch rates (catch/day) for the main target species

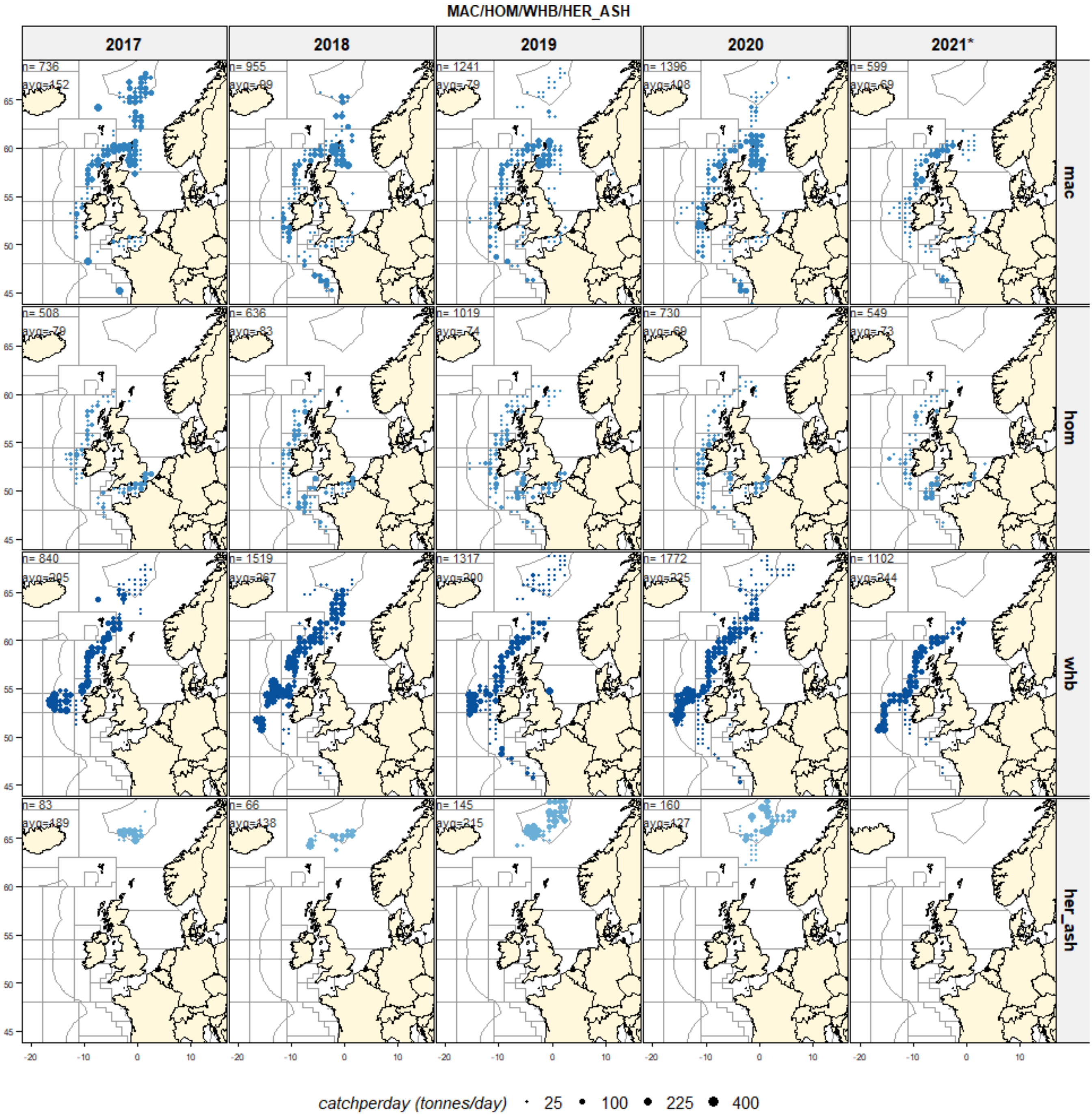

*Figure 3.1.3: PFA fisheries for widely distributed species Average catch per day, per species and per rectangle. N indicates the number of hauls; avg refers to the average catch per day; * denotes incomplete year*

Average fishing depth by rectangle

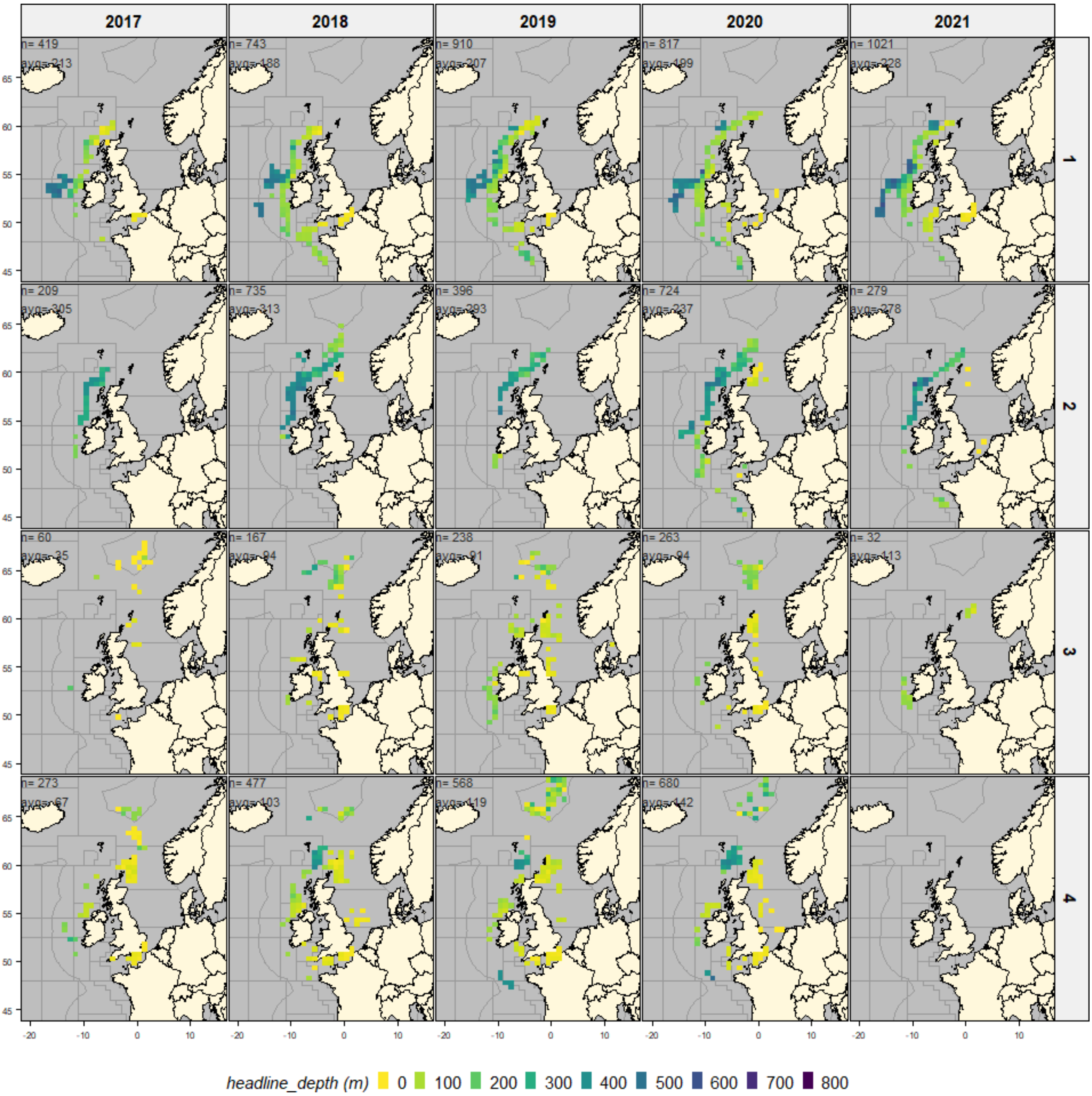

*Figure 3.1.4: PFA fisheries for widely distributed species Average fishing depth (m) by year and quarter. N indicates the number of hauls. Avg refers to the average fishing depth. * denotes incomplete year*

Average temperature at fishing depth by rectangle

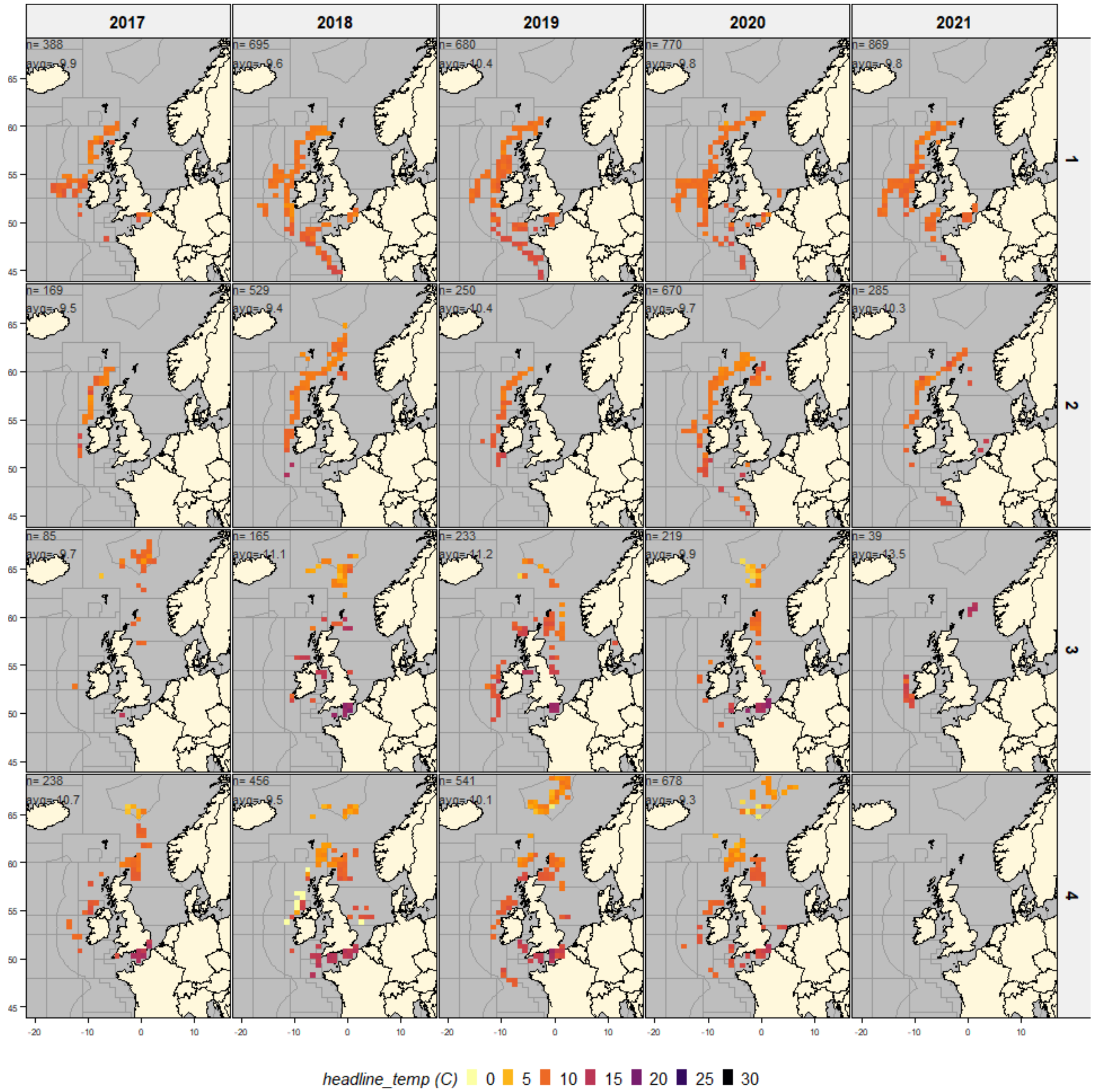

*Figure 3.1.5: PFA fisheries for widely distributed species Average temperature at fishing depth (C) by year and quarter. N indicates the number of hauls. Avg refers to the average temperature. * denotes incomplete year*

Average windspeed by rectangle

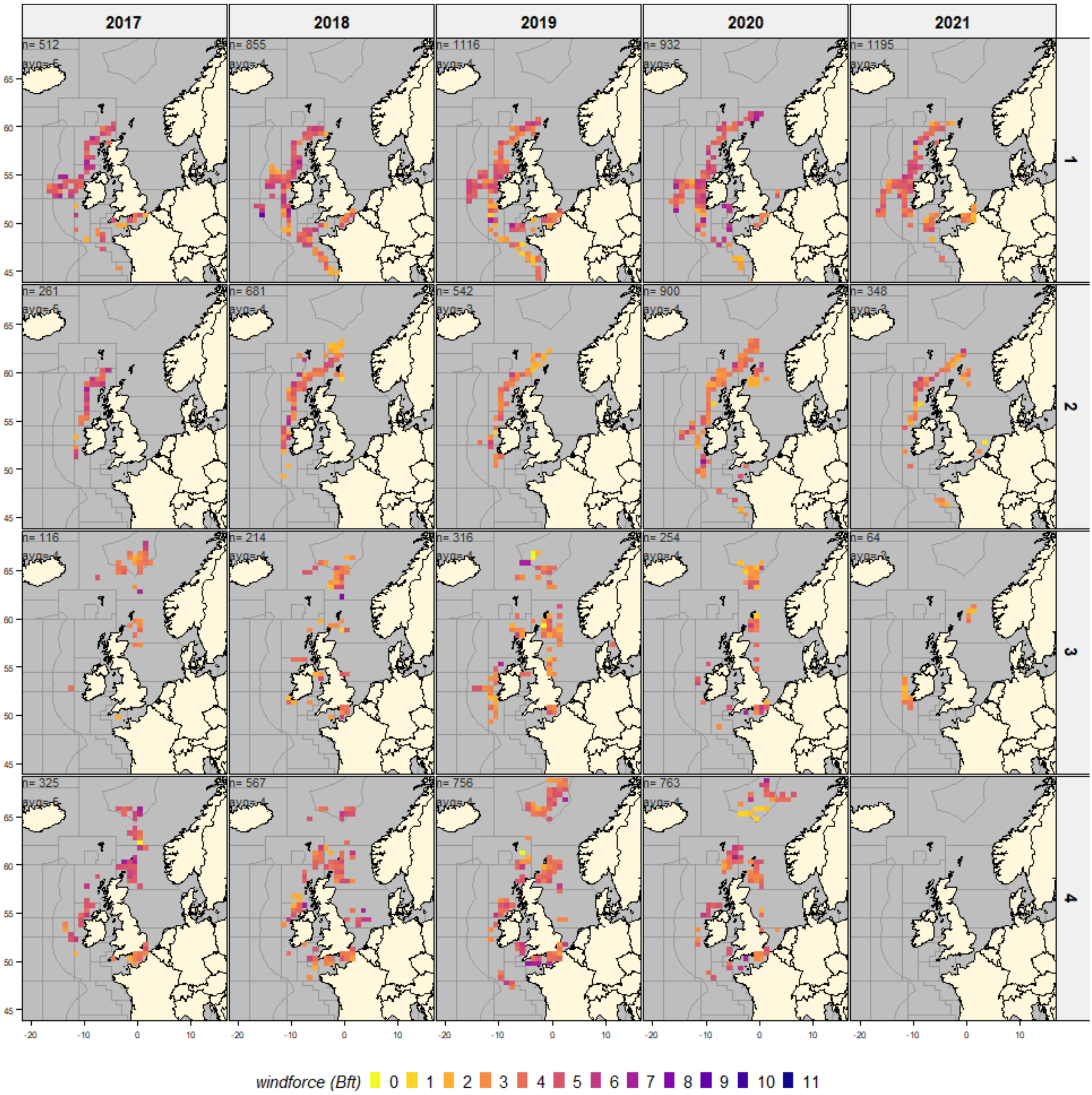

*Figure 3.1.6: PFA fisheries for widely distributed species Average wind speed (Bft) by year and quarter. N indicates the number of hauls. Avg refers to the average wind speed. * denotes incomplete year*

3.2 Mackerel (MAC, Scomber scombrus)

The main Mackerel fishery takes place during months 1, 2, 3, 10, 11. The self-sampling activities for the Mackerel fishery during the years 2017 - 2021 (processed up to 27/07/2021) covered 311 fishing trips with 4440 hauls, a total catch of 279029 tonnes and 85518 individual length measurements. The main fishing areas are 27.2.a, 27.4.a, 27.6.a, 27.7.b, 27.7.j.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	nlength	catchperday
mac	27.2.a	2017	6	9	81	164	13,020	21	1,948	161
mac	27.2.a	2018	5	7	39	66	4,805	9	9	123
mac	27.2.a	2019	4	4	26	45	205	0	291	8
mac	27.2.a	2020	6	7	29	34	634	1	290	22
mac	27.4.a	2017	8	17	93	155	17,325	28	4,475	186
mac	27.4.a	2018	13	24	170	296	28,511	52	5,651	168
mac	27.4.a	2019	14	27	182	341	24,300	45	7,016	134
mac	27.4.a	2020	16	46	272	475	50,545	60	24,971	186
mac	27.4.a	2021*	5	6	22	38	796	3	121	36
mac	27.6.a	2017	10	25	156	264	28,288	45	5,443	181
mac	27.6.a	2018	16	31	238	392	18,024	33	7,905	76
mac	27.6.a	2019	15	43	307	517	21,298	40	7,691	69
mac	27.6.a	2020	13	39	264	476	15,847	19	6,062	60
mac	27.6.a	2021*	14	39	200	329	21,783	91	3,608	109
mac	27.7.b	2017	6	9	51	98	3,640	6	276	71
mac	27.7.b	2018	6	9	33	51	1,111	2	14	34
mac	27.7.b	2019	12	22	73	124	5,386	10	1,849	74
mac	27.7.b	2020	12	22	85	140	6,044	7	2,913	71
mac	27.7.b	2021*	12	17	61	109	776	3	188	13
mac	27.7.j	2017	3	4	6	11	496	1	170	83
mac	27.7.j	2018	8	11	26	38	2,662	5	314	102
mac	27.7.j	2019	8	11	47	89	2,345	4	1,514	50
mac	27.7.j	2020	12	24	77	134	10,734	13	2,495	139
mac	27.7.j	2021*	8	15	40	54	457	2	302	11
mac	(all)	2017		64	387	692	62,769	101	12,312	162
mac	(all)	2018		82	506	843	55,113	101	13,893	109
mac	(all)	2019		107	635	1,116	53,534	99	18,361	84
mac	(all)	2020		138	727	1,259	83,804	100	36,731	115
mac	(all)	2021*		77	323	530	23,812	99	4,219	74
mac	(all)	(all)		468	2,578	4,440	279,032		85,516	108

*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	2017	2018	2019	2020	2021*	all	perc
mac	Jan	18,594	11,592	18,766	20,750	14,862	84,564	29.382%
mac	Feb	8,198	7,613	11,872	19,408	5,706	52,797	18.344%
mac	Mar	4,724	3,307	5,507	7,115	2,782	23,435	8.142%
mac	Apr	1,025	1,225	1,325	797	1,114	5,486	1.906%
mac	May	296	191	488	1,239	94	2,308	0.802%
mac	Jun	0	60	96	175	41	372	0.129%
mac	Jul	88	0	306	83	194	671	0.233%
mac	Aug	247	59	431	242	0	979	0.340%
mac	Sep	9,388	4,822	3,063	6,365	0	23,638	8.213%
mac	Oct	7,972	19,465	11,559	20,400	0	59,396	20.637%
mac	Nov	11,653	9,229	1,618	9,490	0	31,990	11.115%
mac	Dec	1,463	362	0	350	0	2,175	0.756%
mac	(all)	63,648	57,925	55,031	86,414	24,793	287,811	100.000%

*Table 3.2.2: Mackerel. Self-sampling summary with the catch (tonnes) by year and month. * denotes incomplete year*

Mackerel (MAC). Catch by rectangle

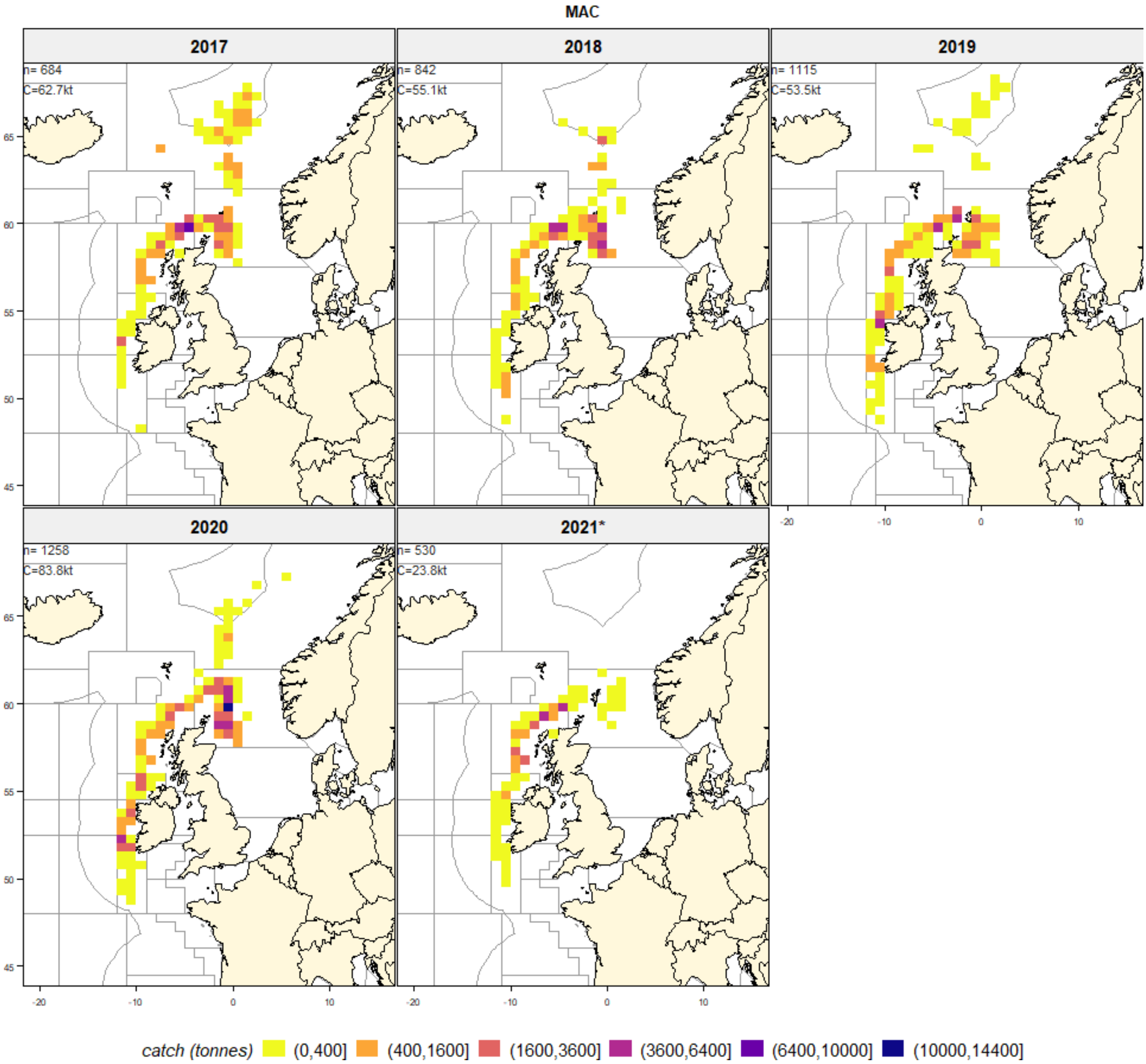

*Figure 3.2.1: Mackerel. Catch per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Mackerel (MAC). Average catch per day

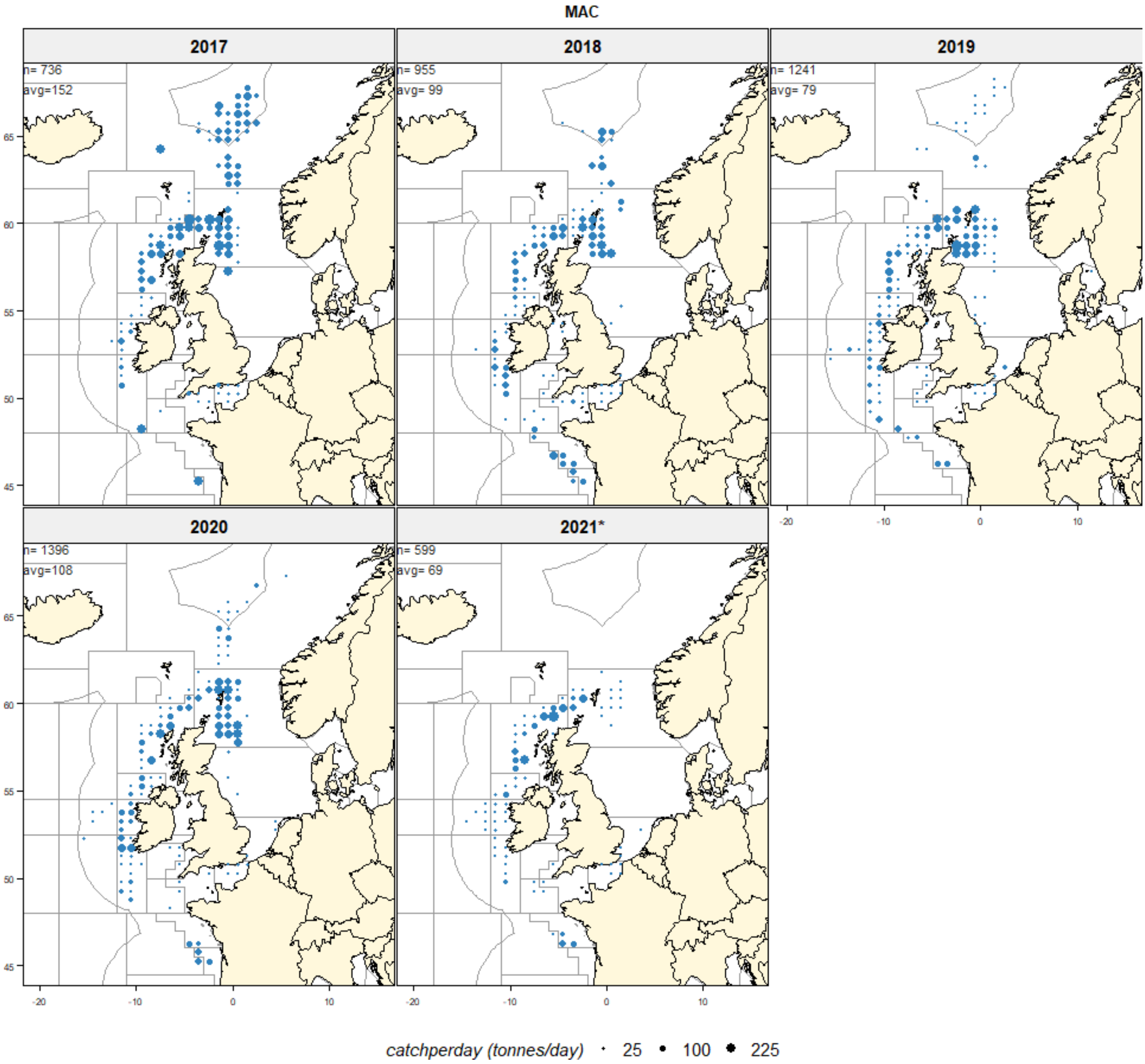

*Figure 3.2.2: Mackerel. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Mackerel (MAC). Spatial-temporal evolution of the fishery

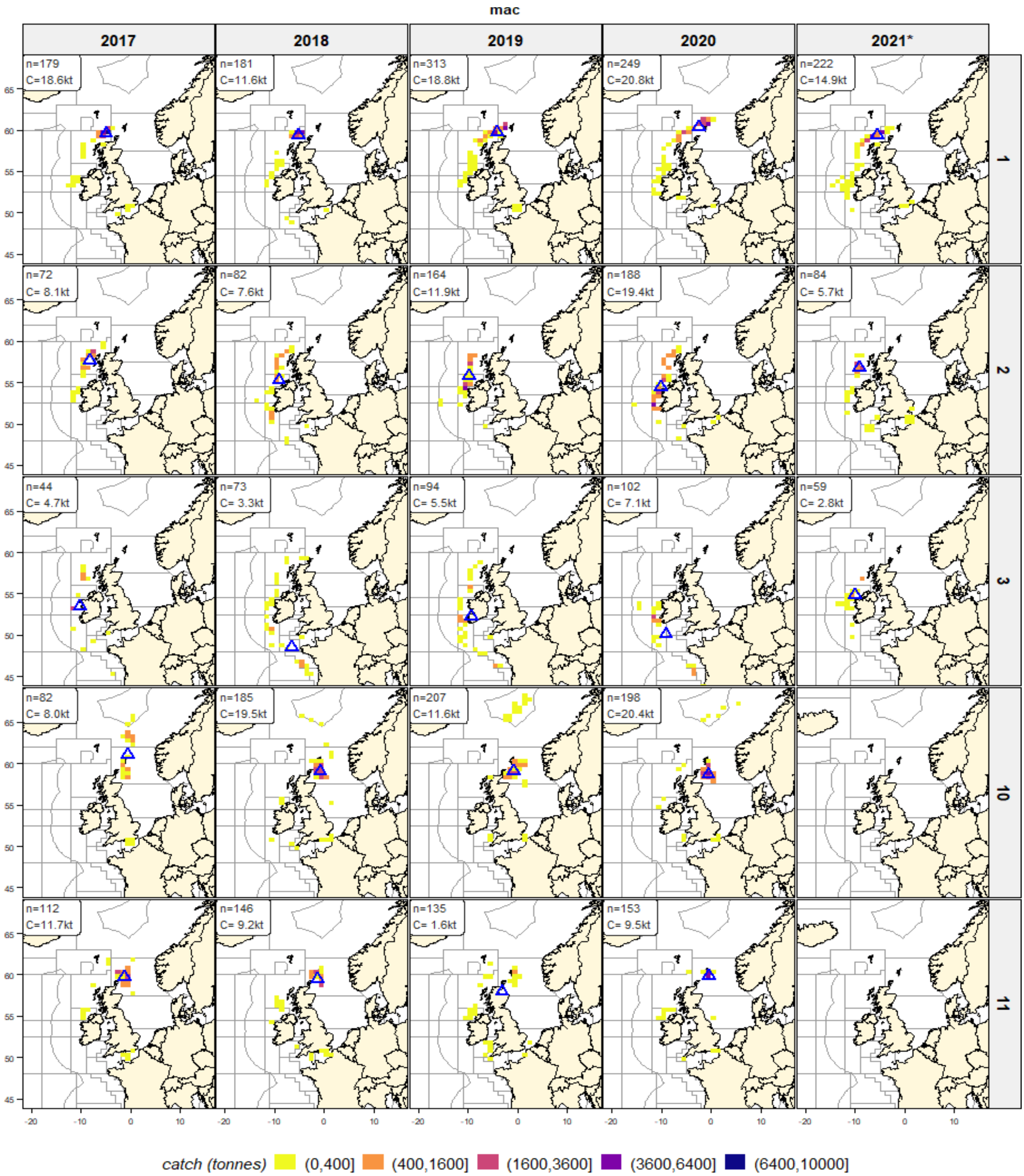

*Figure 3.2.3: Mackerel. Catch per rectangle and per month. N indicates the number of hauls; C refers to the overall catch. The midpoint of the distribution is indicated by the blue triangle. * denotes incomplete year*

Mackerel (MAC). Length distributions of the catch

Median length of Mackerel in the catch in 2021 is 36.4 cm compared to median lengths between 33.6 and 36.3 cm in the preceding years. Note that the data for 2021 is only up to 27/07/2021.

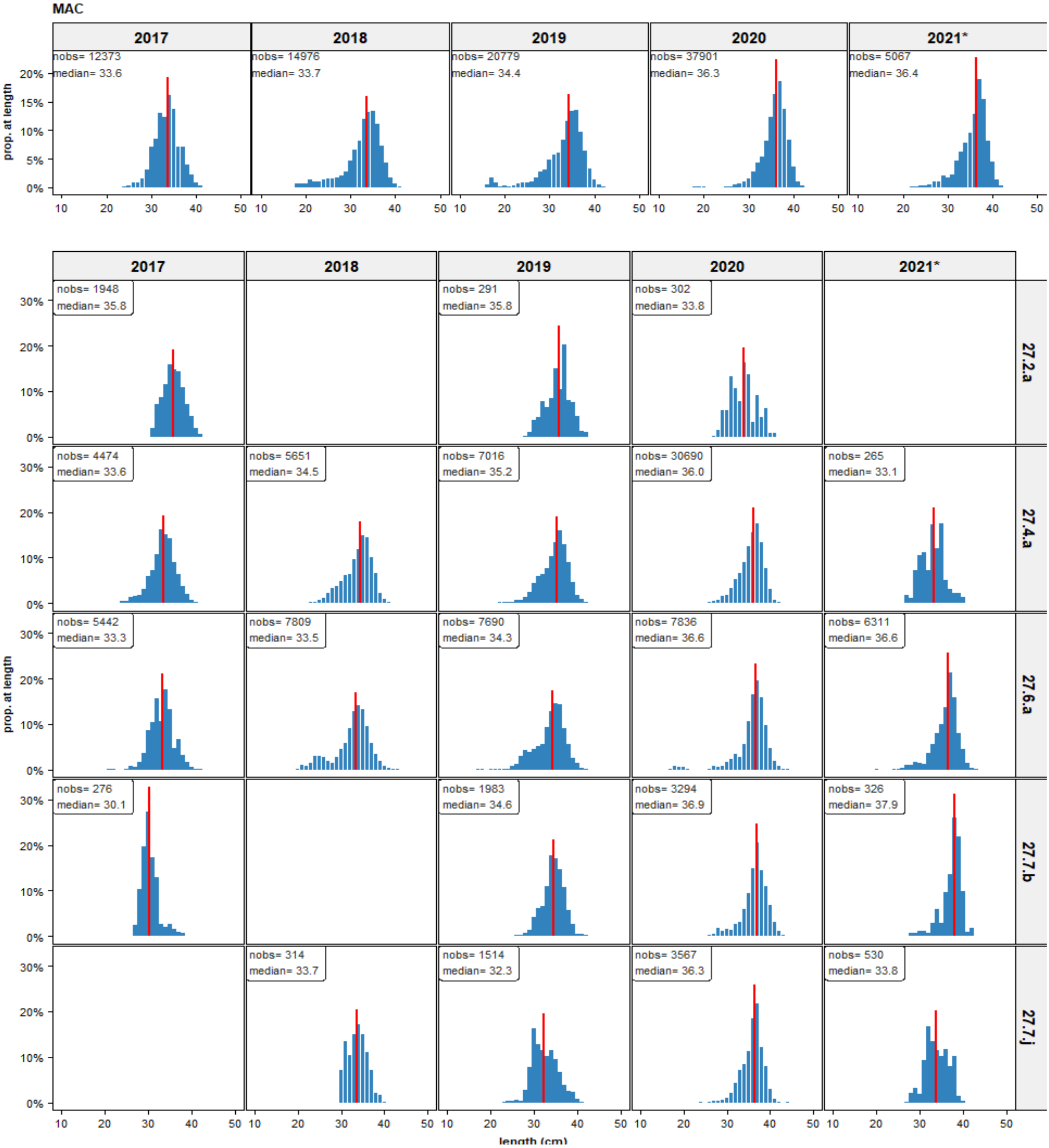

*Figure 3.2.4: Mackerel. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Mackerel (MAC). Weight distributions by year

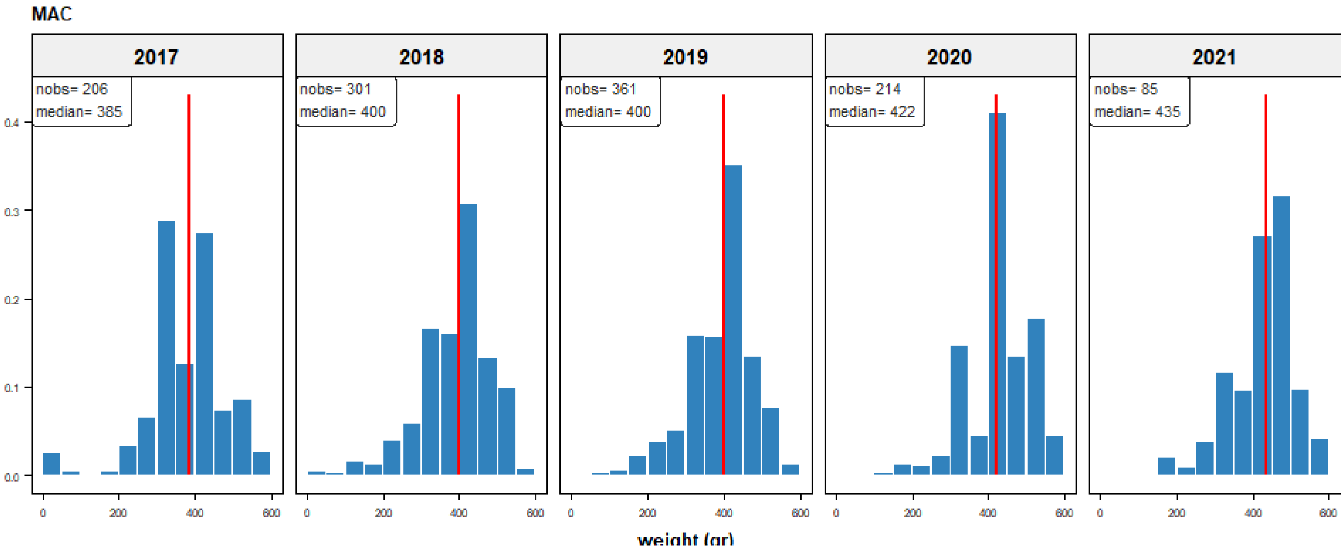

*Figure 3.2.5: Mackerel. Weight distributions (50-gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Mackerel (MAC). Fat percentages by week and year

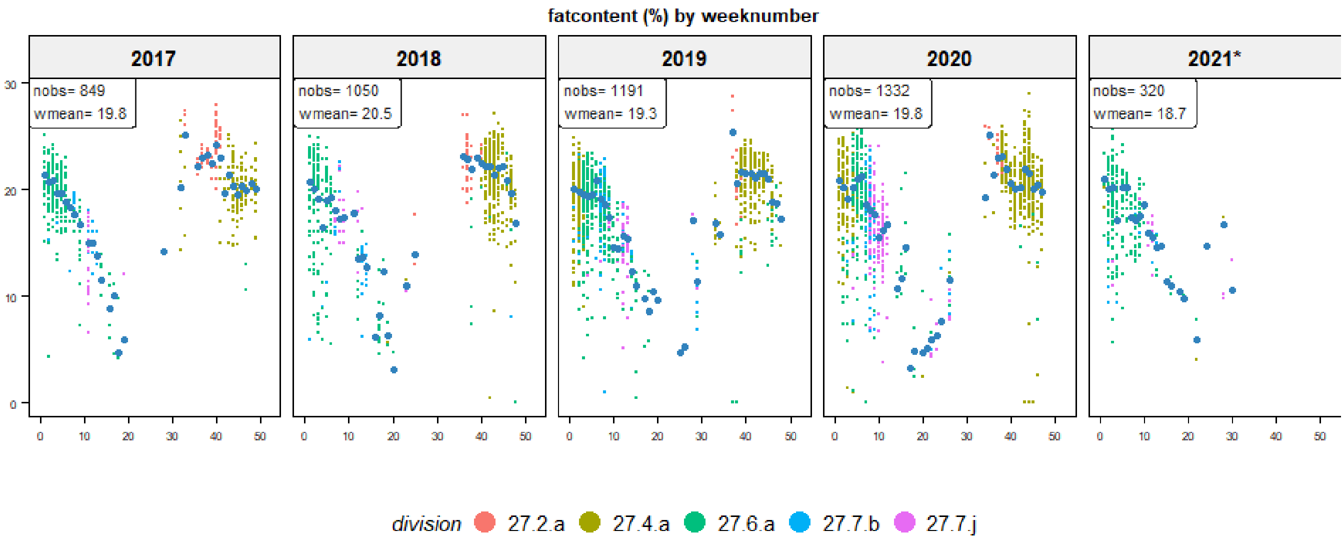

*Figure 3.2.6: Mackerel. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; black dots indicate the weekly averages; * denotes incomplete year*

Mackerel (MAC). Fishing depth distributions by year.

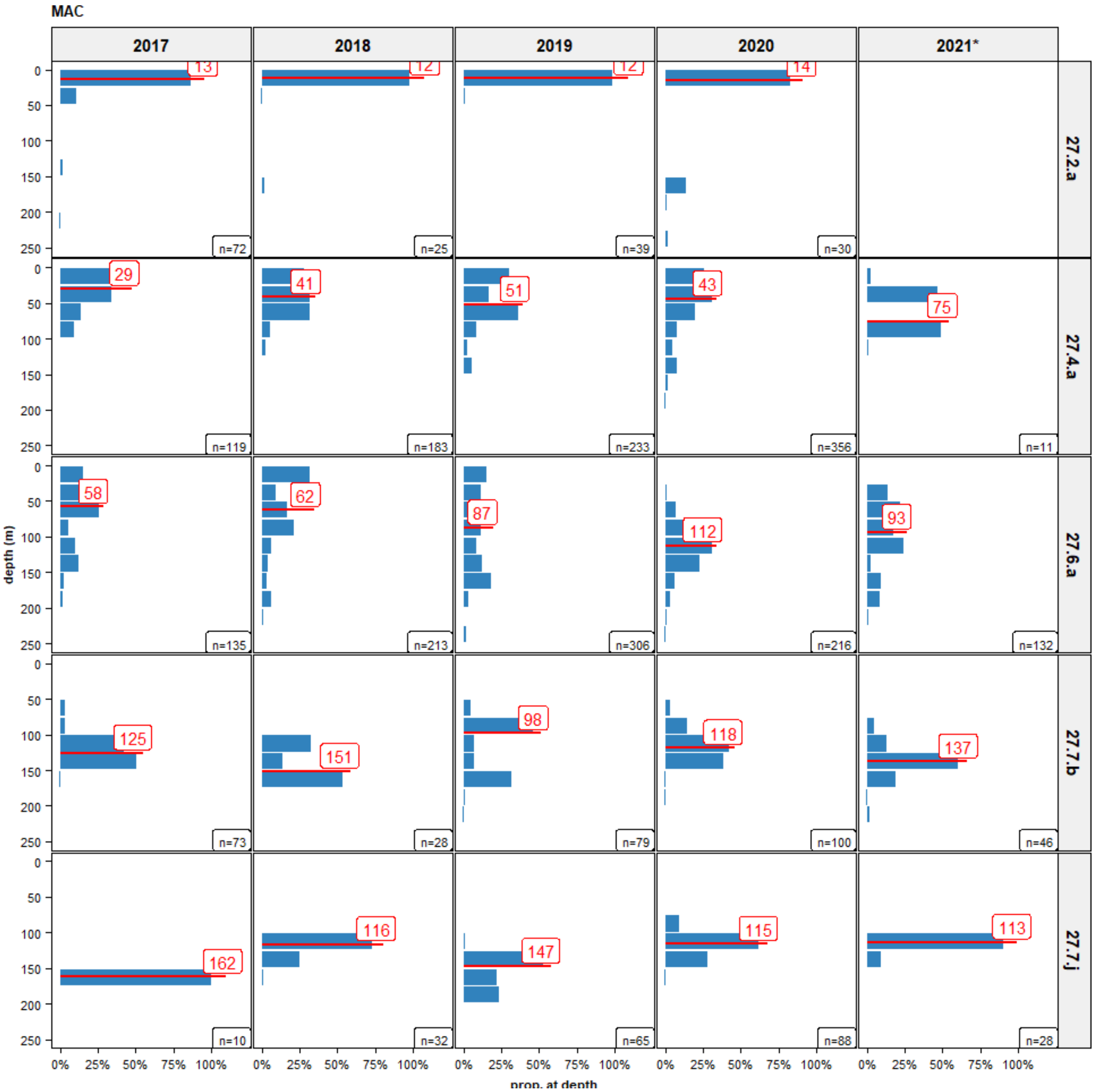

*Figure 3.2.7: Mackerel. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

3.3 Horse mackerel (HOM, Trachurus trachurus)

The main Horse mackerel fishery takes place during months 1, 2, 3, 10, 11. The self-sampling activities for the Horse mackerel fishery during the years 2017 - 2021 (processed up to 27/07/2021) covered 221 fishing trips with 2844 hauls, a total catch of 115986 tonnes and 112735 individual length measurements. The main fishing areas are 27.6.a, 27.7.b, 27.7.d, 27.7.h, 27.7.j.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	nlength	catchperday
hom	27.6.a	2017	8	13	82	159	5,343	28	5,213	65
hom	27.6.a	2018	13	23	125	235	12,053	44	12,015	96
hom	27.6.a	2019	14	30	212	384	13,849	45	7,443	65
hom	27.6.a	2020	8	21	95	168	5,908	24	9,462	62
hom	27.6.a	2021*	10	15	58	80	1,564	11	1,600	27
hom	27.7.b	2017	6	12	57	104	4,741	25	3,459	83
hom	27.7.b	2018	9	11	39	60	2,250	8	1,663	58
hom	27.7.b	2019	12	24	78	129	4,176	13	2,678	54
hom	27.7.b	2020	12	23	84	147	5,226	21	5,478	62
hom	27.7.b	2021*	12	15	67	125	3,432	25	2,698	51
hom	27.7.d	2017	6	15	75	139	7,202	38	1,013	96
hom	27.7.d	2018	5	13	73	138	6,234	23	3,898	85
hom	27.7.d	2019	8	14	76	141	7,102	23	9,123	93
hom	27.7.d	2020	8	23	99	152	8,200	33	13,474	83
hom	27.7.d	2021*	3	3	8	14	688	5	143	86
hom	27.7.h	2017	2	5	18	30	1,329	7	0	74
hom	27.7.h	2018	9	13	50	89	6,282	23	7,804	126
hom	27.7.h	2019	6	6	13	21	984	3	2,663	76
hom	27.7.h	2020	2	2	2	2	55	0	0	28
hom	27.7.h	2021*	9	11	50	95	5,904	42	13,140	118
hom	27.7.j	2017	3	5	7	13	160	1	463	23
hom	27.7.j	2018	7	10	30	45	813	3	519	27
hom	27.7.j	2019	10	14	58	110	5,002	16	1,520	86
hom	27.7.j	2020	12	27	92	172	5,138	21	4,589	56
hom	27.7.j	2021*	11	20	63	92	2,352	17	2,674	37
hom	(all)	2017		50	239	445	18,775	99	10,148	79
hom	(all)	2018		70	317	567	27,632	101	25,899	87
hom	(all)	2019		88	437	785	31,113	100	23,427	71
hom	(all)	2020		96	372	641	24,527	99	33,003	66
hom	(all)	2021*		64	246	406	13,940	100	20,255	57
hom	(all)	(all)		368	1,611	2,844	115,987		112,732	72

*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	2017	2018	2019	2020	2021*	all	perc
hom	Jan	9,613	11,518	11,547	7,178	6,285	46,141	32.603%
hom	Feb	3,124	5,961	5,304	4,799	12,679	31,867	22.517%
hom	Mar	227	3,581	4,083	1,263	584	9,738	6.881%
hom	Apr	0	31	45	0	48	124	0.088%
hom	May	155	6	41	529	2	733	0.518%
hom	Jun	0	226	1,357	649	25	2,257	1.595%
hom	Jul	186	15	5,467	419	1,586	7,673	5.422%
hom	Aug	58	0	8	0	0	66	0.047%
hom	Sep	134	1,910	2,343	3,911	0	8,298	5.863%
hom	Oct	4,620	1,954	3,555	4,062	0	14,191	10.027%
hom	Nov	3,027	3,925	6,076	3,228	0	16,256	11.486%
hom	Dec	129	1,117	990	1,943	0	4,179	2.953%
hom	(all)	21,273	30,244	40,816	27,981	21,209	141,523	100.000%

*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

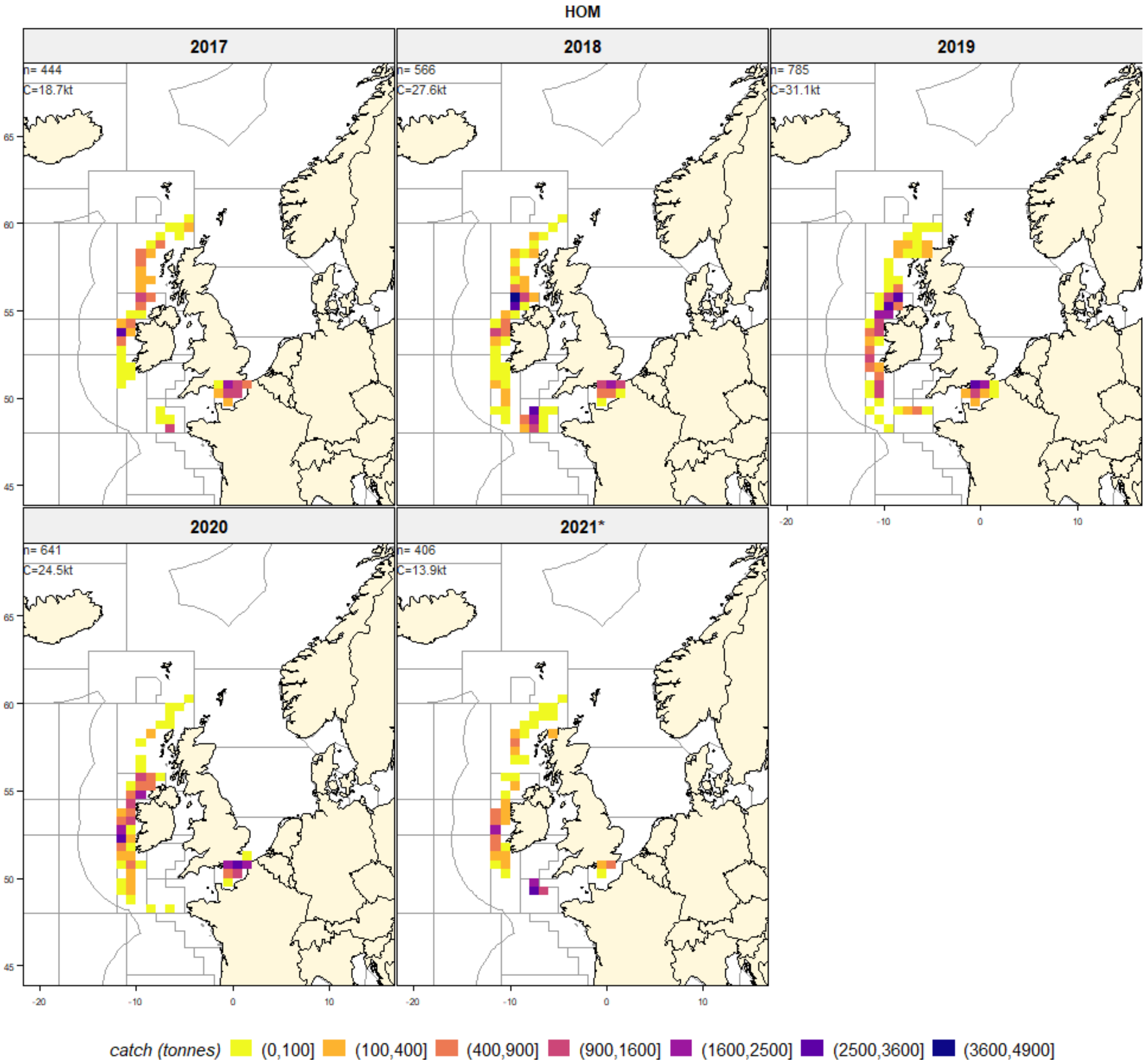

*Figure 3.3.1: Horse mackerel. Catch per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Horse mackerel (HOM). Average catch per day

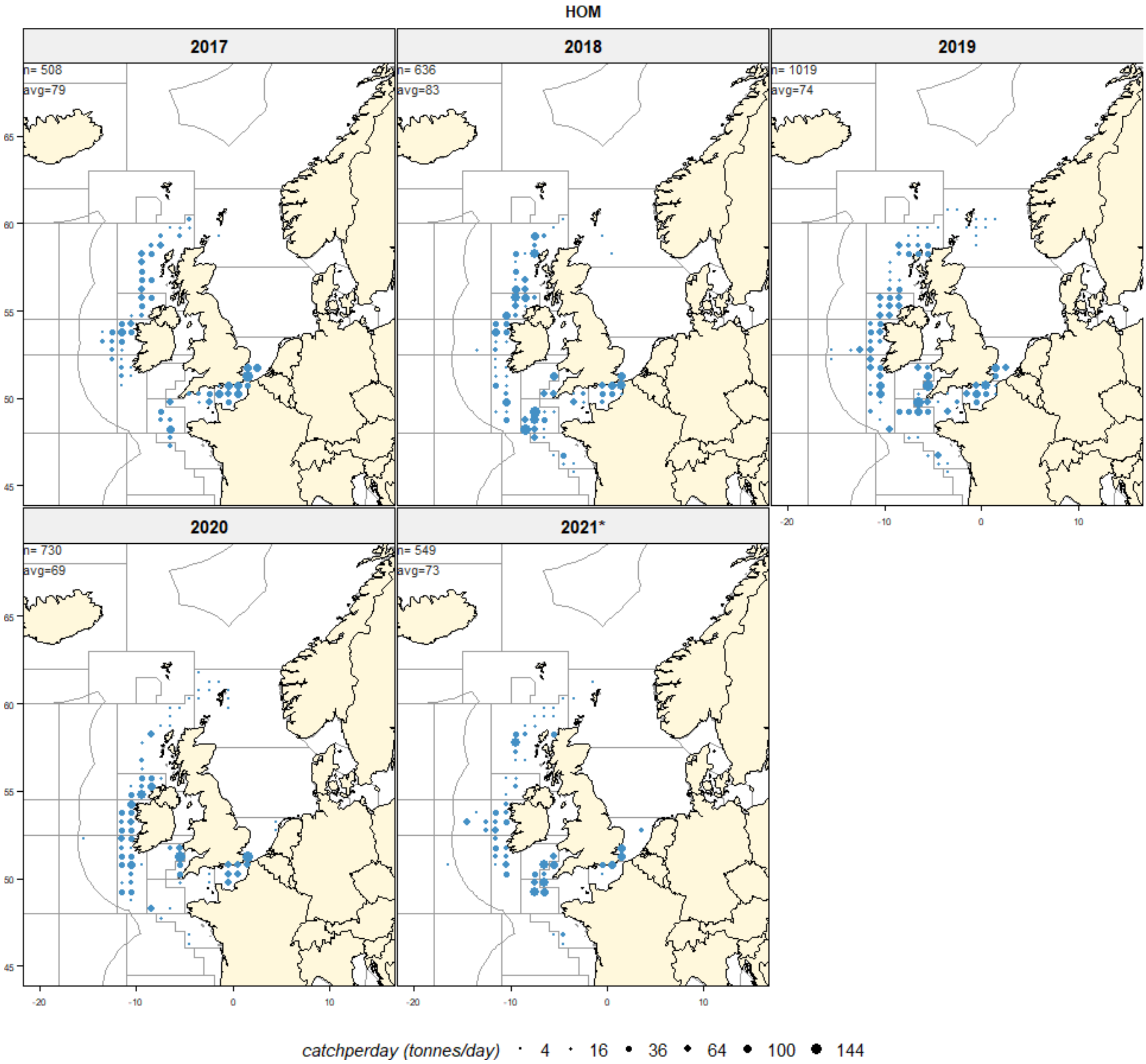

*Figure 3.3.2: Horse mackerel. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Horse mackerel (HOM). Spatial-temporal evolution of the fishery

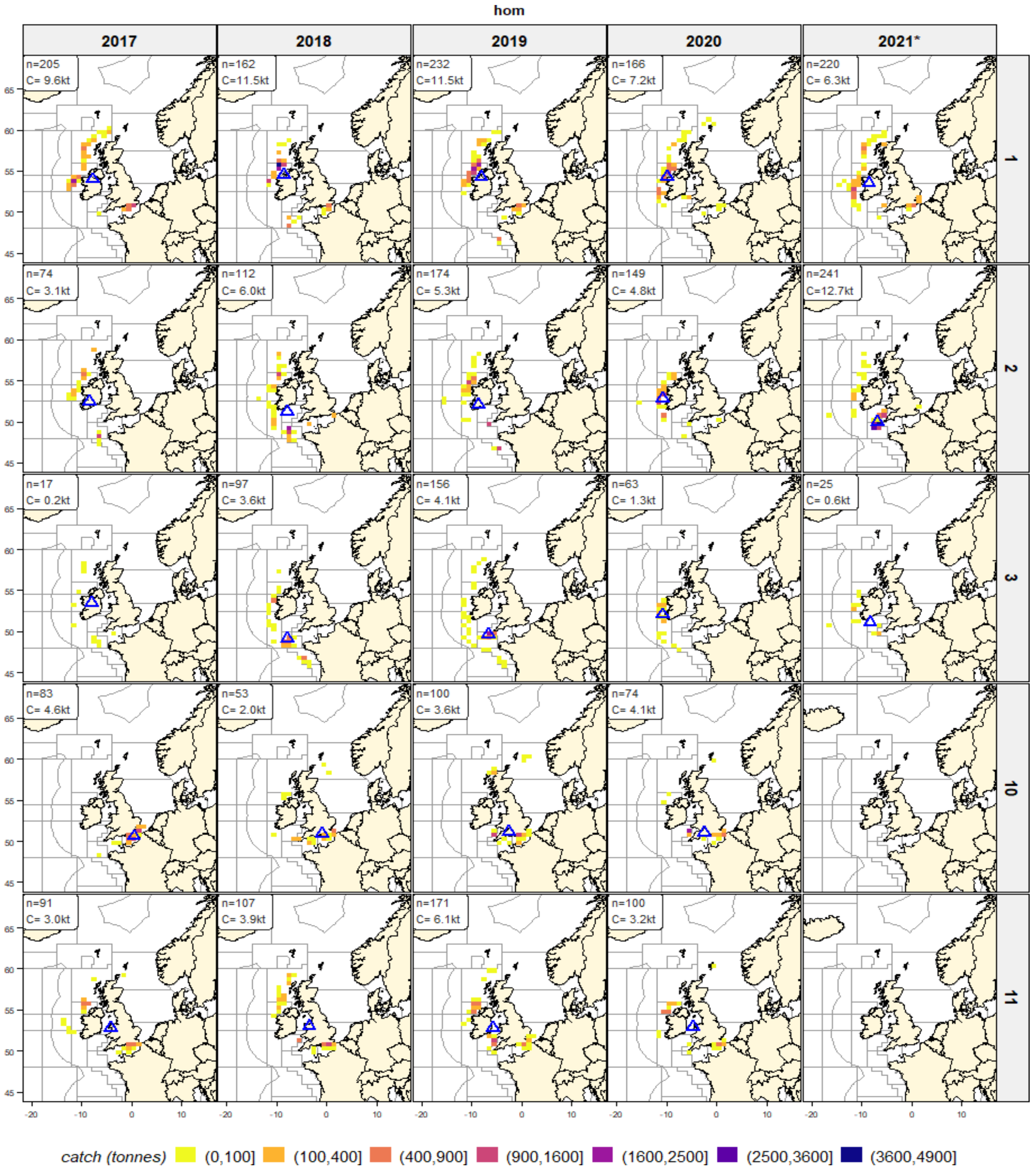

*Figure 3.3.3: Horse mackerel. Catch per rectangle and per month. N indicates the number of hauls; C refers to the overall catch. The midpoint of the distribution is indicated by the blue triangle. * denotes incomplete year*

Horse mackerel (HOM). Length distributions of the catch

Median length of Horse mackerel in the catch in 2021 is 22.0 cm compared to median lengths between 22.8 and 30.0 cm in the preceding years.

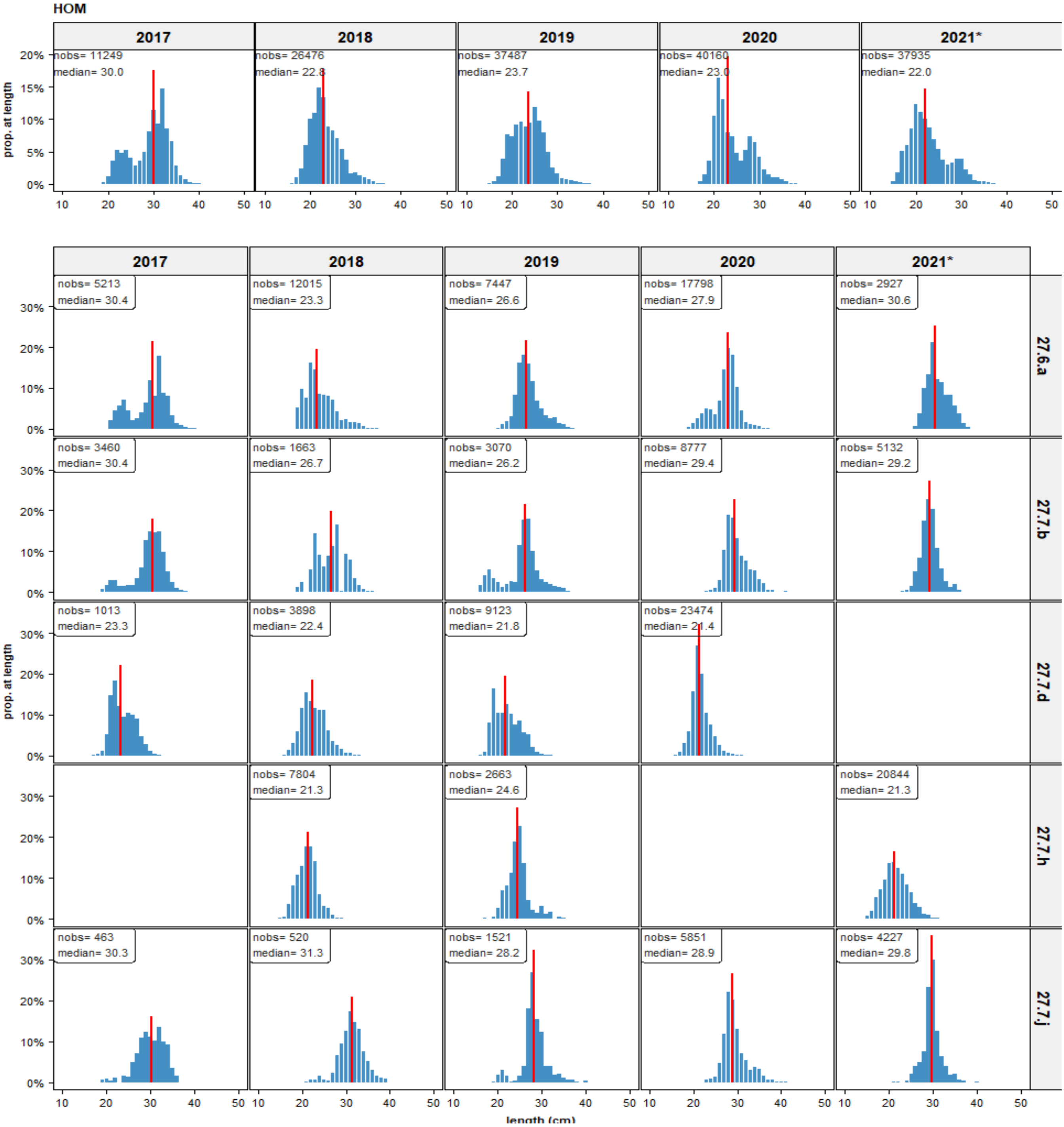

*Figure 3.3.4: Horse mackerel. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Horse mackerel (HOM). Weight distributions by year

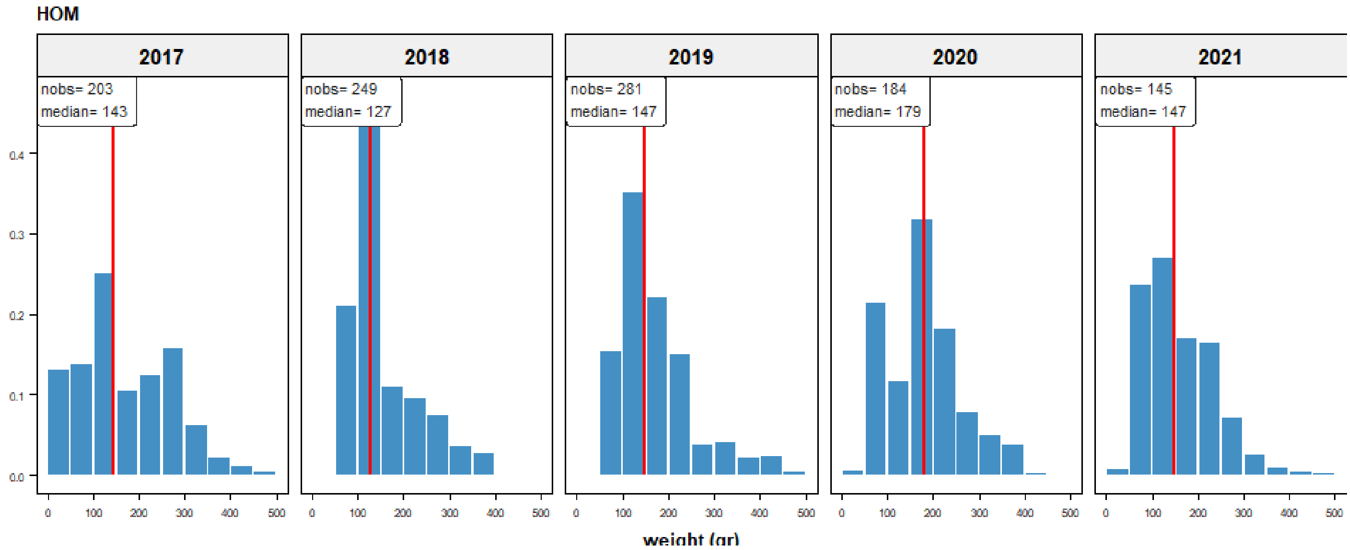

*Figure 3.3.5: Horse mackerel. Weight distributions (50-gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Horse mackerel (HOM). Fat percentages by week and year

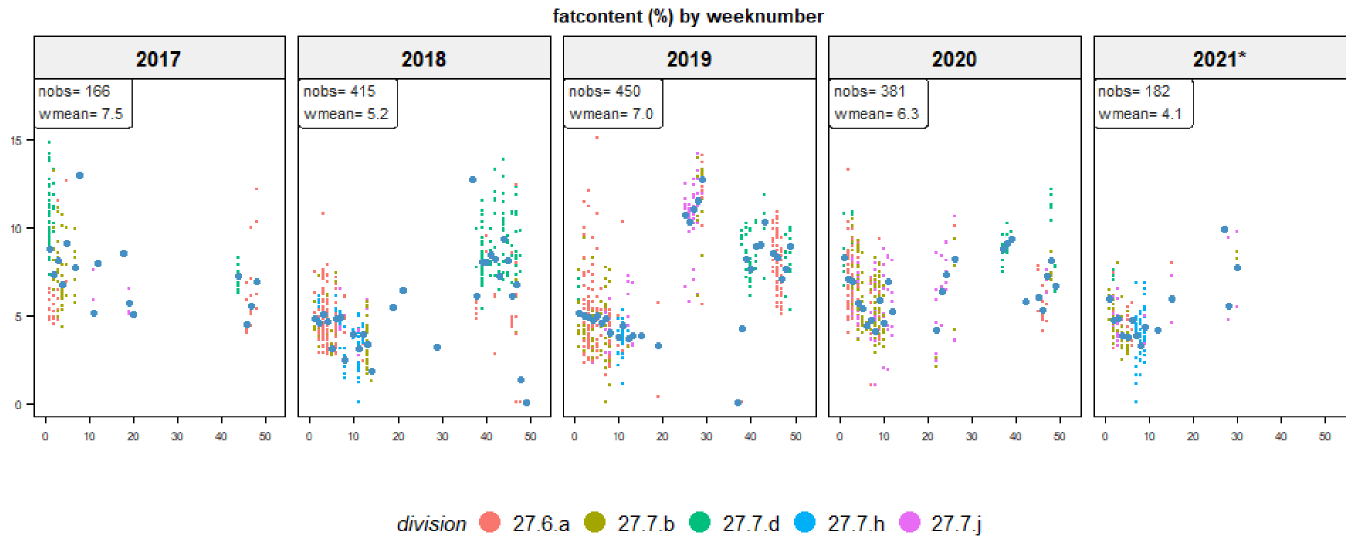

*Figure 3.3.6: Horse mackerel. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; black dots indicate the weekly averages; * denotes incomplete year*

Horse mackerel (HOM). Fishing depth distributions by year.

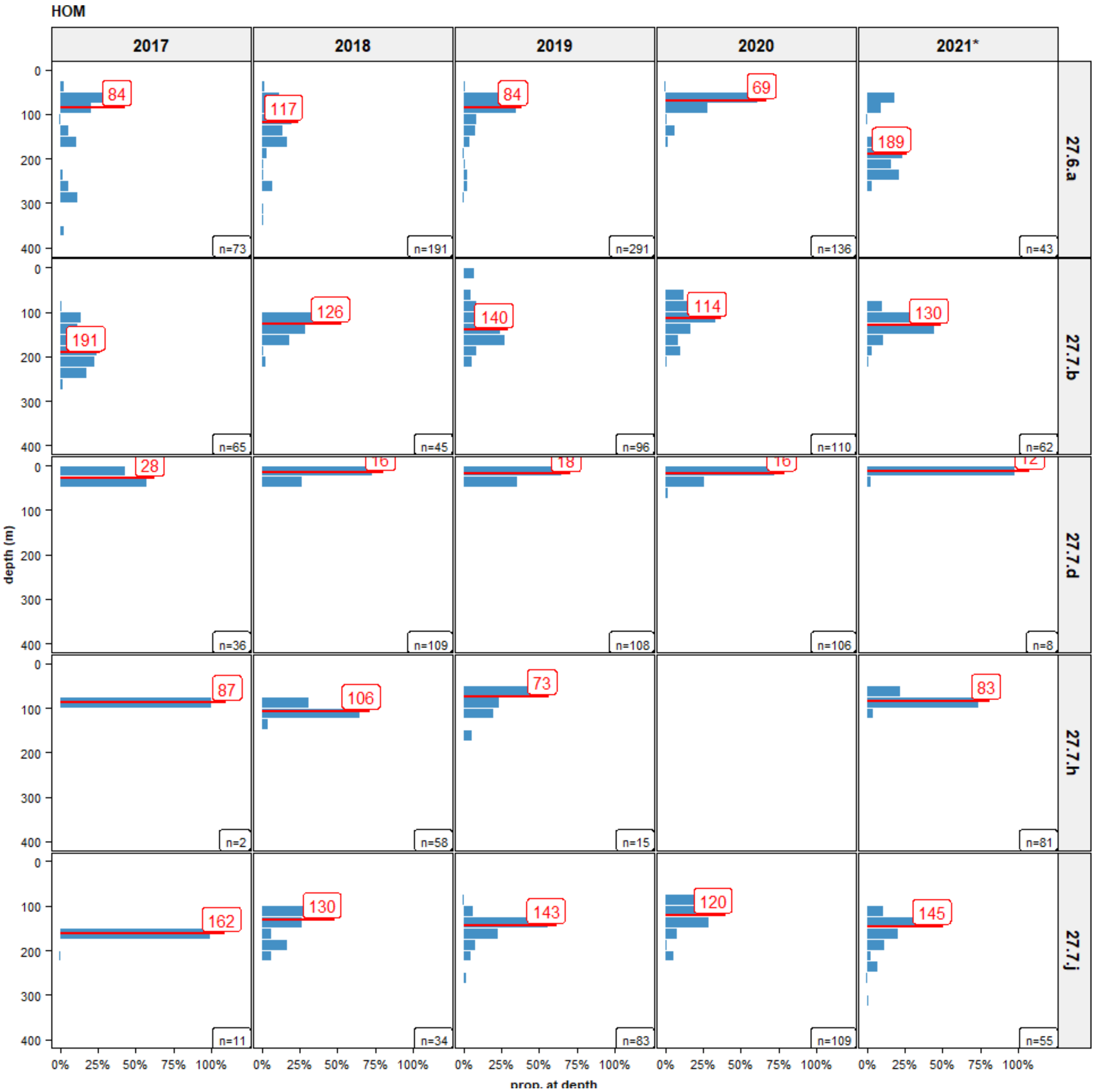

*Figure 3.3.7: Horse mackerel. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

3.4 Blue whiting (WHB, Micromesistius poutassou)

The main Blue whiting fishery takes place during months 2, 3, 4, 5. The self-sampling activities for the Blue whiting fishery during the years 2017 - 2021 (processed up to 27/07/2021) covered 215 fishing trips with 5892 hauls, a total catch of 615193 tonnes and 463807 individual length measurements. The main fishing areas are 27.6.a, 27.7.c, 27.7.k, 27.5.b, 27.2.a.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	nlength	catchperday
whb	27.6.a	2017	7	16	163	378	39,085	50	36,456	240
whb	27.6.a	2018	12	29	340	860	91,738	61	74,164	270
whb	27.6.a	2019	14	35	310	724	75,707	69	37,899	244
whb	27.6.a	2020	13	42	388	949	97,232	58	74,590	251
whb	27.6.a	2021*	12	29	244	564	61,508	56	50,344	252
whb	27.7.c	2017	6	10	97	231	28,731	37	16,945	296
whb	27.7.c	2018	6	9	77	235	30,504	20	21,392	396
whb	27.7.c	2019	10	16	99	246	26,587	24	14,222	269
whb	27.7.c	2020	10	16	128	326	44,309	26	42,574	346
whb	27.7.c	2021*	9	15	102	235	27,074	25	15,081	265
whb	27.7.k	2018	3	3	20	59	7,646	5	3,077	382
whb	27.7.k	2019	4	4	11	17	2,036	2	401	185
whb	27.7.k	2020	5	6	36	93	11,307	7	10,757	314
whb	27.7.k	2021*	4	5	55	150	19,293	18	14,395	351
whb	27.5.b	2017	5	6	40	64	7,960	10	8,226	199
whb	27.5.b	2018	5	7	52	82	7,928	5	5,204	152
whb	27.5.b	2019	4	8	26	34	3,905	4	2,331	150
whb	27.5.b	2020	4	10	56	87	10,220	6	5,854	182
whb	27.5.b	2021*	4	4	10	11	1,440	1	910	144
whb	27.2.a	2017	5	9	56	92	2,587	3	2,597	46
whb	27.2.a	2018	6	8	90	158	12,032	8	12,352	134
whb	27.2.a	2019	4	7	61	130	1,417	1	1,640	23
whb	27.2.a	2020	7	9	103	166	4,902	3	12,185	48
whb	27.2.a	2021*	1	1	1	1	44	0	208	44
whb	(all)	2017		41	356	765	78,363	100	64,224	220
whb	(all)	2018		56	579	1,394	149,848	99	116,189	259
whb	(all)	2019		70	507	1,151	109,652	100	56,493	216
whb	(all)	2020		83	711	1,621	167,970	100	145,960	236
whb	(all)	2021*		54	412	961	109,359	100	80,938	265
whb	(all)	(all)		304	2,565	5,892	615,192		463,804	240

*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	2017	2018	2019	2020	2021*	all	perc
whb	Jan	211	956	4,286	9,526	26,974	41,953	6.45%
whb	Feb	8,026	19,108	17,700	4,050	19,223	68,107	10.47%
whb	Mar	24,864	35,934	23,289	42,640	33,431	160,158	24.62%
whb	Apr	27,316	56,296	26,391	62,049	26,698	198,750	30.55%
whb	May	9,395	26,731	17,280	24,321	10,449	88,176	13.55%
whb	Jun	0	5,094	13	878	337	6,322	0.97%
whb	Jul	0	0	129	61	199	389	0.06%
whb	Aug	1,265	4,218	337	1,388	0	7,208	1.11%
whb	Sep	537	413	463	1,035	0	2,448	0.38%
whb	Oct	76	217	2,406	2,497	0	5,196	0.80%
whb	Nov	5,934	6,618	14,197	11,018	0	37,767	5.81%
whb	Dec	1,674	6,951	9,631	15,845	0	34,101	5.24%
whb	(all)	79,298	162,536	116,122	175,308	117,311	650,575	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

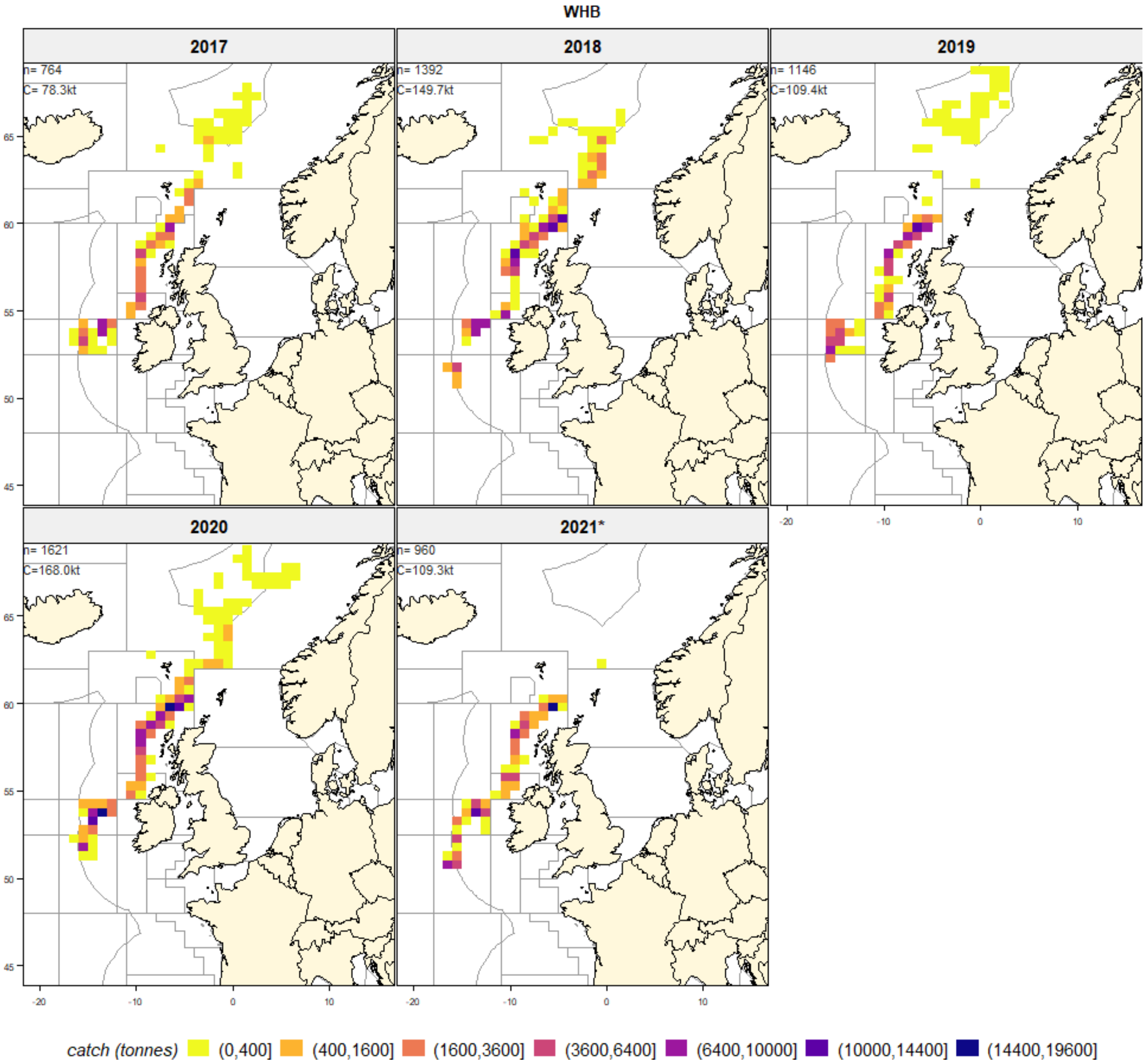

*Figure 3.4.1: Blue whiting. Catch per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Blue whiting (WHB). Average catch per day

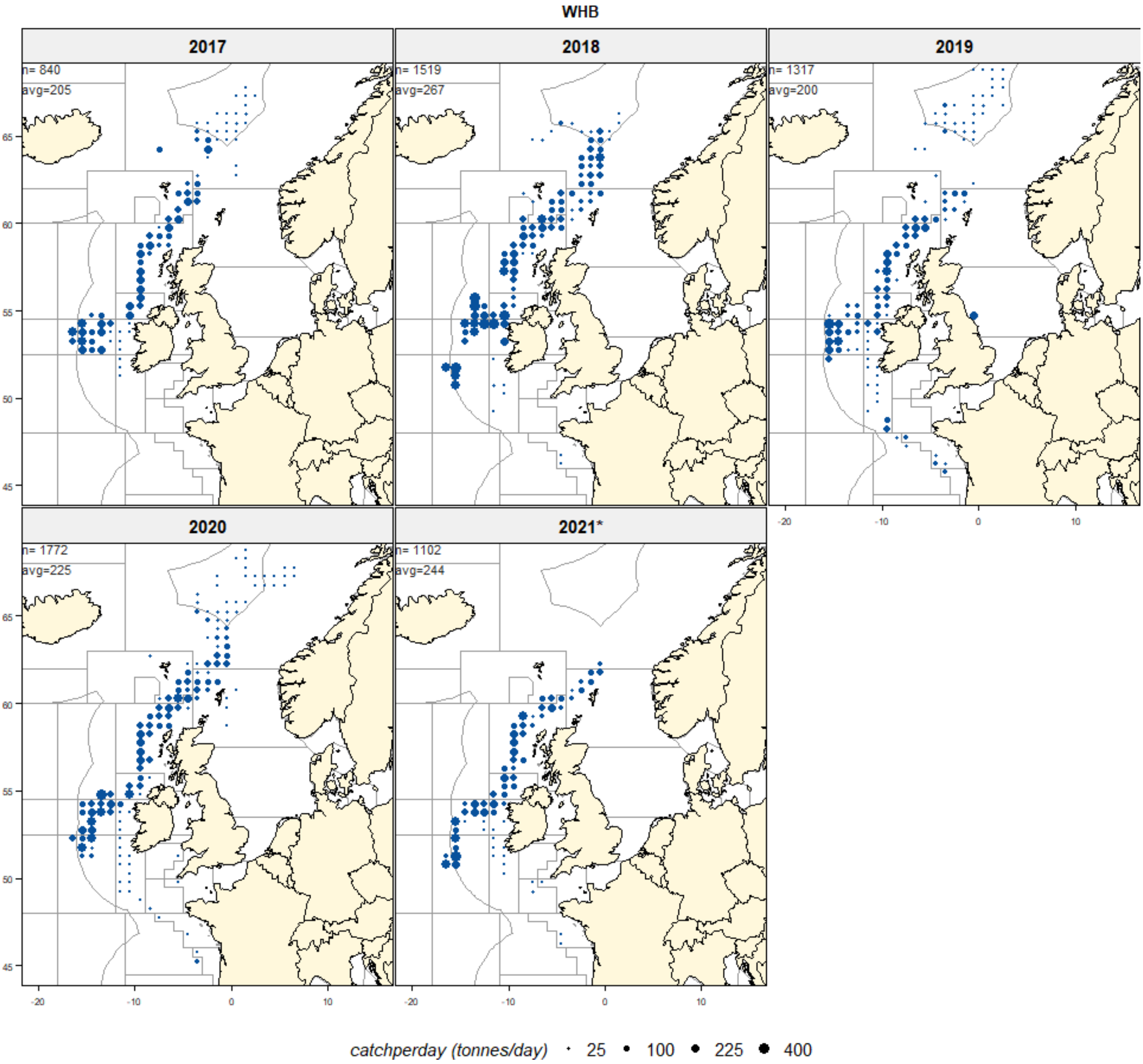

*Figure 3.4.2: Blue whiting. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Blue whiting (WHB). Spatial-temporal evolution of the fishery

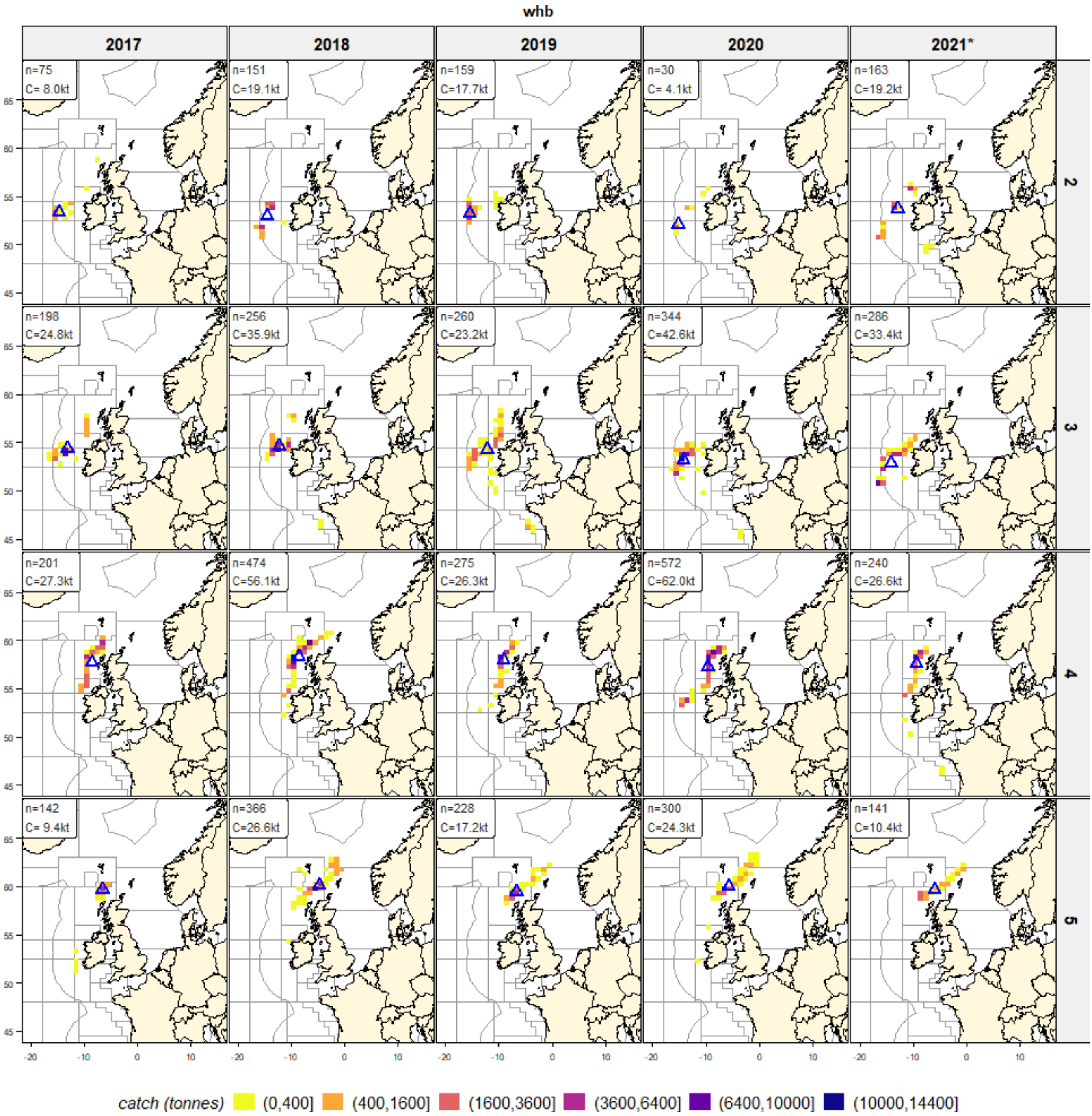

*Figure 3.4.3: Blue whiting. Catch per rectangle and per month. N indicates the number of hauls; C refers to the overall catch. The midpoint of the distribution is indicated by the blue triangle. * denotes incomplete year*

Blue whiting (WHB). Length distributions of the catch

Median length of Blue whiting in the catch in 2021 is 27.9 cm compared to median lengths between 24.2 and 27.7 cm in the preceding years. Note that the data for 2021 is only up to 27/07/2021.

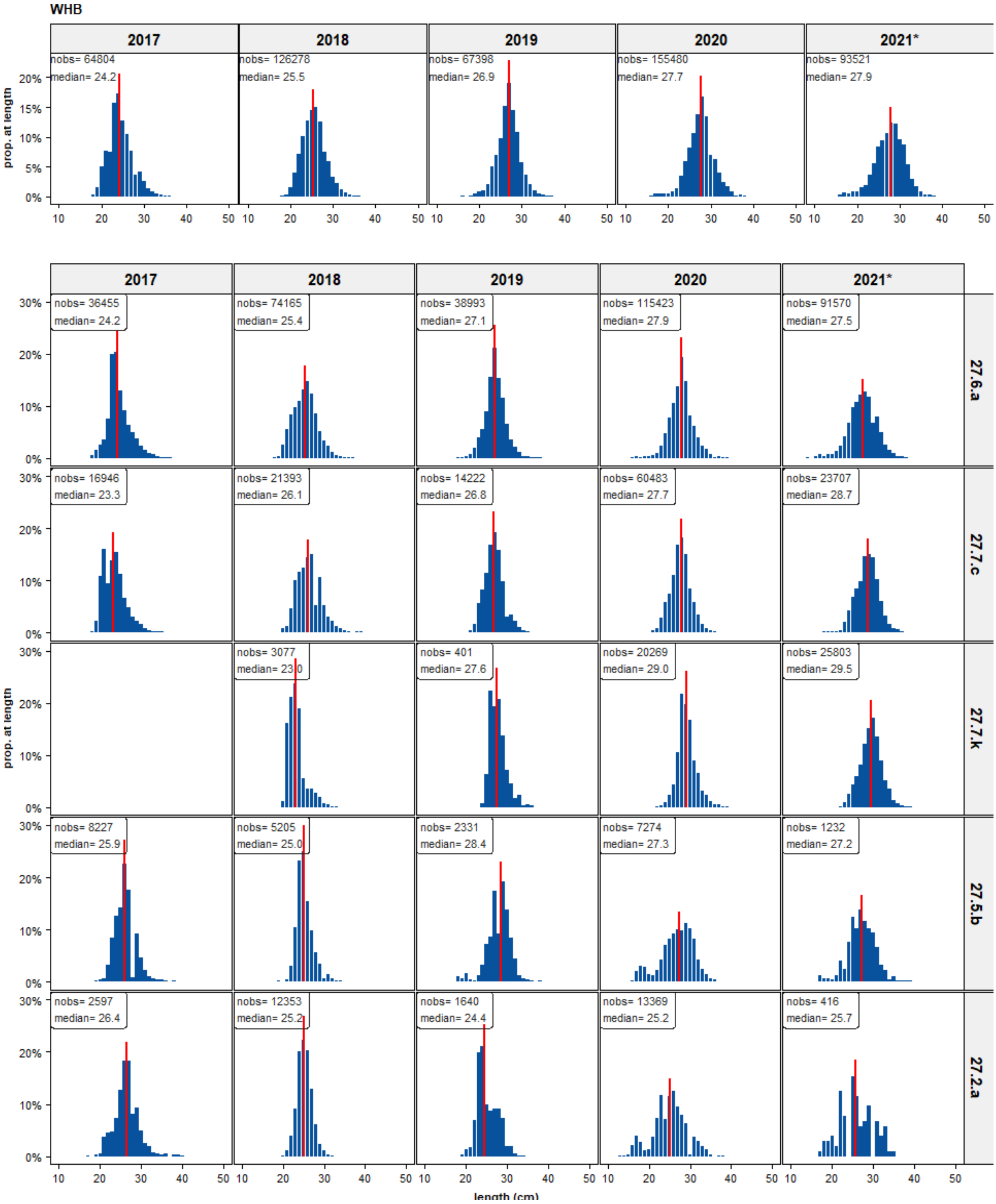

*Figure 3.4.4: Blue whiting. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Blue whiting (WHB). Weight distributions by year

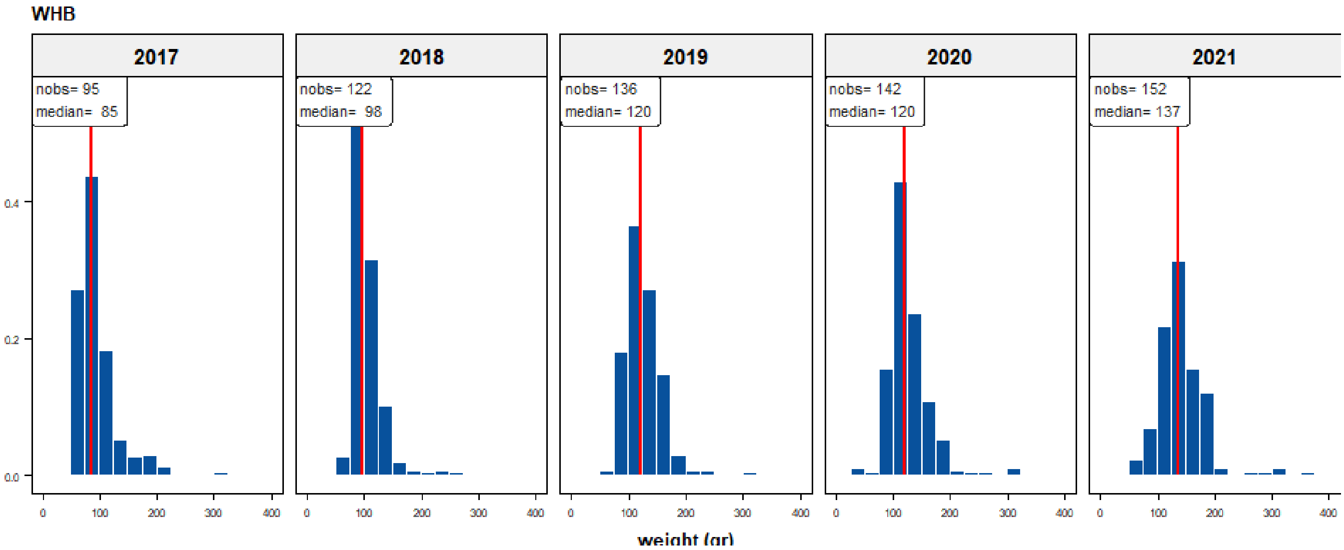

*Figure 3.4.5: Blue whiting. Weight distributions (25-gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Blue whiting (WHB). Fat percentages by week and year

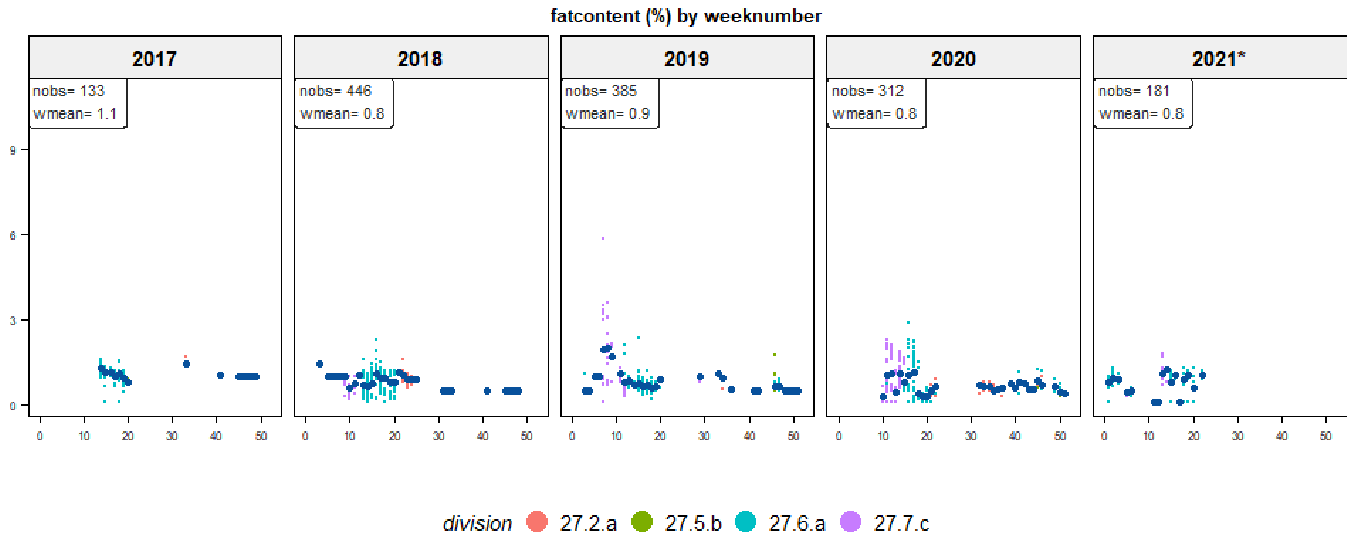

*Figure 3.4.6: Blue whiting. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; black dots indicate the weekly averages; * denotes incomplete year*

Blue whiting (WHB). Fishing depth distributions by year.

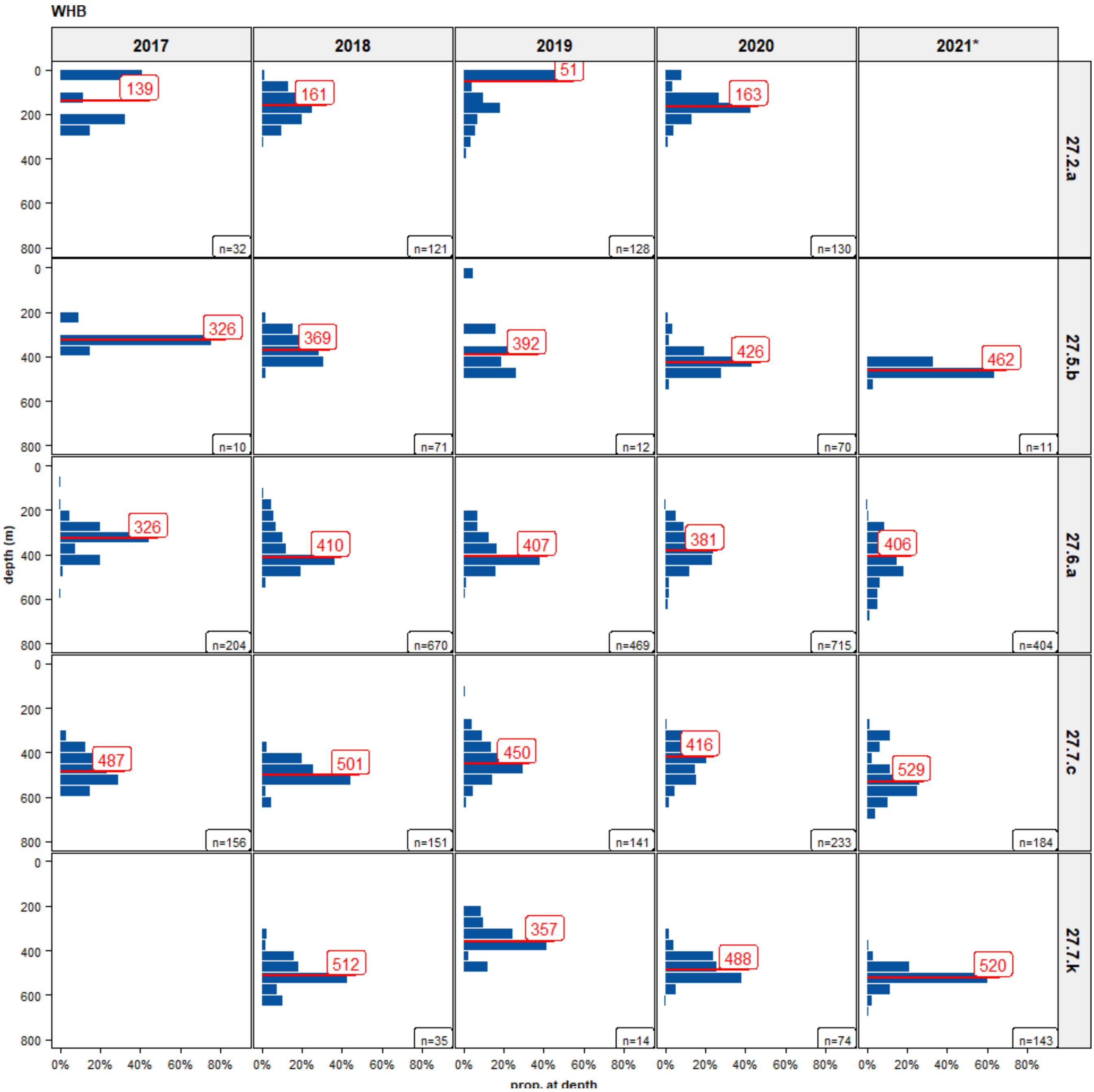

*Figure 3.4.7: Blue whiting. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

3.5 Herring 'Atlanto-scandian' (HER_ASH, Clupea harengus)

The main Herring 'Atlanto-scandian' fishery takes place during months 9, 10, 11. The self-sampling activities for the Herring 'Atlanto-scandian' fishery during the years 2017 - 2021 (processed up to 27/07/2021) covered 27 fishing trips with 456 hauls, a total catch of 36003 tonnes and 10327 individual length measurements. The main fishing areas are 27.2.a.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	nlength	catchperday
her_ash	27.2.a	2017	4	7	42	83	7,950	100	2,210	189
her_ash	27.2.a	2018	4	5	37	68	5,278	100	490	143
her_ash	27.2.a	2019	4	5	57	145	12,249	100	3,714	215
her_ash	27.2.a	2020	8	10	83	160	10,526	100	3,913	127
her_ash	(all)	2017		7	42	83	7,950	100	2,210	189
her_ash	(all)	2018		5	37	68	5,278	100	490	143
her_ash	(all)	2019		5	57	145	12,249	100	3,714	215
her_ash	(all)	2020		10	83	160	10,526	100	3,913	127
her_ash	(all)	(all)		27	219	456	36,003		10,327	164

*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). * denotes incomplete year*

Herring 'Atlanto-scandian' (HER_ASH). Catch by month

species	month	2017	2018	2019	2020	all	perc
her_ash	May	0	0	0	26	26	0.07%
her_ash	Aug	118	51	0	41	210	0.58%
her_ash	Sep	6	405	361	65	837	2.33%
her_ash	Oct	7,825	4,820	8,066	7,514	28,225	78.41%
her_ash	Nov	0	0	3,821	2,878	6,699	18.61%
her_ash	(all)	7,949	5,276	12,248	10,524	35,997	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

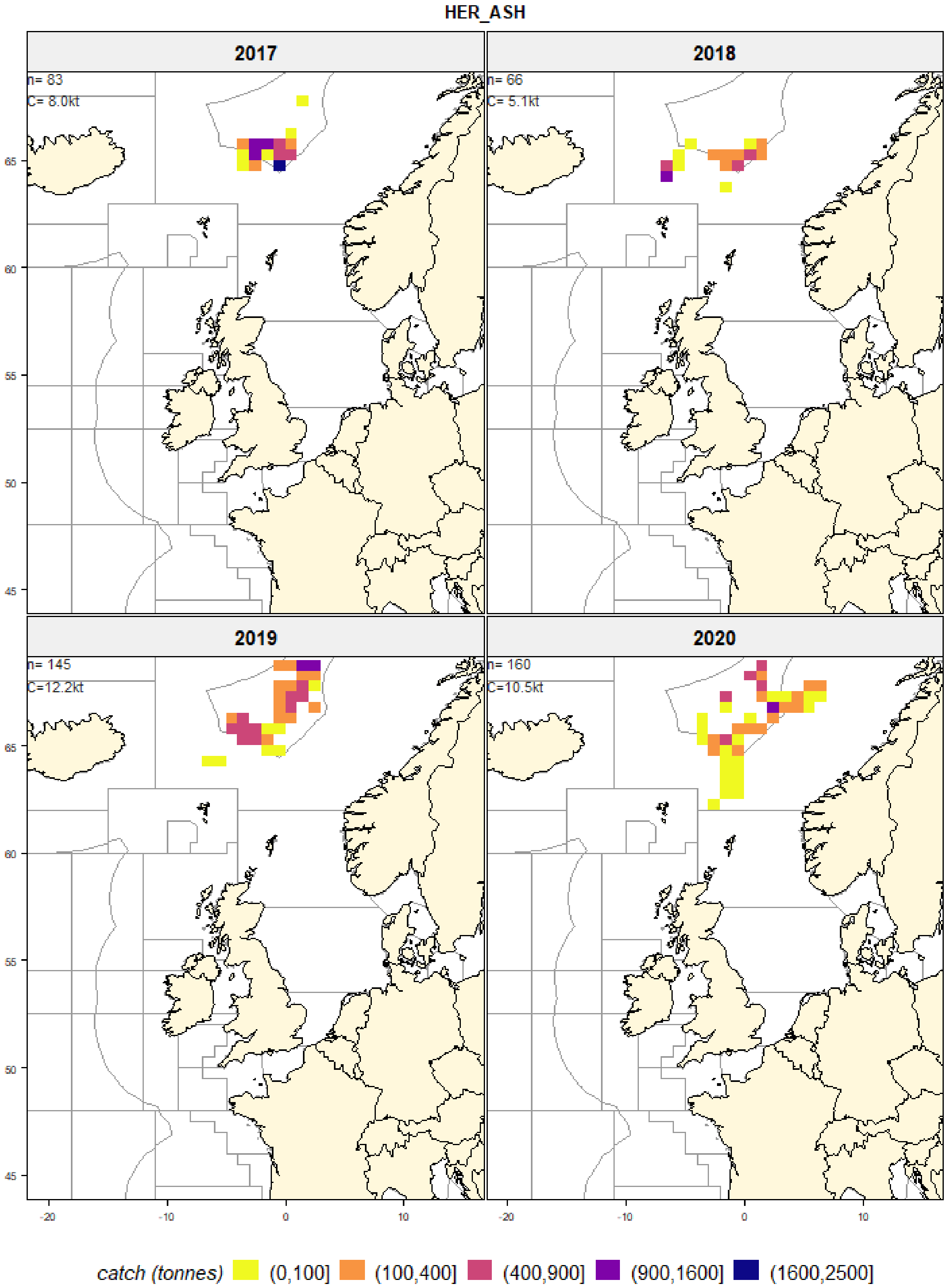

*Figure 3.5.1: Herring 'Atlanto-scandian'. Catch per rectangle. N indicates the number of hauls; Catch refers to the total catch per year. * denotes incomplete year*

Herring 'Atlanto-scandian' (HER_ASH). Average catch per day

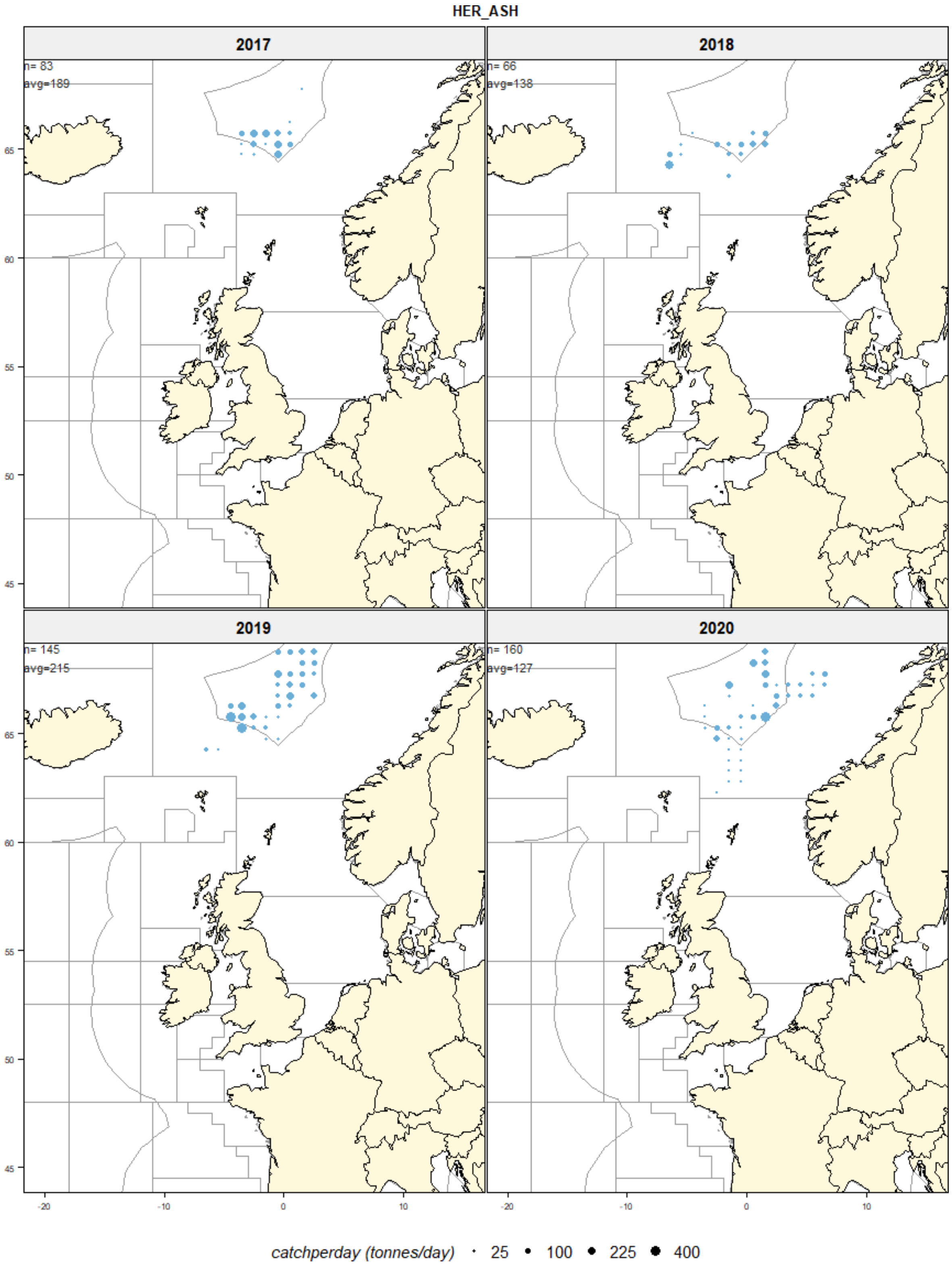

*Figure 3.5.2: Herring 'Atlanto-scandian'. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day. * denotes incomplete year*

Herring 'Atlanto-scandian' (HER_ASH). Spatial-temporal evolution of the fishery

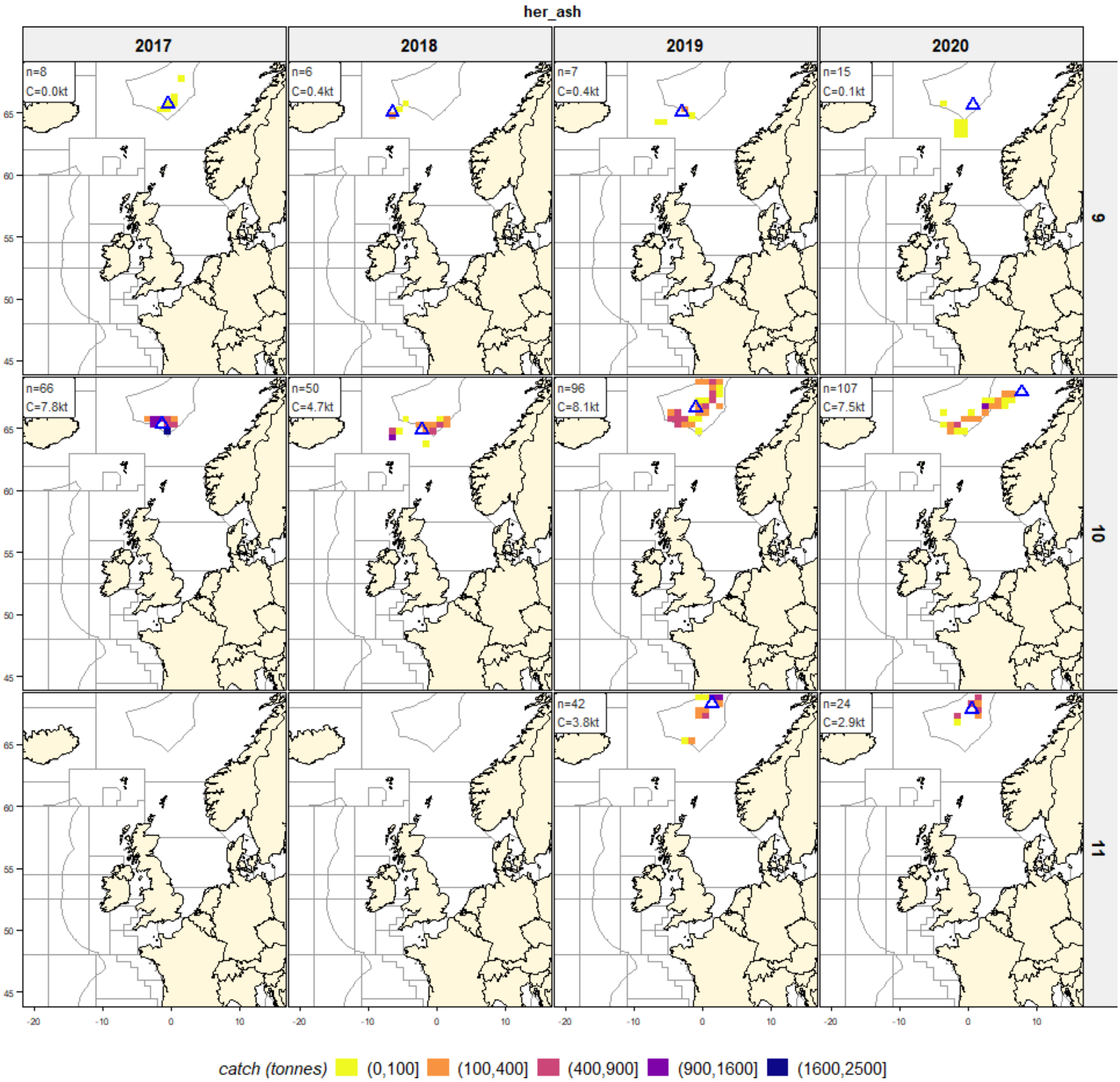

*Figure 3.5.3: Herring 'Atlanto-scandian'. Catch per rectangle and per month. N indicates the number of hauls; C refers to the overall catch. The midpoint of the distribution is indicated by the blue triangle. * denotes incomplete year*

Herring 'Atlanto-scandian' (HER_ASH). Length distributions of the catch

Median length of Herring 'Atlanto-scandian' in the catch in 2021 is NA cm compared to median lengths between 31.6 and 35.8` cm in the preceding years.

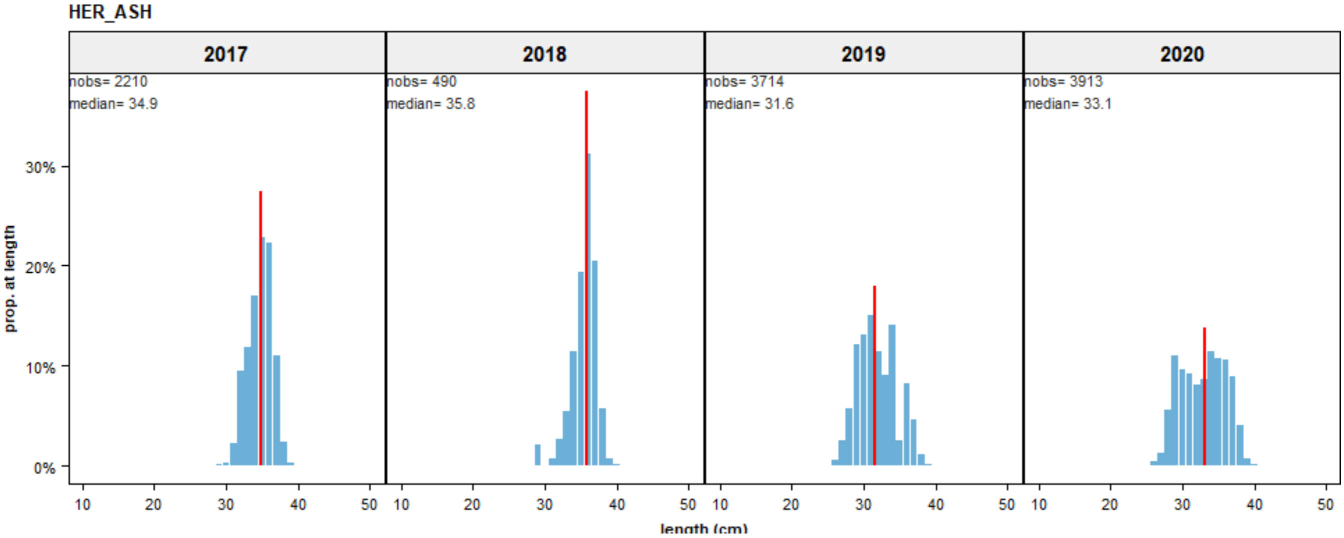

*Figure 3.5.4: Herring 'Atlanto-scandian'. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length. * denotes incomplete year*

Herring 'Atlanto-scandian' (HER_ASH). Weight distributions by year

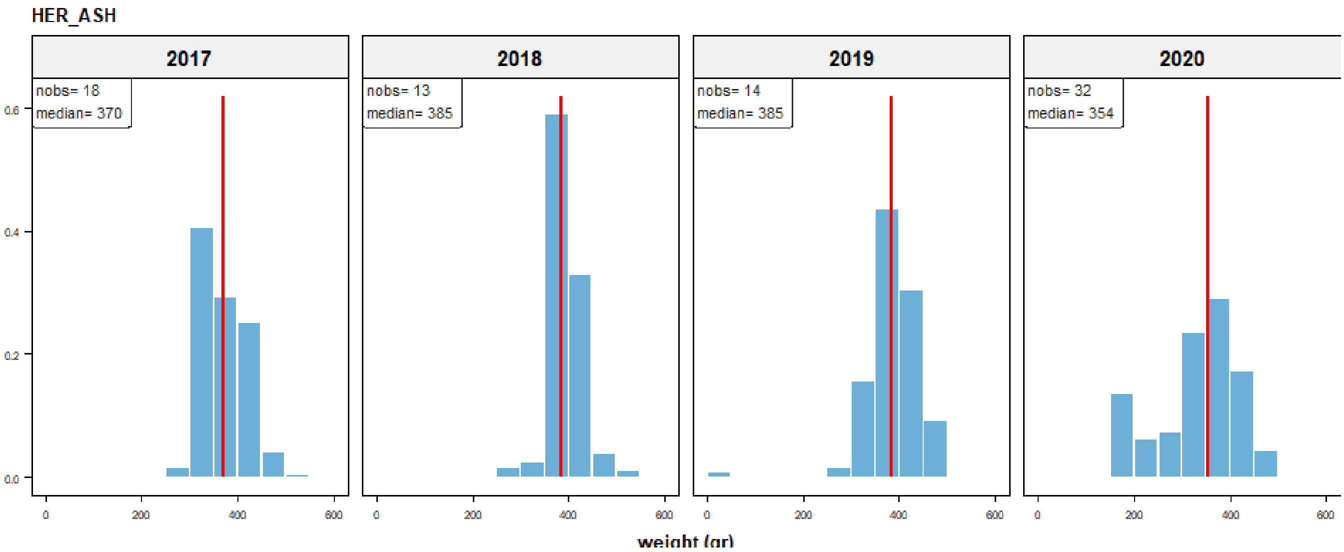

*Figure 3.5.5: Herring 'Atlanto-scandian'. Weight distributions (50-gram classes). Nobs refers to the number of batches where average weight was measured; median denotes the median length; * denotes incomplete year*

Herring 'Atlanto-scandian' (HER_ASH). Fat percentages by week and year

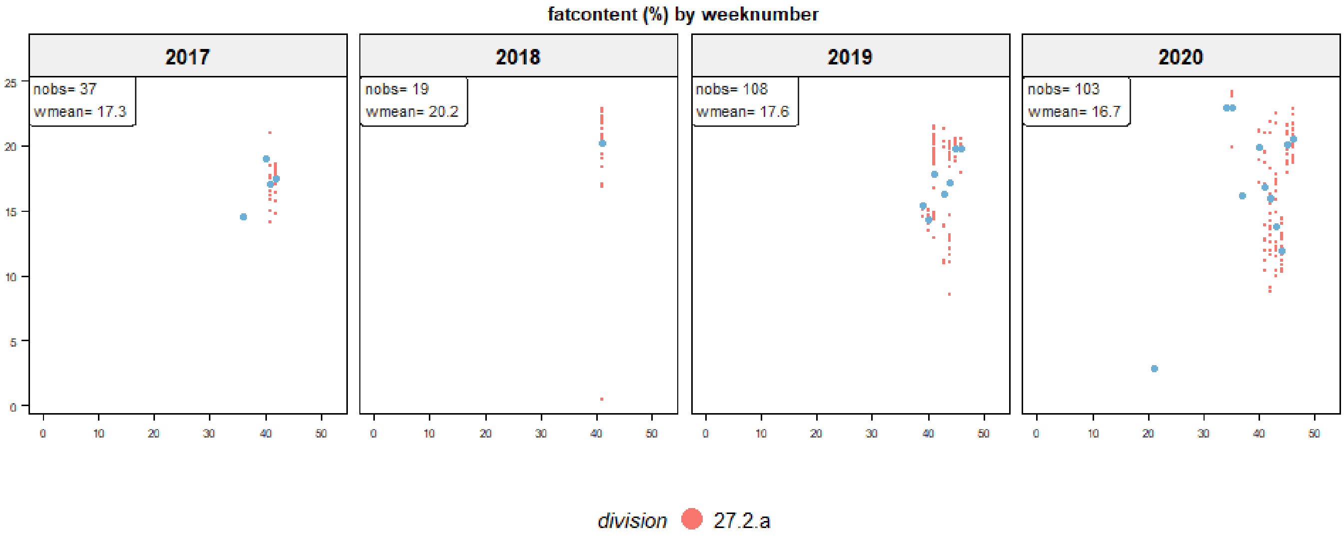

*Figure 3.5.6: Herring 'Atlanto-scandian'. Average fat percentage by week. Nobs refers to the number of batches where average fat was measured; black dots indicate the weekly averages; * denotes incomplete year*

Herring ‘Atlanto-scandian’ (HER_ASH). Fishing depth distributions by year.

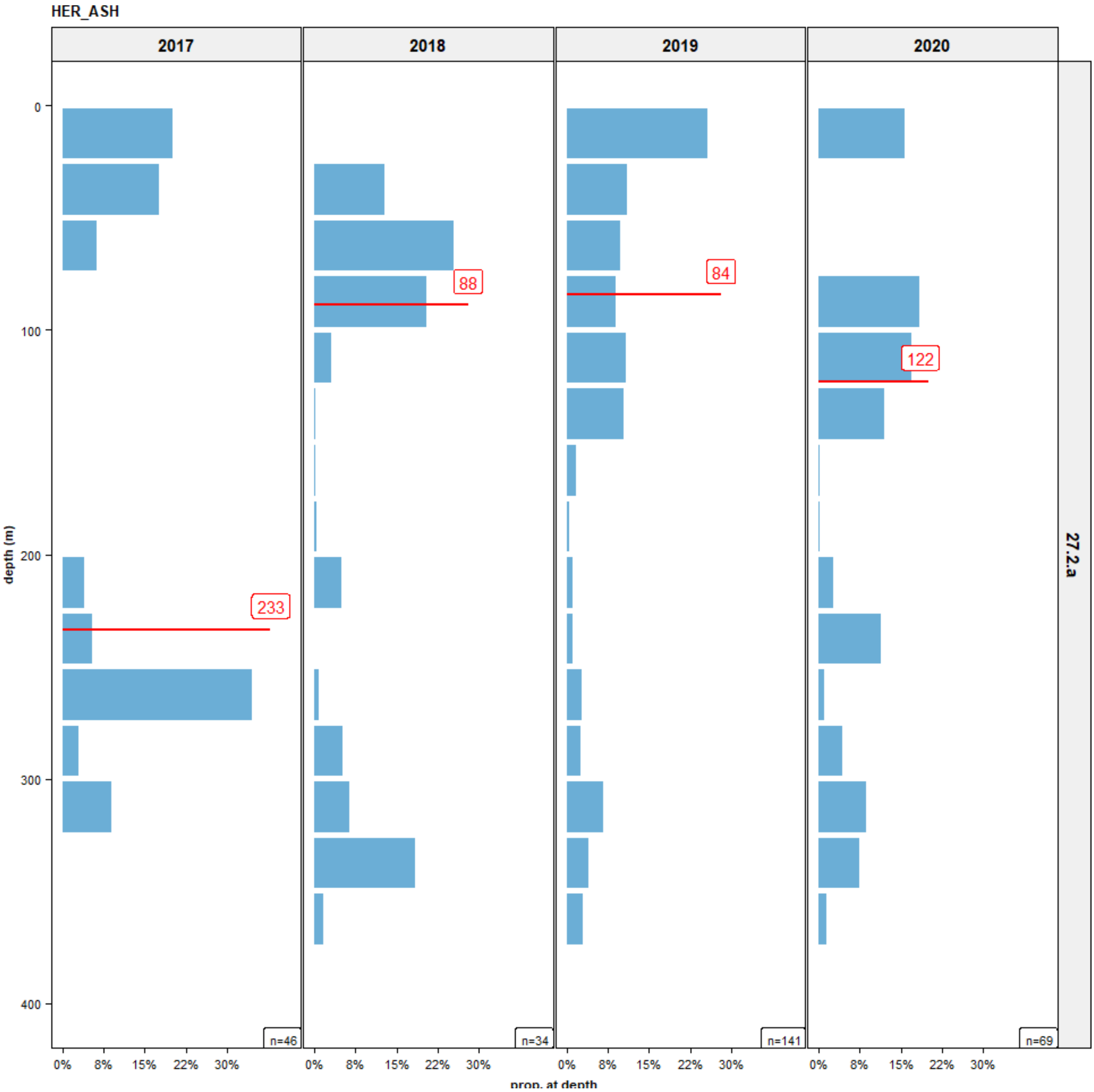

*Figure 3.5.7: Herring ‘Atlanto-scandian’. Depth distributions by year and division. N is number of observations; median depth in red; * denotes incomplete year*

4 Discussion and conclusions

The PFA self-sampling program has been carried out for the seventh year in a row (2015-2021). Here, results have been presented for the years 2017-2021 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 the 'widely distributed fishery' has been approached by selecting all combination of vessel-trip-weeks where hauls were taken in a certain area and where the catch composition consisted of a minimum percentage of certain species (blue whiting, mackerel, horse mackerel, Atlanto-scandian herring) and a minimum weekly 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. Trips from 2017 up to 27/07/2021 have been processed for this overview. Pelagic fisheries within the Pelagic Freezer-trawler Association are carried out by vessels from different countries. Overall, around 48% of the catch volume of trips in this overview were taken by Dutch trawlers, 22% German trawlers, 14% UK trawlers and 16% other countries. Blue whiting constitutes the majority of the catch in those trips (54%), followed by mackerel (23%) and horse mackerel (12%). Atlanto-scandian herring only constitutes around 3% of the volume in the PFA widely distributed fishery. Note that the North Sea herring fishery is not included in this overview.

The **Mackerel fishery** takes place from October through to March of the subsequent year. Minor by-catches of mackerel may also occur during other fisheries. Overall, the self-sampling activities for the mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 357 fishing trips with 4940 hauls, a total catch of 287836 tonnes and 91096 individual length measurements. The main fishing areas are ICES division 27.4.a and division 27.6.a. Compared to the previous years, mackerel in the catch in 2021 have been relatively large with a median length of 36.4 cm compared to 33.6-36.2 in the preceding years. Also, the median weight has been somewhat higher with median weight of 435 gram compared to 385-422 gram in the preceding years.

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 2017 - 2021 (up to 27/07/2021) covered 243 fishing trips with 3446 hauls, a total catch of 141548 tonnes and 153307 individual length measurements. The main fishing areas are ICES division 27.6.a, division 27.7.b and division 27.7.d. Horse mackerel have a wide range in the length distributions in the catch. Median lengths in divisions 27.6.a, 27.7.b and 27.7.j have fluctuated between 26.2 and 31.3 cm (with one low median length of 23.3 cm in 27.6.a in 2018). In ICES divisions 27.7.d and 27.7.h, median lengths in the catch are smaller and fluctuated between 21.3 and 24.6 cm.

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 horse mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 240 fishing trips with 6560 hauls, a total catch of 650604 tonnes and 507481 individual length measurements. The main fishing areas are ICES division 27.6.a, division 27.7.c and division 27.7.k. Compared to the previous years, blue whiting in the catch in 2021 have been relatively large with a median length of 27.9 cm compared to 24.2-27.2 in the preceding years. Also, the median weight has been somewhat higher with median weight of 137 gram compared to 85-120 gram in the preceding years.

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 horse mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 27 fishing trips with 456 hauls, a total catch of 36003 tonnes and 10327 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 relatively narrow range in the length distributions in the catch. Median lengths have been between 31 and 36 cm.

5 Acknowledgements

The skippers, officers and the quality managers of the PFA vessels are putting in a lot of effort and dedication 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 have any questions on the PFA self-sampling program or the specific results presented here. Detailed length compositions (e.g., CSV files) can be made available on request.

Working Document WGWIDE 2021

Overview of the Scottish Pelagic Industry Self-Sampling Programme with potential data opportunities relevant to stock assessment

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1. Purpose

Data collected by industry has the potential to provide data to stock assessment and contribute to the quality of stock assessment and ICES advice. This working document provides:

- An overview of the Scottish pelagic industry self-sampling programme.
- A summary of the Scottish pelagic industry self-sampling data collected since 2018 for mackerel, herring and blue whiting.
- Example data: distribution maps of self-sampling / co-sampling and the biological data available for mackerel in 2021, alongside Marine Scotland Science (MSS) onshore sampling data for the same fishery/period.

This is a preliminary presentation of the work carried out by the Scottish Pelagic Industry Self-sampling Programme, to communicate its future data contribution to WGWIDE.

2. The Scottish Pelagic Industry Self-Sampling Programme

The Scottish Pelagic Industry Self-Sampling Programme[1] has been developed by the Scottish Pelagic Fishermen's Association (SPFA), Shetland UHI (SUHI)[2] and Marine Scotland Science (MSS) with the support of the EU H2020 project PANDORA.

Building on an initial feasibility study[3], the self-sampling programme began in 2018. Initial expectations for a limited pilot programme have been far exceeded, and by 2020 commitment to full voluntary participation by SPFA member vessels (representing 20 out of 21 Scottish pelagic vessels) was achieved, covering data collection from herring, mackerel and blue whiting fisheries. With routine procedures[4] now firmly established, the Scottish pelagic industry are committed to the continuation of the self-sampling programme beyond 2021.

The industry data collection programme comprises two parts. The first part, the self-sampling scheme, requires vessel crews to sample fish from every haul of every trip. Fish length (cm) and weight (g) data are

[1] The pelagic self-sampling is part of the SPFA Data Collection Strategy

[2] NAFC Marine Centre merged into the Shetland UHI organization on 1st August 2021

[3] Pelagic-self-sampling_FIS020-report_FINAL.pdf (scottishpelagic.co.uk)

[4] Methods and protocols manual for the Scottish pelagic self-sampling programme

collected as the fish are pumped onboard pelagic vessels, and haul information is recorded to connect the biological sample data to the location and date/time of the catch, and other operational and environmental parameters. The second part, the co-sampling scheme, added to the programme in 2020, requires samples of fish to be frozen and brought ashore for biological sampling on length, sex, maturity and age by scientists at SUHI and MSS laboratories. The procedure for collecting frozen samples is described in more detail below.

As part of the programme, vessel crews undertake training and are provided with all the necessary tools, including measuring boards, sampling protocols, data recording sheets and – more recently – electronic keypads for paperless data entry and standardised recording. Data quality checks are in place as part of the programme's Data Chain of Custody; and the quality of self-sampling data have been examined by comparing the data against landings that have been sampled through the current MSS onshore sampling (as carried out by MSS and the designated agent NAFC, now SUHI).

The SPFA Data Policy describes the conditions and procedures regarding data access and use by the scientific community. All Data Products are by default publicly available.

3. Summary of industry self-sampling data collection (2018-2021)

Industry are keen to engage in the self-sampling programme, with the participation of SPFA member vessels increasing each year from 35% in 2018 to 100% in 2020 (Table 1).

Table 1. Number of unique vessels/trips/hauls/fish sampled (length and weight), from a total of 20 SPFA member vessels.

	2018	2019	2020	2021
Herring				
No. unique vessels	7	5	15	n/a
No. trips	41	14	65	n/a
No. hauls	73	30	128	n/a
No. fish	7,882	3,640	15,396	n/a
Mackerel (Autumn, Oct/Nov)				
No. unique vessels	7	7	15	n/a
No. trips	29	20	67	n/a
No. hauls	53	39	133	n/a
No. fish	6,165	4,191	15,119	n/a
Mackerel (Winter, Jan/Feb)				
No. unique vessels	n/a	7	14	18
No. trips	n/a	23	45	67
No. hauls	n/a	42	82	138
No. fish	n/a	4,862	9,140	15,822
Blue whiting				
No. unique vessels	n/a	1	5	9
No. trips	n/a	4	20	40
No. hauls	n/a	16	69	125
No. fish	n/a	1,893	8,002	15,110

4. Results of industry self-sampling and Marine Scotland Science onshore sampling for mackerel 2021 (Winter Jan/Feb)

Industry data are shown below, alongside MSS onshore sampling data. Biological data collection from onshore sampling of pelagic landings in Scottish ports has been carried out by MSS since around 1970. These data are used to provide numbers-at-age for use in stock assessment. The sampling programme is overseen by MSS and is currently undertaken by MSS and SUHI (and Marine Institute, Ireland for blue whiting). The data comprise biological information such as length, maturity and age, collected from samples of landings obtained opportunistically from the vessels at Scottish ports. The sample can be allocated to a fishing trip and the statistical rectangles reported for that trip, but not to individual hauls and their associated locations. Typically, around 50% of trips are sampled each year under the MSS onshore sampling scheme.

4.1 Sample location

Participation in the self-sampling programme requires that all hauls from all trips are sampled. With full participation of the fleet, full spatial and temporal coverage of the fishery can be achieved. This census approach enables greater reach of the self-sampling data compared to the MSS onshore sampling programme (Fig. 1) and includes sampling of landings abroad. The self-sampling data can be further resolved with individual haul locations (not shown here).

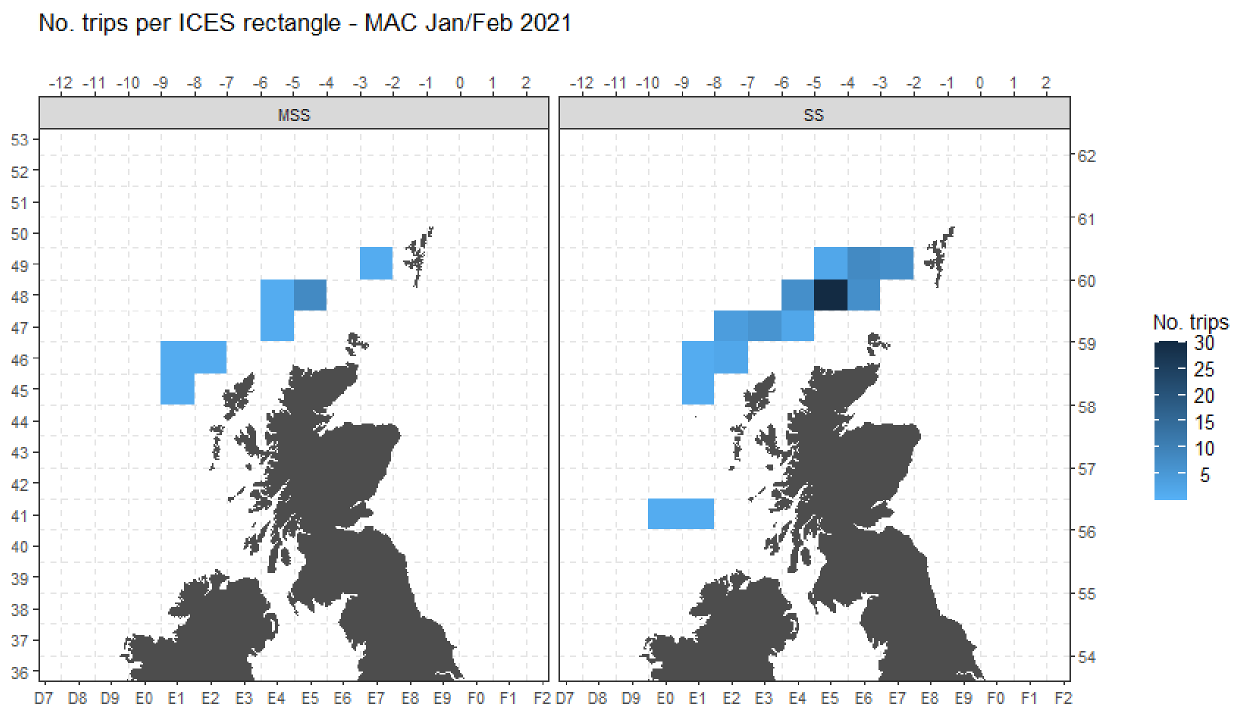

Figure 1. Sample locations from industry self-sampling and Marine Scotland Science sampling for mackerel 2021 (Winter, Jan/Feb). Number of trips per ICES rectangle, mapped by dataset, where MSS=onshore sampling overseen by MSS, and SS=self-sampling undertaken by SPFA vessels.

4.2 Sample length distribution

In 2021, 14 trips were sampled by both the self-sampling programme and the onshore sampling overseen by MSS (Fig. 2). The two datasets demonstrated similar length distributions for all but one trip.

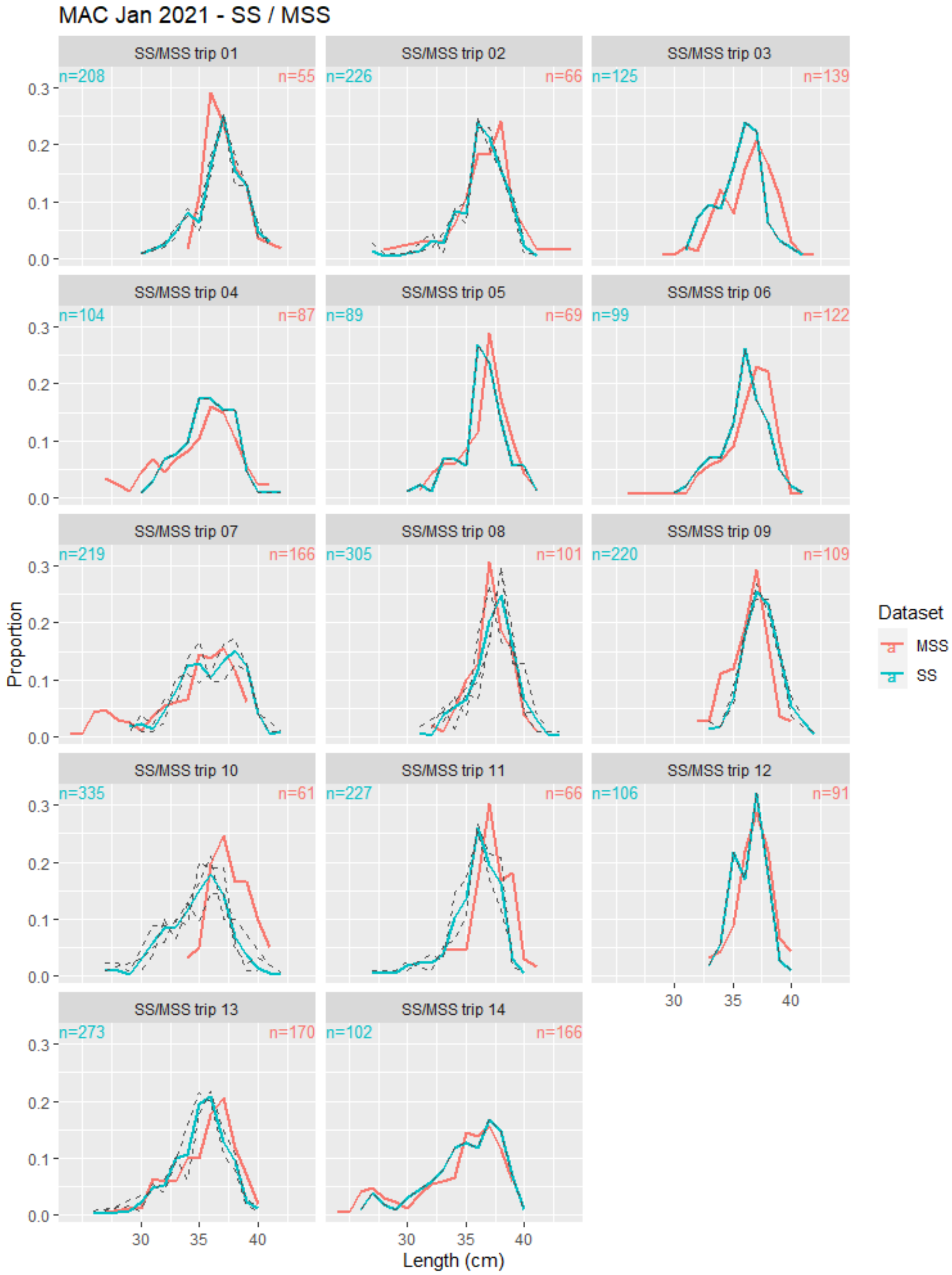

Figure 2. Length distribution from industry self-sampling and Marine Scotland Science sampling for mackerel 2021 (Winter, Jan/Feb). Length distribution of fish by trip where data coincides from each dataset. MSS=onshore sampling overseen by MSS, and SS=self-sampling undertaken by SPFA vessels. For the self-sampling data, the blue line shows the length distribution across all hauls in a single trip, while the dotted black line shows the length distribution for each haul within a trip. Trip codes have been anonymised for vessel confidentiality.

4.3 Sample length-weight relationship

The mean weights-at-length from the self-sampling data for mackerel in January and February in 2021 were compared with the monthly weight-length relationships currently used by MSS (Fig. 3). The observed self-sampling weight data indicate that the pooled mean weight of fish of intermediate lengths is greater than that predicted by the L-W relationships used by MSS, in spring 2021. Sampling both lengths and weights enables seasonal and inter-annual variations in growth patterns of cohorts to be captured and incorporated into stock assessments. It also provides valuable data for research on species ecology.

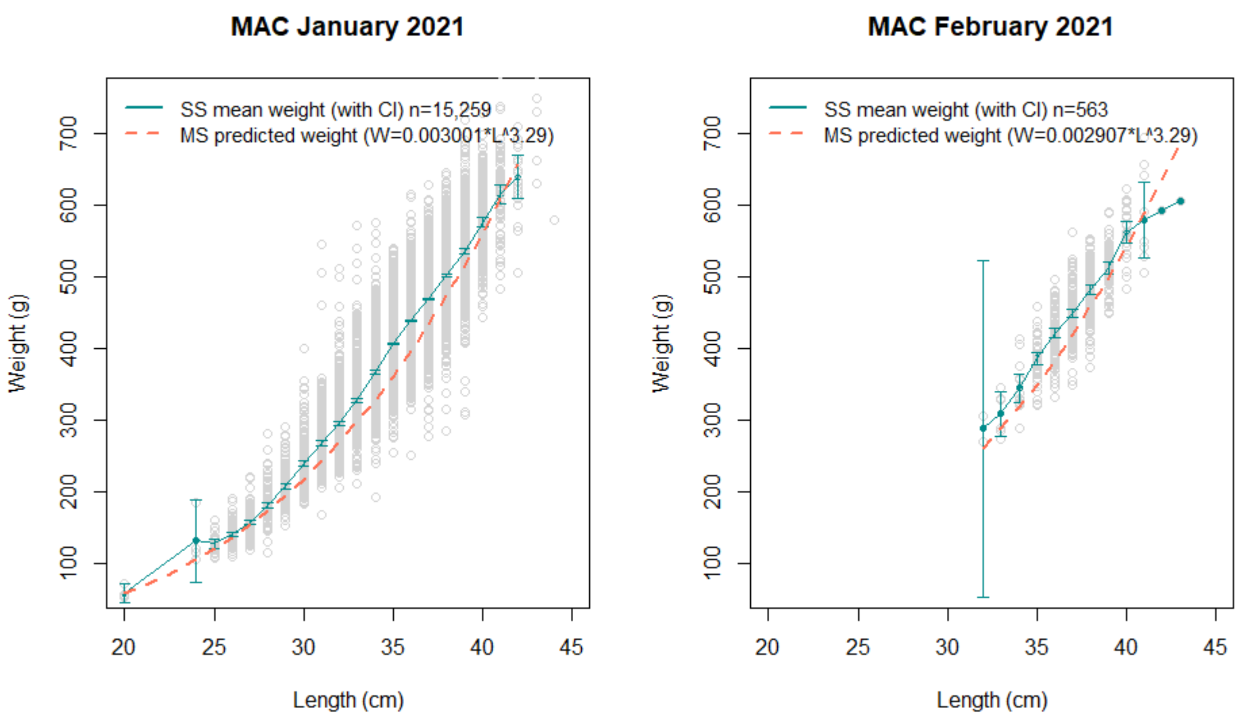

Figure 3. Fish length-weight relationship for mackerel 2021 (Winter, Jan/Feb). Fish length-weight relationship by month with SS weight-length dataset (grey circles). MSS=onshore sampling overseen by MSS (data plotted as predicted weight-at-length), and SS=self-sampling undertaken by SPFA vessels (data plotted as mean weight-at-length with confidence interval [CI]).

5. Co-sampling: age, length, sex and maturity data collection

Since 2020, fish samples are frozen and brought ashore for additional biological sampling on age, length, sex, and maturity by scientists at the SUHI and MSS laboratories. An electronic 'coin-toss' is used to randomly select the trips required to collect frozen samples. From each selected trip one box of fish is collected from each haul.

5.1 Sampling locations

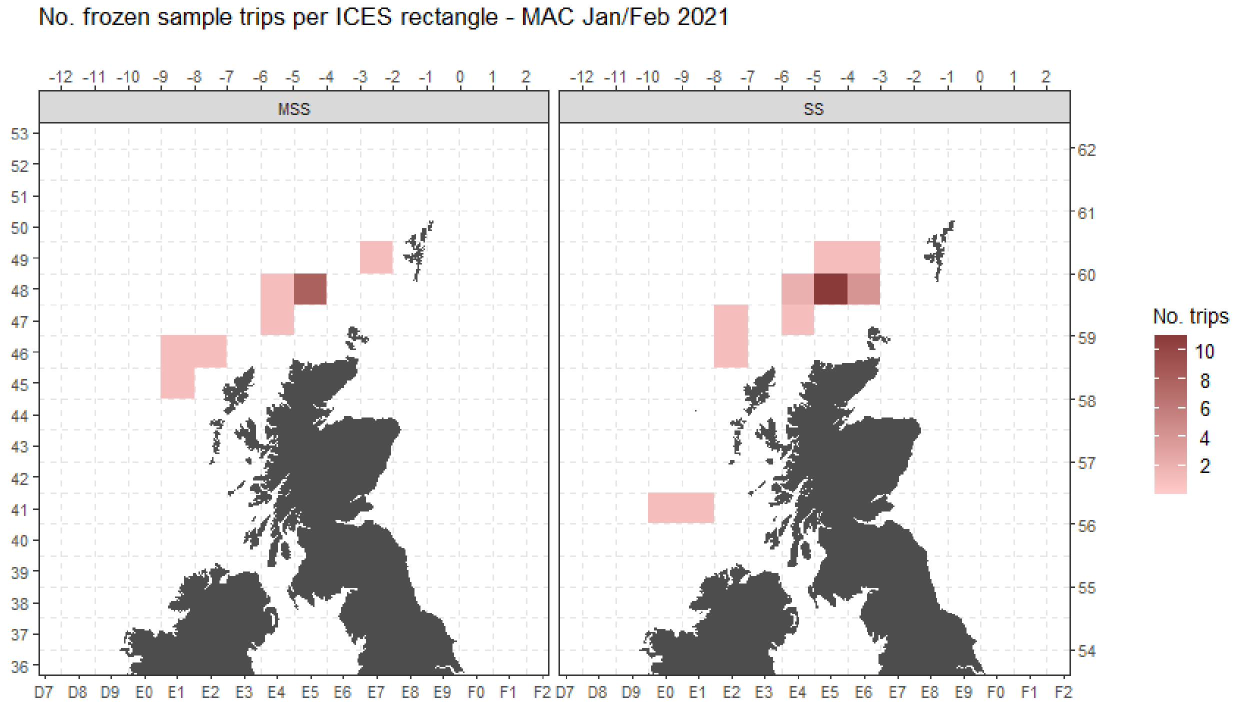

Figure 4. Sample locations of frozen samples collected via self-sampling and sample locations from MSS onshore sampling for mackerel 2021 (Winter, Jan/Feb). Number of trips per ICES rectangle, mapped by dataset, where MSS=onshore sampling overseen by MSS, and SS=self-sampling undertaken by SPFA vessels.

6. Conclusions

Industry self-sampling and co-sampling can be used to obtain biological data on commercial catches, provided that the sampling design and methods result in data that are representative of the catch composition.

The Scottish Pelagic Industry Self-sampling Programme offers several opportunities in efforts to ensure continuous improvements in the quality of stock assessment and ICES advice. In particular:

- Sample coverage can be representative of the fishing behaviour of the fleet as all but one vessel participate, and vessels that land catches overseas will also provide samples.
- Sample coverage can be representative of the spatial distribution of the fleet since every haul can be sampled.
- Samples include direct measurements of both the weight and length of fish, allowing monitoring of changes in fish growth.
- Co-sampling of frozen samples from randomly selected trips is an efficient and effective way to collect age, sex and maturity data.

Inclusion of new biological data into an existing time series has the potential to cause a shift in the data, which could be misinterpreted as a change in the structure of the stock. Therefore, prior to the introduction of any new data, examination of the resulting effects on estimates will be required. As more data are collected through the Scottish Pelagic Industry Self-sampling Programme, additional comparative work will be undertaken. Further assurances will also be made to ensure long-term access to the industry collected data.

The North Sea Mackerel Egg Survey: Changing from the Annual to Daily Egg Production Method.

Working Document for ICES WGWIDE, online meeting, 25 - 31 August 2021

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Introduction

The working group on mackerel and horse mackerel egg surveys (WGMEGS) coordinates the Mackerel and Horse Mackerel Egg Survey in the Northeast Atlantic and the Mackerel Egg Survey in the North Sea with the purpose of estimating the spawning stock biomass of the different NEA mackerel spawning components since 1977 (Lockwood et al. 1981). These surveys are carried out triennially, although the North Sea survey is normally completed one year after the western and southern area surveys. The survey for the western area mackerel was initiated in 1977. The southern area was later added in 1992 (ICES, 1993).

Egg production survey methods

Egg production surveys provide a method of estimating SSB, independent of any data on commercial catches, to be integrated in or used to inform the stock assessment process.

The underlying concept for egg production methods is very simple; if we know how many eggs have been spawned over a period of time (e.g. daily or annually) in the spawning area (egg production), and we know how many eggs an average individual mature female can produce over the same period (fecundity), then we can estimate the size of the spawning population (Bernal et al., 2012).

There are two primary methods (Gunderson 1993; Hunter and Lo 1993), namely the annual egg production method (AEPM) and the daily egg production method (DEPM). The first method is designed for species with a determinate fecundity, i.e. those in which all the eggs to be spawned during the year are present and identifiable in the ovary immediately prior to spawning (Potential fecundity). With the AEPM, estimated egg production is integrated over the whole annual spawning season, using data from a series of surveys, and how many eggs are produced on average per unit mass of spawning female in the year. Whereas the application of AEPM is suitable only for determinate annual spawners, the DEPM can in principle be applied to indeterminate and determinate spawners that release pelagic eggs in a series of batches and for which the daily spawning fraction and batch fecundity can be estimated with sufficient accuracy (Kraus et al., 2012).

The DEPM can be used for species with an indeterminate fecundity, in which the potential annual fecundity is not fixed before the onset of spawning (Stratoudakis et al., 2006) and previtellogenic oocytes are recruited over the spawning season. The DEPM requires a single ichthyoplankton survey covering the entire spawning area during a brief period of the spawning season to estimate the mean daily egg production and to have representative samples of spawning adults during the survey period in order to estimate the mean daily fecundity (batch fecundity, spawning fraction and sex ratio) per unit mass of adults, at or near the annual peak of spawning (Parker, 1980, Stratoudakis et al., 2006). Accordingly the DEPM provides a snapshot rather than an integrated view of the spawning season (Stratoudakis et al., 2006).

The main difference of the DEPM in relation to the AEPM method resides on the appropriate measure of fecundity, which in the case of indeterminate spawners has to be based on the number of oocytes released per fish in each spawning event (batch fecundity) and the proportion of females reproducing daily (spawning fraction) (Stratoudakis et al., 2006).

Mackerel egg survey

Since 1977 the AEPM has been used for estimation of NEA mackerel SSB (Lockwood et al. 1981; Lockwood 1988) under the assumption that mackerel has a determinate fecundity. However, Greer Walker et al. (1994) had shown that the assumption of mackerel having a determinate fecundity was not conclusive and concluded ‘that for all practical purposes the mackerel should be considered as having a determinate fecundity”. Priede and Watson (1993; 1997) compared the use of the Daily Egg Production Method (DEPM) and Annual Egg Production Method (AEPM) for the estimation of spawning-stock biomass (SSB) in mackerel during the 1989 and 1992 egg surveys. These estimations showed inconsistent results.

In 2012 WGMEGS coordinated the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA) (ICES, 2012b) to discuss spawning strategies of mackerel and horse mackerel and to make recommendations on the survey design. The reason for organising this workshop was that observations from egg surveys in 2007 and 2010 seemed to indicate that mackerel (and horse mackerel) have an indeterminate fecundity type. This workshop recommended that extra adult samples should be collected on surveys to investigate the estimation of DEPM adult parameters, and to attempt a contrast between AEPM and DEPM results and review fecundity samples collected in previous surveys for DEPM adult parameters

The North Sea Mackerel Egg Survey (NS-MEGS) is designed to estimate the spawning stock biomass (SSB) of the North Sea spawning component of Northeast-Atlantic mackerel. Up to 2017 this was done utilizing the annual egg production method (AEPM). This method estimates and combines total annual egg production (TAEP), realized fecundity per gram female, and sex (male to female) ratio to calculate SSB. TAEP of mackerel spawning in the North Sea is based on counts of freshly spawned (stage 1) eggs from plankton catches, which ideally cover the entire spawning area and season. Temporal coverage is achieved through several passes of the entire spawning area during the spawning season. Realized fecundity is estimated based on histological examinations of pre-spawning (for potential fecundity) and spawning ovaries (for atresia estimation) from caught mackerel. For details on methods see the respective WGMEGS survey manuals (ICES 2019 a, b).

The NS-MEGS was first carried out in 1980, and continued on an annual basis until 1984, before being conducted biennially until 1990. No NS-MEGS surveys were carried out between 1990 and 1996. The survey was restarted in 1996 and has been carried out triennially since, similar to the Northeast-Atlantic MEGS (NEA-MEGS), however it always takes place one year after the western and southern surveys. In the early years of the survey, prior to 1990, more than 90 ship days were allocated to the survey, however since the re-instatement of the survey in 1996 this effort was much reduced to approximately 30 days per year. The number of participating nations also declined, from at least three in the beginning to two after 1996 (at first Norway and Denmark, later Norway and The Netherlands). After the 2011 survey, and coinciding with the 2014 benchmark for mackerel stock assessment, Norway decided to withdraw from the NS-MEGS, leaving The Netherlands as the only participating nation (ICES 2014). In an effort to continue providing good quality data the Netherlands increased its survey time from 15 to 20 days after the withdrawal of Norway.

Spatial and temporal coverage had already been impacted when the survey was re-initiated in 1996, due to the reduction in available survey effort, and this became even more serious with the withdrawal of the Norwegian participation. Due to technical difficulties with the Dutch survey vessel the 2014 North Sea survey had to be postponed until 2015. In 2020 Covid-19 measures again prevented the survey being carried out, so it was postponed until 2021.

Prior to 2011 Norway was responsible for calculating TAEP and SSB for North Sea mackerel. After the withdrawal of Norway, discrepancies in the estimation of the TAEP were found compared to the current method described in the WGMEGS manual. This discrepancy rendered the 2015 and 2017 estimates inconsistent with the earlier estimations in the NS-MEGS time series. This became particularly noticeable for the 2015 NS-MEGS (Figure 1 and Table 1). The 2015 egg production curve is almost entirely below the curves of the 2008 and 2011 surveys, but still delivers a higher TAEP estimate. In addition, the 2017 egg production curve does not really suggest a higher TAEP than the one of 2005. However, the 2017 TAEP exceeds 2005 by almost a third.

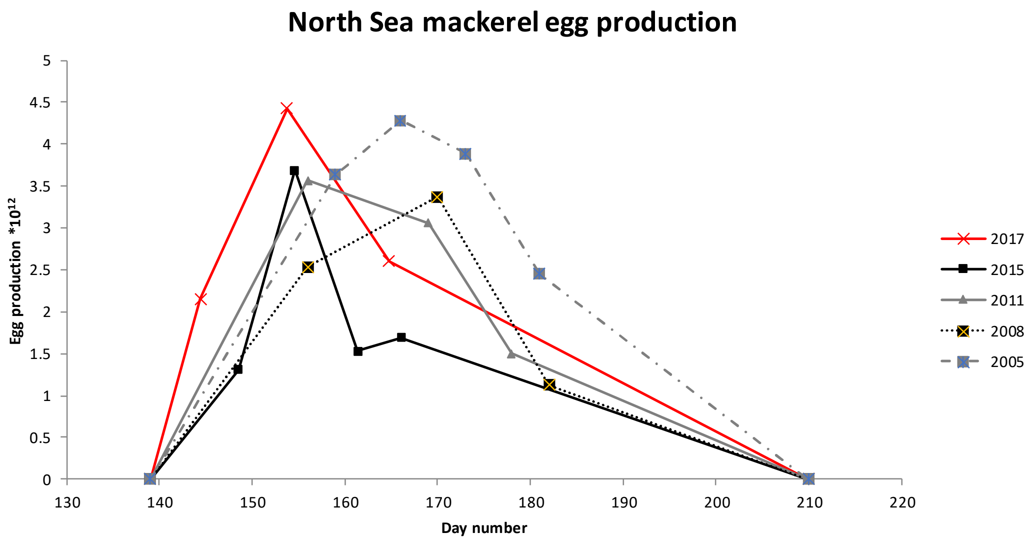


Figure 1: Annual egg production curves for North Sea mackerel (prior to 2015 the Lockwood egg development equation was used, since 2015 the Mendiola equation was used).

Table 1: Egg production estimates from egg surveys 2005 – 2017 in the North Sea and corresponding SSB based on a standard fecundity of 1401 eggs/g/female.

Year	Egg prod $*10^{12}$	SSB $*10^3$ tons
2005	155	223
2008	108	154
2011	116	165
2015	119	170
2017	201	287

These inconsistencies in the time series have remained unexplained. Currently it is not known how TAEP was calculated by Norway before they withdrew from the survey, the methodology used was never described in the WGMEGS manual. However, two reasons may explain the discrepancies:

1. As documented in the survey manual (ICES 2019b) WGMEGS had decided in 2013 to replace the Lockwood development equation with one developed by Mendiola. As a result, in 2015, the Netherlands used the Mendiola equation for the first time in the North Sea convert egg abundance into daily production. Using the Mendiola equation leads to higher egg production compared to the Lockwood equation. The time series for the western and southern surveys has been recalculated using the Mendiola equation, this work still needs to be carried out for the North Sea.

2. For the recent egg surveys, and following the latest versions of the MEGS manual, TAEP was calculated as the area under the histogram, while according to the methodology for surveys prior to 2015, the area under the curve was utilized (ICES 1997, 2000, 2003, 2006, 2009, 2012), which may also contribute to a lower estimate in those years.

The North Sea time series data still awaits thorough quality assurance checks and re-analysis with respect to the above-mentioned inconsistencies.

Another problem for the NS-MEGS is that since 1982 it has been impossible to collect pre-spawning mackerel, which are necessary to estimate the potential fecundity. For North Sea SSB estimation MEGS have used the realized fecundity value from the 1982 estimate (Iversen and Adoff, 1983). Both in 1998 and 2001 the realized fecundity in the western area was re-estimated but considered to be rather low (ICES 2002) and WGMEGS decided to reject these estimations (ICES 2000, 2003).

In 2018 WGMEGS, (ICES 2018), after assessing the quality of the 2017 NS-MEGS results, decided that future North Sea surveys, starting in 2020, would use a DEPM sampling scheme rather than AEPM. Even with the inclusion of Denmark the limited ship time available would not be sufficient to provide adequate coverage of mackerel spawning in the North Sea either temporally or spatially using the AEPM approach (ICES 2018). The DEPM only requires one full coverage of the spawning area over a shorter time period, and preferably during peak spawning. Full coverage of the spawning area can, due to its spatial confinement, be much easier achieved in the North Sea than in the open Northeast-Atlantic. Sampling during peak spawning is preferred because of the increased chances of catching spawning mackerel for batch fecundity and spawning fraction estimations. However, this method also requires a large number of adult samples to be collected and analysed to estimate reliable batch fecundity and spawning fraction estimation. However because only one coverage of the spawning area is necessary for daily egg production, it was predicted that sufficient ship time would be available to collect the higher number of adult samples necessary. The application of DEPM would enable WGMEGS to deliver a more robust estimate of the SSB of the North Sea mackerel stock component compared to any of the previous years since 1996.

Because of the Covid-19 pandemic, the 2020 NS-MEGS had to be postponed to 2021, when it was carried out successfully in May-June. For the first time, the entire North Sea spawning area could be covered and enough adult female mackerel were caught for the necessary fecundity and spawning fraction estimations. It is, therefore, anticipated that for the first time a robust estimate of the SSB of the North Sea spawning component of mackerel will become available.

References

Bernal, M., Somarakis, S., Witthames, P. R., van Damme, C. J. G., Uriarte, A., Lo, N. C. H., and Dickey-Collas, M. 2012. Egg production methods in marine fisheries: an introduction. Fisheries Research, 117–118: 1–5.

Gunderson, D.R. (1993) Surveys of Fisheries Resources. Wiley, New York. 248 pp.

Greer Walker, M., P. R. Witthames & I. Bautista de los Santos (1994) Is the fecundity of the Atlantic mackerel (Scomber scombrus: Scombridae) determinate?, Sarsia, 79:1, 13-26.

Hunter, J.R. and Lo, N.C.H. (1993) Ichthyoplankton methods for estimating fish biomass: introduction and terminology. Bulletin of Marine Science 53, 723–727.

ICES. 1993. Report of the Mackerel / Horse mackerel Egg Production Workshop. ICES CM 1993/H:4. 142 pp.

ICES 1997. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. Lisbon, Portugal, 3 – 7 February 1997. ICES CM 1997/H:4. 48 pp.

ICES 2000. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. Santander, Spain, 18 – 21 January 2000. ICES CM 2000/G:01. 54 pp.

ICES 2002. Report of the Working Group on Mackerel and Horse Mackerel Surveys. ICES CM 2002/G:06.

ICES 2003. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. 1 – 4 April 2003, Lisbon, Portugal. ICES CM 2003/G:7 Ref. D. 57 pp.

ICES. 2006. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 27–31 March 2006, Vigo, Spain. ICES CM 2006/LRC:09, Ref. RMC. 75 pp.

ICES. 2009. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 20–24 April 2009, Hamburg, Germany. ICES CM 2009/LRC:09. 107 pp.

ICES. 2012. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 18-21 April 2012, Galway, Ireland. ICES CM 2012/SSGESST:04. 135 pp.

ICES 2012b. Report of the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA), 16-17 April 2012, Galway, Ireland. ICES CM 2012/SSGESST:05. 28 pp.

ICES. 2014. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 7-11 April 2014, Reykjavik, Iceland. ICES CM 2014/SSGESST:14. 110 pp.

ICES. 2018. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 9-13 April 2018, Marine Institute, Dublin, Ireland. ICES CM 2018/EOSG:17 70 pp.

ICES 2019a. Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel. Series of ICES Survey Protocols SISP 5. 89 pp. http://doi.org/10.17895/ices.pub.5139

ICES 2019b. Manual for mackerel and horse mackerel egg surveys, sampling at sea. Series of ICES Survey Protocols SISP 6. 82 pp. http://doi.org/10.17895/ices.pub.5140

Iversen, S.A. and Adoff, G.R. 1983. Fecundity observations on mackerel from the Norwegian coast. ICES C.M.1983, H:45, 6pp.

Kraus et al., 2012 G. Kraus, H.-H. Hinrichsen, R. Voss, E. Teschner, J. Tomkiewicz, F.W. Köster. Robustness of egg production methods as a fishery independent alternative to assess the Eastern Baltic cod stock (*Gadus morhua callarias* L.). Fisheries Research, 117–118 (2012), pp. 75-85

Lockwood, S. J., Nichols, J. H., and Coombs, S. H. 1977. The development rates of mackerel (*Scomber scombrus* L.) eggs over a range of temperature. ICES CM 1977/J:13, 8pp.

Lockwood, S.J., Nichols, J.H., Dawson, W.A., 1981. The estimation of a mackerel (*Scomber scomber L*.) spawning stock size by plankton survey. J. Plankton Res. 3, 217−233.

Lockwood, S.J. – 1988. The mackerel. Its biology, assessment and the management of a fishery. Fishing Book News Ltd. Farn-ham, Surrey England. 181 pp.

Parker, K. (1980) A direct method for estimating northern anchovy, *Engraulis mordax*, spawning biomass. Fishery Bulletin 78, 541–544.

Priede, I.G., Watson, J.J., 1993. An evaluation of the daily egg production method for estimating biomass of Atlantic mackerel (*Scomber scombrus*). Bull. Mar. Sci. 53, 891−911.

Priede, I.G., Watson, J.J., 1997. Some observations on spawning biology of Atlantic mackerel (*Scomber scombrus*) and the application of egg production methods for estimation of spawning stock biomass. Ozeanografika, 2, 149-163.

Stratoudakis, Y., Bernal, M., Ganias, K., and Uriarte, A. 2006. The daily egg production method: recent advances, current applications and future challenges. Fish and Fisheries, 7: 35–57.

The WESPAS Survey & Mackerel

WD to WGWIDE 2021

August 25-31, 2021

Andrew Campbell,

Marine Institute, Ireland

Introduction

The WESPAS (Western European Shelf Pelagic Acoustic Survey) is an annual survey conducted by the Fisheries Ecosystems Advisory Services division of the Irish Marine Institute. The survey is an amalgamation of the Irish component of the Malin Shelf herring acoustic survey which has been carried out annually since 2008 in ICES subareas 6a and 7bc and the boarfish acoustic survey which was first conducted in 2011 in 7hjk and the north of 8c on a commercial vessel. In 2016 the surveys were combined into the WESPAS survey and have been conducted by the RV Celtic Explorer since this time. The survey runs for 6 weeks in June and July over 2 legs covering the shelf waters from 47˚30’ N to 58˚30’ N. The 2021 survey track is shown in fig 1.

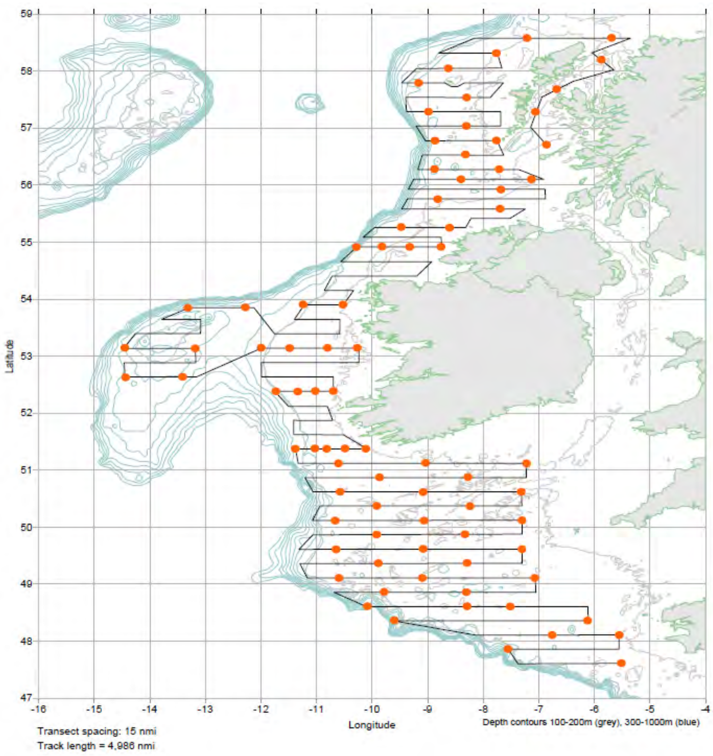


Fig 1: WESPAS 2021 survey track with CTD stations.

Since 2017 the survey has started in the south in north Biscay and worked in a northerly direction in a series of parallel transects spaced 10-15nm apart. The western extent of the transects coincides with the shelf break and depths of approximately 300m with the exception of the Porcupine bank (400m). The easterly extent of the transects generally coincides with the land mass (min. depth 50m) with the exception of Celtic Sea transects. Transects may extend further east or west than planned as they are usually only ended once a number of miles have been completed with no acoustic detections. The survey design consists of a number of strata (species specific) with a total transect length of approximately 5000nm (9250 km) and area coverage of 65,000 nm^2 (225,000 km^2).

Acoustic data is collected by a Simrad EK60 on 4 frequencies (18,38,120 and 200kHz). Echograms are scrutinised by experienced scientists with individual schools identified to species level where possible. Annual survey estimates of abundance at age at species level are generated using the StoX software package.

The RV Celtic Explorer is equipped with twin electric motor propulsion powered by a diesel engine and meets the ICES criteria for research vessel standards with respect to underwater radiated noise (CRR209).

Biological sampling is carried out in response to acoustic registrations using a single midwater pelagic trawl 85m in length with a fishing circle of 420m. Mesh size in the wings is 2.4m, reducing to 10cm in the cod end. The net is fished with a vertical opening of approximately 25m and monitored via a headline transducer and door sensors. On selected hauls, cameras and lighting are mounted in the net. Tow speed is approximately 4-4.5 knots with tow duration dependent on real time information on catch from the headline transducer. The net is weighted by a pair of chain clumps of 750 kg each, ensuring a rapid descent to the targeted fishing depth. During the shooting of the net, the vessel steams ahead at approximately 1-1.5 knots during which time the gear sinks rapidly. The warp length depends on fishing (target) depth and varies between 50 and 800m. Once the target has been sampled the gear is hauled. During the hauling of the gear, the vessels' speed is reduced to approximately 1-1.5 knots reducing the door spread and warps are winched at approximately 1.25 m/s such that a trawl with a fishing depth of 150m would typically have a warp length of 700m and require 10 minutes of hauling to retrieve the doors. The fishing power of the net during shooting and hauling is considered to be minimal.

Once on deck, all components of the catch are sorted and identified. Length frequency and length weight data recorded for each species component. Subsampling for age determination is carried out for Herring, Boarfish and Horse Mackerel. Haul level information is used by StoX in the estimate of abundance at age for each target species with hauls assigned to individual acoustic registrations within the StoX project.

A number of additional scientific programmes are carried out during the WESPAS survey including

- CTD monitoring of water column structure at approximately 80 predetermined stations on the survey track. Water samples are taken at a range of depths and further analysed for
    - Coloured Dissolved Organic Matter
    - Chlorophyll
- Zooplankton and jellyfish
- Seabird and marine mammal observations

Water column structure

Approximately 80 CTD casts are conducted each year at predetermined stations to record conductivity and temperature depth profiles and also to secure water samples at various depths for the ancillary science programs. CTD casts are also often accompanied by zooplankton sampling.

The survey takes place during summer when thermal stratification is established over much of the continental shelf. The local extent to which stratification is established in any one year depends on a number of factors including thermal heating, vertical mixing induced by wind and wave activity, proximity to shore and the effects of coastal runoff and the prevailing tidal conditions particular to the locality and the springs-neaps tidal cycle.

There is significant variability in both the depth and gradient of any thermocline over the survey area. The surface temperature (@10m) from the 2016-2021 surveys is shown in figure 2.

WESPAS 2016-2021, Temp @ 10m

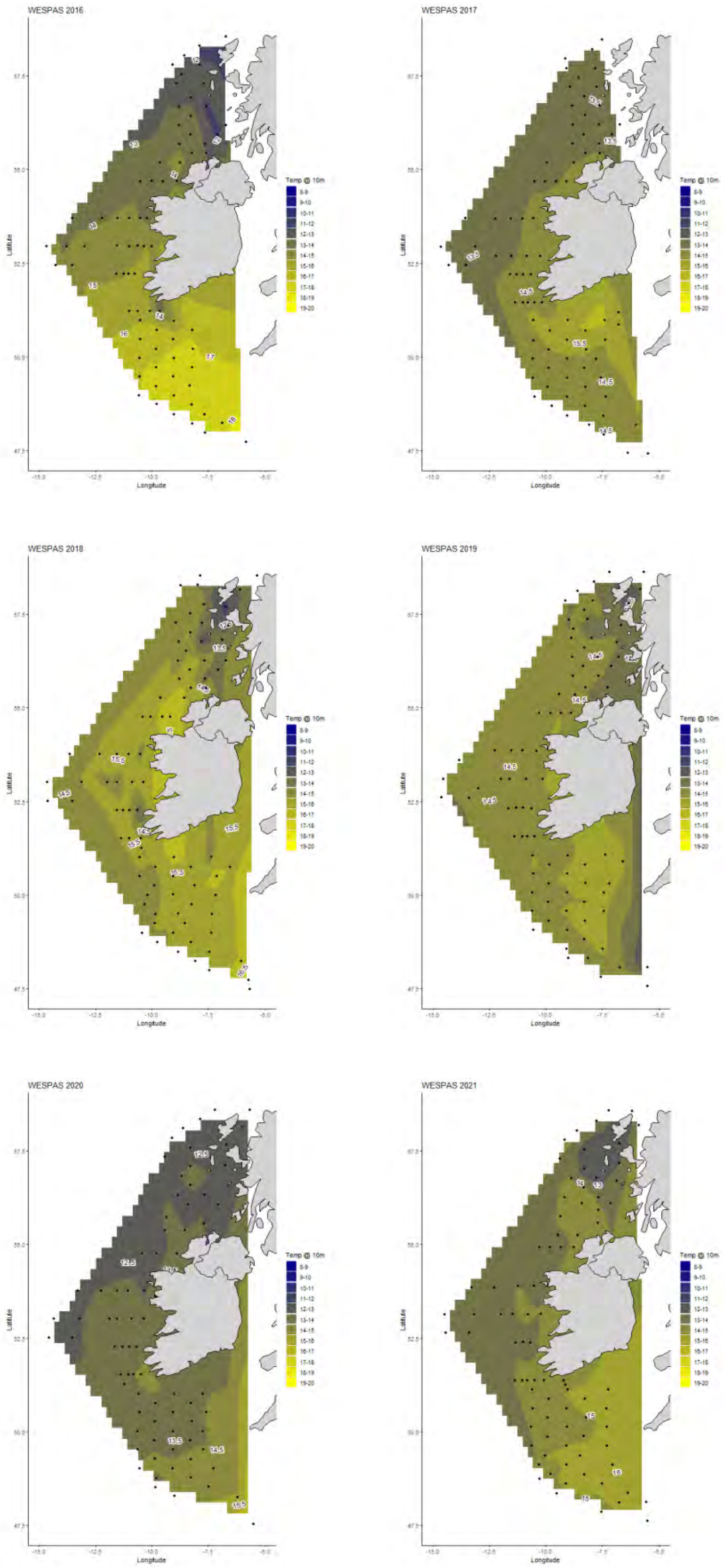


Fig. 2 Temperature at 10m depth from WESPAS surveys 2016-2021.

A wide range of surface temperatures have been recorded over the survey area. At the southern extremes, surface temperatures of 16 ˚C are common although 18 ˚C was recorded in the Celtic Sea and Northern Biscay in 2016, although it should be noted that in 2016, the survey ran north to south such that observations in the south in 2016 would be approximately 6 weeks later in the years since. At the most northern stations, temperatures are typically in the range 12-13 ˚C. 2016 appears to be a particularly warm year, particularly in the south whereas 2020 is the coolest overall. The corresponding temperatures at 25m and 50m are shown in figures 3 and 4 respectively.

WESPAS 2016-2021, Temp @ 25m

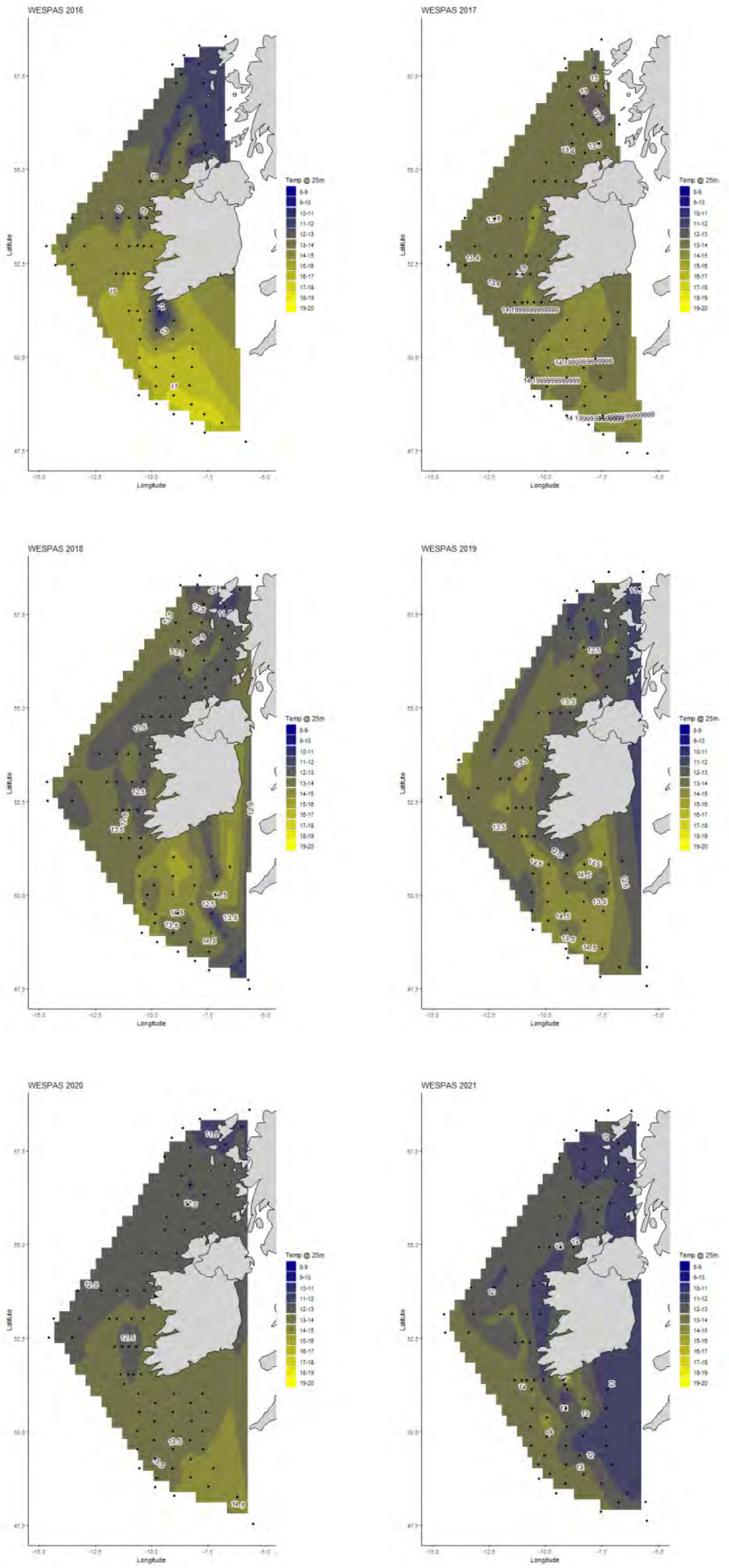


Fig. 3 Temperature at 25m depth from WESPAS surveys 2016-2021.

WESPAS 2016-2021, Temp @ 50m

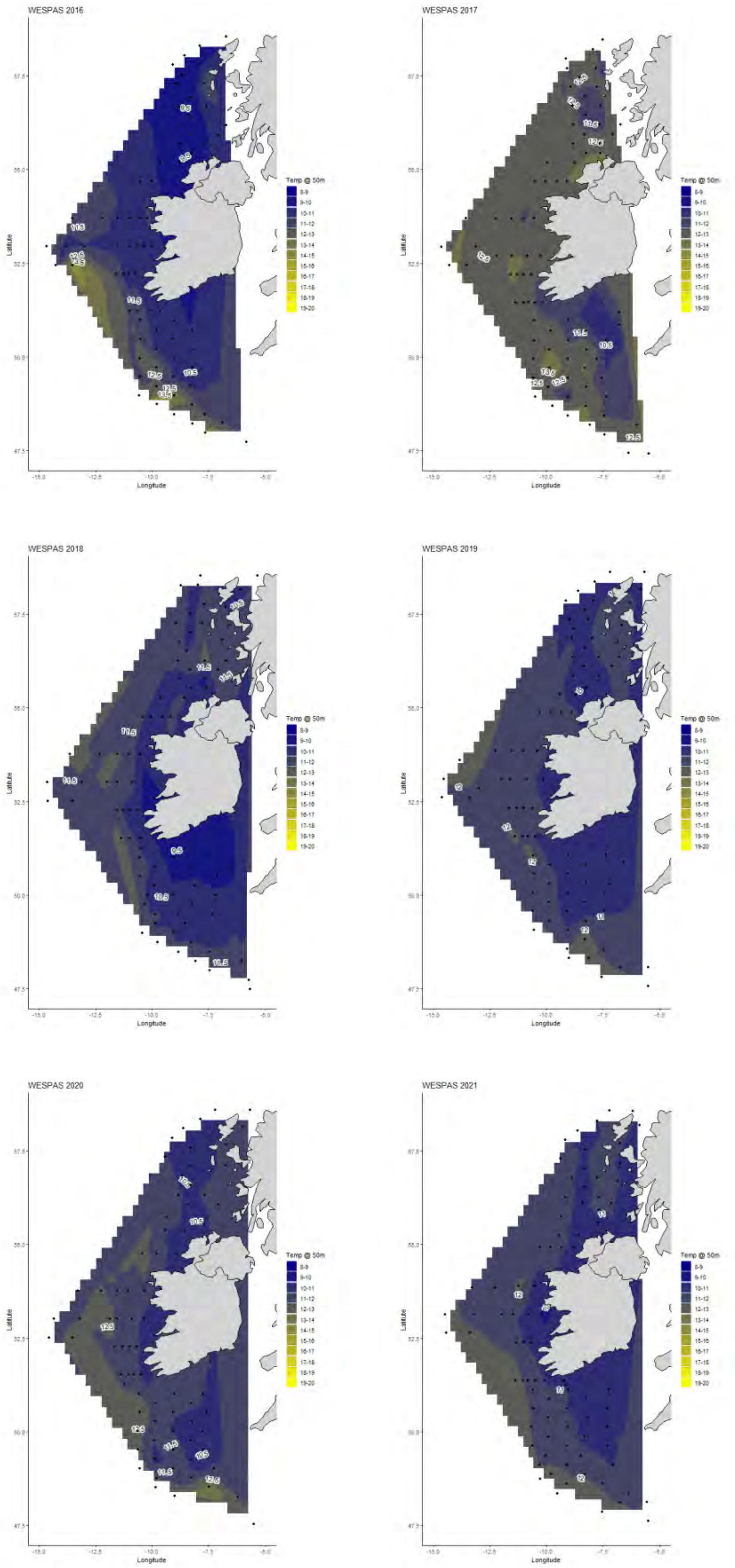


Fig. 4 Temperature at 50m depth from WESPAS surveys 2016-2021.

Temperatures at 25m vary between 12 and 17˚C indicating that the warm mixed surface layer frequently extends to depths greater than 25m. Temperatures at 50m tend to be more uniform across the survey area in any year, varying by a maximum of 2˚C between the most southerly and northerly stations and are rarely below 10˚C but indicate that the thermocline is usually at a depth of less than 50m.

Individual CTD profiles reveal the degree of stratification typically found over the geographic extent of the survey. CTD stations in the Celtic Sea tend to be associated with strong thermal stratification which is reduced somewhat closer to the shelf edge. Fig 5 shows the vertical profile from 6 Celtic Sea stations in 2017

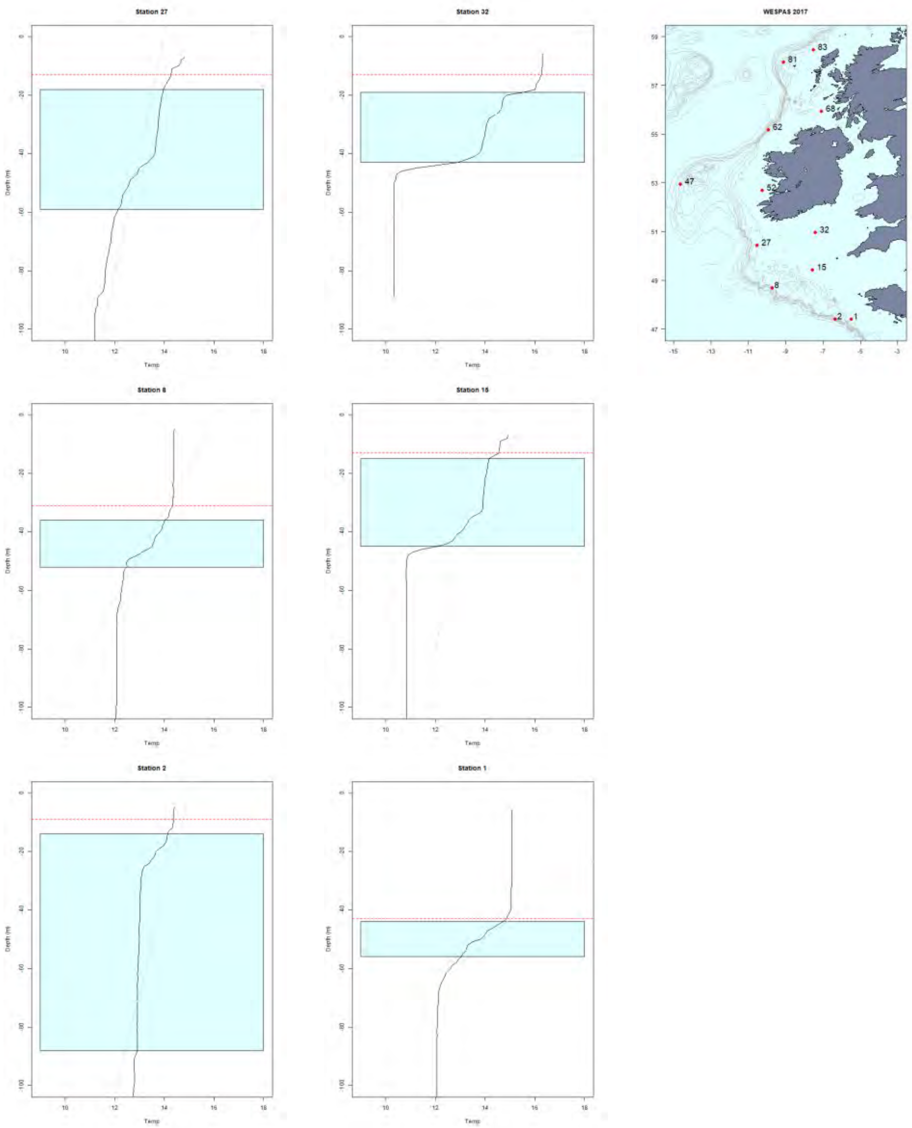


Fig. 5. Selected CTD temperature profiles, Celtic Sea & Northern Biscay, WESPAS 2017. Red dashed line indicates the mixed layer depth, blue shading the thermocline as calculated using the scheme of Chu and Fan (2016)

Stations on the Porcupine Bank where depths reach 400m typically show a more uniform temperature profile with stratification increasing closer to the Irish coast. Varying degrees of stratification are found to the North of Ireland and West of Scotland. Figure 6 shows a selection of profiles recorded during 2017. The position of the relevant CTD stations are indicated on the map.

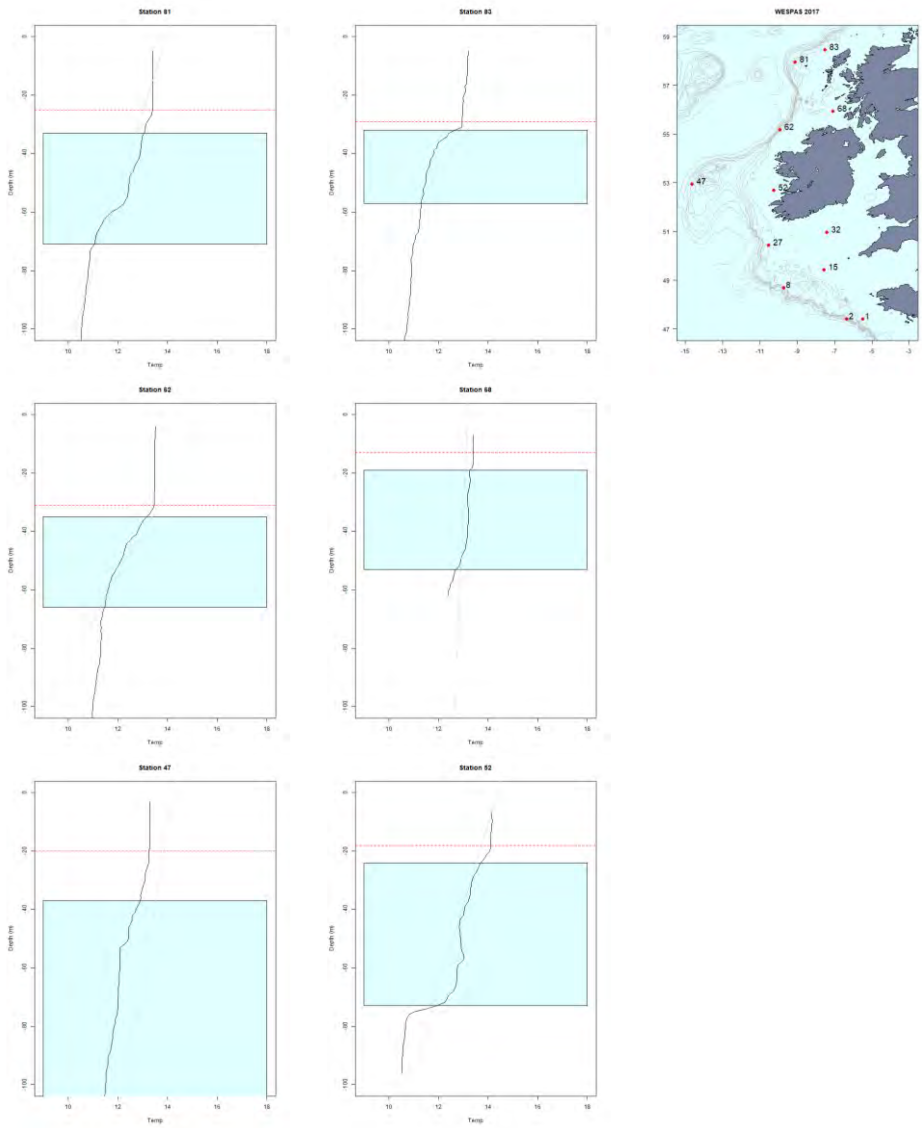


Fig. 6. Selected CTD temperature profiles, Porcupine Bank, West of Ireland and Scotland, WESPAS 2017. Red dashed line indicates mixed layer depth, blue shading the thermocline as calculated using the scheme of Chu and Fan (2016)

Across the survey area, mixed layer depth is variable – generally between 20 and 30m but extending to 50m in deeper waters to the west where the thermal gradient is also weaker. Surface to bottom temperature differences vary from close to zero to 6˚C with a median of approximately 3.5˚C. The minimum bottom temperature is rarely below 9 ˚C. Figure 7 shows the distribution of temperature difference values between the surface and bottom for each survey year.

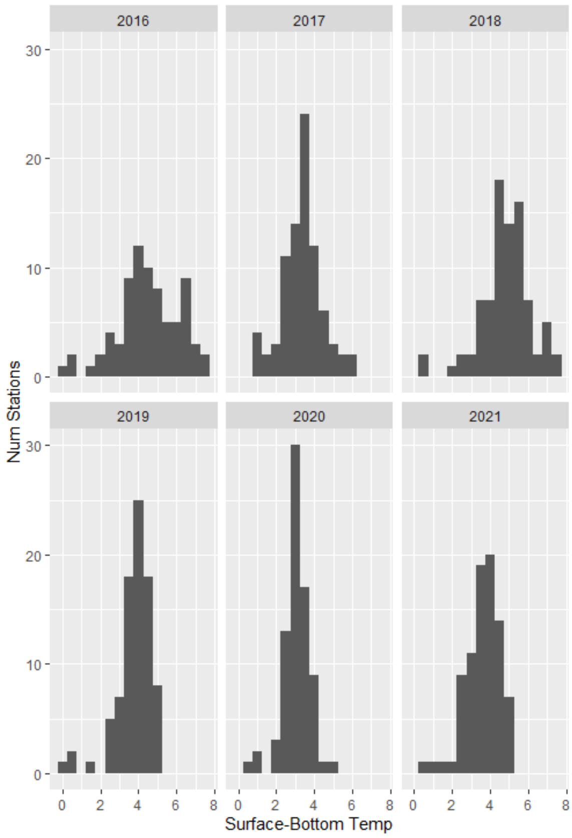


Fig.7. Distribution of Surface-Seabed temperature differences by survey year

Chu and Fan (2017) Exponential leap-forward gradient scheme for determining the isothermal layer depth from profile data. Journal of Oceanography, 73, 503-526

Fishing Haul Samples

A number of hauls are undertaken each year (35-65) in order to provide biological samples for the verification and quantification of acoustic registrations. The majority of hauls are conducted for the purposes of sampling the survey target species (Herring, Boarfish and Horse Mackerel) but are also carried out to validate acoustic marks or layers of unknown or non-target species. The complete catch from each haul is separated by species and sampled for length and weight and further subsampling for age, sex, maturity and genetics (herring only) for the target species. Also recorded during fishing operations are a number of metrics associated with the fishing tow including tow speed, door spread, tow duration, warp length, headline depth and temperature at the headline. Tow depth varies according to the position of the target, duration is generally between 30 and 60 minutes but occasionally shorter if the headline transducer indicates a potentially large catch.

Figure 8 shows the location of the hauls from each of the surveys between 2016 and 2021. Hauls with no Mackerel, those with Mackerel present and those with 20kg or more of Mackerel are indicated.

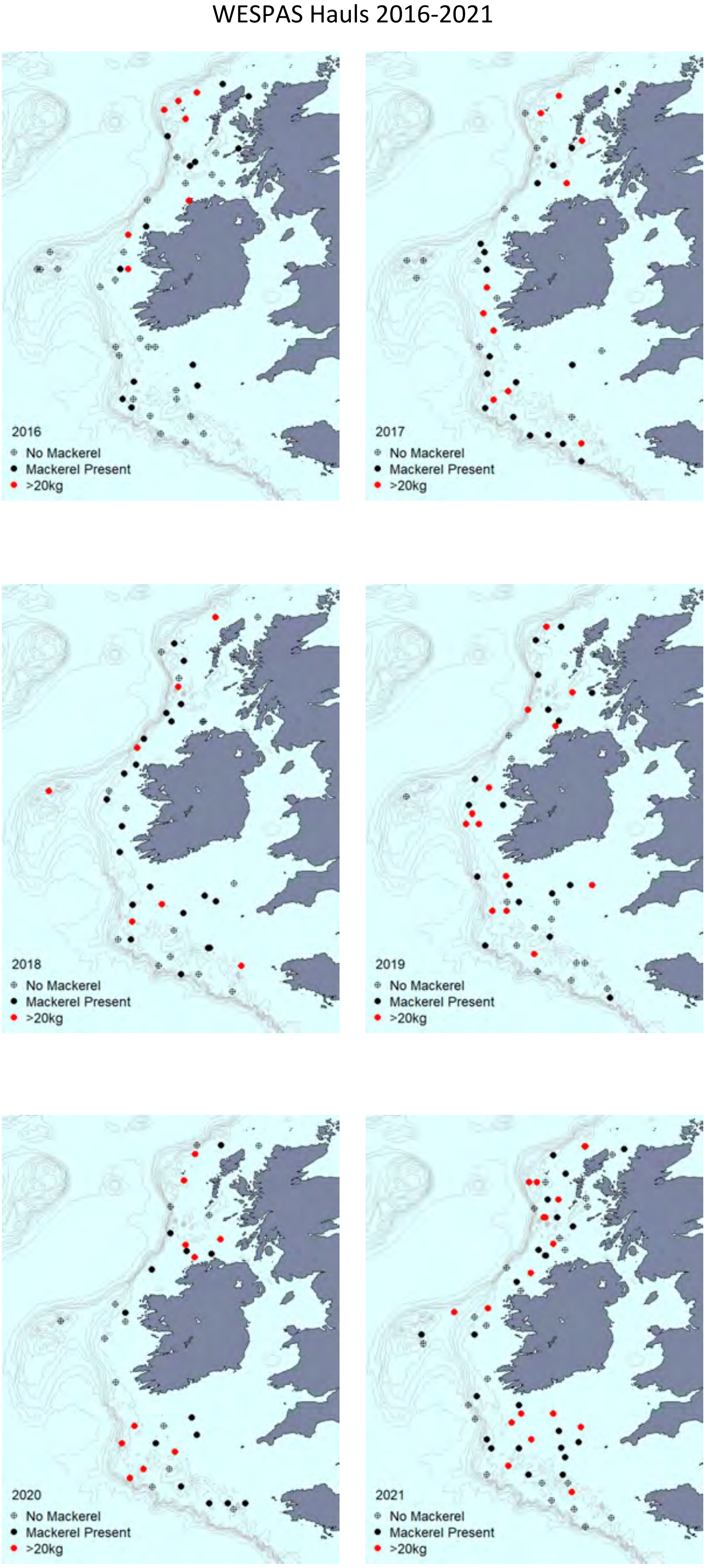


Figure 8. WESPAS survey hauls indicating those with no mackerel, those with mackerel (filled circles) and those with greater than 20kg of mackerel (red).

Mackerel has been caught in over 60% of the survey hauls in each year with the exception of 2016 when most of the hauls carried out in the Celtic Sea and SW or Ireland did not contain any mackerel. Surface temperatures in this area in 2016 were the highest in the time series, in excess of 17˚C south of 50˚N although it should also be noted that the survey was conducted from north to south in this year such that the sampling in southern waters will be several weeks later than that in surveys since 2017. The highest proportion of hauls containing mackerel (2/3) is recorded in 2020 (a relatively cool year).

Aside from the distribution noted for 2016, there appears to be little geographical variation in the distribution of hauls containing or devoid of mackerel. Hauls containing over 20kg of Mackerel are also widely distributed over the survey area. The table below details the proportion of hauls containing mackerel for the survey time series.

Year	Hauls	With Mackerel	>20kg Mackerel	Catch Rate (kg/km2) (CR >0)		
				25^{th}	Median	75^{th}
2016	47	20 (43%)	7 (15%)	25	48	274
2017	42	27 (64%)	10 (23%)	23	85	237
2018	42	27 (64%)	7 (15%)	15	46	162
2019	45	30 (60%)	13 (28%)	14	62	289
2020	35	23 (66%)	10 (29%)	30	70	247
2021	65	40 (62%)	18 (28%)	24	85	210
All	276	167 (61%)	65 (24%)	18	70	225

The catch rate per haul is calculated on the basis of an estimated swept area. The net is designed to have a wingspread of 42m. Combined with the fishing time (the time spent (min) at the target depth *i.e.* excluding shooting and haul period) and tow speed (knots) recorded during the fishing operation, the swept area in square km is calculated as

Swept area = (fishingtime*60) * (wingspread/1000) * (towspeed*0.514/1000)

The catch rate per station for each of the surveys is shown in figure 9.

WESPAS Hauls 2016-2021, Mackerel catch rates (kg/km2)

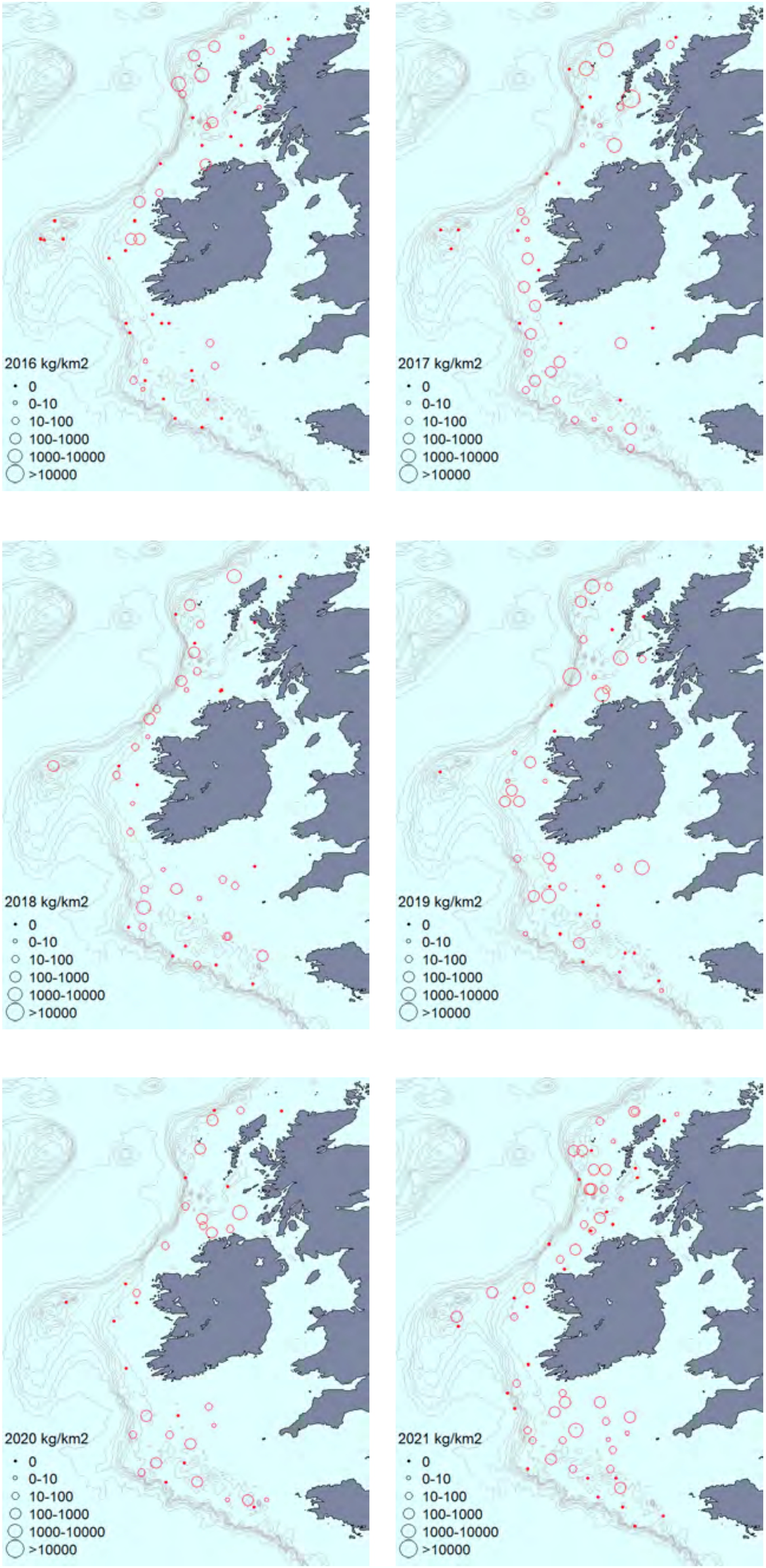


Figure 9. WESPAS surveys 2016-2021. Mackerel catch rates

Catch by depth

Hauls are carried out at various depths, depending on the acoustic data with targets situated both above and below the thermocline although the majority (approximately ¾) are below 50m (median fishing depth 92m, 276 observations). Most hauls take place within 50m of the seabed as determined by the height of the footrope (bottom depth - headline depth - net opening)

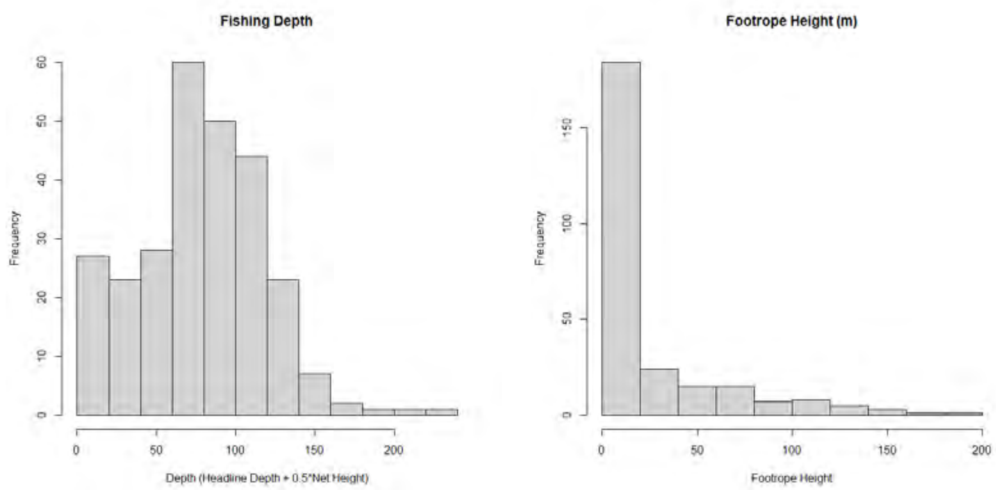


Figure 10: Distribution of fishing depth and footrope height, all hauls 2016-2021.

For all hauls containing mackerel, the relation between catch rate and fishing depth is shown in figure 11.

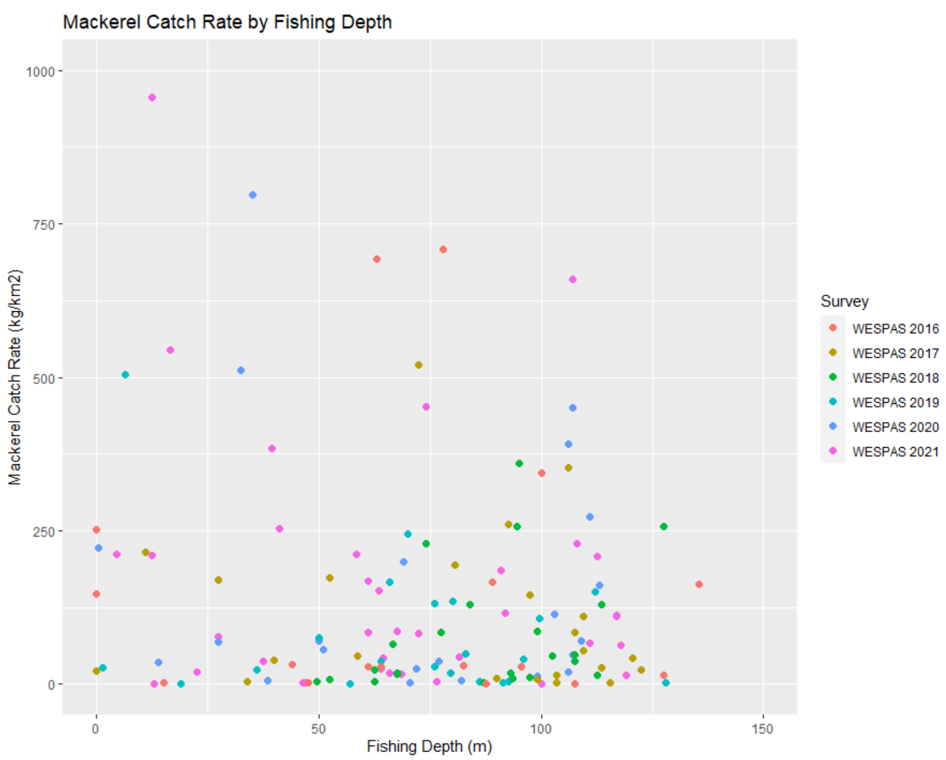


Figure 11. Mackerel catch rate (kg/km^2) by fishing depth (depth of midpoint of vertical net opening)

The majority of hauls contain less than 20kg mackerel. However, a total of 65 hauls have 20kg or more. The fishing depth of this subset of hauls is shown in figure 12.

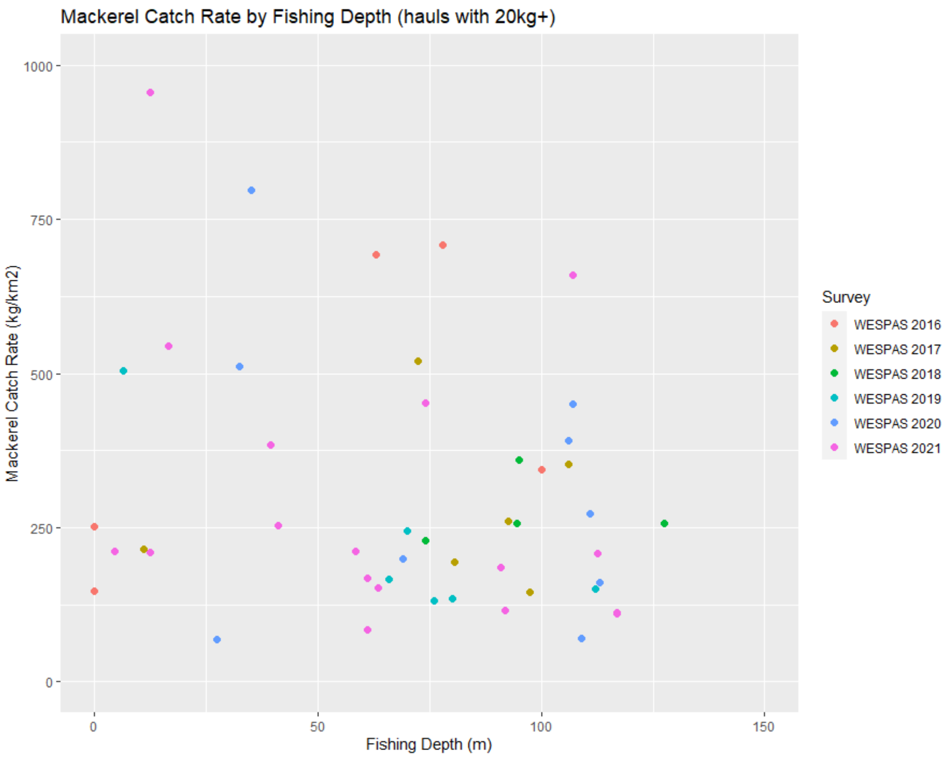


Figure 12. Mackerel catch rate (kg/km^2) by fishing depth (depth of midpoint of vertical net opening) for hauls with over 20kg of mackerel.

Length Structure

As mackerel is not a target species for the WESPAS survey, samples are not collected for ageing. However, a length frequency is recorded for each species caught during the survey. The aggregated mackerel length frequency for each survey is shown in figure 13.

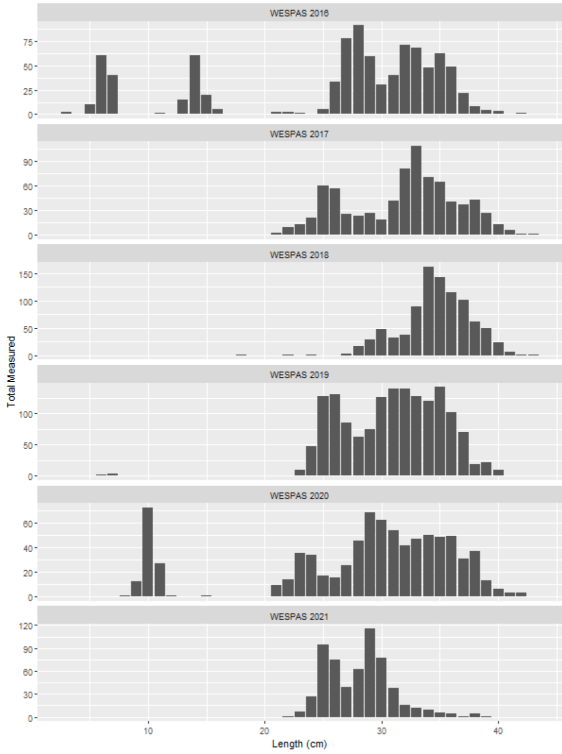


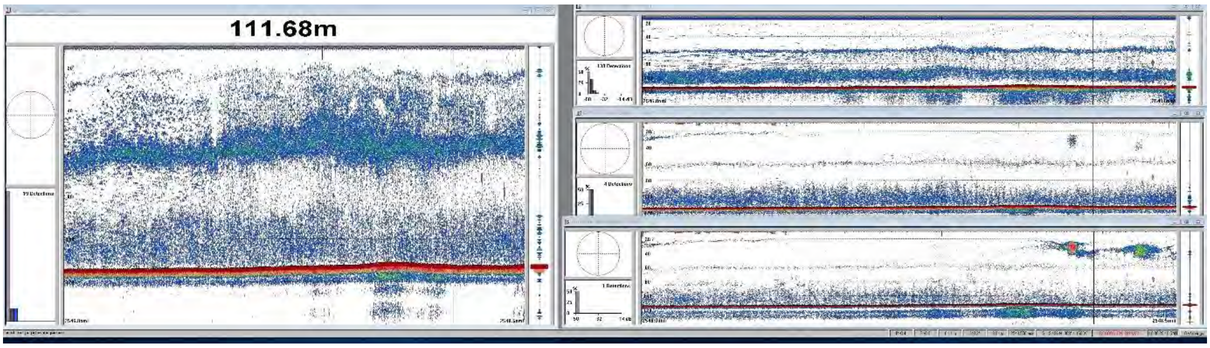
Figure 13. Mackerel length frequency from all samples by survey year (5566 specimens, average 75 per haul)

Although variable with occasional hauls of juvenile fish (in 2016 and 2020), figure 13 indicates that both immature and mature mackerel are to be found over the survey area during June and July. There is some degree of cohort tracking, particularly from 2016-2020 with a peak from 32-36cm (age 3-7). 2021 samples consist primarily of specimens under 30cm (mean length at age 2 = 30.7 cm from 2019 commercial catch sampling).

Acoustic Registrations

Due to its lack of a swim bladder, mackerel is more difficult to detect acoustically and do not show up reliably on the 38kHz echosounder, the frequency used to estimate abundance and biomass of herring, boarfish and horse mackerel on this survey. However, occasionally aggregations can be detected at the higher frequencies available on this survey (in particular 120 and 200kHz). Scientists scrutinising the survey echotraces will identify a mark to species level based on a number of factors including the density, size, shape, depth and location of a mark but also based on the relative response at each frequency. Mackerel marks are usually not selected for sampling as this is not a target species on this survey. Moreover, the design of this survey including the net specifications mean that mackerel is difficult to catch, experience shows it is very capable of avoiding the gear, in particular by diving under the footrope. They are also fast swimmers, easily capable of swimming faster than the gear. Each year however, a number of acoustic marks are designated to be mackerel. These marks can be found close to the surface (Figure 14), close to the bottom (Figure 15) and in midwater (Figure 16), with no apparent trend in their distribution from year to year. It is unclear why mackerel tend to be visible on the echosounder in some areas and years and not in others. Generally during this survey mackerel are caught in hauls where there is little evidence of them appearing on the echosounder. An acoustic estimation of mackerel abundance and biomass from this survey is unreliable at this stage.

Mackerel Marks



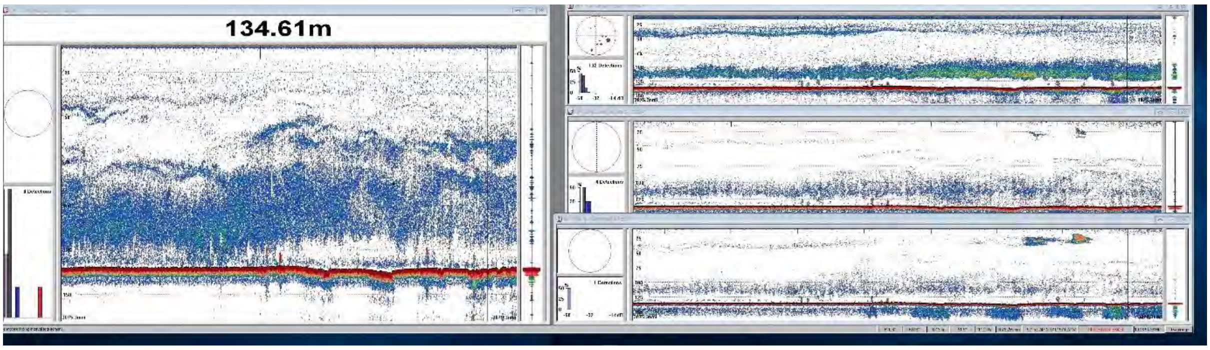


Figure 14. WESPAS 2021 surface marks showing stronger on the higher frequencies (120 and 200kHz)

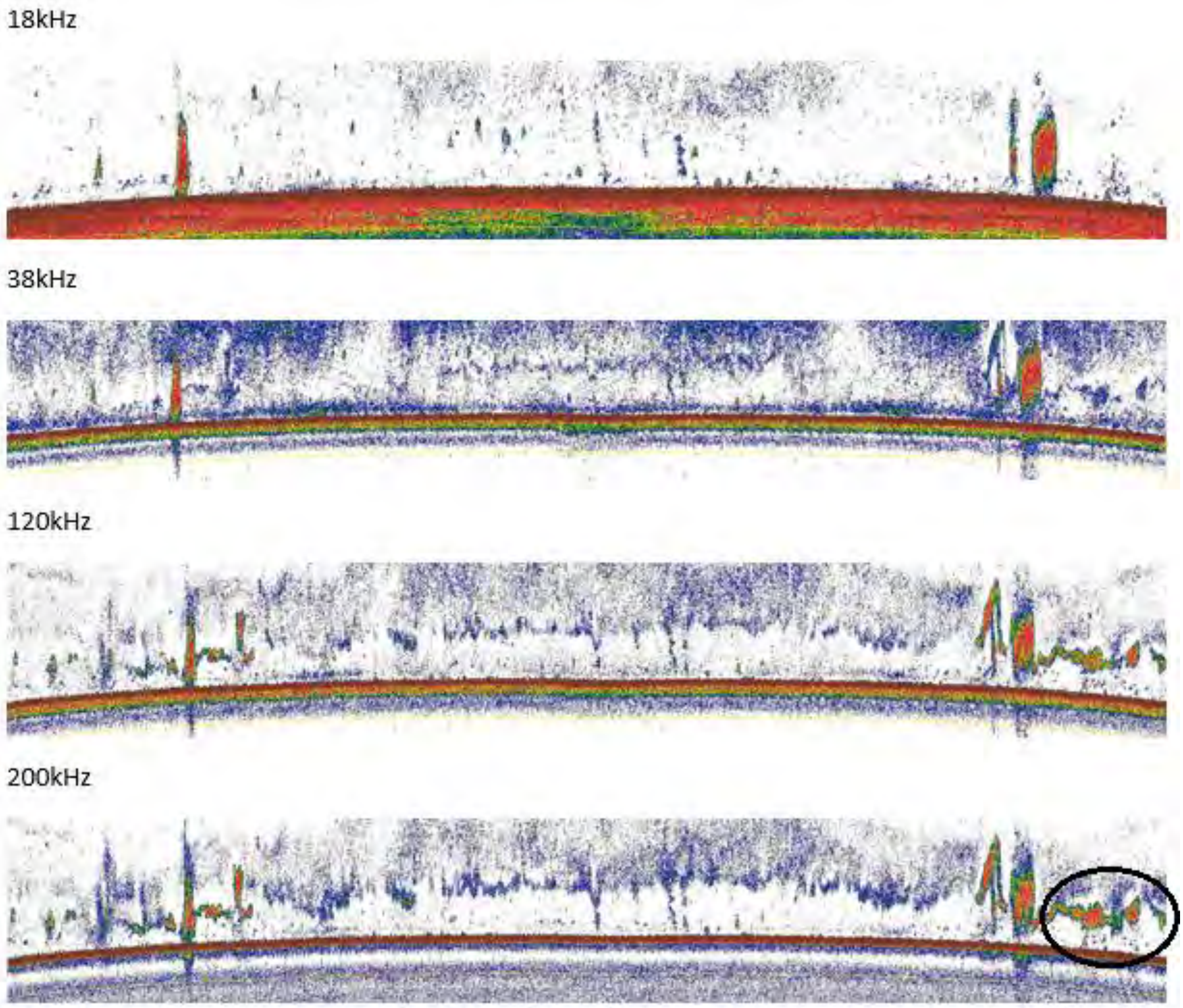


Figure 15. WESPAS 2019 (haul number 38 at 56˚ 36N and 7˚ 53W). Example of mackerel caught at ~160m depth. The target for sampling was the tall echotrace marking on all 4 frequencies on the right hand side of all panels above. This mark has all the attributes of a swim-bladdered fish, and turned out to be blue whiting. The black oval shape shows mackerel marking on the 120 and 200kHz, and very little showing on the lower frequencies (18 and 38 kHz) in this area. The catch for this haul was 104 kg blue whiting and 92 kg mackerel. There is some evidence of mackerel marking on the left hand side of the panels above also, however these marks were not fished on.

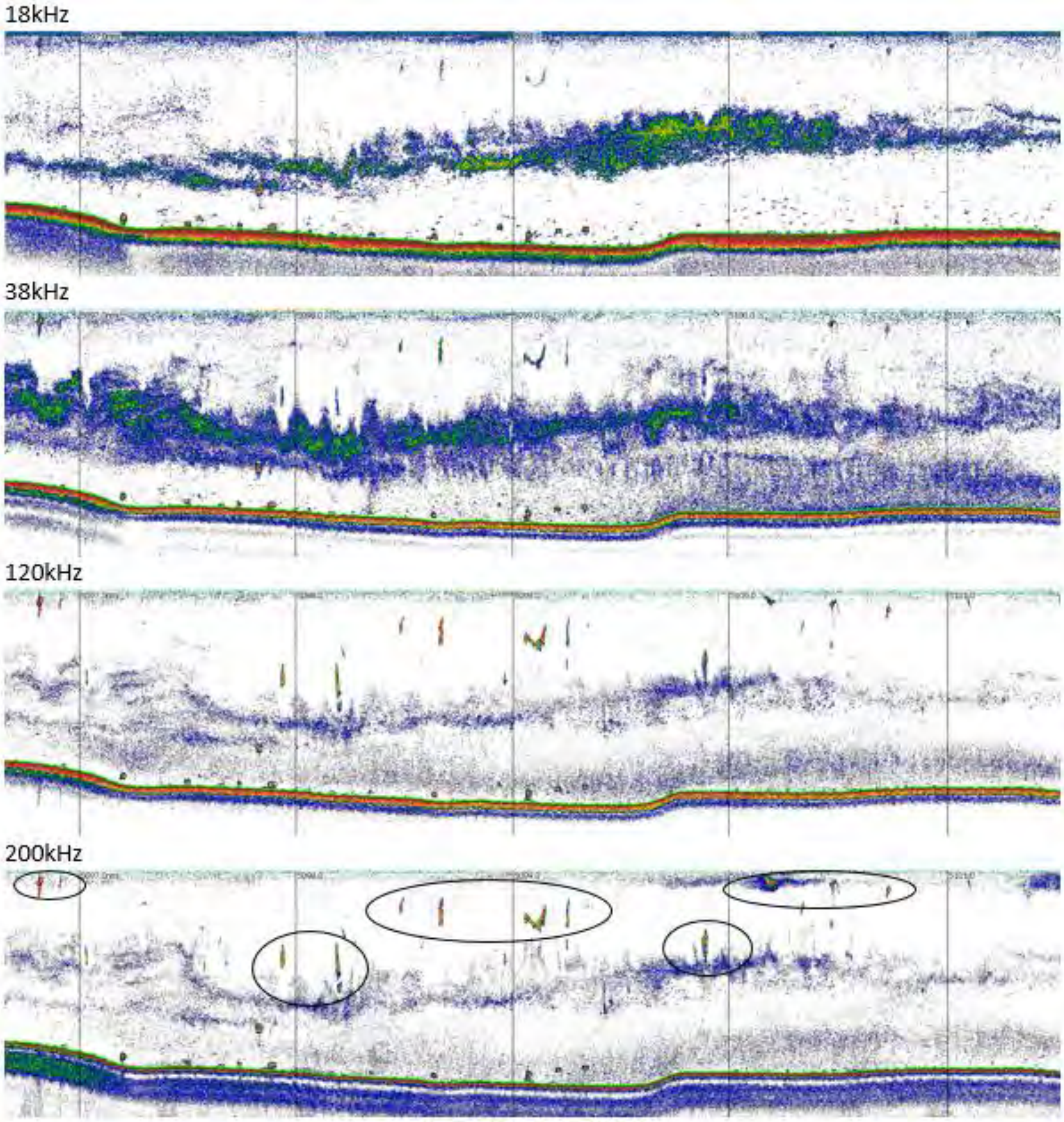


Figure 16. WESPAS 2021 (transect 45 at 56˚ 31N and 7˚ 43W). The black oval shapes show suspected mackerel marks in surface and midwater (surface down to 100m). On the occasions when mackerel show on the echosounder during the survey, the marks tend to show stronger on the 120 and 200kHz. Water depth ~ 190m.

WD ICES WGWIDE 20201

The 2021 updated RFID tag-recapture data on NEA mackerel – Trends in abundance with different filtering

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Summary

A full overview and update of the RFID tagging experiments of mackerel 2011-2021, as well as the recaptures and scanned fish 2012-2020 is given. Since the benchmarking process during ICES IBPNEAMac 2019 and decisions therein, the data included in the SAM stock assessment has been filtered to only include mackerel tagged at ages 5-11, release years 2013 an later and recaptures limited to year 1 and 2 after release. The RFID data set used as input to the SAM stock assessment is a complex one with numbers released per age in a release year, and the numbers scanned and recaptured of these year classes annually in all the years after release; i.e not typical abundance indices per age per year as normally included in age based assessments. Hence, the overview does not only focus on the input data themselves and quality assurance of these, but the actual trends they show for both the different year classes and biomass. Special effort in put on demonstrating trends in actual data included in assessment compared with other ways of filtering the data, such as including more age groups and more years with recaptures after release then the current assessment. Finally, the year class trends, mortality trends in the RFID data are compared with the other age-based input data from commercial catches and the international trawl survey in the Norwegian Sea (IESSNS).

Background

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 tag recapture methodology and data quality assurance

The RFID tagging project on NEA mackerel was initiated in 2011 by IMR, and the data were used in update assessments after the ICES WKWIDE2017 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 tags used for mackerel are passive, commonly called PIT-tags, specifically developed for tagging fish and animals. They are made of biocompatible glass (specific type used for mackerel is ISO FDX-B 134,3 kHz, 3.85x23mm glass tags) which are equipped with a one-time programmable microchip with a unique ID. 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 (SmartSeaFish) 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 the industry it selves 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 has been following up the factories, and delivering the catch data and biological data. Currently the responsibilities are as below:

Iceland: Anna Olavsdottir (HAFRO) responsible scientist

- uploading catch data and biological data to SmartSeaFish database
- allocating recaptures and biological samples to the different landings
- testing the 3 Icelandic factories for efficiency, 10 test tags in 10 different landings every year.
- initiates servicing of RFID-antenna systems if needed
-

Scotland: Steve Mackingson (Scottish Pelagic Fishermen's Association) responsible scientist

- uploading catch data to SmartSeaFish database (we still use Norwegian biological data from same period/ICES area)
- allocating recaptures to the different landings
- testing the 5 Scottish factories for efficiency, 10 test tags in 10 different landings every year/season.
- initiates servicing of RFID-antenna systems if needed
-

Norway: Aril Slotte (IMR) responsible scientist for the Norwegian RFID tagging program for mackerel and herring, main responsible for final estimations needed to procuce the data table delivered to ICES WGWIDE

- uploading catch data and biological data to SmartSeaFish database
- allocating recaptures and biological samples to the different landings (including biological data to Scottish landings)
- Norway now has 15 factories with RFID antenna systems for scanning mackerel and herring. All factories are serviced 1 time per year and when there are apparent issues to be solved
- A new monitoring system has been developed (Figure 1). which is now placed at all 15 Norwegian factories. This monitoring system is continuously overviewing that RFID antennas and readers are functioning. Voltage variations are measured and every 15 min the reading capabilities are tested automatically with a status tag, and these tests are also stored in the SmartFish database for further analyses of efficiency. This monitoring system has replaced the manual testing with 10 test tags in 10 different landings every year/season. The plan is that same systems are

Based on the manual test off recapture efficiencies or the online monitoring, responsible scientists decides if data from a factory has to be excluded from final estimation and data input to ICES WGWIDE assessment. Factories that does not function properly are put in an 'out of order' list (Figure 2), where catch data and recapture data from these 'out of order' periods are excluded during estimation. To conclude with regard to quality assurance we have made progress and current monitoring of efficiencies at factories that has been raised as a main issue is now at an acceptable level. Still, there is need for more quality control of both all raw tag-recapture data, biological data and allocations of these to landings, as well as the final estimations of data included in the ICES WGWIDE stock assessment. In the future we need to develop annual workshops 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 idea is that this should work similarly as post-cruise meetings where all involved scientists take part in final report.

Status of updated RFID tag recapture data

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 1-3, and geographical distributions of data in Figures 3-6.

During the period 2011— 20th Aug 2021 as many as 506465 mackerel have been tagged with RFID (Table 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 6663 RFID-tagged mackerel recaptured up to 31. December 2020 came from landing scanned at 23 European factories processing mackerel for human consumption (Table 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. Recently one factory, Pelagia Austevoll is terminated, so currently 15 factories are scanning for RFID tags in Norway. More systems are also bought by Ireland (3), which up to now has been non-operational.

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.

The exclusion of release years 2011-2012, and recapture years 2012-2013 is mainly based in lack of distributional coverage of scanned fishery, which changed significantly when more countries joined the program and scanned landings from 2014 onwards (Figures 4-5).

The exclusion of recaptures in year 3 or longer after the release year was because data indicated tag loss over time, and that the large majority was recaptured prior to year 3 after release. In year recaptures are not used. However, following recaptures from in year (years out=0) and further through year 1-3+ after tagging, it is apparent that tagged fish are quite quickly distributed in the fishery, and the distributional patterns of recaptures are maintained over time (Figure 6). Hence, potentially more recapture years could be included it one overcame how to adjust for potential tag loss.

The exclusion of ages 1-4, was mainly based in noisy data from these age groups, and the fact that in the early tagging years fish in these age groups were relatively few compared with the scanned fish year 1 and 2 after release. Fish from these ages were not considered representative for the behaviour of the year classes. However, over time this picture has changed considerable. The age structure of tagged and scanned fish year 1-2 after release are now overlapping, and high proportions of tagged mackerel are now at ages 2-4 (Figure 7). This means that given current filtering we will exclude large proportions of the RFID tag recapture data in coming years, so this is a decision that will have to be revised. Hence, in the following focus is on the actual trends and consistency in the RFID tag data, having in mind that the current filtering may have to be revised in near future.

Status of RFID tag recapture data trends and consistency for use in stock assessment

Estimates of year class abundance for unfiltered RFID tag-recapture data show trends over time that seems informative for stock assessment (Figure 8), and this is also supported by the tests of consistency in the data (Figure 9), implying a potential for including younger age groups in future assessments.

However, the information coming the RFID tag data is easier to interpret when comparing age aggregated biomass indices estimated from the RFID data (based on year 1-2 with scanning and recaptures) with SSB from the stock assessment, as shown in Figure 10. The decision to exclude release years 2011-2012 is supported by this plot, showing noisy estimates above the confidence intervals of the assessment. However, by including only release years 2013 onwards as in current assessments, the biomass trend in the RFID tag data are more in line with the SSB of the assessment, especially the decrease in SSB from 2017-2019 is also very evident regardless of ages aggregated from RFID data. This again signifies that over time, and in a future benchmark process, information of tag recaptures from younger age groups may be included again should the bias issues tend to disappear and trends are informative for the assessment.

In recent years we have seen a trend that the information from RFID tag recapture data about abundance in a release year increase when adding one more year with recaptures and scanned data. Figures 11-12 illustrates this issue for single year classes as well as various age aggregated abundance estimates. This support the decision to stick to only using recapture and scanned data for year 1 and 2 after release. Moreover, it also implies the last year included in the stock assessment always based on s will be revised in next update assessment, with a recent clear tendency that adding the second year with data lifts the perception of abundance in a release year.

One more way of looking at the information from RFID tag recapture data relative to the other sources of input data and the stock assessment itself, is to compare signals of total mortality rate (Z) by estimating slope of decrease in abundance of year classes 2003-2014 of fully mature fish aged 4-12 (Figure 13). Here it is apparent that mortality signals from RFID data seem informative following a steady decrease as the catch data, whereas IESSNS data sticks out as a bit noisier trends. When looking at the estimated Z for each data source, it is evident that the RFID data show signals of higher mortality rate than the catch data and WGWIDE2021 assessment, whereas Z estimates for the IESSNS data are even lower. Note that RFID data shows more uncertain estimates of Z for recent year classes with very few years, fewer than the other sources, which means the estimates may change over time. The overall conclusion is still that the RFID data seems quite informative, and that the current filtering and exclusion of data for use in stock assessment should be revised in near future.

Figure 14 demonstrates that recaptures from very young fish tagged in the North Sea at the western Norwegian coast (Bømlo Island) over the year adapted the same migration pattern as the fish tagged at older ages along Ireland-Hebrides. This support the hypothesis that mackerel growing up in the North Sea do not belong to a North Sea component, but to a large dynamic mackerel population changing migration pattern and spawning areas as the stock fluctuates in abundance and age structure.

Link to official publication of all raw data needed to produce input data set to the assessment is: Aril Slotte (IMR), Anna Ólafsdóttir (MFRI), Sigurður Þór Jónsson (MFRI), Jan Arge Jacobsen (FAMRI) and Steve Mackinson (SPFA) (2021) PIT-tag time series for studying migrations and use in stock assessment of North East Atlantic mackerel (Scomber Scombrus) http://metadata.nmdc.no/metadata-api/landingpage/f9e8b1cff4261cf6575e70e56c4c3b3e This is the correct citation when using the data. The data are available through this link as various APIs that are updated daily. There is also an R-package https://github.com/IMRpelagic/taggart can be used to download data from the APIs.

Tables

Table 1. Overview of numbers released in the different RFID tagging experiments, and numbers recaptured per year. Recaptures from experiments and recapture years used in 2021 stock assessment, based on decisions in the ICES IBPNEAMac 2019 (ICES 2019) 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 2021 (see Tables 2-3), due to low efficiency or misfunctions. Recaptures in 2021 are not included in table until ICES WGWIDE 2022.

Survey	N-Released	2012	2013	2014	2015	2016	2017	2018	2019	2020	All years
Iceland 2015	806	0	0	0	6	2	3	0	0	0	11
Iceland 2016	4884	0	0	0	0	59	48	28	19	13	167
Iceland 2017	3890	0	0	0	0	0	28	27	9	13	77
Iceland 2018	1872	0	0	0	0	0	0	5	16	13	34
Iceland 2019	3614	0	0	0	0	0	0	0	5	25	30
Norway2011	31253	9	31	24	32	26	16	20	7	13	178
Ireland-Hebrides 2011	18645	27	24	29	24	17	5	9	7	3	145
Ireland-Hebrides 2012	32135	31	57	60	64	34	21	12	5	6	290
Ireland-Hebrides 2013	22792	0	26	**89**	**104**	61	30	21	10	8	349
Ireland-Hebrides 2014	55184	0	0	112	**311**	**277**	139	91	44	45	1019
Ireland-Hebrides 2015	43905	0	0	0	115	**217**	**177**	93	49	41	692
Ireland-Hebrides 2016	43956	0	0	0	0	124	**324**	**183**	121	92	844
Ireland-Hebrides 2017	56073	0	0	0	0	0	134	**344**	**174**	146	798
Ireland-Hebrides 2018	33475	0	0	0	0	0	0	180	**221**	**206**	607
Ireland-Hebrides 2018-2	4661	0	0	0	0	0	0	24	27	**23**	74
Ireland-Hebrides 2019	51179	0	0	0	0	0	0	0	290	**541**	831
Ireland-Hebrides 2020	48968	0	0	0	0	0	0	0	0	517	517
Ireland-Hebrides 2021	49173	0	0	0	0	0	0	0	0	0	0
All surveys	506465	67	138	314	656	817	925	1037	1004	1705	6663
All Ireland-Hebrides	410973	58	107	290	618	730	830	957	948	1628	6166

Table 2. Overview of numbers of tonnes scanned for RFID tags per factory per year. Data from years used in 2021 stock assessment (2014 and onwards), based on decisions in the ICES IBPNEAMac 2019 (ICES 2019), 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	2013	2014	2015	2016	2017	2018	2019	2020	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**	**8809**	36258
GB01 Denholm Factory	0	0	**14939**	**17509**	**18840**	**17913**	**13609**	**12018**	**13951**	108780
GB02 Lunar Freezing Peterhead	0	0	**22586**	**17830**	**16473**	**9745**	**9857**	**14300**	**24382**	115173
GB03 Lunar Freezing Fraserburgh	0	0	0	8797	14282	12684	**9452**	**5729**		50943
GB04 Pelagia Shetland	0	0	**21436**	**41117**	**40200**	**26935**	**25350**	**15128**	**22573**	192739
GB05 Northbay Pelagic	0	0	0	0	0	0	**15353**	**12667**	**15478**	43498
IC01 Vopnafjord	0	0	**18577**	**18772**	**21716**	**22935**	**18869**	**18547**	**21191**	140607
IC02 Neskaupstad	0	0	0	**6288**	**21887**	**19558**	**16757**	**26633**	**28180**	119303
IC03 Höfn	0	0	0	0	0	0	0	**10592**	**13488**	24080
NO01 Pelagia Egersund Seafood	20930	21442	36724	14375	15905	0	**48373**	**25404**	**51013**	234165
NO02 Skude Fryseri	7546	8250	**16719**	**14172**	**8671**	**16760**	3108	1285	17661	94172
NO03 Pelagia Austevoll	6405	6134	10314	4203	2216	0	**7293**	**3533**	**8351**	48449
NO04 Pelagia Florø	9986	12838	**17379**	**12592**	**7749**	0	0	0		60544
NO05 Pelagia Måløy	13344	14632	**13942**	**21051**	**15762**	**22405**	**13341**	**8591**	**21287**	144355
NO06 Pelagia Selje	17731	26878	**39525**	**41209**	**29897**	**35416**	**28972**	**32047**	**31678**	283354
NO07 Pelagia Liavågen	9442	10968	**22395**	**18144**	**13911**	**19989**	**12398**	**11888**	**17487**	136623
NO08 Brødrene Sperre	14425	15048	**20182**	**34307**	**36736**	**18814**	34280	8515	32333	214641
NO09 Lofoten Viking	0	0	0	0	0	0	3380	2457	**3823**	9660
NO11 Nergård Sild	0	0	0	0	0	0	0	0	**2**	2
NO12 Pelagia Lødingen	0	0	0	0	0	0	0	0	**950**	950
NO14 Nils Sperre	0	0	0	0	0	0	**28304**	**26272**	**30265**	84841
NO15 Grøntvedt Pelagic	0	0	0	0	0	0	6411	0	0	6411
NO16 Vikomar	0	0	0	0	0	0	12512	**6480**	**15679**	34671
All factories	99808	116190	265178	286310	276850	233363	315426	247277	378582	2218984
All factories (data used)			**218140**	**258935**	**244448**	**220679**	**255734**	**217148**	**328588**	**1743672**

Table 3. Overview of numbers of RFID tagged mackerel recaptured per factory per year. Only recaptures from Ireland surveys (Table 1) that are used as basis stock assessment are shown. Recaptures from years used in 2021 stock assessment from 2014 and onwards, based on decisions in the ICES IBPNEAMac 2019 (ICES 2019), 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. See Table 2 for biomass scanned.

Factory	2012	2013	2014	2015	2016	2017	2018	2019	2020	All years
FO01 Vardin Pelagic	0	0	**13**	**35**	**20**	**11**	0	0	0	79
GB01 Denholm Coldstore	0	0	0	**10**	**10**	**24**	**36**	**19**	**46**	145
GB01 Denholm Factory	0	0	**25**	**62**	**77**	**113**	**54**	**53**	**92**	476
GB02 Lunar Freezing Peterhead	0	0	**32**	**49**	**60**	**38**	**41**	**54**	**123**	397
GB03 Lunar Freezing Fraserburgh	0	0	0	9	14	7	**25**	**34**	0	89
GB04 Pelagia Shetland	0	0	**21**	**124**	**148**	**137**	**98**	**82**	**134**	744
GB05 Northbay Pelagic	0	0	0	0	0	0	**57**	**59**	**81**	197
IC01 Vopnafjord	0	0	**22**	**55**	**65**	**59**	**62**	**54**	**146**	463
IC02 Neskaupstad	0	0	0	**19**	**65**	**54**	**35**	**114**	**127**	414
IC03 Höfn	0	0	0	0	0	0	0	**44**	**65**	109
NO01 Pelagia Egersund Seafood	10	22	18	7	1	0	**137**	**80**	**184**	459
NO02 Skude Fryseri	5	6	**21**	**17**	**25**	**51**	13	3	34	175
NO03 Pelagia Austevoll	1	1	7	4	0	0	**28**	**17**	**48**	106
NO04 Pelagia Florø	5	12	**27**	**21**	**16**	0	0	0	0	81
NO05 Pelagia Måløy	5	13	**18**	**43**	**37**	**77**	**36**	**28**	**97**	354
NO06 Pelagia Selje	15	27	**37**	**76**	**59**	**85**	**87**	**153**	**172**	711
NO07 Pelagia Liavågen	10	11	**29**	**31**	**26**	**97**	**48**	**51**	**111**	414
NO08 Brødrene Sperre	7	15	**20**	**56**	**107**	**77**	52	12	0	346
NO09 Lofoten Viking	0	0	0	0	0	0	10	3	**5**	18
NO12 Pelagia Lødingen	0	0	0	0	0	0	0	0	**1**	1
NO14 Nils Sperre	0	0	0	0	0	0	**109**	**68**	**73**	250
NO15 Grøntvedt Pelagic	0	0	0	0	0	0	11	0	0	11
NO16 Vikomar	0	0	0	0	0	0	18	**20**	**89**	127
All factories	58	107	290	618	730	830	957	948	1628	6166
All factories (accept)			**265**	**598**	**715**	**823**	**866**	**898**	1594	**5759**

Figures

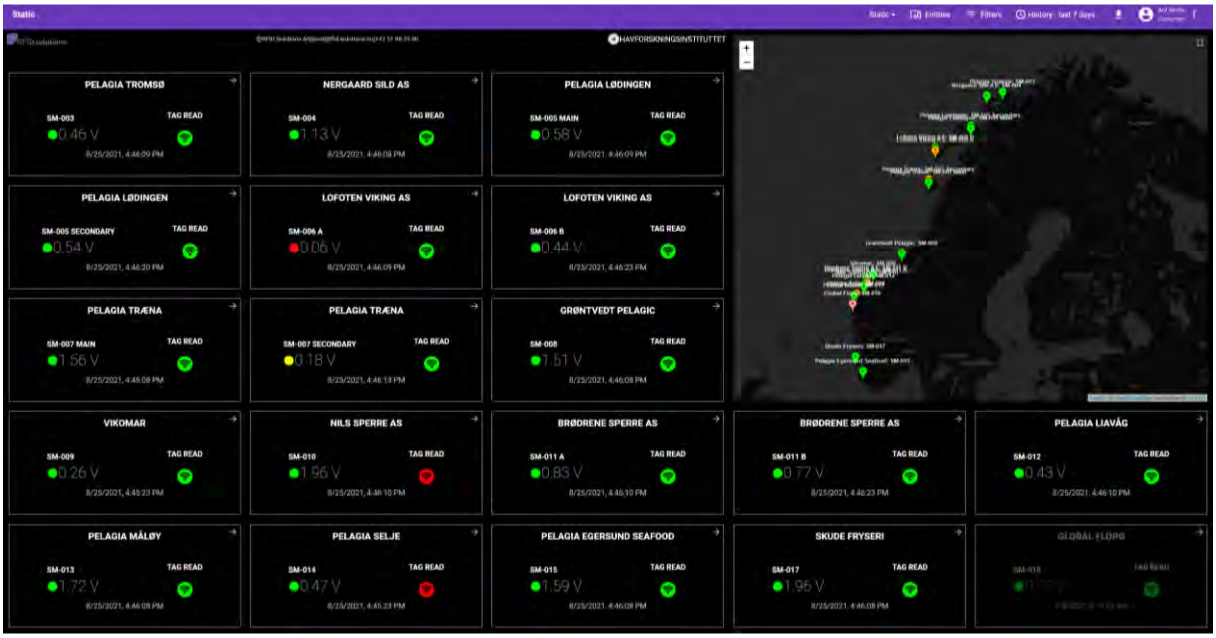
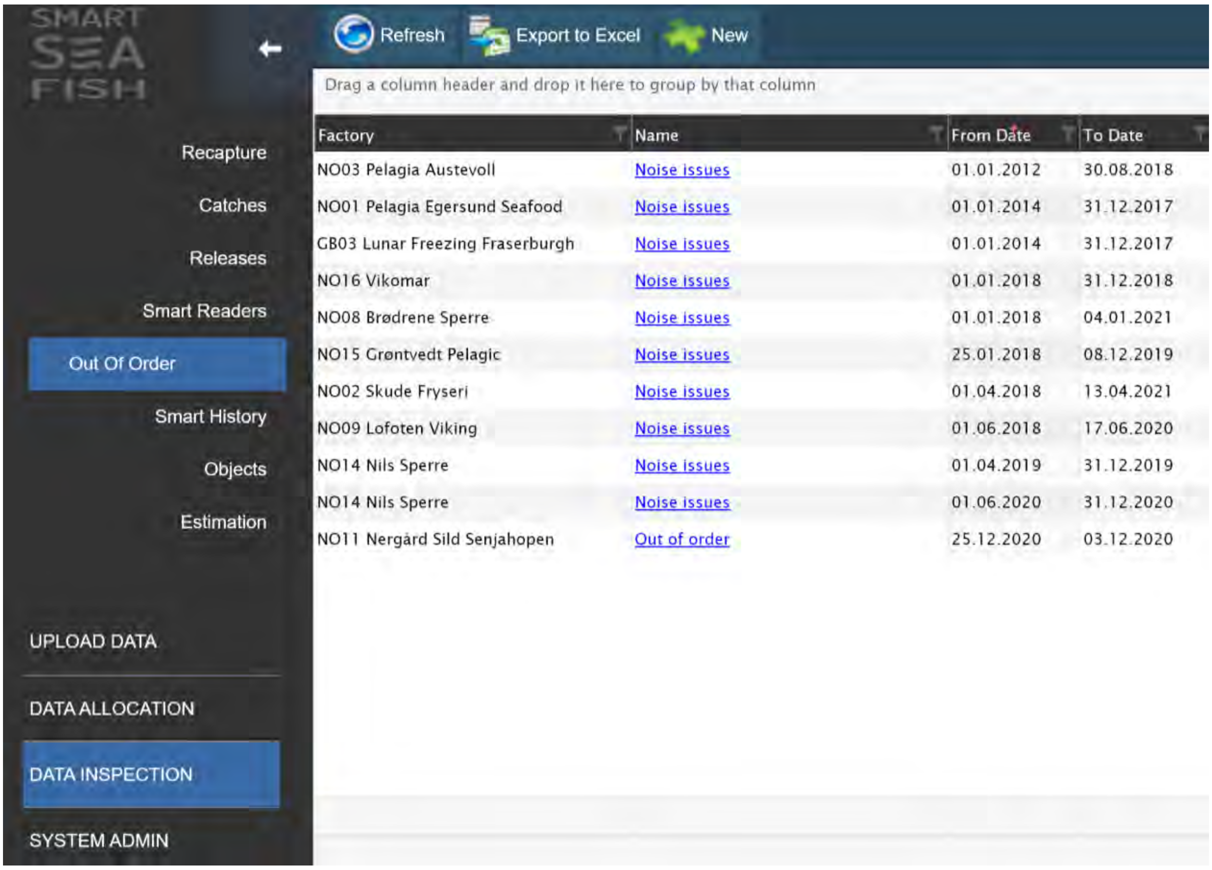


Figure 1. Example of how the new monitoring systems looks like. It follows the traffic light systems, where red implies that we currently may have issues with either voltage variations or reduced efficiency of RFID tags.



Factory	Name	From Date	To Date
NO03 Pelagia Austevoll	Noise issues	01.01.2012	30.08.2018
NO01 Pelagia Egersund Seafood	Noise issues	01.01.2014	31.12.2017
GB03 Lunar Freezing Fraserburgh	Noise issues	01.01.2014	31.12.2017
NO16 Vikomar	Noise issues	01.01.2018	31.12.2018
NO08 Brødrene Sperre	Noise issues	01.01.2018	04.01.2021
NO15 Grøntvedt Pelagic	Noise issues	25.01.2018	08.12.2019
NO02 Skude Fryseri	Noise issues	01.04.2018	13.04.2021
NO09 Lofoten Viking	Noise issues	01.06.2018	17.06.2020
NO14 Nils Sperre	Noise issues	01.04.2019	31.12.2019
NO14 Nils Sperre	Noise issues	01.06.2020	31.12.2020
NO11 Nergård Sild Senjahopen	Out of order	25.12.2020	03.12.2020

Figure 2. Example of how it looks like in the SmartSeaFish web-based software where factories having issues with recapture efficiency are put in an 'Out of order' list. Catch data and recapture data from these factories and periods are excluded in final estimation of data table being included in the ICES WGWIDE stock assessment.

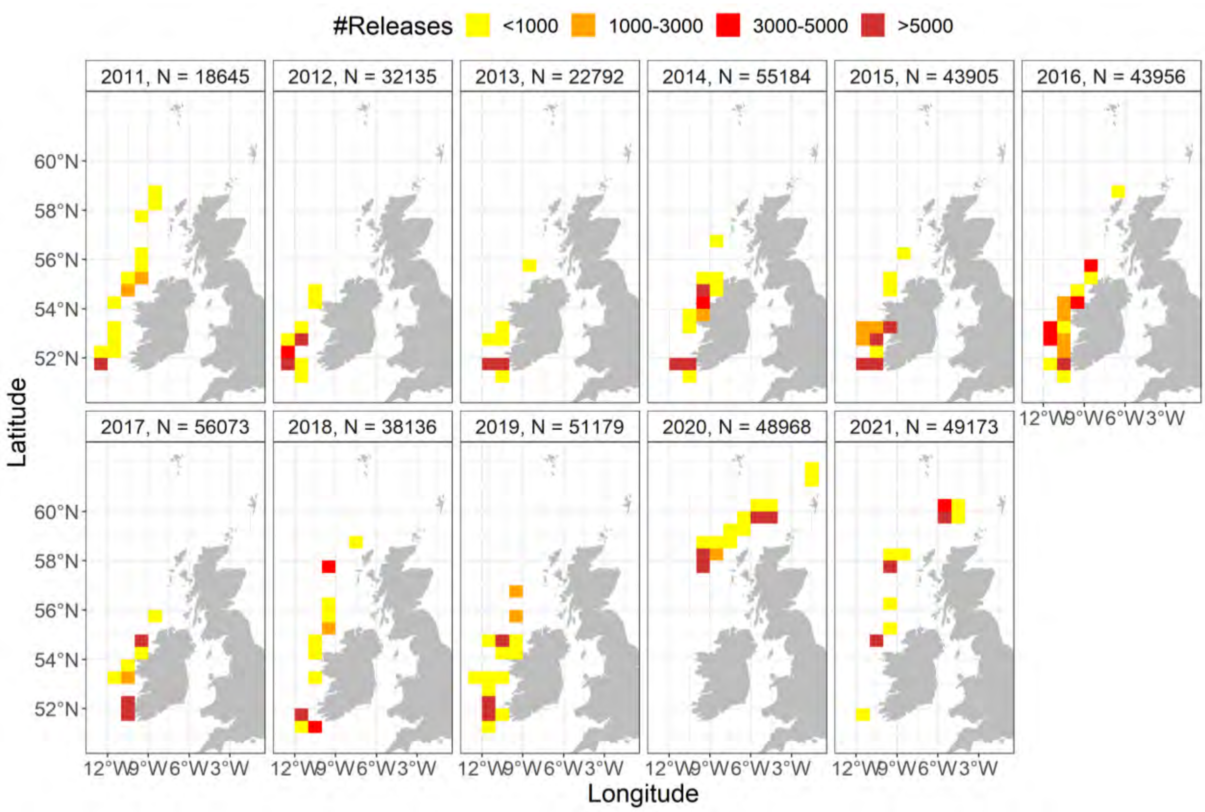


Figure 3. Distribution of RFID tagged mackerel from experiments west of Ireland-Hebrides during 2011-2021. Number of released fish is summed per ICES rectangle. See Table 1 for details on numbers released. Note that data from releases 2011-2012 are not used in the stock assessment, based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019), and data from experiments in 2020-2021 are not included as there are no full years with recaptures yet.

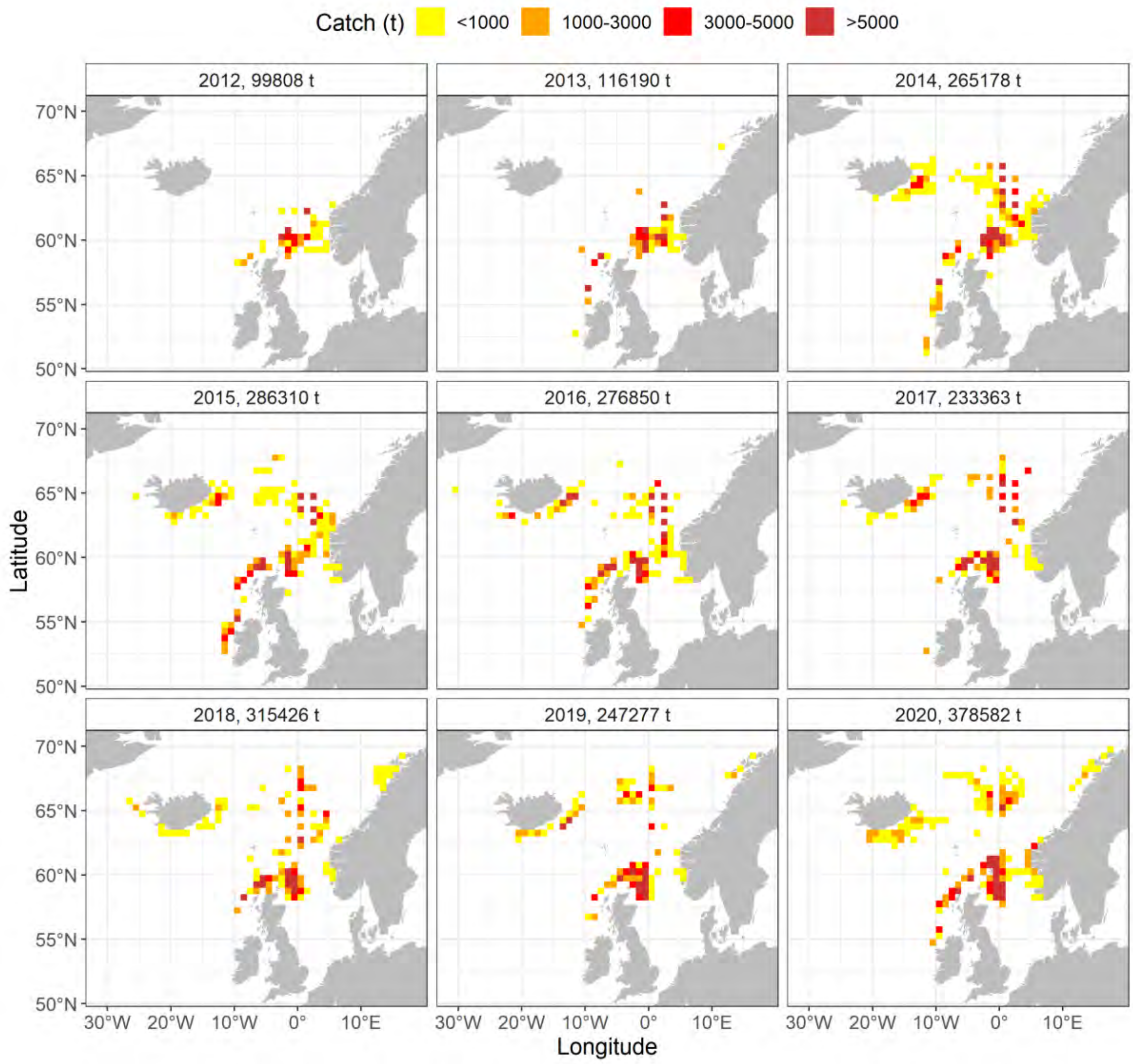


Figure 4. Distribution (summed per ICES rectangle) of catches scanned for RFID tagged mackerel during 2012-2020. Note that data on scanned catches in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019). Detailed data on scanned biomass per factory and year are given in Table 2.

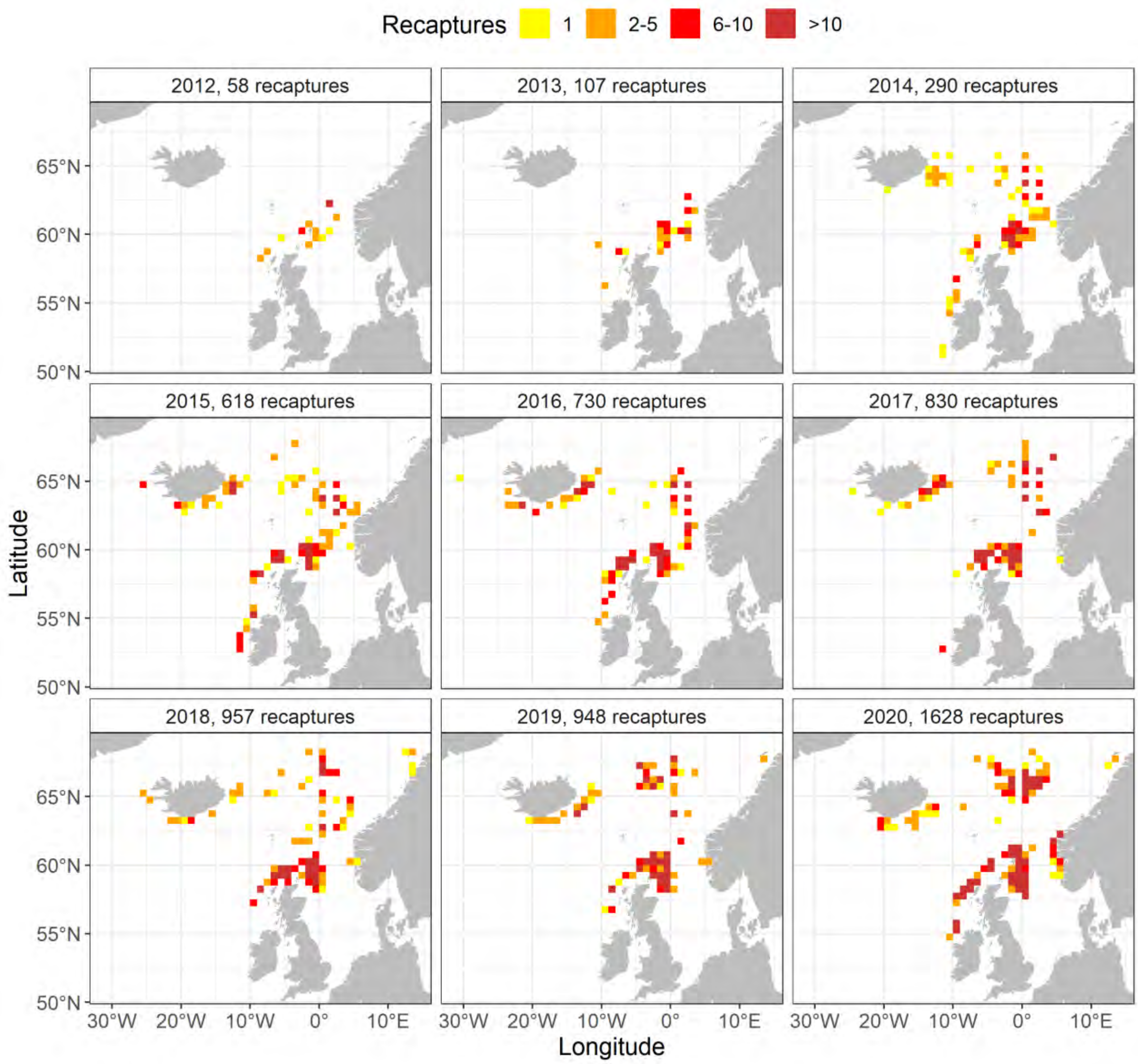


Figure 5. Distribution (summed per ICES rectangle) of recaptures of RFID tagged mackerel during 2012-2020. Note that data on recaptures in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019). Detailed data on recaptures per factory and year are given in Table 3.

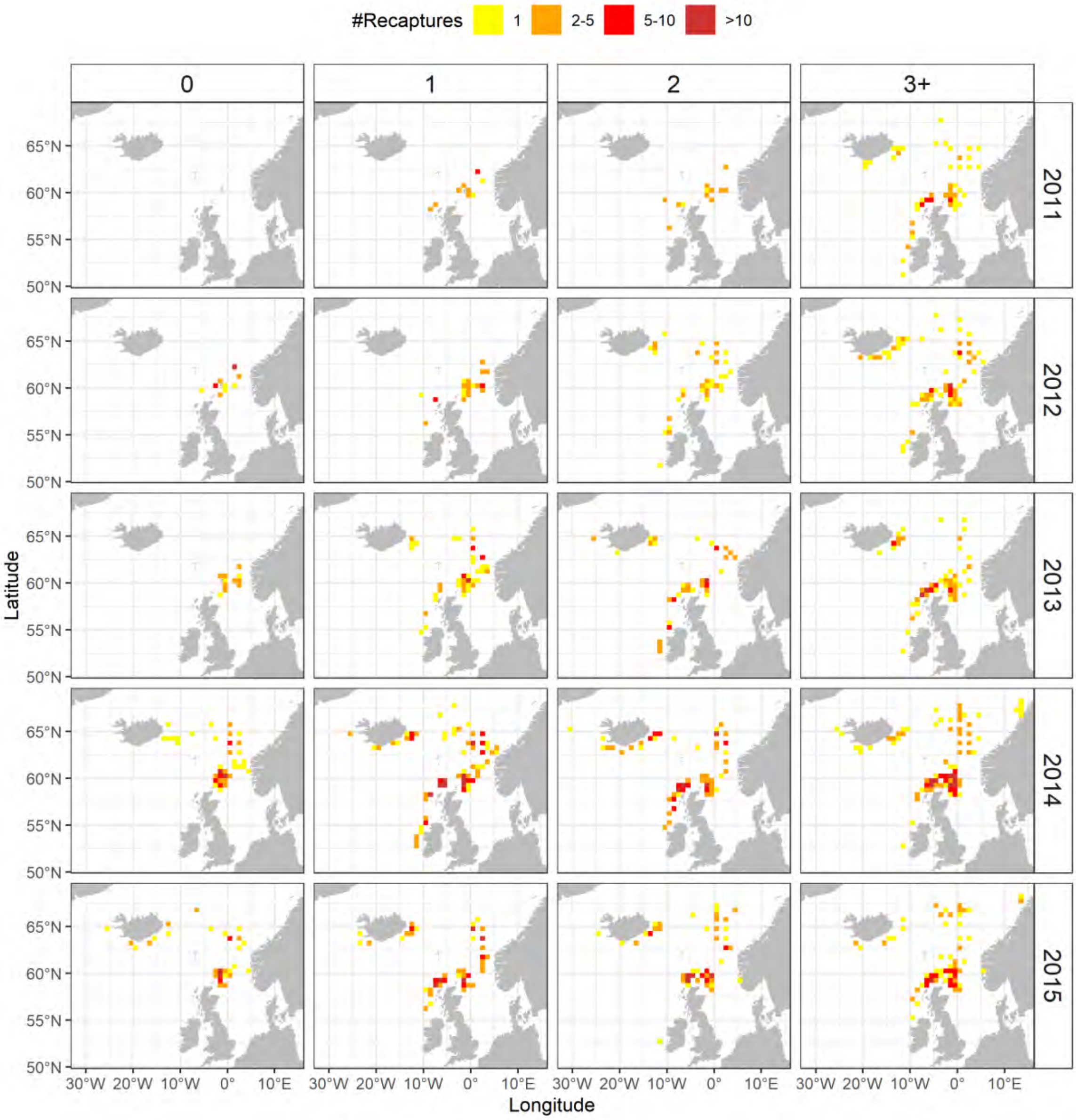


Figure 6. Distribution (summed per ICES rectangle) of recaptures of RFID tagged mackerel related to release years 2011-2015 and years after release (0=same year as tagging, 1= year after tagging etc.). Note that data on recaptures from 2011-2012 release years and from year 0 and 3+ after tagging are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019). Note also tha t in 2011 scanning had not started (Figure 4), so no in year recaptures.

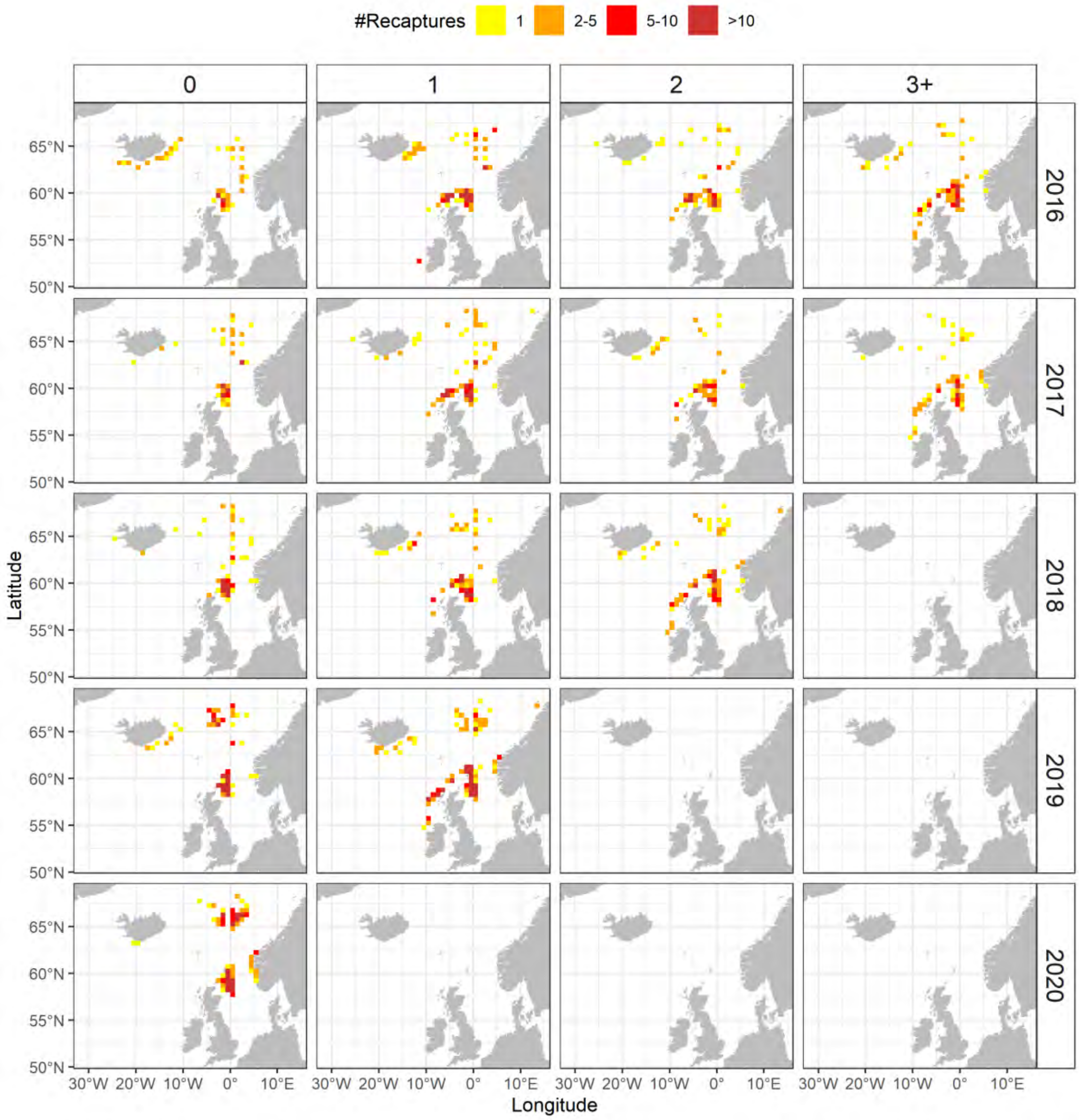


Figure 6 continued for release years 2016-2020. Preliminary recaptures in 2021 are not included as allocations to catches are not completed.

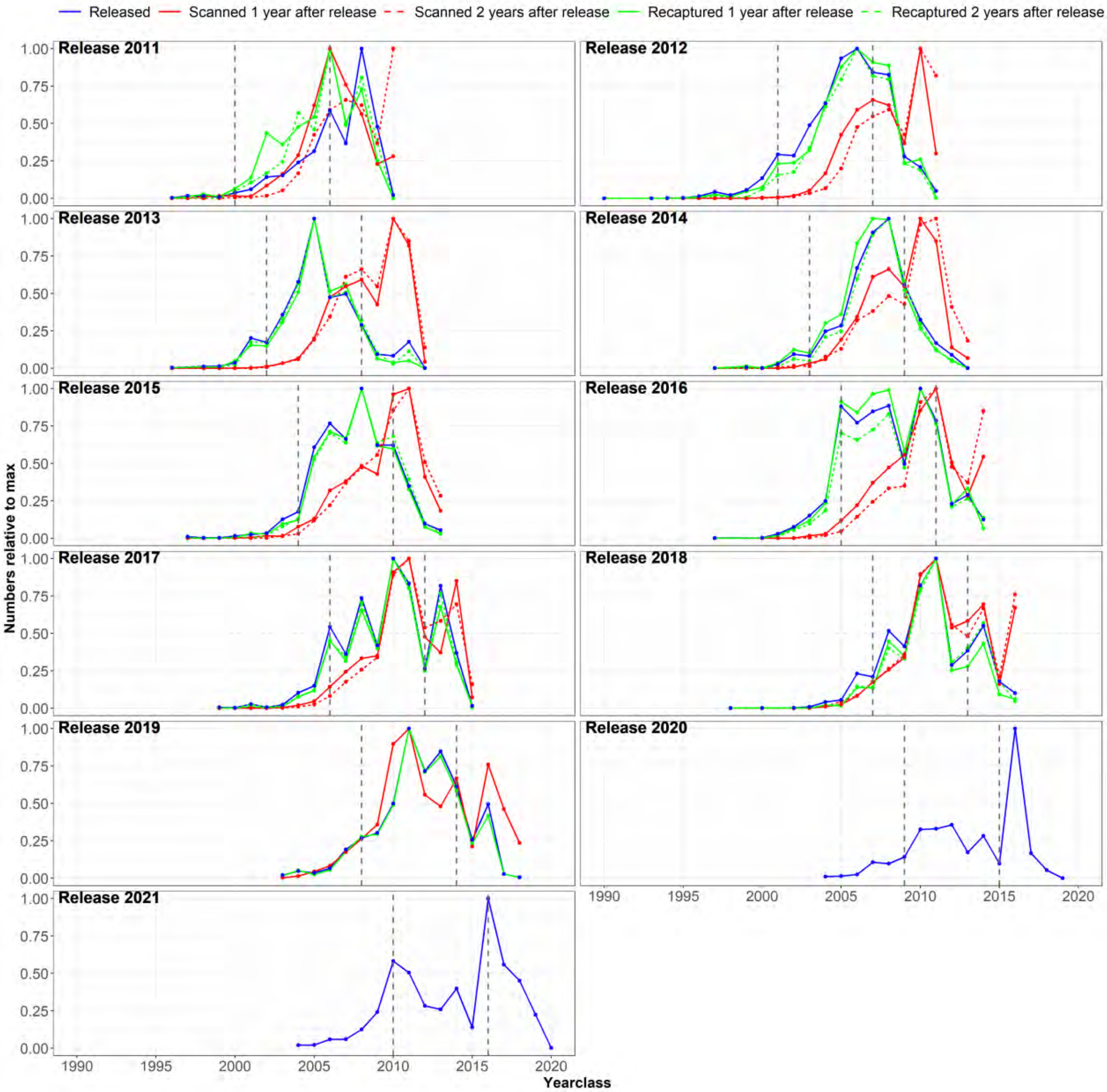


Figure 7. Overview of the relative year class distribution among RFID tagged mackerel per release year from experiments west of Ireland-Hebrides in May-June, compared with the number scanned and recaptured in year 1 and 2 after release of the same year classes. See Figure 3 for distribution of the tagged fish and the respective distribution of recaptures in year 1 and 2 after release in Figures 4-5. 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 2019). 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 1 and 3, also for other tagging experiments not included in the stock assessment.

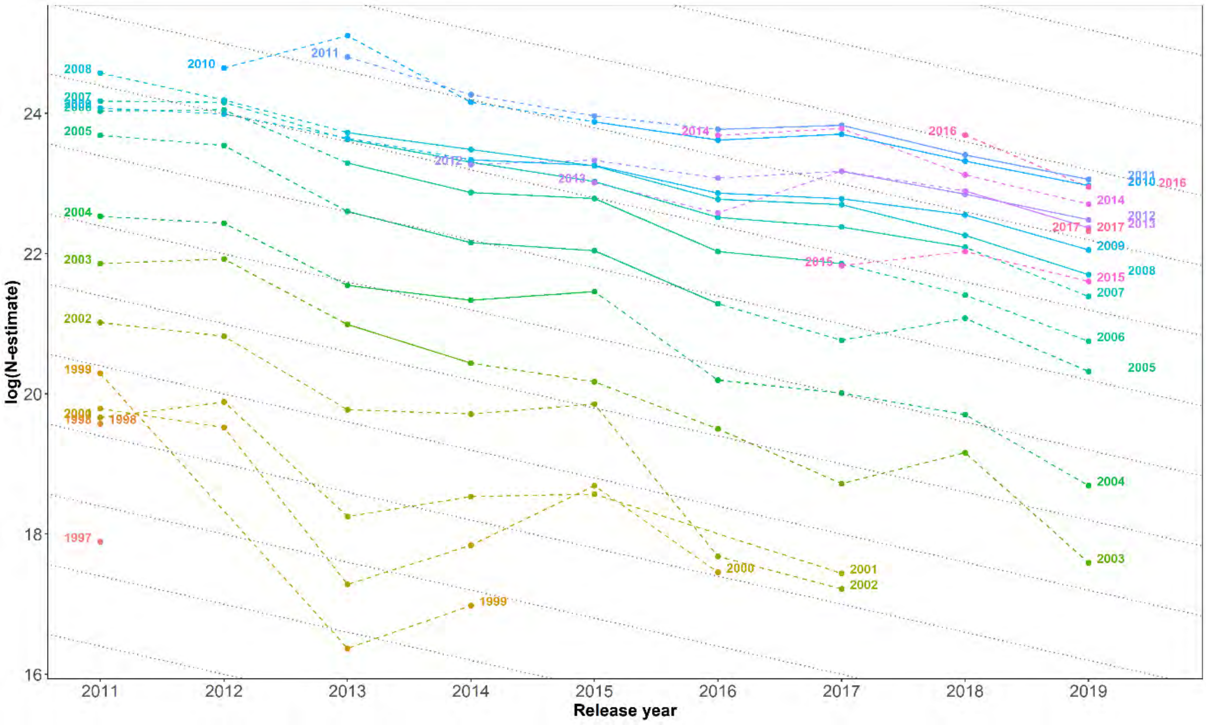


Figure 8. Trends in year class abundance (N=numbers released/numbers recaptured*numbers scanned) from RFID tag-recapture data based on aggregated data on recaptures and scanned numbers in year 1 and 2 after each release year. Data excluded in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019), 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.

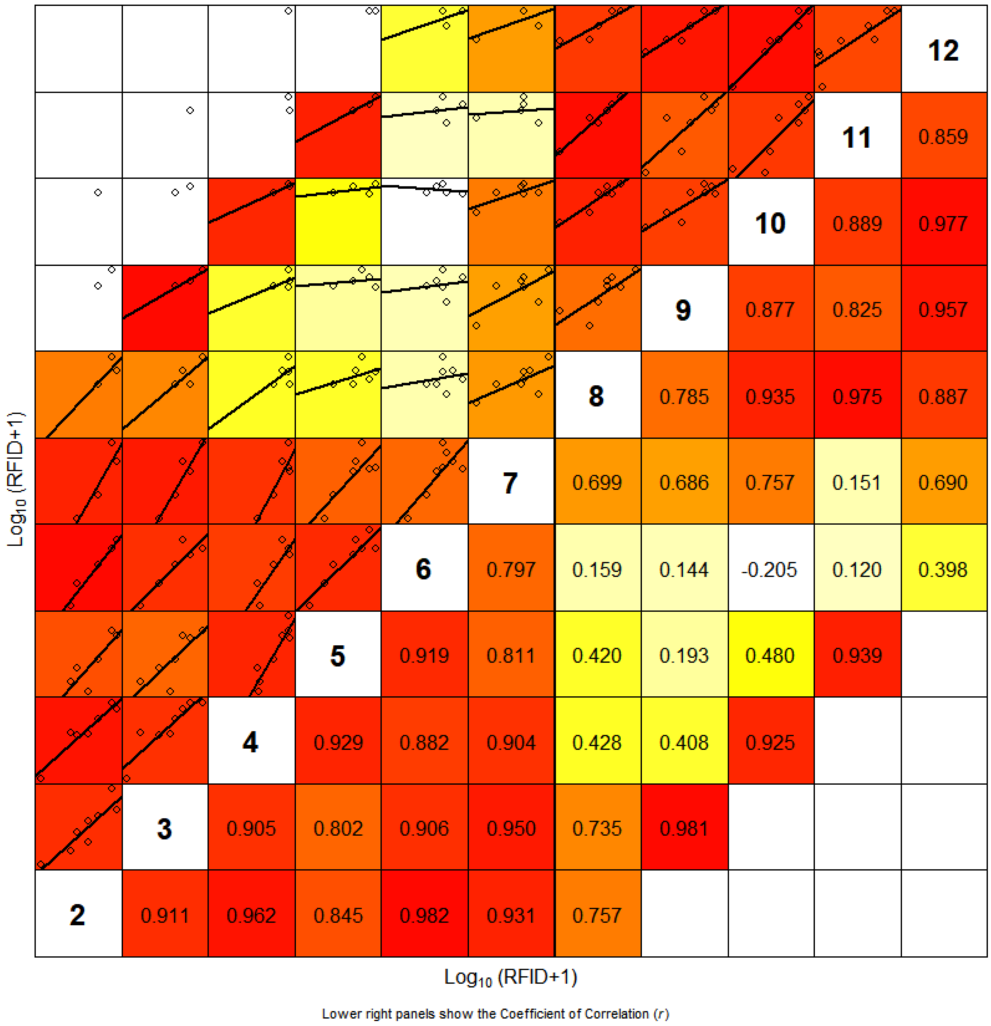


Figure 9. Internal consistency of the of mackerel RFID abundance index from release years 2011 to 2019, based on indices from Figure 8. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

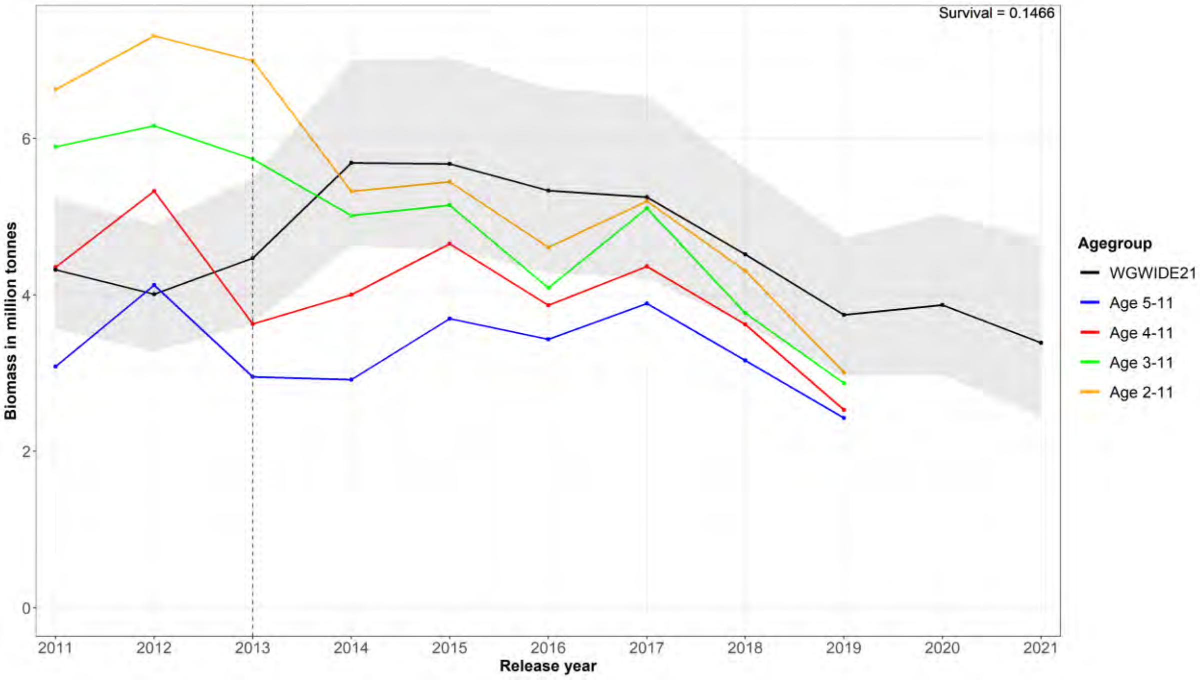


Figure 10. Trends in various age aggregated biomass indices from RFID tag-recapture data compared with the SSB (±95 confidence intervals) from the WGWIDE 2021 stock assessment. Data are based on a combination of estimated numbers by year class from Figure 8 scaled by the preliminary survival parameter estimated by SAM in WGWIDE 2021 (0.1466) and weight at age in stock form same assessment. 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 2019), and the trend of ages 5-11 is representing the subset of ages used in updated assessments. Note that final year with data 2019 is only based on recapture year 1 after release, whereas the other years are based on recapture year 1-2 after release, i.e. completed. In recent years (2016-2018) the estimates have tended to increase when adding the second recapture year (See Figures 11-12).

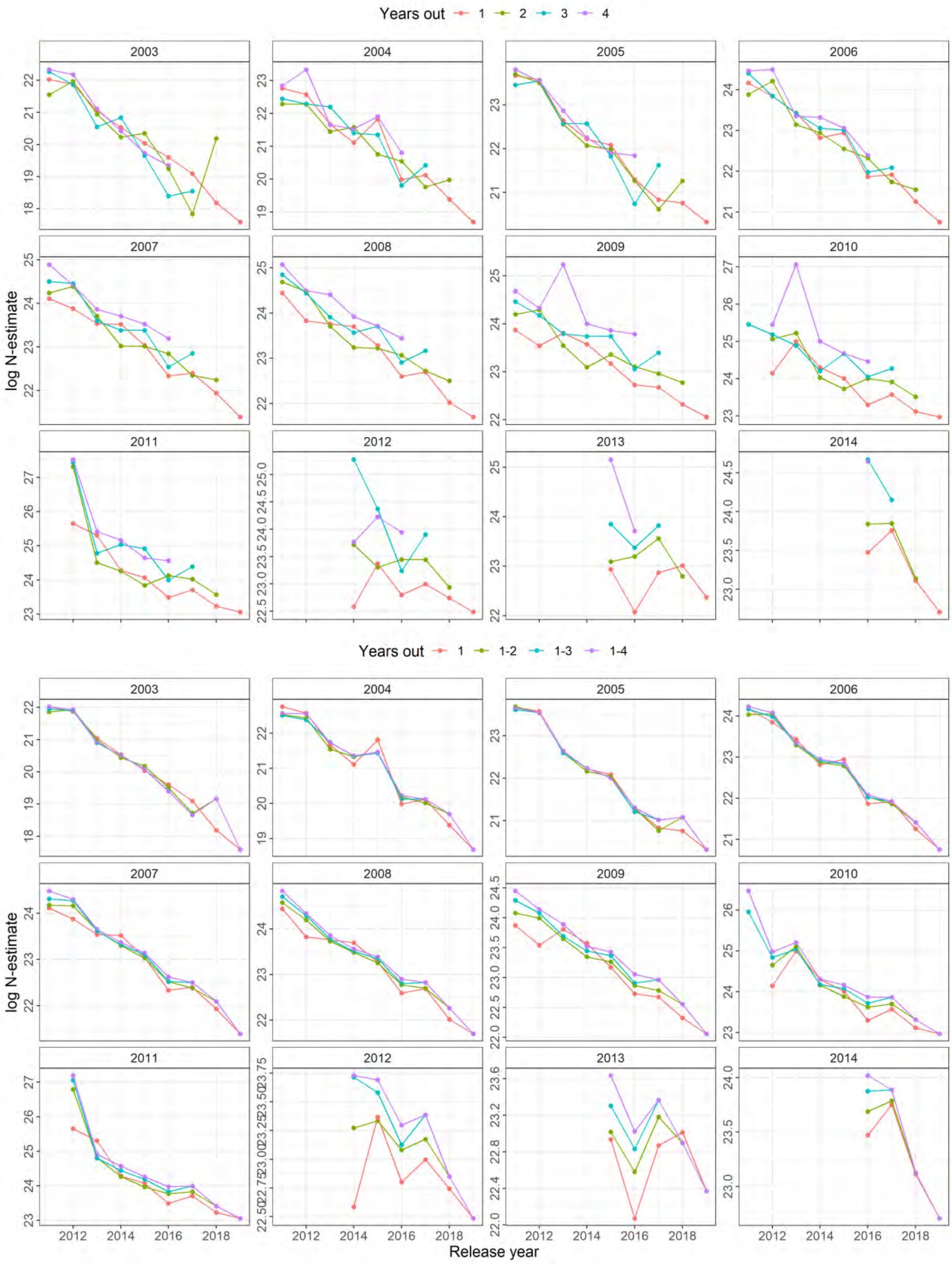


Figure 11. Trends in year class abundance (N=numbers released/numbers recaptured*numbers scanned) from RFID tag-recapture data based on different filtering of recapture year included. Upper panels show the difference between basing the estimate on either year 1, 2, 3, or 4 after release, whereas bottom panels show the difference between using year 1 after release versus various intervals of years after release. Note that data are shown for all ages (1-max 16) with data.

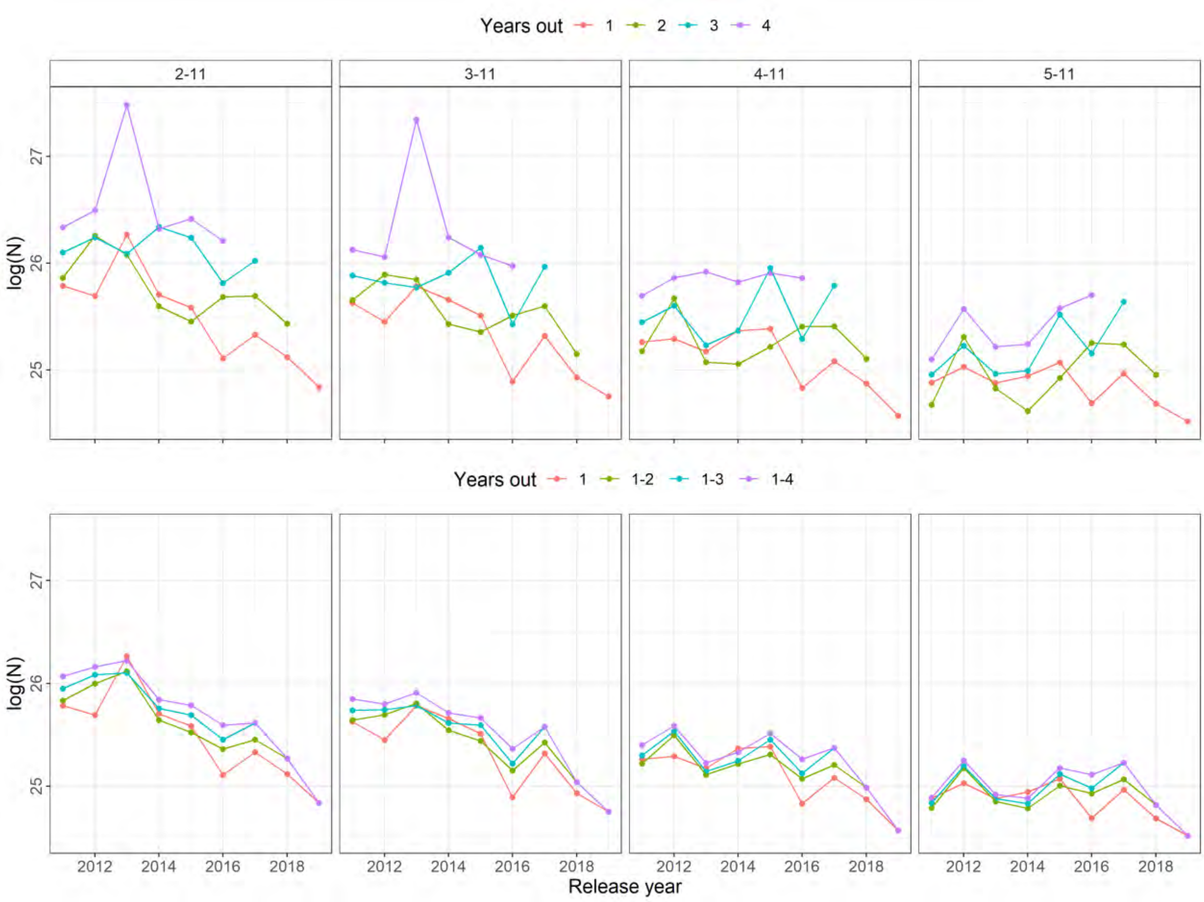


Figure 12. Trends in various age aggregated biomass indices from RFID tag-recapture data based on different filtering of recapture year included. Upper panels show the difference between basing the estimate on either year 1, 2, 3, or 4 after release, whereas bottom panels show the difference between using year 1 after release versus various intervals of years after release.

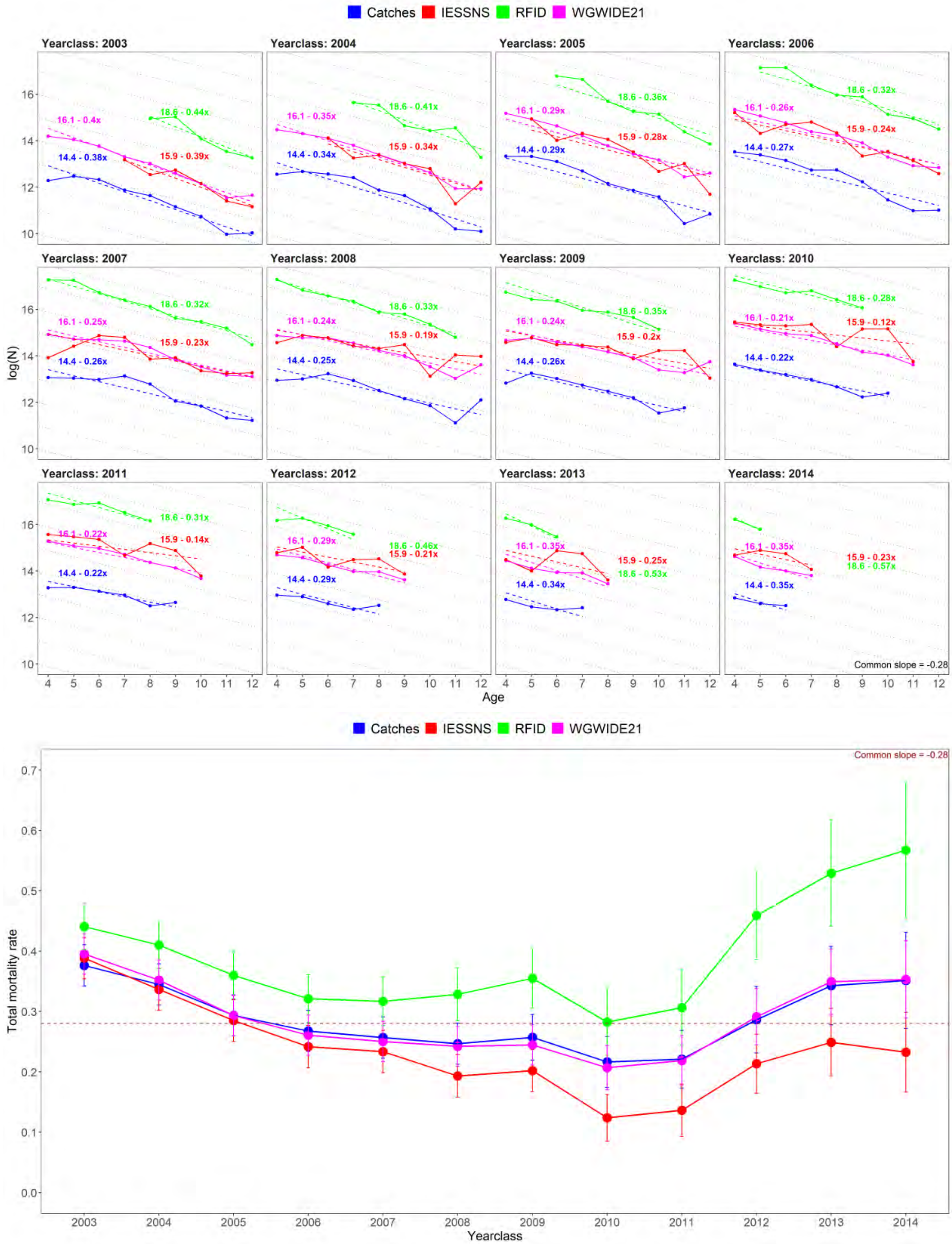


Figure 13. Signals of total mortality rate in input data to the mackerel stock assessment. Upper panels show the trends in year class abundance and estimated slope of decrease from the age 4 when it is fully recruited to the spawning stock until age 12 (interpreted as signal of total mortality), of various sources of unscaled input data to the mackerel stock assessment (RFID, IESSNS and catch data) compared with the final trend estimated in the stock assessment (WGWIDE 2021). Bottom panels summarize the year class differences in estimated total mortality rate (with 95% confidence intervals), and differences between the various data sources.

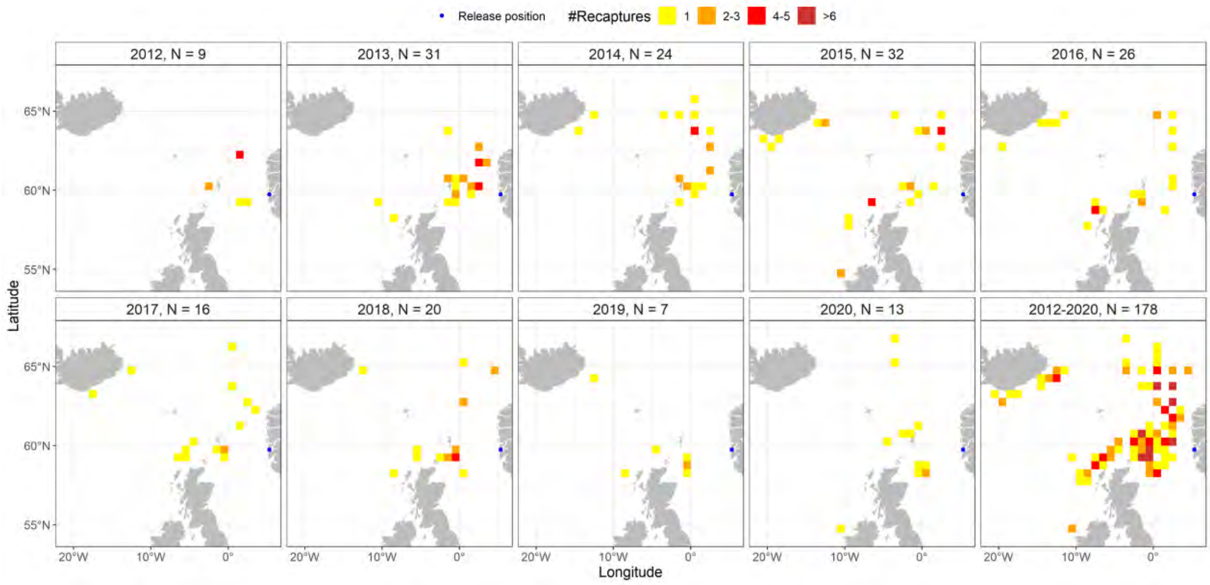


Figure 14. Distribution (summed per ICES rectangle) of recaptures 2012-2020 from an RFID tagging experiment on mackerel in the North Sea at the Norwegian West coast (blue dot) in 2011. This was mainly young mackerel tagged, where 88% were 1 year olds and 6.5% 2 year olds, using the North Sea/Norwegian coast as nursery.

WGWIDE 2021 WD…

Norwegian Spring Spawning Herring stock assessment by means of TISVPA

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The TISVPA (Triple Instantaneous Separable VPA) model (Vasilyev, 2005; 2006) represents fishing mortality coefficients (more precisely – exploitation rates) as a product of three parameters: f(year)*s(age)*g(cohort). The generation ‑ dependent parameters, which are estimated within the model, are intended to adapt traditional separable representation of fishing mortality to situations when several year classes may have peculiarities in their interaction with fishing fleets caused by different spatial distribution, higher attractiveness of more abundant schools to fishermen, or by some other reasons.

The TISVPA model was first presented and tested at the ICES Working Group on Methods of Fish Stock Assessments (WGMG 2006) and was used for data exploration and stock assessment for several ICES stocks, including North ‑ East Atlantic mackerel, blue whiting, NEA cod and haddock and Norwegian spring spawning herring. With respect to NSS herring stock the TISVPA model was used for data exploration for several years, last time - at WGWIDE 2019.

The TISVPA model is applied to NSS herring using the data, kindly presented by Stenevik Erling Kåre. 3 sets of age ‑ structured tuning data were included into analysis: the survey on spawning grounds along the Norwegian coast (survey 1); of young herring in the Barents Sea in May (survey 4); in feeding areas in the Norwegian Sea in May (survey 5).

In order to produce more clear and less controversial signal from all sources of the data the settings of the model were somewhat changed in comparison to those used at WGWIDE 2019: so called “mixed” version, assuming errors both in catch-at-age and in separable approximation; additional restriction on the solution was the unbiased model approximation of logarithmic catch-at-age. The generation ‑ dependent factors in triple ‑ separable representation of fishing mortality coefficients were estimated for the age groups from 5 to 12. For surveys 1 the measure of closeness of fit was the traditional sums of logarithmic squared residuals in abundances assuming lognormal errors. For survey 4 the measure of fit was the absolute median deviation (AMD) of the distribution of logarithmic residuals in abundances. For survey 5 the absolute median deviation was applied to logarithmic residuals in age proportions. For catch-at-age data the measure of fit was the absolute median deviation of the distribution of logarithmic residuals in catch-at-age.

Profiles of the components of the TISVPA loss function with respect to SSB in 2021 are shown in Figure 1. The minima are clear for catch-at-age and all surveys.

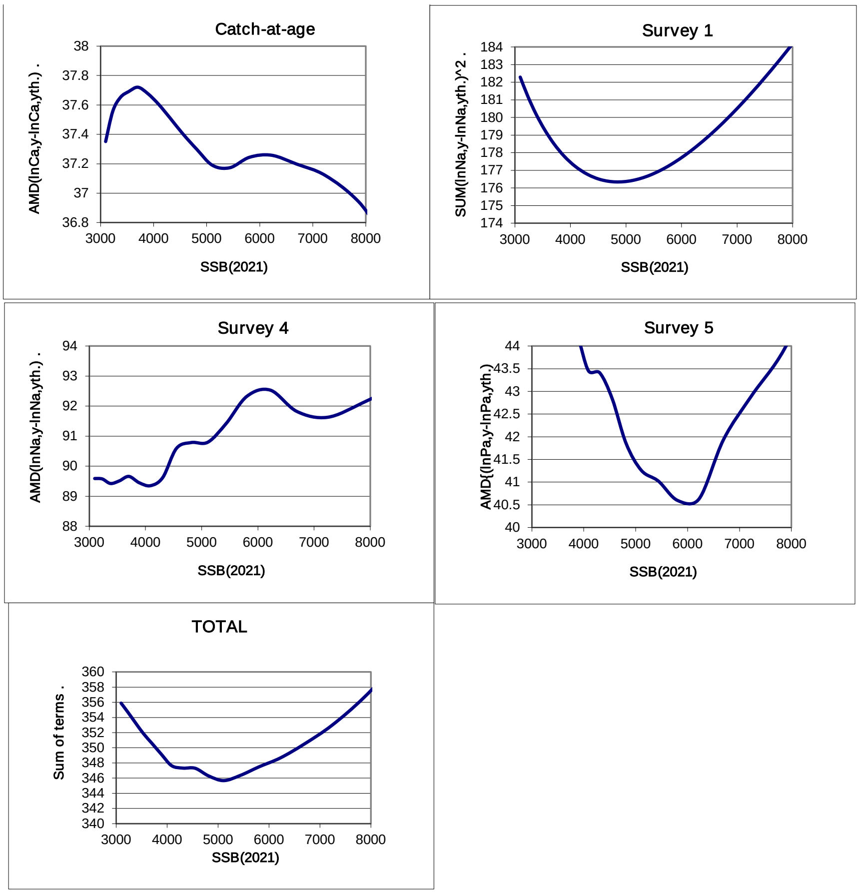

Figure 1. Profiles of the components of the TISVPA objective function.

The estimated selection pattern is given in Figure 2 (selection-at-age in the TISVPA model is normalized to SUM=1 for each year).

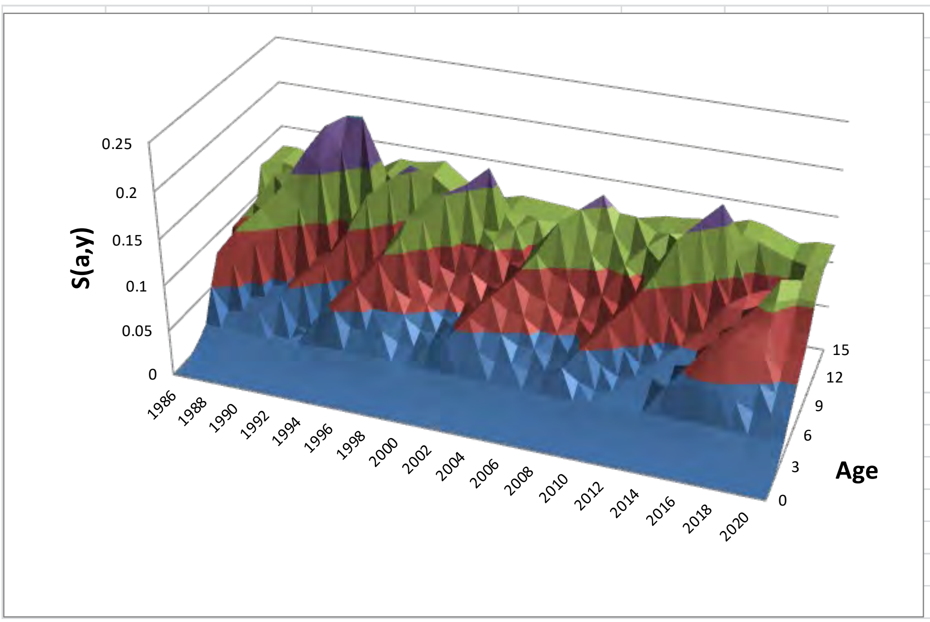

Figure 2. TISVPA – derived selection pattern.

Figure 3 represents the results of retrospective runs.

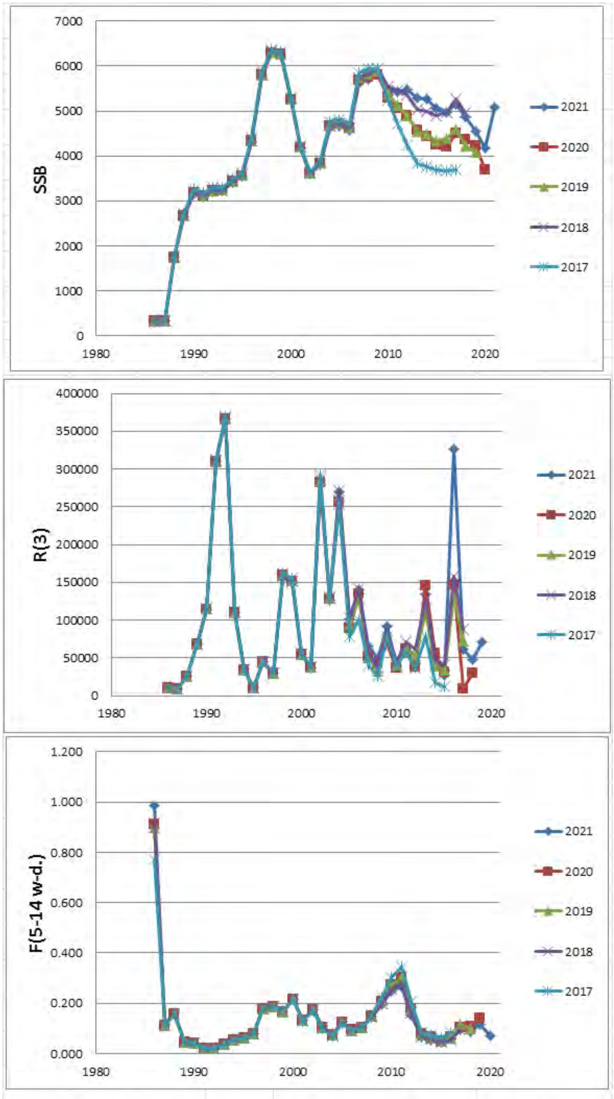

Figure 3. TISVPA retrospective runs

The residuals of the model approximation of the data are presented below.

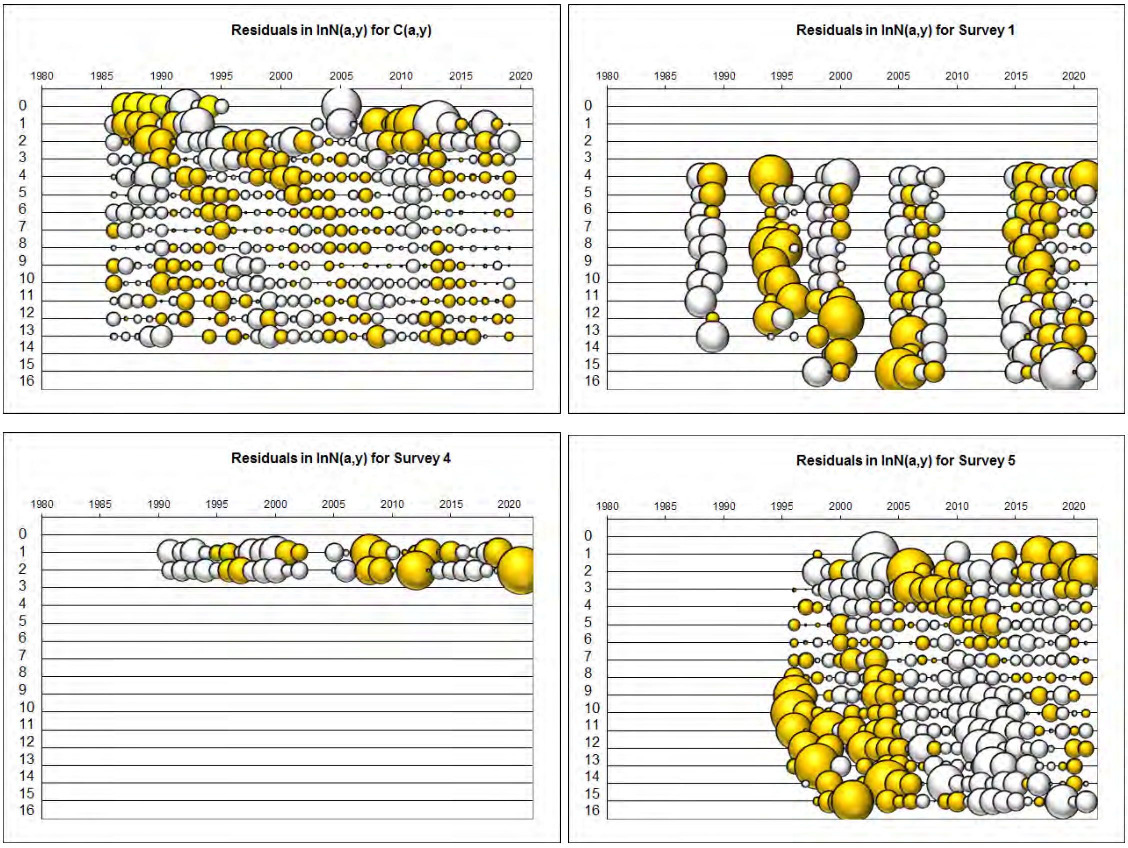

Figure 4. Residuals of the TISVPA data approximation.

The estimates of uncertainty in the results (parametric conditional bootstrap with respect to catch-at-age; “fleet” data were noised by lognormal noise with sigma=0.3) are presented on Figure 5.

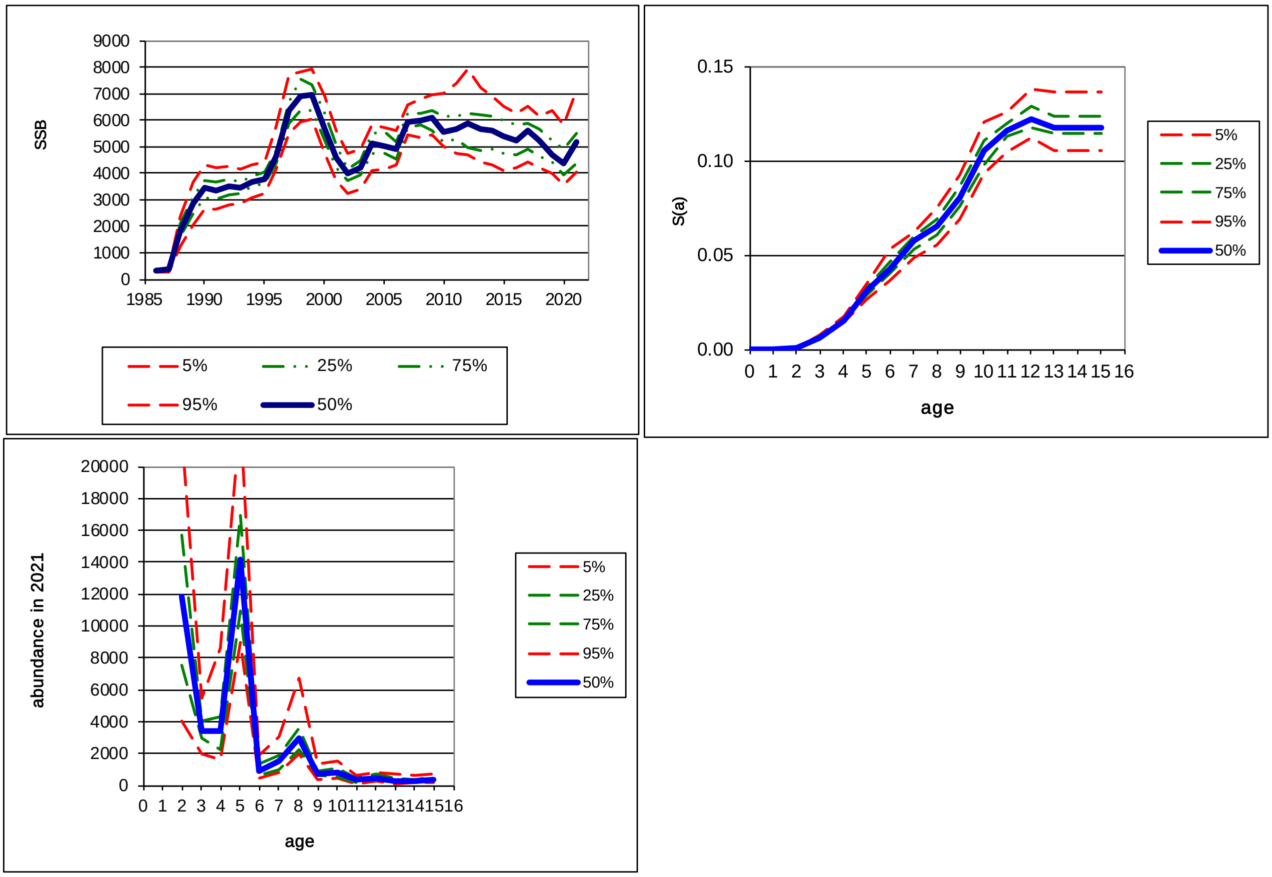

Figure 5. Bootstrap- estimates of uncertainty in the results.

Tables 1-3 represent the results of NSS herring stock assessment by means of TISVPA.

	B(0+)	SSB	R(0)	F(5-14)w-(
1986	1691	331	9992	0.988
1987	2845	332	9091	0.116
1988	3010	1733	25603	0.160
1989	3462	2656	68208	0.047
1990	3932	3166	114264	0.041
1991	4599	3086	309952	0.022
1992	5674	3206	366528	0.022
1993	6819	3218	110224	0.038
1994	7950	3413	34621	0.056
1995	8866	3548	10384	0.064
1996	9156	4325	45026	0.080
1997	9218	5783	29971	0.180
1998	7840	6294	157828	0.188
1999	8177	6254	150571	0.168
2000	7677	5253	54194	0.216
2001	6290	4179	36714	0.132
2002	6284	3602	280801	0.176
2003	7320	3815	126349	0.108
2004	8696	4629	269488	0.079
2005	9312	4661	101257	0.128
2006	10251	4563	140306	0.095
2007	9905	5625	65356	0.104
2008	10233	5712	48510	0.146
2009	9785	5817	91935	0.196
2010	9093	5441	39000	0.250
2011	7881	5419	60828	0.267
2012	7329	5465	42109	0.155
2013	7144	5292	135058	0.066
2014	7228	5267	50014	0.056
2015	7151	5067	26718	0.046
2016	6872	4966	325706	0.060
2017	8149	5152	61479	0.095
2018	8840	4884	47697	0.088
2019	7868	4545	70669	0.116
2020	7888	4175		0.071
2021		5093		

Table 1. NSS herring stock assessments results by means of TISVPA

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986	9992	21453	1672	18029	166	47	62	209	133	63	78	40	133	110	0	3
1987	9091	4058	8721	677	14882	126	26	27	113	41	28	22	14	12	10	1
1988	25603	3692	1648	3528	562	11916	92	15	11	72	15	15	12	6	3	1
1989	68208	10405	1500	666	2958	453	9214	68	8	4	48	4	9	7	2	0
1990	114264	27729	4230	603	570	2518	378	7570	55	6	3	38	3	7	5	5
1991	309952	46455	11273	1715	509	486	2152	313	6245	45	4	1	30	2	6	10
1992	366528	126016	18886	4582	1470	435	417	1840	262	5199	37	3	1	25	0	0
1993	110224	149018	51234	7677	3933	1246	371	357	1573	219	4300	31	2	1	0	0
1994	34621	44812	60585	20823	6579	3317	1018	312	304	1330	174	3383	26	2	1	16
1995	10384	14075	18219	24620	17839	5561	2618	775	256	256	1111	124	2440	20	1	2
1996	45026	4222	5723	7402	21039	14977	4375	1846	524	205	209	897	60	1491	0	0
1997	29971	18306	1716	2317	6305	17437	11724	3156	1251	357	163	171	709	35	755	1
1998	157828	12185	7443	691	1907	5116	13138	8273	2046	678	196	109	125	520	14	271
1999	150571	64168	4954	3000	557	1488	4030	9605	5862	1376	381	102	71	100	292	211
2000	54194	61217	26089	2011	2498	453	1172	3104	6911	4092	921	206	61	38	67	207
2001	36714	22034	24889	10591	1676	1850	352	898	2294	4726	2626	559	94	31	17	114
2002	280801	14927	8958	10112	9019	1351	1344	272	696	1746	3395	1834	398	57	22	32
2003	126349	114165	6069	3622	8535	7302	988	911	198	505	1232	2144	1159	252	35	27
2004	269488	51370	46414	2464	3063	7081	5723	726	644	146	368	864	1366	774	172	73
2005	101257	109564	20884	18849	2100	2565	5770	4426	545	456	105	271	616	895	519	64
2006	140306	41168	44544	8479	15908	1734	2054	4452	3129	373	286	61	178	408	524	181
2007	65356	57044	16736	18083	7207	13105	1406	1594	3261	2099	242	163	31	107	243	219
2008	48510	26572	23190	6797	15343	5922	10032	1086	1171	2273	1370	152	97	16	68	171
2009	91935	19723	10792	9415	5770	12612	4453	6962	770	778	1435	749	81	39	2	162
2010	39000	37378	8017	4352	7915	4745	9765	2998	4442	520	443	783	342	29	21	90
2011	60828	15856	15175	3237	3640	6447	3805	7138	1767	2492	287	190	322	95	11	20
2012	42109	24731	6412	6092	2712	2955	5122	2949	5001	906	1298	140	61	120	35	10
2013	135058	17120	10054	2601	5095	2252	2400	4065	2284	3578	507	743	78	24	58	14
2014	50014	54911	6960	4080	2200	4210	1875	1968	3270	1798	2657	318	514	51	15	61
2015	26718	20334	22325	2828	3486	1852	3436	1564	1625	2655	1440	2006	215	384	35	66
2016	325706	10863	8267	9073	2420	2955	1542	2824	1308	1341	2158	1159	1564	161	292	75
2017	61479	132422	4416	3359	7763	2047	2439	1250	2277	1076	1087	1710	919	1196	114	251
2018	47697	24995	53837	1790	2846	6453	1648	1878	934	1695	834	814	1244	691	824	237
2019	70669	19392	10162	21871	1522	2394	5284	1292	1444	702	1271	640	614	910	492	65
2020	0	28732	7884	4128	18656	1264	1927	4106	980	1050	495	901	455	444	610	475
2021	0	0	11681	3201	3509	15568	1024	1522	3162	737	763	341	606	301	295	405

Table 2. NSS herring. TISVPA. Estimates of abundance-at-age

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986	0.000	0.000	0.005	0.051	0.130	0.471	0.862	0.301	1.063	0.453	0.649	0.960	2.605	2.398	0.000	2.398
1987	0.000	0.000	0.005	0.042	0.106	0.171	0.571	0.948	0.298	1.107	0.488	0.565	0.775	1.392	1.392	1.392
1988	0.000	0.000	0.004	0.033	0.083	0.159	0.191	0.581	0.868	0.290	1.137	0.406	0.447	0.900	0.900	0.900
1989	0.000	0.000	0.001	0.009	0.021	0.046	0.055	0.060	0.148	0.206	0.088	0.214	0.096	0.167	0.167	0.000
1990	0.000	0.000	0.001	0.006	0.016	0.009	0.048	0.053	0.053	0.136	0.197	0.071	0.165	0.122	0.122	0.122
1991	0.000	0.000	0.000	0.003	0.007	0.003	0.006	0.029	0.029	0.031	0.080	0.096	0.035	0.056	0.056	0.056
1992	0.000	0.000	0.000	0.003	0.007	0.008	0.004	0.007	0.032	0.033	0.036	0.080	0.093	0.051	0.000	0.000
1993	0.000	0.000	0.001	0.005	0.012	0.029	0.020	0.010	0.015	0.069	0.076	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.000	0.001	0.008	0.019	0.055	0.068	0.041	0.019	0.030	0.149	0.138	0.122	0.149	0.149	0.149
1995	0.000	0.000	0.001	0.012	0.029	0.058	0.122	0.139	0.078	0.036	0.060	0.266	0.236	0.241	0.241	0.241
1996	0.000	0.000	0.002	0.016	0.039	0.076	0.112	0.222	0.234	0.133	0.062	0.090	0.403	0.339	0.000	0.000
1997	0.000	0.000	0.003	0.029	0.071	0.150	0.201	0.277	0.554	0.618	0.336	0.126	0.176	0.720	0.720	0.720
1998	0.000	0.000	0.003	0.023	0.058	0.098	0.174	0.211	0.271	0.562	0.660	0.294	0.107	0.543	0.543	0.543
1999	0.000	0.000	0.002	0.018	0.044	0.079	0.105	0.168	0.190	0.252	0.543	0.512	0.228	0.383	0.383	0.383
2000	0.000	0.000	0.002	0.020	0.050	0.120	0.129	0.157	0.239	0.281	0.396	0.741	0.662	0.451	0.451	0.451
2001	0.000	0.000	0.001	0.011	0.028	0.081	0.094	0.091	0.104	0.160	0.195	0.225	0.373	0.229	0.229	0.229
2002	0.000	0.000	0.002	0.018	0.046	0.114	0.196	0.207	0.187	0.221	0.370	0.379	0.425	0.404	0.404	0.404
2003	0.000	0.000	0.001	0.013	0.033	0.079	0.117	0.182	0.179	0.167	0.205	0.284	0.279	0.278	0.278	0.278
2004	0.000	0.000	0.001	0.009	0.023	0.044	0.077	0.105	0.151	0.153	0.149	0.154	0.202	0.187	0.187	0.187
2005	0.000	0.000	0.002	0.014	0.035	0.072	0.096	0.155	0.198	0.302	0.320	0.259	0.257	0.296	0.296	0.296
2006	0.000	0.000	0.002	0.016	0.039	0.069	0.114	0.139	0.211	0.283	0.463	0.404	0.311	0.334	0.334	0.334
2007	0.000	0.000	0.002	0.015	0.038	0.083	0.096	0.146	0.167	0.264	0.373	0.509	0.424	0.327	0.327	0.327
2008	0.000	0.000	0.002	0.022	0.053	0.143	0.169	0.179	0.257	0.306	0.533	0.639	0.880	0.490	0.490	0.490
2009	0.000	0.000	0.003	0.025	0.063	0.107	0.249	0.267	0.263	0.401	0.510	0.761	0.888	0.610	0.610	0.610
2010	0.000	0.000	0.003	0.032	0.081	0.097	0.199	0.443	0.441	0.450	0.772	0.806	1.250	0.863	0.863	0.863
2011	0.000	0.000	0.004	0.034	0.085	0.118	0.146	0.278	0.597	0.621	0.669	0.958	0.949	0.931	0.931	0.931
2012	0.000	0.000	0.002	0.021	0.051	0.072	0.101	0.113	0.197	0.418	0.453	0.396	0.510	0.465	0.465	0.465
2013	0.000	0.000	0.001	0.010	0.024	0.033	0.047	0.060	0.063	0.111	0.233	0.209	0.179	0.194	0.194	0.194
2014	0.000	0.000	0.001	0.007	0.017	0.041	0.034	0.044	0.053	0.056	0.104	0.182	0.158	0.138	0.138	0.138
2015	0.000	0.000	0.001	0.006	0.014	0.036	0.045	0.034	0.041	0.051	0.057	0.088	0.148	0.106	0.106	0.106
2016	0.000	0.000	0.001	0.007	0.016	0.044	0.059	0.068	0.048	0.060	0.078	0.073	0.110	0.125	0.125	0.125
2017	0.000	0.000	0.001	0.011	0.028	0.073	0.110	0.138	0.148	0.107	0.140	0.153	0.139	0.230	0.230	0.230
2018	0.000	0.000	0.001	0.010	0.023	0.055	0.086	0.119	0.140	0.154	0.116	0.128	0.135	0.190	0.190	0.190
2019	0.000	0.000	0.001	0.011	0.027	0.051	0.089	0.128	0.165	0.201	0.232	0.146	0.155	0.217	0.217	0.217
2020	0.000	0.000	0.001	0.013	0.031	0.060	0.085	0.111	0.135	0.170	0.224	0.247	0.264	0.258	0.258	0.258

Table 3. NSS herring. TISVPA. Estimates of fishing mortality coefficients

References

1. Vasilyev D. 2005 Key aspects of robust fish stock assessment. M: VNIRO Publishing, 2005. 105 p.

2. Vasilyev D. 2006. Change in catchability caused by year class peculiarities: how stock

assessment based on separable cohort models is able to take it into account? (Some illustrations for triple-separable case of the ISVPA model - TISVPA). ICES CM 2006/O:18. 35 pp

Survey report

MS *Eros* and **MS** *Vendla* **12.-26.02.2021**

Distribution and abundance of Norwegian spring-spawning herring during the spawning season in 2021

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Summary

During the period 12-26th of February 2021 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* and MS *Vendla.* The estimated biomass was around 23 % higher and the estimated total number was about 35 % higher this year compared to the last year's survey. The uncertainty of the estimates in 2021 was approximately equal to last year. The surveyed population of NSS herring was dominated by the 2016 year class; 59 % in number and 48 % in biomass. In this survey, the 2016 year class is estimated to be on the same level as the strong 1983, 1991 and 2002 year classes. The spatial distribution of the spawning stock in 2021 was different compared to the last six surveys as a large fraction of the stock was found at and around the Røst bank west of Lofoten. The herring here were far in their maturation, either spawning or close to spawning, indicating a northern spawning distribution this year. As usual, the herring in the southern part of the spawning area were older than those found in the northern part. 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 12-26.02.2019:

MS *Eros*	
Erling Kåre Stenevik	Cruise leader
Lage Drivenes	Instrument/Acoustics
Jori Neteland-Kyte	Instrument /Acoustics
Ørjan Sørensen	Biology
Jostein Røttingen	Biology
Christine Djønne	Biology
Lea Marie Hellenbrecht	Biology
Sindre Vatnehol	Acoustics
MS *Vendla*	
Are Salthaug	Cruise leader and Survey coordinator
Jarle Kristiansen	Instrument/Acoustics
Kristoffer Ingebrigtsen Monsen	Instrument/Acoustics
Valantine Anthonypillai	Biology
Adam Custer	Biology
Timo Meissner	Biology
Erling Boge	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 survey, hereafter termed the NSSH spawning survey, has continued with a survey design using commercial vessels. In the ICES benchmark assessment of NSS herring in 2016 it was 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. Thus, the results from the NSSH spawning survey, have significant influence on the ICES catch advice.

The objective of the NSSH spawning survey 2021 was to continue the time series of abundance estimates, both mean estimates and uncertainty in, for use in the ICES WGWIDE stock assessment. Moreover, other biological information about the surveyed spawning stock of Norwegian spring-spawning herring is also presented: spatial distribution of biomass and acoustic densities, total biomass and stock numbers with sample uncertainty, spatial patterns in age and maturity and geographical variations in temperature.

Material and methods

Survey design

During the period 12-26th of February 2021 (same period as in 2017-2020) the spawning grounds from Møre (62º20´N) to Troms (70º40´N) were covered acoustically by the commercial fishing vessels MS *Eros* 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 2020 up to the survey start February 12th 2021 (Figure 1). The fishery prior to the survey in 2021 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 around 200 m depth southwards from Træna as also observed in 2016-2020. Moreover, a quite extensive fishery in October-January 2020/2021 occurred along the continental slope north of Andenes in addition to the fishery in the Kvænangen fjord area that also have been taking place the three previous years. Biological samples from catches from the northern fishery indicate that the 2016 year class dominated in this area. The survey coverage was therefore planned to also take account of a potentially large flux of herring entering the spawning area from the north. As seen from Figure 1, the fishery during the survey in 2021 mainly took place between Træna and Vikna (65-66.5°N).

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 assumed density structures of herring during the spawning migration (based on previous surveys and fisheries). All strata this year were covered with a zigzag design since this is the most efficient use of survey effort (Harbitz 2019). The survey planner function in the Rstox package in r was used to generate the transects, and this function generates survey tracks with uniform coverage of strata and a random starting position in the start of each stratum. Each straight line in the zigzag track within a stratum was considered as a transect and a primary sampling unit (Simmonds and MacLennan 2005). Transit tracks between strata, i.e. from the end of the zigzag in one stratum to the start of the zigzag in the next stratum, were not used as primary sampling units. At the start of the survey in 2021 the fishing fleet was located west of Træna which is further north than usual in mid-February. It was estimated that the fleet had moved south to the Sklinna bank area around 65°N when the survey entered this area, therefore the survey coverage (see Aglen 1989) was planned to be relatively low south of 64°N since it was assumed that the fishing fleet followed the front of the herring migrating south and that the abundance of herring south of the fleet therefore was insignificant.

Biological sampling

Trawl sampling was planned to be 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. Vendla used a commercial herring trawl while Eros used a Multpelt 832 scientific sampling trawl. Both vessels used small meshed (20 mm) inner net in the codend and a slit (so called "splitt") close to the codend to avoid too large catches. The following variables of individual herring were analysed for from each station with herring catch: total weight in grams and total length 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 in grams were measured in up to 50 individuals per sample. Some genetic samples and otoliths were also collected to be used in later research projects.

Additional data collection

CTD casts (using Seabird 911 systems) were taken by both vessels, spread out haphazardly in the survey area. These measurements will be used to analyse and explore the temperature conditions during the survey and the temperature and salinity measurements will be used for general oceanographic analyses in future projects. ADCP data was recorded on Eros as described in Annex 2 in Salthaug et al. (2020). These data will later be used to analyse swimming speed and direction of herring below the vessel.

Acoustic data processing

Echosounder data from the 38 kHz transducers was, as usual, the basis for measurement of fish density. The software LSSS version 2.10.0 was use for post-processing. Echogram scrutinisation was carried out by at least two experienced persons. Data was partitioned into the following categories: "herring", "other" and "air bubbles" (upper 20 meters from the transducer near field).

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 version 3.0 (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:

$$\hat{V}\left(\hat{S}_i\right) = \frac{n}{n_i - 1} \sum_{t=1}^{n} w_{it}^2 (s_t - \bar{s})^2 \quad \text{with } \bar{s}_i = \frac{1}{n_i} \cdot \sum_{t=1}^{n_i} s_t \tag{4}$$

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. 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 2021 as another year in the time series.

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

Survey coverage

The cruise tracks of the NSSH spawning survey in 2021 are shown in Figure 2. As mentioned above, the coverage south of 64°N was fairly low since we expected low abundance in this area, which turned out to be the case (see below). Thus, most of the available survey effort was used to carry out dense coverage of the strata north of 64°N. The survey coverage (see Aglen 1989) of the first three strata north of 64°N was 11 while it was 9 in the two northernmost strata. Pelagic trawl hauls were carried out regularly (Fig. 2) in the areas where herring like records were observed on the echo sounder, to confirm the acoustic observations based on species composition in the catch and to obtain biological samples like size, maturity stage and age of herring. A total of 24 CTD casts were carried out in the surveyed area (Fig. 2). Nautical area scattering coefficients (NASC) from acoustic transects by each nautical mile are shown in Figure 3. Significant herring marks on the echosounders started to occur around 65°N as expected, and herring was observed in the entire area north of this. A difference compared with earlier years was that large amounts of herring was observed on the Røst bank west of Lofoten. In earlier years the herring was mainly distributed around the shelf edge further west in this area. Moreover, herring was also abundant in the northernmost stratum and the zero line was not established in the west here.

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 abundance estimates are shown in Table 1 and 2. For quality assurance, independent estimates were made by two scientists, giving less than 0.1% difference between estimates of abundance at age. The 2016 year class (age 5) dominated both in numbers (59 %) and biomass (48 %). The point estimate of total stock biomass (TSB) in the survey area was 4.02 tons which is 23 % higher than last year's estimate (mean of 1000 bootstrap replicates). The time series of total stock biomass from the survey is shown in Figure 4. This year's estimate of TSB is very close to the mean of the time series. The point estimate of total stock number (TSN) in the survey area was 17.3 billion which is 35 % higher than last year's estimate. The time series of total stock number from the survey is shown in Figure 5. This year's estimate of TSN is slightly above the mean of the time series. The relative standard error (CV) of the TSB estimate in 2021 is 15 % (Tab. 2) and the CV of the TSN estimate is 16 % (Tab. 1). These estimates of sample uncertainty are very similar to those from last year's survey. The CV per age (Tab.1 and 2) shows the normally observed pattern with high uncertainty for the very young and old year classes and moderate (20-30 %) for the most abundant ages in the survey. Figure 6a shows estimates of number per year class in the seven most recent surveys. The estimated numbers from the survey in 2021 seems to decline as excepted for the year classes that are fully recruited to the survey and the estimated year class strengths are in line with the estimates from earlier surveys. The number of age 5 (2016 year class) is the highest observed for an age group during the seven last years (Fig. 6a). Figure 6b shows estimates of number per year class from the two most recent IESNS surveys which are carried out in the Norwegian Sea in May together with the two most recent NSSH spawning surveys. Both surveys use the same target strength for herring, but the herring behave very differently during spawning and feeding migration, which may affect the acoustic abundance estimation. Still, the indices of year class abundance and their trends from these surveys are well in line with each other, signifying that both surveys are capturing the dynamics in this stock well despite different survey coverage and design. The 2016 year class started to recruit notably to the IESNS survey as 3 year olds in 2019 and slightly more to the spawning survey as 4 year olds in 2020 while strongly to IESNS in 2020. This indicates that a large proportion of the 2016 year class still was immature as 4 year olds. In the 2021 spawning survey the 2016 year class started to recruit strongly as 5 year olds, however the estimate is a bit lower than in IESNS 2020. Note that the estimates for most year classes are lower in IESNS than in the spawning survey within the same year, despite that the surveys are carried out only 3 months apart. These differences may be due to mortality and/or differences in survey catchability. The time series from the spawning survey of age 5 is shown in Figure 7 for comparison of the 2016 year class estimate with earlier strong year classes, and this year class is estimated to be on the same level as the strong 1983, 1991 and 2002 year classes. Mean weight and length from the 2021 spawning survey are shown in Table 3.

Spatial distribution of the stock

The relative distribution of the estimated biomass per stratum is shown in Figure 8. A large proportion of the biomass (64%) was found in the two strata west of Lofoten on and around the Røst bank. The northernmost stratum also contained a significant proportion of the biomass (17 %). Compared with the most recent surveys the biomass was found further north this year. Age compositions per stratum are shown in Figure 9. The proportions of age 5 (2016 year class) are high in all strata but they decline from north to south, which is in line with the normally observed pattern with the oldest herring furthest south and domination of young herring in the north. However, the proportion of herring older than ten years was significant in all strata south of 69°N and this is also the case for the moderate 2013 year class (age 8). The pattern with large and old fish in the southern part of the spawning area and younger and older herring in the north 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). Figure 10 shows the proportion of different maturation stages in each stratum. Spawning (or running) herring were found in all strata which means that spawning occurred over a large area this year. Most of the sampled individuals were either maturing, ripe or spawning, but a small fraction of the herring in the northernmost stratum was immature and some spent/resting individuals were found south of Lofoten. The fact that a large proportion of the herring from Sklinna and northwards along Vesterålen were in ripe stages (just about to spawn) suggest that the spawning this year would tend to occur in the areas we observed the high densities of herring. Hence, a very northern spawning this year, which also was confirmed through the fishery that was very low at the historically important spawning grounds off Møre and dried out quickly in the Sklinna area after the spawning survey ended.

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 5°-8°C (Figure 11). At typical spawning depths of herring at 100-200 m depth, the temperature conditions were quite similar to those observed during the most recent NSSH spawning surveys.

Quality of the survey

In 2021 both vessels were equipped with multifrequency equipment on a drop keel. Even though the weather conditions were sometimes challenging with occasionally strong wind, acoustic data with good quality was recorded and trawling on registrations could be carried out most of the time. Correction for air bubble attenuation (see Annex 3 in Slotte et al. 2019) had to be done in only a very few instances. As in earlier years, some of the young herring 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 in the north since the zero line not was established on the western limit of the northernmost stratum. However, the capelin survey covered this area a week after and the observations indicates that the amount of herring outside the NSSH spawning survey area was low. It should be noted that it is assumed in the ICES stock assessment of NSS herring that 5 year olds are not fully recruited in this survey (this information is contained in the catchability parameters). To conclude, the acoustic and biological data recorded in 2021 on the NSSH spawning survey were of satisfactory quality and the estimates from the survey are recommended to be used in the stock assessment of Norwegian spring-spawning herring in 2021.

References

Aglen, A. 1989. Empirical results on precision effort relationships for acoustic surveys. Int. Coun. Explor. Sea CM 1989 B:30, 28pp.

Demer, D.A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 pp.

Foote, K. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987.

Harbitz, A. 2019.A zigzag survey design for continuous transect sampling with guaranteed equal coverage probability. Fisheries Research 213, 151-159.

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods in Ecology and Evolution 10:1523–1528.

Jolly, G.M., and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 47: 1282-1291.

Korneliussen, R. J., and Ona, E. 2002. An operational system for processing and visualizing multi-frequency acoustic data. ICES Journal of Marine Science, 59: 293–313.

Korneliussen, R. J., Ona, E., Eliassen, I., Heggelund, Y., Patel, R., Godø, O.R., Giertsen, C., Patel, D., Nornes, E., Bekkvik, T., Knudsen, H.P., Lien, G. The Large Scale Survey System - LSSS. Proceedings of the 29th Scandinavian Symposium on Physical Acoustics, Ustaoset 29 January– 1 February 2006.

MacLennan, D.N., Fernandes, P., and Dalen, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES J. Mar. Sci., 59: 365-369.

Ona, Egil. 1999.An expanded target-strength relationship for herring."ICES Journal of Marine Science: Journal du Conseil 60: 493-499.

Ona, E. (Ed). 1999. Methodology for target strength measurements (with special reference to *in situ* techniques for fish and mikro-nekton. ICES Cooperative Research Report No. 235. 59 pp.

Simmonds, J, and David N. MacLennan. 2005. Fisheries acoustics: theory and practice. John Wiley & Sons, 2008.

Slotte, A. 1998*a*. Patterns of aggregation in Norwegian spring spawning herring (*Clupea harengus* L.) during the spawning season. ICES C. M. 1998/J:32.

Slotte, A. 1998*b*. Spawning migration of Norwegian spring spawning herring (*Clupea harengus* L.) in relation to population structure. Ph. D. Thesis, University of Bergen, Bergen, Norway. ISBN : 82-7744-050-2.

Slotte, A. 1999*a*. Effects of fish length and condition on spawning migration in Norwegian spring spawning herring (*Clupea harengus* L). *Sarsia* **84**, 111-127.

Slotte, A. 1999*b*. Differential utilisation of energy during wintering and spawning migration in Norwegian spring spawning herring. *Journal of Fish Biology* **54**, 338-355.

Slotte, A. 2001. Factors Influencing Location and Time of Spawning in Norwegian Spring Spawning Herring: An Evaluation of Different Hypotheses. In: F. Funk, J. Blackburn, D. Hay, A.J. Paul, R. Stephenson, R. Toresen, and D. Witherell (eds.), Herring: Expectations for a New Millennium. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks, pp. 255-278.

Slotte, A. and Dommasnes, A. 1997. Abundance estimation of Norwegian spring spawning at spawning grounds 20 February-18 March 1997. Internal cruise reports no. 4. Institute of Marine Research, P.O. Box. 1870. N-5024 Bergen, Norway.

Slotte, A. and Dommasnes, A. 1998. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 1998. *Fisken og Havet* 5, 10 pp.

Slotte, A. and Dommasnes, A. 1999. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 1999. *Fisken og Havet* **12**, 27 pp.

Slotte, A and Dommasnes, A. 2000. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2000. *Fisken og Havet* 10, 18 pp.

Slotte, A. and Fiksen, Ø. 2000. State-dependent spawning migration in Norwegian spring spawning herring (*Clupea harengus* L.). Journal of Fish Biology 56, 138-162.

Slotte, A. & Tangen, Ø. 2005. Distribution and abundance of Norwegian spring spawning herring in 2005. Institute of Marine Research, P. O. Box 1870 Nordnes, N-5817 Bergen (www.imr.no). ISSN 1503-6294/Cruise report no. 4 2005.

Slotte, A. and Tangen, Ø. 2006. Distribution and abundance of Norwegian spring spawning herring in 2006. Institute of Marine Research, P. O. Box 1870 Nordnes, N-5817 Bergen (www.imr.no). ISSN 1503-6294/Cruise report no. 1. 2006.

Slotte, A, Johannessen, A and Kjesbu, O. S. 2000. Effects of fish size on spawning time in Norwegian spring spawning herring (*Clupea harengus* L.). Journal of Fish Biology 56: 295-310.

Slotte A., Johnsen, E., Pena, H., Salthaug, A., Utne, K. R., Anthonypillai, A., Tangen , Ø and Ona, E. 2015. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2015. Survey report / Institute of Marine Research/ISSN 1503 6294/Nr. 5 – 2015

Slotte, A., Salthaug, A., Utne, KR, Ona, E., Vatnehol, S and Pena, H. 2016. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2016. Survey report / Institute of Marine Research/ /ISSN 1503 6294/Nr. 17–2016

Slotte, A., Salthaug, A., Utne, KR, Ona, E. 2017. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2017. Survey report / Institute of Marine Research/ ISSN 15036294/Nr. 8 – 2017

Slotte A., Salthaug, A., Høines, Å., Stenevik E. K., Vatnehol, S and Ona, E. 2018. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2018. Survey report / Institute of Marine Research/ISSN 15036294/Nr. 5– 2018.

Slotte, A., Salthaug, A., Stenevik, E.K., Vatnehol, S. and Ona, E. 2019 Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2019. Survey report / Institute of Marine Research/ISSN 15036294/Nr. 2– 2019.

Salthaug, A., Stenevik, E.K., Vatnehol, S., Anthonypillai, V., Ona, E. and Slotte, A. Distribution and abundance of Norwegian spring spawning herring during the spawning season in 2020. Survey report / Institute of Marine Research/ISSN 15036294/Nr. 3– 2020.

Vikebø, F., Korosov, A., Stenevik, E.K., Husebø, Å. Slotte, A. 2012. Spatio-temporal overlap of hatching in Norwegian spring spawning herring and spring phytoplankton bloom at available spawning substrates – observational records from herring larval surveys and SeaWIFS. ICES Journal of Marine Science, 69: 1298-13

Tables

Table 1. Abundance estimates (million individuals) of Norwegian spring-spawning herring during the spawning survey 12.-26. February 2021, based on 1000 bootstrap replicates.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	2	20	47	21	14	0.68
3	41	99	225	112	60	0.53
4	142	285	488	293	106	0.36
5	7197	10124	13346	10210	1892	0.19
6	376	738	1101	733	222	0.30
7	515	729	984	738	149	0.20
8	1352	1890	2627	1932	389	0.20
9	243	423	617	427	116	0.27
10	307	442	626	451	97	0.21
11	166	305	484	312	100	0.32
12	127	216	325	219	61	0.28
13	162	387	653	395	145	0.37
14	129	201	318	208	58	0.28
15	325	502	717	510	119	0.23
16	87	181	301	185	67	0.36
17	213	348	512	353	93	0.26
18	23	99	192	102	54	0.53
20	2	2	6	3	2	0.62
TSN	12888	17124	21790	17250	2705	0.16

Table 2. Abundance estimates (thousand tons) of Norwegian spring-spawning herring during the spawning survey 12.-26. February 2021, based on 1000 bootstrap replicates.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	0	1	3	1	1	0.79
3	3	9	21	10	6	0.56
4	23	43	68	44	14	0.32
5	1352	1900	2492	1912	355	0.19
6	86	160	235	160	45	0.28
7	145	206	278	209	42	0.20
8	404	563	779	575	115	0.20
9	78	133	194	135	36	0.27
10	102	146	206	148	31	0.21
11	58	107	171	110	35	0.32
12	47	78	118	80	22	0.27
13	59	136	223	138	49	0.36
14	46	72	114	75	21	0.28
15	118	184	264	186	44	0.24
16	31	66	109	67	24	0.36
17	79	127	187	129	34	0.26
18	9	37	73	39	20	0.53

Age	5th percentile	Median	95th percentile	Mean	SD	CV
20	1	1	2	1	1	0.59
TSB	3038	3997	5072	4021	622	0.15

Table 3. Estimated length and weight of individuals by age group of Norwegian spring-spawning herring during the spawning survey 12.-26. February 2021, based on 1000 bootstrap replicates.

Age	Mean weight (g)	CV weight	Mean length (cm)	CV length
2	44.3	0.256	19.8	0.096
3	103.1	0.179	25.3	0.045
4	160.3	0.064	28.9	0.018
5	193.0	0.015	30.1	0.003
6	222.4	0.037	31.5	0.010
7	285.1	0.011	33.7	0.004
8	302.1	0.007	34.3	0.002
9	321.1	0.015	35.2	0.005
10	335.6	0.017	35.6	0.006
11	352.0	0.017	36.5	0.005
12	365.5	0.013	36.9	0.004
13	358.1	0.020	36.6	0.009
14	360.7	0.015	36.8	0.004
15	372.6	0.010	37.1	0.003
16	376.7	0.040	37.5	0.008
17	376.3	0.014	37.3	0.004
18	379.7	0.028	37.6	0.009
20	341.7	0.017	35.5	0.000

Figures

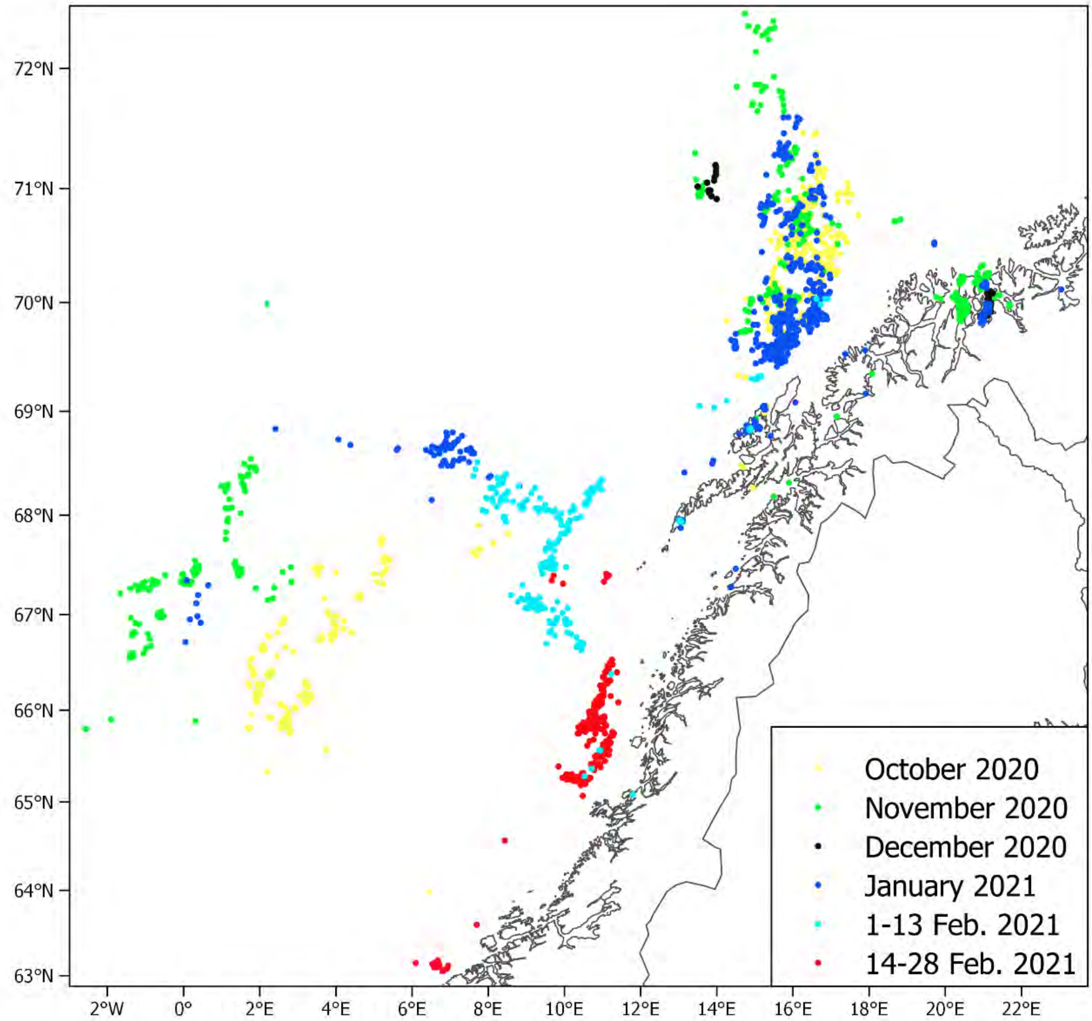


Figure 1. Distribution of commercial catches of Norwegian spring-spawning herring from October 2020 until February 2021, based on electronic logbooks. Each point represent one catch, only catches larger than 10 tons are shown.

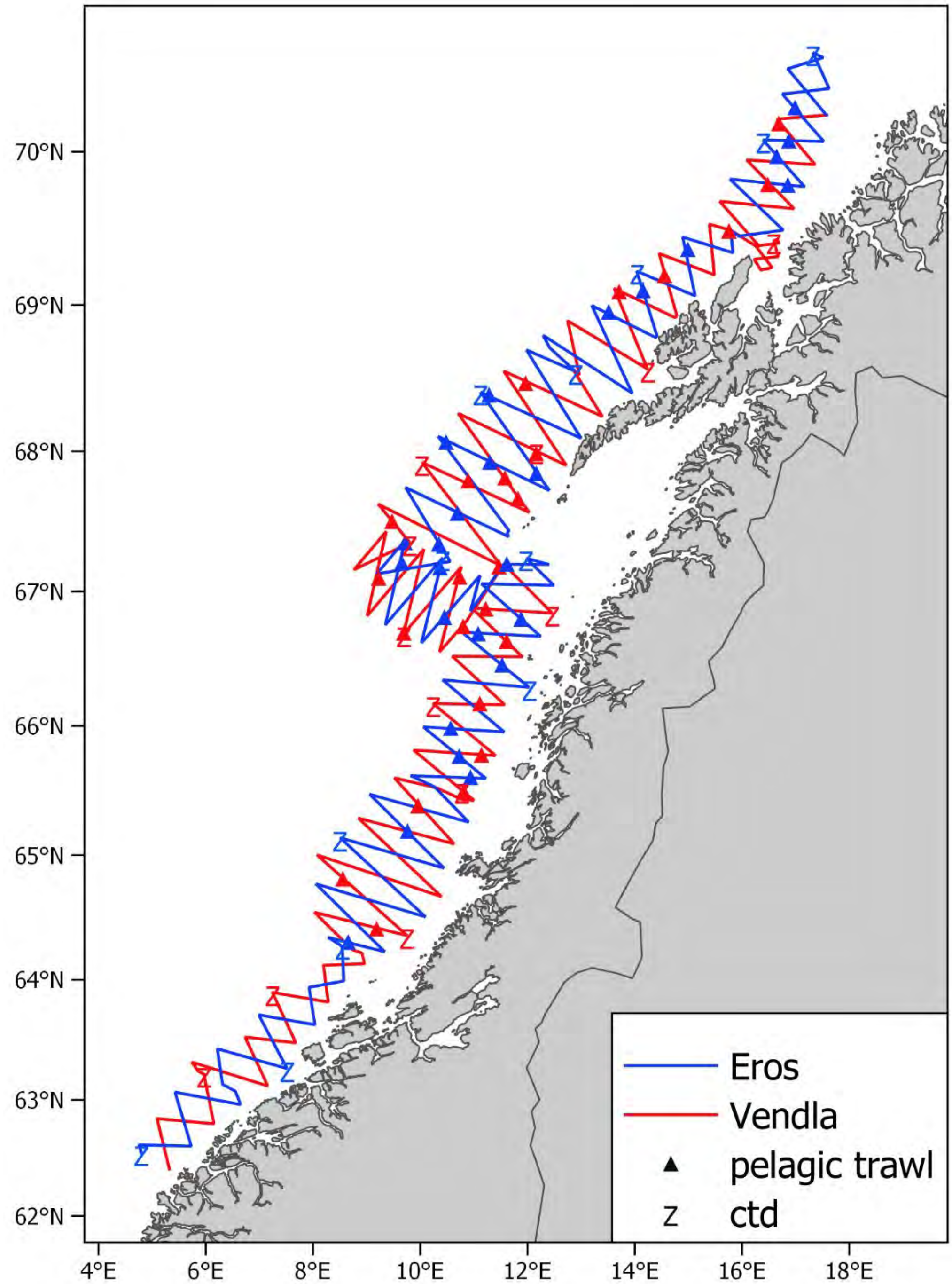


Figure. 2. Cruise tracks (mostly acoustic transects), pelagic trawl stations (triangles), and CTD stations (Z) covered by *Eros* and *Vendla* on the Norwegian spring-spawning herring spawning survey 12.-26. February 2021.

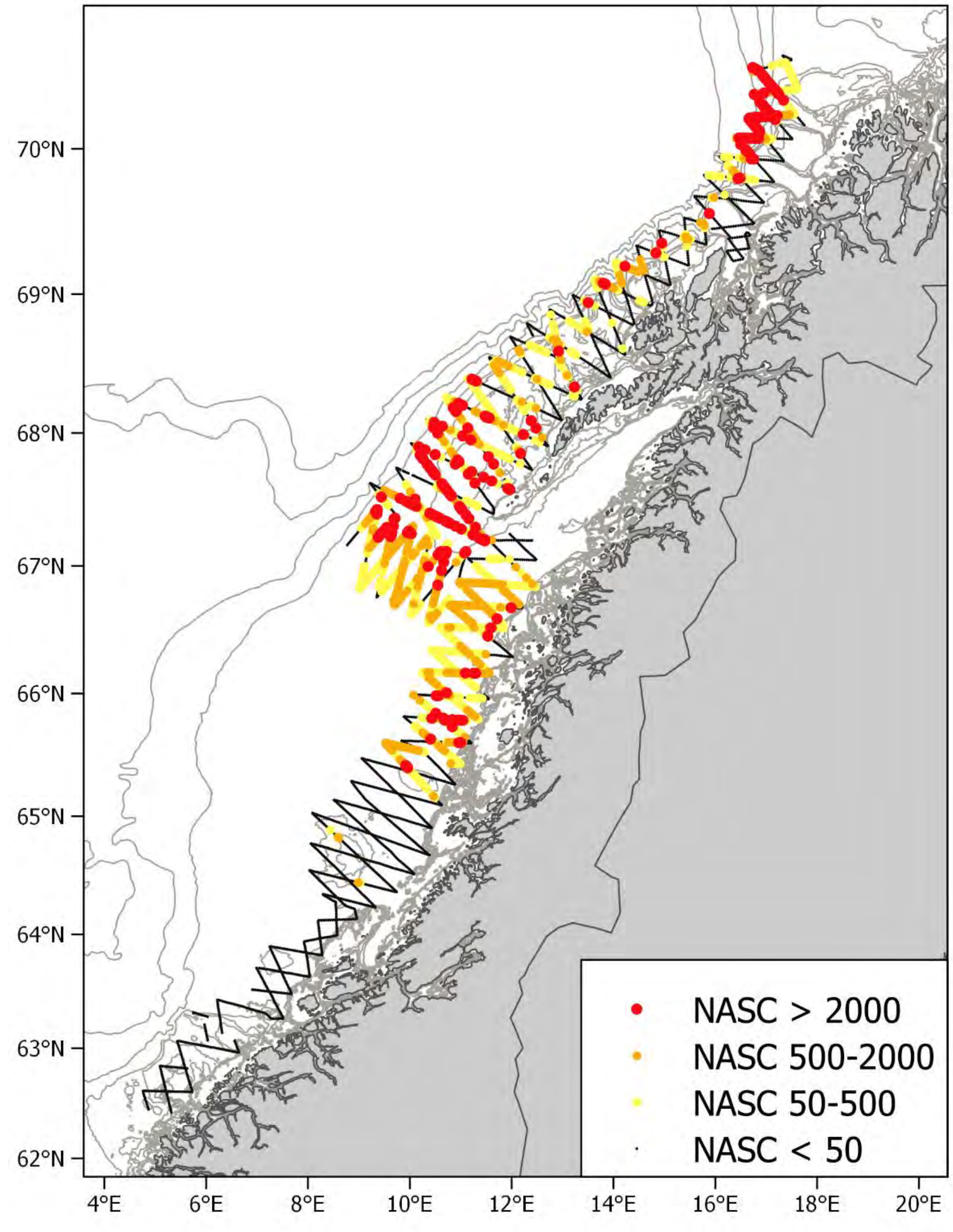


Figure 3. Acoustic densities (NASC) of herring recorded during the Norwegian spring-spawning herring spawning survey 12.-26. February 2021. Points represent NASC values per nautical mile. Depth contours are shown for 50 m, 100 m, 150 m, 200 m, 500 m, 1000 m, 1500 m and 2000 m.

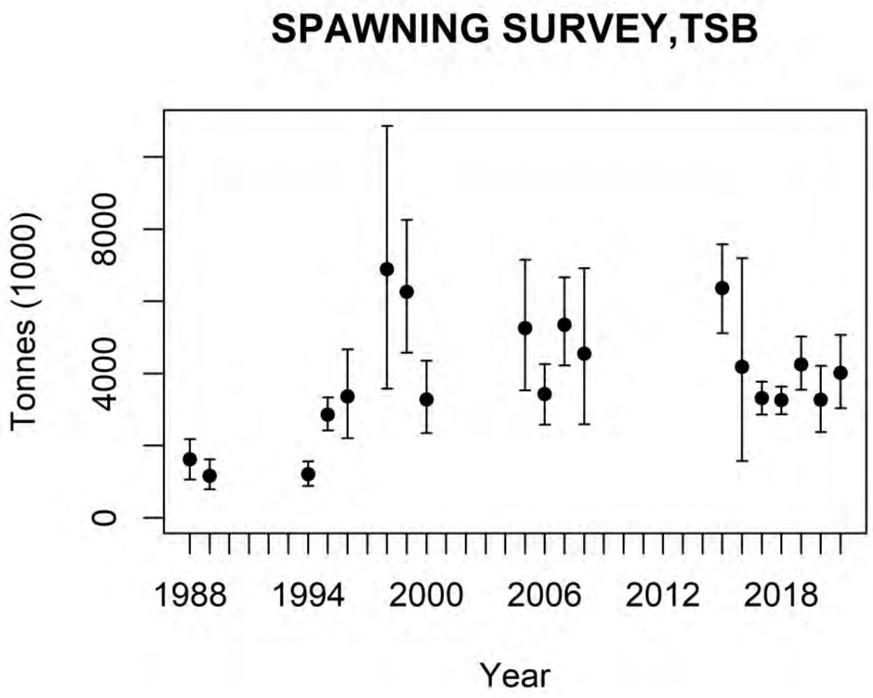


Figure 4. Estimates of total biomass from the Norwegian spring-spawning herring spawning surveys during1988-2021. The estimates are mean of 1000 bootstrap replicates and the error bars represent 90 % confidence intervals.

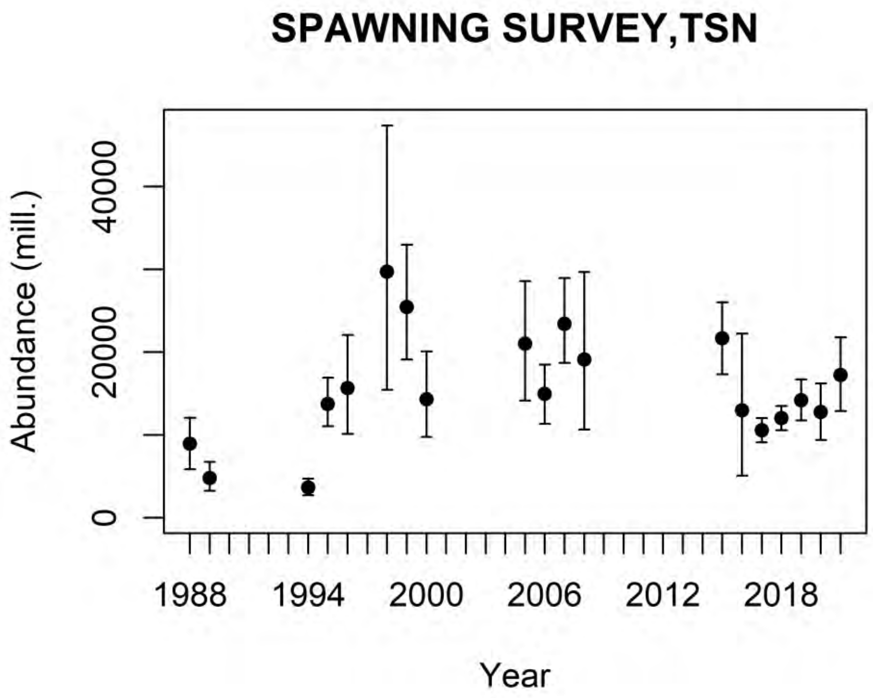


Figure 5. Estimates of total number from the Norwegian spring-spawning herring spawning surveys during1988-2021. The estimates are mean of 1000 bootstrap replicates and the error bars represent 90 % confidence intervals.

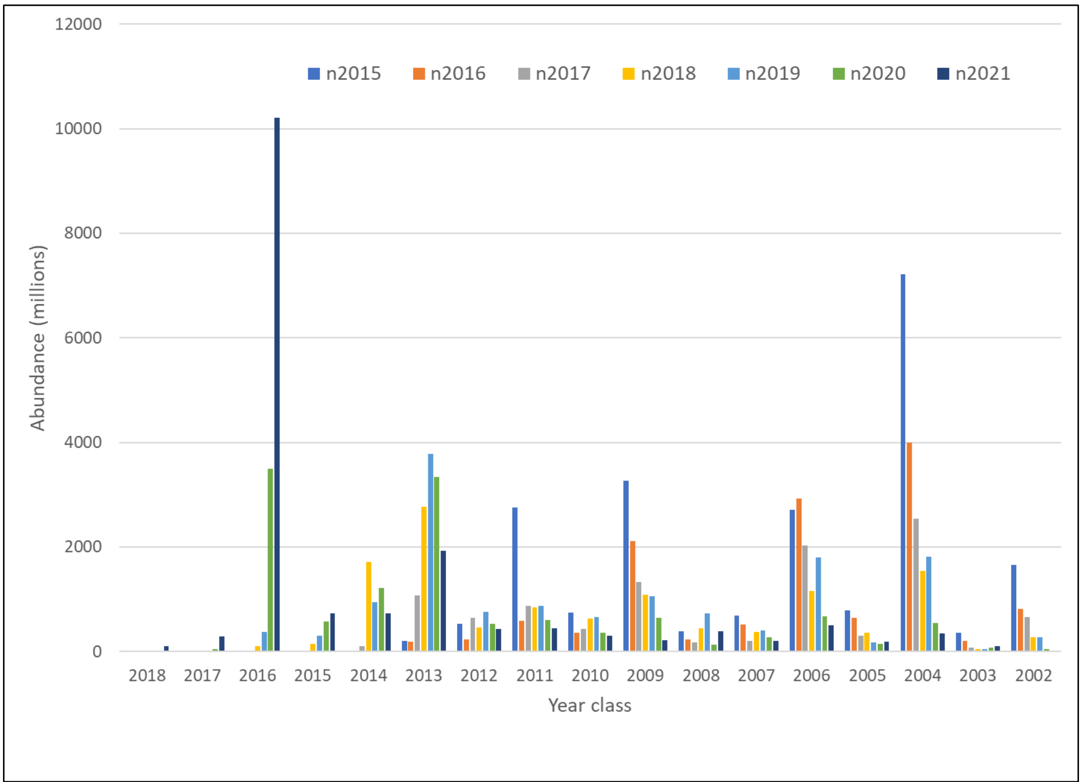


Figure 6a. Abundance by year class estimated during the Norwegian spring-spawning herring spawning surveys 2015-2021 (mean of 1000 bootstrap replicates). Legend: Separate colour for each survey year.

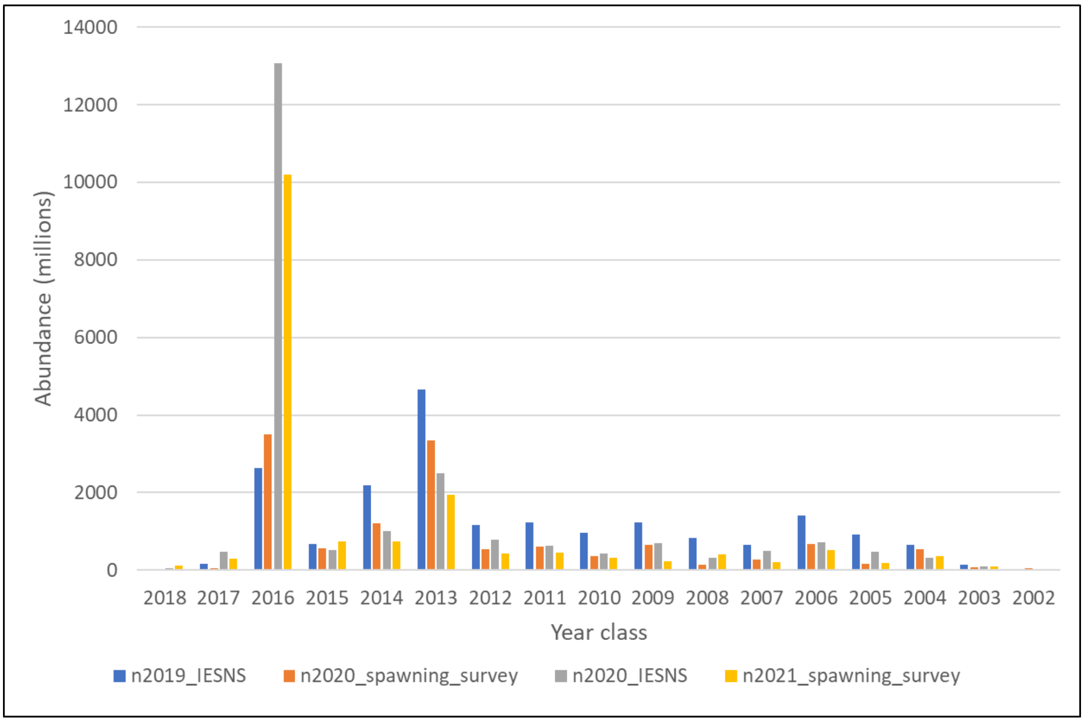


Figure 6b. Abundance by year class estimated during the International Ecosystem Survey in Nordic Seas (IESNS) 2019-2020 and the Norwegian spring-spawning herring spawning survey 2020-2021 (mean of 1000 bootstrap replicates). Legend: Separate colour for each survey and year.

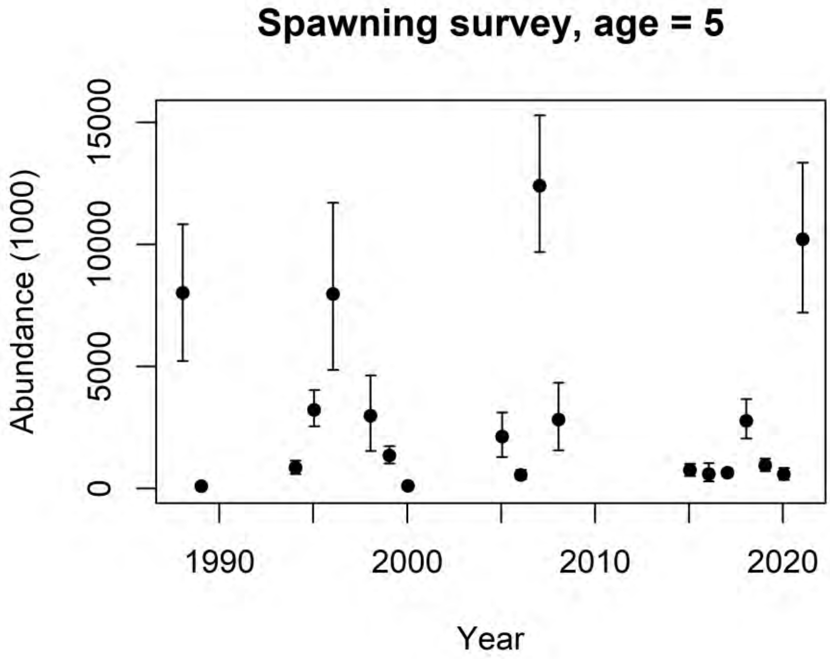


Figure 7. Estimated abundance of 5 year old herring from Norwegian spring-spawning herring spawning surveys during1988-2021. The estimates are mean of 1000 bootstrap replicates and the error bars represent 90 % confidence intervals.

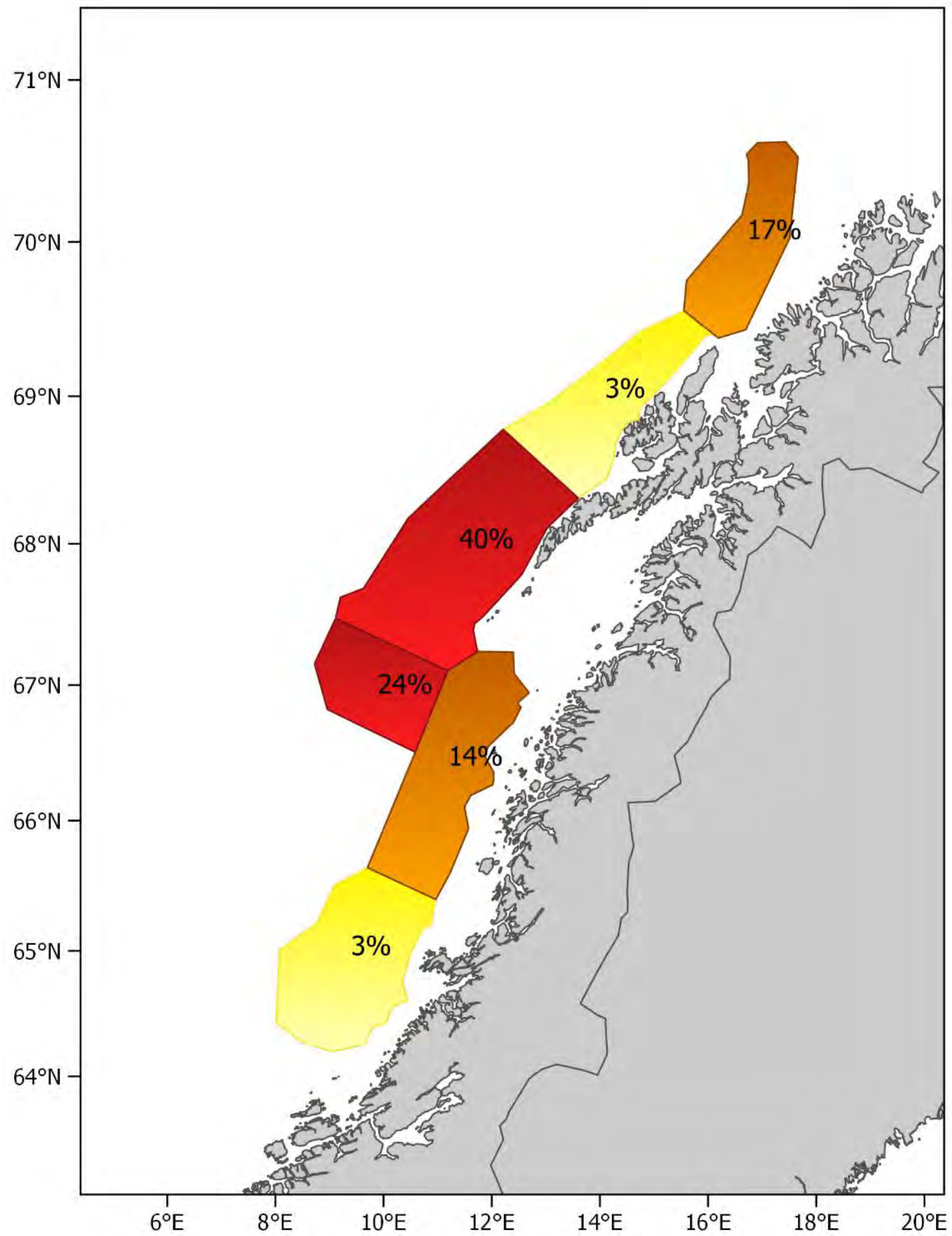


Figure 8. Relative distribution by stratum of the biomass of herring (mean of 1000 bootstrap replicates) from the Norwegian spring-spawning herring spawning survey 12.-26. February 2021.

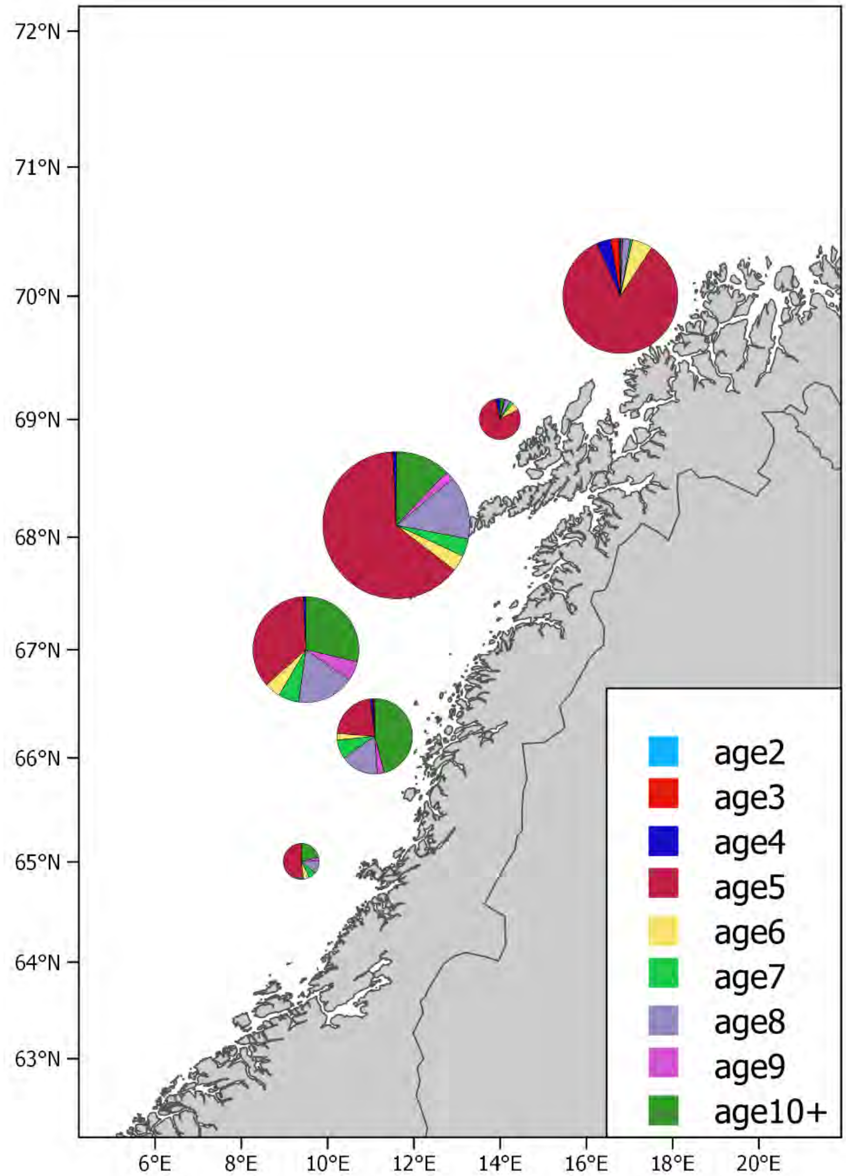


Figure 9. Age distribution per stratum from the Norwegian spring-spawning herring spawning survey 12.-26. February 2021. The area of the bubbles is scaled with the total number estimated in each stratum.

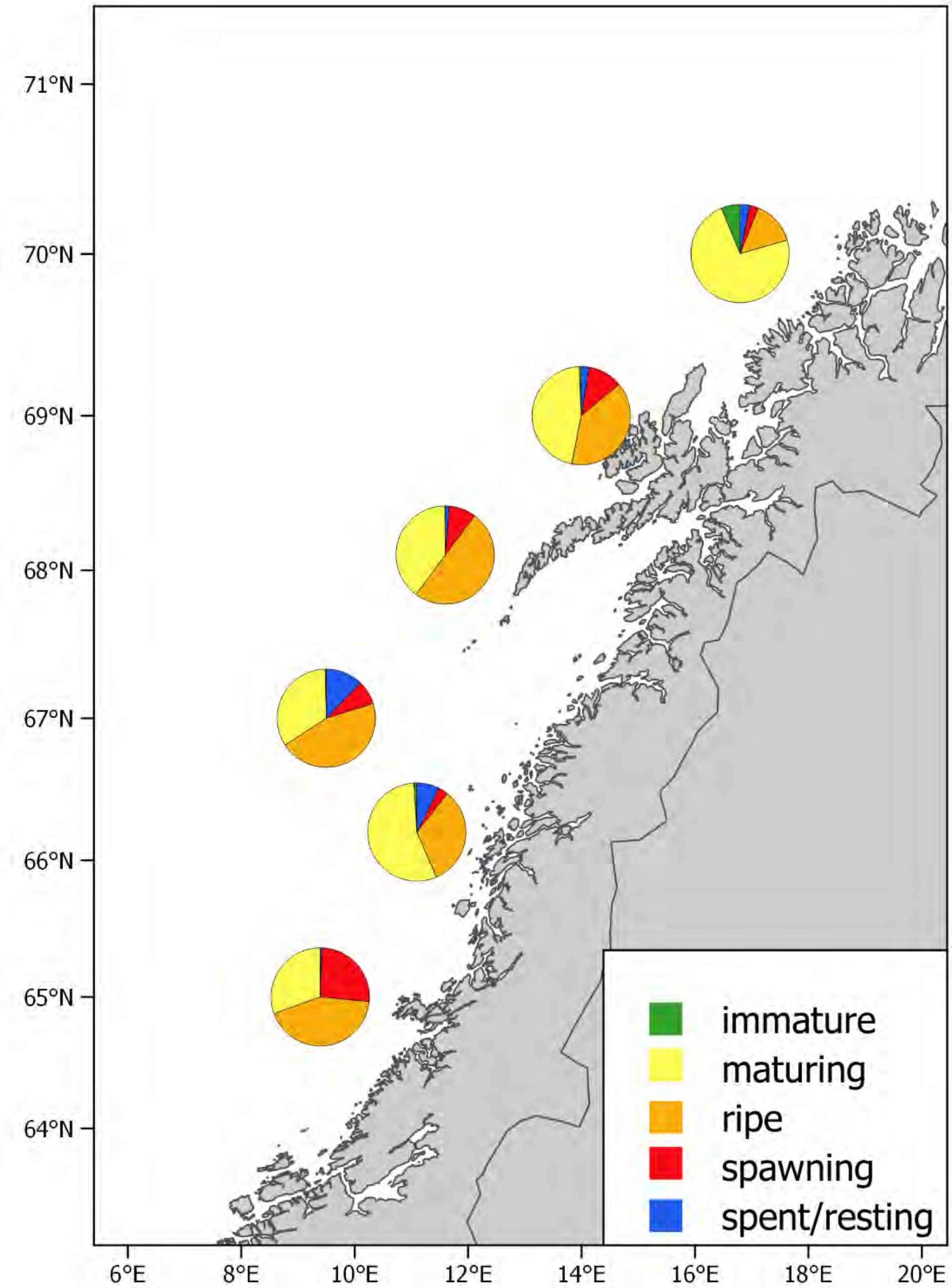


Figure 10. Proportions of different maturity stages from the Norwegian spring-spawning herring spawning survey 12.-26. February 2021.

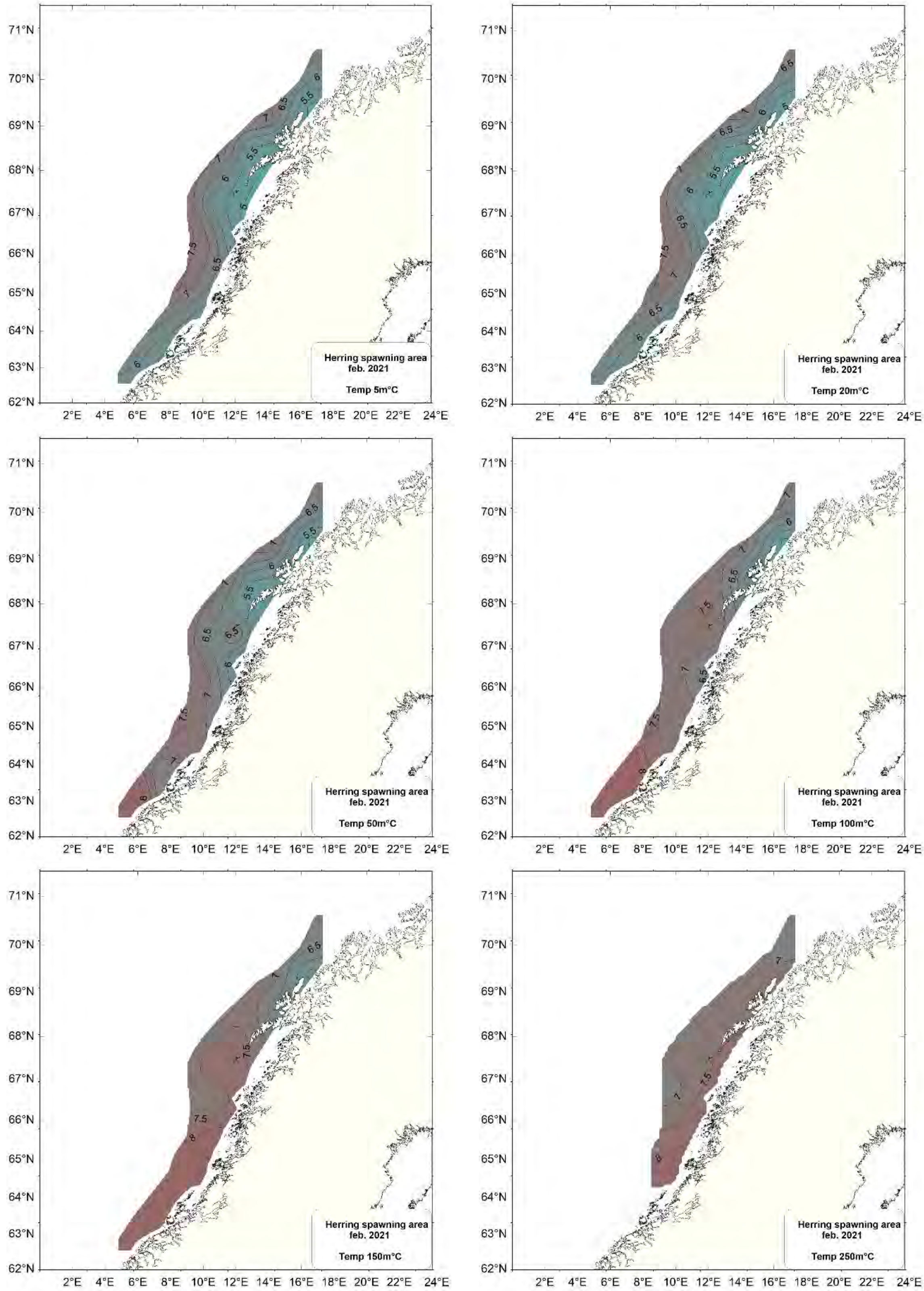
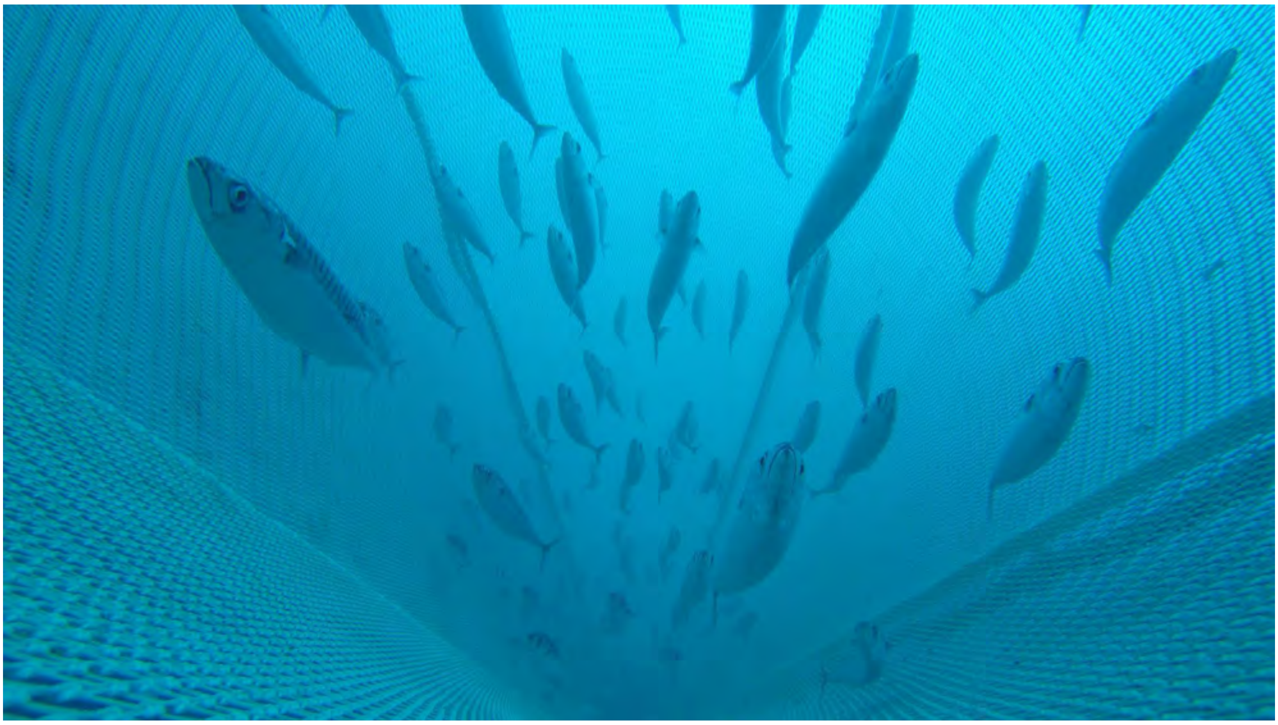


Figure 11. Temperature at 5, 20, 50, 100, 150, 250 m in the area covered during the Norwegian spring-spawning herring spawning survey 12.-26. February 2021.

Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE, No. 09)
ICES HQ, Copenhagen, Denmark, (digital meeting) 25. – 31. August 2021

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
30th June – 3rd August 2021



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Contents

1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from June 30th to August 3rd in 2021 using five vessels from Norway (2), Iceland (1), Faroe Islands (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 now consists of six years (2016-2021).

The survey coverage area included in calculations of the mackerel index was 2.2 million km^2 in 2021, which is 24% smaller coverage compared to 2020. Survey coverage was reduced in the western area as Greenlandic waters, Iceland basin (south of latitude 62°45′) and the Reykjanes ridge (south of latitude 62°45′) were not surveyed in 2021. Furthermore, 0.29 million km^2 was surveyed in the North Sea in July 2021 but those stations are excluded from the mackerel index calculations.

The total swept-area mackerel index in 2021 was 5.15 million tonnes in biomass and 12.2 billion in numbers, a decreased by 58% for biomass and 54% for abundance compared to 2020. Reduced survey coverage in the western area did not contribute to the observed decline as the zero mackerel boundary was established north, west, and south of Iceland. In 2021, the most abundant year classes were 2019, 2016, 2014, 2017 and 2012, respectively. The cohort internal consistency was slightly reduced compared to last year, particularly for ages 5-8 years.

Mackerel was distributed mostly in the central and northern Norwegian Sea, with low densities and limited distribution in Icelandic waters. Mackerel distribution in the North Sea was similar to 2020, but the biomass nearly doubled compared to 2020. Zero boundaries of the summer distribution of mackerel were found in most parts of the survey area, except towards northwest in the Norwegian Sea, southward boundaries in the North Sea and west of the British Isles.

The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2021 was 19.6 billion and the total biomass index was 5.91 million tonnes, which are similar results to 2020. The 2016 year-class (5year olds) dominated in the stock and contributed to 54% and 59% to the total biomass and total abundance, respectively, whereas the 2013 year-class (8-year olds) contributed 13% and 11% to the total biomass and total abundance, respectively. The 2016 year-class is considered fully recruited to the spawning stock in 2021, and also fully recruited to the survey area. The survey is considered to contain the whole adult part of the NSSH stock during the 2021 IESSNS.

The total biomass of blue whiting registered during IESSNS 2021 was 2.2 million tonnes, which is a 22% increase compared to 2020. Stock abundance (ages 1+) was estimated to 26.2 billion compared to 16.5 billion in 2020. The 2020 year-class dominate the estimate in 2021 and contributed 51% and 69% to the total biomass and abundance, respectively.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred between mackerel and North Sea herring in major parts of the North Sea and partly in the southernmost part of the Norwegian Sea. There were also some overlapping distributions of mackerel and Norwegian spring-spawning herring (NSSH) in the western, north-western and north-eastern part of the Norwegian Sea.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 78% of surface trawl stations distributed across the surveyed area from

southwestern part of Iceland, central part of North Sea to southwestern part of the Svalbard. Abundance was greater north of latitude 72°N compared to southern areas. A total of 35 North Atlantic salmon were caught in 25 stations both in coastal and offshore areas from 60°N to 76°N in the upper 30 m of the water column. The salmon ranged from 0.089 kg to 6.5 kg in weight, dominated by postsmolt weighing 89-425 grams and 1 sea-winter individuals (grilse) weighing 1.9-2.4 kg.

Satellite measurements of the sea surface temperature (SST) showed that the central and eastern part of the Norwegian Sea were roughly on same level as average for July 1990-2009. SST was 1-3 °C warmer than the long-term average in the Iceland Sea and the Greenland Sea. The North Sea SST was 1-2 °C warmer than long term average. CTD measurements from the central part of the Norwegian Sea indicated more stratification in the surface layer than in 2020.

Average zooplankton biomass in the Norwegian Sea has been relatively stable since 2013. There was, however, a small decrease in 2021 compared to last year, especially in the central and southern areas. A small increase was observed in the Iceland region compared to last year.

2 Introduction

During approximately five weeks of survey in 2021 (30th of June to 3rd of August), five vessels; the M/V "Eros" and M/V "Vendla" from Norway, R/V "Jákup Sverri" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland 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 from Norway, Iceland and Faroe Islands. 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. Greenland did not participate in 2021.

The North Sea was included in the survey area for the fourth time in 2021, 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 39 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 - 2020 results).

3 Material and methods

Coordination of the IESSNS 2021 was done during the WGIPS 2021 virtual meeting in January 2021, and by correspondence in spring and summer 2021. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were rougher in 2021 with periods of less favourable survey conditions for the Norwegian vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. The weather was windier and rougher sea conditions in longer periods than usual, especially during the last part of the first part and during the second part of the survey for the two Norwegian vessels in central and northern Norwegian Sea. There were also more days with fog in both the southern, central and northern part of the Norwegian Sea than previous years, influencing the visual observations. The Icelandic vessel, operating in Icelandic waters, experienced mostly calm weather with only 12-hours storm delay in total. The weather was mostly calm for the Faroese vessel operating mainly in Faroese, east Icelandic and international waters. The chartered vessel Ceton had excellent weather throughout the survey.

During the IESSNS, the special designed pelagic trawl, Multpelt 832, has 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 led 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 2021. 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.

Vessel	Effective survey period	Length of cruise track (nmi)	Total trawl stations/ Fixed stations	CTD stations	Plankton stations
Árni Friðriksson	5/7-26/7	4322	64/54	53	50
Jákup Sverri	2-19/7	3050	41/34	34	34
Ceton	30/6-9/7	2100	39/39	39	-
Vendla	1/7-3/8	5967	96/74	75	75
Eros	1/7-3/8	5836	79/69	75	75
Total	30/6-3/8	21275	319/270	276	234

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Eros, Vendla, Árni Friðriksson and Jákup Sverri were all equipped with a SEABIRD CTD sensor and Árni Friðriksson and Jákup Sverri moreover also had a water rosette. Eros used a SEABIRD 19+V2 CTD sensor. Ceton used a Seabird SeaCat offline CTD. The CTD-sensors were used for recording temperature, salinity and pressure (depth) from the surface down to 210 m, or to the bottom when at shallower depths.

Zooplankton was sampled with a WP2-net on 4 of 5 vessels, since Ceton did not take any plankton samples. Mesh sizes were 180 µm (Eros and Vendla) and 200 µm (Árni Friðriksson and Jákup Sverri). 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. The Icelandic and Norwegian vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting if catches were more than 500 kg. Sub-sample size ranged from 90 kg (if it was clean catch of either herring or mackerel) to 200 kg (if it was a mixture of herring and mackerel). The biological sampling protocol for trawl catch varied between nations in number of specimens sampled per station (Table 3).

Results from the survey expansion southward into the North Sea are analyzed separately from the traditional survey grounds north of latitude 60°N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017). However, data collected with the IESSNS methodology from the Skagerrak and the northern and western part of the North Sea are now available for 2018, 2019, 2020 and 2021.

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 30th June to 3rd August 2021. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Árni Friðriksson**	**Vendla**	**Ceton**	**Jákup Sverri**	**Eros**	**Influ-ence**
Trawl producer	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Egersund Trawl AS	0
Warp in front of doors	Dynex-34 mm	Dynex -34 mm	Dynex	Dynex – 38 mm	Dynex-34 mm	+
Warp length during towing	350	350	300-350	350	350-400	0
Difference in warp length port/starb. (m)	16	2-10	10	0-7	5-10	0
Weight at the lower wing ends (kg)	2×400 kg	2×400	2×400	2×400	2×400	0
Setback (m)	14	6	6	6	6	+
Type of trawl door	Jupiter	Seaflex 7.5 m^2 adjustable hatches	Thybron type 15	Injector F-15	Seaflex 7.5 m^2 adjustable hatches	0
Weight of trawl door (kg)	2200	1700	1970	2000	1700	+
Area trawl door (m^2)	6	7.5 with 25% hatches (effective 6.5)	8	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	5.2 (4.4-5.7)	4.6 (4.1-5.5)	4.8 (4.3-5.3)	4.5 (3.5-5.3)	4.7 (4.1-5.725)	+
Trawl height (m) mean (min-max)	33 (27-48)	28-37	27 (22-36)	45.1 (39 – 56)	25-32	+
Door distance (m) mean (min-max)	113 (102 - 118)	121.8 (118-126)	140 (125-153)	98.7 (89 – 111)	135 (113-140)	+
Trawl width (m)*	65.6	63.8	75.4	56.6	67.5	+
Turn radius (degrees)	5	5-12	5-10	5-6 BB turn	5-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	4-14, 5-28	6-22, 8-23	4-16	5-24, 6-26	(6-20)	+
Headline depth (m)	0	0	0	0	0	+
Float arrangements on the headline	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 + 2 buoys on each wingtip	Kite + 2 buoy on each wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighed	All weighted	+

* calculated from door distance (Table 6)

Table 3. Protocol of biological sampling during the IESSNS 2021. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Iceland	Norway	Denmark
Length measurements	Mackerel	200/100*	150	100	≥ 125
	Herring	200/100*	200	100	75
	Blue whiting	200/100*	100	100	75
	Lumpfish	all	all	all	all
	Salmon	-	all	all	-
	Capelin		100		
	Other fish sp.	20-50	50	25	As appropriate
Weight, sex and maturity determination	Mackerel	15-25	50	25	***
	Herring	15-25	50	25	0
	Blue whiting	6-50	50	25	0
	Lumpfish	10	1^	25	0
	Salmon	-	0	25	0
	Capelin		100		
	Other fish sp.	0	0	0	0
Otoliths/scales collected	Mackerel	15-25	25	25	***
	Herring	15-25	25	25	0
	Blue whiting	6-50	50	25	0
	Lumpfish	0	1	0	0
	Salmon	-	0	0	0
	Capelin		100		
	Other fish sp.	0	0	0	0
Fat content	Mackerel	0	10**	0	0
	Herring	0	10**	0	0
	Blue whiting	0	10	0	0
Stomach sampling	Mackerel	6	10**	10	0
	Herring	6	10**	10	0
	Blue whiting	6	10	10	0
	Other fish sp.	0	0	10	0
Tissue for genotyping	Mackerel	0	0	0	0
	Herring	0	0	0	0

*Length measurements / weighed individuals
**Sampled at every third station
*** One fish per cm-group ≤ 28 cm and two fish > 28 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

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 2.2 million km² (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 20th 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.

Underwater camera observations during trawling

M/V "Eros" 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 night-time when there was midnight sun and good underwater visibility. Video recordings were collected at 95 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes.

Deep Vision underwater stereo-camera system

A pilot study was conducted onboard M/V "Vendla" during first part of the IESSNS 2021 survey in the southern part of the Norwegian Sea using the underwater stereo camera system Deep Vision (Rosen et al. 2013). The major goal of this pilot study was to explore the practical and operational feasibility of applying and quantifying the use of stereo camera technology related correct species identification, catch numbers and size distribution of different species caught in the Multpelt 832 pelagic trawl, with particular focus on NEA mackerel. A total number of five trawl hauls were conducted onboard Vendla with the deep vision system from 1-18 July 2021. Results will be available later including an evaluation of whether Deep Vision can be used to quantify mackerel catches in a reliable way without collecting the mackerel, but rather trawl with an open cod-end.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by scientific personnel and crew members from the bridge between 1st July and 2nd August 2021 onboard M/V "Eros" and M/V "Vendla", and aboard R/V Árni Friðriksson from 5st until 26th July 2021. On board Jákup Sverri (between 1st and 19th July 2021) opportunistic observations were done from the bridge by crew members.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson", M/V "Eros" 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 Vendla and Eros were calibrated 30th June and 1st July 2021 respectively, for 18, 38, 70, 120 and 200 kHz. Árni Friðriksson was calibrated on May 4th 2021 for frequencies 18, 38, 70, 120 and 200 kHz. Jákup Sverri was calibrated on 22nd April 2021 for 18, 38, 120, 200 and 333 kHz. Ceton did not conduct any acoustic data collection because no calibrated equipment was available, and acoustics are done in the same area and period of the year during the ICES coordinated North Sea herring acoustic survey (HERAS). 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 2021.

	R/V Árni Friðriksson	M/V Vendla	Jákup Sverri	Eros
Echo sounder	Simrad EK80	Simrad EK60	Simrad EK80	Simrad EK80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, **38**, 70, 120, 200, 333	18, 38, 70, 120, 200, 333
Primary transducer	ES38-7	ES38B	ES38-7	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	8	9	6-9	8
Upper integration limit (m)	15	15	15	15
Absorption coeff. (dB/km)	10.5	10.1	10.7	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	3.064	2.43
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	18	21.90	21.9	21.9
2-way beam angle (dB)	-20.3	-20.70	-20.4	-20.7
TS Transducer gain (dB)	27.05	25.46	26.96	25.50
s_A correction (dB)	-0.02	-0.02	-0.16	-0.6
3 dB beam width alongship:	6.42	0.19	6.55	6.87
3 dB beam width athw. ship:	6.47	0.08	5.45	6.83
Maximum range (m)	500	500	500	500
Post processing software	LSSS v.2.10.1	LSSS v.2.8.1	LSSS 2.10.1	LSSS v.2.8

M/V Ceton: No acoustic data collection because other survey in the same area in June/July (HERAS).

Multibeam sonar

Both M/V Eros 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 Eros and Vendla for the entire survey.

Cruise tracks

The five 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, of which 11 are permanent and two dynamic (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 2021 is shown in Figure 3. The cruising speed was between 10-11 knots if the weather permitted, otherwise the cruising speed was adapted to the weather situation.

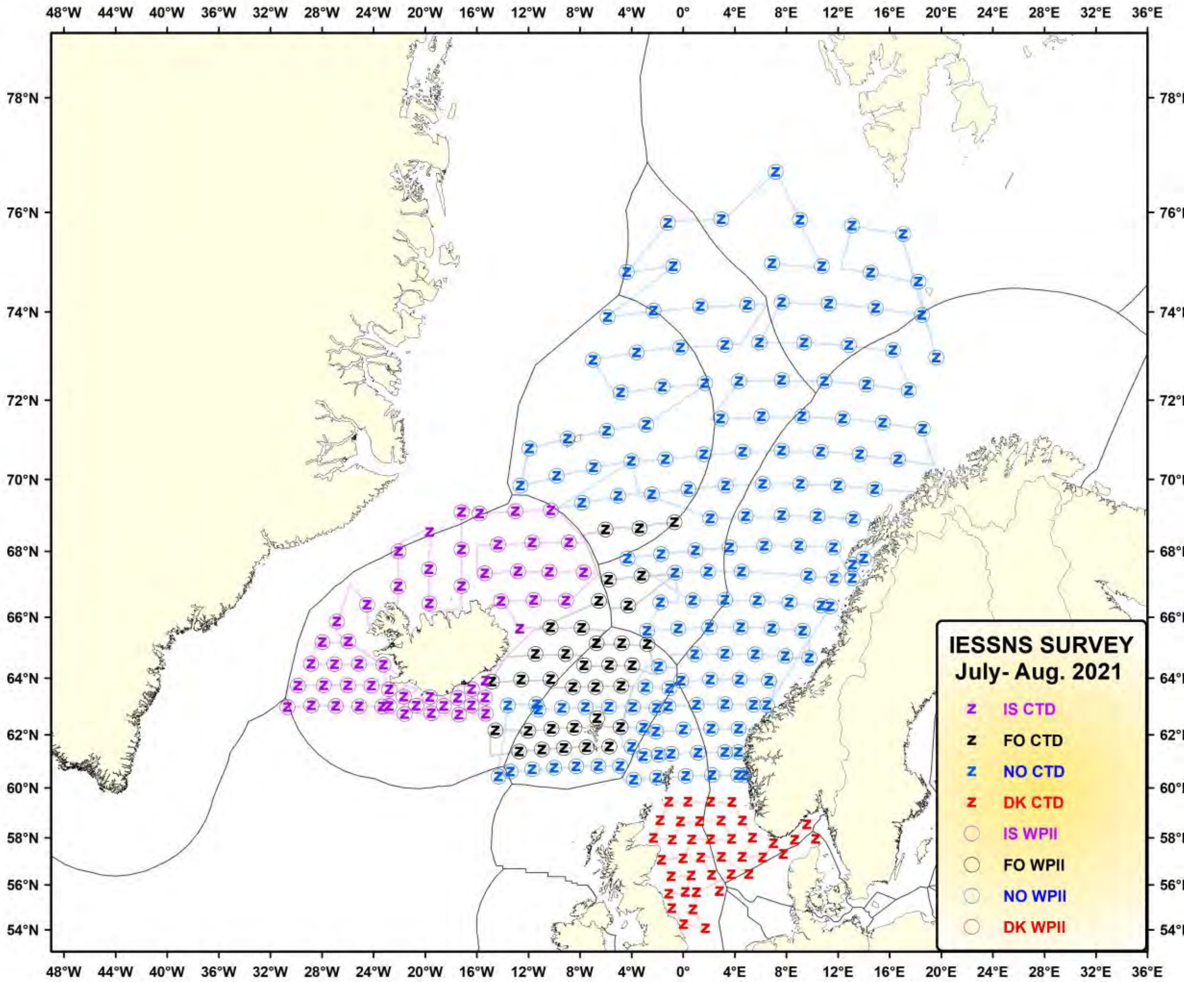


Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS from June 30th to August 3rd 2021. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Jákup Sverri (black), Vendla and Eros (blue), and Ceton (red).

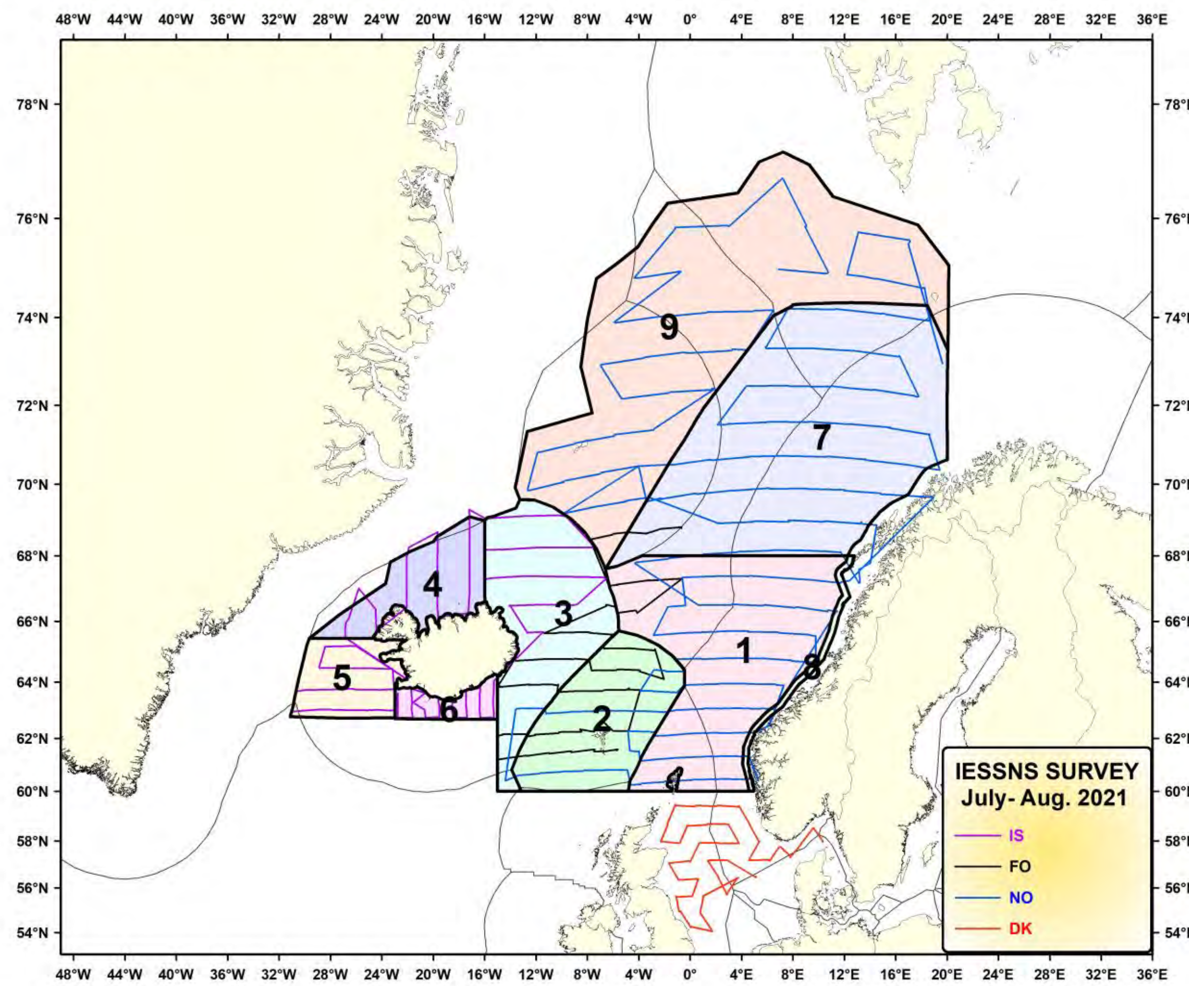


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2021. The dynamic strata are: 4 and 9.

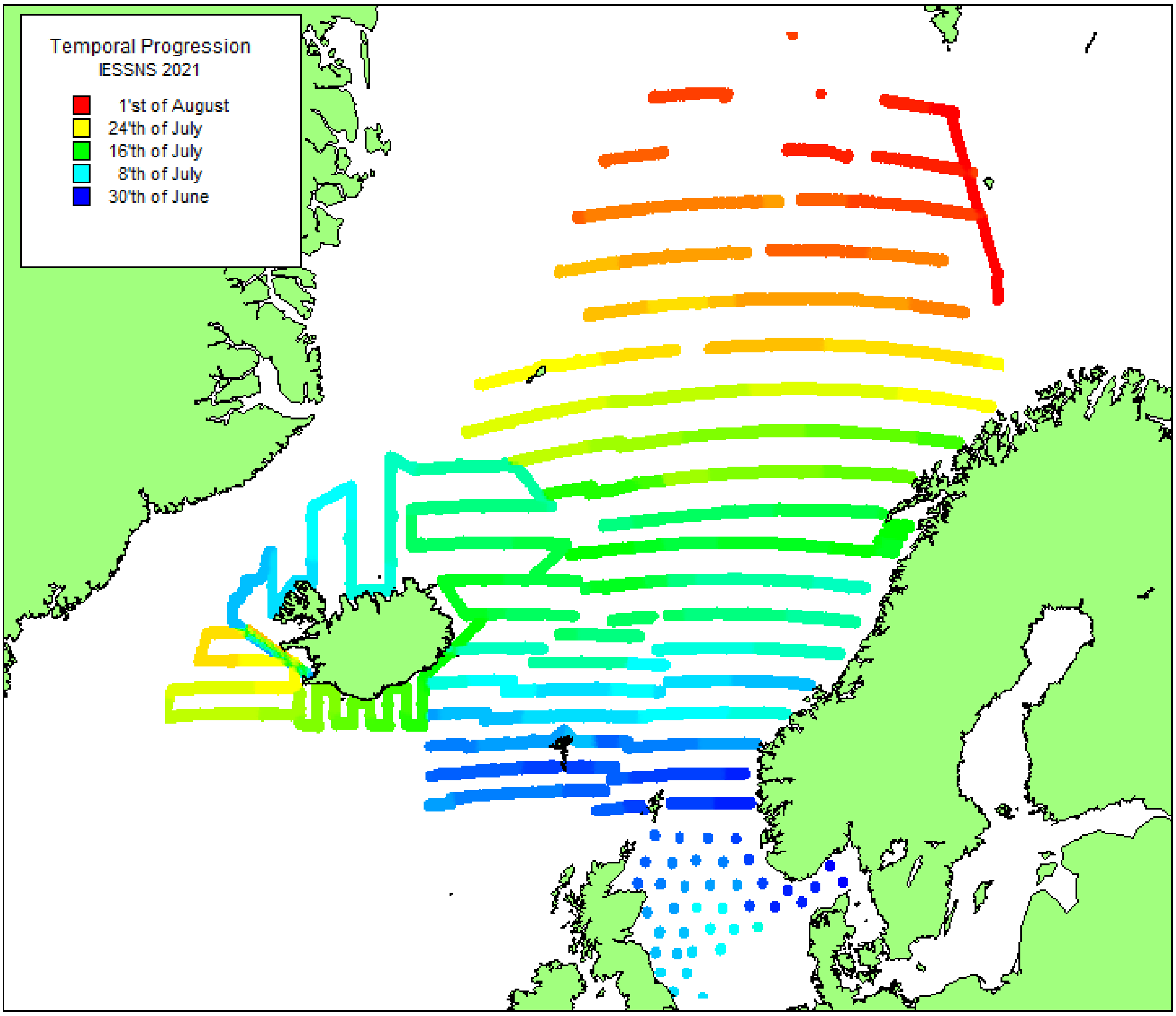


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2021: blue represents effective survey start (30th of June) progressing to red representing a five-week span (survey ended 3rd of August). As Ceton did not record acoustics, they have been represented by station positions.

3.6 StoX

The recorded acoustic and biological 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. Mackerel (swept-area), excluding the North Sea, herring and blue whiting indices were calculated using StoX version 3.1.0. Mackerel index including catch data from the North Sea was calculated using 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 60°N and 77°N and 31°W and 20°E in 2021. The density of mackerel on a trawl station 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). For the Faroese vessel the average door spread was 98.5 m, 1½ m less than the minimum spread in Table 6, so a calculation was done from the standard formulae for 4.5 knots to obtain the trawl width. 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 2021. 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).

	Jákup Sverri	RV Árni Friðriksson	Eros	Vendla	Ceton
Trawl doors horizontal spread (m)					
Number of stations	32	53	59	52	39
Mean	98.7	113	122	113	140
max	111	118	136	125	153
min	89	102	115	105	125
st. dev.	4.6	3.6	4.8	4.6	5.1
Vertical trawl opening (m)					
Number of stations	31	54	59	52	39
Mean	45.1	33.8	28.4	30.4	27
max	56	48.2	33	32	36
min	39	27.5	25	23	22
st. dev.	3.5	3.7	2.9	3.0	3.9
Horizontal trawl opening (m)					
mean	56.6	65.6	67.5	63.8	75.4
Speed (over ground, nmi)					
Number of stations	32	53	59	52	39
mean	4.5	5.2	4.6	4.7	4.8
max	5.3	5.7	5.5	5.6	5.3
min	3.5	4.4	4.1	4.2	4.3
st. dev.	0.4	0.2	0.3	0.3	0.2

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 (NOAA OISST) of sea surface temperature (SST) in the central and eastern part of the Norwegian Sea in July 2021 were roughly on same level as the long-term average for July 1990-2009 based on SST anomaly plots (Figure 4). In the western areas, north of Iceland and the coastal regions of Greenland (The Iceland Sea and the Greenland Sea) the SST was 1-3 °C warmer than the long-term average. South of Iceland and in the Irminger Sea, the SST was on level with the long-term average. Further south, all the way from Greenland to the European Shelf, the SST was slightly warmer (~1 °C). However, along the southern part of the Norwegian Shelf and in the North Sea, the temperatures were 1-2 °C warmer than long term average.

It should be mentioned that the NOAA SST are sensitive to the weather conditions (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 from the survey showed that the upper layer (10 m depth) in 2021 generally was similar to 2020, except for the cold tongue of East Icelandic water, which penetrates into the Norwegian Sea from the Iceland Sea. In 2020 the tongue was clearly visible in the surface layer, but during the 2021 survey it was much less pronounced in the surface layer, indicating that stratification was stronger in this region in 2021 compared to last year (Figure 5). In the deeper layers (50 m and deeper; Figures 6-8), the hydrographical features in the area were similar to previous years. At all depths there is a clear signal from the cold East Icelandic Current which carries cold and fresh water into the central and south-eastern part of the Norwegian Sea. Along the Norwegian Shelf and in the southernmost areas, the water masses are dominated by warmer waters of Atlantic origin.

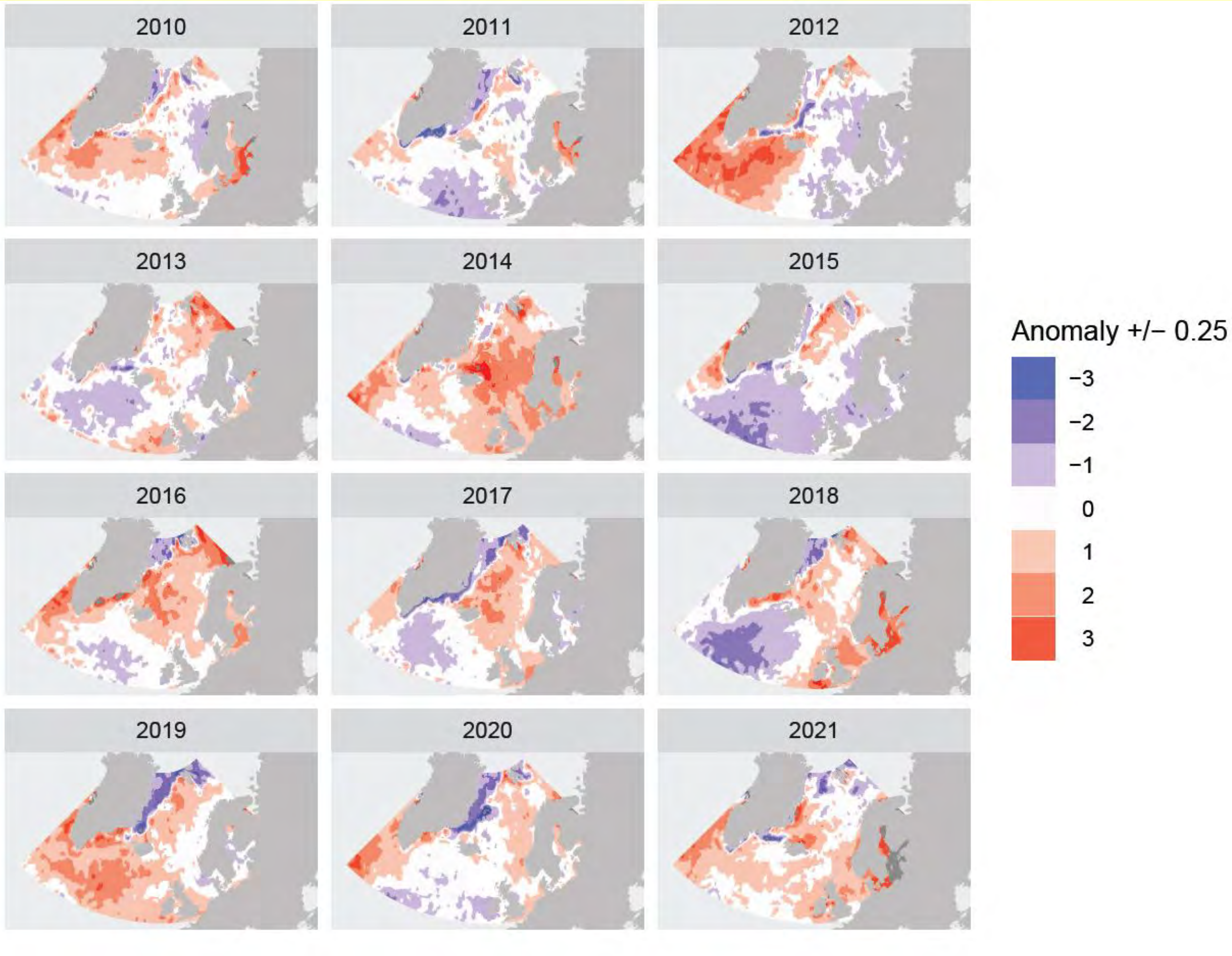


Figure 4. Annual sea surface temperature anomaly (-3 to +3°C) in Northeast Atlantic for the month of July from 2010 to 2021 showing warm and cold conditions in comparison to the average for July 1990-2010. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (Ver. 2.1 NOAA OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

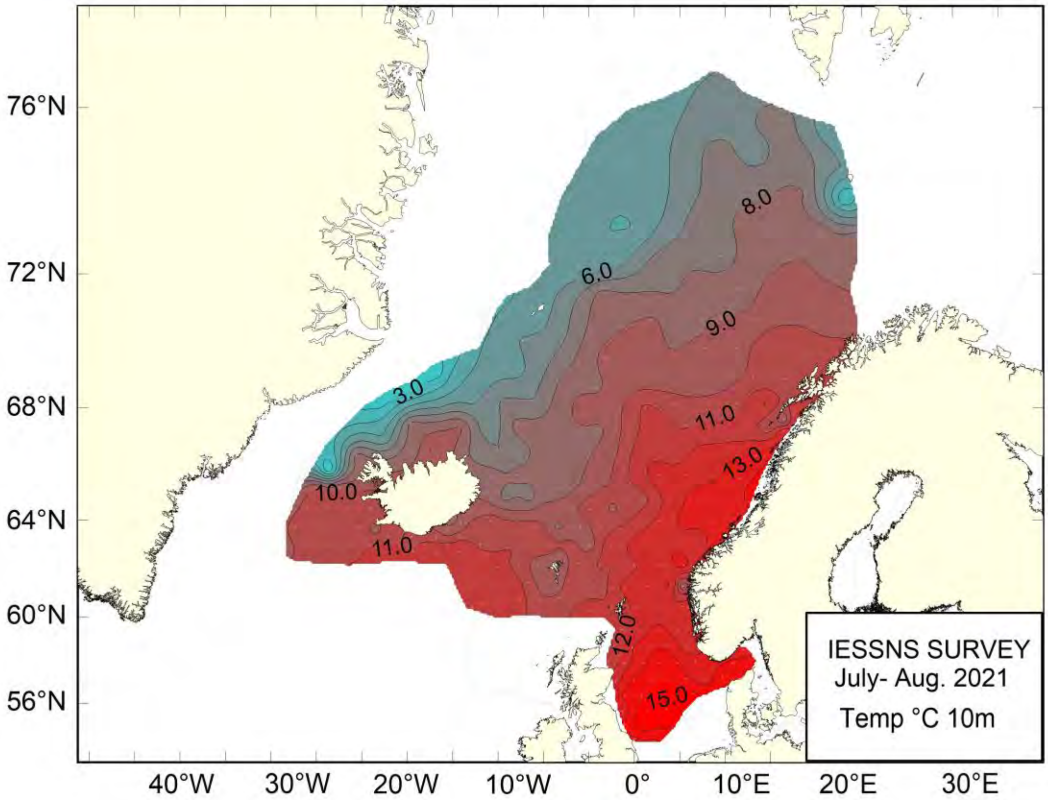


Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2021.

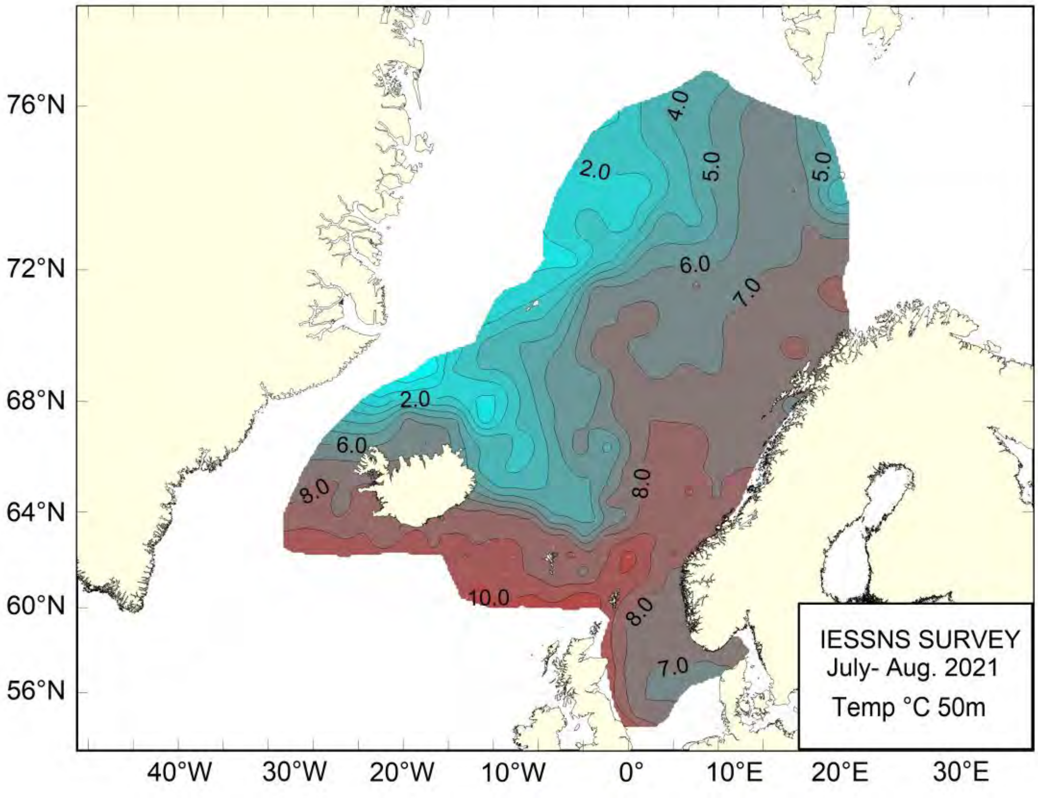


Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2021.

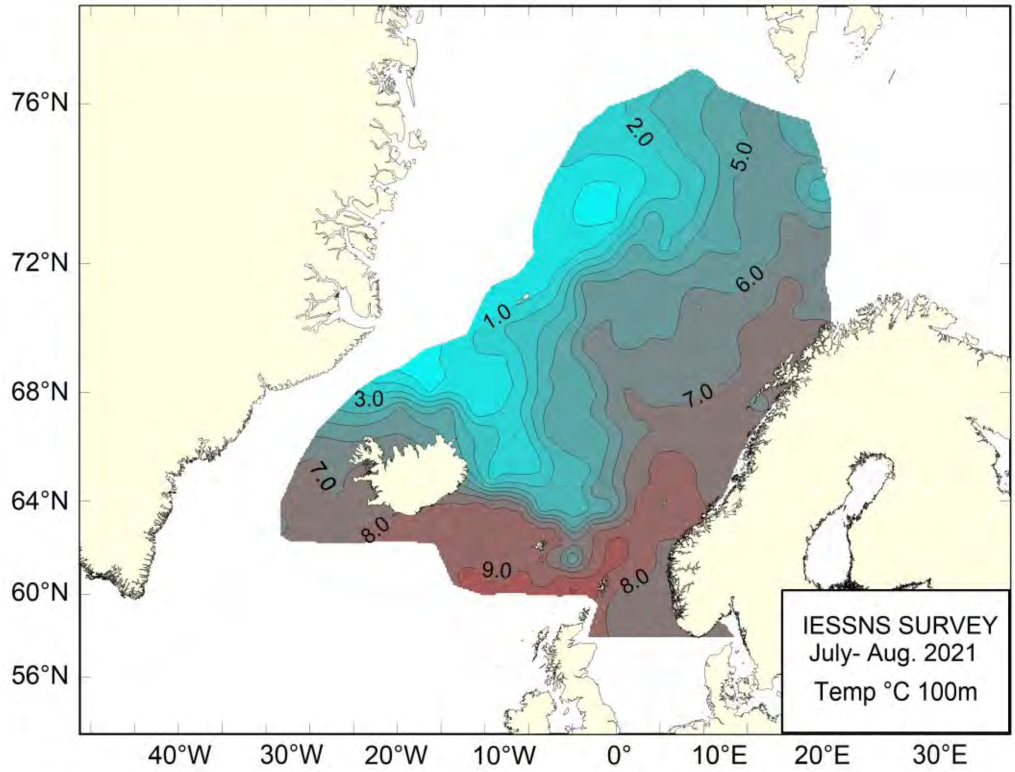


Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2021.

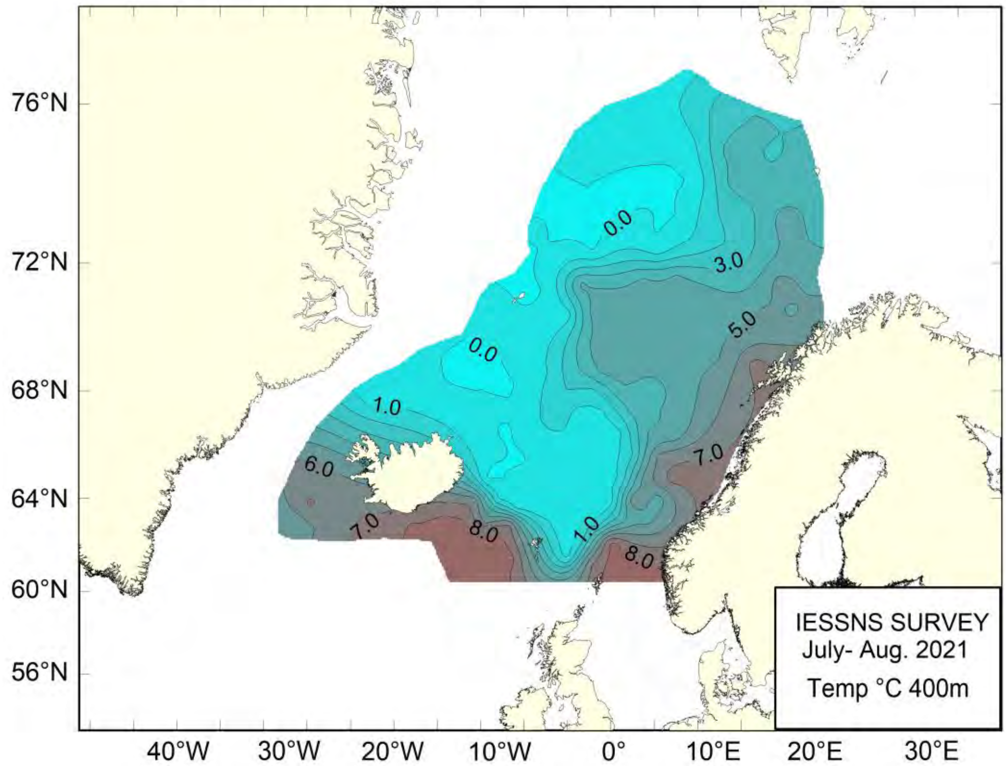


Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2021.

4.2 Zooplankton

The zooplankton biomass varied between areas with a patchy distribution throughout the area (Figure 9a). Greenland waters were not covered in 2021. In the Norwegian Sea areas, the average zooplankton biomass was slightly lower than last year as seen from Figure 9a, and this was especially apparent in the central and southern areas.

The time-series of average zooplankton biomass averaged by three subareas: Greenland region, Iceland region and the Norwegian Sea region is shown in Figure 9b (see definitions in legend). In the Greenland area a decrease was observed in 2019 and further in 2020 from very high values in 2017-2018 (no survey in 2021). A similar trend was also observed in the Icelandic region with somewhat less variations, and a levelling out in 2021 (Figure 9b). The two time-series co-vary (2014-2020, r = 0.89). The biomass indices has varied substantially less ion the Norwegian Sea areas, with a decrease in 2021 from a relatively stable level since 2013 (Figure 9b). The lower variability might in part be explained by the 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.

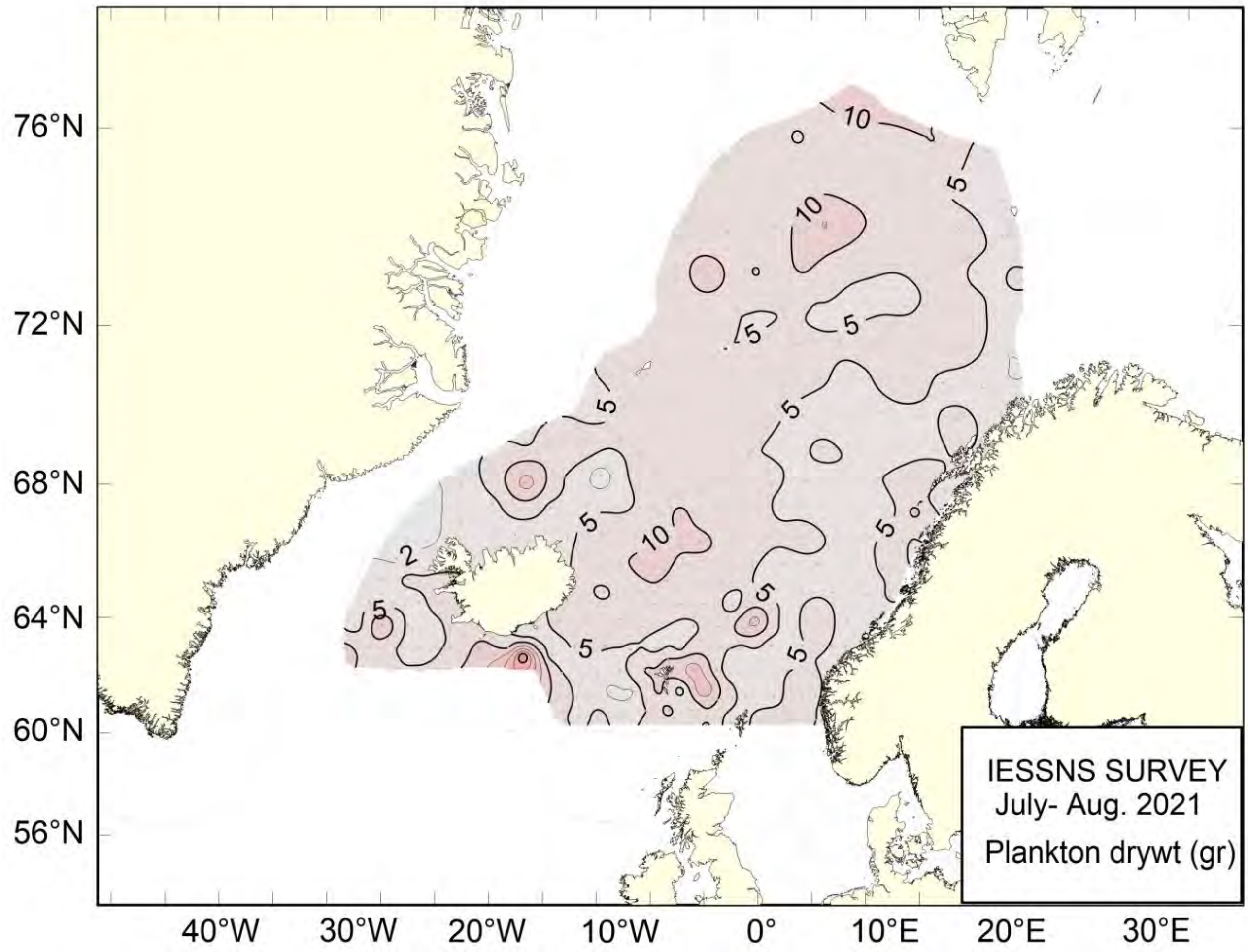


Figure 9a. Zooplankton biomass (g dw/m², 0-200 m) in Nordic Seas in July-August 2021.

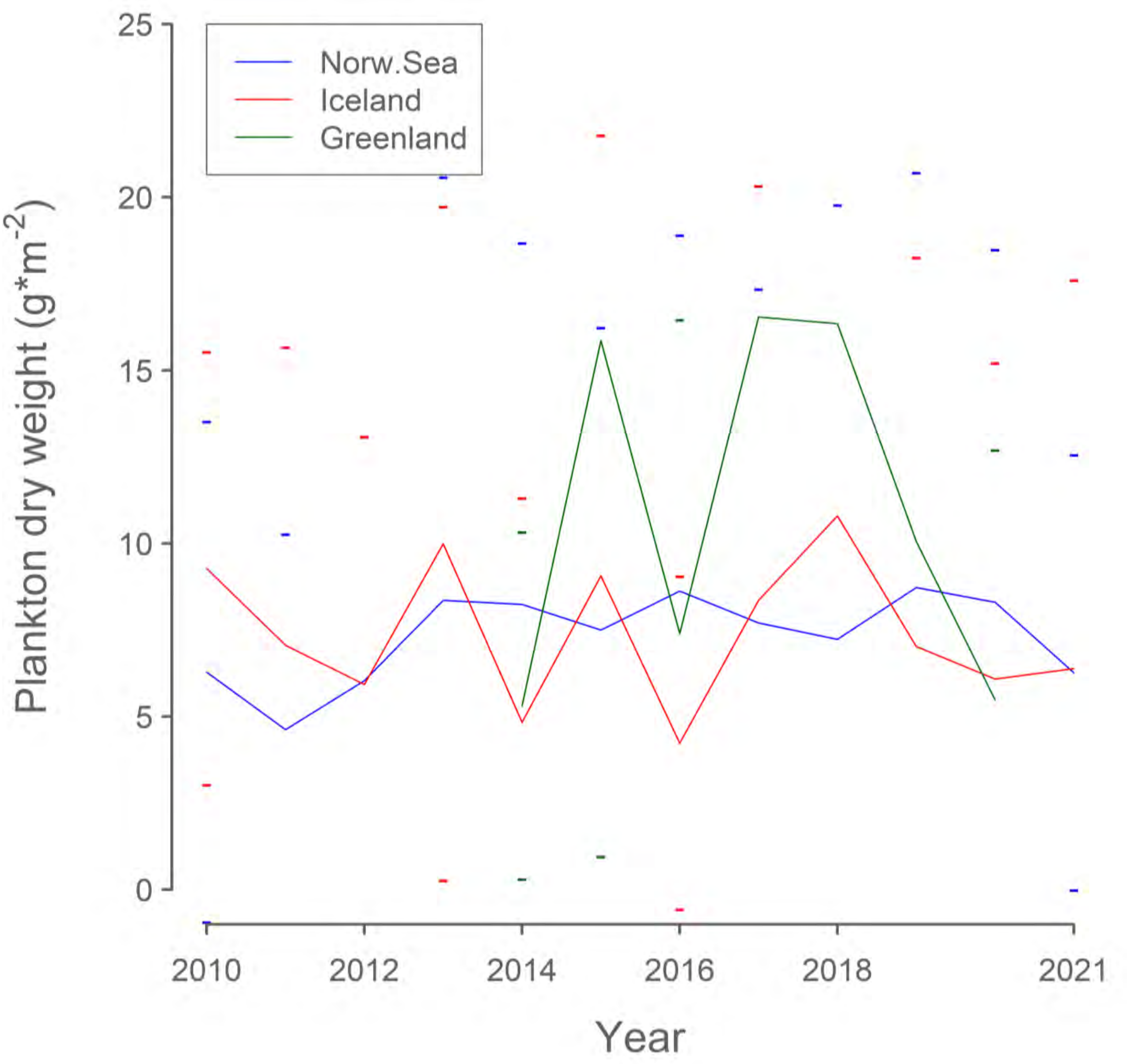


Figure 9b. Zooplankton biomass indices (g dw/m², 0-200 m). Time-series (2010-2021) of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (2014-2020, west of 30°W).

4.3 Mackerel

The total swept-area mackerel index in 2021 was 5.15 million tonnes in biomass and 12.2 billion in numbers, a decreased by 58% for biomass and 54% for abundance compared to 2020. The survey coverage area (excl. the North Sea, 0.29 million km²) was 2.2 million km² in 2021, which is 24% smaller compared to previous years from 2018 to 2020. Reduced survey coverage in the western area did not contribute to the observed decline as the zero mackerel boundary was established north, west, and south of Iceland. The mackerel catch rates by trawl station (from zero to 17 tonnes/km², mean = 2.2 tonnes/km²) measured at predetermined surface trawl stations in 2021 is presented in Figure 10 together with the mean catch rates per 2° lat. x 4° lon. rectangles. The mackerel was mainly distributed in the central Norwegian Sea, extending south into waters southeast of Iceland and into the North Sea. High density areas were only found in international waters in the central Norwegian Sea in 2021. Medium density areas were found in the central and partly northern Norwegian Sea in 2021, with very small concentrations in the western areas (Figure 10), as was also the case in 2020. In Icelandic waters, mackerel density was low, and distribution limited to waters east and southeast of Iceland. This was similar to the 2020 observations. The North Sea, on the other hand, experienced a notable increase. There was a doubling in mean catch rates of mackerel in 2021 compared to previous years, dominated by 1- and 2-year olds. The time series (2010-2021) of absolute distribution maps (Figure 11) and relative distribution maps (Figure 12) show western expansion from 2010 to 2017, then in 2018 there was an obvious decline in geographical distribution and abundance in the west, in 2019 limited abundance of mackerel was measured in Greenland waters, and in 2020 distribution in Icelandic waters had retracted to the southeast coast.

Greenland waters were not surveyed in 2021. However, the zero-line was reached west, south and north of Iceland and the Greenlandic industry did not catch mackerel in Greenlandic waters. Therefore, it is highly unlikely that any mackerel migrated into Greenlandic waters during summer 2021. It is assumed that IESSNS coverage mackerel geographical distribution range in the western area despite reduced survey area size.

The swept area results from the North Sea in 2021 showed almost a doubling in the biomass index from last year (Appendix 1). The increase was mainly due to the high abundances of 1- and 2-year old mackerel.

In summary, we found a substantial decrease in estimated biomass and abundance index of NEA mackerel in the main feeding area during summer for mackerel in 2021 compared to 2020. On the positive side, there seems to be high recruitment and a considerably higher estimated biomass and abundance of juvenile mackerel (1- and 2-years olds) in the North Sea in 2021 compared to 2020.

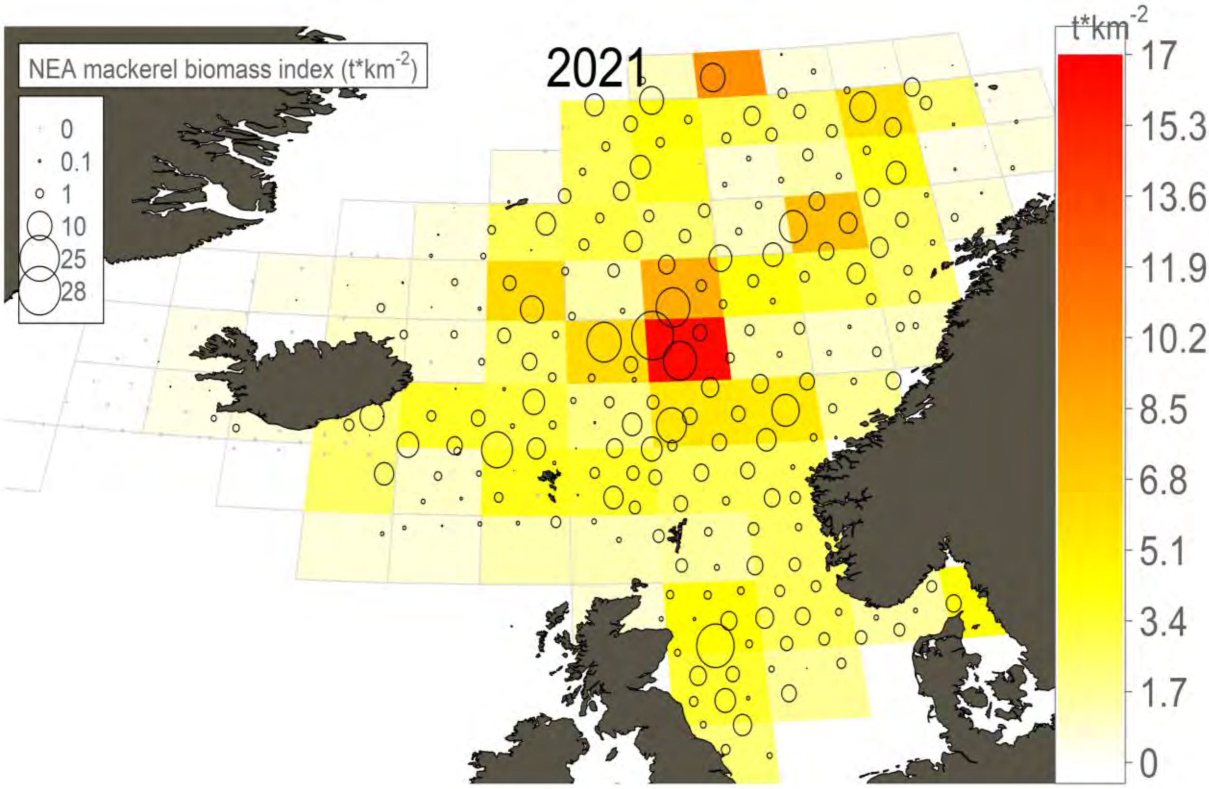


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km^2) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

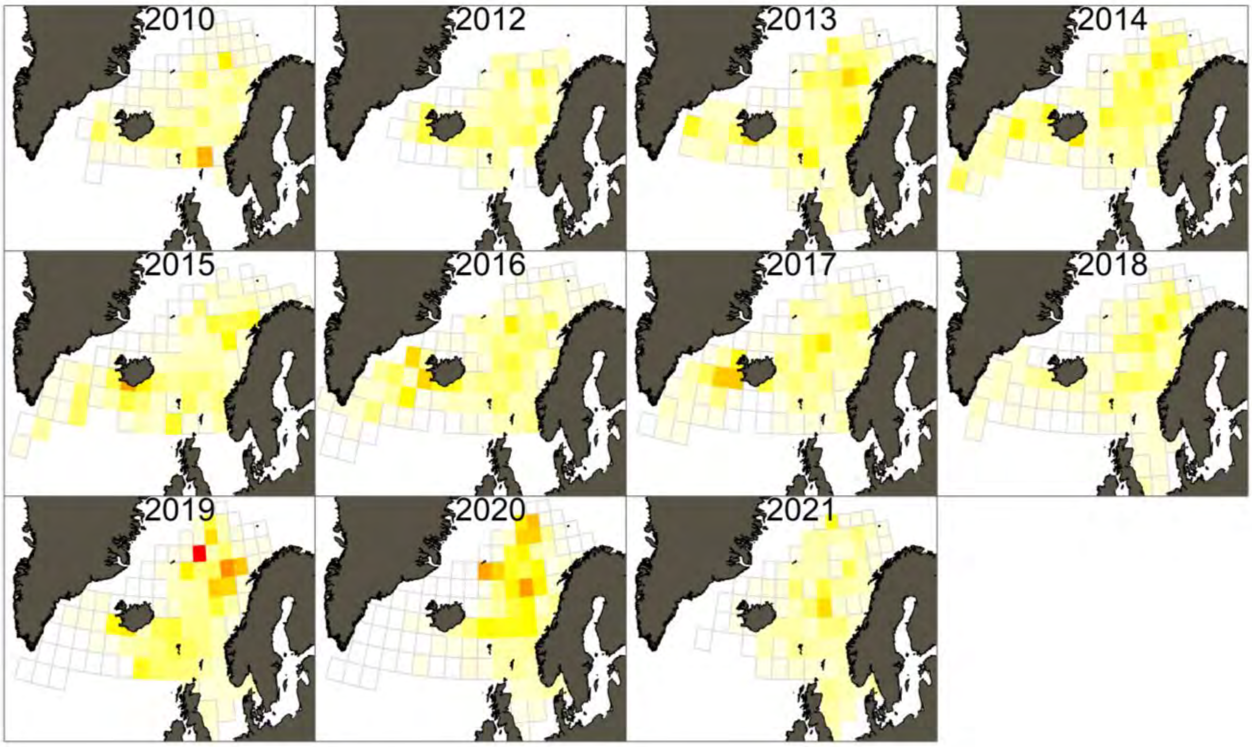


Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the highest year).

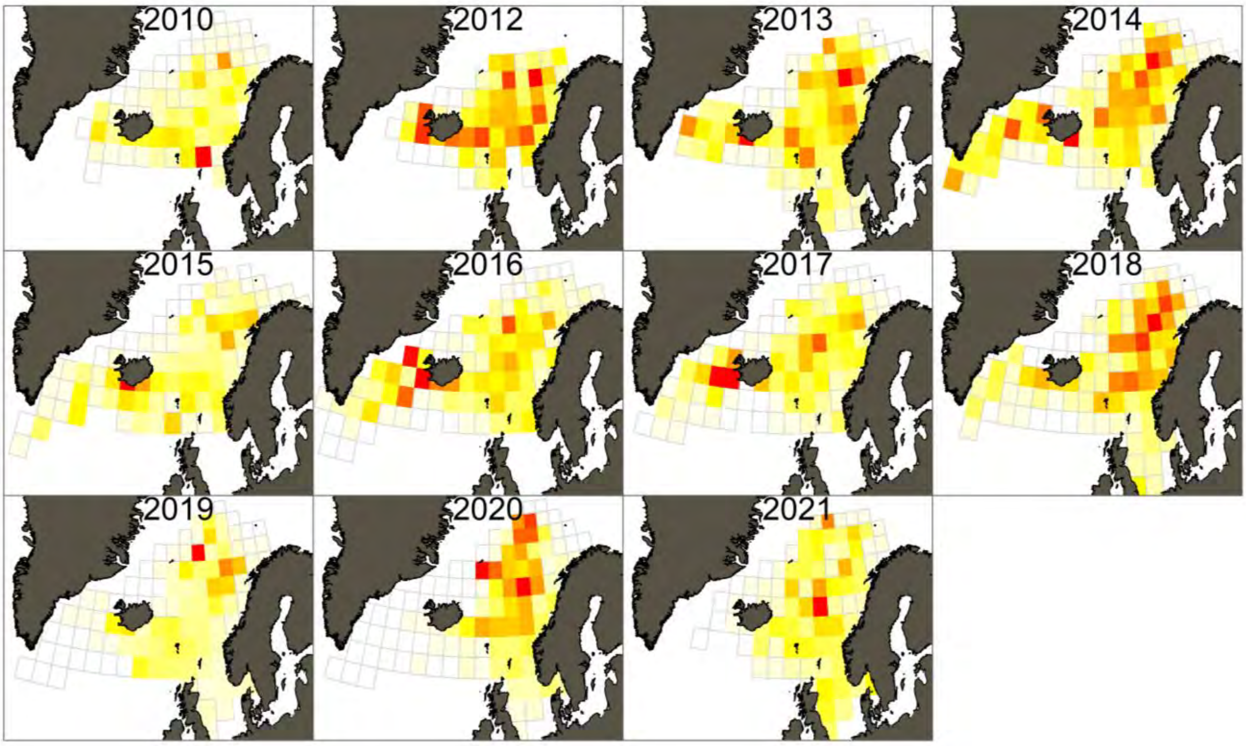


Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the given year).

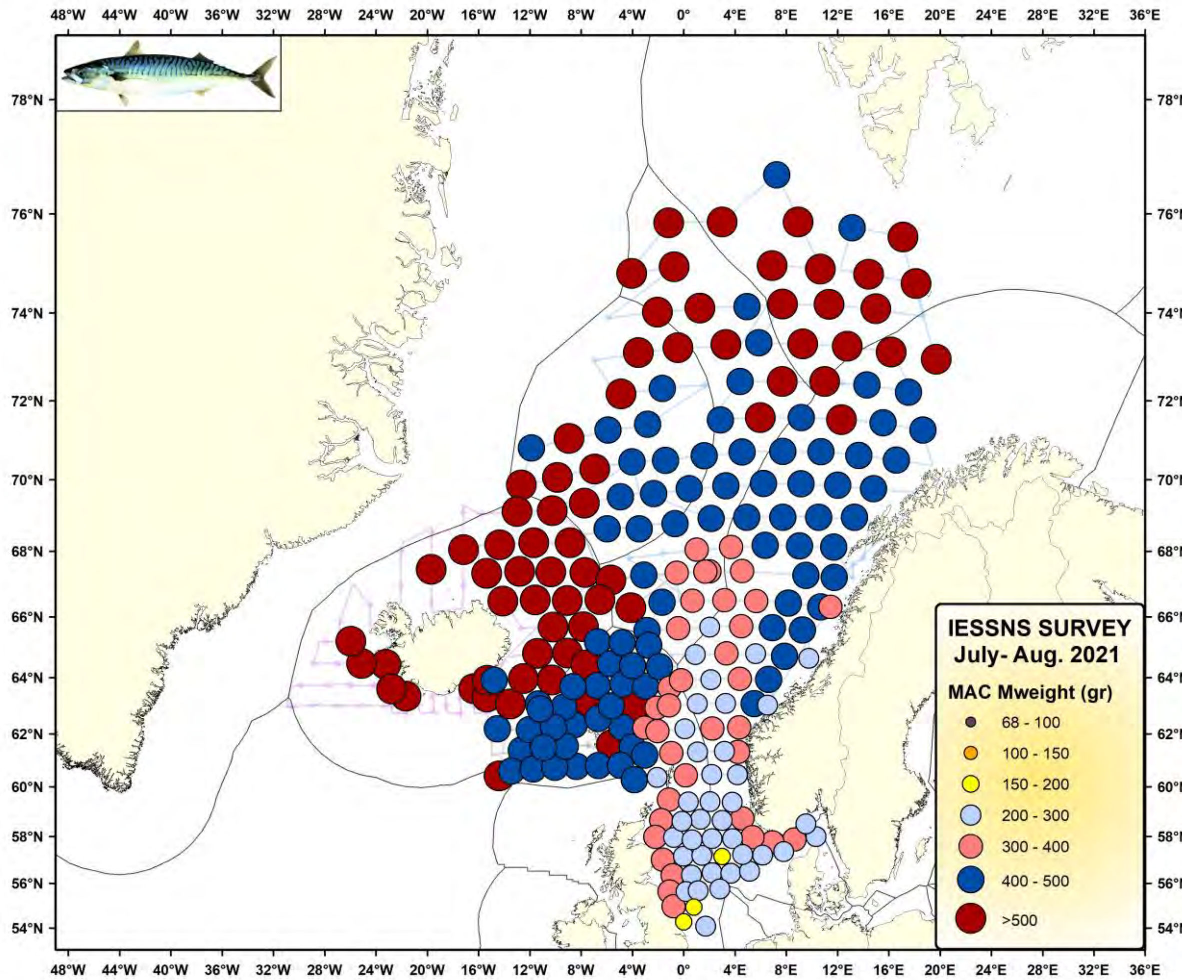


Figure 13. Average weight of mackerel at predetermined surface trawl stations during IESSNS 2021.

The mackerel weight varied between 51 to 874 g with an average of 421 g. The length of mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 21.0 to 43.5 cm, with an average of 35.6 cm. Individuals in the length range 32–36 cm dominated in numbers and biomass. 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 2021 according to the catches are shown in Figure 14.

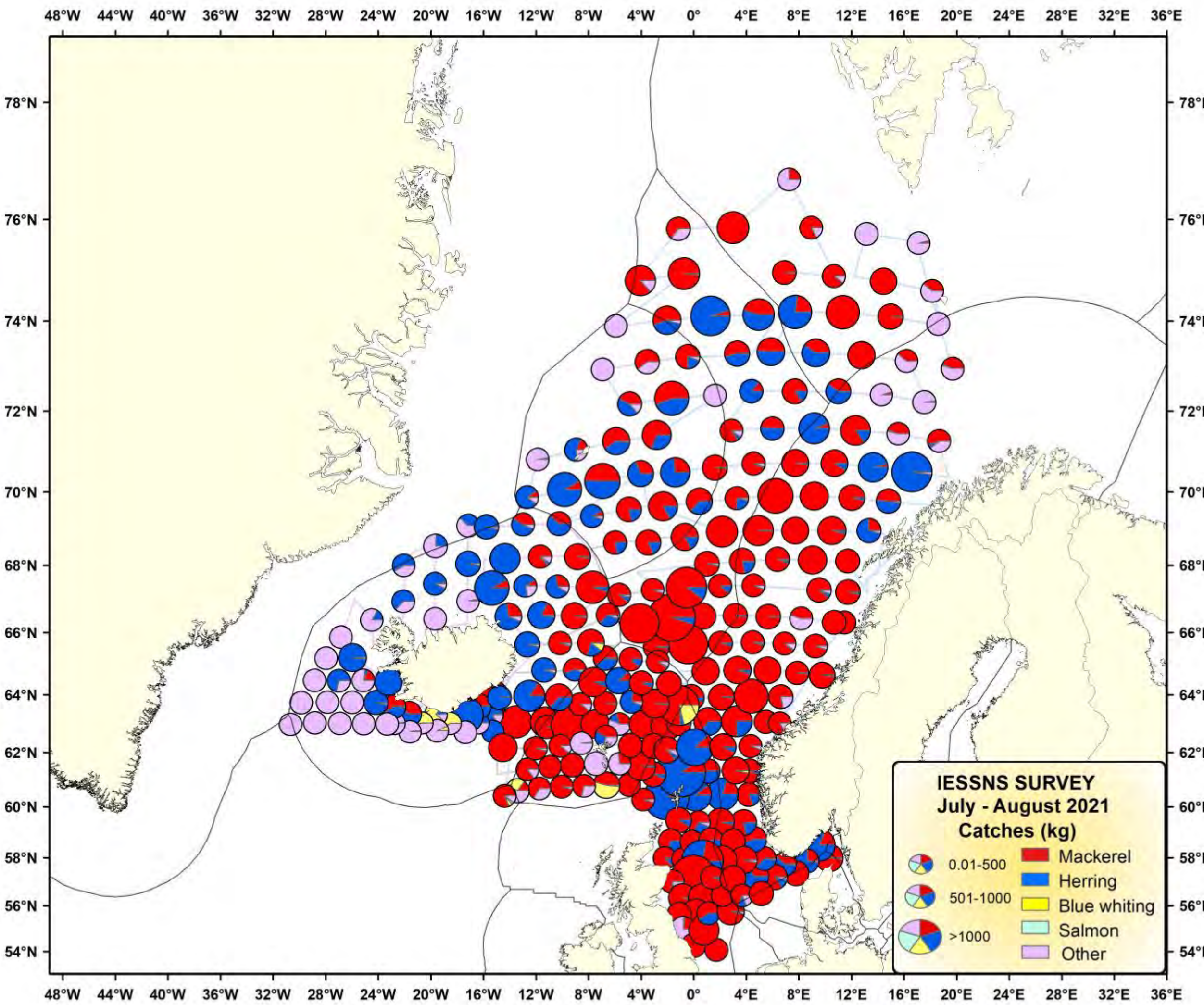


Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, and other (lumpfish)) in 2021 at all surface trawl stations. Vessel tracks are shown as continuous lines.

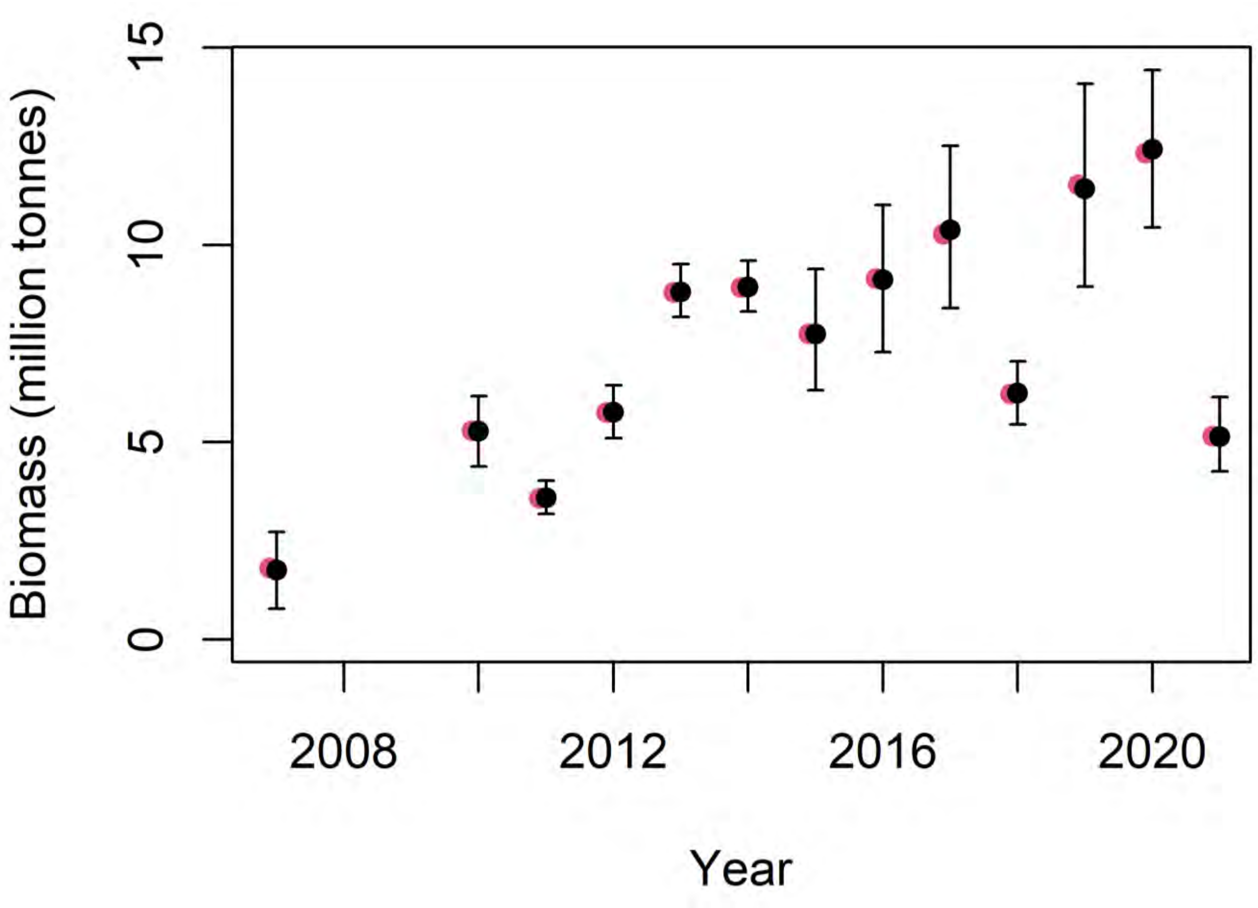
Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2021 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX version 3.10. The mackerel biomass and abundance indices in 2020 were the highest in the time series that started in 2010 (Table 7, Figure 15). In 2021 a drop of more than 50% was observed (Figure 15). The most abundant year-classes were 2019, 2016, 2014, 2017 and 2012, respectively (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- and 2-year olds from the 2019 and 2020 year-classes was quite high, particularly in the North Sea in July 2021, suggesting that these new year-classes may be promising. Variance in age index estimation is provided in Figure 17.

The overall internal consistency plot for age-disaggregated year classes was slightly reduced compared to last year (Figure 19). There is a good to strong internal consistency for the younger ages (1-4 years) and older ages (8-14+ years) with r between 0.70 and 0.89. However, the internal consistency is very poor to moderate (0.02 < r < 0.64) between age 4 to 8. The reason for this poor consistency is not clear.

Mackerel index calculations from the catch in the North Sea (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).



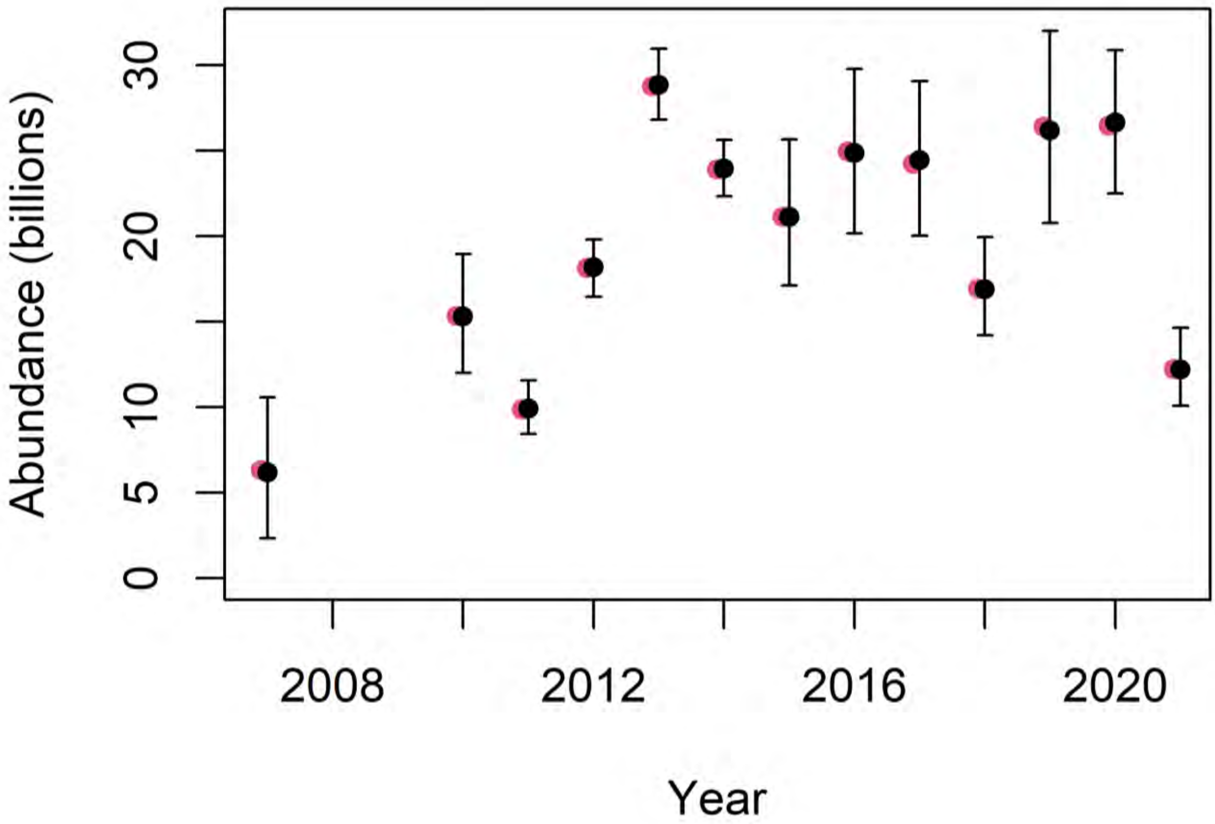


Figure 15. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX for the years 2007 and from 2010 to 2021. The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap.

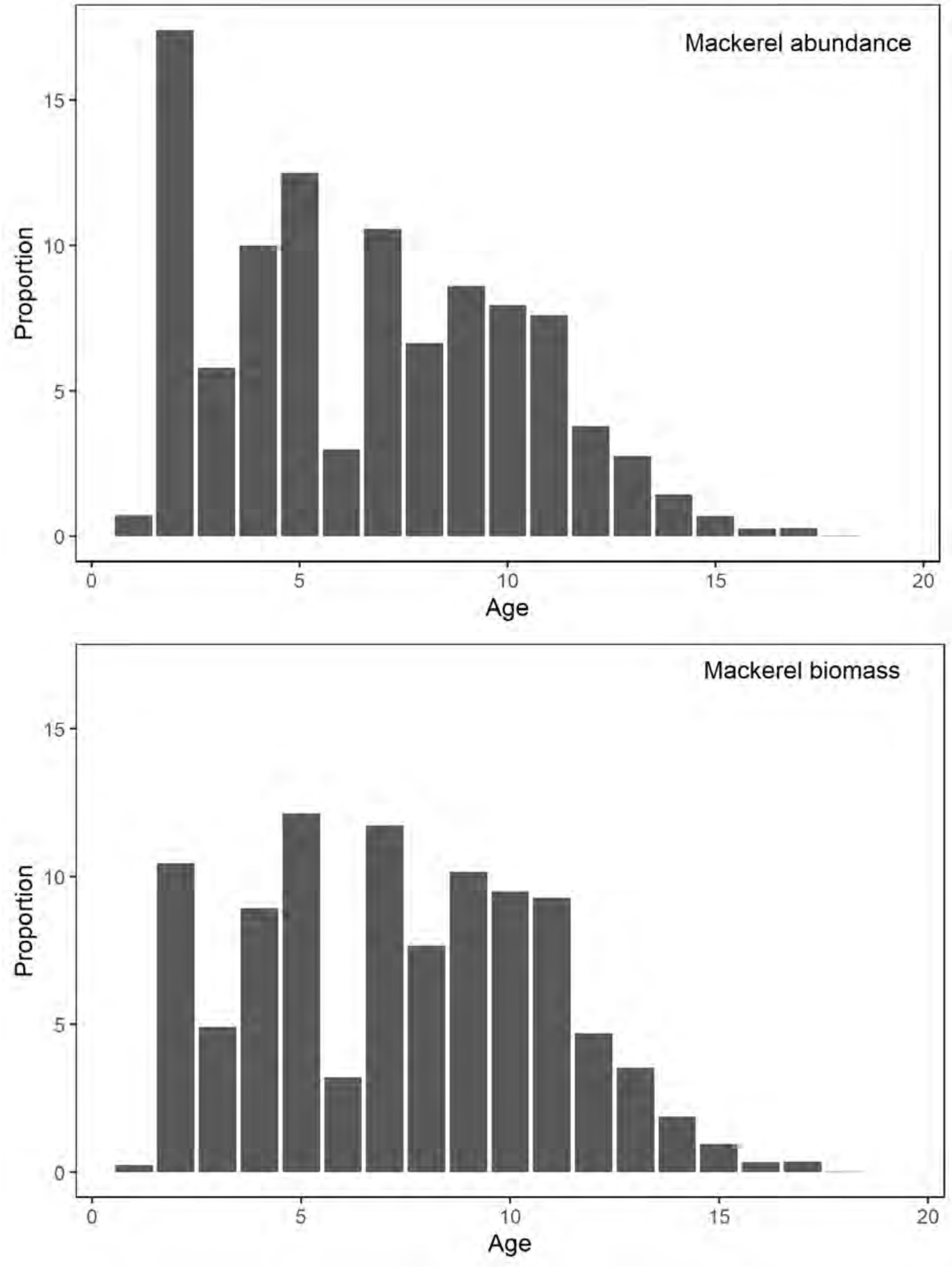


Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2021.

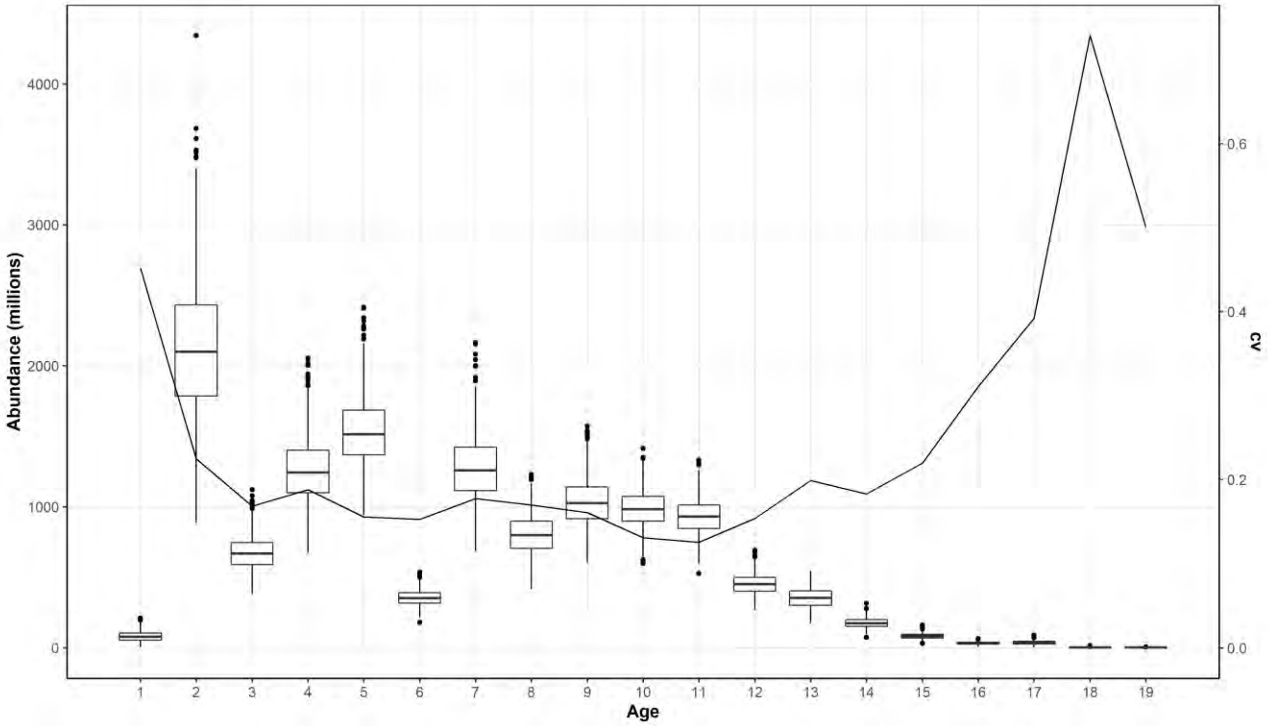


Figure 17. Number by age for mackerel in 2021. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-d) StoX baseline time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (grams) per age, (c) estimated biomass at age (million tonnes) in 2007 and from 2010 to 2021, and (d) estimates of abundance, biomass and mean weight by age and length, including coefficient of variation (cv) based on calculation in StoX for IESSNS 2021 (d). cv* values are from bootstrap calculations but other values from baseline calculations (point estimates).

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
2021	0.09	2.13	0.71	1.22	1.53	0.37	1.29	0.81	1.05	0.97	0.93	0.46	0.34	0.33	12.22

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
2021	140	253	357	377	409	451	467	487	497	505	516	523	544	559

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
2021	0.01	0.54	0.25	0.46	0.62	0.17	0.60	0.39	0.52	0.49	0.48	0.24	0.18	0.19	5.15

d)	Age in years (year class)																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Abundance	Biomass	Mean
Length (cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	num. 10^6	1000 ton	weight (g)
21	5																			5	0	84
22	22																			22	2	90
23	14																			14	1	97
24	7																			7	1	119
25	6																			6	1	141
26	8	2																		11	2	159
27	3	26																		30	5	178
28	10	134	0																	144	29	200
29	13	486	42																	542	122	226
30		708		1																709	178	251
31		548	5	8																561	156	278
32		178	43	30	5															257	76	298
33		37	161	129	55			12												395	129	326
34		6	157	317	214	12	8													713	253	355
35		2	225	416	428	38	58	18		5	0	0								1190	458	385
36		0	67	260	482	93	138	63	22	3	11	10	1							1149	484	422
37			6	55	273	134	386	257	177	169	87	25	1	0	3					1575	722	459
38			2	5	48	41	542	202	411	310	230	90	47	17	8	5	7			1964	954	486
39			0		21	48	131	166	272	298	298	157	129	29	8	8	2			1568	810	517
40						1	28	81	140	150	182	111	70	62	36	8	14		1	884	485	548
41					1	0		10	16	31	105	61	61	49	10	1	6	0		351	204	581
42							1	2	13	3	14	8	24	14	16	11	1			107	67	627
43													3	2	7		4			16	10	655
44											1			1						2	1	687
45																				0	1	738
46																		2		2	2	748
TSN (mil)	88	2128	709	1221	1528	367	1292	811	1052	970	927	462	336	174	87	32	34	2	1	12222	5155	
cv (TSN)*	0.45	0.22	0.17	0.19	0.16	0.15	0.18	0.17	0.16	0.13	0.13	0.15	0.20	0.18	0.22	0.31	0.39	0.86	0.97			
TSB (1000 t)	12	539	253	460	625	166	604	395	523	490	478	242	183	98	49	18	19	2	1	5154		
cv (TSB)*	0.42	0.23	0.17	0.19	0.15	0.15	0.18	0.17	0.16	0.13	0.13	0.15	0.20	0.19	0.22	0.32	0.38	0.87	0.98			
Mean len. (cm)	24.7	30.1	33.9	34.7	35.6	36.8	37.5	37.8	38.4	38.5	39.0	39.2	39.7	40.1	40.4	40.2	40.1	45.9	40.0			
Mean wei. (g)	140	253	357	377	409	451	467	487	497	505	516	523	544	559	568	558	544	743	545			

Table 8. Bootstrap estimates from StoX (based on 500 replicates) of mackerel in 2021. 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	22.6	77.0	144.1	79.8	36.1	0.45
2	1397.9	2100.0	2935.7	2124.0	477.8	0.22
3	498.1	666.6	864.6	671.5	113.3	0.17
4	891.4	1243.2	1686.4	1258.5	236.9	0.19
5	1178.3	1514.8	1929.9	1536.0	239.2	0.16
6	268.5	350.8	445.7	353.1	54.0	0.15
7	962.1	1257.9	1688.1	1278.2	227.0	0.18
8	585.5	797.5	1037.3	801.7	136.4	0.17
9	773.9	1025.1	1329.6	1035.5	166.6	0.16
10	780.8	982.3	1198.9	986.9	129.3	0.13
11	756.2	930.6	1135.3	932.2	117.2	0.13
12	340.5	450.0	569.2	451.4	69.5	0.15
13	242.5	353.8	471.7	354.1	70.6	0.20
14	125.4	173.2	226.1	174.6	32.0	0.18
15	54.3	82.0	113.2	82.3	18.1	0.22
16	15.7	31.4	48.2	31.5	9.8	0.31
17	13.5	33.7	59.6	34.9	13.7	0.39
18	0.0	2.4	7.1	2.8	2.4	0.86
19	0.0	1.3	3.8	1.4	1.3	0.97
Unknown	1.4	6.2	19.3	7.7	5.9	0.77
TSN	10078	12133	14637	12198	1376	0.11
TSB	4.26	5.13	6.15	5.14	0.58	0.11

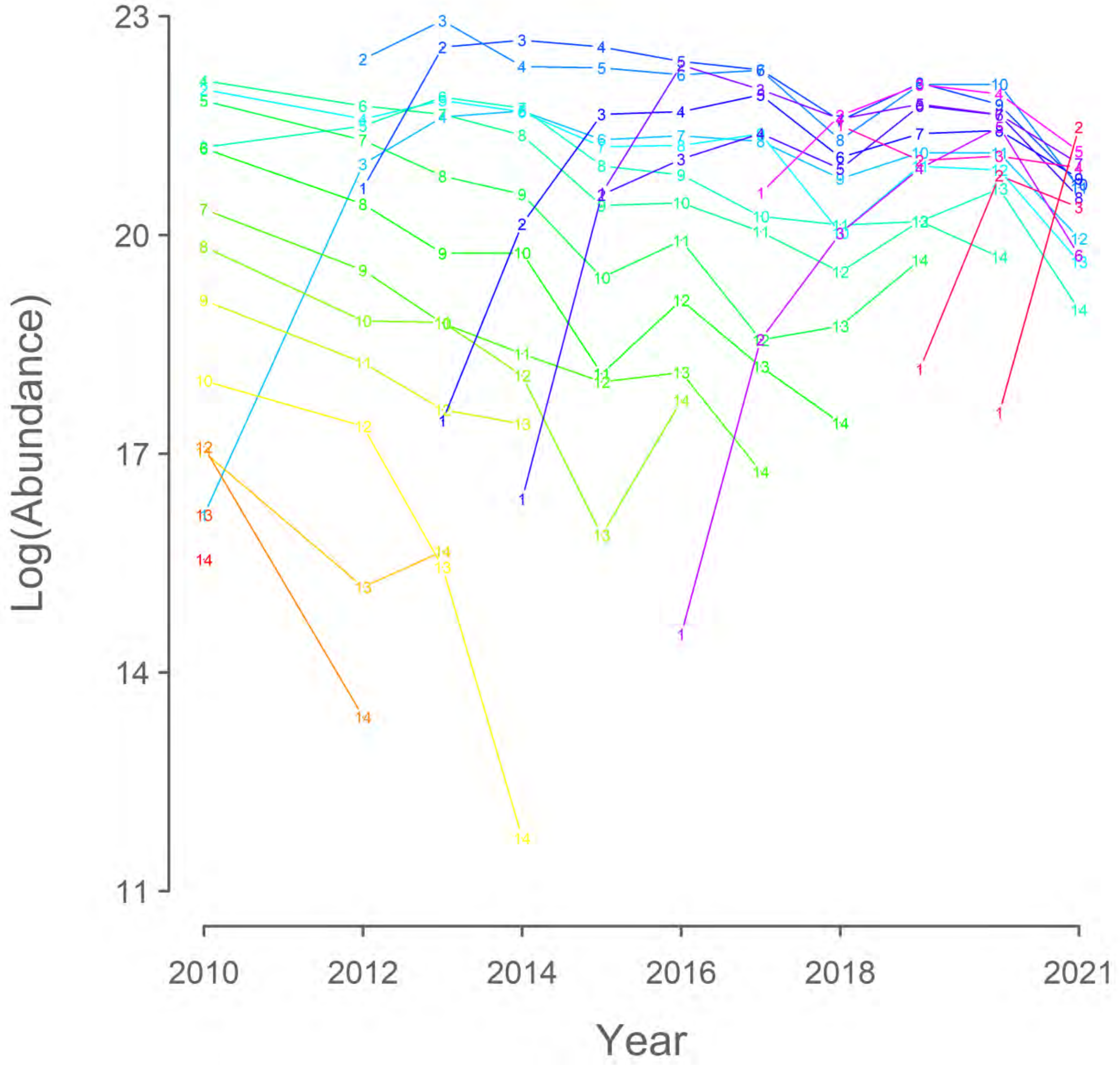


Figure 18. Catch curves in 2021. Each cohort of mackerel is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

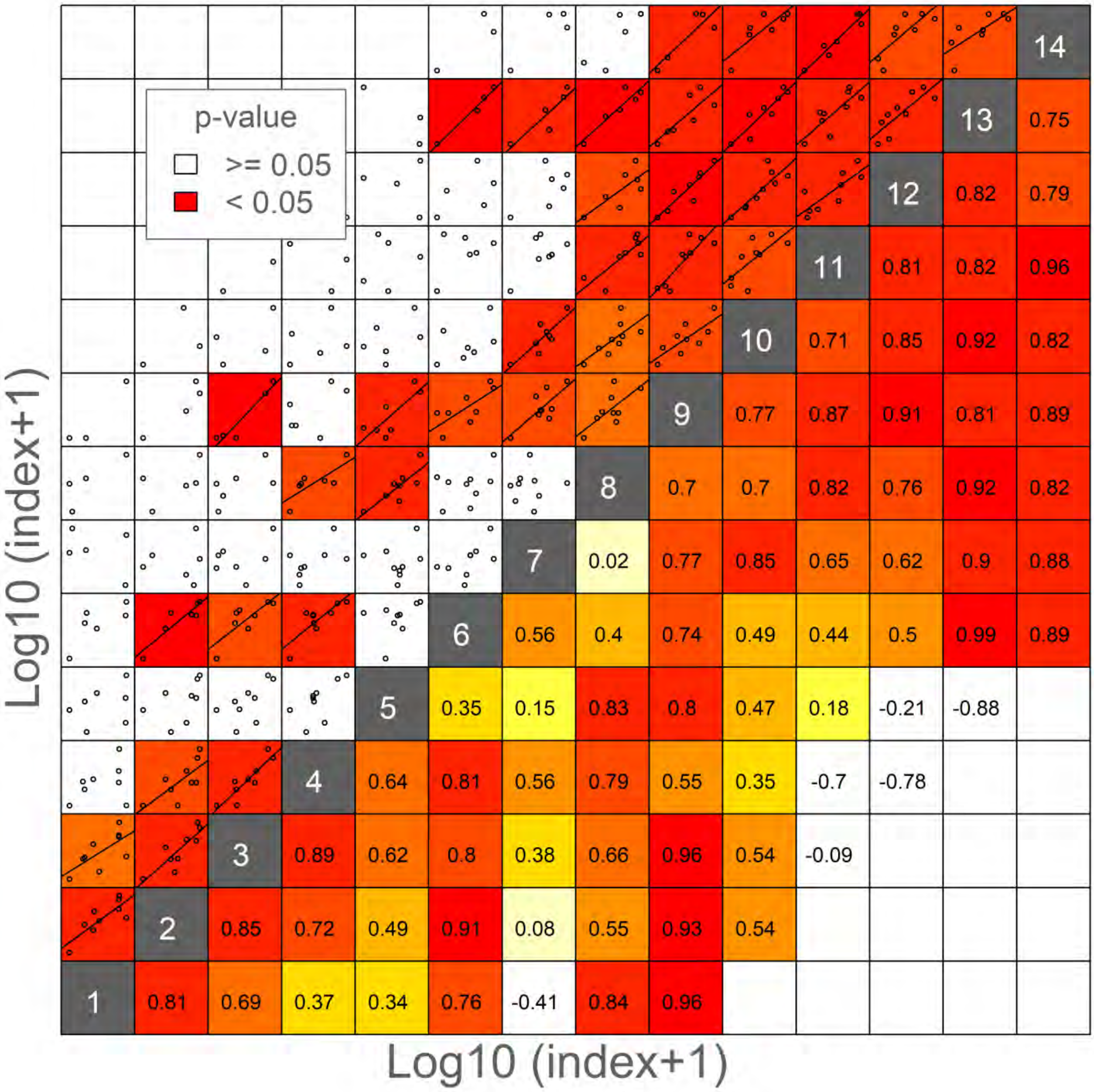


Figure 19. Internal consistency of the of mackerel density index from 2012 to 2021. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

The zero boundaries for mackerel distribution were found in majority of survey area with a notable exception of some mackerel abundance in the north-western region of the Norwegian Sea particularly towards the Fram Strait west of Svalbard.

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, such that it covers the southwestern waters south of 60°N, e.g. UK waters.

The standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 56.6.5-75.4 m; 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.

The large variation in the swept area index in recent years might be due to the large spread in catch rates with a varying proportion taken each year of some few extremely large catches (>10 t/30min). It is suspected that these extreme catches might have relatively high impact on the calculated average, with a potential to bias the survey index. The problem arises if the number of these extreme catches is linked to the distribution of mackerel but not to the biomass. The group recommends investigating this potential problem. In 2021 we had no large or extremely large catch of mackerel compared to e.g. 2019 and 2020.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring (Figure 14). This overlap occurred between mackerel and North Sea herring in major parts of the North Sea and partly in the southernmost part of the Norwegian Sea. There were also some overlapping distributions of mackerel and Norwegian spring-spawning herring (NSSH) in the western, north-western and north-eastern part of the Norwegian Sea.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southwestern (east and north of Iceland) and northern part of the Norwegian Sea basin (Figure 20a). The acoustic registrations in the southern and eastern parts of the Norwegian Sea were low or absent in July 2021. This is in contrast to the more southerly distribution of the adult stock in May, where the herring was observed from the area north of the Faroes northwest towards Iceland. In July 2021 a relatively large part of the adult NSSH stock was distributed north of 68°N (Figure 20a). Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring, while the herring to the south and west in Icelandic waters (west of 14°W south of Iceland) were allocated to Icelandic summer-spawners, and these were removed from the biomass estimation of NSSH, except some putative North Sea herring in the southeastern area north of Shetland (Figure 20b).

The total number of NSSH recorded during IESSNS 2021 was 20.3 billion and the total biomass index was 6.10 million tonnes, which at the same level as in 2020 (20.3 and 5.93, respectively) (Table 10 and 11). The 2016 year-class (5 year olds) dominated in the stock and contributed to 55% and 60% to the total biomass and total abundance, respectively, whereas the 2013 year-class (8 year olds) contributed 13% and 11% to the total biomass and total abundance, respectively (Figure 21 and Table 9). The 2016 year-class was considered to be fully recruited to the adult stock in 2021, and also fully recruited to the survey area.

Bootstrap estimates of numbers by age are shown in Figure 21. The uncertainty (CV) around the age disaggregated abundance indices from the 2021 survey varied around 0.25-0.3 for age groups 4-15 (Figure 21), which is considered satisfactory.

The internal consistency among year classes was generally high, with the lowest correlation (r = 0.57) between age 5 and 6 (Figure 22).

The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. The herring was mainly observed in the upper surface layer as relatively small schools. This shallow distribution of herring might have lead to an unknown portion of herring being in the "blind zone" above the transducer depth of the vessels (i.e. shallower than 10-15 m, Table 4), and therefore not being registered by the vessels. However, the group considered the acoustic biomass estimate of herring to be of good quality in the 2021 IESSNS as in the previous survey years.

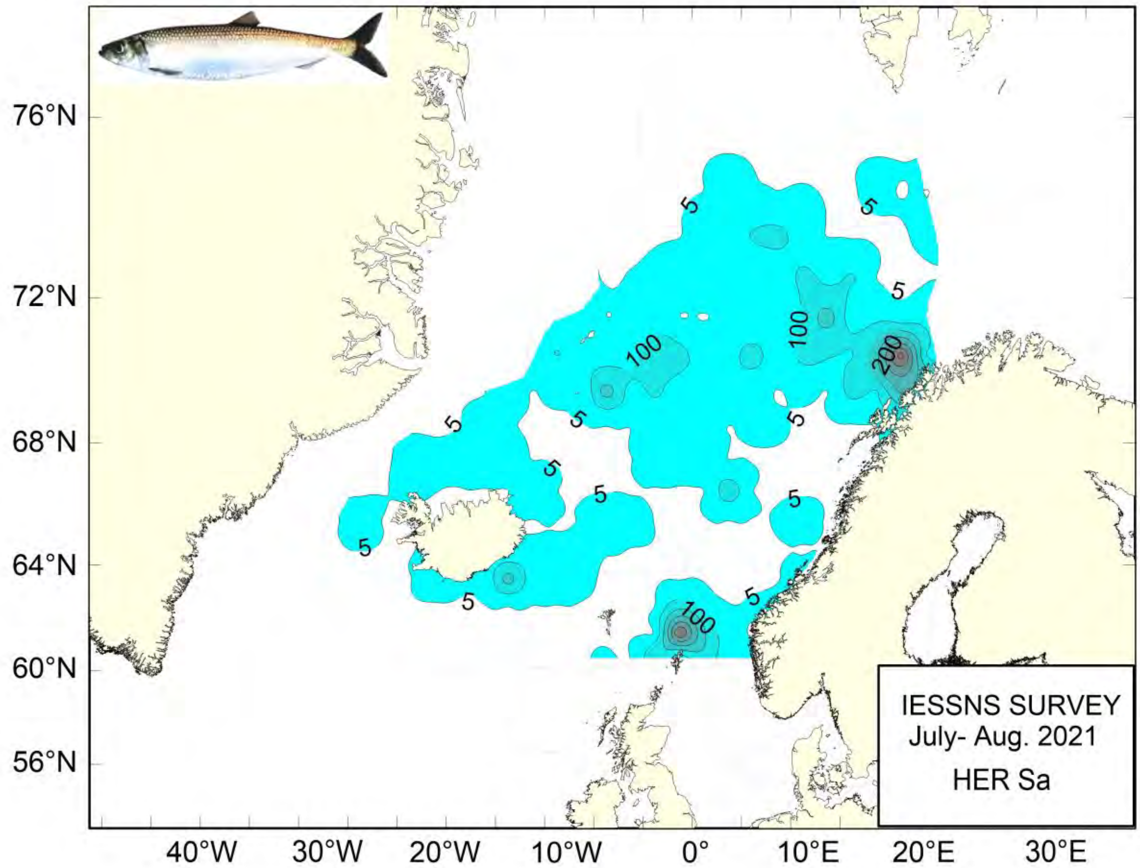


Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2021 presented as contour lines. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Icelandic summer spawners, Faroese autumn spawners and North Sea herring in the southeast.

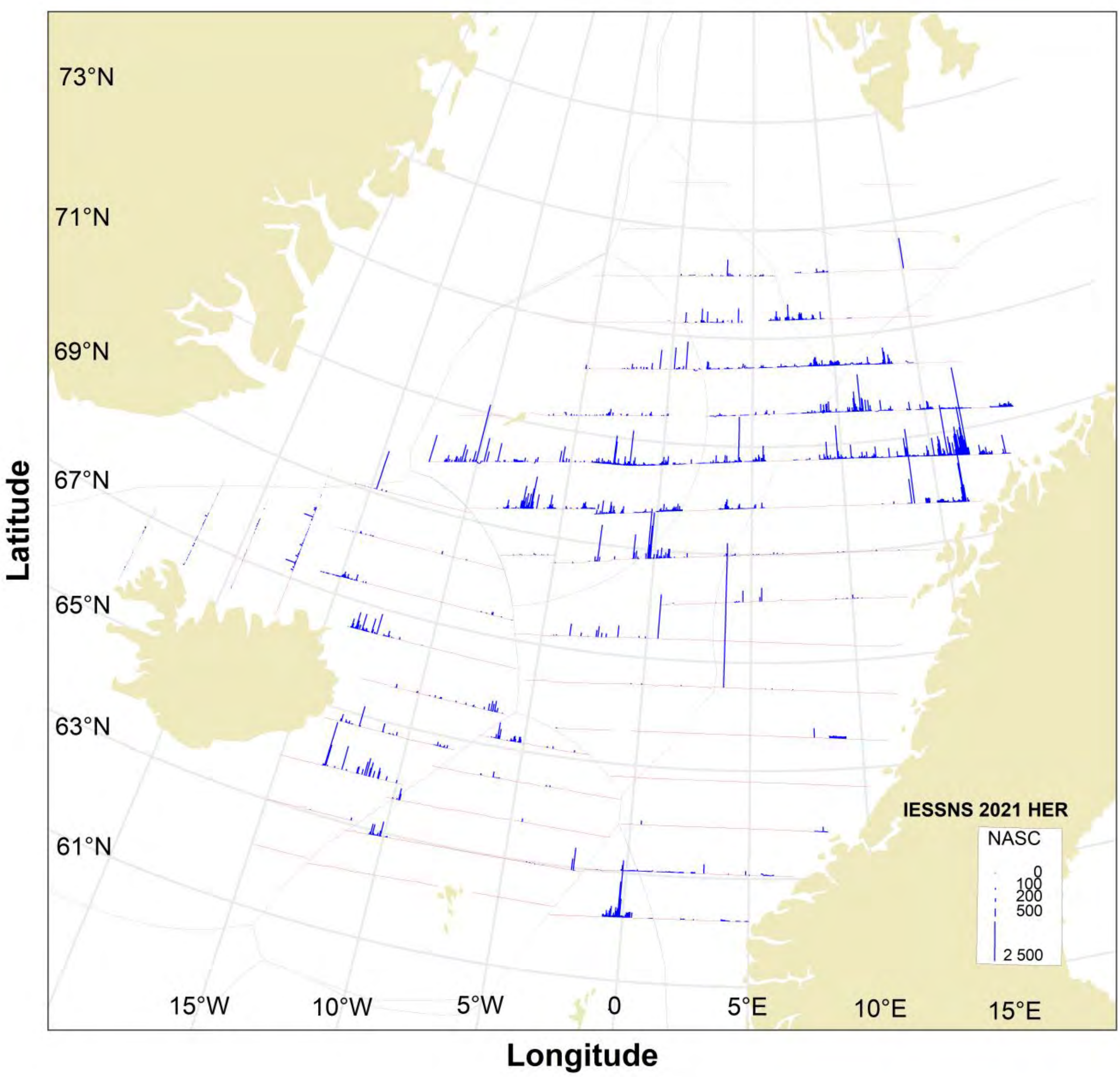


Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring along the cruise tracks in 2021, presented as bar plot.

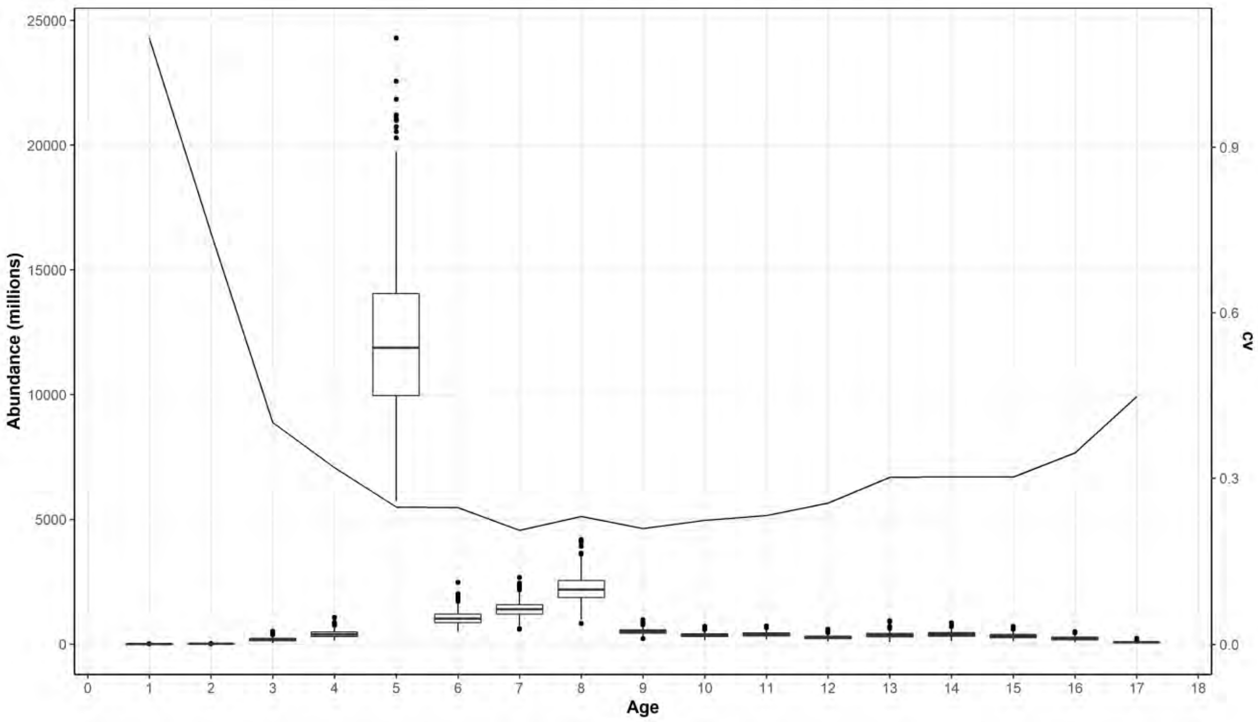


Figure 21. Abundance by age for Norwegian spring-spawning herring during IESSNS 2021. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 9. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2021.

Length	Age in years (year class)																		Number	Biomass	Mean
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	(10^6)	(10^6 kg)	(g)
15-16																					26.5
16-17																					31.8
17-18																					36.0
18-19	0.5																		0.5	0.0	47.8
19-20																				0.2	57.3
20-21			12.8																12.8	0.8	62.5
21-22			18.0																18.0	1.3	69.2
22-23			26.6																26.6	2.3	83.9
23-24			3.3																3.3	0.3	92.0
24-25			5.0																5.0	0.7	126.6
25-26			18.5	6.4															25.0	3.7	153.6
26-27		4.0	29.1	17.5	4.6														55.3	8.9	166.3
27-28			17.1	78.2	56.4	7.5	8.7	1.7											169.6	30.5	184.2
28-29			25.0	40.1	167.9	23.5	7.4	22.2	2.5	3.7									292.2	59.2	205.2
29-30			16.1	73.9	695.0	9.9	18.3	7.5	28.8	11.7	6.0				0.5				867.8	199.4	230.3
30-31			10.9	86.0	2895.6	156.0	25.5	30.6	13.8	12.6	9.5	5.9	7.5	0.6	1.8				3 256.5	823.7	252.4
31-32				48.3	3743.5	146.3	94.3	51.9	24.1	12.7	8.8	13.6	0.7	5.6	0.6				4 150.4	1133.2	273.2
32-33			2.0	28.0	3040.3	161.3	229.2	89.7	27.0	23.1	14.8	8.9	11.8	0.8		0.8	1.8		3 639.4	1080.8	296.8
33-34				16.3	1354.5	279.8	398.2	473.7	68.9	25.8	4.7	6.3	2.9						2 631.0	848.7	320.6
34-35					154.7	230.4	404.9	862.9	97.6	28.3	12.8	15.5	1.4		5.4				1 814.0	626.8	341.3
35-36						30.5	185.3	580.3	122.1	103.0	52.2	30.2	7.6	15.4	3.6	17.7			1 147.8	422.2	359.8
36-37							25.4	94.4	102.4	76.2	131.0	83.6	127.2	112.3	83.3	32.7	17.2		885.7	340.7	378.7
37-38				3.8				11.4	15.2	52.4	132.1	71.5	144.5	165.3	139.5	38.2	24.4		798.2	318.9	394.8
38-39					3.3		0.9			12.0	21.1	32.8	35.3	66.3	89.3	93.3	17.0		371.4	154.5	416.2
39-40													21.0	21.1		45.5	3.4		91.0	40.8	451.0
40-41					1.3									4.5			5.1		10.9	5.2	460.9
																				0.4	
TSN(mill)	0.5	4.0	184.5	398.5	12117.0	1045.4	1398.1	2226.3	502.4	361.5	393.1	268.2	359.8	391.9	324.0	228.2	69.0		20 279.7		
cv (TSN)	1.55	0.87	0.40	0.32	0.25	0.25	0.21	0.23	0.21	0.22	0.23	0.26	0.30	0.30	0.30	0.35	0.45		0.20		
TSB(1000 t)	0.0	0.7	27.4	92.5	3 348.2	316.7	456.3	763.2	173.3	128.5	146.5	101.1	141.9	154.0	128.4	95.3	28.3		6 103.2		
cv (TSB)	1.55	0.87	0.37	0.30	0.25	0.25	0.21	0.23	0.21	0.23	0.24	0.26	0.31	0.30	0.31	0.35	0.45		0.20		
Mean length(cm)	15.3	26.0	26.0	29.3	31.1	32.2	33.0	33.8	33.7	34.6	35.8	35.6	36.4	36.9	36.9	37.6	37.4				
Mean weight(g)	28.7	165.6	166.2	233.9	276.7	300.9	320.5	336.3	333.8	349.9	370.6	371.2	388.1	389.2	392.0	419.5	414.5				

Table 10. IESSNS bootstrap time series (mean of 1000 replicates) from 2016 to 2021. 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	38	119	747	577	1,622	1,636	1,967	1,588	1,274	2,001	2,164	6,245	6,676
2017	1,232	240	1,318	4,653	1,003	1,184	795	1,716	1,004	1,115	1,657	4,040	5,821
2018	0	587	656	864	3,054	924	1,172	746	971	1,078	663	2,704	4,379
2019	0	143	1,910	616	1,101	3,487	814	751	510	780	470	4,660	4,794
2020	0	15	117	8,280	1,710	2,367	4,087	696	520	305	594	1,827	5,991
2021	1	4	184	398	12,117	1,045	1,398	2,226	502	361	393	1,641	6,103

Table 11. IESSNS baseline time series from 2016 to 2021. 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
2021	1	3	196	388	11,988	1,109	1,342	2,292	491	365	386	1,649	6,085

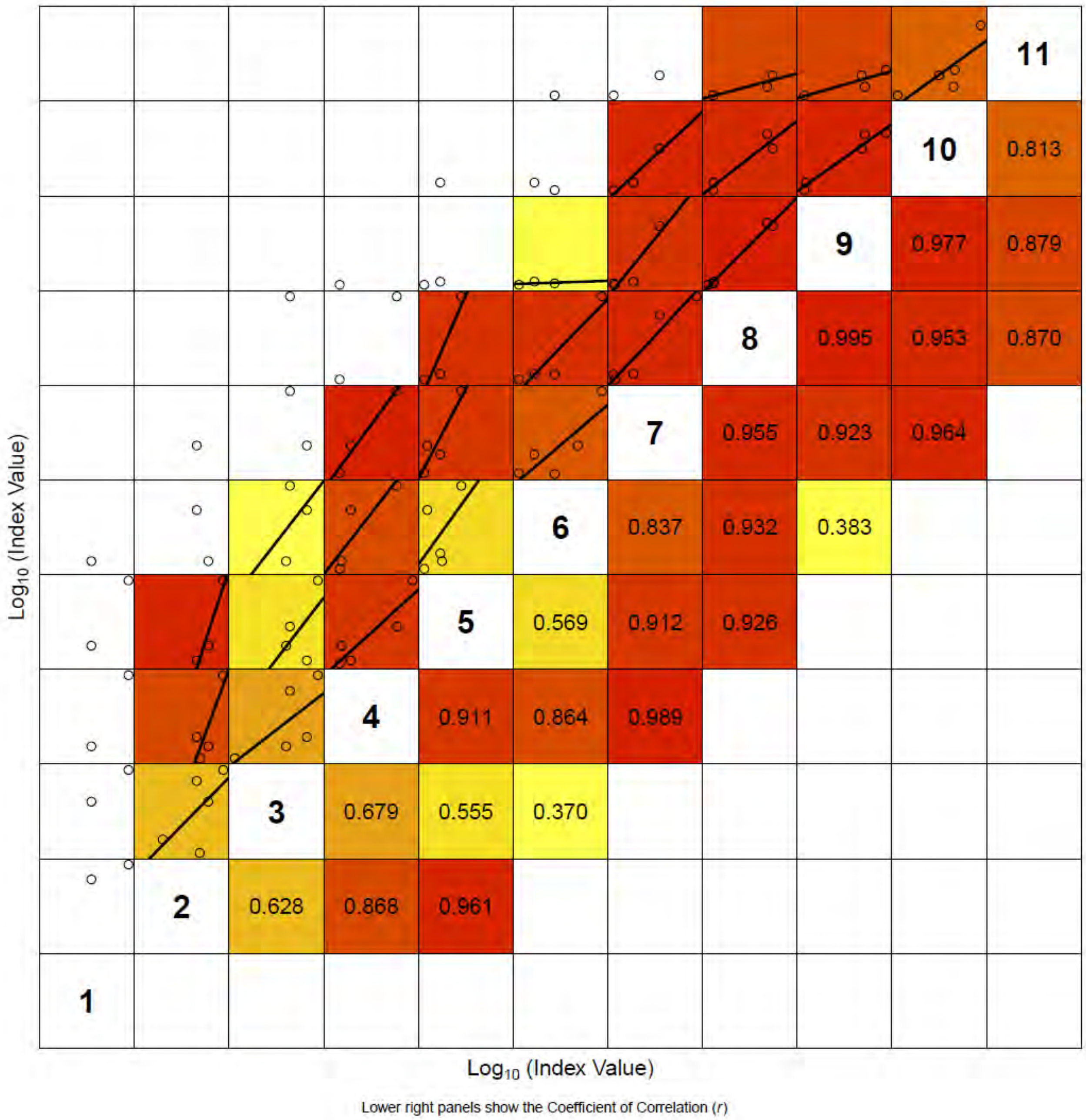


Figure 22. Internal consistency for Norwegian spring-spawning herring within the IESSNS 2021. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows 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 parts of the survey area dominated by warm Atlantic waters and had a continuous distribution from the southern boundary of the survey area (60 °N) to Spitsbergen (72 °N). High blue whiting density (s_A-values) was observed in the southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands, and southeast of Iceland. Concentrations of older fish (age2+) were low and they were mainly observed on the continental slope, both in the eastern and the southern part of the Norwegian Sea (Figure 23). The distribution in 2021 is comparable to 2020 with the exception of more blue whiting recorded south and southwest of Iceland, mostly age-0 fish. As in previous years no blue whiting was registered in the cold East Icelandic Current, between Iceland and Jan Mayen.

The total biomass of blue whiting registered during IESSNS 2021 was 2.2 million tons (Table 12), which is an increase of 24% compared to 2020 (1.8 mill tons). Estimated stock abundance (ages 1+) was 26.2 billion compared to 16.5 billion in 2020, which is an increase of 60%. Age 1 dominated the estimate in 2021 as it contributed 51% and 69% of biomass and abundance, respectively.

Bootstrap estimates of numbers by age, with uncertainty estimates, for blue whiting during IESSNS 2021 are shown in Figure 24. The baseline point estimates from 2016-2021 are shown in table 13. The internal consistency among year classes is shown in Figure 25 and indicates good to moderate consistency for ages 3-6, but poorer fit for other ages.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2021 IESSNS as in the previous survey years.

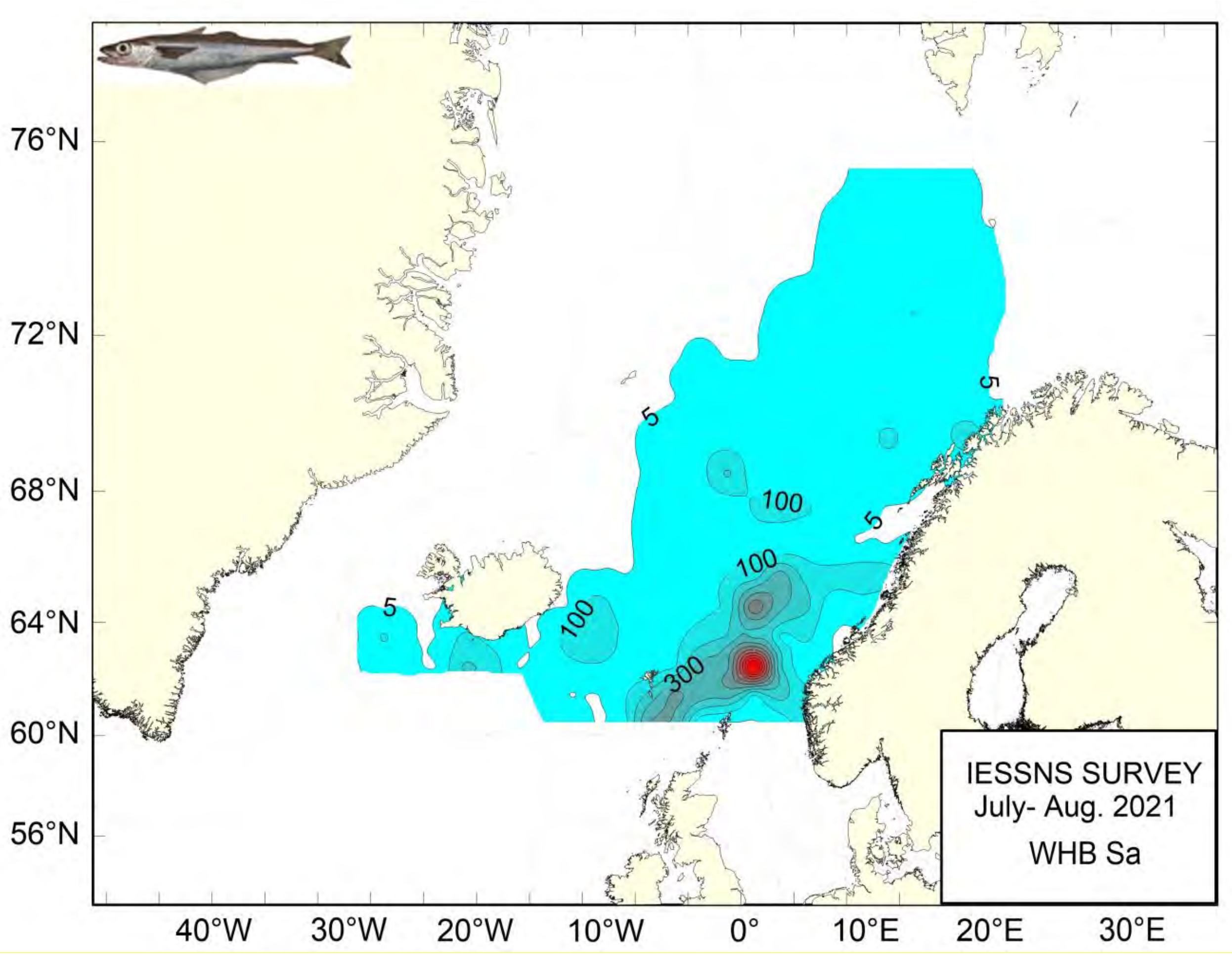


Figure 23a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2021. Presented as contour lines.

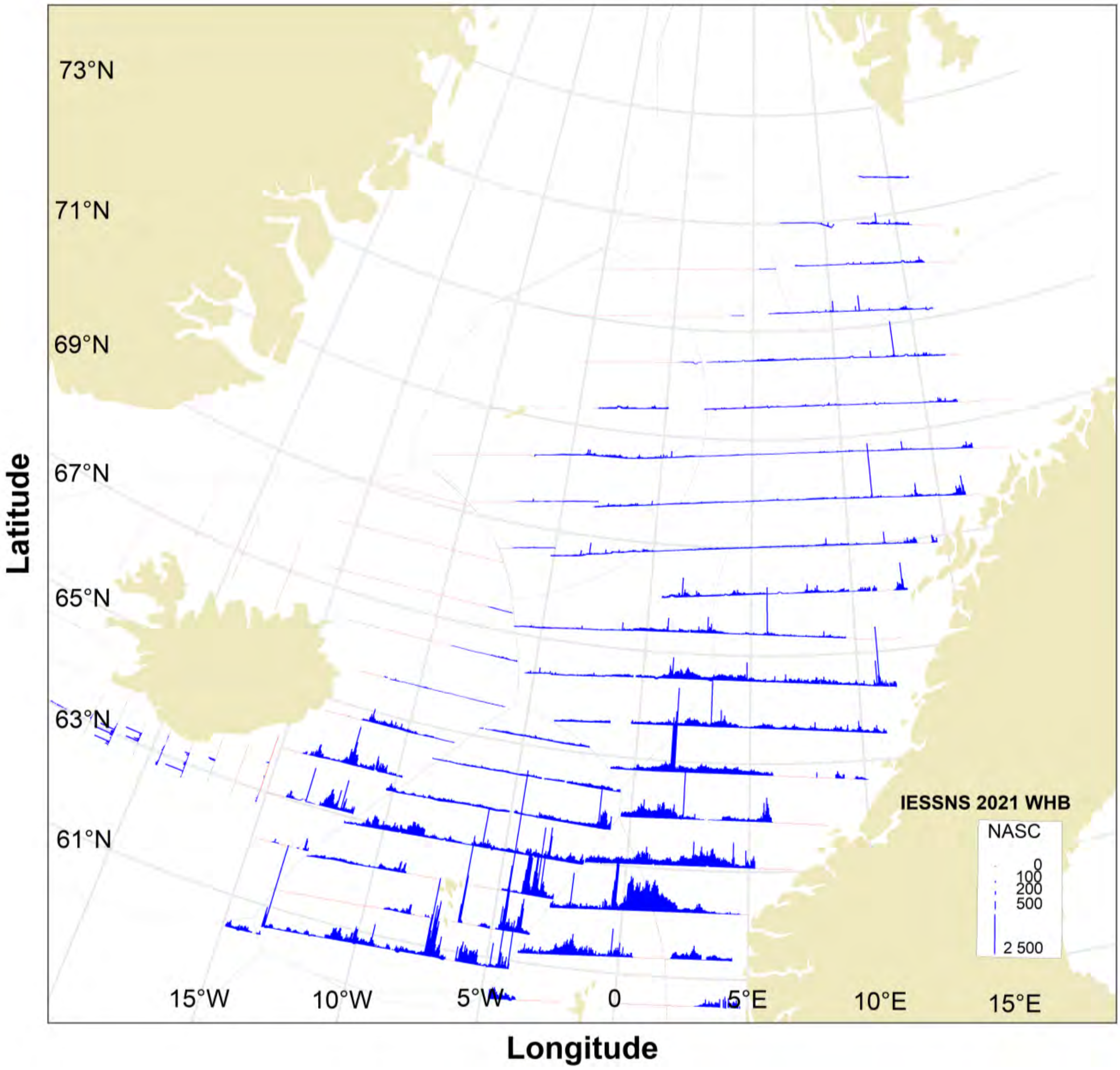


Figure 23b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2021. Presented as bar plot.

Table 12. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2021.

Length	Age in years (year class)											Number	Biomass	Mean
	0	1	2	3	4	5	6	7	8	9	10			weight
(cm)	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	(10^6)	(10^6 kg)	(g)
10-11	27.8											27.8		
11-12	311.1											311.1	0.1	5.0
12-13	961.4											961.4	0.2	5.9
13-14	989.4											989.4	2.6	8.5
14-15	753.9											753.9	9.8	10.5
15-16	588.3											588.3	12.9	14.1
16-17	329.0											329.0	12.8	17.6
17-18	284.6											284.6	12.7	22.2
18-19	175.5	299.0										474.5	9.1	27.9
19-20	34.2	1020.9										1 055.1	9.5	33.3
20-21	14.6	3304.4	19.3									3 338.3	17.5	37.7
21-22		5998.2		57.5								6 055.7	43.6	40.6
22-23		5077.7	31.5									5 109.2	163.6	48.6
23-24		1799.3	255.7	13.6								2 068.6	346.8	57.5
24-25		632.2	276.3	25.3	7.5							941.3	323.9	63.9
25-26		250.5	529.6	279.0	14.0							1 073.1	145.7	71.9
26-27		72.8	754.5	212.8	13.5	8.9						1 062.5	77.9	84.3
27-28		24.5	261.8	427.7	23.1	54.8		13.7				805.6	106.3	98.8
28-29		3.2	167.9	290.8	314.5	83.3	227.2	97.4			11.0	1 195.5	115.6	110.9
29-30		1.4	75.6	79.0	149.1	188.0	321.5	162.6	57.4	33.8	57.8	1 126.2	96.3	120.8
30-31				96.1	234.6	179.0	327.7	128.5		31.4		997.1	156.5	132.8
31-32					89.0	204.0	301.1	98.6				692.7	161.5	146.0
32-33						133.1	234.0	44.8				411.9	156.6	159.7
33-34				12.0			67.4	43.3				122.7	122.8	179.0
34-35							13.2	20.7	13.8	14.1		61.8	80.0	192.7
35-36							0.8	8.2			8.2	17.3	26.3	214.0
36-37								17.0				17.0	14.1	223.5
37-38													4.6	274.2
38-39											7.1	7.1	5.1	330.2
TSN(mill)	4470	18484	2372	1494	845	851	1493	635	71	79	84	30 896.0		
cv (TSN)	0.46	0.17	0.21	0.27	0.32	0.30	0.34	0.37	0.58	0.64	0.72	0.12		
TSB(1000 t)	79.1	1 093.1	242.4	177.4	121.2	134.7	245.4	105.9	11.5	12.2	13.6	2 237.3		
cv (TSB)	0.40	0.17	0.21	0.27	0.32	0.30	0.34	0.36	0.60	0.63	0.62	0.11		
Mean length(cm)	14.5	21.5	25.0	26.7	28.8	29.9	30.3	30.4	29.8	30.8	31.3			
Mean weight(g)	21	62	97	119	145	159	168	175	156	162	197			

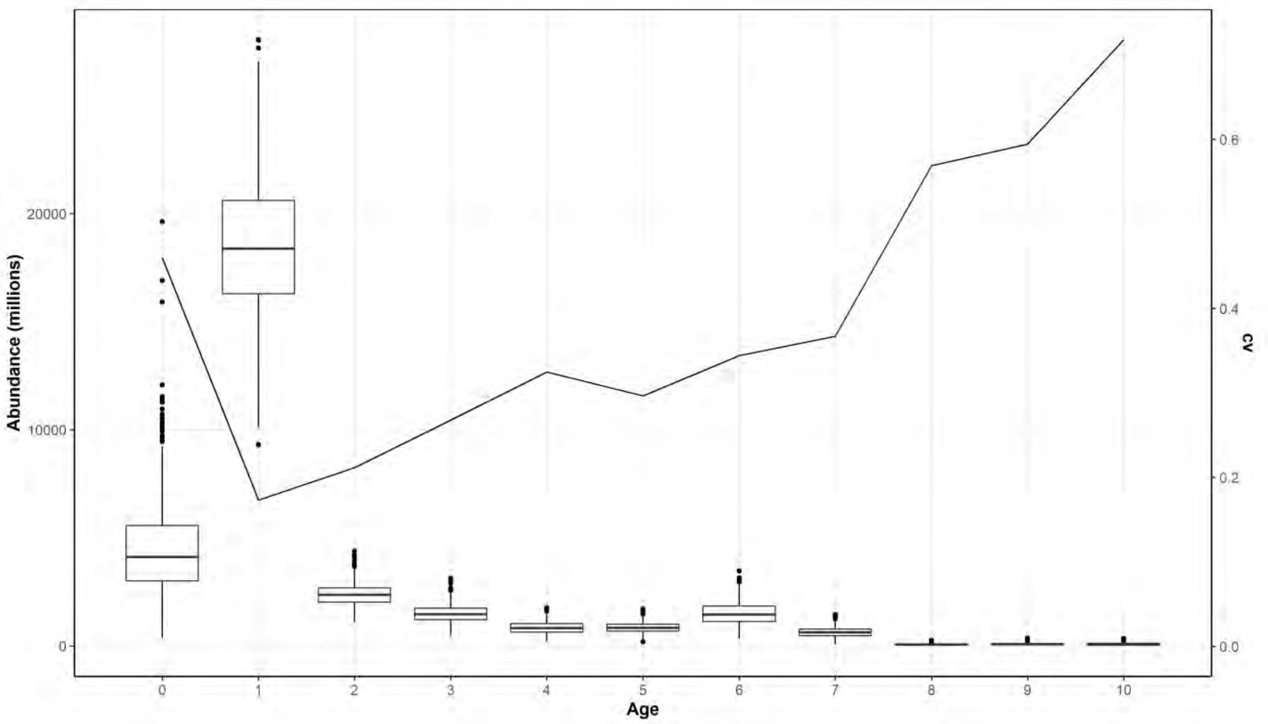


Figure 24. Number by age with uncertainty for blue whiting during IESSNS 2021. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

Table 13. IESSNS baseline time series from 2016 to 2021. 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
2021	4,023	18,056	2,300	1,664	841	982	1,543	609	60	91	74	2,238

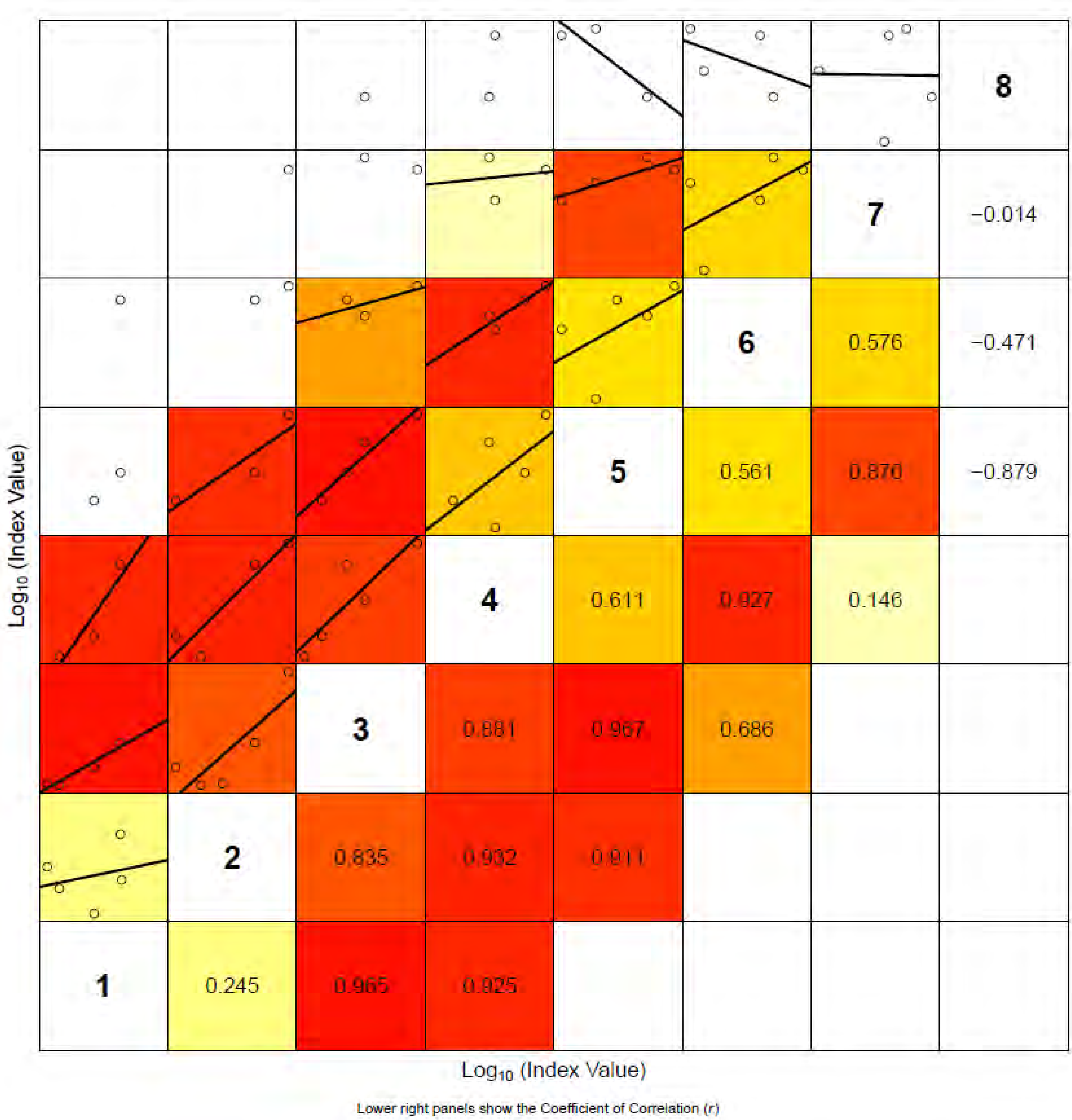


Figure 25. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (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 82% of trawl stations across the five vessels (Figure 26) and where lumpfish was caught, 69% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Iceland to the central Barents Sea in the northeast part of the covered area.

Abundance was greatest north of 72°N, and lowest directly south of Iceland, and western side of the North Sea and central part of the Norwegian 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 5 to 56 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 bimodal distribution but with a peak around 22-30 cm and another around 35-44 cm. Generally, the mean length and mean weight of the lumpfish was highest in Faroese waters, southern part of Iceland and the coastal waters and along the shelf edges of Norway and lowest in the central and northern Norwegian Sea.

A total of 606 fish (451 by R/V "Árni Friðriksson", 55 by M/V "Eros" and 100 by M/V Vendla) between 7 and 56 cm were tagged during the survey (Figure 28).

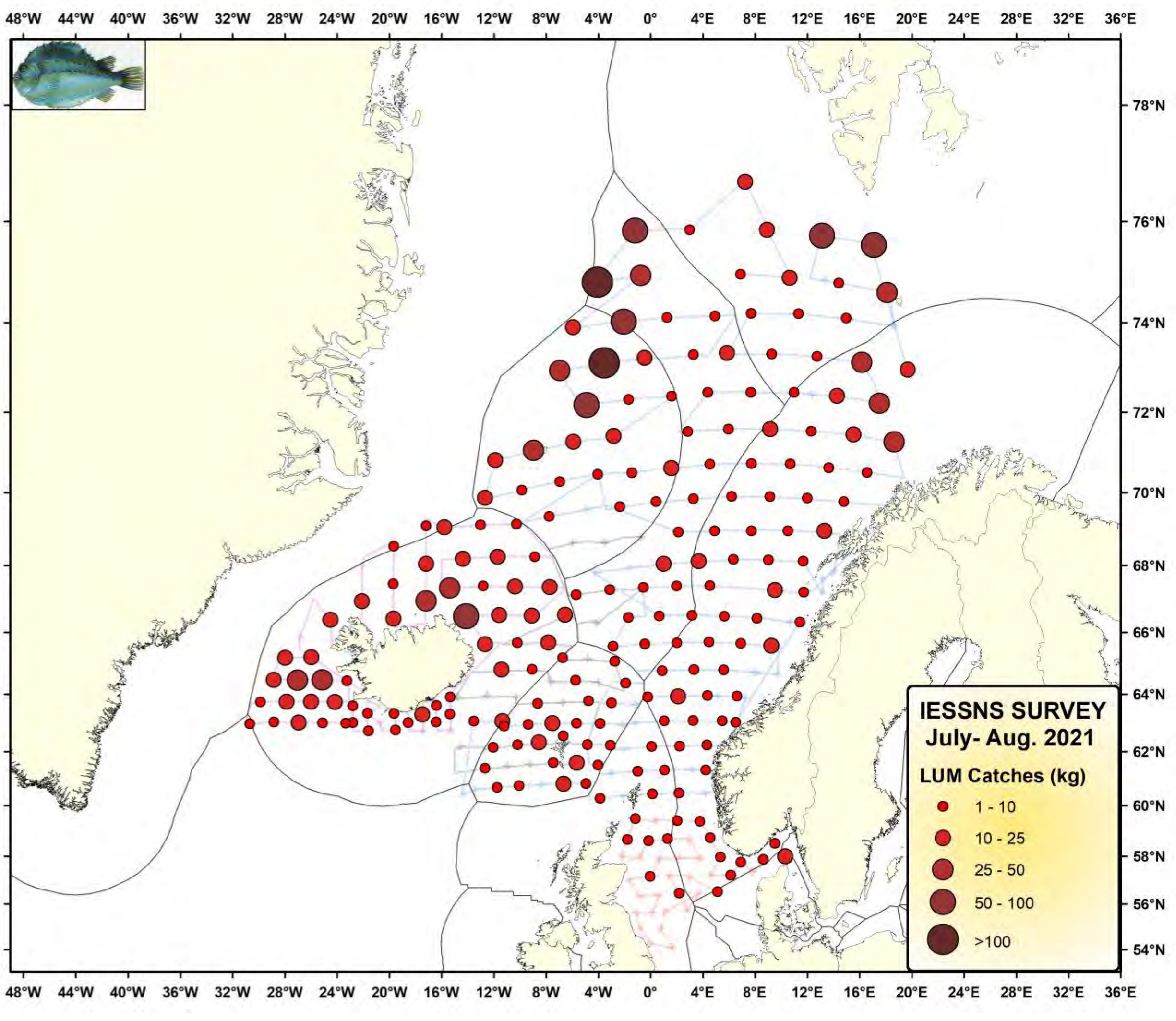


Figure 26. Lumpfish catches at surface trawl stations during IESSNS 2021.

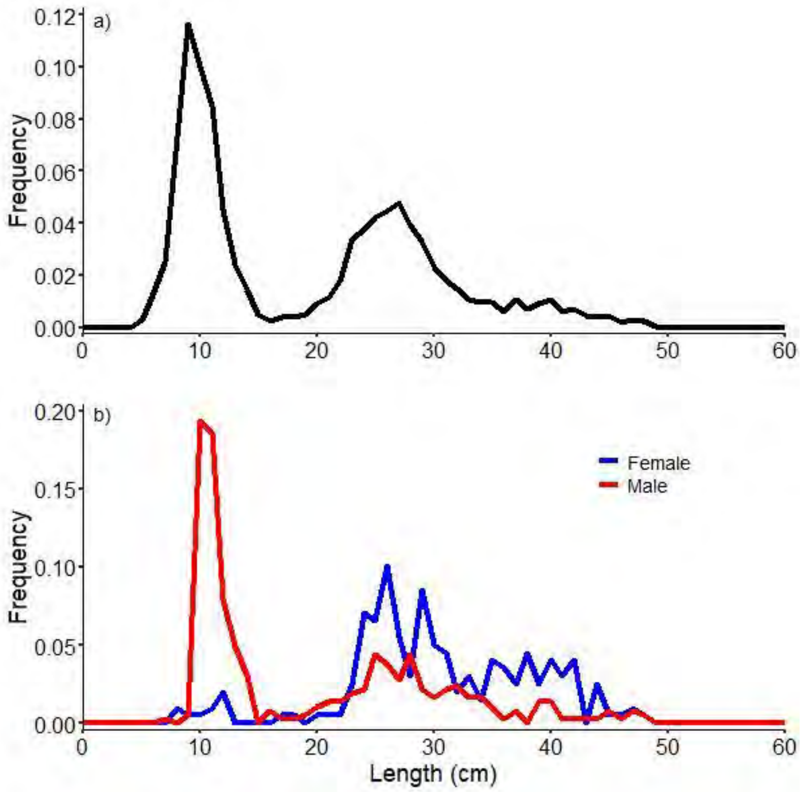


Figure 27. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

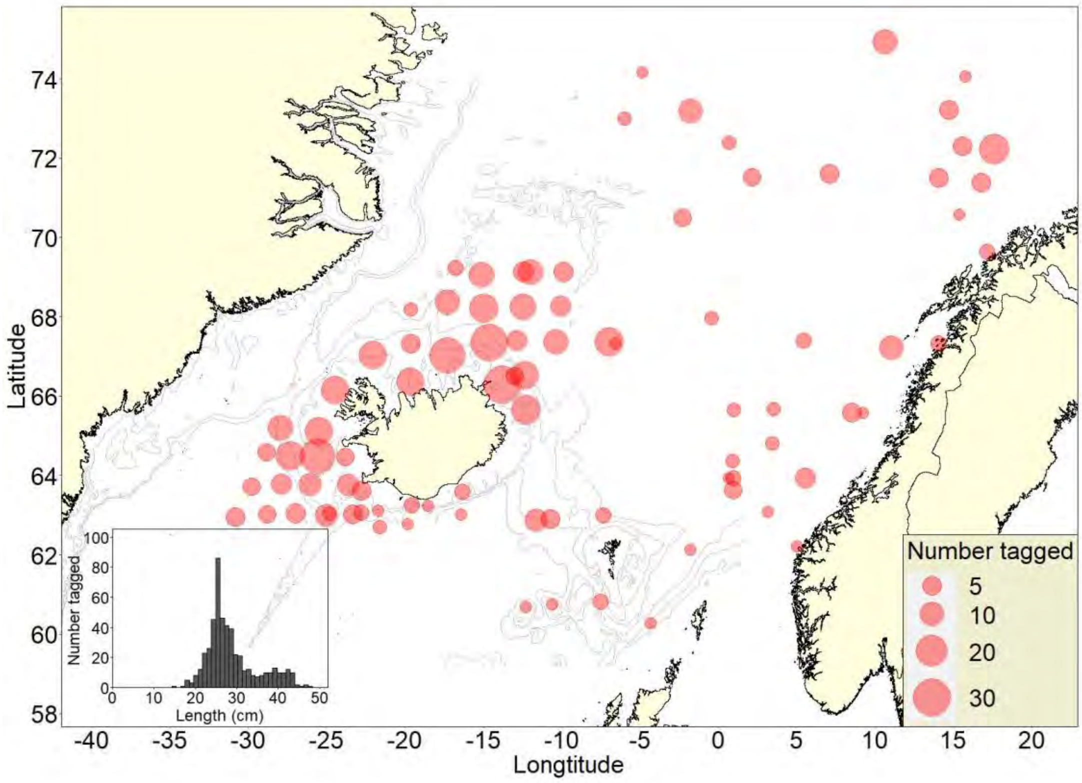


Figure 28. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 35 North Atlantic salmon were caught in 25 stations both in coastal and offshore areas from 60°N to 76°N in the upper 30 m of the water column during IESSNS 2020 (Figure 29). The salmon ranged from 0.089 kg to 6.5 kg in weight, dominated by post-smolt weighing 89-425 grams and 1 sea-winter individuals weighing 1.9-2.4 kg. We caught from 1 to 4 salmon during individual surface trawl hauls. The length of the salmon ranged from 21.5 cm to 87 cm, with a pronounced bimodal distribution of <30 cm and >53 cm long salmon. The entire time series on post-smolt distribution, ecology and genetics with many sampled specimens originating from the IESSNS 2007-2020 surveys, have now been included in two new publications (Utne et al. in press, Gilbert et al. 2021)

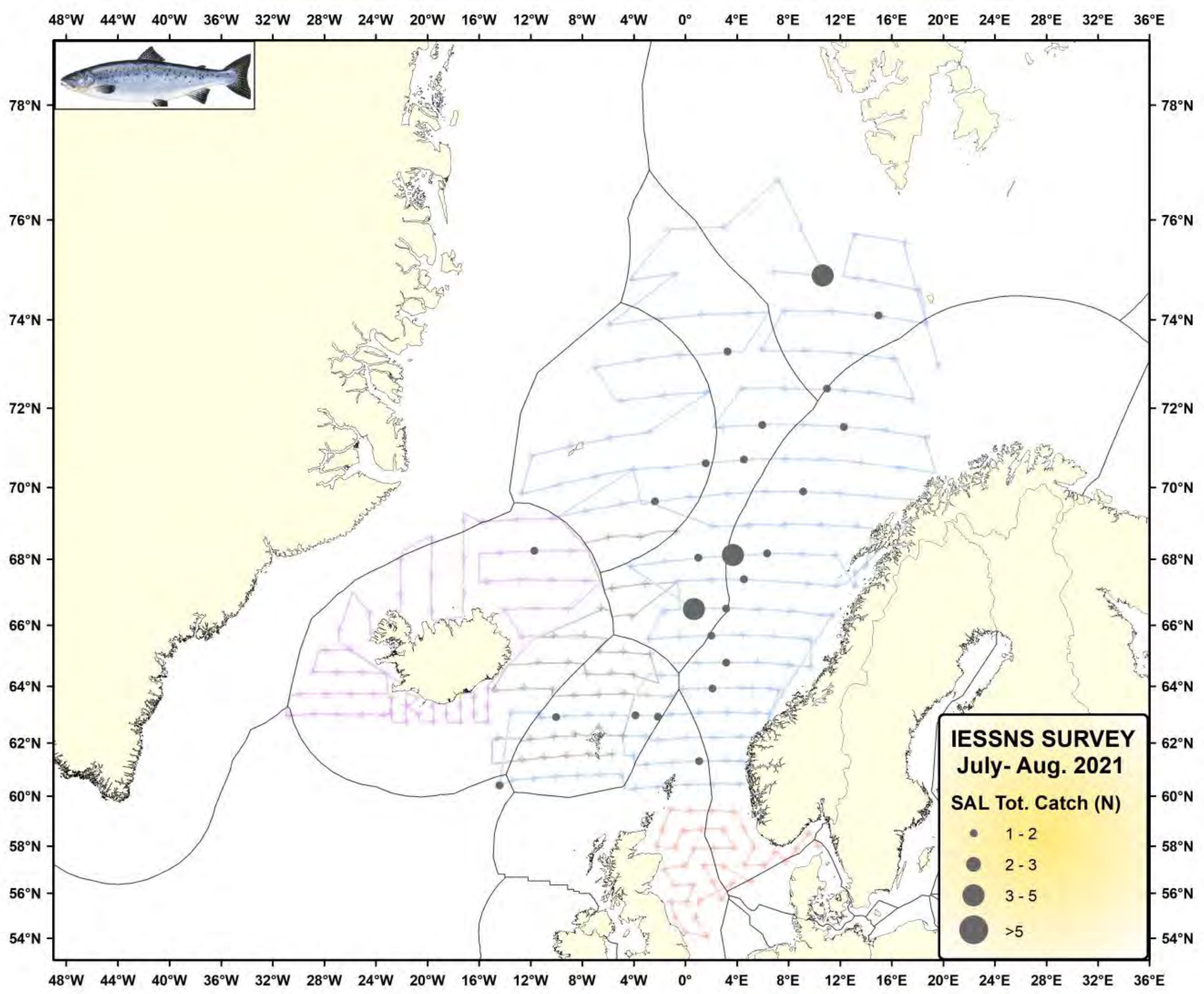


Figure 29. Catches of salmon at surface trawl stations during IESSNS 2021.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 12 stations primarily along the cold fronts: Between East Greenland and Iceland, west and North-East of Jan Mayen and at the entrance to the Barents Sea (Figure 30). This was less than in 2020, where 28 hauls contained capelin (plus 14 in the Greenlandic survey). (Figure 30). Large capelin, total length range 13 cm to 19 cm, was caught at three stations north of Iceland, and the catch weight ranged from 23 kg to 240 kg. This is the first time that such large capelin has been caught in the survey as usually juvenile capelin is caught, length < 12 cm.

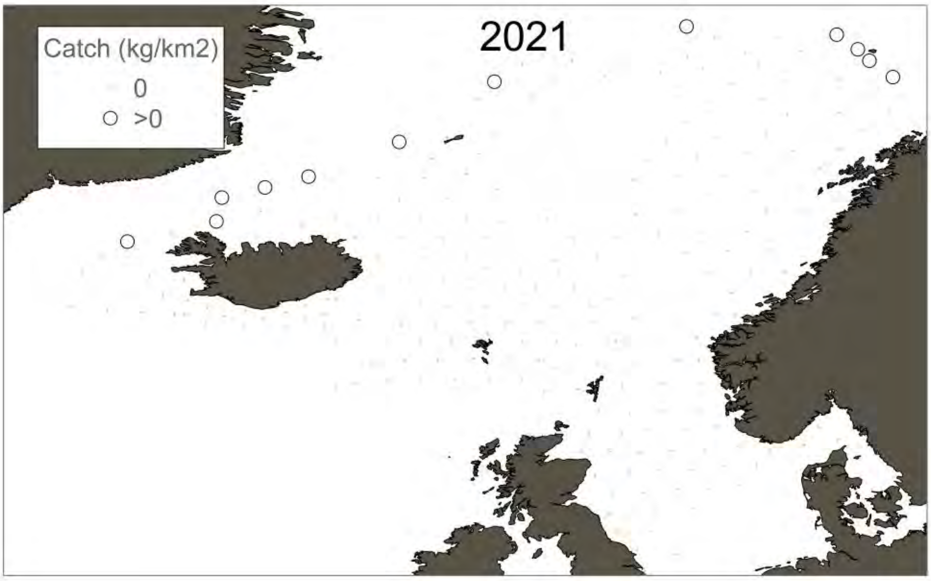


Figure 30. Presence of capelin in surface trawl stations.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Eros" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland and R/V "Jákup Sverri" from Faroe Islands in 2021 (Figure 31). Overall, 1029 marine mammals of 9 different species were observed, which was an increase from 802 marine mammals observed in 2020, The increase in number of marine mammals observed was primarily because R/V "Jákup Sverri" from Faroe Islands participated with opportunistic whale observations in 2021 and not in previous years. Both Eros and Vendla experienced several days with fog and very reduced visibility in the central and north-western region (Jan Mayen area) and northernmost areas between Bear Island and Svalbard. An increased number of days with low visibility possibly influenced the reduced number of marine mammals observed on Eros and Vendla in the normally abundant marine mammal habitats in the northernmost part of the surveyed area. R/V "Árni Friðriksson" had also occasional periods with fog north and south of Iceland, whereas R/V "Jákup Sverri" experienced primarily good visibility throughout the survey.

The species that were observed included; 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*) and white beaked dolphins (*Lagenorhynchus albirostris*). The dominant number of marine mammal observations were found around Iceland, Faroe Islands and along the continental shelf between the north-eastern part of the Norwegian Sea and in a line between Finnmark to southwest of Svalbard. We observed very few marine mammals in the central part of the Norwegian Sea in July 2021. Fin whales (n = 86, group size = 1-8 (average groups size = 2.2)) and humpback whales (n = 21, group size = 1-4 (average groups size = 1.6)) dominated among the large whale species, and they were present west and 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 and northern part of the Norwegian Sea feeding where they probably were feeding on the abundant 2016 herring year-class. Very few sperm whales (n = 9, group size =

1-2 (average groups size = 1.1)) where observed. Killer whales (n = 127, group size = 1-30 (average groups size = 6.4)) dominated in the southern, northern and north-eastern part of the Norwegian Sea, partly overlapping and presumably feeding on NEA mackerel in the upper water masses. Pilot whales (n = 559, group size = 2-150 (average groups size = 37.3)) dominated totally in numbers of observations during IESSNS 2021, with more than 50% of all marine mammal observations. They were exclusively observed around Faroe Islands and east of Iceland, with a hot-spot area north of Faroe Islands. White beaked dolphins (n = 162, group size = 3-15 (average groups size = 7.0)) were present in the northern part of the Norwegian Sea. Minke whales (n = 56, group size = 1-9 (average groups size = 1.8)) were distributed over large areas from western coast of Norway to western part of Iceland, and from 60°N to 75°N, including overlapping and likely feeding on NSS herring in the upper 40 m of the water column. There is now available a new publication summarizing the main results on marine mammals from the IESSNS surveys from 2013 to 2018, with major focus on hot spot areas of fin whales and humpback whales from 2013 to 2018 (Løviknes et al. 2021)

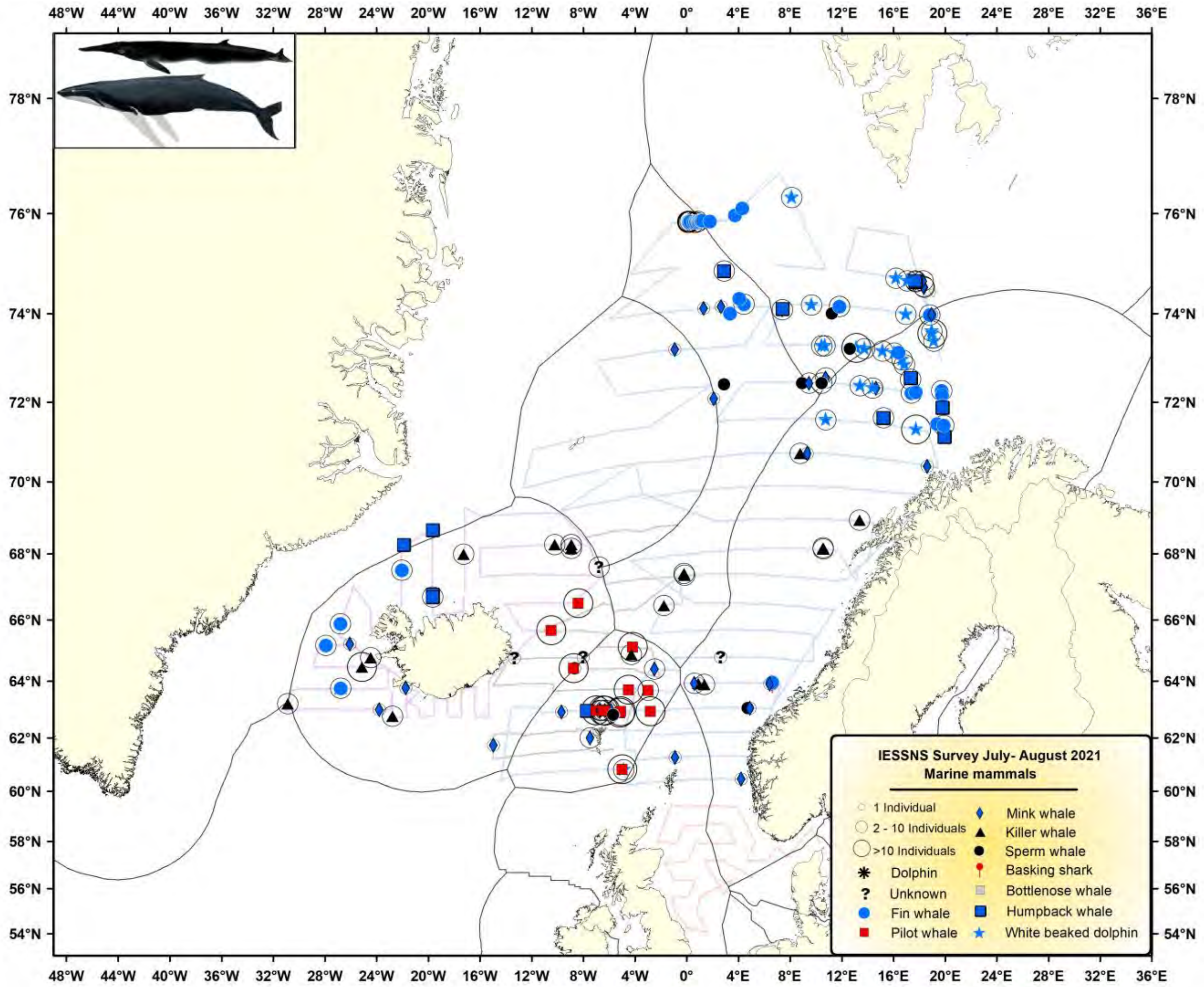


Figure 31. Overview of all marine mammals sighted during IESSNS 2021.

5 Recommendations

The group suggested the following recommendation from WGIPS	To whom
The occasional large catches of mackerel have a relatively large impact on the overall results and possibly bias the stock indices. WGIPS recommends that the ability of the present and alternative methods (such as more advanced statistical models) to represent this overdispersion is evaluated.	National institutes and WGISDAA
The surveys conducted by Denmark in 2018, 2019, 2020 and 2021 have clearly demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak area 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. In 2022 the IESSNS survey in the North Sea have been conducted for five consecutive years (2018-2022). It is recommended that a comprehensive report is written about the major results from the NEA mackerel time series from the IESSNS surveys in the North Sea, where the internal consistency between years in the survey for selected age groups is also evaluated. A major aim will be to at some stage evaluate and consider the possibility to include and implement the IESSNS survey in the North Sea as an abundance index used in ICES for NEA mackerel.	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.
We recommend continuing the international tagging of lumpfish for two new year's; 2022 and 2023, and we encourage all participating country to contribute.
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 slightly change the both the strata system and transect system to accommodate better the curvature of the long east-west transects to avoid empty areas in the overall spatial coverage.
For next year's survey, the group should consider distributing transects differently among vessels, such that synoptic coverage becomes even better than this year and survey time is optimally used.

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9 References

Bachiller E, Utne KR, Jansen T, Huse G. 2018. Bioenergetics modelling of the annual consumption of zooplankton by pelagic fish feeding in the Northeast Atlantic. PLOS ONE 13(1): e0190345. doi.org/10.1371/journal.pone.0190345.

Banzon, V., Smith, T. M., Chin, T. M., Liu, C., and Hankins, W., 2016. A long-term record of blended satellite and in situ sea-surface temperature for climate monitoring, modelling and environmental studies. Earth System Science Data. 8, 165–176, doi:10.5194/essd-8-165-2016.

Foote, K. G., 1987. Fish target strengths for use in echo integrator surveys. Journal of the Acoustical Society of America. 82: 981-987.

Gilbey; J., Utne K.A., Wennevik V. et al. 2021. The early marine distribution of Atlantic salmon in the North-East Atlantic: A genetically informed stocks-specific synthesis. Fish and Fisheries:2021;00:1.-33. DOI:10.1111/faf.12587.

ICES. 2012. Report of the International Bottom Trawl Survey Working Group (IBTSWG), 27–30 March 2012, Lorient, France. ICES CM 2012/SSGESST:03. 323 pp.

ICES 2013a. Report of the Workshop on Northeast Atlantic Mackerel monitoring and methodologies including science and industry involvement (WKNAMMM), 25–28 February 2013, ICES Headquarters, Copenhagen and Hirtshals, Denmark. ICES CM 2013/SSGESST:18. 33 pp.

ICES. 2013b. Report of the Working Group on Improving Use of Survey Data for Assessment and Advice (WGISDAA), 19-21 March 2013, Marine Institute, Dublin, Ireland. ICES CM 2013/SSGESST:07.22 pp.

ICES 2014a. Manual for international pelagic surveys (IPS). Working document of Working Group of International Surveys (WGIPS), Version 1.02 [available at ICES WGIPS sharepoint] 98 pp.

ICES 2014b. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA), 17–21 February 2014, Copenhagen, Denmark. ICES CM 2014/ACOM: 43. 341 pp

ICES. 2017. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January-3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

Jansen, T., Post, S., Kristiansen, T., Oskarsson, G.J., Boje, J., MacKenzie, B.R., Broberg, M., Siegstad, H., 2016. Ocean warming expands habitat of a rich natural resource and benefits a national economy. Ecol. Appl. 26: 2021–2032. doi:10.1002/eap.1384

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019; 10:1523–1528.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquaculture Science. 47: 1282-1291.

Løviknes; S.., Jensen, K.H., Krafft, B.A., Nøttestad, L. 2021. Feeding hotspots and distribution of fin and humpback whales in the Norwegian Sea from 2013 to 2018. Frontiers in Marine Science 8:632720. doi.org/10.3389/fmars.2021.632720

Nikolioudakis, N., Skaug, H. J., Olafsdottir, A. H., Jansen, T., Jacobsen, J. A., and Enberg, K. 2019. Drivers of the summer-distribution of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2011 to 2017; a Bayesian hierarchical modelling approach. ICES Journal of Marine Science. 76(2): 530-548. doi:10.1093/icesjms/fsy085

Nøttestad, L., Utne, K.R., Óskarsson, G. J., Jónsson, S. Þ., Jacobsen, J. A., Tangen, Ø., Anthonypillai, V., Aanes, S., Vølstad, J.H., Bernasconi, M., Debes, H., Smith, L., Sveinbjörnsson, S., Holst, J.C., Jansen, T. and Slotte, A. 2016. Quantifying changes in abundance, biomass and spatial distribution of Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) in the Nordic Seas from 2007 to 2014. ICES Journal of Marine Science. 73(2): 359-373. doi:10.1093/icesjms/fsv218.

Ólafsdóttir, A., Utne, K.R., Jansen, T., Jacobsen, J.A., Nøttestad, L., Óskarsson, G.J., Slotte, A., Melle, W. 2019. Geographical expansion of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2007 - 2014 was primarily driven by stock size and constrained by temperature. Deep-Sea Research Part II. 159, 152-168.

Rosen, S., Jørgensen, T., Hammersland-White, Darren, Holst, J.C. 2013. Canadian Journal of Fisheries and Aquatic Sciences. 70(10):1456-1467. doi.org/10.1139/cjfas-2013-0124.

Salthaug, A., Aanes, S., Johnsen, E., Utne, K. R., Nøttestad, L., and Slotte, A. 2017. Estimating Northeast Atlantic mackerel abundance from IESSNS with StoX. Working Document (WD) for WGIPS 2017 and WKWIDE 2017. 103 pp.

Utne K., Diaz Pauli, B., Haugland, M. et al. 2021. Starving at sea? Poor feeding opportunities for salmon post-smolts in the Northeast Atlantic Ocean. ICES Journal of Marine Science (in press).

Valdemarsen, J.W., J.A. Jacobsen, G.J. Óskarsson, K.R. Utne, H.A. Einarsson, S. Sveinbjörnsson, L. Smith, K. Zachariassen and L. Nøttestad 2014. Swept area estimation of the North East Atlantic mackerel stock using a standardized surface trawling technique. Working Document (WD) to ICES WKPELA. 14 pp.

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. 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 June/July in this area.

In 2021, 39 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 2021 amounted 2429 kg/km^2, which was considerably higher than in the previous years (2020: 1318 kg/km^2, 2019: 1009 kg/km^2, 2018: 1743 kg/km^2). 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 (version 2.7) baseline estimate of mackerel abundance in the North Sea was 560 198 tonnes (Table A1-1). This is based on a preliminary defined polygon for the surveyed area in which the northern border was set to 60°N (border to stratum 1; Fig. 2), and the eastern, southern and western limits were either the coastline or extrapolated using half the longitudinal or latitudinal distance between the adjacent stations.

Table A1-1. StoX (version 2.7) baseline estimate of age segregated and length segregated mackerel index for the North Sea in 2021. Also provided is average length and weight per age class.

Length bin (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number (thousand)	Biomass (ton)	Mean Weight (g)
18-19	85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85	4.3	50
19-20	403	-	-	-	-	-	-	-	-	-	-	-	-	-	-	403	17.5	43.37
20-21	9604	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9604	637.2	66.35
21-22	25212	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25212	1979.4	78.51
22-23	176284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	176284	15888.7	90.13
23-24	349744	-	-	-	-	-	-	-	-	-	-	-	-	-	-	349744	35918.1	102.7
24-25	301762	-	-	-	-	-	-	-	-	-	-	-	-	-	-	301762	34876.6	115.58
25-26	120019	1780	-	-	-	-	-	-	-	-	-	-	-	-	-	121800	15346.9	126
26-27	42253	8853	-	-	-	-	-	-	-	-	-	-	-	-	-	51107	7816	152.93
27-28	91118	42581	-	-	-	-	-	-	-	-	-	-	-	-	-	133699	24132.3	180.5
28-29	384792	157557	-	-	-	-	-	-	-	-	-	-	-	-	-	542349	108574.4	200.19
29-30	312039	148579	1624	1624	-	-	-	-	-	-	-	-	-	-	-	463866	99842.9	215.24
30-31	83197	75339	1584	556	812	-	-	-	-	-	-	-	-	-	-	161488	39089.4	242.06
31-32	5225	64241	5172	2804	781	-	-	-	-	-	-	-	-	-	-	78224	20794.3	265.83
32-33	-	72348	14581	4014	36	283	-	-	-	-	-	-	-	-	-	91262	26475.4	290.1
33-34	-	21964	25330	24418	242	72	-	-	255	-	-	-	-	-	-	72281	22558.5	312.1
34-35	-	5047	27231	35559	17920	2371	1346	255	-	-	-	-	-	-	-	89729	30551.4	340.49
35-36	-	526	-	25732	30513	9483	1088	-	490	-	-	406	-	-	-	68238	25902	379.58
36-37	-	-	-	13000	12936	25200	3039	-	3104	191	-	1413	-	-	-	58885	23118.2	392.6
37-38	-	-	-	1776	2502	11611	10330	1698	122	36	590	1561	-	-	-	30226	12833.9	424.6
38-39	-	-	-	-	-	1557	2113	7946	796	813	648	363	-	-	-	14236	6320.4	443.96
39-40	-	-	-	-	-	-	243	1373	4579	382	-	543	346	-	-	7466	3841.3	514.54
40-41	-	-	-	-	-	-	-	609	281	292	100	109	-	36	-	1425	815.7	572.3
41-42	-	-	-	-	-	-	-	-	373	4171	-	-	324	-	-	4867	2545.5	522.99
42-43	-	-	-	-	-	-	-	36	-	-	-	36	-	-	-	72	51.4	714
43-44	-	-	-	-	-	-	-	-	-	-	-	-	260	36	-	296	221.9	749.27
44-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64	64	44.5	700
TSN(1000)	1901737	598817	75522	109484	65742	50577	18160	11916	9999	5884	1337	4431	930	72	64	2854671	-	-
TSB(1000kg)	291990.5	139041.2	23664.1	37357.4	24174	20502.6	7260.4	5400.4	4774.7	2986.7	563	1850	540.1	48.3	44.5	-	560197.9	-
Mean length (cm)	25.73	29.44	32.88	34.05	34.88	35.98	36.63	38	37.72	40.22	37.71	36.94	40.81	41.5	45	-	-	-
Mean weight (g)	153.54	232.19	313.34	341.21	367.71	405.38	399.8	453.21	477.52	507.57	421.06	417.5	580.52	672	700	-	-	196.24

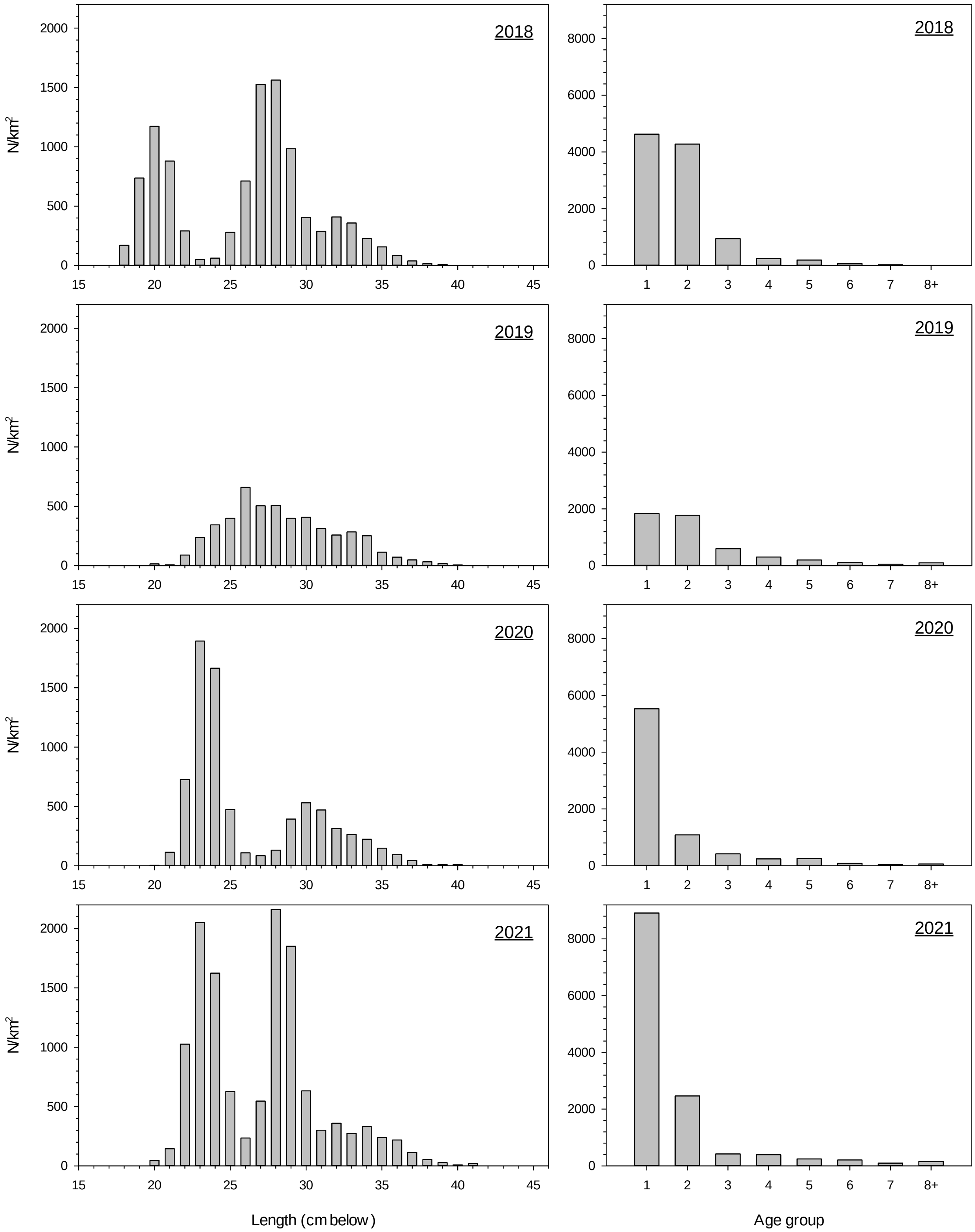

Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018, 2019, 2020 and 2021.

2 Appendix 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 2021.

Table A2-1: Trawl station exclusion list and average horizontal trawl opening per vessel for IESSNS 2021 for calculating the mackerel abundance index.

Vessel	Country	Horizontal trawl opening (m)	Exclusion list	
			Cruise	Stations
Vendla	Norway	63.8	2021816	58,61,62,66,69,71,74,75,80,81,83,87,89,93,98,100, 105,111,122,132,142,146
Eros	Norway	67.5	2021817	32,43,51,61,62,67,69,70,71,73
Árni Friðriksson	Iceland	65.6	A12-2021	298,318,325,333,337,340,343,349,351,357
Jákup Sverri	Faroe Islands	56.6	2130	13,14,27,34,53,68,73 *
Ceton	EU (Denmark)	75.4	IESSNS2021	none

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceded by 2130 (e.g. '21300025')

Working document 10, WGWIDE 2021

Full time-series of catch by rectangle

Martin Pastoors, 27/08/2021

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 available by quarter whereas most recently, the data has been requested by month. Previously, the catch by rectangle has mostly 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 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	2008	2009
HER	0	0	0	0	0	0	0	0	0	0	0	0
HOM	0	0	0	242971	220889	226642	204409	218002	182172	162691	111071	261563
MAC	634501	573960	614831	664986	648890	568184	579449	505956	447288	550033	584410	713180
WHB	0	0	0	0	0	0	0	0	0	0	0	0

Table: Table continues below

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	(all)
0	993001	819755	684723	461383	328679	383081	715545	592555	776193	715429	6470344
252455	211305	181505	220870	141685	108136	113592	122009	118276	144149	128475	3572867
861394	936099	874986	920066	1374495	1166138	1083641	1151726	1016924	831564	1025807	18328508
0	103861	377079	616511	1139737	1389447	1175687	1540077	1698078	1507471	1478397	11026345

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	2008	2009
BEL	0	0	0	0	0	0	0	0	0	0	0	0
DEU	21490	19956	22977	25323	26532	24059	23368	19123	16599	18221	15503	22703
DNK	28157	30208	32693	31133	32180	27198	25311	22921	24230	24877	26726	23228
ESP	44607	45914	38320	44143	31845	23858	34968	53192	54569	63235	64785	114141
EST	0	0	0	0	0	0	0	0	0	0	0	0
FRA	0	0	0	0	0	0	0	0	15968	14997	15454	9740
FRO	11229	11620	21023	24004	19768	14014	13029	9769	12066	13393	11289	14061
GBR.EW	26694	19403	0	25868	26082	24446	21806	14676	7725	14653	2299	2973
GBR.N	8030	0	0	0	0	0	10933	8037	8369	5544	1797	2735
GBR.S	144984	139918	164069	163941	165017	146129	141988	129987	79721	113487	109848	151302
GRL	0	0	0	0	0	0	0	0	0	0	0	0
GUY	0	0	0	0	0	0	0	0	0	0	0	0
IMN	0	0	0	0	0	0	0	0	0	0	0	0
IRL	69171	59578	71226	70443	72173	63588	58929	42530	38563	46675	44318	61086
ISL	0	0	0	0	0	0	0	0	4220	36496	112220	116157
JEY	0	0	0	0	0	0	0	0	0	0	7	7
LTU	0	0	0	0	0	0	0	0	0	0	0	0
NLD	46127	28070	32403	49815	42254	34263	35680	41432	24007	23912	19933	23355
NOR	158179	160728	174098	180595	184291	163404	157363	119680	121981	131697	121470	121225
POL	0	0	0	0	0	0	0	0	0	977	0	0
PRT	2846	1981	2253	3049	2934	2749	2143	1479	2591	2598	2367	1742
RUS	67837	51348	50772	41568	45811	40026	49489	39922	33462	35408	32728	41413
SWE	5146	5233	4995	5099	0	4447	4437	3202	3210	3858	3660	7303
(all)	634497	573957	614829	664981	648887	568181	579444	505950	447281	550028	584404	713171

Table: Table continues below

country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	(all)
BEL	0	0	38	60	0	51	142	128	167	66	124	776
DEU	19055	24082	18974	20933	28451	28207	23411	24857	19882	16904	25031	505641
DNK	41045	29213	36503	33261	41903	45015	40655	37899	29865	30401	34391	729013
ESP	53350	23988	17735	13069	44244	33744	29591	34425	28196	21056	34238	947213
EST	0	0	0	1366	0	0	0	0	0	0	0	1366
FRA	12108	12393	17859	14642	21695	0	20171	22920	21370	17855	21871	239043
FRO	70987	122049	107629	143001	150419	107993	93266	99499	81078	62663	69064	1282913
GBR.EW	17722	20041	19186	16542	26562	32260	23699	26421	20439	16203	22465	428165
GBR.N	4293	11344	14945	12347	20351	12597	2302	16887	14873	11878	14854	182116
GBR.S	138403	150243	135602	134412	240503	202104	190817	182096	154686	123721	166171	3469149
GRL	0	162	5319	52796	78672	30410	36194	46498	63024	30469	26552	370096
GUY	0	0	0	8	8	4	0	0	0	0	0	20
IMN	0	11	0	7	3	4	7	0	3	2	0	37
IRL	57993	63188	63058	56611	103178	88738	76523	84914	66743	53311	74113	1486650
ISL	122337	159008	149584	151326	172960	169257	170374	166601	168328	128076	151533	1978477
JEY	0	6	0	0	6	2	2	0	0	0	0	30
LTU	0	0	0	0	0	553	2539	0	0	0	815	3907
NLD	25062	34500	32554	21159	46665	39807	37752	43765	30392	22697	30321	765925
NOR	233941	208077	176031	164602	277724	242233	210569	222397	187030	159107	211672	4088094
POL	0	0	0	0	0	0	0	0	4056	3706	5302	14041
PRT	2355	938	821	253	636	928	619	633	4564	3941	4799	49219
RUS	59310	73601	74578	80756	116086	128292	121336	138077	118254	126543	128816	1695433
SWE	3428	3247	4563	2906	4421	3930	3662	3700	3965	2957	3668	91037
(all)	861389	936091	874979	920057	1374487	1166129	1083631	1151717	1016915	831556	1025800	18328361

Table 1: Catch of mackerel (tonnes) included in the rectangle data by year and country

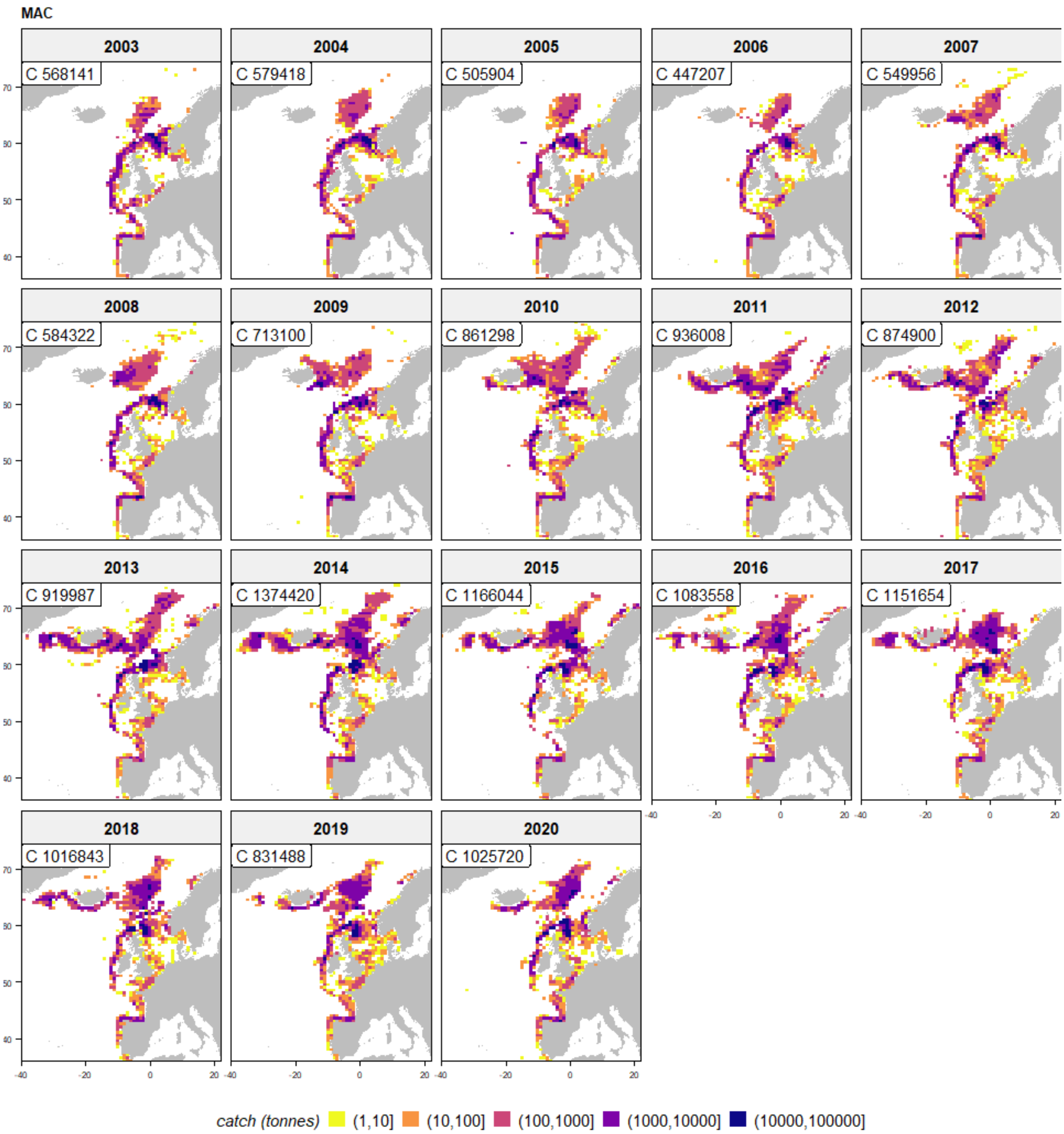

Figure 1: Catch of mackerel (tonnes) by year and rectangle

Horse Mackerel

country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BEL	0	0	0	0	0	0	0	0	0	0	0	0
DEU	12510	15925	18762	22792	18978	12453	5871	12882	16420	21482	21114	22588
DNK	0	12478	14636	20256	14135	9794	7885	0	6097	5935	6100	4674
ESP	34688	34258	32926	27947	26435	23829	27319	34169	36722	54230	32942	12373
FRA	0	0	0	0	0	0	0	0	0	0	0	0
FRO	0	0	808	3846	3695	0	477	477	0	0	0	0
GBR.EW	10430	8294	6405	10251	7418	0	12404	4425	16209	14604	13466	13057
GBR.N	0	0	0	0	426	223	0	0	0	0	0	0
GBR.S	8028	2907	0	1524	0	769	1403	1082	1417	2459	13466	1574
IRL	52212	36482	35854	26432	35359	28856	30091	36508	40779	44475	38464	45306
NLD	103349	59585	86162	68733	73130	64413	61433	0	60459	85042	71981	78552
NOR	7992	36689	20515	10749	25115	27225	5425	12247	72615	12500	13770	3378
PRT	13759	14269	10571	11874	13307	14607	10380	9278	10840	11726	0	0
SWE	0	0	0	0	0	0	0	0	0	0	0	0
(all)	242968	220887	226639	204404	217998	182169	162688	111068	261558	252453	211303	181502

Table: Table continues below

country	2013	2014	2015	2016	2017	2018	2019	2020	(all)
BEL	0	0	63	0	67	44	0	39	213
DEU	27959	19056	10061	13293	8121	8121	8462	959	297809
DNK	0	0	0	0	0	0	0	5733	107723
ESP	39507	32907	37896	32851	33860	37109	44473	53358	689799
FRA	0	0	0	0	5785	3443	1869	4510	15607
FRO	0	0	0	0	50	0	0	0	9353
GBR.EW	45306	9197	0	0	0	0	7657	5854	184977
GBR.N	2325	1578	0	0	0	0	1959	0	6511
GBR.S	675	1650	737	970	0	190	50	0	38901
IRL	35783	32660	21647	27606	23559	25347	28899	17389	663708
NLD	62519	29975	28150	27685	19906	19906	31862	19042	1051884
NOR	6791	14658	9560	11184	11184	10742	11274	12755	336368
PRT	0	0	0	0	19473	13370	7641	8745	169840
SWE	1	1	18	0	0	0	0	83	103
(all)	220866	141682	108132	113589	122005	118272	144146	128467	3572796

Table 2: Catch of horse mackerel (tonnes) included in the rectangle data by year and country

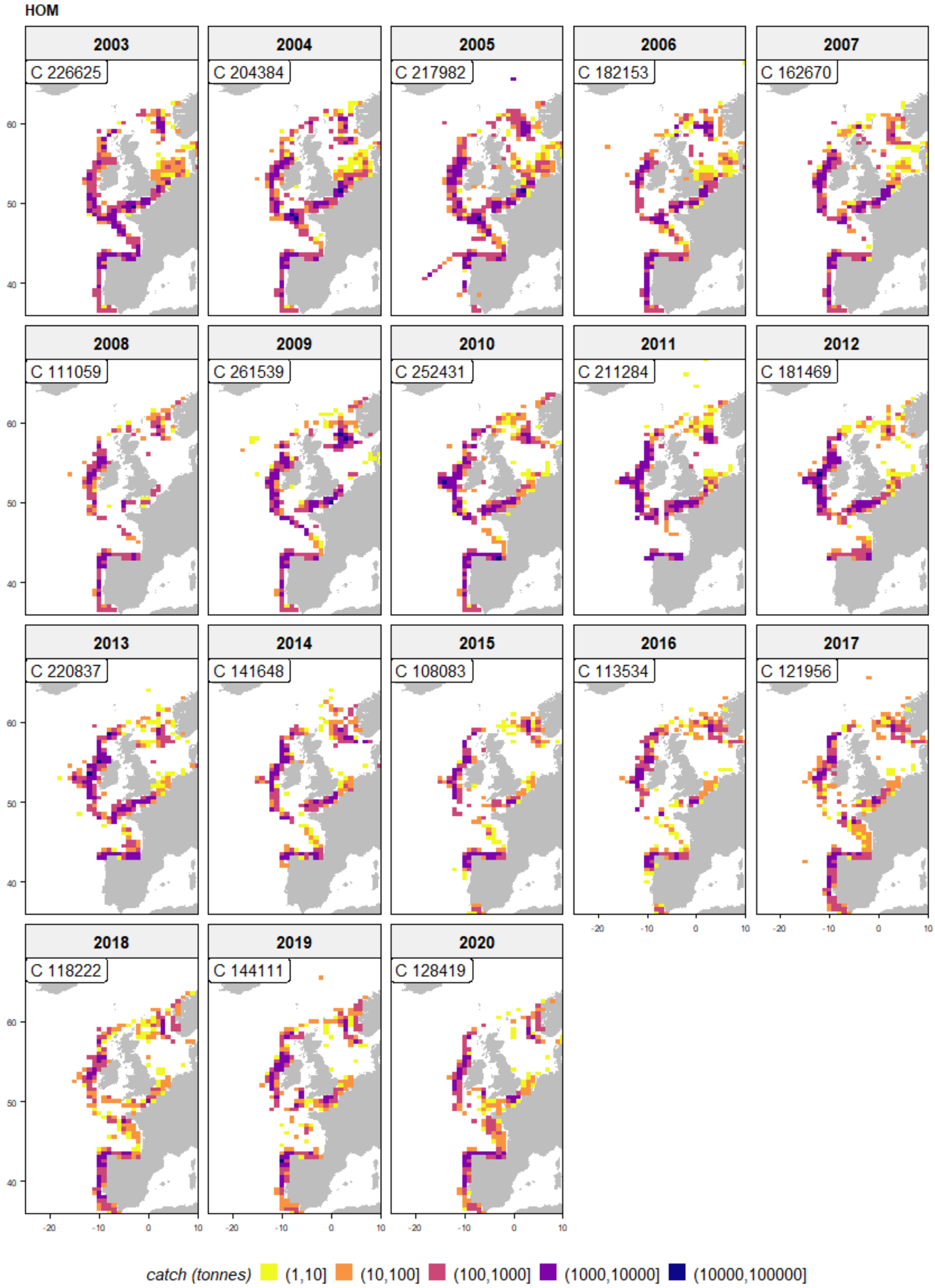

Figure 2: Catch of horse mackerel (tonnes) by year and rectangle

Blue whiting

country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	(all)
ALL	0	377079	0	0	0	0	0	0	0	0	377079
DEU	266	0	11528	24487	24106	20024	45555	47797	38243	42362	254368
DNK	0	0	0	27945	45047	39134	60866	83564	64169	54585	375310
ESP	2416	0	13388	25140	24967	27493	27433	21059	20621	22705	185222
FRA	4337	0	8978	10410	9657	10345	13221	16409	16095	13768	103220
FRO	16404	0	85767	224699	282477	282364	356501	349837	336568	343371	2277988
GBR	0	0	0	0	0	1374	0	1860	0	0	3234
GBR.EW	0	0	0	0	0	0	3442	0	4027	7449	14918
GBR.N	0	0	0	2205	0	0	0	0	2899	2958	8062
GBR.S	1331	0	8166	24630	30508	36896	64690	66514	53830	41173	327738
GRL	0	0	0	0	0	0	20212	23333	19753	19611	82909
IRL	1194	0	13205	21467	24785	26329	43237	49902	38568	39179	257866
ISL	5887	0	104912	182873	214868	186907	228934	292951	268351	243725	1729408
LTU	0	0	0	4718	0	1129	5299	0	0	0	11146
NLD	4595	0	51634	38524	56397	58148	81155	121864	75020	62309	549646
NOR	20539	0	196246	399520	489438	310412	399363	438426	351428	354032	2959404
POL	0	0	0	0	0	0	0	12152	27184	47614	86950
PRT	0	0	2014	1303	1429	1429	1625	1497	2659	2026	13982
RUS	46888	0	120669	151810	185763	173655	188449	170891	188006	181496	1407627
SWE	0	0	0	1	0	42	89	15	43	25	215
(all)	103857	377079	616507	1139732	1389442	1175681	1540071	1698071	1507464	1478388	11026292

Table 3: Catch of blue whiting (tonnes) included in the rectangle data by year and country

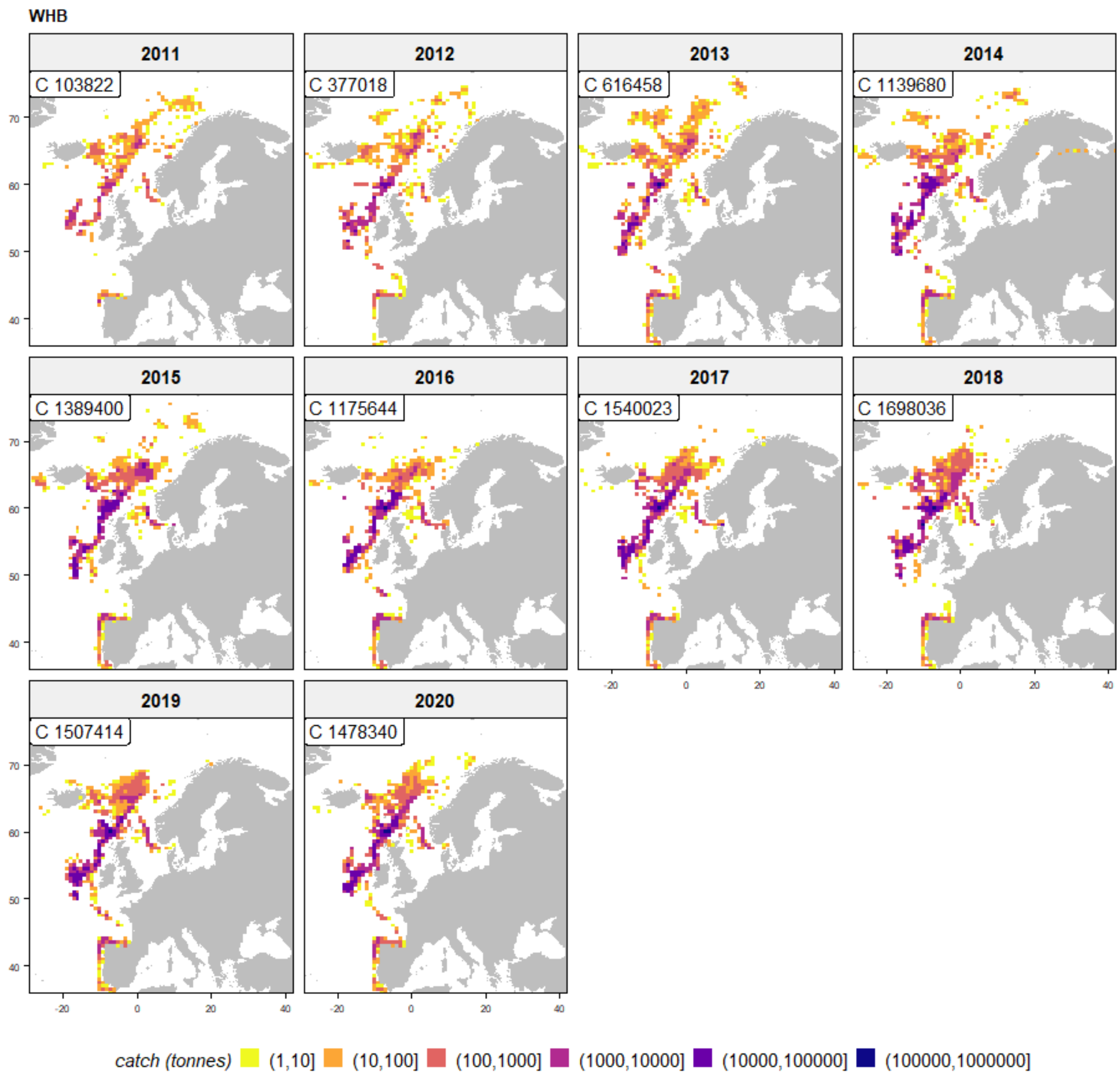

Figure 3: Catch of blue whiting (tonnes) by year and rectangle

Atlanto-scandian herring

country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	(all)
ALL	0	819755	0	0	0	0	0	0	0	0	819755
DEU	13295	0	4243	668	2660	2582	5201	1994	4188	2969	37800
DNK	26732	0	17159	12513	9105	10384	17373	17051	20247	12328	142892
FRO	53270	0	105037	38527	33030	44726	98170	82062	113940	103029	671791
GBR	0	0	0	4233	0	3899	0	0	0	0	8132
GBR.S	14045	0	8342	0	0	0	0	2581	1800	143	26911
GRL	3426	0	11787	13187	12434	17507	12569	2465	3190	3547	80112
IRL	5738	0	3814	705	1399	2048	3494	2428	2775	2703	25104
ISL	151078	0	90729	58827	42626	50457	90400	83392	108044	98171	773724
NLD	8348	0	5625	9175	5248	3519	6678	4289	5110	5059	53051
NOR	572637	0	359458	263252	176321	197500	389383	331717	430501	409348	3130117
POL	0	0	0	0	0	0	0	0	1327	0	1327
RUS	144429	0	78501	60291	45853	50454	91119	64147	84362	75064	694220
SWE	0	0	23	0	0	0	1155	425	705	3065	5373
(all)	992998	819755	684718	461378	328676	383076	715542	592551	776189	715426	6470309

Table 4: Catch of Atlanto-scandian herring (tonnes) included in the rectangle data by year and country

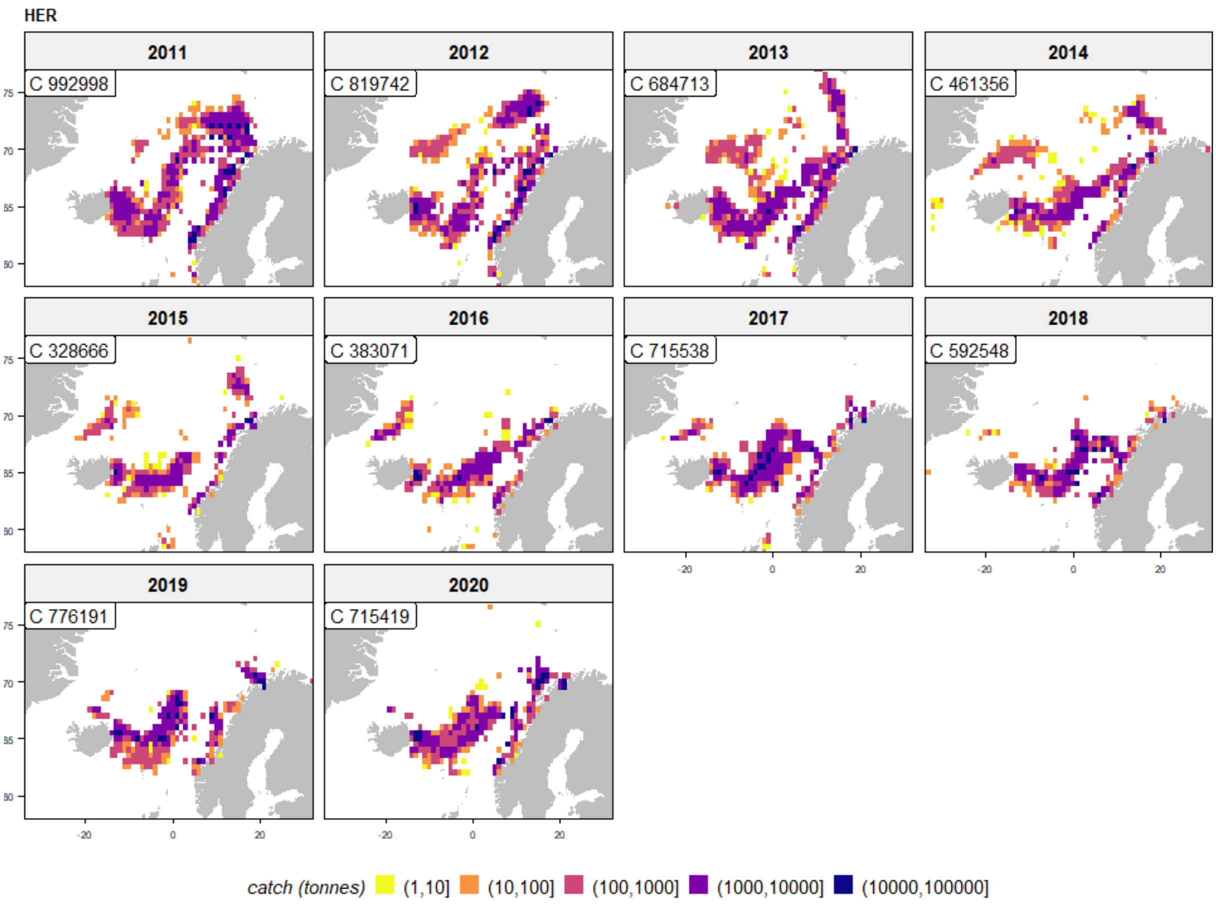

Figure 4: Catch of Atlanto-scandian herring (tonnes) by year and rectangle

Blue whiting

An alternative assessment including more surveys

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Introduction

During WGWIDE 2020 we saw how vulnerable a stock assessment is when we only have one survey input to base the assessment on, and that survey is cancelled. In 2020 it was due to the covid-19 pandemic, but in the future there might be other unforeseen events that may cause the survey being cancelled or something may go wrong in the data collection so that we do not have reliable data for a specific year. To avoid this issue of potentially having no fishery independent data and make the assessment more robust against problems with the IBWSS, we will in this report consider including the IESNS and IESSNS survey data for blue whiting in the assessment.

Data description

For the IESNS survey we have data from 2008 to 20201 and for the IESSNS from 2016 to 2021. We use ages from 1-4+ and 1-6+ from the two surveys. This age selection was made based on the consistency plots in Figure 4. From the original assessment, we also have catch data (ages 1-10+, 1981-2021) and the IBWSS (ages 1-8, 2004-2021), where 2010 and 2020 is missing. The model has been configured based on data available in 2020, but we will include everything that is available at the time of the WGWIDE 2021 meeting in 25.-31. August 2021. An overview of the data selected for the alternative assessment is found in Figure 5 and each time series is plotted in Figure 6 for each age group and Figure 7 for each year class.

Model description

Today's assessment is using the R package stockassessment and the SAM model. Including additional survey data as input in this framework is a relatively simple task. The effort is mostly needed for deciding how to set up the configuration of the model. The procedure of how we have selected the model configuration is that we have included the two additional survey data sources and start out with a default SAM configuration. Then we start at the top of the configuration and make incremental changes and compare different settings until we get the best model fit in terms of AIC. Then we move on to the next configuration setting. We only consider configurations that are somewhat sensible. For instance, we do not consider putting the same catchability on 1 year old and 8-year-old fish, with some other catchability for those in-between. We only consider cases where neighbouring age groups share the same parameters. The final configuration file is included in the appendix. For details on diagnostic, see appendix.

Model output

Once we have fitted the model, we can look at model output. In Figure 1 we have plotted SSB, Fbar and recruitment for the period 1980-2021 according to the fitted model. The black line with grey confidence interval is the official WGWIDE2021 assessment model for comparison.

In terms of SSB, we see a slight increase in the point estimates since around 2013, but the change is well within the confidence interval for the WGWIDE21 assessment model. The main difference is clearly that we get smaller confidence intervals, i.e. higher accuracy, by adding more data to the model. For Fbar the picture is more or less the same, only the alternative model point estimate is lower than WGWIDE for most of the same period. In recruitment we see a bigger discrepancy in 2021. The alternative model gives a higher recruitment in 2021. For all three measures, the confidence intervals are narrower for the alternative model compared to WGWIDE2021. Hence, the alternative assessment is consistent with the WGWIDE2021 assessment, but it has higher accuracy.

Leave-out analysis

A standard diagnostic is to leave out one survey at the time and see what effect this has on the output. This is achieved by taking out one data source at the time and refitting the model. This can give us an idea of how that particular data source affects the total. The leaveout plots are presented in Figure 2.

For the SSB the differences are not so big, but if we for instance take out IBWSS, we see that SSB and its uncertainty will increase a bit in 2020-21. Taking out any of the others have minor effect on SSB. We also see a similar pattern for Fbar. For the recruitment there is more happening. Taking out IESSNS will give the lowest recruitment, while if we take out IBWSS we get the highest for 2021. Going back in time, the leaveout scenarioes give more or less the same result.

Another interesting scenario we can run is: What if we take out all the surveys and run the SAM model with only catch data. The results of such a model run is presented in Figure … compared to the WGWIDE2021 assessment.

Conclusion

This exploratory model run shows that it is possible to include IESNS and IESSNS into the SAM model for Blue Whiting. It reduces the uncertainty and may provide more information about the younger fish. It will certainly reduce the risk for not having any survey to base the assessment on, by having two-three surveys instead of just one. The data is already being collected, and ready to use.

Appendix

Diagnostics

Jit run

A jitter run means that we re-estimate the model using randomly selected initial values and report the maximum difference in each parameter and model output. Ideally there should not be any major changes due to the initial values. The results from the jitter run indicates that there is little effect on the different model parameters due to varying the initial values.

```
##                        max(|delta|)
## logFpar                1.460165e-12
## logSdLogFsta           8.597567e-13
## logSdLogN              8.884005e-13
## logSdLogObs            3.005381e-12
## logSdLogTotalObs       6.362910e-12
## transfIRARdist         8.205492e-12
## itrans_rho             3.820055e-12
## logFScaleMSY           7.991791e-01
## implicitFunctionDelta  6.778069e-01
## logScaleFmsy           7.149034e-01
## logScaleFmax           6.369347e-01
```

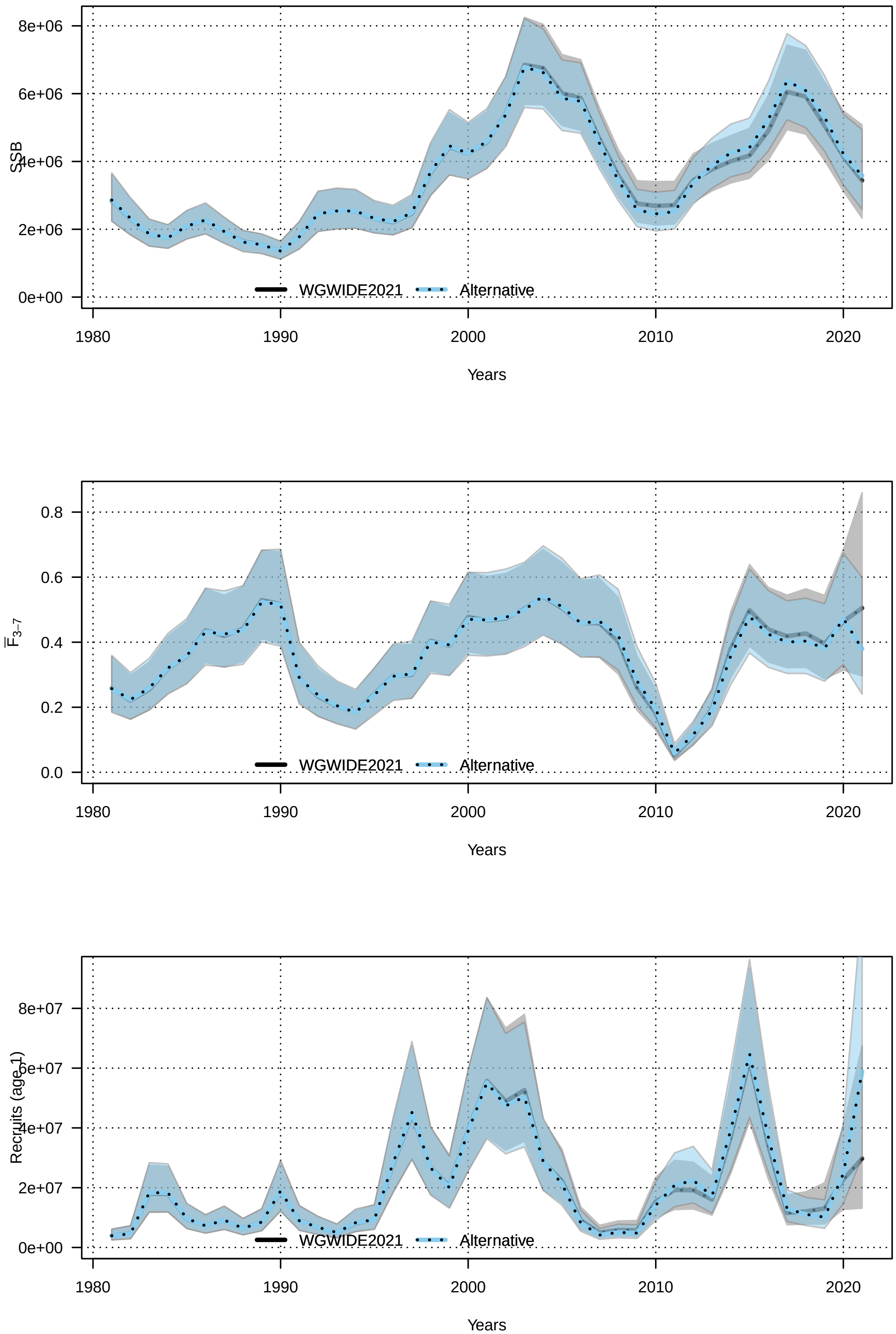

Figure 1: Model output in terms of SSB, Fbar and recruitment with 95 percent confidence intervals.

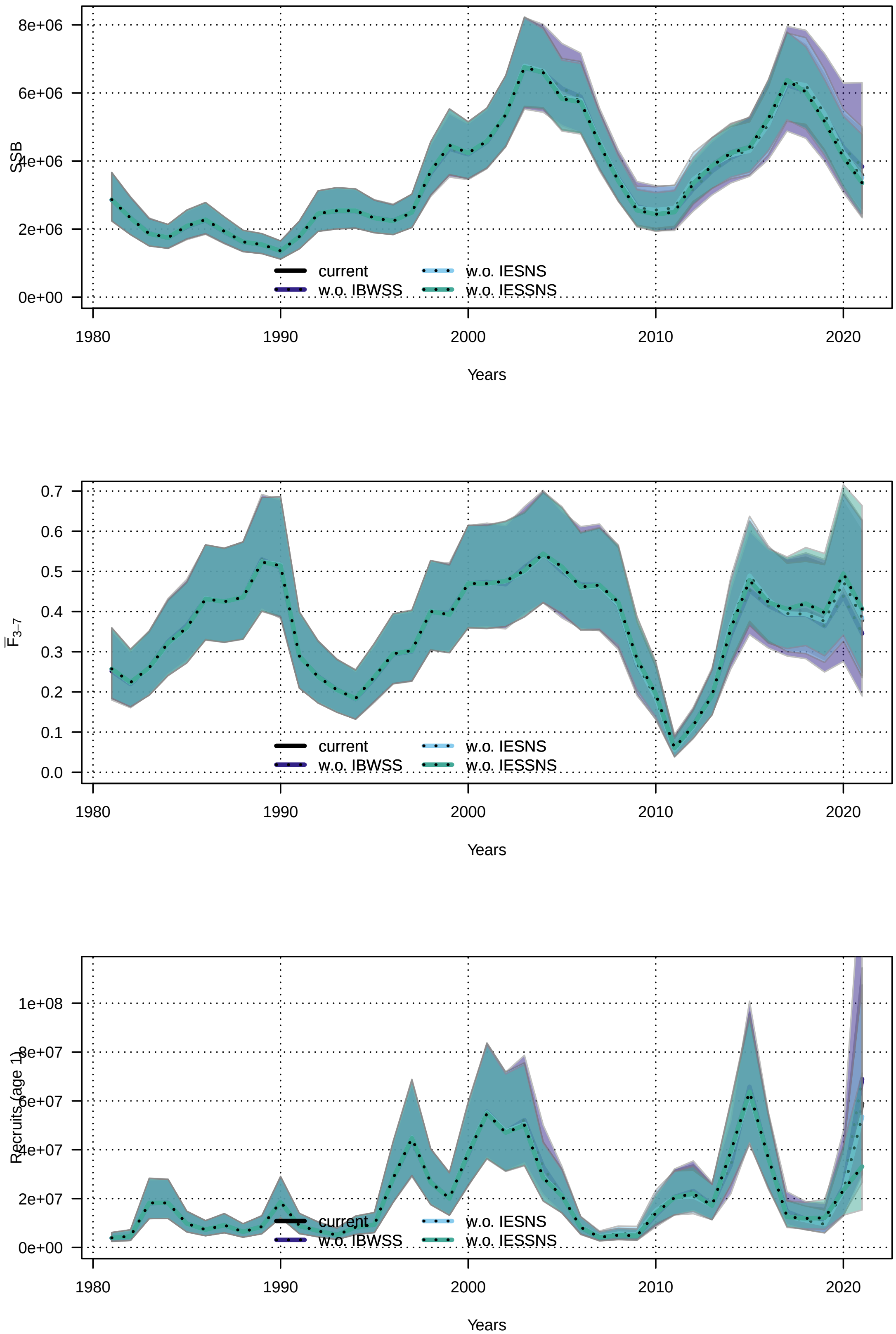

Figure 2: Leaveout plots for alternative assessment.

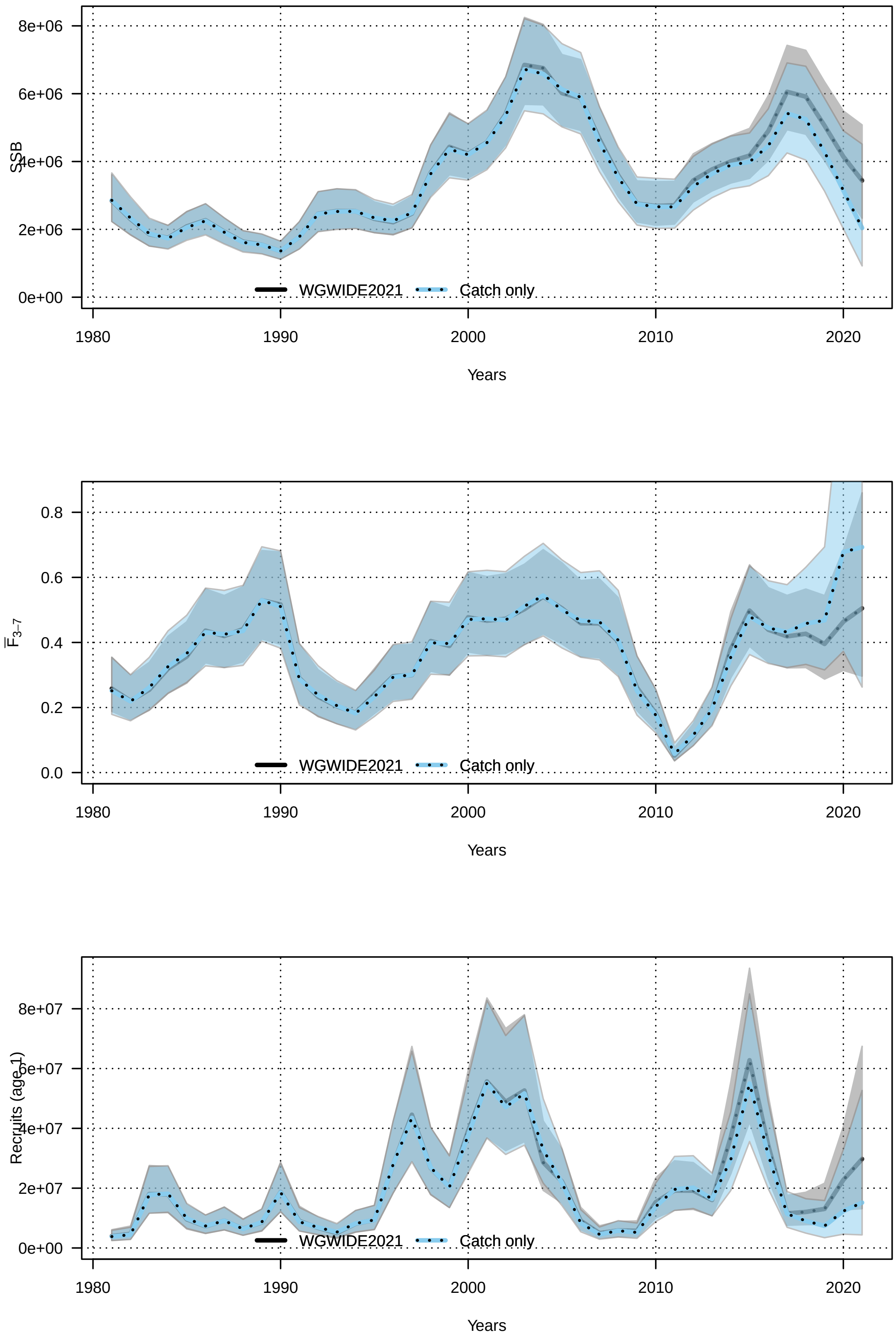

Figure 3: Comparison of assessment with catch only vs WGWIDE2021 assessment.

```
## logScaleF01          8.160139e-01
## logScaleFcrash       6.245671e-01
## logScaleFext         6.302892e-01
## logScaleFlim         6.237161e-01
## logF                 1.702949e-10
## logN                 1.624194e-10
## missing              2.735119e-10
## ssb                  4.437063e-04
## fbar                 3.286099e-11
## rec                  5.357973e-03
## catch                7.252139e-05
## logLik               3.283276e-10
```

Simulation study

Another test is to do a simulation study, where we simulate the processes going into the model and compare this to the model output based on the observations. Ideally, the simulations should stay within the 95% confidence intervals with a probability of 0.95. Here we use 50 simulations. It seems that most of the simulations fall within the confidence intervals, with some exceptions. This is expected.

Retrospective plots

Peeling off one year at the time and fitting the model based on those data. In the retrospective plots (Figure 13) we can see how well the last year's assessment fits with what the model predicts with one more year of data. Mohn's ρ for the retrospective analysis of SSB, Fbar and recruitment is respectively, 0.0783, -0.0756 and -0.0168.

Figures

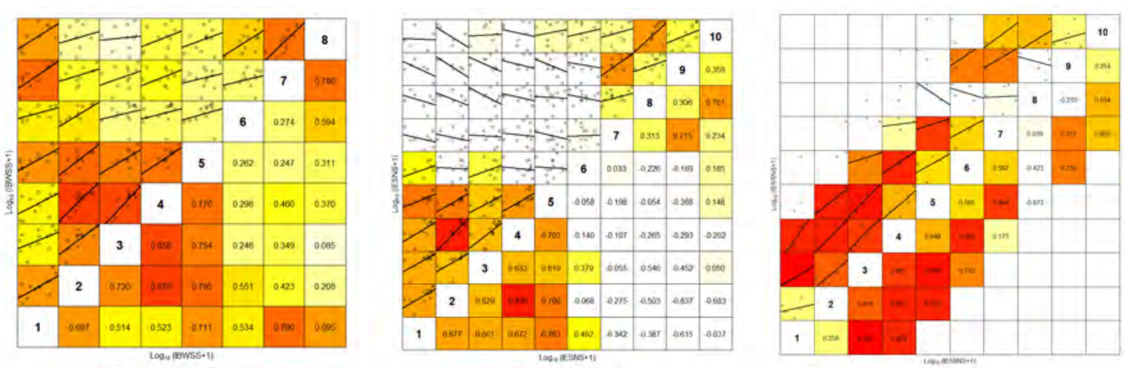

Figure 4: Internal consistency/correlation plots for IBWSS, IESNS and IESSNS. We use $\log(x+1)$ to avoid issues when x is 0. For IBWSS ages 1-8 are used, while in the alternative model 1-4+ and 1-6+ is used for IESNS and IESSNS, respectively.

Figure 5: Dataplot showing for which ages and years we use observations from the different data sources. For all except IBWSS the oldest age group is a plus group.

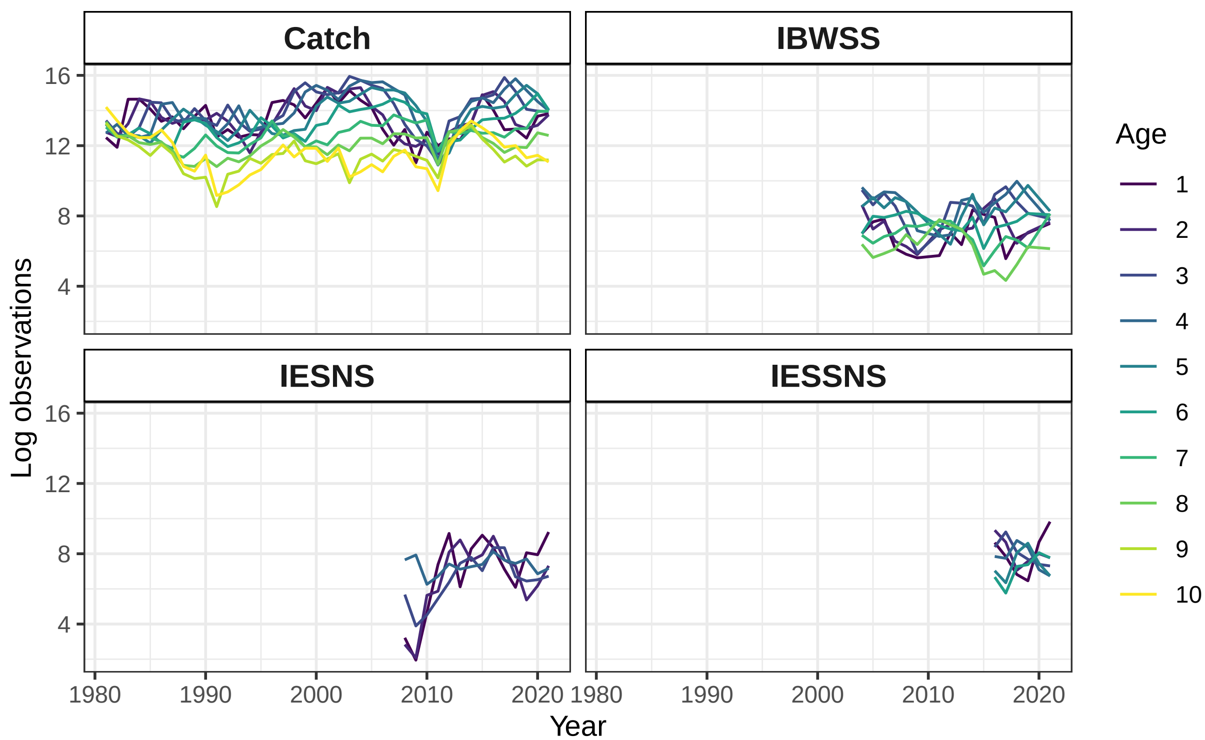

Figure 6: Time series for all data sources on log scale – one line per age group.

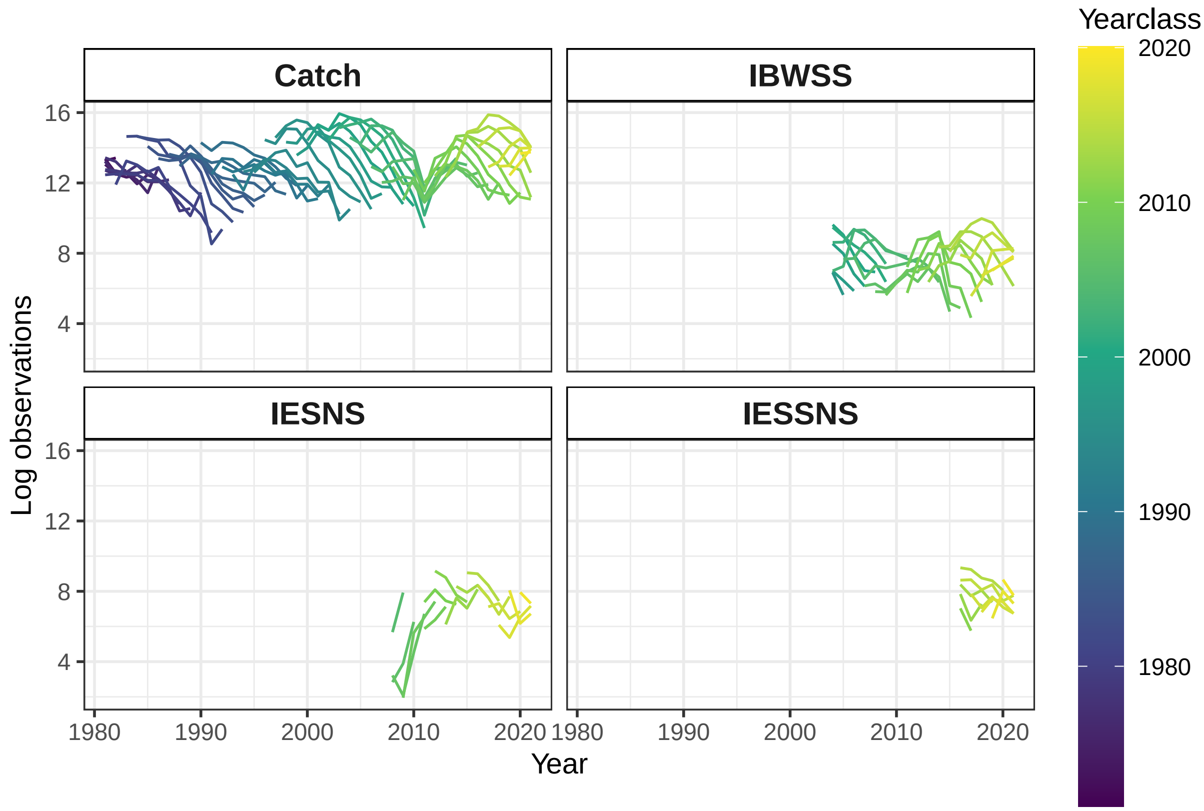

Figure 7: Time series of the different data sources on log scale – one line per year class.

Config

Here we print out the configuration file for the alternative assessment.

```
print(conf)
```

```
## $minAge
## [1] 1
##
## $maxAge
## [1] 10
##
## $maxAgePlusGroup
## [1] 1 0 1 1
##
## $keyLogFsta
##      V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
## [1,]  0  1  2  3  4  5  6  7  8   8
## [2,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [3,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [4,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
##
## $corFlag
## [1] 2
##
## $keyLogFpar
##      V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
## [1,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
```

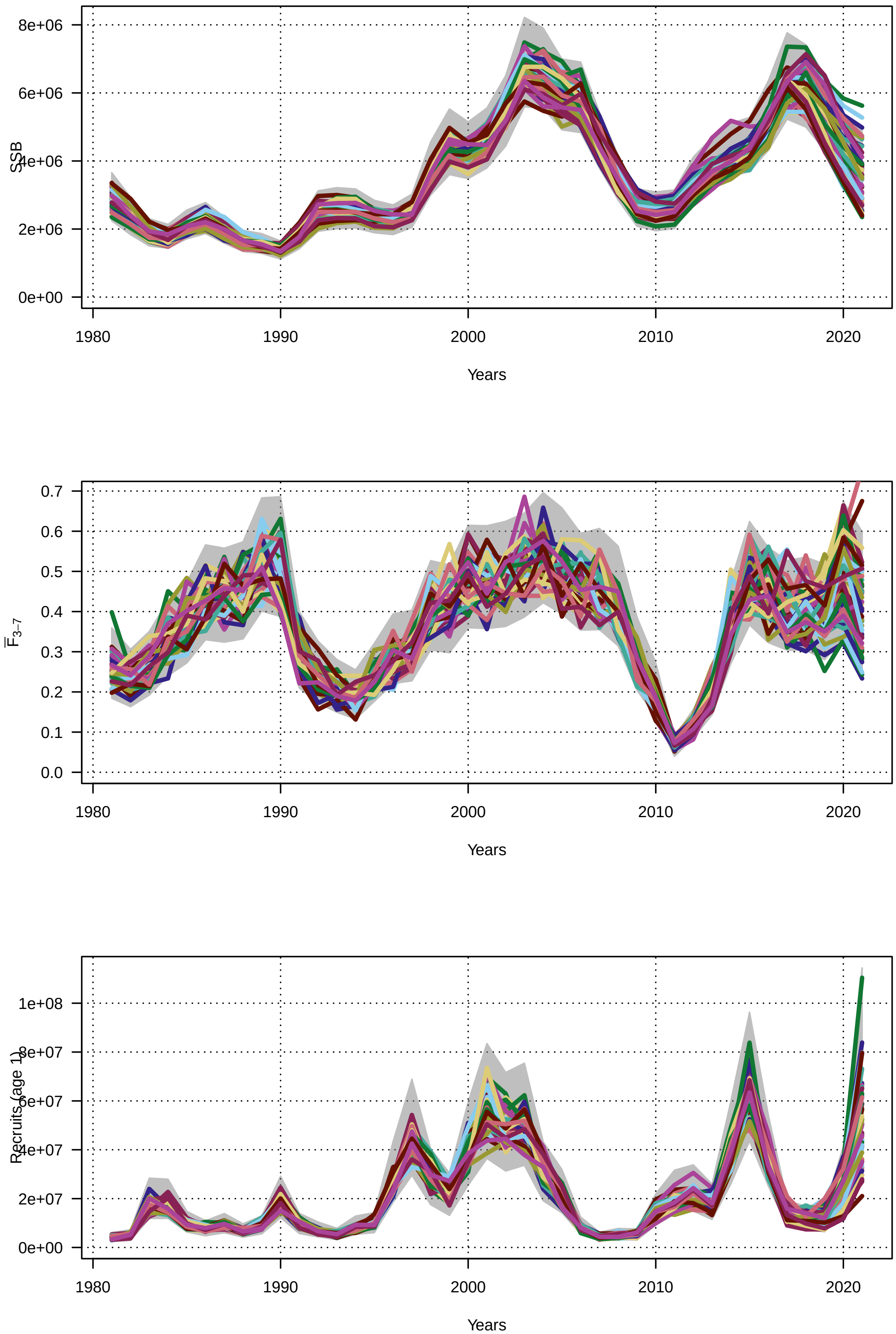

Figure 8: QQ-normality plots for model residuals by data source.

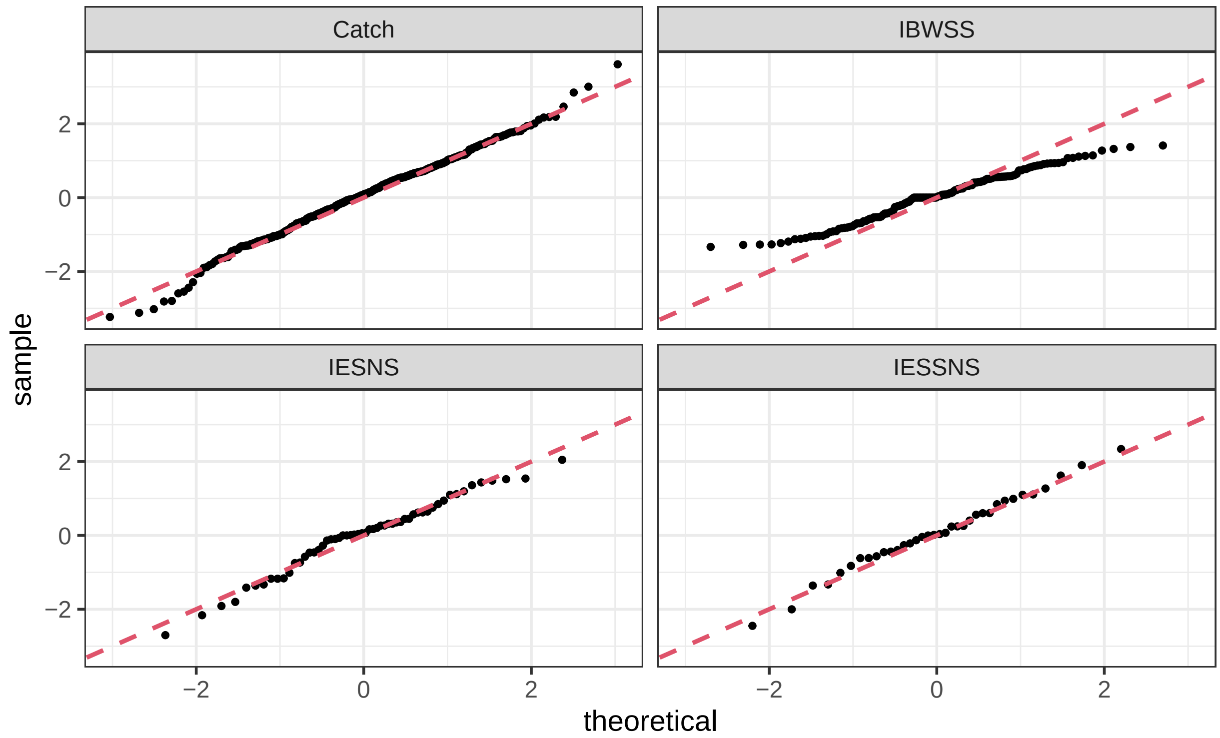

Figure 9: QQ-normality plots for model residuals by data source.

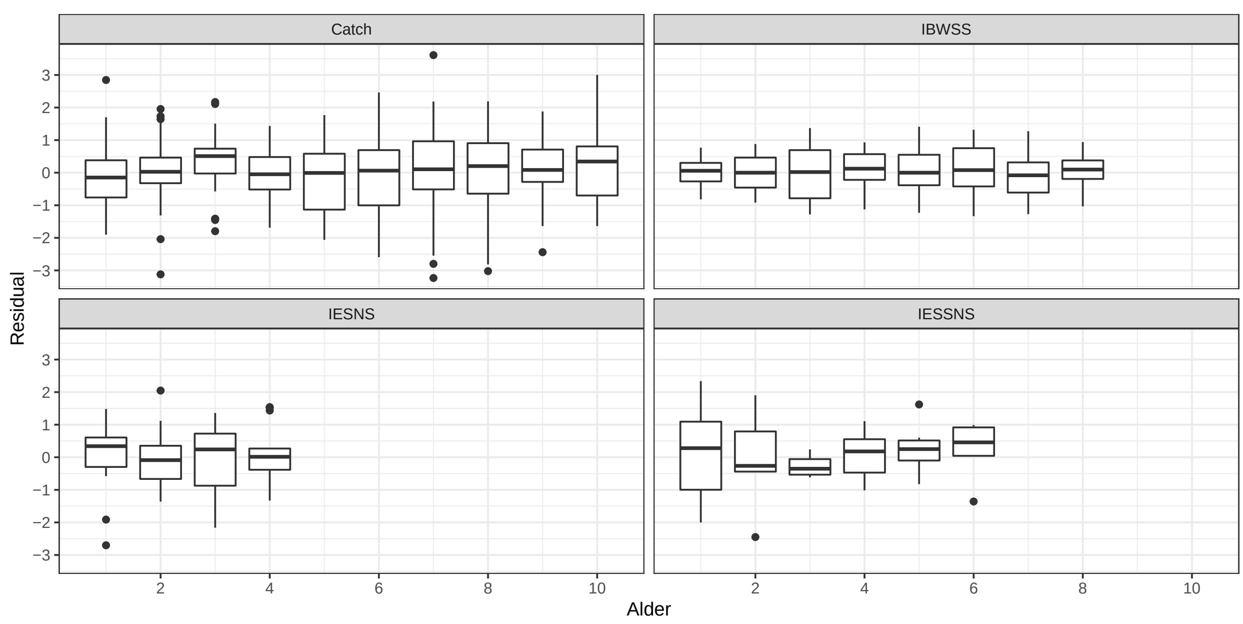

Figure 10: Boxplots of residuals by age for each fleet.

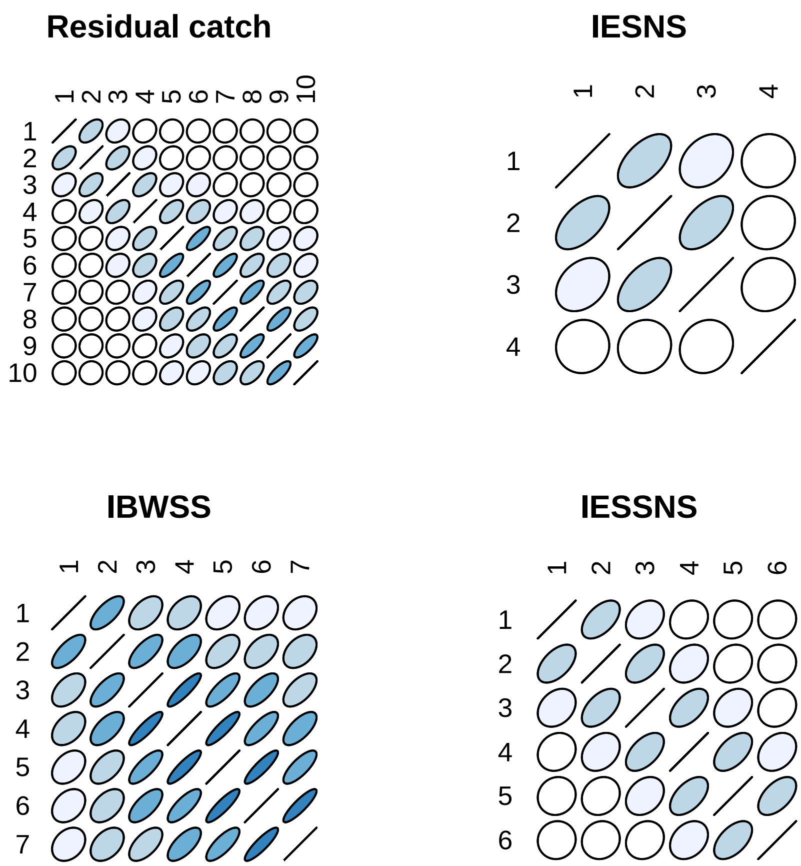

Figure 11: Correlation plot (model estimated).

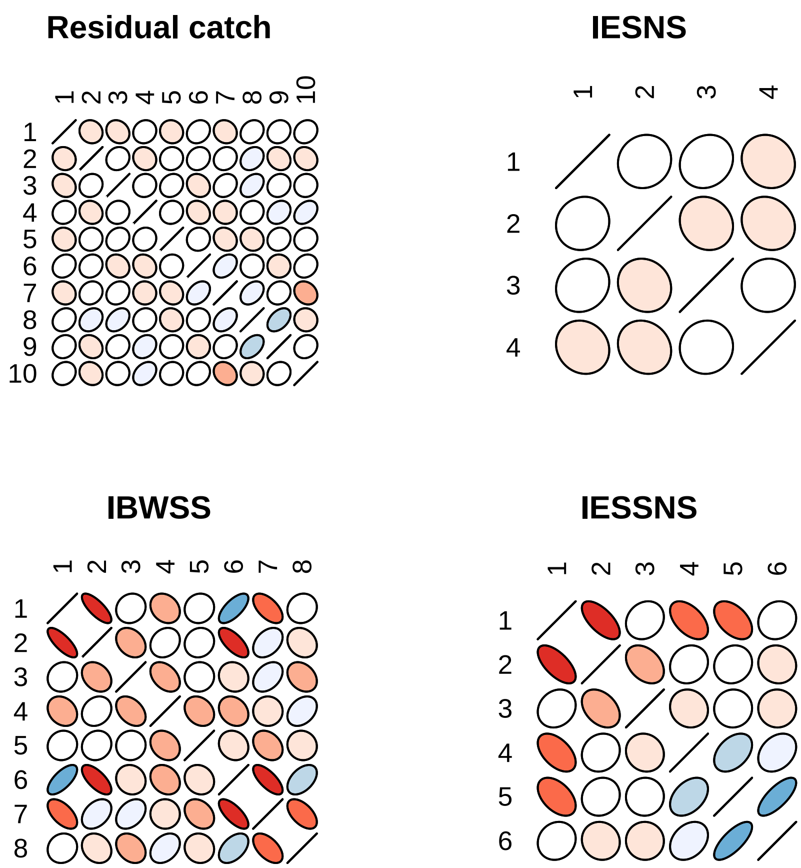

Figure 12: Empirical correlation plot.

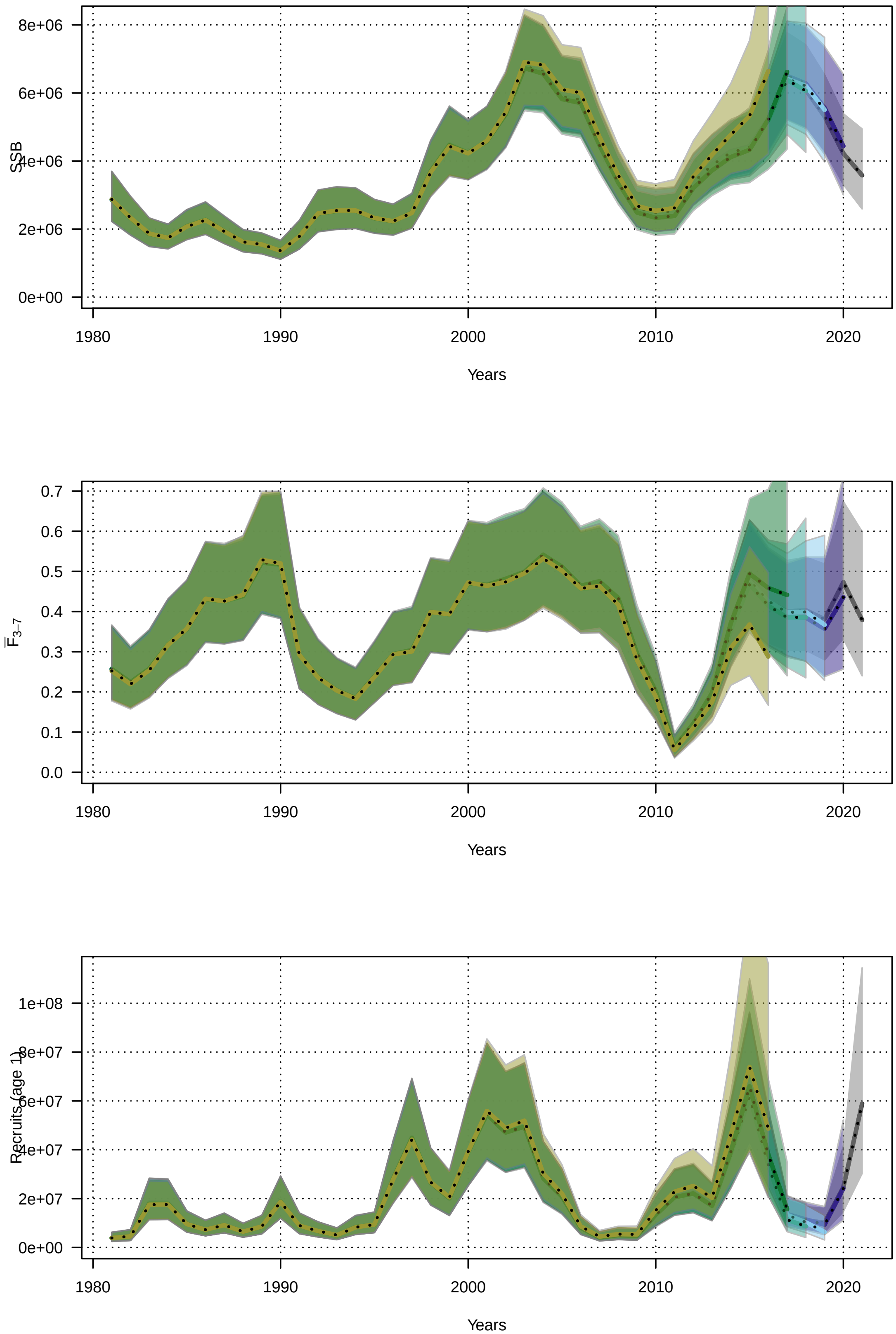

Figure 13: Retrospective plots for SSB, Fbar and Recruitment.

```
## [2,]  0  1  2  3  4  4  4  4 -1  -1
## [3,]  5  6  7  7 -1 -1 -1 -1 -1  -1
## [4,]  8  9 10 10 10 10 -1 -1 -1  -1
##
## $keyQpow
##      V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
## [1,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [2,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [3,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [4,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
##
## $keyVarF
##      V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
## [1,]  0  0  0  0  0  0  0  0  0   0
## [2,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [3,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [4,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
##
## $keyVarLogN
##  [1] 0 1 1 1 1 1 1 1 1 1
##
## $keyVarObs
##      V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
## [1,]  0  1  2  2  2  2  2  2  3   3
## [2,]  4  5  6  7  7  7  8  8 -1  -1
## [3,]  9  9 10 10 -1 -1 -1 -1 -1  -1
## [4,] 11 11 11 11 11 11 -1 -1 -1  -1
##
## $obsCorStruct
## [1] AR AR AR AR
## Levels: ID AR US
##
## $keyCorObs
##      V1 V2 V3 V4 V5 V6 V7 V8 V9
## [1,]  0  0  0  0  1  1  1  1  1
## [2,]  2  2  3  3  3  3  3 -1 -1
## [3,]  4  4  5 -1 -1 -1 -1 -1 -1
## [4,]  6  6  6  6  6 -1 -1 -1 -1
##
## $stockRecruitmentModelCode
## [1] 0
##
## $noScaledYears
## [1] 0
##
## $keyScaledYears
## numeric(0)
##
## $keyParScaledYA
## <0 x 0 matrix>
##
## $fbarRange
## [1] 3 7
##
```

```
## $keyBiomassTreat
## [1] -1 -1 -1 -1
##
## $obsLikelihoodFlag
## [1] LN  ALN LN  LN
## Levels: LN ALN
##
## $fixVarToWeight
## [1] 0
##
## $fracMixF
## [1] 0
##
## $fracMixN
## [1] 0
##
## $fracMixObs
## [1] 0 0 0 0
##
## $constRecBreaks
## numeric(0)
##
## $predVarObsLink
##      V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
## [1,] -1 -1 -1 -1 -1 -1 -1 -1 -1  -1
## [2,] -1 -1 -1 -1 -1 -1 -1 -1 NA  NA
## [3,] -1 -1 -1 -1 NA NA NA NA NA  NA
## [4,] -1 -1 -1 -1 -1 -1 NA NA NA  NA
##
## $hockeyStickCurve
## [1] 20
##
## $stockWeightModel
## [1] 0
##
## $keyStockWeightMean
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $keyStockWeightObsVar
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $catchWeightModel
## [1] 0
##
## $keyCatchWeightMean
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $keyCatchWeightObsVar
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $matureModel
## [1] 0
##
## $keyMatureMean
```

```
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $mortalityModel
## [1] 0
##
## $keyMortalityMean
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $keyMortalityObsVar
##  [1] NA NA NA NA NA NA NA NA NA NA
##
## $keyXtraSd
##      [,1] [,2] [,3] [,4]
```

WGWIDE 2021 WD

Blue Whiting stock assessment by means of TISVPA

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The TISVPA model (Vasilyev, 2005; 2006) was applied to the same data as the SAM model, including surveys data starting from age 1.

In order to produce more clear and less controversial signal from all sources of the data the settings of the model were taken as: so called “mixed” version, assuming errors both in catch-at-age and in separable approximation; additional restriction on the solution was the unbiased model approximation of separable representation of fishing mortality coefficients. The generation - dependent factors in triple - separable representation of fishing mortality coefficients were estimated and applied for age groups from 3 to 7. For the survey the measure of closeness of fit was simple sum of squared logarithmic residuals, and for catch-at-age data – the absolute median deviation (AMD) of residuals in logarithmic catch-at-age as a more robust analogue to the least squares approach. Overall objective function of the model was the sum the two components

Profiles of the components of the TISVPA loss function with respect to SSB in 2021 are shown in Figure 1. As it can be seen, for the model option described above, catch-at-age data and all the “survey” gives generally similar indication about the SSB in 2021.

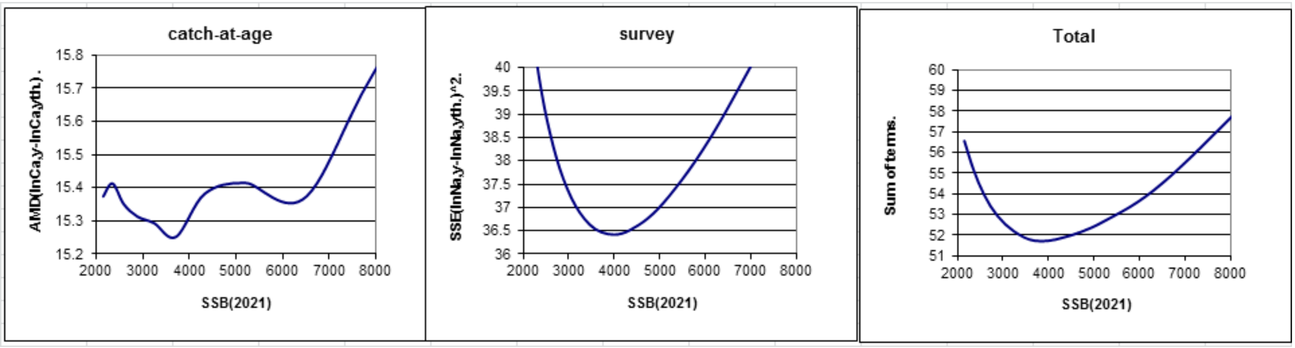

Figure 1. Profiles of the components of the TISVPA objective function

Figure 2 shows the estimates of relative selection by age and years from the "triple-separable model" of the TISVPA (the values are normalized to sum=1 for each year.

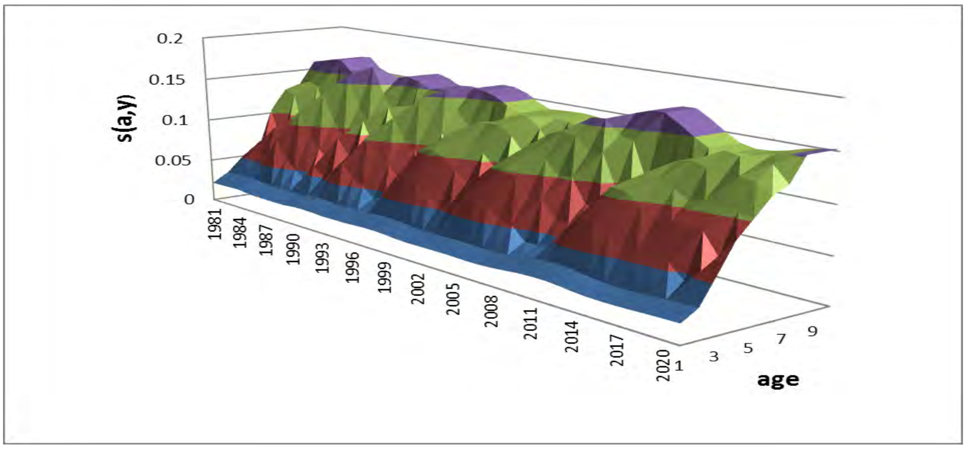

Figure 2. TISVPA-derived selection pattern

Figure 3 represents the results of retrospective analysis.

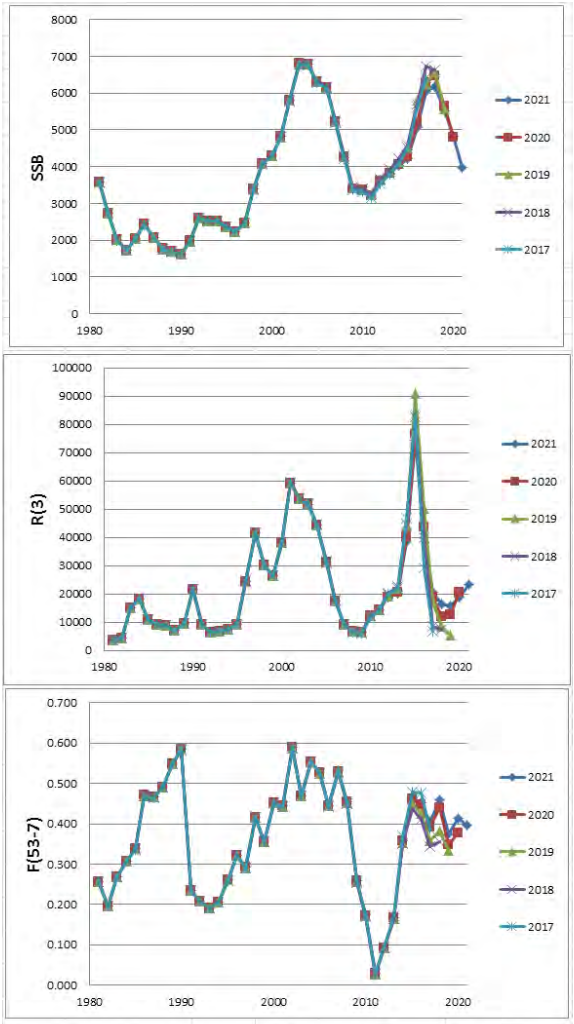

Figure 3. Retrospective runs for TISVPA

The residuals of the model approximation of catch-at-age and survey are presented in Figure 4.

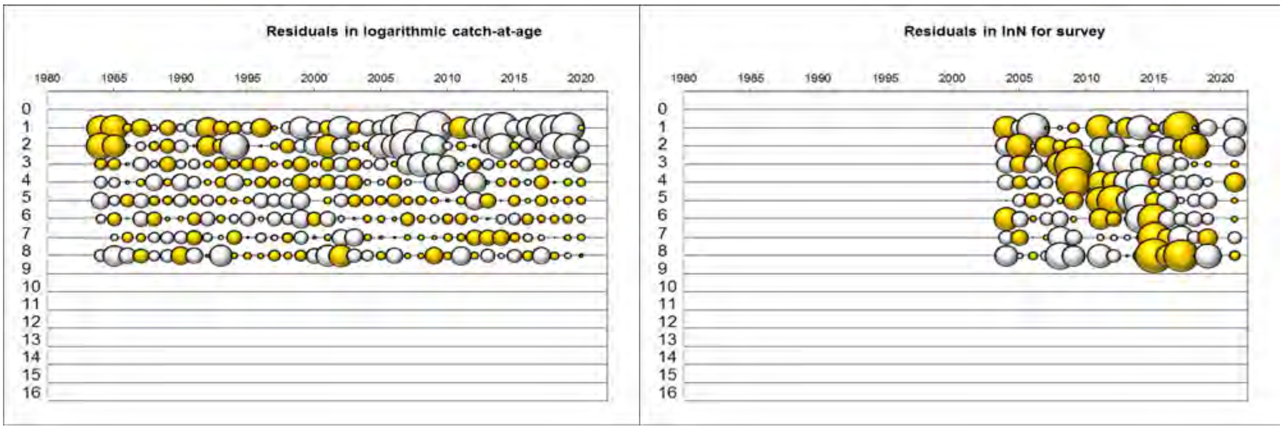

Figure 4. Residuals of the TISVPA data approximation.

The estimates of uncertainty in the results (parametric conditional bootstrap with respect to catch-at-age; survey data were noised by lognormal noise with sigma=0.3) are presented on Figure 5.

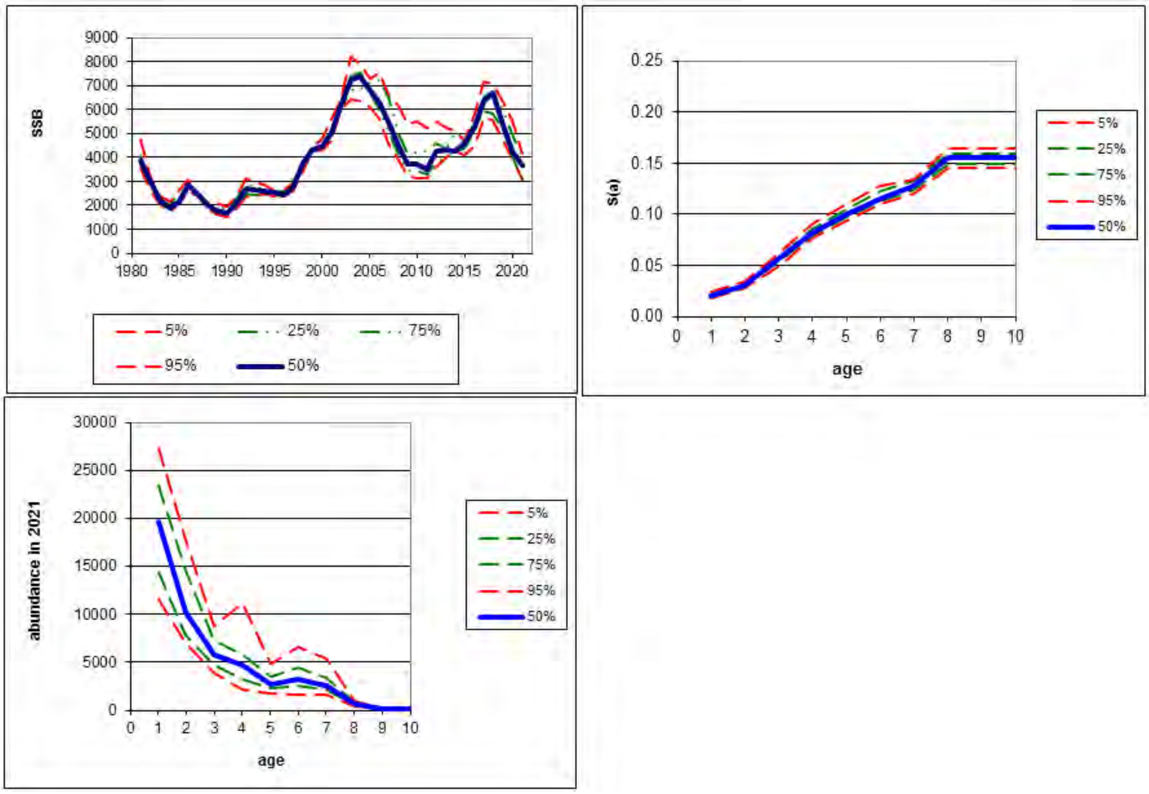

Figure 5. Bootstrap- estimates of uncertainty in the results.

The results of the assessment are presented in the Tables 1-3.

year	B(1+)	SSB	R(1)	F(3-7)
1981	4123	3577	3585	0.257
1982	3226	2740	4351	0.196
1983	2922	2008	15078	0.269
1984	2925	1736	18224	0.308
1985	3194	2045	10888	0.338
1986	3409	2439	9026	0.470
1987	3064	2078	8917	0.467
1988	2619	1768	7131	0.492
1989	2643	1693	9413	0.549
1990	2948	1621	21635	0.586
1991	3491	1980	9249	0.235
1992	3664	2607	6483	0.208
1993	3494	2535	6698	0.192
1994	3452	2520	7450	0.205
1995	3415	2362	9048	0.261
1996	3638	2232	24433	0.322
1997	5192	2466	41442	0.292
1998	6402	3391	30218	0.417
1999	7164	4082	26462	0.356
2000	7683	4305	37919	0.452
2001	9343	4819	59254	0.444
2002	11003	5808	53655	0.589
2003	11787	6805	51647	0.469
2004	10869	6785	44323	0.554
2005	9568	6312	31007	0.526
2006	8736	6160	17310	0.445
2007	6813	5221	9139	0.531
2008	5402	4255	6585	0.455
2009	4323	3402	6310	0.258
2010	4397	3349	12367	0.173
2011	4580	3207	14168	0.028
2012	5041	3602	18720	0.093
2013	5727	3819	20189	0.166
2014	6813	4026	38407	0.358
2015	8444	4214	74138	0.464
2016	9491	5057	39665	0.452
2017	9235	6034	20354	0.403
2018	8616	6186	16227	0.459
2019	7732	5506	15752	0.374
2020	7077	4833	18767	0.413
2021	5930	3982	23249	0.396

Table 1. Blue whiting. The results of the assessment by TISVPA

	1	2	3	4	5	6	7	8	9	10
1981	3585	4194	5442	3561	2551	2192	1867	2047	1761	4447
1982	4351	2751	3147	3887	2564	1575	1258	1059	1054	2497
1983	15078	3418	2066	2283	2703	1841	1000	765	602	894
1984	18224	11080	2446	1442	1496	1768	1208	539	357	591
1985	10888	13485	7681	1617	903	877	997	742	232	645
1986	9026	8104	9674	4673	1009	543	455	562	358	818
1987	8917	6815	5878	6143	2182	506	269	202	219	414
1988	7131	6673	4994	3993	3348	945	256	129	69	105
1989	9413	5422	4832	3483	2447	1623	290	121	49	75
1990	21635	7026	3861	2916	2146	1272	677	84	44	155
1991	9249	16100	4989	2473	1461	1181	513	218	16	32
1992	6483	7254	12225	3555	1701	879	752	295	120	45
1993	6698	5026	5476	8535	2395	1164	548	505	167	75
1994	7450	5271	3870	3979	5645	1600	782	346	320	126
1995	9048	5846	4125	2846	2784	3513	1026	500	201	141
1996	24433	7092	4455	3029	1913	1726	1983	599	266	225
1997	41442	18620	5307	3149	2024	1195	934	937	280	454
1998	30218	31966	13886	3521	2085	1335	700	489	424	172
1999	26462	22971	22799	8256	1836	1254	752	314	166	339
2000	37919	20528	17124	14090	4227	997	767	449	129	310
2001	59254	29065	15285	10863	7262	2000	407	425	189	162
2002	53655	45063	20800	10110	5951	3623	954	180	203	282
2003	51647	41162	33034	13281	5779	2842	1341	349	46	62
2004	44323	39183	30123	20108	7155	3051	1287	584	150	74
2005	31007	33787	28186	17878	9887	3284	1360	473	211	116
2006	17310	23734	25222	17573	8898	4260	1418	618	171	93
2007	9139	13491	17980	16818	9442	4174	1904	681	290	199
2008	6585	7105	10219	12259	9651	4342	1520	710	267	300
2009	6310	5028	5397	7475	7286	5076	1845	578	294	162
2010	12367	4997	3882	4092	5370	4533	2996	965	287	180
2011	14168	9765	3868	2979	3054	3796	2853	1829	562	281
2012	18720	11489	7905	3105	2389	2438	3008	2228	1429	1065
2013	20189	15026	9080	5922	2343	1824	1812	2177	1504	1679
2014	38407	16092	11717	6547	3990	1550	1284	1234	1344	1695
2015	74138	30072	12223	7535	3585	2073	844	752	561	1056
2016	39665	57191	22092	7844	4019	1654	941	405	329	723
2017	20354	30806	42880	14791	4587	2040	712	424	174	404
2018	16227	15940	23168	28505	8535	2481	977	325	212	384
2019	15752	12602	12057	15408	16370	4316	1129	402	133	212
2020	18767	12341	9593	8611	9254	8946	2095	534	186	149
2021	23249	14332	9180	6533	5462	4868	4287	891	220	197

Table 2. Blue whiting. Estimates of abundance-at-age

	1	2	3	4	5	6	7	8	9	10
1981	0.0517	0.0793	0.1257	0.1370	0.2816	0.3597	0.3799	0.4742	0.4742	0.4742
1982	0.0422	0.0646	0.1174	0.1554	0.1342	0.2688	0.3062	0.3712	0.3712	0.3712
1983	0.0590	0.0907	0.1574	0.2586	0.2722	0.2276	0.4267	0.5617	0.5617	0.5617
1984	0.0684	0.1054	0.1991	0.2871	0.3772	0.3881	0.2875	0.6852	0.6852	0.6852
1985	0.0635	0.0978	0.2749	0.2869	0.3251	0.4186	0.3833	0.6194	0.6194	0.6194
1986	0.0775	0.1198	0.2561	0.5663	0.4479	0.4997	0.5812	0.8198	0.8198	0.8198
1987	0.0750	0.1158	0.2051	0.3928	0.6935	0.5258	0.5192	0.7805	0.7805	0.7805
1988	0.0757	0.1169	0.1651	0.3256	0.4971	0.8929	0.5780	0.7918	0.7918	0.7918
1989	0.0807	0.1248	0.2669	0.2747	0.4354	0.6676	1.1015	0.8711	0.8711	0.8711
1990	0.0991	0.1540	0.2572	0.5498	0.4293	0.6974	0.9941	1.2286	1.2286	1.2286
1991	0.0489	0.0749	0.1465	0.1867	0.2952	0.2313	0.3149	0.4430	0.4430	0.4430
1992	0.0417	0.0638	0.1545	0.1902	0.1914	0.2955	0.2082	0.3657	0.3657	0.3657
1993	0.0355	0.0543	0.1074	0.2004	0.1945	0.1912	0.2646	0.3034	0.3034	0.3034
1994	0.0386	0.0589	0.1022	0.1789	0.2679	0.2536	0.2238	0.3335	0.3335	0.3335
1995	0.0468	0.0717	0.0987	0.1916	0.2698	0.4038	0.3395	0.4197	0.4197	0.4197
1996	0.0583	0.0895	0.1288	0.1896	0.2983	0.4193	0.5752	0.5524	0.5524	0.5524
1997	0.0587	0.0903	0.2062	0.1995	0.2332	0.3625	0.4575	0.5584	0.5584	0.5584
1998	0.0799	0.1235	0.3068	0.4653	0.3434	0.3965	0.5710	0.8572	0.8572	0.8572
1999	0.0660	0.1016	0.2484	0.3950	0.4617	0.3324	0.3419	0.6519	0.6519	0.6519
2000	0.0717	0.1106	0.2500	0.4367	0.5490	0.6324	0.3944	0.7321	0.7321	0.7321
2001	0.0647	0.0995	0.1926	0.3525	0.4818	0.5923	0.5994	0.6340	0.6340	0.6340
2002	0.0809	0.1252	0.2737	0.3899	0.5810	0.8101	0.8919	0.8748	0.8748	0.8748
2003	0.0695	0.1071	0.2727	0.3666	0.4050	0.5886	0.7128	0.7000	0.7000	0.7000
2004	0.0800	0.1237	0.3339	0.5208	0.5448	0.5909	0.7811	0.8599	0.8599	0.8599
2005	0.0754	0.1164	0.2929	0.5072	0.6122	0.6233	0.5942	0.7866	0.7866	0.7866
2006	0.0630	0.0969	0.2011	0.3811	0.5101	0.5981	0.5356	0.6123	0.6123	0.6123
2007	0.0712	0.1097	0.2173	0.3627	0.5548	0.7458	0.7732	0.7237	0.7237	0.7237
2008	0.0672	0.1035	0.1422	0.3206	0.4214	0.6372	0.7527	0.6683	0.6683	0.6683
2009	0.0475	0.0728	0.0928	0.1514	0.2665	0.3384	0.4427	0.4276	0.4276	0.4276
2010	0.0382	0.0584	0.0746	0.1123	0.1456	0.2496	0.2830	0.3298	0.3298	0.3298
2011	0.0071	0.0108	0.0199	0.0204	0.0243	0.0305	0.0455	0.0547	0.0547	0.0547
2012	0.0230	0.0351	0.0812	0.0986	0.0806	0.0945	0.1080	0.1872	0.1872	0.1872
2013	0.0357	0.0545	0.1349	0.1966	0.1899	0.1504	0.1599	0.3053	0.3053	0.3053
2014	0.0619	0.0952	0.2332	0.3864	0.4538	0.4246	0.2930	0.5979	0.5979	0.5979
2015	0.0676	0.1041	0.2354	0.4096	0.5393	0.6244	0.5118	0.6733	0.6733	0.6733
2016	0.0630	0.0970	0.2207	0.3439	0.4705	0.6082	0.6192	0.6125	0.6125	0.6125
2017	0.0582	0.0895	0.1929	0.3177	0.3884	0.5215	0.5954	0.5518	0.5518	0.5518
2018	0.0673	0.1036	0.2147	0.3562	0.4686	0.5675	0.6875	0.6692	0.6692	0.6692
2019	0.0605	0.0930	0.1398	0.2994	0.3899	0.5019	0.5368	0.5799	0.5799	0.5799
2020	0.0681	0.1050	0.2076	0.2452	0.4260	0.5512	0.6366	0.6810	0.6810	0.6810
2021	0.0686	0.1056	0.2090	0.3284	0.4071	0.4961	0.5376	0.6869	0.6869	0.6869

Table 3. Blue whiting. Estimates of fishing mortality coefficients

References

. Vasilyev D. 2005 Key aspects of robust fish stock assessment. M: VNIRO Publishing, 2005. 105 p.

. Vasilyev D. 2006. Change in catchability caused by year class peculiarities: how stock assessment based on separable cohort models is able to take it into account? (Some illustrations for triple-separable case of the ISVPA model - TISVPA). ICES CM 2006/O:18. 35 pp

Working Document

Working Group on International Pelagic Surveys
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Working Group on Widely Distributed Stocks
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INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2021

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Material and methods

Survey planning and Coordination

Coordination of the survey was initiated at the meeting of the Working Group on International Pelagic Surveys (WGIPS) in January 2021 and continued by correspondence until the start of the survey. During the survey effort was refined and adjusted by the survey coordinator (Norway) using real time observations. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Celtic Explorer	Marine Institute, Ireland	21/3 – 04/4
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	29/3 – 05/4
Tridens	Wageningen Marine Research, the Netherlands	18/3 – 03/4
Vendla	Institute of Marine Research, Norway	25/3 – 05/4
Vizconde de Eza	Spanish Institute of Oceanography, Spain	18/3 – 23/3

The survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Weather conditions were regarded as exceptionally poor and all vessels experienced multiple days of downtime, with the exception of the Spanish vessel working in the Porcupine Seabight. This considered, the stock was covered comprehensively and contained within the survey area. The entire survey was completed in 19 days, below 21-day target threshold (Figure 4).

Vessel cruise tracks and survey strata are shown in Figure 1. Trawl stations for each participant vessel are shown in Figure 2 and CTD stations in Figure 3. Communication between vessels occurred daily via email to the coordinator (Norway) exchanging up to date information on blue whiting distribution, echograms, fleet activity and biological information. Tridens keeps a weblog during the survey with echograms, catches and additional information.

Sampling equipment

All vessels employed a single midwater trawl for biological sampling, the properties of which are given in Table 1. Acoustic equipment for data collection and processing are presented in Table 2. Survey abundance estimates are based on acoustic data collected from calibrated scientific echo sounders using an operating frequency of 38 kHz. All transducers were calibrated using a standardised sphere calibration (Demer et al. 2015) prior, during or directly after the survey. Acoustic settings by vessel are summarised in Table 2.

Biological sampling

All components of the trawl haul catch were sorted and weighed; fish and other taxa were identified to species level. A summary of biological sampling by vessel is provided in Table 3.

Hydrographic sampling

Hydrographic sampling (vertical CTD casts) was carried out by each vessel at predetermined locations (Figure 3 and Table 3). Depth was capped at a maximum depth of 1000 m in open water, with the exception of the Spanish vessel where the maximum depth was 520 m. Not all pre-planned CTD stations were undertaken due to weather restrictions.

Plankton sampling

Plankton sampling by way of vertical WP2 casts were carried out by the RV *Jákup Sverri* (FO) to a depth of 200 m (Table 3). WP2 casts were also carried out by FV *Vendla*, with a focus on sampling blue whiting eggs to a depth of 400 m.

Acoustic data processing

Echogram scrutinisation for blue whiting was carried out by experienced personnel, with the aid of trawl composition information. Post-processing software and procedures differed among the vessels;

On RV *Celtic Explorer*, acoustic data were backed up every 24 hrs and scrutinised using EchoView (V 11.0) post-processing software for the previous day's work. Data was partitioned into the following categories: blue whiting and mesopelagic fish species. For mesopelagic fish, categorisation was based on criteria agreed at WGIPS 2021 (ICES 2021, Annex 22).

On RV *Jákup Sverri*, acoustic data were scrutinised every 24 hrs on board using LSSS post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside (surface down to 250 m), mesopelagics/krill and blue whiting. Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms. The pearlside layer typically migrated above the transducer depth during night and reappeared on the echogram early in the morning.

On RV *Tridens*, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.10.1) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On FV *Vendla*, the acoustic recordings were scrutinized using LSSS (V. 2.10.1) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On RV *Vizconde de Eza*, acoustic data were backed up every 12 hrs and scrutinised after the survey using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: Blue whiting and Müeller's pearlside which were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

Echogram scrutinisation for mesopelagic fish species was conducted by participants using guidelines developed at WGIPS 2021 (ICES 2021, Annex 22). This process is ongoing and requires further development in terms of categorisation and trawl sampling equipment. Progress updates will be reported through WGIPS.

Due to the bad weather conditions acoustic recording of all vessels suffered from transmission loss and spikes caused by wave impact on the ship's hull (Figure 8e). Scientists onboard RV *Tridens* analysed data collected during the survey to investigate the effects of bias. A case study showed that there was no significant bias and therefore no need to apply filtering or a correction factor. Further details are provided in Annex 1.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V3.0.5) and R-StoX packages software package (RStoX Framework 3.0.12, RStoX Base 1.3.8 and RStoX Data 1.1.3). A description of StoX software package is provided by Johnsen et. al. (2019). Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Baseline survey strata, established in

2017, were adjusted based on survey effort and observations in 2021 (Figure 1). Area stratification and transect design are shown in Figure 1 and 5. Length and weight data from trawl samples were equally weighted and applied across all transects within a given stratum (Figure 5).

Following the decisions made at the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES, ICES 2012), the following target strength (TS)-to-fish length (L) relationship (Pedersen et al. 2011) is used:

$$TS = 20 \log10 (L) - 65.2$$

In StoX an impute super-individual table is produced where abundance is linked to population parameters including age, length, weight, sex, maturity etc. This table is used to split the total abundance estimate by any combination of population parameters. The StoX project folder for 2021 is available on request.

Estimate of relative sampling error

For the baseline run, StoX estimates the number of individuals by length group which are further grouped into population characteristics such as numbers at age and sex.

A total length distribution is calculated, by transect, using all the trawl stations assigned to the individual transects. Conversion from NASC (by transect) to mean density by length group by stratum uses the calculated length distribution and a standard target strength equation with user defined parameters. Thereafter, the mean density by stratum is estimated by using a standard weighted mean function, where each transect density is weighted by transect distance. The number of individuals by stratum is given as the product of stratum area and area density.

The bootstrap procedure to estimate the coefficient of variance randomly replaces transects and trawl stations within a stratum on each successive run. The output of all runs are stored in a RData-file, which is used to calculate the relative sampling error.

Results

Distribution of blue whiting

In total 7,794 nmi (nautical miles) of survey transects were completed across seven strata, relating to an overall geographical coverage of 118,169 nmi² and is comparable to survey effort in 2019 (Figure 1, Tables 3 & 7). Effort in the Porcupine Seabight area was extended in 2021 and included as a new stratum area. The stock was considered well contained within core and peripheral abundance areas (Rockall Bank and south Porcupine Bank). The distribution of blue whiting as observed during the survey is shown in Figures 6 and 7.

The bulk of the stock in 2021 was located within the three strata that cover the shelf edge area (Strata 1-3 inclusive) accounting for 84% of total biomass observed (Table 4). The Rockall Trough, strata 3, contained less biomass than observed in 2019 (41% and 61 % of TSB respectively). Distribution in the Porcupine Bank (stratum 1) decreased by 69% compared to 2019. However, it should be noted that this stratum was subdivided into what is now stratum 7 (Porcupine Seabight). The three strata outside the core shelf edge area (stratum 4, 5, and 6) collectively increased from around 5% in 2019 to 10% in 2021 (Table 4). The new Porcupine Seabight area (stratum 7) contributed around 6% of the overall biomass of blue whiting in 2021.

The two northernmost strata South Faroes (stratum 4) and Shetland Channel (stratum 6) accounted for 3.2% of the biomass (Table 4).

Overall, the distribution of blue whiting was found to be highly compressed against the shelf edge from south to north, with the main body of the stock located in the mid-latitudes to the north of the Porcupine Bank (strata 2-3).

The highest s_A value (73,312 m²/nmi² - per 1 nmi EDSU) observed in the survey in 2021 was recorded by *Celtic Explorer* on the slope in the southern part of stratum 3 (Figure 8c). The second highest density value for the combined survey was also found in the same area in the eastern part of the northern slope of Porcupine Bank (stratum 2). Example echograms are provided in Figures 8a, 8b, 8g, showing high density layers of blue whiting extending onto the shelf area on the Porcupine Bank. Juvenile blue whiting, observed as weak scattering layers were found in the northern stratum of South Faroes and Faroe – Shetland Channel (Figure 8d).

The vertical distribution of blue whiting observed in 2021 did not extend deeper than 750 m as observed in 2018 and so were considered vertically contained in the insonified layer.

Stock size

The estimated total stock biomass of blue whiting for the 2021 international survey was 2.4 million tonnes, representing an abundance of 36.9×10^9 individuals (Table 4). Spawning stock was estimated at 2.3 million tonnes and 18.1×10^9 individuals (Table 5).

Stock composition

Survey samples show the age range of 1 to 13 years were observed during the survey.

The main contribution to the spawning stock biomass was composed of the age groups 5, 7 and 6 years representing 63% of the total. Five year olds (2016 year-class) being most abundant (20%), followed by the 7-year-olds (17%) and lastly the 6-year-olds (16%) (Table 5).

The highest mean lengths of blue whiting were caught in Stratum 1 and 7 (Figure 9). High mean weights were also found in this area but two samples in the northern part (Stratum 3 and 4) also had large blue whiting in relation to weight (Figure 10). Highest mean weight in 2021 was in Stratum 7 (Porcupine Seabight) representing 136g.

This year different age groups dominated in different strata (Figure 12). The oldest and largest fish were found in the southern part of the survey area. In the western and southern part of the Porcupine area (Strata 1 and 7) six-year olds (2015 year-class) dominated. On the northern slope of Porcupine (Stratum 2) two-year olds were the second most important age group, but still five-year olds were dominant. In the northern part of the survey area (Strata 4 and 6) the youngest fish were present, and the 2020 year-class dominated. In the core area (Stratum 3) three, five and seven-year olds were approx. at the same level with 15-16% of the estimate each. (Figure 12). The proportion of the different age groups in the total estimate in 2021 were considered evenly distributed and well represented from 1-7 years (Figure 13).

An uncertainty estimate at age based on a comparison of the abundance estimates was calculated for IBWSS for years 2018, 2019 and 2021 using StoX (Figure 11). By comparing the estimates from 2018 to 2021 it appears that good cohort tracking is achieved in the survey for some year classes. For example, the relative abundance of four year olds in 2018 (2014-year class) was high; the strong abundance of this cohort is also seen in 2019 as five year olds, and to some extent in 2021 as seven year olds. Similarly, the 2015 year-class were picked up as three-year olds in 2018, and subsequently the four and six year olds in 2019 and 2021 respectively are relatively strong. The CV of the abundant age groups 3 to 7 was below 0.25 in 2019 (Figure 11).

The CV of the total estimate of both biomass and abundance were 0.14, which is lower than the years before (0.16 - 0.17)

The survey time series (2004-2021) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A total of 102 CTD casts were undertaken over the course of the survey (Table 1). Horizontal plots of temperature and salinity at depths of 50 m, 100 m, 200 m and 500 m as derived from vertical CTD casts are displayed in Figures 16-19 respectively. A decrease in salinity observed in 2017 persisted through 2018 and 2019, but seems to have reversed again in 2020 with an increasing trend (K.M. Larsen, pers. comm., Faroe Marine Research Institute). This is thought to have limited the western extent of the blue whiting spawning distribution on the Rockall and Hatton Bank areas in recent years.

Mesopelagic fish

Echogram scrutinisation for mesopelagic fish species was conducted by participants during the survey and included in uploads to the ICES database. However, due to the complexities involved and issues regarding representative trawl catches these data are considered as experimental and outputs reported to the ICES database should be treated as such.

Concluding remarks

Main results

- Weather conditions were regarded as exceptionally poor and all vessels experienced multiple days of downtime, except for the Spanish vessel working in the Porcupine Seabight. This considered, the stock was regarded as suitably contained within the survey area.
- The total area surveyed and acoustic sampling effort (miles) was the same as 2019.
- Overall, biological sampling saw an increased number of both measured and aged individuals compared to 2019.
- The International Blue Whiting Spawning Stock Survey 2021 shows a 44% decrease in total stock biomass and a corresponding 46% decrease in total abundance when compared to the 2019 estimate.
- The survey was carried out over 19 days, below the 21-day time window target. With core areas covered well by multiple vessels.
- Estimated uncertainty around the total stock biomass was lower than in 2019, CV=0.14 compared to 0.17.
- The stock biomass within the survey area was dominated by 5, 6 and 7-year-old fish contributing 61% of total stock biomass.
- There was no evidence of blue whiting below 750 m
- Immature fish (mainly 1-year-old) represent 3.6% of the TSB and 10% of TSN.
- The harmonisation of reporting of mesopelagic fish began in earnest and will be developed within the IBWSS survey over the coming years to report abundance and biomass of identified target groups.

Interpretation of the results

- The group considers the 2021 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Sampling effort (biological and acoustic) was comparable to previous years.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and the Hebrides.
- The Northern migratory stock and the Porcupine Seabight; Spatio-temporal survey data and biological data from trawl hauls (RV *Vizconde de Eza*) were comparable in terms of length cohorts. The eastward extension of the survey area is necessary to contain the northern stock. Comparative analysis of age readings is required.

Recommendations

- The group recommends that coverage in the western Rockall/Hatton Bank (stratum 5) should be carried out based on real time observations. That is, effort should not be expended where no aggregations are evident and transects are terminated when no blue whiting is observed for 15 nmi consistent ‘clear water’ miles. This applies to peripheral regions to the west of the Rockall and Hatton Bank areas.

- To facilitate the process of calculating global biomass the group requires that all data be made available at least 72 hours in advance of the meeting start date and made available through the ICES database.
- Hydrographic and Plankton data along with Log book files formats should still be submitted in the PGNAPES format.
- The group recommends that the process of producing output reporting tables, figures and maps from StoX outputs files (StoX 3.2) are standardised and developed by WGIPS for wider use.
- Through WGIPS, agreement needs to be reached on the synchronisation of reporting blue whiting maturity by participants and how this is handled within the ICES database.
- It is recommended that the effective timing of the survey point is maintained to begin around the 20^{th} March in 2022.

Achievements

- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable to 2019.
- All survey data were uploaded to the ICES trawl-acoustic database in advance of the post cruise meeting.
- Mesopelagic fish scrutinisation was carried out by all participants using the guidelines developed during WGIPS.
- Directed trawling on mesopelagic layers was carried out using a range of sampling nets (MiK and Macrozooplankton). Although still experimental, this is a further step towards reporting.

References

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326.

ICES. 2012. Report of the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES), 23–26 January 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGESST:01. 27 pp.

ICES. 2015. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES 2016. First Interim Report of the Working Group of International Pelagic Surveys (WGIPS). ICES CM SSGIEOM/05, 433 pp.

ICES. 2021. Working Group of International Pelagic Surveys (WGIPS). ICES Scientific Reports. 3:40. https://doi.org/10.17895/ices.pub.8055

Johnsen, E, Totland, A, Skålevik, Å, et al. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019; 10: 1523– 1528. https://doi.org/10.1111/2041-210X.13250

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 47(7): 1282-1291.

Pedersen, G., Godø, O. R., Ona, E., and Macaulay, G. J. 2011. A revised target strength–length estimate for blue whiting (*Micromesistius poutassou*): implications for biomass estimates. ICES Journal of Marine Science, doi:10.1093/icesjms/fsr142.

Simmonds, J. and MacLennan D. 2007. Fisheries acoustics, theory and practice. Second edition. Blackwell publishing.

Table 1. Country and vessel specific details, IBWSS March-April 2021.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Trawl dimensions					
Circumference (m)	768	852	860	832	752
Vertical opening (m)	50	45	30-70	45	30
Mesh size in codend (mm)	20	45	40	40	20
Typical towing speed (kts)	3.5-4.0	3.0-4.0	3.5-4.0	3.5-4.0	4.0-4.5
Plankton sampling					
Sampling net	-	WP2 plankton net	-	WP2 plankton net	
Standard sampling depth (m)	-	200	-	400	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25
Standard sampling depth (m)	1000	1000	1000	1000	520

Table 2. Acoustic instruments and settings for the primary acoustic sampling frequency, IBWSS March-April 2021.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Echo sounder	Simrad EK 60	Simrad EK80	Simrad EK 60	Simrad EK 80	Simrad EK 80
Frequency (kHz)	**38**, 18, 120, 200	18, **38**, 70, 120, 200, 333	18, **38**, 70, 120, 200, 333	18, **38**, 70	**38**, 18, 70, 120, 200
Primary transducer	ES 38B	38-7	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	8.7	6	8	8.5	7.5
Upper integration limit (m)	20	15	15	15	15
Absorption coeff. (dB/km)	9.8	10.7	9.5	9.5	9.2
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	3.06	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.6	-20.4	-20.6	-20.7	-20.6
Sv Transducer gain (dB)			27.28		
Ts Transducer gain (dB)	25.65	26.96	27.27	25.18	24.68
s_A correction (dB)	-0.64	-0.16	-0.01	-0.66	-0.54
3 dB beam width (dg)					
alongship:	6.97	6.55	6.86	7.01	6.90
athw. ship:	7.06	6.45	6.89	6.90	7.10
Maximum range (m)	1000	750	750	750	1000
Post processing software	Echoview	LSSS	LSSS	LSSS	Echoview

Table 3. Survey effort by vessel, IBWSS March-April 2021. Directed mesopelagic sampling 150-350 m depth layer) was carried out by the RV *Celtic Explorer* and RV *Tridens* using macrozooplankton and Mik net trawls respectively.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Mesopelagic sampling	Aged fish	Length-measured fish
Celtic Explorer	21/3-04/4	2123	15	19	3	550	6571
Jákup Sverri	25/3-5/4	1100	3	19	-	300	668
Vendla	25/3- 5/4	2100	9	19	-	239	800
Tridens	18/3-3/4	1574	13	31	5	1000	2836
Vizconde de Eza	18/3-23/3	897	5	14	-	-	1144
Total	28/3-11/4	7794	45	102	8	2089	12019

Table 4. Abundance and biomass estimates of blue whiting by strata in 2019 and 2018. IBWSS March-April 2021.

		2021				2019				Difference 2021-2019	
Strata	Name	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB	TSN
1	Porcupine Bank	270	2 232	11.4	11.1	870	8 350	20.7	22.6	-69 %	-73 %
2	N Porcupine Bank	746	6 500	31.6	32.3	572	5 692	13.6	15.4	30 %	14 %
3	Rockall Trough	977	8 094	41.4	40.2	2 555	21 116	60.9	57.2	-62 %	-62 %
4	South Faroes	154	1 413	6.5	7.0	125	1 039	3.0	2.8	24 %	36 %
5	Rockall Bank	41	300	1.7	1.5	29	272	0.7	0.7	43 %	10 %
6	Faroe/Shetland Ch.	34	595	1.5	3.0	47	448	1.1	1.2	-27 %	33 %
7	Porcupine Seabight	139	984	5.9	4.9	0	0				
	Total	2 361	20 119	100	100	4 198	36 918	100	100	-44 %	-46 %

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2021.

	Age in years (year class)										Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012		(10^6)	(10^6 kg)	(g)	
14-15										0	0	0	0.0	0
15-16	24										24	1	21.7	84
16-17	386										386	9	24.0	12
17-18	476										476	13	27.7	6
18-19	403	9									412	13	32.2	2
19-20	228										228	9	39.0	0
20-21	177										177	8	45.1	3
21-22	155										155	8	52.4	0
22-23	67	1	17								85	5	62.0	21
23-24	34	167	41								242	17	68.1	86
24-25		498	327	22	18						865	66	76.5	97
25-26		746	585	154	83	6					1 574	134	85.0	95
26-27		468	685	545	713	9	1	0			2 421	225	92.8	97
27-28		139	483	568	686	160	52	4			2 092	223	106.5	99
28-29		62	255	539	808	573	223	19	1		2 479	294	119.0	100
29-30			38	187	454	681	799	5	1		2 165	287	132.4	100
30-31		6	86	82	586	621	806	40	76		2 302	326	142.1	100
31-32			28	127	286	581	606	25	35	22	1 712	267	155.5	100
32-33				41	225	245	514	21			1 047	176	168.3	100
33-34				4	16	158	238	105			521	98	188.8	100
34-35				2	28	82	69	136	5	21	343	71	206.9	100
35-36				2	9	27	38	55	10	40	181	41	227.4	100
36-37				2		49	12	19	13	1	94	25	254.4	100
37-38						5	7	12	32		57	17	280.3	100
38-39						1		21		8	31	9	296.5	100
39-40							4			8	12	4	345.3	100
40-41									15		15	6	386.3	100
41-42							4				4	1	329.0	100
42-43										6	6	3	432.0	100
43-44										6	6	0	556.0	100
44-45							6				6	3	448.7	100
TSN(mill)	1 948	2 095	2 545	2 275	3 914	3 197	3 379	463	189	114	20 119			
TSB(1000 t)	68.8	179.3	243.9	265.0	470.0	469.0	504.1	98.5	35.2	20.9	2 357.3			
Mean length(cm)	18.1	25.0	26.1	27.5	28.3	30.0	30.5	33.3	33.0					
Mean weight(g)	35	84	98	111	122	144	152	199	206					
% Mature	6	96	95	100	100	100	100	100	100	100				
SSB (1000kg)	3.9	172.0	232.3	264.8	469.5	469.0	504.1	98.5	35.2	20.9	2 270.1			
SSN (mill)	109.1	2010.0	2423.6	2273.4	3910.1	3197.2	3379.0	462.6	189.1	113.7	18 067.7			

Table 6. Time series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS. Total biomass in last column (1000 t).

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
2004	1 097	5 538	13 062	15 134	5 119	1 086	994	593	164		3 505
2005	2 129	1 413	5 601	7 780	8 500	2 925	632	280	129	23	2 513
2006	2 512	2 222	10 858	11 677	4 713	2 717	923	352	198	31	3 512
2007	468	706	5 241	11 244	8 437	3 155	1 110	456	123	58	3 274
2008	337	523	1 451	6 642	6 722	3 869	1 715	1 028	269	284	2 639
2009	275	329	360	1 292	3 739	3 457	1 636	587	250	162	1 599
2010*											
2011	312	1 361	1 135	930	1 043	1 712	2 170	2 422	1 298	250	1 826
2012	1 141	1 818	6 464	1 022	596	1 420	2 231	1 785	1 256	1 022	2 355
2013	586	1 346	6 183	7 197	2 933	1 280	1 306	1 396	927	1 670	3 107
2014	4 183	1 491	5 239	8 420	10 202	2 754	772	577	899	1 585	3 337
2015	3 255	4 565	1 888	3 630	1 792	465	173	108	206	247	1 403
2016	2 745	7 893	10 164	6 274	4 687	1 539	413	133	235	256	2 873
2017	275	2 180	15 939	10 196	3 621	1 711	900	75	66	144	3 135
2018	836	628	6 615	21 490	7 692	2 187	755	188	72	144	4 035
2019	1 129	1 169	3 468	9 590	16 979	3 434	484	513	99	144	4 198
2020*											
2021	1 948	2 095	2 545	2 275	3 914	3 197	3 379	463	189	114	2 357

*Survey discarded.

Table 7. IBWSS survey effort time series.

Survey effort	Survey area (nmi²)	Transect n. miles (nmi)	Trawls	CTDs	Plankton	Bio sampling (WHB) Measured	Aged
2004	149 000		76	196			
2005	172 000	12 385	111	248	-	29 935	4 623
2006	170 000	10 393	95	201	-	7 211	2 731
2007	135 000	6 455	52	92		5 367	2 037
2008	127 000	9 173	68	161	-	10 045	3 636
2009	133 900	9 798	78	160	-	11 460	3 265
2010	109 320	9 015	62	174	-	8 057	2 617
2011	68 851	6 470	52	140	16	3 810	1 794
2012	88 746	8 629	69	150	47	8 597	3 194
2013	87 895	7 456	44	130	21	7 044	3 004
2014	125 319	8 231	52	167	59	7 728	3 292
2015	123 840	7 436	48	139	39	8 037	2 423
2016*	134 429	6 257	45	110	47	5 390	2 441
2017	135 085	6 105	46	100	33	5 269	2 477
2018	128 030	7 296	49	101	45	5 315	2 619
2019	121 397	7 610	38	118	17	6 228	1 938
2021	118 169	7 794	45	102	8	12 019	2 089

* End of Russian participation.

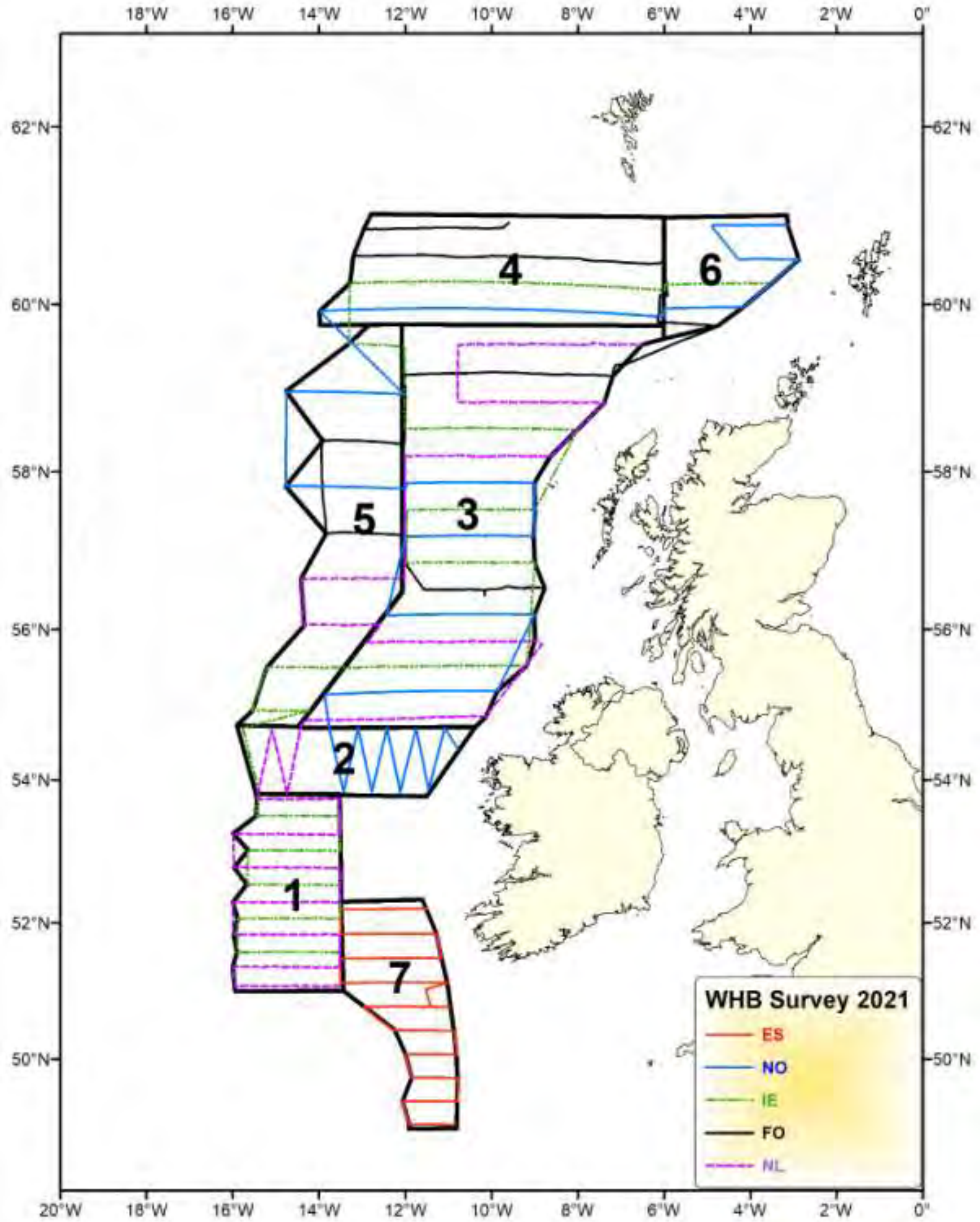


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

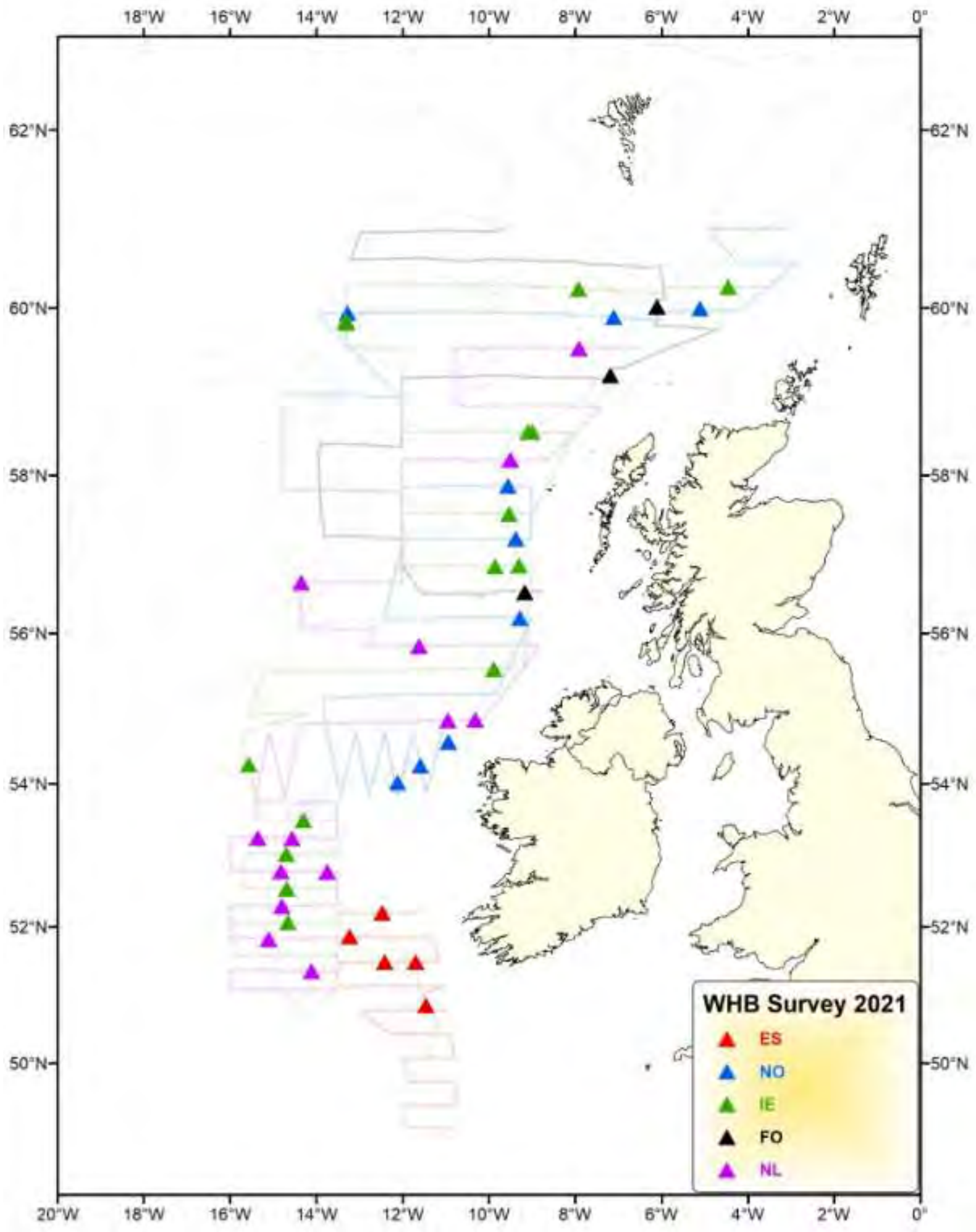


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021. ES: Spain (RV *Vizconde de Eza*); FO: Faroe Islands (RV *Jakúp Sverrí*); IE: Ireland (RV *Celtic Explorer*); NL: Netherlands (RV *Tridens)*; NO: Norway (FV *Vendla*).

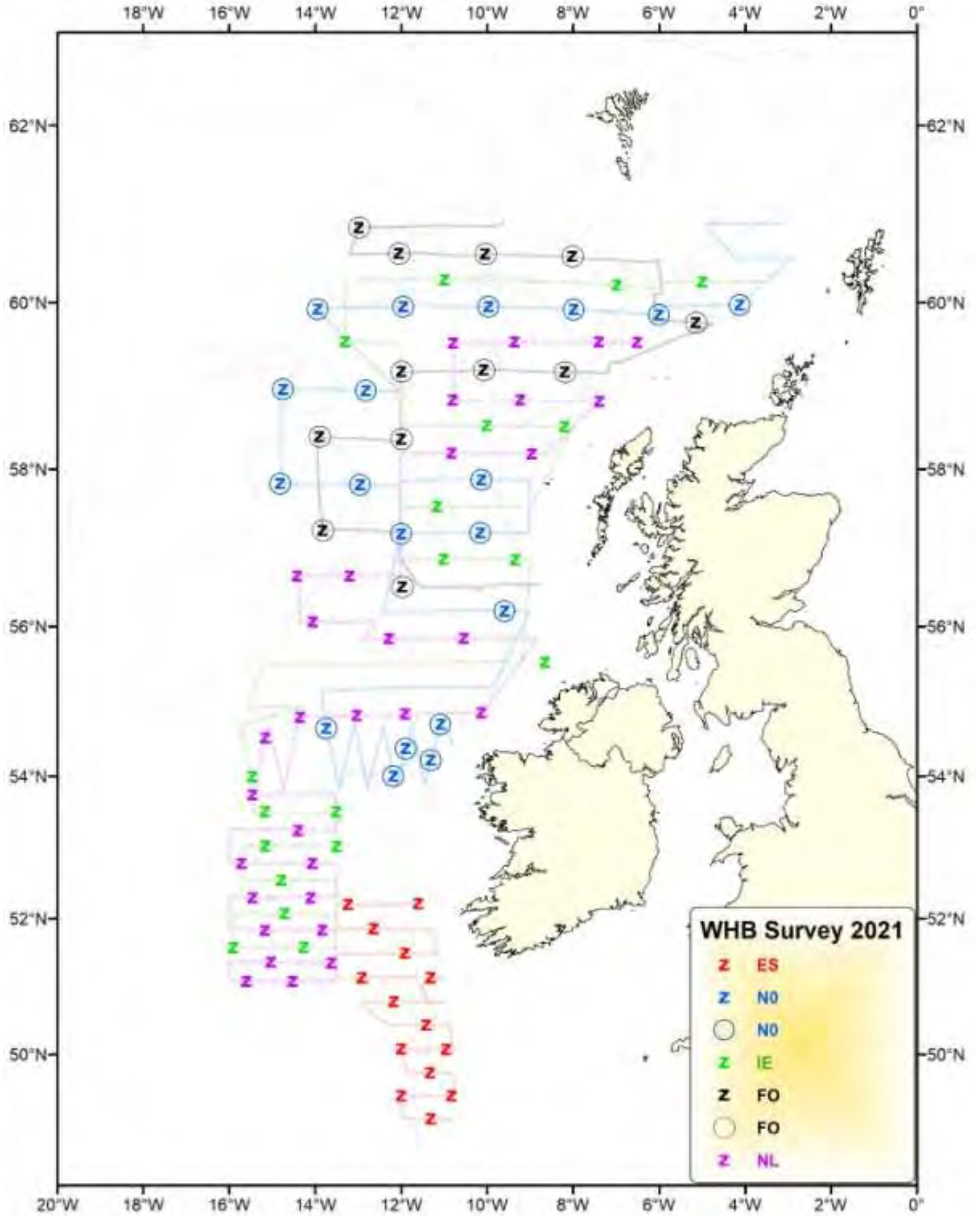


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021. Colour coded by vessel.

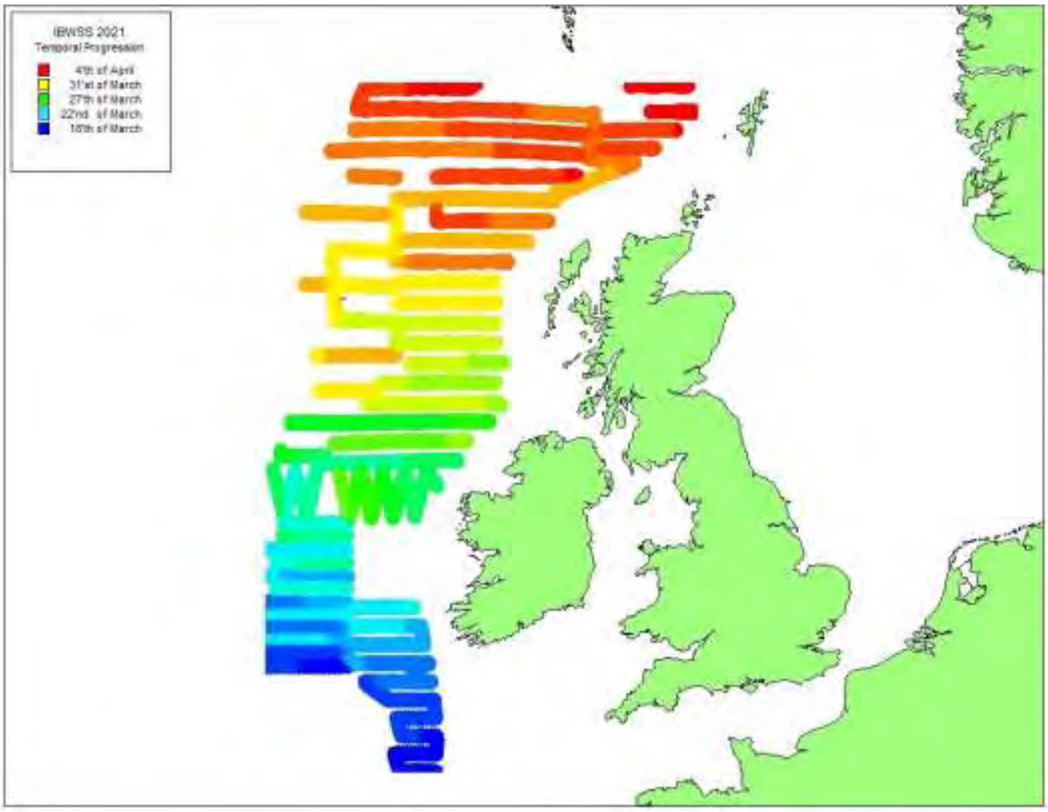


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

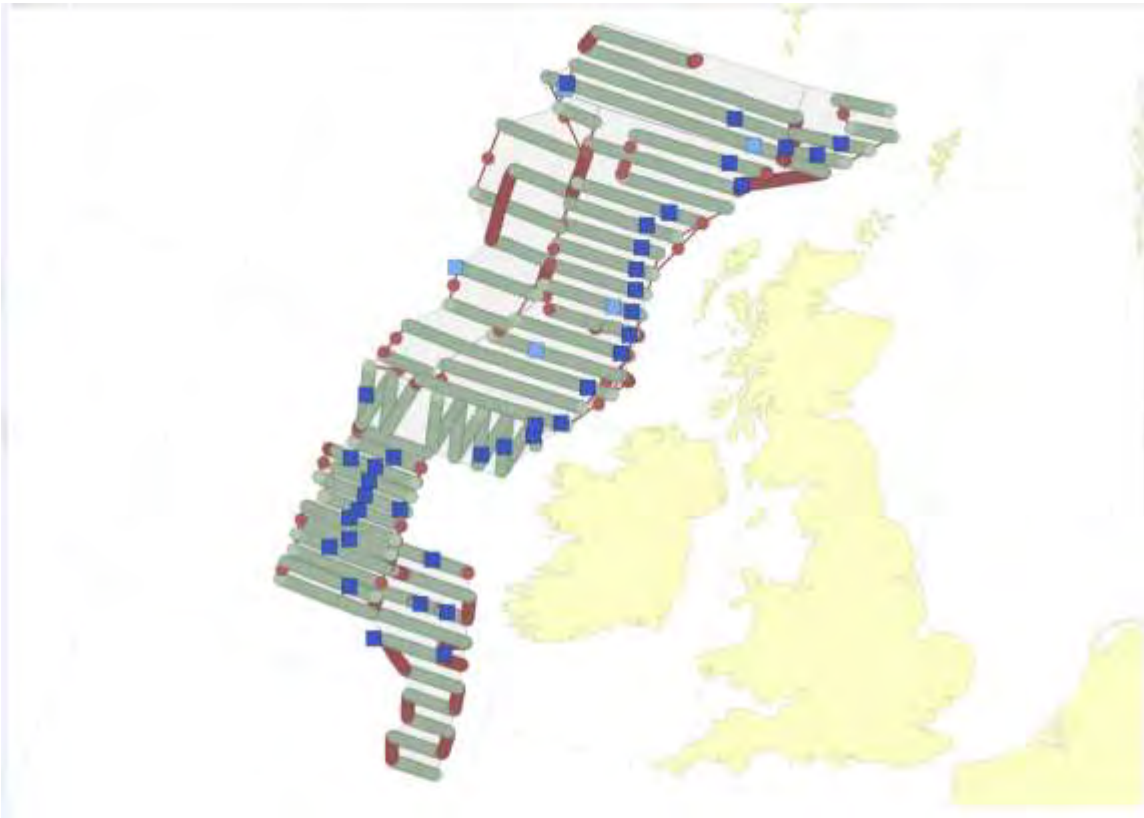


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (dark blue squares) used in the StoX abundance estimation. IBWSS March-April 2021.

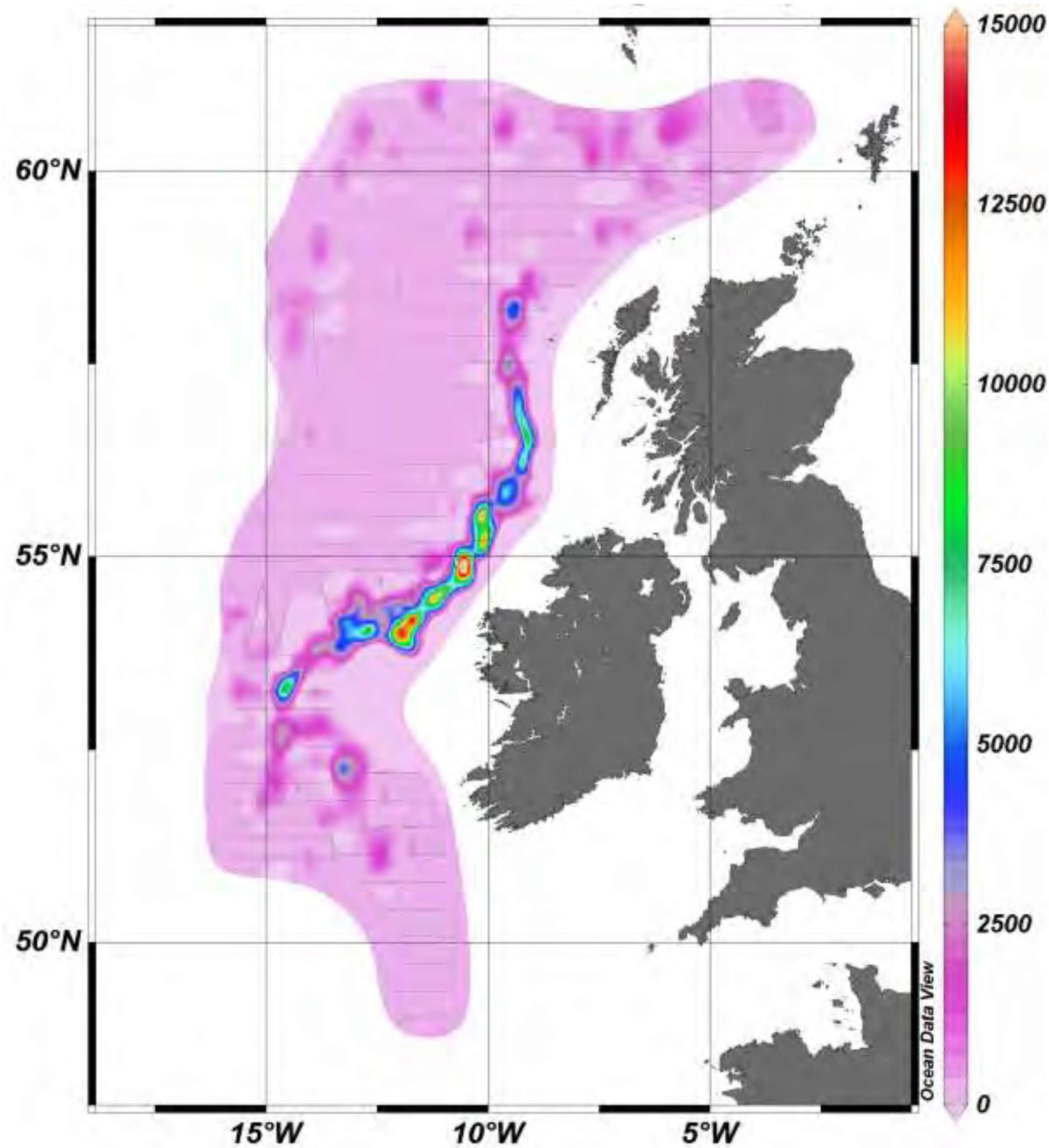


Figure 6. Acoustic density heat map (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

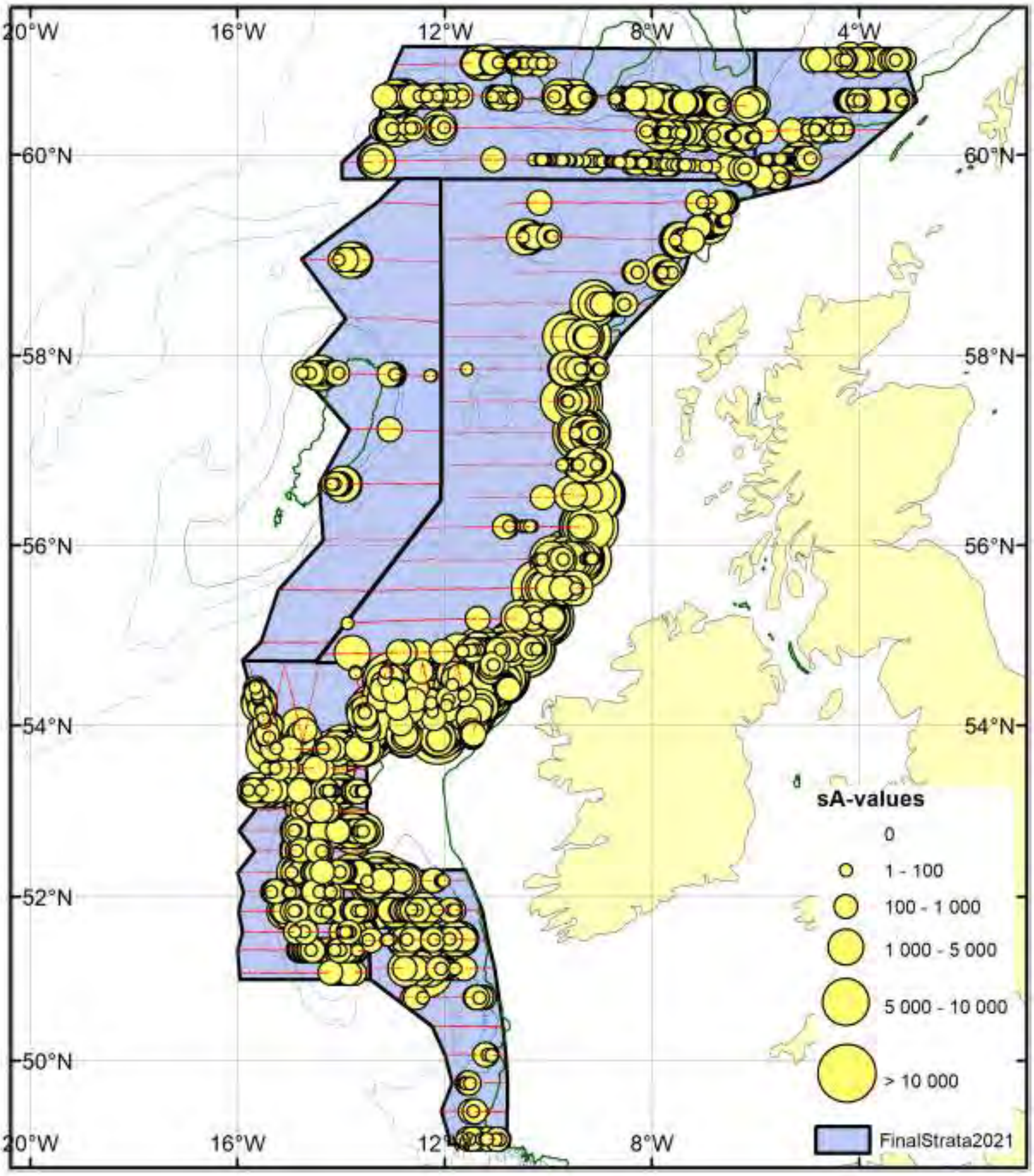
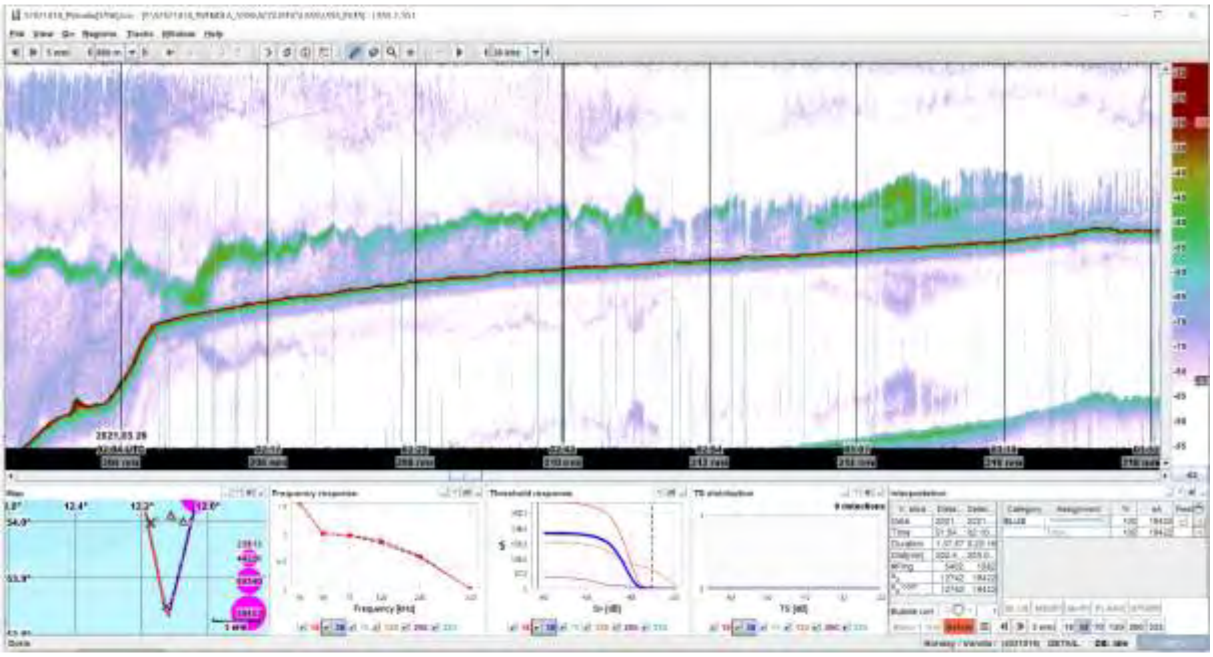
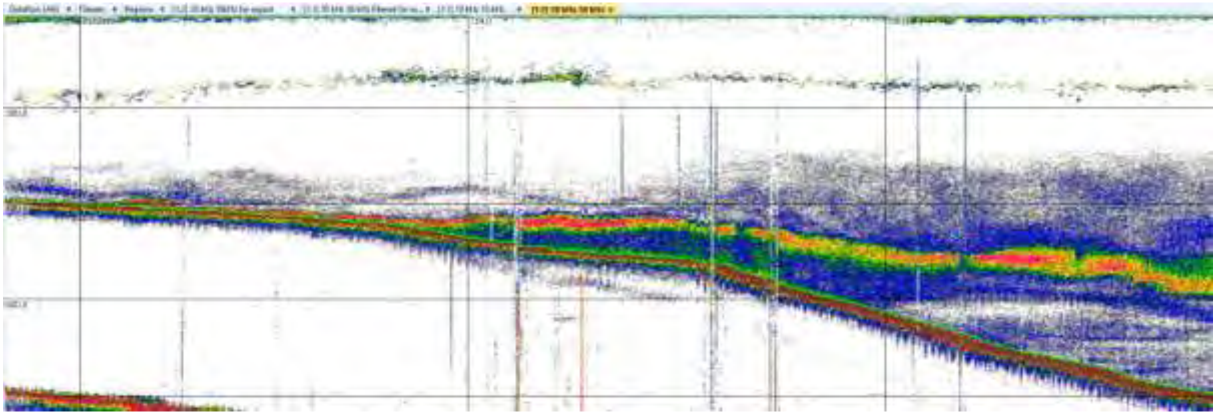


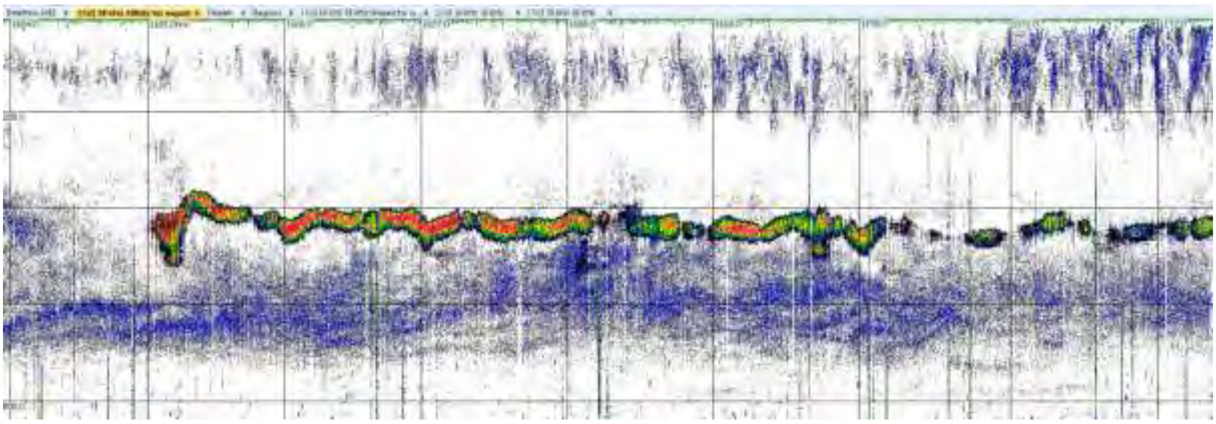
Figure 7. Map of proportional acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi sampling unit. IBWSS March-April 2021.



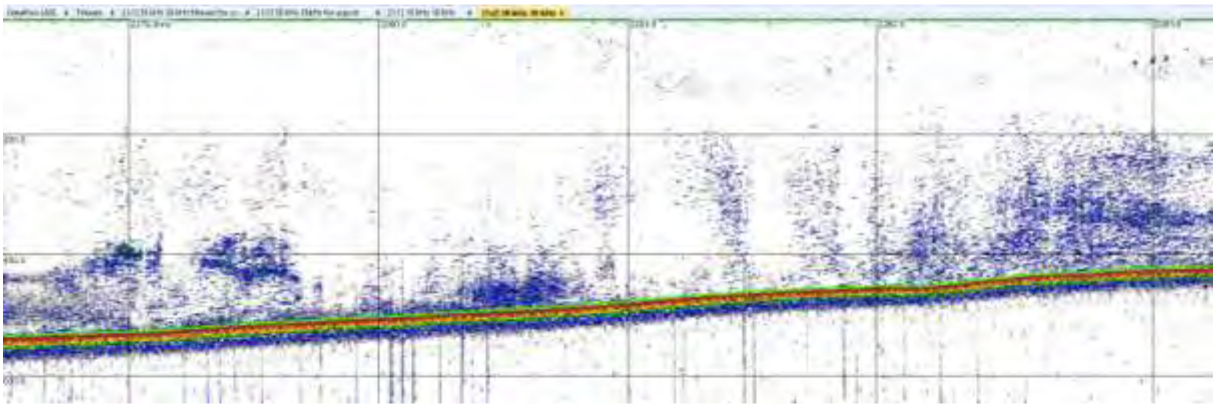
a) High density blue whiting per 1nmi log interval recorded on the northern slope of the Porcupine Bank area (Stratum 2) FV *Vendla*, Norway.



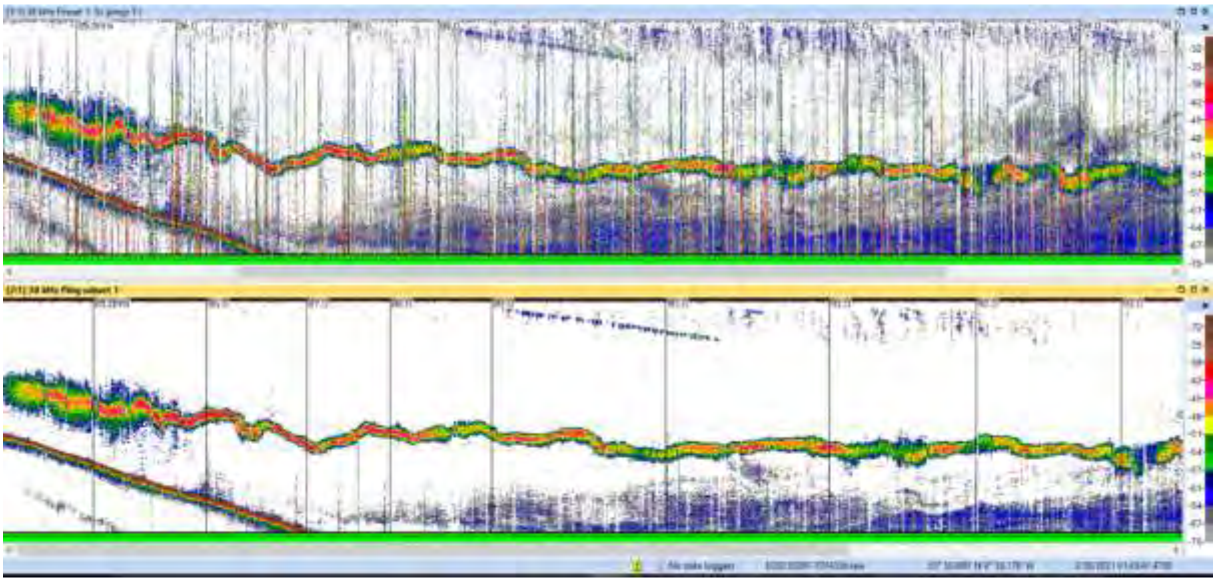
b) High density blue whiting layer per 1nmi log interval at 400- 600m recorded by the RV *Celtic Explorer* in the western Porcupine Bank area (strata 1).



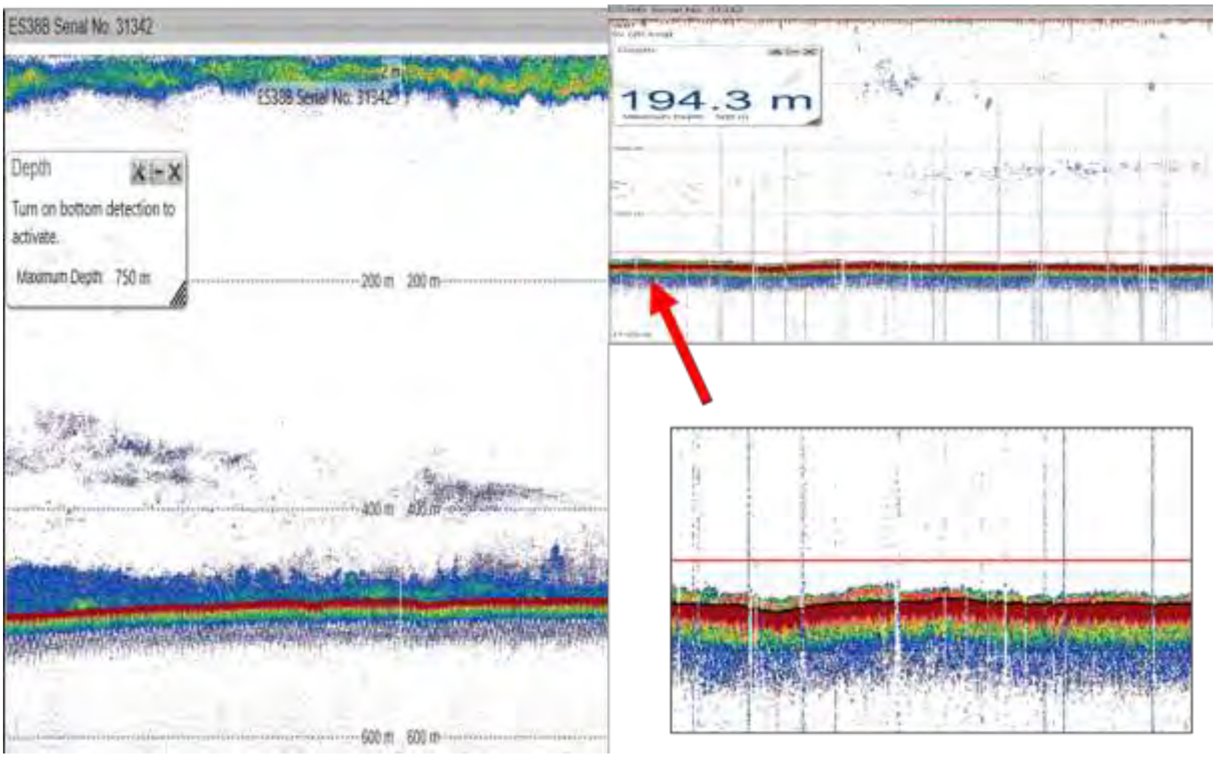
c) Single highest density blue whiting layer per 1nmi log interval (s_A value (73,312 m^2/nmi^2) observed during the survey recorded by the Celtic Explorer in the Rockall Trough area (Stratum 3) in 400 – 500 m.



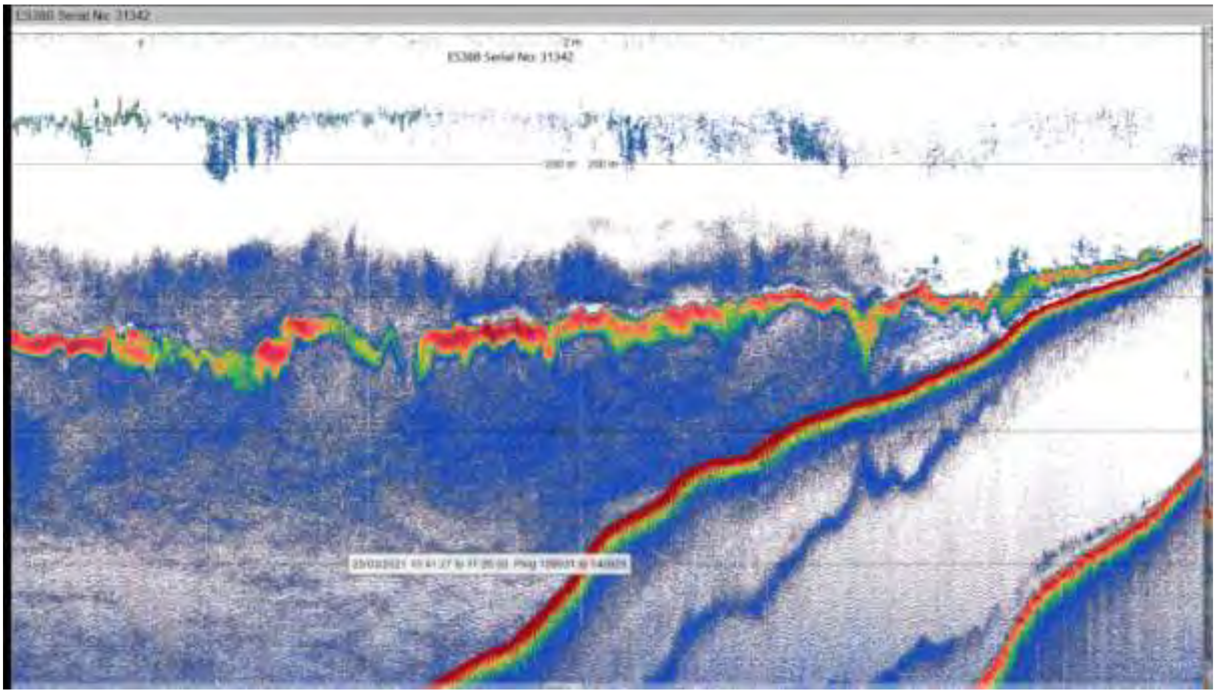
d) Weak scattering of predominantly juvenile blue whiting per 1 nmi log interval along the 400-500 m contour depth. This was an area that some of the fleet were fishing during the survey. Recorded by the RV *Celtic Explorer* in the Faroe – Shetland channel area (Stratum 6).



e) Blue whiting aggregations as observed by Tridens at the shelf edge (55.51N-9.00W). Above: without spike filtering. Below: after spike filtering. Test with spike filtering and removal of transmission loss, showed that there was no significant difference in NASC assigned to blue whiting before and after filtering (See annex 1). The weather conditions did not allow fishing.



f) Left: layer of blue whiting on Rockall Bank (*Tridens* – 19 March, haul1). Right: layer of grey gurnard on Rockall Bank (*Tridens* – 31 March, haul 11).



g) Blue whiting aggregations observed by *Tridens* at the edge of the continental shelf at 54.51N – 10.19W (25 March, haul 9).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2021. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU). All echograms presented at 38 kHz.

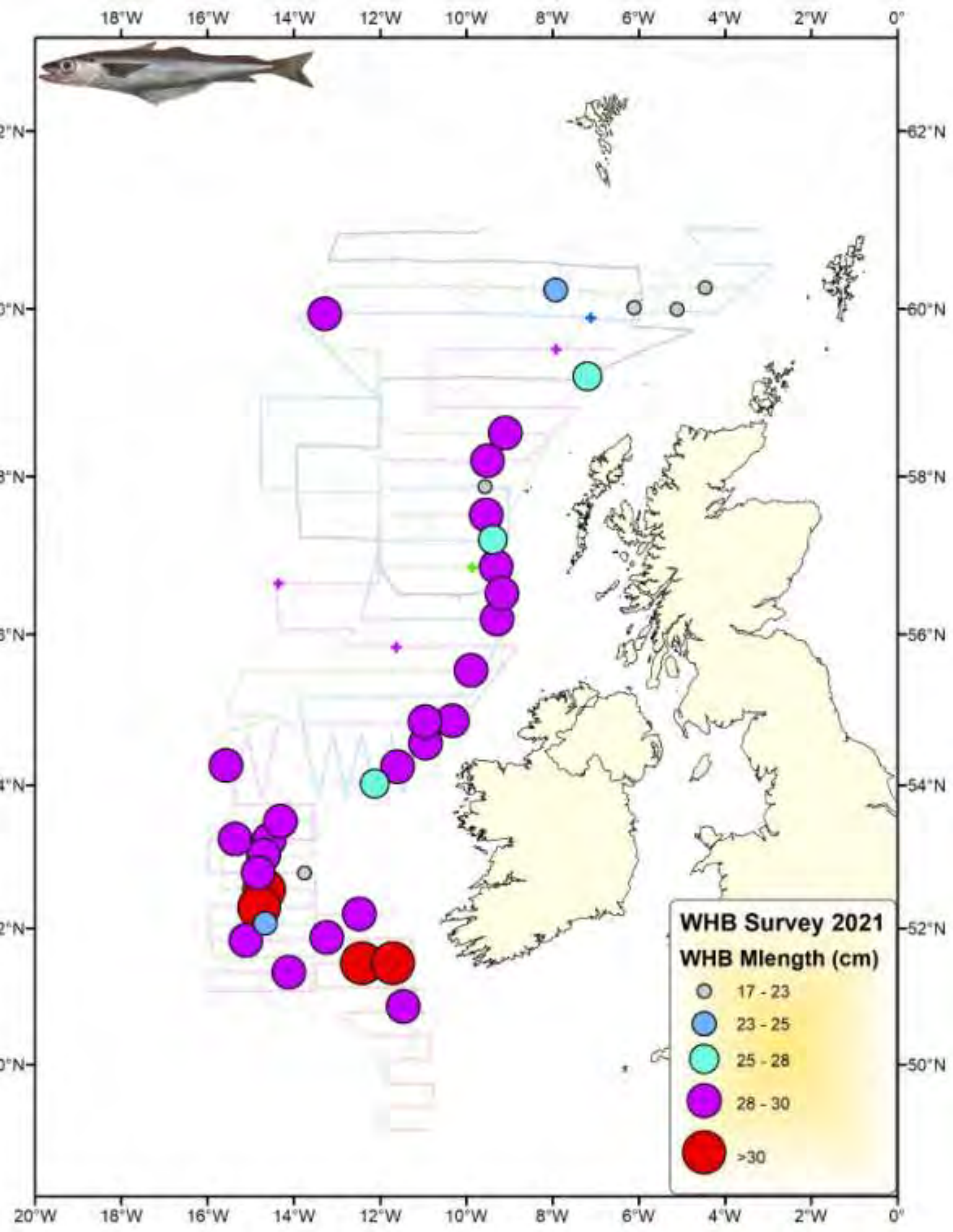


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2021. Crosses indicate hauls with zero blue whiting catches.

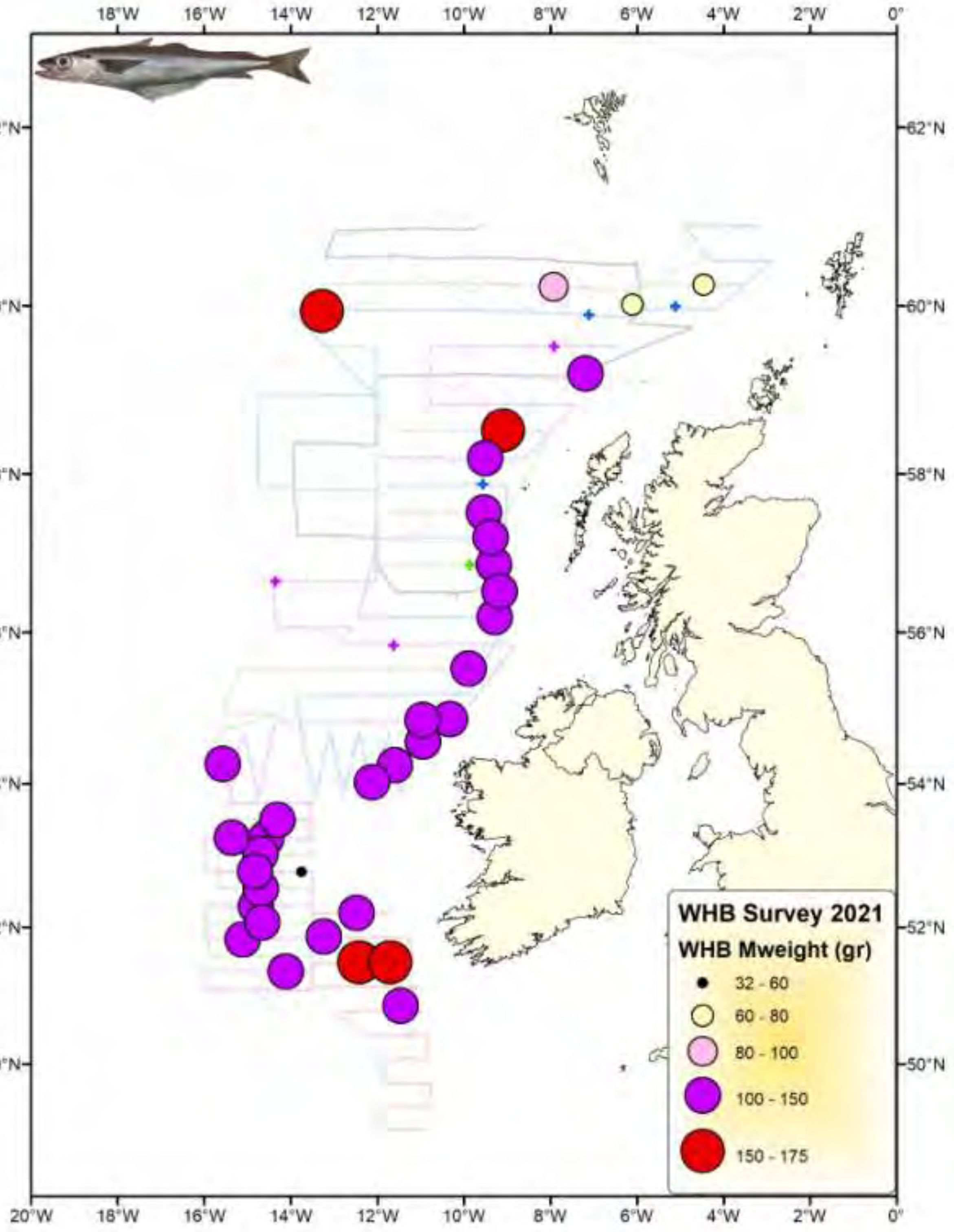


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2021. Crosses indicate hauls with zero blue whiting catches.

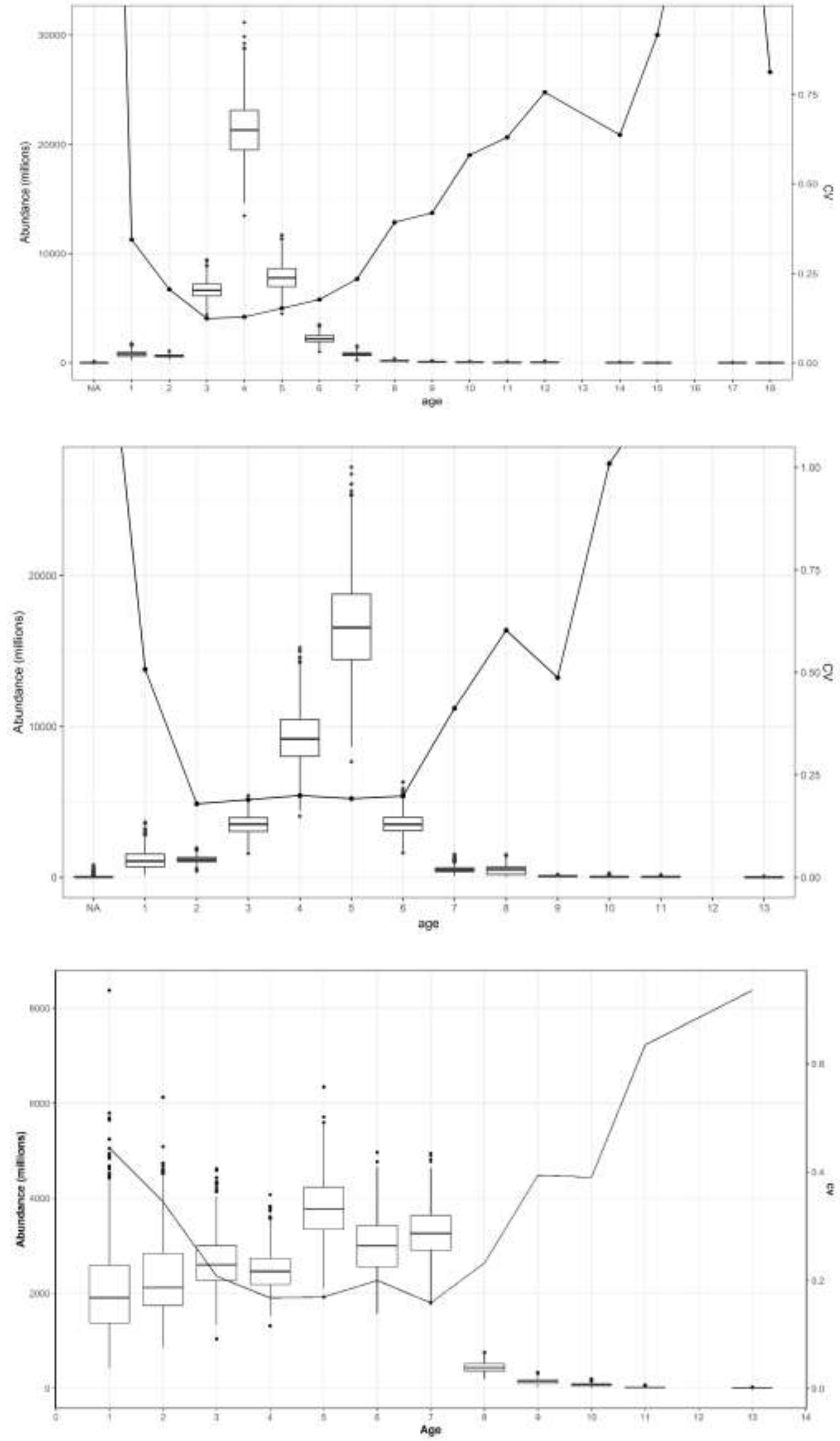


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2018 (top panel), 2019 (middle panel) and 2021 (lower panel). From StoX.

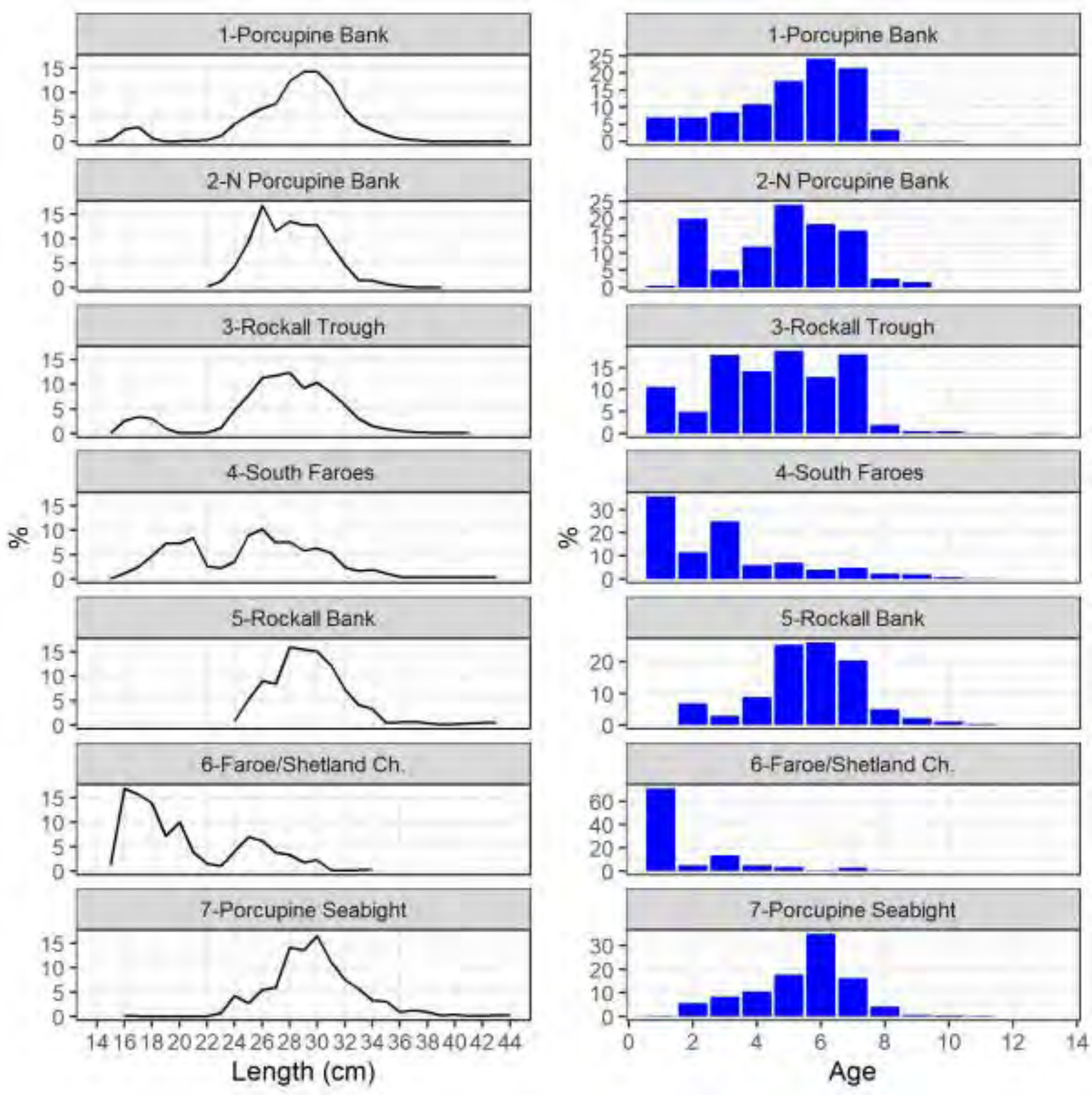


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2021.

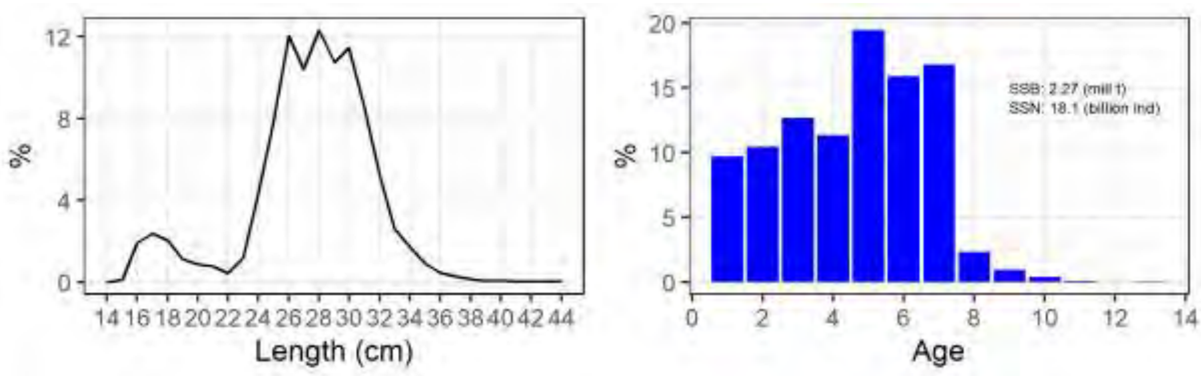


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2021.

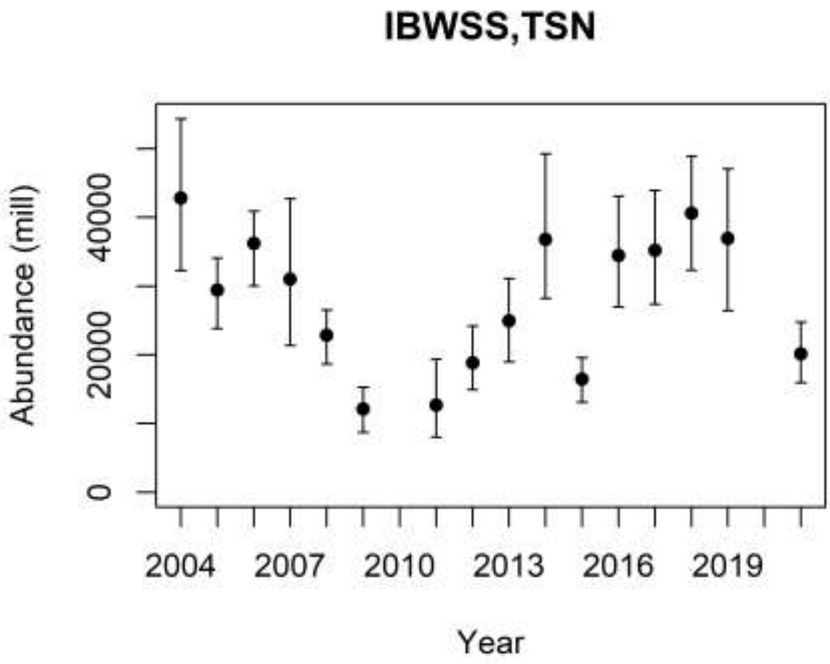


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2021, excluding 2010.

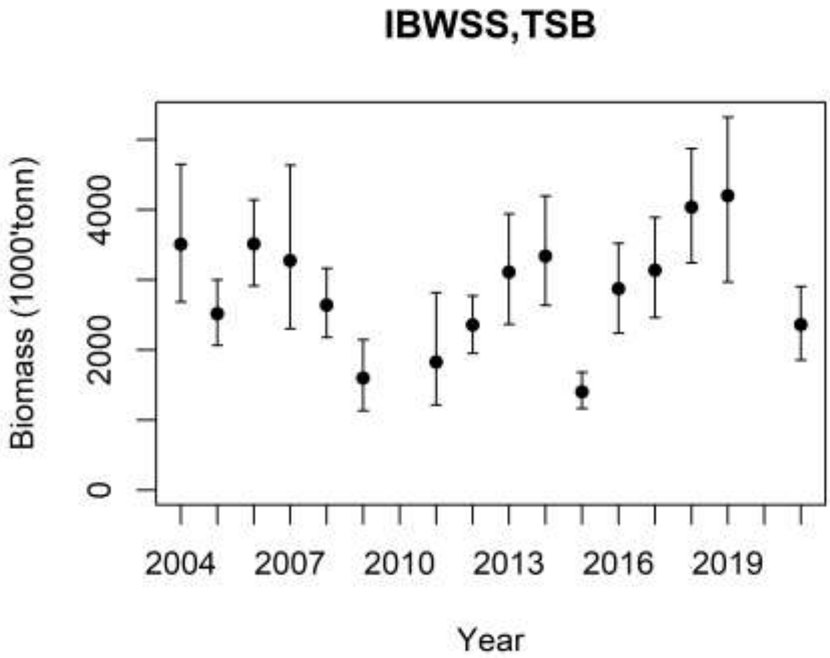
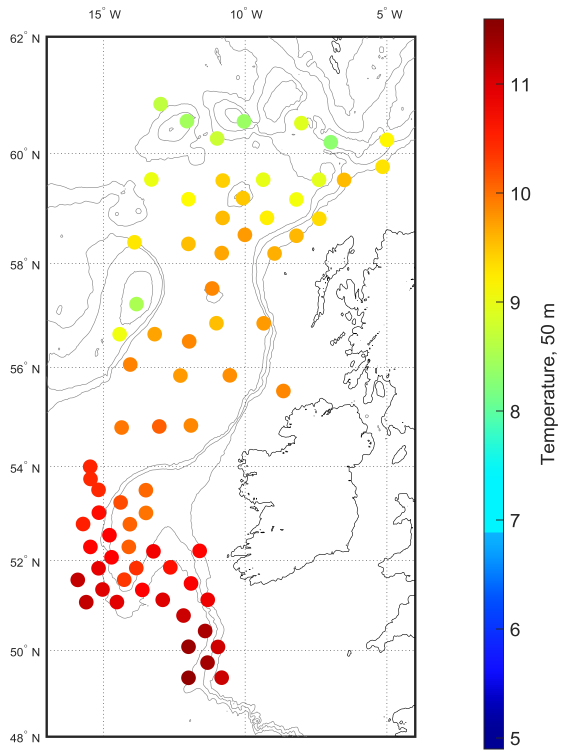


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2021, excluding 2010.



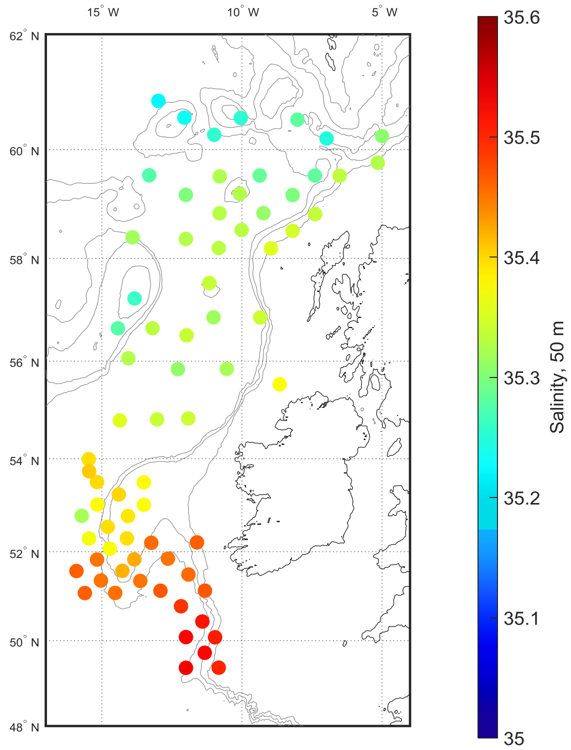
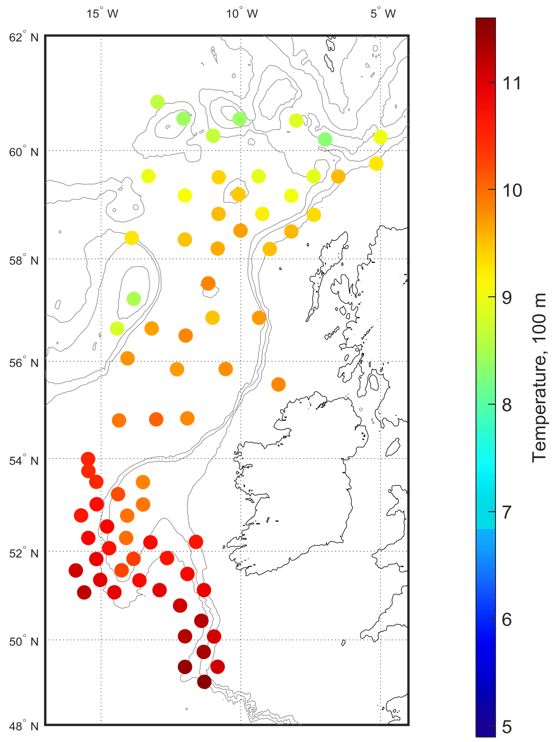


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.



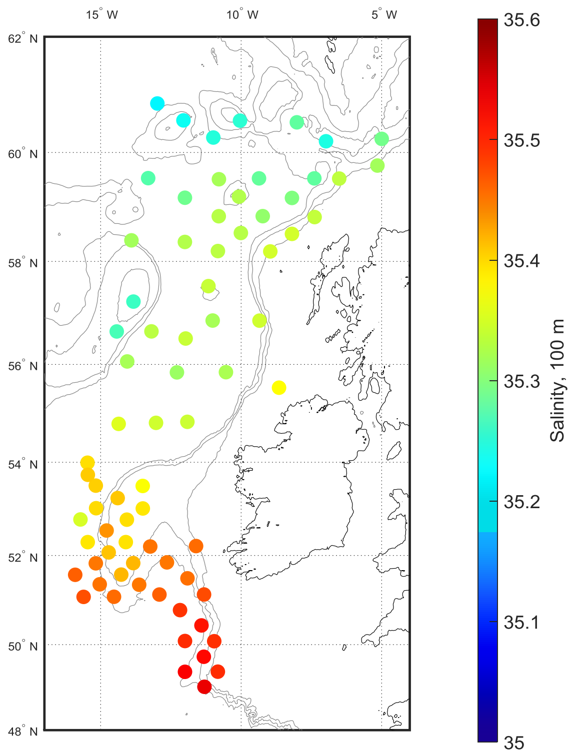


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

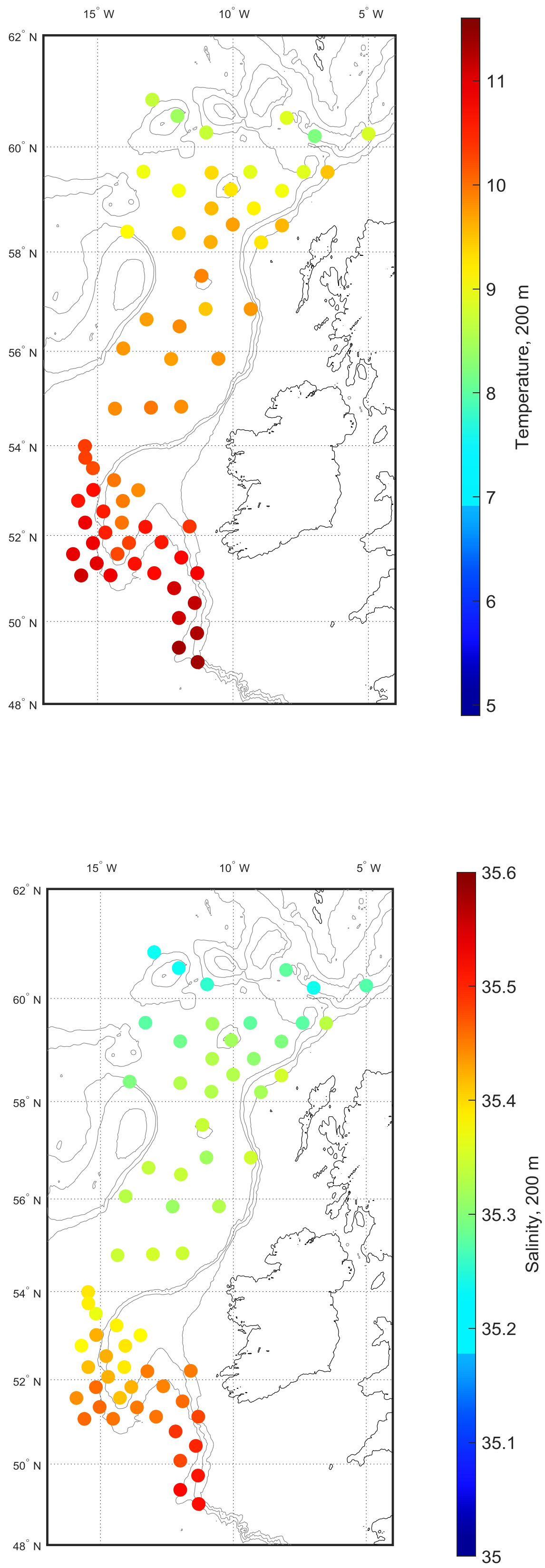


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

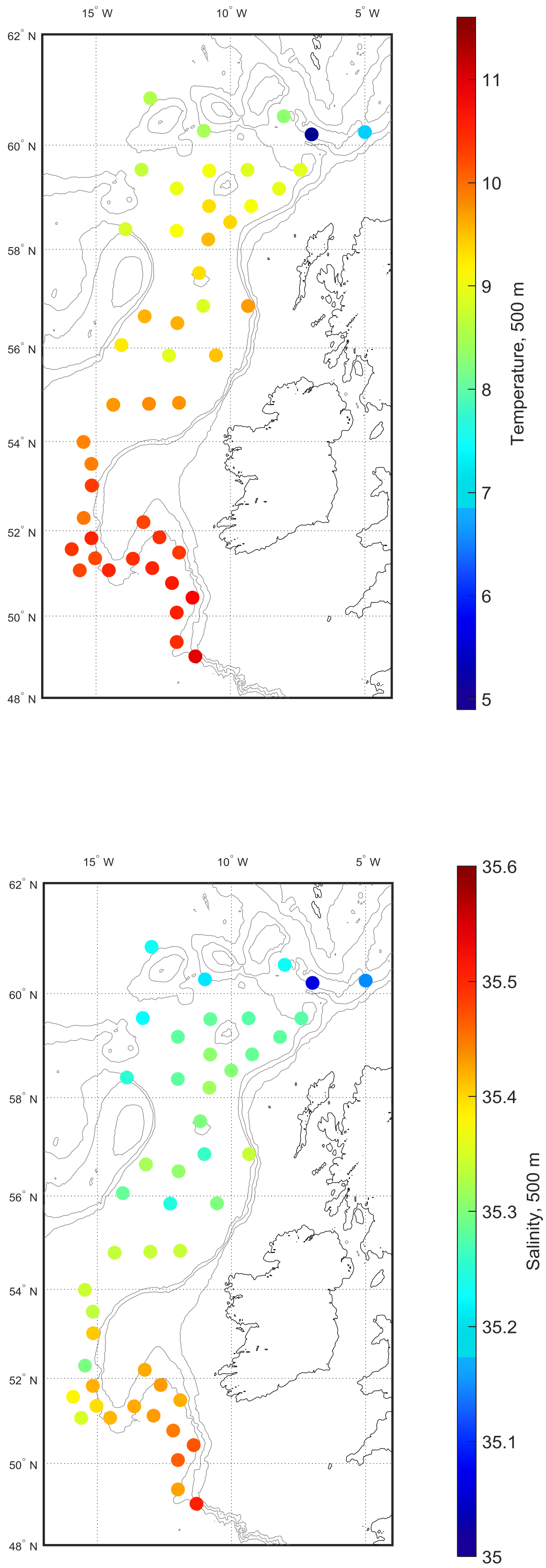


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

Annex 1 – Bad data treatment on board RV Tridens

Part of this year's survey had to be conducted during adverse weather conditions where data quality deteriorated due to vessel motion, increased bubble entrainment and increased noise levels. These factors caused the signal degradation in the form of attenuations, spikes or dropouts. Concerns were especially raised in areas where dense and large aggregations of blue whiting were observed when the weather condition was adverse. Typically, Echoview and LSSS software have generic tools to address these issues, such as noise removal tools (Dunford correction, transient or impulse noise filter) or spike filters. However, such manipulations can come with a cost of data loss or possible additional bias. To understand the effects of this adverse weather condition, a data processing exercise was carried out on board Tridens during the Survey.

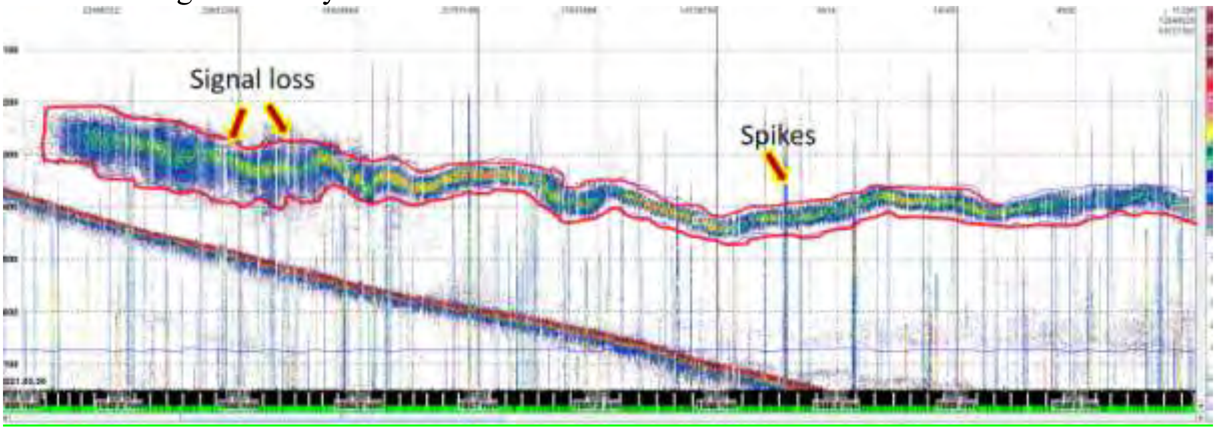


Figure 1 Dense-large aggregation of blue whiting encountered during a period of bad weather (2021 -03-30 early morning). Data contains both spike noise and transmission loss due to abrupt motion of the ship as well as bubble entrainment as a result of bad weather.

The exercise focused on a particular data set where the wind force was 7-8 Beaufort and swell height was greater than 2 m (March 30, 2021). During this time a large and dense aggregation was encountered along the transect where the acoustic recordings were subjected to signal degradation.

The effect of such signal degradation was investigated by using various methods including custom-written R-codes and postprocessing software: LSSS and Echoview. The main objective was to classify the recorded signals as "good pings" and "bad pings".

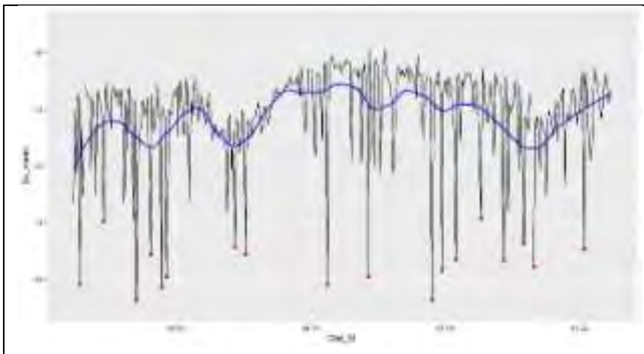
The stepwise processing procedure was as follows;

1- The aggregation was isolated by drawing a line around it.
2- Center of mass (CofMass) of the aggregation was determined per each ping (a function of Echoview that averages the sample depths weighted by sample Sv).
3- A horizontal line connecting the CofMass of each ping was created and a median smoothing filter (moving window of 21 pings) was applied.
4- A region from 5 meter above and below (10 meters in total) of this smoothed CofMass line was integrated per ping.
5- The integrated output values were grouped by 1000 consecutive pings.
6- For each of these 1000 pings a LOESS (local regression smoothing) curve was fitted based on mean Sv values. Using this fitted curve, expected values per each ping were calculated.
7- Standard deviation (SD) per each 1000 ping group was calculated.

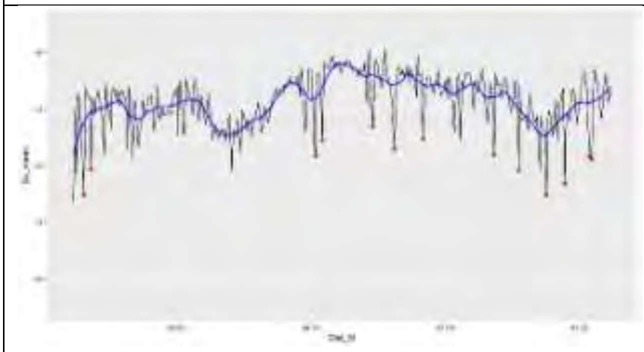
8- The predicted values were subtracted from the observed Sv values per each 1000 ping group and compared against the SD for detection of the outliers (“bad pings”).

9- For outlier-detection a stepwise approach was applied such that,

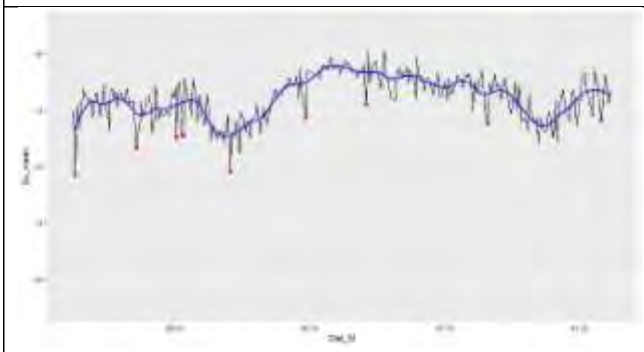
   a. 2*SD was used as a threshold. Values below -2*SD and above +2*SD standard deviations were identified as bad pings and removed from the data.
   b. After removal of bad pings, a new LOESS curve was fitted over the retained values. Again, a new standard deviation was calculated from these retained values and used as threshold for bad pings again.
   c. Same procedure repeated over the same 1000 ping group until no more bad pings were detectable. Then the same procedure was applied to the next ping group.



Step 1



Step 3



Step 5

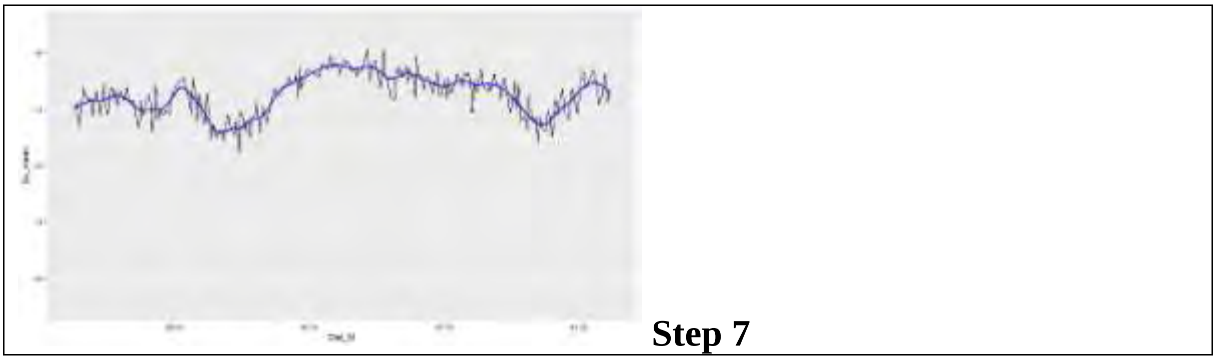


Figure 2 An example of bad ping detection for a group of 1000 pings. For this group, the procedure was finalized in 7 repetitive steps. The red dots indicate the bad pings (beyond SD threshold), the blue line is the fitted LOESS curve. The x axis is the time and the y axis is the mean Sv.

The identified bad-pings were handled in different ways by:

1- Removing all the bad pings
2- Assign bad pings with 0 values
3- Use of the mean value of the surrounding pings

In addition to this custom processing, both Echoview and LSSS has built-in spike filtering algorithms. These algorithms were also used to process separately as well. Results from these different methods were compared with non-cleaned values. The solution where all bad pings were removed resulted in a slightly higher mean Sv. And those where bad pings were assigned to “0” resulted in slightly lower values. However overall variation was less than 5% relative to the uncleaned echograms. Consequently, non-cleaned data was used for the survey calculations.

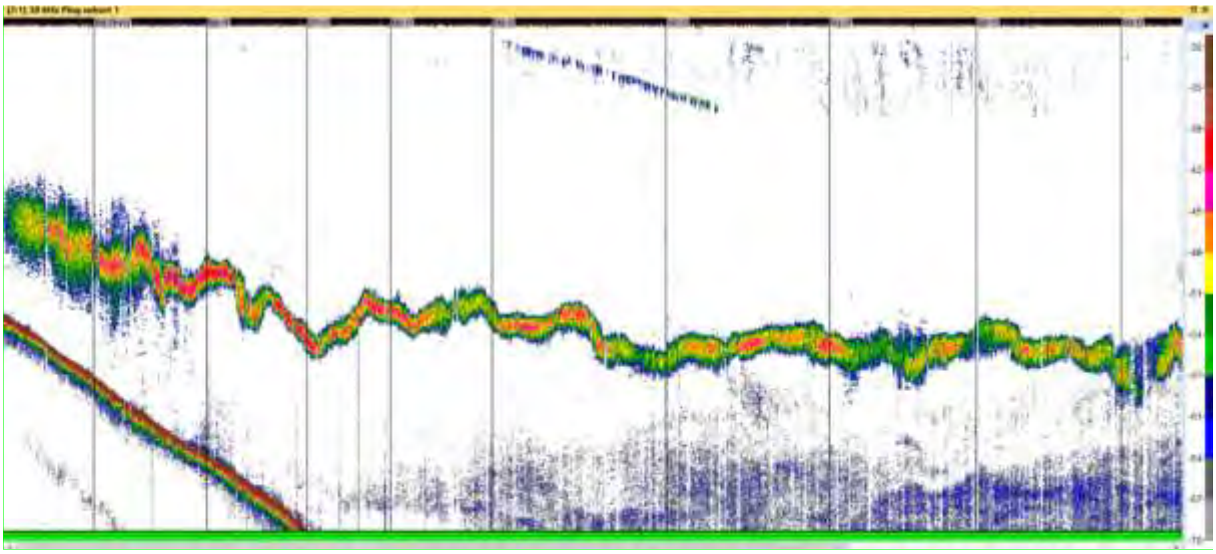


Figure 3 One of the processing solutions where all the identified bad pings were removed using the ping-subset function of Echoview. The resulting echogram looks similar to recordings in good weather.

Working Document to

Working Group on International Pelagic Surveys (WGIPS)
January 2022
and
Working Group on Widely Distributed Stocks (WGWIDE)
25 - 31 August 2021

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in April - May 2021

Post-cruise meeting on Teams, 15-18 June 2021

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 Dr. Fridtjof Nansen

Susan Mærsk Lusseau[2], Matthias Kloppmann[3]
RV Dana

Sigurvin Bjarnason[4]
RV Árni Friðriksson

Eydna í Homrum[5], Jan Arge Jacobsen[5], Leon Smith[5]
RV Jákup Sverri

Maxim Rybakov[6]
RV Vilnyus

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[6] Polar branch of VNIRO («PINRO»), Murmansk, Russia

Introduction

In April-May 2021, five 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 Jakup Sverri, Faroe Islands, R/V Árni Friðriksson, Iceland, R/V Dr. Fridtjof Nansen, Norway and R/V Vilnyus, Russia 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 abundance 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 2021 that are stored in the PGNAPES database and the ICES database and supported by national survey reports from each survey (Dana: Cruise Report R/V Dana Cruise 03/2021. International Ecosystem survey in the Nordic Seas (IESNS) in 2021, Árni Friðriksson: Report on Survey A9-2021, Bjarnason ,2021, Vilnyus: Rybakov PINRO 2021).

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2021 and by correspondence. Planning of the acoustic transects and hydrographic stations and plankton stations were carried out by using the survey planner function in the r-package Rstox version 1.11 (see https://www.hi.no/en/hi/forskning/projects/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, because the transects follow great circles 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	01/5-27/5
Dr. Fridtjof Nansen	Institute of Marine Research, Bergen, Norway	29/4-28/5
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	29/4- 9/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	06/5-25/5
Vilnyus	Polar branch of VNIRO («PINRO»), Murmansk, Russia	28/4-25/5

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 conditions did not affect the survey even if there were some days that were not favourable and prevented trawling, 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	Dr. Fridtjof Nansen	Arni Friðriksson	Jákup Sverri	Vilnyus
Echo sounder	Simrad EK60	Simrad EK80	Simrad EK80	Simrad EK80	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 70, 120, 200	18,**38**, 70, 120, 200, 333	**38**
Primary transducer	ES38BP	ES 38-7	ES38-7	ES38B	ES 38B
Transducer installation	Towed body	Drop keel	Drop keel	Drop keel	Hull
Transducer depth (m)	5 - 7	5.35	8	6-9	4.5
Upper integration limit (m)	10	15	15	15	10
Absorption coeff. (dB/km)	10.3	10.1	10.5	10.7	10.0
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.425	3.06	2.425
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	18	21.9	21.9
2-way beam angle (dB)	-20.5	-20.7	-20.3	-20.4	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.45	27.02	27.05	26.96	26.02
s_A correction (dB)	-0.55	0.02	-0.02	-0.16	-0.67
3 dB beam width (dg)					
alongship:	6.89	6.29	6.42	6.55	6.97
athw. ship:	6.87	6.31	6.47	6.45	7.00
Maximum range (m)	500	500	500	500	500
Post processing software	LSSS	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. Immediately after the 2021 survey an online meeting was held to standardise the scrutiny and to agree on particularly difficult scrutiny situations encountered. 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	**Dr. Fridtjof Nansen**	**Arni Friðriksson**	**Jákup Sverri**	**Vilnyus**
Circumference (m)		**624**	**832**	**832**	**500**
Vertical opening (m)	**20-35**	**25-35**	**20–35**	**45–55**	**50**
Mesh size in codend (mm)	**20/40**	**22**	**20/40**	**45**	**16**
Typical towing speed (kn)	**3.5-4.0**	**3.0–4.5**	**3.1–5.0**	**3.8–.4.9**	**2.9-4.6**

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	Dr. Fridtjof Nansen	Arni Friðriksson	Jákup Sverri	Vilnyus
Length measurements	Herring	200-300	100	300	200-300	300
	Blue whiting	200-300	100	50	100-200	0
	Mackerel	100-200	100	50	100-200	0
	Other fish sp.	50	30	30	100-150	100-300
Weighed, sexed and maturity determination	Herring	50	25-100	100	50-100*	50-100
	Blue whiting	50	25-100	50	50*	0
	Mackerel	50	25-100	50	50	0
	Other fish sp.	0	0	0	0*	25-50
Otoliths/scales collected	Herring	50	25-30	100	50-100	50-100
	Blue whiting	50	25-30	50	50	0
	Mackerel	0	25-30	50	50	0
	Other fish sp.	0	0	0	0	25-50
Stomach sampling	Herring	0	10	10	5	25
	Blue whiting	0	10	10	5	0
	Mackerel	0	10	10	5	0
	Other fish sp.	0	0	0	0	25

* Number of weighed individuals significantly higher.

Acoustic data were analysed using the StoX software package (version 3.1.0) 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: https://www.hi.no/en/hi/forskning/projects/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 5 strata with pre-defined acoustic transects. 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 2. Generally, and in accordance with most WGIPS coordinated surveys, 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. However, due to uneven distribution of younger and older herring in Strata 1 and 3 (see Fig 12) adaptations were made as follows: In Stratum 1, all transects were split in two at 7°W and trawl stations east and west of 7°W were assigned to the respective transects east and west of 7°W; in Stratum 3 the first three transects were split at 5°W – west of 5°W the 5 closest trawl stations were assigned and east of 5°W the four closest trawl stations were assigned.

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 (Foote et al. 1987)

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 except the Russian vessel which used a Djedi net, 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. It has been noted that the Djedy net applied by the Russian vessel in the Barents Sea seems to be less effective in catching zooplankton in comparison to WP2

WPII net applied by other vessels in an overlapping area. Thus, the biomass estimates for the Barents Sea are not directly comparable to the other areas but are comparable among years within the Barents Sea. The Russian data from the Barents Sea are not included in the 2021 report.

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 9-10°C in the southern part of the Norwegian Sea (Figure 5). The Arctic front was encountered below south of 65°N east of Iceland extending eastwards towards about 2° W where it turned north-eastwards 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° W 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 5-6 °C to the Bear Island at 74.5° N in the surface layer.

Relative to the 25 year long-term mean, from 1995 to 2019, the temperatures at 0-50 m were below mean in the southern and eastern parts of the Norwegian Sea and in the Lofoten Basin (Figure 5). Below 50 m depth, the patterns were more fragmented but at 200-500 m depth the Norwegian Basin was in general colder than the long-term mean, probably due to increased influence of Arctic water at this depth (Figure 7). Largest negative temperature anomalies were between Iceland and Faroe Islands due to a more southern located Iceland-Faroe front compared to the long-term mean. This was found for all depths and the temperatures in this region were in some locations 2-3 °C lower than the mean (Figures 5-7). Warmest region relative to the long-term mean was in the eastern Greenland Sea and particular in the upper 200 m with temperatures 2 °C higher than the mean.

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in 6-8 May 2021 are shown in Figure 8. Atlantic water is lying over the colder and fresher intermediate/deep 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 30 years long-term mean, from 1978 to 2007, the temperatures in 2021 near the shelf edge were higher than the mean at 50-400 m depth and lower the mean below this depth. Further westward, the temperatures were both lower and higher than the mean due to meandering or eddies. The pattern of salinity anomaly follows in general the pattern of temperature anomaly. The increased influence of Arctic water observed at 200-500 m (Figures 6-7) can also be observed in the western part of the section at 200-400 m depth with temperature and salinity anomalies lower than the long-term mean (Figure 8).

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 in the last four decades a similar layer has been observed all over the Norwegian Sea. Also, in periods this layer has been less well-defined.

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 sampling area. High biomasses were found east/northeast of Jan Mayen (i.e. in northwestern parts of the Norwegian Sea), north of Faeroe Islands, in the Lofoten/Vesterålen area at the Norwegian coast, and in the northernmost sampled area towards the Bear Island at the entrance to the Barents Sea. Lower biomasses were found in the most central parts of the Norwegian Sea.

Figure 10 shows the zooplankton indices for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional biomass difference, the area was divided into 4 sub-areas 1) the Norwegian Sea Basin (covering the southern Norwegian Sea), 2) the Lofoten Basin (covering the northern Norwegian Sea, 3) the Jan Mayen Arctic front, and 4) East of Iceland. The mean index of sub-area 1 and 2 is also given, called the Norwegian Sea index, and this index cover large parts of the Norwegian Sea. The zooplankton biomass index for the Norwegian Sea was in 2021 8.0 g dry weight m^{-2}, which is at similar level as in previous years, but with a small decrease. The same situation was observed in all sub-areas. Highest biomass (12.3 g dry weight m^{-2}) was observed in the sub-area "Northeast of Iceland".

The zooplankton biomass indices for the Norwegian Sea in May have been estimated since 1995. For the period 1995-2002 the plankton biomass was relatively high (mean 11.5 g), with fluctuations 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 2003-2021. There has been an increasing trend during 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 reasons for the changes in zooplankton biomass are not obvious. It is worth noting that the period with lower zooplankton biomass coincides with higher-than-average heat content in the Norwegian Sea (ICES, 2020) and reduced inflow of Arctic water into the southwestern Norwegian Sea (Kristiansen et al., 2019). Timing effects, such as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. The 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 may be 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.

Norwegian spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2021. The zero-line was believed to be reached for adult NSS herring in most of the areas. It is recommended that the results from IESNS 2021 can be used for assessment purpose. The herring was primarily distributed in the south-western area (Figure 11). In the westernmost area old herring dominated, but in general, the 2016-year-class was the most abundant year class throughout the survey area. 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).

Five year old herring (year class 2016) dominated both in terms of number (53%) and biomass (46 %) on basis of the StoX bootstrap estimates for the Norwegian Sea (Table 2). This year class as 5 year old is as large as the 2004 year class was at same age (Figure 13), and this puts the magnitude of the 2016 year class into perspective as a large year class. There was a slight decrease in abundance of the 2016 year class from last year, which is not expected for young herring. However, the decrease was small and within the uncertainty estimates of abundance of 4 year old herring last year and 5 year old herring this year. The 2004 year class, which has dominated the stock together with the 2002 year class, still contributes significantly to the biomass of older age-groups (see paragraph on issues with age determination below). Herring aged 12-18 years old thus comprised 13% of the numbers and 21% of the biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 14 and Table 2. The relative standard error (CV) of the total biomass estimate is 15 % and 16 % for the total numbers estimate, and the relative standard error for the dominating age groups is around 20 % (Figure 14 and Table 5).

The total estimate of herring in the Norwegian Sea from the 2021 survey was 23 billion in number and the biomass was 5.1 million tonnes. The biomass estimate is 0.90 million tonnes (21 %) higher than the 2020 survey estimate while the estimated number is 2% higher in 2021. 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 16), with the lowest abundance occurring in 2017. The 2016 year class now appears to be fully recruited, distributed widely in the feeding area and more dominant than the older year classes.

The Barents Sea was also covered adequately in 2021. The results based on bootstrap are shown in Table 4 and Figure 15. The estimated total abundance (125 million) and biomass (4.3 thousand tonnes) of herring in the Barents Sea was the lowest observed in the time series that started in 1991. The 3 year olds (2018 year class) was the most abundant year class in the Barents Sea.

In the last 6 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. As a follow-up on that work, a new exchange and following workshop are currently being planned and sampling of exchange material has started. 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 the cruise tracks of the Norwegian vessel did not cover strata 1 and 3. However, in strata 2 and 4 there was overlap between the Norwegian vessel and the Danish vessel and the age distributions from those strata seem to be relatively similar between the two vessels (Figure 17). In stratum 1 there was overlap between the Icelandic and Faroese vessel and the difference in age distributions mainly reflected differences in the length distribution.

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. 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).

In the IESNS 2021 survey, all herring in Stratum 1 was allocated to NSSH. This year there were only minor issues with mixing, because only limited amounts of herring of autumn spawning type were caught.

Blue whiting

The spatial distribution of blue whiting in 2021 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 off Norway and along the Scotland – Iceland ridge (Figure 18). Blue whiting was distributed similar as last year. The largest fish were found in the western and northern part of the survey area (Figure 19). 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 2021 was 0.85 million tonnes, which is a 118 % increase from the biomass estimate in 2020 (0.39). The abundance index for 2021 was 13.9 billion, which is 184 % higher than in 2020 (4.9). Age 1 is totally dominating the acoustic estimate (50 % of the biomass and 74% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20 and Table 3. The relative standard error (CV) of total biomass estimate is 14 % and 14 % also for total numbers (Table

3). The 2021 estimate of one-year old blue whiting was the highest in the IESNS time series (from 2008). The survey group compared age and length distributions by vessel and strata (Figure 21 and 22) and no clear differences were found compared to earlier years.

Mackerel

Trawl catches of mackerel are shown in Figure 23. Mackerel was present in the southern and eastern part of the Norwegian Sea (as far north as 68°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.

Pink Salmon

Pink salmon is a relatively new species in the Nordic Seas and was caught in the IESNS surveys since 2017 – and only every other year, when the odd-year spawning component conducts oceanic migrations. This is in accordance with observations of spawning pink salmon in particularly northern Norwegian rivers in later years. In 2021 a total of 91 pink salmon were caught during the survey. The distribution area was mainly on and off the Norwegian shelf and north off the Faroe Plateau.

General recommendations and comments

Recommendation	Addressed 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

Next year's post-cruise meeting

We will aim for next meeting in 14-16 June 2022. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2021 was generally below the long-term mean (1995-2019) in the Norwegian Sea, but the pattern was more fragmented 50-200 m.
- The 2021 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters decreased marginally from last year.

- The total biomass estimate of NSSH in herring in the Norwegian Sea was 5.1 million tonnes, which is a 21 % increase from the 2020 survey estimate. The estimate of total number of NSSH was 23 billion, which is 2 % higher than in the 2020 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 (53%) and biomass (46%), and it is on the same level as the strong 2004 year class at the same age (in the 2009 survey). In numbers, the estimate of the 2016 year class decreased from age four to age five. This is not the usual pattern for NSS herring, but the decrease was small and within the uncertainty estimates of abundance of four year old herring in 2020 and five year old herring in 2021.
- The estimated total abundance and biomass of herring in the Barents Sea was the lowest observed in the time series that started in 1991.
- The biomass of blue whiting measured in the 2021 survey increased by 118 % from last year's survey and 184 % in terms of numbers. Age 1 (2020 year class) is the dominating year class (50 % of the biomass and 74% by number), and this year's estimate of one year olds is the highest in the time series.

References

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep. 144: 1–57.

ICES 2009. Report of the PGNAPES Scrutiny of Echogram Workshop (WKCHOSCRU) 17–19 February 2009, Bergen, Norway ICES CM 2009/RMC

ICES. 2012. Report of the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES), 23–26 January 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGESST:01. 27 pp.

ICES. 2015. Report of the Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT), 7-11 September 2015, Hamburg, Germany. ICES CM 2015/SSGIEOM:18. 107pp.

ICES. 2016. Report of the Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR), 7-11 December 2015, Reykjavik, Iceland. ICES CM 2015/SSGIEA:10. 150 pp.

ICES. 2017. Workshop on Stock Identification and Allocation of Catches of Herring to Stocks (WKSIDAC). ICES WKSIDAC Report 2017 20-24 November 2017. Galway, Ireland. ICES CM 2017/ACOM:37. 99 pp.

ICES. 2020. Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR; outputs from 2019 meeting). ICES Scientific Reports. 2:29. 46 pp. http://doi.org/10.17895/ices.pub.5996

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019, 10:1523–1528.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Can.J. Fish. Aquat. Sci. 47: 1282-1291.

Kristiansen, I., Hátun H., Petursdottir, H., Gislason, A., Broms, C., Melle, W., Jacobsen, J.A., Eliasen S.K., Gaard E. 2019. Decreased influx of Calanus spp. into the south-western Norwegian Sea since 2003. Deep Sea Research, 149, 103048

Skjoldal, H.R., Dalpadado, P., and Dommasnes, A. 2004. Food web and trophic interactions. *In* The Norwegian Sea ecosystem. Ed. by H.R. Skjoldal. Tapir Academic Press, Trondheim, Norway: 447-506

Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2021.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	01/05-27/05	2056	20	35	476	1537	35
Jákup Sverri	29/4-9/5	1334	16	22	361	1547	21
Árni Fridriksson	8/5-23/5	2980	22	38	1531	5537	34
Dr. Fridtjof Nansen	29/4-28/5	4518	37	47	362	1149	45
Vilnyus	29/4-21/5	3540	58	50	151	362	50
Total		**14428**	**153**	**192**	**2881**	**10132**	**185**

Table 2. IESNS 2021 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring. The estimates are mean of 1000 bootstrap replicates in Stox.

Length	Age in years (year class)																			Number	Biomass	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003		(10^6)	(10^6 kg)	(g)
15-16																						
16-17																						
17-18																			8.4	8.4	0.3	31.5
18-19																			4.2	4.2	0.2	40.0
19-20																			66.8	66.8	2.9	43.6
20-21			270.1	16.4																286.5	15.3	53.4
21-22			318.4																0.2	318.6	19.5	61.4
22-23			236.4	2.3															0.1	238.8	16.6	73.4
23-24			147.5	49.5															0.7	197.7	16.1	90.6
24-25			9.5	155.8																165.4	16.8	110.6
25-26		23.1	5.6	156.9	12.0														0.2	197.8	24.2	123.4
26-27	14.9	10.5	34.8	91.6	158.6															310.3	41.8	136.6
27-28			42.1	171.9	389.2	6.0	5.9													615.1	92.0	152.0
28-29			31.6	232.3	1138.6	5.3	14.2													1 422.0	231.6	163.9
29-30			12.8	258.4	2834.1	13.6	59.8	13.5	12.8			2.9								3 207.8	570.5	178.3
30-31				91.2	3052.8	93.4	116.3	87.0	40.8	32.1	3.6									3 517.2	685.8	195.7
31-32				40.6	2619.6	126.1	108.4	168.9	22.6		31.4	21.3								3 138.9	688.2	218.5
32-33				10.3	1431.7	264.5	199.8	181.6	38.7	29.8	45.9									2 202.4	517.3	235.2
33-34				12.6	221.4	107.0	311.6	616.5	19.7	32.0	4.2	5.3								1 330.4	343.7	259.9
34-35					47.9	55.0	175.0	622.0	104.6	54.6	4.4	1.1								1 064.7	298.0	281.7
35-36						27.3	44.3	300.6	150.7	103.5	51.3	66.5	45.8	52.0	34.8	2.3	12.2			891.2	269.5	304.6
36-37							15.9	41.6	88.1	163.3	226.6	189.5	178.3	201.8	160.9	95.8	6.5			1 368.3	450.6	332.1
37-38								7.1	20.0	120.2	97.1	159.8	141.7	269.5	324.2	248.3	38.9	5.8		1 432.6	496.3	349.0
38-39									2.8	15.3	11.9	15.3	65.0	72.8	189.4	182.2	76.7	2.8		634.2	235.1	373.7
39-40													11.5	19.2	42.8	37.6	42.1	5.6		158.8	61.6	388.9
40-41																	6.1		2.7	8.8	2.3	387.8
TSN(mill)	14.9	33.6	1108.8	1289.9	11906.0	698.2	1051.1	2038.8	500.8	550.8	476.4	461.7	442.3	615.3	752.1	566.1	182.4	14.2		22 983.8		
cv (TSN)	1.20	1.22	0.50	0.19	0.20	0.22	0.21	0.19	0.20	0.25	0.25	0.26	0.30	0.30	0.31	0.31	0.35	0.64		0.16		
TSB(1000 t)	2.0	3.7	82.2	196.7	2 329.5	163.8	259.5	546.2	140.9	166.2	148.2	150.7	149.9	212.0	267.7	201.8	66.2	5.5		5 096.3		
cv (TSB)	1.20	1.22	0.45	0.18	0.20	0.21	0.20	0.19	0.20	0.25	0.26	0.27	0.31	0.30	0.31	0.31	0.35	0.64		0.15		
Mean length(cm)	26.0	25.3	23.5	27.3	29.9	32.0	32.7	33.7	34.7	35.6	35.9	36.2	36.6	36.7	37.1	37.2	37.9	37.7				
Mean weight(g)	137.0	110.3	98.3	157.7	195.2	237.1	256.5	276.4	295.3	312.7	325.6	334.6	342.7	347.9	359.0	359.1	363.9	382.0				

Table 3. IESNS 2021 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting. The estimates are mean of 1000 bootstrap replicates in Stox.

Length	Age in years (year class)											Number	Biomass	Mean
	1	2	3	4	5	6	7	8	9	10	Unknown			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011		(10^6)	(10^6 kg)	(g)
15-16														
16-17	67.8	6.7									0.3	74.8	1.8	24.1
17-18	888.9	13.9										902.9	26.3	29.7
18-19	2344.4	65.7										2 410.1	81.6	34.5
19-20	3056.6	65.1										3 121.7	124.7	40.3
20-21	2457.7	32.4	10.0									2 500.2	117.2	47.0
21-22	1048.4	143.0	3.7									1 195.2	63.8	53.6
22-23	331.6	191.2	61.6									584.4	36.0	62.0
23-24	55.4	348.1	43.6									447.1	32.2	73.5
24-25	5.6	319.8	91.0	3.0								419.3	33.9	82.6
25-26	4.4	139.4	201.4	9.6	2.5							357.4	34.3	96.9
26-27		145.4	150.9	46.3		35.1		10.4				388.1	42.0	109.7
27-28		27.9	147.3	36.4	4.8	1.6	18.3					236.4	27.6	118.6
28-29	2.8	2.0	64.8	45.4	11.4	43.0	16.4	10.1				195.7	26.3	135.9
29-30			43.7	83.8	77.8	5.3	14.4					225.0	35.3	159.2
30-31			2.8	23.2	66.9	126.6	44.4	6.7		12.3		282.9	48.4	173.0
31-32				35.6	45.5	134.7	34.3	29.5	8.3			287.9	55.6	195.2
32-33			11.5	18.9	19.5	49.1	24.1	11.5				134.5	28.2	210.9
33-34					18.2	13.9	9.6	8.3	7.0		0.1	57.1	13.1	233.4
34-35					2.2	12.7	27.5				0.2	42.5	10.0	242.0
35-36					10.1						0.3	10.3	2.4	235.1
36-37						11.9						11.9	3.4	283.0
37-38														
38-39						7.8					1.3	9.1	2.9	316.4
39-40											5.3	5.3	1.4	462.0
> 40											3.8	3.8	2.8	732.0
TSN(mill)	10264	1500	832	302	259	442	189	77	15	12		13 903.3		
cv (TSN)	0.17	0.23	0.25	0.32	0.38	0.46	0.40	0.66	0.77	1.21		0.14		
TSB(1000 t)	424.9	110.1	86.8	45.3	47.2	79.1	34.1	13.6	3.4	2.1		851.2		
cv (TSB)	0.16	0.22	0.26	0.33	0.39	0.46	0.41	0.66	0.76	1.21		0.14		
Mean length(cm)	19.3	23.1	25.7	28.2	30.0	30.6	30.4	30.3	31.8	30.0				
Mean weight(g)	43	77	106	147	179	184	178	179	223	175				

Table 4. IESNS 2021 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring. The estimates are mean of 1000 bootstrap replicates in Stox.

Length (cm)	Age in years (year class) 1 2020	2 2019	3 2018	4 2017	5 2016	Number (10^6)	Biomass (10^3 kg)	Mean weight (g)
9-10	7.1					7.1	32	4.6
10-11	8.5					8.5	49	5.8
11-12	2.8					2.8	25	9.0
12-13	2.8					2.8	31	11.0
13-14								
14-15								
15-16								
16-17		1.7				1.7	50	29.0
17-18			5.7			5.7	187	32.9
18-19			18.8			18.8	733	39.0
19-20			29.2			29.2	1291	44.3
20-21			23.1			23.1	1165	50.4
21-22			5.2	1.4		6.6	378	57.4
22-23			2.6	0.7		3.3	208	62.9
23-24			1.9			1.9	131	68.0
24-25				0.2		0.2	20	92.0
25-26								
26-27					0.2	0.2	20	92.0
27-28								
28-29								
29-30								
TSN(mill)	21.2	1.7	86.5	2.3	0.2	125.1		
cv (TSN)	0.81	0.84	0.37	0.58	0.78	0.36		
TSB(t)	138.3	50.5	3 974.7	137.8	20.1	4 321.4		
cv (TSB)	0.81	0.84	0.37	0.53	0.78	0.37		
Mean length(cm)	10.1	16.0	19.3	22.2	26.0			
Mean weight(g)	7	29	47	68	92			

Figures

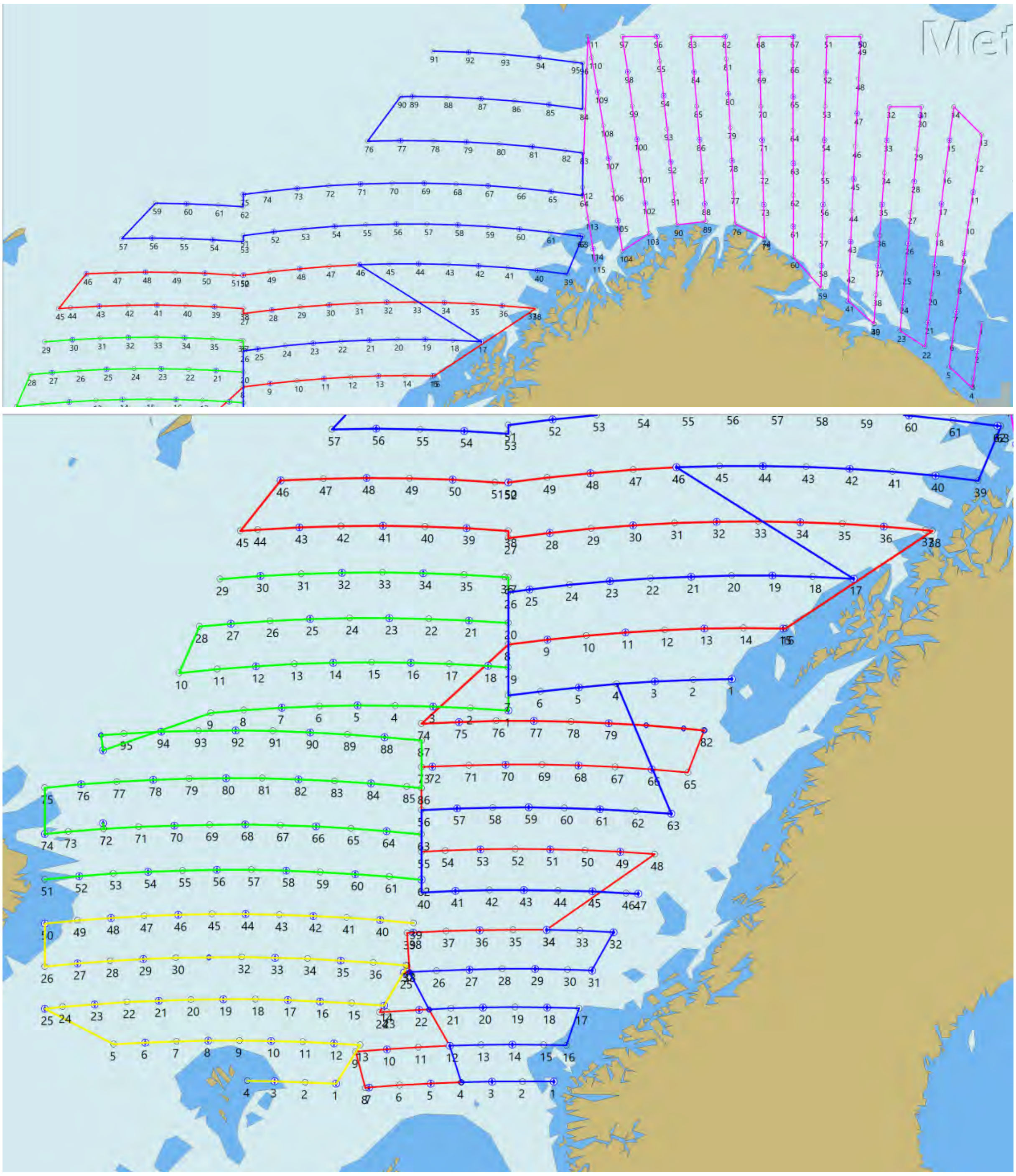


Figure 1. The pre-planned strata and transects for the IESNS survey in 2021 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends.

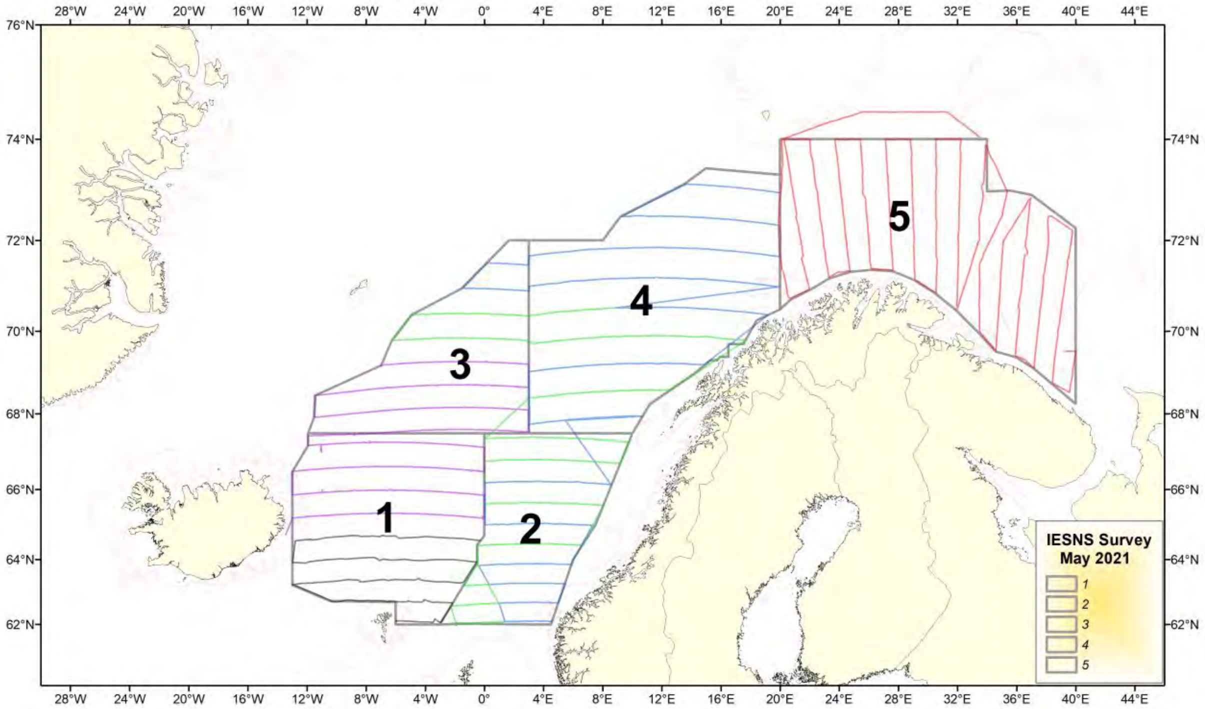


Figure 2. Cruise tracks and strata (with numbers) for the IESNS survey in May 2021.

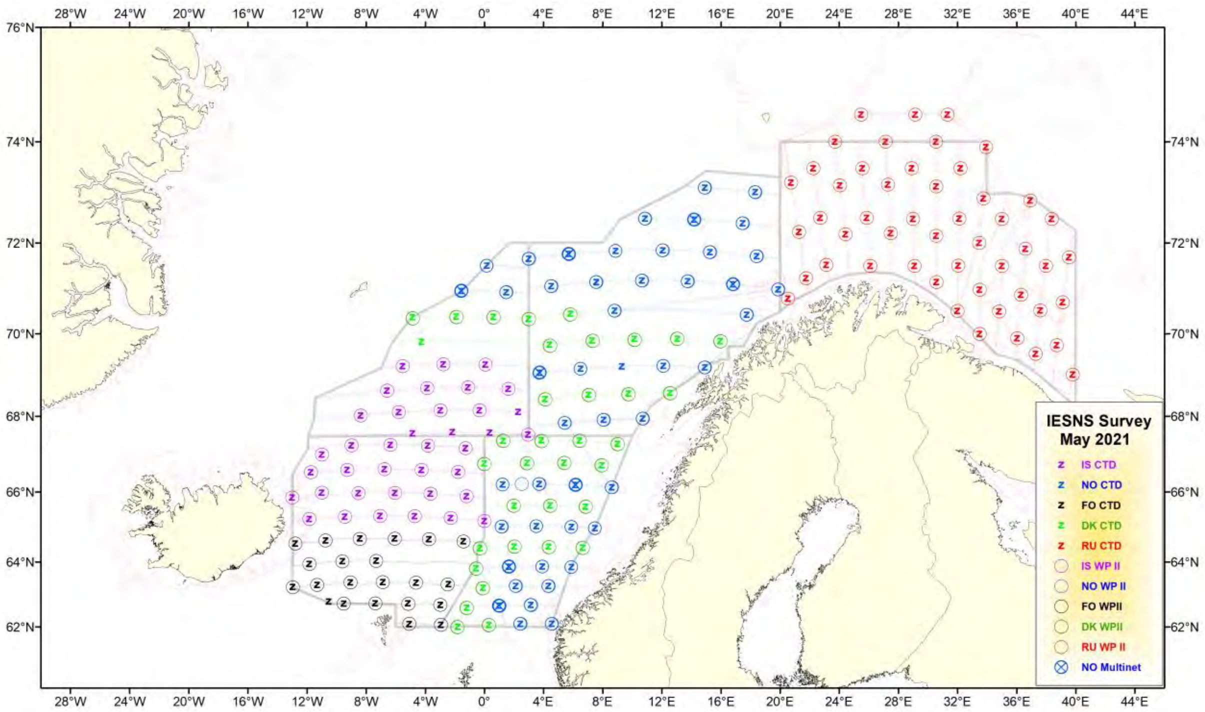


Figure 3a. IESNS survey in May 2021: location of hydrographic and plankton stations. The strata are shown.

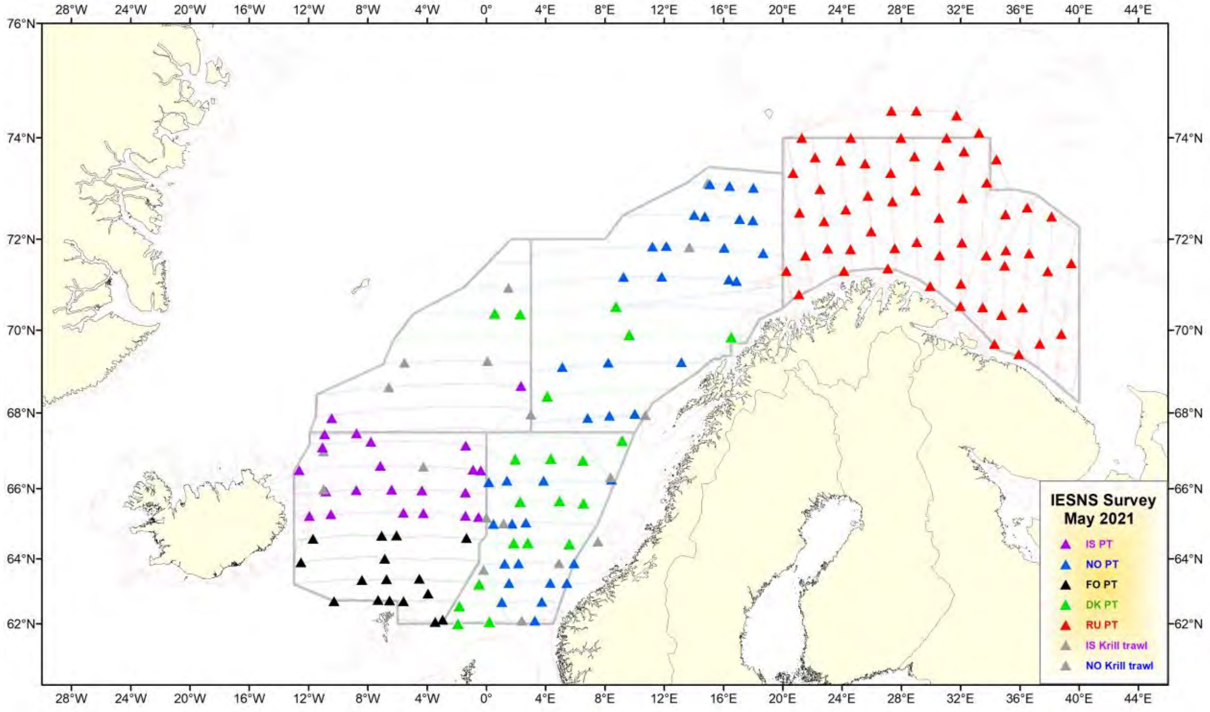


Figure 3b. IESNS survey in May 2021: location of pelagic trawl stations. The strata are shown.

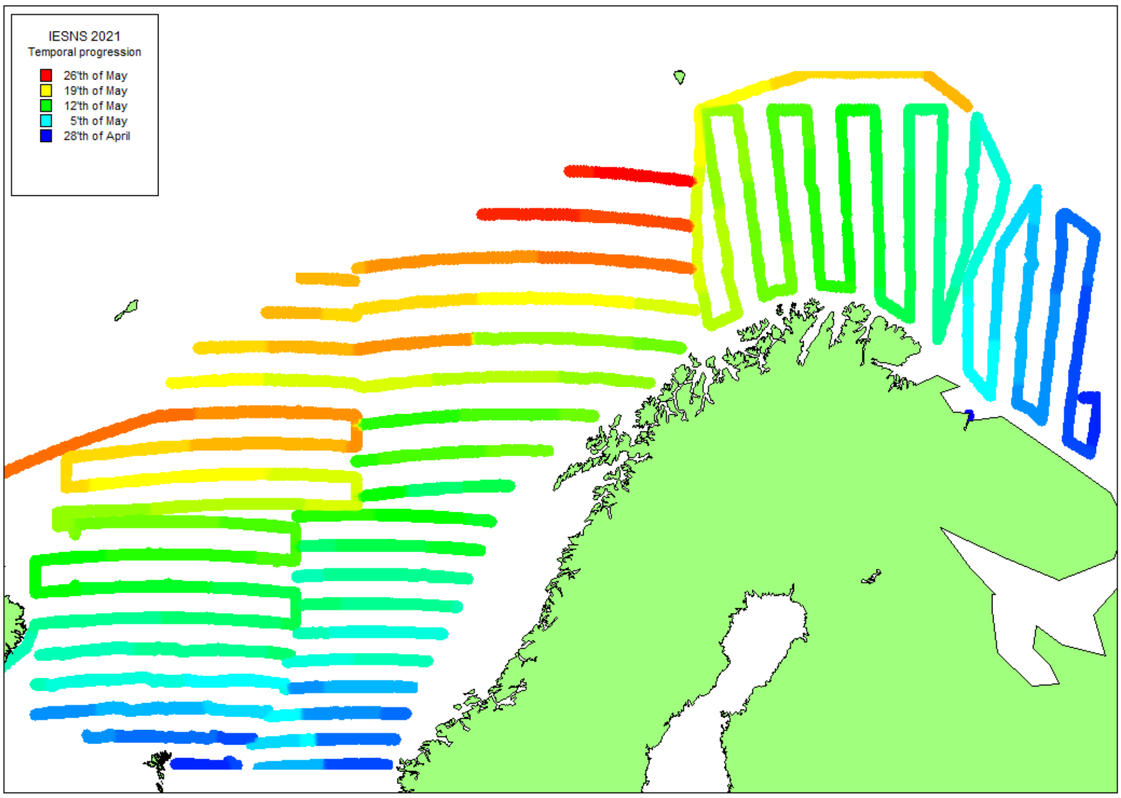


Figure 4. Temporal progression IESNS in May 2021.

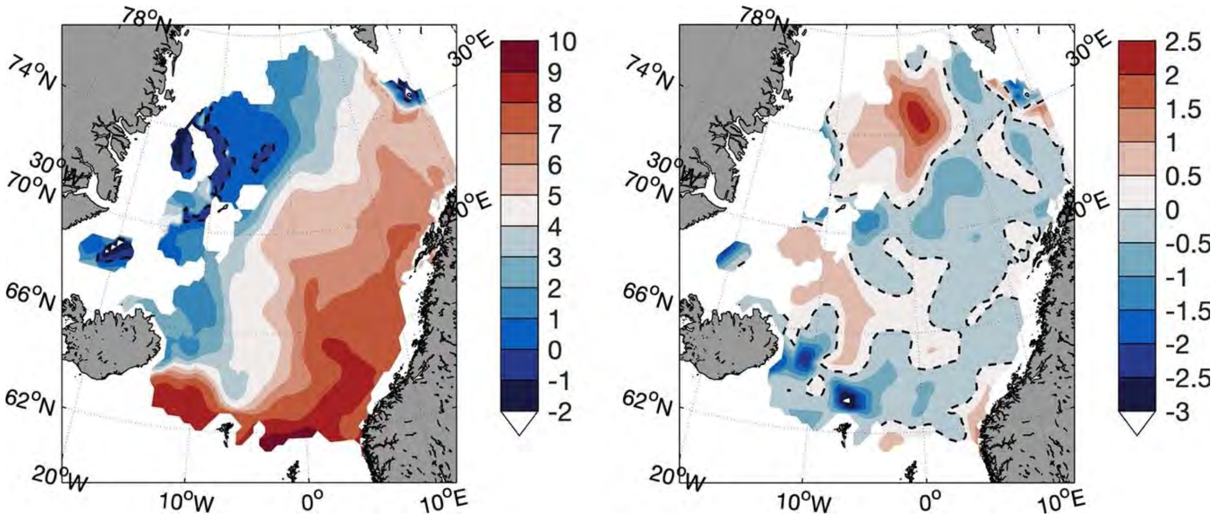


Figure 5. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2021. Anomaly is relative to the 1995-2019 mean.

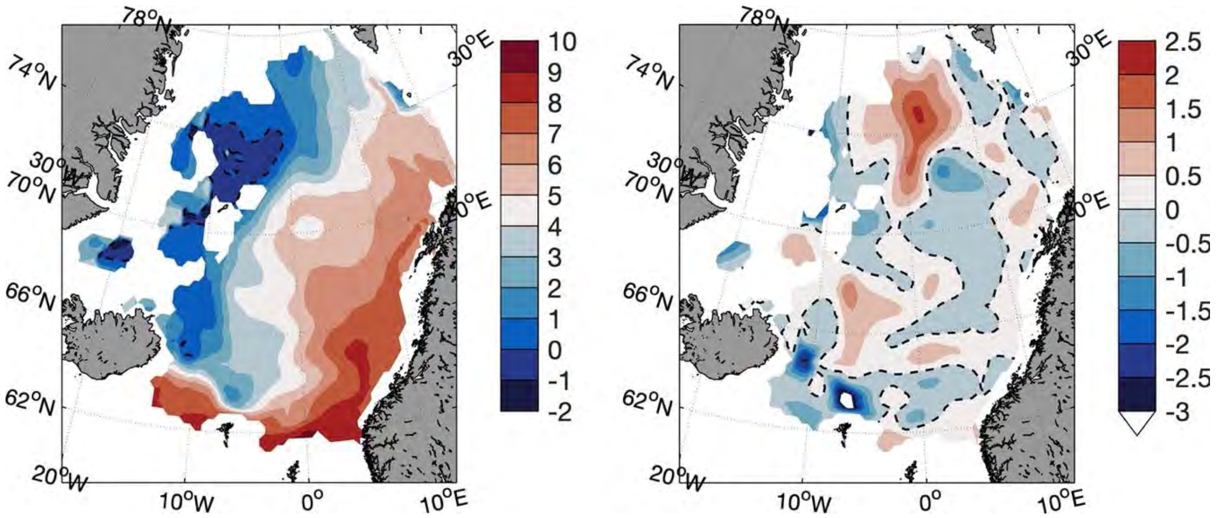


Figure 6. Same as above but averaged over 50-200 m depth.

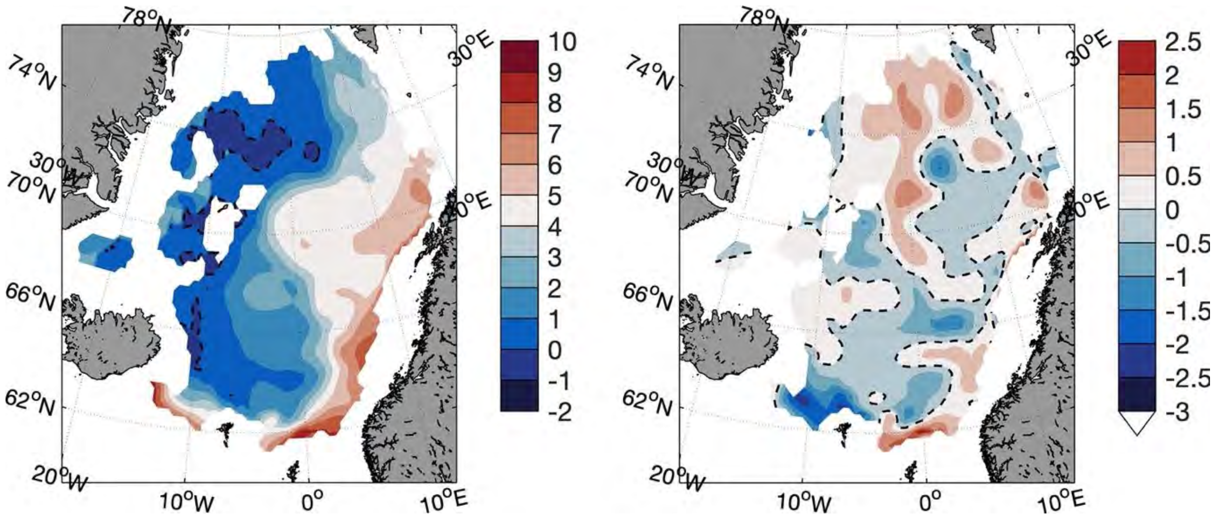


Figure 7. Same as above but averaged over 200-500 m depth.

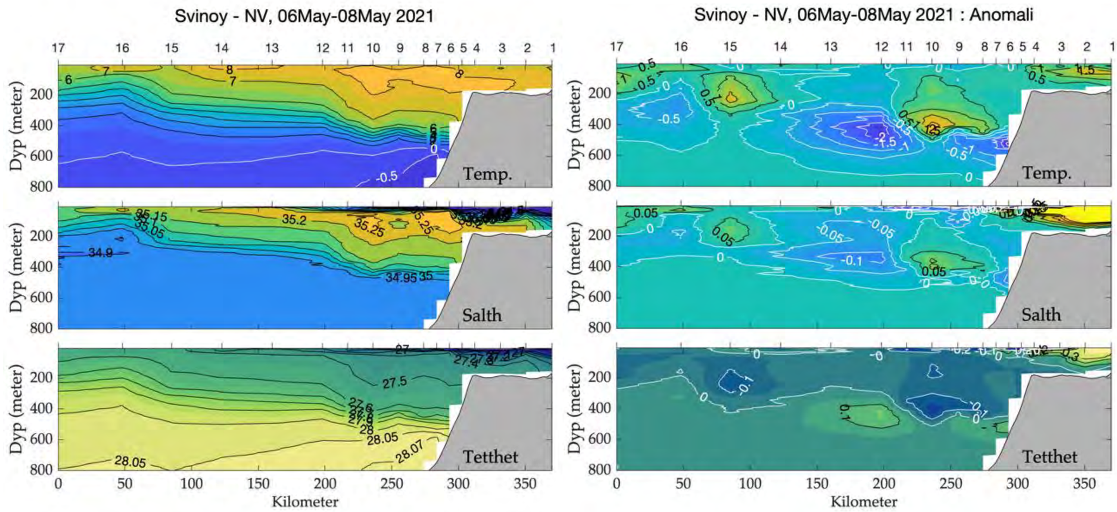


Figure 8. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinøy section, 6-8 May 2021. Anomalies are relative to 30 years long-term mean (1978-2007).

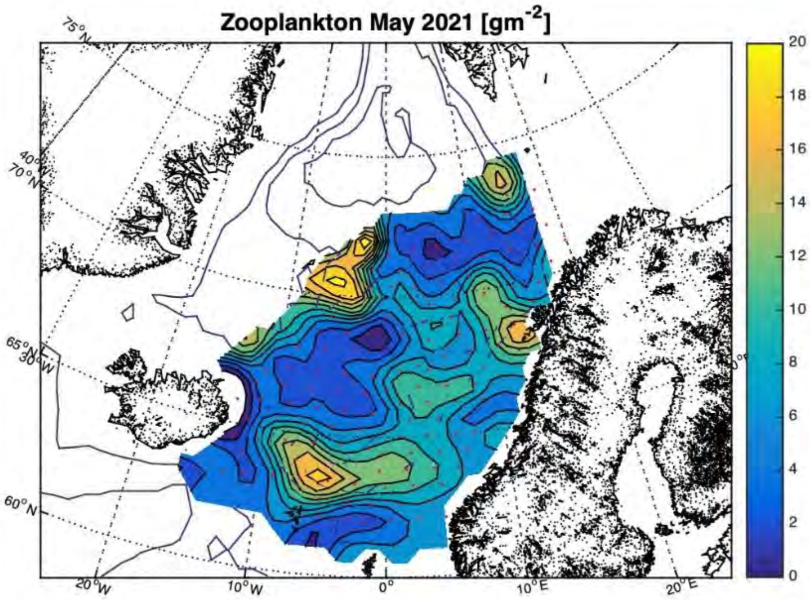


Figure 9. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May 2021.

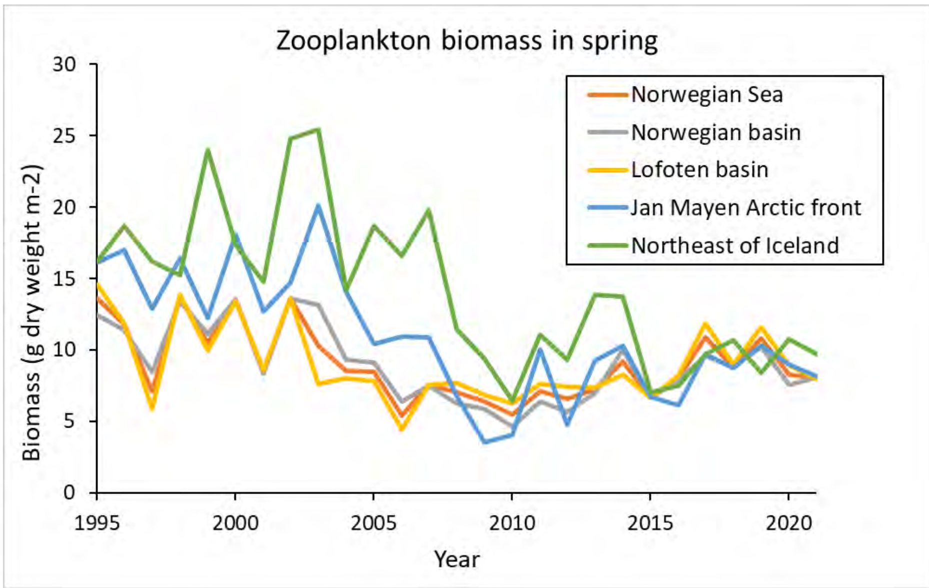
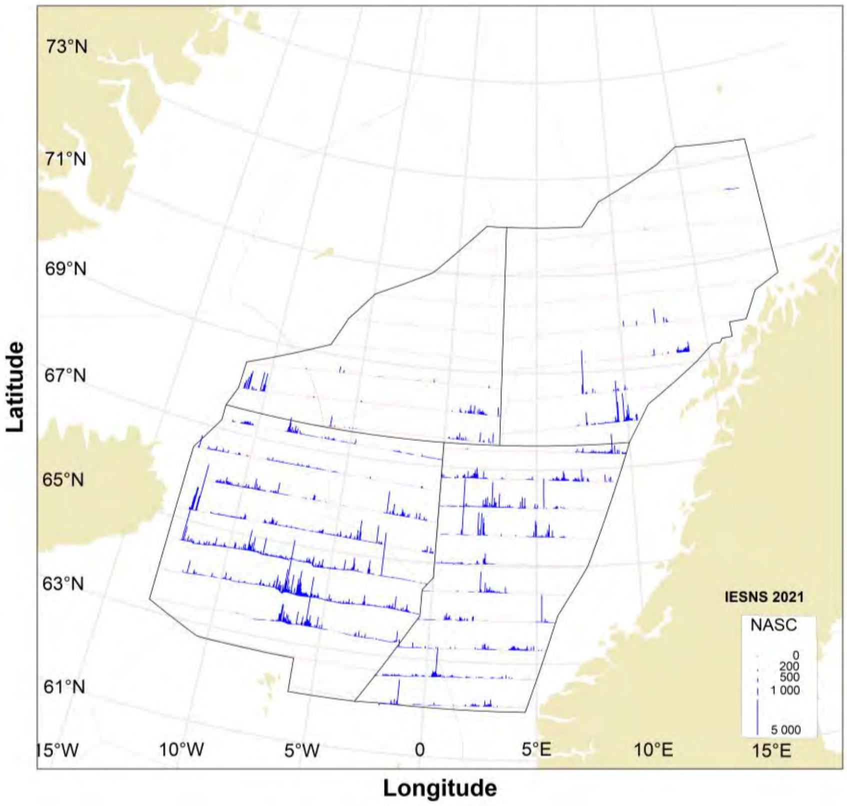


Figure 10. Indices of zooplankton biomass (g dry weight m^{-2}) sampled by WP2 in May in the Norwegian Sea and adjacent waters from 1995-2021.

(a)



(b)

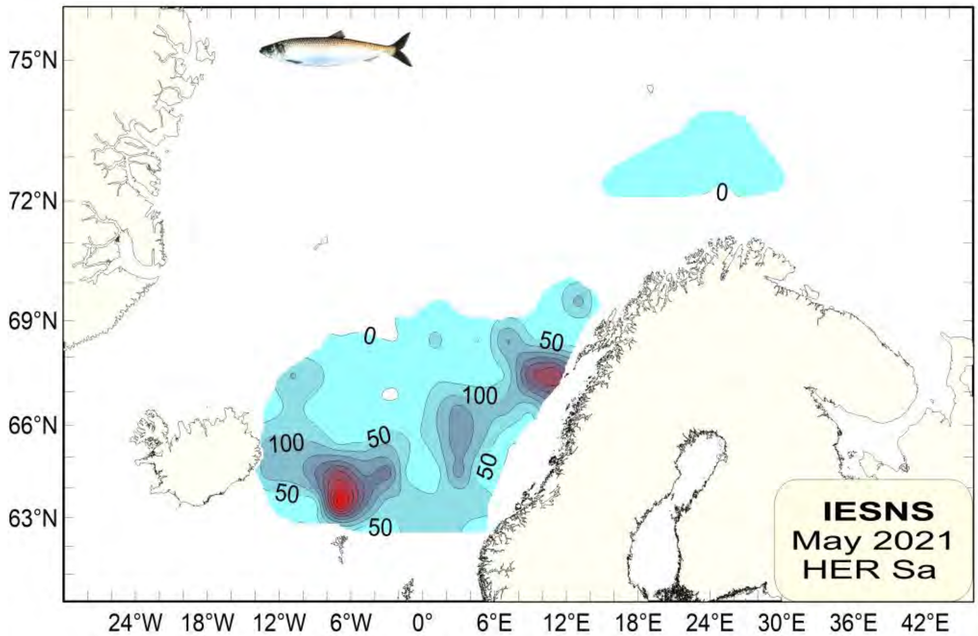


Figure 11. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2021 in terms of NASC values (m^2/nm^2) averaged for every 1 nautical mile and (b) represented by a contour plot. Note that

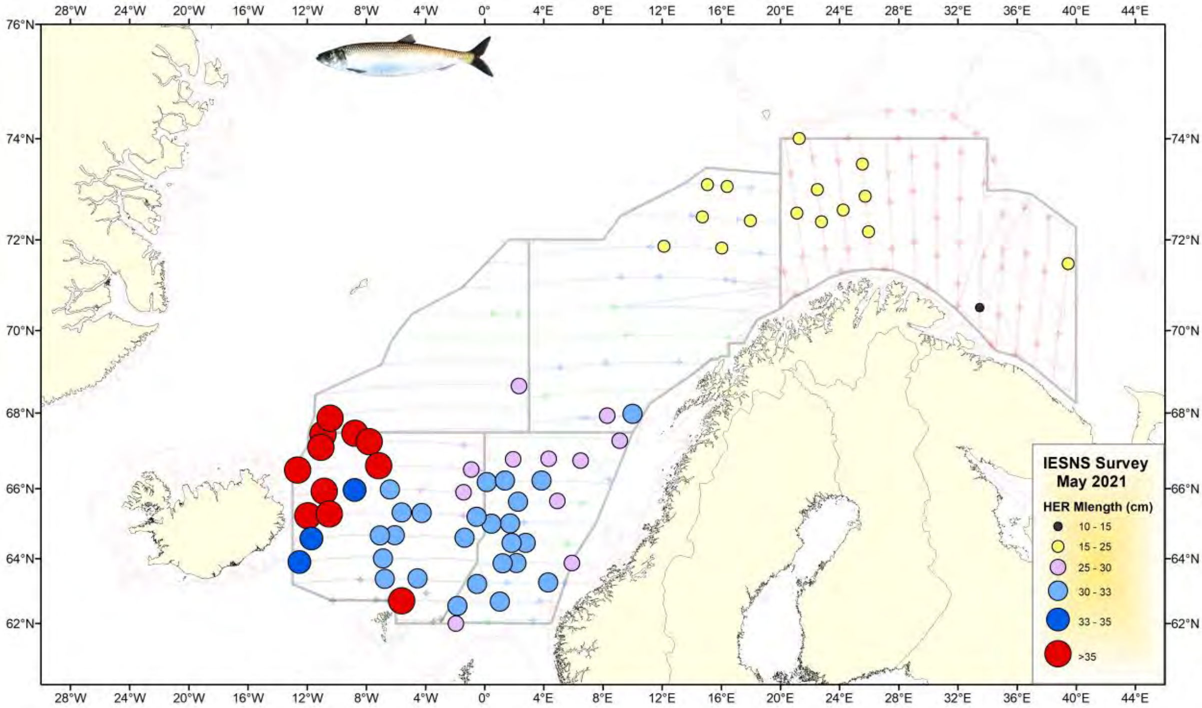


Figure 12. Mean length of Norwegian spring-spawning herring in all hauls in May 2021. The strata are shown.

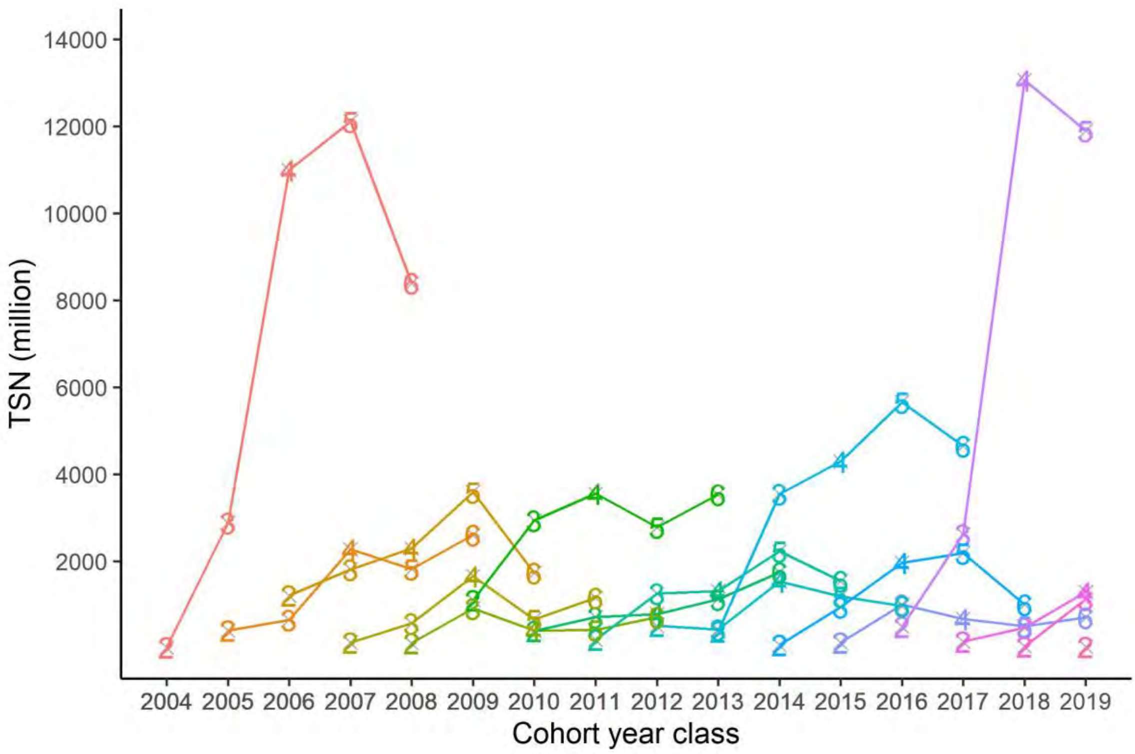


Figure 13. Tracking of the Total Stock Number at age (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

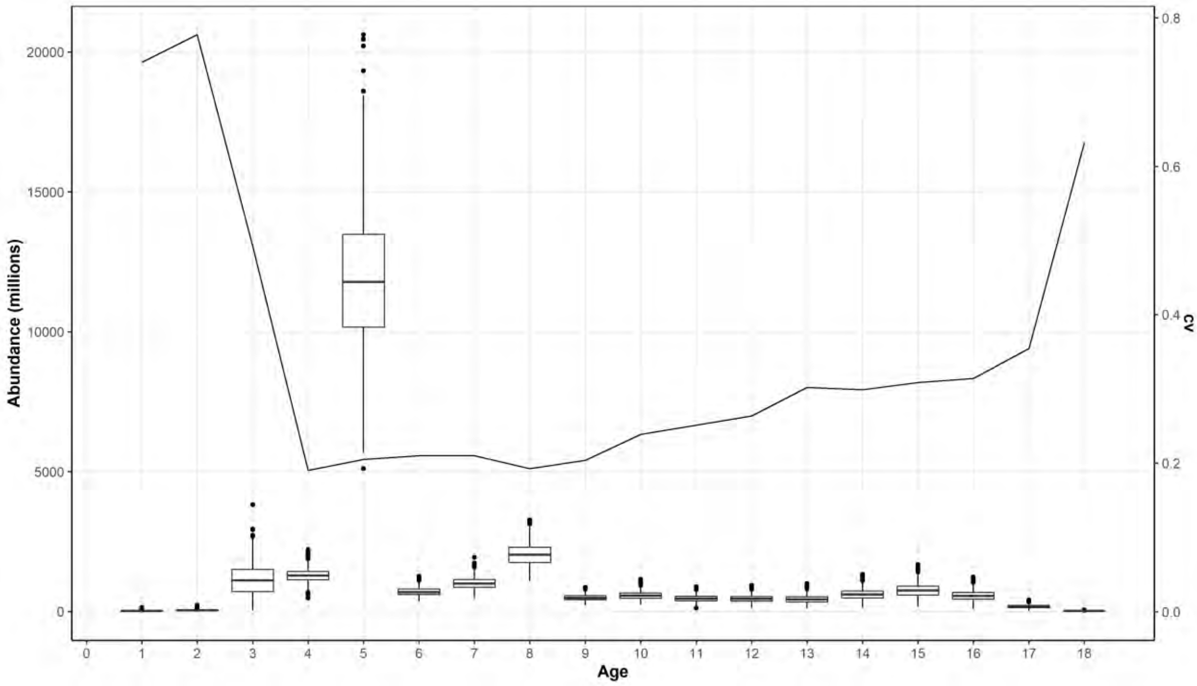


Figure 14. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

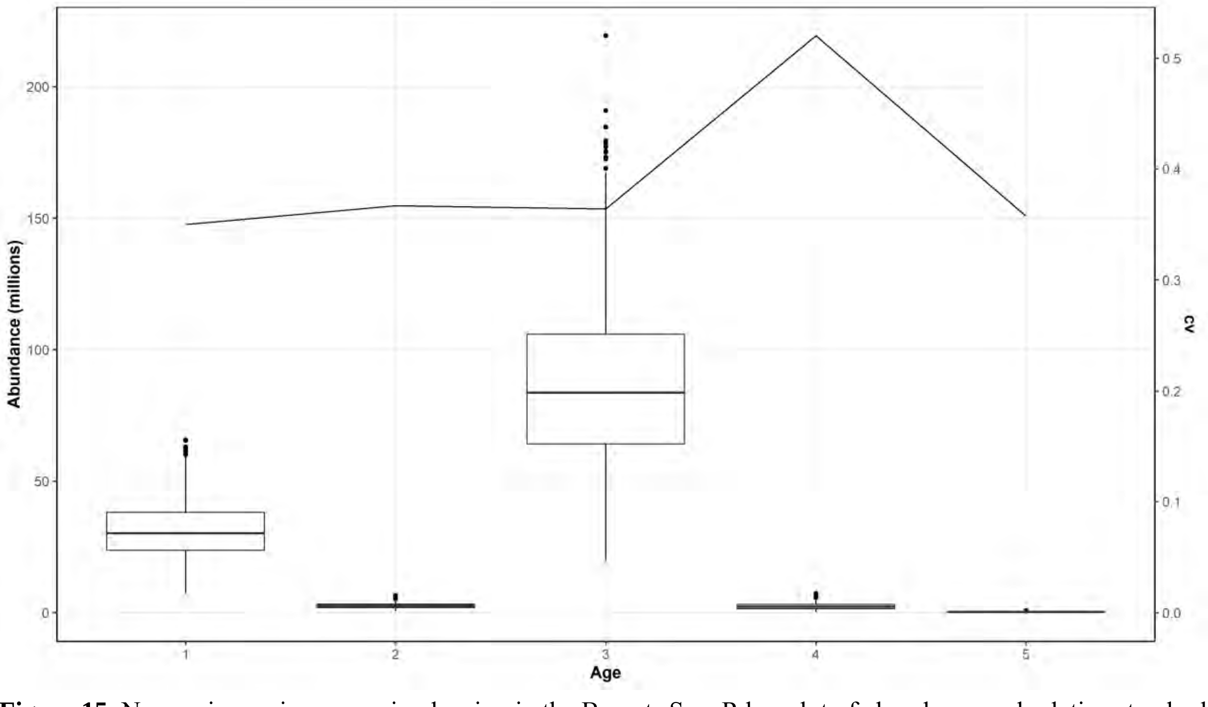


Figure 15. Norwegian spring-spawning herring in the Barents Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

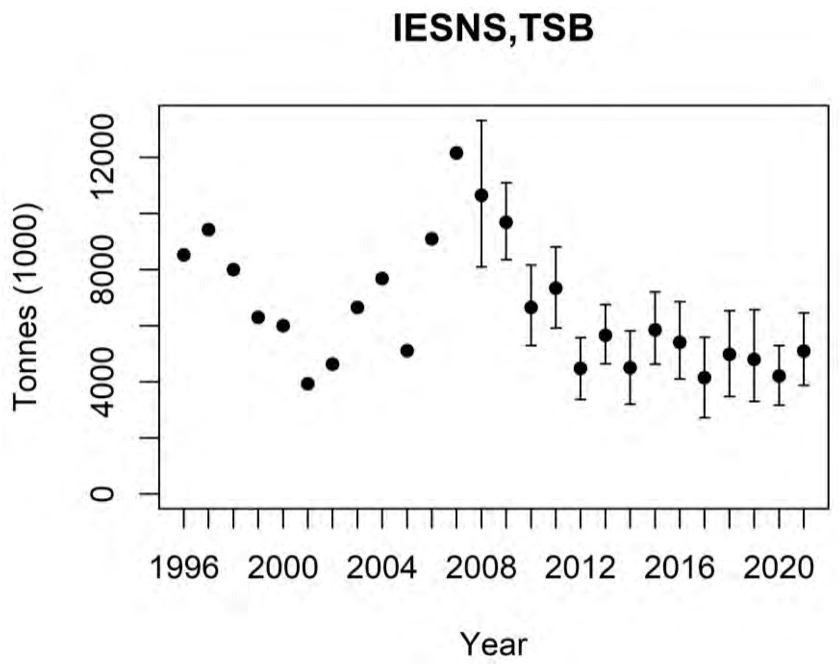


Figure 16. Biomass estimates of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2021 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2021; bootstrap means with 90% confidence interval; calculated on basis of standard stratified transect design).

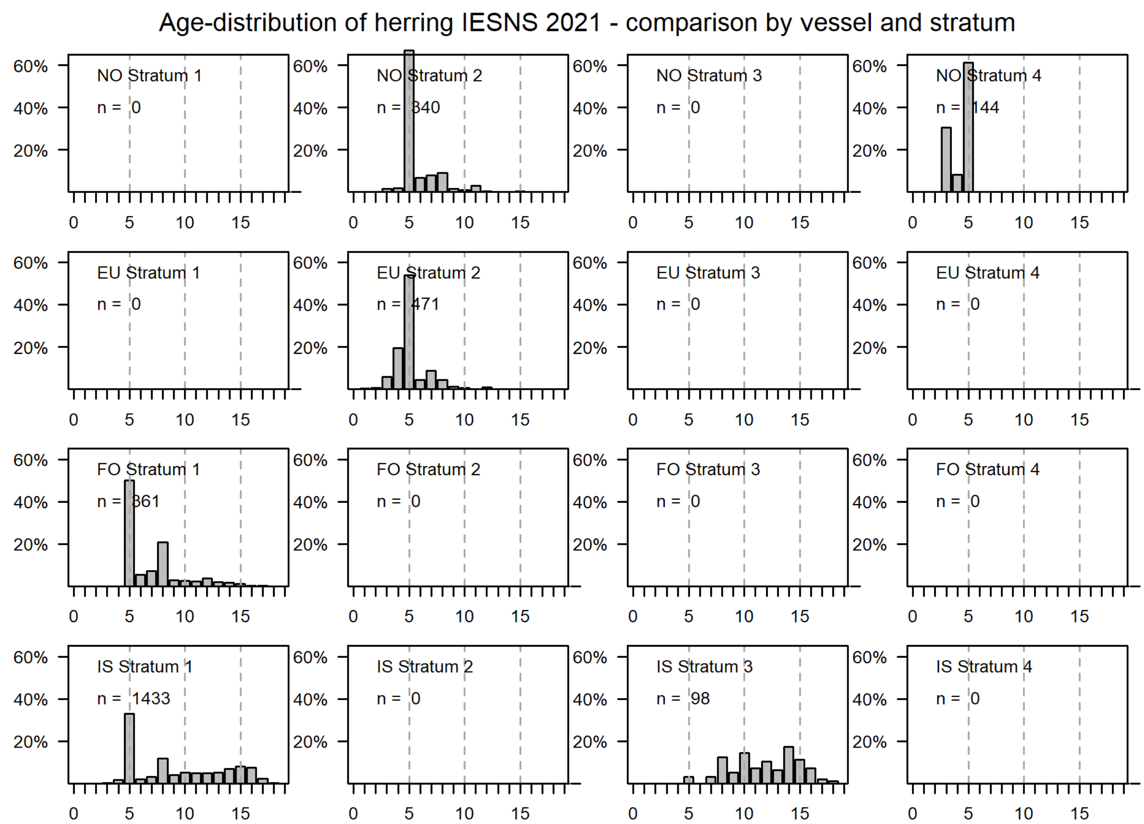
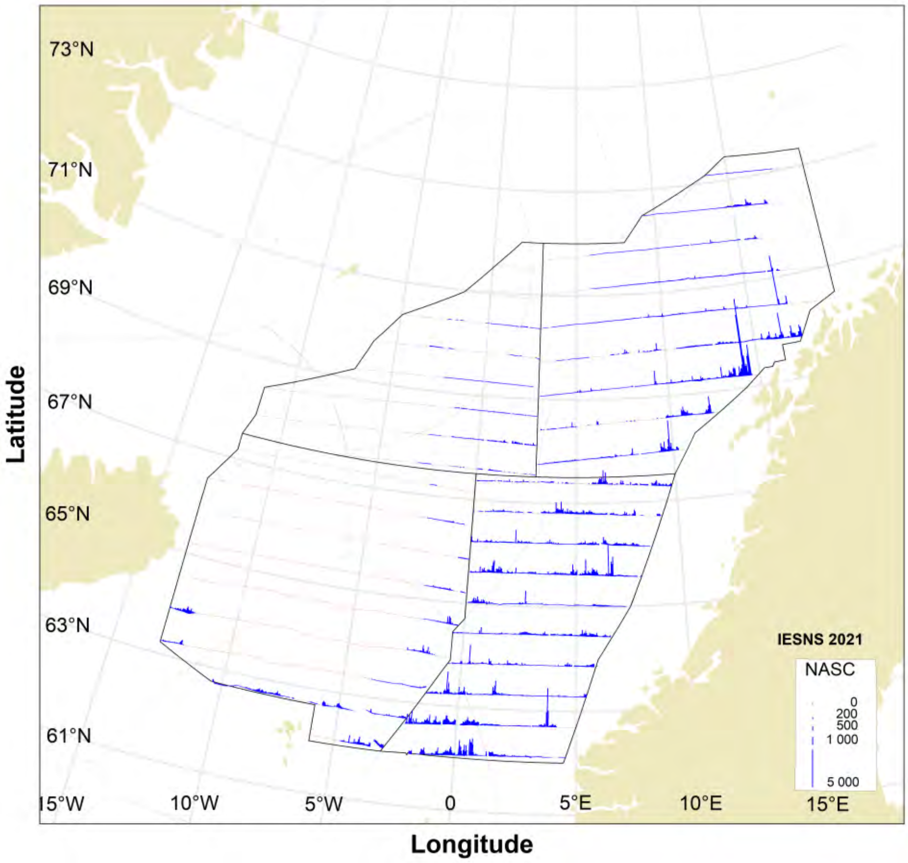


Figure 17. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2021 (Barents Sea not included). The strata are shown in Figure 3.

(a)



(b)

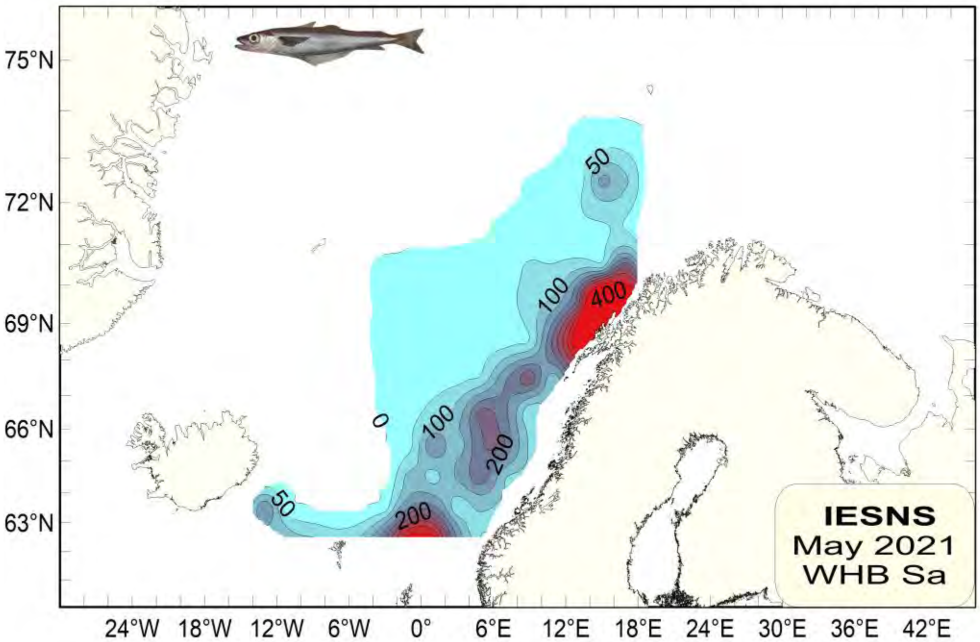


Figure 18. Distribution of blue whiting as measured during the IESNS survey in May 2021 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile and (b) represented by a contour plot.

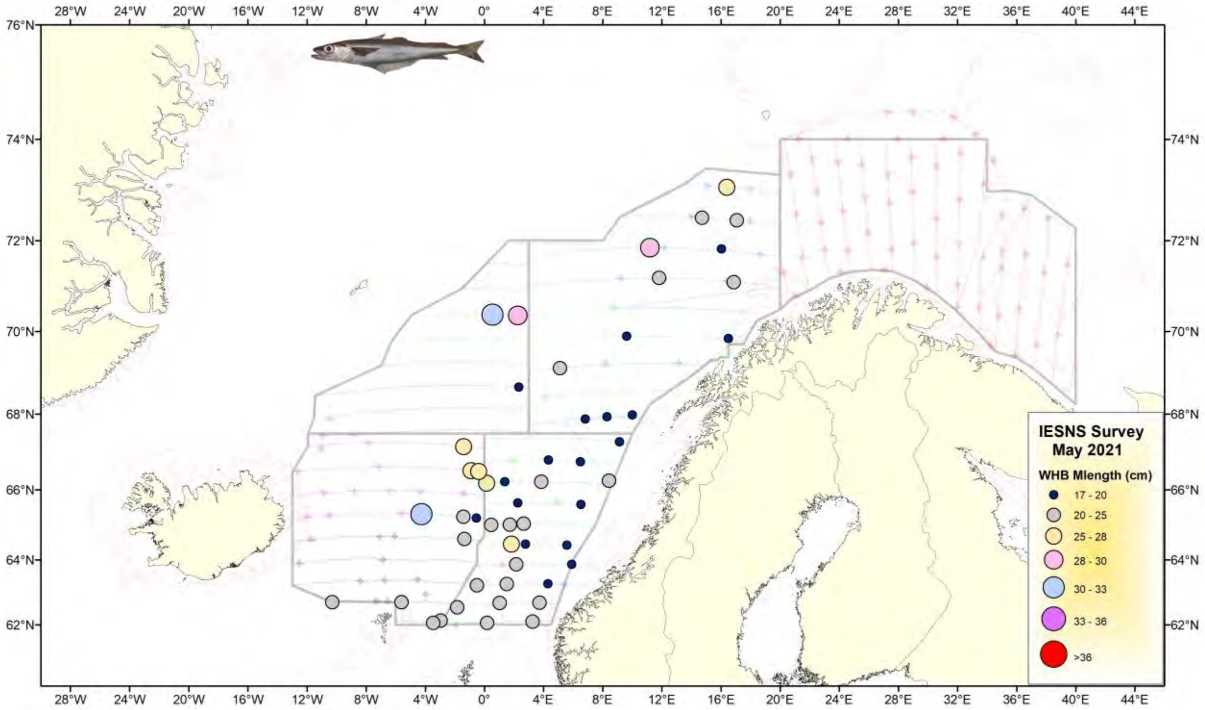


Figure 19. Mean length of blue whiting in all hauls in IESNS 2021. The strata are shown.

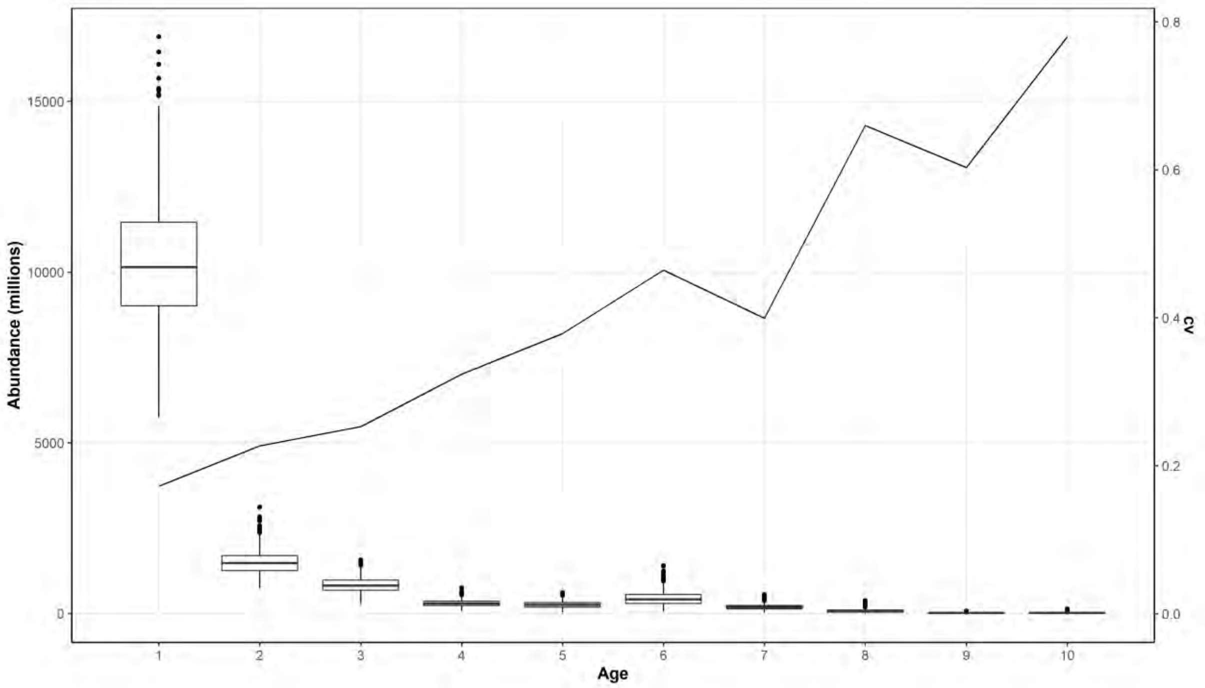


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

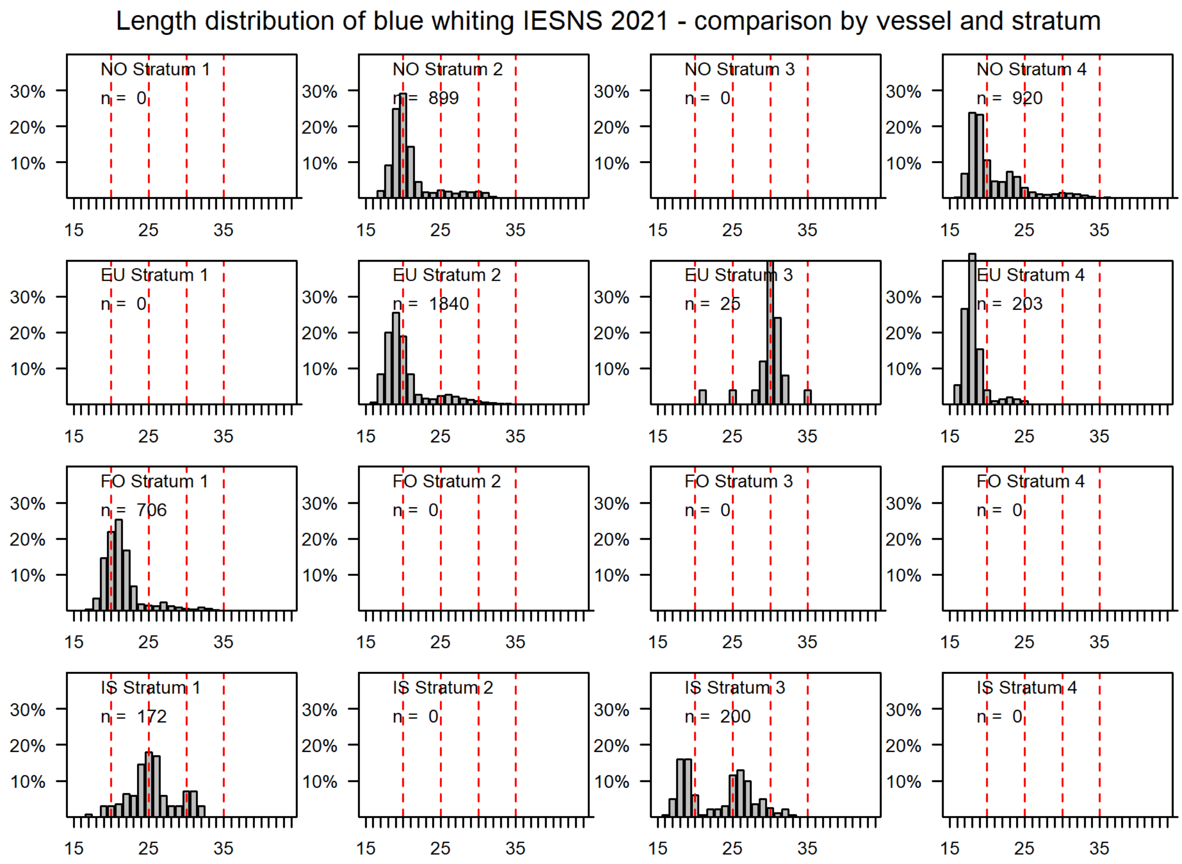


Figure 21. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2021 (Barents Sea not included). The strata are shown in Figure 3.

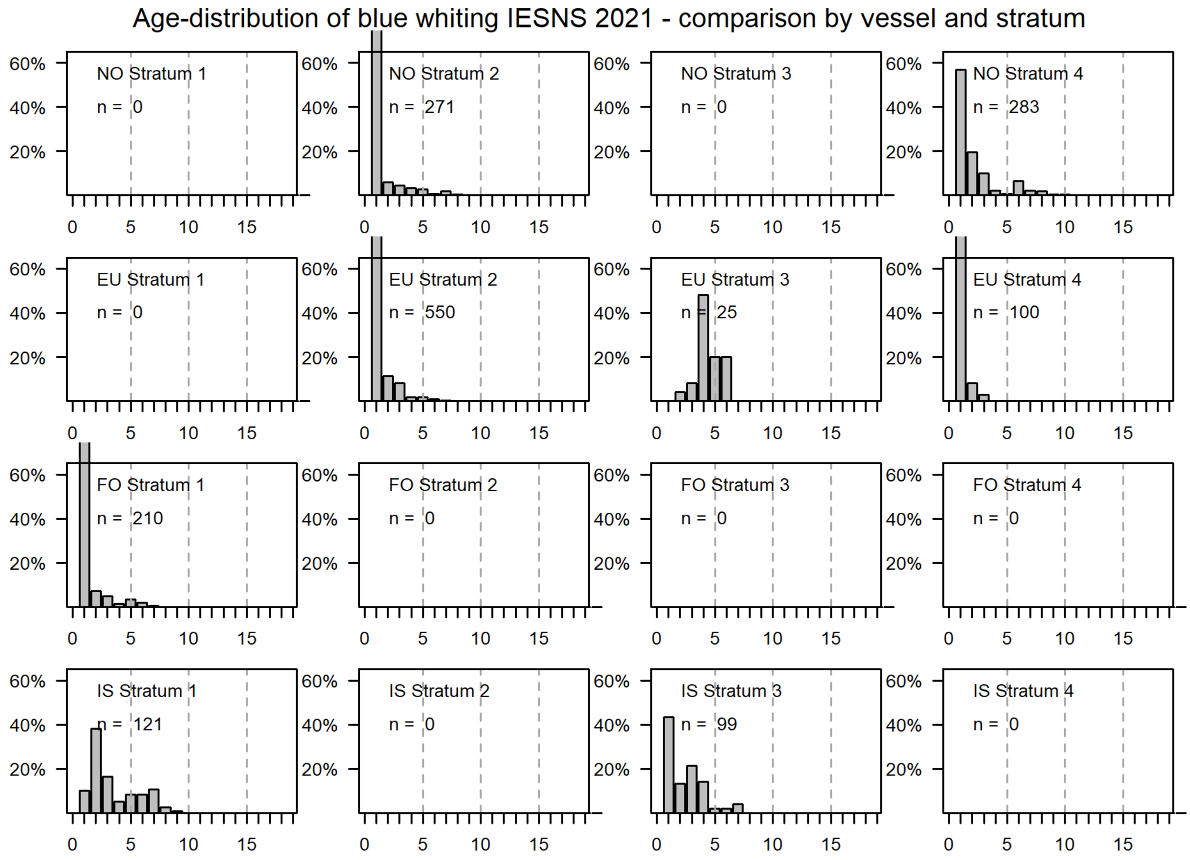


Figure 22. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2021 (Barents Sea not included). The strata are shown in Figure 3.

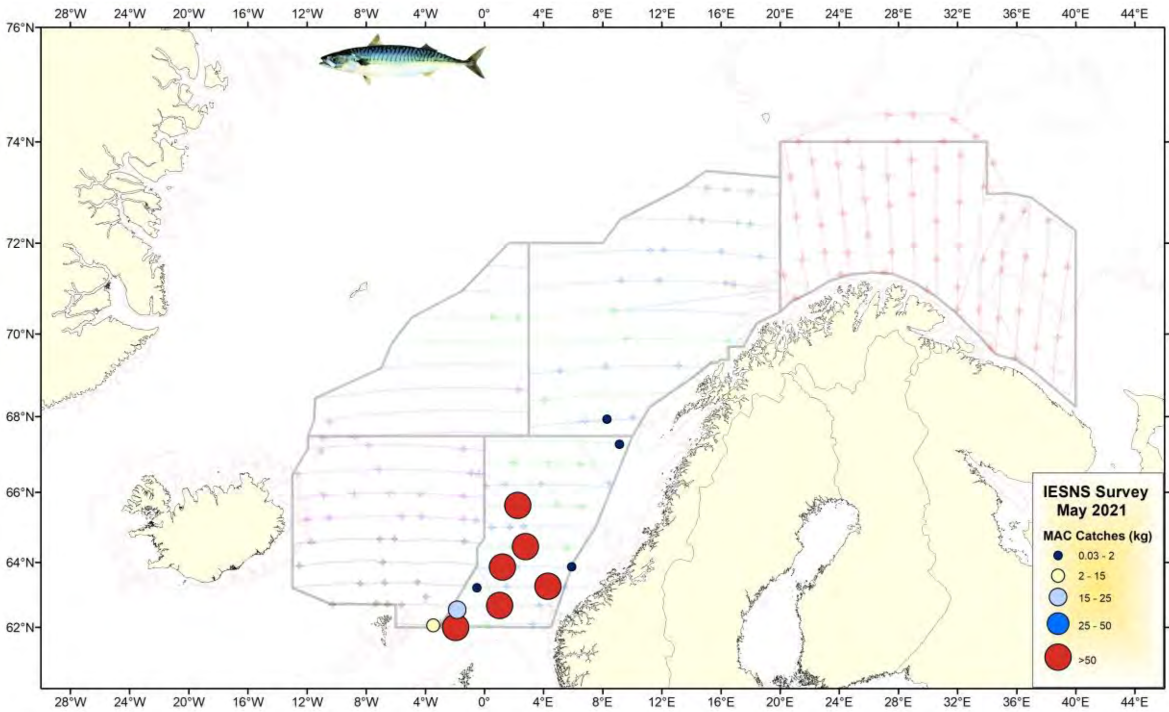


Figure 23. Pelagic trawl catches of mackerel in IESNS 2021. The strata are shown.

2021 mackerel egg exploratory survey (0321H)

Finlay Burns[1], Brendan O' Hea[2]

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Introduction

WGMEGS, the ICES working group tasked with coordinating the triennial Mackerel and Horse mackerel egg surveys (MEGS) has since 2007 been observing and reporting on the offshore westwards and northwards expansion of mackerel spawning. During this period it had been noted that although the proportion of spawning taking place in these northern and western areas had indeed been small (in comparison to the total annual egg production) it had nevertheless been increasing with every survey. The results from the recent triennial MEGS surveys in 2016 and 2019 provided clear evidence that this was no longer the case demonstrating a significant and unprecedented shift with emphasis moving away from the traditional spawning hotspot areas of Biscay and the Celtic Sea and instead over a large swathe of open ocean often well away from the continental shelf. During the last 2 triennial surveys some of the highest spawning densities were observed to the west and Northwest of Scotland and importantly very close to the northern and north-western survey boundary (see figures 1 and 2).

During the last NEA mackerel benchmark in 2017 (ICES,2017) and as part of the WGMEGS survey review process a commitment was made to undertake exploratory icthyoplankton surveys within the mackerel spawning boundary regions in the North and Northwest and where the MEGS surveys have hitherto struggled to delineate a hard spawning boundary. During 2017 and 2018 exploratory surveys undertaken by Ireland and Scotland and utilising Gulf 7 samplers successfully mapped and delineated a mackerel spawning boundary within the offshore areas of Hatton Bank/South Iceland Basin and the Scotland-Faroe-Iceland Ridge (ICES,2018). The results from these surveys played a useful role in informing the survey planning process ahead of the 2019 MEGS triennial survey but left the Norwegian Sea/Shelf as an area that still provided a level of uncertainty and especially with recent MEGS survey results providing compelling evidence (ICES,2021) that mackerel appear to be favouring the North-eastern route as they head North towards their summer feeding grounds. This survey aims to conclude this exploratory objective by surveying mackerel spawning activity up and along the Norwegian Shelf and during the month when the highest mackerel spawning densities are likely to be encountered within this region. An additional objective included completion of several icthyoplankton transects undertaken within the Northern North Sea area and that will feed directly into the North Sea Mackerel Egg Survey (NSMEGS) dataset. In contrast to the previous exploratory surveys in 2017 and 2018, trawling was scheduled during this survey with midwater trawl deployments being planned within both the North Sea and Norwegian Sea areas. Information on adult mackerel being requested for both batch fecundity and spawning fraction estimation for the NSMEGS (south of 62N) as well as contribute to ongoing research taking place at the Institute of Marine Research (IMR) in Bergen.

Survey

Survey methodology

The 76m Scottish pelagic fishing trawler, *Altaire*, was chartered to undertake survey 0321H, from 7th to the 22nd June 2021. The samples were collected and analysed in accordance with the WGMEGS sampling at sea manual (ICES, 2019). Double oblique deployments were conducted at every sampled station and these were taken to within 10m of the bottom or to a maximum depth of 200m, whichever is shallower. Scotland utilises a Gulf VII plankton sampler which is towed at a speed of 4 knots and uses a 250 µm plankton net. Valeport replica electronic flowmeters and a RBR Duo CTD attached to the sampler, monitored volume as well as recording depth, temperature and salinity during each deployment. Real-time sampler depth was monitored using a ScanMar depth sensor, also attached to the sampler. Whilst completing transects for the NSMEGS component (south of 62N) half degree longitude station spacing was retained thereby ensuring consistency between NSMEGS participants. During the exploratory plankton survey component (North of 62N) the nominal station spacing was increased to one degree of longitude. This is consistent with the previous exploratory surveys undertaken and maximises the geographical area that can be completed. Survey protocols for sample treatment as well as data work up for all stations presented within this working document are as per the WGMEGS at sea protocols for surveying in the North Sea. On retrieval the plankton net was washed down in seawater with the plankton being fixed in 4% buffered formalin. All samples were analysed within 36 hours of being fixed, with all eggs being extracted and retained for analysis. All mackerel eggs were subsequently identified, counted and their development stage determined.

Survey summary

Altaire departed from Peterhead at around mid-afternoon on the 7th June in near perfect weather conditions and headed North towards the survey starting point on the East side of Muckle Flugga, Shetland. After completion of the flowmeter calibrations Altaire headed East to commence surveying on the 60.75N transect. Whilst still awaiting final clearance for permission to survey within the Norwegian EEZ, Altaire was able to complete an additional partial transect at 59.75N during the 9th June, however with the permit being issued Altaire was then able to continue surveying back on to the 60.75N transect heading eastwards towards the Norwegian coast before turning North and then west on the 61.75N transect towards Tampen and to the North of Shetland. This concluded the NSMEGS component and from here the station spacing increased to 1 degree of longitude with double alternate transect spacing employed on the Northwards outbound survey plan. Following this plan and with weather conditions being generally calm although largely overcast Altaire was able to make excellent progress completing transects at 63.45N, 65.45N, 67.45N before completion of a the final outbound transect at 68.15N on the 16th June. During the inbound track Altaire proceeded south interlacing to complete the transects 'missed' during the outbound route North. As regards the geographic extent of the transect to the west, the intention was to survey at least as far west as the 1000m isobath, which was achieved and in several cases the transects were extended even further west and out over 2000m(figure 3). After completion of a survey track of almost 2900 nm Altaire finally returned back to Peterhead in the early hours of the 22nd June.

Temperature

Surface temperatures encountered during the survey (taken at 5m depth) ranged from 9 degrees Celsius in the northernmost latitudes surveyed to almost 14 degrees further south and within the North Sea area over towards the Norwegian Coast. A period of relatively settled weather experienced prior to as well as during the survey period almost certainly contributed to the stratification observed throughout the survey with temperature profiles recording an average drop in temperature of approximately 3 degrees Celsius when comparing surface temperatures with those recorded at 50m depth. Figures 4 – 6 provide heat plots for 5, 20 and 50m temperatures recorded in Celsius during the survey.

Results

Egg Abundance

87 Gulf deployments were made in total with 9 flowmeter calibration runs and a further 78 plankton deployments. These yielded 5123 mackerel eggs of all stages, of which 1671 were recently spawned stage 1 eggs. Mackerel eggs were recorded from every deployment with stage 1 eggs being recorded on all but 2 of the stations completed. The numbers of mackerel eggs extracted from the Gulf VII samples were standardised and the stage 1 data presented as numbers /m^2/day (see figure 7). Egg counts across the entire surveyed area were low to moderate with the highest egg counts generally being encountered within the southern half (south of 66N) of the survey area and reducing gradually as the survey proceeded Northwards until counts were entirely down to single figures on transects West of Lofoten and with even the surface temperatures cooled to levels approaching the perceived temperature threshold for spawning in mackerel.

Trawling

The vessel's own midwater trawl was deployed 5 times (fig. 8) during the survey, and was successful in catching mackerel on two of those occasions. All trawl deployments were towed for approximately 1 hour. An attempt was made to collect adult fish for fecundity analysis as part of the NSMEGS, however the night-time deployment at Tampen was unsuccessful. Further North it became clear that within a well stratified water column with relatively warm surface layer that Altaire's unfloated net would struggle to get close enough to the surface to be effective and unsurprisingly the trawls undertaken close to the Norwegian Coast at 63.75N and again at 66.75N were unsuccessful. Even with the trawl headline at 25 – 30m from the surface (*shallowest that net could operate*) the sub 7.5 Celcius temperature recorded on the trawl headline sensor appeared to be too cold for mackerel. As an alternative method 3 sessions with rod and line were also tried at the surface but also with no success. The last two trawl deployments were undertaken on the inbound track and towards the western edge of transects at 64.75N 4E (AE03/04) and also 62.75N 1.25E (AE03/05) respectively and where stratification was less defined resulting in the layer of warm water extending deeper and importantly within reach of the midwater trawl. Trawl AE03/04 yielded 19 mackerel whereas AE03/05 was successful in catching approximately 180kgs mackerel of which 104 randomly selected fish were sampled. Length, sex, maturity (*Walsh scale*) and age (*otoliths removed for ageing back in the lab*) were determined for each of the 123 mackerel sampled. In addition 60 ovary samples were collected for colleagues in IMR Bergen in order to progress current ongoing collaborative research being undertaken into spawning fish within the Northern region.

The sampled adults sampled ranged from between 28 and 41cm in length with the overwhelming majority within the length range 32 – 35cm. This translated into an age profile that spanned from ages 2 - 15 but where where over 80% of those sampled were between ages 2 – 5 with age 4 being the most prevalent year class. Unsurprisingly, of the 123 mackerel sampled almost 60% were found to be maturity stage 5 (*partially spent*) while almost 20% were stage 6 (*spent*). Perhaps more surprisingly almost 15% were stage 4 (*spawning*) (see figs. 9-11).

Additional Sampling IESNS – Faroe Islands

17 additional plankton samples were collected for WGMEGS by the Faeroe Islands during the IESNS survey and within the of region extending from the east side of Iceland across to the north of Shetland. This survey took place between April 29th and 8th May. These samples were collected using a vertically deployed WP2 net that is deployed to a depth of 50m. The samples from these deployments have yet to be processed but the results will be available prior to WGMEGS in 2022 and incorporated into the WG report.

Conclusions/Discussion

The exploratory egg survey successfully completed the transects allocated to it within the North Sea area south of 62Nn with 29 stations being incorporated into the NSMEGS dataset. As regards the exploratory objective this has also been completed successfully with Altaire delivering a comprehensive snapshot of mackerel spawning within the area of the Norwegian Sea and during the period when as has already been stated mackerel spawning activity would expect to be at its peak. Despite completing the most northerly transect at 68.25N the survey was unable to find a hard spawning boundary albeit the numbers being encountered were very low within these high latitudes. This contrasts markedly with the previous exploratory surveys undertaken further West around Hatton Bank and North to Iceland during 2017 and 2018 and that were able to reaffirm the existence of a cold water barrier stretching from the East coast of Iceland across to the Faroe/Shetland and demonstrating very little if any mackerel spawning taking place in June at latitudes North of the Faroe Islands. The situation up and along the Norwegian Sea is very different with the influence of the Norwegian Current keeping sea surface temperatures (within the surface layers in anycase) within a range that is tolerable for spawning mackerel. Nevertheless, the spawning levels observed in the sampled stations North of 62 degrees are overall very low with an estimated contribution to the overall total annual egg production (TAEP) of around 2%. Looking ahead to the

2022 survey, there is no immediate requirement for WGMEGS to significantly extend the survey coverage in this region much beyond what was undertaken in 2019.

An additional and secondary objective was to assess the existence (or otherwise) of a boundary between the North Sea and the western area component. The results from this survey highlight clearly that no boundary currently exists with continuous spawning taking place from the southern North Sea right up to and almost certainly beyond Lofoten in the North. Historically, a mismatch in timing and location of peak spawning may well have helped to preserve some degree of spatial separation between the components but on the evidence of this survey it is no longer there.

All the information gathered from these exploratory egg surveys as well as the additional samples received from the various Nordic surveys since 2017 are invaluable and provide a unique opportunity not available during the triennial survey year to map the distribution of spawning mackerel within the northern boundary regions. Knowledge gleaned is crucial during the planning and execution of the triennial survey in 2022.

Special thanks to Aril Slotte for assistance/advice provided during the permit application process and also to Eydna í Homrum and Sólva Eliasen for the collection of additional WP2 samples during the IESNS surveys.

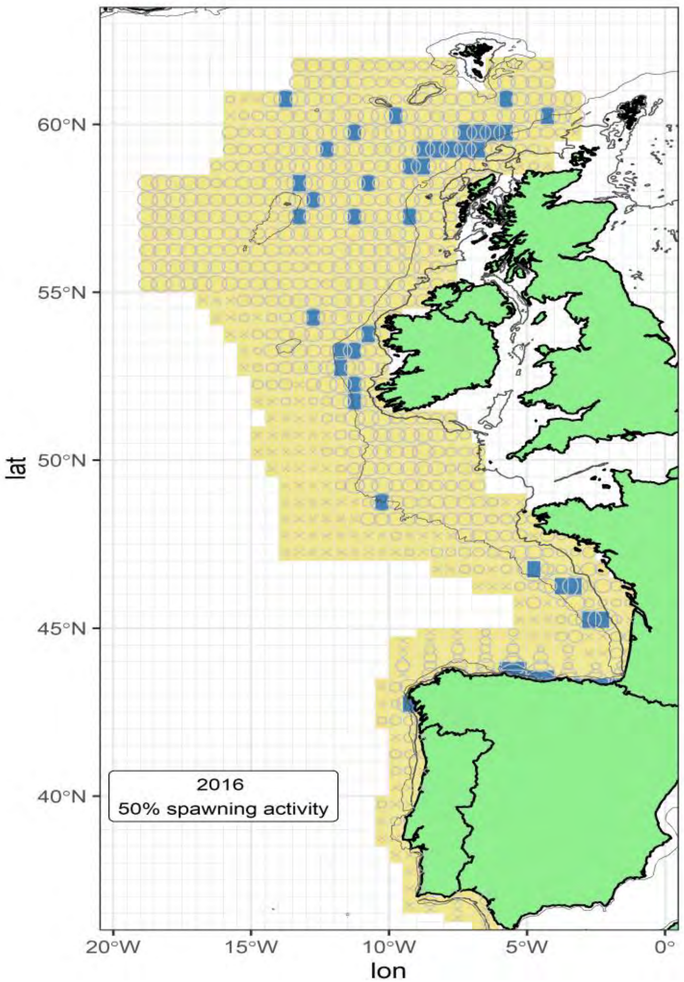
References

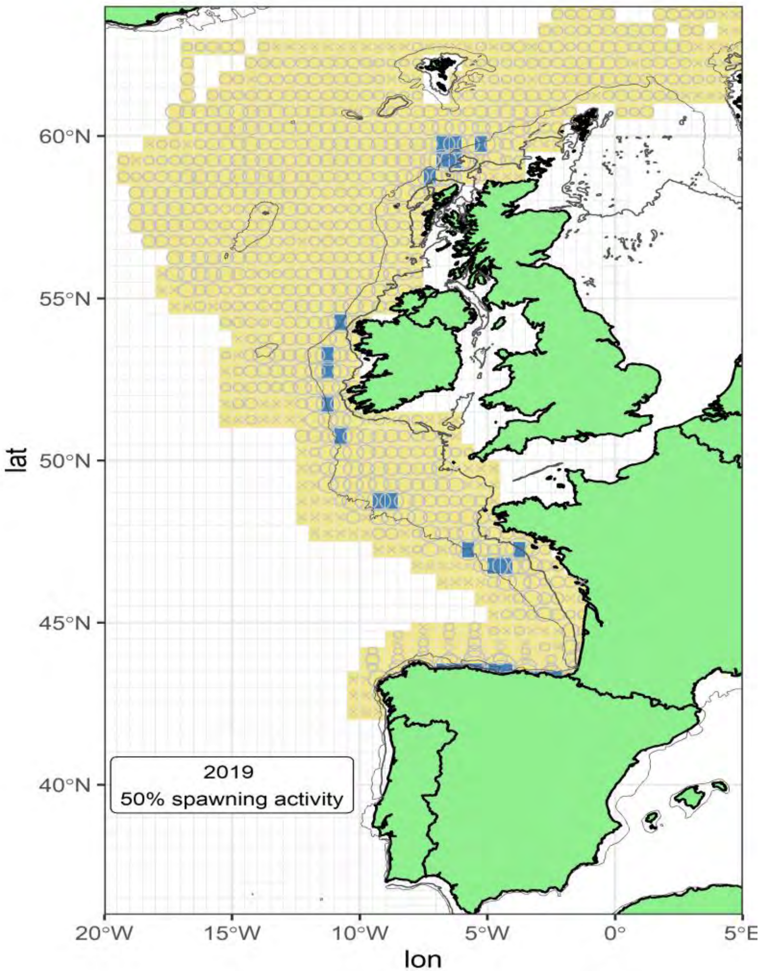
ICES, 2017. Report on the Benchmark Workshop on Widely Distributed Stocks (WKWIDE). ICES CM 2017/ACOM:36, 201pp

ICES,2018. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 28 August- 3 September 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM: 23. 488 pp. *(Annex 6, WD XVIII)*

ICES, 2019. Manual for mackerel and horse mackerel egg surveys, sampling at sea. Series of ICES Survey Protocols SISP 6. 82 pp. http://doi.org/10.17895/ices.pub.5140

ICES, 2021. ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS: outputs from 2020 meeting)





Figures 1 and 2: Mean egg production (stage 1 eggs/m2/day) by half ICES rectangle for all MEGS stations sampled in 2016 and 2019. Egg production values are square root transformed. (Crosses denote locations where sampling was undertaken but where no spawning was recorded). Area in yellow denotes the maximum geographical survey extent for the western survey area. Area/stations capturing 50% of spawning activity within that year are overlaid in blue.

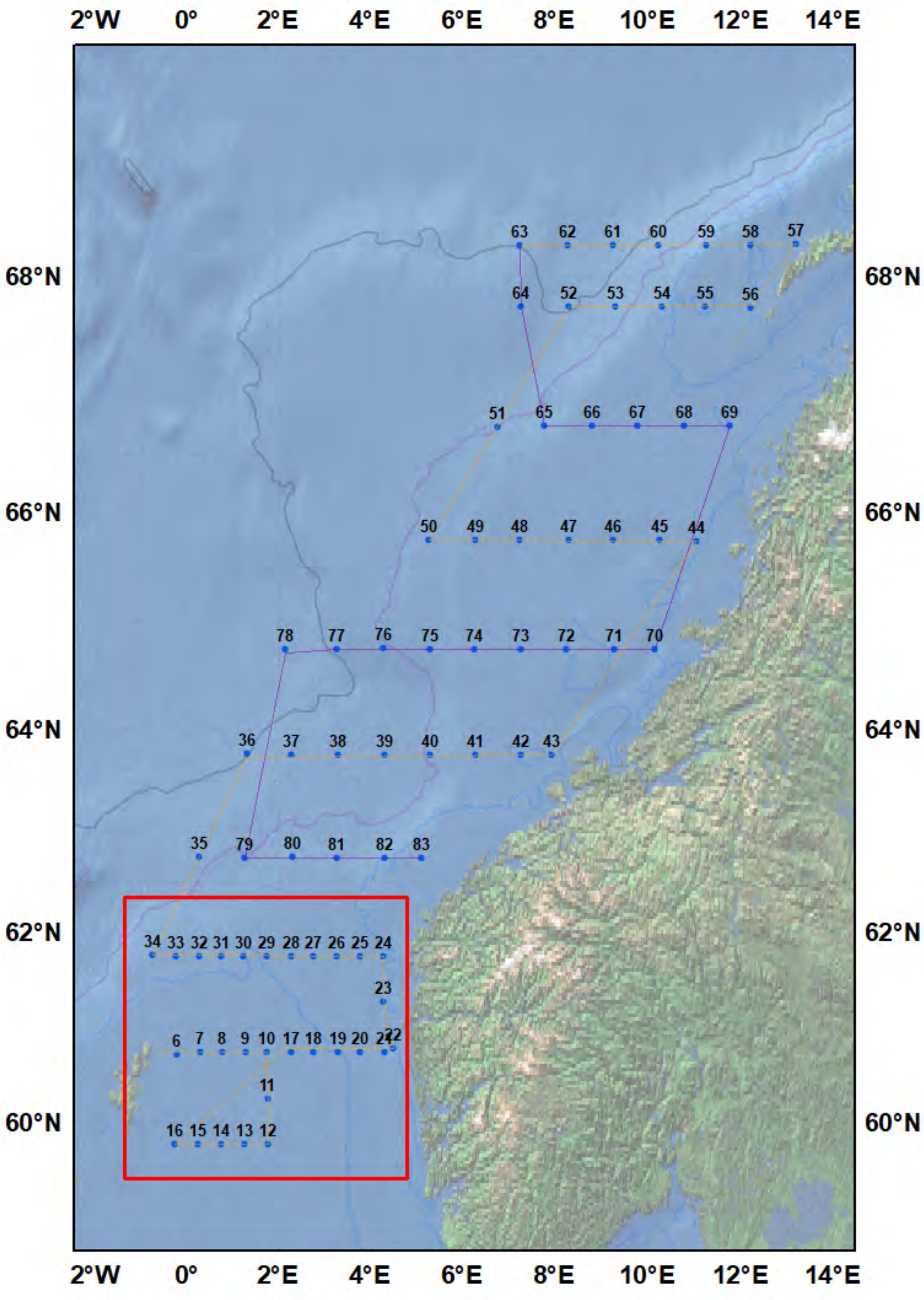
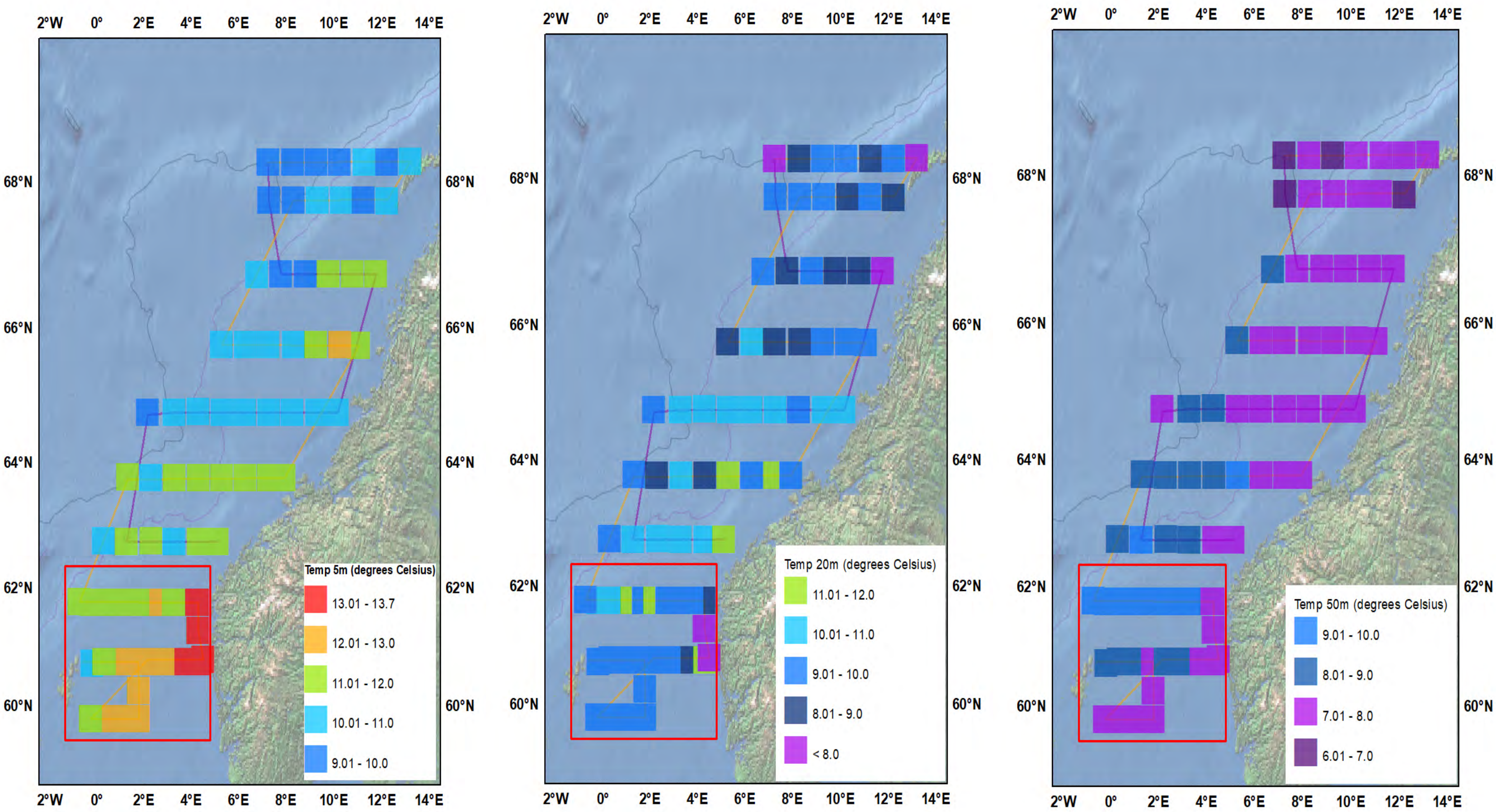


Figure 3: Survey track and stations for 0321H egg survey. Outbound track – orange and inbound track – purple. Red outline denotes 29 icthyoplankton stations undertaken south of 62N and contributing to NSMEGS. Isobaths at 200, 1000 and 2000m are also included for reference.



Figures 4 - 6: Survey 0321H temperatures recorded during Gulf VII deployments at 5m, 20m and 50m

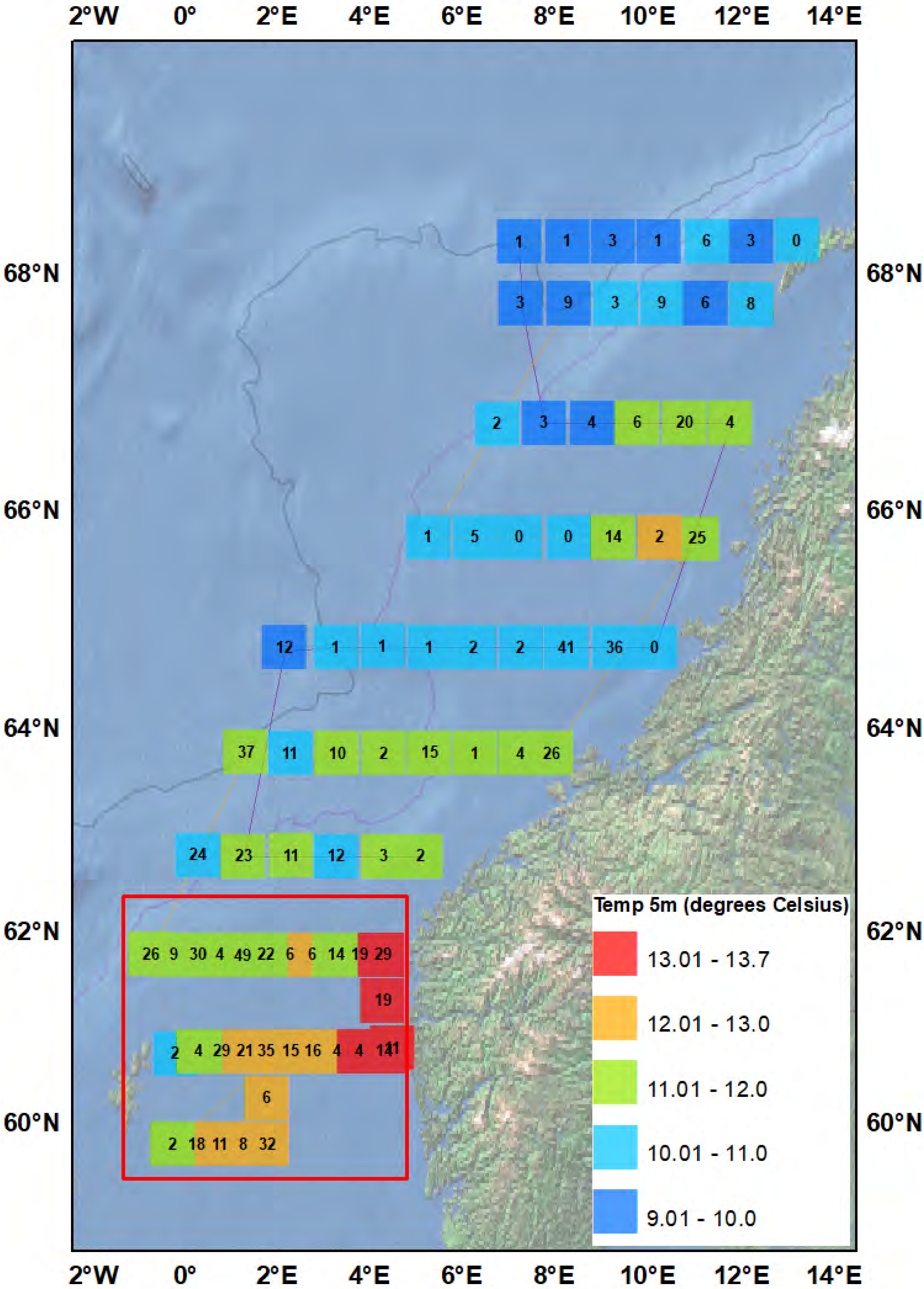


Figure 7: Mackerel stage 1 egg counts/m^2/day survey 0321H, for all stations sampled. The coloured squares represent the surface temperature in degrees Celsius at 5m depth during the icthyoplankton deployments.

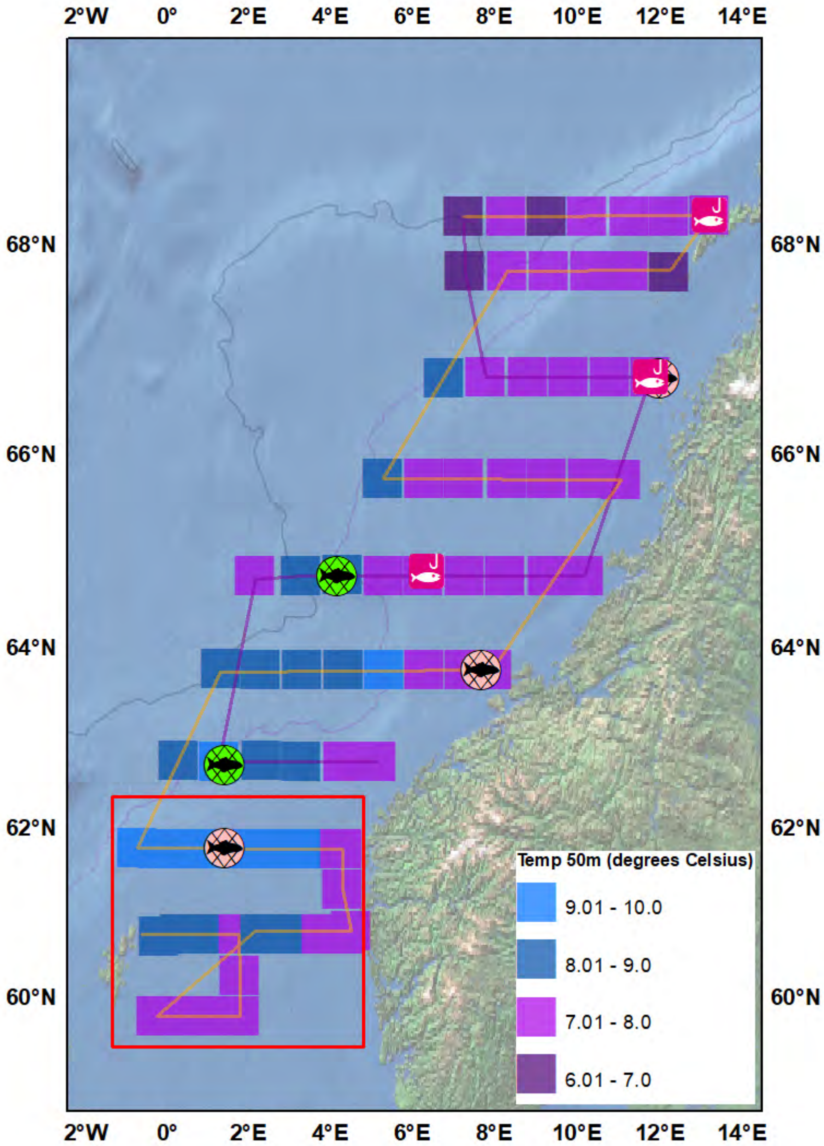
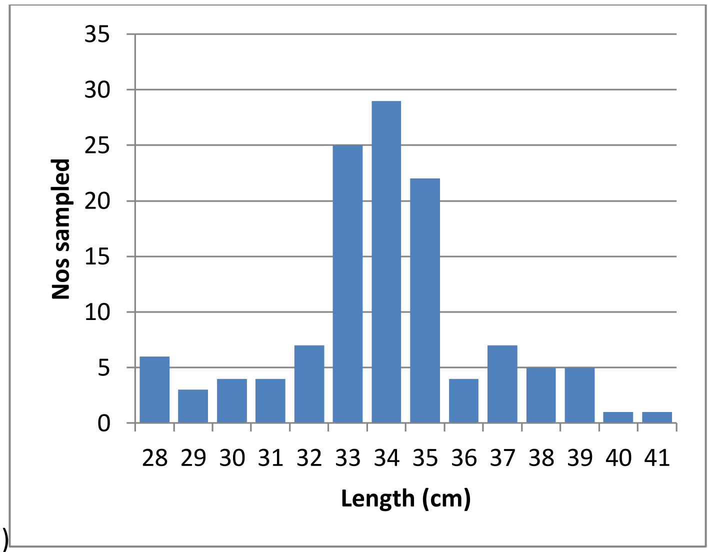


Figure 8: 0321H Trawl deployment. Red fish icons denote unsuccessful deployments, green fish icons denote deployments where mackerel were caught. Rod and line deployment locations (unsuccessful) are also presented. Temp profile at 50m is also underlaid for reference.



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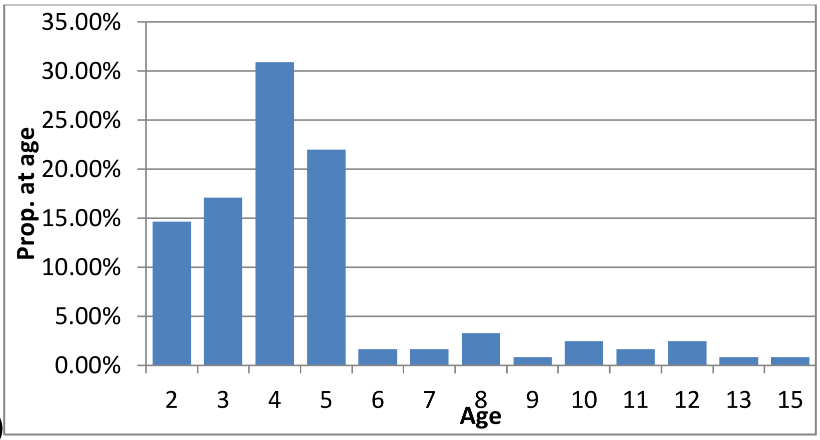

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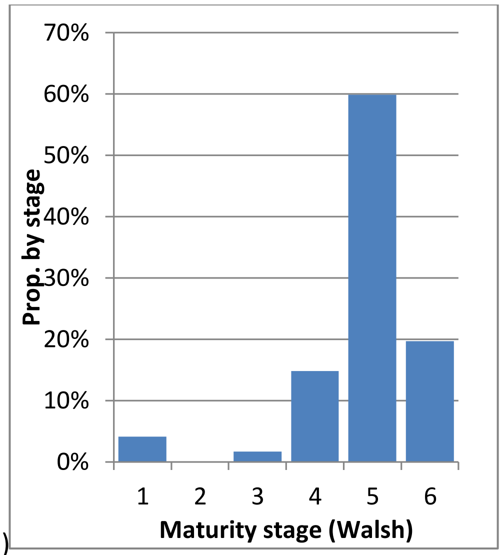

3)

Figures 9- 11: Histograms presenting summarised biological parameters of adult mackerel sampled during survey 0321H. From the top - 1) length(cms), 2) age profile by proportion of total sampled and also 3) maturity profile also as a proportion of total sampled. Combined total of 123 mackerel sampled from trawl deployments AE03/04 and AE03/05.