WORKING GROUP ON WIDELY DISTRIBUTED STOCKS (WGWIDE)

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Contents

i Executive summary

The Working Group on Widely Distributed Stocks (WGWIDE) reports on the status and considerations for management of Northeast-Atlantic mackerel, blue whiting, Western and North Sea horse mackerel, Northeast-Atlantic boarfish, Norwegian spring-spawning herring, striped red mullet (Subareas 6, 8 and Divisions 7.a-c, e-k and 9.a), and red gurnard (Subareas 3, 4, 5, 6, 7, and 8) stocks.

Northeast-Atlantic (NEA) Mackerel. This species is widely distributed throughout the ICES area and currently supports one of the most valuable European fisheries. Mackerel is fished by a variety of fleets from many countries (ranging from open boats using handlines on the Iberian coasts to large freezer trawlers and Refrigerated Sea Water (RSW) vessels in the Northern Area). The assessment methodology was modified during the 2019 inter-benchmark process. The 2019 WGWIDE assessment was an update of the benchmarked assessment incorporating a new year for the catch information, for all surveys (egg survey, IESSNS survey and recruitment index) and for the RFID tagging recapture. After a strong increase from the late 2000s to 2014, the SSB has been declining since 2015, but remains at high levels (well above MSY $B_{trigger}$), The estimated fishing mortality has been steadily declining since the mid-2000s, and is now estimated to be close to F_{MSY}. This decrease of the fishing mortality, while the stock has been sustaining high catches (consistently in excess to ICES advice) is explained by a succession of good recruitments, indicating a current high productivity for this stock.

Blue Whiting. This pelagic gadoid is widely distributed in the eastern part of the North Atlantic. The assessment this year followed the Stock Annex based the conclusions from the Inter-Benchmark Protocol of Blue Whiting (IBPBLW 2016). The method for calculating mean weight at age for the preliminary (2019) was however changed, such that the observed values were used. Previously, a three year average was used. Most of the annual catches are taken in the first half-year, which makes it possible to use preliminary catches for 2019 in the assessment. This is done to reduce the effect of potential biases from the single survey used for this assessment. The SSB of the stock is large but declining since 2018. F has been reduced in recent years, but is still above F_{MSY}. Recruitments in 2017–2019 are estimated to be low, following a period of high recruitments.

Western Horse Mackerel. This species is widely distributed throughout the Northeast Atlantic: it 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. The stock is assessed using the Stock Synthesis integrated assessment model. The 2019 assessment is an update of the benchmark assessment with the inclusion of the 2018 data. According to the assessment results, the 20154-2018 recruitment estimates are the highest observed since 2008 (and higher than the geometric mean estimated over the years 1983–2018). Fishing mortality since 2012 has been decreasing overall, dropping to low values in 2015–2018 due to lower catches and a reduced proportion of fraction of the adult population in the exploited stock; it is however currently above F_{MSY}. SSB in 2017 was estimated as the lowest in the time-series, below the limit reference point and is just above in 2018. The updated assessment shows the same trend as the previous ones, but rescales the absolute level of SSB and F over the most recent decade and, although this years' revision is smaller, this indicates that there is still considerable uncertainty associated with it. An inter-benchmark workshop occurred prior to the 2019 assessment working group: the workshop revised the biomass reference points from 911587t to 1168272t for $MSYB_{trigger}$ and 0.108 to 0.074 for F_{MSY}, hence the significant drop in advice. .

North Sea Horse Mackerel. After being benchmarked in January 2017, the CGFS and NS-IBTS survey indices were modelled with a zero-inflated model to produce a combined index. The observed trend in the last decade suggests that the stock is still at a low level in comparison with values earlier in the time-series. In 2017, the survey index showed a declining trend, and the stock remained at a low level in 2018. The result of the Length-Based Methods to estimate proxy MSY reference points for North Sea Horse Mackerel indicated that in 2018 fishing mortality was slightly above F_{MSY}.

Northeast Atlantic Boarfish. This is a small, pelagic, planktivorous, shoaling species, found at depths of 0 to 600 m. The species is widely distributed from Norway to Senegal. The directed fishery for boarfish in the NEA is a relatively new one with large catches during the early 2000s when the fishery was unregulated. Catches have reduced significantly since 2012 to the current level. Annual catch advice is provided using the data limited category 3 approach based on output from an exploratory Bayesian surplus production assessment model. The assessment model utilises catch data, an acoustic survey estimate of stock size and indices from a number of bottom-trawl surveys. The current assessment indicates that biomass peaked in 2012 at twice the historic mean before a rapid decline until 2014. Since this time the biomass level has been relatively stable.

Norwegian Spring Spawning Herring. This is one of the largest herring stocks in the world. It is highly migratory and distributed throughout large parts of the NE Atlantic. This stock was benchmarked in 2016 (WKPELA). The assessment model introduced in the benchmark (XSAM), incorporates uncertainty in the input data, and has been used to provide advice after the benchmark. The SSB on 1 January 2019 is estimated by XSAM to be above B_{pa} (3.184 million t). The stock is declining and there is an upward revision of SSB for later years in this year's assessment. The revision is, however, within the confidence limits of the model. Fishing mortality in 2018 is estimated to be below the management plan F that was used to give advice for 2018. A new management plan was implemented for the 2019 advisory year.

Striped Red Mullet in North Sea, Bay of Biscay, Southern Celtic Seas, Atlantic Iberian Waters. This stock has been considered by WGWIDE since 2016. It is a category 5 stock without information on abundance or exploitation in relation to proxy reference points and indicators, and the evaluation is based on commercial landings. A time series of biological sampling of catches is being developed, and it may be possible to produce an analytical assessment in the near future, The advice for this stock, following the ICES precautionary approach, was given in 2017 for 2018, 2019 and 2020.

Northeast-Atlantic Red Gurnard. This stock was first considered by WGWIDE in 2016, and this represents the second time the group has advised upon it. This is a category 6 stock, with large uncertainties in landings data due to poor resolution at the species level. Landings have fluctuated without trend since 2006, and discards remain significant –over 90% of catch in some cases. There remains no indication of where fishing mortality is relative to proxies and no stock indicators, and the evaluation is based on commercial landings, given the caveat that they will be incomplete. Advice for this stock is provided on the basis of the ICES precautionary approach for 2020 and 2021.

ii Expert group information

Expert group name	Working Group on Widely Distributed Stocks (WGWIDE))
Expert group cycle	Annual
Year cycle started	2019
Reporting year in cycle	1/1
Chair(s)	Guðmundur J. Óskarsson, Iceland
Meeting venue(s) and dates	28 August –3 September 2019, Santa Cruz, Tenerife, Spain, 41 participants

1 Introduction

1.1 Terms of References (ToRs)

The Working Group on Widely Distributed Stocks (WGWIDE), chaired by Guðmundur J. Óskarsson, Iceland, met at Instituto Español de Oceanografía (IEO), Santa Cruz, Tenerife, Spain28 August – 3 September 2019 to:

a) Address generic ToRs for Regional and Species Working Groups;
b) Prepare a draft plan for a scoping workshop on the management needs for Atlantic mackerel;
c) Prepare establishment of an RFID tag data preparation group for mackerel and Norwegian spring spawning herring, which shall:
   i. Carry out quality assurance of the tag-recapture data for use in stock assessment
   ii. Explore potential sources of bias in the tag-recapture data that may affect the stock assessment
   iii. Explore the trends (indexes of abundance by age and biomass) in the tag data outside stock assessment
   iv. Explore the basis for the low survival rate estimated for the tagged mackerel when scaling the data in the SAM stock assessment.

The RFID tag data preparation group will be chaired by Aril Slotte, Norway, and meet in spring on an annual basis and report to WGWIDE members no later than one month prior the WGWIDE meeting.

1.1.1 The WG work 2019 in relation to the ToRs

With respect to ToR a, WGWIDE adopted the assessments of all the eight stocks, which formed the basis for stock status and the premise for the forecasts and advice. Based on the assessments the group produced a draft advice on TAC for seven of the stocks, while a multi-annual advice from 2017 was in force for one (striped red mullet). The individual stock report sections were not reviewed in plenary due to time constraints but audited by WG members right after the meeting. The summary sheets for all stocks were reviewed and agreed upon in plenary.

In relation to ToR b, there came up a misunderstanding of what the ToR was sup-pose to address. The understanding during the meeting was that the WG should address upcoming management strategy evaluation (MSE) work on mackerel. As such, the WG discussed the pros and cons of the two requests on MSE on mackerel that ICES received in June 2019. These requests involve so called “short cut ap-proach” and “full feedback approach”. The WG decided to report on this discus-sion to ACOM in a formal letter (see Section 1.1.2 below). After the WGWIDE meet-ing this misunderstanding was discovered when it was revealed to the WG that ToR b was referring to the work of WKRRMAC (ICES 2019f). Fortunately, the WG did also discuss the outcome of the WKRRMAC during two subgroup meetings and provided comments and action points to the different future research topics in this report (section 1.12.1). It should therefore be considered as response to ToR b and not to the letter to ACOM as indicated in its heading (section 1.1.2).

The WG tackled the ToR c on a sub-group meeting during WGWIDE. The RFID tagging project was introduced by the chair of this new “survey” group. If it will have the status as “survey group” or “Working group” within ICES is not certain yet. The needs, tasks and expected outcomes of these new group were discussed in relation to for example expertise participation, data and funding. Previously outlined ToRs for this group were considered appropriate and adopted by the WG. This "survey" group, chaired by Aril Slotte, Norway, will meet in April 2020 for the first time and report to WGWIDE 2020.

1.1.2 A letter to ACOM regarding upcoming MSE work on mackerel

During WGWIDE 2019 the requests received by ICES concerning MSE for NEA Mackerel were discussed, under meeting ToR b (prepare a draft plan for a scoping workshop on the management needs for Atlantic mackerel).

WGWIDE acknowledge that this involves work on two requests to ICES received from The European Union, Norway and the Faroe Islands on the evaluation of long-term management strategies for Northeast Atlantic Mackerel. One request involves the so called "short cut approach" (A) and the other the "full feedback approach" (B). WGWIDE was informed that ACOM had rejected request A for the time being for a number of reasons including the tight time constraint. However, WGWIDE considers that addressing request A might still be feasible in the coming year as detailed below, while some concerns were raised regarding request B. WGWIDE discussed both resources to handle the requests and then concerns about usefulness and reliability of these two different MSE approaches.

Concerns with the MSE requests and ACOM preference for full feedback approach

Based on the experiences of some WGWIDE members familiar with the full-feedback MSE undertaken for North Sea stocks, WGWIDE expressed concerns with regard to the implementation of this approach for conducting an MSE of the mackerel stock. While the full-feedback method can be very useful for testing specific aspects of the assessment process (*e.g.* the sensitivity of the assessment model to the types, amount and quality of the input data), it is not necessarily the optimal approach for testing the effect of different harvest control rules (HCRs). In order to conduct a full-feedback approach it is necessary to focus much more on the technical aspects of the simulations (how to generate input to the stock assessments) than with the short-cut approach. Given the extensive computing requirements this leads to the risk that there is insufficient time for a broad exploration of the sensitivity to *e.g.* the number of iterations or different forms and parameterizations of harvest control rules.

Short-cut methods

It is recognized that short-cut methods also suffer from disadvantages, notably from estimating realistic levels of uncertainty and patterns in bias, although these disadvantages could be circumvented by allowing for standard tools to be developed for estimating such processes (similar to parameterizing for *EqSim*) and by combining hind-casts (*e.g.* as presented for blue whiting at WGWIDE 2019) with forward looking MSEs. In the present situation, where the clients of the ICES advice have been well accustomed to the evaluation of MSE through short-cut methods, WGWIDE considers it important to develop an advice that is based on that approach, as a minimum. An important benefit is that short-cut methods allow for an easier exploration and explanation of the results that are presented.

A short cut method that has already been applied for NEA Mackerel MSE in 2017 is the so called Muppet at MFRI in Iceland (contact person Höskuldur Björnsson). This tool could be reapplied with the current request.

Full-feedback methods

When developing a full-feedback approach for mackerel, an important challenge will be to generate input data for the assessment that is sufficiently well characterized. In the current SAM assessment there are a number of process that are not well understood, particularly in relation to how the tagging data work within the SAM model and simulating the tagging input data for the assessment contained within the full feedback simulations may be challenging. In addition, the handling of observation variances and process error are specific challenges for SAM models. Handling those in the context of a full-feedback model can be expected to provide useful insights into the working of the SAM model, but would not necessarily help in the understanding of the effects of different harvest control rules. Two different tools have been proposed to be developed in dealing with the full feedback approach: (1) FLR at the Wageningen Marine Research in the Netherlands (contact person Thomas Brunel) and (2) FLBEIA at AZTI in Spain (contact person Sonia Sanchez). Both options require considerable development work on the various challenges involved in such a request and are dependent on securing funding.

After having prepared this letter, a notice was received by a WGWIDE member (Thomas Brunel) that was, different from other members, more in favour of using the full feedback approach. To reflect on the whole discussion, his arguments are found as **annex** to this letter.

WGWIDE request that these concerns will be addressed by ACOM prior to committing to undertake either of these requests. Further preparation work will depend on the decisions made on this by ACOM.

Sincerely,

WGWIDE members

Annex to the WGWIDE letter reflecting Thomas Brunel thoughts:

The letter indicates that the group has a clear preference for the short-cut approach over the full feedback approach. The argument for the short cut is that it is simpler to implement, easier to understand, and works faster. The full-feedback is presented as overly technical and time consuming. On this last point, I agree, although I think this is not a major problem, since we have enough time to carry out the work (unlike the North Sea MSEs, for which time constrains have made computing time a big problem).

There are different challenges in both approaches, but I personally find the challenge in the full-feedback approach more straightforward to tackle :

- In the short cut, the challenge is the definition of the errors that will be applied each year to the operating model (OM) to mimic the assessment. I know of 2 ways to define these errors (see WKMSE2 p25) :
    - 1) run analytical retrospective of the current assessment and use for each year/iteration in the simulation the errors taken from one of the retro peels. For the mackerel, analytical retrospectives are meaningless, since the RFID series is currently only 5 years long.
    - 2) use the assessment standard deviations on N@age + an autocorrelated term, which variance and autocorrelation parameters are manually tuned/calibrated so that the final error on SSB and F_{bar} has a desired CV and autocorrelation (e.g. as observed in the historical retro). That is what we did in the 2014 MSE and I think something similar was done in 2017 as well. Reading both reports, I feel that the choice of what is that desired level of uncertainty and autocorrelation is not based on very solid basis, and the decision is basically based on what the modeller "feels" like a right value.
- In the full feedback the crucial part is in the definition of the observation model, that will generate the input data to SAM from the OM. The WKMSE2 gives ample instructions on how that can be done, and that does not represent a particular difficulty for the mackerel. Even for the tags, the same approach as for the surveys can be used. I

think this “technical aspect” is easier to understand and to implement that “technical aspects” related to generating noise for the shortcut approach.

The letter refers to the handling of the process error in the full feedback approach as major a problem. I think that with the full feedback, we have in the MSE a model that has potentially the same issue with its process error as the current assessment, and if we define an appropriate observation model, the problems we have currently with the process error (being large and autocorrelated) will be reproduced in the same way in future assessments. In the shortcut approach, however, it is unclear how we should take the process error into account.

For me the inconvenient is that we would simulate in the long term using the same observation errors as currently, which could lead us in situations where the input data become so bad (if there is a strong autocorrelation in the error, as for the egg survey), that in real life we would not use them. Or similarly, runs in which the data becomes so bad that the model wouldn’t fit. But we can figure out ways around such problems. There are in the package FLSAM, function to run SAM in MSEs that deal with such problems.

So, basically, I do have a slight preference for the full feedback approach. Off course, it will all depend on who volunteers to do the work. I guess if Muppet is used, there is no choice. If another tools is built for the occasion (maybe FLR ... and maybe FLBEIA...combined with FLSAM) then I think we should consider doing the full feedback approach.

1.2 Participants at the meeting

WGWIDE 2018 was attended by 38 delegates from the Netherlands, Ireland, Spain, Norway, Germany, Portugal, Iceland, UK (England and Scotland), Faroe Islands, France, Denmark, Greenland, Russia and Sweden. Three other fisheries scientists participated by correspondence. The full list of participants, which are all authors of this report, is in Annex 1.

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

1.3 Overview of stocks within the WG

Currently there are eight widely distributed and highly migratory stocks assessed in the WG with different methods, as indicted in the table below:

Stock	Ices code	Category	Assessment method
Boarfish	Boc.27.6-8	3	Fproxy multiplier/ DLS category 3
Red gurnard	Gur.27.3-8	6	Qualitative evaluation
Norwegian spring-sp. herring	Her.27.1-24a514a	1	XSAM
Western horse mackerel	Hom.27.2a4a5b6a7a-ce-k8	1	Stock Synthesis (SS)
North Sea horse mackerel	Hom.27.3a4bc7d	3	Fproxy multiplier/ DLS category 3.1.0
NE-Atlantic mackerel	Mac.27.nea	1	SAM
Striped red mullet	Mur.27.67a-ce-k89a	5	Qualitative evaluation
Blue whiting	Whb.27.1-91214	1	SAM

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 sections of this report.

Generally, the amount and quality of available data to the WG have improved in the most recent years. This applies especially to the data limited stocks of red gurnards and striped red mullet, which will allow for benchmark assessments in the near future. Some short comings in data accessibility remains though and as previously highlighted, to facilitate age-structured assessment, samples should be obtained from all countries with catches of the relevant species.

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.

At WKRRMAC (ICES. 2019f) a roadmap for the delivery of future research needs for the management of fisheries on mackerel was addressed (see section 1.12.1 below). The outcome included many important and relevant fields of research but seemingly not aspects related to accuracy and quality assurance of catch levels data. The WG highlights the importance of reliable catch data, including discards, for the analytical stock assessments. Development of any quality assurance procedure or methods to evaluate these data, is of major importance and are encouraged. This applies to all the stocks assessed within WGWIDE.

A specific issue on the catch data have been mentioned several times by the WG. It is on species allocation of catches of red gurnard. Before 1977, red gurnard was not specifically reported. Still, gurnards are not always reported by species, but rather as mixed gurnards. This makes interpretations of the records of official landings difficult and needs to be improved.

1.4.3 Discards

From 2015 onwards a landing obligation for European Union fisheries was introduced for fisheries directed on small pelagic fish including mackerel, horse mackerel, blue whiting and herring. However, as the landing obligation was introduced stepwise by fisheries at present discarding of small pelagic species can still legally occur in other fisheries. From 2019 onwards the landings obligation is generally effective. A general discard ban is already in place for Norwegian, Faroese and Icelandic fisheries.

Historically discarding in pelagic fisheries was 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.

Historically, 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 & van Helmond 2007, Ulleweit & Panten 2007, Borges *et al.* 2008, van Helmond *et al.* 2009, 2010, 2011, van Overzee *et al.* 2013, Ulleweit *et al.* 2016). 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

A Workshop on Age Reading of Atlantic mackerel otoliths (WKARMAC2) took place in October 2018 with 23 participants from 14 laboratories (ICES 2019c).

The workshop achieved quite a lot in terms of ironing out, through on-screen discussion of difficult and/or old otoliths and calibration, some of the differences in age interpretation between readers. Ageing guidelines were revised and the modifications agreed between the participants. The participants agreed to employ the revised ageing guidelines in their age estimations.

The overall result of the workshop exercise shows an improvement in the agreement between readers (66.8% agreement, 31.4% CV), and especially Expert readers (73.2% agreement, 16.4% CV), regarding the exercise carried out before the workshop, which shows the usefulness of the on-screen discussion of difficult otoliths previous to the workshop exercise. However, the agreement between readers for otoliths with older ages (from age 6) continues to be very low (40-58% all readers; 53-71% Experts).

Two exchanges of otoliths took place, one previous to the workshop and another during the workshop. They were performed via SmartDots, the web application developed by ICES to facilitate the setup of Exchanges, Workshops and Training. In addition, a Small exchange with Norwegian otoliths from tag-recaptured experiments was carried out during the workshop with the results being discussed after completion. Images of these otoliths were also discussed during the workshop, which proved to be very interesting due to the importance of these otoliths of known age.

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 Small exchange with Norwegian otoliths from the tag-recapture experiments will also be included in the reference otolith collection.

At the NEA mackerel Inter-benchmark in 2019, there were concerns related to this age reading quality described above, directly applicable to the quality of the catch-at-age data and potentially survey data. Preliminary analyses were made to evaluate the impacts of these errors, while those results were not applicable to the stock level. WGWIDE stretch the need for investigating impacts of ageing error on stock assessments further. This includes development or agreement on some standardized sensitivity analyses for this purpose, which would be applicable to the different stocks.

1.4.4.2 Horse mackerel

A workshop on age reading of *Trachurus*, *T. mediterraneus* and *T. picturatus* was carried out in November 2019 with fifteen age readers from nine 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, this group reached an agreement on defining an ageing guideline and a reference collection presented in this report and the aim is to employ these tools for all laboratories.

1.4.4.3 Norwegian Spring-spawning Herring

A workshop on age reading of Norwegian Spring-spawning herring was carried out in November 2015. The meeting was attended by 12 experts from four countries. The workshop was a request from WGWIDE to WGBIOP to review any technical problems regarding age-reading of Norwegian spring-spawning herring between Norway, Denmark, Iceland and the Faroe Islands. This workshop was initiated after the IESNS survey in 2015, because there were concerns regarding dissimilarities between the age distributions from the different nations.

The workshop concluded that the different ages obtained from scale and otolith readings could be due to a number of issues relating to identification of the first winter ring and age interpretation of older fish, additionally confounded by stock mixing issues. Final conclusions could not be reached based on the samples from this workshop. With regards to the issue with sampling methods, WKPELA in March 2016 concluded that in general the biological samples are representative with regards to length distribution of NSS herring in the IESNS survey.

In 2016 an otolith- and scale exchange took place, aiming at a workshop in 2017. Unfortunately, the workshop was postponed, mainly because there were quite large discrepancies among readers, and the organisers were sceptical that a workshop would resolve the discrepancies without further preparations (e.g. other statistical analyses of the exchange results).

1.4.4.4 Blue Whiting

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

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

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

The reoccurring problems among age readers were identification of the position of the first annual growth ring, false rings and interpretation of the edge. In order to outcome those problems, age validations studies on blue whiting otoliths were further recommended and should be conducted until the next age reading workshop. The next workshop on the age estimation of blue whiting will be carried out in June 2021. An exchange for age reading inter-calibration was in preparation and is planning to start until the end of 2019. An age validation study on this species is planned to going on together with the preparation of the 2021 age reading workshop.

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 Scheme has been realized, which was the second exercise for the striped red mullet. For details see section 12.7.

1.4.4.7 Red gurnard

Age data were available for red gurnards from the EVHOE and IGFS surveys. Understanding of this stock would be improved by reading otoliths from other surveys in the assessment area (e.g. NS-IBTS, SCO-WCS, CGFS) which contribute to perceptions of red gurnard stock statuvs in terms of their cpue series.

1.5 Quality Control and Data Archiving

1.5.1 Current methods of compiling fisheries assessment data

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

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

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

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

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

1.5.2 Quality of the Input data

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

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

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

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

There exist gaps in some dataseries, 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.

1.5.3 Stock data problems relevant to data collections

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. 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 should be monitored and sampled for discard 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

Stock	Data Problem	How to be addressed in	By who
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
Boarfish	Boarfish only measured to the 1 cm on the IBTS by some countries	Following the MoU between ICES and EU, boarfish (*Capros aper*) was included into WGWIDE. Boarfish should be measured to the 0.5 cm on the IBTS due to the small length range and the relatively high ages observed.	ICES IBTSWG
Horse Mackerel – Western Stock	Missing sampling data for the northern distribution area (27.2a and 4.a in Quarter 3 and 4	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	Absence of length distribution in the discard component	Sampling of length distribution of discarded individuals	National institutes
Horse Mackerel – North Sea Stock	Very 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 (considerably lower than the 1 sample/1000 tonnes recommended for this stock by EU)	Sampling effort should be increased by nations with little or no samples.	National laboratories; RCG NS&EA
Red gurnard	Discard and slippage information	Discard rates for this species can be very high (up to 100% of catch at a trip level). Alternative data sources and methods for estimation (e.g. CCTV systems) should be investigated.	National laboratories
Red gurnard	Stock area	Red gurnard is found all along the Iberian continental shelf. There are no records of catches of red gurnards in SA5, and this area could be removed from the data call.	
Northeast Atlantic Blue whiting	Submission of data	Data submissions must include all the data outlined in the data call and be submitted by the deadline. Should the data submitter be unavailable after the data has been submitted (e.g. vacation) an alternative contact should be available who can be contacted in the event of any queries.	National laboratories

1.5.4 Quality control of data and assessments, auditing

As a quality control of the data and the assessment, each participant at the WGWIDE meeting was appointed to auditing a single stock. The auditing process is according to ICES guidelines and involves filling out a specific audit template as a part of the process. Two to three persons audited each stock, where one got the task to verify consistency in input data, the assessment results in the report/advice sheet and the assessment runs (numbers etc.), while 1-2 read thoroughly through the advice sheet and the report as described in the audit template.

1.6 Comment on update and benchmark assessments

Update assessments were presented to the WG for all the eight stocks in the group. Western and North Sea horse mackerel were assessed on basis of benchmark that took place in January 2017 (ICES 2017a) and NEA mackerel on inter-benchmark that took place in 2019 (ICES 2019b). In same way, blue whiting and Norwegian spring-spawning herring were assessed on basis of the latest benchmarks (ICES 2016b and ICES 2016f, respectively). One deviation was made from the (inter-) benchmark assessment, the stock weights in the assessment year for blue whiting was determined from preliminary catch data instead of applying three years' average (see section 2). This was considered to be improvements by the WG. The other three stocks addressed by the WG have not been benchmarked recently but were still assessed by the WG.

1.7 Latest benchmark results

None of the eight fish stocks within the WG have been taken to benchmark assessment since presented in the last year's report. Inter-benchmark assessments were conducted in 2019 for NEA mackerel (IBPNEAMAC) and western horse mackerel (IBPWHM).

The main task of IBPNEAMAC (ICES. 2019d) was to investigate the stock assessment model configuration, with a specific focus on the influence of the tagging data on the assessment. After thorough review of the data and analyses the group made a number of decisions with regard to the data that should be included in the assessment model and the statistical approach to model these data. The final accepted assessment from this inter-benchmark, led to a significant upward revision in the estimates of SSB, a downwards revision of the estimates of F in recent years, and a change in the pattern of estimated recruitment in recent years. There were also raised concerns related to the age reading quality, directly applicable to the quality of the catch-at-age data and potentially survey data on basis of new information from WKARMAC2 (ICES. 2019c). The impact of ageing error on the perception of the stock turned out to be minimal and was therefore not considered an issue for this inter-benchmark, although recommendations were made to improve in this field.

The work of IBPWHM (ICES. 2019e) was focussed on reviewing and updating (if necessary) the MSY and PA reference points for Western Horse Mackerel. An additional ToR covered exploratory work into the development of an alternative assessment method.

Retrospective bias in the assessment implemented at the benchmark of 2017 arose during the subsequent update assessments of 2017 and 2018, leading to inappropriate management advice when combined with the reference points estimated during the benchmark exercise, principally because of an inappropriate basis for the B_{lim} reference point. The interbenchmark conducted a number of *EqSim* analyses for a number of combinations of candidate B_{lim} values, using the full SRR time series or a subset of more contemporary data and based on 3 alternative assessment outputs (the 2017 benchmark and the 2017 and 2018 update assessments). Consideration of 3 separate assessments allowed the benchmark to explore the sensitivity of the reference point estimates to the retrospective bias issue. The rationale behind using a subset of the data was to explore the effect of excluding the large 1982 year-class. Candidates for B_{pa} or B_{lim} included the B_{loss}, and SSB in either 2001 (associated with a large recruitment) or 2003 (the minimum SSB observed during the stable part of the assessment output).

There is no evidence of a stock-recruit relationship or a stable proportion of alternative functional forms, with variability between time periods, assessments and sensitivity to individual data points. As a result, a segmented regression with a breakpoint constrained at B_{lim} was considered the most appropriate parameterisation of recruitment. It was also concluded that the 1982 year-class and also its effect during the years following its recruitment to the fishery should be discounted given the length of time since this observation and the lack of a comparable recruitment since. Data since 1995 is considered to be more likely reflective of the near future recruitment regime. The benchmark concluded on a B_{lim} value derived from setting B_{pa} (/1.4) to the SSB in 2003 from the most recent update assessment (2018) with B_{loss} considered inappropriate due to retrospective revision. Moreover, 2003 was considered more appropriate than 2001 since the rationale for 2001 would be its association with a strong year class. Given the weak support for a relationship between stock and recruitment this was considered inappropriate. MSY reference points were estimated using the *EqSim* software. Sensitivity to the default settings with regard to the number of years for the fishery selection and biological vectors, recruitment autocorrelation and trimming of extreme recruitments was investigates and found to be minimal.

1.8 Planning future benchmarks

While five of the major stocks within the group has been benchmarked recently or gone through an inter-benchmark procedure (2016-2019), boarfish, red gurnard and striped red mullet have not been benchmarked yet at all, and there is a need for benchmark assessments on those. This has been mentioned before for boarfish, while a recent more availability on data for red gurnard and striped red mullet makes them also candidates for benchmark. The WG have requested benchmarks on these in 2021.

1.9 Special Requests to ICES regarding stocks within WGWIDE

Three requests have been directed to WGWIDE since the WGWIDE 2018 meeting took place, (1) on the long-term management strategies on Northeast Atlantic Mackerel (short cut approach), (2) on the long-term management strategies on Northeast Atlantic Mackerel (full feedback approach), and (3) on assessing the risks of limiting the TAC for Boarfish to areas 6 and 7.

ICES considered that the time frame given for dealing with the short cut approach MSE for the mackerel (section 1.9.1) was too short and the advice for 2020 was therefore based on MSY approach. The full feedback approach MSE (section 1.9.2) will be addressed by a specific WG in the winter 2019/20. As a part of it, a draft plan for a scoping workshop on the management needs for Atlantic mackerel was prepared at WGWIDE 2019 (ToR B of WGWIDE). The request on the TAC area limitation of boarfish (section 1.9.3) is addressed in this report in Annex 7.

1.9.1 Request to ICES on Advise on the long-term management strategies on Northeast Atlantic Mackerel (short cut approach), dated 4 June 2019

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

In order to revise the long-term management strategy for mackerel in the North Atlantic, ICES is requested to evaluate the following harvest control rule:

ICES is requested to update all Tables 2-10 as provided in its response to the EU, Norway and Faroe Islands request to ICES to evaluate a multi-annual management strategy for mackerel in the North East Atlantic (ICES 2017), using:
• A range of $B_{trigger}$ from two to five million tonnes with an appropriate range of target Fs, including the combination of $B_{trigger}$= 2.5Mt and F_{target} = 0.23(MSY values).
• A harvest control rule with a fishing mortality equal to the target F when SSB is at or above $B_{trigger}$.
• In the case that the SSB is forecast to be less than $B_{trigger}$ at spawning time in the year for which the TAC is to be set, the TAC shall be fixed consistently with a fishing mortality that is given by: $F = F_{target}*SSB/B_{trigger}$.

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

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

Evaluation and performance criteria
Each alternative shall be assessed in relation to how it performs in the short term (2020-2024), medium term (2025-2034) and long term (2035-2054) in relation to:
• Average SSB
• Average yield
• Indicator for year to year variability in SSB and yield
• Risk of SSB falling below Blim

Evaluation of the management strategies shall be simulated with appropriate assessment uncertainty representing the present assessment model and input data. ICES is invited to use the values established by WKMSYREF4 (ICES 2017) as default if it is not possible to estimate present assessment uncertainty for NEA mackerel.

Deadline for ICES
The special request on the short cut approach should be finalized by ICES in due time before the ICES WGWIDE meeting starting 28th of August 2019 and Coastal States Negotiations on NEA mackerel in October 2019.

References:
ICES, 2017. Report of the Workshop to consider FMSY ranges for stocks in ICES categories 1 and 2 in Western Waters (WKMSYREF4), 13–16 October 2015, Brest, France.

ICES CM 2015/ACOM:58. 187 pp

ICES, 2017. EU, Norway, and the Faroe Islands request concerning long-term management strategy for mackerel in the Northeast Atlantic. ICES Special Request Advice. http://ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu-fo-no.2017.19.pdf

1.9.2 Request to ICES on the long-term management strategies on Northeast Atlantic Mackerel (full feedback approach), dated 4 June 2019

Request to ICES:

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

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

- A range of $B_{trigger}$ from two to five million tonnes with an appropriate range of target Fs
- A harvest control rule with a fishing mortality equal to the target F when SSB is at or above $B_{trigger}$.
- In the case that the SSB is forecast to be less than $B_{trigger}$ at spawning time in the year for which the TAC is to be set, the TAC shall be fixed consistently with a fishing mortality that is given by: $F = F_{target}*SSB/B_{trigger}$

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

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

Evaluation and performance criteria

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

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

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

A. Investigating alternative plausible recruitment dynamics and scenarios, *B.* *Alternative natural mortality assumptions,*

C. *The potential impact of density dependent growth.*

Deadline for ICES

The special request on the full feedback approach should be finalized by ICES in due time before the ICES WGWIDE meeting in August 2020 and Coastal States Negotiations on NEA mackerel in October 2020.

References:

ICES, 2017. EU, Norway, and the Faroe Islands request concerning long-term management strategy for mackerel in the Northeast Atlantic. ICES Special Request Advice. http://ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu-fo-no.2017.19.pdf

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

1.9.3 Request to ICES for assessing the risk on sustainable management of limiting the TAC for Boarfish to areas 6 and 7

Details of the request

ICES is requested to analyse for Boarfish in subarea 8b and 8c (TAC currently covering subareas 6, 7 and 8) the role of the Total Allowable Catch instrument. It is asked to assess the risks of limiting the TAC for Boarfish to areas 6 and 7 in light of the requirement to ensure that the stock concerned is exploited sustainably in the short and medium term.

ICES is further requested to assess the potential contribution of the application of other conservation tools in absence of TACs for Boarfish in subarea 8b and 8c to the requirement that the stocks concerned are managed in a sustainable manner.

ICES asked this request to be addressed by answering the following series of six questions:

1. Was the TAC restrictive in the past?
2. Is there a targeted fishery for the stock or are the species mainly discarded?
3. Is the stock of large economic importance or are the species of high value?
4. How are the most important fisheries for the stock managed?
5. What are the fishing effort and stock trends over time?
6. What maximum effort of the main fleets can be expected under management based on FMSY (ranges) for the target stocks, and has the stock experienced similar levels of fishing effort before?

A concluding section is provided.
Upon clarification with DGMARE: It is asked to assess the risks of limiting the TAC for Boarfish to areas 6, 7 and 8a and d.

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

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

Analytical (category 1) type of assessments are available for the four main 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 fluctuations in the catches of the four stocks since 1988 are shown in Figure 1.10.1.

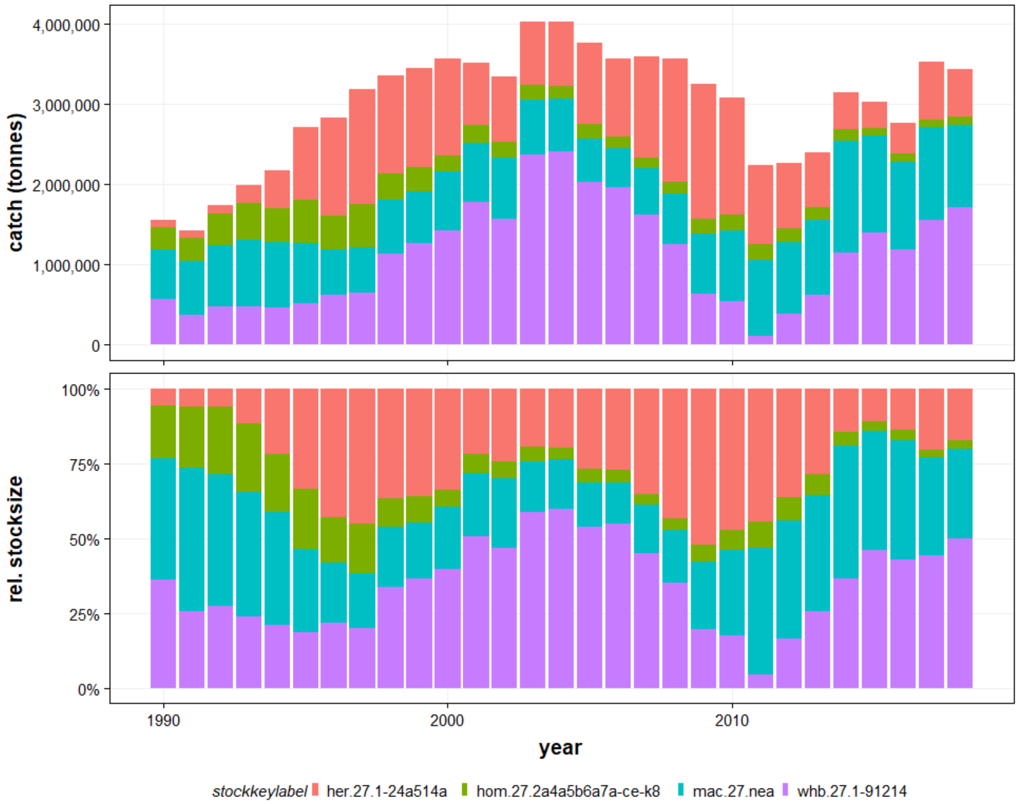

Figure 1.10.1: Catch of mackerel, western horse mackerel, blue whiting and Norwegian spring-spawning herring

The trends in SSB of the four stocks are shown in Figure 1.10.2, both in absolute biomass (tonnes) and in relative proportions. At present, pelagic biomass of these species has been fluctuating around 15 million tonnes. The contributions of Norwegian Spring-spawning herring and Western horse mackerel has decreased in recent year while Northeast Atlantic mackerel and Blue whiting has increased.

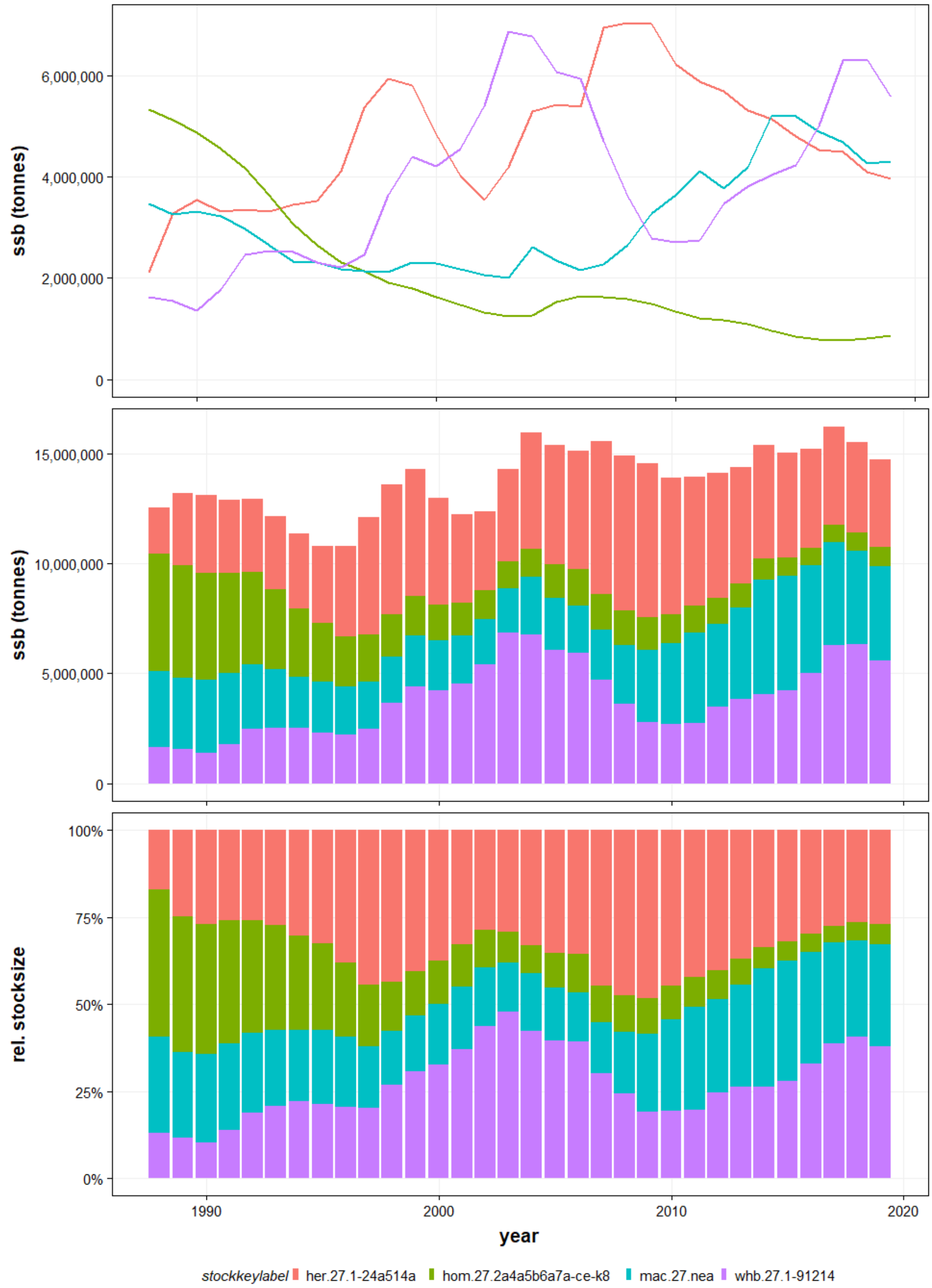

Figure 1.10.2: SSB of mackerel, western horse mackerel, blue whiting and Norwegian spring-spawning herring

An overview of the key variables for each of the stocks (Fishing pressure (F), recruitment (R) and Spawning-stock biomass (SSB)) is shown in Figure 1.10.3. From these comparisons it can be concluded that the fishing mortality of mackerel and blue whiting has generally been higher than the fishing mortality of horse mackerel and herring. Recruitment levels of blue whiting and herring are on a comparable scale and substantially higher and horse mackerel (except for the 1982-year class) and mackerel. Biomass trends of the different stocks are somewhat on the same level but show very different tendencies.

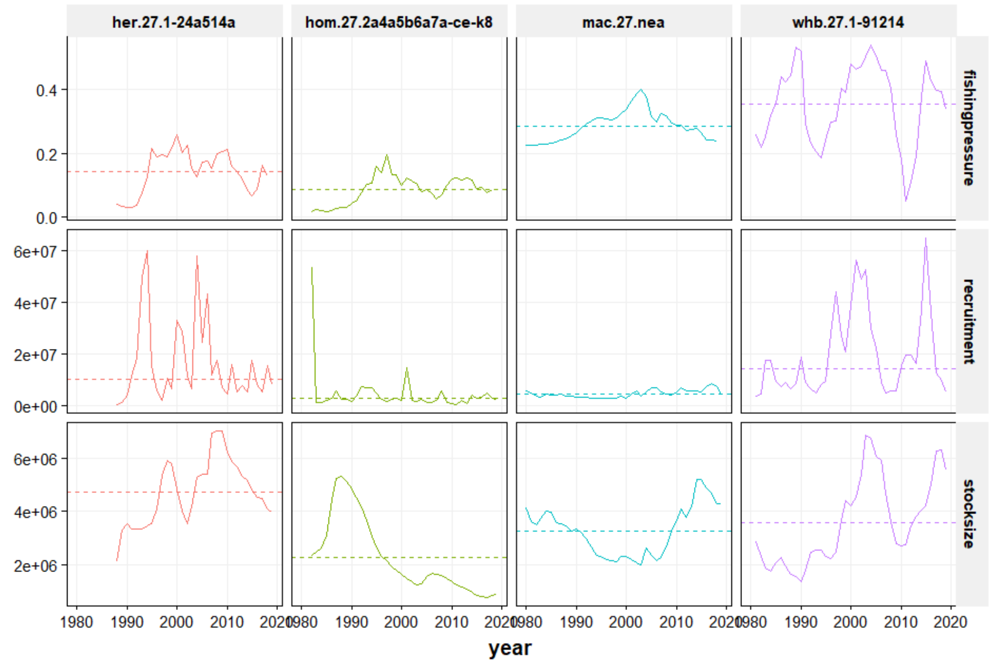

Figure 1.10.3: SSB of mackerel, western horse mackerel, blue whiting and Norwegian spring-spawning herring. Dotted lines indicate the mean of the time-series.

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. 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 sections by stock, the catch by rectangle has been presented by quarter for a single year. In this overview, WGWIDE has now collated all the catch by rectangle data that is available for herring, blue whiting, mackerel and horse mackerel. For horse mackerel and mackerel, a long time series is available, starting in 2001 (HOM) and 1998 (MAC). The time series for herring and blue whiting are shorter (starting in 2011) although additional information could still be derived from earlier WG reports.

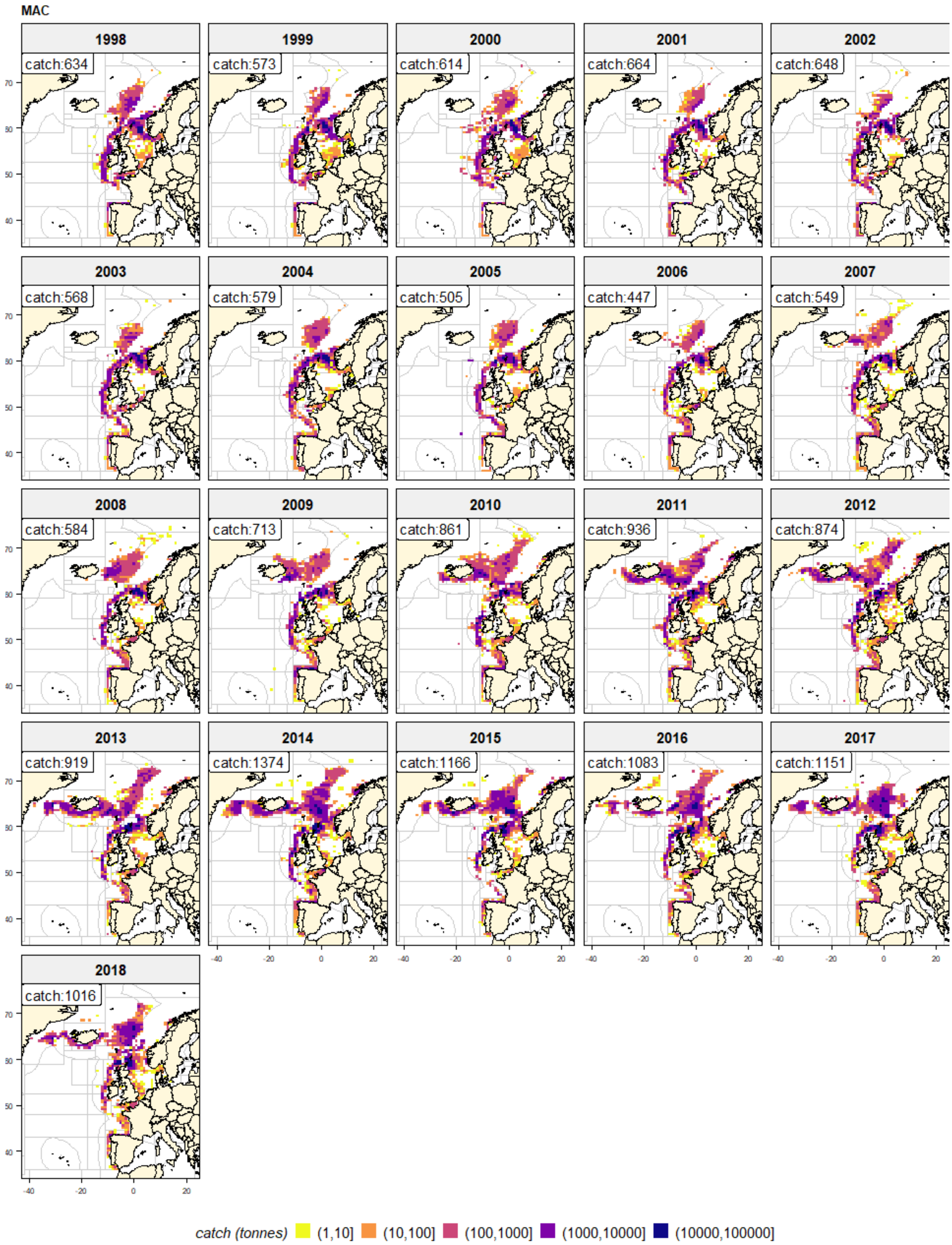

Figure 1.10.4: Catch of mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

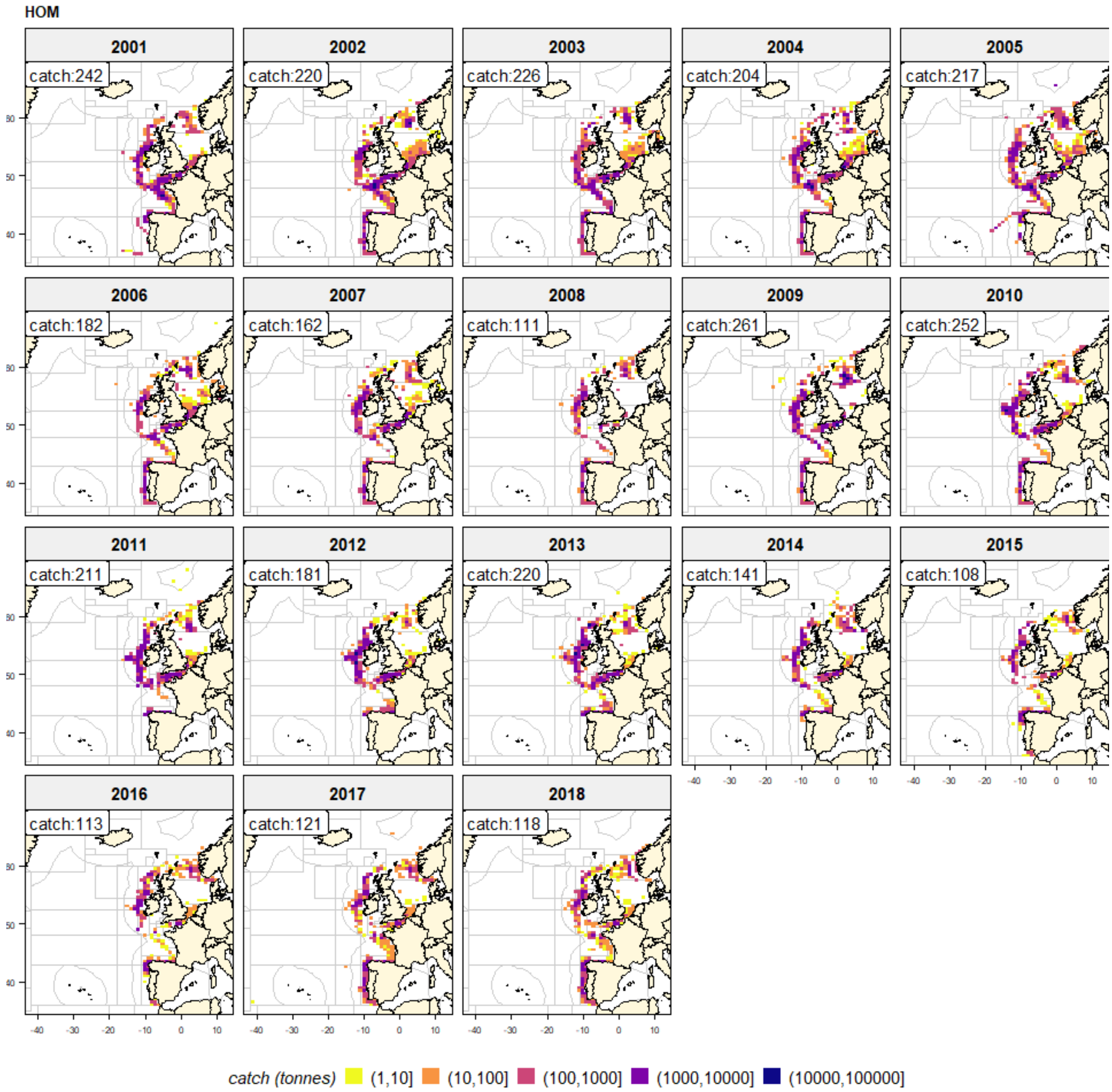

Figure 1.10.5: Catch of horse mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

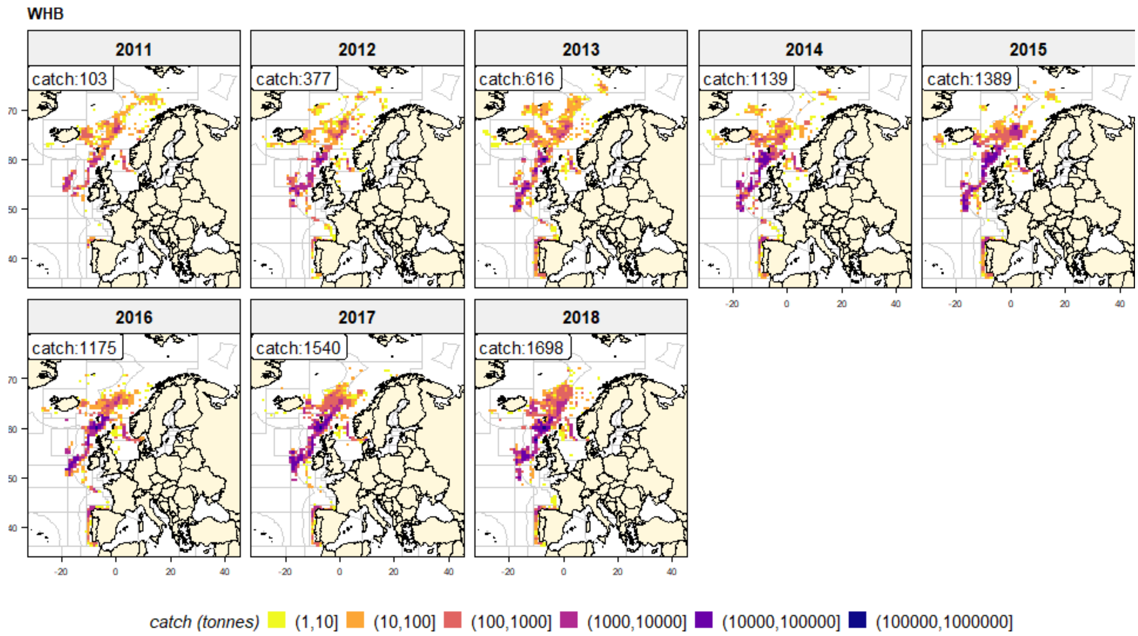

Figure 1.10.6: Catch of blue whiting (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

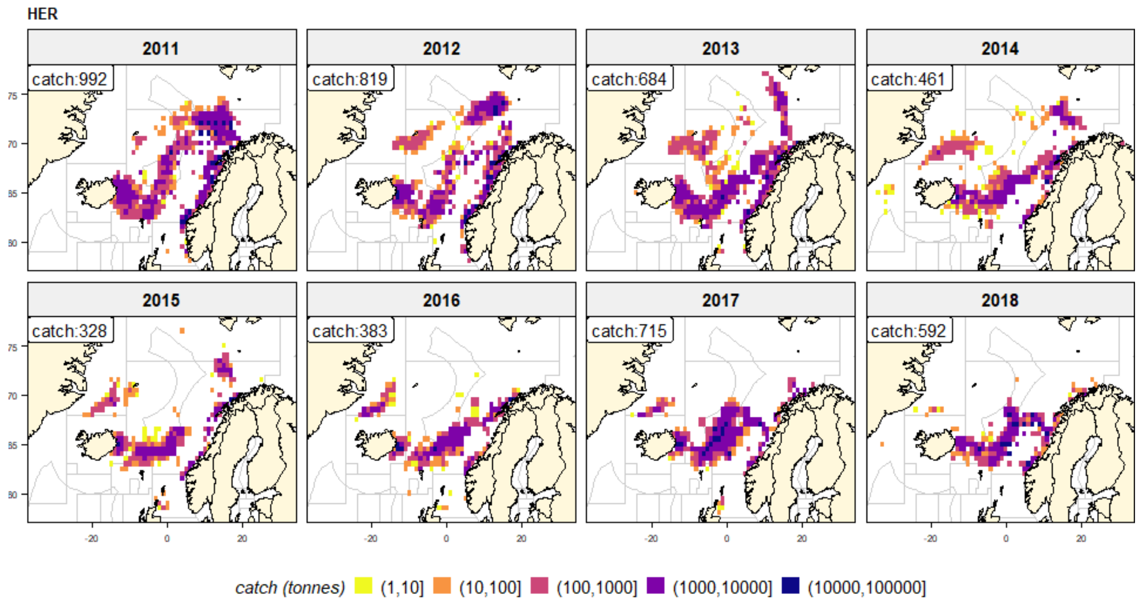

Figure 1.10.7: Catch of Atlanto-scandian herring (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

1.11 Ecosystem considerations for widely distributed and migratory pelagic fish species

Number of studies demonstrate that environmental conditions (physical, chemical and biological) largely influence fish stocks 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 others relevant Integrated Assessment groups within ICES in the near future, will help in operationalizing ecosystem approach for the widely distributed pelagics assessed in WGWIDE. The text below was largely provided by WGINOR (ICES 2016e; 2018a; 2019a).

1.11.1 Climate variability and climate change

The North Atlantic Oscillation (NAO) corresponds with the alternation of 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 has 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 20 years long-term mean (ICES, 2015). The NAO index has been positive throughout the period 2014-2018. Such a consistent long period without the NAO index changing sign is very unusual. The last comparable period during which the NAO index was consistently positive was in the period 1992–1995.

The classical measure of global warming is the northern hemisphere Temperature anomaly (NHT) (Jones and Moberg, 2003) which is computed as the anomaly in the annual mean of seawater and land air surface temperature over the northern hemisphere. During the last three decades, NHT anomalies have exhibited a strong warming trend. Pelagic planktivorous species such as Northeast Atlantic mackerel (Astthorsson *et al.*, 2012; ICES, 2013; Nøttestad *et al.* 2016), Norwegian spring-spawning herring and blue whiting may and have been 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.

1.11.2 Circulation pattern

The circulation of the North Atlantic Ocean is characterized by two large gyres: theSubpolar 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.

1.11.3 Recent trends in oceanography and zooplankton in Norwegian Sea

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

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

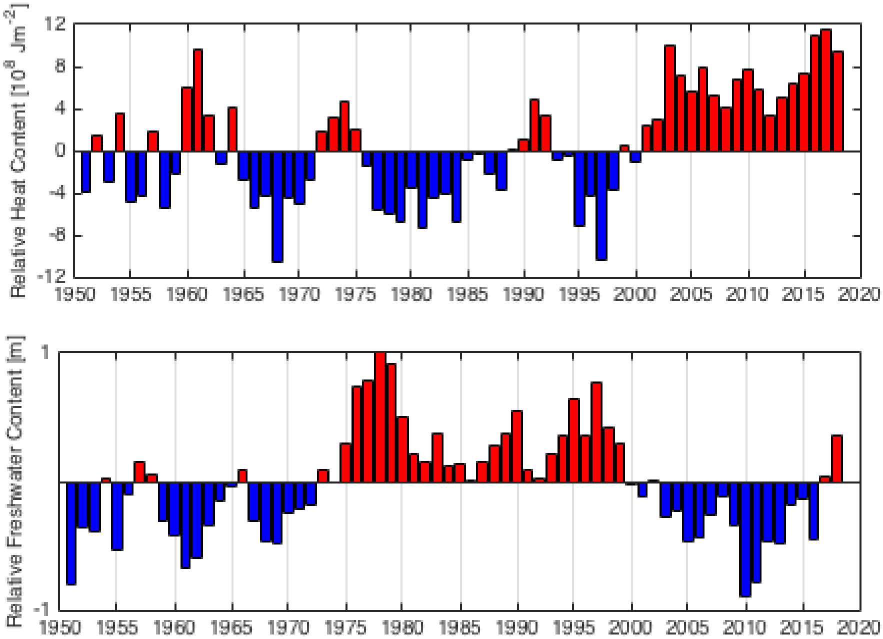

Figure 1.11.1. Time-series of anomalies of heat content (upper panel) and salinity (lower panel) of and the Atlantic waters in Norwegian Sea for the years 1951-2018(ICES 2019a).

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

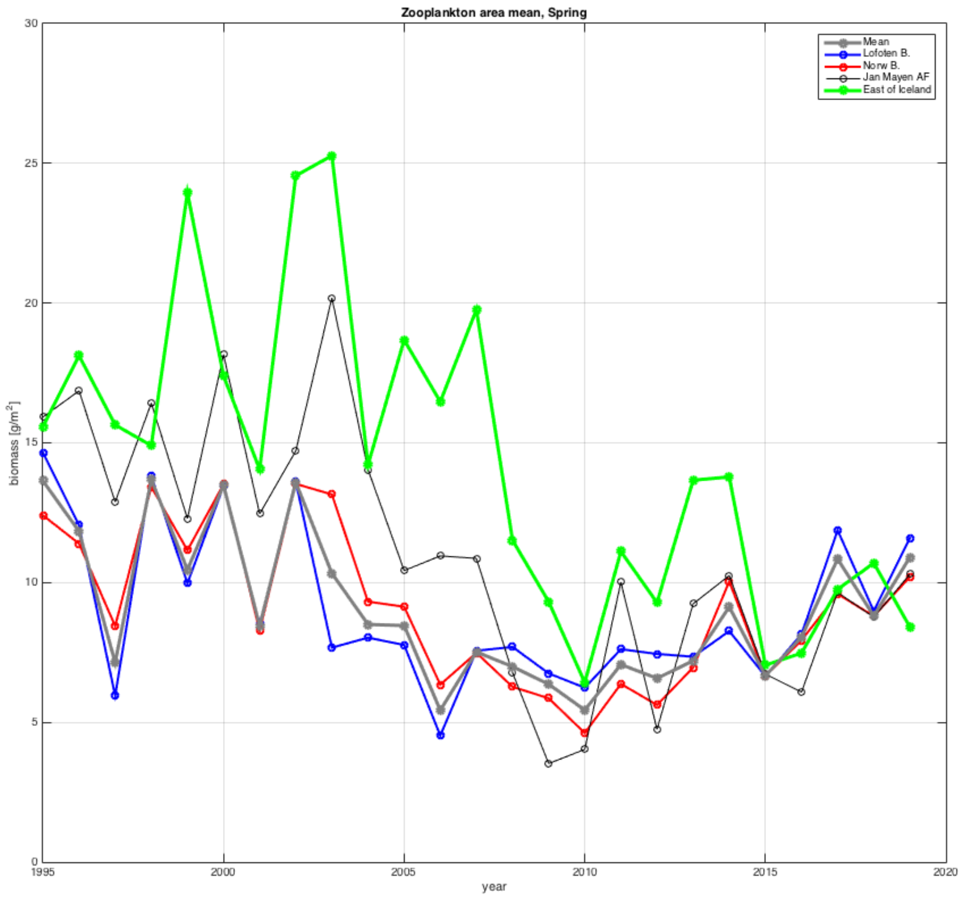

Figure 1.11.2. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in different areas in and near Norwegian Sea from 1995 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (ICES 2019b; see details on methods and areas in ICES 2016a).

1.11.4 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). In this WGWIDE report, several aspects of interaction between the pelagic fish stocks are addressed in the stock specific sections.

1.12 Future Research and Development Priorities

As part of the planning towards future benchmark assessments, the working group started in 2014 preparing a list of research priorities for each stock that can potentially improve the quality of the advice generated for each stock. This list is updated in every WG meeting, by removing issues when having been addressed adequately or as well as possible, and adding new ones when they arise. We have considered scientific research, improvements to data collection and development of assessment techniques, both generally and on a stock-by-stock basis, as appropriate. The most important of these developments are described below.

In general, more focus should be towards integrated ecosystem assessments for the stocks within WGWIDE. Some of the WGWIDE members also participate in the work of the Working Group on Integrated Assessment for Norwegian Sea (WGINOR), which help in communication between these two groups. However, there are also other regional Integrated Ecosystem Assessment groups that could be relevant to WGWIDE and the stocks assessed by it. We hope to put more emphasis on this in the coming years.

1.12.1 NEA Mackerel

WGWIDE comments to the WKRRMAC Roadmap for the priorities for future research for Northeast Atlantic mackerel.

Fisheries managers, researchers and fishers participated in the ICES Workshop on a Research Roadmap for Mackerel (WKRRMAC) co-chaired by Carl O'Brien (UK) and Mark Dickey-Collas (ICES) at its meeting held in Bremerhaven, Germany on 7–9 May 2019. The main aim of the workshop was to produce a roadmap for the delivery of future research needs for the management of fisheries on mackerel in the Northeast Atlantic. The workshop was convened to address the challenges to the evidence base for the provision of ICES advice and took place against a backdrop of another revision to the fishing opportunities advice which resulted from an inter-benchmark review of the performance of the stock assessment model earlier in 2019. The output of the workshop is a list of suggested further research and methods intended to improve the evidence base for the fisheries management of mackerel.

WGWIDE in 2019 considered the outcomes of WKRRMAC 2019 and specifically the roadmap that resulted from it. Below is a summary of the 9 elements of the roadmap and the WGWIDE comments and actions to it.

1. **Explore new funding mechanisms of research for the management of this valuable fishery. Action: Coastal States ministries and fisheries.**

This is clearly an issue that needs to be handled by Coastal States and fisheries. One new development of funding mechanisms that could be mentioned is the initiation of PhD students that are funded by industry. More generally it would be important to reflect on the current funding mechanisms for (coordinating) research and the potential role of the fishing industry to support the knowledge base for mackerel.

2. **Invest and better coordinate building fisheries science expertise. Action: Coastal States ministries, national research authorities, fishing industry with support from ICES.**

WGWIDE discussed which expertise is currently lacking in the assessment process for mackerel. We concluded that an important deficit is the fact that there only very few modelling experts available that fully understand the model framework and also few people that can explain the results to a wider audience of non-experts. It is highly recommended that this situation is improved by:

- Making modelling experts available in the relevant expert groups
- Better documentation (manuals!) of the methods being deployed
- Train up a wider group of experts to become comfortable in using advanced models (ICES training courses, University courses on advanced assessment modelling)
- Approaching assessments as team activities instead of as one assessment expert being responsible for the assessment of a particular stock

Catch sampling is an important element of any stock assessment and likewise for mackerel. Traditionally the catch sampling is approached on a national basis. Recent developments of a so-called "herring-lottery" in Norway could provide a new model of organizing catch sampling, where samples need to be taken on the basis of the distribution of catches. Similarly, the age reading could also be distributed out internationally, so that it becomes more randomized. This would require an international coordination which is similar to the approaches being used in the ICCAT world.

3. **Evaluate management and advisory mechanisms that will result in more robust quality assured advice on optimised yield (the trade-off between MSY and stability in TAC). The evaluation to be done by managers and fishers and facilitated by scientists. Action: to be facilitated by ICES, managers, fishing industry**

WGWIDE members that participated in WKRRMAC noted that there were regular discussions about the need for a quality assurance programme on the ICES assessments and advice, but that that topic did not receive a lot of attention in the WKRRMAC report or the research roadmap. WGWIDE notes that taking up quality assurance is a big task but also one that is required to improve the robustness of the scientific advice. Implementing stock assessments in the ICES Transparent Assessment Framework (TAF) is one of the steps that needs to be taken.

In addition, WGWIDE recommends to:

- Develop tools to assess the consequences of uncertainties in sampling, ageing and surveys. Quality-control plot of catches and sampling for all nations together should be prepared. The information needed for such an analysis needs to be included in the data call.
- Documentation of manuals and procedures for sampling and surveys in a language that can be understood within the WG.
- Benchmarks and MSEs are currently treated as different processes. Benchmarks are mostly triggered by WG members (in some cases requested by clients) and management plan evaluations are mostly triggered by clients (as special requests). A more tight coupling of MSEs and benchmarks would be beneficial because it could be used as a tool to explore the consequences of different assessment approaches and management approaches to achieve the objectives of management. This type of approach would allow the testing of new data sources in the assessment approach before it is actually included in the standard assessments. It was noted that sufficient resources need to be available for dealing with MSEs.

4. Explore which surveys contribute the strongest signal into the stock assessment, and reconcile survey information. Action: ICES and fishing industry scientists

In the WKRRMAC report, this topic is linked to the concept of cost-benefit analysis, whereby the cost of data sources if offset the contributions they make to the assessment and advice. WGWIDE acknowledges that this is important work that needs to be carried out and agrees with WKRRMAC that "it should be carried out by individuals/institutes not directly involved in the sampling/surveying of mackerel".

The contribution of the available data sources to the current assessment framework (SAM) can relatively easily be seen by the leave-one-out analysis. However, this contribution may change every year. Therefore it is recommended to display the results for a number of years (e.g. last 5 years).

An important question that needs to be addressed is how the SAM model deals with the number of observation in the different data series? Analysis carried out during the IBPNEAMAC 2019 suggested if the tagging data was included twice in the assessment model, it would receive a higher weight in the overall model fit. This type of number-of-observations-dependency would need to be better evaluated in a sensitivity analysis.

The issue of getting more information out of the egg survey was raised. The egg survey is a very large effort that takes place every three years (for the western area) and the subsequent year (for the North Sea). However, the contributions in terms of understanding on the developments of mackerel stocks (temporal, spatial) are relatively limited compared to the investment in the survey. This could partly be remedied by merging the western and the North Sea egg survey, although this would require a redistribution of effort. In addition, there could be more focus on the dissemination of results, not just in the final numbers that come out, but also the analysis of the sensitivity and variability of the results. For example, disseminating the variability in fecundity, the temporal-spatial spread in samples etc. In addition, one could look for a more broader sampling approach, e.g. loading the egg survey vessels with a Multpelt trawl (and acoustic recording?) could be explored.

To explore the contributions of surveys to the model it is also important to improve process knowledge that is currently missing for understanding the variability and biases in the surveys:

- IESSNS
  - Annual effects
  - Possibilities to expand to the southwest. Is it possible to use the method there or not?
- Egg survey

    - Why is the fit to the assessment so poor compared to the other data?
    - Determinate vs indeterminate spawner
    - Daily egg production vs Annual egg production
    - Understanding sampling and fecundity estimation and variability for mackerel
- Tagging data
    - Potential spatial and age bias (which areas are tagged)
    - Understanding the role of tagging data in the model
- Recruitment index
    - Catchability variability
    - Expand to the Southern Norwegian Sea

5. Explore expanding existing surveys (those with larger contributions to the stock assessment), to seasons and areas they currently do not cover. Action: national fisheries institutes and academics

Key actions:

- Expand the swept-area survey towards the south (involve EU more broadly);
- Explore the possibility to carry out CUFES sampling on May-July surveys?
- Explore expanding tagging areas towards Spain and North Sea. Tagging can be used for the assessment but also in understanding migration patterns
- Explore scanners for tagging in the Southern countries (e.g. France, Spain).

6. Further extend the winter acoustic survey time series and contribute ship time and researchers to these efforts. Action: national fisheries institutes and academics.

A winter acoustic survey on the mackerel stock while it is concentrated in large schools in the northern North sea and southern Norwegian sea was seen as promising but needs a lot of development. This would require international coordination. Funding mechanisms are required (see point 1). Possibly involving industry vessels for data collection in addition to survey vessels. WGWIDE could invite the initiator of this survey (Paul Fernandes, University of Aberdeen) to explore potential mechanisms for setting up such a survey.

7. Build mechanisms to incorporate industry sampling of biological information into the formal stock assessment process Action: ICES and fishing industry scientists (workshop planned 2019)

This has been handled through WKSCINDI and later in WGCATCH. The discussion on the "herring-lottery" is part of this.

For WGWIDE, it would also be relevant to involve the fishing industry in e.g. blue whiting length sampling within the assessment year.

8. Develop pragmatic approaches for formalising the flow of information of industry perceptions of the state of the stock and the fishery into the assessment process. Action: ICES and fishing industry scientists

Earlier examples with using industry perceptions through e.g. the North Sea fishermen survey or the Faroe fishermen observations have proven to be problematic because the information could not be directly used in the assessment. More generally, when "perceptions" from industry would solicited, a transparent and scientifically underpinned observation mechanism would be required. This could perhaps be linked with the ICES Social Science Group (add ToR?).

The current basis of the "information from stakeholders" in the ICES advice is not well documented and therefore not very useable for scientific understanding.

9. Develop methods for industry surveys that maintain credible methods and scientific rigor. Action: national fisheries institutes, academics and industry fisheries scientists

Industry surveys require scientific coordination through WGIPS, appropriate quality assurance mechanisms and scientific manuals.

Minimum landing size

In addition to the issues raised by the WKRRMAC regarding the research needs for mackerel, WGWIDE noted that the minimum landing size of mackerel is an outstanding issue that has been raised in the ICES advice for some years already but that has not been addressed yet. ICES has been recommending that the existing management measures to ensure the protection on the North Sea component (no mackerel fishing in divisions 3.a and 4.b–c, or in Division 4.a during the period 15 February–31 July, and a 30 cm minimum conservation reference size) should remain in place for precautionary reasons. But it was also noted that an evaluation of the relevance of the minimum conservation reference size of 30 cm in relation to the minimum size of 20 cm for the western stock should be carried out.

1.12.2 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.

1.12.3 NSS Herring

The 2016 benchmark assessment of Norwegian spring-spawning herring tackled most of the issues raised in last year's WGWIDE report with the aim of improving the assessment of the stock. The remaining issues and general future research of relevance for the assessment includes the following:

The Norwegian spawning ground survey was reintroduced in 2015 as part of the tuning series (fleet 1). However, changes had been made to the survey compared to the older part of the series. The 2016 benchmark accepted the inclusion of the surveys from 2015 as part of the same tuning series, but it would be relevant to explore further if the series since 2015 should be a separate tuning series due to the changes in the survey, particularly since 2019 will provide the fifth estimate from the survey since it was reintroduced.

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

Inclusion of a new tuning series (tagging data based on RFID) in the assessment

Get information about uncertainty in catches from all countries (currently only available from Norway).

1.12.4 Western horse mackerel

Considering the potential of mixing between Western and North Sea horse mackerel occurring in Division 7.d and 7.e, better 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 (Farrel *et al* 2018) which concluded that the spawners of North Sea and Western horse mackerel can be genetically identified as two distinct stocks. However, at present it is not yet possible to separate the two stocks when they occur in mixed samples. Therefore, a follow-up project has been initiated to carry out a full genome sequencing of horse mackerel which will allow for future analysis of mixed samples. Results are expected in 2020.

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

1.12.5 North Sea horse mackerel

To improve the knowledge base for North Sea horse mackerel about the degree of connection and migrations in between the North Sea and the Western Stock, catch sampling carried out by several pelagic fishery companies is being explored to give information on the separation between North Sea and Western horse mackerel. To improve the abundance indicators the potential application of a commercial fishery search time index will be explored. Horse mackerel is fished while it is very close to the bottom in relatively dispersed, small schools. The fishery is mostly executed using long hauls and there may be extensive search time involved. Handled in an appropriate statistical framework, taking into account the nature of the fishery and other factors such as seasonality and alternative fishing opportunities, the search time and catch rates could provide for an indication of changes in stock size over time. Catch rates in areas 27.7.e, 27.7.d and southern North Sea will be analysed from skippers' private logbooks.
The exploration of additional survey data has already been initiated in 2015 and resulted in the inclusion of the French CGFS index into the assessment of North Sea horse mackerel. In January 2017, the North Sea horse mackerel was benchmarked (ICES, 2017a). Based on capacity to model the overdispersion and the high proportion of zero values in the survey catch data the hurdle model was concluded the best option to combine the NS-IBTS and the CGFS survey information and estimating a joint annual survey index to be used for assessing the status of the stock. Future work will focus on the assessment of the importance of considering the spatial component when modelling the joint CGFS and IBTS survey index.

Studies on stock identity and the degree of connection and migrations between the North Sea and the Western Stock are considered very 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 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). However, with the available information it was not yet possible to determine the genetic composition of mixed samples of non-spawning fish. Therefore, a full genome sequencing exercise has been initiated to allow for future mixed-sample analyses. Results are expected to be available in 2020.

1.12.6 Boarfish

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

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

At WGWIDE 2018, an issue list was prepared for the stock and it still applies for potential benchmark in 2021.

1.13 Decision made new WGWIDE chair and on next year´s meeting

At the 2019 WGWIDE meeting, Andrew Campbell from Ireland was elected as a new chair for the next three years (2020-2022).

The WG aim for next meeting at ICES HQ, Copenhagen, in the period 25 August – 1 September 2020.

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

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

2.1 ICES advice in 2018

ICES notes that fishing mortality has increased from a historical low in 2011 to above F_{MSY} since 2014. Spawning-stock biomass increased after 2010 and peaked in 2017. SSB is currently above MSY $B_{trigger}$. Recruitment in 2018 is estimated to be low for the third year in a row, following high recruitment in 2014-15.
ICES advised that when the MSY approach is applied, catches in 2019 should be no more than 1 143 629 tonnes.

2.2 The fishery in 2018

The total catch in 2018 was 1711 kt. 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 (88%) were taken in the first two quarters of the year and the largest part of this west of the British Isles and east, south and west of the Faroes. Smaller quantities were taken along the coast of Spain and Portugal. The fishery in the latter half of the year was concentrated in the central Norwegian Sea and east of the Faroes. The multinational fleet currently targeting blue whiting consists of several types of vessels from 16 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 2016) it was decided to use preliminary within year catch-at-age data in the assessment to get additional information to the within year IBWSS result. In most recent years around 90% of the annual catches of the age 3+ fish are taken in the first half year, which makes it reasonable to estimate the total annual catch-at-age from reported first semester data. The catch data sections in this report give first a comprehensive description of the 2018 data as reported to ICES and then a section including a brief description of the 2019 preliminary catch data.

2.3.1 Officially reported catch data

Official catches in 2018 were estimated to 1 711 477 tonnes based on data provided by WGWIDE members. Data provided as catch by rectangle represented more than 99% of the total WG catch in 2018. Total catch by country for the period 1988 to 2018 is presented in Table 2.3.1.1 and in Figure 2.3.1.1.

The spatial and temporal distribution of catches in 2018 (Figure 2.2.1, 2.2.2 and Table 2.3.1.2, 2.3.1.3), is quite similar to the distribution in previous years. The majority of catches is coming from the spawning area. The 2018 catches have largest contribution from ICES area 27.5.b, 27.6.a and 27.7.c (Figures 2.3.1.1 to 2.3.1.7). The temporal allocation of catches has been relatively stable in recent years (Figure 2.3.1.4). In the first two quarters, catches are taken over a broad area, with the highest catches in 27.5.b, 27.6.a, 27.6.b, 27.7.c and 27.7.k, while later in the year catches is mainly taken further north in area 27.2.a and in the North Sea (27.4.a) (Figure 2.3.1.6 and 2.3.1.7 and Table 2.3.1.3). The proportion of catches originating from the Northern areas has been decreasing from 2014 to 2016, in 2017 and 2018 an increase of 8% and 1% was observed, respectively.

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

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

The blue whiting discards data produced by Portuguese vessels operating with bottom otter trawl within the Portuguese reaches of ICES Division 27.9.a is 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 were it was significant (2004, 2006, 2010) was ranging between 43% and 38% (in weight). In 2018, discards were 40% of the total catches for blue whiting in 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 last day catch 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 11% (in weight) in 2015 (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 the Denmark, France, Portugal, Spain, UK (England and Wales) and UK (Scotland), to the working group. The discards constituted 0.25% of the total catches, 4309 tonnes.

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 10% of the total catches of blue whiting in 2018.

2.3.1.1 Sampling intensity

Sampling intensity for blue whiting with detailed information on the number of samples, number of fish measured, and number of fish aged by country and quarter is given in Table 2.3.1.1.1 and are presented and described by year, country and area (Table 2.3.1.1.2, 2.3.1.1.3 and 2.3.1.1.4). In total 2003 length samples, 1565 age samples, were collected from the fisheries in 2018, 131779 fish were measured and 1565 were aged. The percentage of catches covered by the sampling program was 87% in 2018. The most intensive sampling took place in the area 27.4.a, 27.5.b, 27.6.a, 27.7.k, 27.8.b, 27.8.c and 27.9.a. No sampling was carried out by Greenland, Poland, Sweden and the UK (England, Wales, Northern Ireland) representing together 3% 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

The age-length key for the sampled catches on ICES area 27.6.a (as an example) 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 InterCatch program was used to calculate the total international catch-at-age, and to document how it was done.

2.3.2 Preliminary 2019 catch data (Quarters 1 and 2)

The preliminary catches for 2019, quarters 1 and 2, and the expected whole 2019 catches as reported by the WGWIDE members (Table 2.3.2.3).

The spatial distribution of these 2019 preliminary catches is similar to the distribution in 2018. The majority of catches are coming from the areas 27.5.b, 27.6.a, 27.6.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 and quarter 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.

A comparison of the preliminary and the final catch for 2017 and 2018 (Table 2.3.2.4) shows a good agreement (i.e. max 0.3 % deviation).

WGWIDE estimated the expected total catch for 2019 from the sum of declared national quotas, corrected for expected national uptake and transfer of these quotas (Table 2.3.2.3).

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

2.3.3 Catch-at-age

Catch-at-age numbers are presented in Table 2.3.3.1. Catch proportions at age are plotted in Figure 2.3.3.1. Strong year classes that dominated the catches can be clearly seen in the early 1980s, 1990 and the late 1990s. In recent years, the age compositions are dominated by the younger ages (ages 3-5) with the 2014 year class contributing most.

Catch curves for the international catch-at-age dataset (Figure 2.3.3.2) indicate a consistent decline in catch number by cohort in years with rather high landings (and probably similar high effort). The catch curves for year classes 2010-2011 show a consistent decline in the stock numbers with an estimated total mortality (Z=F+M) around 0.6-0.7 for the ages fully recruited to the fisheries.

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 1983—2019 used in the stock assessment. Mean weight at age for ages 3—9 reached a minimum around 2007, followed by an increase until 2010—2012, and a decrease in the recent years, even though mean weights for ages 2-5 have shown an increase since 2017.

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 however the only survey used as input to the assessment model. The cruise report from IBWSS in spring 2019 is available as a working document to this report. The survey group considers that the 2019 estimate of abundance as robust.

The updated survey time-series (2004-2019) show variable internal consistency (Figure 2.3.7.1.1. B) for the main age groups.

The distribution of acoustic backscattering densities for blue whiting for the last 4 years is shown in Figure 2.3.7.1.2. The bulk of the mature stock was located from the north Porcupine to the Hebrides core area in a corridor close to the shelf edge. This is comparable to what was observed in 2018.

The abundance estimate of blue whiting for IBWSS are presented in Table 2.3.7.1.1. In comparison to the results in 2018, there is a small increase in the observed stock biomass (+4%) and in stock numbers (+9%).

The stock biomass within the survey area was dominated by 4, 5 and 6-year-old fish, contributing 82% of total-stock biomass. The age structure of the 2019 estimate is consistent with the age structure from the 2018 estimate.

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

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

2.3.7.2 Other surveys

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

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

Norwegian bottom-trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March where blue whiting are regularly caught as a bycatch species. This survey gives the first reliable indication of year-class strength of blue whiting. 1 group is defined in this survey 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 greater than 15 cm and 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. 1 group is defined in this survey as less than 23 cm in March (Table 2.3.7.2.4).

The International Survey in Nordic Seas and adjacent waters in July-August (IESSNS). Blue whiting are from 2016 included as a main target species in this survey and methods are changed to sample blue whiting. This was a recommendation from WGWIDE 2015 to try to have one more time-series for blue whiting. The time-series is currently too short for assessment purposes.

2.4 Stock assessment

The presented assessment in this report follows the recommendations from the Inter-Benchmark Protocol of Blue Whiting (IBPBLW) convened by correspondence from 10 March to 10 May 2016 (ICES, 2016a) to use the SAM model.

The configuration of the SAM model (see the Stock Annex for details) includes the same settings as agreed during IBPBLW 2016, but due to a new version of SAM, the actual values have changed in 2017. The new SAM version begins with 0 for parameters, while the old version begins with 1. The Stock Annex has been updated accordingly.

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) show a quite random distribution of residuals. There might be an indication of "years effect" (too low index) for the IBWSS 2015 observations. The strong 2014 year class gives all positive residuals for IBWSS.

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. There are only a very few abrupt changes in the estimated parameters over the time-series presented. Observation noises for the IBWSS increase in 2019 for the youngest (ages 1-2) and oldest ages (7-8). The lowest observation noise has in all years been from catches ages 3-8.

The process error residuals ("Joint sample residuals") (Figure 2.4.2) are reasonable randomly distributed, except in the terminal year where process error on N is mainly positive and process error on F is mainly negative for the dominating year classes in the fishery. Process noise SAM is implemented as a "process mortality, Z"; these deviations in mortalities are shown in Figure 2.4.3. The deviations in mortality (plus or minus mortality) seems fairly randomly distributed without very pronounced clusters. Process noise presented as number of fish (Figure 2.4.4) shows similarly no alarming patterns.

The correlation matrix between ages for the catches and survey indices (Figure 2.4.5) show a modest observation correlation for the younger ages and a stronger correlation for the older ages. This difference is more distinct for catches, probably because it includes older ages (1-10+) than the survey data (ages 1-8).

Figure 2.4.6 presents exploitation pattern for the whole time-series. There are no abrupt changes in the exploitation pattern from 2010 to 2019, even though the landings in 2011 were just 19% of the landings in 2010, which might have given a different fishing practice. 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).

The retrospective analysis (Figure 2.4.7) shows an unstable assessment with substantial downward revision of SSB in the 2015 assessment (due to the 2015 low survey indices) followed by an increase in 2016. The addition of 2019 data gives an upward revisions of SSB and downward revision of F. The use of "preliminary" catches (here in the retrospective analysis it is actually the final catches that are used for the period before 2018). Mohn's rho by year and as the average value over the last five years are presented in (Table 2.4.2). Even though the annual values might be high (reflecting large changes from one year to the next) the average Mohn's rho is rather low indicating no serious bias.

Stock summary results with added 95% confidence limits (Figure 2.4.8 and Table 2.4.5) show a decrease in fishing mortality in the period 2004—2011, followed by a steep increase in F up to 2015 and a decrease in F in 2016-2019. Recruitment increased from low recruitments in 2006–2009 to a historically high recruitment in 2015. This is followed by a lower recruitment in 2016 and a much lower recruitments in 2017-2019. SSB has increased in the period 2010-2018, followed by a large reduction. SSB in 2020 is 4325386 tonne and above MSY $B_{trigger}$.

2.4.1 Alternative model runs

The assessment models TISVPA and XSA were run for a better screening of potential errors in input and for comparison with the SAM results. All three models gave a similar result with respect SSB dynamics (Figure 2.4.1.1), even though the absolute values differ between models. For F, SAM estimates a reduction since 2016, XSA an increase and TISVPA a rather constant F since 2016.

All three models show a low recruitment in the most recent years . The XSA configuration uses a stock size dependent catchability for the youngest ages. SAM and TISVPA assume a stock size independent catchability. This difference might explain the higher XSA estimate of recruitment in the last two years.

2.5 Final assessment

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

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

The model was run for the period 1981—2019, with catch data up to 2018 and preliminary catch data for the first semester of 2019 raised to expected annual catches, and survey data from March-

April, 2004–2019. SSB 1st January in 2020 is estimated from survivors and estimated recruits (for 2020 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 2.4.3–2.4.4 and summarized in Table 2.4.5 and Figure 2.4.8. Residuals of the model fit are shown in Figures 2.4.1 and 2.4.2.

2.6 State of the Stock

F has increased from a historic low at 0.052 in 2011 to 0.488 in 2015 followed by a decrease in F to 0.335 in 2019. F has been above F_{MSY} (0.32) since 2014. SSB increased from 2010 (2.71 million tonnes) to 2018 (6.32 million tonnes), followed by a decline to 2020 (4.32 million tonnes). SSB has been above B_{pa} (2.25 million tonnes) since 1997.

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

2.7 Biological reference points

In spring of 2016, the Inter-Benchmark Protocol on Blue Whiting (IBPBLW 2016) 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} (See Table below).The table below summaries the currently used reference points.

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

2.8 References

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

2.9 Short-term forecast

2.9.1 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 (2018 year class) and the 2–group (2017 year class) indices from the survey in 2019 were approximately at the median and below the median of the historical range, respectively.

The International Blue Whiting Spawning Stock Survey (IBWSS) is not designed to give a representative estimate of the abundance of immature blue whiting. However, the 1-group indices appear to be fairly consistent with corresponding indices from older ages. The 1-group (2018 year class) index from the survey in 2019 was the slightly above the middle of the historic range. The 2-group in 2019 (2017 year class) was in the lower end in the time-series.

The Norwegian bottom-trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March 2018, showed that 1-group blue whiting was above the median in the time series(Table 2.3.7.2.2). However, the index is in 2019 is low compared to the strong year-classes observed earlier. This index should be used as a presence/absence index, in the way that when blue whiting is present in the Barents Sea, this is usually a sign of a strong year class, as all known strong year classes have been strong also in the Barents Sea.

The 1-group estimate in 2019 (2018 year class) from the Icelandic bottom-trawl survey showed a decrease compared to 2018 and was the lowest observed in the time-series.

The 1-group estimate in 2019 (2018 year class) from the Faroese Plateau spring bottom-trawl survey was the lowest observed in the time-series.

In conclusion, the indices from available survey time-series indicate that the 2017 year class is in the low end and it corresponds to the SAM assessment results. The 2018 year classes estimated from surveys are also in the low end, which also is the result of the SAM assessment where it is in the lower end. It was therefore decided not to change the SAM estimate of the 2017 and 2018 year classes.

No information is available for the 2019 and 2020 year classes and the geometric mean of the full time-series (1981—2018) was used for these year classes (14.8 billion at age 1 in 2019) (Table 2.8.1.1).

2.9.2 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.

2.9.2.1 Input

Table 2.8.2.1 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 (2017—2019) 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 2018 and 2019 are assumed as estimated by the SAM model, as additional survey information was not conflicting this result. Recruitment in 2020 and 2021 are assumed at the long-term average (geometric mean for the full time-series, minus the last year (1981-2018).

As the assessment uses preliminary catches for 2019 an estimate of stock size exist for the 1 January 2020. The normal use of an "intermediate year" calculation is not relevant in this case. F in the "intermediate year" (2019) is as calculated by the assessment model. Catches in 2019 is the (model input) preliminary catches (1444301 tonnes). Intermediate year assumptions are summarised in Tables 2.8.2.1.1 and 2.8.2.1.2

2.9.2.2 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 implies fishing mortality to be at F_{MSY} = 0.32 which will give a TAC in 2020 at 1161615 tonnes. This corresponds to a 1.6 % increase compared to the ICES advice last year, and 19.6% reduction compared to the preliminary estimate of catches in 2019. SSB is predicted to decrease by 20.6 %, if the advised catches are taken.

2.10 Comparison with previous assessment and forecast

Comparison of the final assessment results from the last 5 years is presented in Figure 2.9.1. The last three assessments, with the inclusion of the preliminary catches in 2016, had previously shown a tendency for overestimating SSB and underestimating F. This was partly because the previous assessments used a three years average of the mean weights at age for the preliminary catch data in previous year. Due to a decreasing trend in mean weight for the main age classes in the fishery, these values were an overestimate compared to the final mean weights obtained in the following year. This gave a tendency to overestimate SSB and underestimate F.

For 2019, the preliminary mean weights as observed were used in the assessment. This has partly removed the previously observed bias in SSB and F. The upward revision in SSB and downward revision in F this year are however mainly due to a higher than expected survey indices, mainly for the large 2014 year-class.

2.11 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 2.4.8). The retrospective analysis (Figure 2.4.7), the comparison of SSB and F estimated by three different assessment programs TISVPA, XSA and SAM (Figure 2.4.1.1) and the comparison of the 2015-2019 assessments (Figure 2.9.1) suggest a consistent assessment for the last three years (with inclusion of preliminary catch data). The preliminary 2016-2018 catches in weight correspond well with the final catch statistics (Table 2.3.2.4).

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, biased survey indices will still give a biased stock estimate with the new SAM configuration.

During the WGWIDE 2017 (ICES 2017), a comparison between the mean length-at-age, by quarter and ICES division was been made. This comparison reveals a considerable lower mean length-at-age from the Faroese catch-at-age data. The 2018 catch-at-age from Faroese Islands, provided for this year assessment, were based on the age reading guidelines from the last workshop on blue whiting ageing (WKARBLUE2) and no significant deviations of the mean length-at-age have been found (Figure 2.3.1.2.1). The Faroese catch-at-age data from the previous years are under revision and the assessment will be updated, when the data become available.

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.

2.12 Management considerations

The assessment estimates a low 2018 year class, which is confirmed by a series of surveys not used in the assessment model. This low recruitment in combination with low 2016-2017 year classes will result in a decrease in stock size, and a reduction in fishing opportunities when the 2016 - 2018 year classes are fully selected in the fishery.

2.13 Ecosystem considerations

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

2.14 Regulations and their effects

There is an agreed long-term management strategy agreed by the European Union, the Faroe Islands, Iceland and Norway. However there is no agreement between the Coastal States EU, Norway, Iceland and the Faroe Island on the share of the blue whiting TAC.

WGWIDE members estimate the total expected catch to be around 1.444 million tonnes in 2019, whereas the TAC advice for 2019, according to the long-term management strategy was≤ 1,143,629 tonnes.

2.14.1 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 FMSY (0.32).
- The HCR was found to be precautionary both with and without the 20% TAC change limits above Bpa. However, the 20% TAC change limits can lead to the TAC being lowered significantly if the stock is estimated to be below Bpa, while also limiting how quickly the TAC can increase once the stock is estimated to have recovered above Bpa.
- The evaluation found that including a 10% interannual quota flexibility ('banking and borrowing') in the LTMS had an insignificant effect on the performance of the HCR.

2.15 Recommendations

The WGWIDE expert group analysed the mean length at age by area and by quarter of the data submitted from the different institutes/member states and differences have been identified in the data from the northern and southern areas. Due to the impact that biased age classifications could have on the blue whiting stock assessment, an inter-calibration exercise and a workshop is needed to review the age criteria used on this species. The impact of these uncertainties on age reading on the stock assessment results and uncertainties should be investigated.

2.16 Tables

Table 2.3.1.1. Blue whiting. ICES estimated catches (tonnes) by country for the period 1988–2018.

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2003
Denmark	18941	26630	27052	15538	34356	41053	20456	12439	52101	26270	61523	82935
Estonia					6156	1033	4342	7754	10982	5678	6320	
Faroes	79831	75083	48686	10563	13436	16506	24342	26009	24671	28546	71218	329895
France		2191				1195		720	6442	12446	7984	14149
Germany	5546	5417	1699	349	1332	100	2	6313	6876	4724	17969	22803
Iceland		4977						369	302	10464	68681	501493
Ireland	4646	2014			781		3	222	1709	25785	45635	22580
Japan					918	1742	2574					
Latvia					10742	10626	2582					
Lithuania						2046						
Netherlands	800	2078	7750	17369	11036	18482	21076	26775	17669	24469	27957	48303
Norway	233314	301342	310938	137610	181622	211489	229643	339837	394950	347311	560568	834540
Poland	10											
Portugal	5979	3557	2864	2813	4928	1236	1350	2285	3561	2439	1900	2651
Spain	24847	30108	29490	29180	23794	31020	28118	25379	21538	27683	27490	13825
Sweden ***	1229	3062	1503	1000	2058	2867	3675	13000	4000	4568	9299	65532
UK (England + Wales)****												
UK (Northern Ireland)												
UK (Scotland)	5183	8056	6019	3876	6867	2284	4470	10583	14326	33398	92383	27382
USSR / Russia *	177521	162932	125609	151226	177000	139000	116781	107220	86855	118656	130042	355319
Greenland***												
Unallocated												
TOTAL	557847	627447	561610	369524	475026	480679	459414	578905	645982	672437	1128969	2321406

*** From 1992 only Russia.**

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

***** 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 1988–2018.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Denmark	89 500	41 450	54 663	48 659	18 134	248	140	165	340	2 167	35 256	45 178	39 395	60 868	87 348
Estonia	**														
Faroes	322 322	266 799	321 013	317 859	225 003	58 354	49979	16405	43290	85 768	224 700	282 502	282 416	356 501	349 838
France		8 046	18 009	16 638	11 723	8 831	7839	4337	9799	8 978	10 410	9 659	10 345	13 369	16 784
Germany	15 293	22 823	36 437	34 404	25 259	5 044	9108	278	6239	11 418	24 487	24 107	20 025	45 555	47 708
Iceland	379 643	265 516	309 508	236 538	159 307	120 202	87942	5887	63056	104 918	182 879	214 870	186 914	228 934	292 944
Ireland	75 393	73 488	54 910	31 132	22 852	8 776	8324	1195	7557	13 205	21 466	24 785	27 657	43 238	49 903
Lithuania			4 635	9 812	5 338						4 717		1 129	5 300	
Netherlands	95 311	147 783	102 711	79 875	78 684	35 686	33762	4595	26526	51 635	38 524	56 397	58 148	81 156	121 864
Norway	957 684	738 490	642 451	539 587	418 289	225 995	194317	20539	118832	196 246	399 520	489 439	310 412	399 363	438 426
Poland														15 889	12 152
Portugal	3 937	5 190	5 323	3 897	4 220	2 043	1482	603	1955	2 056	2 150	2 547	2 586	2 046	2 497
Spain	15 612	17 643	15 173	13 557	14 342	20 637	12891	2416	6726	15 274	32065	29 206	31 952	28 920	24 718
Sweden	19 083	2 960	101	464	4	3	50	1	4	199	2	32	42	90	16
UK (England + Wales)	2 593	7 356	10 035	12 926	14 147	6 176	2475	27	1590	4 100	11	131	1374+	3 447	1 864
UK (Northern Ireland)										1 232	2 205	1 119			4 508
UK (Scotland)	57 028	104 539	72 106	43 540	38 150	173	5496	1331	6305	8 166	24 630	30 508	37 173	64 724	66 682
Russia	346 762	332 226	329 100	236 369	225 163	149 650	112553	45841	88303	120 674	152 256	185 763	173 655	188 449	170 892
Greenland										2 133				20 212	23 333
Unallocated									3 499						
TOTAL	2380161	2034309	1976176	1625255	1260615	641818	526357	103620	384021	628169	1155279	1396244	1 181 850	1 558 061	1 711 477

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

+ data from 2016 updated in the 2018.

Table 2.3.1.2. Blue whiting. ICES estimated catches (tonnes) by country and area for 2018.

ICES Div.	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden*	UK (England + Wales)	UK (Northern Ireland)	UK (Scotland)	Total
27.2.a	27	30484	546	10377	2171	43232		6789	2106	104		39058		0	24			**134917**
27.3.a	41													15				**57**
27.4.																	56	**56**
27.4.a	7	7019	124	1037	1468	7244		1751	22763	86		1854						**43353**
27.4.b	14								5						0			**19**
27.5.a					199	8085												**8284**
27.5.b	1222	192299	1999	3543	16328	186887		2842	1820	6488		84620	14					**498062**
27.6.a	23441	50340	8212	25725	3164	23060	10184	65446	198503	5475		15760	672		1836		12469	**444288**
27.6.b	7134	14061	1631	298		8290	9117	6702	98671			6092	10			1324	16153	**169483**
27.7.b	2011		21	1637			753	3					4				371	**4801**
27.7.c	53451	43655	3885	5090		11244	29846	29919	99347			11751	91			3184	37611	**329075**
27.7.d			0															**0**
27.7.e			23												2			**25**
27.7.f															0			**0**
27.7.g			2				1						1		1			**4**
27.7.h			10				1						23		1			**34**
27.7.j			28	1				375					368				21	**793**
27.7.k		11980				4653		8035	15212			11757	11					**51648**
27.8.a			277				0						2					**279**
27.8.b			26					1					158		1			**186**
27.8.c			0										18934					**18934**
27.8.d			0				1						15					**15**
27.9.a											2497		4417					**6915**
27.12.b						249												**249**
27.14.a					3													**3**
Total	**87348**	**349838**	**16784**	**47708**	**23333**	**292944**	**49903**	**121864**	**438426**	**12152**	**2497**	**170892**	**24718**	**16**	**1864**	**4508**	**66682**	**1711477**

***only landings.**

Table 2.3.1.3. Blue whiting. ICES estimated catches (tonnes) by quarter and area for 2018

Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4	2018*	Total
27.2.a	373	49294	46937	38314		**134917**
27.3.a		25	32			**57**
27.4					56	**56**
27.4.a	14	15891	12183	15265		**43353**
27.4.b	0	14	5	0		**19**
27.5.a		3068	3812	1404		**8284**
27.5.b	63607	375061	3	59391		**498062**
27.6.a	82165	345772	7	16322	22	**444288**
27.6.b	164263	5121	7	3	89	**169483**
27.7.b	4026	773	2			**4801**
27.7.c	322229	6779	60	6		**329075**
27.7.d	0					**0**
27.7.e	0	6	17	2		**25**
27.7.f			0			**0**
27.7.g		1	2	1		**4**
27.7.h	8	17	7	1		**34**
27.7.j	164	324	267	38		**793**
27.7.k	47491	4147	9	1		**51648**
27.8.a	79	91	106	3		**279**
27.8.b	49	50	33	54		**186**
27.8.c	5096	7057	4149	2633		**18934**
27.8.d		0	9	6		**15**
27.9.a	896	2487	1701	1830		**6915**
27.12.b				249		**249**
27.14.a			3			**3**
Total	**690461**	**815979**	**69349**	**135521**	**167**	**1711477**

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 1988–2018 by area.

Area	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**

* Data from UK(England + Wales) not included (2004-2007).

** Data from UK(England + Wales) and Sweden not included (2008-2011).

Table 2.3.1.5. Blue whiting. ICES estimates(tonnes) of catches, landings and discards by country for 2018.

	Catches	BMS landings	Landings	Discards	% discards
Denmark	87348		87308	40	0.05
Faroe Islands	349838		349838		
France	16784		16409	375	2.23
Germany	47708		47708		
Greenland	23333		23333		
Iceland	292944		292944		
Ireland	49903		49903	0	
Netherlands	121864		121864		
Norway	438426		438426		
Poland	12152		12152		
Portugal	2497		1497	1000	40.05
Russia	170892		170892		
Spain	24718		21993	2725	11.02
Sweden*	16		16		
UK (England)	1864	16	1845	3	0.15
UK(Northern Ireland)	4508		4508		
UK(Scotland)	66682		66515	167	0.25
Total	**1711477**	**16**	**1707152**	**4309**	**0.25**

***only landings.**

Table 2.3.1.6. Blue whiting. ICES estimated catches (tonnes) inside and outside NEAFC regulatory area for 2018 by country.

	Catches inside NEAFC RA	Catches outside NEAFC RA	Total catches
Denmark	1228	86120	87348
Faroe Islands	5426	344412	349838
France	670	16114	16784
Germany	4425	43283	47708
Greenland	104	23229	23333
Iceland	27458	265486	292944
Ireland	0	49903	49903
Netherlands	5218	116646	121864
Norway	67651	370776	438426
Poland	91	12062	12152
Portugal	0	2497	2497
Russia	64113	106778	170892
Spain	15	24704	24718
Sweden*	0.02	15	16
UK (England + Wales)**	0	1864	1864
UK(Northern Ireland)	0	4508	4508
UK(Scotland)	0.733	66681	66682
Total in 2018	**176399**	**1535078**	**1711477**

*** only landings.**

**** those values are assumed.**

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 2000-2018.

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**

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 2018.

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	87348	86	27	27	1135	1135	13	13
Faroe Islands	349838	90	18	18	1837	1756	5	5
France	16784	0	314	0	7167	0	0	427
Germany	47708	8	3	3	205	133	3	4
Greenland	23333	0	0	0	0	0	0	0
Iceland	292944	97	90	90	1961	2250	8	7
Ireland	49903	98	15	15	3498	1511	30	70
Netherlands	121864	86	71	71	16323	1744	14	134
Norway	438426	100	222	222	9660	2078	5	22
Poland	12152	0	0	0	0	0	0	0
Portugal	2497	100	59	59	3760	531	213	1506
Russia	170892	86	183	183	51117	1750	10	299
Spain	24718	95	867	867	30221	3080	125	1223
Sweden*	16	0	0	0	0	0	0	0
UK (England + Wales)	1863.7	0	5	0	82	0	0	44
UK(Northern Ireland)	4508	0	0	0	0	0	0	0
UK(Scotland)	66682	78	129	10	4813	458	7	72
Total	**1711477**	**87**	**2003**	**1565**	**131779**	**16426**	**10**	**77**

* only landings.

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 2018.

	Catch (tonnes)	No. Age samples	No. Length Measured	No. Aged
Denmark				
1	60288	12	445	445
2	27038	14	671	671
3	17	0	0	0
4	5	1	19	19
Total	87348	27	1135	1135
Faroe Islands				
1	132791	7	768	694
2	174913	8	765	762
3	3364	0	0	0
4	38770	3	304	300
Total	349838	18	1837	1756
France				
1	4030	0	2380	0
2	8004	0	2025	0
3	574	0	547	0
4	4176	0	2215	0
Total	16784	0	7167	0
Germany				
1	8381	0	0	0
2	30809	0	0	0
3	4933	3	205	133
4	3585	0	0	0
Total	47708	3	205	133
Greenland				
2	14763	0	0	0
3	107	0	0	0
4	8462	0	0	0
Total	23333	0	0	0
Iceland				
1	29146	13	309	325
2	194904	50	1091	1250
3	28519	10	214	250
4	40375	17	347	425
Total	292944	90	1961	2250
Ireland				
1	43746	13	3023	1308
2	6156	2	475	203
4	1	0	0	0
Total	49903	15	3498	1511
Netherlands				
1	41283	50	10923	1229
2	72350	21	5400	515
3	4502	0	0	0
4	3729	0	0	0
Total	121864	71	16323	1744

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 2018.

	Catch (tonnes)	No. Age samples	No. Length Measured	No. Aged
Norway				
1	258673	41	1913	1017
2	163910	100	4097	726
3	12821	74	3337	335
4	3023	7	313	0
Total	438426	222	9660	2078
Poland				
4	12152	0	0	0
Total	12152	0	0	0
Portugal				
1	350	9	565	89
2	649	15	1280	125
3	910	24	1315	145
4	588	11	600	172
Total	2497	59	3760	531
Russia				
1	43886	65	15476	569
2	101891	74	22228	938
3	8455	32	9642	195
4	16660	12	3771	48
Total	170892	183	51117	1750
Spain				
1	5906	172	5182	626
2	9714	269	8779	626
3	5129	175	7706	914
4	3970	251	8554	914
Total	24718	867	30221	3080
Sweden*				
3	15.5	0	0	0
4	0.025	0	0	0
Total	16	0	0	0
UK (England + Wales)				
1	0	0	0	0
2	1837	0	44	0
3	2	0	38	0
4	24	0	0	0
Total	1864	0	82	0
UK (Northern Ireland)				
1	4508	0	0	0
Total	4508	0	0	0
UK (Scotland)				
1	57474	10	1864	458
2	9041	0	0	0
2018**	167	0	2949	0
Total	66682	10	4813	458
Total Geral	**1711477**	**1565**	**131779**	**16426**

*** only landings.**

**** 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 2018.

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	134917	103	98	15162	1006	7	112
27.3.a	57	0	0	0	0	0	0
27.4	56	74	0	686	0	0	12308
27.4.a	43353	188	144	6666	703	16	154
27.4.b	19	0	0	0	0	0	0
27.5.a	8284	1	1	19	25	3	2
27.5.b	498062	151	139	25167	3147	6	51
27.6.a	444288	271	96	19870	3143	7	45
27.6.b	169483	46	34	6065	1028	6	36
27.7.b	4801	0	0	0	0	0	0
27.7.c	329075	105	84	14813	2979	9	45
27.7.d	0	0	0	0	0	0	0
27.7.e	25	0	0	0	0	0	0
27.7.f	0	0	0	0	0	0	0
27.7.g	4	2	0	44	0	0	11881
27.7.h	34	15	0	78	0	0	2296
27.7.j	793	0	0	0	0	0	0
27.7.k	51648	43	43	8543	784	15	165
27.8.a	279	32	0	409	0	0	1467
27.8.b	186	193	147	1374	0	0	7406
27.8.c	18934	421	421	21646	1540	81	1143
27.8.d	15	0	0	0	0	0	0
27.9.a	6915	358	358	11237	2071	300	1625
27.12.b	249	0	0	0	0	0	0
27.14.a	3	0	0	0	0	0	0
TOTAL	**1711477**	**2003**	**1565**	**131779**	**16426**	**10**	**77**

Table 2.3.2.1. Blue whiting. ICES estimated preliminary catches (tonnes) in 2019 by quarter and area. Data submitted to InterCatch.

ICES div.	Quarter 1	Quarter 2	2019*	Total
27.2.a	447	13193		**13641**
27.3.a	0	0		**0**
27.4			**129**	**129**
27.4.a	232	4224		**4455**
27.4.b	0			**0**
27.5.a	8	5		**13**
27.5.b	45466	289865		**335331**
27.6.a	59671	234102	**4**	**293776**
27.6.b	67972	1848	**77**	**69897**
27.7.b	280	1959		**2239**
27.7.c	415686	13133		**428818**
27.7.g		0		**0**
27.7.h		17		**17**
27.7.j	0	2		**3**
27.7.k	102995			**102995**
27.8.a	1			**1**
27.8.b	11			**11**
27.9.a	203	260		**464**
27.12	51			**51**
Total	**693023**	**558608**	**209**	**1251841**

*** Data assign for 2019 were provided by year, due to sampling intensity.**

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 2019 preliminary data (quarters 1 and 2). Data submitted to InterCatch.

ICES div.	Catch (ton)	No. samples	No. Measured	No. Aged
27.4	129	0	0	0
27.2.a	13641	0	0	0
27.2.a.2	0	0	0	0
27.3.a	0	0	0	0
27.4.a	4455	0	0	0
27.4.b	0	0	0	0
27.5.a	13	0	0	0
27.5.b	334158	47	4658	1362
27.5.b.1	535	0	0	0
27.5.b.2	638	0	0	0
27.6.a	293776	25	2682	1634
27.6.b	48693	23	5394	923
27.6.b.2	21204	5	1118	374
27.7.b	2239	0	0	0
27.7.c	352501	95	21802	1793
27.7.c.2	76317	31	3999	1927
27.7.g	0	0	0	0
27.7.h	17	0	0	0
27.7.j	3	0	0	0
27.7.j.2	0	0	0	0
27.7.k	92381	19	4565	965
27.7.k.2	10614	6	1027	437
27.8.a	1	0	0	0
27.8.b	11	0	0	0
27.9.a	464	5	249	192
27.12	51	0	0	0
Total	**1251841**	**256**	**45494**	**9607**

Table 2.3.2.3. Blue whiting. ICES estimates of catches (tonnes) in 2019, based on (initial) declared quotas and expected uptake estimated by WGWIDE.

Country	Prelim Q1-Q2 catch	Expected remaining catch or total year catch	Total catch
Denmark	68,290	0	68,290
Faroe Islands	306,282	18,626	324,908
Germany	0	31,979	31,979
Greenland	0	19,692	19,692
France	0	13,327	13,327
Iceland	224,870	1,857	226,727
Ireland	35,961	0	35,961
The Netherlands	54,725	34,456	89,181
Norway	333,171	23,100	356,271
Poland	11,304	0	11,304
Portugal	464	2,000	2,464
Russia	162,735	33,265	196,000
United Kingdom	59,961	209	60,170
Spain	0	8,000	8,000
Sweden	0	27	27
Total	1,257,762	186,539	1,444,301
EU	230,704	89,998	320,703
Non-EU	1,027,058	76,848	1,103,906
	Best estimate of catches in 2019		**1,444,301**

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		

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

Table 2.3.3.1. Blue whiting. Catch-at-age numbers (thousands) by year. Discards included since 2014. Values for 2019 are preliminary.

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

Year Age	1	2	3	4	5	6	7	8	9	10+
2002	1821053	3232244	3291844	2242722	1824047	1647122	344403	168848	102576	142743
2003	3742841	4073497	8378955	4824590	2035096	1117179	400022	121280	19701	27493
2004	2156261	4426323	6723748	6697923	3044943	1276412	649885	249097	75415	36805
2005	1427277	1518938	5083550	5871414	4450171	1419089	518304	249443	100374	55226
2006	412961	939865	4206005	6150696	3833536	1718775	506198	181181	67573	36688
2007	167027	306898	1795021	4210891	3867367	2353478	935541	320529	130202	88573
2008	408790	179211	545429	2917190	3262956	1919264	736051	315671	113086	126637
2009	61125	156156	231958	594624	1596095	1156999	592090	251529	88615	48908
2010	349637	222975	160101	208279	646380	992214	702569	256604	70487	43693
2011	162997	101810	63954	53863	69717	116396	120359	55470	25943	12542
2012	239667	351845	663155	141854	106883	203419	363779	356785	212492	157947
2013	228175	508122	848597	896966	462714	224066	321310	397536	344285	383601
2014	588717	584084	2312953	2019373	1272862	416523	386396	462339	526141	662747
2015	2944849	2852384	2427329	2465286	1518235	707533	329882	258743	239164	450046
2016	1239331	3518677	2933271	1874011	1367844	756824	339851	185368	131039	288635
2017	401947	1999011	7864694	4063916	1509651	777185	263007	110351	63945	149369
2018	418781	541041	3572357	7340084	2983975	1022883	424206	150753	90387	163289
2019	62481	204969	1574606	3595548	4765543	1503323	451127	144760	43247	83582

Table 2.3.4.1. Blue whiting. Individual mean weight (kg) at age in the catch. Preliminary values for 2019.

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
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

Year Age	1	2	3	4	5	6	7	8	9	10+
2010	0.052	0.064	0.110	0.154	0.154	0.163	0.175	0.187	0.200	0.272
2011	0.055	0.079	0.107	0.136	0.169	0.169	0.179	0.189	0.214	0.270
2012	0.041	0.072	0.098	0.140	0.158	0.172	0.180	0.185	0.189	0.203
2013	0.051	0.077	0.094	0.117	0.139	0.162	0.185	0.188	0.198	0.197
2014	0.049	0.078	0.093	0.112	0.128	0.155	0.178	0.190	0.202	0.217
2015	0.039	0.070	0.094	0.117	0.137	0.155	0.174	0.183	0.193	0.201
2016	0.047	0.066	0.084	0.107	0.125	0.142	0.152	0.167	0.184	0.206
2017	0.056	0.072	0.080	0.094	0.113	0.131	0.148	0.172	0.190	0.212
2018	0.055	0.080	0.091	0.098	0.111	0.129	0.142	0.165	0.175	0.216
2019	0.057	0.087	0.099	0.110	0.117	0.129	0.144	0.164	0.176	0.252

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

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

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

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB
2004	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

*Survey discarded.

Table 2.3.7.2.1. Blue whiting. Estimated abundance of 1 and 2 year old blue whiting from the International Norwegian Sea ecosystem survey, 2003–2018.

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

***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

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

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

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

Table 2.4.1. Blue whiting. Parameter estimates, from final assessment (2019) and retrospective analysis (2015-2018).

Parameter Year	2015	2016	2017	2018	2019
Random walk variance					
-F Age 1-10	0.40	0.39	0.38	0.38	0.37
Process error					
-log(N) Age 1	0.58	0.60	0.63	0.61	0.61
--- Age 2-10	0.17	0.18	0.18	0.18	0.18
Observation variance					
-Catch Age 1	0.46	0.45	0.44	0.43	0.45
--- Age 2	0.30	0.28	0.29	0.28	0.31
--- Age 3-8	0.20	0.20	0.20	0.19	0.19
--- Age 9-10	0.40	0.40	0.40	0.40	0.39
-IBWSS Age 1	0.75	0.82	0.73	0.72	0.81
--- Age 2	0.31	0.32	0.30	0.32	0.38
--- Age 3	0.45	0.45	0.42	0.43	0.41
--- Age 4-6	0.45	0.42	0.39	0.38	0.37
--- Age 7-8	0.38	0.40	0.47	0.51	0.54
Survey catchability					
-IBWSS Age 1	0.06	0.06	0.07	0.06	0.07
--- Age 2	0.12	0.12	0.12	0.11	0.11
--- Age 3	0.37	0.38	0.38	0.38	0.36
--- Age 4	0.70	0.69	0.70	0.68	0.67
--- Age 5-8	0.91	0.89	0.90	0.87	0.86
Rho					
--	0.92	0.92	0.93	0.93	0.93

Table 2.4.2. Blue whiting. Mohn's rho by year and average over the last five years (n=5).

Year	R(age 1)	SSB	Fbar(3-7)
2014	-0.393	0.293	-0.274
2015	-0.347	-0.143	0.277
2016	0.197	0.034	-0.075
2017	-0.161	-0.133	0.214
2018	0.036	-0.140	0.152
rho.mean	-0.134	-0.018	0.059

Table 2.4.3. Blue whiting. Estimated fishing mortalities. Catch data for 2019 are preliminary.

Year Age	1	2	3	4	5	6	7	8	9	10+
1981	0.078	0.118	0.171	0.210	0.243	0.316	0.345	0.444	0.490	0.490
1982	0.067	0.102	0.147	0.181	0.206	0.268	0.291	0.371	0.406	0.406
1983	0.078	0.116	0.169	0.208	0.236	0.310	0.334	0.416	0.444	0.444
1984	0.096	0.142	0.211	0.263	0.302	0.394	0.415	0.505	0.527	0.527
1985	0.102	0.151	0.231	0.294	0.346	0.447	0.464	0.559	0.574	0.574
1986	0.114	0.169	0.269	0.359	0.434	0.555	0.574	0.692	0.706	0.706
1987	0.101	0.150	0.248	0.339	0.417	0.542	0.562	0.675	0.677	0.677
1988	0.098	0.148	0.253	0.349	0.441	0.580	0.591	0.695	0.676	0.676
1989	0.113	0.170	0.303	0.418	0.527	0.690	0.715	0.843	0.803	0.803
1990	0.105	0.158	0.291	0.406	0.511	0.668	0.717	0.854	0.817	0.817
1991	0.059	0.088	0.166	0.233	0.289	0.367	0.396	0.465	0.449	0.449
1992	0.048	0.072	0.139	0.194	0.232	0.284	0.310	0.368	0.361	0.361
1993	0.042	0.063	0.126	0.176	0.206	0.246	0.269	0.320	0.315	0.315
1994	0.037	0.055	0.115	0.162	0.187	0.221	0.244	0.295	0.289	0.289
1995	0.047	0.070	0.150	0.215	0.242	0.282	0.313	0.383	0.368	0.368
1996	0.056	0.085	0.186	0.271	0.296	0.345	0.382	0.474	0.451	0.451
1997	0.055	0.084	0.190	0.281	0.299	0.347	0.381	0.476	0.454	0.454
1998	0.070	0.110	0.252	0.382	0.405	0.468	0.506	0.628	0.590	0.590
1999	0.064	0.102	0.240	0.374	0.398	0.458	0.482	0.596	0.560	0.560

Year Age	1	2	3	4	5	6	7	8	9	10+
2000	0.074	0.118	0.282	0.450	0.499	0.576	0.588	0.706	0.666	0.666
2001	0.069	0.110	0.264	0.429	0.490	0.567	0.567	0.673	0.637	0.637
2002	0.064	0.103	0.251	0.418	0.502	0.594	0.595	0.701	0.665	0.665
2003	0.067	0.106	0.261	0.440	0.542	0.632	0.624	0.704	0.664	0.664
2004	0.068	0.107	0.268	0.459	0.588	0.686	0.682	0.744	0.702	0.702
2005	0.059	0.094	0.239	0.420	0.557	0.651	0.655	0.700	0.663	0.663
2006	0.051	0.081	0.209	0.373	0.510	0.599	0.607	0.637	0.603	0.603
2007	0.047	0.077	0.197	0.356	0.504	0.605	0.630	0.660	0.627	0.627
2008	0.041	0.067	0.171	0.307	0.442	0.531	0.565	0.590	0.569	0.569
2009	0.026	0.043	0.111	0.194	0.282	0.337	0.367	0.382	0.370	0.370
2010	0.019	0.031	0.079	0.134	0.194	0.231	0.254	0.258	0.252	0.252
2011	0.006	0.009	0.024	0.040	0.056	0.066	0.073	0.075	0.075	0.075
2012	0.012	0.020	0.052	0.084	0.119	0.139	0.158	0.165	0.165	0.165
2013	0.019	0.034	0.091	0.148	0.209	0.241	0.277	0.292	0.292	0.292
2014	0.036	0.064	0.180	0.292	0.406	0.467	0.537	0.571	0.568	0.568
2015	0.045	0.082	0.234	0.381	0.526	0.610	0.690	0.732	0.724	0.724
2016	0.038	0.069	0.201	0.329	0.455	0.538	0.607	0.640	0.633	0.633
2017	0.035	0.064	0.191	0.310	0.424	0.501	0.558	0.583	0.578	0.578
2018	0.034	0.062	0.189	0.307	0.418	0.497	0.557	0.579	0.576	0.576
2019	0.028	0.052	0.162	0.263	0.355	0.422	0.475	0.488	0.488	0.488

Table 2.4.4. Blue whiting. Estimated stock numbers-at-age (thousands). Preliminary catch data for 2019 have been used.

Year Age	1	2	3	4	5	6	7	8	9	10+
1981	3896876	3492597	4871007	2093891	2627921	2153014	1650416	1738083	1216486	2951678
1982	4630424	2917499	2528049	3301226	1598544	1512881	1303118	1015736	886131	1927262
1983	17678275	3689975	1882874	1834658	1928848	1225298	1017655	857480	626680	1262180
1984	17723928	14056528	2427175	1238806	1273828	1401313	819180	554020	484216	932256

Year Age	1	2	3	4	5	6	7	8	9	10+
1985	9543383	13320605	9633102	1451713	753924	913924	750203	461578	268372	727320
1986	7272374	6414112	9356762	5492602	937539	454417	472050	377560	232213	500050
1987	9132926	5095624	4105139	6793112	2551160	395339	253474	237604	156824	293766
1988	6437259	6908547	3541005	2890386	3688443	1252497	198439	125507	99098	171218
1989	8612583	4634745	5000149	2436690	2123685	1675041	350727	102311	60197	115618
1990	18742380	6071502	3108680	2744591	1483283	1182786	559053	120505	33129	84570
1991	8944058	15607133	4297830	1806968	1491047	868106	558493	188955	32441	45039
1992	6715037	7285087	12506819	3315816	1270988	795566	486310	287451	101283	39141
1993	5089008	5134499	5254883	9687193	2261655	980787	518006	283412	157318	74460
1994	8033603	3536421	4046815	3408563	6881206	1441016	762408	326991	206137	116946
1995	9374009	5852874	3159661	2577279	2848615	3748967	1035469	540324	218570	184810
1996	27736116	7129129	4070132	2398183	1566377	1866177	2235425	641166	304831	247248
1997	44065482	21186978	5465815	2565642	1428114	1075534	1064253	1211517	288089	332121
1998	26947826	36987626	16269113	3483215	1384172	930528	781084	602526	614854	292253
1999	20741960	20740261	27179283	10393488	1717461	779068	522937	409836	237132	426968
2000	38741897	15631400	16543550	15681925	4319771	1105193	471896	323231	154091	312783
2001	56204092	30868396	12173267	10707964	7428567	1696945	490394	226938	161246	178587
2002	49118731	45568623	20309186	8322894	5478866	3398658	694437	255236	102946	154501
2003	52873853	39112707	35025533	13545304	5059887	2973377	1214003	348080	89487	106983
2004	29806946	42005953	30021789	20918856	7277417	2462826	1318581	506050	152639	81125

Year Age	1	2	3	4	5	6	7	8	9	10+
2005	22383995	22907020	28674529	18110397	10790277	3251624	1115168	518475	194586	99714
2006	9029595	15894983	22513302	19372863	9487707	4479140	1364412	486872	220152	121600
2007	4912498	6134558	13271167	16017943	10370614	4702075	1840967	611444	230227	164203
2008	5795362	3509986	4413604	11107332	9224656	4942632	1867227	759340	237143	199906
2009	5717271	4044320	2450635	3754299	7000979	4756794	2210150	861048	326583	190172
2010	15629189	4941581	2398985	1897417	3408214	4382146	2856638	1217416	418810	269718
2011	19530150	13653303	3322078	1684645	1646850	2644032	2728079	1377509	825674	398698
2012	19666112	15578182	12565693	2335933	1213771	1640203	2350394	2133180	1091964	911564
2013	16561619	16449374	11666941	7481074	2257018	1109546	1388478	1649435	1360434	1393334
2014	37382298	13131769	13874711	8092127	4449641	1371109	940364	1004844	1026638	1508860
2015	64931228	32784290	10908640	8617890	4279090	1764228	745265	522430	485513	1068627
2016	36012234	58459167	21601034	7829243	4446954	1848161	717154	355683	223797	602550
2017	12772968	29542948	46531673	15623163	4732406	2228178	759299	290397	164278	383498
2018	9856549	10175002	23263586	31440843	9331101	2657503	997009	323802	148486	277502
2019	5466776	7044995	10228252	16037027	18749727	4968279	1315218	447418	138539	216660

Table 2.4.5. Blue whiting. Estimated recruitment 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 2019 are included.

Year	R(age 1)	Low	High	SSB	Low	High	Fbar (3-7)	Low	High	TSB	Low	High
1981	3896876	2489342	6100263	2846619	2233607	3627870	0.257	0.186	0.356	3343500	2673113	4182014
1982	4630424	2936887	7300526	2304898	1828845	2904869	0.219	0.161	0.297	2771494	2238241	3431793
1983	17678275	11403660	27405360	1858580	1506437	2293040	0.251	0.188	0.337	2861615	2324804	3522379
1984	17723928	11541642	27217758	1744170	1437627	2116077	0.317	0.240	0.418	3046970	2452354	3785761
1985	9543383	6250679	14570604	2078674	1710733	2525752	0.356	0.273	0.465	3204588	2608905	3936282
1986	7272374	4790094	11041000	2263816	1866673	2745452	0.438	0.337	0.570	3104859	2566763	3755762
1987	9132926	6002314	13896362	1926457	1591061	2332555	0.421	0.323	0.549	2813755	2329199	3399115
1988	6437259	4223292	9811850	1635851	1362246	1964409	0.443	0.340	0.577	2427085	2016017	2921969
1989	8612583	5630452	13174180	1546980	1292158	1852055	0.531	0.409	0.688	2398767	1982599	2902292
1990	18742380	12073288	29095370	1360972	1126775	1643846	0.519	0.393	0.684	2504729	1995610	3143735
1991	8944058	5714284	13999334	1779798	1423554	2225191	0.290	0.213	0.396	3220186	2510433	4130600
1992	6715037	4336390	10398447	2458820	1941223	3114427	0.232	0.170	0.316	3523473	2786577	4455238
1993	5089008	3256529	7952642	2536460	2012814	3196336	0.205	0.150	0.278	3420502	2734553	4278517
1994	8033603	5173862	12474003	2529314	2029095	3152848	0.186	0.136	0.253	3412013	2763725	4212371
1995	9374009	6095731	14415341	2309839	1894920	2815609	0.240	0.180	0.321	3359104	2757252	4092328
1996	27736116	18077467	42555304	2208021	1829036	2665534	0.296	0.223	0.393	3715742	3015623	4578404

Year	R(age 1)	Low	High	SSB	Low	High	Fbar (3-7)	Low	High	TSB	Low	High
1997	44065482	28775928	67478857	2457528	2031284	2973214	0.300	0.227	0.396	5388585	4221497	6878330
1998	26947826	17716639	40988888	3643947	2968036	4473784	0.403	0.308	0.525	6757753	5379486	8489143
1999	20741960	13560362	31726948	4406105	3577162	5427141	0.390	0.298	0.511	7158771	5800381	8835283
2000	38741897	25326341	59263774	4222027	3496188	5098557	0.479	0.370	0.620	7437292	6046579	9147868
2001	56204092	36978866	85424468	4552790	3785445	5475682	0.463	0.357	0.601	8969231	7207515	11161559
2002	49118731	32310079	74671737	5408962	4487435	6519731	0.472	0.363	0.614	10363526	8352423	12858864
2003	52873853	35189022	79446489	6867451	5676958	8307598	0.500	0.390	0.641	11842067	9665842	14508259
2004	29806946	19758274	44966176	6783789	5666909	8120791	0.537	0.421	0.684	10443214	8667067	12583348
2005	22383995	14867884	33699701	6084043	5088722	7274042	0.504	0.392	0.648	8616632	7185805	10332363
2006	9029595	5935661	13736226	5934656	4943004	7125252	0.459	0.355	0.595	7801807	6498799	9366068
2007	4912498	3209526	7519066	4706700	3904871	5673177	0.458	0.350	0.600	5753500	4782808	6921199
2008	5795362	3738612	8983607	3619929	2959058	4428398	0.403	0.299	0.543	4441932	3646020	5411588
2009	5717271	3587927	9110325	2779726	2211779	3493512	0.258	0.186	0.358	3498267	2803095	4365843
2010	15629189	10039318	24331487	2713336	2115726	3479746	0.178	0.126	0.253	3799359	2990497	4827000
2011	19530150	12632711	30193579	2747257	2156219	3500305	0.052	0.035	0.077	4505291	3535106	5741736
2012	19666112	12933873	29902563	3477167	2797733	4321604	0.110	0.081	0.149	5176218	4155705	6447338
2013	16561619	10904850	25152773	3812909	3126908	4649409	0.193	0.145	0.257	5678694	4630818	6963687
2014	37382298	24357428	57372075	4050639	3357100	4887455	0.376	0.285	0.496	6714472	5444800	8280218

Year	R(age 1)	Low	High	SSB	Low	High	Fbar (3-7)	Low	High	TSB	Low	High
2015	64931228	41984711	100419038	4229586	3475339	5147528	0.488	0.374	0.637	8267016	6501844	10511410
2016	36012234	22678031	57186666	5017692	3981388	6323733	0.426	0.318	0.570	9341505	7181935	12150446
2017	12772968	7579852	21523998	6295525	4822504	8218476	0.397	0.286	0.550	9153979	6933676	12085268
2018	9856549	5319672	18262697	6315041	4620979	8630149	0.394	0.263	0.590	8213238	5977386	11285415
2019	5466776	2151558	13890231	5576649	3722192	8355027	0.335	0.197	0.570	6887458	4587618	10340241
2020				4325386*						5700362*		

***assuming long term GM(1981-2018) recruitment (14872450) and weight at age as average over 2017-2019**

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 2019 are included.

Year	Estimate	Low	High	Observed catch
1981	787954	559923	1108852	922980
1982	542653	409706	718741	550643
1983	507233	389448	660641	553344
1984	556434	425583	727517	615569
1985	635872	494977	816872	678214
1986	760976	593813	975195	847145
1987	638147	498366	817134	654718
1988	569393	445099	728396	552264
1989	619196	487448	786552	630316
1990	554092	433229	708675	558128
1991	405970	312825	526849	364008
1992	436412	341704	557371	474592
1993	440682	343516	565330	475198
1994	427876	331807	551760	457696
1995	507164	399455	643915	505176
1996	596929	470197	757820	621104
1997	640252	499350	820912	639681
1998	1070793	829910	1381593	1131955
1999	1248963	964168	1617879	1261033
2000	1505625	1172188	1933911	1412449
2001	1546213	1203135	1987120	1771805
2002	1711828	1332093	2199814	1556955
2003	2194948	1716704	2806423	2365319
2004	2313302	1817118	2944976	2400795
2005	2014019	1585530	2558307	2018344
2006	1868076	1471476	2371571	1956239
2007	1564711	1230188	1990199	1612269
2008	1173138	915397	1503451	1251851

Year	Estimate	Low	High	Observed catch
2009	653482	508924	839100	634978
2010	472279	361420	617142	539539
2011	137370	100382	187988	103771
2012	326245	256616	414768	375692
2013	590657	463820	752177	613863
2014	1112707	868768	1425140	1147650
2015	1336495	1050650	1700108	1390656
2016	1232532	966207	1572266	1180786
2017	1473370	1154261	1880700	1555069
2018	1691316	1318577	2169423	1709856
2019	1465267	1121211	1914899	1444301

Table 2.8.1.1. Blue whiting. Input to short-term projection (median values for exploitation pattern and stock numbers).

Age	Mean weight in the stock (kg)	Mean weight in the catch (kg)	Proportion mature	Natural mortality	Exploitation pattern	Stock number(2020) (thousands)
Age 1	0.057	0.057	0.11	0.20	0.085	14872450
Age 2	0.087	0.087	0.40	0.20	0.156	4350212
Age 3	0.099	0.099	0.82	0.20	0.484	5474034
Age 4	0.110	0.110	0.86	0.20	0.784	7120291
Age 5	0.117	0.117	0.91	0.20	1.058	10095469
Age 6	0.129	0.129	0.94	0.20	1.258	10768766
Age 7	0.144	0.144	1.00	0.20	1.417	2668431
Age 8	0.164	0.164	1.00	0.20	1.456	669720
Age 9	0.176	0.176	1.00	0.20	1.455	224837
Age 10	0.252	0.252	1.00	0.20	1.455	178582

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

Values	Value	Notes
F ages 3-7 (2019)	0.335	From the assessment (preliminary 2019 catches)
SSB (2020)	4325386	From forecast; in tonnes
R age 1 (2019)	5466776	From the assessment; in thousands
R age 1 (2020)	14872450	GM (1981–2018); in thousands
R age 1 (2021)	14872450	GM (1981–2018) ; in thousands
Total catch (2019)	1444301	Preliminary 2019 catches as estimated by the WG, based on declared quotas and expected uptake; in tonnes

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

Basis	Catch (2020)	F(2020)	SSB(2021)	% SSB change*	% Catch change**	% Advice change***
Long-term management strategy (F=FMSY)	1161615	0.320	3435240	-20.6	-19.6	1.6
MSY approach: FMSY	1161615	0.320	3435240	-20.6	-19.6	1.6
F = 0	0	0.000	4558202	5.4	-100.0	-100.0
Fpa	1738144	0.530	2887400	-33.2	20.3	52.0
Flim	2464861	0.880	2210394	-48.9	70.7	115.5
SSB (2021) = Blim	3258019	1.476	1499411	-65.3	125.6	184.9
SSB (2021 = Bpa	2421569	0.855	2250182	-48.0	67.7	111.7
SSB (2021) = MSY Btrigger	2421569	0.855	2250182	-48.0	67.7	111.7
F = F (2019)	1207680	0.335	3391192	-21.6	-16.4	5.6
SSB (2021) = SSB (2020)	239207	0.058	4325277	-0.0	-83.4	-79.1
Catch (2020) = Catch (2019)	1444788	0.418	3165186	-26.8	0.0	26.3
Catch (2020) = Catch (2019) -20 %	1155502	0.318	3441089	-20.4	-20.0	1.0
Catch (2020) = Advice (2019) -20 %	914820	0.242	3671942	-15.1	-36.7	-20.0
F = 0.05	208483	0.050	4355152	0.7	-85.6	-81.8
F = 0.1	406117	0.100	4163213	-3.7	-71.9	-64.5
F = 0.15	593517	0.150	3981748	-7.9	-58.9	-48.1
F = 0.16	629820	0.160	3946657	-8.8	-56.4	-44.9

Basis	Catch (2020)	F(2020)	SSB(2021)	% SSB change*	% Catch change**	% Advice change***
F = 0.17	665741	0.170	3911957	-9.6	-53.9	-41.8
F = 0.18	701285	0.180	3877642	-10.4	-51.4	-38.7
F = 0.19	736456	0.190	3843708	-11.1	-49.0	-35.6
F = 0.2	771258	0.200	3810150	-11.9	-46.6	-32.6
F = 0.21	805695	0.210	3776964	-12.7	-44.2	-29.5
F = 0.22	839773	0.220	3744145	-13.4	-41.9	-26.6
F = 0.23	873494	0.230	3711689	-14.2	-39.5	-23.6
F = 0.24	906863	0.240	3679593	-14.9	-37.2	-20.7
F = 0.25	939884	0.250	3647850	-15.7	-34.9	-17.8
F = 0.26	972561	0.260	3616459	-16.4	-32.7	-15.0
F = 0.27	1004898	0.270	3585413	-17.1	-30.4	-12.1
F = 0.28	1036898	0.280	3554710	-17.8	-28.2	-9.3
F = 0.29	1068567	0.290	3524345	-18.5	-26.0	-6.6
F = 0.3	1099906	0.300	3494315	-19.2	-23.8	-3.8
F = 0.31	1130921	0.310	3464614	-19.9	-21.7	-1.1
F = 0.32	1161615	0.320	3435240	-20.6	-19.6	1.6
F = 0.33	1191992	0.330	3406189	-21.3	-17.5	4.2
F = 0.34	1222054	0.340	3377457	-21.9	-15.4	6.9
F = 0.35	1251807	0.350	3349039	-22.6	-13.3	9.5
F = 0.45	1533028	0.450	3081403	-28.8	6.1	34.0
F = 0.5	1663178	0.500	2958178	-31.6	15.2	45.4

***) SSB 2021 relative to SSB 2020.**

****) Catch 2020 relative to expected catch in 2019 (1444301 tonnes).**

*****) Catch 2020 relative to advice for 2019 (1143629 tonnes).**

2.17 Figures

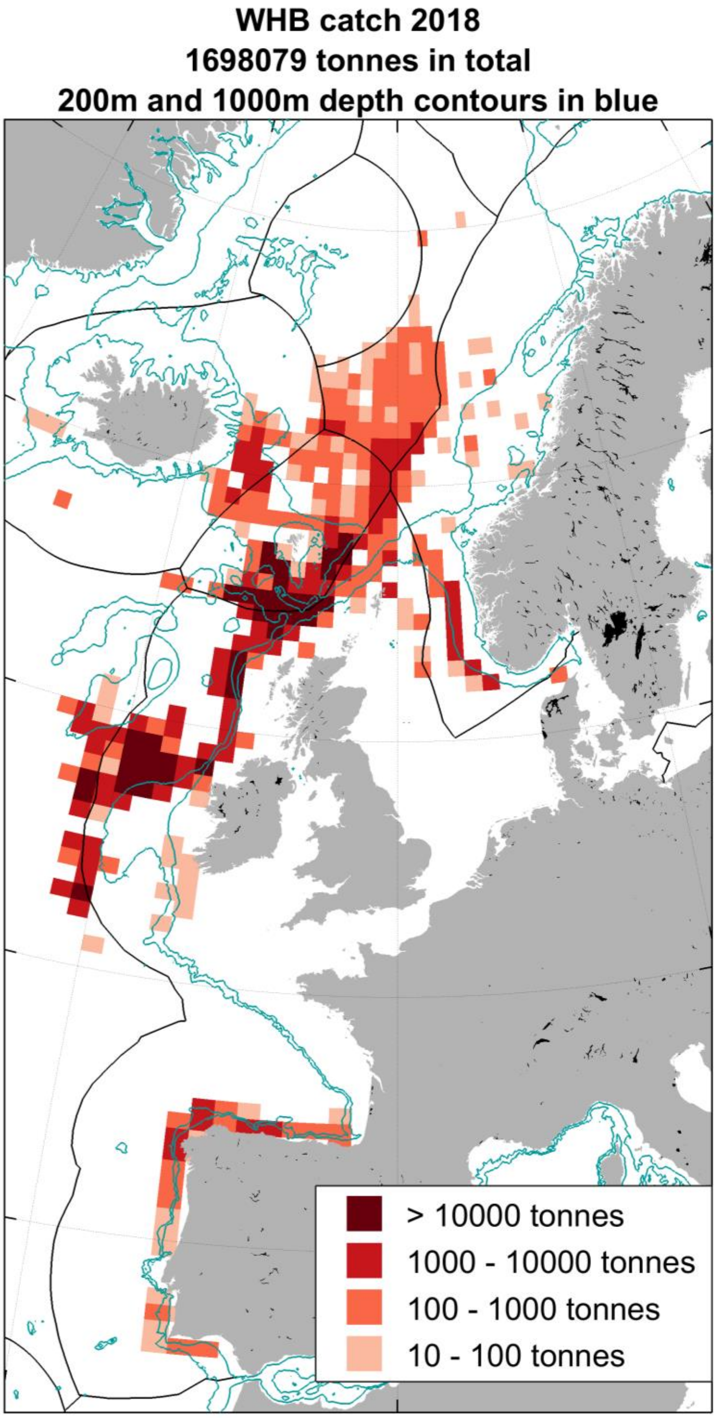


Figure 2.2.1. Blue whiting landings (ICES estimates) in 2018 by ICES rectangle. The 200 m and 1000 m depth contours are indicated in blue. The catches on the map constitute 98.8 % of the total landings.

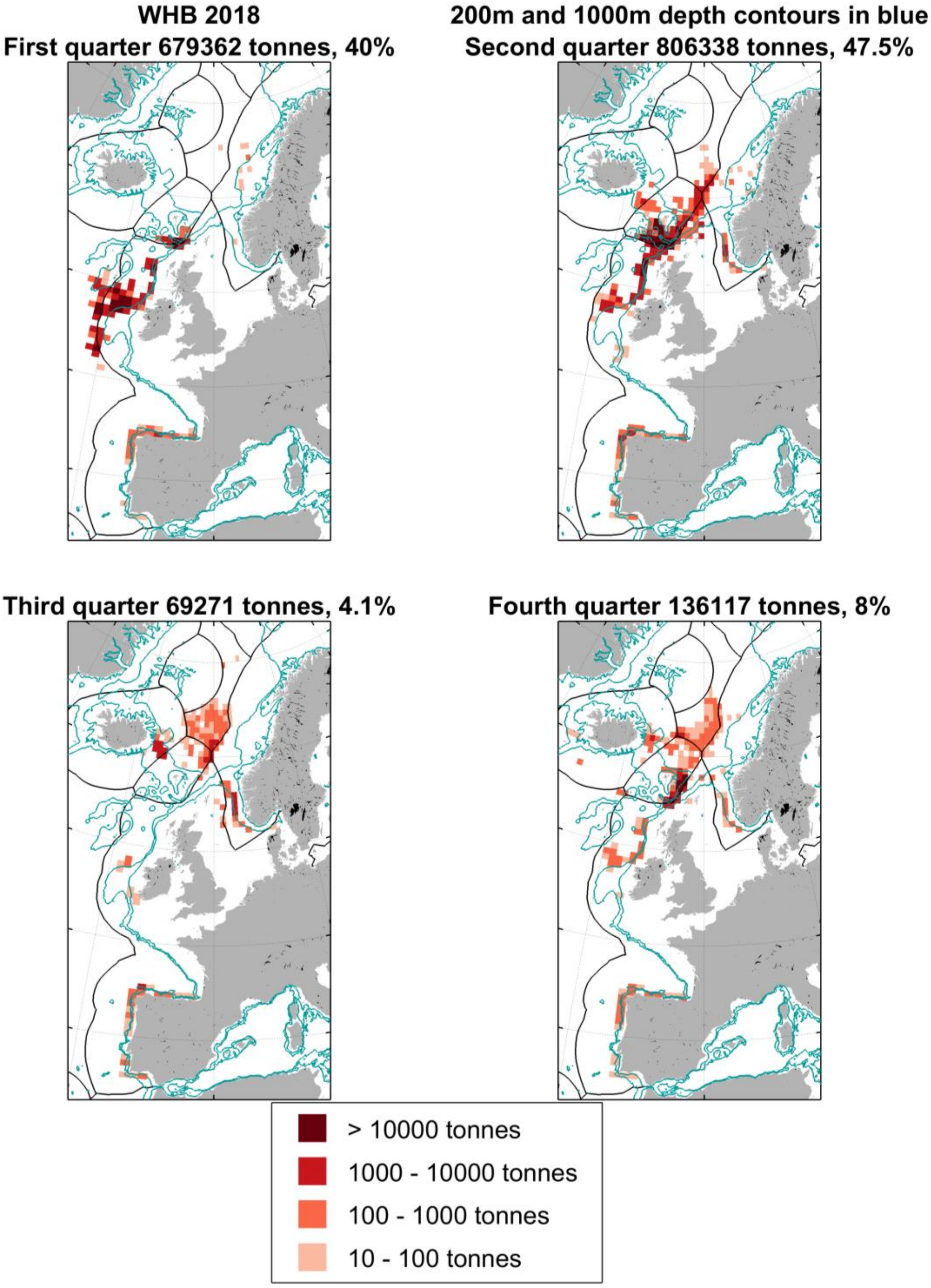


Figure 2.2.2. Blue whiting total catches per quarter (ICES estimates) 2018 by ICES rectangle. The 200 m and 1000 m depth contours are indicated in blue. The catches on the map constitute 99.6 % of the total landings.

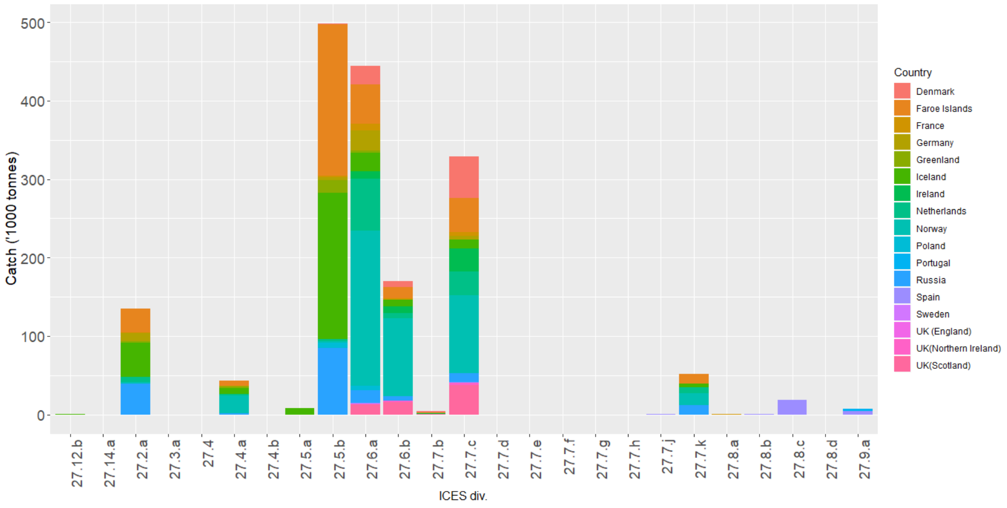
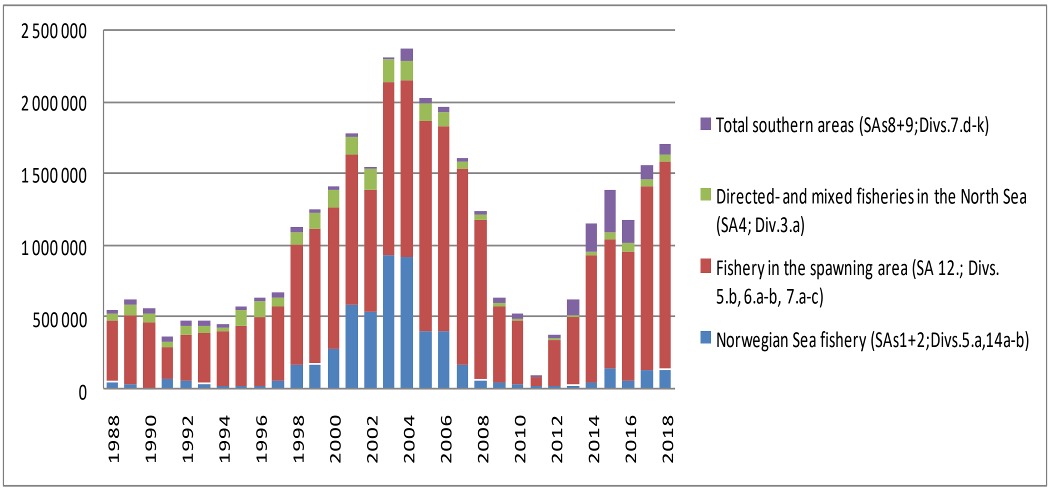


Figure 2.3.1.1. Blue whiting. ICES estimated catches ('1000 tonnes) in 2018 by ICES division and country.

A



B

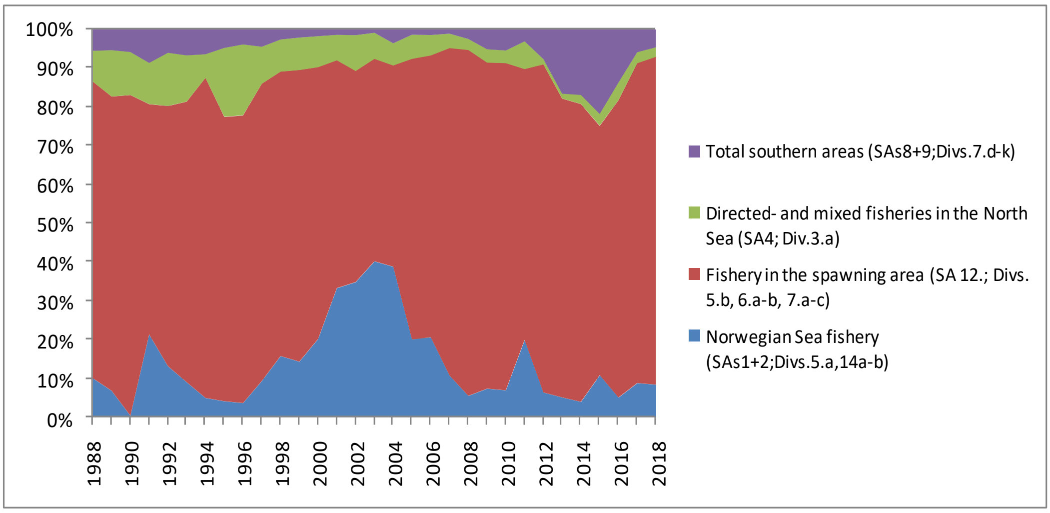


Figure 2.3.1.2. Blue whiting.(A) ICES estimated catches (tonnes) of blue whiting by fishery subareas from 1988-2018 and (B) the percentage contribution to the overall catch by fishery subarea over the same period.

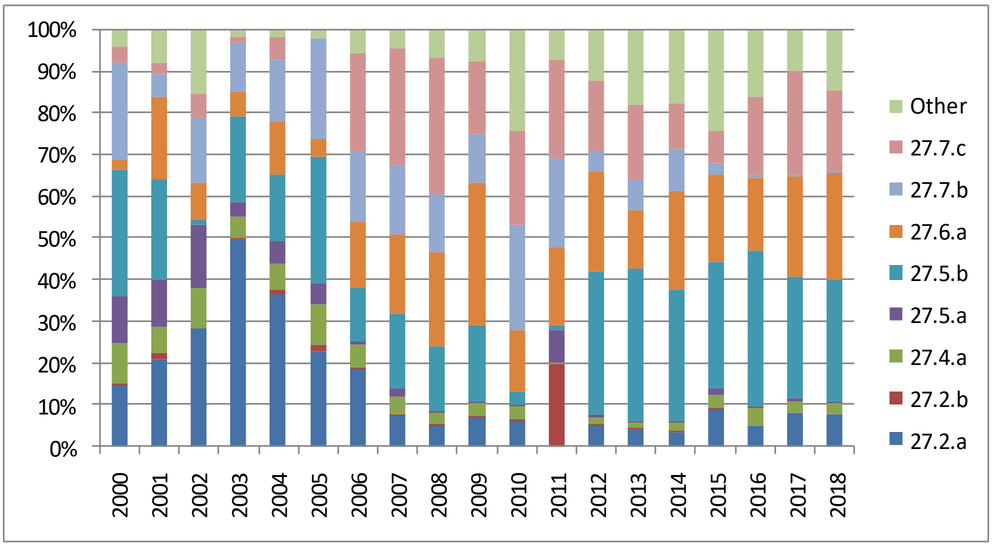


Figure 2.3.1.3. Blue whiting. Distribution of 2018 ICES estimated catches (in percentage) by ICES division area.

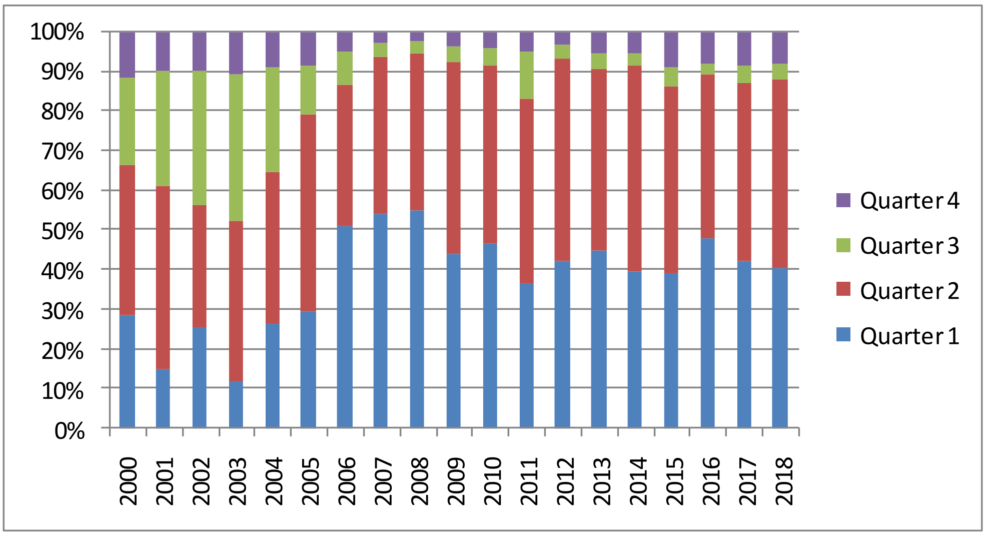


Figure 2.3.1.4. Blue whiting. Distribution of 2018 ICES estimated catches (in percentage) by quarter.

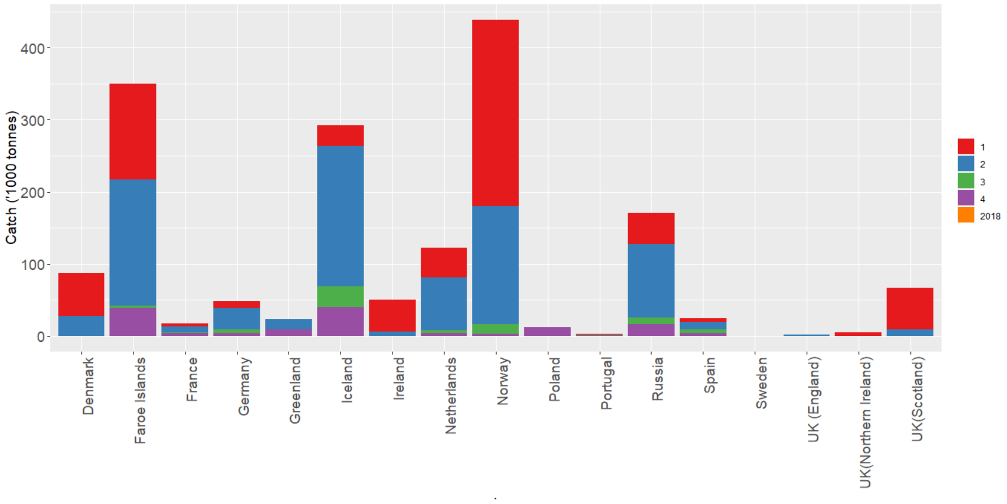


Figure 2.3.1.5. Blue whiting. Distribution of 2018 ICES estimated catches ('1000 tonnes) by country and by quarter. Discard data from UK (Scotland) were not assigned by quarter due to sampling intensity.

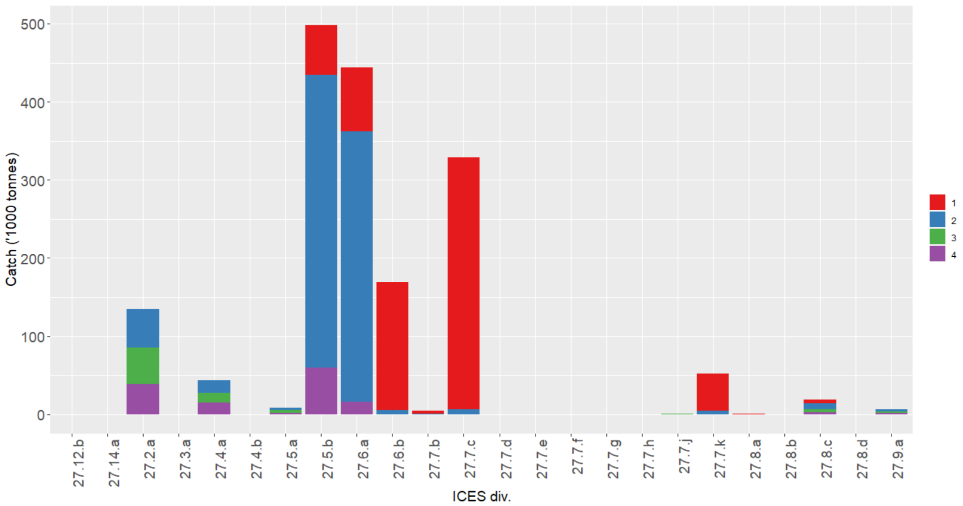


Figure 2.3.1.6. Blue whiting. Distribution of 2018 ICES estimated catches ('1000 tonnes) by ICES division and by quarter.

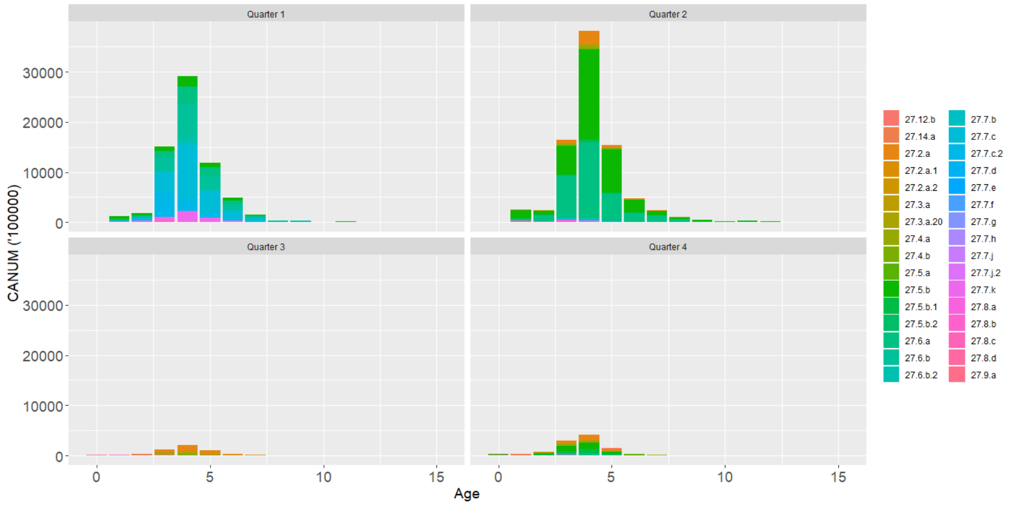


Figure 2.3.1.7. Blue whiting. Catch-at-age numbers (CANUM) distribution by quarter and ICES division for 2018.

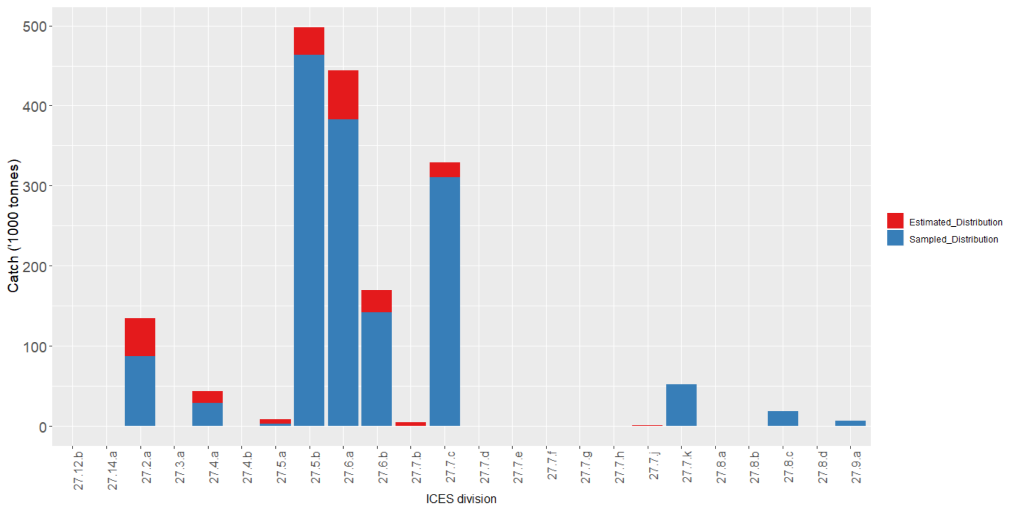


Figure 2.3.1.1.1. Blue whiting. 2018 ICES catches ('1000 tonnes) sampled and estimated by ICES division.

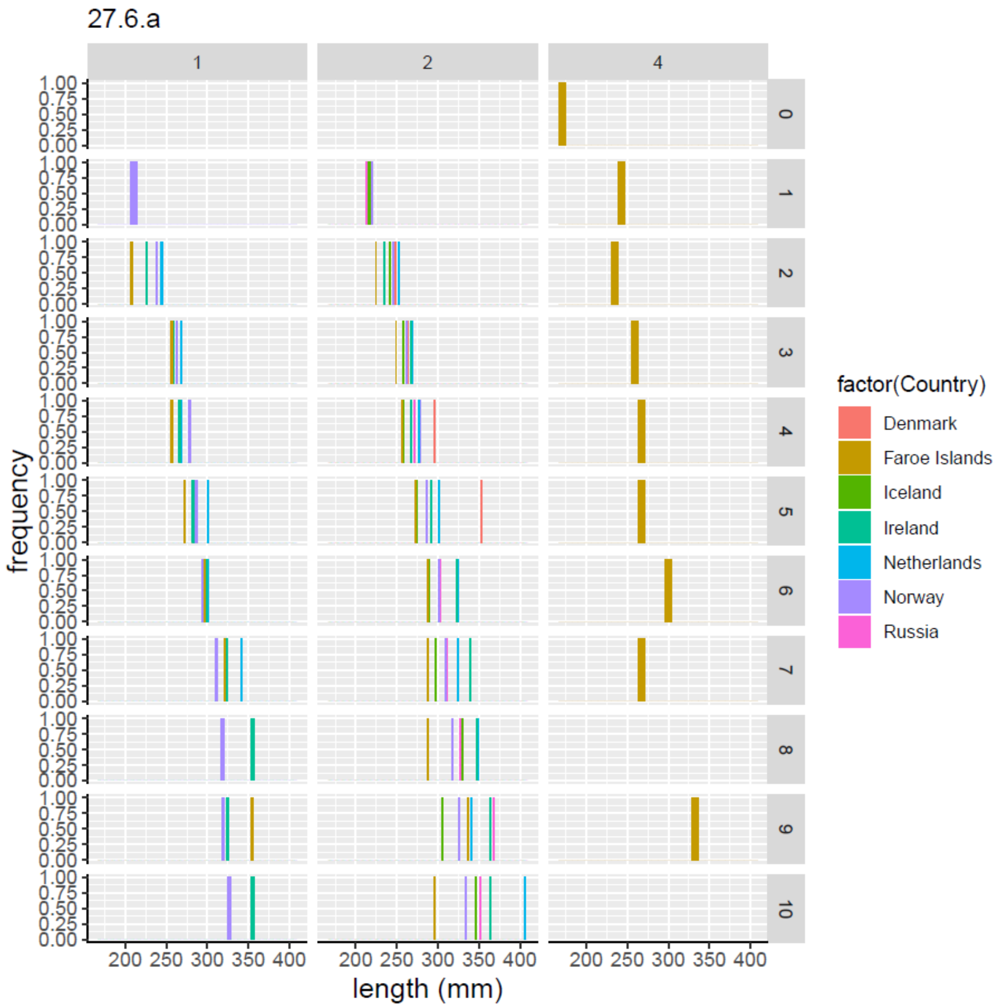


Figure 2.3.1.2.1. Blue whiting. Mean length (mm) by age (0-10 year), by quarter (1,2,4), by country for ICES division area 27.6.a. These data only comprises the 2018 ICES catch-at-age sampled estimates for ICES division 27.6.a.

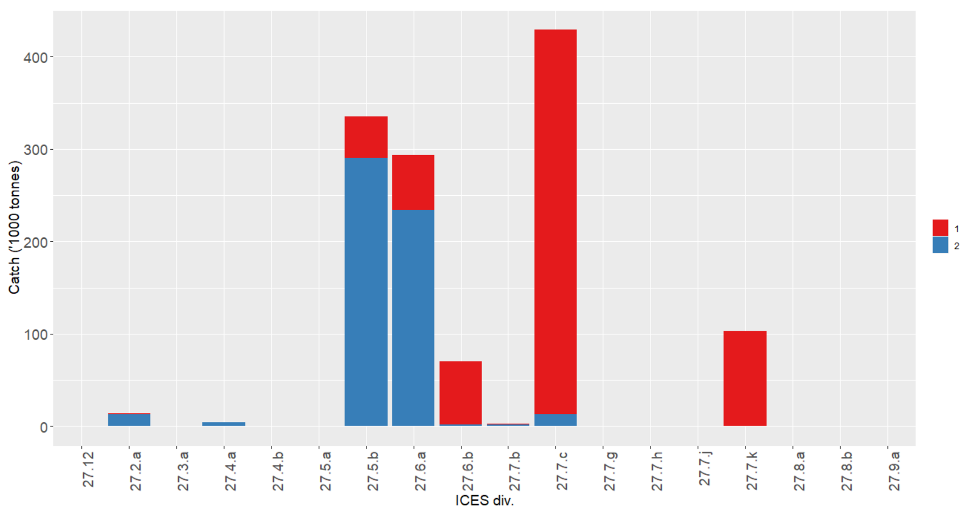


Figure 2.3.2.1. Blue whiting. Distribution of 2019 preliminary catches (tonnes) (1st semester) by ICES division and quarter.

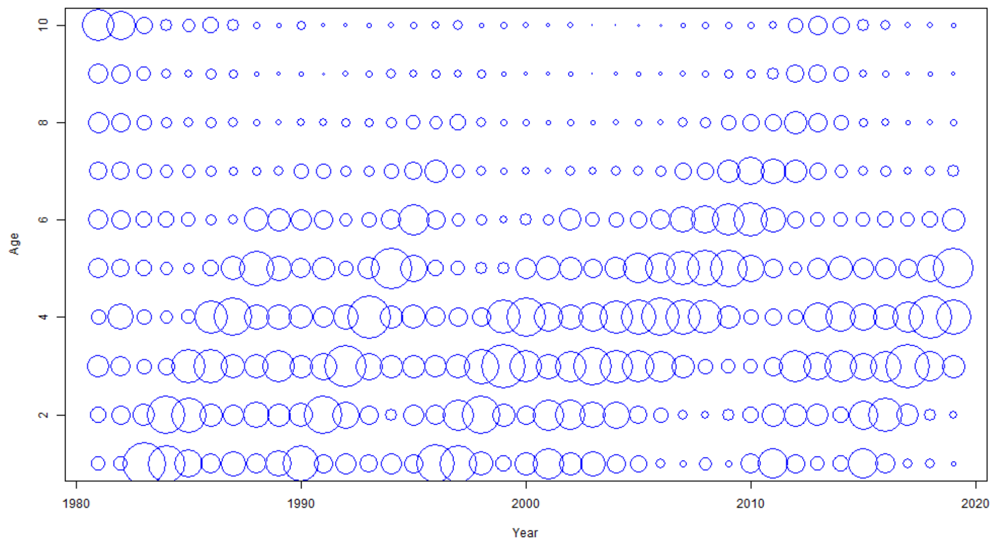


Figure 2.3.3.1. Blue whiting. Catch proportion at age, 1981-20189. Preliminary values for 20198 have been used.

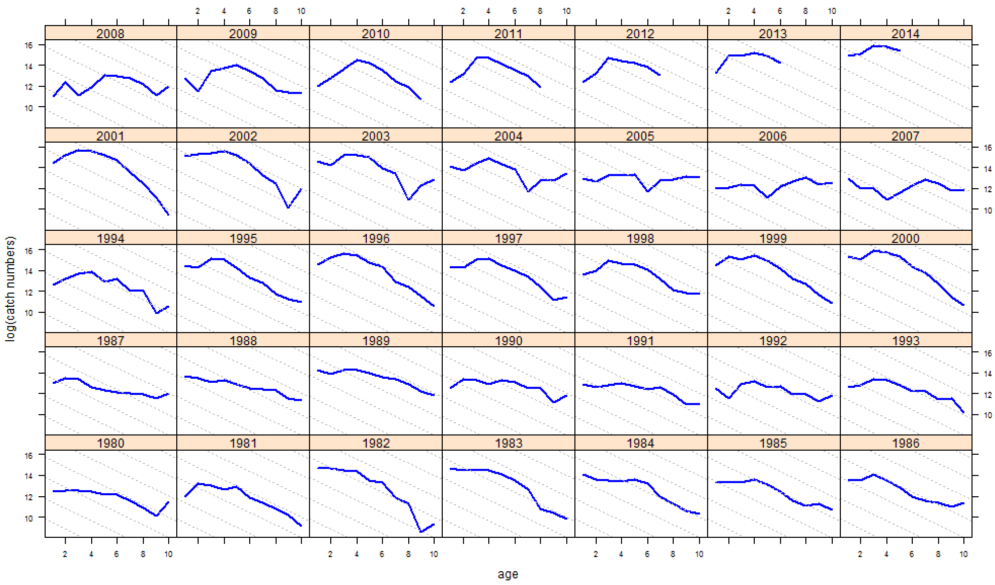


Figure 2.3.3.2. Blue whiting. Age disaggregated catch (numbers) plotted on log scale. The labels for each panel indicate year classes. The grey dotted lines correspond to *Z*=0.6. Preliminary catch-at-age for 2019have been used.

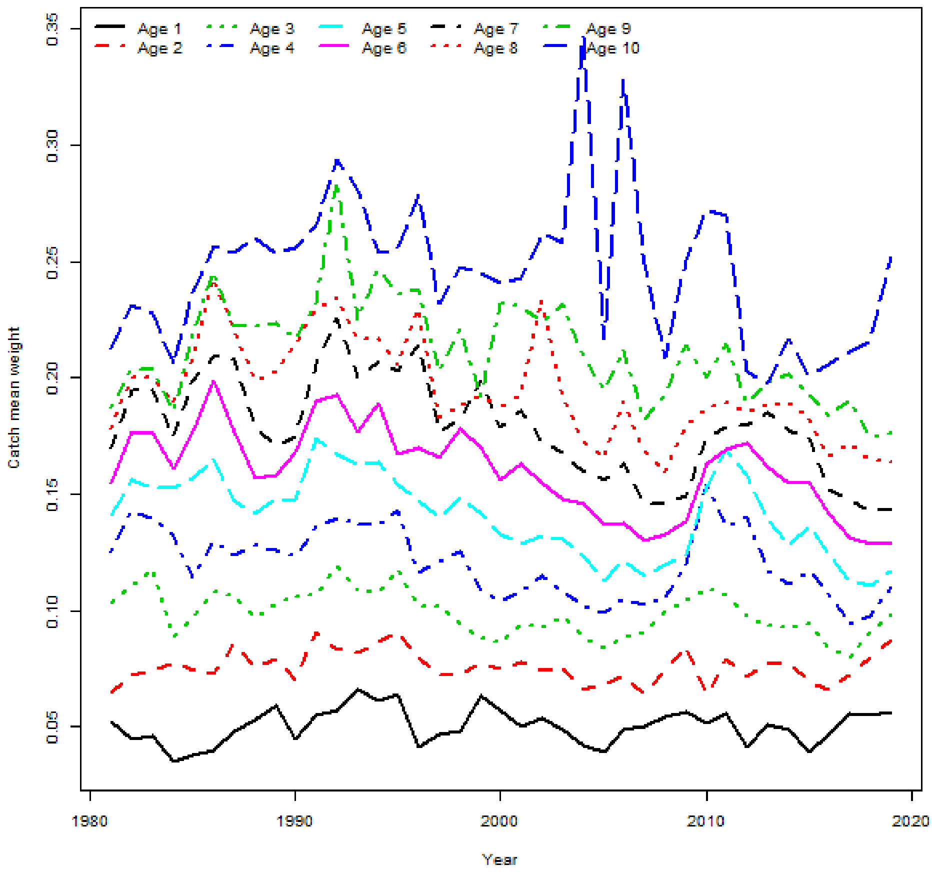


Figure 2.3.4.1. Blue whiting. Mean catch (and stock) weight (kg) at age by year. Preliminary values for 2019 have been used

A **B**

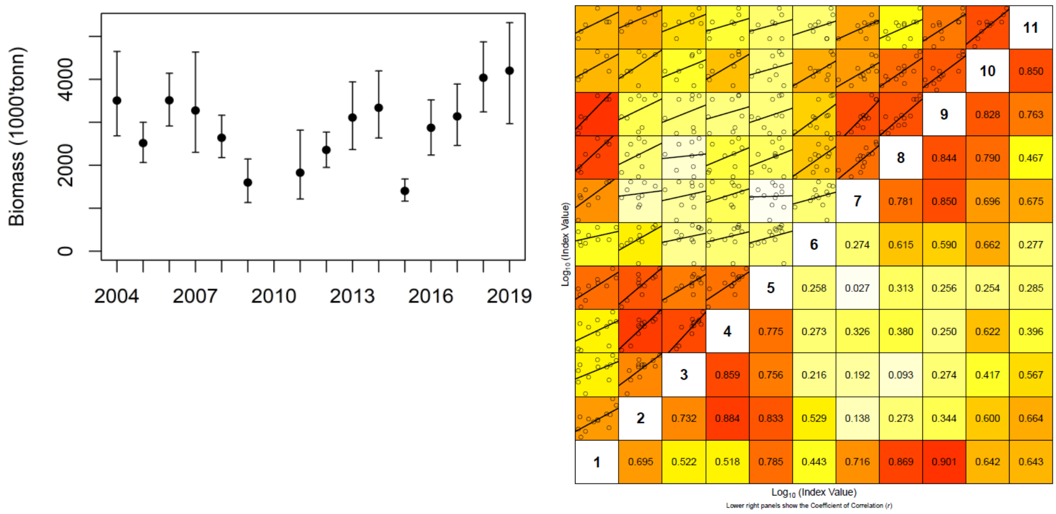


Figure 2.3.7.1.1. Blue whiting. (A) Estimate of total biomass from the International blue whiting spawning stock survey. The black dots and error bands are StoX estimates with 90 % confidence intervals. (B) Internal consistency within the International blue whiting spawning stock survey. The upper left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

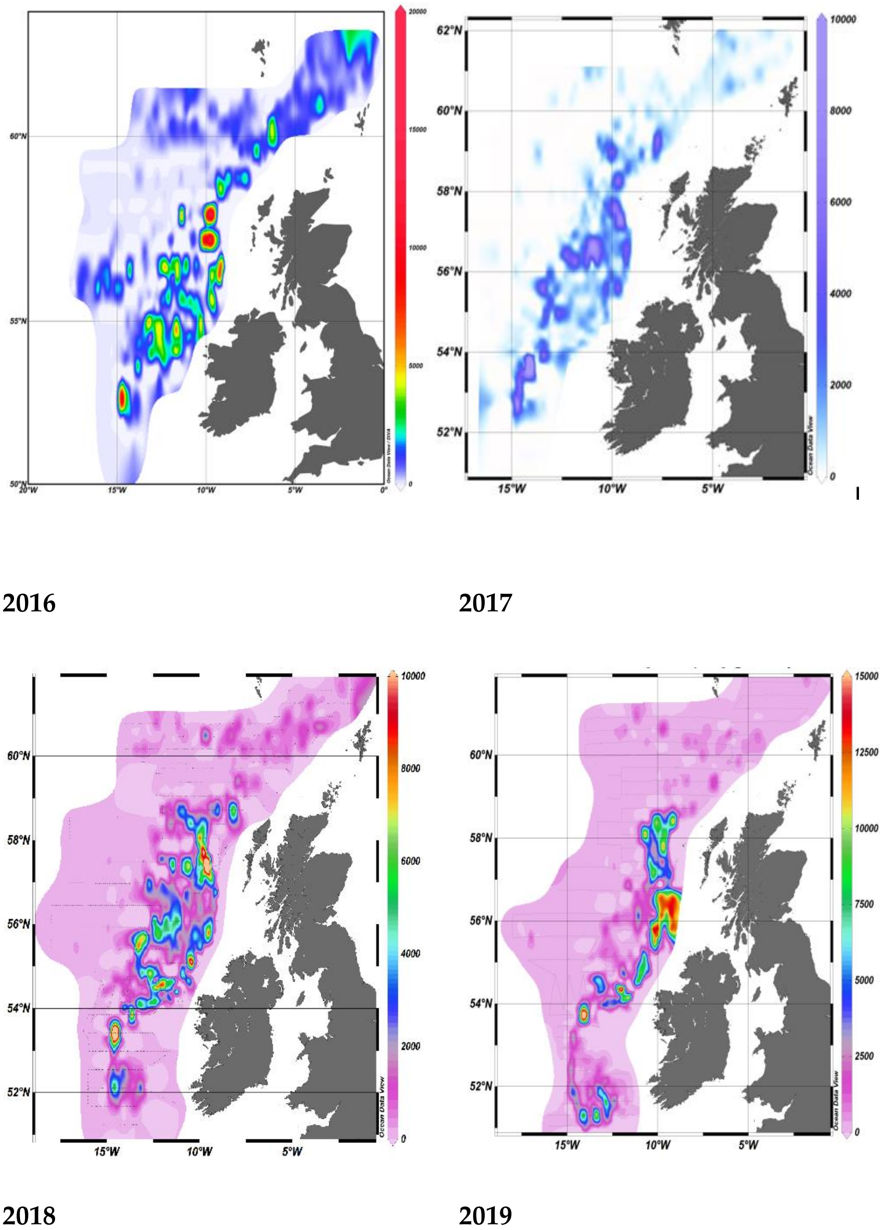


Figure 2.3.7.1.2. Map of blue whiting acoustic density (sA, m2/nm2) found during the spawning survey in spring 2016—2019.

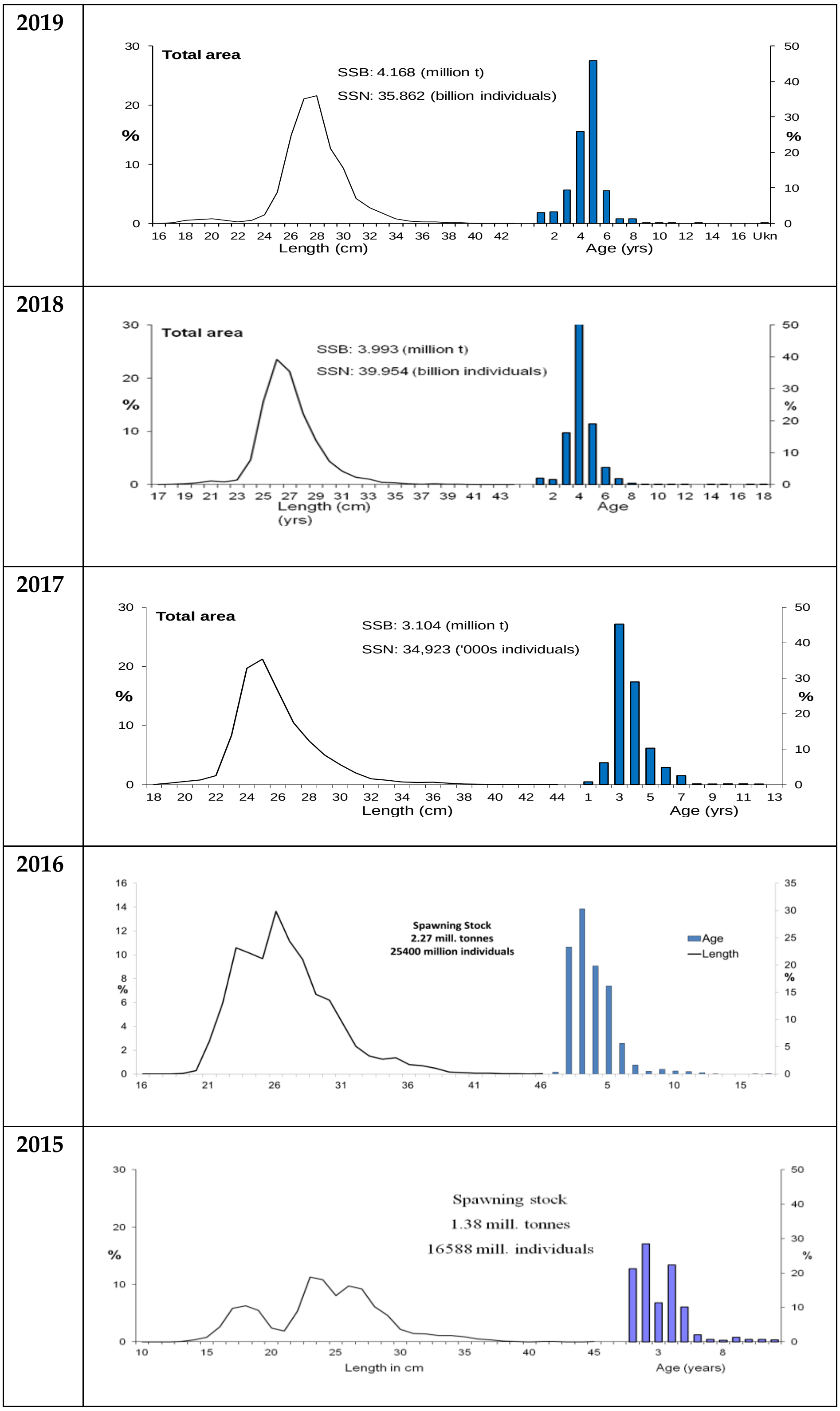


Figure 2.3.7.1.3. Blue whiting.Length (line) and age (bars) distribution of the blue whiting stock in the area to the west of the British Isles, spring 2015 (lower panel) to 2019 (upper panel).Spawning-stock biomass and numbers are given.

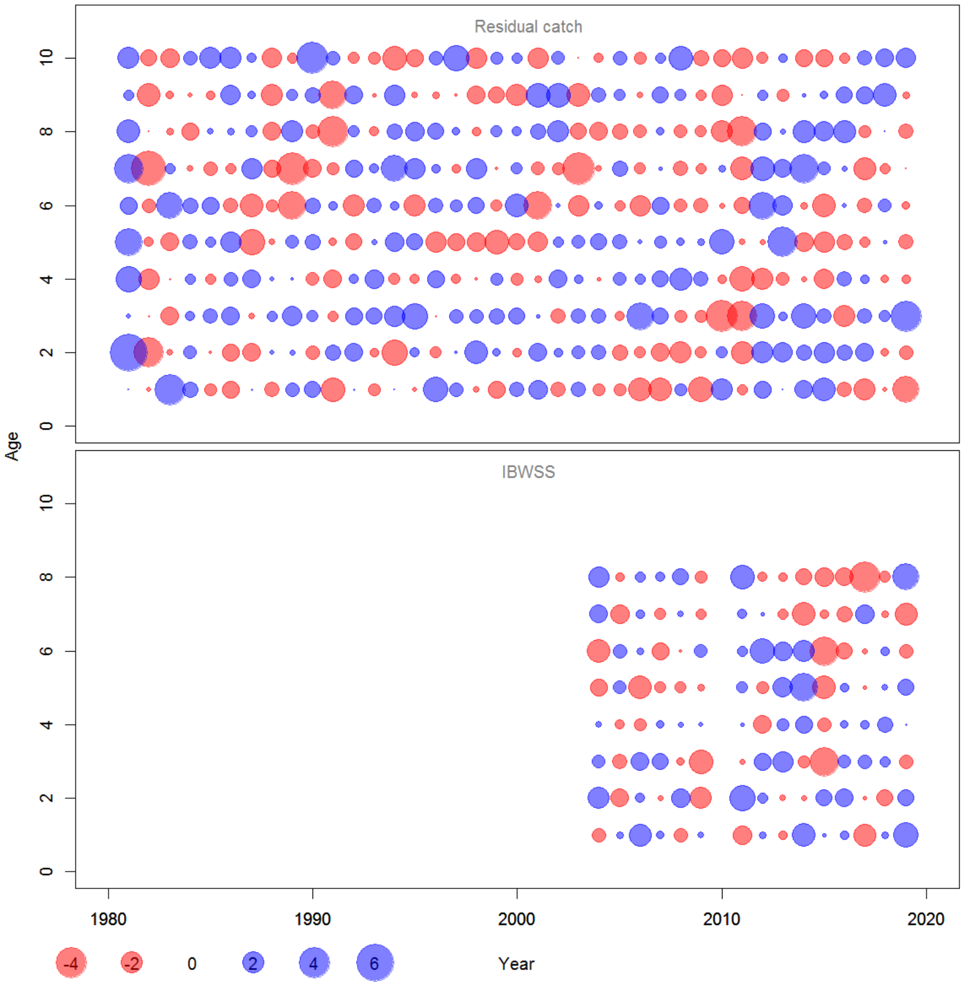


Figure 2.4.1. Blue Whiting.OSA (One Step Ahead) residuals (see Berg and Nielsen, 2016) from catch-at-age and the IBWSS survey. Red (lighter) bubbles show that the observed value is less than the expected value. Preliminary catch data for 2019 have been used.

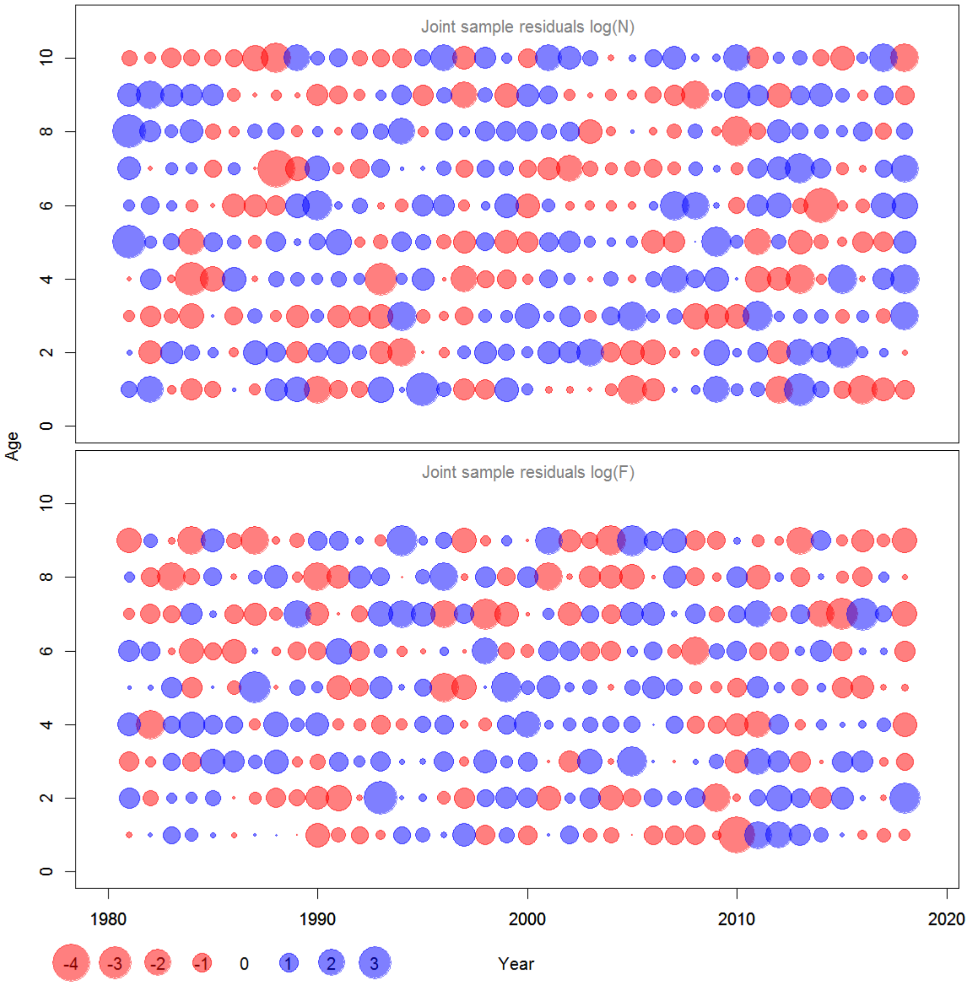


Figure 2.4.2. Blue whiting. Joint sample residuals (Process errors) for stock number and F at age. Red (lighter) bubbles show that the observed value is less than the expected value. Preliminary catch data for 2019 have been used.

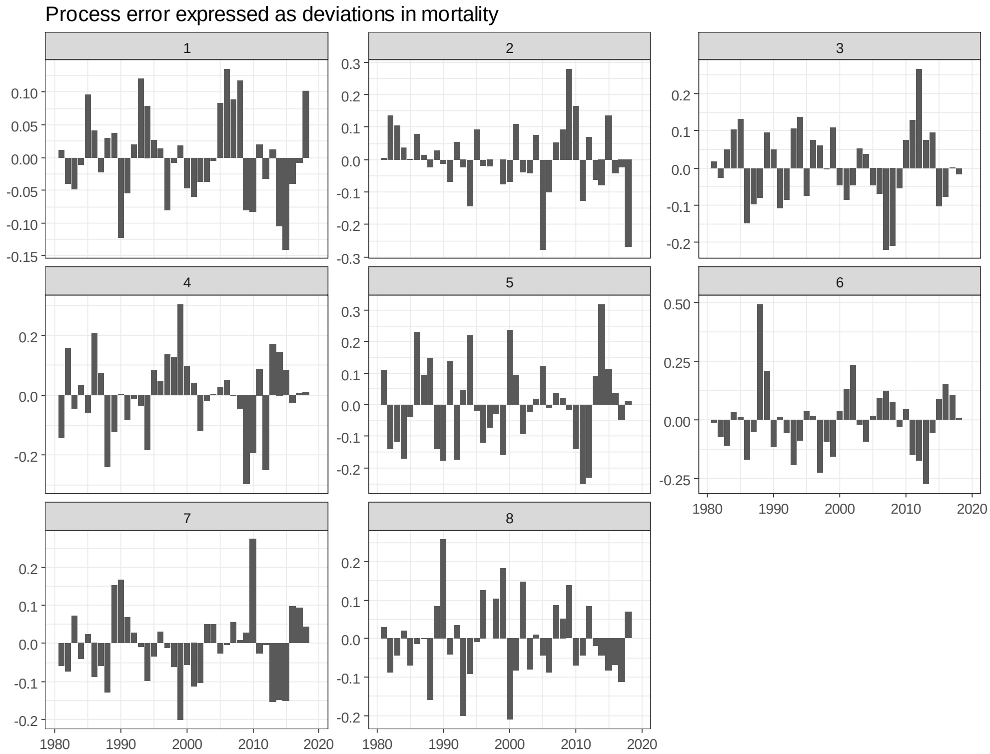


Figure 2.4.3. Blue whiting. Process errors expressed as deviation in instantaneous mortality at age by age and year.

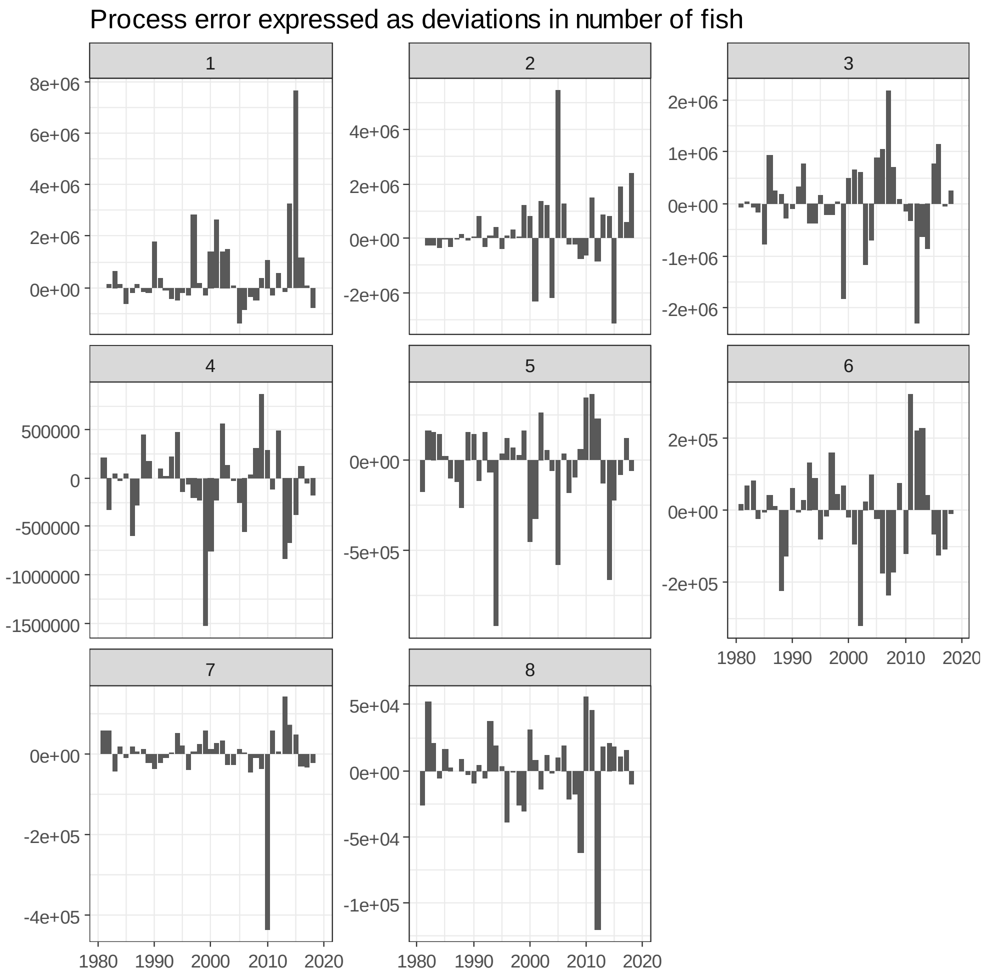
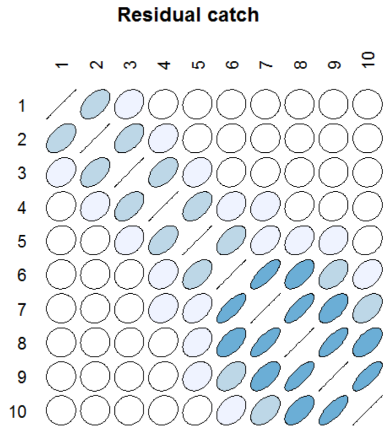


Figure 2.4.4. Blue whiting. Process errors expressed as deviation in instantaneous mortality at age by age and year.



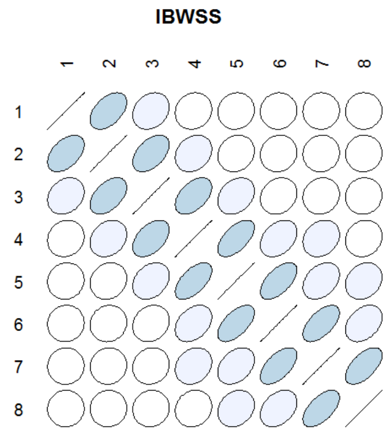


Figure 2.4.5. Blue whiting. The correlation matrix between ages for the catches and survey indices. Each ellipse represents the level curve of a bivariate normal distribution with the corresponding correlation. Hence, the sign of a correlation corresponds to the sign of the slope of the major ellipse axis. Increasingly darker shading is used for increasingly larger absolute correlations, while uncorrelated pairs of ages are depicted as circles with no shading.

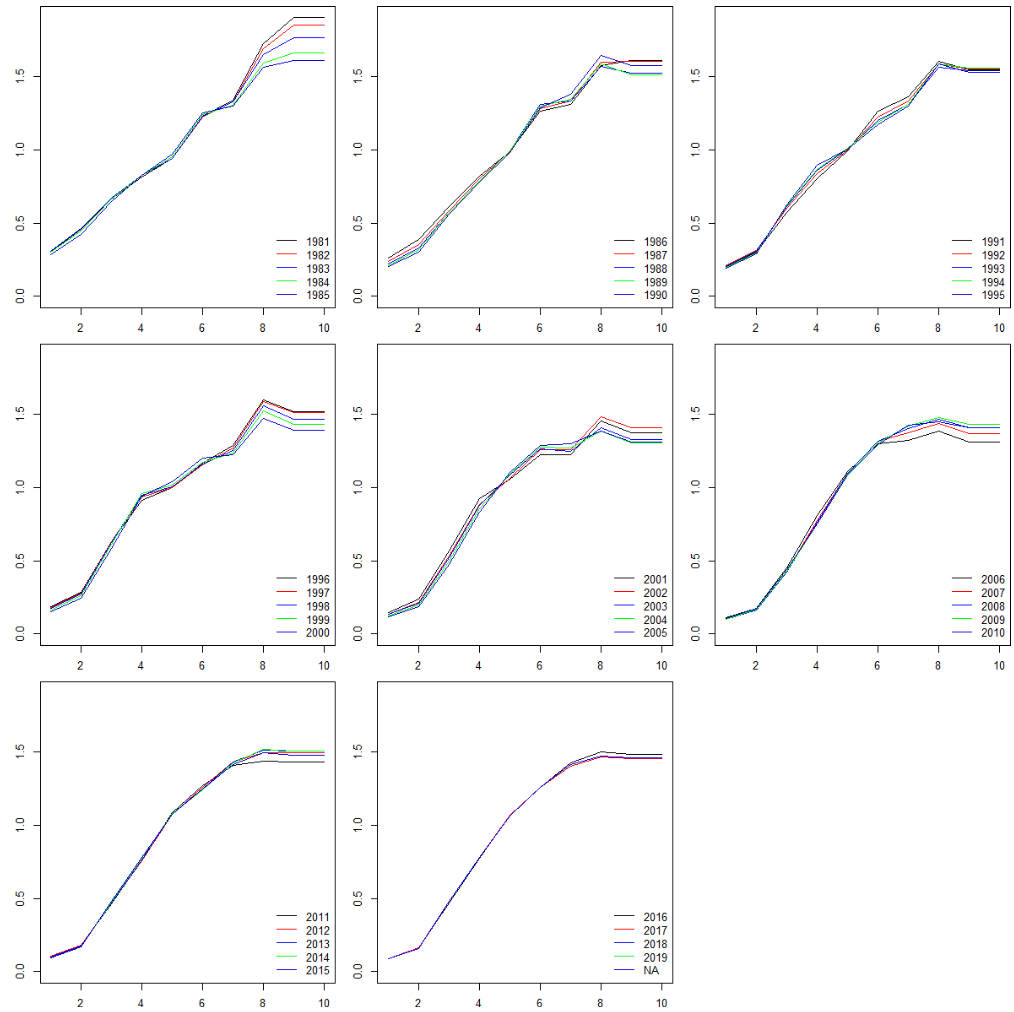


Figure 2.4.6. Blue whiting. Exploitation pattern by 5-years' time blocks. Values for 2019 are preliminary.

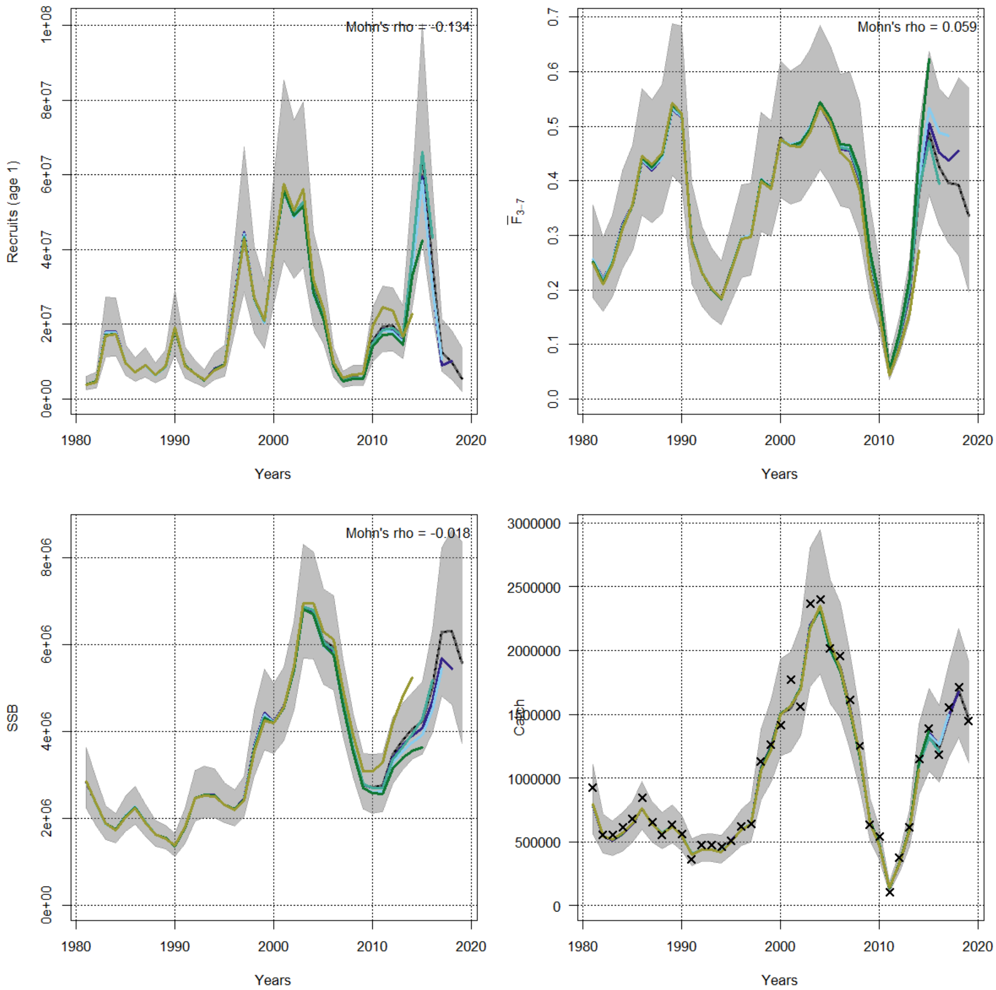


Figure 2.4.7. Blue whiting. Retrospective analysis of recruitment (age 1), SSB (tonnes), F and total catch using the SAM model. The 95% confidence interval is shown for the most recent assessment.

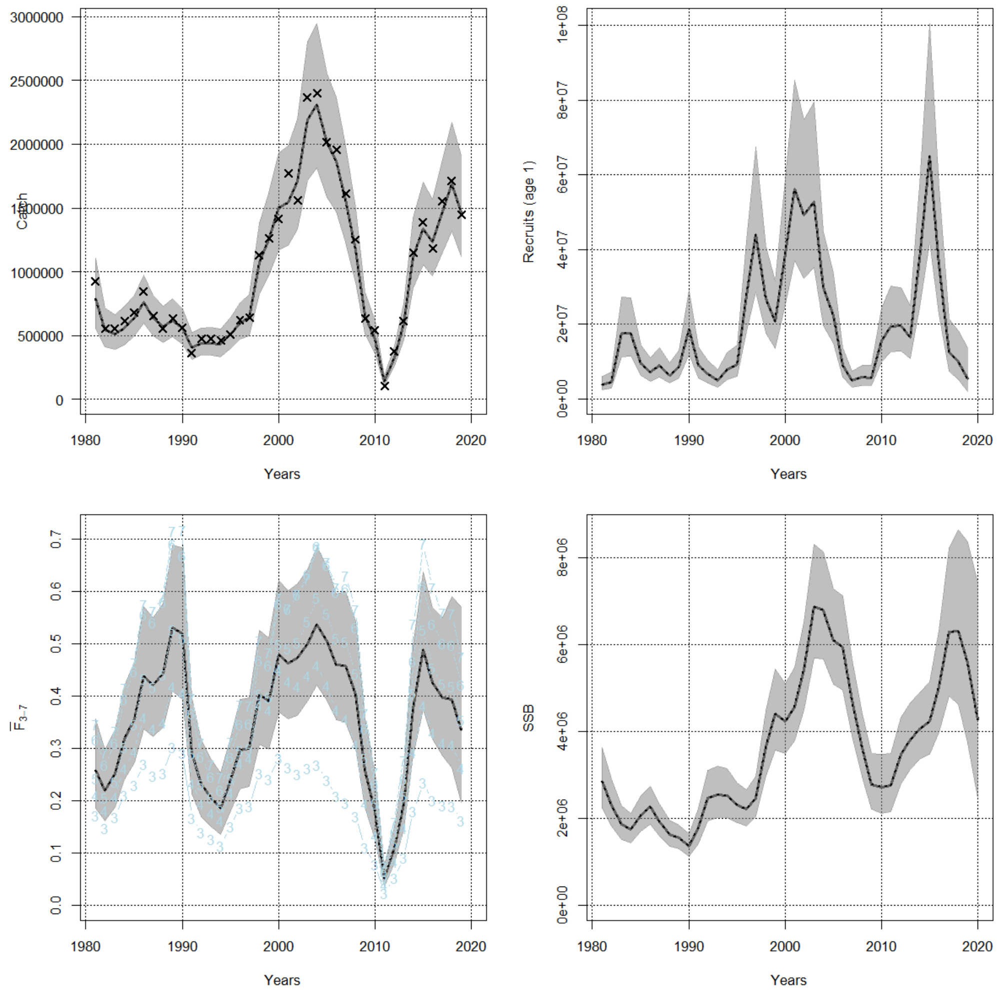


Figure 2.4.8. Blue whiting. SAM final run: Stock summary, total catches (tonnes), recruitment (age 1), F and SSB (tonnes). The graphs show the median value and the 95% confidence interval. The catch plot does also include the observed catches (x). Catches for 2019 are preliminary.

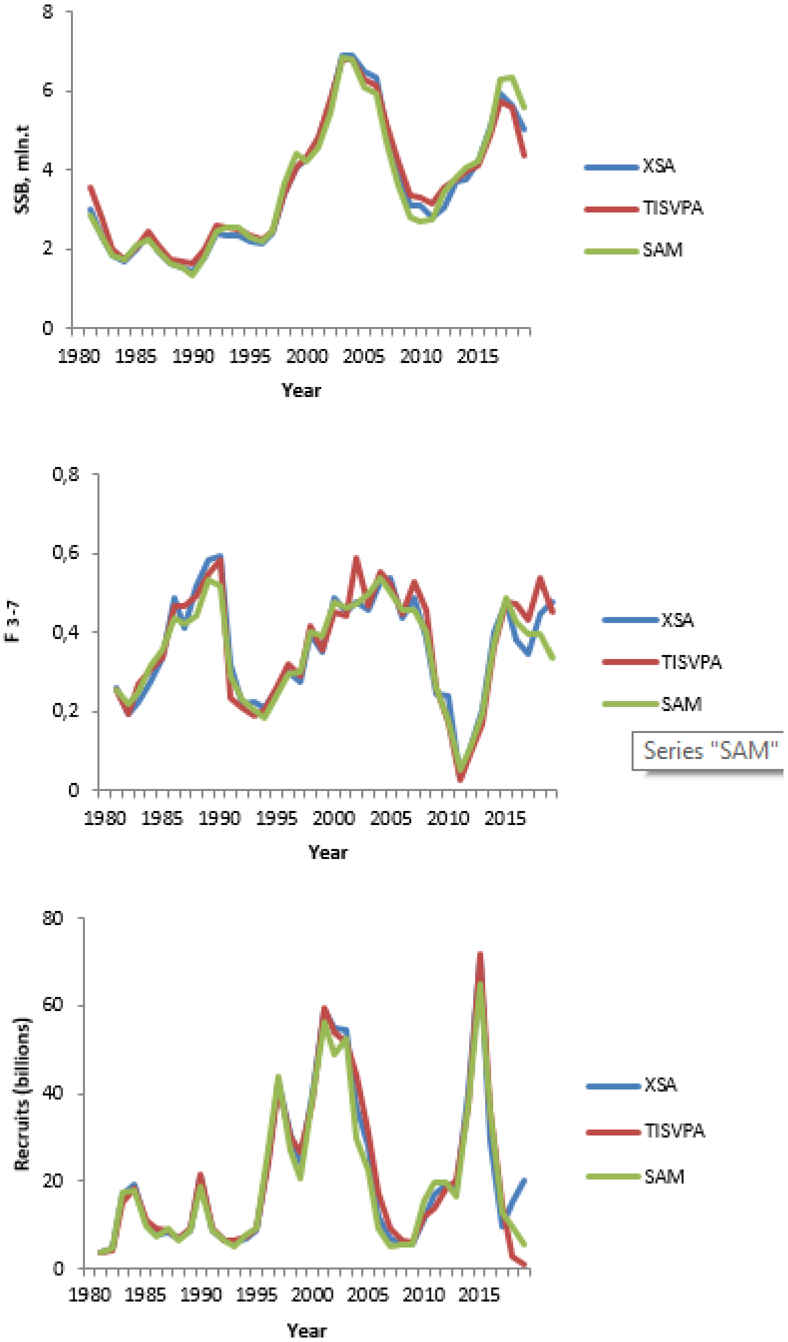


Figure 2.4.1.1. Blue whiting. Comparison of SSB, F and recruitment estimated by the assessment programs XSA, TISVPA and SAM. Catch values for 2019 are preliminary.

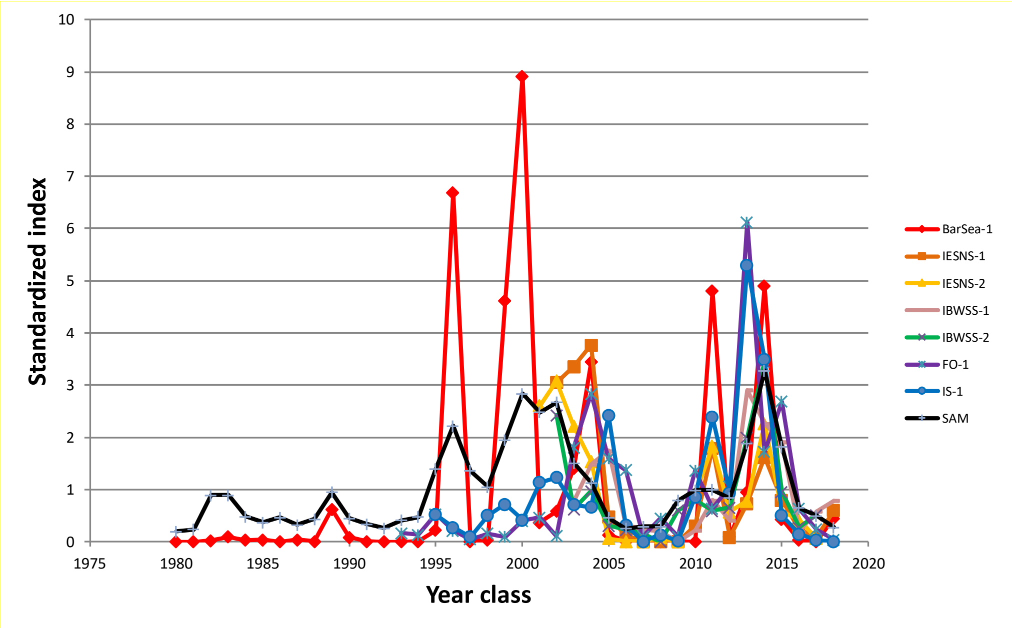


Figure 2.8.1.1. Blue whiting young fish indices from five different surveys and recruitment index from the assessment, standardized by dividing each series by their mean. BarSea - Norwegian bottom-trawl survey in the Barents Sea, IESNS: International Ecosystem Survey in the Nordic Seas in May (1 and 2 is the age groups), IBWSS: 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.

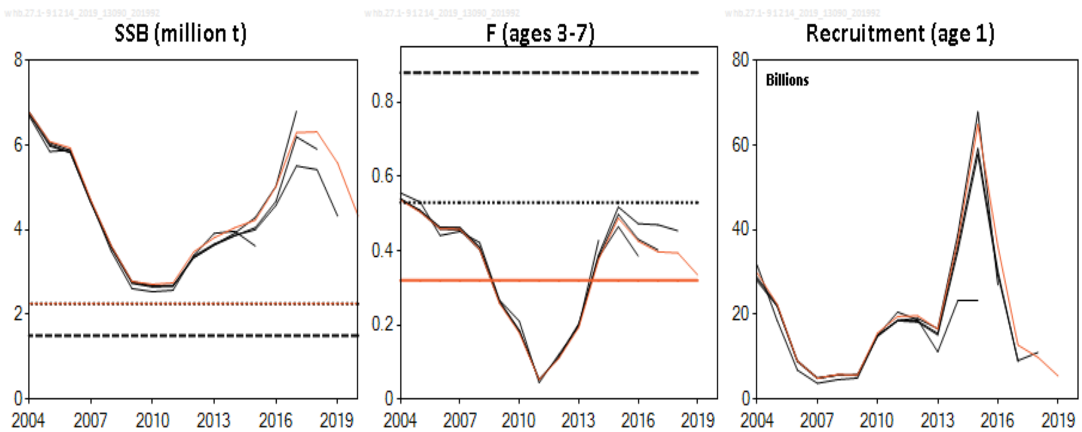


Figure 2.9.1. Blue whiting. Comparison of the 2015 - 2019 assessments.

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 southwest of Ireland. The boarfish fishery is conducted primarily in shelf waters and the first landings were reported in 2001. Landings were at very low levels from 2001-2005. The main expansion period of the fishery was 2006-2010 when unrestricted landings increased from 2 772 t to 137 503 t. A restrictive TAC of 33 000 t was implemented in 2011. In 2011, ICES was asked by the European Commission to provide advice for 2012. In 2019, ICES has been considering this stock for 9 years.

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 2019 only data from these areas were utilized.

3.1 The fishery

3.1.1 Advice and management applicable from 2011 to 2018

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.1.2 The fishery in recent years

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

From 2001 to 2006 only Ireland reported landings of boarfish. In 2007 UK-Scotland reported landings of 772 t. Scottish landings peaked at 9 241 t in 2010 and have declined since then with no fishery in 2015. Denmark joined the fishery in 2008 and landed 3 098 t. Danish landings increased to 39 805 t in 2010 but have declined considerably to only 29 t in 2015 and were null in 2016 and 2017. The vast majority of catches have come from ICES Division 27.7.j and 27.7.h (Figure 3.1.2.1 and Table 3.1.2.1). Since 2011 landings have been regulated by a TAC.

In 2014 and subsequent years, the TAC has not been caught. This is thought to be partly due to lesser availability of fishable aggregations, and partly due to economic and administrative reasons. According to the industry, fishable aggregations were not always available during the fishery. The season coincides with the mackerel and horse mackerel fisheries. Also, the Irish quota was allocated to individual boats, with non-specialist vessels receiving allocations that were not used.

In 2015 Q3 and Q4 individual boat quotas have been removed in Ireland, in an attempt to allow the specialist 6-7 vessels to target the stock without (what the industry considers to be unnecessary) constraints. The same year, the Netherlands (375 t), UK England (104 t) and Germany (4 t) reported boarfish landings for the first time. These landings were mainly bycatch from freezer trawlers.

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

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

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

3.1.3 The fishery in 2018

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

3.1.4 .Regulations and their effects

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

3.1.5 Changes in fishing technology and fishing patterns

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

3.1.6 Discards

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

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

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

3.2 Biological composition of the catch

3.2.1 Catches in numbers-at-age

Catch number-at-age were prepared for Irish, Danish, Dutch, German and English landings using the ALK in Table 3.2.1.1 together with available samples from the fishery (Table 3.2.1.2). This general ALK was constructed based on 814 aged fish from Irish, Danish and Scottish caught samples from 2012 (see the stock annex for a description of ALKs prior to 2012). In 2018 allocations to unsampled metiers were made according to Table 3.2.1.3. In total 12 samples with the appropriate .5 cm length bin measurements were collected in 2018 (Table 3.2.1.4). These samples covered the most heavily fished areas (Table 3.2.1.5) and equated to one sample per 940 t landed. The samples comprised 556 fish measured for length frequency.

The results of the application of the ALK to commercial length-frequency data available for the years 2007-2018 to produce a proxy catch numbers-at-age are available in Table 3.2.1.6. There have been no strong year classes with poor cohort tracking in the catch numbers. A high number of 2 year olds are present in the 2015 data but this does not echo in the number of 3 year-old fish in 2016. The modal age from 2007-2011 was 6 and in 2012-2018 it was 7. It should be noted that in WGWIDE 2011 and 2012 the +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 Hussy *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 un-sampled metiers in 2018. Length-frequencies of the international commercial landings by year are presented in Table 3.2.2.1.

Sampling in the early years of the fishery (2006-2009) was sparse as there was no dedicated sampling programme in place. The sampling programme was initiated in 2010 and good coverage of the landings has been achieved since then. Full details of the sampling programme in the earlier years are presented in the stock annex. Until 2017, boarfish was not included on the DCF list of species for sampling. Irish sampling comprises only samples from Irish registered vessels. Samples are collected onboard 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 0.5cm below for length frequency. Following standard protocols 5 fish per 0.5cm 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 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

A full description of the Boarfish Acoustic Survey (BFAS) which was initiated in July 2011 is given in the stock annex. This survey is run in conjunction with the Malin Shelf herring survey. These surveys are collectively known as the Western European Shelf Pelagic Acoustic Survey (WESPAS).

Change in abundance calculation method

Acoustic data collected during the WESPAS survey since 2016 were analysed using the StoX software package (ICES 2015a). This package was adopted for WGIPS coordinated surveys in 2016 and has been implemented for all international multi-vessel coordinated surveys within the group (IBWSS, IESSNS, IESSNS and HERAS). The Irish Marine Institute has adopted StoX as the primary abundance calculation tool for national and international acoustic survey data going forward as part of a transitional process initiated during WKEVAL (ICES 2015b). A detailed comparative review of the Irish national method and StoX was carried out on herring during WGIPS 2016 using HERAS and IBWSS data. A difference of 1% in the total herring biomass estimated by the national method compared to the StoX method for HERAS data was found. Abundances at age showed a greater difference which maybe more related to survey design for the 2015 data set. Regardless, the national abundance by age estimates were all contained within the uncertainty levels surrounding the StoX estimates (ICES 2016). The Irish national abundance is thus considered comparable with StoX going forward.

A description of the StoX application can be found at the following weblink: http://www.imr.no/forskning/prosjekter/stox/nb-no. Survey design and execution for the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (IPS) (ICES 2015a).

Survey results 2019

The estimate of boarfish biomass from 2011 to 2019 is presented in Table 3.3.1.1 and the spatial distribution of the echotraces attributed to boarfish each year can be seen in Figure 3.3.1.1. In 2019, the WESPAS survey provided continuous coverage from 47°30N to 59°30N covering an area coverage of 56, 366 nmi^2 (boarfish strata) using 5,956 nmi of transect miles. In total, 45 trawl stations were undertaken with 18 hauls containing boarfish providing 3,807 individual lengths, 1,400 length and weight measurements and 808 otoliths for use during the analysis.

The 2019 estimate of total biomass was similar to 2018 (186,520 t in 2018, 179,156 t in 2019), although the age structure was notably different. The Celtic Sea strata contained 61.8% of the total biomass and 74.2% of total abundance observe during the survey. The southern Celtic Sea was found to contain a higher than previously observed abundance of immature fish along the southernmost transects. This was most notable for the 1-year old fish (2018-year class) representing over 27% of total abundance for the strata.

The age composition of the stock in 2019 survey was dominated by older age classes (> 7 years) in terms of biomass (Ranking: 15+ yrs (35.8%), 7-year-old fish (12.3%), 10-year-old fish (10.0%) and 9-year-old fish (9.5%). In terms of abundance, young immature fish were well represented with age classes ranked as follows; 1-year-old fish (20%), 15+ yrs (19.5%), 7-year-old fish (11.4%)

and 2-year-old fish (11.4%). The contribution of immature fish to the total estimate of abundance is the highest in the time series, indicating a potentially strong merging year class (5.5% of total biomass and 30.7% of total abundance). Numbers at age are variable across years and this inter-annual variability is likely due to the use of an age-length-key rather than actual survey aged samples. Aging of survey caught fish would likely improve the ability to track cohorts more effectively within the survey index and reduce this potential source of error.

3.3.2 International bottom trawl survey (IBTS) Indices Investigation

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

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

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

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

For subsequent surplus production modelling (see Section 3.6.3), biomass indices were extracted from each of the IBTS surveys using a delta-lognormal model (Stefánsson 1996). Many of the surveys exhibited a large proportion of zero tows with occasionally very large tows, hence the decision to explicitly model the probability of a non-zero tow and the mean of the positive tows. A delta-lognormal fit comprises fitting two generalized linear models (GLMs). The first model (binomial GLM) is used to obtain the proportion of non-zero tows and is fit to the data coded as 1 or 0 if the tow contained a positive or zero CPUE, respectively. The second model is fit to the positive only CPUE data using a lognormal GLM. Both GLMs were fit using ICES rectangle and year as explanatory factor variables. Where the number of tows per rectangle was less than 5 over the entire series, they are grouped into an “others” rectangle. An index per rectangle and year is constructed, according to Stefánsson (1996), by the product of the estimated probability of a positive tow times the mean of the positive tows. The station indices are aggregated by taking estimated average across all rectangles within a year. To propagate the uncertainty, all survey index analyses were conducted in a Bayesian framework using MCMC sampling (Kery 2010). As WinBugs is no longer updated, the analyses were migrated from WinBUGS to JAGS in 2017. Indeed, JAGS has an almost identical language to WinBUGS and its outputs have been proven equivalent to the previous software (Plummer 2003; Spiegelhalter *et al.* 2003). In 2018, the assessment was reverted back to WinBUGS as it MCMC sampler appeared more efficient than that of JAGS. The outputs derived from both software implementations are similar.

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

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

Age	0	1	2	3	4	5	6	7	8	9
MW (g)	0.84	6.65	14.6	19.5	23.7	26.8	33.3	37.7	40	47.1
10	11	12	13	14	15	16	17	18	19	20
50.2	51.2	62.8	56.4	62.2	68.9	50.5	86.7	77.9	64.6	63.5
21	22	23	24	25	26	27	28	29		
75	86	71	77	84.4	79.4	-	67.6	52.8		

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

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

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

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

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

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

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

3.5 Recruitment

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

3.6 Exploratory assessment

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

3.6.1 IBTS data

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

Some of the IBTS CPUE indices displayed marked variability with a large proportion of zero tows and occasionally very large tows (*e.g*. West of Scotland survey, Figure B.4.7 stock annex). More southern surveys displayed a consistently higher proportion of positive tows. The variability of the data is reflected in the estimated mean CPUE indices (Figure 3.6.1.2). The West of Scotland survey index had been increasing between 2000 and 2009 but is uncertain, whereas the estimated indices from the other series are typically less variable (Figure 3.6.1.2). In 2014 four of the five current bottom trawl surveys experienced a sharp decline in CPUE, particularly the West of Scotland, the Spanish North Coast, the Spanish Porcupine and Irish Groundfish surveys. Both

Spanish surveys remained low in 2015 whereas the latest IGFS and EVHOE surveys indicate an increase. In 2016, values were similar to those of the previous year for all surveys. In 2017, surveys suggest that the stock abundance increased compared to the year before. The only exception is the EVHOE survey but its coverage was only partial year due its research vessel breakdown. The CEFAS English Celtic Sea Groundfish Survey displays a steady increase from the mid-1980s to 2002 with a large but somewhat uncertain estimate in 2003 (Figures 3.6.1.2 & 3.6.1.3). The spatial extent of each survey is shown in Figure 3.3.2.1.

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

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

3.6.2 Biomass estimates from acoustic surveys

The Boarfish Acoustic Survey (BFAS) series was initiated in July 2011 and is now in its 9th year. The initial survey in 2011 collected data over 24 hours. Since 2012, acoustic data has been collected between the hours of 04:00 and 00:00. The 2011 data was reworked in 2015 to exclude the data between 00:00 and 04:00. A TS model of -66.2dB was developed in 2013 [Fässler *et al.* (2013); odonnell_implementation_2013] and is applied to all surveys in the time series (Figure 3.3.1.1). Over the time series of the survey total biomass has been estimated in the range 863 kt (in 2012) to 70 kt (2016). The precision on the estimates has been good, with coefficients of variation in the range 11 to 21. An overall downward trend is evident in the first years while estimates have been more stable since 2014. No strong evidence exists for removing any of the survey points from the time series although 2016 may look like an outlier.

It should be noted that two acoustic surveys are conducted annually to the south of the southern limit of the dedicated Boarfish survey. In 2016 the PELACUS recorded an increase in biomass from 2015 although not of the order of the decrease seen further north. The Spanish PELGAS surveys recorded low levels of biomass, similar to that in 2015. Both these surveys take place 2-3 months prior to the boarfish survey.

3.6.3 Biomass dynamic model

In 2012 an exploratory biomass dynamic model was developed. This was a Bayesian state space surplus production model (Meyer & Millar 1999), incorporating the catch data, IBTS data, and acoustic biomass data. This assessment was then 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 again 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. The stock was moved from a category 1 assessment to a category 3 with the results of the surplus production model being used to calculate an index for the data limited stock approach.

Since 2014, the procedure used to run the model did not change. Only the length of the time series used increase yearly. Details of this exploratory run used to calculate the DLS index are described below. Further model development work is undertaken since 2015 but did not lead to any change so far.

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 the estimation the biomass is scaled by the carrying capacity, denoting the scaled biomass $P_t = B_t / K$. 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, $B_t = P_tK$, and the measurement errors are assumed lognormally 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 ~ U(0.001, 2)*
- Natural logarithm of the carrying capacity: *ln(K) ~ U(ln(max(C), ln(10.sum(C)) = U(ln(144047), ln(4450407))*
- Proportion of carrying capacity in first year of assessment: *a ~ 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: 2011–2019

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

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

IBTS surveys

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

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

First 9 years omitted from ECSGFS

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

Catches

2003–2019 time series

Priors

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

Run convergence

Parameters for the 2019 model run converged with good mixing of the chains and Rhat values lower than 1.1 indicating convergence (Figures 3.6.3.1 & 3.6.3.2). MCMC chain autocorrelation was rather high but was compensated by long MCMC chains providing representative samples of the parameter posteriors (Figure 3.6.3.3).

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

Results

Trajectories of observed and expected indices are shown in Figure 3.6.3.6, along with the stock size over time and a harvest ratio (total catch divided by estimated biomass). Parameter estimates from the model run are summarized in Table 3.6.3.1. Biomass in 2019 is estimated to be 282 kt, continuing the relatively stable but low trend since 2014. The extremely low biomass estimate from the 2016 acoustic survey appears considered as an outlier by the model. Retrospective plots of TSB and F, presented in Figure 3.6.3.7, show that the perception of the stock is stable through time with the exception of 2013 prior to the inclusion of the lower biomass estimates of the acoustic surveys since 2014.

3.6.4 Pseudo-cohort analysis

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

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

It can be seen from the text table below that *Z* = *M* in 2007, the initial year of the expanded fishery, while *F* is negligible. *F* increased to a high of 0.29 in 2012 and has gradually reduced down to 0.15 in 2015 and 2016. In 2017, it increased up to 0.17. There was a weak correlation between catches and pseudo-cohort *F* ($r^2 = 0.48$). Recent *F* estimated this way is close to *FMSY* (0.149) and above *F0.1* (0.13).

Year	Z.(7-14)	F.(Z-M)	Catch.(t)
2007	0.17	0.01	21 576
2008	0.33	0.17	34 751
2009	0.36	0.2	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	0.2	75 409
2014	0.37	0.21	45 231
2015	0.31	0.15	17 766
2016	0.31	0.15	19315
2017	0.33	0.17	17388

3.6.5 State of the stock

The most recent year assessment indicates that total stock biomass increased from a low to average level from the early to mid-1990s (Figure 3.6.3.6). The stock fluctuated around this level until 2009, before increasing until 2012. A sharp decline is seen between 2013 and 2014. Since 2014, the abundance has remained low but stable, averaging around 300kt. There was concern in 2014 that this decline was exaggerated by an unusually low acoustic biomass estimate that led to a downward revision in stock trajectory. However, the 2014 survey is considered satisfactory in terms of containment. The comparably low 2014 biomass estimate was supported by results of the 2015 survey. The 2016 biomass estimate, the lowest of the time series is considered an outlier and has little influence on stock abundance estimates. The 95% uncertainty bounds are large and increasing with subsequent assessments. This reflects the uncertainty in the survey indices, and short exploitation history of the stock and the treatment of the acoustic survey as a relative biomass index. As more data accumulates from this survey, it is expected that the prior will become increasingly updated, and potentially less variable.

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

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

Estimates of recruitment are not available from the stock assessment. However, an independent index of recruitment is available from groundfish surveys (Section 3.5). Observations from the survey recruitment of 1 year olds show a weak but downward negative trends since 2010 (Figure 3.5.1).

3.7 Short Term Projections

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

3.8 Long term simulations

No long term simulations were conducted.

3.9 Candidate precautionary and yield based reference points

3.9.1 Yield per Recruit

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

3.9.2 Precautionary reference points

It does not appear that boarfish is an important prey species in the NE Atlantic (Section 3.13). ICES (2007) considered that precautionary *F* targets (*Fpa*) should be consistent with F130 625 t based on the exploratory assessment in 2019).

3.9.3 Other yield based reference points

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

3.10 Quality of the assessment

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

Additional work to improve the surplus production model were undertaken in since 2015 and will continue next year. An issue list has developed and a benchmark is planned for 2020.

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

3.11 Management considerations

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

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

3.12 Stock structure

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

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

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

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

Whilst the current assessment and management area constitutes the majority of the most northern population it should be extended into Northern Portuguese waters and repeated genetic monitoring of the stock in this region should be conducted to ensure the validity of this delineation. Based on analyses of IBTS data (ICES 2013) 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 North-east 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 includes 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.

2) Category 6: Category 6 - negligible landings stocks and stocks caught in minor amounts as bycatch

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

4) If the stock, estimated in the 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.

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

6) 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.

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

  a) 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.

  b) 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.

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

3.15 References

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3.16 Tables

Table 3.1.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Landings, discards and TAC by country by year (t), 2001–2018. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes

	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Unalloc	Discards	Total	TAC
2001			120							120	
2002			91							91	
2003			458						10929	11387	
2004			675						4476	5151	
2005			165						5795	5959	
2006			2772						4365	7137	
2007			17615			772			3189	21576	
2008	3098		21585			0.45			10068	34751	
2009	15059		68629						6682	90370	
2010	39805		88457			9241			6544	144047	
2011	7797		20685			2813			5802	37096	33000
2012	19888		55949			4884			6634	87355	82000
2013	13182		52250			4380			5598	75409	82000
2014	8758		34622			38			1813	45231	133957
2015	29	4	16325	375	104				929	17766	53296
2016	337	7	17496	171	21				1283	19315	47637
2017	548		15485	182	0.13				1173	17388	27288
2018	94		9513	172	0.08	0.23	148		1359	11286	20380

Table 3.1.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Landings by year (t), 2001–2018 (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

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

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

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

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

Year	Area	Denmark	Germany	Ireland	Netherlands	England	Scotland	Spain	Total
2017	7.j			33	9				43
2017	8.a	271		10543					10814
2017	8.d			915					915
2018	ALL	94		9513	172	0.08	0.23	148	9928
2018	6.a	67		269	78				414
2018	7.b	19		163	9				191
2018	7.c	2			0.51				3
2018	7.f				3				3
2018	7.h	6		2582	46	0.08			2634
2018	7.j			1163	22		0.23		1185
2018	8.a			5182					5182
2018	8.b				14				14
2018	8.c							54	54
2018	8.d			154					154
2018	9.a							94	94
ALL	ALL	90438	12	422891	900	125	22128		536639

Table 3.1.2.3. Boarfish in ICES Subareas 27.6, 7, 8. Discards of boarfish in demersal and non-target pelagic fisheries by year (t), 2003–2018. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

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

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	1	1													
8	1	1													
8		1													
8		1	1												
9		1	1												
10			1												
10			1												
10			2	10	3										
11			1	29	14	2	2								
12				9	21	21	18	2	2	1					
12				4	17	22	38	12	8						1
12					5	9	42	37	14	6	2		1	1	1
13					2	4	31	28	24	12	6	2	3	1	5
14					1	3	25	22	21	14	6	5	4	2	11
14							6	8	18	22	8	3	7	1	20
14						1	1	2	3	8	1	6	6	6	30
15							1	1		2	2	2	5	2	19
16										2				2	19
16															8
16															1
17															1
18															1
18															1
18															1

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

Year	landings	% landings covered by sampling programme	no. samples	no. measured	no. aged
2001	120	0	0	0	0
2002	91	0	0	0	0
2003	11387	0	0	0	0
2004	5151	0	0	0	0
2005	5959	0	0	0	0
2006	7137	0	0	0	0
2007	21576	NA	3	217	0
2008	34751	NA	1	152	0
2009	90370	NA	9	1475	0
2010	144047	NA	95	10675	403*
2011	37096	NA	27	4066	704
2012	87355	NA	80 (68)***	9656 (8565)***	814**
2013	75409	NA	76	9392	0****
2014	43418	NA	54	7008	0****
2015	17766	NA	32	3356	0****
2016	18031	NA	27	3861	0****
2017	16215	NA	18	1140	0****
2018	9834	NA	12	556	0****

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

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

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

******2012 ALK used**

Table 3.2.1.3. Boarfish in ICES Subareas 5, 27.6, 7, 8. The allocation of Age length keys to unsampled metiers in 2018

Country	Area	Quarter	landed	ALK
DK	7.b	1	19	IE_7.j_Q3
DK	7.c	1	2	IE_7.h_Q1
DK	7.h	1	6	IE_7.h_Q1
ES	8.c	2	54	IE_8.a_Q1
IE	7.b	1	148	IE_7.j_Q3
IE	7.b	4	15	IE_7.j_Q3
IE	7.h	1	2278	IE_7.h_Q1
IE	7.h	3	135	IE_7.h_Q3
IE	7.h	4	169	IE_7.h_Q4
IE	7.j	1	16	IE_7.h_Q1
IE	7.j	3	1147	IE_7.j_Q3
IE	8.a	1	4032	IE_8.a_Q1
IE	8.a	4	1150	IE_8.a_Q4
IE	8.d	4	154	IE_7.h_Q3 IE_8.a_Q4 IE_7.h_Q4
NL	7.b	1	8	IE_7.j_Q3
NL	7.b	2	0.88	IE_7.j_Q3
NL	7.c	1	0.51	IE_7.h_Q1
NL	7.f	4	3	IE_7.h_Q3 IE_7.j_Q3 IE_7.h_Q4
NL	7.h	1	0.38	IE_7.h_Q1
NL	7.h	2	46	IE_7.h_Q1 IE_7.h_Q3
NL	7.h	4	0.07	IE_7.h_Q4
NL	7.j	2	8	IE_7.j_Q3
NL	7.j	3	14	IE_7.j_Q3
NL	8.b	2	14	IE_8.a_Q1
UKE	7.h	2	0.08	IE_7.h_Q1 IE_7.h_Q3
UKS	7.j	2	0.23	IE_7.j_Q3

Table 3.2.1.4. Boarfish in ICES Subareas 27.6, 7, 8. Catch per country and corresponding number of samples collected in 2018.

Country	Official Catch	Num Samples	Num Measured	Num Aged
DK	94			
ES	673			
IE	9602	12	556	
NL	172			
UKE	744			
UKS	1			

Table 3.2.1.5. Boarfish in ICES Subareas 27.6, 7, 8. Catch per area and corresponding number of samples collected in 2018

Area	Official Catch	Num Samples	Num Measured	Num Measured per 1000t
27.9.a	94			
27.6.a	414			
27.6.b	4			
27.7.b	192			
27.7.c	33			
27.7.e	734			
27.7.f	7			
27.7.g	5			
27.7.h	2733	6	298	109
27.8.a	5182	5	239	46
27.8.b	14			
27.8.c	397			
27.8.d	154			
27.7.j	1319	1	19	14
27.7.k	3			

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 2007-2018

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

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 2007-2018.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
4.5									14				14
5									878				878
5.5									515				515
6				156					810		765		1731
6.5				439					14		4607	203	5263
7				1090	522	56	52		513	417	5250	405	8305
7.5			1354	1574			551		10598	1684	12616	2635	31012
8			677	375	1345	185	1419		80716	8685	11473	4703	109578
8.5				1082		555	3592	1064	49508	6412	10115	3559	75887
9			677	5382	851	555	7263	327	10219	7104	3874	6554	42806
9.5		7473	17367	7883	7012	641	47509	4916	213	23065	14047	6196	136322
10	9609	11209	54130	29410	33243	2791	94702	31649	1211	46010	32346	5559	351869
10.5		52308	174796	130889	15848	6132	59833	71344	3865	39071	36242	4450	594778
11	84555	63517	343283	361774	70615	24571	18359	108261	12226	14181	32445	17658	1151445
11.5		59781	321637	655875	93487	81928	20938	82470	28142	18249	31589	22826	1416922
12	44199	119561	297737	739025	189434	264888	98564	84288	41613	30975	33618	24070	1967972
12.5		70990	207739	564347	114904	398772	204868	112826	42461	51110	41650	24514	1834181
13	82633	52308	147965	353484	133539	419060	315063	172416	59990	57000	46495	30665	1870618
13.5		29890	149314	246146	51235	307533	285688	153742	52625	58696	43121	38698	1416688
14	117224	22418	105782	224611	50857	176710	210137	138549	50139	76872	45353	34080	1252732
14.5		14945	71273	127711	25309	89726	105571	74059	28771	37755	39524	29908	644552

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
15	65338	33627	47816	125463	25569	52791	62175	43347	16087	23137	21854	15561	532765
15.5		11209	13082	81386	5473	25065	31122	22629	8572	7841	4932	5778	217089
16	13452	11209	19397	24256	4181	13149	14990	7672	4331	625	1020	1948	116230
16.5		3736	4061	6209	2280	2738	4918	2134	2081	128		54	28339
17		3736	677	1913	456	827	1109	1361	289				10368
17.5							407		23				430
18				283			296						579
18.5							592						592

Table 3.3.1.1. Boarfish in ICES Subareas 27.6. 7, 8. Acoustic survey abundance and biomass estimates from 2011-2019

	Abundance								
Age	2011	2012	2013	2014	2015	2016	2017	2018	2019
	-	-	-	-	-	-	-	-	-
1	5	21.5	-	-	198.5	4.6	110.9	76.7	782.3
2	11.6	10.8	78	-	319.2	35.7	126.7	31.2	389.1
3	57.8	174.1	1842.9	15	16.6	45.5	344.6	115	96.8
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3	93.1
5	436.7	95	381.6	102.3	80	6	156	106.7	88.2
6	1165.9	736.1	253.8	104.9	112	10	209	165.9	105.9
7	1184.2	973.8	1056.6	414.6	437.4	169	493.1	320.7	445.7
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7	182.6
9	1094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4	288.
10	1031.5	955.9	703.8	332.3	360	96.6	285.8	624.7	290.1
11	332.9	650.9	263.7	129.9	131.7	17	120.9	339.2	49.6
12	653.3	1099.7	202.9	104.9	113	32	82.1	264.1	192.2
13	336	857.2	296.6	166.4	174	48.7	74.4	198.4	79.1
14	385	655.8	169.8	88.5	108	18.3	220.4	116.5	57.2
15+	3519	6353.7	1464.3	855.1	1195	400.1	931	302.4	758.9
TSN ('000)	11104	14257	9091	3098	3996	1157	4387	3221	3899
TSB (t)	670176	863446	439890	187779	232634	69690	230062	186252	179156
SSB (t)	669392	861544	423158	187654	226659	69103	218810	184624	169213
CV	21.2	10.6	17.5	15.1	17	16.4	21.9	19. 9	19.8

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

EVHOE

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

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

IGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2003		1	32	22	7	22	129	172	879	2942	2322	1326	3822	4628	2898	896	163	38		
2004		23	63	34	8	96	532	1431	369	344	410	2253	4320	4698	3966	1017	87	2	1	
2005		8	59	52	20	203	1024	585	288	636	341	3463	11457	11348	7955	1744	382	2	1	
2006	5	60	68	48	35	212	969	621	2046	4190	8044	7946	24208	42119	32168	12296	2454	532		
2007	1	6	44	18	31	501	923	1251	1638	1166	2510	3581	8275	10740	7093	1934	92			
2008			26	18	23	127	672	531	2095	13780	17664	19268	16980	19484	15953	8789	1747	76	1	
2009		3	80	76	25	94	228	486	1000	1139	9081	7749	5138	6921	5592	1084	68	1		
2010		6	42	3	18	199	272	463	920	393	7914	34236	28611	16063	8161	1974	433			
2011		6	14	5	4	189	772	586	555	670	2578	20171	22082	10829	5298	2207	266	9	6	
2012		7	36	20	10	131	271	378	702	2144	1183	11105	34010	22742	10906	3903	525	4		

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2013	1	3	9	9	20	127	352	340	1320	2833	3971	15572	51637	52868	20485	6560	492	20		
2014		10	68	54	4	18	13	25	60	130	1127	3251	19125	23016	10355	2988	284	18		
2015		3	11	16	24	193	1008	3708	848	105	713	6314	29727	48221	33024	17350	1885	531		
2016	4	31	121	63	7	67	186	1515	4057	2891	1349	4110	32753	57753	40907	15527	3670	86		
2017		6	53	10169	689915	6406	1751	715	11818	21886	10164	11841	25588	42311	35049	17110	3299	369		
2018	4	51	247	140	32	45	286	585	1195	6107	17006	15167	48895	61832	36519	10722	2030	63		

SPNGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1991		1			31	690	1311	313	49	9	6	7	7	4				6		
1992		57	38	9	178	3290	2743	282	48	10	8	69	162	390	779	246	95			
1993		57	1206	488	97	3730	3753	421	105	54	7	4	8	3	2					
1994	1	40	33		342	4789	10162	8920	3195	53	106	20	9	12	1					
1995		84	108	4	342	3063	2157	220	84	65	58	105	105	90	20	4				
1996		218	537	143	245	4457	4449	267	820	722	82	145	126	219	96	39	2			
1997	2	102	809	441	235	3458	6824	2189	1923	534	156	353	161	88	3					
1998	3	2	7	4	49	1920	4685	1815	337	153	125	88	147	135	86	13	2	3		
1999		6	59	13	134	2736	3010	193	106	83	109	143	390	645	402	69				
2000		7	3729	2046	17	554	1947	489	277	486	756	1252	999	1021	199	34	13			

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2001		68	4	1	153	3241	5085	659	225	206	205	236	692	407	120	22	9			
2002		4	20		133	2333	2013	284	50	58	54	60	231	314	72	9				
2003		4	950	567	4	77	221	57	39	28	16	22	17	23	16	5	1			
2004		6	22	4	43	2289	3808	443	110	83	58	219	931	776	303	2	1			
2005		16	451	25	9	754	1007	207	85	102	30	54	257	218	90	44	2			
2006		14	156	160	50	2238	8913	4507	175	94	9	36	229	419	169	9	2			
2007		49	40	1	111	3025	6620	1099	129	260	81	7	93	215	89	21	3			
2008	7	4	92	247	1	936	1561	1326	234	1483	304	537	11	833	201	186	11			
2009	1	17	53	125	9	2582	3816	4105	119	250	45	142	59	819	120	17	1	1		
2010		55	102	5	232	13090	22032	3169	1160	1056	89	82	179	1007	1981	518	9			
2011		29	260	105	46	2805	5511	1278	148	340	145	100	144	591	724	134	3	1		
2012		29	132	35	556	7550	7844	1364	88	53	59	170	1051	2394	1553	432	21			
2013			2	11	126	2163	4664	854	302	609	251	61	110	123	140	64	7			
2014		75	117	6	12	263	465	79	1083	1175	1174	1266	998	2444	3623	817	31	1		
2015		13	67	3	58	1889	4248	534	75	465	750	970	695	1173	1473	453	70	1		
2016		0.16	0.85	0.04	0.39	9	24	4	9	7	3	6	5	6	2	0.25	0.03			
2017	0.01	0.2	0.18	0.01	0.14	6	18	7	1	2	3	4	6	10	9	2	0.11	0.03		
2018			0.02		0.43	7	15	2	0.61	0.91	2	4	9	20	26	6	0.04	0.02		0.02

SPPGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2001		2		2	2	4		88	10	104	266	323	1334	2259	460	81				
2002									1	4	90	212	791	843	313	60				
2003						1		3	15	22	21	62	268	426	249	51	2	1		
2004		1				5	2		4	5	18	100	312	483	319	43	1			
2005		1		1	6	1	18	10	9	14	7	101	530	935	705	226	18			
2006			1	1	6	91	89	21	34	75	27	45	335	670	555	197	10	1		
2007					3	4	9	15	12	9	27	25	72	151	144	26	4			
2008		1				1	13	7	16	13	55	106	237	457	302	78	5			
2009		6	5		2	7	8	1		1	154	318	924	1201	1172	324	7			
2010	1			1	5	14	3	1	5	2	31	284	521	717	459	123	10			
2011								3	16	18	5	147	671	792	429	122	13		2	
2012				1	1			2	2	1	8	70	369	468	218	66	3			
2013				1		7	22	6	9		1	42	435	889	480	141	12	1		
2014		10	9		1		3	17	62	11	6	85	2453	6703	3168	2115	162	82		
2015				2	1			1	1			32	300	471	316	151	43			
2016			0.04				0.02		0.16	0.06		0.1	2	4	3	1	0.25			
2017		1	0.35				0.2			0.02	0.35	0.52	3	10	10	5	0.33			
2018		0.04	0.02	0.02								0.68	21	66	45	21	3			

WCSGFS

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1986								0.5												
1987								0.5	0.5	2	0.5									
1988				0.5																
1989							0.5													
1990				1		0.5	1	2	24	54	50	43	12	1						
1991						1	0.5	8	38	183	266	316	48	16						
1992						1		10	38	468	1145	4001	1626	486						
1993							4		2	9	60	155	72	16		0.5				
1994									0.5	0.5	0.5			0.5						
1995									8	36	194	294	398	199	22					
1996				2		4	3				1	55	610	1574	304					
1997			4			0.5	6	9	4	6	25	108	203	157	40	4				
1998				1		1	5	2		1	2		3							
1999			1			2	5	1	1		1	2	1							
2000							2	2	39	110	216	288	182	92	46	6				
2001		1						1	4	15	28	59	134	240	103	10	4			
2002						1	8	2	1	82	742	3211	5601	5772	1497	167	1			

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2003			1				3	52		53	281	1473	3066	4895	3083	309	28			
2004				1			2	2	43	82	743	4569	8600	9514	5692	948	84			
2005		2					24	3	23	25	110	435	1085	1708	792	130	6			
2006		1	2	1		1	4		10	218	232	452	1396	2852	2051	434	72			
2007			2	2		2	1	3	21	159	780	2923	5194	6888	5283	1523	116			
2008		1	1			16	37	36	187	468	1395	3213	9893	22758	18399	6288	575	71		
2009			1			1		4	52	2442	2093	440	331	287	246	129	10			
2010											530	1443	1384	1357	828	149	29			
2011		1	4	1		1	5	254	1015	2034	7613	18918	14478	6445	2006	236	23			
2012			1			1	2		103	9	1267	6545	26337	29361	27333	15857	1505	496		
2013				1			1			1	143	3201	15282	11288	3934	858	6	1		
2014		48	457	386	48	3	7	63	21	98	876	11668	30267	39236	10933	1363	111	1		
2015			4	18	14	115	102	18	5			30	262	345	220	86	10	1		1
2016				1	2	49	1413	2439	2065	342	436	4088	24632	33254	14568	3484	508	102		
2017																				
2018																				

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

EVHOE (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1997	23	1877	6003	3741	3911	3938	7066	5867	4218	4832	4259	1461	2428	1699	1214	623
1998	31	12978	15997	6247	6247	5591	7435	5732	3777	4806	4386	1463	2843	1635	1619	676
1999	65	7577	31224	19915	8732	3499	3308	2715	1905	2720	2357	744	1540	975	893	285
2000	216	17676	27730	12586	17986	15525	18740	14297	9737	11041	9490	3208	5160	3797	2556	1266
2001	733	14389	41313	20357	25467	21921	16211	9247	4525	4543	3951	1332	2057	1322	1099	578
2002	43	6720	31728	18455	12784	8389	7115	4767	2851	3429	3018	994	1806	1123	1009	421
2003	64	509	3993	7348	18371	17276	16113	10798	6270	7620	6852	2267	4294	2501	2456	1009
2004	545	1265	1975	1261	1722	2227	4124	3228	2061	2871	3058	1066	2426	939	1509	901
2005	1070	2101	2603	1497	2099	3015	7160	5992	4177	5301	4873	1642	3144	1796	1776	833
2006	217	35834	26593	4803	2199	1386	1489	1332	947	1521	1484	485	1170	557	725	311
2007	662	16817	122140	65369	16986	4919	4316	2967	1715	2452	2392	788	1802	820	1124	484
2008	3244	41612	258758	168378	134062	77106	37738	18750	8277	9132	8183	2660	4868	2458	2992	1226
2009	328	13338	36829	12194	5626	5982	7788	5443	3054	4443	4230	1364	3079	1382	1965	618
2010	666	33602	83903	35048	21677	23503	34210	23037	12643	16303	14519	4647	9008	4716	5551	1689
2011	370	2212	12471	14982	28729	26114	31844	23915	15535	19473	16964	5542	10176	6534	5663	2262
2012	738	20090	34348	11535	11098	10795	14979	13308	9004	15662	14714	4598	11467	5540	7325	2325
2013	142	1647	3695	3805	10388	9207	11385	11271	8299	14485	13797	4374	10961	5364	6893	2550
2014	2081	1524	2365	3805	12988	17314	27692	24954	17460	27410	25016	7911	18267	9918	11160	3465

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2015	6086	19233	175572	108367	35891	17618	33197	26770	17433	25562	22840	7208	15396	8396	9445	3078
2016	1256	7360	21027	18355	32937	28679	43627	41581	30274	49797	45444	14238	33654	17999	20815	6633
2017	234	187	263	50	0.92											
2018	66693	61905	37678	23753	16636	14374	22348	19805	13380	22885	20805	6396	15571	8029	9892	2972

EVHOE (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1997	1215	159	659	623	848	768	214	325	543	100	158	51	314	416
1998	1224	232	904	676	965	1042	327	476	752	187	231	93	461	353
1999	647	62	474	285	477	509	91	246	317	53	62	27	123	197
2000	2604	253	1384	1266	1782	1538	374	714	1022	198	245	99	491	921
2001	959	153	684	578	780	710	304	456	508	254	147	129	290	306
2002	796	117	572	421	617	625	192	324	429	128	113	65	227	244
2003	1838	326	1387	1009	1462	1557	491	763	1104	310	322	155	644	532
2004	917	382	1142	901	1100	1160	817	925	962	726	360	366	715	181
2005	1368	285	1065	833	1140	1184	486	639	877	332	308	201	546	394
2006	445	125	464	311	434	496	245	308	373	184	116	93	242	103
2007	678	204	715	484	668	778	381	467	594	282	198	146	385	150
2008	1876	492	1919	1226	1765	2062	1064	1237	1523	698	420	352	835	460

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2009	1114	309	1064	618	956	1295	398	493	957	155	306	78	611	235
2010	3457	690	2957	1689	2745	3490	921	1368	2435	312	669	160	1331	868
2011	4513	597	3197	2262	3408	3485	1077	1762	2339	616	619	388	1126	1414
2012	4142	920	4165	2325	3703	4595	1448	2356	3218	979	908	490	1815	928
2013	4068	981	4205	2550	3816	4494	1872	2650	3227	1384	914	692	1830	944
2014	7107	1227	5977	3465	5645	6813	1636	2961	4634	782	1438	607	2443	1853
2015	5952	1033	5325	3078	4950	5809	1744	2969	3937	1097	1193	763	1965	1551
2016	12839	2342	11704	6633	10734	12885	3911	6423	8785	2322	2219	1174	4413	3266
2017														
2018	5679	1014	5603	2972	4952	5987	1726	3238	4008	1258	991	634	1973	1357

IGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2003	55	126	517	929	2306	1859	1433	1244	842	1549	1546	495	1309	576	842	317
2004	120	418	1422	594	396	484	1303	1341	993	1713	1773	589	1491	618	948	390
2005	119	814	982	379	542	665	2302	2884	2364	4129	4140	1360	3431	1569	2142	822
2006	176	850	1572	1988	4719	5051	6885	7522	5179	12177	13018	4151	12178	4448	8189	3297
2007	68	1052	1866	1385	1605	1648	2625	2628	1855	3547	3577	1145	3059	1292	1987	723
2008	44	589	1710	3445	12363	12597	13266	9219	5227	7773	7797	2576	6069	2491	3886	2029

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2009	159	268	776	1076	3174	4543	5513	3620	1839	2701	2706	886	2101	818	1373	491
2010	51	374	746	902	3021	6591	17251	13258	8630	10098	8924	3002	5053	3150	2750	1284
2011	25	642	951	598	1500	3223	10092	8432	5965	6989	6169	2095	3519	2333	1835	1014
2012	63	302	673	754	1773	2197	7201	8422	7104	10272	9476	3134	6741	3972	3834	1736
2013	21	373	862	1243	3026	3903	10918	13284	10691	18929	17531	5483	13636	7177	8471	2878
2014	132	29	47	90	423	794	2958	4429	3697	7450	7127	2213	5965	2873	3818	1248
2015	30	814	3473	1377	516	943	4845	7454	5858	14016	14639	4623	13524	5243	9030	3979
2016	215	282	2400	2888	2682	1761	4458	7773	6173	16077	17088	5386	16240	6066	10938	4231
2017	10228	696697	6080	9322	16417	11347	9585	8818	5853	12738	13721	4436	12670	4564	8475	3944
2018	438	273	1086	2052	7920	9719	13658	14344	10383	20166	20022	6346	17086	7532	11049	3955

IGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2003	467	148	527	317	462	585	287	324	441	179	151	109	263	96
2004	543	189	584	390	537	672	317	350	525	203	181	103	362	108
2005	1289	400	1283	822	1177	1509	689	703	1154	349	363	175	724	286
2006	3989	1708	5570	3297	4613	6048	3673	3775	4731	2459	1728	1496	2924	605
2007	1072	332	1196	723	1058	1334	553	722	999	387	322	193	645	207
2008	2183	900	2996	2029	2637	3017	2303	2367	2409	1758	763	917	1451	424

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2009	727	261	802	491	707	955	390	433	738	217	255	109	508	128
2010	2303	414	1616	1284	1786	1832	742	897	1330	395	371	197	742	715
2011	1683	267	1165	1014	1352	1212	568	780	873	441	245	225	488	552
2012	2907	548	2360	1736	2447	2518	1096	1491	1807	781	498	392	991	850
2013	5165	980	4941	2878	4530	5265	1784	2964	3613	1312	941	666	1862	1291
2014	2146	499	2236	1248	1967	2437	883	1317	1717	598	480	308	941	478
2015	4494	1690	6438	3979	5486	6393	3990	4977	4886	3470	1767	2000	3002	743
2016	5302	2226	7389	4231	6036	8062	4880	4910	6258	3105	1902	1596	3719	819
2017	4195	1923	6278	3944	5266	6491	4624	4744	5168	3422	1778	1896	3186	640
2018	6037	1863	6800	3955	5887	7590	3544	4077	5658	2144	1691	1104	3320	1222

SPNGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	1	1403	881	103	15	6	5	3	2	2	2	0.62	0.98	0.78	0.5	0.18
1992	104	4609	1830	95	17	13	41	53	36	103	156	57	175	37	120	64
1993	1751	5508	2424	164	50	19	6	3	2	2	2	0.67	1	0.79	0.56	0.29
1994	73	10576	12411	3844	643	57	35	17	5	5	4	1	2	1	2	0.27
1995	196	4230	1525	107	66	51	64	48	30	41	35	11	22	14	13	4
1996	898	6707	2908	584	554	254	109	66	38	72	68	20	54	23	36	11

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1997	1352	7306	5446	1609	680	249	203	121	67	69	56	18	22	18	11	4
1998	13	4493	3640	638	175	100	79	58	37	55	53	17	40	19	25	9
1999	78	4258	1802	116	93	80	113	121	85	191	195	61	175	70	117	35
2000	5782	1661	1324	346	518	553	750	537	315	443	379	116	237	139	146	37
2001	73	5952	3099	309	205	161	197	190	149	199	175	58	115	77	62	25
2002	24	3316	1395	104	54	43	55	63	47	98	88	26	70	37	46	10
2003	1521	203	155	38	26	16	14	10	5	9	9	3	7	3	4	2
2004	32	4268	2243	177	83	68	171	219	186	303	279	89	209	118	125	37
2005	492	1253	702	108	78	46	51	60	51	84	78	25	59	33	35	15
2006	330	7296	7378	1191	85	34	36	56	44	116	112	33	100	43	68	14
2007	90	6646	3990	367	180	106	37	30	18	55	54	16	50	20	35	8
2008	343	1736	1886	629	908	597	329	178	62	202	183	47	158	53	122	28
2009	195	4487	5078	1085	167	103	78	71	26	174	155	37	147	56	113	9
2010	162	24558	13572	1504	792	346	101	85	41	222	365	132	436	76	306	146
2011	394	5730	3656	431	244	163	94	77	38	141	182	61	198	48	140	50
2012	196	11653	5359	384	62	55	160	276	202	620	657	201	638	228	440	140
2013	13	4763	2946	446	439	276	110	59	30	45	49	17	44	16	28	16
2014	198	542	611	767	1131	910	875	626	323	711	913	317	926	228	635	271

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2015	83	4207	2430	248	462	516	616	432	233	403	463	158	419	125	281	130
2016	1	23	17	7	6	4	4	3	2	2	2	0.65	1	0.75	0.93	0.24
2017	0.39	16	14	3	2	2	3	2	2	3	3	1	3	1	2	0.76
2018	0.02	15	9	1	1	1	3	3	2	5	7	2	7	2	5	2

SPNGFS (16–29)

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

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2003	2	0.83	3	2	2	3	2	2	2	1	0.73	0.5	1	0.42
2004	85	14	63	37	61	76	14	25	52	0.4	14	0.2	28	23
2005	24	4	22	15	22	22	9	16	15	9	4	4	8	6
2006	32	8	35	14	27	42	9	15	29	2	8	0.9	15	6
2007	15	4	20	8	15	22	7	11	15	4	4	2	8	2
2008	36	10	81	28	54	73	32	63	47	37	9	19	18	0.28
2009	34	6	58	9	34	62	8	29	37	3	6	2	11	1
2010	130	91	206	146	178	245	145	135	213	104	90	52	180	4
2011	59	33	84	50	68	103	48	45	85	27	33	14	66	4
2012	198	73	266	140	215	295	122	161	220	86	71	43	141	26
2013	16	7	21	16	19	22	16	17	18	13	6	6	13	3
2014	291	168	402	271	348	488	259	240	412	163	165	82	329	25
2015	138	74	193	130	166	221	140	127	185	91	67	46	134	17
2016	0.53	0.09	0.49	0.24	0.43	0.56	0.13	0.24	0.38	0.05	0.09	0.02	0.18	0.12
2017	1	0.42	1	0.76	1	1	0.65	0.71	1	0.4	0.42	0.22	0.82	0.15
2018	2	1	3	2	3	4	2	2	3	1	1	0.61	2	0.24

SPPGFS (0–15)

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

SPPGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2001	158	21	170	62	133	183	29	87	112	16	21	8	42	33
2002	80	14	73	40	66	81	20	38	55	12	14	6	28	20
2003	38	12	43	23	36	50	17	24	36	10	12	6	23	7
2004	45	15	49	27	42	59	19	24	44	9	14	4	29	8
2005	88	34	115	68	97	126	62	74	97	45	32	23	64	13
2006	63	26	88	53	74	94	49	60	73	39	26	20	50	8
2007	15	7	19	11	16	23	11	10	19	5	7	3	13	2
2008	40	14	51	27	42	57	24	30	43	16	14	8	27	6
2009	137	54	161	109	146	183	88	102	145	65	53	32	107	23
2010	69	22	79	46	69	89	37	47	66	25	21	12	42	13
2011	78	21	82	48	73	91	37	49	66	24	20	12	41	17
2012	43	10	46	26	40	50	18	28	35	13	10	7	20	9
2013	71	23	93	47	75	102	41	56	74	28	22	15	44	11
2014	476	160	791	417	626	739	420	632	530	423	185	252	288	61
2015	44	19	63	37	52	67	47	45	52	30	14	15	29	8
2016	0.36	0.16	0.51	0.29	0.41	0.57	0.34	0.32	0.45	0.2	0.14	0.1	0.27	0.05
2017	0.92	0.49	2	1	1	2	1	1	1	1	0.45	0.5	0.91	0.08

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2018	5	2	9	5	7	9	5	6	7	4	2	2	4	0.53

WCSGFS (0–15)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986			0.38	0.12												
1987		0.01	0.58	0.64	1	0.76	0.18	0.05	0.01							
1988	0.5															
1989		0.3	0.2													
1990	1	2	10	21	46	39	31	16	7	5	4	2	0.76	0.96	0.12	0.3
1991		2	23	52	175	185	193	105	45	36	28	9	5	5	2	1
1992		2	34	115	616	975	1952	1270	712	662	524	178	157	152	61	41
1993		2	2	4	23	41	80	52	29	26	21	7	6	6	2	2
1994		0.01	0.15	0.34	0.48	0.33	0.13	0.06	0.01	0.09	0.08	0.02	0.08	0.03	0.06	
1995		0.21	3	15	74	114	190	151	103	121	101	33	54	42	27	11
1996	2	5	2	0.03	1	6	67	153	112	391	353	95	318	144	224	29
1997	4	4	11	6	12	22	63	62	47	69	60	19	40	25	23	7
1998	1	4	4	0.67	1	1	0.72	0.65	0.56	0.45	0.38	0.15	0.15	0.22		0.08
1999	1	5	3	0.8	0.47	0.58	1	0.7	0.4	0.31	0.25	0.09	0.05	0.08		0.02
2000		2	16	41	124	143	179	116	65	68	59	20	30	19	16	7

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2001	1	0.11	2	5	17	21	40	44	30	70	67	20	58	25	39	9
2002		6	8	35	291	631	1838	1814	1320	2185	1935	594	1386	781	858	225
2003	1	2	42	28	127	272	867	971	691	1498	1519	476	1339	536	892	248
2004	1	2	16	57	327	770	2590	2686	1983	3447	3359	1079	2693	1240	1707	569
2005	2	15	19	19	53	93	276	325	236	519	501	153	429	188	286	76
2006	4	4	12	39	183	196	341	423	294	781	834	261	795	283	543	172
2007	4	3	14	56	339	638	1707	1727	1220	2309	2385	775	2056	820	1341	522
2008	2	41	110	208	689	989	2324	3054	2082	6013	6662	2108	6560	2164	4517	1712
2009	1	2	100	387	1816	1538	759	363	137	139	136	46	95	43	58	32
2010				17	160	347	785	626	398	580	549	179	394	189	245	87
2011	6	31	531	1086	3514	5387	10238	7369	4589	4924	4157	1403	2004	1489	988	477
2012	1	5	28	97	469	1148	4804	6462	5298	9990	10765	3610	9632	3810	6155	3487
2013	1	0.6	0.43	5	101	381	2420	3378	3003	4670	4228	1361	3064	1852	1769	647
2014	891	55	60	67	509	1549	6999	8472	6502	12849	11622	3475	9135	4722	5898	1390
2015	22	173	73	7	2	3	31	57	49	106	108	34	97	41	63	25
2016	1	946	2978	1730	751	680	3544	5695	4735	10264	9850	3016	8414	3926	5481	1626
2017																
2018																

WCSGFS (16–29)

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1986														
1987														
1988														
1989														
1990	0.63		0.06	0.3	0.33	0.06		0.03	0.03					0.3
1991	3		1	1	2	1		0.5	0.5					1
1992	96		30	41	56	30		15	15					41
1993	4		1	2	2	1	0.05	0.6	0.5	0.1		0.05		2
1994	0.02		0.03		0.02	0.03		0.02	0.02					
1995	27	1	13	11	17	14	1	6	8		1		2	10
1996	94	14	112	29	78	126	14	49	77		14		28	15
1997	17	2	12	7	12	13	2	6	9	0.8	2	0.4	4	5
1998	0.15			0.08	0.08									0.08
1999	0.05			0.02	0.02									0.02
2000	14	2	8	7	10	10	3	4	7	1	2	0.6	4	5
2001	19	5	21	9	17	25	7	10	18	2	5	1	9	3
2002	528	68	446	225	405	497	85	214	317	33	68	17	136	140
2003	446	143	480	248	401	592	182	215	439	62	140	31	280	77

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2004	986	267	957	569	866	1129	387	487	832	190	259	95	517	215
2005	144	37	156	76	130	180	51	79	127	26	36	13	72	27
2006	252	100	322	172	261	379	165	176	290	87	93	43	186	35
2007	715	252	835	522	738	934	439	520	719	305	240	152	480	130
2008	2042	894	2945	1712	2424	3210	1695	1969	2499	1258	872	664	1673	247
2009	37	12	43	32	41	42	28	35	33	26	11	13	22	8
2010	149	41	140	87	130	166	64	72	123	30	38	15	75	35
2011	1016	93	520	477	678	590	124	249	388	47	91	24	182	362
2012	3477	1393	4814	3487	4404	4621	3430	4089	3703	3171	1490	1834	2485	658
2013	1296	179	971	647	999	1064	267	524	712	172	179	86	358	382
2014	3236	508	3097	1390	2616	3468	678	1499	2242	273	497	137	994	757
2015	34	11	41	25	36	44	23	28	33	17	10	9	20	8
2016	2933	713	3140	1626	2666	3504	1214	1736	2465	697	713	399	1324	616
2017														
2018														

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

	Mean	SD	2.5	25	50	75	97.5

r	3.34e-01	1.77e-01	4.16e-02	2.01e-01	3.19e-01	4.49e-01	7.15e-01
K	6.28e+05	4.33e+05	2.86e+05	4.15e+05	5.16e+05	6.73e+05	1.84e+06
F_{MSY}	1.67e-01	8.84e-02	2.08e-02	1.00e-01	1.60e-01	2.24e-01	3.58e-01
B_{MSY}	1.57e+05	1.08e+05	7.15e+04	1.04e+05	1.29e+05	1.68e+05	4.60e+05
TSB	3.04e+05	1.46e+05	1.48e+05	2.16e+05	2.71e+05	3.47e+05	6.68e+05

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

Age	ln(Raised Numbers)											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	0	0	7	8	0	3	6	0	9	5	8	6
2	6	9	10	9	8	7	9	7	12	8	8	7
3	8	10	11	11	11	9	12	11	10	9	9	8
4	11	12	13	13	10	11	11	12	10	10	10	10
5	11	12	13	13	10	12	11	11	10	10	10	10
6	11	12	13	14	12	12	11	11	10	10	10	10
7	10	12	13	13	12	13	13	12	11	11	11	11
8	10	11	12	13	12	13	12	12	11	11	11	10
9	11	11	12	13	11	13	12	12	11	11	10	10
10	11	11	12	12	11	12	12	11	10	10	10	10
11	10	10	11	11	11	11	11	10	9	9	9	9
12	10	10	11	12	11	11	11	10	9	9	9	9
13	8	9	11	11	10	11	11	10	10	10	9	9
14	10	10	10	11	10	10	10	10	9	9	9	8
15+	12	12	12	13	12	12	12	12	11	11	11	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
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
Catches (t)	21576	34751	90370	144047	37096	87355	75409	45231	17766	19315	17388	11138
Corr coef landings vs F	0.39											

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

Year	TSB.2.5	TSB.50	TSB.97.5	F.2.5	F.50	F.97.5
1991	104000	197700	496285			
1992	165905	300500	739097			
1993	199407	360900	878267			

Year	TSB.2.5	TSB.50	TSB.97.5	F.2.5	F.50	F.97.5
1994	235400	426850	1041000			
1995	201500	366350	899982			
1996	207100	373000	903305			
1997	179602	317600	765847			
1998	242700	428050	1021975			
1999	182302	320200	791482			
2000	154002	272900	660172			
2001	171505	297350	714487			
2002	149800	260000	627970			
2003	136600	236350	576497	0.02	0.05	0.08
2004	189405	323400	781082	0.01	0.02	0.03
2005	180802	313900	747595	0.01	0.02	0.03
2006	214302	363850	886197	0.01	0.02	0.03
2007	179000	310250	728577	0.03	0.07	0.12
2008	223210	377300	894492	0.04	0.09	0.16
2009	229107	382600	909390	0.1	0.24	0.39
2010	350102	587550	1380950	0.1	0.25	0.41
2011	319807	536150	1287950	0.03	0.07	0.12
2012	477200	777850	1847950	0.05	0.11	0.18
2013	326102	549350	1314975	0.06	0.14	0.23
2014	153605	256700	631292	0.07	0.18	0.29
2015	182700	305600	730650	0.02	0.06	0.1
2016	127402	214400	518787	0.04	0.09	0.15
2017	225200	377400	906160	0.02	0.05	0.08
2018	233602	388400	944762	0.01	0.03	0.05
2019	147505	270900	668122			

3.17 Figures

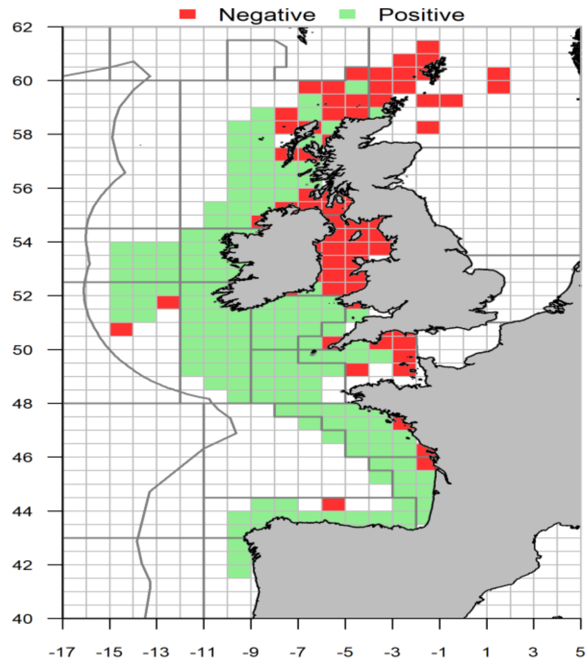

Figure 3.1. Boarfish in ICES Subareas 4, 27.6, 7, 8 and 9. Distribution of boarfish in the NE Atlantic area based on presence and absence in IBTS surveys (all years).

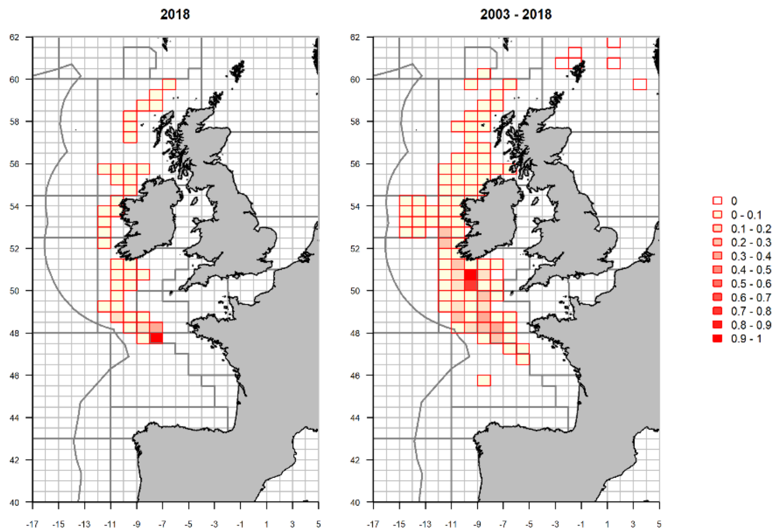

Figure 3.1.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Combined Irish boarfish landings 2003-2018 by ICES rectangle (Right). Irish boarfish landings 2018 by ICES rectangle (Left).

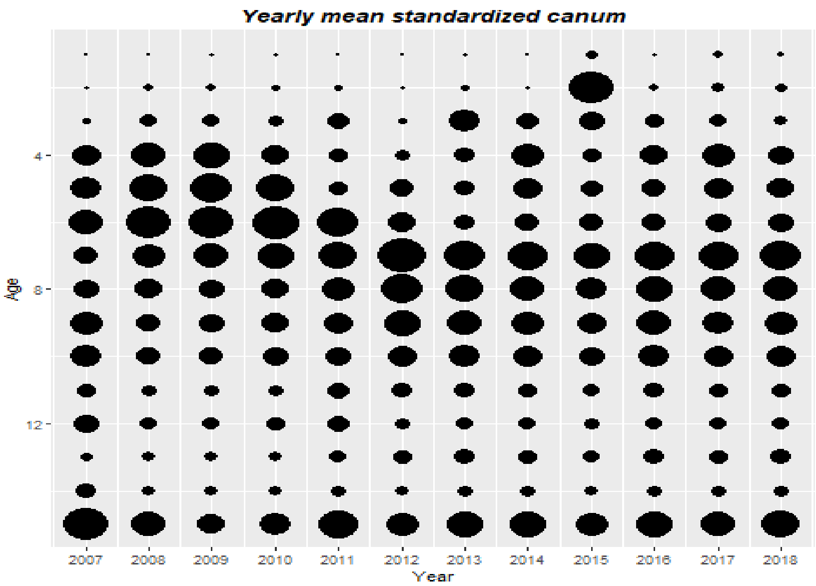

Figure 3.2.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Catch numbers-at-age standardised by yearly mean. 15+ is the plus group.

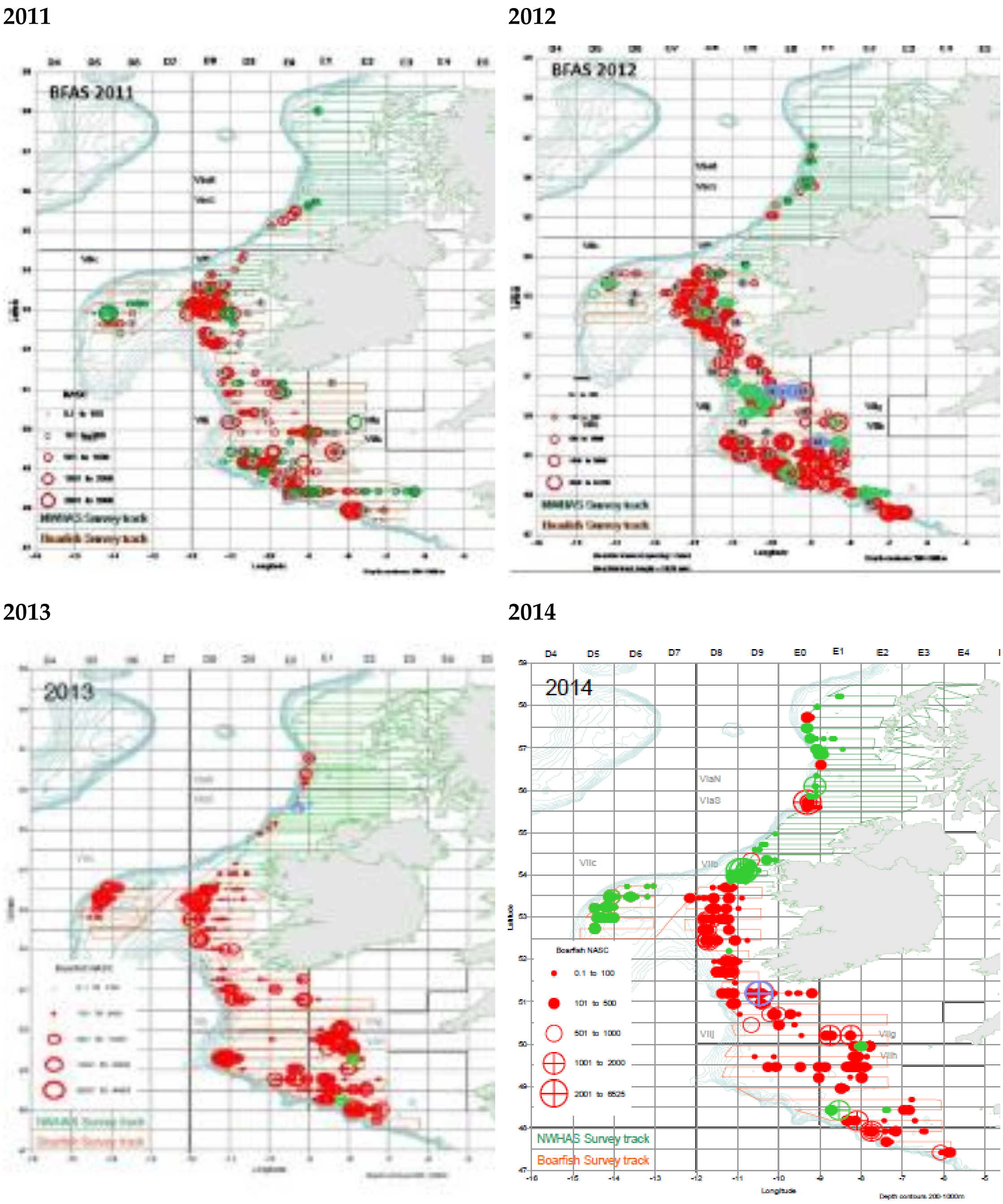

Figure 3.3.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey track and haul positions from acoustic survey 2011-2018.

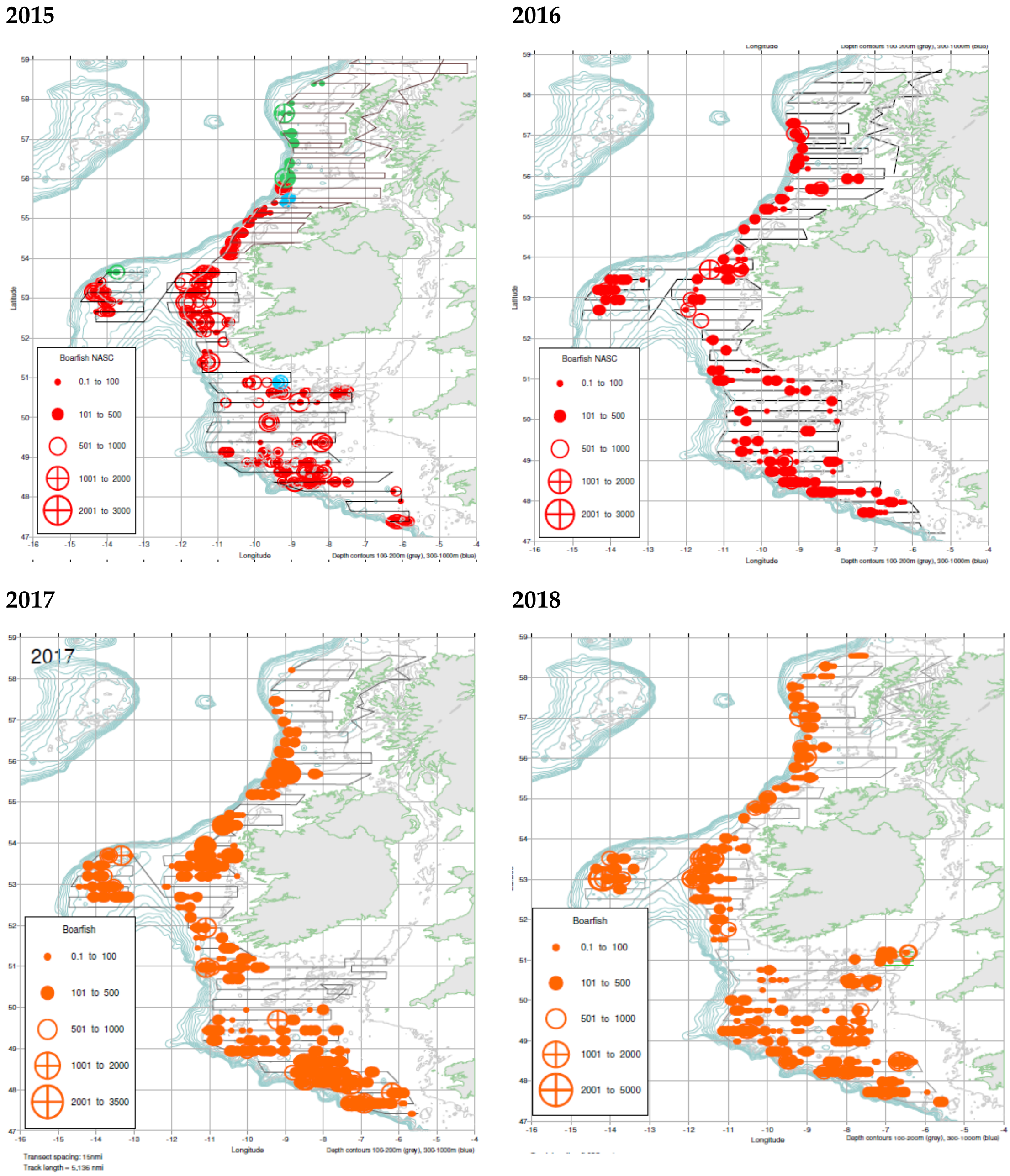

Figure 3.3.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey track and haul positions from acoustic survey 2011-2018.

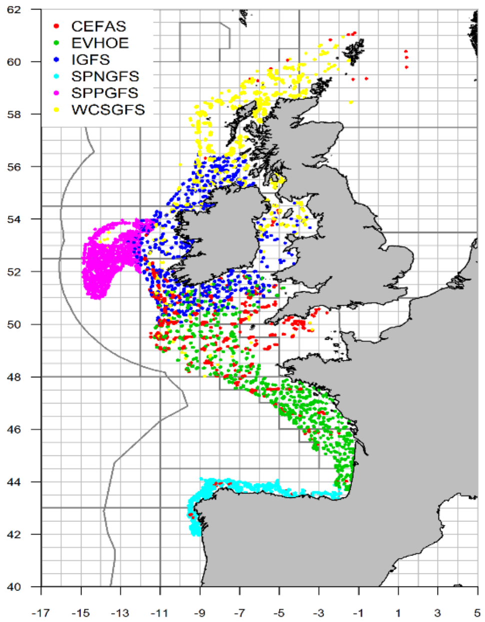

Figure 3.3.2.1. Boarfish in ICES Subareas 27.6, 7, 8. The haul positions of bottom trawl surveys analysed as an index for boarfish abundance. Note the Portuguese Groundfish survey included here was not included in the 2016 assessment.

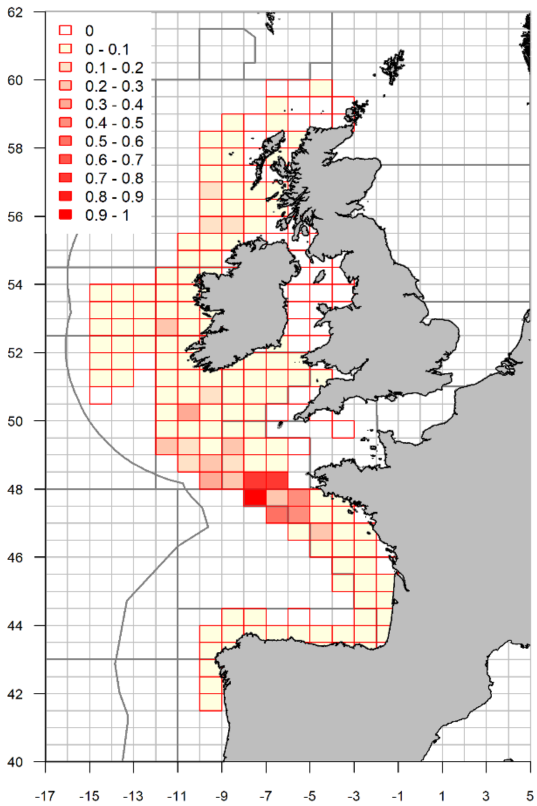

Figure 3.3.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Distribution of boarfish in the NE Atlantic showing proposed management area.

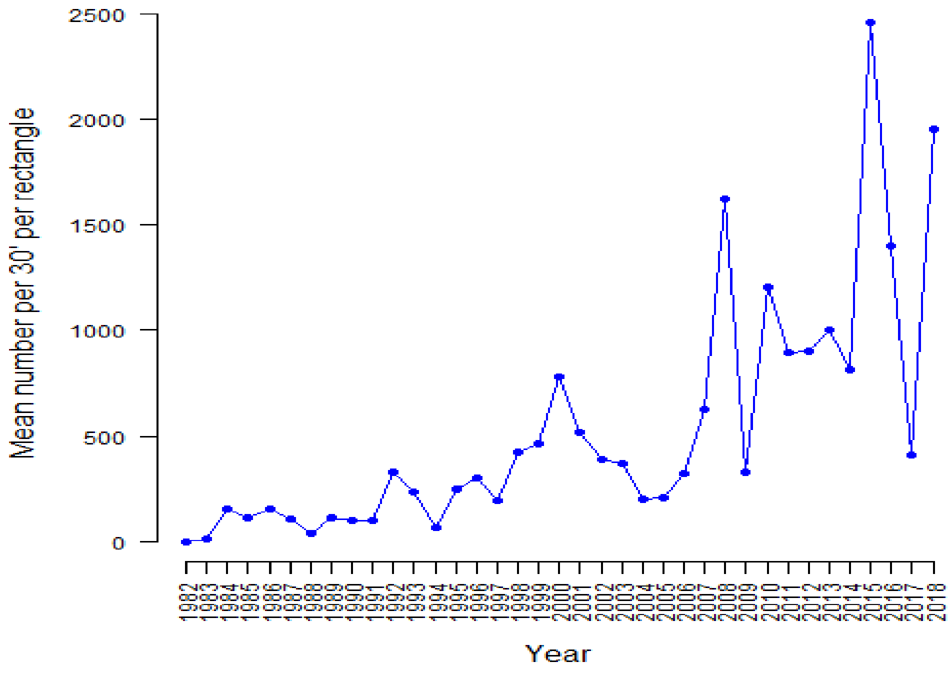

Figure 3.3.2.3. Boarfish in ICES Subareas 27.6, 7, 8. CPUE in number per 30 minute haul of boarfish per rectangle in the western IBTS survey 1982 to 2018.

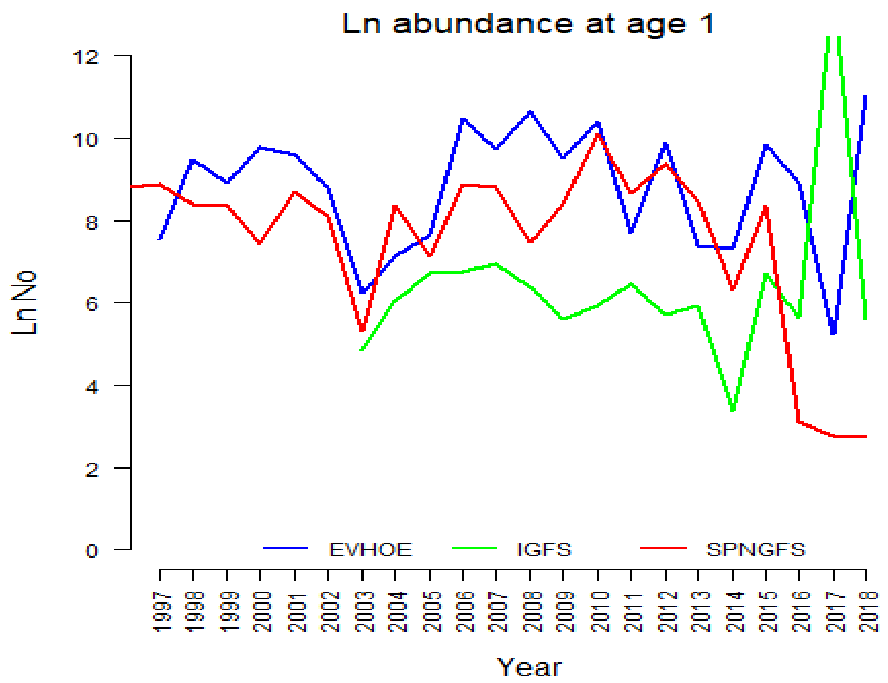

Figure 3.5.1. Boarfish in ICES Subareas 27.6, 7, 8. Recruitment-at-age 1, from various IBTS.

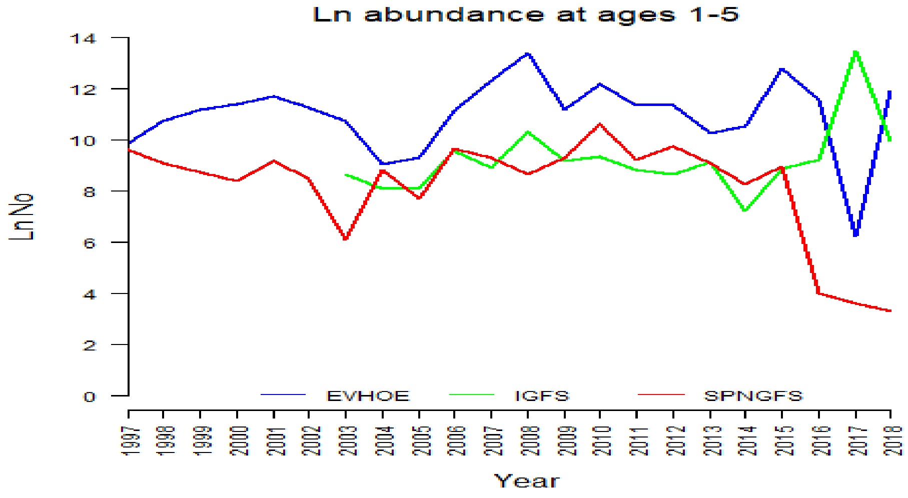

Figure 3.5.2. Boarfish in ICES Subareas 27.6, 7, 8. Recruitment-at-ages 1-5, from various IBTS.

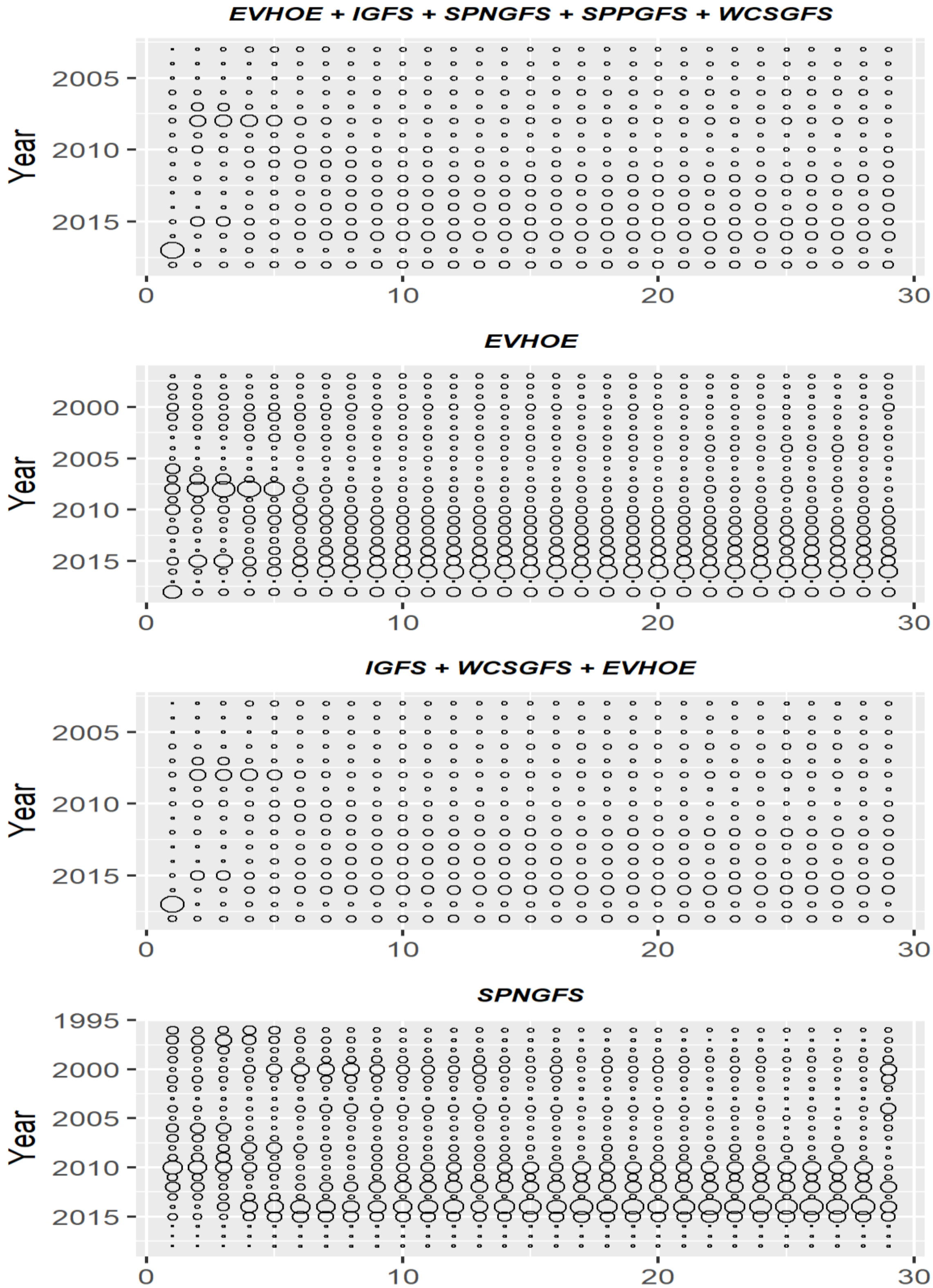

Figure 3.6.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Abundance-at-age in constituent western IBTS. Yearly mean standardised abundance-at-age.

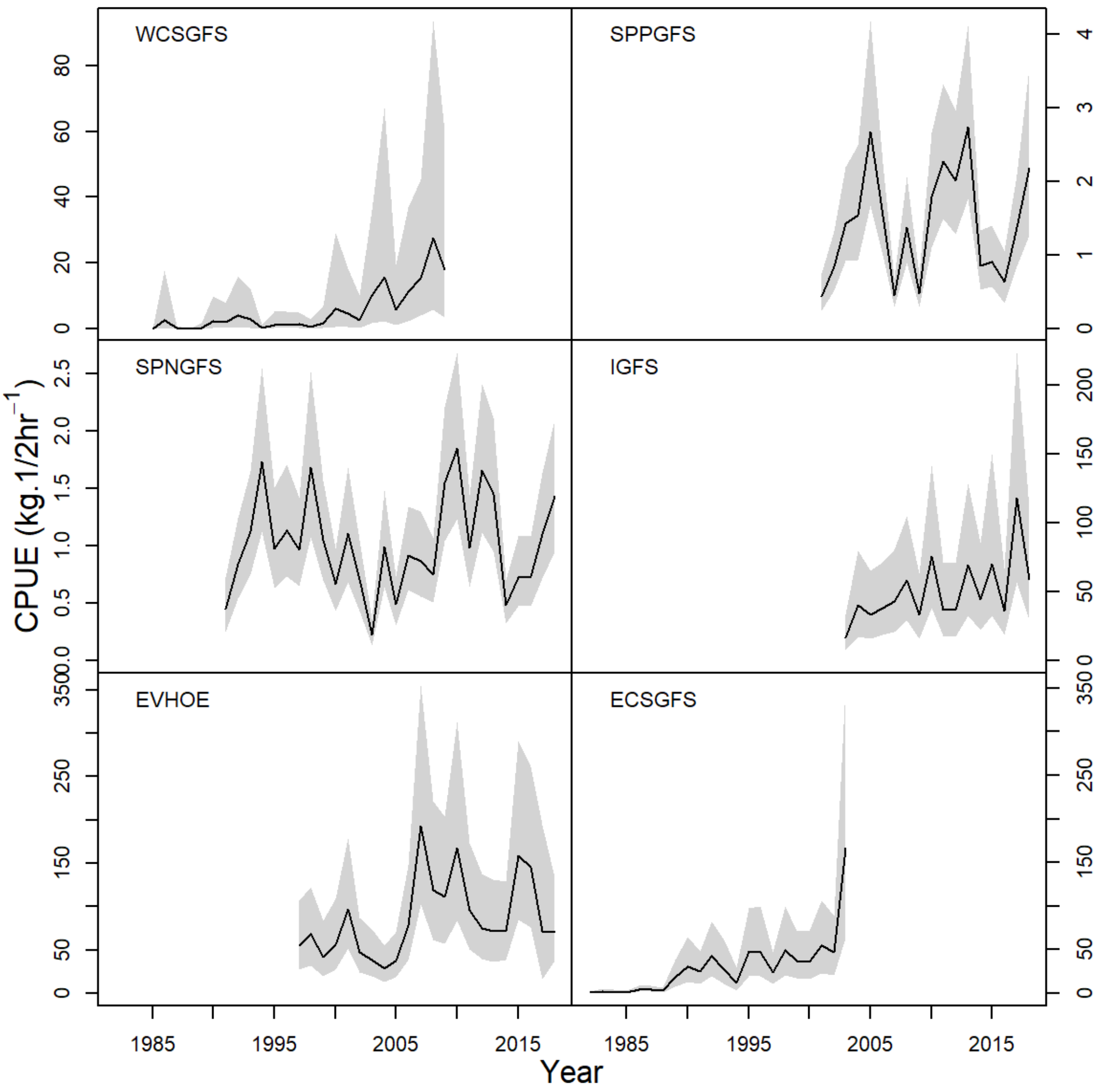

Figure 3.6.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish IBTS survey CPUE fitted delta-lognormal mean (solid line) and 95% credible intervals (grey region).

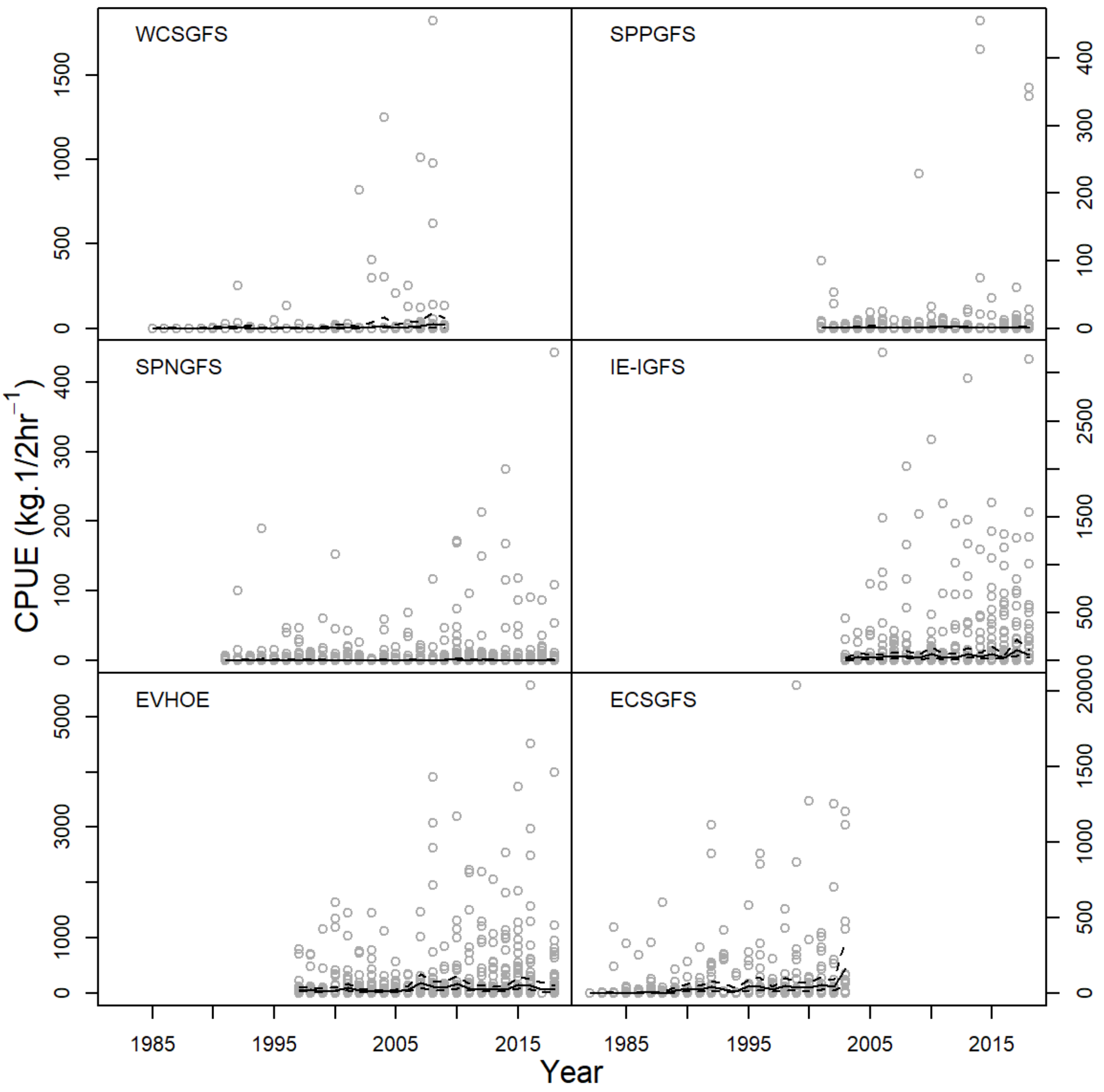

Figure 3.6.1.3. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish IBTS survey CPUE data (grey points) and fitted delta-lognormal mean (solid line) and 95% credible intervals (dashed lines).

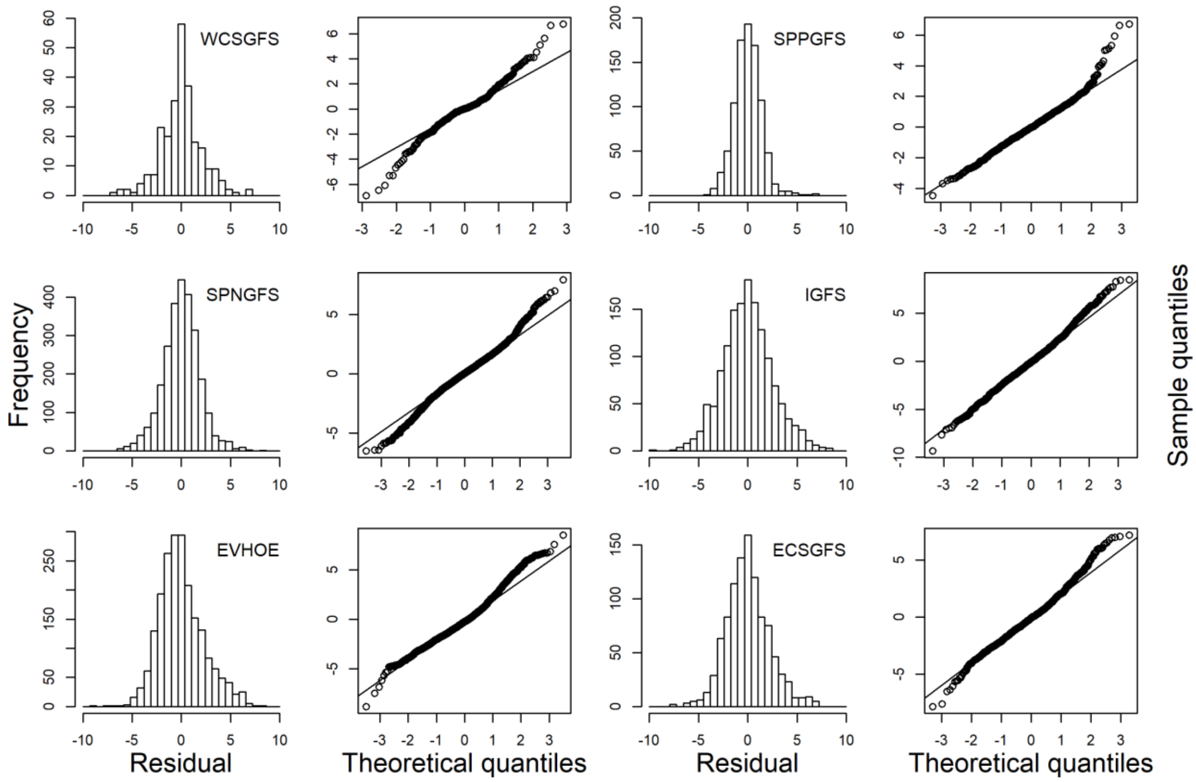

Figure 3.6.1.4. Boarfish in ICES Subareas 27.6, 7, 8. Diagnostics from the positive component of the delta-lognormal fits

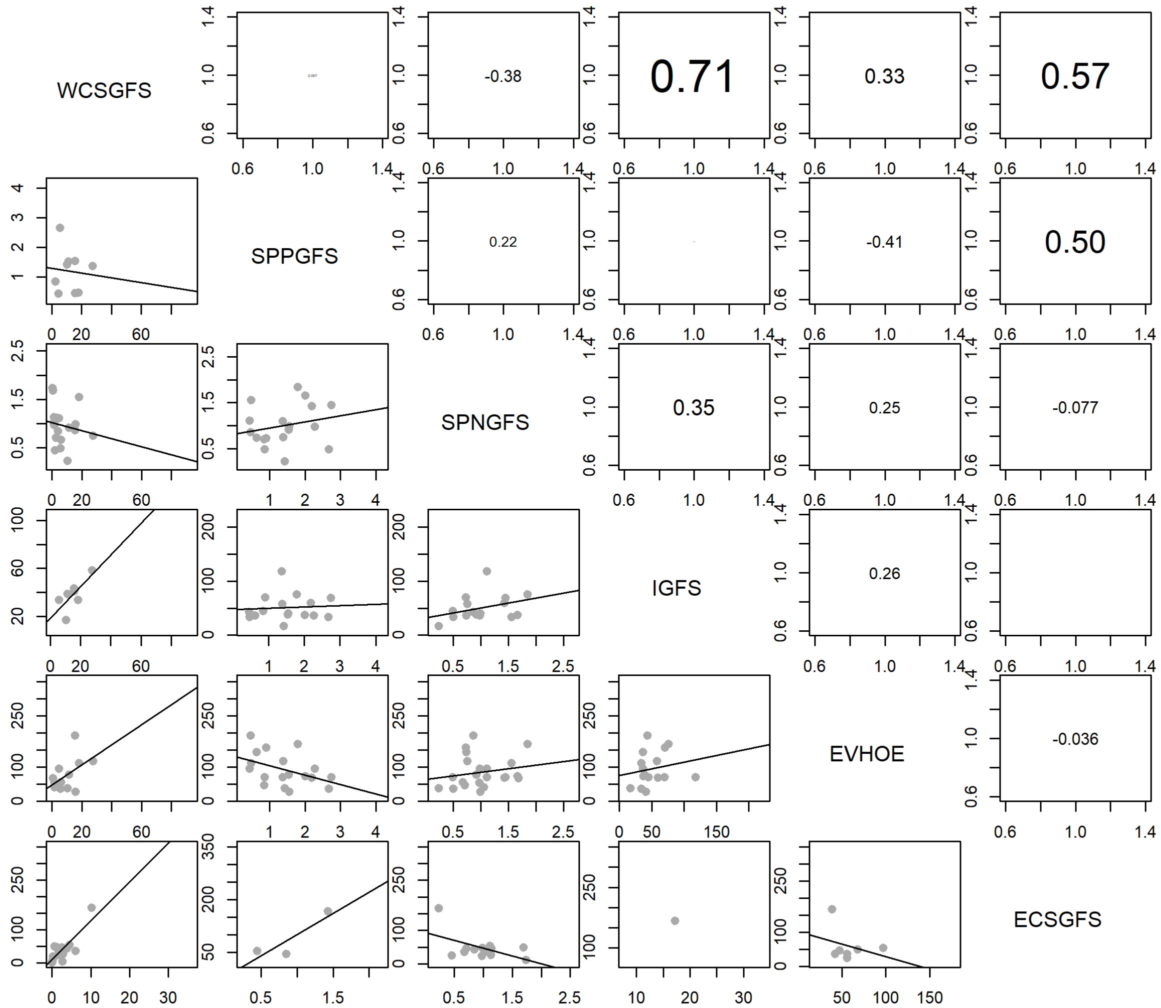

Figure 3.6.1.5. Boarfish in ICES Subareas 27.6, 7, 8. Pair-wise correlation between the annual mean survey indices.

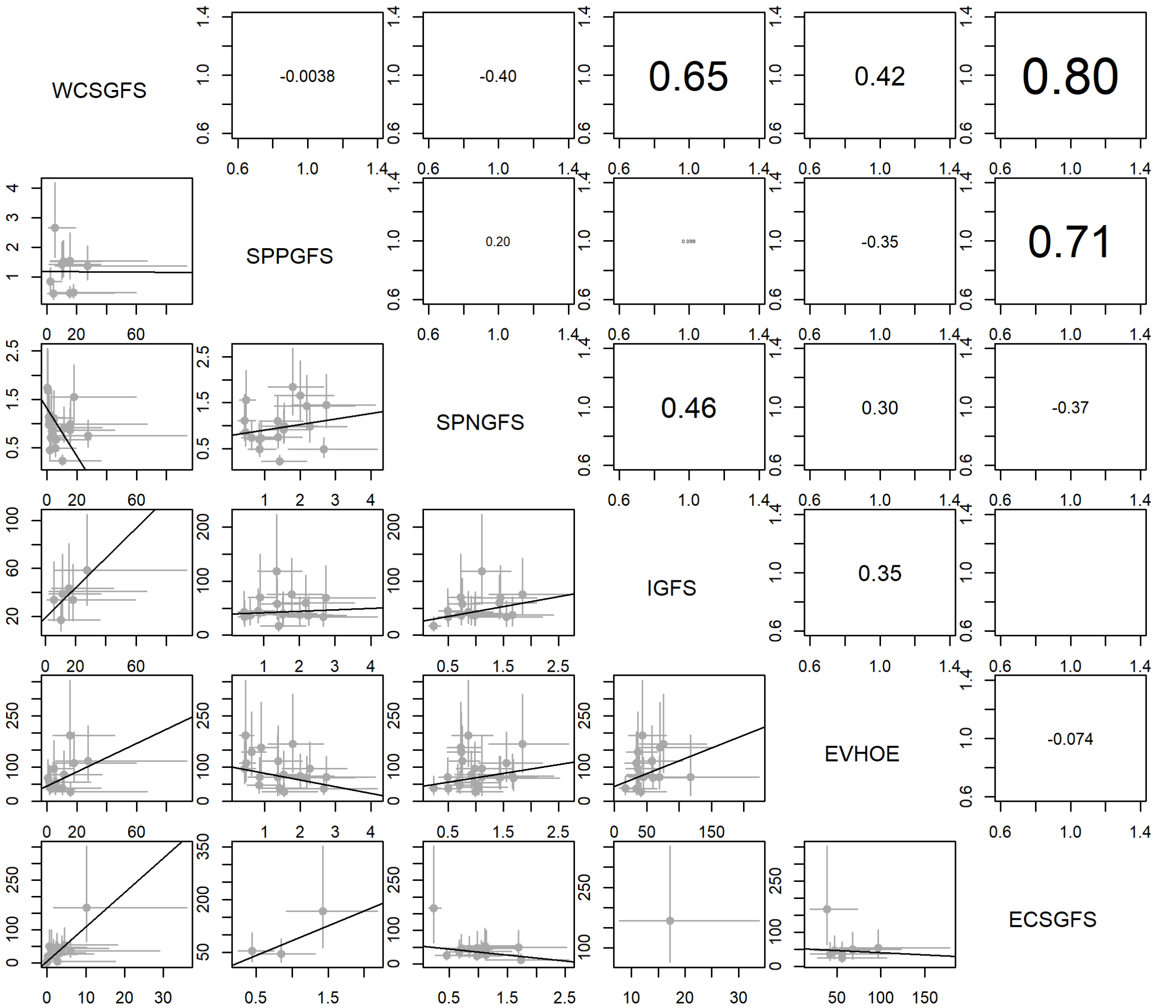

Figure 3.6.1.6. Boarfish in ICES Subareas 27.6, 7, 8. Weighted correlation between the annual mean survey indices. Correlations are weighted by the sum of the pair-wise variances.

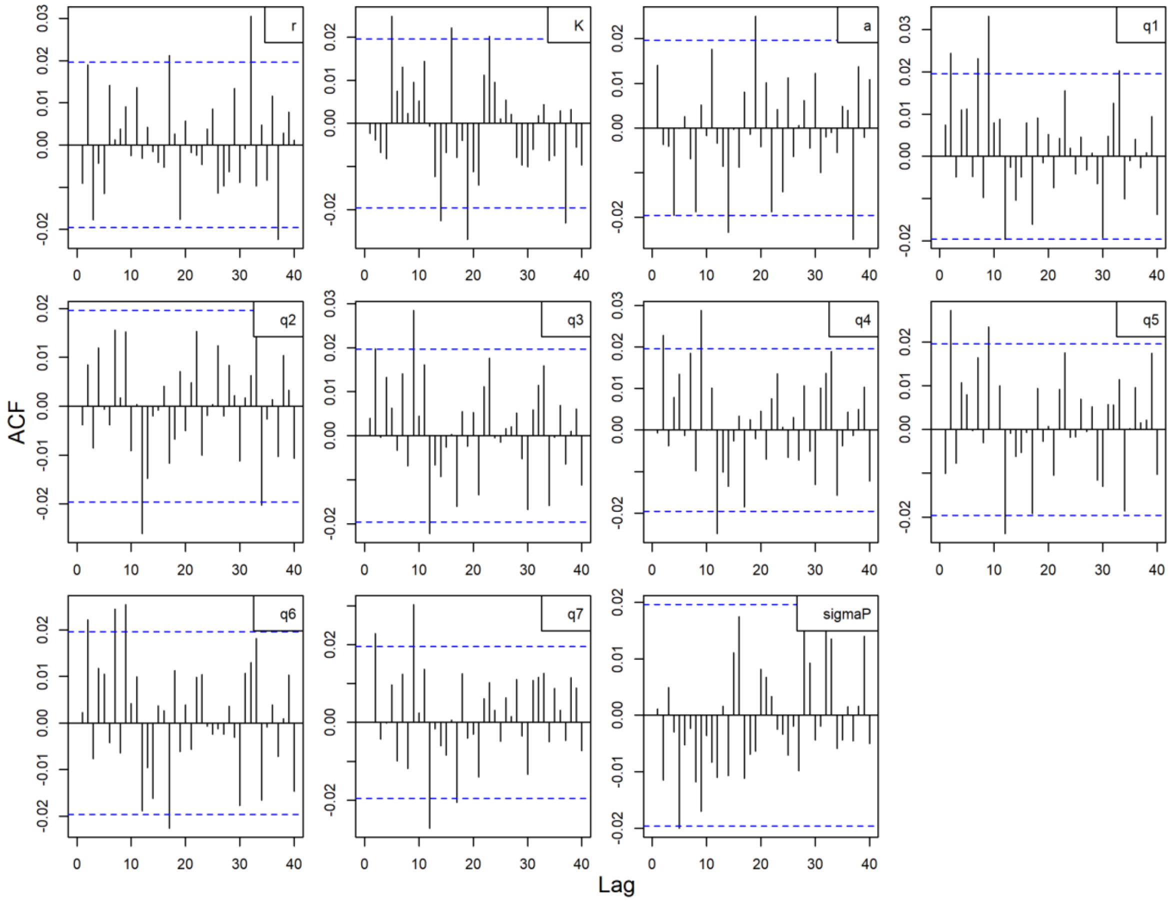

Figure 3.6.3.1. Boarfish in ICES Subareas 27.6, 7, 8. Parameters for final run converged with good mixing of the chains.

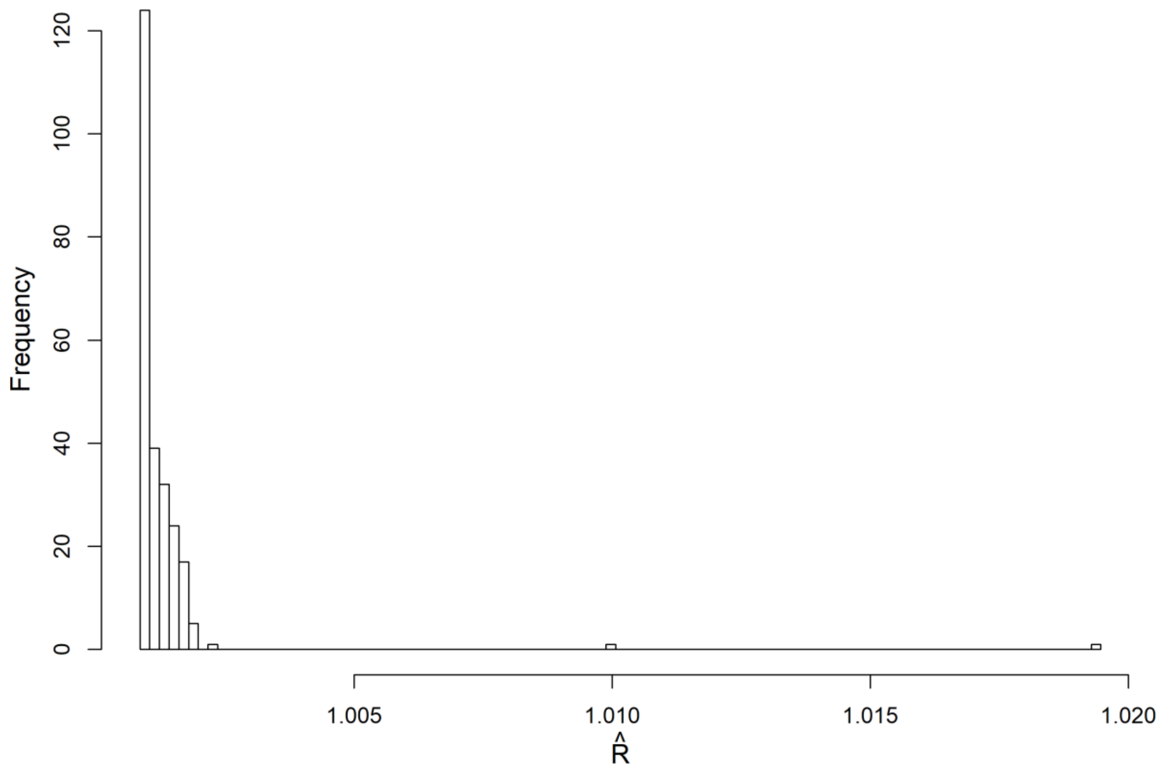

Figure 3.6.3.2. Boarfish in ICES Subareas 27.6, 7, 8. Rhat values lower than 1.1 indicating convergence.

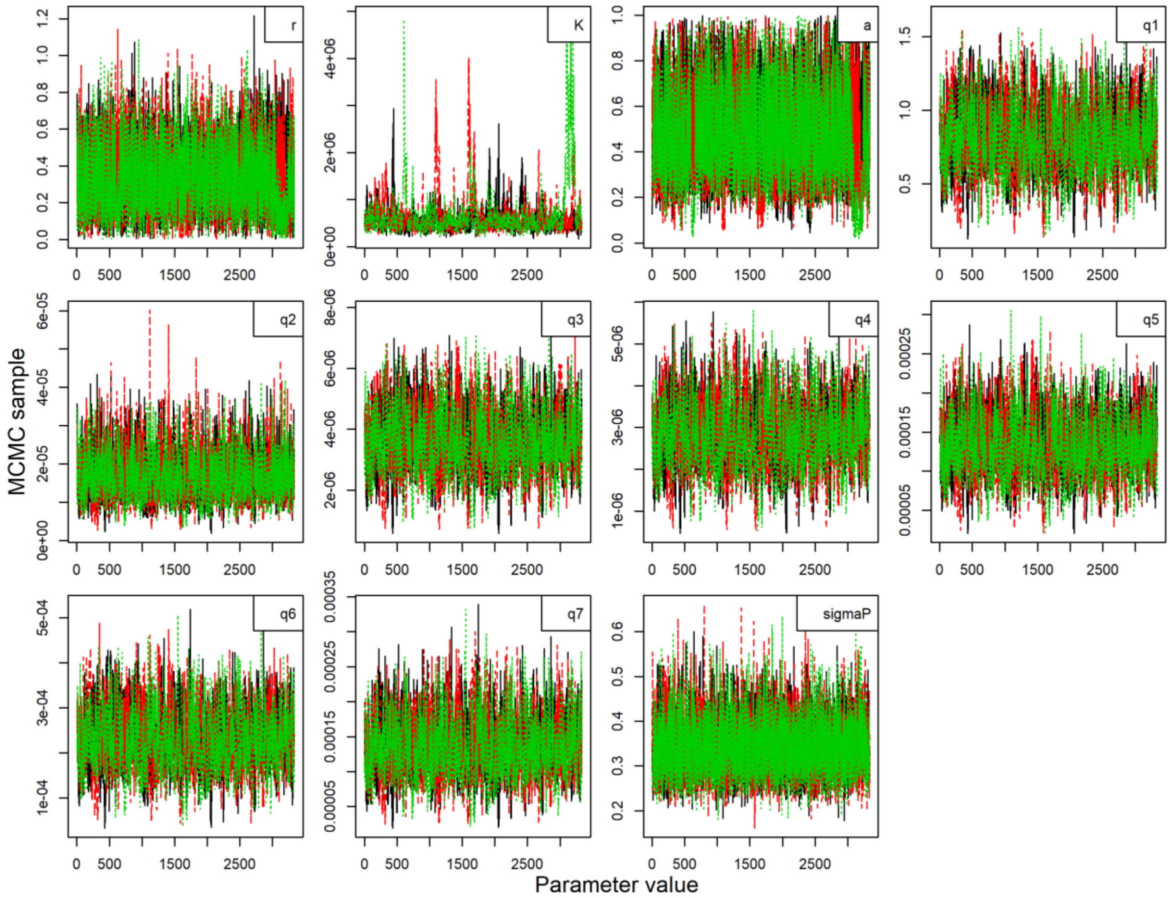

Figure 3.6.3.3. Boarfish in ICES Subareas 27.6, 7, 8. MCMC chain autocorrelation for final run.

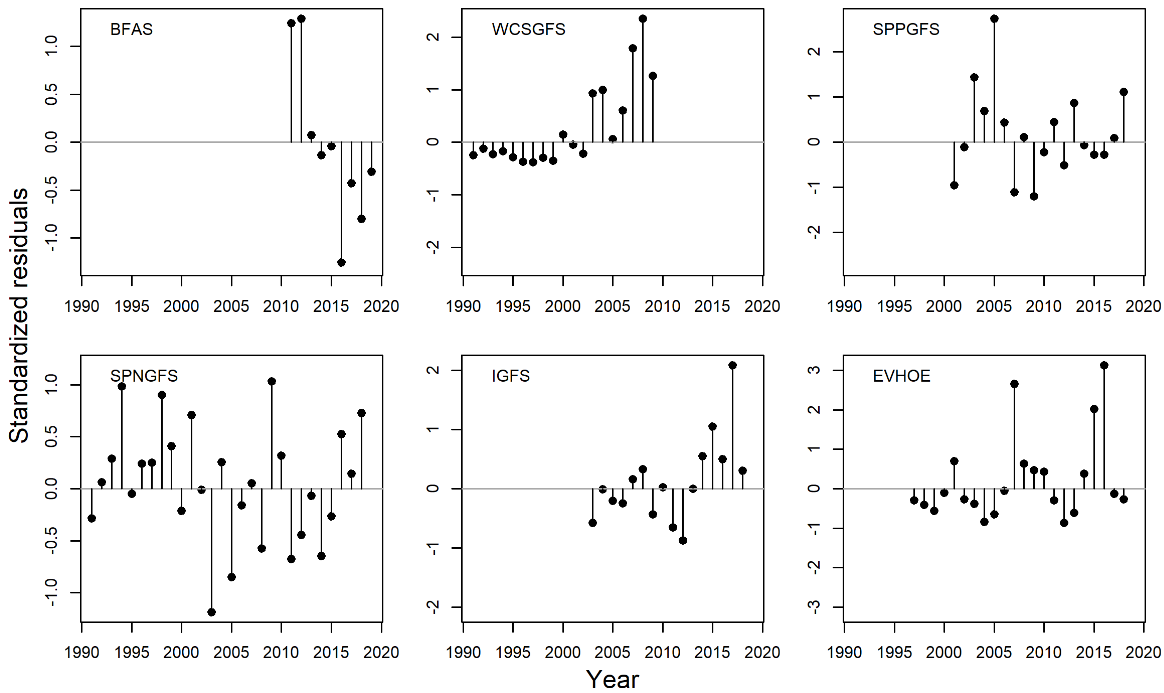

Figure 3.6.3.4. Boarfish in ICES Subareas 27.6, 7, 8. Residuals around the model fit for the final assessment run.

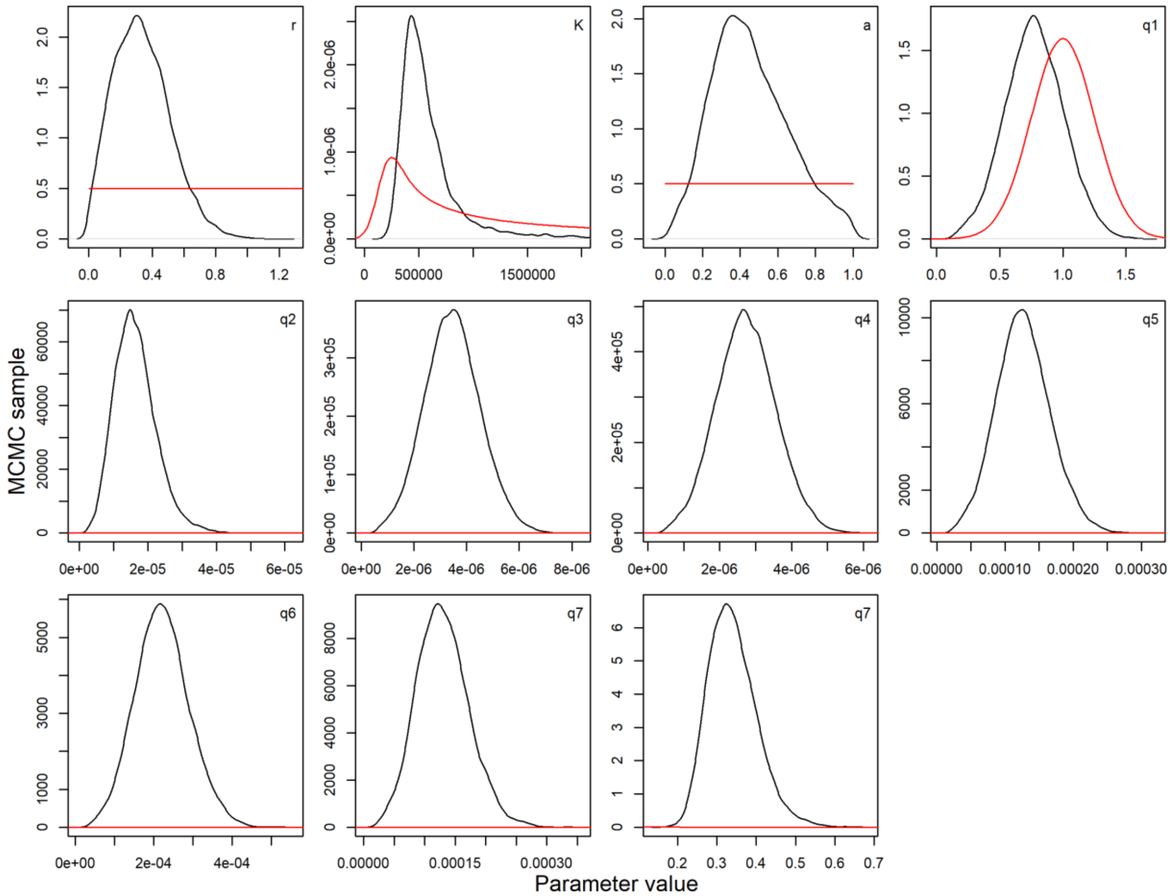

Figure 3.6.3.5. Boarfish in ICES Subareas 27.6, 7, 8. Prior (red) and posterior (black) distributions of the parameters of the biomass dynamic model.

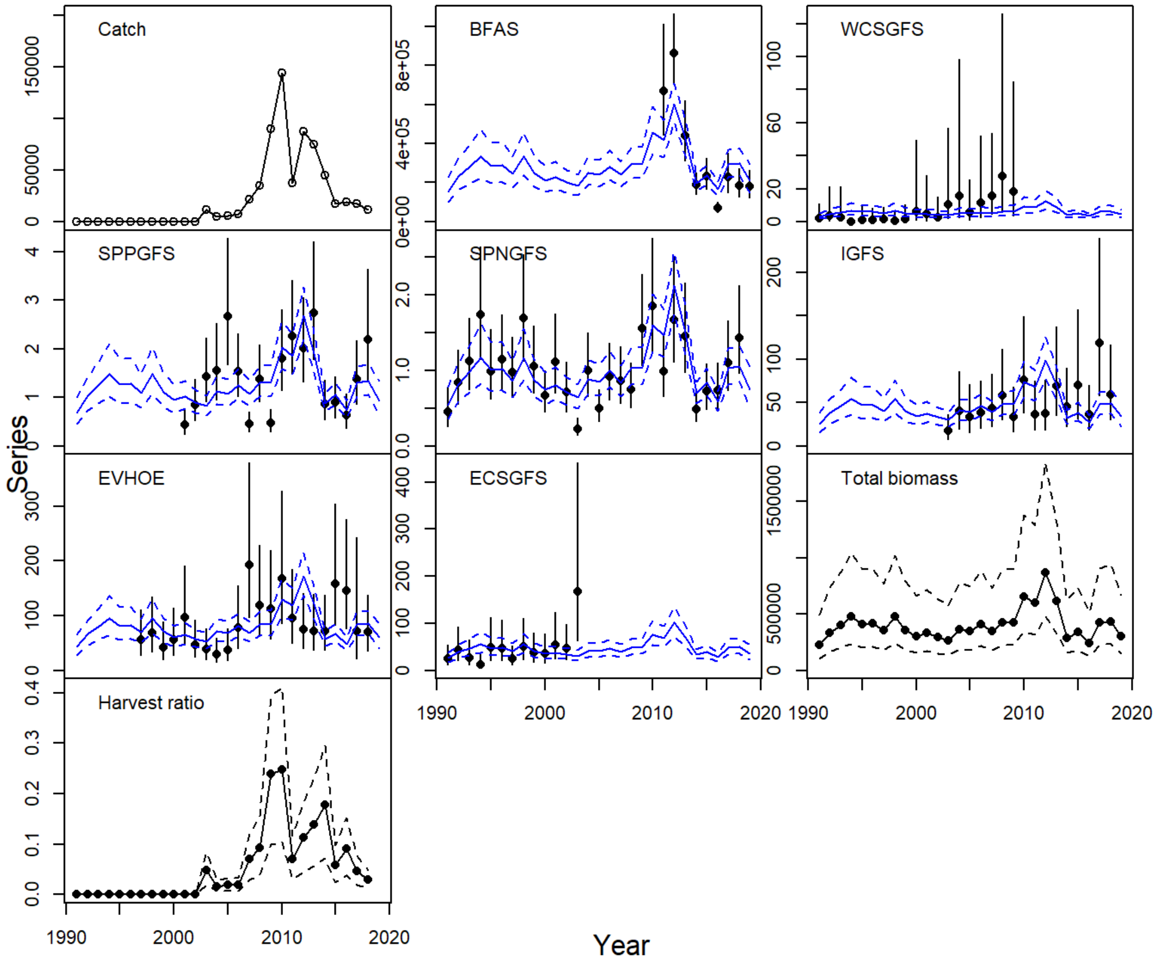

Figure 3.6.3.6. Boarfish in ICES Subareas 27.6, 7, 8. Trajectories of observed and expected indices for the final assessment run. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

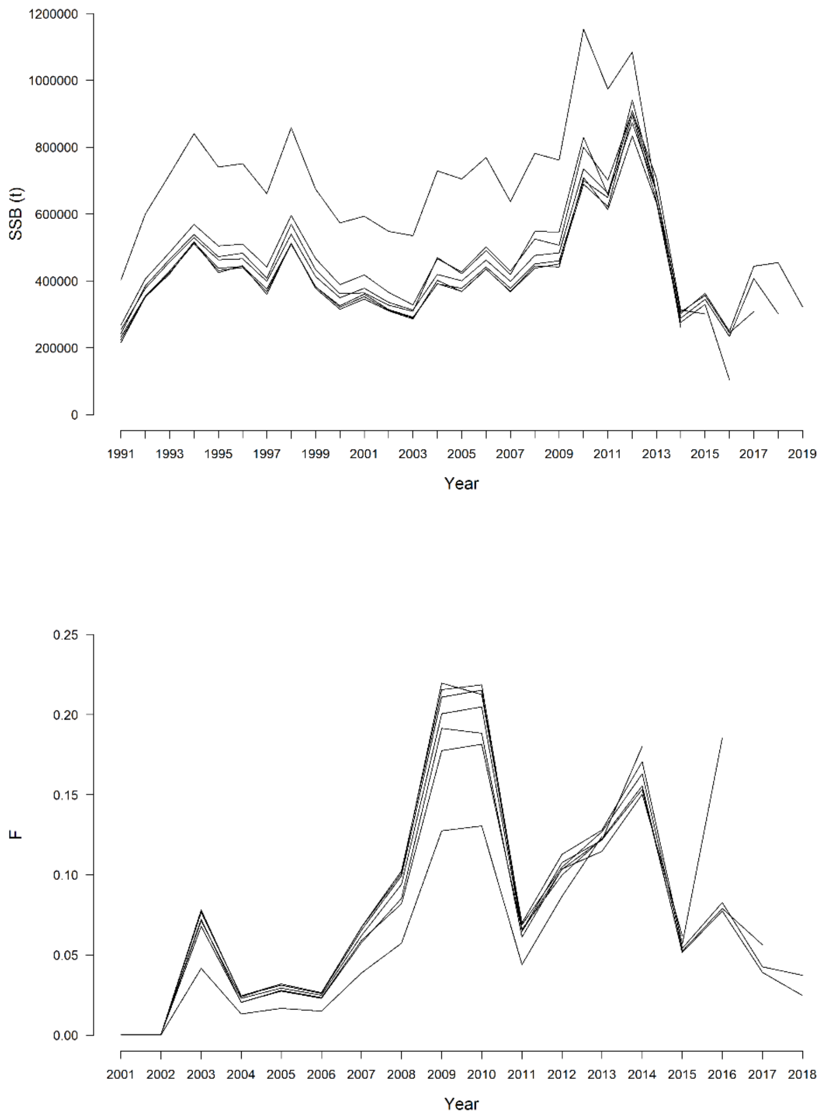

Figure 3.6.3.7. Boarfish in ICES Subareas 27.6, 7, 8. Retrospective plot of total stock biomass (above) and fishing mortality (below) from the surplus production model in 2013-2019.

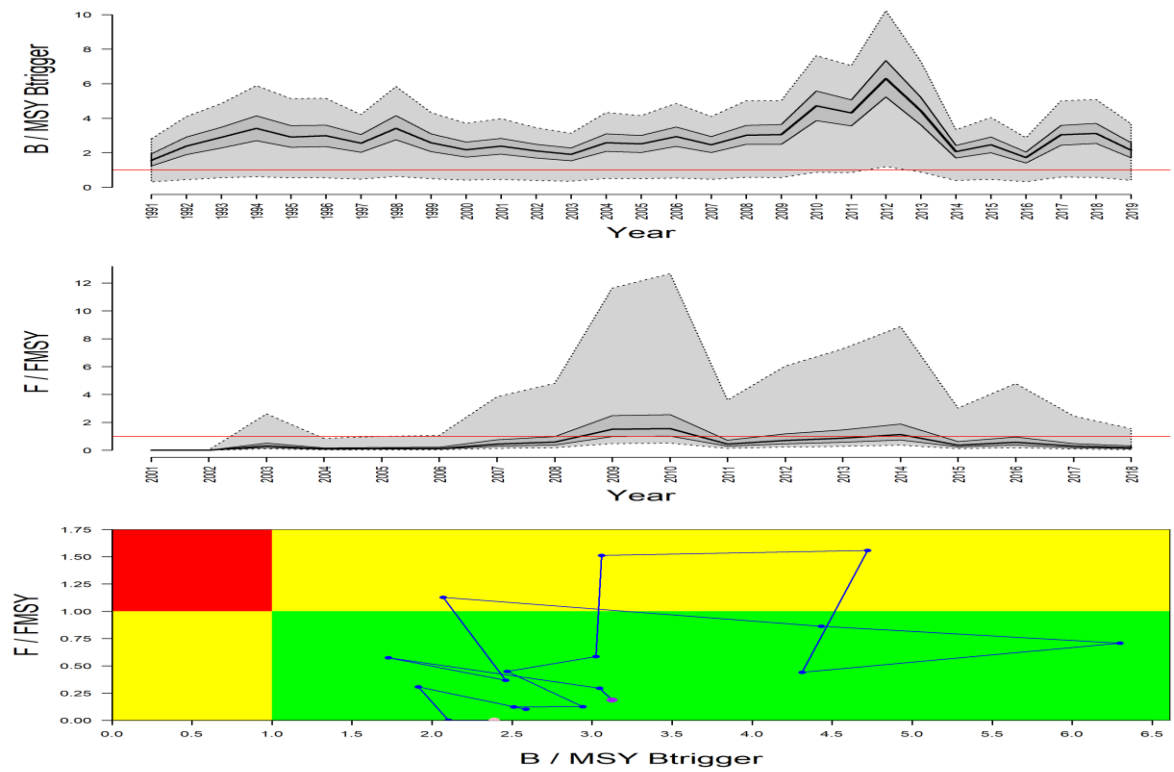

Figure 3.6.6.1. Boarfish in ICES Subareas 27.6, 7, 8. Ratios 'B / MSYBtrigger' and 'F / FMSY' through time and corresponding Kobe plot. Confidence intervals (50 and 95%) are given for the first two panels, the third displays median estimates only with the pink point representing the first point of the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

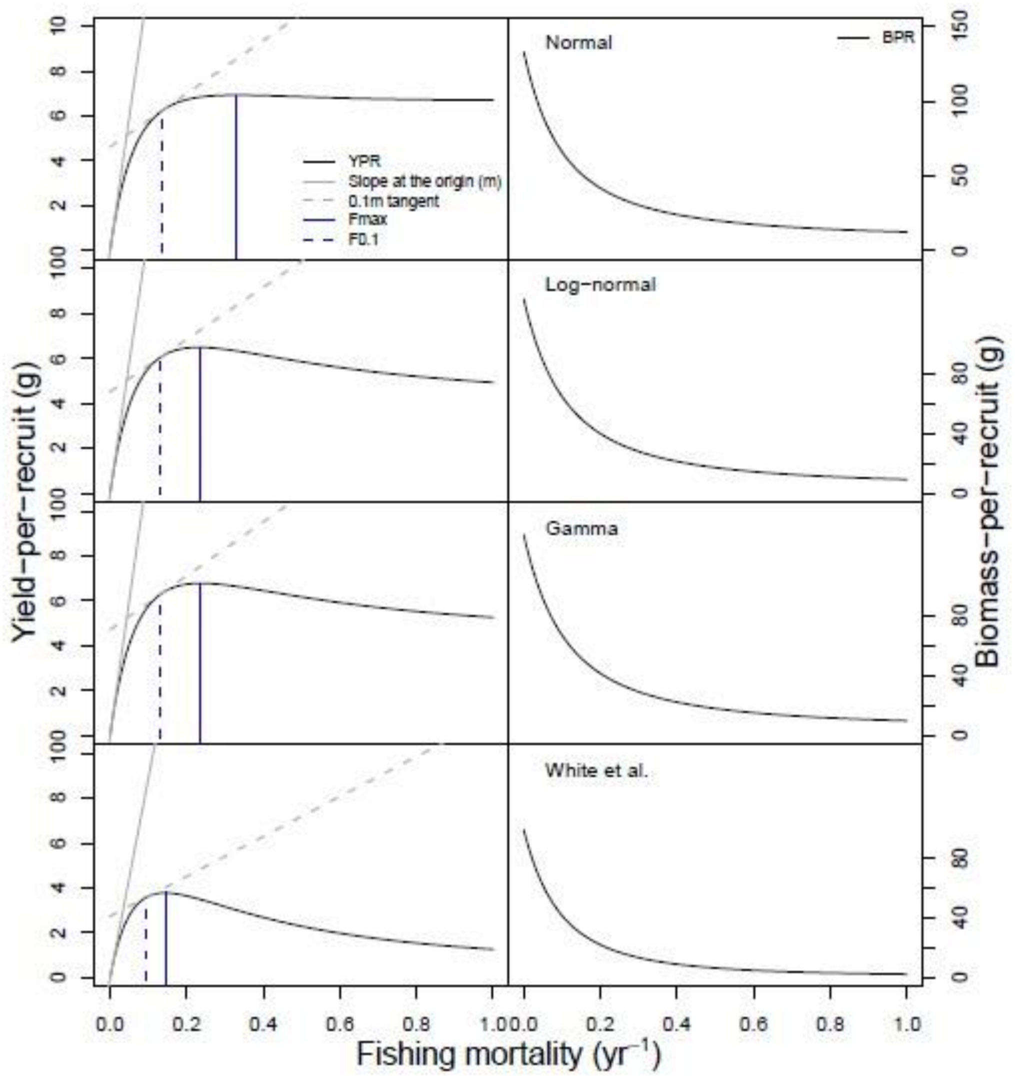

Figure 3.9.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White *et al*. 2011.

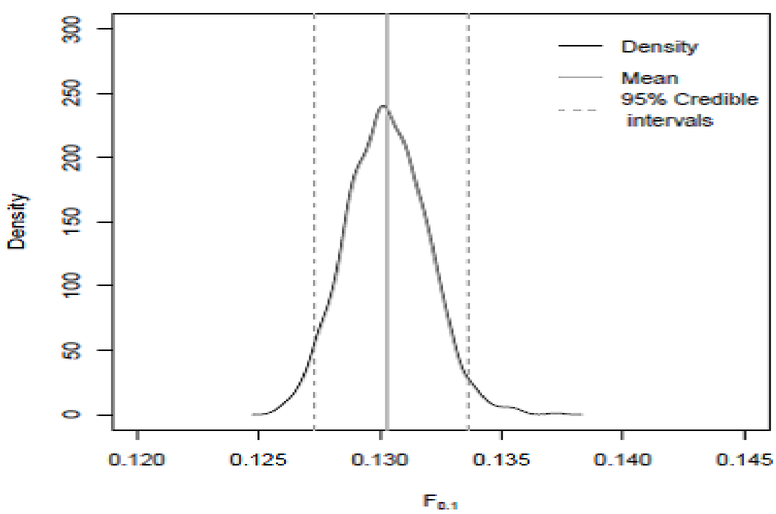

Figure 3.9.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Sensitivity of estimation of F0.1.

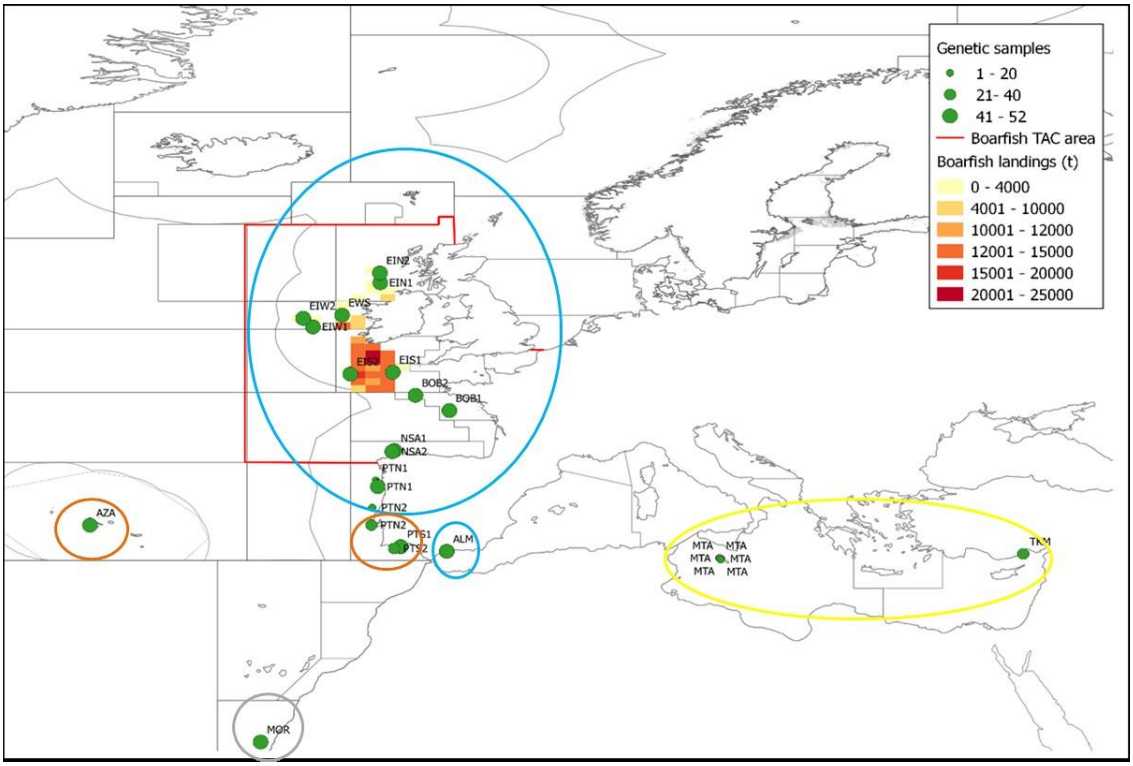

Figure 3.12.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish samples included in the genetic stock identification study are indicated in green. Population clusters identified by the STRUCTURE analyses are indicated by colour coded circles.

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

4.1 ICES advice in 2018

ICES noted that the stock is declining but estimated to be above MSY $B_{trigger}$ (3.184 million tonnes) in 2018. Since 1998 four large year classes have been produced (1998, 1999, 2002, and 2004). The 2005 to 2015 year classes are estimated to be average or small. The 2016 year-class, however, is estimated to be above average. Fishing mortality has been increasing since 2015 and is above F_{MSY} in 2017

A long-term management plan agreed by the EU, Faroe Islands, Iceland, Norway and Russia, is operational since 2019. ICES evaluated the plan and concludes that it is in accordance with the precautionary approach. The management plan implies maximum catches of 588 562 t in 2019.

4.2 The fishery in 2018

4.2.1 Description and development of the fisheries

The distribution of the 2018 Norwegian spring-spawning herring (NSSH) fishery for all countries by ICES rectangles per year is shown in Figure 4.2.1.1 and for annual quarter in Figure 4.2.1.2. The 2018 herring fishing pattern was similar to recent years. The fishery began in January on the Norwegian shelf and focused on overwintering, pre-spawning, spawning and post-spawning fish (Figure 4.2.1.2 quarter 1). In the second quarter, the fishery was insignificant (Figure 4.2.1.2 quarter 2, 0.1% of total catch). In summer, the fishery had moved into Faroese, Icelandic and Greenlandic waters (Figure 4.2.1.2 quarter 3). In autumn, the fishery partly shifted to the overwintering area in the fjords and oceanic areas off Lofoten, and the central part of the Norwegian Sea. In particular, the catches in the international part of the Norwegian Sea were high (Figure 4.2.1.2 quarter 4) but in contrast to 2017 the fishery in 2018 was more easterly distributed. The landings in the 1st quarter constituted 25% of the total landings and the largest proportion of the landings were in the 4th quarter (70%). The proportion of landings among quarters was similar to the fishery in 2017.

4.3 Stock Description and management units

4.3.1 Stock description

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

4.3.2 Changes in migration

Generally, it is not clear what drives the variability in migration of the stock, but the biomass and production of zooplankton are likely factors, as well as feeding competition with other pelagic fish species (e.g. mackerel) and oceanographic conditions (e.g. limitations due to cold areas). Beside environmental factors, the age distribution in the stock will also influence the migration. Changes in migration pattern of NSSH, as well as 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. No large year classes have entered the stock since 2004, although the 2013 year class is estimated to be above average (since 1988) and was in 2018 observed feeding in the north-eastern part of the Norwegian Sea in May and July. 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) in 2017/2018 while the older fish seemed to have had an oceanic wintering area. A similar wintering pattern was observed in 2018/2019. The oldest and largest fish move farthest south and west during feeding, and the older year classes were in May and July 2019 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 2018 were available from Denmark, Faroe Islands, Germany, Greenland, Iceland, Ireland, The Netherlands, Norway, Russia, the UK (Scotland) and Sweden. The total working group catch in 2018 was 592 899 tonnes (Table 4.4.1.1) compared to the ICES-recommended catch of maximum 384 197 tonnes. The majority of the catches (96%) were taken in area 2.a as in previous years. Samples were not provided by Greenland, the UK or Sweden (less than 1 % of the total catch were taken by these countries). Sampled catches accounted for 97 % of the total catches, which is on a similar level as in previous years. The sampling levels of catches in 2018 in total, by country and by ICES division is shown in Table 4.4.1.2, 4.4.1.3 and 4.4.1.4. Catch by nation, ICES division and quarter are shown in Table 4.4.1.5. The software SALLOC (ICES, 1998) was used to calculate total catches in numbers-at-age and mean weight at age representing the total catch. Samples allocated (termed fill-in in SALLOC) to cells (nation, ICES division and quarter) without sampling information are shown in Table 4.4.1.5.

4.4.2 Discards

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

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

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

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

4.4.3 Age composition of the catch

The estimated catch-at-age in numbers by years are shown in Table 4.4.3.1. The numbers are calculated using the SALLOC software. In 2018, about 16 % of the catches (in numbers) were taken from the 2013 year class, followed by the 2006 (13%) and 2011 and 2009 (both 11%) year classes. The 2004 year class still contributes, with 8 % of the catches in 2018.

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 more flat 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 2018 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 in 2014 and seem to have decreased slightly during the most recent years. 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; however there is an observed increase in mean weight in 2019 for ages older than 5 year. 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 potential 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 recent years since all year classes have to be fully matured before included. Therefore, assumptions have to be made for recent year classes. For recent year classes, WGWIDE (2010) decided to use average back-calculated maturity for "normal" and "big" year-classes, respectively and thereby reducing maturity-at-age for ages 4, 5 and 6 when strong year classes enter the spawning stock. The default maturity ogives used for "normal" and "big" year-classes are given in the text table below.

age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
normal ycl	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
strong ycl	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 2019 the year 2014 could be updated with back-calculated values in the present assessment. Assumed and updated values are shown in figure 4.4.5.1. 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 M are in accordance to previous years and their justification is provided in the stock annex. Information about deviations from these levels in the time-series, e.g. due to diseases, are also provided in the stock annex.

4.4.7 Survey data

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

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

The cruise reports from the IESNS and spawning survey in 2019 are available as working documents to this report. Both surveys were successfully conducted in 2019.

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.

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 number of all age groups decreased suddenly in "Fleet 5" and this is seen as a drop in the catch curves that year. This drop has continued for some of the year classes and the year classes 1998 and 1999 are disappearing faster from the stock than expected. This observed fast reduction in these age classes may also be influenced by the changes in "Fleet 5" catchability, with seemingly higher catchability in years 2006—2009. Like the catch curves from commercial landings, the corresponding curves from "Fleet 5" are also quite flat for year classes 2005 onwards. As "Fleet 1" was not conducted in the years 2009–2014, there is a gap in the catch curves, making it difficult to interpret them.

4.4.8 Sampling error in catches and surveys

Sampling errors for Norwegian catch-at-age for the years 2010-2018 is estimated using ECA (Salthaug and Aanes 2015, Hirst *et al.* 2012). Using the Taylor function (Aanes 2016a) to model the sampling variance of the catches yields a very good fit ($R^2_{adj} = 0.94$) and using this function to impute missing sampling variances for catch-at-age yields relative standard errors shown in Table 4.4.8.1. It is assumed that the relative standard errors in the total catches are equal to the Norwegian catches (which comprise ~60% of the total catches). Sampling errors for survey indices are estimated using StoX (http://www.imr.no/forskning/prosjekter/stox/nb-no). For Fleet 1 estimates are available for the years 1988–1989, 1994–1996, 1998–2000, 2005–2008, and 2015–2019, for Fleet 4 estimates of sampling errors are available for 2009–2019, and for Fleet 5 for 2008–2019. Missing values for sampling variances are imputed using the Taylor function which provides goods fits (R^2_{adj}'s are 0.94, 0.97, 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 is made available for the working group.

4.5 Stock assessment

The first benchmark of the NSSH took place in 2008. The assessment tool TASACS was then chosen to be the standard assessment tool for the stock. The second benchmark took place in 2016 (ICES 2016c) 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 2019

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 sum of national quotas) along with the precision of the prediction. This was changed in 2017 as 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 2019 assessment, i.e. the catch prediction for 2019 is not included when fitting the model to data. The resulting estimated selection pattern is gradual (Figure 4.5.1.1) and in line with the current knowledge about the fishery. It is important to notice that this has marginal effect on the assessment, but larger effects on the prediction and short-term forecast.

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

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

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

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

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

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

The negative residuals tracing the 1983 year class for catch-at-age represents low fishing mortalities examining the type 1 residuals (Figure 4.5.1.4). This effect is less pronounced considering the type 2 residuals. The type 2 residuals are qualitatively comparable with the type 1 residuals but generally display more mixed residuals as predicted by the theory. Otherwise the residuals for catch-at-age appears fairly mixed apart for some serial correlation for age 2 and 3 (which are very low), and some negative residuals for the plus group the most recent years. The residuals for Fleet 1 in 1994 and 2015 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 10+ in 2015 and 2016 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. However, these data points are given low weights (Figure 4.5.1.3) as they are found imprecise (Tables 4.4.8.1–4.4.8.4). Some serial correlation for residuals for ages 3 and 4 in Fleet 1 can also be detected, but is down weighted by the same reasons. 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 comparing 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 tends 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 Fleet 1, 4 and 5 such that the optimum for the marginal likelihood is clearly defined. The point estimates of SSB and F is insensitive to different values of h.

The retrospective runs for this model shows estimates which is within the estimated levels of precision (Figure 4.5.1.7), and has a reasonably low Mohn's rho value of ~0.05 (Mohn, 1999; Brooks and Legault, 2016). The indices from Fleet 1 indicate, on average, a relatively larger abundance than the indices from Fleet 5 for 2015-2019 which is supported by the positive residuals for ages 9–10+ (Figure 4.5.1.4). Consequently, the increased estimates of SSB and decreased estimates of F after 2014 is a response to the indices from Fleet 1 which was not conducted in the years 2009–2014. Note that the retrospective estimates are remarkably stable from 2015 and onwards. To illustrate the conflict in data and increased uncertainty in estimates the most recent years, the abundance indices are scaled to the absolute abundance by the estimated catchabilities. Then the spawning-stock biomass based on each survey index is calculated using the stock weights at age and proportion mature at age (Figure 4.5.1.8). Here we see a fairly good temporal match between the model estimate of SSB and the survey SSBs except for the years 2015 and 2016 for Fleet 1, which display a significantly faster reduction in the stock compared to Fleet 5 which shows a more flat trend in the same years. Also, both Fleet 1 and Fleet 5 indicate an increase in SSB from 2017 and onwards. It is worth noticing that although the point estimate of SSB based on Fleet 1 appear very much higher than Fleet 5 in 2015 and 2016, the uncertainty in the estimates are very high, such that the respective estimates do not appear as significantly different. However, the effect on the final assessment is to lift the point estimate of SSB and increase the uncertainty which is in accordance with the data used (Figure 4.5.1.9).

The final assessment results are shown in Figure 4.5.1.9. The estimates of fishing mortality for 2017 is rather high, as a response to the high catch in 2017 with a point estimate of 0.162. In 2018 the fishing mortality is estimated to be lower than 2017 (F=0.128 with 95% confidence interval between 0.092-0.163), but still higher than in 2015. The spawning stock shows a declining trend since 2009, and the 95% confidence interval of the stock level in 2019 ranges from ~3.211 to ~4.717 million tonnes which is barely above B_{mp}=3.184 million tonnes, such that the probability of the stock being above B_{lim}=2.5 million tonnes is high. Note the rather large uncertainty in the absolute levels since the peak in 2009 with the further increase in the most recent years. This high uncertainty is a result of the conflicting signals in data concerning the degree of decrease in the stock over this time period.

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

4.5.2 Exploratory assessments

4.5.2.1 TASACS

TASACS was run according to the benchmark in 2008 using the VPA population model in the TASACS toolbox with the same model options as the benchmark (see Stock Annex). The information used in the TASACS run is catch data and survey data from eight surveys. The analysis was restricted to the years 1988—2019. The model was run with catch data from 1988 to 2018, and projected forwards through 2019 assuming Fs in 2019 equal to those in 2018, to include survey data from 2019. The larval survey (SSB fleet) was discontinued in 2017 and no new information is therefore available from this survey. Additionally, no new indices were provided for fleets 6 and 7 due to bad survey coverage in these surveys.

The model fit to the tuning data is shown with Q-Q plots in Figure 4.5.2.1.1. Surveys 1, 2, 3 and 7 seem to fit rather well to the assumed linear relationship in the TASACS model, but surveys 4, 6 and 8 have rather poor fit. Since 2016 the TASACS run Q-Q plots for fleet 5 shows a poorer fit compared to earlier assessments. This is mainly caused by a change in estimated catchability.

Particularly Survey 8 (larval survey) seems to have a poor fit. This can also be seen as a block of positive residuals for this survey in later years (Figure 4.5.2.1.2). 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 4.5.2.1.3. The time-series of SSB show similar trends for XSAM and TASACS. For most of the years, the estimates from TASACS are within the confidence limits estimated by XSAM. The SSB on 1 January 2019 is estimated by TASACS to be 3.797 million tonnes, which is slightly lower than the estimated value from TISVPA and to the point estimate from XSAM.

4.5.2.2 TISVPA

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

Rather similar signals by position of minima with respect to SSB (2019) were obtained from catch-at-age and surveys 1, 4 and 5. The position of the overall objective function of the model, indicates the SSB value in 2019 about 4.0 million tonnes (see WD02).

The results from TISVPA are compared to those from XSAM and TASACS in Figure 4.5.2.1.3.

4.6 NSSH reference points

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

4.6.1 PA reference points

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

4.6.2 MSY reference points

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

4.6.3 Management reference points

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

4.7 State of the stock

The SSB on 1 January 2019 is estimated by XSAM to be 3.965 million tonnes which is above B_{pa} (3.184 million t). The stock is declining and the SSB time-series from the 2019 assessment is in line with the SSB time-series from the 2018 assessment. In the last 20 years, several large year classes have been produced (1998, 1999, 2002, and 2004). The following year classes are estimated to be average or small. Fishing mortality in 2018 is estimated to be 0.128 which is above the management plan F that was used to give advice for 2018. A new management plan has been implemented for the 2019 advisory year.

4.8 NSSH Catch predictions for 2019

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 were performed to determine levels of precision in the forecast. Table 4.8.1.1 list 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 (2016—2018).

For the weight-at-age in the stock, the values for 2019 were obtained from the commercial fisheries in the wintering areas in January. For the years 2020 and 2021 the average of the last 3 years (2017 —2019) 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 (1988-2019) 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.

The average fishing mortality defined as the average over the ages 5 to 12+ is 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 previous years for this stock but the age range is shifted from 5-11 to 5-12+ from 2018.

There was no agreement on the sharing of the TAC for 2019. To obtain an estimate of the total catch to be used as input for the catch-constraint projections for 2019, the sum of the unilateral quotas was used. In total, the expected outtake from the stock in 2019 amounts to 773 750 tonnes. F in 2019 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 of 773 750 tonnes is taken in 2019, it is expected that the SSB will decrease from 3.965 million tonnes (95% confidence interval 3.212 to 4.717 million tonnes) on 1 January in 2019 to 3.660 million tonnes in 2020. The weighted F over ages 5-12 are 0.186.

4.9 Comparison with previous assessment

A comparison between the assessments 2008—2019 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 (2018) this was further changed to 5—12+.

The table below shows the SSB (thousand tonnes) on 1 January in 2018 and weighted F in 2017 as estimated in 2018 and 2019.

	ICES 2018	WG 2019	%difference
SSB(2018)	3 826	4 103	7.2%
Weighted F (2017)	0.174	0.162	-6.9%

4.10 Management plans and evaluations

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

The implemented long-term management strategy of Norwegian spring spawning herring is consistent with the precautionary approach and the MSY approach (WKNSSHREF, ICES, 2018?; WKNSSHMSE, ICES, 2018??) 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}, when it is not possible to fish 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.

4.11 Management considerations

Perception of the stock has not changed much since last year's assessment (estimated SSB in 2018 is 7 % higher in this year's assessment). Results of exploratory runs by other models match with those of XSAM.

Historically, the size of the stock has shown large variations and dependency on the irregular occurrence of very strong year classes. Between 1998 and 2004 the stock produced several strong year classes which lead to an increase in SSB until 2009. Since then, SSB has declined due to absence of strong year classes after 2004.

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

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

4.12 Ecosystem considerations

NSS herring juveniles and adults are an important part of the ecosystems in the Barents Sea, along the Norwegian coast, in the Norwegian Sea and in adjoining 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.

- The stock's more westerly feeding distribution in recent years (ICES 2019a; 2019b) 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 (Nøttestad *et al.*, 2014; ICES, 2015b; 2017b; 2019b).
- Where herring and mackerel overlap spatially they compete for food to some extent (Bachiller *et al.*, 2015; Debes *et al.*, 2012; Langøy *et al.*, 2012; Óskarsson *et al.*, 2016) but studies showing mackerel being more effective feeder might indicate that the herring is forced to the western and northern fringe of Norwegian Sea, although higher zooplankton biomass there could also attract the herring (Nøttestad *et al.*, 2014; ICES, 2015b; 2016b).
- 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).
- The 2016 year class of herring is the strongest since the 1991 year class in the Barents Sea as 3 year old based on the May survey 2019 (ICES, 2019a). This is indication of good recruitment to the stock over the next two-three years.
- Herring growth (i.e. length-at-age) varied over the period 1994-2015 and was negatively related to stock size (Homrum *et al.*, 2016), which indicates interaction between fish density and prey availability.
- Following a maximum in zooplankton biomass during the early 2000s the biomass declined with a minimum in 2006. From 2010, the trend turned to an increase and in May 2019 the biomass was around the long-term mean. Interestingly, all the areas, excluding

east of Iceland and on few occasions Jan Mayen AF (Figure 6.2), show parallel 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, 2019c). However, during the last two years, 2017 and 2018, the temperature remained relatively warm while the salinity had a marked decrease. Two different mechanisms can explain this, increased fraction of sub-polar 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.

4.13 Changes in fishing patterns

The fishery for Norwegian spring spawning herring has generally been described as progressing clockwise in the Nordic Seas as the year progresses. In the recent years (after ~2013) this pattern has changed, because there has been an extended fishery in the south and southwestern areas in the Norwegian Sea in the 3rd and 4th quarters and thus almost 70% of the herring catch was taken in the last quarter of 2018. The majority of the catches in the 4th quarter are now taken in the central parts of the Norwegian Sea, whereas in the preceding years there was a more significant fishery in northeastern areas (outside northern Norway and southwest of the Bear Island). This change in migration resulted in late arrival at the Norwegian coast for this part of the stock during the winter in recent years. The Norwegian coastal fleet (smaller vessel that cannot go that far offshore) could therefore not access this herring during the winter fishery and targeted younger fish (mostly of the 2013 year class) which overwintered in Norwegian fjords.

4.14 Recommendation

No recommendations

4.15 References

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4.16 Tables

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

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

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

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

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

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

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

Table 4.4.1.3 Norwegian spring-spawning herring. Sampling coverage by country in 2018.

COUNTRY	OFFICIAL CATCH	% catch covered by sampling programme	NO. SAM-PLES	NO. MEAS-URED	NO. AGED
Denmark	17051.6	100	7	632	160
Faroe Islands	82062.3	95	9	582	582
Germany	1989.4	93	3	185	185
Greenland	2465.3	0	0	0	0
Iceland	83393	100	58	2796	1396
Ireland	2428.5	95	2	122	96
Norway	332027.5	99	83	2158	2158
The Netherlands	4289.6	50	10	604	250
UK_Scotland	2581.6	0	0	0	0
Sweden	425	0	0	0	0
Russia	64185	100	81	15027	1220
Total for Stock	592898.8	97	253	22106	6047

Table 4.4.1.4 Norwegian spring-spawning herring. Sampling coverage by ICES Division in 2018.

Area	Official Catch	No Sam-ples	No Aged	No Meas-ured	No Aged/ 1000 tonnes	No Measured/ 1000 tonnes
2.a	570284.6	229	5456	20934	10	37
4.a	309.8	0	0	0	0	0
5.a	22304	24	591	1172	26	53
14.a	0.34	0	0	0	0	0
Total	592898.8	253	6047	22106	10	37

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	2.a	124493.2	
2	Norway	2	2.a	831.4	1
3	Norway	3	2.a	1421.1	4
4	Norway	4	2.a	204972	
5	Norway	2	4.a	1	1
6	Norway	3	4.a	240.3	4
7	Norway	4	4.a	68.5	4
8	Iceland	3	2.a	1162	
9	Iceland	4	2.a	59927	
10	Iceland	3	5.a	14336	
11	Iceland	4	5.a	7968	
12	Faroe Islands	2	2.a	0.3	1,16,24
13	Faroe Islands	3	2.a	4433	14
14	Faroe Islands	4	2.a	77629	
15	Sweden	1	2.a	425	1,16,24
16	Denmark	1	2.a	17051.6	
17	Germany	1	2.a	0.4	1,16,24
18	Germany	2	2.a	2.1	1,16,24
19	Germany	3	2.a	132.9	20
20	Germany	4	2.a	1854	
21	Greenland	3	2.a	898.4	8,29
22	Greenland	4	2.a	1566.6	4,9,14,20,27,30
23	Greenland	3	14.a	0.3	8,29
24	Ireland	1	2.a	2306	
25	Ireland	4	2.a	122.5	4,9,14,20,27,30
26	Netherlands	3	2.a	51.9	27
27	Netherlands	4	2.a	4237.7	
28	Russia	1	2.a	37	1,16,24

29	Russia	3	2.a	8964		
30	Russia	4	2.a	55184		
31	Scotland	1	2.a	2581.6	1,16,24	

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

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

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

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

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

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

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

	age															
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1966	0.008	0.017	0.040	0.063	0.246	0.260	0.265	0.301	0.410	0.425	0.456	0.460	0.467	0.446	0.459	0.472
1967	0.009	0.015	0.036	0.066	0.093	0.305	0.305	0.310	0.333	0.359	0.413	0.446	0.401	0.408	0.439	0.430
1968	0.010	0.027	0.049	0.075	0.108	0.158	0.375	0.383	0.364	0.382	0.441	0.410		0.517	0.491	0.485
1969	0.009	0.021	0.047	0.072		0.152	0.296		0.329	0.329	0.341					0.429
1970	0.008	0.058	0.085	0.105	0.171		0.216	0.277	0.298	0.304	0.305	0.309				0.376
1971	0.011	0.053	0.121	0.177	0.216	0.250		0.305	0.333		0.366	0.377	0.388			
1972	0.011	0.029	0.062	0.103	0.154	0.215	0.258		0.322							
1973	0.006	0.053	0.106	0.161	0.213		0.255									
1974	0.006	0.055	0.117			0.249										
1975	0.009	0.079	0.169	0.241			0.381									
1976	0.007	0.062	0.132	0.189	0.250			0.323								
1977	0.011	0.091	0.193	0.316	0.350				0.511							
1978	0.012	0.100	0.210	0.274	0.424	0.454				0.613						
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						

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

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

	age														
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
2017		0.092	0.143	0.205	0.241	0.292	0.322	0.350	0.360	0.382	0.392	0.391	0.396	0.399	0.407	0.394
2018		0.068	0.127	0.207	0.240	0.276	0.321	0.348	0.371	0.380	0.399	0.404	0.400	0.407	0.408	0.418

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
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

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

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

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

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

**** 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. Mature at age. The time-series was provided by WKHERMAT in 2010 and are used in the assessment since 2010.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
1951	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
1952	0	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1
1953	0	0	0	0	0.3	0.4	0.9	1	1	1	1	1	1	1	1	1
1954	0	0	0	0	0.1	0.7	0.9	1	1	1	1	1	1	1	1	1
1955	0	0	0	0.1	0.4	0.4	1	1	1	1	1	1	1	1	1	1
1956	0	0	0	0	0.5	0.7	0.6	1	1	1	1	1	1	1	1	1
1957	0	0	0	0	0.3	0.8	0.8	0.7	1	1	1	1	1	1	1	1
1958	0	0	0	0	0.3	0.5	0.9	0.9	1	1	1	1	1	1	1	1
1959	0	0	0	0	0.7	0.8	1	0.9	1	1	1	1	1	1	1	1
1960	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
1961	0	0	0	0	0.1	0.8	1	0.9	1	1	1	1	1	1	1	1
1962	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1963	0	0	0	0	0.1	0.4	1	1	1	1	1	1	1	1	1	1
1964	0	0	0	0	0.1	0.4	0.8	1	1	1	1	1	1	1	1	1
1965	0	0	0	0	0.5	0.4	0.9	0.8	1	1	1	1	1	1	1	1
1966	0	0	0	0	0.5	0.7	0.9	1	1	1	1	1	1	1	1	1
1967	0	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1
1968	0	0	0	0	0	0.7	0.9	1	1	1	1	1	1	1	1	1
1969	0	0	0	0.1	0.2	0.3	1	1	1	1	1	1	1	1	1	1
1970	0	0	0	0	0.4	0.3	0.4	1	1	1	1	1	1	1	1	1
1971	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1972	0	0	0	0	0.4	0.3	1	1	1	1	1	1	1	1	1	1
1973	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1	1
1974	0	0	0	0	0.6	0.9	1	1	1	1	1	1	1	1	1	1
1975	0	0	0	0.1	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1976	0	0	0	0.1	0.9	0.9	1	1	1	1	1	1	1	1	1	1
1977	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1	1

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
1986	0	0	0	0	0.5	0.9	0.9	1	1	1	1	1	1	1	1	1
1987	0	0	0	0	0.1	0.8	0.9	0.9	1	1	1	1	1	1	1	1
1988	0	0	0	0	0.2	0.7	0.9	1	1	1	1	1	1	1	1	1
1989	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
1990	0	0	0	0.2	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1991	0	0	0	0	0.9	0.9	1	1	1	1	1	1	1	1	1	1
1992	0	0	0	0	0.8	1	1	1	1	1	1	1	1	1	1	1
1993	0	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1
1994	0	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1
1995	0	0	0	0	0	0.6	1	1	1	1	1	1	1	1	1	1
1996	0	0	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1
1997	0	0	0	0.1	0	0.4	0.9	1	1	1	1	1	1	1	1	1
1998	0	0	0	0	0.6	0.4	0.9	1	1	1	1	1	1	1	1	1
1999	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
2000	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2001	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
2002	0	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1
2003	0	0	0	0	0.2	0.7	1	1	1	1	1	1	1	1	1	1
2004	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1
2005	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2006	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2007	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2016	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2017	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2018	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2019	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1

Table 4.4.7.1. Norwegian Spring-spawning herring. Estimated indices (with 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	375	299	8066	86	33	11	38	22	41	0	0	0	0	8970	1631
1989	164	17	336	89	3995	106	12	8	59	0	4	39	0	8	4835	1175
1990	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
1991	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
1992*	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
1993*	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
1994	43	99	48	851	480	73	15	152	43	1838	3	3	0	0	3651	1215
1995	4	409	4643	3186	1986	292	18	0	141	76	2299	0	0	0	13053	3669
1996	126	147	1885	7923	2384	887	314	0	0	121	0	1830	0	0	15616	3382
1997*	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
1998	41	330	984	3012	13089	8214	1909	588	194	35	0	359	0	1415	30169	7008
1999	119	1572	379	1366	2593	9356	6979	1632	495	124	0	0	360	359	25333	6235
2000	1399	672	2617	103	485	1139	4193	2864	547	48	2	0	15	217	14301	3282
2001**	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2002**	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2003**	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2004**	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
2005	39	270	662	2086	5871	8223	660	457	183	113	557	1138	595	6	20859	5223
2006	27	98	6073	478	912	3291	3290	122	67	25	72	54	265	63	14836	3392
2007	32	369	1594	12175	622	646	2842	3258	137	223	34	179	262	554	22925	5238
2008	15	70	2449	2699	9060	530	476	1599	1600	153	104	49	138	152	19094	4581
2009	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2010	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2011	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2012	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2013	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2014	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
2015	230	516	2748	768	3223	377	650	2868	720	7251	336	1733	50	229	21712	6390
2016	17	218	253	539	404	2288	242	569	2792	681	4144	197	982	107	13433	4338
2017	13	95	1078	666	868	411	1376	176	231	1903	295	2600	74	697	10486	3295
2018	95	145	1779	2780	485	824	622	1083	463	378	1188	360	1524	321	12047	3260
2019	2	360	304	939	3655	799	896	644	1034	740	395	1845	209	2201	14139	4249

Table 4.4.7.2. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in May/June from IESNS. Values in the years 2009–2019 are estimated with StoX. "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
2007	2.1	3.7	12.5	1.9	0
2008^					
2009	0.286	0.286	0.215	0.072	0
2010	5.121	1.366	0	0	0
2011	1.079	3.802	0.039	0	0
2012	0.884	0.015	0	0	0
2013	0.132	1.982	0.264	0.088	0
2014	3.727	3.055	1.797	0.131	0.044
2015	0.33	11.471	1.218	0.198	0
2016	1.677	5.463	1.668	0.103	0.042
2017	14.658	3.266	0	0	0

	age				
Year	**1**	**2**	**3**	**4**	**5**
2018	6.866	17.404	0.943	0.009	0
2019	0.112	2.305	17.315	0.023	0

***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 2008-2019 are estimated indices by StoX. "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	1240	631	10809	8271	14827	1513	2257	4848	2734	449	149	151	270	491	48665	10558
2009	0	144	1669	2159	12300	8994	9527	2147	1435	2466	1411	188	193	123	231	43082	9728
2010	234	125	542	2334	1781	8351	5988	5601	869	882	983	578	90	72	57	28622	6633
2011	0	1205	977	1528	3607	2564	9420	4542	4298	825	892	712	261	37	39	30917	7395

	Age															Total
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass**
2012	0	378	2895	412	670	1646	2560	4226	2026	2097	298	607	315	155	47	18331	4435
2013	0	205	776	3955	434	1211	2036	3070	4652	2767	1873	692	805	186	83	22747	5888
2014	17	517	1231	798	2790	749	1065	2681	2285	2842	1119	778	350	76	198	17505	4555
2015	0	385	468	1299	1176	3548	1399	1160	3178	2523	4350	712	788	262	194	21443	5846
2016	0	75	3549	1508	2215	1779	2683	929	1143	1770	1851	2877	928	439	136	21889	5419
2017	11	132	1063	4363	1192	1522	874	1453	327	727	975	1785	2229	538	238	17441	4203
2018	0	500	1052	2063	5686	973	1434	561	1328	338	689	1565	1478	1529	488	19684	5042
2019	6	167	2595	691	2170	4785	1255	1208	922	1295	805	687	1381	938	816	19728	4874

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	0.35	0.201	0.262	0.108	0.346	0.454	0.395	0.306	0.352	0.49	0.361
1989	0.261	0.486	0.456	0.401	0.125	0.461	0.703	0.737	0.468	0.602	0.617
1990	0.3	0.285	0.498	0.324	0.333	0.139	0.613	0.585	0.538	0.512	0.549
1991	0.467	0.358	0.492	0.597	0.305	0.352	0.14	0.507	0.824	1.329	0.577
1992	0.606	0.319	0.242	0.416	0.627	0.323	0.399	0.139	0.508	0.75	0.589
1993	0.374	0.252	0.173	0.183	0.355	0.455	0.249	0.285	0.117	NA	NA
1994	0.362	0.243	0.171	0.121	0.152	0.3	0.361	0.233	0.236	0.103	0.405
1995	0.637	0.206	0.123	0.104	0.103	0.138	0.3	0.298	0.195	0.185	0.093
1996	0.248	0.239	0.1	0.08	0.092	0.118	0.174	0.401	0.372	0.198	0.095
1997	0.272	0.163	0.132	0.077	0.074	0.098	0.125	0.203	0.279	0.243	0.112
1998	0.186	0.195	0.136	0.121	0.077	0.085	0.12	0.163	0.225	0.261	0.138
1999	0.415	0.16	0.236	0.161	0.116	0.079	0.087	0.129	0.173	0.306	0.144
2000	0.307	0.185	0.107	0.238	0.171	0.118	0.084	0.09	0.141	0.194	0.162
2001	0.535	0.175	0.153	0.116	0.231	0.178	0.129	0.095	0.11	0.192	0.211
2002	0.202	0.144	0.103	0.134	0.125	0.249	0.179	0.133	0.102	0.124	0.186
2003	0.428	0.191	0.125	0.099	0.15	0.152	0.269	0.191	0.141	0.107	0.132
2004	0.223	0.264	0.18	0.116	0.1	0.171	0.16	0.257	0.212	0.151	0.103
2005	0.277	0.114	0.179	0.151	0.103	0.093	0.166	0.166	0.232	0.199	0.104
2006	0.221	0.19	0.099	0.186	0.151	0.1	0.098	0.182	0.189	0.248	0.12
2007	0.357	0.139	0.121	0.077	0.156	0.136	0.099	0.11	0.218	0.261	0.153
2008	0.165	0.235	0.108	0.102	0.072	0.144	0.134	0.106	0.121	0.249	0.157
2009	0.17	0.146	0.157	0.086	0.093	0.075	0.159	0.133	0.116	0.137	0.161
2010	0.202	0.175	0.142	0.146	0.089	0.1	0.082	0.15	0.148	0.124	0.135
2011	0.135	0.202	0.174	0.138	0.142	0.098	0.108	0.103	0.181	0.168	0.144
2012	0.315	0.142	0.215	0.167	0.131	0.133	0.099	0.127	0.122	0.211	0.165
2013	0.276	0.203	0.131	0.194	0.17	0.13	0.136	0.106	0.151	0.158	0.218
2014	0.594	0.253	0.206	0.134	0.214	0.193	0.145	0.157	0.12	0.185	0.188
2015	0.47	0.297	0.208	0.212	0.156	0.24	0.198	0.155	0.174	0.144	0.185

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2016	0.516	0.22	0.223	0.17	0.184	0.152	0.212	0.192	0.15	0.178	0.134
2017	0.295	0.2	0.128	0.169	0.135	0.153	0.13	0.176	0.162	0.131	0.118
2018	0.27	0.26	0.204	0.133	0.156	0.149	0.171	0.148	0.184	0.176	0.111
2019	0.332	0.22	0.191	0.174	0.173	0.184	0.203	0.214	0.229	0.288	0.24

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	0.324	0.341	0.165	0.448	0.553	0.703	0.536	0.604	0.527	NA
1989	0.639	0.332	0.444	0.193	0.428	0.69	0.754	0.486	NA	0.502
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	0.434	0.509	0.271	0.307	0.464	0.657	0.395	0.521	0.229	0.804
1995	0.318	0.186	0.203	0.225	0.342	0.631	NA	0.402	0.46	0.218
1996	0.398	0.227	0.166	0.216	0.268	0.337	NA	NA	0.415	0.229
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	0.333	0.262	0.205	0.149	0.165	0.227	0.294	0.375	0.546	0.23
1999	0.237	0.323	0.244	0.212	0.16	0.17	0.235	0.305	0.413	0.281
2000	0.285	0.211	0.43	0.306	0.254	0.191	0.207	0.298	0.509	0.359
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	0.348	0.286	0.222	0.177	0.164	0.286	0.31	0.379	0.422	0.218
2006	0.435	0.176	0.307	0.267	0.201	0.201	0.415	0.473	0.587	0.311
2007	0.325	0.236	0.151	0.29	0.288	0.208	0.202	0.404	0.363	0.26
2008	0.468	0.215	0.21	0.161	0.3	0.308	0.236	0.236	0.395	0.312
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Year/Age	3	4	5	6	7	8	9	10	11	12
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2014	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2015	0.302	0.209	0.277	0.202	0.324	0.287	0.207	0.281	0.169	0.217
2016	0.365	0.353	0.299	0.319	0.218	0.357	0.296	0.208	0.284	0.18
2017	0.438	0.257	0.286	0.269	0.318	0.244	0.383	0.36	0.227	0.196
2018	0.399	0.23	0.209	0.306	0.273	0.29	0.257	0.309	0.323	0.2
2019	0.327	0.339	0.265	0.197	0.274	0.268	0.288	0.259	0.279	0.186

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

Year/age	2
1991	0.418
1992	0.359
1993	0.327
1994	0.287
1995	0.394
1996	0.669
1997	0.887
1998	0.425
1999	0.422
2000	0.323
2001	0.395
2002	0.437
2003	NA
2004	NA
2005	0.428
2006	0.312
2007	0.441
2008	0.627

Year/age	2
2009	0.655
2010	0.514
2011	0.439
2012	1.032
2013	0.486
2014	0.454
2015	0.37
2016	0.415
2017	0.45
2018	0.347
2019	0.474

Table 4.4.8.4 Norwegian spring-spawning herring. Relative standard error of Fleet 5 used by XSAM.

Year/Age	3	4	5	6	7	8	9	10	11	12+
1996	0.201	0.134	0.152	0.192	0.237	0.344	0.772	0.91	0.437	0.214
1997	0.27	0.207	0.14	0.151	0.226	0.245	0.422	0.515	0.377	0.217
1998	0.356	0.274	0.197	0.144	0.162	0.236	0.295	0.42	NA	0.327
1999	0.233	0.367	0.283	0.215	0.156	0.183	0.291	0.387	0.986	0.373
2000	0.261	0.22	0.494	0.352	0.263	0.176	0.188	0.248	0.382	0.416
2001	0.17	0.258	0.256	0.422	0.409	0.213	0.188	0.268	0.492	0.419
2002	0.181	0.164	0.258	0.298	0.354	0.292	0.24	0.226	0.258	0.429
2003	0.18	0.162	0.163	0.255	0.302	0.443	0.398	0.242	0.229	0.236
2004	0.253	0.189	0.154	0.16	0.276	0.319	0.517	0.369	0.357	0.225
2005	0.138	0.261	0.245	0.182	0.188	0.311	0.351	0.448	0.385	0.238
2006	0.371	0.149	0.259	0.238	0.18	0.177	0.307	0.304	0.425	0.233
2007	0.218	0.184	0.137	0.266	0.238	0.178	0.187	0.311	0.333	0.219
2008	0.313	0.159	0.17	0.148	0.254	0.231	0.193	0.221	0.339	0.277
2009	0.248	0.234	0.155	0.167	0.164	0.234	0.257	0.226	0.258	0.302
2010	0.324	0.229	0.245	0.17	0.183	0.186	0.29	0.289	0.282	0.296
2011	0.282	0.254	0.207	0.224	0.165	0.196	0.198	0.294	0.288	0.277

Year/Age	3	4	5	6	7	8	9	10	11	12+
2012	0.218	0.346	0.308	0.249	0.224	0.199	0.237	0.235	0.374	0.273
2013	0.298	0.202	0.342	0.268	0.237	0.215	0.195	0.22	0.242	0.245
2014	0.267	0.296	0.22	0.3	0.276	0.222	0.231	0.219	0.273	0.259
2015	0.336	0.264	0.27	0.208	0.259	0.271	0.213	0.225	0.198	0.239
2016	0.208	0.254	0.232	0.245	0.222	0.285	0.272	0.245	0.242	0.198
2017	0.276	0.198	0.269	0.254	0.29	0.257	0.366	0.303	0.282	0.193
2018	0.277	0.236	0.186	0.282	0.257	0.322	0.262	0.363	0.306	0.191
2019	0.224	0.306	0.233	0.193	0.266	0.268	0.286	0.264	0.295	0.204

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

Parameter	Estimate	Std. Error	CV	Estimate 2018	Std. Error 2018
$\log(N_{3,1988})$	7.075	0.17	0.024	7.072	0.173
$\log(N_{4,1988})$	6.604	0.209	0.032	6.606	0.212
$\log(N_{5,1988})$	9.584	0.076	0.008	9.577	0.079
$\log(N_{6,1988})$	4.812	0.369	0.077	4.792	0.371
$\log(N_{7,1988})$	3.487	0.506	0.145	3.474	0.508
$\log(N_{8,1988})$	3.115	0.554	0.178	3.132	0.557
$\log(N_{9,1988})$	4.08	0.445	0.109	4.079	0.455
$\log(N_{10,1988})$	3.275	0.645	0.197	3.28	0.653
$\log(N_{11,1988})$	3.054	0.693	0.227	2.989	0.716
$\log(N_{12,1988})$	3.502	0.728	0.208	3.479	0.732
$\log(q_3^{F1})$	-9.594	0.188	0.02	-9.544	0.199
$\log(q_4^{F1})$	-8.102	0.138	0.017	-8.064	0.14
$\log(q_5^{F1})$	-7.555	0.125	0.017	-7.507	0.126
$\log(q_6^{F1})$	-7.31	0.124	0.017	-7.31	0.127
$\log(q_7^{F1})$	-7.165	0.138	0.019	-7.134	0.14
$\log(q_8^{F1})$	-6.925	0.099	0.014	-6.917	0.103
$\log(q_2^{F4})$	-14.304	0.177	0.012	-14.46	0.189

Parameter	Estimate	Std. Error	CV	Estimate 2018	Std. Error 2018
$\log(q_3^{F5})$	-7.609	0.111	0.015	-7.597	0.116
$\log(q_4^{F5})$	-7.157	0.1	0.014	-7.127	0.104
$\log(q_5^{F5})$	-6.911	0.098	0.014	-6.891	0.102
$\log(q_6^{F5})$	-6.779	0.101	0.015	-6.768	0.106
$\log(q_7^{F5})$	-6.707	0.108	0.016	-6.693	0.112
$\log(q_8^{F5})$	-6.533	0.114	0.017	-6.509	0.119
$\log(q_9^{F5})$	-6.517	0.127	0.02	-6.508	0.133
$\log(q_{10}^{F5})$	-6.477	0.143	0.022	-6.439	0.15
$\log(q_{11}^{F5})$	-6.442	0.143	0.022	-6.438	0.15
$\log(\sigma_1^2)$	-5	1.472	0.294	-5	1.486
$\log(\sigma_2^2)$	-2.718	0.271	0.1	-2.651	0.275
$\log(\sigma_4^2)$	-2.167	0.31	0.143	-2.108	0.314
$\log(\sigma_R^2)$	-0.146	0.261	1.793	-0.09	0.267
$\log(h)$	1.587	0.068	0.043	1.581	0.07
μ_R	9.344	0.173	0.018	9.361	0.18
α_Y	-0.537	0.311	0.579	-0.535	0.32
β_Y	0.806	0.112	0.139	0.803	0.115
α_{2U}	-1.241	0.172	0.139	-1.245	0.176
α_{3U}	-0.621	0.1	0.161	-0.615	0.102
α_{4U}	-0.215	0.064	0.296	-0.201	0.066
α_{5U}	0.046	0.054	1.167	0.054	0.057
α_{6U}	0.201	0.059	0.292	0.195	0.061
α_{7U}	0.265	0.063	0.238	0.261	0.066
α_{8U}	0.324	0.07	0.215	0.316	0.072
α_{9U}	0.364	0.076	0.208	0.373	0.079
α_{10U}	0.431	0.082	0.192	0.425	0.085
β_U	0.602	0.054	0.09	0.605	0.055

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	648	1183	738	14526	123	33	23	59	26	21	33
1989	1171	251	953	617	12016	101	27	17	40	16	39
1990	4311	471	211	807	518	10008	84	21	13	30	43
1991	11347	1746	400	179	679	432	8355	68	17	10	58
1992	18561	4608	1495	341	152	570	363	6964	56	14	56
1993	49849	7540	3951	1271	287	127	476	302	5760	46	57
1994	59854	20247	6460	3333	1038	232	103	385	243	4560	80
1995	15663	24302	17340	5440	2618	780	179	80	298	182	3436
1996	5726	6352	20760	14511	4158	1760	513	129	58	205	2240
1997	2182	2317	5392	17165	11110	2807	1133	337	90	39	1366
1998	10787	880	1922	4338	13067	7731	1754	665	209	54	760
1999	6420	4355	725	1487	3340	9542	5391	1120	411	122	458
2000	33024	2599	3630	567	1136	2477	6764	3615	702	243	303
2001	29019	13382	2176	2720	425	833	1768	4615	2236	409	270
2002	11483	11767	11348	1735	1999	317	618	1273	3201	1476	451
2003	6659	4650	9941	9165	1280	1400	230	433	864	2121	1287
2004	58091	2700	3939	8216	7199	943	1022	167	305	581	2234
2005	24506	23573	2295	3282	6640	5548	702	740	121	214	1752
2006	43239	9939	19938	1891	2622	5079	3936	479	501	80	1138
2007	12056	17537	8452	16503	1520	2049	3728	2709	331	346	718
2008	17519	4883	14876	6963	12697	1152	1500	2544	1800	222	729
2009	7027	7068	4131	12259	5393	8888	814	1032	1628	1134	635
2010	4663	2819	5917	3389	9486	3849	5794	545	642	969	1094
2011	15793	1871	2350	4859	2697	7154	2689	3629	343	395	1122
2012	5255	6343	1563	1927	3911	2105	5390	1835	2427	223	962
2013	8010	2125	5314	1288	1550	3095	1611	3969	1299	1700	834
2014	5362	3245	1791	4361	1036	1227	2410	1206	2912	939	1984
2015	17625	2176	2761	1494	3546	838	983	1896	926	2199	2341

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2016	8039	7156	1858	2323	1234	2893	682	787	1499	717	3634
2017	5185	3263	6105	1557	1903	988	2309	537	612	1139	3380
2018	15643	2101	2760	5007	1233	1421	725	1684	386	417	3235
2019	8111	6343	1784	2296	4042	941	1069	537	1257	272	2585

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	0.049	0.065	0.029	0.04	0.047	0.051	0.152	0.232	0.349	0.195	0.195
1989	0.011	0.021	0.017	0.026	0.033	0.038	0.076	0.107	0.15	0.092	0.092
1990	0.004	0.012	0.014	0.023	0.031	0.031	0.052	0.073	0.1	0.07	0.07
1991	0.001	0.005	0.011	0.018	0.024	0.025	0.032	0.043	0.057	0.045	0.045
1992	0.001	0.004	0.013	0.023	0.029	0.03	0.034	0.04	0.054	0.053	0.053
1993	0.001	0.005	0.02	0.052	0.061	0.057	0.063	0.068	0.084	0.1	0.1
1994	0.001	0.005	0.022	0.091	0.136	0.112	0.098	0.106	0.135	0.151	0.151
1995	0.003	0.008	0.028	0.119	0.248	0.268	0.175	0.17	0.223	0.329	0.329
1996	0.005	0.014	0.04	0.117	0.243	0.29	0.271	0.209	0.245	0.432	0.432
1997	0.007	0.037	0.067	0.123	0.213	0.32	0.383	0.327	0.358	0.465	0.465
1998	0.007	0.043	0.106	0.112	0.164	0.21	0.299	0.331	0.388	0.424	0.424
1999	0.004	0.032	0.097	0.12	0.149	0.194	0.25	0.317	0.375	0.501	0.501
2000	0.003	0.028	0.139	0.139	0.16	0.187	0.232	0.33	0.389	0.553	0.553
2001	0.003	0.015	0.077	0.158	0.141	0.149	0.179	0.216	0.265	0.261	0.261
2002	0.004	0.019	0.064	0.154	0.206	0.172	0.205	0.237	0.262	0.254	0.254
2003	0.003	0.016	0.041	0.091	0.155	0.164	0.169	0.201	0.246	0.272	0.272
2004	0.002	0.013	0.032	0.063	0.11	0.145	0.172	0.172	0.203	0.325	0.325
2005	0.002	0.017	0.044	0.075	0.118	0.193	0.233	0.24	0.265	0.397	0.397
2006	0.002	0.012	0.039	0.068	0.097	0.159	0.224	0.219	0.221	0.378	0.378
2007	0.004	0.015	0.044	0.112	0.127	0.162	0.232	0.259	0.249	0.229	0.229
2008	0.008	0.017	0.044	0.105	0.207	0.197	0.225	0.297	0.312	0.254	0.254
2009	0.013	0.028	0.048	0.106	0.187	0.278	0.251	0.324	0.369	0.331	0.331
2010	0.013	0.032	0.047	0.078	0.132	0.209	0.318	0.314	0.337	0.459	0.459

Year/Age	2	3	4	5	6	7	8	9	10	11	12+
2011	0.012	0.03	0.048	0.067	0.098	0.133	0.232	0.252	0.279	0.305	0.305
2012	0.006	0.027	0.043	0.068	0.084	0.117	0.156	0.195	0.206	0.202	0.202
2013	0.004	0.021	0.048	0.068	0.084	0.1	0.14	0.16	0.174	0.095	0.095
2014	0.002	0.011	0.031	0.057	0.062	0.071	0.09	0.114	0.131	0.072	0.072
2015	0.001	0.008	0.023	0.041	0.053	0.057	0.073	0.085	0.106	0.073	0.073
2016	0.002	0.009	0.026	0.049	0.072	0.075	0.088	0.101	0.125	0.102	0.102
2017	0.003	0.017	0.048	0.083	0.142	0.16	0.166	0.18	0.234	0.184	0.184
2018	0.003	0.014	0.034	0.064	0.121	0.135	0.149	0.142	0.2	0.195	0.195
2019	0.003	0.013	0.035	0.066	0.111	0.127	0.144	0.145	0.192	0.155	0.155

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)	High	Low	Stock Size: SSB	High	Low	Catches	Fishing Pressure: F	High	Low
	millions			thousnd tonnes			thousand tonnes	Ages 5-12		
1988	648	954	342	2122	2424	1819	135	0.042	0.061	0.023
1989	1171	1651	691	3281	3750	2812	104	0.033	0.049	0.018
1990	4311	5389	3232	3550	4046	3054	86	0.031	0.045	0.016
1991	11347	13415	9278	3324	3788	2861	85	0.031	0.046	0.017
1992	18561	21519	15603	3352	3794	2910	104	0.038	0.055	0.022
1993	49849	55929	43769	3323	3720	2925	232	0.076	0.103	0.049
1994	59854	66667	53041	3452	3847	3056	479	0.126	0.16	0.091
1995	15663	18216	13111	3524	3904	3145	906	0.216	0.262	0.17
1996	5726	6922	4530	4109	4493	3726	1220	0.189	0.224	0.154
1997	2182	2771	1592	5373	5833	4914	1427	0.194	0.226	0.161
1998	10787	12701	8872	5941	6448	5435	1223	0.19	0.224	0.156
1999	6420	7715	5126	5816	6345	5288	1235	0.214	0.253	0.174
2000	33024	37454	28595	4842	5326	4358	1207	0.257	0.306	0.208
2001	29019	33078	24960	4018	4453	3584	766	0.203	0.246	0.16
2002	11483	13542	9423	3552	3955	3148	808	0.225	0.273	0.178

Year	Recruitment (Age 2)	High	Low	Stock Size: SSB	High	Low	Catches	Fishing Pressure: F	High	Low
2003	6659	8029	5289	4192	4640	3743	790	0.151	0.183	0.119
2004	58091	65225	50958	5292	5836	4748	794	0.127	0.154	0.101
2005	24506	28317	20694	5425	5997	4853	1003	0.171	0.206	0.136
2006	43239	49327	37152	5396	5961	4831	969	0.175	0.212	0.137
2007	12056	14414	9698	6952	7654	6250	1267	0.153	0.184	0.122
2008	17519	20732	14307	7050	7796	6303	1546	0.198	0.238	0.159
2009	7027	8576	5477	7030	7829	6231	1687	0.205	0.244	0.166
2010	4663	5799	3527	6231	7009	5452	1457	0.213	0.258	0.169
2011	15793	19015	12570	5878	6680	5077	993	0.159	0.194	0.124
2012	5255	6627	3882	5692	6518	4866	826	0.141	0.173	0.108
2013	8010	10073	5948	5322	6129	4516	685	0.121	0.15	0.091
2014	5362	7008	3716	5154	5963	4346	461	0.084	0.105	0.062
2015	17625	22504	12745	4798	5569	4028	329	0.067	0.087	0.048
2016	8039	11102	4975	4535	5262	3808	383	0.087	0.111	0.062
2017	5185	7916	2454	4490	5205	3775	722	0.162	0.205	0.119
2018	15643	25104	6182	4103	4818	3389	593	0.128	0.163	0.092
2019	8111	19137	0	3965	4717	3212				
Aver-age	16338	19588	13179	4721	5303	4139	791	0.142	0.174	0.110

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	2019							
	Stockno.	Natural	Ma-turity	Proportion of M	Proportion of F	Weight	Exploita-tion	Weight
age	1-Jan.	mortal-ity	ogive	before spawn-ing	before spawn-ing	in stock	pattern	in catch
2	8111	0.9	0	0	0	0.054	0.004	0.127
3	6343	0.15	0	0	0	0.104	0.02	0.208
4	1784	0.15	0.4	0	0	0.151	0.051	0.245
5	2296	0.15	0.8	0	0	0.203	0.097	0.286

6	4042	0.15	1	0	0	0.277	0.164	0.325
7	941	0.15	1	0	0	0.311	0.188	0.346
8	1069	0.15	1	0	0	0.331	0.213	0.364
9	537	0.15	1	0	0	0.355	0.215	0.376
10	1257	0.15	1	0	0	0.353	0.284	0.387
11	272	0.15	1	0	0	0.363	0.23	0.392
12	2585	0.15	1	0	0	0.381	0.23	0.394
Input for	**2020 and 2021**							
	Stockno.	**Natural**	**Ma-turity**	**Proportion of M**	**Proportion of F**	**Weight**	**Exploita-tion**	**Weight**
age	**1-Jan.**	**mortal-ity**	**ogive**	**before spawn-ing**	**before spawn-ing**	**in stock**	**pattern**	**in catch**
2	11428	0.9	0	0	0	0.054	0.014	0.127
3		0.15	0	0	0	0.111	0.07	0.208
4		0.15	0.4	0	0	0.163	0.187	0.245
5		0.15	0.8	0	0	0.225	0.358	0.286
6		0.15	1	0	0	0.273	0.573	0.325
7		0.15	1	0	0	0.307	0.662	0.346
8		0.15	1	0	0	0.327	0.756	0.364
9		0.15	1	0	0	0.35	0.793	0.376
10		0.15	1	0	0	0.357	1	0.387
11		0.15	1	0	0	0.362	0.897	0.392
12		0.15	1	0	0	0.377	0.897	0.394

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

Basis:	
SSB (2019):	3.965 million t
Landings(2019):	773 750 t (sum of national quotas)
SSB(2020):	3.652 million t
Fw5-12(2019)	0.186
Recruitment(2019-2021):	8.111, 11.428, 11.428

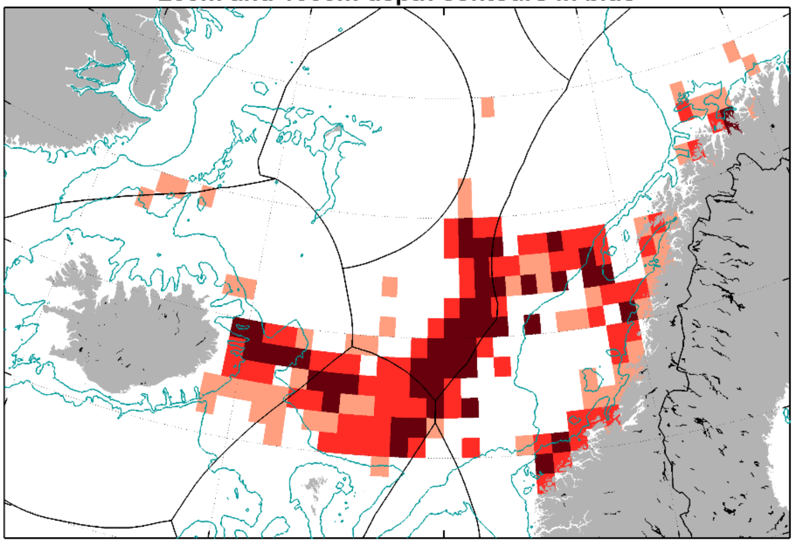
The catch options:

Rationale	**Catches (2020)**	**Basis**	**FW (2020)**	**SSB (2021)**	**P(SSB2021 <Blim)**	**% SSB change**	**%TAC change**	**%CATCH change**
Management plan	525594	F=0.14	0.14 (0.112,0.185)*	3.660 (2.787,4.773)*	0.004	0 (-9,14)*	-11	-32
Fmsy	584722	F=0.157	0.157 (0.127,0.207)*	3.611 (2.748,4.710)*	0.006	-2 (-11,12)*	-1	-24
Zero Catch	0	F=0	0	4.106 (3.212,5.171)*	0	12 (4,26)*	-100	-100
Fpa	818335	0.227	0.227 (0.179,0.299)*	3.414 (2.540,4.468)*	0.02	6 (-17,8)*	39	6
Flim	1018785	0.291	0.232 (0.232,0.404)*	3.246 (2.385,4.341)*	0.056	-11 (-22,3)*	32	73
$SSB_{2021}=B_{lim}$	1920272	F=0.638	0.638 (0.497,1.072)*	2.500 (1.591,3.525)*	0.501	-32 (-47,-15)*	226	148
$SSB_{2021}=B_{pa}$	1092679	F=0.316	0.316 (0.25,0.428)*	3.184 (2.320,4.277)*	0.065	-13 (-24,1)	41	86
Status quo	683925	F=0.186	0.186 (0.15,0.242)*	3.527 (2.670,4.541)*	0.01	-4 (-13,9)*	16	-12

*95% confidence interval

4.17 Figures

NSSH catch 2018
592556 tonnes in total
200m and 1000m depth contours in blue



- > 3000 tonnes
- 300 - 3000 tonnes
- 10 - 300 tonnes

Figure 4.2.1.1. Total reported landings (ICES estimates) of Norwegian spring-spawning herring in 2018 by ICES rectangle. Landings below 10 tonnes per statistical rectangle are not included. The landings with information on statistical rectangle constitute 99.9% of the reported landings.

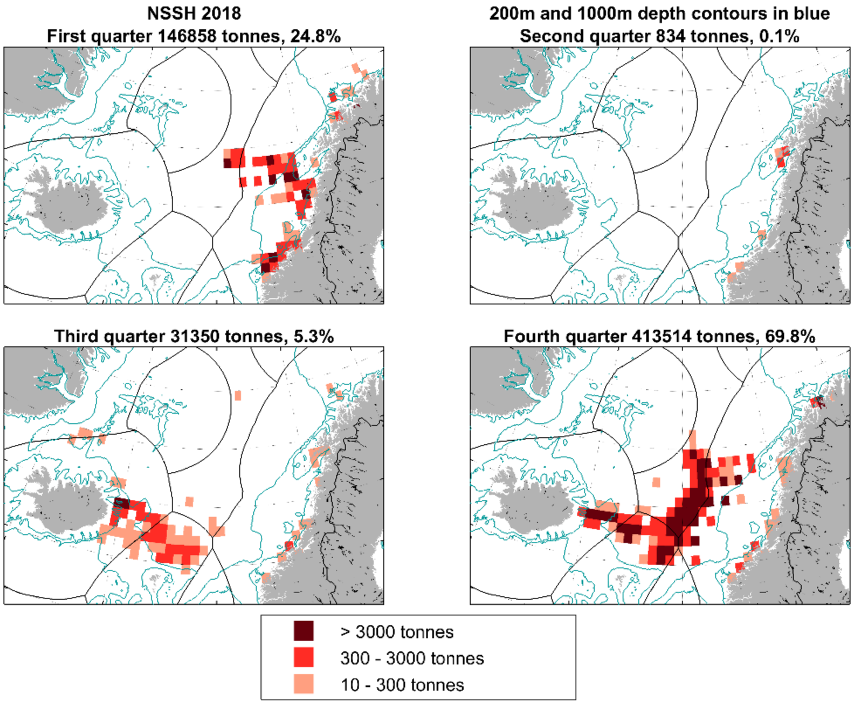


Figure 4.2.1.2. Total reported landings (ICES estimates) of Norwegian spring-spawning herring in 2018 by quarter and ICES rectangle. Landings below 10 tonnes per statistical rectangle are not included. The landings with information on statistical rectangle constitute 99.9% of the reported landings.

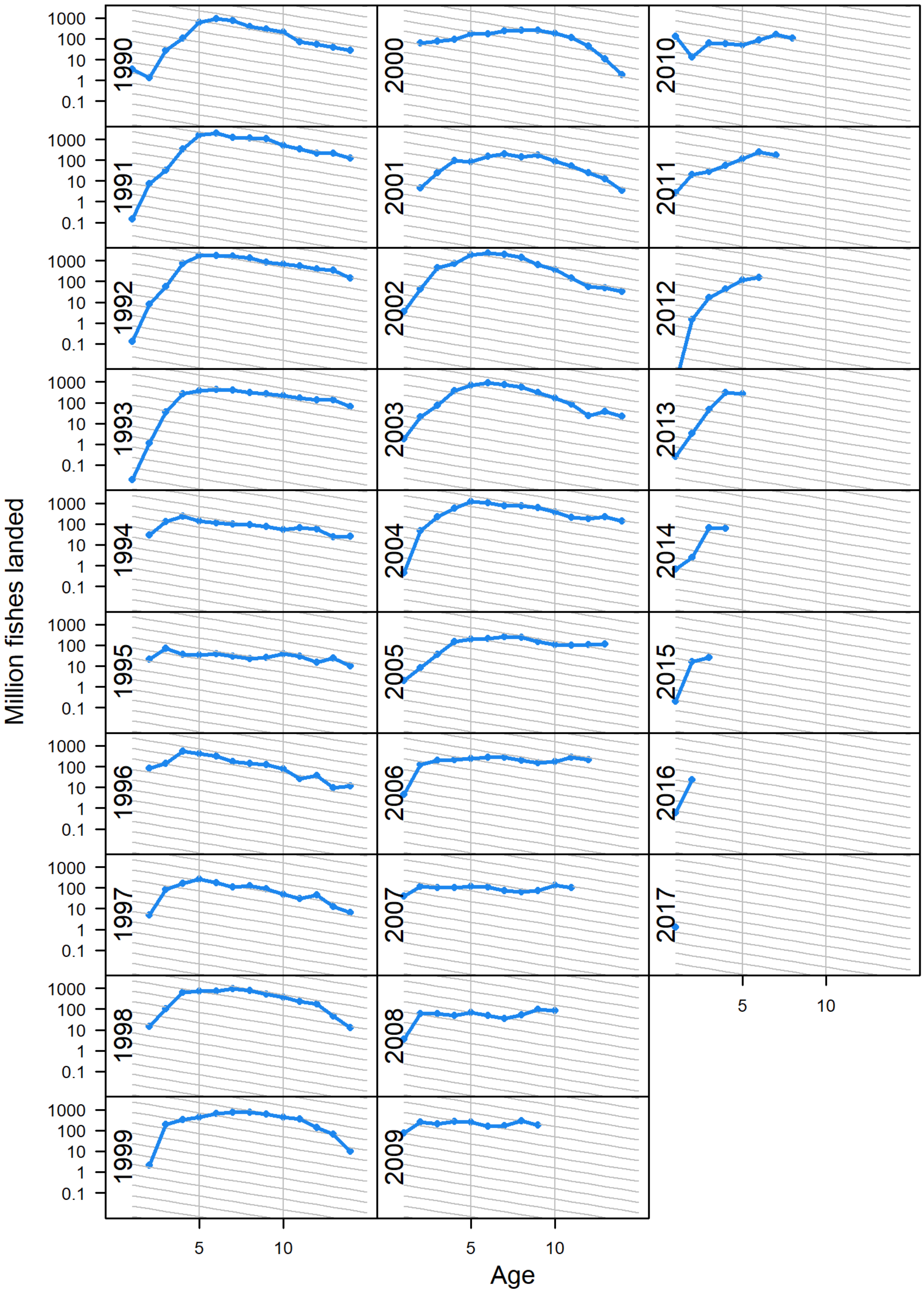


Figure 4.4.3.1. Norwegian spring spawning herring. Age disaggregated landings in numbers plotted on a log scale. Age is on x-axis. The labels indicate year classes and grey lines correspond to Z = 0.3.

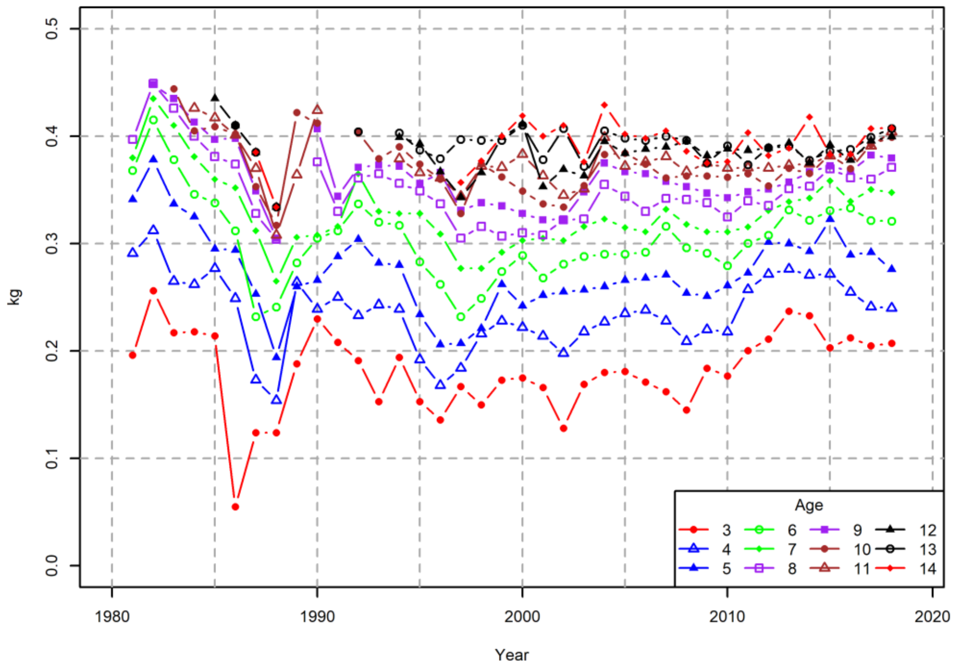


Figure 4.4.4.1.Norwegian spring spawning herring. Mean weight at age by age groups 3–14 in the years 1981—2018 in the landings.

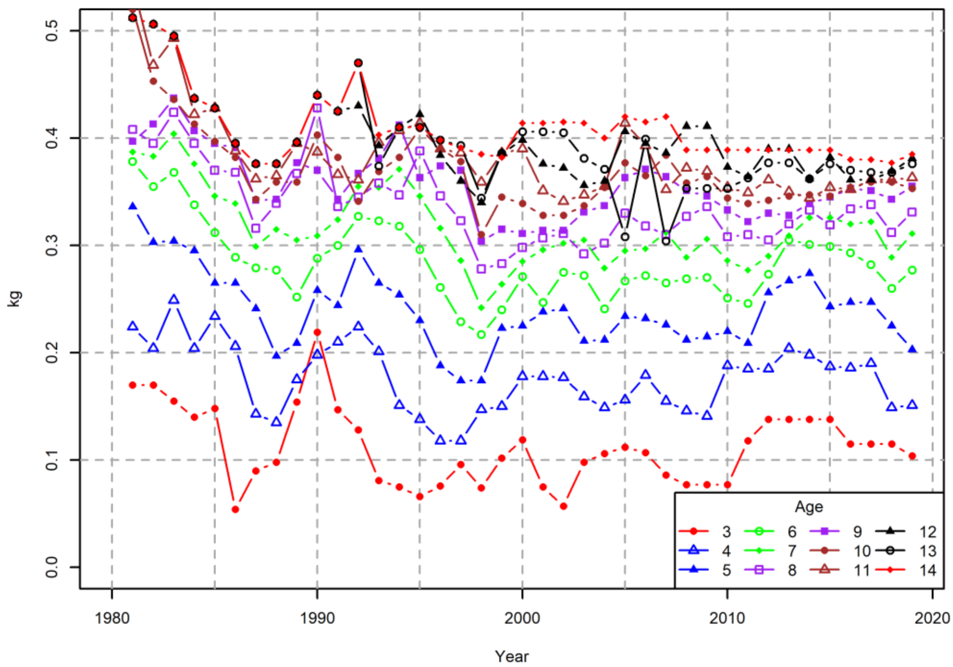


Figure 4.4.4.2.Norwegian spring-spawning herring. Mean weight at age in the stock by age groups 3–14 for the years 1981—2019.

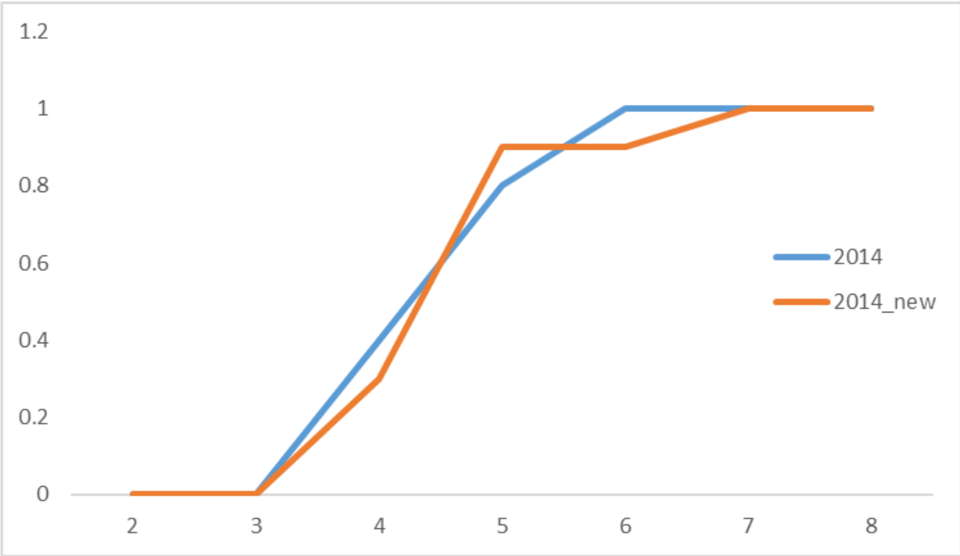


Figure 4.4.5.1. Assumed (blue line) and updated (orange line) maturity-at-age for the year 2014.

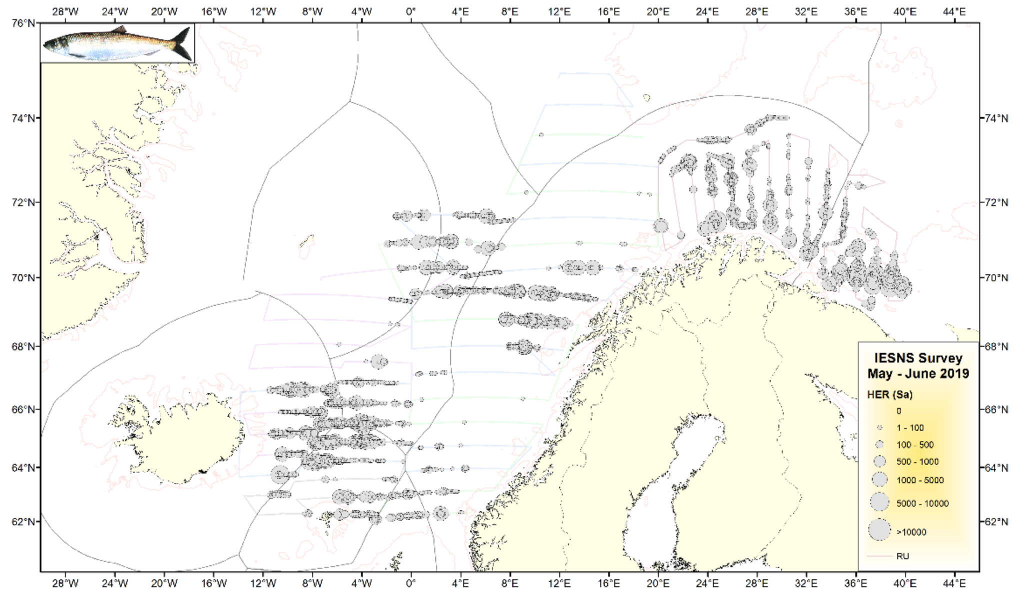


Figure 4.4.7.1. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2019 in terms of NASC values (m²/nm²) for every 1 nautical mile.

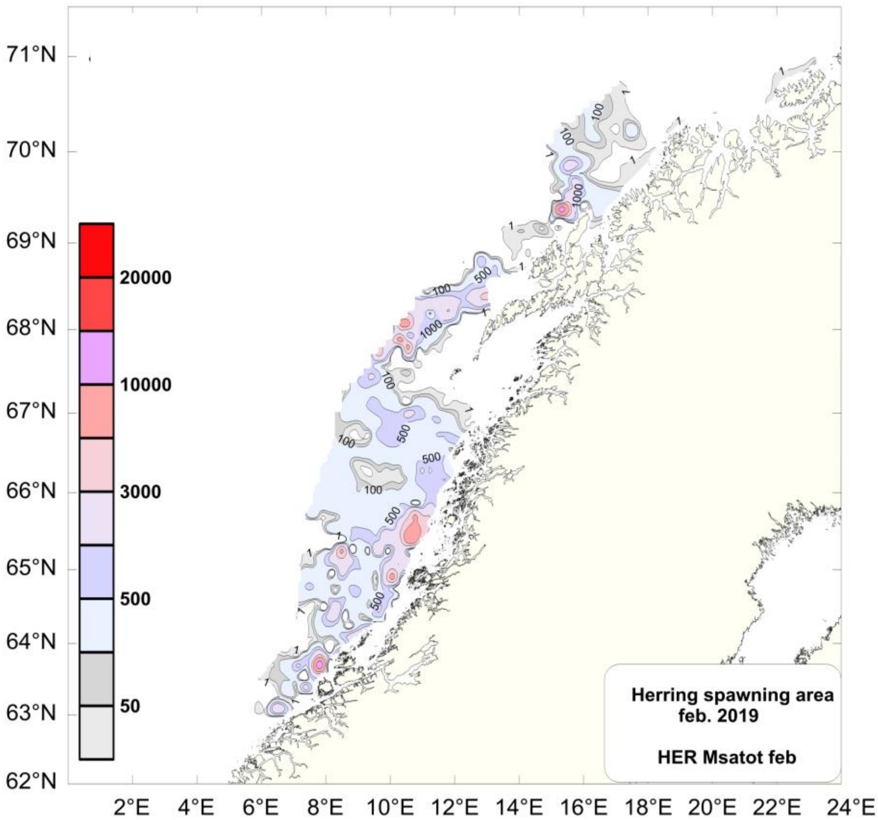


Figure 4.4.7.2. Norwegian acoustic survey on the NSSH spawning grounds. Distribution and acoustic density of herring recorded in 2019.

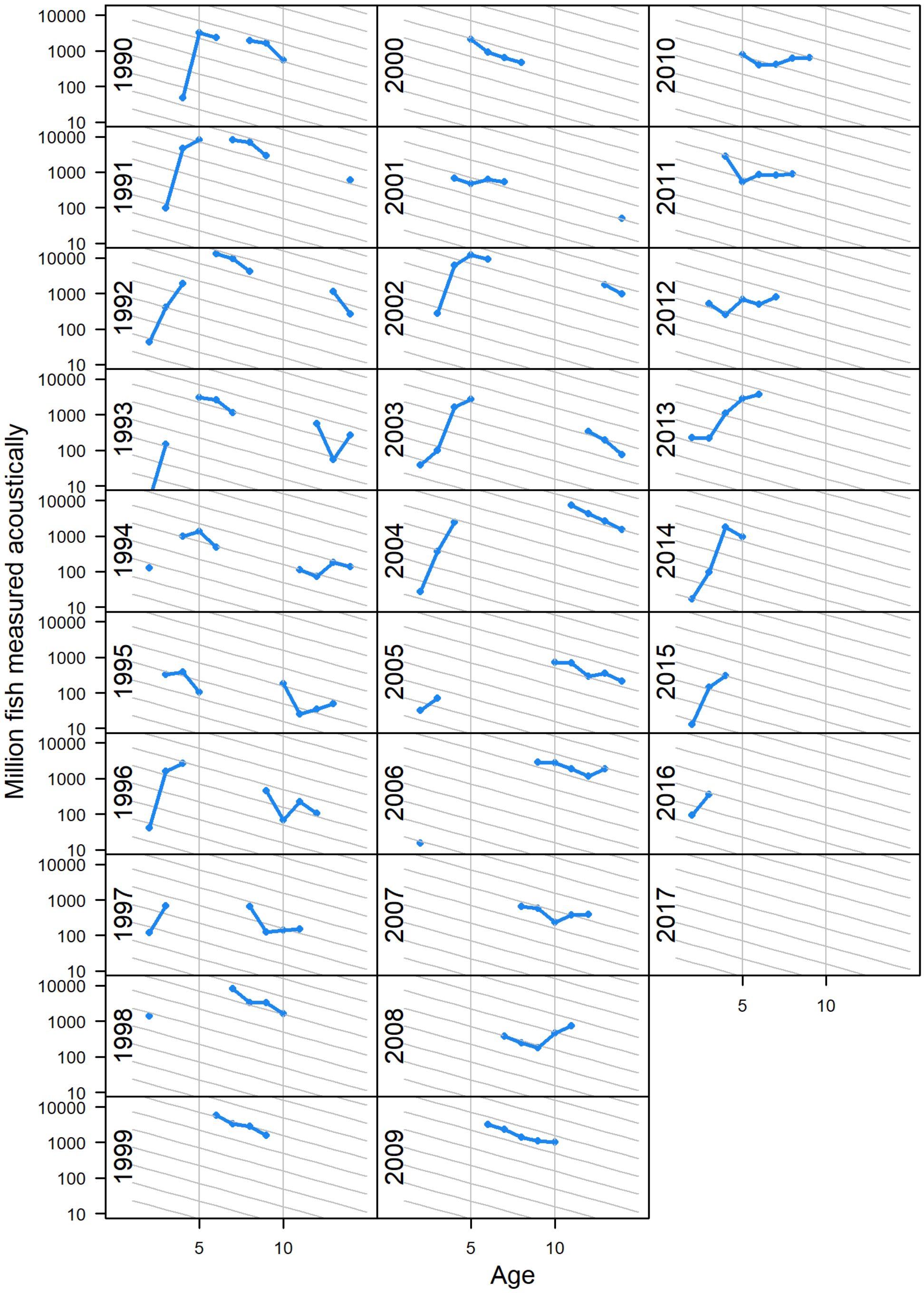


Figure 4.4.7.3. Norwegian spring spawning herring. Age disaggregated abundance indices (millions) from the acoustic survey on the spawning area in February-March (survey 1) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z = 0.3. Age is on x-axis. The labels indicate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

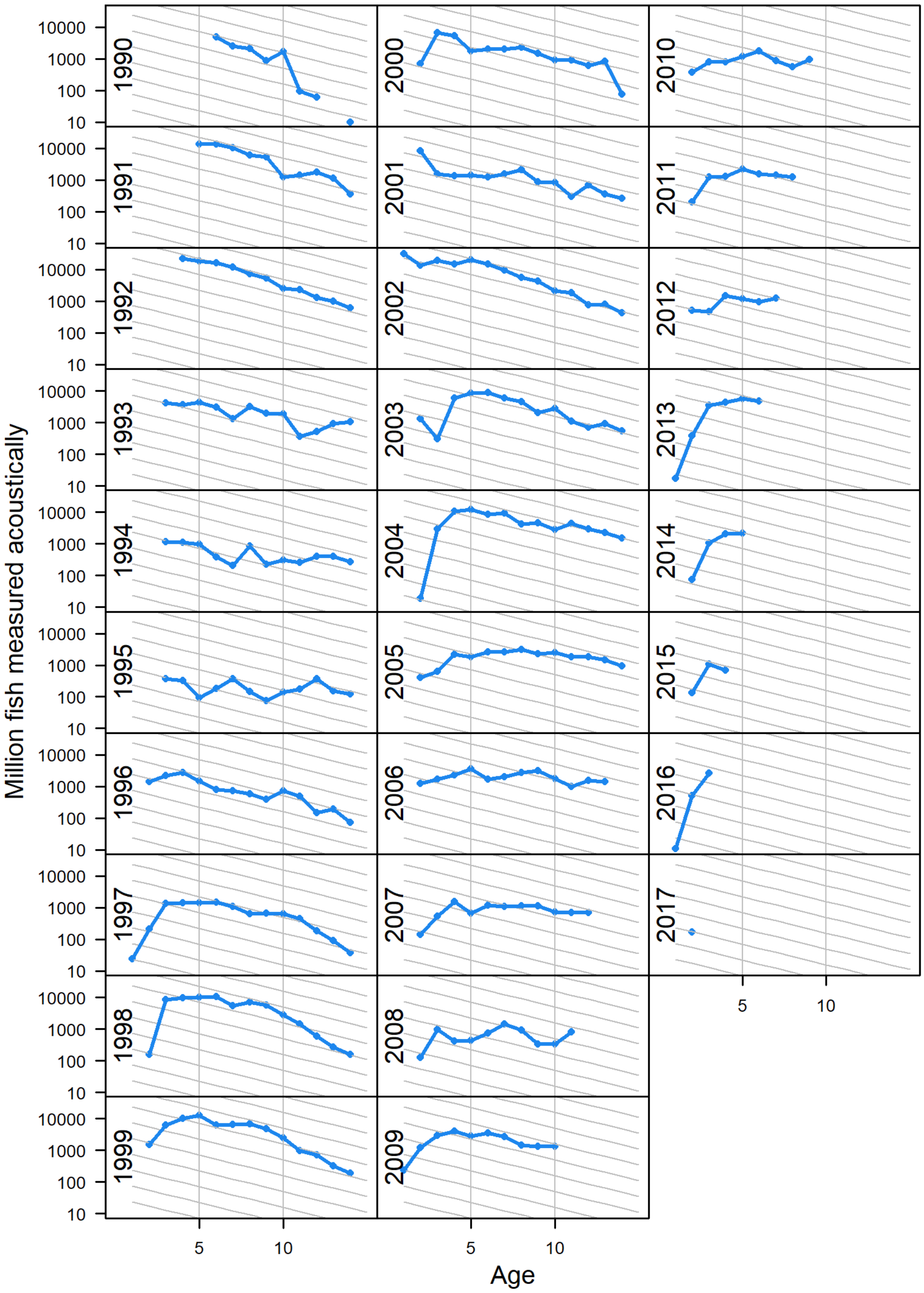


Figure 4.4.7.4. Norwegian spring spawning herring. Age disaggregated abundance indices (millions) from the acoustic survey on the feeding area in the Norwegian Sea in May (survey 5) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z = 0.3.

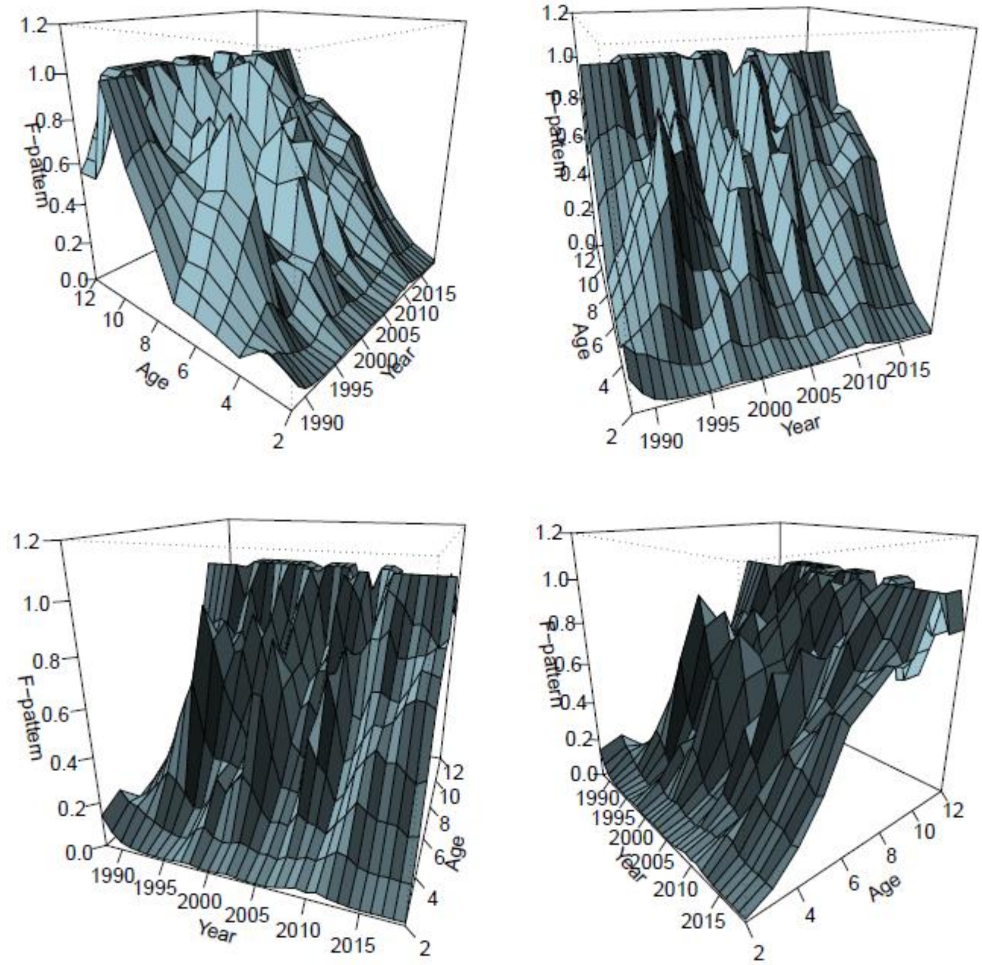


Figure 4.5.1.1. Estimated exploitation pattern for the years 1988–2019 by the XSAM model fit. All panels shows includes the same data, but shown at different angles to improve visibility at different time periods

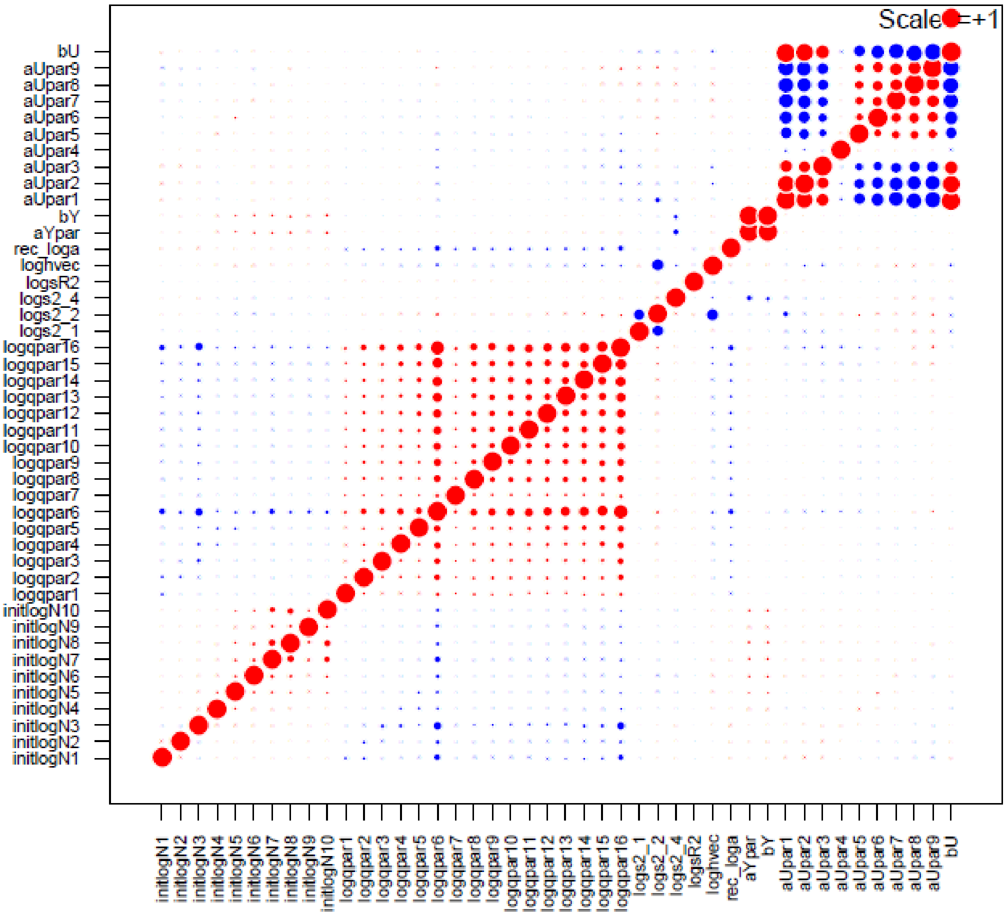


Figure 4.5.1.2. Norwegian spring spawning herring. Correlation between estimated parameters in the final XSAM model fit.

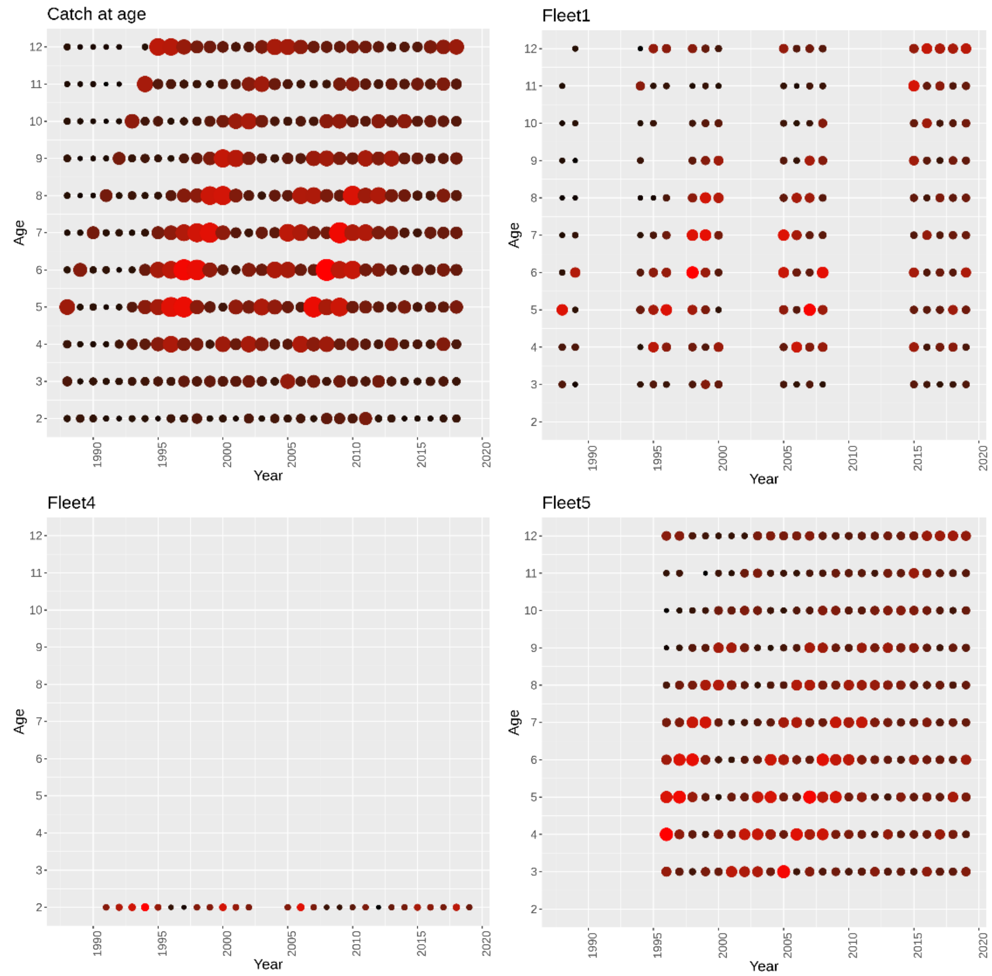


Figure 4.5.1.3. Norwegian spring spawning herring. Weights (inverse of variance) of data-input of the final XSAM model fit.

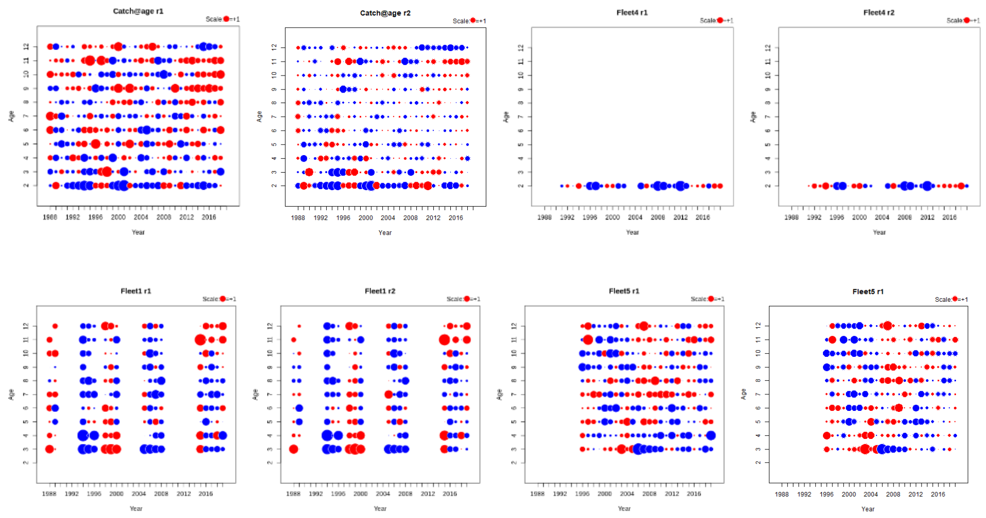


Figure 4.5.1.4. Norwegian spring spawning herring. Standardized residuals type 1 (left) and type 2 (right) (see text) of data-input of the final XSAM model fit.

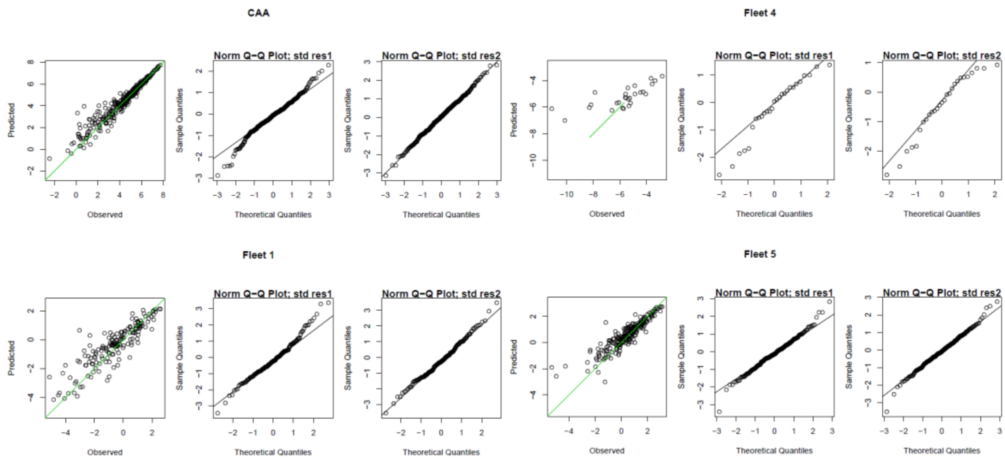


Figure 4.5.1.5. Norwegian spring spawning herring. Observed vs. predicted values (left column) and qq-plot based on type 1 (middle) and type 2 (right) residuals (see text) based on the final XSAM model fit.

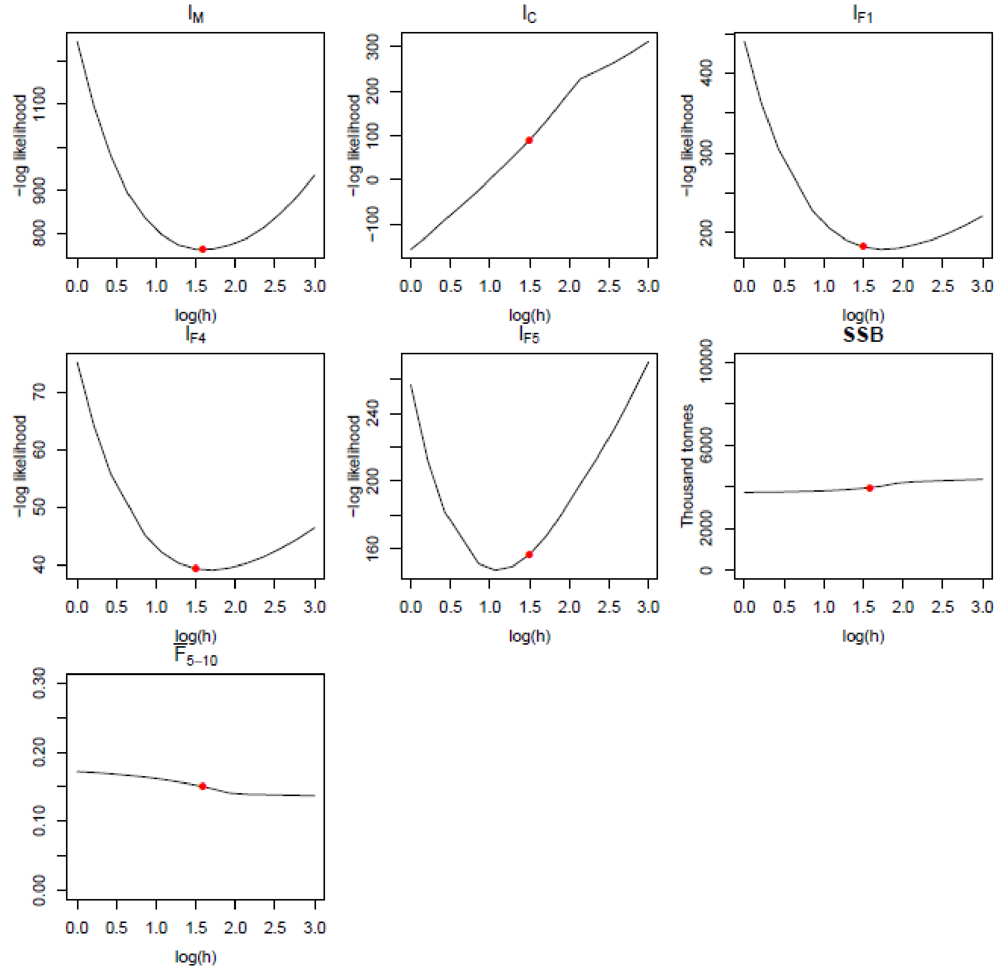


Figure 4.5.1.6. Norwegian spring spawning herring. Profiles of marginal log-likelihood l_M, the catch component l_C, Fleet 1 component l_{F1}, Fleet 4 component l_{F4}, Fleet 5 component l_{F5}, point estimate of SSB and average F (ages 5-12+) in 2018 over the common scaling factor for variance in data h for the final XSAM fit. The red dots indicate the value of the respective scaling factors for which the log-likelihood is maximized.

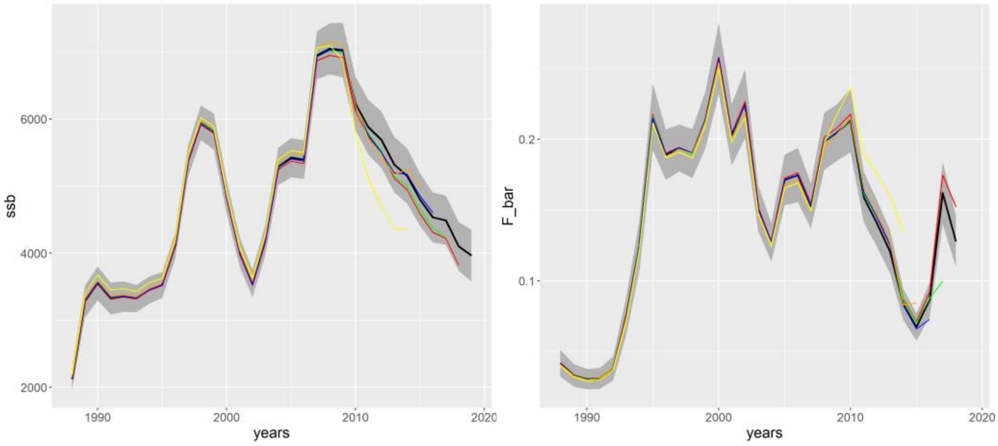


Figure 4.5.1.7. Norwegian spring spawning herring. Retrospective XSAM model fits of SSB and weighted average of fishing mortality ages 5-12 for the years 2012-2018.

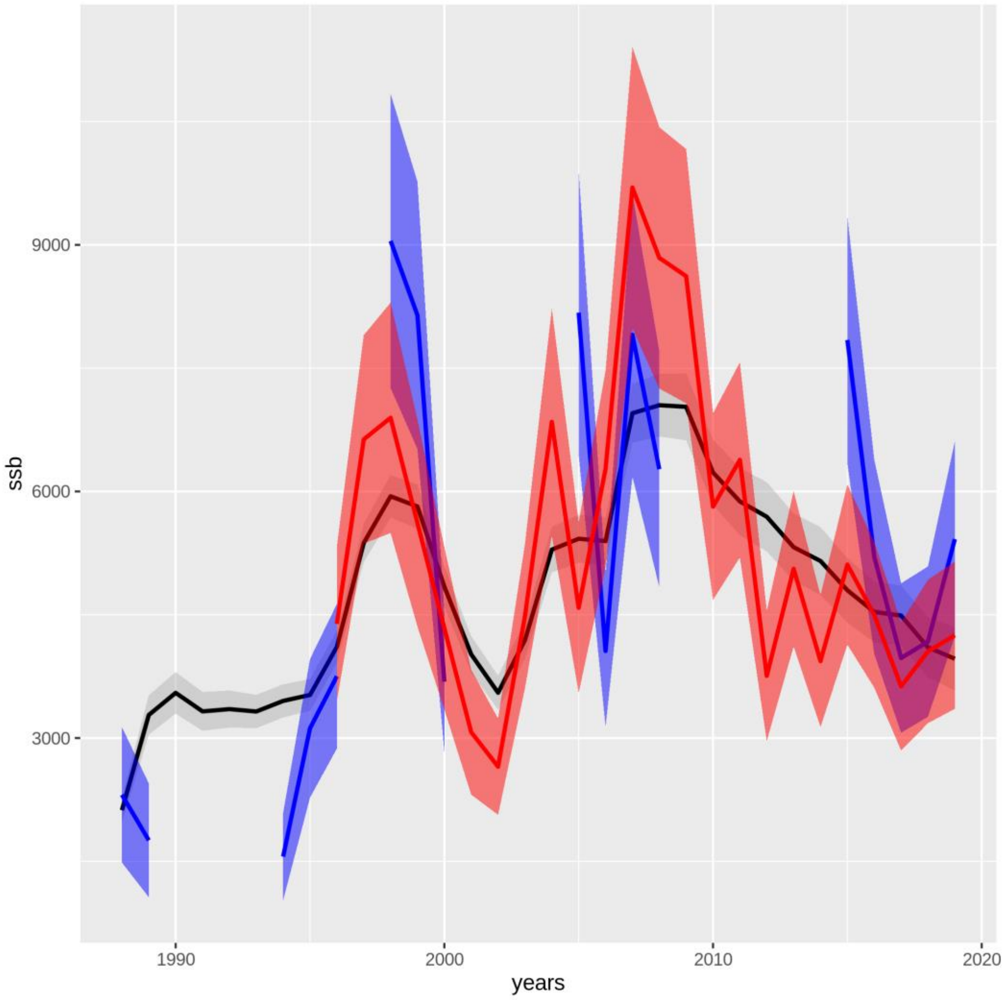


Figure 4.5.1.8. Norwegian spring spawning herring. Point estimates of Spawning-stock biomass by years 1988-2019 from model (black lines) and by survey indices from Fleet 1 (red) and Fleet 5 (blue). Shaded area is approximate to standard deviation.

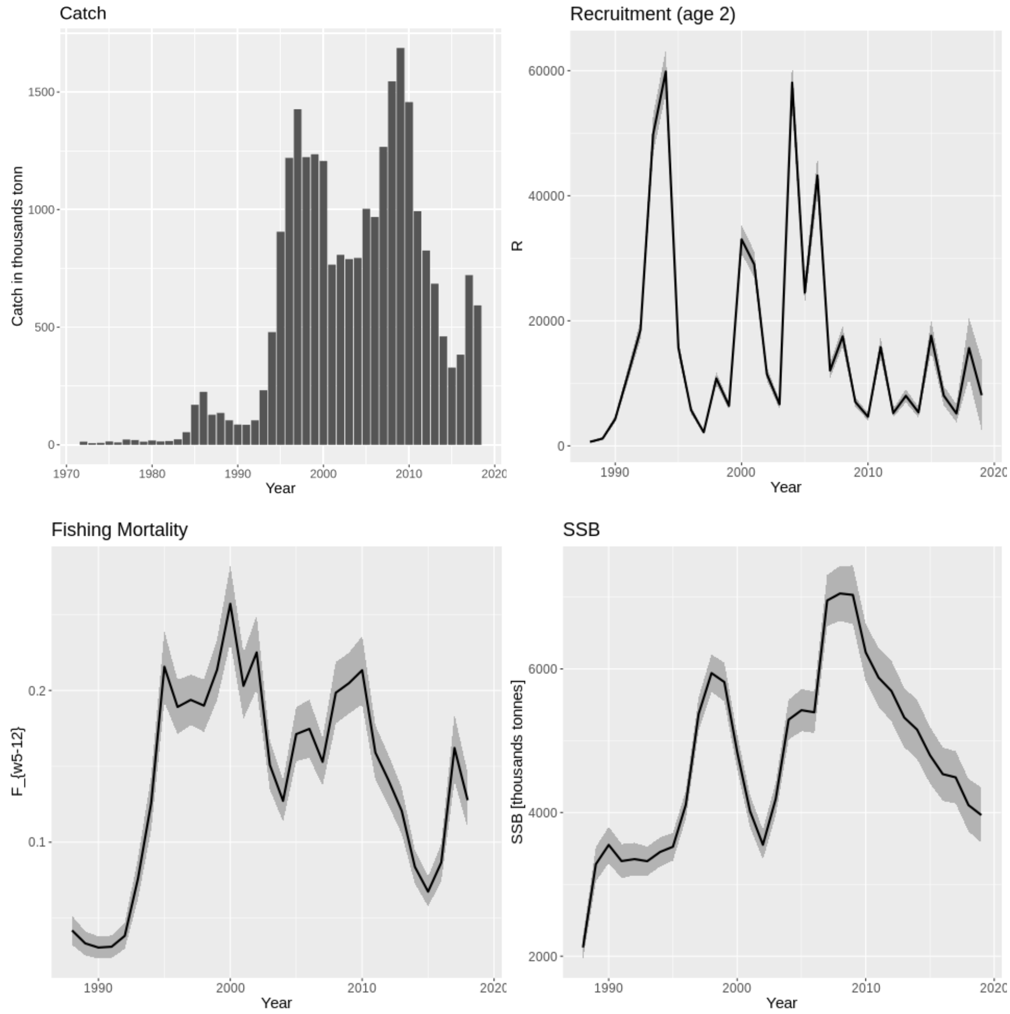


Figure 4.5.1.9. Total reported landings 1988-2018, estimated recruitment, weighted average of fishing mortality (ages 5-12) and spawning-stock biomass for the years 1988–2019 based on the final XSAM model fit.

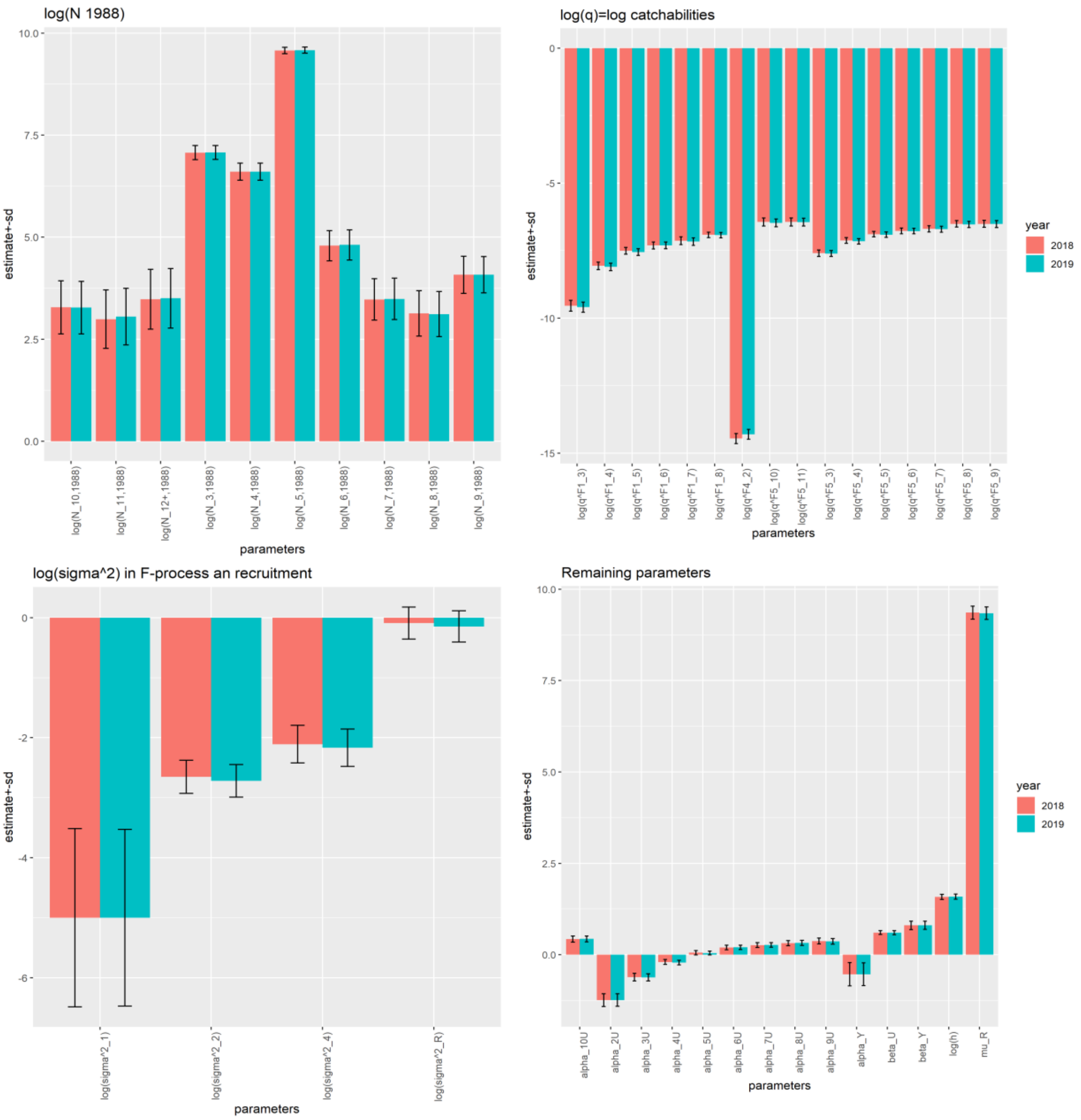


Figure 4.5.1.10. Norwegian spring-spawning herring. A visual representation of parameter estimates of the final XSAM model fit, table 4.5.1.1. The estimates from last year's assessment are also shown (blue).

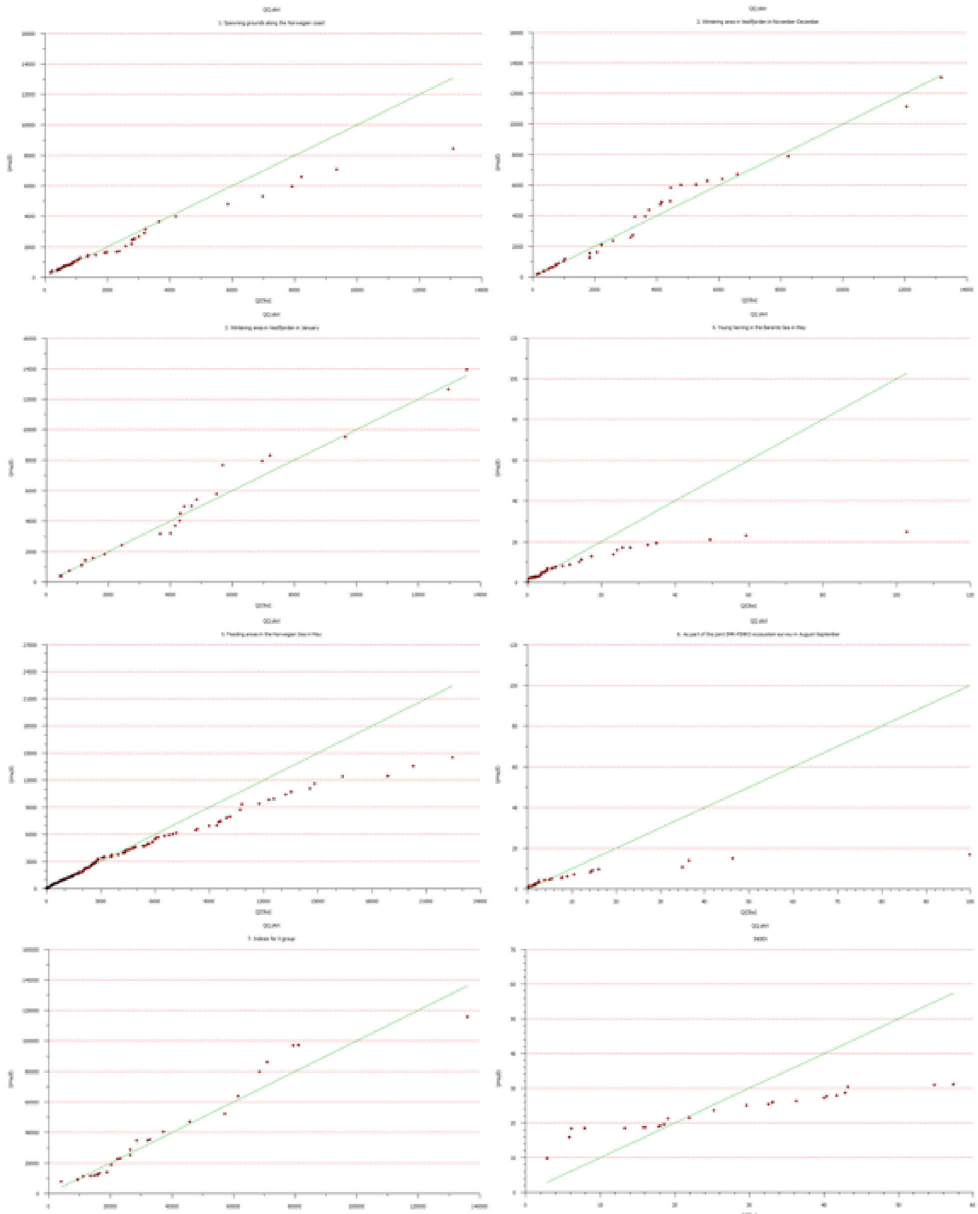


Figure 4.5.2.1.1. Norwegian spring spawning herring. Q-Q plot from the eight different surveys used in tuning in TASACS. First row starts with survey 1 and the last one in row four is larval survey.

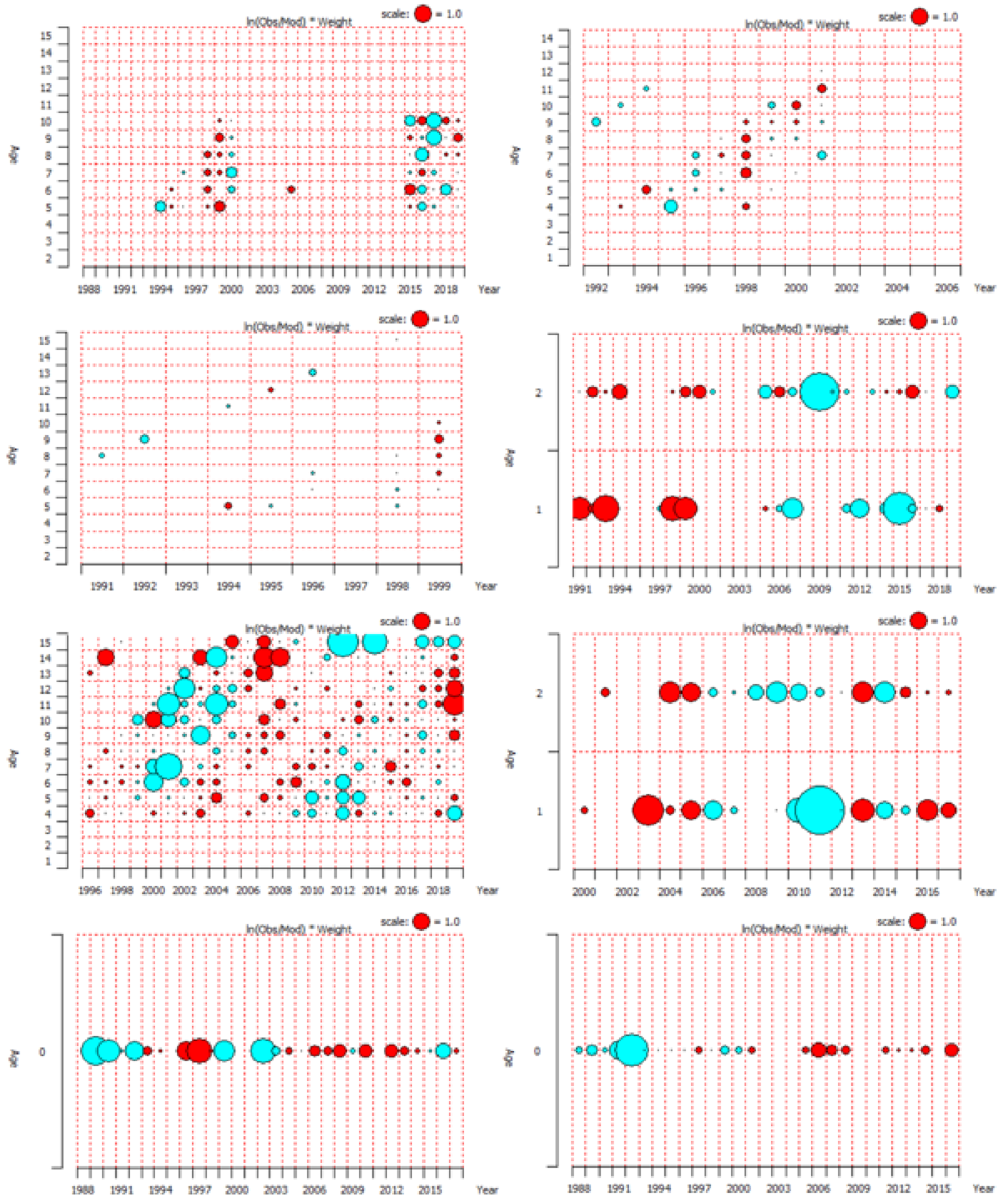


Figure 4.5.2.1.2. Norwegian spring-spawning herring. Residual sum of squares in the surveys separately from TASACS. First row starts with survey 1 and the last one in row four is larval survey.

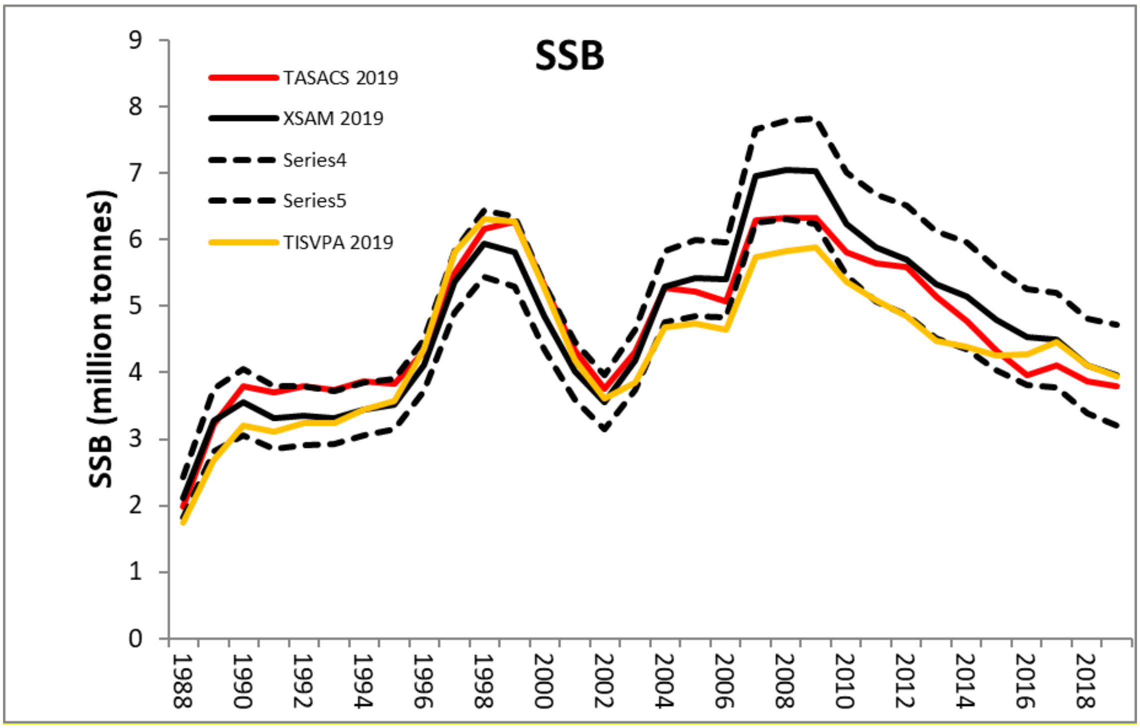


Figure 4.5.2.1.3. Comparison of SSB time-series from the final assessment from XSAM and exploratory runs from TASACS (following the 2008 benchmark procedure) and TISVPA. 95% confidence intervals from the XSAM final assessment are shown (dotted lines).

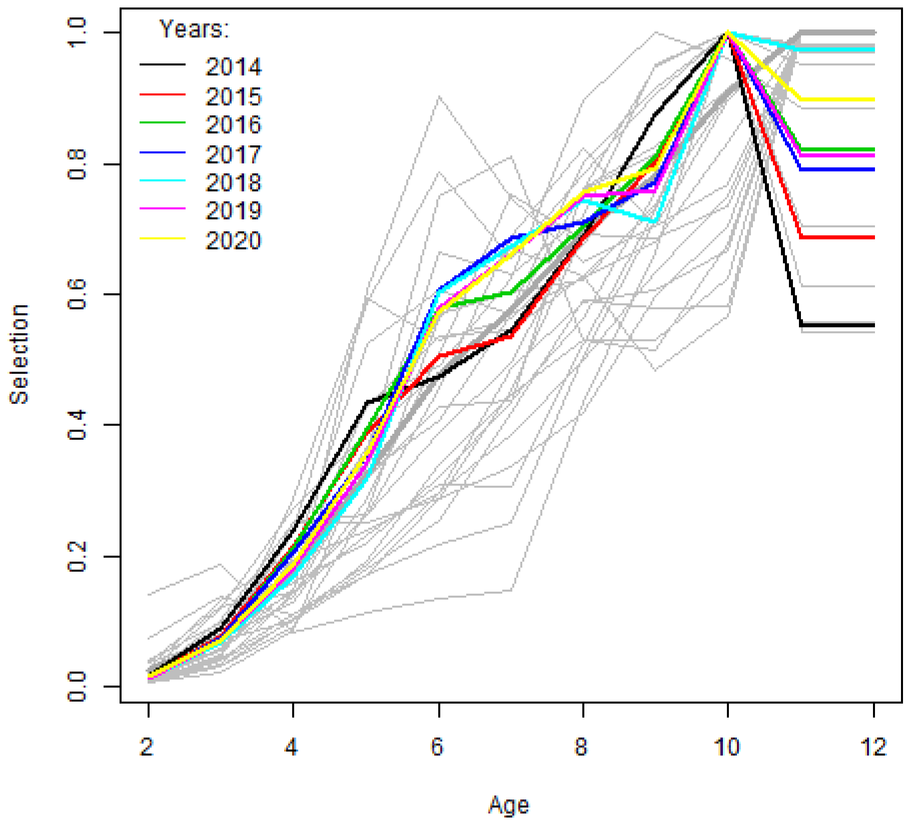


Figure 4.8.1.1. Estimated selection pattern by XSAM; thin grey lines shows annual estimates 1988–2018, the median value is indicated by the thick grey line, while selected years (estimates for 2014–2018 and predictions for 2019-2020) are shown in colours as indicated in the legend.

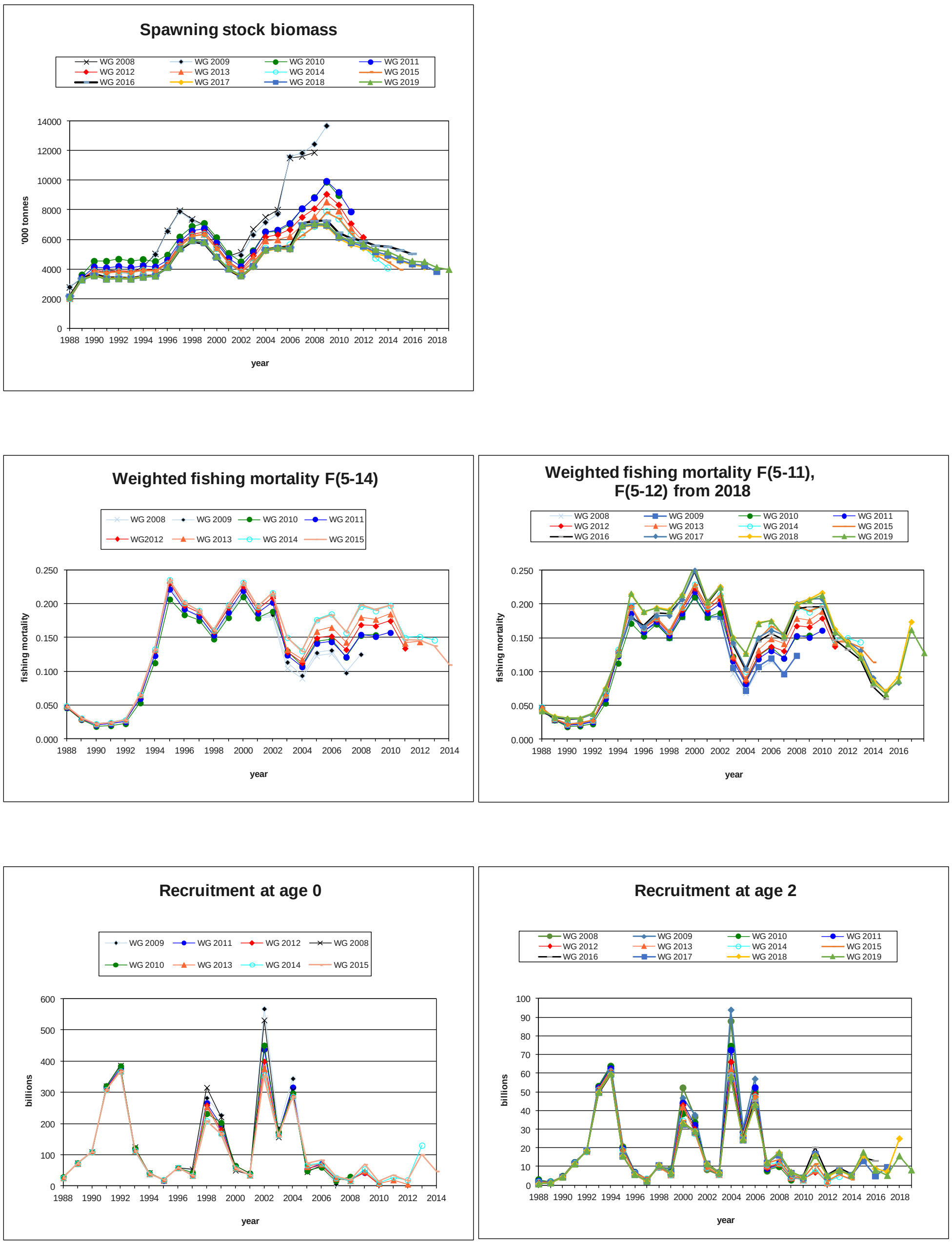


Figure 4.9.1. Norwegian spring spawning herring. Comparisons of spawning stock; weighted fishing mortality F(5-14) and F(5-11/5-12); and recruitment at age 0 and age 2 with previous assessments. In 2016 the proportion mature in the years 2006–2011 was changed; recruitment age changed from 0 to 2 and fishing mortality is calculated over ages 5 to 11. In 2018 (WKNSSHREF) the age range for the fishing mortality changed to ages 5 to 12.

5 Horse Mackerel in the Northeast Atlantic

5.1 Fisheries in 2018

The total international catches of horse mackerel in the North East Atlantic are shown in Table 5.1.1 and Figure 5.4.1. Since 2011 the southern horse mackerel stock is assessed by ICES WGHANSA. The total catch from all areas in 2018 for the Western and North Sea stock was 116,456 tons which is 18,916 tons more than in 2017 and reaches a similar level as 2016 again. France, Germany and the Netherlands have a directed trawl fishery and Norway and France a directed purse-seine fishery for horse mackerel. Spain has directed as well as mixed trawl and purse-seine fisheries targeting horse mackerel. In earlier years most of the catches were used for meal and oil while in later years most of the catches have been used for human consumption.

The quarterly catches of North Sea and western horse mackerel by Division and Subdivision in 2018 are given in Table 5.1.2 and the distributions of the fisheries are given in Figure 5.1.1.a–d. The maps are based on data provided by Belgium, France, Germany, Ireland, Netherlands, Norway, Portugal, Spain and Scotland representing 99% of the total catches. The distribution of the fishery is similar to the recent years.

The Dutch, Danish, Irish and German fleets operated mainly in the North and West of Ireland and the Western waters off Scotland. The French fleet were in the Bay of Biscay and West Scotland whereas the Norwegian fleet fished in the North-eastern part of the North Sea. The Spanish fleet operated mainly in waters of Cantabrian Sea and Bay of Biscay.

First quarter: The fishing season with most of the catches 56,726 tons (49% of the total catches). 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: 11,177 tons. As usual, catches were significantly lower than in the first quarter as the second quarter is the main spawning period. Most of the catches were taken West of Ireland and along the Spanish coast. (Figure 5.1.1.b)

Third quarter: 19,600 tons. Most of the catches were taken in Spanish waters and at the Norwegian coast. Also some smaller catches were reported in the Southern part of the North Sea (Figure 5.1.1.c).

Fourth quarter: Catches were 28,877 tons. The catches were distributed in four main areas (Figure 5.1.1.d):

- Spanish waters,
- Northern Irish waters and West of Scotland
- Norwegian coast
- East part of Channel

5.2 Stock Units

For many years the Working Group has considered the horse mackerel in the Northeast Atlantic as separated into three stocks: the North Sea, the Southern and the Western stocks (ICES 1990, ICES 1991). For further information see Stock Annex Western Horse Mackerel and to 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, 2017)

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. Catch statistics were reviewed since 1990 onward for Western stock and since 2000 onward for North Sea stock. Main mismatches between the catch statistics in working group reports and these reviewed data were originated by several reasons such as late availability of some data for the report or the availability of only official catch figures.

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 2018 were allocated to the three stocks as follows:

Western stock: 3 and 4 quarter: Divisions 3.a and 4.a. 1-4 quarter: 2.a, 5.b, 6.a, 7.a–c, e–k and 8.a-e.

North Sea stock: 1 and 2 quarter: Divisions 3.a and 4.a 1-4 quarter: Divisions 4.b, 4.c and 7.d.

Southern stock: Division 9.a. All catches from these areas were allocated to the southern stock. This stock is now dealt with by another working group (ICES WGHANSA).

The catches by stock are given in Table 5.4.1 and Figure 5.4.1. The catches by ICES sub-Area and division for the Western and North Sea stocks for period 1992-2018 are shown in Figures 5.4.2-3. The catches by stock and countries for the period 1997-2018 are given in Table 5.4.2-5.4.3.

5.5 Estimates of discards

Over the years only Netherlands had provided data on discards and in some few years also Germany and Spain. Since 2017 more countries are providing such data, in 2018 8 of 12 countries. The provided discard rate is less than 2.5 % in weight for the combined Horse mackerel stocks. The discard rate for the North Sea stock is estimated to be 1.8% and for the Western stock 2.6% in 2017.

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*.

T. mediterraneus fishery takes mainly place in the eastern part of ICES Division 8.c. There is not a clear trend in *T. mediterraneus* catches in this area but in the last year's show a low level (Table 5.6.1). Information of *T. picturatus* fishery is available in the WGHANSA Report (Working Group on Horse Mackerel, Anchovy and Sardine).

Taking into account that the assessment is only made for *T. trachurus*, the Working Group recommends that the TACs and any other management regulations which might be established in the future should be related only to *T. trachurus* and not to Trachurus spp. More information is needed about the *Trachurus spp*. before the fishery and the stock can be evaluated.

5.7 Length Distribution by Fleet and by Country:

Ireland, Germany, Netherlands, France, Scotland and Spain provided length distributions for their catches in 2018. The length distributions are covering app. 84% 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 be separate into three stocks:

- North Sea (4a part of the year, 4b, 4c and 7d)
- Western (4a part of the year, 5b, 6a, 7a-c,e-k, 8a-d)
- Southern (9a)

Catches in biomass between 2000 and 2018 are shown in figure 5.4.1 indicated an overall decline in the catches of horse mackerel, but with a relative increase in southern horse mackerel in the recent years. A deeper analysis on the development of the catches by age groups has be done for the 2017 report (Pastoors 2017).

In this analysis it was indicated that there is an increase in the catches of juveniles in the Western and North Sea stocks in recent years. This could be an indication of a stronger recruitment of horse mackerel which has been reported by surveys and fishermen. However, it is also an alarming signal if a larger proportion of the catch consists of juveniles. This catches could be seen mostly in area 7.d and to a lesser extend also in area 7e.

5.9 Quality and Adequacy of fishery and sampling data

Table 5.9.1 shows a summary of the overall sampling intensity on horse mackerel catches in recent years in all areas 1992—2018 and in the Western and North Sea stock areas for the following years. Since 2011 the Southern horse mackerel is dealt with by ICES WGHANSA.

Countries that usually carried out sampling were Ireland, the Netherlands, Germany, Norway and Spain and they covered 42—100% of their respective catches. In 2018 France, Germany, Ireland, the Netherlands, UK (Scotland) and Spain provided samples and length distributions and Germany, Ireland, the Netherlands, and Spain provided also age distributions. However, the lack of age distribution data for relatively large portions of the horse mackerel catches continues to have a serious effect on the accuracy and reliability of the assessment and the Working Group remain especially concerned about the low number of fish which are aged.

Table 5.9.2 shows the sampling intensity for the Western stock in 2018, table 5.9.3 shows the sampling intensity for the North Sea stock in 2018.

An analysis on the sampling intensity was carried out for in period 2000-2018 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 (length) and weight at age which are often used as inputs for the stock assessment models. In addition, in case of horse mackerel the impact of temporal (quarter) and spatial (area by ICES division) factors have to be taken in account in order to obtain a reliable estimate of the commercial catches.

Figure 5.9.1 shows the proportion of sampled catches by division for the North Sea stock. In general all ICES divisions show low levels of sampling especially in the last years. The sampling intensity in relation to the length composition of catch was 62% but in relation to age composition it dropped again dramatically in 2018 (Figure 5.9.2). However, due a coding error sampling data were provided late during WGWIDE and were not considered for figure 5.9.3 (included it would be around 40%, see Table 5.9.3). In addition, divisions that are usually not sampled can be 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 7.d. Therefore, these estimates can be biased, especially, since samples are usually less than the recommended 100 fish/sample. (Table 5.9.1)

The proportion of the sampled catches by region for the Western stock are showed in figure 5.9.5. Most of the regions present an adequate level of sampling although the Biscay and Channel regions show low levels of sampling in the last years. However, no samples were available for the Northern regions of the Western stock distribution. The general index of sampling intensity is around 69 %, although divisions (regions) that are not sampled can affect the precision and accuracy of total catch-at-age and weight at age (Figure 9.5.6). In general, there has been a significant increase in number of measured individuals per 1000 t in recent years produced by the large increase of number of sampled individuals in division 8.b.

Length distributions were supplied by a number of countries. However, as some countries only deliver catch-at-age distributions and others only length distributions of the catch, the obtained catch-at-age and length distributions are not reflecting the total catch especially in case of North Sea horse mackerel. Furthermore, some of the length distributions are only taken from discards of non-horse mackerel targeting fleets omitting the horse mackerel targeting fleet. This lack of coverage might also have a serious effect on the accuracy and reliability of the assessment and is a matter of concern for the Working Group.

5.10 References

Brunel, T., 2017. Revision of the Maturity Ogive for the Western Spawning Component of NEA Mackerel. Working document to WKWIDE, 6pp.

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

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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	2010
2	36	42	176	27	366.34	572	1847	1667

Subarea	1979	1980	1981	1982	1983	1984	1985	1986
2	**2**	**-**	**+**	**-**	**412**	**23**	**79**	**214**
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

[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 (1000 t) by Division and Subdivision in 2018.

Division	1Q	2Q	3Q	4Q	TOTAL
2.a+5.b	294	265	3	157	718
3	0	0	20	399	419
4.a	771	684	6005	2642	10123*
4.bc	1	211	258	950	1419
7.d	1669	279	1855	8094	11897
6.a,b	31212	159	2	7505	38950**
7.a–c,e–k	19088	3640	1733	3226	27687
8.a-e	3691	5942	9705	5902	25240
Sum	56726	11177	19600	28877	116455

*** for the total 20t were added which were only declared as yearly catch**

**** for the total 55t were added which were only declared as yearly catch**

Table 5.4.1 HORSE MACKEREL general. Landings and discards (t) by year and Division, for the North Sea, Western, and Southern horse mackerel stocks. (Data submitted by Working Group members.)

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)[x]	All sto-cks
1982	2,788*		-	1,247		4,035	-		-	6,283	32,231	3,073	-	61,197	65,232	39,726	104,958
1983	4,420*		-	3,600		8,020	412		-	24,881	36,926	28,223	-	90,442	98,462	48,733	147,195
1984	25,893*		-	3,585		29,478	23		94	31,716	38,782	25,629	500	96,744	126,222	23,178	149,400
1985	-		22,897	2,715		26,750	79		203	33,025	35,296	27,740	7,500	103,843	129,455	20,237	150,830
1986	-		19,496	4,756		24,648	214		776	20,343	72,761	43,405	8,500	145,999	170,251	31,159	201,806
1987	1,138		9,477	1,721		11,634	3,311		11,185	35,197	99,942	37,703	-	187,338	199,674	24,540	223,512
1988	396		18,290	3,120		23,671	6,818		42,174	45,842	81,978	34,177	3,740	214,729	236,535	29,763	268,163
1989	436		25,830	6,522		33,265	4,809		85304**	34,870	131,218	38,686	1,150	296,037	328,825	29,231	358,533
1990	2,261		17,437	1,325		18,762	11,414	14,878	112753**	20,794	182,580	46,302	9,930	398,645	419,668	24,023	441,430
1991	913	0	11,400	600	0	12,913	3,200	2,725	56,157	29,726	149,975	42,840	5,440	290,063	302,976	34,992	337,968
1992	0	0	13,955	688	400	15,043	13,457	2,374	103,725	39,061	182,770	54,172	1,820	397,379	412,422	27,858	440,280

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)[x]	All sto-cks
1993	0	0	3,895	8,792	930	13,617	0	850	141,220	65,397	193,291	44,726	8,600	454,084	467,701	31,521	499,222
1994	0	0	2,496	2,503	630	5,629	759	2,492	106,911	69,616	193,689	35,501	3,935	412,903	418,532	28,442	446,974
1995	112	0	7,948	8,666	30	16,756	13,151	128	92,728	83,568	320,329	28,707	2,046	540,657	557,413	25,147	582,560
1996	1,657	0	7,558	9,416	212	18,843	3,366	0	16,783	81,311	254,049	48,360	16,870	420,739	439,582	20,400	459,982
1997	0	0	14,078	5,452	10	19,540	2,601	2,037	63,646	40,145	321,017	40,806	158	470,410	489,950	29,491	519,441
1998	3,693	0	10,530	16,194	83	30,500	2,544	3,693	17,001	35,073	284,529	38,571	913	382,324	412,824	41,574	454,398
1999	0	0	9,335	27,889	0	37,224	2,557	2,095	47,315	40,381	158,733	48,350	0	299,431	336,655	27,733	364,388
2000	0	176	25,931	19,019	4	45,130	919	1,014	4,314	20,735	121,171	54,197	382	202,732	247,862	26,160	274,022
2001	43	212	6,686	21,390	0	28,331	310	134	11,438	24,839	117,038	75,067	254	229,081	257,411	24,912	282,323
2002	0	639	15,303	11,323	0	27,264	1,324	174	36,221	14,843	87,354	55,897	307	196,120	223,384	23,665	247,049
2003	49	622	10,309	21,049	0	32,028	36	1,843	21,272	23,772	102,379	41,711	842	191,856	223,885	19,570	243,455
2004	303	133	18,544	16,455	0	35,435	42	48	11,708	22,177	99,284	24,126	2,356	159,742	195,177	23,581	218,758

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)x	All stocks
2005	0	1,331	13,995	15,460	62	30,848	176	284	24,983	22,053	91,211	41,491	1,802	182,001	212,850	23,111	235,961
2006	185	2,192	7,996	23,789	78	34,240	27	58	27,152	15,722	77,394	34,121	1,353	155,827	190,067	24,557	214,624
2007	11	2,051	9,114	29,789	139	41,103	366	110	4,940	25,949	63,224	28,396	370	123,356	164,459	23,423	187,882
2008	27	910	2,582	32,185	0	35,704	572	3	12,107	25,867	70,570	33,756	474	143,349	179,053	23,596	202,649
2009	21	314	18,975	25,537	1,036	45,883	1,847	17	58,738	17,775	71,378	33,580	447	183,782	229,665	26,496	256,161
2010	0	100	1,969	22,077	2	24,149	1,667	88	11,442	23,199	126,624	39,659	432	203,112	227,261	27,217	254,478
2011	0	0	10,435	17,184	0	27,619	648	0	14,723	39,496	103,156	35,245	430	193,698	221,317	22,575	243,892
2012	0	355	1,559	19,464	0	21,378	66	9	3,311	44,971	101,012	17,209	3,279	169,858	191,236	25,316	216,552
2013	0	17	1,453	17,175	0	18,645	30	10	6,702	43,266	83,684	26,983	4,582	165,258	183,903	29,382	213,285
2014	1	2	2,597	10,772	7	13,380	424	4,096	10,573	32,444	56,081	30,844	1,896	136,360	149,740	29,205	178,945
2015	3	644	770	8,581	2,004	12,002	10	65	9,078	24,153	41,063	19,822	4,228	98,419	110,421	33,179	143,600
2016	2	1,628	975	11,209	1,527	15,341	45	0	8,960	32,186	35,692	17,511	4,417	98,811	114,151	41,081	155,232

Year	3.a	4.a	4.b,c	7.d	Disc	NS Stock	2.a 5.b	3.a	4.a	6.a,b	7.a-c, e-k	8.a-e	Disc	Western Stock	W + NS Stock	Southern Stock(9.a)[x]	All sto-cks
2017	0	22	2,557	10,787	1,213	14,579	5	697	9,332	28,170	22,510	18,307	3,939	82,961	97,540	37,088	134,956
2018	0	1,418	1,413	11,677	265	14,773	718	380	8,547	38,896	27,140	23,393	2,609	101,683	116,456	31,920	148,376

***Divisions 3.a and 4.b,c combined.**

****Norwegian catches in 4.b included in Western horse mackerel.**

[x] Southern Horse Mackerel is assessed by ICES WGHANSA since 2011

Table 5.4.2 National catches of the Western Horse mackerel stock.

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	18	19	21	0	-	-	-	-	-
Denmark	62,897	31,023	26,040	16,385	21,254	10,147	11340	11,667	10,155
Estonia	78	22	-	0	-	-	-	3,826	3,695
Faroe Islands	1,095	216	1,040	24	800	671	4	8,056	10,690
France	39,188	26,667	25,141	20,457	15,145	18,951	10,381	17,744	16,364
Germany, Fed.Rep.	28,533	33,716	23,549	13,014	11,491	12,658	15,696	26,432	34,607
Ireland	74,250	73,672	57,983	55,229	51,874	36,422	35,857	-	-
Lithuania	-	-	-	-	-	-	-	40986	41,057
Netherlands	82,885	103,246	83,450	57,261	73,440	44,997	48,924	10729	24,909
Norway	45,058	13,363	46,648	1,982	7,956	36,164	20,371	16,272	16,636
Russia	554	345	121	80	16	3	2	567	216
Spain	31,087	43,829	39,831	24,204	23,537	24,763	24,599	4,617	3,560
Sweden	1,761	3411	1,957	1009	68	561	1,002	458	210
UK (Engl. + Wales)	19,778	13,068	9,268	4,554	7,096	5,970	4,438	1,522	143
UK (N. Ireland)	-	1,158	-	625	1140	1129	914	14,506	17,962
UK (Scotland)	32,865	18,283	11,197	10,283	8,026	2,905	721	2356	1802
Unallocated	17,158	15,262	23,763	-2757	6,978	472	16,765	159,737	182,006
Discard	158	913	-	382	254	307	842	-	-
Total	437,363	378,213	350,009	202,732	229,075	196,120	191,856	11,667	10,155

Country	2006	2007	2008	2009	2010	2011	2012	2013
Belgium	-	-	-	-	19	2	0.2	14
Denmark	8,411	7,617	5,261	6,027	5,940	6,108	4,002	6,820
Faroe Islands	-	478	841	-	377	349	-	
France	11,031	12,748	12,626	-	260	8,271	1,797	3,595
Germany, Fed.Rep.	10,862	5,784	11,801	15,122	17,688	21,114	17,063	24,835
Ireland	26,779	29,759	35,332	40,754	44,488	38,466	45,239	35,791
Lithuania	6,828	5,467	5,548	-	-	-	-	
Netherlands	37,130	29,462	43,648	39,453	61,504	55,690	66,396	53,697
Norway	27,114	4,182	12,223	59,764	11,978	13,755	3,251	6,596
Spain	13,877	14,277	19,851	21,077	38,745	34,581	13560	22,541
Sweden	-	76	8	258	2	90	-	1
UK (Engl. + Wales)	3,574	5,482	3,365	6,482	12,714	11,716	12,122	3,959
UK (N. Ireland)	103	-	-	-	59	198	-	2,325
UK (Scotland)	468	776	1,077	1,412	2,349	2,928	1,335	504
Unallocated	8,292	6,878	-8,703	-7,014	6,556	-	1815	-
Discard	1353	370	474	447	432	430	3,280	4,582
Total	155,822	123,356	143,352	183,782	203,111	193,698	169,860	165,260

Country	2014	2015	2016	2017	2018
Belgium					
Denmark	5,945	4,556	321	4,541	6,302
Faroe Islands	68	-	-	180	-
France	3,428	3,247	2,797	3,923	3,443
Germany, Fed.Rep.	17,161	9,417	11,414	7,172	4,734
Ireland	32,667	21,654	27,605	23,560	25,347
Lithuania	-	-	2,596	-	-
Netherlands	25,053	24,958	23,792	14,269	25,942
Norway	14,353	8,897	9,438	9,885	9,319
Spain	19,442	13,071	14,235	14,901	20,362
Sweden	0	10	-	41	23
UK (Engl. + Wales)	4,832	2,063	842	549	2,443
UK (N. Ireland)	1,579	1,204	-		1,080
UK (Scotland)	1,389	738	970	-	-
Unallocated	8,545	4,377	1,010	3,994	74
Discard	1,896	4,228	4,417	3,928	2,609
Total	136,360	98,419	98,810	82,950	101,682

Table 5.4.3. National catches of the North Sea Horse mackerel stock.

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	-	19	21			30	5	4	4	-
Denmark	180	1,481	3,377	4,403	885	2,315	3,301	8,690	3,987	8,353
Faroe Islands	-	-	135	-	-	28	804	21	-	-
France	3,246	2,399	-	-		1,246	2,326	231	5,236	1,205
Germany, Fed.Rep.	7,847	5,844	5,920	3,728	974	6,532	2,936	5,194	2,725	11,034
Ireland	-	2,861	27	201	338	61	-	1	753	10,863
Lithuania	-	10,711	-	-	-	-	-	-	-	26,779
Netherlands	36,855	-	8,117	8,697	13,867	12,209	24,119	26,303	27,730	6,829
Norway	-	-	238	105	36	525	144	22	204	37,130
Sweden	-	3,401	5	40	46	16	72	98	4	27,114
UK (Engl. + Wales)	269	907	11	1,585	3,425	2,322	1,966	5,633	3,859	-
UK (Scotland)	29	-	-	421	-	2	1	2	-	13,878
Unallocated	-28,896	2,794	19,373	25,944	8,805	1,981	-3,645	-13,064	-13,719	-
Discard	10	83	-	4	-		-	-	62	3,583
Total	19,540	30,500	37,224	45,128	28,376	27,267	32,029	33,135	30,845	155,094

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium				4	16		46	51.077	74
Denmark	1,283	252	57	72	15	142	1514	1,020	552
Faroe Islands	-	-	-	-	-	-	0		
France	4,380	5,349	2,247	-	813	273	1,047	1,010	1,742
Germany, Fed.Rep.	1,125	65	1,081	1,539	3,794	3,461	5,356	2,941	1,619
Ireland	2,077		887	25	-	-	0		0
Lithuania	1,999	297	-	-	-	-	0		0
Netherlands	27,285	31,153	19,439	22,546	17,093	16,289	12,157	8,725	4,925
Norway	113	1,243	21	12,855	526	7,359	129	377	0
Sweden	9	21	36	401	-	-	0		1
UK (Engl. + Wales)	595	6921	1,061	1,435	1,890		935	4,401	4,198

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
UK (Scotland)	300	625	7	4	111	93	240	172	262
Unallocated	-5,004	-4,960	10,869	5,964	-116	0	0	0	
Discard	78	139	-	1,036	2	0	0	0	7
Total	34,240	41,105	35,705	45,881	24,144	27,617	21,424	18,696	13,380

Country	2015	2016	2017	2018
Belgium	63	51	67	44
Denmark	800	268	294	397
Faroe Islands	0	0	4	0
France	934	1,322	1,863	1,443
Germany, Fed.Rep.	644	1,879	949	2,766
Ireland	0	0	0	0
Netherlands	3,305	3,892	5,638	5,184
Norway	662	1,701	5	1,423
Sweden	9	0	0	0
UK (Engl. + Wales)	3,581	4,697	4,546	3,250
UK (Scotland)	0	0	0	0
Unallocated	0	0	0	0
Discard	2,004	1,527	1,213	265
Total	12,002	15,337	14,579	14,773

Table 5.6.1. Catches (t) of *Trachurus mediterraneus* in Divisions 8.ab, 8.c and Sub-Area 7

	7	8.ab	8.c East	8.c West	TOTAL
1989	0	23	3903		3926
1990	0	298	2943		3241
1991	0	2122	5020		7142
1992	0	1123	4804		5927
1993	0	649	5576		6225
1994	0	1573	3344		4917
1995	0	2271	4585		6856

	7	8.ab	8.c East	8.c West	TOTAL
1996	0	1175	3443		4618
1997	0	557	3264		3821
1998	0	740	3755		4495
1999	0	1100	1592		2692
2000	59	988	808		1854
2001	1	525	1293		1820
2002	1	525	1198		1724
2003	0	340	1699		2039
2004	0	53	841		894
2005	1	155	1005		1162
2006	1	168	794		963
2007	0	126	326		452
2008	0	82	405		487
2009	0	42	1082		1124
2010	0	97	370		467
2011	0	119	1096		1225
2012	0	186	667	116	969
2013	0	52	238	0	290
2014	0	130	1160	0	1290
2015	0	8	890	0	899
2016	0	5	471	0	476
2017	0	18	684	0	702
2018	0.4	38	640	0	

Table 5.7.1 Horse mackerel general. Length distributions (%) by country, area and fleet in 2018. (0%= <0.5%)

	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Germany	Germany	Germany	Germany	Germany	France	France	France	France	France	France	Ireland	UK (Scotland)	UK (Scotland)	UK (Scotland)
	6a	7b	7d	7h	7j	4a	6a	7d landings	7d	7e	7d	7d	7d	7d	7d	7d	all	4a	4a	6a
cm	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all	OTM_SPF_32-69_0_0_all landg	OTM_SPF_32-69_0_0_all BMS	OTM_SPF_32-69_0_0_all	OTB_DEF_70-99_0_0 disc	OTB_DEF_70-99_0_0 landg	OTB_SPF_70-99_0_0_all disc	OTM_SPF_32-69_0_0_all disc	OTM_SPF_32-69_0_0_all landg	SSC_DEF_70-99_0_0_all disc	HM-All	TR1 discards	TR2 discards	discards
5																				
6														1						
7																				
8																				
9																9				
10											0			1		9				
11											1					20				
12											1					11				
13											4		1			19				
14								0			3		3			13				
15								0			0		2	0		9				
16								0			1		4	0		8	0			
17			0					1		1	5	0	7	14		3	0			
18			1					7		13	11		10	7			0			
19			6	1				7	2	26	10		13	11			0			
20			8	2	1		0	13	2	27	6	2	10	28			0			
21	2		10	10	1		0	8	4	17	8	1	5	12	3		0			
22	4		19	15	1		3	18	10	7	16	9	7	9	6		2			1
23	12		11	30			14	11	15	3	12	16	14	8	6		5			1
24	23	4	11	22	1		25	11	15	2	11	26	9	2	18		9	0	2	1
25	17	10	12	10	2		20	10	17	2	5	17	6	4	21		10	0		1
26	13	9	10	3	4		9	8	13	0	3	10	4	1	23		9	1		3
27	7	6	7	1	2		5	4	15	1	2	4	1	1	4		6	1		6
28	5	5	4		1		4	1	6	0	0	6	1	0	7		5	2	2	6
29	4	8	2		4	0	4		2		0	2	0		5		6	3	3	4
30	3	9	0	1	3	0	3	0			0	3	2		1		6	7	12	2
31	3	11		1	9	1	3	0			0	2	0		4		9	9	13	6
32	2	12		1	25	17	3				0	1			0		9	12	18	9
33	2	7			13	33	3				0	1	0				9	17	15	15
34	2	8		1	13	33	2				0						7	15	22	15
35	1	9		1	12	17	1										4	9	6	7
36	1	2			3		1						0				2	5	3	7
37		1			4		0					0					1	6	3	9
38							0										1	5	1	4
39		1					0										0	3		2
40							0										0	2	1	1
41							0										0	1		1
42+							0										0	0		0

Table 5.7.1 continued

cm	Spain 8.c.e GNS_DEF_60-79_0_0 landg	Spain 8.c.w GNS_DEF_60-79_0_0 landg	Spain 8.c GNS_DEF_80-99_0_0 disc	Spain 8.c GNS_DEF_80-99_0_0 landg	Spain 8.c.w GNS_DEF_80-99_0_0 landg	Spain 8.c.e GTR_DEF_60-79_0_0 landg	Spain 8.b LLS_DEF_0_0_0 landg	Spain 8.c OTB_DEF_>=55_0_0 disc	Spain 8.c.e OTB_DEF_>=55_0_0 landg	Spain 8.c.w OTB_DEF_>=55_0_0 landg	Spain 8.a OTB_DEF_>=70_0_0 landg	Spain 8.b OTB_DEF_>=70_0_0 disc	Spain 8.b OTB_DEF_>=70_0_0 landg	Spain 8.d.2 OTB_DEF_>=70_0_0 disc	Spain 8.d.2 OTB_DEF_>=70_0_0 landg	Spain 6.b.2 OTB_DEF_70-99_0_0 disc	Spain 7.b OTB_DEF_70-99_0_0 disc	Spain 7.c.2 OTB_DEF_70-99_0_0 disc
5																		
6																		
7												0		0				
8												0		0				
9												8		8				
10												16		16				
11								1				14		14				
12								13				14		14				
13								8				17		17				
14								4				15		15				
15		0						3				7		7				
16		0						2				3		3				
17		0						3	0			2		2				
18		1						0	0			1		1				
19		1		0				4	3	0		1		1				
20		2	1					6	5	1		0		0				
21	0	3	2	1	0			8	4	1		0		0				
22	0	5	6		1	1		6	3	2	0	0		0		0	0	0
23	2	5	6	2	2	1		8	4	5	0	0		0		1	1	1
24	7	8	3	2	2			7	3	12	0	0		0		4	3	4
25	6	9	6	3	5			4	2	7	0	1		1		4	4	4
26	5	8	11	2	4	2		8	4	9	0	0		0		6	6	7
27	13	11	9	2	4			4	4	7	0	0		0		5	6	6
28	20	11	6	5	6	3		2	7	10	1	0		0		3	7	6
29	29	9	20	7	7	2	50	3	5	9	1	0	0	0	2	3	7	6
30	13	8	8	9	7	1		1	6	12	2	0	1	0	3	4	10	8
31	4	7	7	8	5	29	50	0	9	9	4	0	2	0	6	6	12	10
32	0	5	1	5	4	1		2	8	6	3	0	6	0	12	9	12	12
33	0	4	2	7	3	1		1	6	3	9	0	9	0	11	13	11	11
34	0	2		8	2	58			8	3	7	0	14	0	12	17	10	12
35	0	1	0	8	3			1	7	2	17	0	16	0	14	12	4	6
36	0	1		7	4				8	1	10		19		12	9	4	5
37	0	0	0	4	4	1			1	1	14		11		8	2	1	2
38	0	0	2	5	6				1	0	16		16		13	0	1	1
39	0	0	2	6	7				1	0	5		6		5	0	0	0
40	0	0	4	5	7					0	2		1		1	0	0	0
41		0	1	4	6				0	0	0		1		0			
42+	0		3	2	10				0	0	6		0		0			

Table 5.7.1 continued

cm	Spain 7.g OTB_DEF_70-99_0_0 disc	Spain 7.h OTB_DEF_70-99_0_0 disc	Spain 7.j.2 OTB_DEF_70-99_0_0 disc	Spain 7.k.2 OTB_DEF_70-99_0_0 disc	Spain 8.c OTB_MPD_>=55_0_0 disc	Spain 8.c.e OTB_MPD_>=55_0_0 landg	Spain 8.c.w OTB_MPD_>=55_0_0 landg	Spain 8.b PS_SPF_0_0_0 landg	Spain 8.c.e PS_SPF_0_0_0 landg	Spain 8.c.w PS_SPF_0_0_0 landg	Spain 8.a PTB_DEF_>=70_0_0 disc	Spain 8.b PTB_DEF_>=70_0_0 disc	Spain 8.d.2 PTB_DEF_>=70_0_0 disc	Spain 8.c PTB_MPD_>=55_0_0 disc	Spain 8.c.e PTB_MPD_>=55_0_0 disc	Spain 8.c.e PTB_MPD_>=55_0_0 landg	Spain 8.c.w PTB_MPD_>=55_0_0 landg
5																	
6																	
7																	
8															1		
9											7	7	7		11		
10											18	18	18		12		
11								0							7		
12								0	1	0	3	3	3		6	1	
13								1	7	1	12	12	12		2	6	
14								4	11	4	6	6	6		2	16	
15								12	7	8	17	17	17			9	
16								25	3	3						8	
17					6			17	2	1	5	5	5			3	
18					6			10	2	1					4	3	
19					17		0	6	2	3						1	
20					16		1	2	2	7						1	
21					19		3	1	2	10				4	14	1	
22		0	0	0	3		4	1	2	10				18	11	1	
23		1	1	2	4		10	1	1	11				4	21	1	
24		2	2	5	3	0	13	1	1	10				45	7	2	
25		4	3	5	5	3	12	0	2	11	4	4	4	15		2	0
26		5	4	7	3	6	11	1	2	8	3	3	3	8		3	1
27	4	6	5	6	5	5	9	1	3	5	13	13	13	5		6	1
28	3	7	6	5	6	11	7	2	4	2	4	4	4			4	2
29	1	7	7	5	2	13	6	2	6	2	5	5	5			6	1
30		10	9	8	4	14	5	2	7	1						8	4
31	5	13	12	9	0	19	5	1	7	1	3	3	3			4	5
32	4	12	11	11	1	15	4	1	8	1						5	5
33	17	11	11	11	0	6	1	1	6	0						4	10
34	25	11	12	12		3	3	2	5	0						2	10
35	24	5	7	6	0	2	1	2	3	0					1	1	11
36	14	4	5	5		2	1	1	2	0						1	15
37	3	1	2	1	0	1	0	1	1	0						0	9
38	1	1	1	1	0	0	1	1	1	0						0	6
39		0	0	0		0	1	0	1	0						0	4
40	0	0	0	0		0	0		0	0						0	5
41						0	0		0	0						0	5
42+							0		0	0						0	2

Table5.9.1. Summary of the overall sampling intensity on horse mackerel catches in recent years in all areas 1992—2017

Year	TOTAL CATCH (ICES estimate)	% catch covered by sampling programme*	No. samples	No. Measured	No. Aged
1992	436 500	45	1 803	158447	5797
1993	504190	75	1178	158954	7476
1994	447153	61	1453	134269	6571
1995	580000	48	2041	177803	5885
1996	460200	63	2498	208416	4719
1997	518900	75	2572	247207	6391
1998	399700	62	2539	245220	6416
1999	363033	51	2158	208387	7954
2000	247862	50	378	33317	4126
2001	257411	61	467	46885	7141
2002	223384	68	540	79103	6831
2003	223885	77	434	59241	8044
2004	195177	62	518	62720	9273
2005	212850	76	573	67898	8840
2006	190067	75	602	57701	9905
2007	164459	58	397	41046	8061
2008	179053	72	488	46768	8870
2009	229665	84	902	57505	10575
2010	227261	82	710	49307	14159
2011	221317	71	502	40492	7484
2012	191236	69	501	41148	8220
2013	183903	75	686	87300	9776
2014	149740	83	650	53945	8085
2015	110421	68	825	39415	7034
2016	114151	76	1033	93853	6675
2017	97539	63	1113	116722	8221
2018	116455	74	1584	117768	6965

***Percentage related to catch (catch at age) acc. to ICES estimation**

Table 5.9.2. Horse mackerel sampling intensity for the Western stock in 2018 .

COUNTRY	CATCH	% CATCH SAMPLED*	NO. SAMPLES	NO. MEASURED	NO. AGED
Denmark	6356	0	0	0	0
France**	3926	-	148	2926	0
Germany	4735	47	21	7790	513
Ireland	25347	96	44	9160	2560
Netherlands	25942	83	45	6971	1103
Norway	9320	0	0	0	0
Spain	22342	97	979	86448	2561
Sweden	25	0	0	0	0
UK (England)**	2450	-	12	379	0
UK(Northern Ireland)	1080	0	0	0	0
UK(Scotland)**	158	-	122	1606	0
Total	101682	69	1371	115280	6737

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

****provided only length distributions**

Table 5.9.3. Horse mackerel sampling intensity for the North Sea stock in 2018

COUNTRY	CATCH	% CATCH SAMPLED*	NO. SAMPLES	NO. MEASURED	NO. AGED
Belgium	44	0	0	0	0
Denmark	403	0	0	0	0
France**	1666	0	136	1286	0
Germany	2766	43	50	1035	228
Netherlands***	5184	100	11	2398	274
Norway	1423	0	0	0	0
Sweden	0	0	0	0	0
UK (England)	3250	0	0	0	0
UK(Scotland)**	37	0	27	167	0
Total	14773	40	224	4886	502

***Percentage based on ICES estimate with regards to age samples. **provided only length distributions**

***** due to coding error sampling data were provided late during WGWIDE**

5.12 Figures

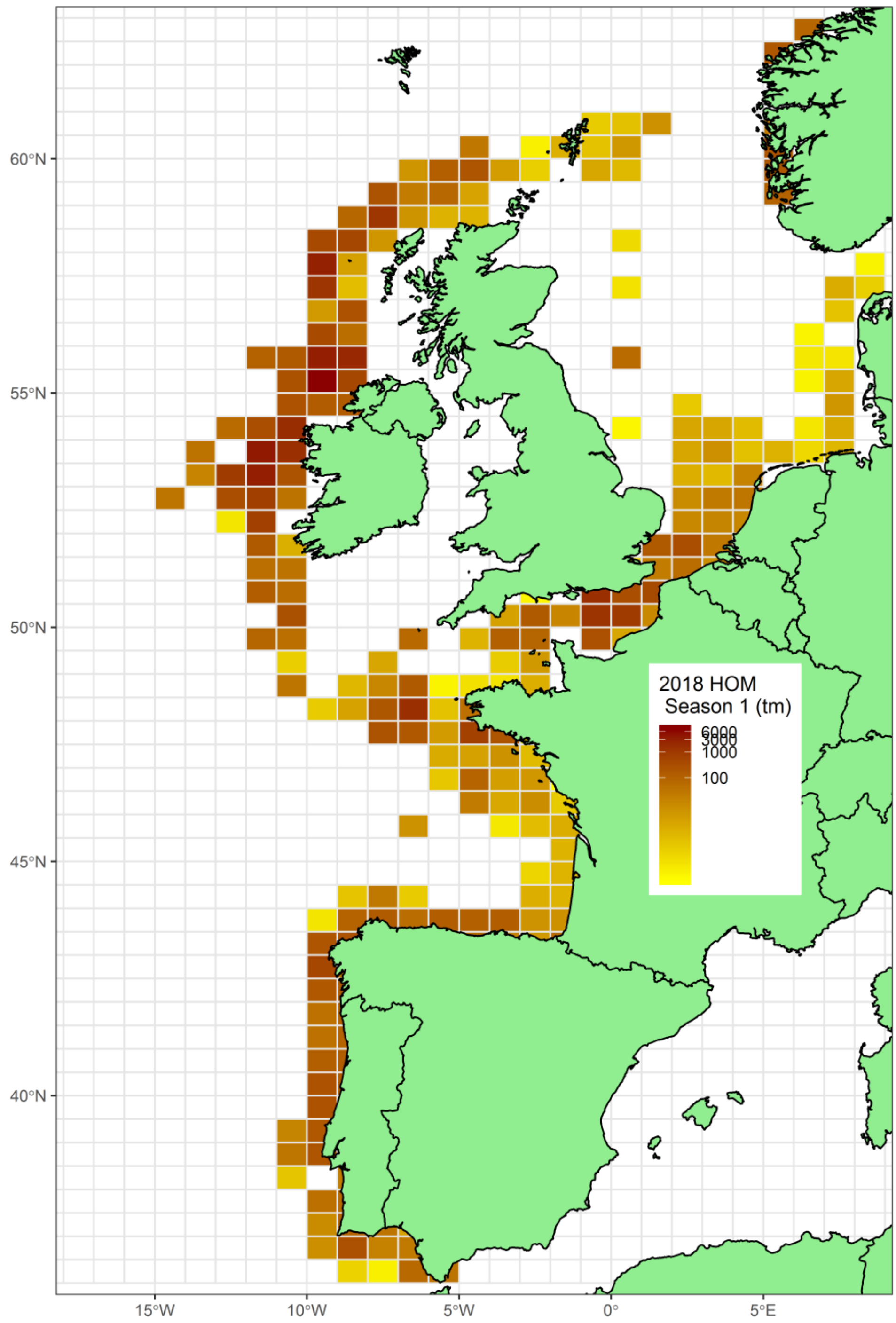

Figure 5.1.1a. Horse mackerel catches 1st quarter 2018.

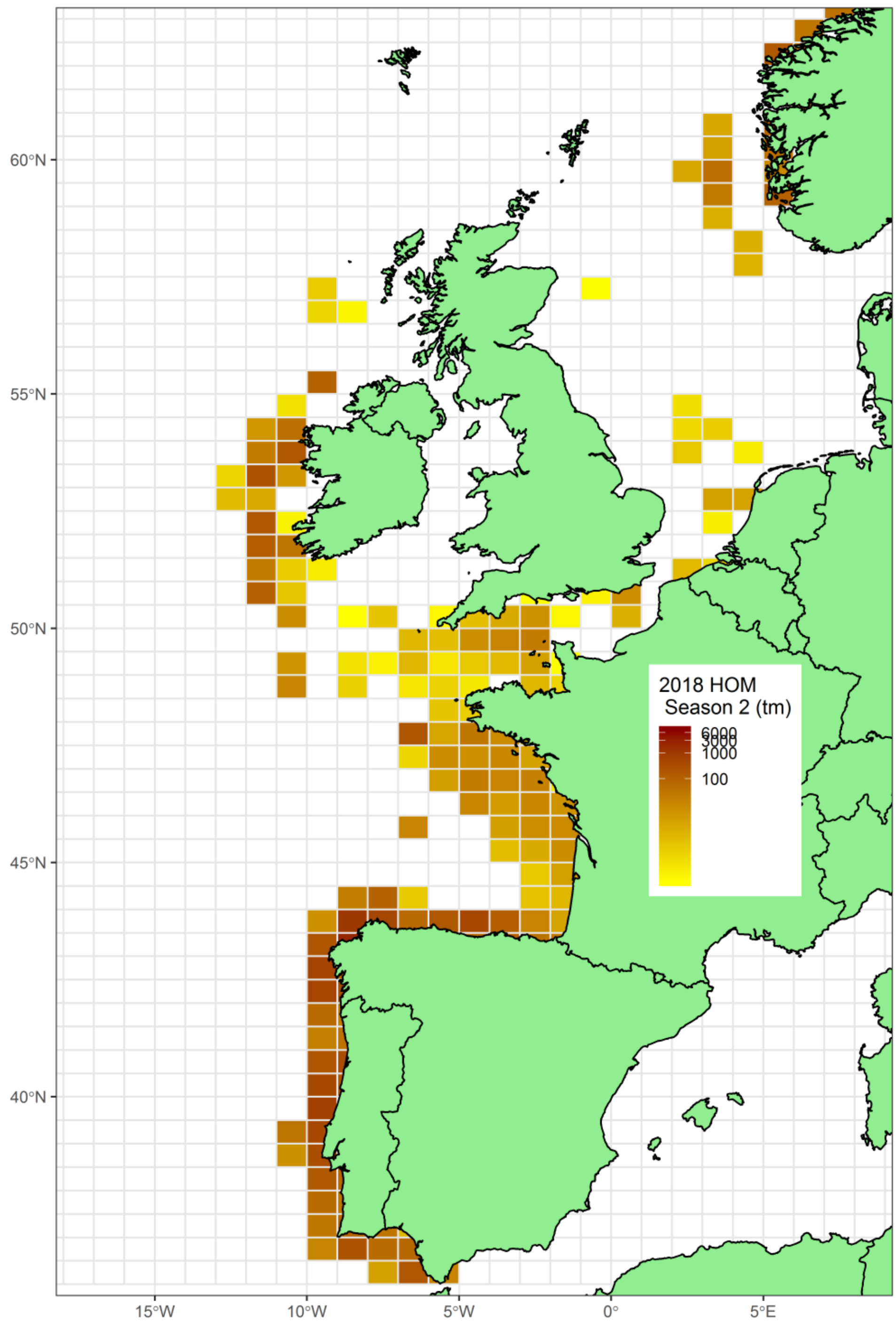

Figure 5.1.1b. Horse mackerel catches 2nd quarter 2018.

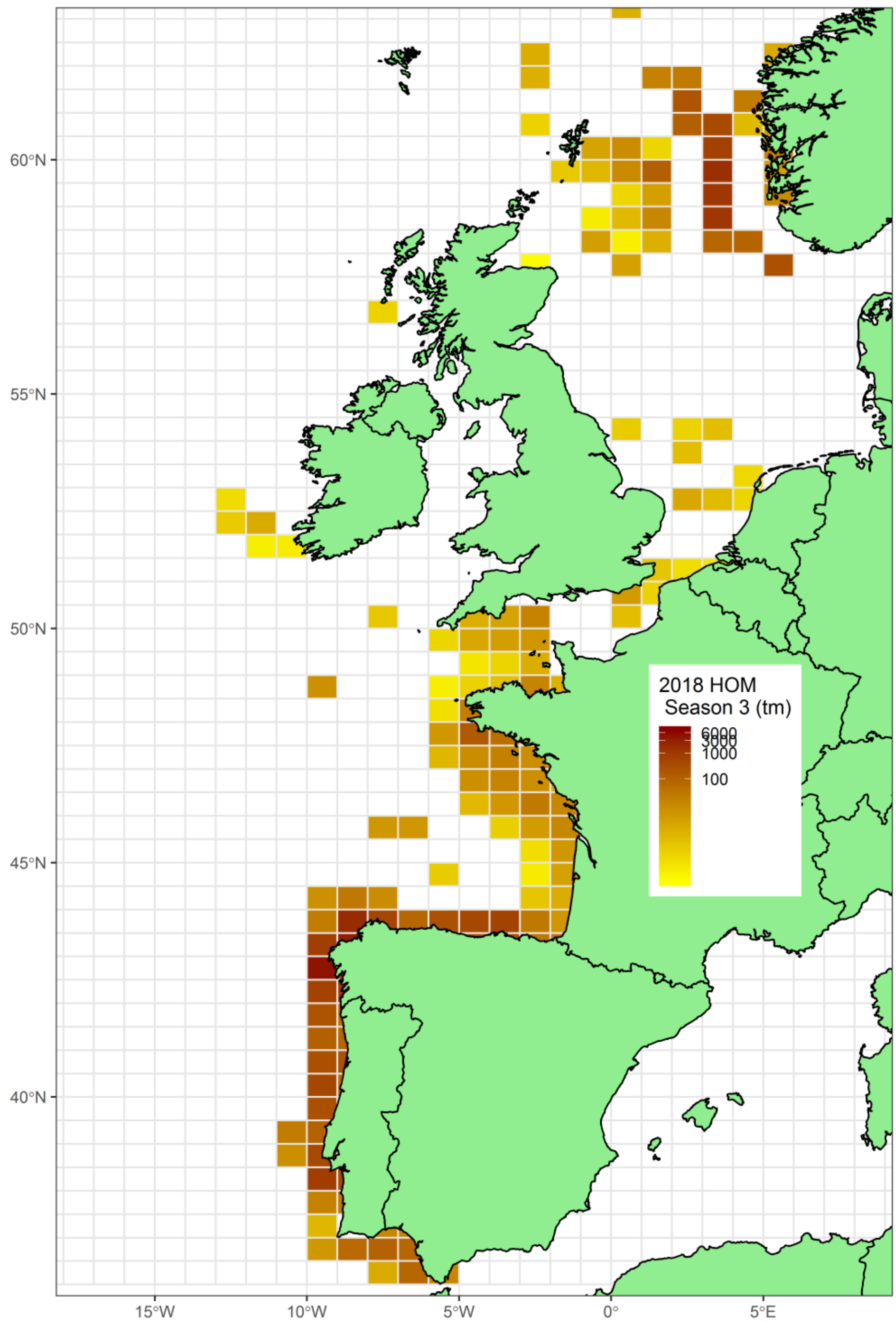

Figure 5.1.1c. Horse mackerel catches 3rd quarter 2018.

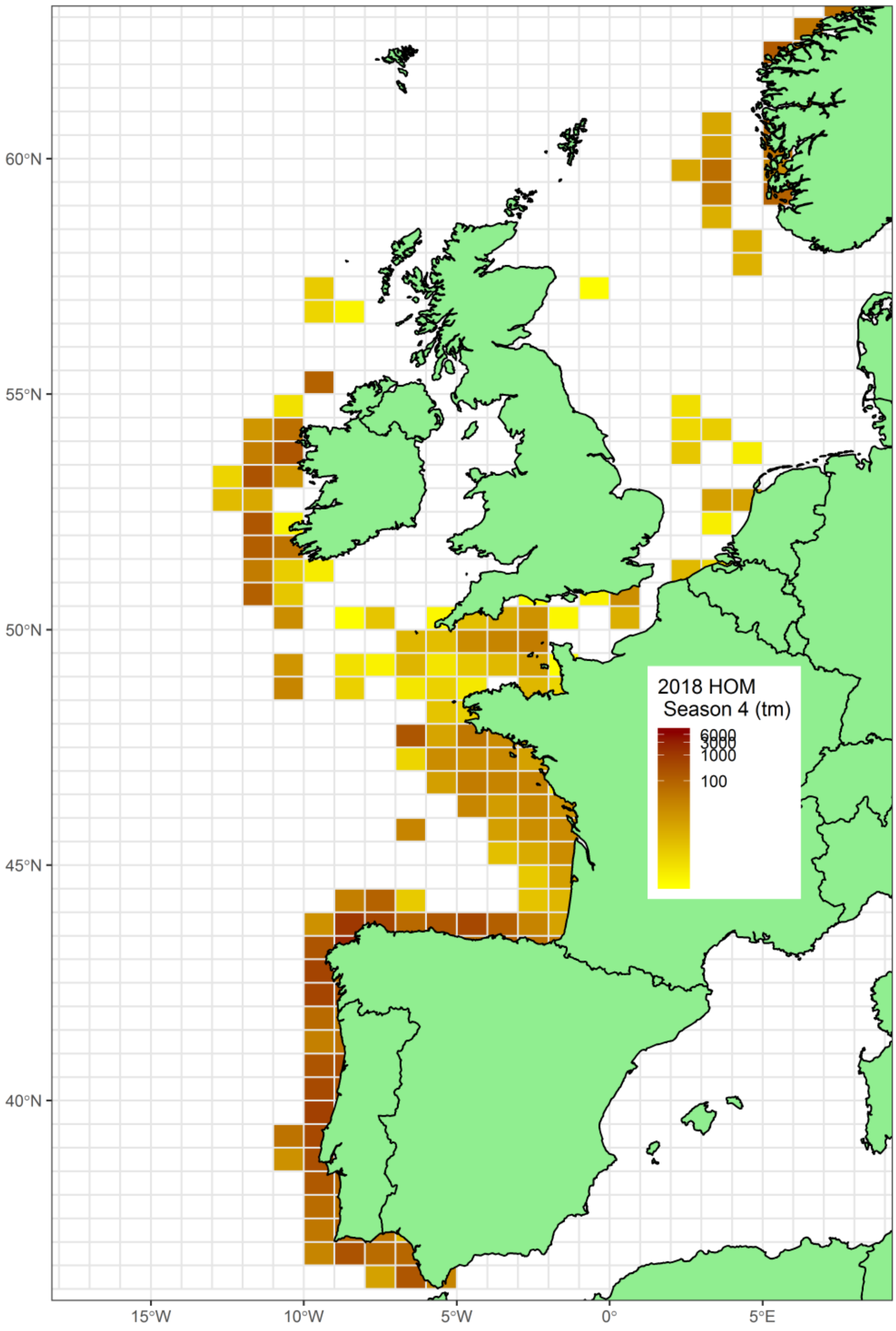

Figure 5.1.1d. Horse mackerel catches 4th quarter 2018.

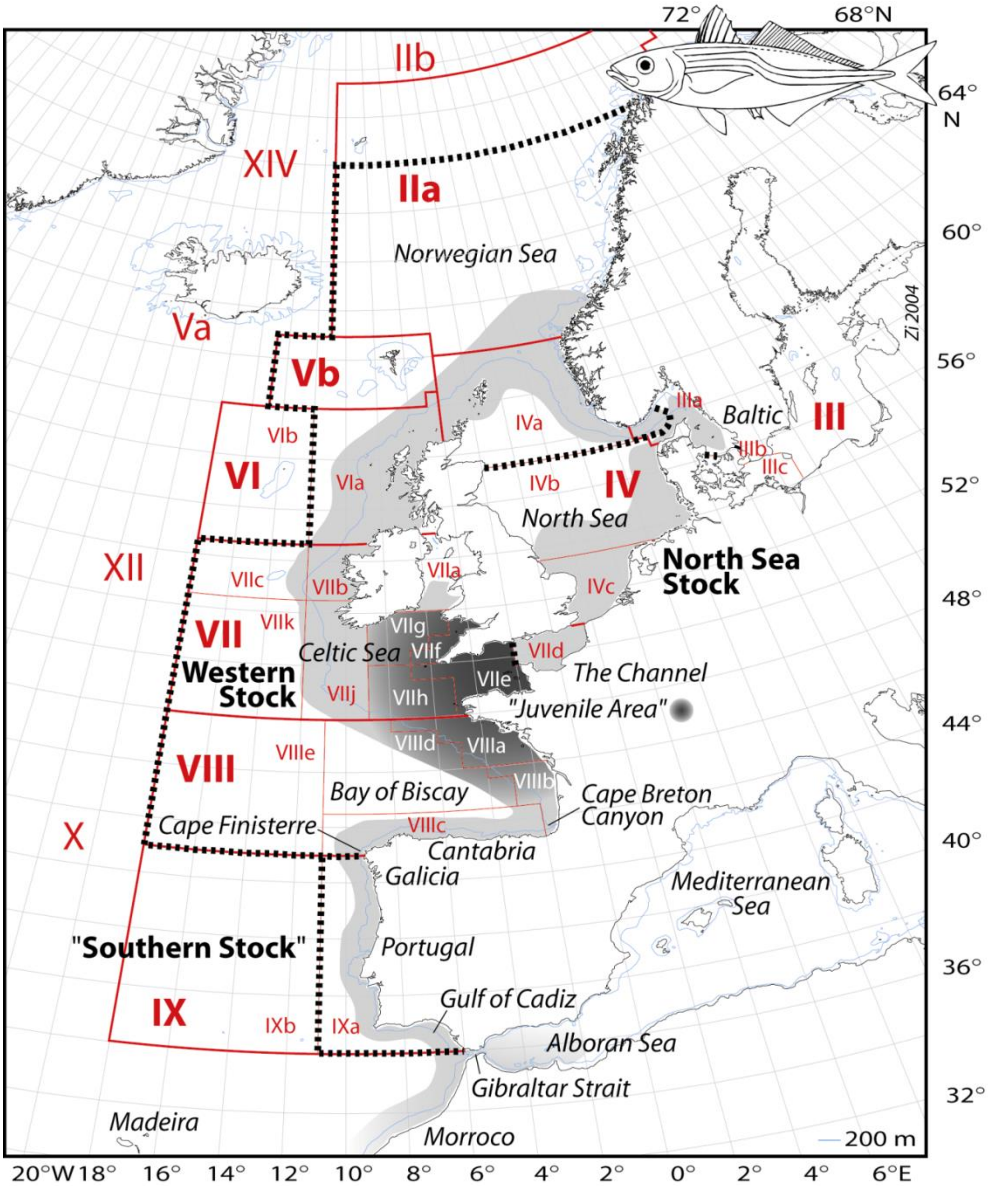

Figure 5.2.1: Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by the 2004 WG MHSA. Note that the "Juvenile Area" is currently only defined for the Western Stock distribution area – juveniles do also occur in other areas (like in Div. 7.d). Map source: GEBCO, polar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

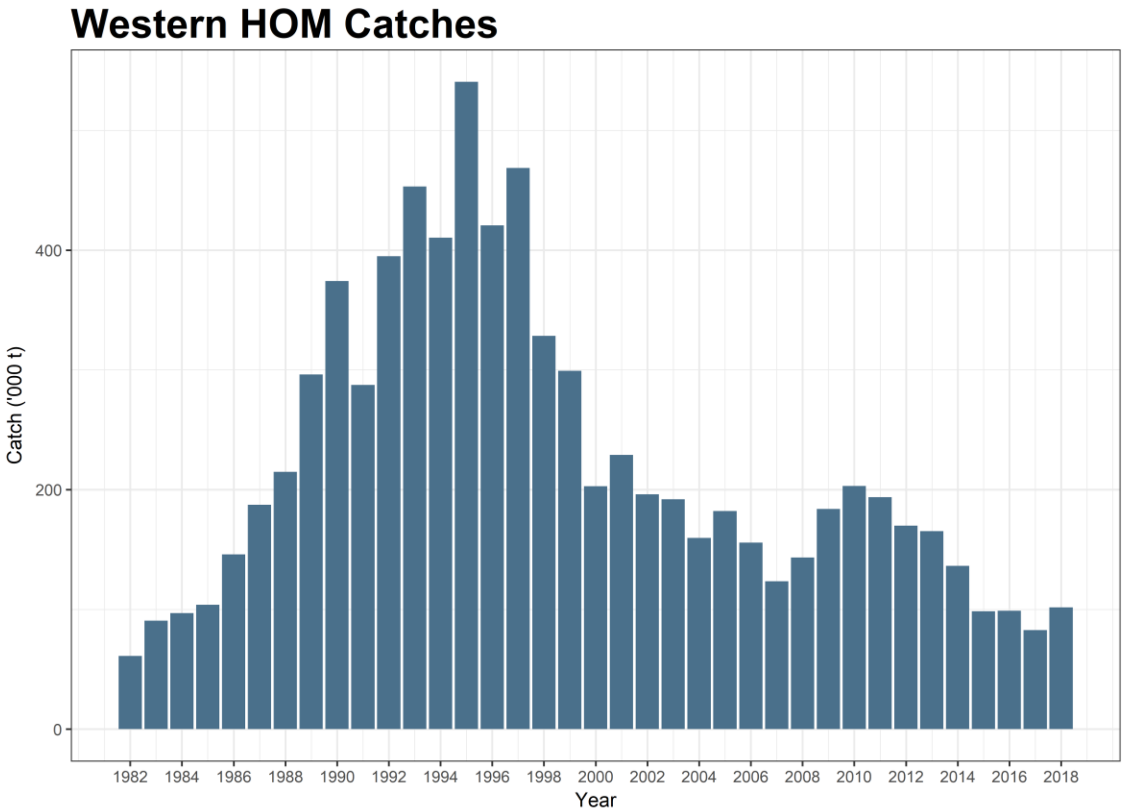

Figure 5.3.1. Total catch for Western Horse Mackerel stock, period 1982-2018.

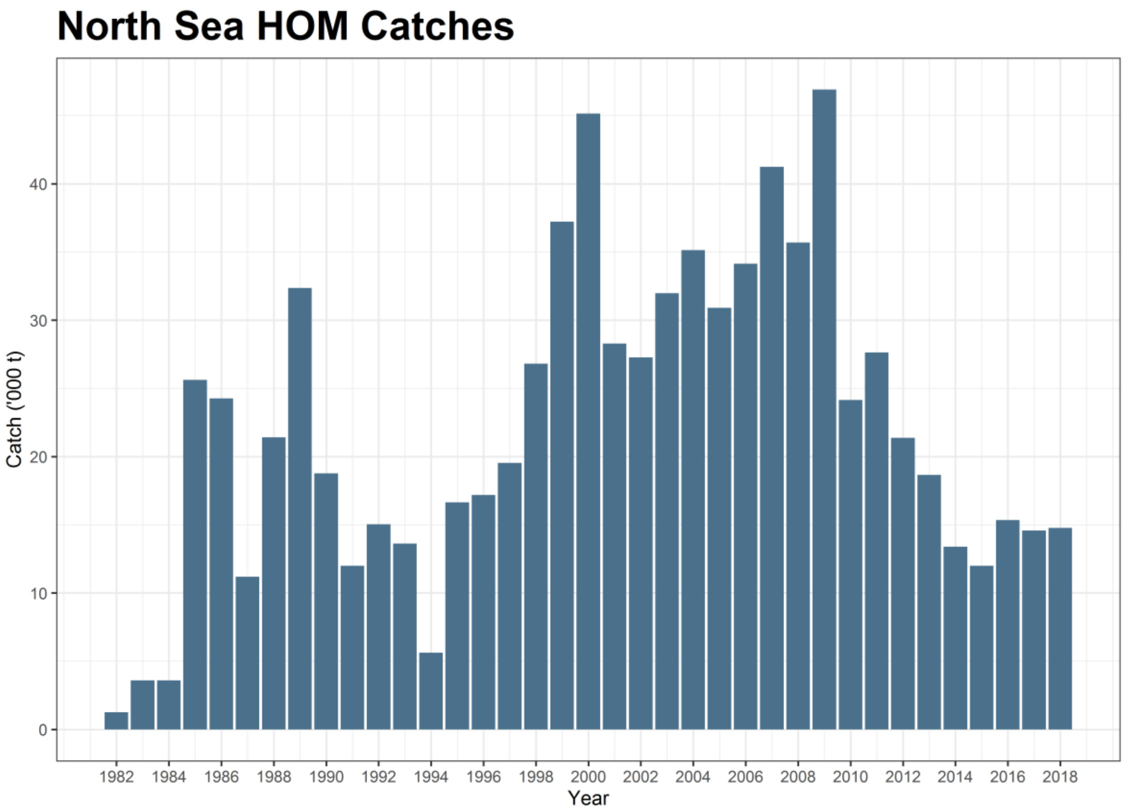

Figure 5.3.4. Total catch for North Sea Horse Mackerel stock, period 1982-2018

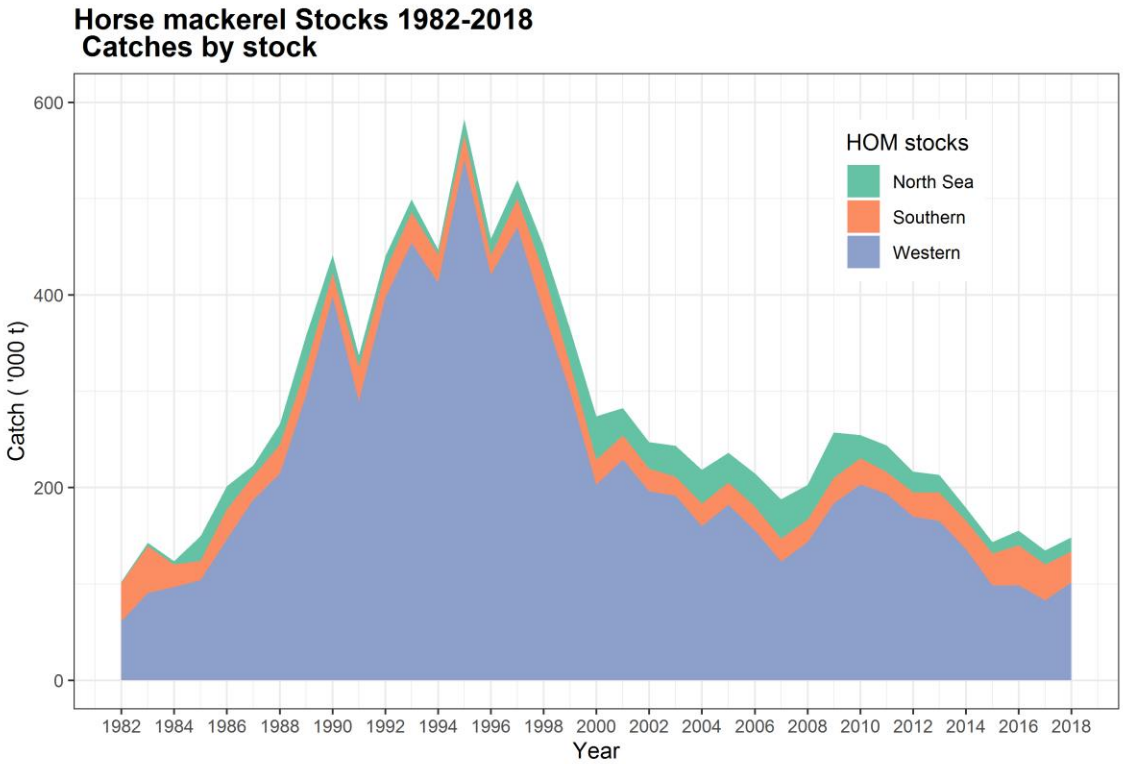

Figure 5.4.1 Horse mackerel general. Total catches in the northeast Atlantic during the period 1982—2018. The catches taken from the southern, western and North Sea horse mackerel stocks are shown in relation to the total catches in the northeast Atlantic. Catches from Div. 8.c were transferred from southern stock to western stock from 1982 onwards. Southern horse mackerel is assessed by ICES WGHANSA since 2011.

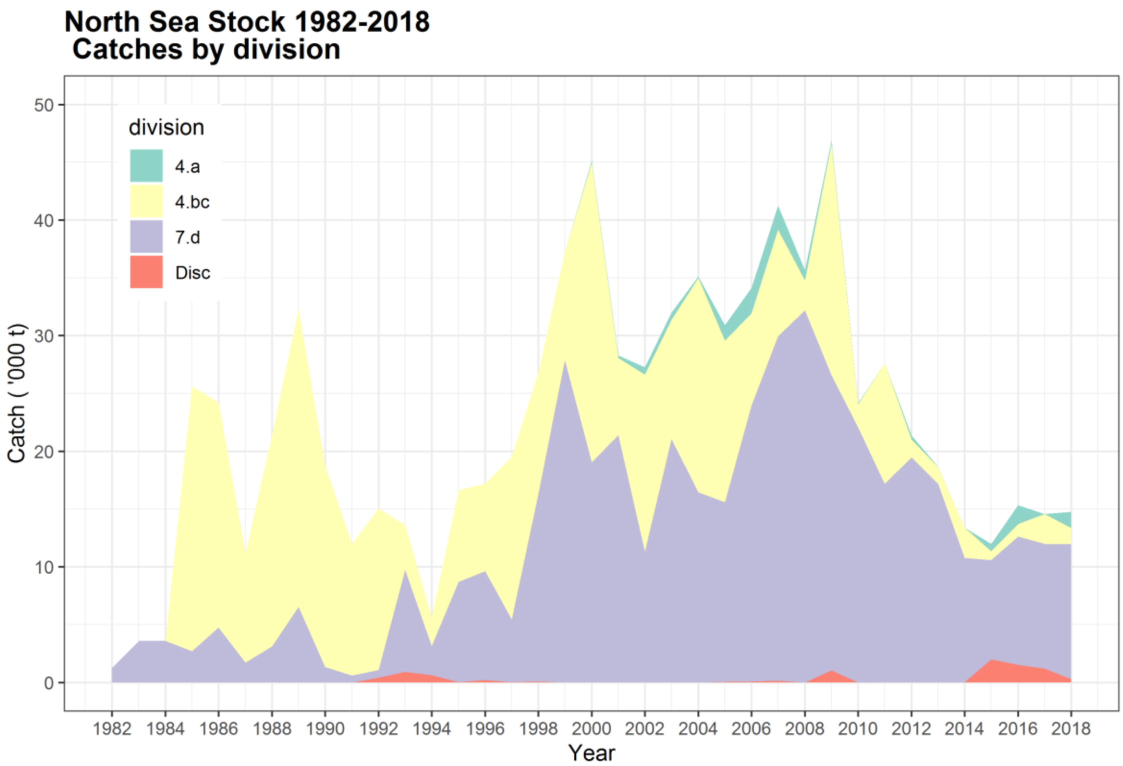

Figure 5.4.2. North Sea horse mackerel stock. Total catches by Division during the period 1982–2018.

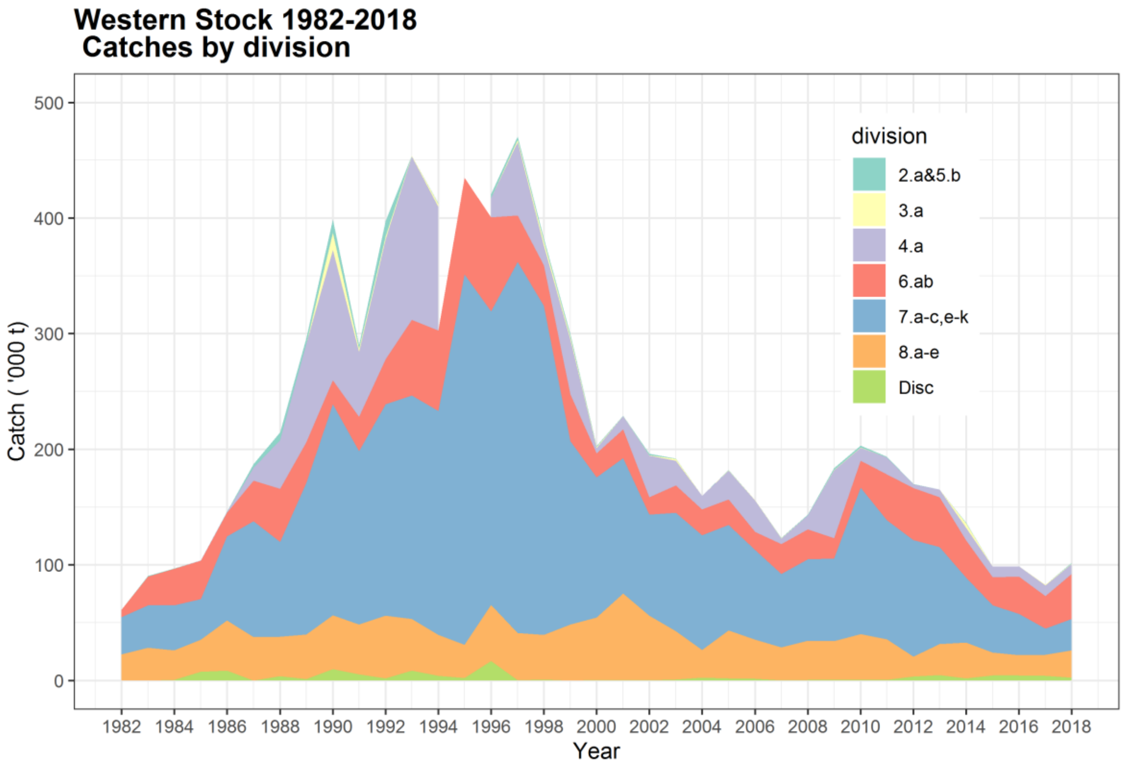

Figure 5.4.3. Western horse mackerel stock. Total catches by Sub-Area during the period 1982–2018.

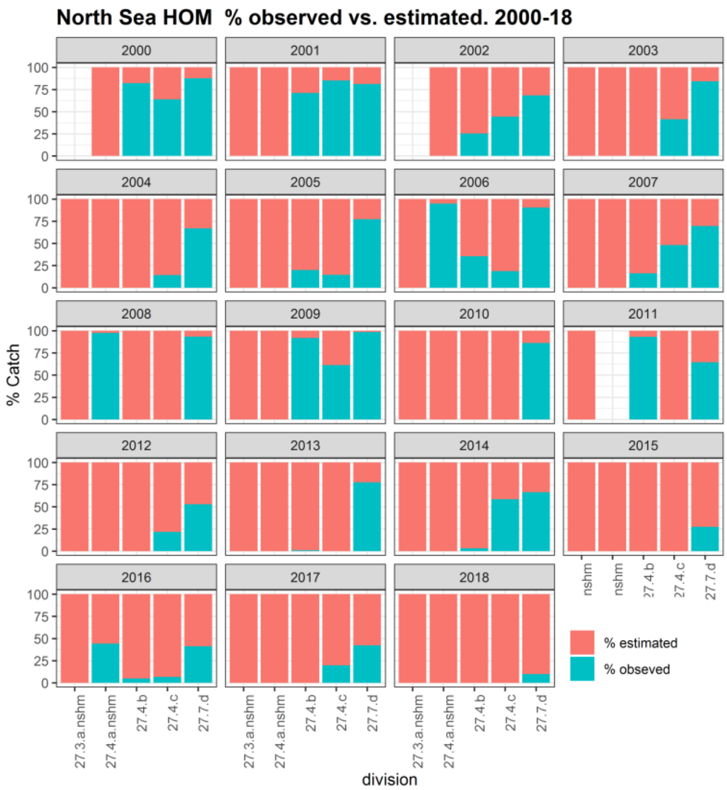

Figure 5.9.1 North Sea horse mackerel stock. Percentage sampled catch (blue) vs. unsampled catch (red) by division and year. Period 2000–2018.

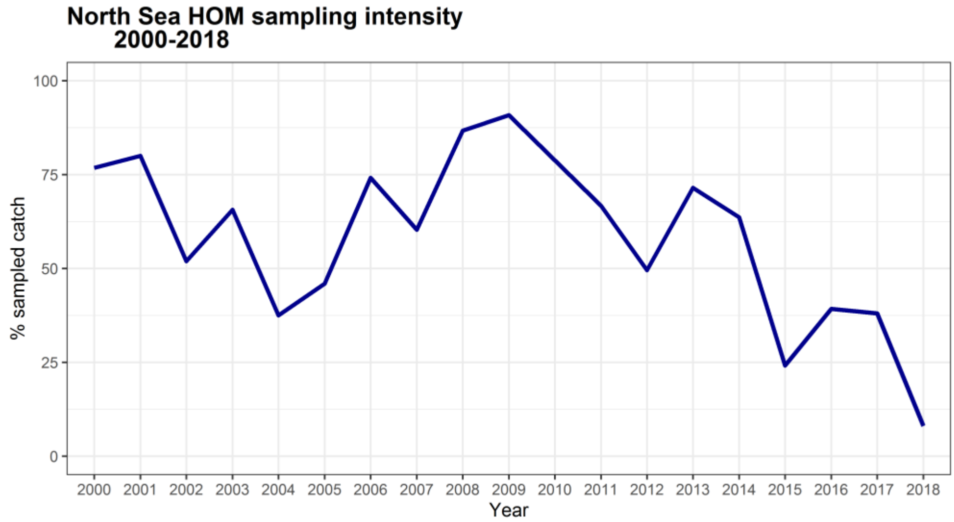

Figure 5.9.2. North Sea horse mackerel stock. Sampling intensity index as percentage sampled catch in total catch by year (Delayed submitted sample unconsidered). Period 2000–2018.

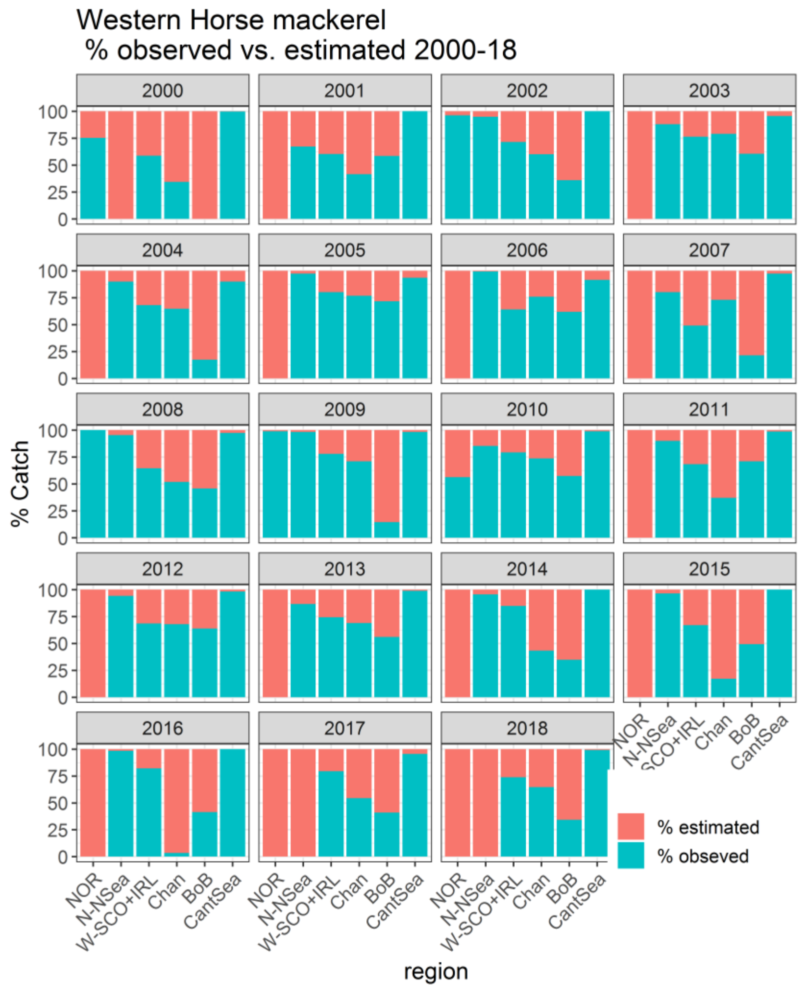

Figure 5.9.5. Western horse mackerel stock. Percentage sampled catch (blue) vs. unsampled catch (red) by division and year. Period 2000–2018. Area of distribution of Western stock was divided into different regions. Chan: (7.e,f,h); W-SCO+IRL (7.a-c, 7.j-k and 6.a); BoB (8.a,b,d); CanSea(8.c); N-Nsea (3.a and 4.a); NOR (2.a and 5.a).

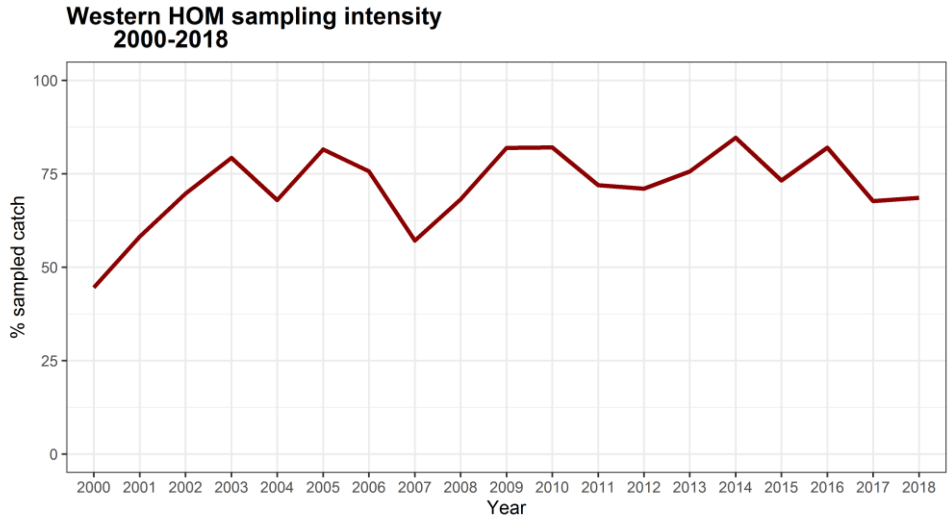

Figure 9.5.6. Western horse mackerel stock. Sampling intensity index as percentage sampled catch in total catch by year. Period 2000–2018.

6 North Sea Horse Mackerel: Divisions 27.4.a (Q1 and Q2), 27.3.a (excluding Western Skagerrak Q3 and Q4), 27.4.b, 27.4.c and 27.7.d

6.1 ICES Advice Applicable to 2019

In 2012 the North Sea horse mackerel (NSHM) was classified as a category 5 stock, based on the ICES approach to data-limited stocks (DLS). Since then, a progressive reduction of TAC was advised by ICES, from 25500 tonnes in 2013–2014 to 15200 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 Channel Ground Fish Survey (CGFS) since 2014. Additionally, in 2015, information on discards in non-directed fisheries became available that has been taking into account in the advice since 2017.

In 2017, this stock was benchmarked and the NS-IBTS and CGFS survey indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHM stock was upgraded to category 3. The joint index showed an increasing trend in 2014 to 2016, but was followed by a decrease again in 2017. In 2018, the index remained at a similar level as in 2017. The application of the HCR 3.1 (ICES, 2012, comparison of the two latest index values with the three preceding values multiplied by the recent advised catch) resulted in an index ratio (mean index value of two most recent years (A) over mean index value of three preceding years (B); A/B ratio) of 0.39, meaning that an 80% uncertainty cap was applied. Length Based DLS methods indicated that the F in 2018 was slightly above the F_{MSY} proxy, and stock size relative to reference points was unknown. However, since the precautionary buffer was already applied to the advice in 2017 (i.e. within the last three years), the precautionary buffer was not applied this time. This resulted in a catch advice for 2020 and 2021 of 14014 tonnes. Considering the 5.05% discards rate (based on 2017 and 2018), the corresponding wanted catches are advised to be 13305 tonnes.

6.2 Fishery of North Sea horse mackerel stock

Based on historical catches taken by the Danish industrial fleet for reduction into fish-meal and fish oil in the 1970s and 1980s, approximately 48% of the EU North Sea horse mackerel TAC was taken by Denmark. Catches were taken in the fourth quarter mainly in Divisions 27.4.b and 27.7.d. The 1990s saw a drop in the value of industrial fish, limited fishing opportunities and steep increases in fuel costs that affected the Danish quota uptake. In 2001, an individual quota scheme for a number of species was introduced in Denmark, but not for North Sea horse mackerel. This lead to a rapid restructuring and lower capacity of the Danish fleet, which in combination with the above mentioned factors led to a decrease of the Danish North Sea horse mackerel catches.

Since the 1990's, a larger portion of catches has been taken in a directed horse mackerel fishery for human consumption by the Dutch freezer-trawler fleet. This is possible because Denmark has traded parts of its quota with the Netherlands for other species. However due to the structure of the Danish quota management setup only a limited amount of quota can be made available for swaps with other countries. These practical implications of the management scheme largely explain the consistent underutilisation of the TAC over the period 2010-2013 (approximately

50%). However, following the sharp reduction in TAC in 2014 uptake increased significantly in the years thereafter (Figure 6.2.1). In 2018 97% of the TAC was used, with the highest catches taken by the Netherlands, followed by UK, Germany, France and Norway (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 North Sea horse mackerel (Section 5, Table 5.4.1). The catches were relatively low during the period 1982—1997 with an average of 18000 tonnes, but increased between 1998 (30500 tonnes) and 2000 (45130 tonnes). From 2000 to 2010, the catches varied between 24149 and 45883 tonnes. Since 2014 a steep decline in catches is observed, both due to the reduction in the TAC since 2014 but also due to the underutilization of the quota. In 2018 the catch was 14773 tonnes, with 80.5% of total catch being caught in area 27.7.d.

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 2018, the Netherlands accounted for most of the landings, followed by UK, Germany, France and Norway (Figure 6.2.5). The majority was caught in quarter 4 in 27.7d, whereas the Norwegian catches were taken during quarter 1 and 2 in 27.4.a. Most of the discards were reported in 27.7.d during quarters 2, 3 and 4 by the French bottom-trawl fleet. Discarding in the target pelagic fisheries is considered negligible. New information in 2015 from bottom-trawl fisheries not directed at horse mackerel indicated an overall discard rate of 16.7% for the stock as a whole, while in 2016 this rate was 10%. In 2017 and 2018 the discard rate was 8.3 and 1.8%, respectively. Complete discard information for earlier years has not been submitted to ICES. However, information from national discard reports for the non-directed bottom-trawl fisheries indicates a similar level of discarding in earlier years.

6.3 Biological Data

6.3.1 Catch in Numbers at Age

In 2018, as already occurred in recent years, there has been a marked reduction in the coverage of biological sampling. Samples were only available from one country in Q4 area 27.7.d at the start of the working group. Another sampling for the same area but for Q3 and Q4 were only submitted during the working group. Due to time constraints the sample could not be included in the analysis for this year. Even included the delayed delivered sample, only a small part (40%) of landings was sampled, in comparison to 2013 and 2014 when 71% and 63% were sampled respectively (Section 5, Figure 5.9.1). In addition, this low coverage is carried mostly out in quarter Q4 in division 27.7.d. Although most landed catch was taken from 27.7.d and in quarter 4 (82% of landings in division 27.7.d and 68% in quarter Q4, Figure 6.3.1) still parts of the landings were fished in other areas and quarters. 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. Due to the low level of sampling effort out of area 27.7.d, there is not enough information to represent the age distribution in those areas, and hence shown is only the one observed in 27.7.d in quarters 3 and 4. Catch-at-age for the whole period 1995-2018 are given in Table 6.3.2 and in Figures 6.3.1-6.3.3, but these are also based only on Q4, 27.7.d data in 2018. 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. In parallel to the rejuvenation of catches, the comparison of catch-at-age data after 1998 by area (Figure 6.3.2) shows that since 2010 commercial catches have increased in area 27.7.d in comparison to the areas 27.3.a and 4a,b and c where the opposite pattern was found.

Although the 2015 cohort seems to be clear in the catch-at-age distribution, in general cohort structure is not clearly detectible in the data. In addition to the low sampling levels, this may partly be due to the shifts in distribution of the fishery. In addition, it may partly be due to age reading difficulties, which are a known to be encountered (e.g. Bolle *et al*., 2011). Most clearly detectable is the relatively large 2001 year class, although it is not clearly present in the catch in all years. There are indications that environmental circumstance may be an important factor (possibly stronger than stock size) contributing to spawning success in horse mackerel. This is for example illustrated by the largest year classes (1982 and 2001) observed in the Western stock which incidentally were produced at the lowest observed stock sizes. Since 2001 is considered to have been a relatively strong year class in the Western stock as well, it is plausible that circumstances in the North Sea were similar to those in Western areas and also allowed for relatively high spawning success in the North Sea.

Lastly, potential mixing of fish from the Western and North Sea stock in area 27.7.d and 27.7.e in winter may also confuse the cohort signals. For example, the large recruitment in the Western stock may have led to more of these fish being located in the North Sea stock area as age 1 fish in 2002. On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated in 2015 with University College Dublin (Ireland) with the intention of clarifying the mixing among the North Sea and the Western horse mackerel stocks. Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015, 2016, and 2017, with a specific focus on the separation between horse mackerel in the western waters and horse mackerel in the North Sea. The result of the research indicated that the western horse mackerel stock is clearly genetically different from the North Sea stock (Farrell and Carlsson, 2019). However, with the available information it was not yet possible to determine the genetic composition of mixed samples of non-spawning fish. Therefore, a full genome sequencing exercise has been initiated to allow for future mixed-sample analyses. Results are expected to be available in 2020.

6.3.2 Mean weight at age and mean length at age

The mean weight and mean length-at-age in the commercial catches of 2018 are presented in Tables 6.3.3 and 6.3.4 respectively by quarter. As explained for the distribution of catch-at-age by area, due to the sampling coverage in 2018 are only detailed for Q3 and Q4 for area 27.7.d.

The mean annual weight and length over the period 2000–2018 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 2006 there seems to be a slight but steady increase in both weight and length until 2015, when a declining pattern is observed. It may be hypothesized that this is due to density-dependent effects, due to the relatively successful recruitment of 2015.

6.3.3 Maturity-at-age

Peak spawning in the North Sea falls 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 estimate the negative gradient of the slope and get an estimate of total mortality (Z). Fully selected ages 3 to 14 from the 1992–2016 period provide complete data for the 1992 to 2006 cohorts (Figure 6.4.1). The estimated negative gradients by cohort (Figure 6.4.2) indicate an increasing trend in total mortality for the period examined, with a marked increment in the cohorts 2005 and 2006. However, due to the low quality of the signals for some cohorts these Z estimates has to be considered with caution.

An analysis of the catch number at age data carried out in 2011 showed that only the 1vs.2, 2vs.3, 7vs.8 and 8vs.9 age groups were positively and significantly correlated in the catch. This analysis was not updated this year but these results suggest limitations in the catch-at-age data.

6.4.2 Assessment models and alternative methods to estimate the biomass

In 2002 Rückert *et al.* estimated the North Sea horse mackerel biomass based on a ratio estimate that related CPUE data from the IBTS to CPUE data of whiting (*Merlangius merlangus*). The applied method assumes that length specific catchability of whiting and horse mackerel are the same for the IBTS gear. Subsequently, they use the total biomass of whiting derived from an analytical stock assessment (MSVPA) to estimate the relationship between CPUE and biomass.

At the 2014 WGWIDE meeting some exploratory model fits were attempted with the JAXass model, using the data available. The JAXass (JAX assessment) model is a simple statistical catch-at-age model fitted to an age-aggregated index of (2+) biomass, total catch data and proportions at age from the catch. It is based on Per Sparre's "separable VPA" model, an ad hoc method tested for the first time at WGWIDE in 2003, and later 2004. A new analysis using this model was also done in 2007 using an IBTS index. In 2014 the model has been coded in ADMB (Fournier *et al.*, 2012) and updated with an improved objective function (dnorm), extra years of data and new methods for calculating the index (see above).

Difficulties in fitting an assessment model for this stock include:

- Unclear stock boundaries
- Difficulty aging horse mackerel
- Lack of strong cohort signals in CAA 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 in the MSE 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.

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. Therefore egg abundance could only be considered a relative index of SSB. The mackerel egg surveys in the North Sea do not cover the spawning area of horse mackerel.

6.4.3.2 IBTS Survey Data

Many pelagic species are frequently found close to the bottom during daytime (which is when the 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). Eaton *et al.* (1983) argued that horse mackerel of 2 years and older are predominantly demersal in habit. Therefore, in the absence of a targeted survey for this stock, the IBTS is considered a reasonable alternative. IBTS data are also used in the assessment of the southern horse mackerel stock.

IBTS data from quarter Q3 were obtained from DATRAS and analysed. Based on a comparison of IBTS data from all 4 quarters in the period 1991—1996, Rückert *et al.* (2002) showed that horse mackerel catches in the IBTS were most abundant in the third quarter of the year. In 2013 WGWIDE considered that using an 'exploitable biomass index' estimated with the abundance by haul of individuals larger than 20 cm is the most appropriate for the purpose of interpreting trend in the stock.

To create indices, a subset of ICES rectangles was selected. Rectangles that were not covered by the survey more than once during the period 1991—2012 were excluded from the index area. In 2012, WGWIDE expressed concern that the previously selected index area did not sufficiently cover the distribution area of the stock, especially in years that the stock would be relatively more abundant and spread out more. Rückert *et al.* (2002) also identified a larger distribution area of the North Sea stock. Based on the above, 61 rectangles were identified to be included in the index area as shown in Figure 6.4.3.

6.4.3.3 The French Channel Groundfish Survey (CGFS) in Q4

In order to improve data basis for the North Sea horse mackerel assessment, alternative survey indices have been explored. Previous indices used 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 Ground Fish Survey in 27.7.d (CGFS) in Quarter 4. The CGFS is carried out since 1990 and has frequent captures of horse mackerel. Though this survey is conducted in a different quarter than the North Sea IBTS, the observed seasonal migration patterns of horse mackerel indicate that fish move into the channel following quarter Q3, so the timing is considered appropriate.

In 2015, the RV "Gwen Drez" was replaced by the RV "Thalassa" to carry out the CGFS survey. In 2014 an inter-calibration process was conducted to quantify the differences in catchability for a large number of species. ICES reviewed this inter-calibration exercise and found a number of drawbacks that may undermine the reliability of the estimated conversion factors. The main concerns were:

- The analyses were limited in the number of tows. Considering that a number of these tows could be zeros for one of the two vessels and possibly resulting in highly uncertain estimates.
- Lack of length-specific correction factor.

- At a standardized depth of 50 m and above, wing spread estimates for the R/V Thalassa as measured by the MARPORT sensor were deemed erroneous, which may question the validity of estimated area swept by the net on the R/V Thalassa and the effect it may have on correction factors for species caught at depth at 50m and greater.
- A number of tow locations including areas outside 27.7.d were excluded. Changing the depth range of a survey can add serious bias in the calibration and the current approach seems to be ignoring this issue.
- Correction coefficients were not measured without error.

However, these limitations were considered by WGWIDE to be of minor importance for the North Sea horse mackerel since:

- Despite being still a low sample size the North Sea horse mackerel was present in all the 32 paired hauls.
- There are no important differences in size distribution (Figure 6.4.4).
- The analysis with and without the areas excluded in the new sampling design did not show important differences (ICES, 2017).
- CPUE of North Sea horse mackerel for hauls deeper than 50 m was relatively low (Figure 6.4.5), and it is expected than the potential problems in determining the conversion factor bellow that depth range would have a relatively minor impact in the estimated abundance.

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

6.4.3.4 Calculation of CPUE

Data of the NS-IBTS (Q3) and CGFS (Q4) for were extracted from the DATRAS website, and a similar temporal coverage was selected (1992-2018). However, during the process of calculating CPUE (in number per hour trawling) a mistake was discovered in the calculation for the years 2016 and 2017. The assessment of 2017 and 2018 did not take into account potential sub-sampling of survey catches and the type of data that is reported in DATRAS (either raw and unstandardized, or already standardized as CPUE). Figures 6.4.6 and 6.4.7 demonstrate the differences in the survey index values between the old and new calculation of CPUE for the exploitable and juvenile sub-stock, respectively. The values of 2016 and 2017 with the old calculation are higher than with the new calculation, thereby changing the perception of the stock trend. However, using the index values of the new calculation would not have changed the catch advise for 2018 and 2019. This is because the index (A/B) ratio would still have indicated an increasing stock trend of more than 20%, and thus would have led to the application of the precautionary buffer.

6.4.3.5 Modelling the survey data

In January 2017, a benchmark process was conducted for NSHM (ICES, 2017). Based on capacity to model the overdispersion and the high proportion of zero values in the survey catch data, the hurdle model was considered the best option of all model alternatives tested. The log-likelihood ratio test, the AIC and the evidence ratio statistic supported that the model that best represented the data was a hurdle model with Year and Survey as explanatory factors (including the interaction term) in the count model (GLM-negative binomial), and Year and Survey (without the interaction) in the zero model (GLM-binomial).

The probability of having a CPUE of zero was modelled by a logistic regression with a GLM-binomial distribution model:

$$logit(\pi_i) = Intercept_{zero} + Year_{i,zero} + Survey_{i,zero}$$

Where π_i is the mean probability of having a CPUE of zero in haul i as a function Year and Survey.

The expected CPUE of North Sea horse mackerel per haul i, conditional to not having a zero in hurdle models (not having a false zero in zero-inflated models), was modelled with a GLM-negative binomial distribution model:

$$\log(CPUE_i) = Intercept_{count} + Year_{i,count}\ x\ Survey_{i,count}$$

This model was used to synthesise the information from both the CGFS and IBTS and predict the average annual CPUE index as an indicator of trends in stock abundance. One model is created for the juvenile (<20cm) and for the exploitable (>20cm) sub-stock separately. The contribution of the two surveys to the combined index is weighted taken into consideration their respective surface coverage as well as the mean wing spread. This index model allowed upgrading the NSHM to a category 3 stock within the ICES classification.

The model for the adult sub-stock that was run this year returned a warning despite the fact that the model converged. All parameter coefficients were estimated, but not the standard error for the intercept and the parameter θ of the count model (GLM negative binomial). To check the robustness of the hurdle model, 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 zero-inflated model returned similar parameter coefficients as the hurdle model from 2018 that returned no warning (ICES, 2018), as well as similar index values as the hurdle model from this year. The hurdle model from this year and its resulting index values where thus considered robust. However, if the warning continues to appear in future assessments, more testing and further investigation is needed to resolve the warning.

6.4.4 Summary of index trends

The survey index for both the juvenile and exploitable sub-stock experienced a marked decline in the 1990s and fluctuated at relatively low levels thereafter (Figures 6.4.8; Table 6.4.1). This reduction was partly due to the decline of the average abundance per haul over time, but also due to the increase of hauls with zero catch of horse mackerel, particularly for the adult sub-stock in the NS-IBTS (Figure 6.4.9). Since 2013 a slight decrease in zero hauls was observed for the juvenile sub-stock (<20 cm) in both surveys. However, only for the NS-IBTS has the mean CPUE of juveniles increased, while it has decreased for the CGFS again after 2014 (Figure. 6.4.10). Because of the high weight of the NS-IBTS in the joint survey index, the joint survey index for the juvenile sub-stock shows an increasing but fluctuating trend since 2013 (Figure 6.4.8). The latter is likely caused due to some hauls with high catches of juveniles in 2016 and 2018 in the NS-IBTS (Figure 6.4.10). After the decline of the survey index for the adult sub-stock in 2017, the index value of 2018 remained at a similarly low level for each individual survey (Figure 6.4.10) as well as for the joint survey index (Figure 6.4.8).

The size distribution in the NS-IBTS suggest the entrance of a new cohort in 2018 (between 5-9 cm in the IBTS (Figure 6.4.11). The size distribution in the CGFS shows a small mode of 5–8 cm and a large mode of 10–13 cm (Figure 6.4.12). However, despite the index of abundance of individuals smaller than 20 cm could be considered a recruitment index, it has to be considered with caution. Preliminary examinations of how the juvenile (0–19cm) indices relate to subsequent exploitable abundance (20+ cm) do not indicate strong linkages. The very high juvenile indices in the early 2000s in the IBTS were not subsequently picked up in the exploitable component. Hence while increases in the juvenile indices are encouraging, whether these lead to increases in the exploitable component of the stock need to be confirmed in the future with observations in the 20+ cm indices.

6.4.5 Data Limited Stock methods and MSY proxy reference points

As part of the ICES approach to provide advice within the MSY framework for stocks of category 3 and 4, different Data Limited methods to estimate MSY proxy reference points for the North Sea horse mackerel were previously explored (Pérez-Rodríguez, 2017). The Length Based Indicators is the DLS method used in this assessment.

Although this length based method will have to be applied in the future to a longer time-series of catch length frequencies, so far only length data have been collected for 2016 to 2018. Data come from commercial catch sampling and the self-sampling programme of the PFA. All samples originate from region 27.7.d. In 2018, the F/F_{MSY} proxy based on the commercial catch samples indicated that fishing mortality was slightly above F_{MSY}, with F/F_{MSY}=1.048, as was also the case in 2016 and 2017 (Figure 6.4.13). Similarly, the F/F_{MSY} proxy based on the PFA self-sampling programme resulted in F/F_{MSY}=1.055 (Figure 6.4.13). These suggest that the fishing pressure is above F_{MSY}.

6.4.6 Ongoing work

To improve the knowledge base for North Sea horse mackerel about the degree of connection and migrations in between the North Sea and the Western Stock, catch sampling carried out by several pelagic fishery companies is being explored to give information on the separation between North Sea and Western horse mackerel. To improve the abundance indicators the potential application of a commercial fishery search time index will be explored. Horse mackerel is fished while it is very close to the bottom in relatively dispersed, small schools. The fishery is mostly executed using long hauls and there may be extensive search time involved. Handled in an appropriate statistical framework, taking into account the nature of the fishery and other factors such as seasonality and alternative fishing opportunities, the search time and catch rates could provide for an indication of changes in stock size over time. Catch rates in areas 27.7.e, 27.7.d and southern North Sea will be analysed from skippers' private logbooks.

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). However, with the available information it was not yet possible to determine the genetic composition of mixed samples of non-spawning fish. Therefore, a full genome sequencing exercise has been initiated to allow for future mixed-sample analyses. Results are expected to be available in 2020.

6.5 Basis for 2019 Advice. ICES DLS approach.

Stock advice for NSHM is biannual. In 2019 the advice for years 2020 and 2021 was provided. In 2016 it was the first time that the IBTS and CGFS were modelled together to produce a joint abundance index. The index indicated that the adult sub-stock did not further decline in 2018, but remained at similar low levels as in 2017, compared to higher levels in 2014 to 2016. There are some signs of improved recruitment in a number of consecutive years, but the trend of the abundance index for the juvenile sub-stock is fluctuating and, when separated, the two surveys, NS-IBTS and CGFS, do not show the same trend. It remains to be seen if the weak signs of improved recruitment result in higher adult abundance. Furthermore, the fisheries in the area mainly focusses on small fish. With this pattern of exploitation, mostly immature individuals are caught which might hinder the recovery of the stock by removing an important portion of the recent year classes before they enter the spawning stock. Related to this concern, in the autumn of 2018, the Pelagic Freezer-trawler Association (PFA, the Netherlands) has implemented a voluntary move-away scheme to avoid the catch of small horse mackerel in 27.7.d. The trigger in the move-away scheme was a catch of more than 25% in a haul consisting of small fish (more than 250 fish in a carton of 23 kg, equating to around 18 cm). When the trigger was reached, all vessels of the PFA would be notified and instructed to move out of the area with a distance of at least 5 NM. The move-away scheme has been triggered 17 times during the period October – December 2018.

The index ratio (A/B ratio) for the adult sub-stock in the current assessment was 0.39. This indicates that the decline in the abundance index was more than 20%, and therefore, an 80% uncertainty cap was applied. The F/F_{MSY} ratio in 2018 was higher than 1, indicating that the fishing mortality is higher than F_{MSY}. Because the precautionary buffer was last applied in 2017 (i.e., within the last three years), the buffer was not applied in the current advice. Under these circumstances and based on the last year's catch advice of 17517 tonnes, ICES advices that catches of NSHM in 2020 and 2021 should be no more than 14014 tonnes. With an average discard rate of 5.05% (2017-2018), this implies landings of no more than 13305 tonnes.

6.6 Management considerations

In the past, Division 27.7.d was included in the management area for Western horse mackerel together with Divisions 27.2.a, 27.7.a–c, 27.7.e–k, 27.8.a, 27.8.b, 27.8.d, 27.8.e, Subarea 6, EU and international waters of Division 5.b, and international waters of Subareas 12 and 14. ICES considers Division 27.7.d 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 of 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.

6.7 References

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6.8 Tables

Table 6.3.1. North Sea Horse Mackerel stock. Catch in numbers (1000) by quarter and area in 2018 (distribution based on one sample only due to low sampling level)

	Number/1000					
1Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0.01	17.06	0.00	0.01	36.92	54.00
1	0.60	1431.57	0.17	0.94	3098.01	4531.30
2	1.07	2564.35	0.31	1.69	5549.40	8116.83
3	0.29	688.42	0.08	0.45	1489.79	2179.04
4	0.72	1709.26	0.21	1.13	3698.93	5410.24
5	0.10	236.72	0.03	0.16	512.27	749.27
6	0.02	35.97	0.00	0.02	77.85	113.86
7	0.02	37.10	0.00	0.02	80.28	117.42
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
Sum	2.81	6720.45	0.81	4.43	14543.44	21271.95
2Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0.00	15.15	0.40	4.27	6.17	25.99
1	0.25	1271.31	33.22	357.99	517.71	2180.49
2	0.45	2277.27	59.50	641.27	927.37	3905.87
3	0.12	611.36	15.97	172.15	248.96	1048.57
4	0.30	1517.91	39.66	427.43	618.14	2603.44
5	0.04	210.22	5.49	59.20	85.61	360.55

6	0.01	31.94	0.83	9.00	13.01	54.79
7	0.01	32.94	0.86	9.28	13.42	56.50
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
Sum	1.18	5968.10	155.94	1680.58	2430.39	10236.20
3Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0	0	4.21	1.50	41.03	46.74
1	0	0	353.31	125.54	3443.08	3921.92
2	0	0	632.88	224.87	6167.52	7025.27
3	0	0	169.90	60.37	1655.73	1886.00
4	0	0	421.84	149.89	4110.93	4682.66
5	0	0	58.42	20.76	569.33	648.51
6	0	0	8.88	3.15	86.52	98.55
7	0	0	9.16	3.25	89.22	101.63
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
Sum	0	0	1658.61	589.32	16163.34	18411.28

4Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0	0	0.16	20.86	179.06	200.07
1	0	0	13.39	1750.26	15025.14	16788.79
2	0	0	23.99	3135.20	26914.25	30073.44
3	0	0	6.44	841.67	7225.38	8073.50
4	0	0	15.99	2089.75	17939.58	20045.33
5	0	0	2.21	289.41	2484.47	2776.10
6	0	0	0.34	43.98	377.54	421.86
7	0	0	0.35	45.35	389.34	435.04
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
Sum	0	0	62.88	8216.49	70534.77	78814.14

14Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0.01	32.21	4.77	26.63	263.18	326.80
1	0.85	2702.88	400.10	2234.73	22083.94	27422.51
2	1.53	4841.62	716.69	4003.03	39558.54	49121.41
3	0.41	1299.78	192.40	1074.65	10619.86	13187.10
4	1.02	3227.16	477.70	2668.20	26367.58	32741.67
5	0.14	446.93	66.16	369.52	3651.68	4534.43
6	0.02	67.92	10.05	56.15	554.91	689.06
7	0.02	70.04	10.37	57.91	572.25	710.58
8	0	0	0	0	0	0

9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
Sum	4.00	12688.55	1878.24	10490.82	103671.94	128733.56

Table 6.3.2. Numbers at age (millions), weight at age (kg) and length at age (cm) for the North Sea horse mackerel 1995-2017 in the commercial fleet catches (2018 distribution based on one sample only due to low sampling level).

Catch number																								
Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	1.8	4.6	12.6	2.3	12.4	70.2	12.8	60.4	13.8	15.7	52.4	5	3.4	1.7	34.1	3.3	8.1	9.5	7.6	15.4	49.7	3.6	20.7	27.42
2	3.1	13.8	27.2	22.1	31.5	78	36.4	16.8	56.2	17.5	29.8	23.7	15.5	8.8	13.9	22.5	23.3	24.3	10	15.3	23.8	65.2	20.9	49.12
3	7.2	11	14.1	36.7	23.1	28.4	174.3	19.3	23.4	34.4	27.8	61.5	22.8	36.1	28.4	10.7	76.5	20.4	21.3	8.7	10.1	15.9	62.6	13.19
4	10.3	11.9	14.9	38.8	17.6	21.4	87.8	11.9	33.2	14.5	12.6	40.9	82.6	16.7	22.1	15.7	37.3	40.2	22.2	30.2	5.8	9.8	10.2	32.74
5	12.1	9.6	14.6	20.8	23.1	31.3	18.5	5.6	26.9	27.8	16.7	73	71.2	36.4	17.3	23.7	14.6	25.8	27.1	13.8	7.2	7.7	6	4.53
6	13.2	12.5	12.4	12.1	26.2	19.6	11.5	5.8	10.6	20.2	5.2	23.4	30.5	36.1	16.3	15.9	9.9	20.8	6	7.1	3.8	5.7	3.4	0.69
7	11.4	8	10.1	14	20.6	19.5	18.3	5.5	6.3	10.6	2.9	13.7	23.9	27.3	21.5	27.6	5.8	3.1	7.2	2.7	3.3	2.5	2.8	0.71
8	12.6	6.6	8.6	10.8	21.8	9	14.7	10.5	9.6	3.8	2.4	5.9	17.3	21.9	47.1	5.6	6	5	4.3	3.4	1.4	5.1	2.4	
9	7.3	1.5	2.5	8.3	12.9	11.5	10.2	6.3	10.9	5.4	3.8	1.6	7.9	10.2	11.2	6.3	3.4	4.6	4	0.9	1.6	1.2	0.9	
10	5.9	5.3	0.8	4	8.2	9	10	6.8	1.5	11	5.8	1.4	1.7	7.5	9.3	8.3	10.1	1.5	5.4	1	0.9	0.1	0.3	
11	0	0.3	0.3	2.7	2.1	7	9.6	5.1	3.4	6.2	2.3	0.2	0.6	1.9	7.2	2.9	6.9	0.5	3.7	1.3	0.2	0.1	0.5	
12	8.8	1.3	0.3	0.7	0.4	3.1	5.4	3	3.3	4.5	4.1	1.7	0.2	2.1	3.7	0.3	3.6	0.1	1	0.4	0.9	0.4	0	
13	0.2	8.9		1.8	1.4	1.6	3.7	2.2	2.3	6.2	2.5	0.6	0.7	0.4	0.3	0.3	0.8		0.6	0	0.2	1.4	0	
14	4.4	8	1.4	0.3	3.8		2	1.3	3.4	2.3	9.9	1	0.7	2.4	0.9	0.2	0.3	0.2	0	0.2	0.2	0.5	0.3	
15+				5.1	4	12.2	5.8	2.7	4.7	8.5	9.6	0.8		1	6.1	1.1	0.5		0.1	0.1			0.3	

kg	weight																							
Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	0.076	0.107	0.063	0.063	0.063	0.075	0.067	0.066	0.075	0.076	0.07	0.074	0.615	0.063	0.074	0.077	0.061	0.069	0.077	0.078	0.062	0.07	0.06	0.061
2	0.126	0.123	0.102	0.102	0.102	0.1	0.09	0.096	0.105	0.105	0.087	0.098	0.081	0.096	0.087	0.101	0.092	0.09	0.099	0.11	0.099	0.093	0.086	0.093
3	0.125	0.143	0.126	0.126	0.126	0.137	0.094	0.129	0.122	0.122	0.104	0.116	0.104	0.109	0.113	0.118	0.096	0.118	0.112	0.113	0.13	0.115	0.113	0.131
4	0.133	0.156	0.142	0.142	0.142	0.152	0.117	0.155	0.136	0.146	0.133	0.124	0.115	0.125	0.134	0.137	0.115	0.142	0.138	0.135	0.15	0.126	0.131	0.147
5	0.146	0.177	0.16	0.16	0.16	0.165	0.159	0.171	0.164	0.174	0.159	0.141	0.13	0.145	0.152	0.155	0.145	0.152	0.166	0.144	0.169	0.158	0.173	0.170
6	0.164	0.187	0.175	0.175	0.175	0.192	0.183	0.195	0.18	0.198	0.197	0.178	0.163	0.161	0.182	0.183	0.166	0.172	0.18	0.177	0.196	0.155	0.189	0.189
7	0.161	0.203	0.199	0.199	0.199	0.194	0.198	0.216	0.193	0.224	0.238	0.212	0.192	0.193	0.195	0.206	0.193	0.183	0.2	0.184	0.26	0.162	0.177	0.201
8	0.178	0.195	0.231	0.231	0.231	0.216	0.201	0.227	0.212	0.229	0.248	0.247	0.197	0.221	0.258	0.199	0.193	0.188	0.216	0.201	0.29	0.235	0.188	
9	0.165	0.218	0.25	0.25	0.25	0.244	0.237	0.228	0.24	0.256	0.259	0.236	0.257	0.286	0.253	0.241	0.305	0.212	0.223	0.222	0.265	0.246	0.222	
10	0.173	0.241	0.259	0.259	0.259	0.283	0.246	0.253	0.27	0.29	0.287	0.286	0.255	0.295	0.322	0.227	0.334	0.204	0.226	0.22	0.312	0.359	0.233	
11	0.317	0.307	0.3	0.3	0.3	0.286	0.26	0.303	0.24	0.3	0.335	0.237	0.517	0.273	0.422	0.284	0.345	0.275	0.242	0.264	0.262	0.369	0.257	

kg	**weight**																						
12	0.233	0.211	0.329	0.329	0.329	0.354	0.286	0.293	0.298	0.297	0.349	0.261	0.279	0.309	0.447	0.234	0.408	0.195	0.263	0.287	0.318	0.379	
13	0.241	0.258	0.367	0.367	0.367	0.316	0.287	0.317	0.356	0.301	0.338	0.267	0.339	0.375	0.383	0.288	0.474		0.262	0.252	0.351	0.242	
14	0.348	0.277	0.299	0.299	0.299		0.295	0.32	0.316	0.338	0.373	0.302	0.414	0.277	0.362	0.315	0.415	0.187	0.559	0.408	0.235	0.39	0.214
15+	0.348	0.277	0.36	0.36	0.36	0.35	0.336	0.389	0.353	0.402	0.375	0.404		0.389	0.46	0.351	0.475		0.339	0.273		0.378	0.26

cm	**length**																							
Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	19.2	19.2	19.2	19.2	19.2	19.1	19.5	19.4	20.3	19.8	18.1	20.1	19.9	20	20.3	20.8	19.2	19.9	20.9	20.4	19.8	20	19.1	19.5
2	22	22	22	22	22	21.5	21.5	21.7	22.3	22.2	21.5	22	20.8	21.6	21.6	22.6	21.7	21.7	22.4	22.9	22.9	22	21.3	22.2
3	23.5	23.5	23.5	23.5	23.5	23.9	21.9	23.8	23.7	23.6	22.9	23.4	22.5	23.2	23.2	23.9	23	23.5	23.5	23.6	24.6	23.6	23.3	24.7
4	24.8	24.8	24.8	24.8	24.8	24.9	23.4	25.4	24.6	25.2	24.7	24.1	23.6	24.1	24.6	25	24.5	25	25.3	24.8	25.8	24.8	24.1	25.6
5	25.5	25.5	25.5	25.5	25.5	26	26.7	26.3	26.2	26.6	25.9	25.4	24.4	25.6	25.8	25.7	25.9	25.7	27	25.4	26.6	26.4	26.7	26.8
6	26.4	26.4	26.4	26.4	26.4	27.6	27.5	27.4	27.3	27.5	27.7	27	26.6	26.3	27.2	27.1	27.6	27	27.1	27.3	28.2	26.1	27.5	27.5
7	27.2	27.2	27.2	27.2	27.2	28.1	28.1	28.6	28.2	28.8	29.8	28.6	27.8	28.1	28.1	28.3	27.7	27.1	28.3	27.5	30.4	27.5	27.5	28.0
8	29.2	29.2	29.2	29.2	29.2	28.6	28.5	29.3	29	29.2	30.4	29.8	28.1	28.8	30.6	28.4	27.8	27	28.9	28	31.7	30.2	28	
9	29.5	29.5	29.5	29.5	29.5	29.9	29.8	29.4	29.9	30.4	30.8	30.8	30.1	31.2	31.1	30.2	31.9	28.6	29.2	28.8	30.5	30.5	29.1	
10	29.5	29.5	29.5	29.5	29.5	31.2	30.2	30.3	30.9	31.4	31.8	31.5	31	31.8	32.5	30	32.5	28	29.5	29.2	32.5	34.7	29.5	
11	30.6	30.6	30.6	30.6	30.6	31.5	30.7	31.4	30.7	31.9	33.8	31.2	39.5	31.6	35	32.2	33.2	30.1	30	30.7	31.5	35.2	31.1	
12	32.1	32.1	32.1	32.1	32.1	33.6	32	31.6	31.9	31.7	35.6	30.8	31.5	32.2	35.3	30.8	34.6	27.5	30.4	30.6	32.3	35.5		
13	33.3	33.3	33.3	33.3	33.3	33.3	31.7	32.4	32.8	31.9	34	32.1	33.4	33.9	34	31.8	36.4		32.1	30	32.5	31.5		
14	31.1	31.1	31.1	31.1	31.1		32.1	32.4	32.5	33	34.4	32.5	34.5	32.3	34.2	33	36	27.5	38.5	36	30.5	36.1	30.5	
15+	32.5	32.5	32.5	32.5	32.5	33.8	33.4	34.3	33.6	34.8	35.2	35.3		35.1	36.1	34.5	36.9		34.2	32.5		36.1	31.5	

Table 6.3.3. North Sea Horse Mackerel stock. Mean weight at age (kg) in the catch by area for all quarters in 2018 (distribution based on one sample only due to low sampling level).

Q1-Q4						
Ages	27.3.a (Q1,2)	27.4.a(Q1,2)	27.4.b	27.4.c	27.7.d	Total
0	0.027	0.027	0.027	0.027	0.027	0.027
1	0.061	0.061	0.061	0.061	0.061	0.061
2	0.093	0.093	0.093	0.093	0.093	0.093
3	0.131	0.131	0.131	0.131	0.131	0.131
4	0.147	0.147	0.147	0.147	0.147	0.147
5	0.170	0.170	0.170	0.170	0.170	0.170
6	0.189	0.189	0.189	0.189	0.189	0.189
7	0.201	0.201	0.201	0.201	0.201	0.201
8						
9						
10						
11						
12						
13						
14						
15						

Table 6.3.4. North Sea Horse Mackerel stock. Mean length (cm) at age in the catch by area for all quarters in 2018 (distribution based on one sample only due to low sampling level).

1-4Q						
Ages	27.3.a (Q1,2)	27.4.a(Q1,2)	27.4.b	27.4.c	27.7.d	Total
0	15.1	15.1	15.1	15.1	15.1	15.1
1	19.5	19.5	19.5	19.5	19.5	19.5
2	22.2	22.2	22.2	22.2	22.2	22.2
3	24.7	24.7	24.7	24.7	24.7	24.7
4	25.6	25.6	25.6	25.6	25.6	25.6
5	26.8	26.8	26.8	26.8	26.8	26.8
6	27.5	27.5	27.5	27.5	27.5	27.5
7	28.0	28.0	28.0	28.0	28.0	28.0
8						
9						
10						
11						
12						
13						
14						
15						

Table 6.4.1. North Sea Horse Mackerel. CPUE Indices of abundance (individuals/hour) for juvenile (<20cm) and exploitable (>20cm) sub-stocks, estimated as a combined index for the NS-IBTS Q3 (North Sea only, no 27.7.d included) and the Channel Ground Fish Survey in Q4 (CGFS, 27.7.d). The survey indices are derived from the prediction of a hurdle model fit to data over the period 19922018.

	Juvenile sub-stock (<20 cm)			Exploitable sub-stock (>20 cm)		
Year	**Index**	**CI_low**	**CI_high**	**Index**	**CI_low**	**CI_high**
1992	4047	1958	8398	1449	580	3105
1993	1630	814	2990	555	272	987
1994	2561	1317	4756	1277	590	2446
1995	1997	1058	3671	1518	572	3067
1996	833	381	1834	1066	446	2116

	Juvenile sub-stock (<20 cm)			Exploitable sub-stock (>20 cm)		
Year	**Index**	**CI_low**	**CI_high**	**Index**	**CI_low**	**CI_high**
1997	2223	1023	4926	668	290	1259
1998	672	339	1279	413	191	777
1999	1343	734	2392	465	219	862
2000	973	532	2008	377	196	690
2001	2157	1139	4449	574	276	1026
2002	2512	1254	5062	436	217	851
2003	1801	970	3183	295	141	592
2004	934	500	1691	375	178	694
2005	839	468	1564	681	316	1337
2006	444	240	790	744	343	1519
2007	633	346	1147	354	155	741
2008	369	200	685	166	79	377
2009	730	399	1313	75	34	159
2010	1621	833	3188	210	88	413
2011	533	299	1101	242	109	501
2012	313	164	676	153	82	413
2013	1021	552	1956	108	48	251
2014	1530	844	2683	327	152	708
2015	1482	736	2885	442	192	937
2016	3033	1576	5919	442	193	827
2017	943	463	1896	145	65	333
2018	3195	1517	6844	172	79	371

6.9 Figures

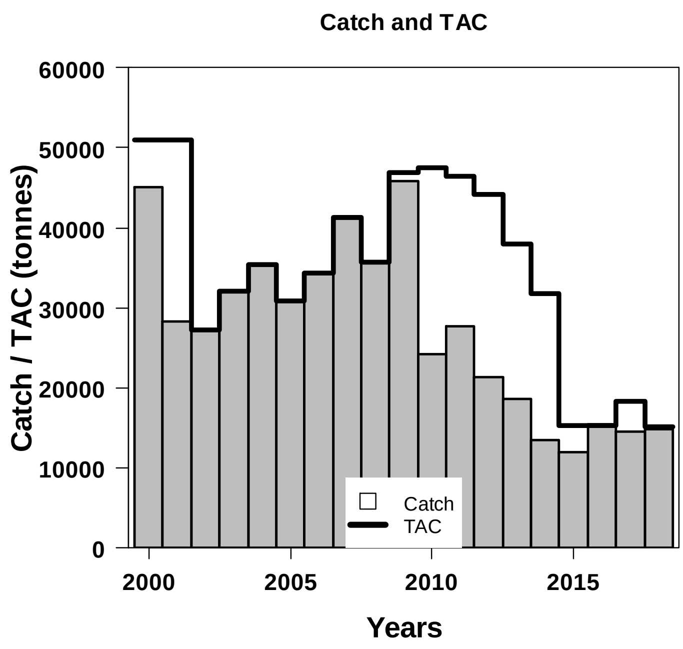


Figure 6.2.1. North Sea horse mackerel. Utilisation of quota from 2000 to 2018.

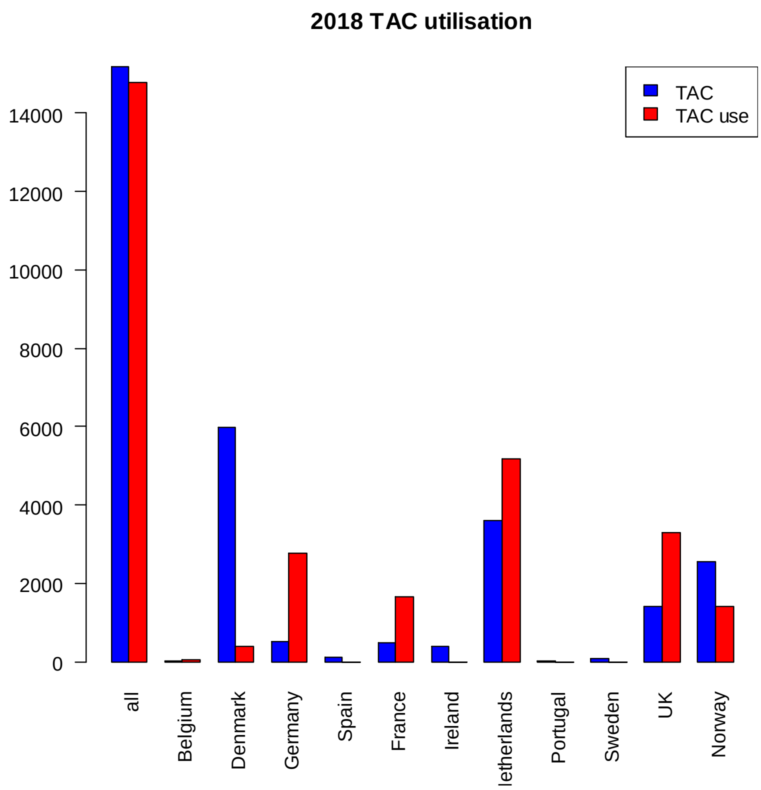


Figure 6.2.2. North Sea horse mackerel. Utilisation of quota by country in 2018.

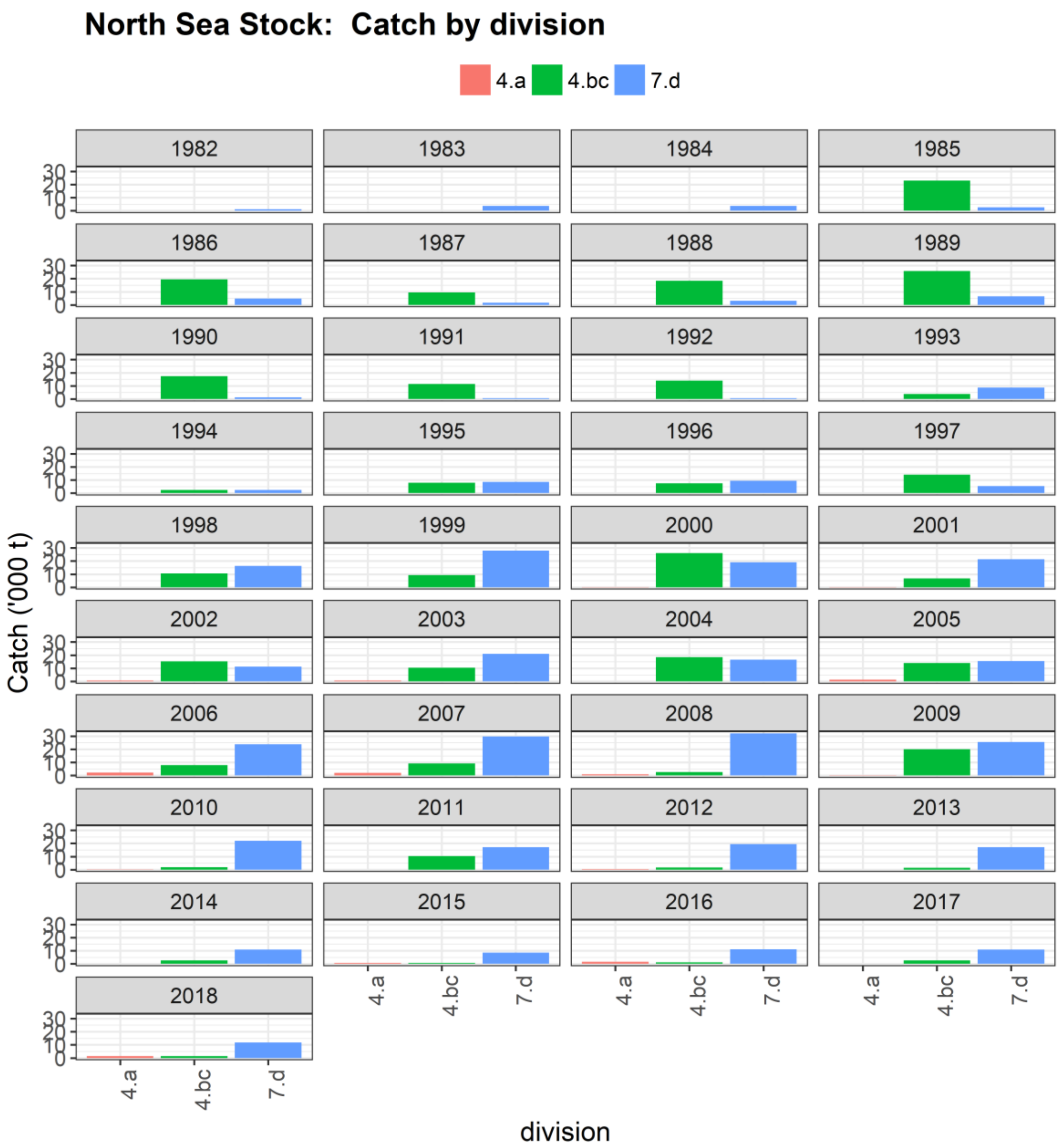


Figure 6.2.3. North Sea horse mackerel. Catch in (1000 t) by division and year from 1982 to 2018.

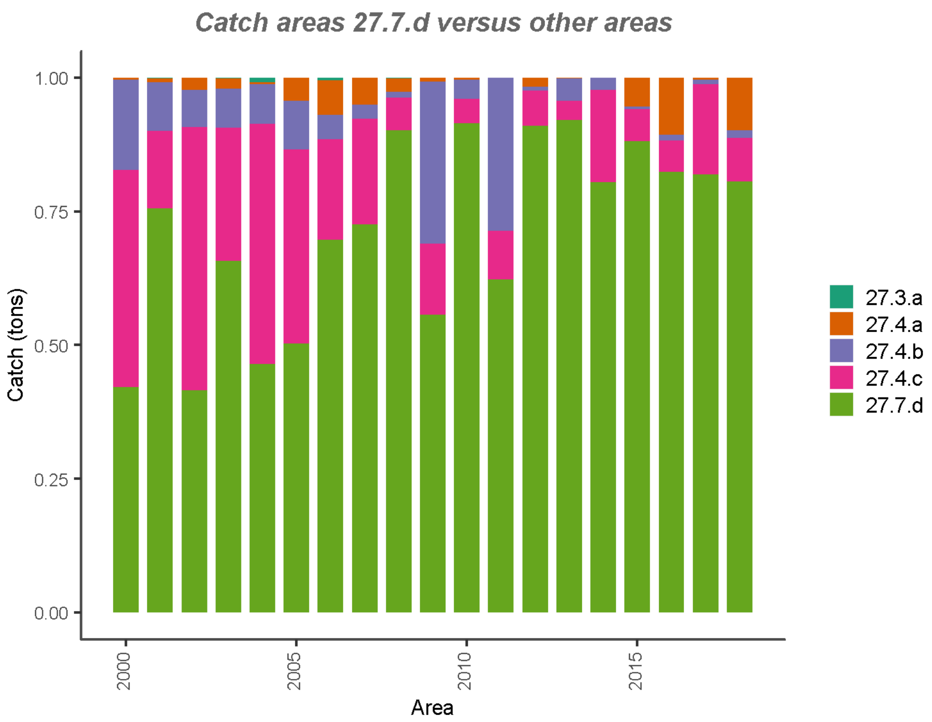
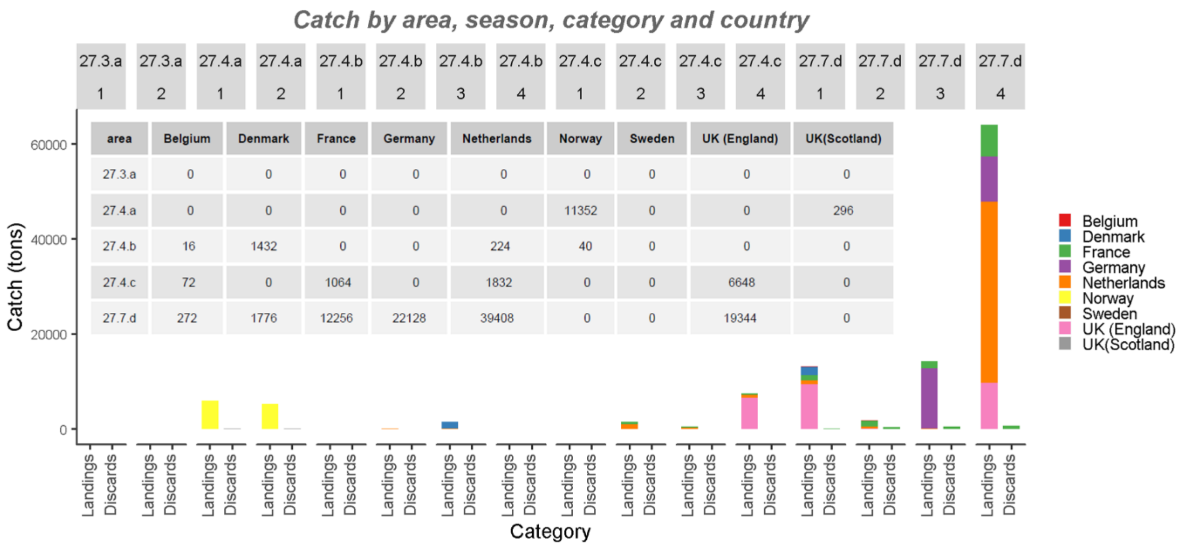


Figure 6.2.4. North Sea horse mackerel. Proportion of catches by ICES division from 2000 to 2018.



area	Belgium	Denmark	France	Germany	Netherlands	Norway	Sweden	UK (England)	UK(Scotland)
27.3.a	0	0	0	0	0	0	0	0	0
27.4.a	0	0	0	0	0	11352	0	0	296
27.4.b	16	1432	0	0	224	40	0	0	0
27.4.c	72	0	1064	0	1832	0	0	6648	0
27.7.d	272	1776	12256	22128	39408	0	0	19344	0

Figure 6.2.5. North Sea Horse Mackerel. Total catch (in tonnes) by ICES division, quarter, catch category and country in 2018.

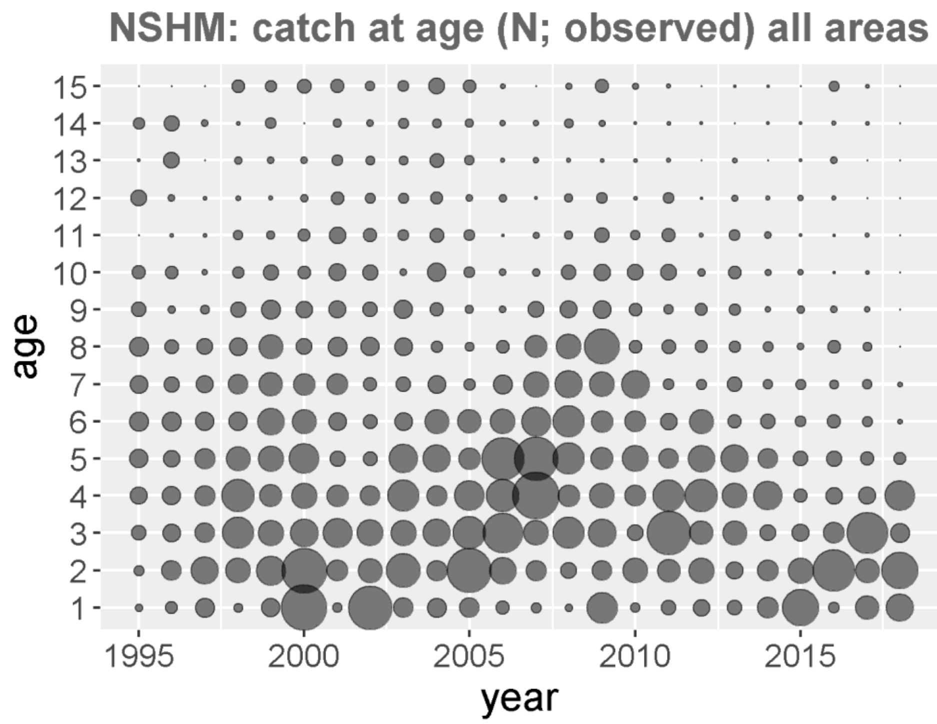
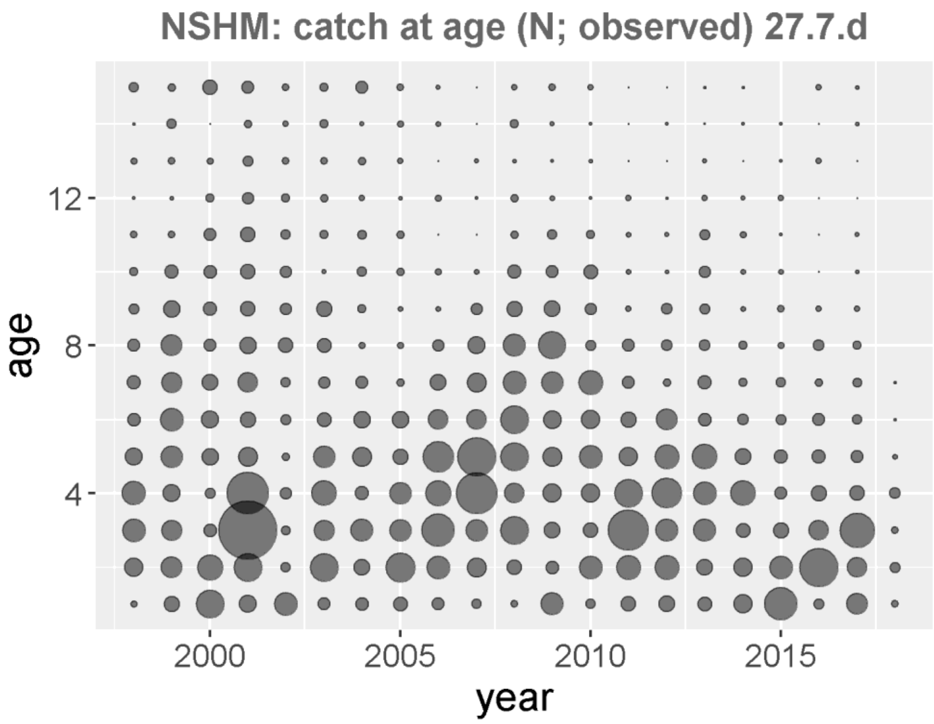


Figure 6.3.1. North Sea horse mackerel age distribution in the catch for 19952018. The area of bubbles is proportional to the catch number. Note that age 15 is a plus group.



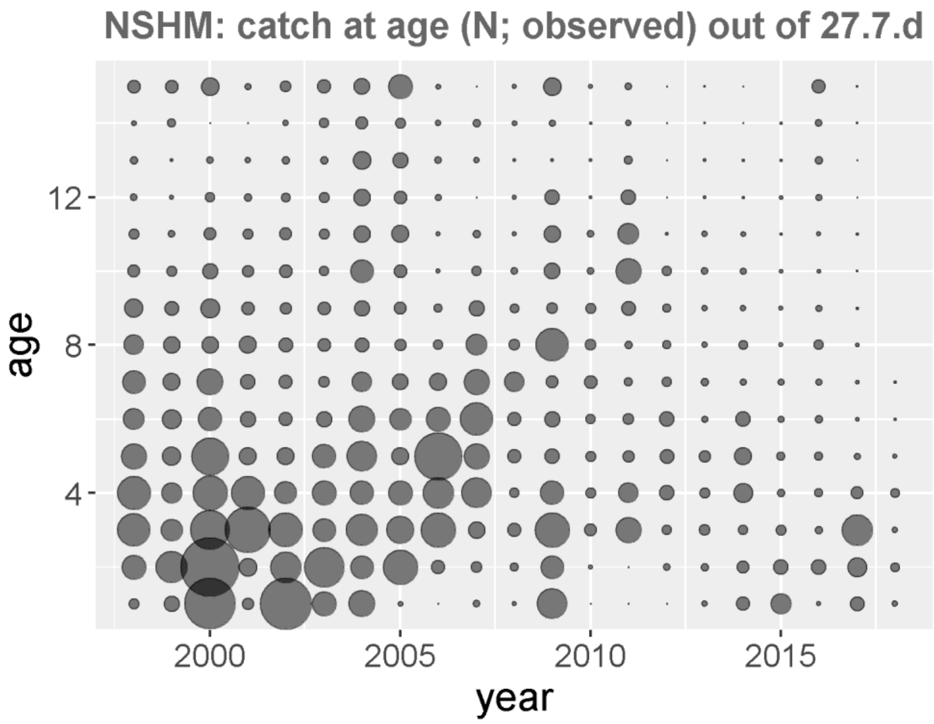


Figure 6.3.2. North Sea horse mackerel. Bubble plots of age distribution in the catch by area for 1998-2018 for area 7.d (upper panel) and out of 7.d (bottom panel). The area of bubbles is proportional to the total catch number for the stock. Note that age 15 is a plus group.

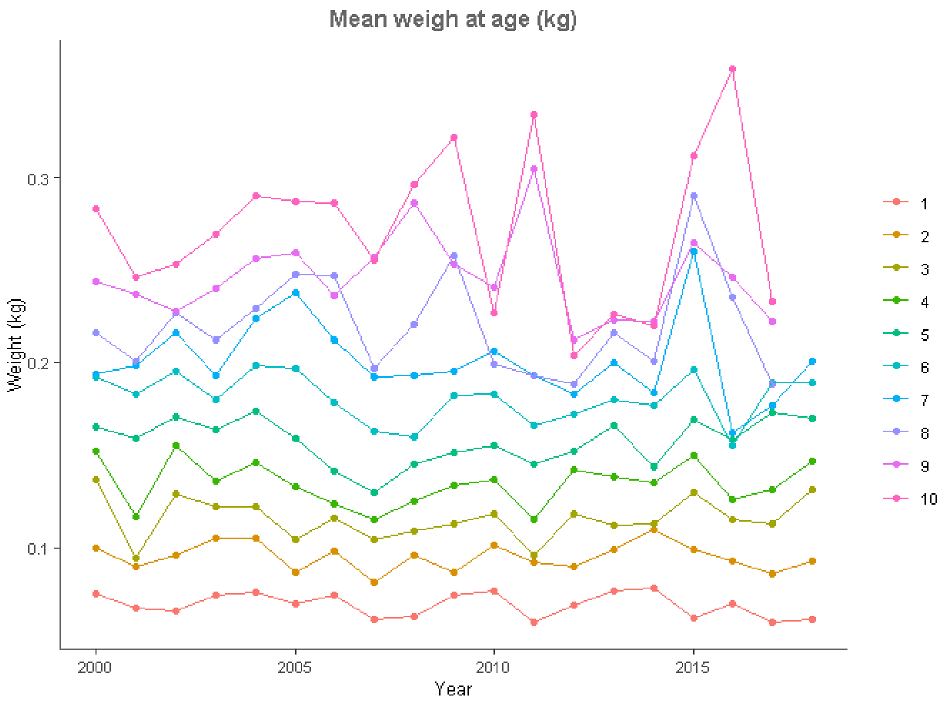


Figure 6.3.3. North Sea horse mackerel. Mean weight at age in commercial catches over the period 20002018.

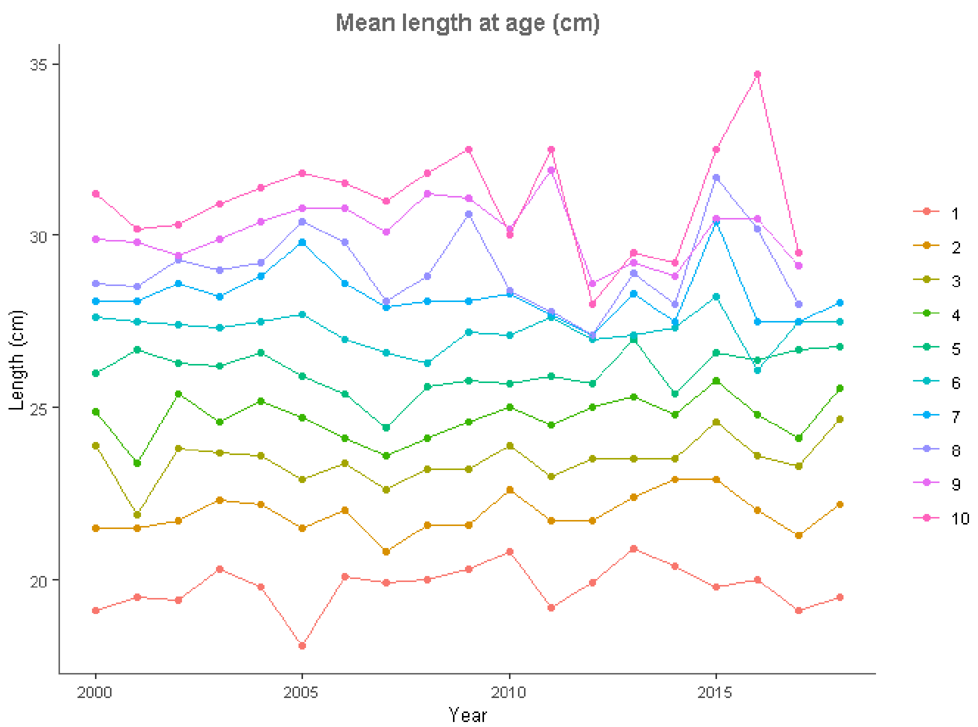


Figure 6.3.4. North Sea horse mackerel. Mean length at age in commercial catches over the period 20002018.

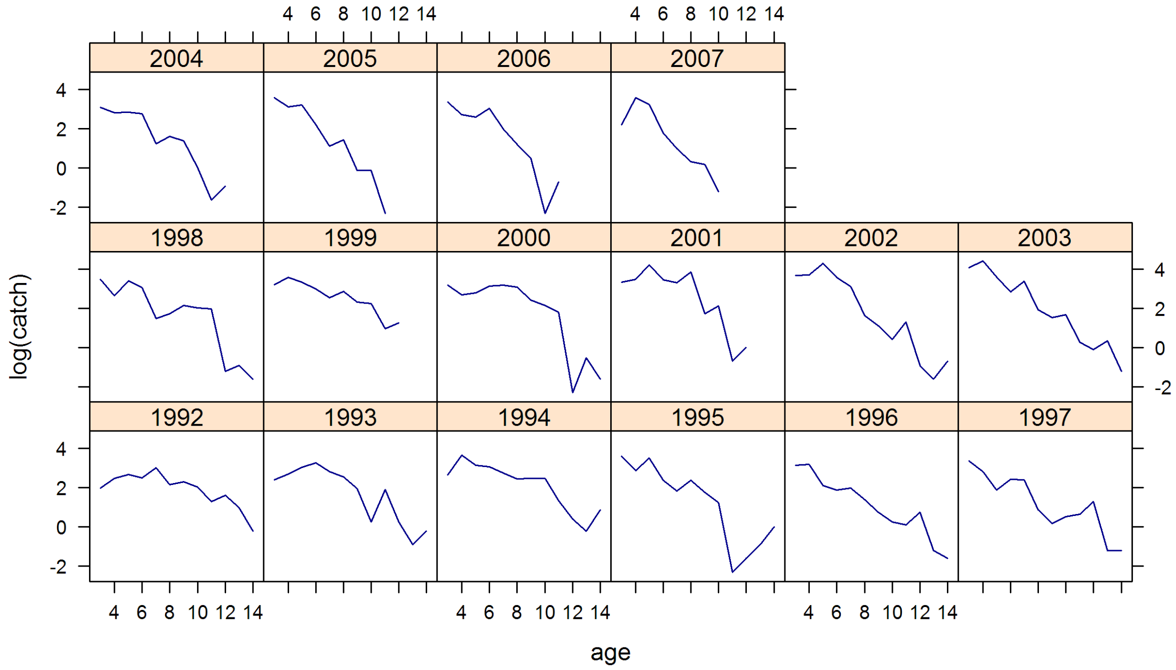


Figure 6.4.1. North Sea Horse Mackerel. Catch curves for the 1994 to 2007 cohorts, ages from 3 to 14. Values plotted are the log(catch) values for each cohort in each year. The negative slope of these curves estimates total mortality (Z) in the cohort.

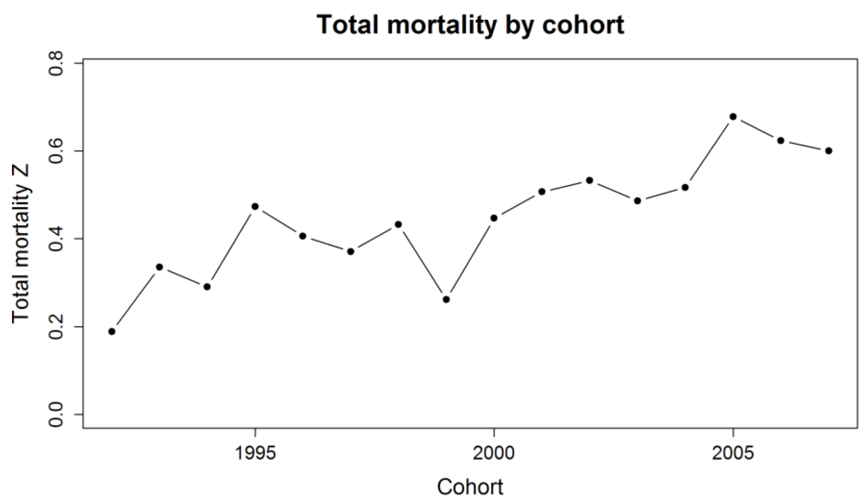


Figure 6.4.2. North Sea Horse Mackerel. Total mortality by cohort (Z) estimated from the negative gradients of the 1992—2006 cohort catch curves (Figure 6.4.1).

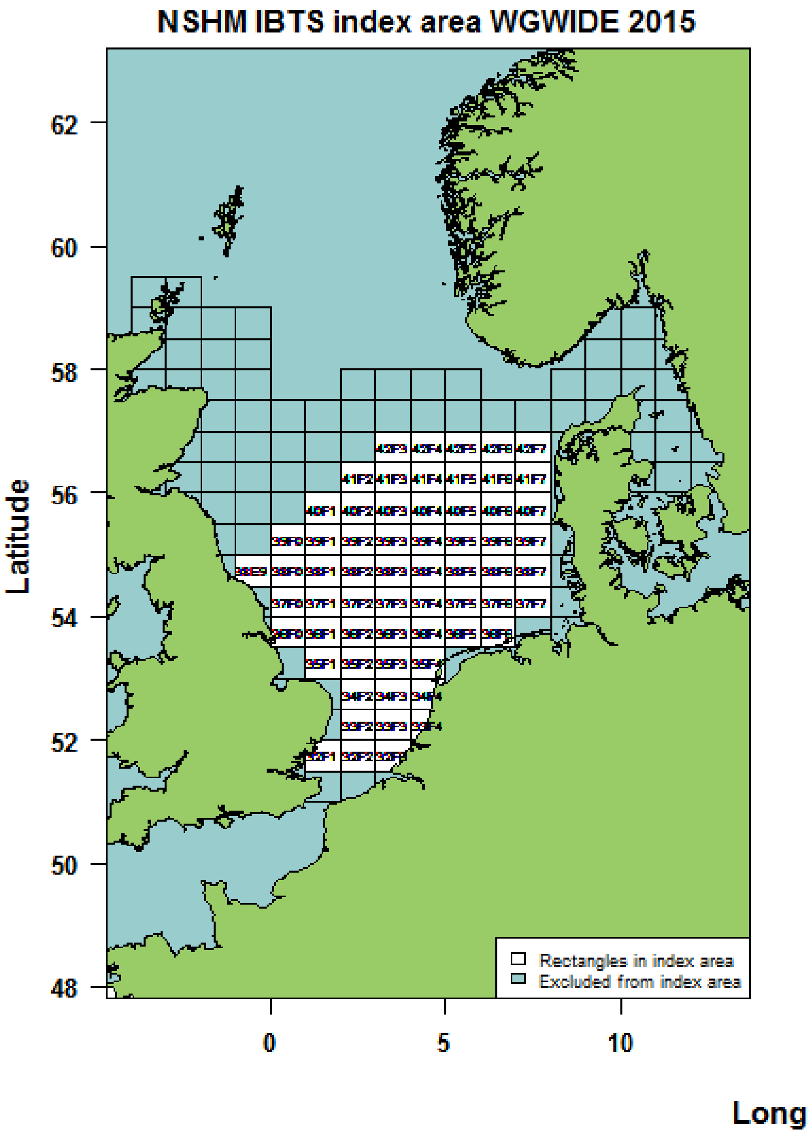


Figure 6.4.3. North Sea horse mackerel. ICES rectangles selected in 2013 and currently used by the working group.

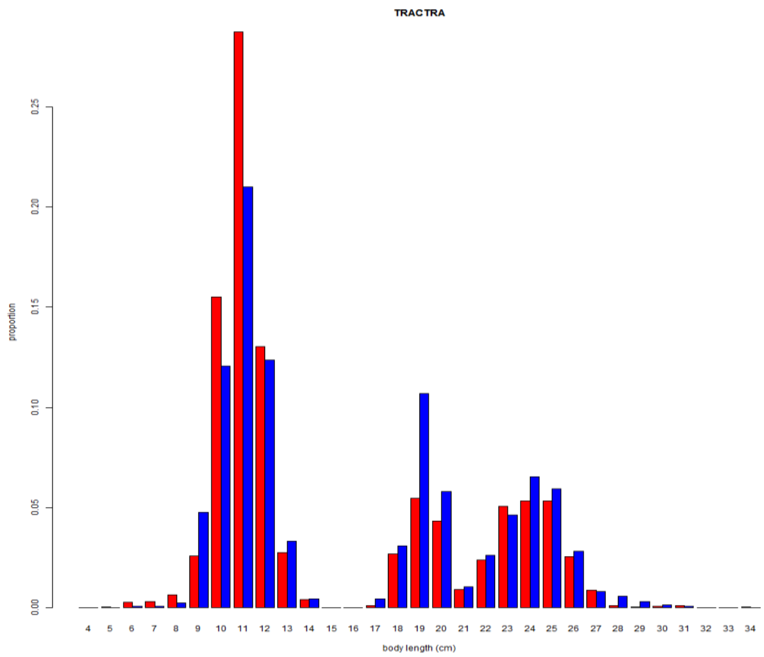


Figure 6.4.4. North Sea horse mackerel. Size distribution of North Sea horse mackerel catches during the inter-calibration exercise conducted in 2014 between the RV Gwen Drez (red bars) and Thalassa (blue bars).

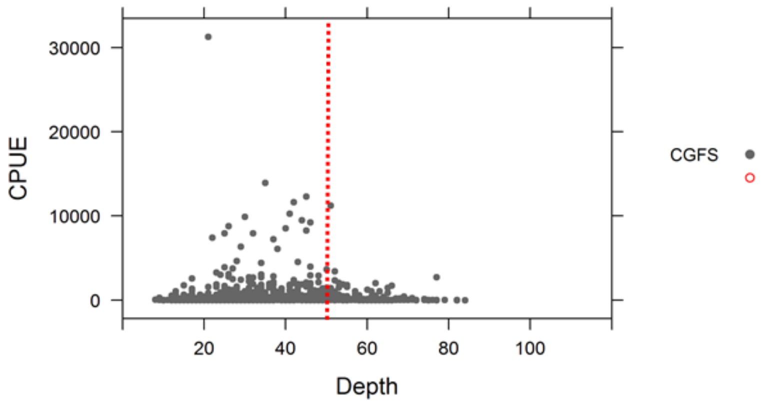


Figure 6.4.5. North Sea horse mackerel. CPUE by depth for the CGFS survey from 1992 to 2017.

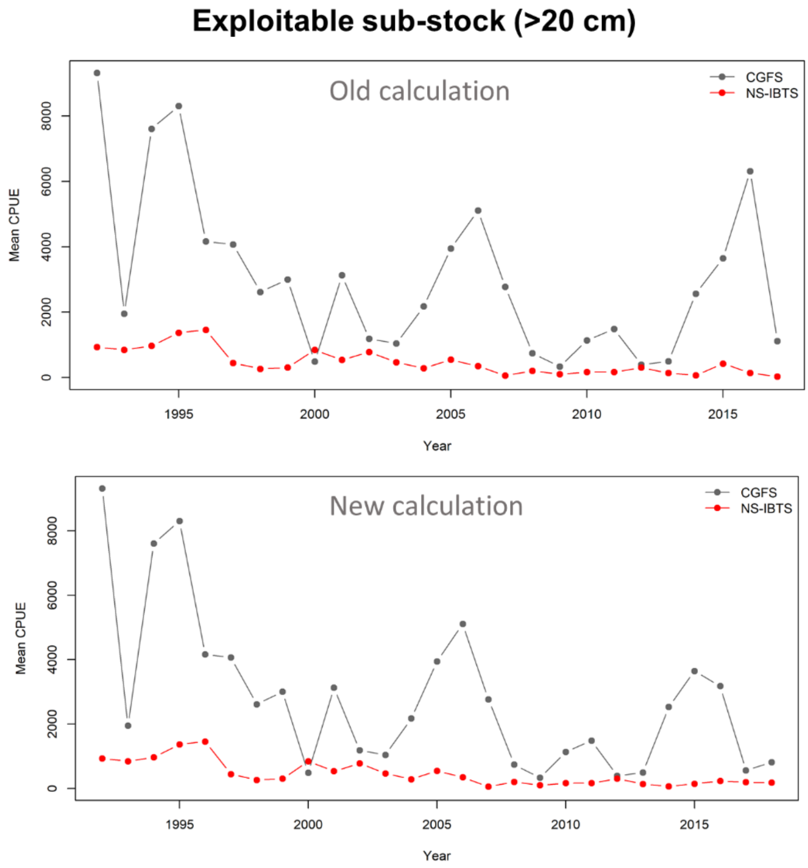


Figure 6.4.6. North Sea horse mackerel. Mean CPUE per year of the exploitable sub-stock (>20 cm) from 1992 to 2018. Mean CPUE is calculated based on the CPUE per haul per survey. Top panel: time series based on old calculation of CPUE (i.e. as done in assessment of 2017), bottom panel: time series based on new calculation of CPUE (as done in assessment in 2019). The old calculation was only applied to calculate the index of 2016 and 2017.

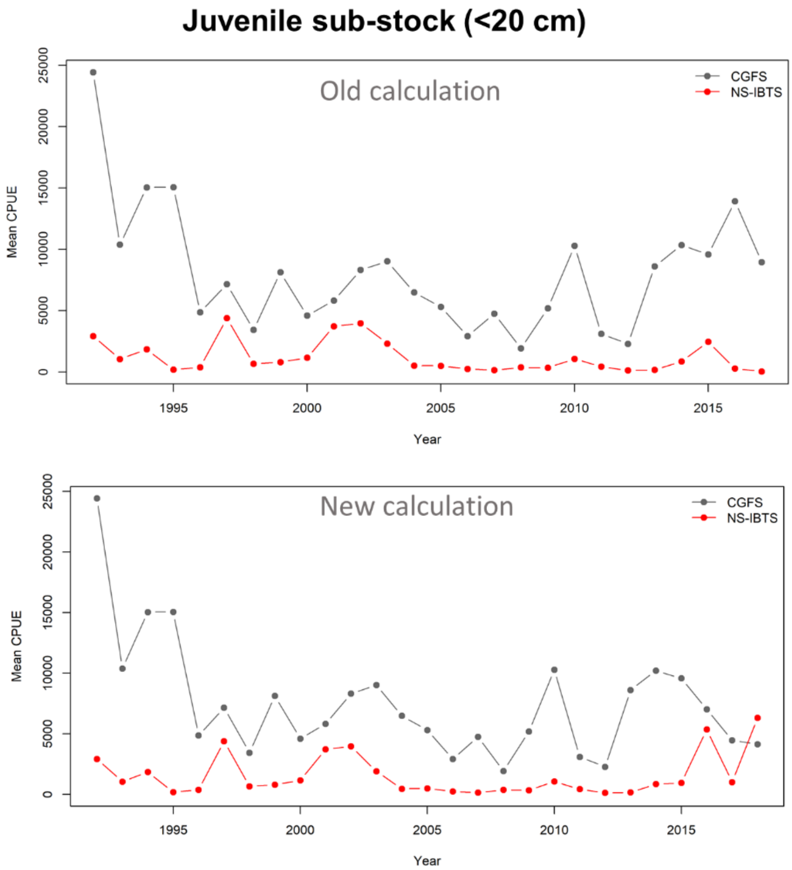
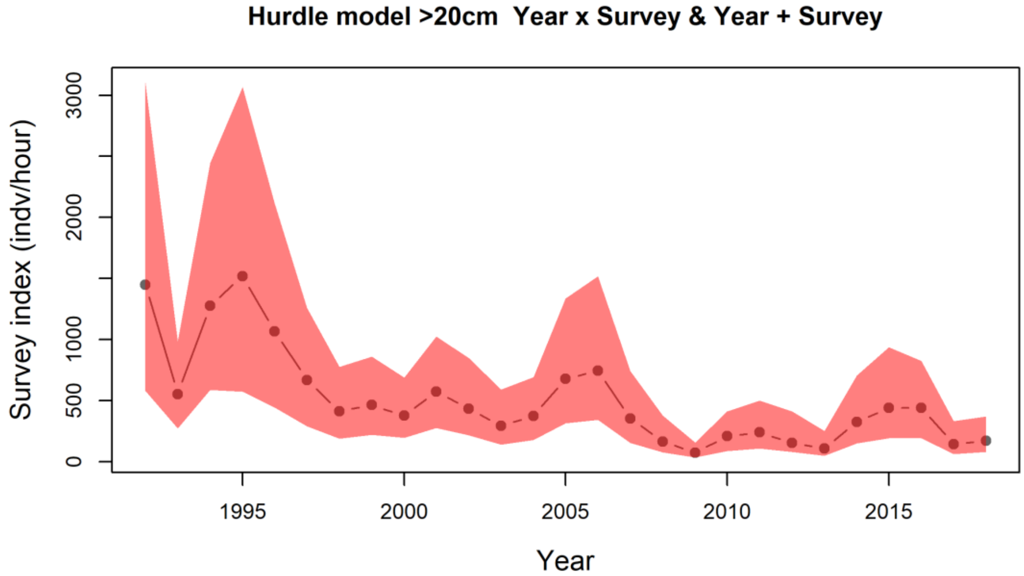


Figure 6.4.7. North Sea horse mackerel. Mean CPUE per year of the juvenile sub-stock (<20 cm) from 1992 to 2018. Mean CPUE is calculated based on the CPUE per haul per survey. Top panel: time series based on old calculation of CPUE (i.e. as done in assessment of 2017), bottom panel: time series based on new calculation of CPUE (as done in assessment in 2019). The old calculation was only applied to calculate the index of 2016 and 2017.



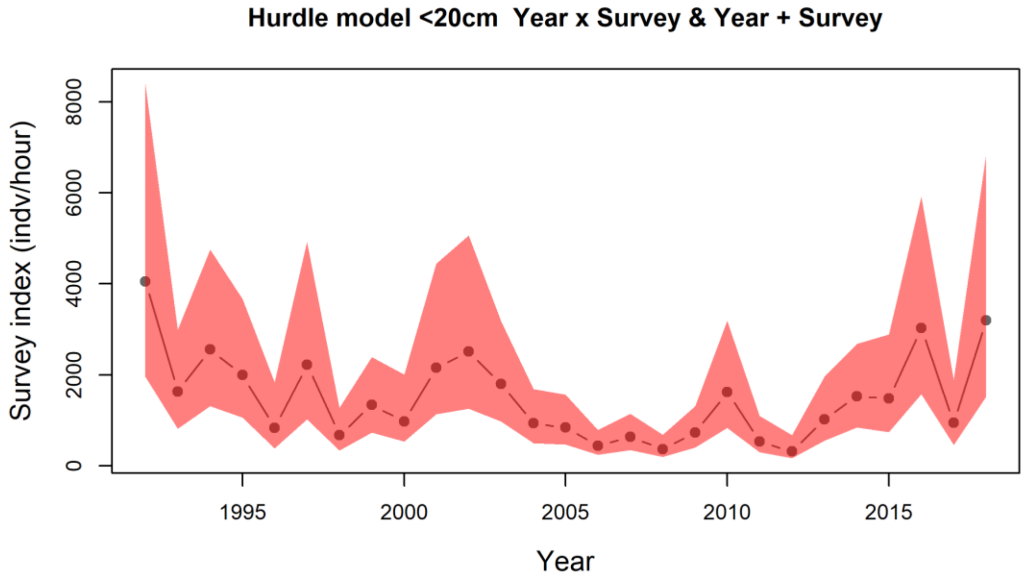


Figure 6.4.8. North Sea Horse Mackerel. Joint CPUE survey index (indiv/hour) derived from the hurdle model fit to the IBTS survey in the North Sea and the CGFS survey in the English channel. Top: exploitable sub-stock (>20 cm), bottom: juvenile sub-stock (<20 cm). The abundance index values are presented as number of individuals per hours. The red shaded area represents the confidence interval, which is determined by bootstrap resampling of Pearson residuals with 1000 iterations.

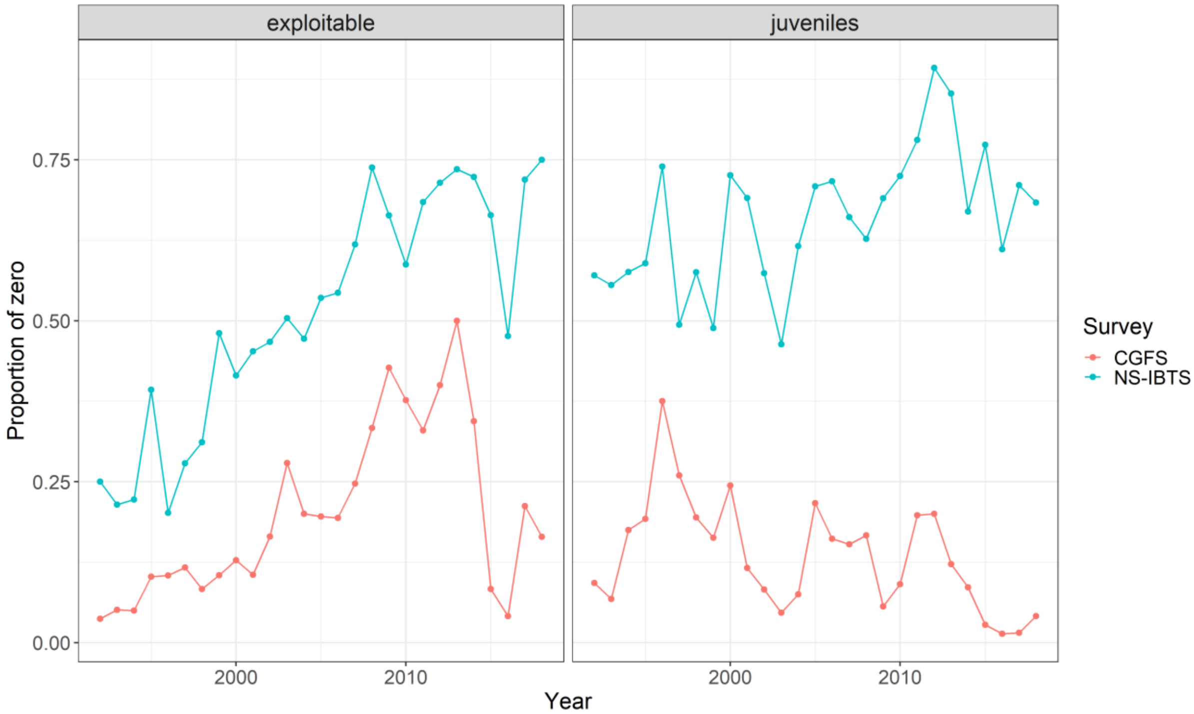


Figure 6.4.9. North Sea horse mackerel. Proportion of hauls with zero catch for the exploitable (>20cm) and juvenile (<20 cm) sub-stocks in the NS-IBTS (blue) and the CGFS (red) from 1992 to 2018.

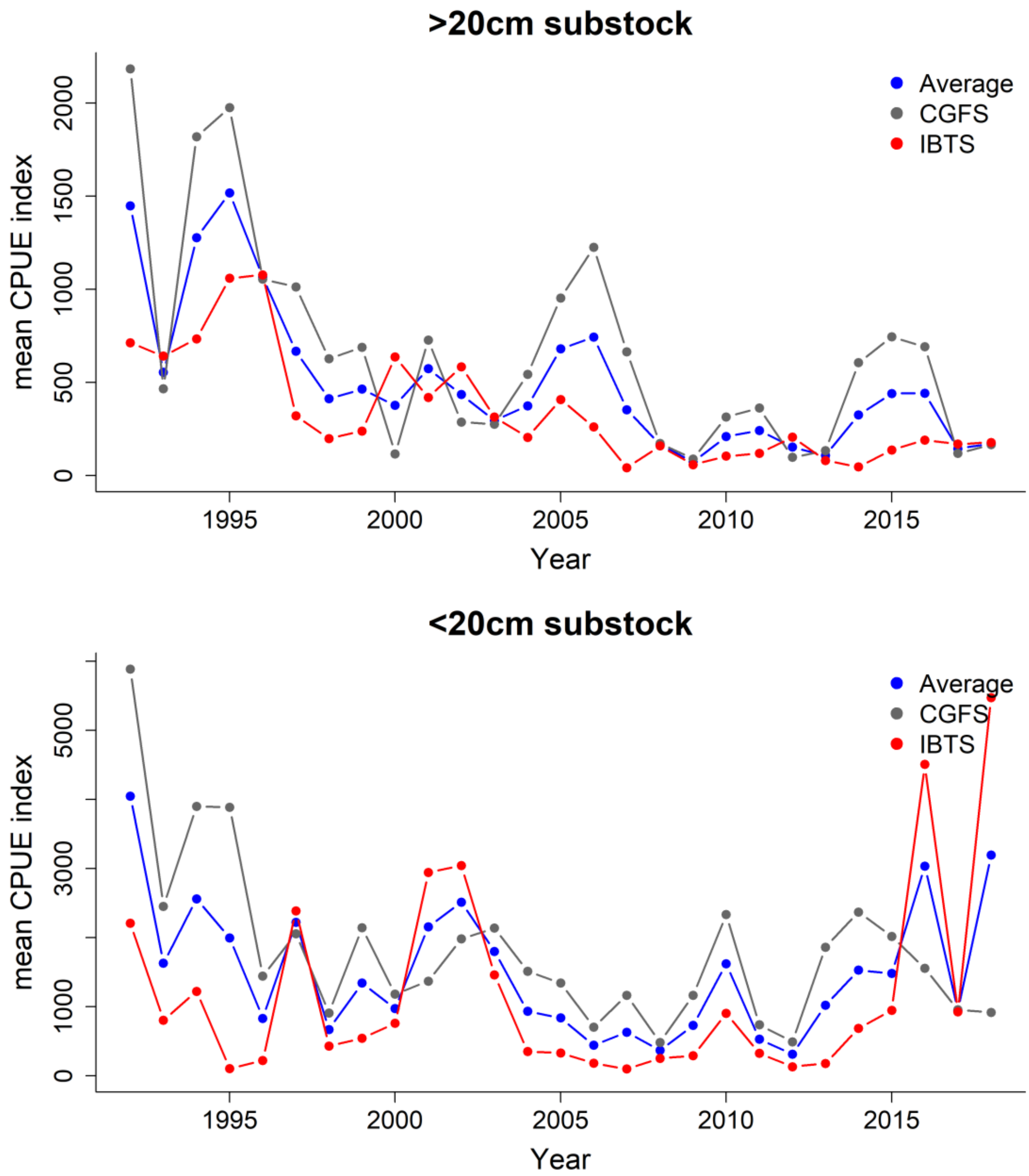


Figure 6.4.10. North Sea Horse Mackerel. Mean CPUE survey index (individuals/hour) obtained from the hurdle model fit to the IBTS survey in the North Sea (in red), the CGFS survey in the English channel (in grey) and the joint survey index (in blue). Top: exploitable sub-stock (>20cm), bottom: juvenile sub-stock (<20 cm); The abundance index values are presented as number of individuals per hours.

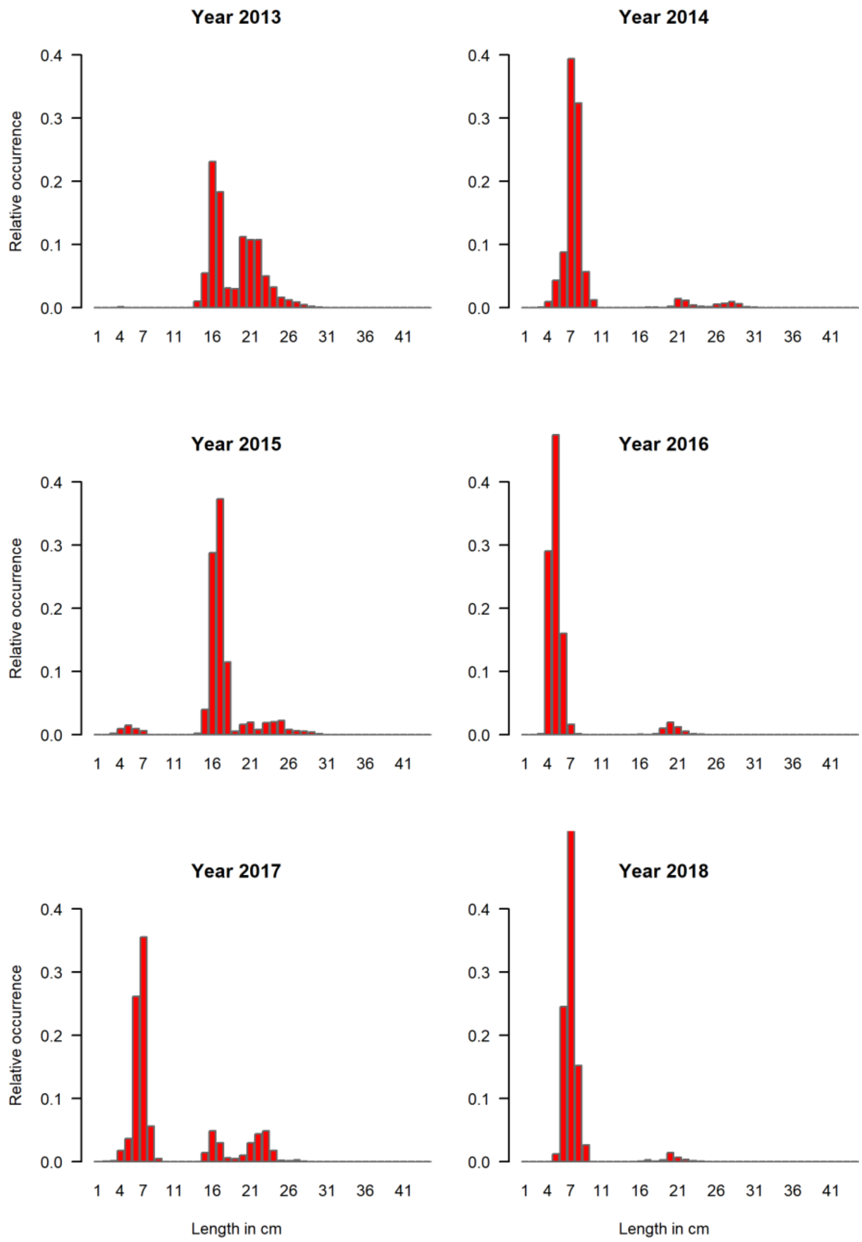


Figure 6.4.11. North Sea horse mackerel. Relative occurrence by length for the period 20132018 in the NS-IBTS.

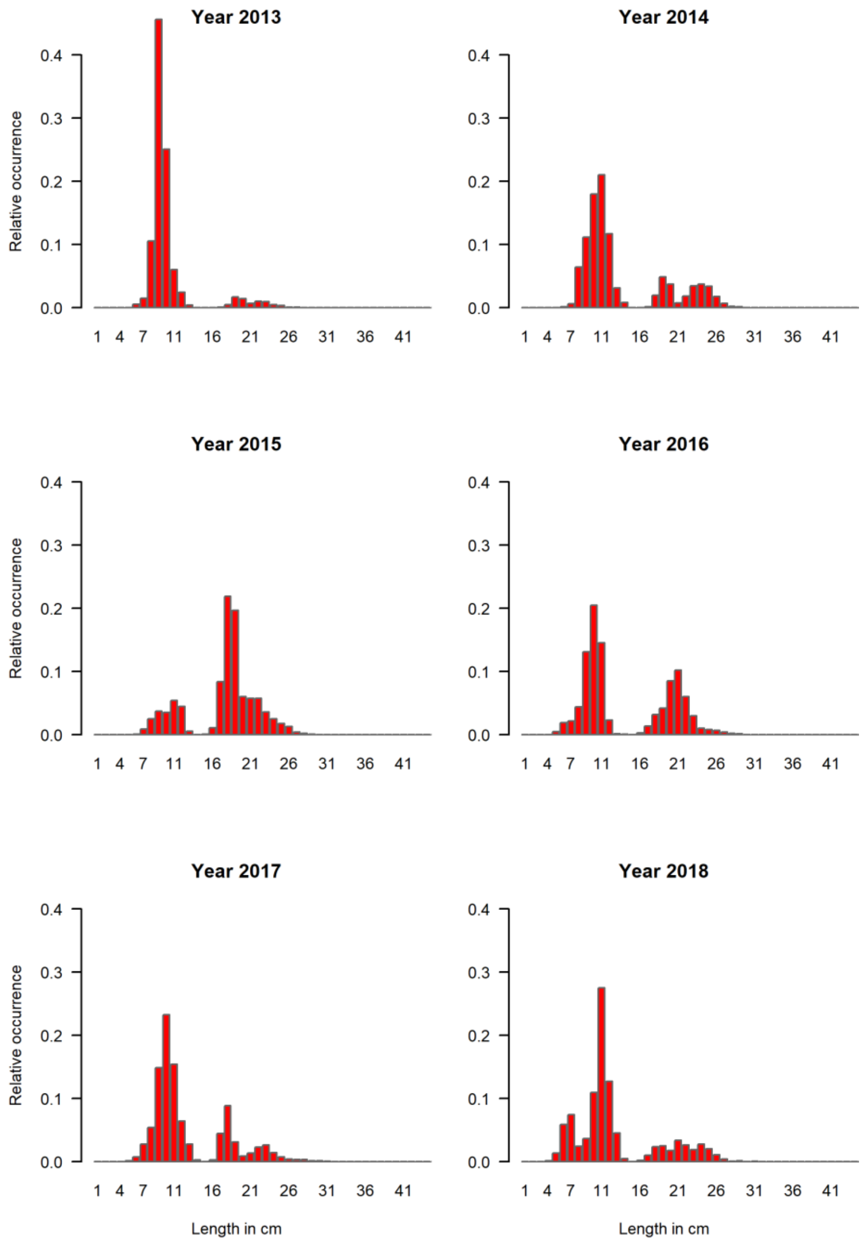


Figure 6.4.12. North Sea horse mackerel. Relative occurrence by length for the period 20132018 in the CGFS.

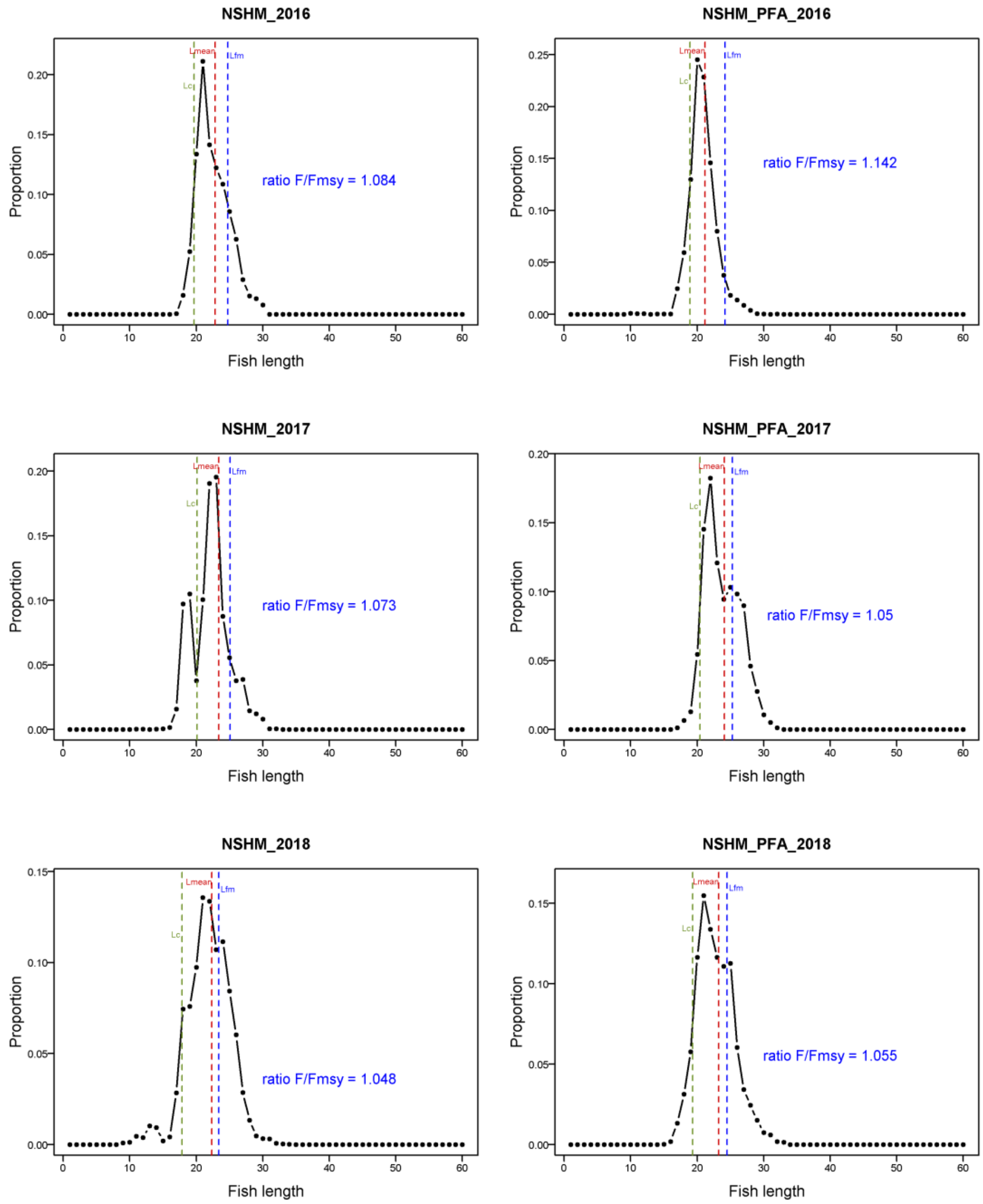


Figure 6.4.13. Length distribution (cm), estimated parameters L_c, L_{mean}, $L_{f=m}$ (cm) and F/F_{MSY} ratio for 2016, 2017 and 2018. Left column: based on commercial catch samples, right column: samples from the Pelagic Freezer-Trawler Association (PFA, The Netherlands) self-sampling programme. Samples were taken in ICES division 27.7.d.

7 Western Horse Mackerel –in Subarea 8 and divisions 2.a, 3.a (Western Part), 4.a, 5.b, 6.a, 7.a–c and 7.e–k

7.1 ICES advice applicable to 2018 and 2019

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

For 2018 the TAC set in EU waters (EU 2018/120) was the following:

Areas in EU waters	TAC 2018	Stocks fished in this area
2.a, 4.a, 5.b, Subareas 6, 7.a-c, 7.e-k, 8.abde, 12, 14	99 470 t	Western stock & North Sea stock in 4.a 1-2 quarters
4.b,c, 7.d	12 629 t	North Sea stocks
Division 8.c	16 000 t	Western stock

For 2019 the TAC set in EU waters (EU 2018/124) was the following:

Areas in EU waters	TAC 2019	Stocks fished in this area
2.a, 4.a, 5.b, Subareas 6, 7.a-c, 7.e-k, 8.abde, 12, 14	119 118	Western stock & North Sea stock in 4.a 1-2 quarters
4.b,c, 7.d	15 179	North Sea stocks
Division 8.c	18 858	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 2018 ICES advised on the basis of MSY approach that Western horse mackerel catches in 2019 should be no more than 145 237 tonnes. The Western horse mackerel TAC for 2019 is 137 976 tonnes, the TAC for EU waters only is 136 376 tonnes. The TAC should apply to the total distribution area of this stock. The EU horse mackerel catches in Division 3.a are taken outside the horse mackerel TACs.

7.1.1 The fishery in 2018

Information on the development of the fisheries by quarter and division is shown in Tables 5.1.1 and 5.1.2 and in Figures 5.1.1.a–d. The total catch allocated to western horse mackerel in 2018 was 101 682 t which is 18 721 t more than in 2017 and 43 555 t less than ICES advice. The catches of horse mackerel by country and area are shown in Tables 7.1.1.1-5 while the catches by quarter since 2000 are shown in Figure 7.1.1.1

7.1.2 Estimates of discards

Discard data are available since 2000 for few countries. Until 2013 however the estimates available are considered an underestimation of the overall amount (Figure 7.1.2.1).

In 2018 most countries have presented discard information. Countries that reported discard for horse mackerel were Denmark, France, Spain, Sweden and UK (England and Wales) as well as UK (Scotland). 2018 discard for Germany, Ireland, the Netherlands and Norway is considered equal to zero. Discards for western horse mackerel were 2 609 tonnes, equal to 2.6 % in weight of the total catches, a decrease in comparison to last year.

Discard data are included in the assessment as part of the total catches.

Length frequency distributions of discard were provided by Spain and France but not included in the assessment.

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 (only quarters 3 and 4 of area 4.a are included in this 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 stock is caught in these areas following the yearly distribution described in Section 5.3 (Figure 7.1.3.1). The western stock is considered a management unit and advised accordingly. At present there are no international agreed management measures. EU regulates the fishery by TAC. This TAC is now set in accordance with the distribution of the stock although catches in 3.a are taken outside the TAC.

7.2 Scientific data

7.2.1 Egg survey estimates

In 2019 the triennial mackerel and horse mackerel egg survey was carried out in the western and southern spawning areas and a working document with preliminary results of the survey was presented to WGWIDE members (WD08: O'Hea *et al*. 2019). Details of this mackerel and horse mackerel egg survey are also given in section 8.6.1 of this report.

Sampling was undertaken in 7 sampling periods. Egg abundance plots displaying the spatial distribution of stage 1 western horse mackerel eggs are presented for periods 3 – 7 (Figures 7.2.1.1 – 7.2.1.5). Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning. In general, egg numbers were low but occasional stations with high counts were found. No horse mackerel eggs were found in period 2. In period 7, eggs were found from the Celtic Sea to the west of Scotland (Fig. 7.2.1.5) with peak spawning taking place in this period and high egg numbers found in the Celtic Sea and Porcupine.

Final survey results will be available at WGMEGS in April 2020.

The mean daily stage I egg production estimates (DEP) for each survey period plotted against the mid-period days is shown in figure 7.2.1.6. The results from previous surveys are also included in the figure for comparison. The shape of the egg production curve does not suggest that those dates should be altered for 2019 (Fig. 7.2.1.6). The total annual egg production was estimated at 1.78 x 10^{14}. This is a decrease of almost 53% on 2016 which was 3.31 × 10^{14} and is the lowest estimate of annual egg production ever recorded for this species.

Western horse mackerel continues its decline with an even lower egg production estimate than was observed in 2016 and at the time that was the lowest recorded estimate for this survey. The time series of TAEP estimates used in the assessment is shown in Table 7.2.1.1.

Fecundity investigations

This year for Western horse mackerel only DEPM ovary samples were collected in periods 6 and 7, during the peak time of spawning. Horse mackerel fecundity results are not available at this time and have not been presented. All samples will be analysed and results presented at the 2020 WGMEGS meeting.

The Western horse-mackerel egg data of the DEPM survey are still under revision. Data are expected to be analysed and results will be presented at the 2020 WGMEGS.

7.2.2 Other surveys for western horse mackerel

Bottom-trawl surveys

An update bottom-trawl survey index for recruitment was available for 2018: the index is based on IBTS surveys conducted by Ireland, France and Scotland covering the main distribution of the stock (Bay of Biscay, Celtic Sea, West of Ireland and West of Scotland) from 2003 to 2018, and uses a Bayesian Delta-GLMM for the calculation of an index of juvenile abundance based on catch rates (ICES 2017b). The updated index is shown in Figure 7.2.2.1 (top panel) and data for 2017-2019 indices given in Table 7.2.2.1. The 2017 data point was highly uncertain due to the very little coverage of the French survey: the French research vessel had technical issue and could therefore only cover less than 1/3 of the stations usually sampled. Despite this high uncertainty, the 2017 data point suggested a very strong recruitment to be expected the following year. This perception was confirmed by the presence of numerous small fish in the 2017 and 2018 catch data. The overall trend suggests an increase in recruitment from 2013 to 2017 and a decrease back down to 2015 levels in 2018.

Further information on how the recruitment index is estimated can be found in the stock annex, in ICES (2008/ACOM:13), ICES (2009/RMC:04) and in ICES (2017b).

Acoustic surveys

In the Bay of Biscay two coordinated acoustic surveys are taking place at the spring time, PELGAS (Ifremer-France) and PELACUS (IEO-Spain).

8c was covered by the R/V Miguel Oliver from 27th March until 13th a¡ April within the survey PELACUS 0319.

Horse mackerel mainly occurred at the inner part of the Bay of Biscay and also close to 9a, where the southern component is located. This area yielded 50% of the total biomass estimates. Only few schools were recorded in the central part of the Cantabrian Sea as shown in Figure 7.2.2.2. Younger fish (age groups 1-2) represented up to 75% of the total abundance (Figure 7.2.2.4) and the contribution of adult fish is around 25%, higher than that observed in 2018.

7.2.3 Effort and catch per unit effort

No new information was presented on effort and catch per unit effort. Further information can be found in the stock annex.

7.2.4 Catch in numbers

In 2018, the Netherlands (6.a, 7.bhj), Ireland (6.a, 7.bg), Germany (6.a, 7.e) and Spain (8.bc) provided catch in numbers-at-age (Figure 7.2.4.1). The catch sampled for age readings in 2018 covered 69%, in 2017 covered 68% and in 2016 covered 82%. In addition, France (7.e, 8.ab), England (7.eg) and Scotland (4.a, 6.a) provided catch in number-at-length.

The total annual and quarterly catches in number for western horse mackerel in 2018 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 Figure 7.2.4.2. It 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 has now 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.

In addition, Germany, Spain, Ireland and the Netherlands provided the Age Length Keys (ALK) which were used in 2018.

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 2018 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

Mean weight-at-age in the stock is presented in Table 7.2.5.3. 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 the fishing industry

The fishing industry in conjunction with the Pelagic AC (PELAC) has been working actively on a large-scale genetics project on stock identification. In 2018, the results of the genetic analysis have been published (Farrel *et al* 2018) which concluded that the spawners of North Sea and Western horse mackerel can be genetically identified as two distinct stocks. However, at present it is not yet possible to separate the two stocks when they occur in mixed samples. Therefore, a follow-up project has been initiated to carry out a full genome sequencing of horse mackerel which will allow for future analysis of mixed samples. Results are expected in 2020.

7.2.10 Data exploration

The length frequency distributions of the catches for the whole fleet included in the model are shown in Figures 7.2.10.1-2. The length distributions available for 2015-2018 show a considerable amount of very small fish, mostly driven by the Spanish catches. Length frequency distribution from discards was analysed alongside the length frequency distribution from the landings during the 2018 assessment. The huge numbers of small individuals from the discards had a strong impact on the overall LFD of the catches. These data were not available at the benchmark and to include those in the assessment model would require major changes in the modelling structure: for this reason were only used in the explorative analysis last year.

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 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 represents different part of the stock. Negative correlations between indices that should represent the same portion of the population might cause problem in the fitting. The correlation between time-series was therefore estimated and presented in Figure 7.2.10.5. There was no strong correlation between the IBTS recruitment index and the other two surveys, just a slightly positive correlation between IBTS and PELACUS, and negative but highly uncertain correlation between IBTS and the egg survey. On the other hand, the egg survey, which aims to represent the adult portion of the stock was strongly positively correlated with PELACUS.

7.2.11 Assessment model, diagnostics

A one fleet, one sex, one area stock synthesis model (SS; Stock Synthesis v3.30; Methot, 2011) is used for the assessment of western horse mackerel stock in the Northeast Atlantic. A description of the model can be found in the stock annex. The assessment is presented as an update to the 2018 assessment and sees the inclusion of the 2018 estimates for the IBTS and PELACUS surveys used, the 2018 length frequency distribution from the catches and the PELACUS survey and the 2018 total catch and conditional ALKs.

Fits to the available data are given in Figure 7.2.11.1, and model estimates with associated precision in Figure 7.2.11.2. Model estimates and residual patterns are similar to those presented in the benchmark (ICES, 2017b) and remain unchanged from last year assessment for almost all variables, except for some pattern arising with the latest year of ALK. Recruitment estimates were unchanged from last year's assessment. The model fitting to the most recent length frequency distributions and the conditional ALKs remain not optimal, due to changes in the overall pattern of the catches with a significant increase of smaller fish compared to the past.

Retrospective plots are shown for 10 years (Figure 7.2.11.3). Major rescaling of the estimates are observed in correspondence of the availability of a new egg survey data point. The inclusion of the 2016 length frequency distribution also caused a major deviation from the previous year assessment. The 2019 assessment now shows a change in the previously observed retrospective bias pattern with a minor revision downwards of the SSB, and a minor revision upwards of F, with little change to recruitment compared to last year's model.

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 2018 information from the 2 surveys available, is presented as the final assessment model. Stock numbers-at-age and fishing mortality-at-age are given in Tables 7.3.1.1 and 7.3.1.2, and a stock-summary is provided in Table 7.3.1.3, and illustrated in Figure 7.2.11.2. SSB peaked in 1988 following the very strong 1982 year class. Subsequently SSB slowly declined till 2003 and then recovered again following the moderate-to-strong year class of 2001 (a third of the size of the 1982 year class). Year classes following 2001 have been weak: 2010, 2011, and 2013 recruitments in particular have been estimated as the lowest values in the time-series together with the 1983. The 2008 year class has been estimated to be fairly strong. Recruitment estimates for 20142018 are the highest observed since 2008 and are higher than the geometric mean estimated over the years 1983-2018. SSB in 2017 is estimated as the lowest in the time-series. Fishing mortality was increasing after 2007 as a result of increasing catches and decreasing biomass as the 2001 year class was reduced. Since 2012 F has then been decreasing, dropping to low values in 20152018 due to lower catches and a reduced proportion of the adult population in the exploited stock.

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 F in 2018 and is the average of ages 1 to 10. Natural mortality is assumed to be 0.15 across all ages. The proportion mature for this stock has a logistic form with fully mature individuals at age 4 as used in the assessment model. In 2017, the expected landings for the intermediate year were set to the level that corresponds to the 2017 TAC in EU waters. This year it was set at 80% of the total TAC, to reflect the catch uptake of the past 3 years. Note that -despite the plus group in the catch being equal to 15+- the true population in SS model is set to arrive up to age 20 (as from literature) and is therefore estimated accordingly.

Output

A range of predicted catch and SSB options from the short-term forecast are presented in Table 7.4.2.

7.5 Uncertainties in the assessment and forecast

Despite the increased amount of data used and information available to the stock assessment, the model still suffers from a retrospective pattern whenever a new year of data is included. This year rescaling is however small compared to past assessment and changes direction compared to the past 5 years (rescaling biomass down rather than up and vice-versa for F_{1-10}).

The fitting to the fishery independent indices remains good for two of the three surveys used: a degradation of the fitting to the IBTS recruitment index was observed last year, but the estimates remained within the confidence intervals provided. This still holds true for the 2015-2017 period, and to a lesser extent for 2018, with the predicted estimates under-estimating the IBTS observations. The fit to the acoustic index remains poor.

The change in selectivity, which is detected from both the length and the age composition of the catch data, is not entirely picked up from the model. In general, the model tends to overestimate the mean age of the last decade. The selectivity issue should be further investigated and somehow addressed: for example, it is not clear whether the high presence of small specimen in the landings data is due to the inclusion of BMS individuals in the overall catch instead of having it as discard (the discard ban was implemented in 2015 for pelagic species) or if this is due to an effective change in selectivity (i.e. catchability of the gear and availability of the stock).

The model fixes the realised fecundity with a constant number of eggs/kg independently of the individual weight. However, western horse mackerel is known to be an indeterminate spawner, which implies this relationship being not appropriate when it comes to the use of an egg survey as index of spawning biomass. During the benchmark it was attempted to estimate the parameters relative to fecundity, but the information provided was not sufficient. The inclusion of this feature, whenever appropriate data become available, would help to improve the reliability of the assessment.

The assumed value for M should be investigated. However, there is no data available (such as tagging) that could assist in estimating M more accurately. Nevertheless, total mortality appears to be low, given the persistence of the 1982 year class in the catch data.

In general Stock Synthesis tends to underestimate the uncertainty of the main variables: in the present case, the estimated uncertainty, despite being low, remains higher than the yearly fluctuations; it is therefore considered reasonable.

The assessment, as was developed at the benchmark, has an increased amount of information for providing more robust estimates of recruitment, which is also informed by the strong, occasional year classes observed in the catch. On the contrary, the SSB is informed only by the triennial egg survey and by the acoustic survey (which only covers a small part of the stock distribution and size ranges, has a really low weight in the model and is really noisy): a new index for the spawning biomass would therefore be beneficial for the future stability of this assessment. The development of a SSB index from the IBTS survey as well as merging the information available from the PELACUS and the PELGAS acoustic survey in the Bay of Biscay should be pursued.

7.6 Comparison with previous assessment and forecast

A comparison of the update assessment with the historic ones (previous 4 years) is shown in Figure 7.2.11.4: the new information created a downward rescaling of the assessment biomass, comparable to the 2017 assessment over the last 15 years of the time series, and upward revision of F. Recruitment, on the other hand, remains fairly stable.

7.7 Management Options

7.7.1 MSY approach

In 2017 stochastic equilibrium analyses were carried out using the eqSim software (WKWIDE 2017) to provide an estimate for F_{MSY} and other biological reference points. During WGWIDE 2017 further investigations were carried out and summarised in a Working Document attached to WGWIDE 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 IBPWHM document (ICES, 2019).

SSB in 2003 was adopted as a proxy for B_{pa} on the basis that fishing mortality had been relatively low for the data period (F_{bar} mean ~0.11, natural mortality = 0.15), and there was no indication of impaired recruitment below the associated B_{lim}, despite a continuing decline in SSB. F_{MSY} was derived from stochastic simulations as before and evaluated at 0.074. These updated reference points were used to set the 2020 advised catch.

7.7.2 Management plans and evaluations

An overview of earlier management plans and management plans 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.

New work on the development of a potential Harvest Control Rule (HCR) and rebuilding plan for Western horse mackerel has been initiated by the Pelagic Advisory in 2018 and 2019, respectively. The PELAC requested Landmark Fisheries Research (Canada) to develop a proof-of-concept of a Management Strategy Evaluation (MSE) testing different types of HCRs. Previously, Landmark Fisheries Research has done similar exercises for e.g. Sablefish in British Columbia.

The approach presented by Landmark Fisheries Research was based on a full-feedback MSE with an embedded stock assessment model included. The approach explicitly recognizes both biomass and fishery objectives. Simulated outcomes under alternative rebuilding plans defined by alternative harvest control rules can be used to examine potential trade-offs among stock rebuilding and fishery performance objectives in both the short and long-term. As expected, risks of the stock being below B_{lim} are highest in the short term; however, long term performance clearly demonstrates the precautionary aspects of the simulated rebuilding plans. In particular, all harvest control rules lead to stock growth in the long term, but with different outcomes in terms of yield, yield variability, and probably of fishery closure. Although some rules led to more rapid stock growth, they did so at considerably higher cost to the fishery than other rules. So far no uncertainty in the initial conditions have been included. Nevertheless, these results suggest that a full MSE could be used to identify management procedures that provide acceptable trade-offs between fishing and spawning biomass conservation of Western horse mackerel.

7.8 Management considerations

The 2001 year class has now entered the plus group and there are no detectable very strong year classes entering the fishery, even though a higher amount of age 1-2 fish have been observed in the catches in the past 3-4 years.

The revision of the reference points (increase of biomass and decrease of F reference points) combined with the downward re-scaling of the assessment with this year's data leads to an advice which is much lower than the advice was for 2019.

The egg survey index that was available for 2019, together with the acoustic survey index, were not included in the current assessment. The basis for this decision was the relative importance of the age and length catch composition in driving the assessment. Sensitivity analyses to the inclusion of these data points were run and led to a further downscaling of the biomass estimate for 2019. Further sensitivity analyses were run by using data up to 2015 and 16, when the last egg survey was available, and they showed that the survey points for 2016 had very little influence on the assessment compared to when the 2016 catch age and length distribution were included. Since no mid-year data were available for this fishery it was decided best not to include the latest survey information this year and have all data in the model up 2018.

The TAC has only been given for parts of the distribution and fishing areas (EU waters). The Working Group advises that the TAC should apply to all areas where western horse mackerel are caught. Note that subarea 8.c is now included in the Western stock distribution area. If (as planned) the management area limits are revised, measures should be taken to ensure that misreporting of juvenile catch taken in subareas 7.e,h and 7.d (the latter then belonging to the North Sea stock management area) is effectively hindered. The mismatch between TAC and fishing areas and the fact that the TAC is only applied to EU waters has resulted in the catch prior to 2007 exceeding those advised by ICES.

7.9 Ecosystem considerations

Knowledge about the distribution of the western horse mackerel stock is mostly gained from the egg surveys and the seasonal changes in the fishery. Based on these observations it is not possible to infer a similar changing trend in the distribution of western horse mackerel as for NEA mackerel. However, from catch data it appears that the stock is concentrated in the southern areas and it is mostly characterized by small individuals.

7.10 Regulations and their effects

There are no horse mackerel management agreements between EU and non EU countries. The TAC set by EU therefore only apply to EU waters and the EU fleet in international waters. The minimum landing size of horse mackerel by the EU fleet is 15 cm (10% undersized allowed in the catches).

The stock allocations were changed in 2005 following the results of the HOMSIR project (Abaunza *et al.* 2003) and 8.c now belongs to the western stock. Landings from 7.d are now allocated to the North Sea horse mackerel. A research project is currently underway in the Netherlands and Ireland, to review the stock separation between the Western stock and the North Sea stock in the Channel area (see North Sea horse mackerel section in the report).

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.

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. However, there has been a gradual shift from an industrial fishery for meal and oil towards a human consumption fishery.

7.12 Changes in the environment

Migrations are closely associated with the slope current, and horse mackerel migrations are known to be modulated by temperature. Continued warming of the slope current is likely to affect the timing and spatial extent of this migration.

Since the strong 1982 year class of the western stock started to appear in the North Sea in 1987 a good correspondence between the modelled influx of Atlantic water to the North Sea in the first quarter and the horse mackerel catches taken by Norwegian purse-seiners in the Norwegian EEZ (NEZ) later (October-November) the same year (Iversen *et al.* 2002, Iversen WD presented in ICES 2007/ACFM:31) has been noted in most years.

7.13 References

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7.14 Tables

Table 7.1.1.1. Western horse mackerel. Catches (t) in Subarea 2. (Data as submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987
Denmark	-	-	-	-	-	-	-	39
France	-	-	-	-	1	1	-[2]	-[2]
Germany, Fed.Rep	-	+	-	-	-	-	-	-
Norway	-	-	-	412	22	78	214	3,272
USSR	-	-	-	-	-	-	-	-
Total	-	+	-	412	23	79	214	3,311

	1988	1989	1990	1991	1992	1993	1994	1995
Faroe Islands	-	-	9643	1,115	9,157[3]	1,068	-	950
Denmark	-	-	-	-	-	-	-	200
France	-2	-	-	-	-	-	55	-
Germany, Fed. Rep.	64	12	+	-	-	-	-	-
Norway	6,285	4,770	9,135	3,200	4,300	2,100	4	11,300
USSR / Russia (1992 -)	469	27	1,298	172	-	-	700	1,633
UK (England + Wales)	-	-	17		-	-	-	-
Total	6,818	4,809	11,414	4,487	13,457	3,168	759	14,083

	1996	1997		1998	1999	2000	2001	2002	2003
Faroe Islands	1,598	799[3]		188[3]	132[3]		-	-	-
Denmark	-	-		1,755[3]	-		-	-	-
France	-	-		-	-		-	-	-
Germany	-	-		-	-		-	-	-
Norway	887	1,170		234	2,304	841	44	1,321	22
Russia	881	554		345	121	78	16	3	2
UK (England + Wales)	-	-		-	-	-	-	-	-
Estonia	-		78	22	-	-	-	-	-
Total	3,366	2,601		2,544	2557	919	60	1,324	24

	2004	2005	2006	2007	2008	2009	2010	2011
Faroe Islands	-	-	3	-	-	-	222	224
Denmark	-	-	-	-	-	-	-	-
France	-	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-	-	1
Norway	42	176	27	-	572	1,847	1,364	298
Russia	-	-	-	-	-	-	-	-
UK (England + Wales)	-	-	-	-	-	-	-	-
Estonia	-	-	-	-	-	-	-	-
Total	42	176	27	0	572	1,847	1,586	-

[2]Included in Subarea 4.
[3]Includes catches in Div. 5.b.
[4]Taken in Div. 5.b

Table 7.1.1.1 cont. Western horse mackerel. Catches (t) in Subarea 2. (Data as submitted by Working Group members).

	2012	2013	2014	2015	2016	2017	2018[1]
Faroe Islands	-	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	-
France	+	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-
Netherlands	-	-	107	-	-	-	-
Norway	66	30	302	10	45	5	718
Russia	-	-		-	-	-	-
UK (England + Wales)	-	-		-	-	-	-
Estonia	-	-		-	-	-	-
Total	66	30	409	10	45	5	718

[1]Preliminary
[2]Included in 4.
[3]Includes catches in Div. 5.b.
[4]Taken in Div. 5.b.

Table 7.1.1.2. Western horse mackerel. Catches (t) in North Sea Subarea 4 and Skagerrak Division 3.a by country. (Data submitted by Working Group members). Catches partly concern the North Sea horse mackerel.

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Belgium	8	34	7	55	20	13	13	9	10
Denmark	199	3,576	1,612	1,590	23,730	22,495	18,652	7,290	20,323
Faroe Islands	260	-	-	-	-	-	-	-	-
France	292	421	567	366	827	298	231[2]	189[1]	784[1]
Germany, Fed.Rep.	+	139	30	52	+	+	-	3	153
Ireland	1,161	412	-	-	-	-	-	-	-
Netherlands	101	355	559	2,029[2]	824	160[2]	600[2]	850[3]	1,060[3]
Norway[2]	119	2,292	7	322	[2]	203	776	11,728[3]	34,425[3]
Poland	-	-	-	2	94	-	-	-	-
Sweden	-	-	-	-	-	-	2	-	-
UK (Engl. + Wales)	11	15	6	4	-	71	3	339	373
UK (Scotland)	-	-	-	-	3	998	531	487	5,749
USSR	-	-	-	-	489	-	-	-	-
Total	2,151	7,253	2,788	4,420	25,987	24,238	20,808	20,895	62,877

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belgium	10	13	-	+	74	57	51	28	-
Denmark	23,329	20,605	6,982	7,755	6,120	3,921	2,432	1,433	976
Estonia	-	-	-	293	-	-	17	-	-
Faroe Islands	-	942	340	-	360	275	-	-	296
France	248	220	174	162	302	-	-	-	-
Germany, Fed.Rep.	506	2,469[4]	5,995	2,801	1,570	1,014	1,600	7	37
Ireland	-	687	2,657	2,600	4,086	415	220	1,100	8,152
Netherlands	14,172	1,970	3,852	3,000	2,470	1,329	5,285	6,205	52
Norway	84,161	117,903	50,000	96,000	126,800	94,000	84,747	14,639	43,888
Poland	-	-	-	-	-	-	-	-	-
Sweden	-	102	953	800	697	2,087	-	95	1761
UK (Engl. + Wales)	10	10	132	4	115	389	478	40	10
UK (N. Ireland)	-	-	350	-	-	-	-	-	-
UK (Scotland)	2,093	458	7,309	996	1,059	7,582	3,650	2,442	10,511
USSR / Russia (1992 -)	-	-	-	-	-	-	-	-	-
Unallocated+discards	12,482[3]	-317[3]	-750[3]	-278[5]	-3,270	1,511	-28	136	-31,615
Total	112,047	145,062	77,904	114,133	140,383	112,580	98,452	26,125	34,068

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	19	21	-	-	-	-	-	-	-
Denmark	2,048	2,026	7	98	53	841	48	216	60
Estonia	-	-	-	-	-	-	-	-	-
Faroe Islands	28	908	24	0	671	5	76	35	0
France	379	60	49	-	-	255	-	1	-
Germany	4,620	4,072	0	0	4	534	0	44	1
Ireland	-	404	32	332	11	93	378	-	-
Lithuania	-	-	-	-	-	-	-	-	-
Netherlands	4,548	3,285	10	1	0	36	0	0	0
Norway	13,129	44,344	1,141	7,912	34,843	20,349	10,687	24,733	27,087
Russia	-	-	2	-	-	-	-	-	-
Sweden	1,761	1,957	1,009	68	561	1,002	567	216	0
UK (Engl. + Wales)	1	12	-	-	-	-	0	-	-
UK (Scotland)	3,041	1,658	3,054	3,161	252	0	0	22	61
Unallocated+discards	737	-325	10	0	0	-36	0	0	0
Total	30,311	58,422	5,338	11,572	36,395	23,079	11,756	25,267	27,210

[1] Includes Division 2.a. [2] Estimated from biological sampling. [3] Assumed to be misreported. [4] Includes 13 t from the German Democratic Republic. [5] Includes a negative unallocated catch of -4,000 t.

Table 7.1.1.2 cont. 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	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[1]	2018[1]
Denmark	37	7	21	289
Faroe Islands	0	0	67	0
France	12	4	1	2
Germany, Fed.Rep.	6	28	1	1
Ireland	8	-	-	-
Netherlands	-	0	14	7
Lithuania	12	130	-	-
Norway	8,887	8,765	9,880	8,601
Sweden	10	0	41	23
UK (Engl. + Wales)	134	13	4	0
UK (Scotland)	36	14	-	-
Unallocated +discards	32	97	87	162**
Total	9,175	9,057	10,117	9,085

**** 3t landings from UK (Northern Ireland incl.)**

Table 7.1.1.3 Western horse mackerel. Catches (t) in Subarea 6 by country. (Data submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Denmark	734	341	2,785	7	-	-	-	769	1,655
Faroe Islands	-	-	1,248	-	-	4,014	1,992	4,450[2]	4,000[2]
France	45	454	4	10	14	13	12	20	10
Germany, Fed. Rep.	5,550	10,212	2,113	4,146	130	191	354	174	615
Ireland	-	-	-	15,086	13,858	27,102	28,125	29,743	27,872
Netherlands	2,385	100	50	94	17,500	18,450	3,450	5,750	3,340
Norway	-	5	-	-	-		83	75	41
Spain	-	-	-	-	-		-[1]	-[1]	-[1]
UK (Engl. + Wales)	9	5	+	38	+	996	198	404	475
UK (N. Ireland)						-	-	-	-
UK (Scotland)	1	17	83	-	214	1,427	138	1,027	7,834
USSR.	-	-	-	-	-	-	-	-	-
Unallocated + disc						-19,168	-13,897	-7,255	-
Total	8,724	11,134	6,283	19,381	31,716	33,025	20,455	35,157	45,842

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	973	615	-	42	-	294	106	114	780
Faroe Islands	3,059	628	255	-	820	80	-	-	-
France	2	17	4	3	+	-	-	-	53
Germany, Fed. Rep.	1,162	2,474	2,500	6,281	10,023	1,430	1,368	943	229
Ireland	19,493	15,911	24,766	32,994	44,802	65,564	120,124	87,872	22,474
Netherlands	1,907	660	3,369	2,150	590	341	2,326	572	1335
Norway	-	-	-	-	-	-	-	-	-
Spain	-[1]	-[1]	1	3	-	-	-	-	-
UK (Engl. + Wales)	44	145	1,229	577	144	109	208	612	56
UK (N.Ireland)	-	-	1,970	273	-	-	-	-	767
UK (Scotland)	1,737	267	1,640	86	4,523	1,760	789	2,669	14,452
USSR/Russia (1992-)	-	44	-	-	-	-	-	-	-
Unallocated + disc.	6,493	143	-1,278	-1,940	-6,960[3]	-51	-41,326	-11,523	837

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Total	34,870	20,904	34,456	40,469	53,942	69,527	83,595	81,259	40,983

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark		79							
Faroe Islands	-	-							
France	221			428	55	209	172	41	411
Germany	414	1031	209	265	149	1337	1413	1958	1025
Ireland	21951	31736	15843	20162	12341	20903	15702	12395	9780
Lithuania									2822
Netherlands	983	2646	686	600	450	847	3702	6039	1892
Spain	-	-						0	0
UK (Engl.+Wales)	227	344	41	91		46	5	52	
UK (N.Ireland)	1132	-	79	272	654	530	249	210	82
UK (Scotland)	10147	4544	1839	3111	1192	453	377	62	43
Unallocated+disc.	98	1507	0	0	0	0	0	0	0
Total	34815	41887	18697	24929	14840	24325	21619	20757	16055

[1]Included in Subarea 7. [2]Includes Divisions 3.a, 4.a, b and 6.b. [3]Includes a negative unallocated catch of -7000 t.

Table 7.1.1.3. cont. Western horse mackerel. Catches (t) in Subarea 6 by country. (Data submitted by Working Group members).

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015
Denmark					58	1,131	433	856	3,045
Faroe Islands		573		66					
France		73			246			195	65
Germany	1,835	5,097	635	773	6,508	671	8,616	4,194	1,980
Ireland	20,010	18,751	16,596	19,985	23,556	29,282	19,979	15,745	10,894
Lithuania	80	641							
Netherlands	2,177	3,904	2,332	1,684	6,353	12,653	11,078	8,580	6,211
Norway	2	20	27	18	48	2			
Spain	0								
UK (Engl. + Wales)	332			463			451	18	58
UK (N.Ireland)				59	198		2,325	1,579	1,204
UK (Scotland)	38	588	243	89	2,528	1,231	385	1,277	696
Unallocated+disc.	0	0	0	0	230	2	-	123	
Total	24,474	29,648	19,833	23,136	39,726	44,973	43,266	32,567	24,153

Country	2016	2017[1]	2018[1]
Denmark		3,462	4,982
Faroe Islands		113	
France	23	1,025	197
Germany	4,069	2,884	2,779
Ireland	15,381	15,123	17,959
Lithuania	2,510		
Netherlands	9,246	5,497	11,921
Norway			
Spain			
UK (Engl. + Wales)		66	32
UK (N.Ireland)	0		1,026
UK (Scotland)	956		

Country	2016	2017[1]	2018[1]
Unallocated+disc.		116	55
Total	32,186	28,286	38,950

[1]Preliminary.

Table 7.1.1.4. Western horse mackerel. Catches (t) in Subarea 7 by country. (Data submitted by the Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Belgium	-	1	1	-	-	+	+	2	-
Denmark	5,045	3,099	877	993	732	1477**	30408**	27,368	33,202
France	1,983	2,800	2,314	1,834	2,387	1,881	3,801	2,197	1,523
Germany, Fed.Rep.	2,289	1,079	12	1,977	228	-	5	374	4,705
Ireland	-	16	-	-	65	100	703	15	481
Netherlands	23,002	25,000	27500**	34,350	38,700	33,550	40,750	69,400	43,560
Norway	394	-	-	-	-	-	-	-	-
Spain	50	234	104	142	560	275	137	148	150
UK (Engl. + Wales)	12,933	2,520	2,670	1,230	279	1,630	1,824	1,228	3,759
UK (Scotland)	1	-	-	-	1	1	+	2	2,873
USSR	-	-	-	-	-	120	-	-	-
Total	45,697	34,749	33,478	40,526	42,952	39,034	77,628	100,734	90,253

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Faroe Islands	-	28	-	-	-	-	-	-	-
Belgium	-	+	-	-	-	1	-	-	18
Denmark	34,474	30,594	28,888	18,984	16,978	41,605	28,300	43,330	60,412
France	4,576	2,538	1,230	1,198	1,001	-	-	-	30,571
Germany, Fed.Rep.	7,743	8,109	12,919	12,951	15,684	14,828	17,436	15,949	28,267
Ireland	12,645	17,887	19,074	15,568	16,363	15,281	58,011	38,455	43,624
Netherlands	43,582	111,900	104,107	109,197	157,110	92,903	116,126	114,692	131,701
Norway	-	-	-	-	-	-	-	-	-
Spain	14	16	113	106	54	29	25	33	6
UK (Engl. + Wales)	4,488	13,371	6,436	7,870	6,090	12,418	31,641	28,605	17,464

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
UK (N.Ireland)	-	-	2,026	1,690	587	119	-	-	1,093
UK (Scotland)	+	139	1,992	5,008	3,123	9,015	10,522	11,241	7,902
Unallocated + discards	28,368	7,614	24,541	15,563	4010***	14,057	68,644	26,795	58,718
Total	135,890	192,196	201,326	188,135	221,000	200,256	330,705	279,100	379,776

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Faroe Islands	-	-		550	-	-	3,750	3,660	
Belgium	-	-	-	-		-			
Denmark	25,492	19,166	13,794	20,574	10,094	10,499	11,619	9,939	6,838
France	22,095	25,007	20,401	9,401	5,220	5,010	5,726	7,108	6,680
Germany	24,012	13,392	9,045	7,583	10,212	13,319	16,259	9,582	6,511
Ireland	48,860	25,816	32,869	29,897	23,366	13,533	8,469	20,405	16,841
Lithuania	-	-							3,606
Netherlands	95,753	63,091	44,806	37,733	32,123	38,808	32,130	26,424	29,165
Spain	-	58	50	7	11	1	27	12	3
UK (Engl. + Wales)	11,925	7,249	4,391	5,913	4,393	3,411	4,097	2,670	2,754
UK (N.Ireland)	27	-	546	868	475	384	209		21
UK (Scotland)	5,095	4,994	5,142	1,757	1,461	268	1,146	59	365
Unallocated+discards	12,706	31,239	-9,515	2,888	434	17,146	16,553	11,875	4,679
Total	245,965	190,012	121,530	117,170	87,788	102,379	99,985	91,733	77,463

Table 7.1.1.4. cont. Western horse mackerel. Catches (t) in Subarea 7 by country. (Data submitted by the Working Group members).

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

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015
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[1]	2018[1]
Faroe Islands			
Belgium			
Denmark	314	1057	1,031
France	551	595	1,067
Germany	7313	4077	1,401
Ireland	12193	7857	7,169
Lithuania	86		
Netherlands	14415	8445	14,009
Norway			
Spain	0		0
UK (Engl. + Wales)	820	478	2,410
UK (Scotland)			
UK (Northern Ireland)			52
Unallocated+discards	1692	830	548
Total	37384	23340	27,687

[1]Preliminary. [2]French catches landed in the Netherlands

Table 7.1.1.5. Western horse mackerel. Catches (t) in Subarea 8 by country. (Data submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Denmark	-	-	-	-	-	-	446	3,283	2,793
France	3,361	3,711	3.073	2,643	2,489	4,305	3,534	3,983	4,502
Netherlands	-	-	-	-	-2	-2	-2	-2	-
Spain	34,134	36,362	19,610	25,580	23,119	23,292	40,334	30,098	26,629
UK (Engl.+Wales)	-	+	1	-	1	143	392	339	253
USSR	-	-	-	-	20	-	656	-	-
Total	37,495	40,073	22,684	28,223	25,629	27,740	45,362	37,703	34,177

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	6,729	5,726	1,349	5,778	1,955	-	340	140	729
France	4,719	5,082	6,164	6,220	4,010	28	-	7	8,564
Germany, Fed. Rep.	-	-	80	62	-		-	-	-
Netherlands	-	6,000	12,437	9,339	19,000	7,272	-	14,187	-
Spain	27,170	25,182	23,733	27,688	27,921	25,409	28,349	29,428	31,082
UK (Engl.+Wales)	68	6	70	88	123	753	20	924	430
Unallocated+discards	-	1,500	2,563	5,011	700	2,038	-	3,583	-2,944
Total	38,686	43,496	46,396	54,186	53,709	35,500	28,709	48,269	37,861

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark	1,728	4,769	2,584	582					1,513
France	1,844	74	7	5,316	13,676	4,908	2,161	3,540	3,944
Germany	3,268	3,197	3,760	3,645	2,293	504	72	4,776	3,326
Ireland	-	-	6,485	1,483	704	1,314	1,882	1,808	158
Lithuania	-	-							401
Netherlands	8,123	13,821	11,769	35,106	12,538	6,620	1,047	6,372	6,073
Spain	23,599	24,461	24,154	23,531	24,752	24,598	16,245	16,624	13,874
UK (Engl. + Wales)	9	28	121	1,092	1,578	982	516	838	821
UK (Scotland)	-	-	249						
Unallocated+discards	1,884	-8658	5,093	4,365	1,705	2,785	2,202	7,302	4,013

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	40,455	37,692	54,222	75,120	57,246	41,711	24,125	41,260	34,122

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Denmark	2,687	3,289	3,109	632	200	581	14			
France	10,741	2,848			326	1,218	2,849	2,277	1,618	2,219
Germany		918	281	64	61		417	19	49	4
Ireland	694					39			0	32
Netherlands	211	6,269	1,848	98	49	7	1,057	526	635	1
Spain	14,265	19,840	21,071	38,742	34,581	13,502	22,542	19,443	13,072	14,235
UK (Engl. + Wales)		120	224	112	28		104	35	72	9
Unallocated+dis-cards		67	913	7,412	417	431	2,055	182	9,314	6,643
Total	28,598	33,352	27,447	47,060	35,662	15,777	29,039	22,483	24,760	23,143

Country	2017	2018[1]
Denmark	1	
France	2,303	2,176
Germany	210	554
Ireland	580	219
Netherlands	313	6
Spain	14,901	20,362
UK (Engl. + Wales)		2
Unallocated+discards	2,907	1,921
Total	21,213	25,240

[1]Preliminary. [2]Included in Subarea 7. [3]French catches landed in the Netherlands

Table 7.2.1.1. Western horse mackerel. The time series of Total Annual Egg Production (TAEP) estimates (10^{12} eggs).

Year	TAEP	CV
1992	2094	0.14
1995	1344	0.76
1998	1242	0.46
2001	864	0.32
2004	884	0.32
2007	1486	0.61
2010	1033	0.37
2013	366	0.34
2016	331	0.36
2019	178	0.48

Table 7.2.2.1. Western horse mackerel. The time series of recruitment estimates from the IBTSSurvey 20172019.

Year	2019	2019 CV	2018	2017
2003	684217	0.2958	649889	624707
2004	2295299	0.3061	2232665	2114140
2005	2027050	0.3235	1947555	1802510
2006	1397314	0.3228	1344055	1304070
2007	2886675	0.2808	2791339	2413940
2008	6888222	0.2960	6725228	6509750
2009	1061126	0.2678	1010931	1042330
2010	808159	0.2921	773303	751727
2011	169028	0.3354	162735	156774
2012	4102691	0.3041	3947958	3882690
2013	1034260	0.2338	979157	980778
2014	2688011	0.2396	2636896	2579760
2015	3789317	0.2668	3650668	3567990
2016	4913923	0.2923	4742525	4751750
2017	8855563	0.4553	8446544	
2018	3750158	0.2933		

Table 7.2.2.2. Western horse mackerel. The time series of biomass for the PELACUS acoustic survey (in tonnes).

Year	Biomass	CV
1992	57188	0.32
1993	25028	0.32
1995	93825	0.32
1997	74364	0.32
1998	139395	0.32
1999	71744	0.32
2000	26192	0.32
2001	40864	0.32
2002	41788	0.32
2003	26647	0.32
2004	23992	0.32
2005	40082	0.32
2006	13934	0.32
2007	28173	0.32
2008	33614	0.32
2009	24020	0.32
2010	53417	0.32
2011	7687	0.32
2012	15479	0.32
2013	5532	0.32
2014	30454	0.32
2015	67068	0.32
2016	32581	0.32
2017	13845	0.32
2018	9270	0.32
2019	13075	0.32

Table 7.2.4.1. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2018 (15 = 15+ group)

Q1																			
Age	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.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.d.2	total
0					0					0								0	0
1		0			0					0			26730	49	47	1	0	0	26826
2	1	149			0	64	0	952		83		5	2457	17	142	44	0	0	3916
3	17	1803	102	0	3	827	0	10870		1069	0	44	283	66	87	529	0	0	15701
4	908	96655	13965	11	366	4409	1	61065		5697	0	151	147	60	112	880	0	0	184427
5	159	16979	4052	3	106	238	0	2575		308	0	101	128	24	128	1244	0	0	26047
6	139	14803	5931	5	156	110	0	1451	439	143	0	285	142	12	259	886	0	0	24762
7	34	3576	1189	1	31	81	0	670	732	104	0	435	93	7	360	409	0	0	7721
8	15	1640	773	1	20	23	0	70	439	30	0	574	48	4	346	254	0	0	4237
9	54	5729	2307	2	61	72	0	70	732	93	0	874	35	2	350	217	0	0	10596
10	175	18614	6720	5	176	85	0	503	732	110	0	822	16	1	276	113	0	0	28348
11	30	3228	709	1	19	11	0	140		15	0	1285	20	1	305	34	0	0	5797
12	17	1834	637	0	17	21	0	70	146	27	0	694	8	1	82	21	0	0	3576
13	8	878	253	0	7	6	0			8	0	307	2	0	30	9	0	0	1508
14	16	1691	496	0	13	6	0	70		8	0	275	2	0	27	62	0	0	2666
15	117	12426	4333	3	114	71	0	558	293	91	0	479	2	0	44	130	0	0	18661
sum	1690	180005	41466	32	1088	6026	1	79064	3514	7787	0	6331	30112	244	2596	4832	1	0	364791

Q2																					
Age	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	total
0					0			0			0										0
1		0			0			0			0				22149	113	4789	554	3	334	27942
2	1	1			0	15	0	0	212		18				2013	29	320	6844	4	30	9488
3	15	12	4	0	0	191	0	0	3753	17	230	0	0		191	53	142	17568	9	3	22189
4	819	642	497	1	62	1020	0	2	17385	349	1224	0	1		117	41	218	7654	5	2	30039
5	144	112	144	0	18	55	0	0	1429	65	66	0	0		112	7	205	3402	3	2	5765
6	125	99	211	0	27	26	0	0	147	111	31	0	1		127	5	411	900	1	2	2224
7	30	25	42	0	5	19	0	0	181	75	22	0	1		83	5	560	204	1	1	1254
8	14	11	28	0	3	5	0	0		41	6	0	1		42	4	460	179	1	1	796
9	49	38	82	0	10	17	0	0	506	67	20	0	1		31	2	417	287	1	0	1529
10	158	126	239	1	30	20	0	0	147	284	24	0	2		18	2	378	319	1	0	1748
11	27	22	25	0	3	3	0	0		57	3	0	0		24	2	532	162	1	0	861
12	16	12	23	0	3	5	0	0	147	24	6	0	0		19	2	344	137	0	0	737
13	7	6	9	0	1	1	0	0		85	2	0	0		16	1	133	60	0	0	323
14	14	11	18	0	2	1	0	0		37	2	0	0		18	1	133	166	0	0	405
15	105	84	154	0	19	16	0	0	147	275	20	0	1	265	54	3	245	210	0	1	1602
sum	1525	1202	1477	3	185	1394	0	3	24055	1489	1673	0	11	265	25014	270	9287	38645	28	377	106902

Table 7.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2018 (15 = 15+ group)

Q3																							
Age	27.2.a	27.3.a	27.4.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	total
0					0		0				0		0				8276	18	266	4530	0	1	13092
1	0	0	0	1	0		0	383	53	18	21	4921	256				3658	16	2264	20889	0	7	32487
2	0	0	0	0	0	0	0	290	40	13	16	3733	194	0	0		102	26	847	10851	0	5	16119
3	0	0	1	3	0	0	4	25	3	1	1	317	16	0	1		45	13	261	9959	0	4	10655
4	4	34	59	198	15	1	412	28	4	1	2	364	19	1	55		72	7	178	13110	0	4	14569
5	1	4	13	32	0	0	3	4	1	0	0	55	3	0	0		53	5	272	7152	0	2	7602
6	1	9	1307	35	0	0	4	9	1	0	0	116	6	0	1		56	4	595	3917	0	2	6064
7	1	5	722	12	0	0	1	1	0	0	0	8	0	0	0		39	2	716	352	0	1	1859
8	0	1	8	4	0		0	2	0	0	0	28	1			2	27	0	815	991	0	1	1880
9	0	3	2387	14	0		0	8	1	0	0	106	5			14	32	1	852	376	0	1	3802
10	2	14	3560	48	0	0	2	7	1	0	0	96	5	0	0	58	34	1	1274	146	0	1	5250
11	0	2	1029	8	0		0	17	2	1	1	214	11			82	20	0	598	19	0	0	2004
12	0	1	966	4	0		0	20	3	1	1	253	13			209	20	0	512	14	0	0	2018
13	0	1	1269	2	0		0	10	1	0	1	134	7			103	8	0	167	21	0	0	1725
14	0	0	1	3	0		0				0		0			136	5	0	73	14	0	0	232
15	1	9	5828	32	0		0	78	11	4	4	998	52			760	12	0	206	75	0	0	8069
sum	11	84	17151	396	16	1	426	882	122	41	48	11343	590	1	56	1363	12459	94	9895	72416	0	30	127426

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	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d.2	total
0								0				0		0			940	11266	44	174		221	12645
1	3	8	51	144	0			0	6092	2079		5	7	454			675	7295	19	1276	1543	98	19749
2	0	1	7	21	0	6	0	1	4621	1577		4	5	345	0	0		413	49	387	5996	3	13436
3	1	1	10	28	0	52	0	6	392	134		0	0	29	0	0	31	104	31	230	4789	1	5840
4	270	683	4588	13027	0	5330	1	654	451	154		0	0	34	1	6	93	121	9	220	3427	2	29071
5	32	82	553	1571	0	39	0	5	69	23		0	0	5	0	0	192	103	6	331	1553	2	4566
6	69	175	1167	3314	0	50	0	6	10	49	108	0	0	11	0	0	232	135	3	620	924	2	6873
7	37	94	625	1775	0	12	0	1	10	3		0	0	1	0	0	129	104	1	638	197	1	3627
8	6	16	109	310	0			0	2	12	25	0	0	3			32	61	0	595	733	0	1905
9	27	67	451	1280	0			0		45	105	0	0	10			36	54	0	599	446	1	3120
10	108	275	1833	5206	0	29	0	4		41	95	0	0	9	0	0	10	53	0	937	997	1	9598
11	16	40	270	766	0			0		91	213	0	0	20			5	52	0	553	205	0	2231
12	8	19	129	365	0			0		107	251	0	0	23			2	72	1	592	175	0	1745
13	5	14	93	263	0			0		57	133	0	0	12			1	33	0	242	183	0	1038
14	1	3	23	65				0				0		0				32	0	196	31	0	352
15	70	176	1177	3340	0			0		422	990	1	1	92			132	101	0	703	66	0	7271
sum	653	1655	11085	31474	0	5517	1	677	11647	4791	1920	12	16	1048	1	6	2510	19998	163	8295	21265	333	123066

Table 7.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (thousands) at age by quarter and area in 2018 (15 = 15+ group)

Q1-4																								
Age	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	total
0						0		0			0	0		0			940	19542	62	440	4530	0	223	25736
1	3	8	51	145	0	0		0	6475	2131	18	26	4927	711			675	59833	196	8377	22986	3	440	107004
2	3	1	7	170	0	6	0	1	4991	1617	13	1184	3738	640	0	0	5	4986	121	1696	23734	4	38	42957
3	33	1	10	1837	0	158	0	14	1436	137	2	14625	335	1345	0	1	75	624	162	720	32844	10	8	54376
4	2000	718	4588	110042	0	19807	14	1495	5908	159	3	78452	714	6974	2	62	245	456	117	728	25071	5	8	257565
5	336	86	556	18612	0	4236	3	132	366	24	0	4004	121	382	0	1	293	396	42	937	13351	3	6	43887
6	334	183	2464	18175	0	6192	5	192	155	50	108	1599	667	190	0	2	517	459	25	1885	6627	1	5	39837
7	102	99	1345	5367	0	1243	1	39	110	3	0	851	814	128	0	2	563	317	15	2274	1163	1	2	14438
8	36	17	116	1956	0	800	1	24	33	12	25	70	508	41	0	1	608	177	9	2216	2156	1	2	8809
9	129	71	2834	7031	0	2389	2	71	97	46	105	577	905	128	0	1	924	151	5	2219	1325	1	2	19014
10	443	289	5381	23894	0	6989	6	212	112	42	96	650	1112	147	0	2	890	121	4	2865	1575	1	2	44833
11	74	42	1297	4007	0	734	1	22	31	93	213	141	271	49	0	0	1372	115	3	1988	420	1	1	10875
12	40	20	1094	2206	0	659	1	20	46	109	252	218	424	70	0	0	906	119	4	1530	347	0	1	8065
13	21	15	1362	1145	0	262	0	8	18	58	134	1	220	29	0	0	410	59	2	572	273	0	1	4589
14	32	3	23	1761		513	0	15	8	0	0	70	37	10	0	0	410	58	1	429	274	0	0	3645
15	293	185	6996	15815	0	4488	4	133	165	432	994	711	1568	255	0	1	1636	168	3	1199	481	0	1	35529
Sum	3879	1739	28124	212163	0	48475	37	2377	19949	4914	1963	103179	16361	11098	3	73	10468	87584	772	30074	137158	30	740	721159

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

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	0.003	0.000	0.000	0.070	0.051	0.000	0.013	0.009	0.037	0.017	0.003	0.051	0.002	0.209	0.048
1	0.013	0.027	0.000	0.006	0.000	0.000	0.094	0.000	0.070	0.083	0.792	0.452	0.210	0.804	0.068	0.381	0.316	0.336	0.228	0.321	1.744
2	0.073	0.008	0.832	0.017	0.000	0.002	0.021	0.000	0.155	0.193	0.125	0.379	3.145	2.231	2.275	1.627	0.636	0.289	0.451	0.705	0.423
3	0.465	0.113	0.015	2.080	0.005	0.000	0.007	0.072	0.479	0.062	0.278	0.058	0.399	1.814	2.981	2.528	1.685	0.610	0.224	0.575	0.545
4	0.040	0.185	0.125	0.015	2.332	0.010	0.015	0.063	0.212	0.551	0.194	0.215	0.183	0.930	0.653	1.409	1.240	0.917	0.411	0.392	0.425
5	0.046	0.053	0.517	0.144	0.030	3.075	0.065	0.018	0.115	0.335	0.883	0.365	0.154	0.257	0.302	0.885	0.750	0.878	0.801	0.415	0.230
6	0.040	0.154	0.077	0.346	0.225	0.007	3.248	0.050	0.036	0.171	0.437	1.123	0.134	0.395	0.180	0.487	0.528	0.732	0.697	0.488	0.238
7	0.031	0.182	0.132	0.044	0.379	0.143	0.042	4.404	0.071	0.075	0.168	0.487	0.765	0.124	0.193	0.494	0.412	0.646	0.572	0.897	0.328
8	0.006	0.062	0.117	0.056	0.089	0.313	0.138	0.042	4.776	0.059	0.066	0.236	0.367	0.789	0.186	0.496	0.267	0.508	0.377	0.752	0.458

year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9	0.001	0.011	0.051	0.021	0.073	0.040	0.234	0.205	0.128	3.547	0.081	0.191	0.141	0.391	0.198	0.424	0.231	0.268	0.188	0.381	0.301
10	0.006	0.019	0.014	0.032	0.053	0.033	0.034	0.287	0.243	0.070	3.793	0.106	0.149	0.333	0.196	0.459	0.173	0.123	0.050	0.133	0.159
11	0.023	0.012	0.000	0.001	0.011	0.067	0.056	0.048	0.352	0.042	0.046	3.710	0.077	0.207	0.316	0.331	0.203	0.079	0.060	0.078	0.102
12	0.064	0.059	0.002	0.003	0.004	0.031	0.060	0.083	0.052	0.151	0.079	0.039	3.168	0.218	0.231	0.610	0.105	0.119	0.064	0.059	0.087
13	0.099	0.082	0.006	0.013	0.003	0.005	0.018	0.047	0.120	0.028	0.225	0.083	0.035	3.283	0.193	0.339	0.227	0.103	0.064	0.049	0.039
14	0.067	0.132	0.018	0.004	0.001	0.001	0.017	0.031	0.062	0.024	0.041	0.235	0.050	0.135	1.204	0.178	0.199	0.144	0.035	0.065	0.044
15	0.028	0.160	0.176	0.120	0.178	0.113	0.112	0.063	0.195	0.088	0.115	0.111	0.126	0.511	0.571	0.976	0.488	0.421	0.252	0.224	0.251

Table 7.2.4.3. cont. Western horse mackerel. Marginal age-distribution

year	2003*	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Timing	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
Sex	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
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
0	0.007	0.077	0.005	0.007	0.018	0.104	0.164	0.015	0.004	0.018	0.325	0.066	0.295	0.462	0.361	0.089
1	1.115	0.548	0.257	0.184	0.112	0.269	0.297	0.235	0.059	0.166	0.478	0.090	0.373	0.581	0.468	0.369
2	1.759	0.400	0.591	0.200	0.133	0.084	0.108	0.422	0.213	0.147	0.120	0.286	0.088	0.336	0.091	0.148
3	0.488	1.677	1.072	0.260	0.140	0.185	0.196	0.239	0.366	0.222	0.118	0.119	0.178	0.064	0.456	0.188

year	2003*	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
4	0.514	0.280	1.865	0.315	0.214	0.197	0.138	0.101	0.177	0.591	0.265	0.097	0.109	0.107	0.119	0.888
5	0.307	0.341	0.241	1.663	0.389	0.291	0.125	0.105	0.122	0.193	0.859	0.214	0.085	0.065	0.172	0.151
6	0.204	0.240	0.258	0.198	1.198	0.189	0.216	0.177	0.133	0.131	0.232	0.527	0.159	0.050	0.079	0.137
7	0.168	0.169	0.213	0.128	0.166	1.027	0.199	0.380	0.205	0.097	0.086	0.195	0.409	0.078	0.049	0.050
8	0.180	0.112	0.153	0.145	0.100	0.172	0.942	0.255	0.204	0.088	0.064	0.075	0.094	0.279	0.076	0.030
9	0.352	0.179	0.078	0.058	0.074	0.127	0.236	0.984	0.210	0.157	0.072	0.057	0.044	0.066	0.182	0.066
10	0.197	0.188	0.093	0.041	0.030	0.087	0.145	0.242	0.826	0.142	0.108	0.082	0.038	0.036	0.043	0.155
11	0.110	0.115	0.147	0.059	0.024	0.050	0.105	0.119	0.306	0.559	0.072	0.082	0.043	0.036	0.022	0.038
12	0.094	0.043	0.082	0.110	0.029	0.044	0.073	0.084	0.101	0.174	0.366	0.085	0.041	0.051	0.021	0.028
13	0.030	0.046	0.024	0.044	0.048	0.032	0.029	0.051	0.061	0.083	0.074	0.198	0.025	0.056	0.024	0.016
14	0.026	0.015	0.026	0.026	0.026	0.046	0.023	0.052	0.034	0.040	0.056	0.087	0.168	0.064	0.025	0.013
15	0.140	0.073	0.064	0.085	0.063	0.083	0.137	0.152	0.122	0.105	0.085	0.082	0.055	0.216	0.116	0.123

***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
2007	0	0	0	0	0	0	0	0	2	3	3	3	1	4	4	15
2007	0	0	0	0	0	0	0	0	0	1	4	0	0	3	6	11
2007	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	15
2007	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	14
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2008	0	0	0	0	2	1	0	4	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2008	0	0	0	0	14	19	4	52	1	0	0	0	0	0	0	0
2008	0	0	0	0	14	46	13	197	3	1	0	0	0	0	0	0
2008	0	0	0	0	7	29	15	353	1	7	1	0	1	0	0	0
2008	0	0	0	0	5	18	9	391	9	8	2	2	0	1	1	0
2008	0	0	0	0	0	6	5	358	27	18	7	3	2	1	4	3
2008	0	0	0	0	0	3	2	276	39	32	12	2	7	3	8	7
2008	0	0	0	0	0	0	4	188	39	35	27	6	5	7	4	8
2008	0	0	0	0	0	0	2	79	25	29	28	7	2	7	13	16
2008	0	0	0	0	0	0	0	42	12	24	25	9	7	6	10	18
2008	0	0	0	0	0	0	0	14	9	25	19	5	5	6	5	28
2008	0	0	0	0	0	0	0	3	4	9	12	4	3	4	6	34
2008	0	0	0	0	0	0	0	1	1	8	11	6	7	3	4	20
2008	0	0	0	0	0	0	0	2	0	0	8	4	6	0	10	18
2008	0	0	0	0	0	0	0	0	0	3	4	2	0	1	7	26
2008	0	0	0	0	0	0	0	0	1	2	1	1	0	0	3	23
2008	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	13
2008	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	4
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2009	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	5	4	6	1	0	3	0	0	0	0	0	0	0
2009	0	0	0	6	24	36	25	8	37	0	0	0	0	0	0	0
2009	0	0	0	0	23	64	67	26	167	5	2	3	0	0	0	0
2009	0	0	0	0	5	41	70	36	262	10	4	1	0	1	1	0
2009	0	0	0	0	1	12	45	22	314	22	8	2	2	0	0	5
2009	0	0	0	0	0	2	28	14	301	32	17	6	2	4	1	2
2009	0	0	0	0	0	1	11	5	229	38	17	17	6	1	2	9
2009	0	0	0	0	0	0	1	3	154	25	21	15	6	4	7	19
2009	0	0	0	0	0	0	0	4	87	21	19	12	9	1	8	27
2009	0	0	0	0	0	0	0	0	44	10	12	10	2	6	4	32
2009	0	0	0	0	0	0	0	0	17	4	10	15	3	4	3	26
2009	0	0	0	0	0	0	0	0	6	7	13	11	4	3	0	17
2009	0	0	0	0	0	0	0	0	2	2	7	8	3	3	1	18
2009	0	0	0	0	0	0	0	0	0	0	6	3	3	3	2	16
2009	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	20
2009	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	11

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
2009	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2010	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0
2010	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	5	4	1	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	2	4	7	3	3	0	1	0	0	0	0	0	0
2010	0	0	0	0	13	17	27	19	5	25	1	1	0	0	0	0
2010	0	0	0	0	4	12	17	26	12	69	3	2	1	1	0	1
2010	0	0	0	0	0	2	13	31	11	103	3	0	4	0	0	1
2010	0	0	0	0	0	1	10	13	11	145	4	5	1	1	1	1
2010	0	0	0	0	0	2	3	12	6	149	9	6	3	1	1	5
2010	0	0	0	0	0	0	1	1	2	133	6	12	5	2	1	8
2010	0	0	0	0	0	0	1	1	2	86	10	9	4	4	3	15
2010	0	0	0	0	0	0	1	1	3	57	8	10	3	2	1	6
2010	0	0	0	0	0	0	0	0	1	30	9	7	6	3	2	11
2010	0	0	0	0	0	0	0	1	0	18	10	5	7	1	2	16
2010	0	0	0	0	0	0	0	0	1	14	8	7	8	3	3	15

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2010	0	0	0	0	0	0	0	0	0	12	2	7	4	3	3	13
2010	0	0	0	0	0	0	0	0	0	3	3	6	1	4	0	17
2010	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	17
2010	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	9
2010	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
2011	0	0	7	2	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	20	10	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	17	39	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	10	52	2	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	9	51	4	1	0	0	0	0	0	0	0	0	0	0
2011	0	0	8	33	17	4	2	1	2	0	2	0	0	0	0	0
2011	0	0	4	15	21	18	8	7	5	2	10	1	1	0	0	0
2011	0	0	0	2	18	23	15	17	14	5	28	2	0	0	0	2
2011	0	0	0	0	2	10	18	28	17	7	81	1	0	1	0	1
2011	0	0	0	0	0	3	6	27	19	7	120	3	2	1	0	2
2011	0	0	0	0	1	2	4	9	9	6	136	2	6	2	1	4
2011	0	0	0	0	0	1	1	2	6	4	132	6	7	4	1	10
2011	0	0	0	0	0	1	1	1	1	2	99	11	7	7	1	9

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2011	0	0	0	0	0	0	0	0	2	0	73	9	11	8	1	10
2011	0	0	0	0	0	0	0	0	0	0	44	15	8	3	3	10
2011	0	0	0	0	0	0	0	0	0	1	32	6	14	10	2	11
2011	0	0	0	0	0	0	0	0	0	0	27	4	6	9	2	18
2011	0	0	0	0	0	0	0	0	0	0	8	6	8	8	1	15
2011	0	0	0	0	0	0	0	0	0	0	4	5	4	2	2	8
2011	0	0	0	0	0	0	0	0	0	0	3	3	4	5	1	9
2011	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3
2011	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2012	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	1	21	22	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	20	51	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	10	92	6	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	4	107	14	1	1	0	0	0	0	0	0	0	0
2012	0	0	0	0	97	28	3	2	1	2	0	1	0	0	0	0
2012	0	0	0	2	74	27	16	2	6	5	0	15	1	0	1	0
2012	0	0	0	0	26	34	20	9	16	16	5	44	0	1	0	1

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2012	0	0	0	0	6	12	17	22	17	32	4	85	6	2	1	1
2012	0	0	0	0	0	4	8	13	26	26	8	113	2	4	0	4
2012	0	0	0	0	0	1	5	9	8	12	13	119	3	5	3	2
2012	0	0	0	0	0	0	0	2	7	12	1	118	7	5	2	4
2012	0	0	0	0	0	0	0	2	4	4	3	90	2	6	4	9
2012	0	0	0	0	0	0	0	0	1	1	5	71	6	6	4	8
2012	0	0	0	0	0	0	0	0	2	2	3	55	8	6	4	11
2012	0	0	0	0	0	0	0	0	0	1	2	25	3	5	5	16
2012	0	0	0	0	0	0	0	0	0	0	1	14	2	5	5	10
2012	0	0	0	0	0	0	0	0	0	0	1	4	1	2	4	3
2012	0	0	0	0	0	0	0	0	0	0	0	2	1	2	3	3
2012	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	5
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2013	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	1	6	5	0	0	0	0	0	0	0	0	0	0
2013	0	0	1	2	18	20	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
2013	0	0	0	2	14	59	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	1	27	116	1	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	18	153	8	1	0	0	0	0	0	0	0	0
2013	0	0	0	0	9	141	33	5	2	1	1	0	1	0	0	0
2013	0	0	0	0	4	103	47	6	5	6	6	2	19	1	1	0
2013	0	0	0	0	2	44	38	14	6	19	16	4	56	4	2	0
2013	0	0	0	0	0	11	20	13	14	26	18	2	90	5	6	3
2013	0	0	0	0	0	3	10	13	10	15	13	7	119	4	2	3
2013	0	0	0	0	0	1	2	4	11	13	11	3	91	7	6	5
2013	0	0	0	0	0	0	2	4	0	0	9	3	68	5	7	3
2013	0	0	0	0	0	0	0	0	0	3	1	2	60	3	4	8
2013	0	0	0	0	0	0	0	0	2	2	2	0	49	6	3	9
2013	0	0	0	0	0	0	0	0	0	0	0	1	29	4	9	7
2013	0	0	0	0	0	0	0	0	0	0	1	0	23	3	2	12
2013	0	0	0	0	0	0	0	0	0	0	0	1	13	3	8	8
2013	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	7
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
2013	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2014	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	5	6	2	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	8	22	4	9	8	0	0	0	0	0	0	0	0	0
2014	0	0	6	17	10	16	27	2	1	0	0	0	0	0	0	0
2014	0	0	4	6	8	34	54	7	0	0	0	0	0	0	0	0
2014	0	0	0	0	8	24	83	21	0	0	0	0	0	0	0	0
2014	0	0	0	0	2	17	76	35	2	1	2	1	0	3	0	0
2014	0	0	0	0	0	8	65	30	7	6	3	5	5	9	1	0
2014	0	0	0	0	1	4	38	23	3	5	8	6	10	27	6	3
2014	0	0	0	0	0	2	9	10	9	11	13	9	13	42	3	2
2014	0	0	0	0	0	0	2	5	3	3	9	12	10	27	8	7
2014	0	0	0	0	0	0	0	1	6	2	3	6	8	31	4	5
2014	0	0	0	0	0	0	0	0	0	0	4	2	5	24	2	6
2014	0	0	0	0	0	0	0	0	0	1	0	3	4	16	8	5
2014	0	0	0	0	0	0	0	0	0	0	2	0	2	13	4	5
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	3

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	3
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2015	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	8	2	2	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	22	5	4	2	0	0	0	0	0	0	0	0	0
2015	0	0	0	15	22	4	2	2	0	0	0	0	0	0	0	0
2015	0	0	0	8	12	13	11	16	0	0	0	0	0	0	0	0
2015	0	0	0	5	16	9	11	43	1	1	0	0	0	0	0	0
2015	0	0	0	3	4	3	18	82	3	1	1	0	0	0	1	0
2015	0	0	0	0	1	5	15	85	8	2	2	1	1	1	5	1
2015	0	0	0	0	0	0	12	75	11	3	0	0	4	4	15	5
2015	0	0	0	0	0	1	4	36	10	6	1	5	9	5	34	5

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2015	0	0	0	0	0	0	2	20	7	4	5	7	9	3	51	7
2015	0	0	0	0	0	1	0	9	0	10	6	5	10	4	43	12
2015	0	0	0	0	0	0	0	2	1	4	5	7	6	6	42	11
2015	0	0	0	0	0	0	0	0	0	2	2	1	2	1	32	9
2015	0	0	0	0	0	0	0	1	0	0	0	1	3	2	18	4
2015	0	0	0	0	0	0	0	0	0	0	1	0	2	1	5	5
2015	0	0	0	0	0	0	0	0	0	0	0	1	1	0	6	3
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
2016	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	22	1	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	21	3	2	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	16	13	6	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	9	14	9	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	10	13	3	1	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2016	0	0	0	3	12	4	4	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	4	0	2	1	1	0	0	0	0	0	0	0
2016	0	0	0	0	1	1	4	4	5	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	2	12	12	0	0	0	1	0	0	0
2016	0	0	0	0	0	0	1	8	15	2	0	0	1	0	0	0
2016	0	0	0	0	0	0	1	7	15	4	1	1	2	2	7	4
2016	0	0	0	0	0	0	1	7	7	2	0	2	5	3	5	7
2016	0	0	0	0	0	0	0	0	2	0	3	2	5	5	5	7
2016	0	0	0	0	0	0	0	0	1	1	1	1	2	4	7	6
2016	0	0	0	0	0	0	0	1	0	0	0	0	3	6	5	7
2016	0	0	0	0	0	0	0	0	0	0	0	0	1	5	13	7
2016	0	0	0	0	0	0	0	0	0	0	0	0	1	3	9	3
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7
2016	0	0	0	0	0	0	0	0	0	2	0	0	0	1	6	5
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2017	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2017	10	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	10	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	10	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	10	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	4	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	29	10	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	22	34	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	23	74	3	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	19	79	35	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	7	40	70	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	1	22	98	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	8	97	2	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	4	104	11	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	112	23	1	0	0	0	0	0	0	0	0	0	0
2017	0	0	1	105	53	11	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	69	112	44	13	0	0	0	0	0	0	0	0	0
2017	0	0	1	47	88	128	39	5	1	0	0	0	0	0	0	0
2017	0	0	0	27	50	145	83	12	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2017	0	0	0	6	29	117	136	50	4	7	1	0	0	0	0	2
2017	0	0	0	3	20	107	53	83	21	28	1	0	0	0	0	1
2017	0	0	0	0	6	73	24	27	99	74	11	0	0	0	1	2
2017	0	0	0	0	3	33	13	7	46	137	14	1	2	2	2	5
2017	0	0	0	0	2	7	3	11	40	97	80	7	2	3	8	6
2017	0	0	0	0	0	2	4	2	30	69	22	35	9	10	7	8
2017	0	0	0	0	0	0	1	2	10	47	16	20	31	16	15	6
2017	0	0	0	0	0	0	0	1	9	16	7	12	16	16	17	5
2017	0	0	0	0	0	0	0	0	3	14	6	10	6	9	27	4
2017	0	0	0	0	0	0	0	0	2	4	3	2	10	4	10	2
2017	0	0	0	0	0	0	0	0	0	5	3	2	0	1	2	1
2017	0	0	0	0	0	0	0	0	0	3	0	0	3	1	1	1
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2018	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2018	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	13	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	14	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	3	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	2	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	18	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	18	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	11	83	8	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	54	42	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	56	31	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	66	24	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	55	61	19	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	42	102	41	5	0	0	0	0	0	0	0	0	0	0	0
2018	0	21	184	100	49	0	0	0	0	0	0	0	0	0	0	0
2018	0	10	112	104	167	1	0	0	0	0	0	0	0	0	0	0
2018	0	0	70	119	431	11	1	0	0	0	0	0	0	0	0	0
2018	0	0	15	113	584	52	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	52	531	79	27	3	3	2	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2018	0	0	0	6	409	146	49	10	3	3	0	0	0	0	0	0
2018	0	0	0	3	175	203	140	39	13	6	0	1	0	0	0	1
2018	0	0	0	0	81	145	217	93	15	15	4	0	0	0	0	0
2018	0	0	0	0	24	74	177	158	54	12	19	1	1	0	0	0
2018	0	0	0	0	3	34	130	59	138	61	55	8	0	0	0	2
2018	0	0	0	0	3	15	78	25	43	139	121	30	9	4	3	13
2018	0	0	0	0	0	3	41	40	16	65	229	39	16	8	4	40
2018	0	0	0	0	0	2	13	12	14	40	192	116	33	10	8	62
2018	0	0	0	0	0	0	2	7	4	27	102	63	91	27	18	106
2018	0	0	0	0	0	0	1	1	2	16	62	21	70	47	32	115
2018	0	0	0	0	0	0	0	2	1	6	26	15	16	15	45	135
2018	0	0	0	0	0	0	0	0	0	0	4	8	8	7	11	128
2018	0	0	0	0	0	0	0	0	0	1	5	1	4	7	3	79
2018	0	0	0	0	0	0	0	0	0	0	1	0	4	6	5	37
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	32
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	9
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10

Table 7.2.4.5. Western horse mackerel. Catch-at-lengh 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
Timing		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
Sex		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
Sample number		34	42	50	40	47	53	57	37	46	87	68	49	48	66	63	82	101	108	104
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
	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
	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
	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
	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
	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
	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
	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	0.000
	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	0.004
	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	0.008
	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	0.013
	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	0.005

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	0.002
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	0.004
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	0.007
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	0.015
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	0.026
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	0.037
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	0.062
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	0.070
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	0.058
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	0.046
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	0.039
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	0.032
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	0.033
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	0.043
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	0.060
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	0.073
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	0.098
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	0.090

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	0.051
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	0.033
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	0.036
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	0.026
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	0.014
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	0.009
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	0.004
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	0.001
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	0.001
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
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
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
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
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
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
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
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

Table 7.2.4.6. Western horse mackerel. Catch-at-lengh distribution from the combined international bottom trawl survey.

year		1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018
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
Fleet		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
catch		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
Length bins (cm)	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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
	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
	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	0.000
	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	0.003
	11	0.000	0.024	0.002	0.000	0.002	0.006	0.014	0.000	0.257	0.000	0.006	0.113	0.000	0.000	0.009	0.003	0.058	0.009	0.112	0.077
	12	0.000	0.128	0.043	0.017	0.009	0.002	0.046	0.000	0.092	0.000	0.001	0.025	0.000	0.000	0.024	0.015	0.108	0.014	0.097	0.144
	13	0.000	0.055	0.066	0.028	0.016	0.002	0.025	0.000	0.063	0.000	0.000	0.007	0.001	0.000	0.080	0.012	0.126	0.003	0.060	0.096
	14	0.000	0.016	0.047	0.084	0.013	0.000	0.006	0.000	0.038	0.000	0.000	0.009	0.000	0.001	0.083	0.003	0.095	0.009	0.034	0.038
	15	0.000	0.011	0.029	0.140	0.005	0.000	0.019	0.000	0.018	0.000	0.000	0.017	0.004	0.003	0.020	0.001	0.035	0.053	0.014	0.051

year	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018
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	0.068
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	0.081
18	0.000	0.015	0.148	0.045	0.005	0.000	0.003	0.000	0.004	0.024	0.000	0.012	0.019	0.003	0.021	0.066	0.020	0.059	0.120	0.091
19	0.004	0.009	0.163	0.073	0.005	0.000	0.001	0.000	0.002	0.019	0.001	0.001	0.017	0.012	0.020	0.081	0.022	0.059	0.076	0.072
20	0.026	0.000	0.083	0.008	0.005	0.000	0.007	0.000	0.005	0.016	0.018	0.002	0.009	0.057	0.024	0.195	0.036	0.057	0.043	0.039
21	0.089	0.002	0.032	0.031	0.007	0.002	0.012	0.000	0.013	0.018	0.126	0.002	0.047	0.117	0.013	0.235	0.053	0.059	0.034	0.050
22	0.298	0.000	0.012	0.017	0.003	0.007	0.007	0.002	0.010	0.030	0.123	0.008	0.087	0.171	0.011	0.089	0.059	0.052	0.031	0.032
23	0.337	0.003	0.014	0.026	0.007	0.035	0.023	0.004	0.004	0.056	0.129	0.026	0.073	0.142	0.022	0.039	0.083	0.073	0.035	0.019
24	0.159	0.003	0.028	0.032	0.011	0.066	0.064	0.025	0.008	0.073	0.078	0.035	0.072	0.070	0.026	0.009	0.100	0.061	0.031	0.027
25	0.055	0.003	0.042	0.053	0.003	0.076	0.125	0.109	0.047	0.098	0.083	0.063	0.071	0.064	0.024	0.034	0.068	0.053	0.021	0.024
26	0.013	0.023	0.042	0.040	0.008	0.039	0.123	0.244	0.083	0.179	0.136	0.087	0.090	0.086	0.038	0.028	0.026	0.045	0.028	0.020
27	0.011	0.077	0.025	0.042	0.029	0.029	0.109	0.293	0.074	0.134	0.141	0.091	0.136	0.083	0.048	0.027	0.011	0.039	0.027	0.013
28	0.004	0.183	0.023	0.030	0.099	0.044	0.084	0.141	0.037	0.098	0.058	0.088	0.103	0.076	0.077	0.016	0.007	0.017	0.022	0.013
29	0.000	0.168	0.031	0.044	0.212	0.146	0.094	0.089	0.015	0.097	0.037	0.069	0.077	0.051	0.127	0.027	0.007	0.009	0.013	0.009
30	0.001	0.080	0.029	0.047	0.275	0.179	0.100	0.062	0.008	0.061	0.029	0.059	0.056	0.039	0.134	0.021	0.003	0.002	0.007	0.012
31	0.001	0.045	0.017	0.016	0.166	0.120	0.067	0.021	0.001	0.041	0.022	0.033	0.042	0.014	0.080	0.013	0.006	0.000	0.002	0.012
32	0.000	0.019	0.009	0.017	0.078	0.062	0.016	0.008	0.001	0.028	0.005	0.017	0.040	0.004	0.047	0.016	0.005	0.003	0.003	0.005
33	0.000	0.002	0.005	0.000	0.024	0.029	0.010	0.002	0.000	0.006	0.003	0.009	0.014	0.002	0.014	0.008	0.003	0.002	0.004	0.001

year	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2013	2014	2015	2016	2017	2018
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	0.001
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
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
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	0.000
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
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
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
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
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
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
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 7.2.5.1. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2018 (15 = 15+ group)

Q1																			
weight	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.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.d.2	total
0					0.010					0.010								0.010	0.010
1					0.014					0.014			0.012	0.027	0.023	0.046	0.025	0.014	0.020
2	0.112	0.112			0.050	0.051	0.051	0.050		0.050		0.100	0.028	0.074	0.041	0.085	0.071	0.050	0.056
3	0.096	0.095	0.075	0.075	0.074	0.074	0.074	0.072		0.074	0.059	0.109	0.052	0.093	0.072	0.102	0.091	0.074	0.077
4	0.114	0.114	0.122	0.122	0.112	0.096	0.096	0.094		0.101	0.132	0.118	0.090	0.113	0.108	0.125	0.115	0.103	0.106
5	0.170	0.170	0.171	0.171	0.161	0.130	0.130	0.131		0.144	0.184	0.147	0.105	0.144	0.132	0.147	0.134	0.151	0.137
6	0.206	0.204	0.209	0.209	0.208	0.200	0.200	0.188	0.226	0.204	0.231	0.176	0.118	0.162	0.152	0.171	0.157	0.207	0.171
7	0.232	0.232	0.230	0.230	0.237	0.257	0.257	0.251	0.275	0.248	0.278	0.193	0.135	0.182	0.177	0.195	0.182	0.244	0.201
8	0.240	0.238	0.248	0.247	0.252	0.278	0.278	0.257	0.282	0.264	0.282	0.222	0.152	0.195	0.206	0.215	0.208	0.257	0.219
9	0.259	0.261	0.255	0.255	0.256	0.260	0.260	0.304	0.294	0.258	0.297	0.239	0.177	0.214	0.227	0.234	0.231	0.257	0.236
10	0.270	0.269	0.265	0.265	0.269	0.307	0.307	0.331	0.289	0.284	0.295	0.269	0.199	0.260	0.254	0.260	0.261	0.272	0.260
11	0.277	0.278	0.266	0.273	0.274	0.283	0.283	0.244		0.278	0.353	0.280	0.210	0.272	0.267	0.295	0.280	0.275	0.261
12	0.326	0.328	0.303	0.304	0.323	0.419	0.419	0.551	0.399	0.368	0.384	0.320	0.250	0.282	0.313	0.312	0.317	0.343	0.334
13	0.330	0.334	0.302	0.303	0.309	0.344	0.344			0.324	0.344	0.355	0.263	0.282	0.348	0.344	0.347	0.314	0.321
14	0.313	0.314	0.275	0.274	0.275	0.279	0.279	0.278		0.277	0.281	0.362	0.279	0.273	0.359	0.403	0.385	0.275	0.317
15	0.341	0.341	0.327	0.326	0.330	0.360	0.360	0.341	0.326	0.342	0.347	0.409	0.278	0.291	0.400	0.463	0.452	0.333	0.358

Q2																					
Weight	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	total
0					0.010			0.010			0.010										0.010
1					0.014			0.014			0.014				0.012	0.015	0.025	0.034	0.025	0.012	0.018
2	0.112	0.112			0.050	0.051	0.051	0.050	0.052		0.051				0.027	0.053	0.043	0.079	0.071	0.027	0.048
3	0.096	0.096	0.075	0.075	0.074	0.074	0.074	0.074	0.077	0.059	0.074	0.059	0.059		0.053	0.079	0.074	0.094	0.091	0.052	0.070
4	0.114	0.114	0.122	0.122	0.112	0.096	0.096	0.101	0.100	0.132	0.099	0.132	0.132		0.092	0.092	0.097	0.118	0.115	0.091	0.102
5	0.170	0.170	0.171	0.171	0.161	0.130	0.130	0.144	0.125	0.184	0.138	0.184	0.184		0.105	0.130	0.120	0.136	0.134	0.104	0.129
6	0.206	0.206	0.209	0.209	0.208	0.200	0.200	0.204	0.211	0.243	0.203	0.231	0.231		0.118	0.171	0.142	0.162	0.157	0.120	0.162
7	0.232	0.232	0.230	0.230	0.237	0.257	0.257	0.248	0.215	0.292	0.251	0.278	0.278		0.135	0.194	0.169	0.194	0.182	0.137	0.189
8	0.240	0.240	0.247	0.247	0.252	0.278	0.278	0.264		0.281	0.270	0.282	0.282		0.151	0.216	0.201	0.218	0.208	0.158	0.208
9	0.259	0.259	0.255	0.255	0.256	0.260	0.260	0.258	0.221	0.317	0.259	0.297	0.297		0.174	0.222	0.222	0.237	0.231	0.179	0.223
10	0.270	0.270	0.265	0.265	0.269	0.307	0.307	0.284	0.302	0.302	0.293	0.295	0.295		0.220	0.288	0.260	0.263	0.261	0.227	0.261
11	0.277	0.277	0.273	0.273	0.274	0.283	0.283	0.278		0.353	0.280	0.353	0.353		0.225	0.293	0.276	0.298	0.280	0.231	0.268
12	0.326	0.326	0.304	0.304	0.323	0.419	0.419	0.368	0.397	0.337	0.389	0.384	0.384		0.275	0.324	0.316	0.312	0.317	0.274	0.322
13	0.330	0.330	0.303	0.303	0.309	0.344	0.344	0.324		0.344	0.332	0.344	0.344		0.313	0.356	0.346	0.344	0.347	0.309	0.331
14	0.313	0.313	0.274	0.274	0.275	0.279	0.279	0.277		0.281	0.278	0.281	0.281		0.302	0.347	0.356	0.396	0.385	0.299	0.320
15	0.341	0.341	0.326	0.326	0.330	0.360	0.360	0.342	0.457	0.359	0.350	0.347	0.347	0.614	0.336	0.450	0.393	0.488	0.452	0.329	0.399

Table 7.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2018 (15 = 15+ group)

Q3																							
Weight	27.2.a	27.3.a	27.4.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	total
0					0.010		0.010				0.010		0.010				0.010	0.011	0.025	0.024	0.024	0.013	0.016
1	0.037	0.037		0.037	0.014		0.014	0.061	0.061	0.061	0.052	0.061	0.033				0.020	0.051	0.044	0.055	0.042	0.020	0.039
2	0.100	0.100		0.100	0.088	0.101	0.084	0.081	0.081	0.081	0.075	0.081	0.063	0.101	0.101		0.049	0.072	0.077	0.090	0.085	0.058	0.073
3	0.114	0.114		0.114	0.100	0.109	0.097	0.120	0.120	0.120	0.111	0.120	0.092	0.109	0.109		0.090	0.090	0.101	0.115	0.112	0.082	0.101
4	0.158	0.158		0.158	0.129	0.138	0.126	0.136	0.136	0.136	0.129	0.136	0.116	0.138	0.138		0.102	0.122	0.132	0.136	0.135	0.110	0.125
5	0.214	0.214	0.254	0.214	0.172	0.179	0.170	0.149	0.149	0.149	0.149	0.149	0.150	0.179	0.179		0.121	0.140	0.151	0.161	0.160	0.153	0.157
6	0.251	0.251	0.330	0.251	0.205	0.205	0.206	0.289	0.289	0.289	0.273	0.289	0.240	0.205	0.205		0.137	0.173	0.174	0.182	0.180	0.201	0.206
7	0.294	0.294	0.304	0.294	0.245	0.246	0.245	0.181	0.181	0.181	0.194	0.181	0.219	0.246	0.246		0.153	0.187	0.194	0.211	0.199	0.234	0.206
8	0.294	0.294	0.283	0.294	0.257		0.257	0.301	0.301	0.301	0.292	0.301	0.275			0.291	0.173	0.216	0.215	0.220	0.219	0.249	0.240
9	0.320	0.320	0.330	0.320	0.257		0.257	0.367	0.367	0.367	0.345	0.367	0.301			0.298	0.194	0.243	0.237	0.238	0.240	0.253	0.267
10	0.312	0.312	0.328	0.312	0.241	0.231	0.245	0.404	0.404	0.404	0.378	0.404	0.325	0.231	0.231	0.295	0.210	0.260	0.262	0.275	0.269	0.271	0.283
11	0.333	0.333	0.334	0.333	0.275		0.275	0.377	0.377	0.377	0.357	0.377	0.316			0.303	0.227	0.251	0.281	0.297	0.288	0.278	0.293
12	0.374	0.374	0.361	0.374	0.343		0.343	0.371	0.371	0.371	0.365	0.371	0.354			0.337	0.245	0.268	0.297	0.323	0.308	0.335	0.315
13	0.321	0.321	0.339	0.321	0.314		0.314	0.410	0.410	0.410	0.391	0.410	0.353			0.346	0.257	0.267	0.310	0.348	0.328	0.317	0.323
14	0.436	0.436		0.436	0.275		0.275				0.275		0.275			0.383	0.291	0.273	0.351	0.387	0.364	0.295	0.338
15	0.356	0.356	0.345	0.356	0.333		0.333	0.397	0.397	0.397	0.384	0.397	0.359			0.430	0.305	0.273	0.397	0.521	0.415	0.352	0.377

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	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d.2	total
0								0.010				0.010		0.010			0.010	0.010	0.008	0.024		0.010	0.014
1	0.037	0.037	0.037	0.037	0.061			0.014	0.061	0.061		0.045	0.061	0.042			0.022	0.023	0.068	0.036	0.080	0.020	0.040
2	0.100	0.100	0.100	0.100	0.081	0.101	0.101	0.084	0.081	0.081		0.071	0.081	0.069	0.101	0.101		0.048	0.079	0.063	0.092	0.049	0.075
3	0.114	0.114	0.114	0.114	0.120	0.109	0.109	0.097	0.120	0.120		0.105	0.120	0.101	0.109	0.109	0.100	0.085	0.094	0.092	0.113	0.091	0.102
4	0.158	0.158	0.158	0.158	0.136	0.138	0.138	0.126	0.136	0.136		0.125	0.136	0.123	0.138	0.138	0.105	0.101	0.118	0.124	0.135	0.102	0.126
5	0.214	0.214	0.214	0.214	0.149	0.179	0.179	0.170	0.149	0.149		0.150	0.149	0.150	0.179	0.179	0.123	0.122	0.135	0.149	0.161	0.126	0.154
6	0.251	0.251	0.251	0.251	0.289	0.205	0.205	0.206	0.181	0.289	0.297	0.262	0.289	0.256	0.205	0.205	0.133	0.138	0.169	0.171	0.184	0.136	0.193
7	0.294	0.294	0.294	0.294	0.181	0.246	0.246	0.245	0.181	0.181		0.202	0.181	0.206	0.246	0.246	0.144	0.152	0.184	0.190	0.215	0.150	0.200
8	0.294	0.294	0.294	0.294	0.301			0.257	0.203	0.301	0.308	0.286	0.301	0.283			0.165	0.169	0.208	0.213	0.224	0.171	0.226
9	0.320	0.320	0.320	0.320	0.367			0.257		0.367	0.367	0.330	0.367	0.323			0.186	0.193	0.238	0.237	0.238	0.194	0.256
10	0.312	0.312	0.312	0.312	0.404	0.231	0.231	0.245		0.404	0.404	0.360	0.404	0.351	0.231	0.231	0.185	0.212	0.259	0.263	0.277	0.209	0.271
11	0.333	0.333	0.333	0.333	0.377			0.275		0.377	0.377	0.343	0.377	0.336			0.190	0.235	0.253	0.284	0.298	0.226	0.285
12	0.374	0.374	0.374	0.374	0.371			0.343		0.371	0.371	0.362	0.371	0.360			0.190	0.255	0.269	0.305	0.322	0.243	0.305
13	0.321	0.321	0.321	0.321	0.410			0.314		0.410	0.410	0.378	0.410	0.372			0.190	0.264	0.268	0.321	0.341	0.250	0.307
14	0.436	0.436	0.436	0.436				0.275				0.275		0.275				0.297	0.273	0.360	0.376	0.278	0.352
15	0.356	0.356	0.356	0.356	0.397			0.333		0.397	0.397	0.376	0.397	0.372			0.901	0.320	0.273	0.397	0.475	0.315	0.416

Table 7.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch-at-age by quarter and area in 2018 (15 = 15+ group)

Q1-4																								
Weight	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	total
0						0.010		0.010			0.010	0.010		0.010			0.010	0.010	0.010	0.025	0.024	0.024	0.011	0.015
1	0.037	0.037	0.037	0.037	0.061	0.014		0.014	0.061	0.061	0.042	0.048	0.061	0.029			0.022	0.017	0.044	0.032	0.057	0.027	0.017	0.032
2	0.106	0.100	0.101	0.106	0.081	0.096	0.101	0.076	0.067	0.070	0.066	0.059	0.081	0.058	0.101	0.101	0.100	0.038	0.070	0.056	0.086	0.073	0.047	0.064
3	0.105	0.114	0.112	0.103	0.120	0.088	0.092	0.088	0.099	0.103	0.097	0.087	0.096	0.085	0.076	0.092	0.105	0.070	0.089	0.084	0.106	0.094	0.076	0.088
4	0.136	0.158	0.154	0.133	0.136	0.127	0.130	0.121	0.118	0.121	0.118	0.108	0.134	0.109	0.134	0.136	0.112	0.096	0.112	0.115	0.129	0.118	0.102	0.115
5	0.192	0.214	0.230	0.188	0.149	0.173	0.175	0.166	0.140	0.142	0.147	0.137	0.163	0.146	0.183	0.181	0.136	0.114	0.137	0.138	0.152	0.138	0.134	0.145
6	0.228	0.251	0.285	0.224	0.289	0.208	0.207	0.206	0.216	0.256	0.274	0.223	0.258	0.225	0.223	0.214	0.156	0.128	0.168	0.160	0.175	0.160	0.164	0.184
7	0.263	0.294	0.296	0.259	0.181	0.236	0.238	0.242	0.216	0.209	0.214	0.222	0.240	0.232	0.267	0.257	0.170	0.144	0.187	0.183	0.204	0.184	0.189	0.199
8	0.267	0.294	0.287	0.262	0.301	0.248	0.247	0.254	0.261	0.292	0.296	0.273	0.290	0.273	0.282	0.282	0.224	0.161	0.208	0.209	0.219	0.209	0.207	0.224
9	0.290	0.320	0.322	0.286	0.367	0.255	0.255	0.256	0.297	0.327	0.342	0.296	0.332	0.284	0.297	0.297	0.239	0.184	0.228	0.231	0.237	0.232	0.219	0.246
10	0.291	0.312	0.317	0.288	0.404	0.253	0.248	0.254	0.340	0.368	0.376	0.338	0.342	0.312	0.274	0.252	0.249	0.210	0.272	0.260	0.269	0.262	0.243	0.269
11	0.305	0.333	0.331	0.301	0.377	0.269	0.273	0.274	0.316	0.342	0.354	0.296	0.367	0.301	0.353	0.353	0.258	0.224	0.273	0.277	0.297	0.281	0.251	0.277
12	0.350	0.374	0.366	0.347	0.371	0.306	0.304	0.330	0.402	0.389	0.370	0.443	0.369	0.368	0.384	0.384	0.283	0.256	0.292	0.308	0.317	0.315	0.296	0.319
13	0.326	0.321	0.330	0.327	0.410	0.303	0.303	0.311	0.367	0.385	0.390	0.384	0.384	0.344	0.344	0.344	0.299	0.274	0.305	0.331	0.344	0.344	0.295	0.320
14	0.375	0.436	0.425	0.365		0.275	0.274	0.275	0.279	0.279	0.277	0.277	0.281	0.276	0.281	0.281	0.371	0.292	0.310	0.356	0.390	0.382	0.287	0.331
15	0.348	0.356	0.350	0.347	0.397	0.327	0.326	0.331	0.373	0.383	0.384	0.384	0.366	0.355	0.347	0.347	0.585	0.310	0.355	0.397	0.487	0.447	0.332	0.387

Table 7.2.5.2. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2018 (15 = 15+ group)

Q1																			
cm	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.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.d.2	mean
0					11.7					11.7								11.7	11.7
1					13.1					13.1			12.5	14.3	15.5	17.5	14.1	13.1	14.2
2	24.5	24.5			19.5	19.6	19.6	19.6		19.5		23.0	16.7	21.0	18.3	21.7	20.4	19.5	19.6
3	23.3	23.2	22.1	22.1	22.1	22.0	22.0	21.9		22.0	20.5	23.7	20.5	22.7	21.9	23.1	22.3	22.0	22.0
4	24.9	24.9	25.8	25.8	25.1	23.9	23.9	23.8		24.2	25.9	24.4	24.6	24.2	24.8	24.9	24.2	24.4	24.6
5	28.3	28.3	28.8	28.8	28.0	25.7	25.7	25.8		26.8	28.3	26.3	25.9	26.1	26.4	26.4	25.6	27.3	26.6
6	29.9	29.8	30.5	30.5	30.4	29.9	29.9	29.4	30.8	30.2	30.9	28.0	26.9	27.3	27.6	27.7	27.3	30.3	28.5
7	30.8	30.8	31.4	31.4	31.6	32.2	32.2	31.5	33.1	31.9	33.1	29.0	28.1	28.4	28.8	29.1	28.9	31.8	29.9
8	31.6	31.5	32.1	32.1	32.2	32.7	32.7	33.5	32.5	32.4	32.6	30.4	29.2	29.0	30.1	30.1	30.1	32.3	30.9
9	32.3	32.4	32.7	32.7	32.6	31.9	31.9	34.5	33.3	32.3	33.5	31.2	30.7	30.1	30.9	31.0	31.0	32.4	31.7
10	32.7	32.7	33.1	33.1	33.2	33.9	33.9	34.9	33.3	33.5	33.5	32.5	32.0	33.1	32.1	32.2	32.3	33.3	32.7
11	33.0	33.1	33.3	33.5	33.6	34.2	34.2	33.5		33.8	35.5	33.0	32.5	33.6	32.6	33.6	33.1	33.6	33.1
12	34.6	34.6	34.5	34.6	34.9	36.6	36.6	39.5	37.5	35.7	36.7	34.6	34.5	34.5	34.5	34.3	34.6	35.3	35.2
13	34.7	34.8	34.7	34.7	34.8	35.2	35.2			35.0	35.2	35.9	35.0	34.5	35.7	35.5	35.6	34.8	35.3
14	34.4	34.4	33.6	33.6	33.7	34.7	34.7	35.5		34.1	33.7	36.1	35.7	35.5	36.2	37.5	36.9	33.8	35.5
15	35.3	35.3	35.1	35.1	35.2	35.8	35.8	35.5	34.5	35.4	35.1	37.6	35.6	33.5	37.4	39.3	39.0	35.2	36.4

Q2																					
cm	27.2.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	mean
0					11.7			11.7			11.7										11.7
1					13.1			13.1			13.1				12.4	12.2	14.1	15.7	14.1	12.4	13.3
2	24.5	24.5			19.5	19.6	19.6	19.5	19.5		19.6				16.6	19.3	17.3	21.1	20.4	16.6	18.5
3	23.3	23.3	22.1	22.1	22.1	22.0	22.0	22.0	22.3	20.5	22.0	20.5	20.5		20.6	22.4	22.7	22.5	22.3	20.5	21.8
4	24.9	24.9	25.8	25.8	25.1	23.9	23.9	24.2	24.1	25.9	24.1	25.9	25.9		24.8	23.7	24.7	24.4	24.2	24.7	24.7
5	28.3	28.3	28.8	28.8	28.0	25.7	25.7	26.8	25.5	28.3	26.4	28.3	28.3		25.9	25.8	26.3	25.6	25.6	25.9	26.4
6	29.9	29.9	30.5	30.5	30.4	29.9	29.9	30.2	30.5	31.1	30.1	30.9	30.9		26.9	27.7	27.5	27.2	27.3	27.0	28.3
7	30.8	30.8	31.4	31.4	31.6	32.2	32.2	31.9	31.5	33.2	32.0	33.1	33.1		28.1	29.0	28.8	29.0	28.9	28.2	29.7
8	31.6	31.6	32.1	32.1	32.2	32.7	32.7	32.4		33.0	32.5	32.6	32.6		29.2	30.2	30.0	30.2	30.1	29.6	30.5
9	32.3	32.3	32.7	32.7	32.6	31.9	31.9	32.3	30.3	34.4	32.1	33.5	33.5		30.6	30.4	31.0	31.2	31.0	30.8	31.3
10	32.7	32.7	33.1	33.1	33.2	33.9	33.9	33.5	33.5	33.7	33.7	33.5	33.5		32.9	33.7	32.4	32.3	32.3	33.2	33.0
11	33.0	33.0	33.5	33.5	33.6	34.2	34.2	33.8		35.5	34.0	35.5	35.5		33.2	34.0	33.1	33.8	33.1	33.5	33.5
12	34.6	34.6	34.6	34.6	34.9	36.6	36.6	35.7	35.5	34.3	36.1	36.7	36.7		35.5	35.5	34.7	34.3	34.6	35.5	35.2
13	34.7	34.7	34.7	34.7	34.8	35.2	35.2	35.0		35.2	35.1	35.2	35.2		37.0	36.5	35.7	35.5	35.6	36.8	35.9
14	34.4	34.4	33.6	33.6	33.7	34.7	34.7	34.1		33.7	34.3	33.7	33.7		36.6	36.3	36.1	37.3	36.9	36.5	35.8
15	35.3	35.3	35.1	35.1	35.2	35.8	35.8	35.4	38.5	35.4	35.6	35.1	35.1	43.5	37.9	38.8	37.3	40.0	39.0	37.6	37.9

Table 7.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2018 (15 = 15+ group)

Q3																							
cm	27.2.a	27.3.a	27.4.a	27.6.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	mean
0					11.7		11.7				11.7		11.7				11.7	11.5	14.6	14.0	13.9	12.2	12.9
1	17.6	17.6		17.6	13.1		13.1	19.6	19.6	19.6	18.3	19.6	15.7				15.0	18.4	17.3	18.3	16.7	13.9	16.9
2	24.0	24.0		24.0	22.9	24.0	22.5	21.5	21.5	21.5	21.1	21.5	20.3	24.0	24.0		20.1	21.3	21.2	22.1	21.7	20.0	21.3
3	25.0	25.0		25.0	24.0	24.7	23.8	24.3	24.3	24.3	23.8	24.3	22.9	24.7	24.7		24.6	23.2	23.4	24.1	23.9	22.4	24.0
4	27.6	27.6		27.6	26.2	26.9	26.0	25.2	25.2	25.2	25.1	25.2	24.7	26.9	26.9		25.7	25.3	25.8	25.7	25.6	24.7	25.7
5	30.4	30.4	30.0	30.4	28.9	29.5	28.7	26.0	26.0	26.0	26.3	26.0	26.8	29.5	29.5		27.1	26.3	27.2	27.2	27.2	27.3	27.5
6	31.9	31.9	33.8	31.9	30.7	30.9	30.7	33.2	33.2	33.2	32.6	33.2	31.5	30.9	30.9		28.2	27.9	28.6	28.4	28.4	29.9	30.1
7	33.6	33.6	32.5	33.6	32.7	33.0	32.6	27.5	27.5	27.5	28.4	27.5	30.1	33.0	33.0		29.3	28.6	29.6	29.9	29.6	31.3	30.0
8	33.6	33.6	31.5	33.6	32.3		32.3	33.6	33.6	33.6	33.3	33.6	32.8			33.5	30.5	30.2	30.6	30.3	30.4	31.9	31.7
9	34.4	34.4	33.8	34.4	32.4		32.4	36.0	36.0	36.0	35.3	36.0	33.8			33.8	31.7	31.4	31.5	31.2	31.4	32.2	32.8
10	34.2	34.2	33.7	34.2	32.5	32.2	32.6	37.2	37.2	37.2	36.4	37.2	34.8	32.2	32.2	33.6	32.5	32.2	32.6	32.8	32.7	33.1	33.6
11	34.9	34.9	34.0	34.9	33.6		33.6	36.4	36.4	36.4	35.8	36.4	34.7			34.0	33.4	31.8	33.4	33.7	33.5	33.6	34.1
12	36.2	36.2	35.1	36.2	35.3		35.3	36.2	36.2	36.2	36.0	36.2	35.6			35.3	34.2	34.3	34.0	34.7	34.3	35.0	34.9
13	34.4	34.4	34.1	34.4	34.8		34.8	37.5	37.5	37.5	37.0	37.5	35.9			35.6	34.7	34.4	34.5	35.7	35.0	34.9	35.2
14	38.0	38.0		38.0	33.8		33.8				33.8		33.8			36.8	36.2	35.5	36.1	37.0	36.4	34.3	36.2
15	35.6	35.6	34.4	35.6	35.2		35.2	37.0	37.0	37.0	36.7	37.0	36.0			38.3	36.8	35.5	37.6	41.0	38.1	35.9	37.1

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	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d.2	mean
0								11.7				11.7		11.7			11.5	11.9	10.8	14.8		11.7	12.6
1	17.6	17.6	17.6	17.6	19.6			13.1	19.6	19.6		17.4	19.6	17.0			15.3	15.6	20.5	16.7	21.3	15.0	17.3
2	24.0	24.0	24.0	24.0	21.5	24.0	24.0	22.5	21.5	21.5		20.8	21.5	20.7	24.0	24.0		19.9	21.9	21.2	22.3	20.1	21.7
3	25.0	25.0	25.0	25.0	24.3	24.7	24.7	23.8	24.3	24.3		23.5	24.3	23.4	24.7	24.7	25.5	24.2	23.3	23.8	24.0	24.7	24.3
4	27.6	27.6	27.6	27.6	25.2	26.9	26.9	26.0	25.2	25.2		25.0	25.2	24.9	26.9	26.9	25.9	25.6	25.0	25.8	25.5	25.7	26.0
5	30.4	30.4	30.4	30.4	26.0	29.5	29.5	28.7	26.0	26.0		26.4	26.0	26.5	29.5	29.5	27.3	27.2	26.1	27.2	27.2	27.4	27.7
6	31.9	31.9	31.9	31.9	33.2	30.9	30.9	30.7	27.5	33.2	33.6	32.2	33.2	32.0	30.9	30.9	28.0	28.3	27.7	28.5	28.5	28.2	29.7
7	33.6	33.6	33.6	33.6	27.5	33.0	33.0	32.6	27.5	27.5		28.9	27.5	29.2	33.0	33.0	28.7	29.2	28.5	29.4	30.1	29.1	30.0
8	33.6	33.6	33.6	33.6	33.6			32.3	28.5	33.6	34.0	33.2	33.6	33.1			30.1	30.3	29.8	30.5	30.5	30.4	31.3
9	34.4	34.4	34.4	34.4	36.0			32.4		36.0	36.0	34.8	36.0	34.6			31.3	31.6	31.2	31.5	31.2	31.7	32.7
10	34.2	34.2	34.2	34.2	37.2	32.2	32.2	32.6		37.2	37.2	35.9	37.2	35.6	32.2	32.2	31.2	32.6	32.1	32.7	32.9	32.5	33.4
11	34.9	34.9	34.9	34.9	36.4			33.6		36.4	36.4	35.5	36.4	35.3			31.5	33.8	31.9	33.6	33.8	33.3	34.1
12	36.2	36.2	36.2	36.2	36.2			35.3		36.2	36.2	35.9	36.2	35.8			31.5	34.7	34.4	34.4	34.7	34.1	34.8
13	34.4	34.4	34.4	34.4	37.5			34.8		37.5	37.5	36.6	37.5	36.4			31.5	35.1	34.3	35.0	35.4	34.4	34.9
14	38.0	38.0	38.0	38.0				33.8				33.8		33.8				36.5	35.5	36.4	36.6	35.7	36.6
15	35.6	35.6	35.6	35.6	37.0			35.2		37.0	37.0	36.4	37.0	36.3			49.8	37.3	35.5	37.8	39.7	37.1	38.2

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	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d.2	mean
0								11.7				11.7		11.7			11.5	11.9	10.8	14.8		11.7	12.6
1	17.6	17.6	17.6	17.6	19.6			13.1	19.6	19.6		17.4	19.6	17.0			15.3	15.6	20.5	16.7	21.3	15.0	17.3
2	24.0	24.0	24.0	24.0	21.5	24.0	24.0	22.5	21.5	21.5		20.8	21.5	20.7	24.0	24.0		19.9	21.9	21.2	22.3	20.1	21.7
3	25.0	25.0	25.0	25.0	24.3	24.7	24.7	23.8	24.3	24.3		23.5	24.3	23.4	24.7	24.7	25.5	24.2	23.3	23.8	24.0	24.7	24.3
4	27.6	27.6	27.6	27.6	25.2	26.9	26.9	26.0	25.2	25.2		25.0	25.2	24.9	26.9	26.9	25.9	25.6	25.0	25.8	25.5	25.7	26.0
5	30.4	30.4	30.4	30.4	26.0	29.5	29.5	28.7	26.0	26.0		26.4	26.0	26.5	29.5	29.5	27.3	27.2	26.1	27.2	27.2	27.4	27.7
6	31.9	31.9	31.9	31.9	33.2	30.9	30.9	30.7	27.5	33.2	33.6	32.2	33.2	32.0	30.9	30.9	28.0	28.3	27.7	28.5	28.5	28.2	29.7
7	33.6	33.6	33.6	33.6	27.5	33.0	33.0	32.6	27.5	27.5		28.9	27.5	29.2	33.0	33.0	28.7	29.2	28.5	29.4	30.1	29.1	30.0
8	33.6	33.6	33.6	33.6	33.6			32.3	28.5	33.6	34.0	33.2	33.6	33.1			30.1	30.3	29.8	30.5	30.5	30.4	31.3
9	34.4	34.4	34.4	34.4	36.0			32.4		36.0	36.0	34.8	36.0	34.6			31.3	31.6	31.2	31.5	31.2	31.7	32.7
10	34.2	34.2	34.2	34.2	37.2	32.2	32.2	32.6		37.2	37.2	35.9	37.2	35.6	32.2	32.2	31.2	32.6	32.1	32.7	32.9	32.5	33.4
11	34.9	34.9	34.9	34.9	36.4			33.6		36.4	36.4	35.5	36.4	35.3			31.5	33.8	31.9	33.6	33.8	33.3	34.1
12	36.2	36.2	36.2	36.2	36.2			35.3		36.2	36.2	35.9	36.2	35.8			31.5	34.7	34.4	34.4	34.7	34.1	34.8
13	34.4	34.4	34.4	34.4	37.5			34.8		37.5	37.5	36.6	37.5	36.4			31.5	35.1	34.3	35.0	35.4	34.4	34.9
14	38.0	38.0	38.0	38.0				33.8				33.8		33.8				36.5	35.5	36.4	36.6	35.7	36.6
15	35.6	35.6	35.6	35.6	37.0			35.2		37.0	37.0	36.4	37.0	36.3			49.8	37.3	35.5	37.8	39.7	37.1	38.2

Table 7.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch-at-age by quarter and area in 2018 (15 = 15+ group)

Q1-4																								
cm	27.2.a	27.3.a	27.4.a	27.6.a	27.7.a	27.7.b	27.7.c	27.7.c.2	27.7.e	27.7.f	27.7.g	27.7.h	27.7.j	27.7.j.2	27.7.k	27.7.k.2	27.8.a	27.8.b	27.8.c	27.8.c.e	27.8.c.w	27.8.d	27.8.d.2	mean
0						11.7		11.7			11.7	11.7		11.7			11.5	11.8	11.3	14.7	14.0	13.9	11.9	12.6
1	17.6	17.6	17.6	17.6	19.6	13.1		13.1	19.6	19.6	17.0	17.8	19.6	15.1			15.3	13.9	17.0	16.0	18.6	14.5	13.7	15.9
2	24.3	24.0	24.0	24.3	21.5	23.6	24.0	21.8	20.6	20.8	20.5	20.1	21.5	20.0	24.0	24.0	23.0	18.3	20.9	19.6	21.8	20.6	19.1	20.4
3	24.1	25.0	24.8	24.0	24.3	23.1	23.4	23.1	23.2	23.4	23.2	22.7	22.8	22.6	21.9	23.3	24.5	22.5	22.9	22.9	23.5	22.5	22.5	23.1
4	26.2	27.6	27.4	26.0	25.2	26.2	26.3	25.7	24.6	24.7	24.7	24.3	25.5	24.5	26.2	26.5	25.1	25.2	24.6	25.3	25.1	24.4	24.9	25.3
5	29.4	30.4	30.1	29.2	26.0	29.0	29.1	28.5	25.9	25.9	26.4	25.9	26.9	26.6	28.7	29.1	26.8	26.6	26.1	26.8	26.6	25.8	27.0	27.1
6	30.9	31.9	32.7	30.7	33.2	30.6	30.7	30.6	30.0	31.9	32.7	30.8	31.9	30.9	30.9	30.9	28.0	27.6	27.6	28.0	28.0	27.4	28.8	29.2
7	32.2	33.6	33.0	32.0	27.5	32.0	32.2	32.2	29.6	29.3	29.7	30.4	30.7	30.9	33.1	33.0	28.9	28.7	28.6	29.1	29.6	29.0	30.1	29.9
8	32.6	33.6	32.5	32.4	33.6	32.1	32.1	32.2	31.7	33.3	33.5	33.4	33.1	32.7	32.6	32.6	31.2	29.8	29.8	30.3	30.3	30.1	31.0	31.1
9	33.4	34.4	34.0	33.2	36.0	32.7	32.7	32.5	33.3	34.5	35.1	33.7	34.8	33.2	33.5	33.5	32.0	31.1	30.7	31.3	31.2	31.1	31.8	32.2
10	33.5	34.2	33.9	33.3	37.2	32.8	32.7	32.8	35.1	36.0	36.3	35.0	35.1	34.4	33.1	32.6	32.4	32.5	33.0	32.5	32.6	32.3	33.0	33.2
11	34.0	34.9	34.4	33.8	36.4	33.4	33.5	33.6	35.0	35.6	35.8	34.6	36.0	34.4	35.5	35.5	32.8	33.2	33.1	33.2	33.7	33.1	33.5	33.7
12	35.4	36.2	35.6	35.3	36.2	34.6	34.6	35.0	36.5	36.4	36.1	37.2	36.0	35.8	36.7	36.7	33.8	34.7	34.8	34.4	34.5	34.5	34.9	35.0
13	34.5	34.4	34.3	34.6	37.5	34.7	34.7	34.8	36.0	36.6	36.9	36.8	36.6	35.6	35.2	35.2	34.4	35.4	35.2	35.2	35.5	35.5	35.2	35.3
14	36.2	38.0	37.7	35.9		33.6	33.6	33.7	34.7	34.7	34.1	35.1	33.7	34.1	33.7	33.7	36.4	36.3	35.9	36.2	37.1	36.8	35.1	36.0
15	35.4	35.6	35.0	35.4	37.0	35.1	35.1	35.2	36.2	36.6	36.7	36.6	35.8	35.8	35.1	35.1	42.2	36.9	36.8	37.5	40.0	38.8	36.5	37.4
																				28.9	29.9	29.0	28.4	29.5

Table 7.2.5.3. Western horse mackerel. Stock weights-at-age (kg).

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

Table 7.2.6.1. Western horse mackerel. Maturity-at-age.

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0	0	0.4	0.8	1	1	1	1	1	1	1	1
1983	0	0	0.3	0.7	1	1	1	1	1	1	1	1
1984	0	0	0.1	0.6	0.85	1	1	1	1	1	1	1
1985	0	0	0.1	0.4	0.8	0.95	1	1	1	1	1	1
1986	0	0	0.1	0.4	0.6	0.9	1	1	1	1	1	1
1987	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1988	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1989	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1990	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1991	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1992	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1993	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1994	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1995	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1996	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1997	0	0	0.1	0.4	0.6	0.8	1	1	1	1	1	1
1998	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
1999	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2000	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2001	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2002	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2003	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2004	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2005	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2006	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2007	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2008	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2009	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2010	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2011	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2012	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2013	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2014	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2015	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2016	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2017	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1
2018	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1

Table 7.2.8.1. Western horse mackerel. Potential fecundity (10^6 eggs) per kg spawning female vs. weight in kg.

	1987		1992		1995		1998		2000		2001		2001 (cont)	
	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.
1	0.168	1.524	0.105	1.317	0.13	1.307	0.172	1.318	0.258	0.841	0.086	0.688	0.165	1.382
2	0.179	0.916	0.109	2.056	0.157	1.246	0.104	0.867	0.268	0.747	0.08	0.812	0.166	1.579
3	0.192	2.083	0.11	1.869	0.168	1.699	0.112	1.312	0.304	1.188	0.081	0.535	0.167	1.479
4	0.233	1.644	0.112	1.772	0.179	1.135	0.206	0.382	0.311	1.411	0.095	0.88	0.113	0.527
5	0.213	1.066	0.115	1.188	0.189	1.529	0.207	0.78	0.337	0.613	0.11	1.164	0.14	0.876
6	0.217	2.392	0.119	1.317	0.168	1.1	0.109	1.133	0.339	1.571	0.113	1.106	0.122	0.589
7	0.277	1.617	0.12	1.413	0.209	1.497	0.132	1.02	0.341	1.522	0.095	0.823	0.12	0.68
8	0.279	1.018	0.123	1.293	0.215	1.524	0.2	1.088	0.355	1.056	0.11	0.883	0.121	0.578
9	0.274	1.62	0.123	1.991	0.218	1.616	0.152	1.417	0.357	0.604	0.108	0.823	0.139	0.723
10	0.3	1.513	0.131	1.617	0.226	1.883	0.149	1.004	0.367	1.15	0.097	0.741	0.144	1.213
11	0.32	1.647	0.135	0.793	0.22	1.324			0.393	1.279	0.101	0.853	0.144	1.265
12	0.273	1.956	0.131	1.039	0.236	1.221			0.393	0.668	0.106	1.133	0.171	0.956
13	0.212	2.83	0.136	1.06	0.261	1.21			0.413	0.694	0.107	0.935	0.121	0.607
14	0.268	1.687	0.138	1.489	0.245	1.445			0.421	1.339	0.107	0.494	0.122	0.689
15	0.32	1.088	0.147	1.214	0.306	1.693			0.423	0.798	0.11	0.85	0.139	0.915
16	0.318	1.208	0.151	1.158	0.314	1.312			0.445	1.03	0.111	0.67	0.153	0.943
17	0.343	1.933	0.16	1.349	0.46	1.575			0.446	1.208	0.103	0.632	0.154	0.709
18	0.378	1.429	0.165	1.359	0.449	1.43			0.152	0.643	0.111	0.547	0.156	0.773
19	0.404	1.849	0.165	0.945					0.165	0.579	0.118	0.88	0.162	1.158
20	0.428	2.236	0.167	1					0.175	0.596	0.107	0.944	0.174	1.389
21	0.398	1.538	0.168	1.545					0.179	0.997	0.104	0.724	0.175	1.426
22	0.431	1.223	0.18	1.299					0.19	0.744	0.111	0.86	0.179	1.248
23	0.432	1.465	0.174	1.487					0.197	0.613	0.11	0.728	0.179	1.236
24	0.421	1.843	0.178	1.594					0.203	0.702	0.111	0.544	0.18	2.353
25	0.481	1.757	0.185	1.475					0.219	0.472	0.129	0.935	0.184	2.255
26	0.494	1.611	0.195	1.41					0.223	0.806	0.114	0.901	0.139	0.931
27	0.54	1.754	0.203	1.937					0.227	0.606	0.114	0.557	0.161	1.037

	1987		1992		1995		1998		2000		2001		2001 (cont)	
28	0.564	2.255	0.205	1.534					0.289	1.273	0.151	1.377	0.162	0.893
29	0.585	1.221	0.213	1.577					0.294	1.395	0.153	1.596	0.169	0.691
30			0.222	0.958					0.3	1.305	0.154	1.699	0.18	1.609
31			0.275	2.444							0.103	0.679	0.185	1.776
32											0.12	1.14	0.211	2.102
33											0.12	0.631	0.224	1.466
34											0.121	0.834	0.162	0.849
35											0.144	0.626	0.17	0.668
36											0.116	0.668	0.187	1.453
37											0.118	1.194	0.198	1.371
38											0.112	0.779	0.219	1.847
39											0.126	0.782	0.22	1.578
40											0.139	1.244	0.201	0.878
41											0.119	1.212	0.206	1.196
42											0.109	0.755	0.223	1.115
43											0.122	0.841	0.225	1.43
44											0.131	0.929	0.233	1.724
45	8										0.135	0.862	0.241	1.131
46											0.142	1.834	0.219	0.96
47											0.146	1.689	0.237	1.33
48											0.148	1.357	0.241	0.918
49											0.151	1.817	0.34	0.605
50											0.164	1.631	0.407	1.189
51											0.164	1.052		

Table 7.3.1.1. Western horse mackerel. Final assessment. Numbers-at-age (thousands).

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	53382300	872954	2734190	6602200	942448	1418900	1323560	646061	279226	244275	239555	403699	651144	1024300	482479	173355	158794	145049	132119	120003	1238800
1983	1158030	45916200	748836	2333050	5599730	795620	1194580	1112890	542938	234609	205226	201254	339149	547024	860508	405327	145634	133401	121854	110992	1141510
1984	1333480	995831	39340600	637006	1968490	4694880	664596	996122	927335	452287	195416	170934	167622	282471	455605	716698	337587	121295	111107	101489	1043180
1985	2088790	1146830	853675	33511600	538722	1655480	3935480	556241	833188	775461	378177	163390	142918	140148	236171	380925	599220	282251	101413	92894	957036
1986	2795780	1796700	983915	728704	28441400	455175	1395100	3312420	467941	700786	652183	318047	137409	120191	117861	198614	320349	503930	237366	85286	882965
1987	5837920	2404500	1540400	838387	616593	23935300	381849	1168610	2772970	391640	586462	545767	266147	114985	100577	98627	166201	268069	421690	198629	810235
1988	2499700	5019830	2059320	1308990	706127	515750	19940300	317512	970956	2303250	325261	487040	453234	221021	95488	83523	81903	138019	222614	350186	837795
1989	2561810	2149150	4296550	1747170	1099520	588544	427926	16509500	262653	802923	1904400	268921	402667	374713	182729	78945	69052	67713	114107	184045	982156
1990	1778360	2202480	1839210	3643840	1466600	915621	487833	353924	13642200	216960	663149	1572790	222089	332540	309453	150904	65195	57026	55920	94233	963085
1991	3602290	1528240	1880570	1550710	3028510	1205440	747705	397153	287773	11086900	176288	538792	1277810	180432	270164	251406	122597	52966	46329	45430	858983
1992	7301920	3095000	1303510	1581330	1282980	2474300	977648	604319	320535	232128	8941170	142157	434459	1030350	145489	217842	202716	98854	42708	37356	729249

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1993	7133100	6267700	2627230	1082620	1281160	1019610	1944420	764224	471366	249804	180845	6964910	110730	338401	802531	113319	169673	157891	76995	33264	597090
1994	7142930	6117310	5296260	2156590	859851	991829	777657	1472620	577118	355560	188349	136330	5250090	83464	255069	604900	85413	127888	119008	58033	475115
1995	4893430	6124710	5164770	4337970	1706480	662413	752251	585490	1105370	432682	266451	141119	102136	3933110	62526	191079	453145	63984	95803	89151	399389
1996	2363350	4188080	5122420	4128640	3293910	1245080	472193	530387	410950	774487	302956	186511	98769	71481	2752530	43757	133721	317116	44777	67044	341883
1997	1556860	2024160	3515610	4133720	3185680	2454680	909222	341539	382124	295622	556803	217751	134042	70979	51368	1978000	31444	96092	227880	32177	293853
1998	2579310	1330770	1682120	2764450	3052430	2240360	1677860	613211	229078	255750	197690	372219	145543	89586	47437	34329	1321900	21014	64217	152289	217881
1999	2832050	2209680	1118550	1362000	2145200	2291810	1650050	1224610	445895	166332	185593	143426	270022	105578	64984	34410	24901	958859	15243	46581	268507
2000	2115690	2426130	1856980	905289	1056140	1609100	1686100	1202920	889425	323376	120560	134489	103923	195641	76493	47082	24930	18041	694689	11043	228279
2001	14918600	1814630	2051410	1526830	721018	820634	1232420	1282650	912538	673985	244943	91303	101844	78694	148144	57922	35651	18877	13661	526022	181215
2002	2062900	12785300	1528020	1668800	1194250	547045	611664	910935	944805	671277	495535	180051	67108	74852	57837	108877	42569	26201	13873	10040	519771
2003	1645380	1768590	10787000	1249310	1316510	916368	413021	458303	680400	704838	500544	369427	134219	50024	55795	43111	81156	31730	19530	10341	394911
2004	2385730	1410890	1493540	8840310	989529	1015520	696039	311443	344555	510934	529045	375633	277214	100712	37535	41865	32348	60894	23808	14654	304070

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2005	1447860	2047550	1196860	1238310	7141420	783389	794558	541578	241776	267245	396155	410138	291189	214889	78068	29095	32452	25074	47202	18455	247056
2006	1262660	1242400	1735290	989915	996212	5622960	609133	614178	417613	186258	205802	305028	315774	224186	165439	60103	22400	24984	19304	36339	204408
2007	2205920	1083990	1055470	1444190	804807	795355	4441990	478805	481781	327327	145945	161238	238964	247376	175623	129602	47083	17547	19572	15122	188594
2008	5610870	1894730	923249	884205	1187300	652059	638938	3554130	382470	384599	261235	116465	128663	190682	197392	140137	103414	37569	14002	15617	162551
2009	1376270	4817210	1610140	768975	719821	949584	516141	503298	2794020	300437	302018	205117	91441	101016	149706	154973	110021	81190	29495	10993	139878
2010	982298	1180470	4073840	1324430	612884	559835	728065	393084	382243	2119700	227833	228993	155510	69324	76581	113492	117485	83406	61549	22360	114374
2011	553877	841964	994808	3320800	1039540	467132	419456	541121	291184	282788	1567390	168434	169276	114951	51242	56606	83889	86839	61650	45494	101067
2012	2280130	474695	709135	809726	2599970	789713	348685	310515	399218	214539	208245	1153980	123997	124611	84618	37720	41668	61751	63923	45381	107884
2013	1048390	1954590	400246	578837	637010	1987670	593739	260102	230881	296461	159239	154536	856282	92005	92458	62784	27987	30916	45817	47428	113715
2014	4004110	898417	1645340	325325	452116	482409	1478380	437875	191153	169447	217461	116781	113321	627879	67462	67794	46035	20521	22668	33594	118153
2015	2837020	3432430	757514	1343020	255933	345641	362696	1102800	325579	141951	125770	161376	86654	84083	465872	50055	50301	34156	15226	16819	112590
2016	3263620	2434110	2907090	625496	1077410	200768	267621	279103	846485	249660	108809	96391	123671	66405	64434	357001	38357	38545	26174	11667	99165

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2017	5070720	2799840	2060490	2397220	500647	842640	154917	205195	213439	646677	190654	83079	73592	94416	50696	49191	272542	29283	29426	19982	84611
2018	2887740	4352750	2377310	1712500	1944440	398487	663347	121323	160355	166659	504779	148799	64837	57431	73682	39563	38388	212686	22851	22964	81622

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	0.0007	0.0034	0.0087	0.0147	0.0194	0.0221	0.0234	0.0239	0.0241	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242
1983	0.0009	0.0046	0.0117	0.0199	0.0262	0.0299	0.0317	0.0324	0.0327	0.0328	0.0328	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329
1984	0.0008	0.0040	0.0104	0.0176	0.0232	0.0264	0.0280	0.0286	0.0289	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290	0.0290
1985	0.0006	0.0032	0.0083	0.0140	0.0185	0.0211	0.0224	0.0229	0.0231	0.0231	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232
1986	0.0008	0.0039	0.0101	0.0171	0.0225	0.0257	0.0271	0.0278	0.0280	0.0281	0.0281	0.0281	0.0282	0.0282	0.0282	0.0282	0.0282	0.0282	0.0282	0.0282	0.0282
1987	0.0010	0.0050	0.0128	0.0217	0.0286	0.0326	0.0345	0.0353	0.0356	0.0357	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358
1988	0.0011	0.0056	0.0144	0.0244	0.0321	0.0367	0.0388	0.0397	0.0400	0.0402	0.0402	0.0402	0.0402	0.0403	0.0403	0.0403	0.0403	0.0403	0.0403	0.0403	0.0403
1989	0.0011	0.0057	0.0148	0.0251	0.0330	0.0377	0.0399	0.0408	0.0411	0.0413	0.0413	0.0413	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1990	0.0016	0.0080	0.0206	0.0350	0.0461	0.0526	0.0557	0.0569	0.0574	0.0576	0.0577	0.0577	0.0577	0.0577	0.0577	0.0577	0.0577	0.0577	0.0577	0.0577	0.0577
1991	0.0018	0.0091	0.0233	0.0395	0.0521	0.0595	0.0629	0.0643	0.0649	0.0651	0.0652	0.0652	0.0652	0.0653	0.0653	0.0653	0.0653	0.0653	0.0653	0.0653	0.0653
1992	0.0027	0.0139	0.0357	0.0605	0.0798	0.0910	0.0963	0.0985	0.0993	0.0996	0.0998	0.0998	0.0999	0.0999	0.0999	0.0999	0.0999	0.0999	0.0999	0.0999	0.0999
1993	0.0036	0.0184	0.0474	0.0804	0.1060	0.1209	0.1279	0.1308	0.1319	0.1324	0.1326	0.1326	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327
1994	0.0038	0.0193	0.0496	0.0841	0.1109	0.1265	0.1338	0.1369	0.1380	0.1385	0.1387	0.1388	0.1388	0.1388	0.1388	0.1389	0.1389	0.1389	0.1389	0.1389	0.1389
1995	0.0057	0.0287	0.0739	0.1253	0.1652	0.1885	0.1995	0.2040	0.2057	0.2064	0.2067	0.2068	0.2069	0.2069	0.2069	0.2069	0.2069	0.2069	0.2069	0.2070	0.2070
1996	0.0049	0.0250	0.0645	0.1093	0.1441	0.1644	0.1739	0.1779	0.1794	0.1800	0.1802	0.1803	0.1804	0.1804	0.1804	0.1804	0.1804	0.1805	0.1805	0.1805	0.1805
1997	0.0069	0.0351	0.0904	0.1532	0.2020	0.2305	0.2439	0.2494	0.2515	0.2524	0.2527	0.2529	0.2530	0.2530	0.2530	0.2530	0.2530	0.2530	0.2530	0.2530	0.2530
1998	0.0047	0.0237	0.0611	0.1036	0.1366	0.1558	0.1649	0.1686	0.1701	0.1706	0.1709	0.1710	0.1710	0.1711	0.1711	0.1711	0.1711	0.1711	0.1711	0.1711	0.1711
1999	0.0047	0.0239	0.0615	0.1043	0.1376	0.1569	0.1660	0.1698	0.1713	0.1718	0.1721	0.1722	0.1722	0.1722	0.1723	0.1723	0.1723	0.1723	0.1723	0.1723	0.1723
2000	0.0035	0.0178	0.0458	0.0776	0.1023	0.1167	0.1235	0.1263	0.1274	0.1278	0.1280	0.1280	0.1281	0.1281	0.1281	0.1281	0.1281	0.1281	0.1281	0.1281	0.1281
2001	0.0043	0.0219	0.0564	0.0957	0.1261	0.1439	0.1523	0.1557	0.1570	0.1576	0.1578	0.1579	0.1579	0.1579	0.1580	0.1580	0.1580	0.1580	0.1580	0.1580	0.1580
2002	0.0039	0.0200	0.0514	0.0871	0.1149	0.1310	0.1387	0.1418	0.1430	0.1435	0.1437	0.1438	0.1438	0.1438	0.1438	0.1438	0.1439	0.1439	0.1439	0.1439	0.1439

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2003	0.0037	0.0190	0.0490	0.0831	0.1096	0.1250	0.1323	0.1353	0.1364	0.1369	0.1371	0.1372	0.1372	0.1372	0.1372	0.1372	0.1372	0.1372	0.1372	0.1373	0.1373
2004	0.0029	0.0145	0.0374	0.0634	0.0836	0.0954	0.1009	0.1032	0.1041	0.1044	0.1046	0.1046	0.1047	0.1047	0.1047	0.1047	0.1047	0.1047	0.1047	0.1047	0.1047
2005	0.0030	0.0155	0.0398	0.0675	0.0891	0.1016	0.1075	0.1099	0.1109	0.1112	0.1114	0.1115	0.1115	0.1115	0.1115	0.1115	0.1115	0.1115	0.1115	0.1115	0.1115
2006	0.0026	0.0131	0.0336	0.0570	0.0752	0.0858	0.0907	0.0928	0.0936	0.0939	0.0940	0.0941	0.0941	0.0941	0.0941	0.0941	0.0941	0.0941	0.0941	0.0942	0.0942
2007	0.0021	0.0105	0.0271	0.0459	0.0605	0.0690	0.0730	0.0746	0.0753	0.0755	0.0756	0.0757	0.0757	0.0757	0.0757	0.0757	0.0757	0.0757	0.0757	0.0757	0.0757
2008	0.0025	0.0128	0.0328	0.0557	0.0734	0.0838	0.0886	0.0906	0.0914	0.0917	0.0918	0.0919	0.0919	0.0919	0.0919	0.0919	0.0919	0.0920	0.0920	0.0920	0.0920
2009	0.0035	0.0176	0.0453	0.0769	0.1014	0.1156	0.1224	0.1251	0.1262	0.1266	0.1268	0.1269	0.1269	0.1269	0.1269	0.1269	0.1269	0.1269	0.1270	0.1270	0.1270
2010	0.0042	0.0211	0.0544	0.0922	0.1216	0.1387	0.1467	0.1501	0.1514	0.1519	0.1521	0.1522	0.1522	0.1522	0.1522	0.1522	0.1523	0.1523	0.1523	0.1523	0.1523
2011	0.0043	0.0217	0.0559	0.0947	0.1249	0.1424	0.1507	0.1541	0.1555	0.1560	0.1562	0.1563	0.1563	0.1564	0.1564	0.1564	0.1564	0.1564	0.1564	0.1564	0.1564
2012	0.0041	0.0206	0.0530	0.0899	0.1185	0.1352	0.1431	0.1463	0.1476	0.1481	0.1483	0.1484	0.1484	0.1484	0.1484	0.1485	0.1485	0.1485	0.1485	0.1485	0.1485
2013	0.0044	0.0222	0.0573	0.0971	0.1280	0.1460	0.1545	0.1580	0.1594	0.1599	0.1601	0.1602	0.1603	0.1603	0.1603	0.1603	0.1603	0.1603	0.1603	0.1603	0.1603
2014	0.0041	0.0206	0.0530	0.0899	0.1185	0.1352	0.1431	0.1463	0.1476	0.1481	0.1483	0.1484	0.1484	0.1484	0.1484	0.1485	0.1485	0.1485	0.1485	0.1485	0.1485
2015	0.0032	0.0161	0.0415	0.0704	0.0928	0.1058	0.1120	0.1145	0.1155	0.1159	0.1160	0.1161	0.1161	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2016	0.0033	0.0166	0.0428	0.0726	0.0958	0.1093	0.1156	0.1182	0.1192	0.1196	0.1198	0.1199	0.1199	0.1199	0.1199	0.1199	0.1199	0.1200	0.1200	0.1200	0.1200
2017	0.0027	0.0136	0.0350	0.0593	0.0782	0.0892	0.0944	0.0966	0.0974	0.0977	0.0979	0.0979	0.0979	0.0980	0.0980	0.0980	0.0980	0.0980	0.0980	0.0980	0.0980
2018	0.0031	0.0156	0.0401	0.0680	0.0897	0.1023	0.1083	0.1107	0.1117	0.1121	0.1122	0.1123	0.1123	0.1123	0.1124	0.1124	0.1124	0.1124	0.1124	0.1100	0.1100

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	53382300	2935860	2328100	61197	0.0263	0.009	0.023	0.019
1983	1158030	3446520	2480650	90442	0.0365	0.012	0.031	0.026
1984	1333480	4151730	2629270	96244	0.0366	0.011	0.027	0.023
1985	2088790	4826900	3097870	96343	0.0311	0.009	0.022	0.018
1986	2795780	5324590	4443340	137499	0.0309	0.010	0.026	0.022
1987	5837920	5569200	5253010	187338	0.0357	0.013	0.033	0.028
1988	2499700	5586800	5325910	210989	0.0396	0.015	0.038	0.031
1989	2561810	5443620	5131330	209583	0.0408	0.015	0.039	0.032
1990	1778360	5198190	4871080	275968	0.0567	0.021	0.054	0.045
1991	3602290	4818350	4553440	287438	0.0631	0.024	0.061	0.051
1992	7301920	4409600	4170400	393631	0.0944	0.037	0.093	0.077
1993	7133100	3942740	3644200	453246	0.1244	0.049	0.124	0.103
1994	7142930	3508890	3078290	412291	0.1339	0.051	0.129	0.108
1995	4893430	3211190	2663000	538950	0.2024	0.076	0.193	0.160
1996	2363350	2850950	2302530	422396	0.1834	0.066	0.168	0.140
1997	1556860	2611420	2147540	534673	0.2490	0.093	0.236	0.196
1998	2579310	2231460	1911070	325340	0.1702	0.063	0.159	0.133
1999	2832050	2020200	1799520	298992	0.1662	0.063	0.160	0.134
2000	2115690	1812740	1621070	202732	0.1251	0.047	0.119	0.099
2001	14918600	1720890	1482230	229081	0.1546	0.058	0.147	0.122
2002	2062900	1690930	1328200	196120	0.1477	0.053	0.134	0.112
2003	1645380	1753680	1239480	191856	0.1548	0.050	0.128	0.106
2004	2385730	1819180	1271170	159742	0.1257	0.038	0.097	0.081
2005	1447860	1872800	1536410	182001	0.1185	0.041	0.104	0.086
2006	1262660	1846270	1651270	155827	0.0944	0.035	0.088	0.073
2007	2205920	1791180	1629560	123356	0.0757	0.028	0.071	0.059
2008	5610870	1741480	1585800	143349	0.0904	0.034	0.086	0.071
2009	1376270	1678370	1484240	183782	0.1238	0.047	0.118	0.098

Year	Recruit (thousands)	Total Biomass	Spawning biomass	Catch	Yield/SSB	Fbar(1-3)	Fbar(4-8)	Fbar(1-10)
2010	982298	1581550	1331920	203112	0.1525	0.056	0.142	0.118
2011	553877	1455360	1211620	193698	0.1599	0.057	0.146	0.121
2012	2280130	1318660	1164950	169859	0.1458	0.055	0.138	0.115
2013	1048390	1191900	1087630	165258	0.1519	0.059	0.149	0.124
2014	4004110	1070020	955525	136360	0.1427	0.055	0.138	0.115
2015	2837020	998288	838866	98419	0.1173	0.043	0.108	0.090
2016	3263620	994641	786772	98810	0.1256	0.044	0.112	0.093
2017	5070720	1024920	761613	82961	0.1089	0.036	0.091	0.076
2018	2887740	1106230	811685	101682	0.1253	0.041	0.105	0.087

Table 7.4.1. Western Horse Mackerel. Short term prediction: INPUT DATA. *geometric mean of the recruitment time series from 1983 to 2018.

Age	N	Mat	M	PF	PM	Swt
0	2584327*	0.000	0.15	0	0	0.000396
1	3156580	0.000	0.15	0	0	0.014395
2	2082290	0.047	0.15	0	0	0.040471
3	2163020	0.269	0.15	0	0	0.068313
4	475737	0.731	0.15	0	0	0.099264
5	1069770	0.953	0.15	0	0	0.130931
6	130353	0.993	0.15	0	0	0.161589
7	218408	0.999	0.15	0	0	0.190145
8	231966	1.000	0.15	0	0	0.216006
9	815246	1.000	0.15	0	0	0.23894
10	230667	1.000	0.15	0	0	0.258956
11	96303	1.000	0.15	0	0	0.27621
12	85735	1.000	0.15	0	0	0.290939
13	108424	1.000	0.15	0	0	0.303419
14	59631	1.000	0.15	0	0	0.313927
15	52144	1.000	0.15	0	0	0.322733
16	335581	1.000	0.15	0	0	0.330083

Age	N	Mat	M	PF	PM	Swt
17	36219	1.000	0.15	0	0	0.336199
18	36347	1.000	0.15	0	0	0.341275
19	24079	1.000	0.15	0	0	0.345479
20	84110	1.000	0.15	0	0	0.352296

Table 7.4.2. Western Horse Mackerel. Short term prediction; single area management option table. OPTION: Catch constraint 110 381 t (80% of 2019 EU TAC).

Scenarios	F_{factor}	F_{bar}	Catch_2019	Catch_2020	SSB_2020	SSB_2021	Change_SSB_2020-2021(%)	Change_Catch_2019-2020(%)
$B2021=B_{pa}$	can not be reached even by setting F to 0							
F = 0	0.00	0.000	110381	0	950867	1159081	21.90	-100.00
	0.10	0.009	110381	12482	950867	1147889	20.72	-88.69
	0.20	0.017	110381	24846	950867	1136809	19.55	-77.49
	0.30	0.026	110381	37093	950867	1125840	18.40	-66.40
	0.40	0.035	110381	49225	950867	1114981	17.26	-55.40
	0.50	0.044	110381	61243	950867	1104230	16.13	-44.52
	0.60	0.052	110381	73148	950867	1093587	15.01	-33.73
	0.70	0.061	110381	84941	950867	1083051	13.90	-23.05
	0.80	0.070	110381	96622	950867	1072620	12.80	-12.46
F_{MSY}	0.85	0.074	110381	102391	950867	1067472	12.26	-7.24
	0.90	0.078	110381	108194	950867	1062294	11.72	-1.98
Fstq	1.00	0.087	110381	119658	950867	1052071	10.64	8.40
	1.10	0.096	110381	131014	950867	1041950	9.58	18.69
F_{lim}	1.18	0.103	110381	140328	950867	1033653	8.71	27.13
	1.20	0.105	110381	142263	950867	1031931	8.53	28.88

Scenarios	F_{factor}	F_{bar}	Catch_2019	Catch_2020	SSB_2020	SSB_2021	Change_SSB_2020-2021(%)	Change_Catch_2019-2020(%)
	1.30	0.113	110381	153407	950867	1022011	7.48	38.98
	1.40	0.122	110381	164447	950867	1012191	6.45	48.98
	1.50	0.131	110381	175383	950867	1002469	5.43	58.89
	1.60	0.139	110381	186216	950867	992844	4.41	68.70
	1.70	0.148	110381	196949	950867	983315	3.41	78.43
	1.80	0.157	110381	207581	950867	973881	2.42	88.06
	1.90	0.165	110381	218114	950867	964542	1.44	97.60
	2.00	0.174	110381	228548	950867	955295	0.47	107.05
B2021=B_{lim}	3.41	0.297	110381	365559	950867	834480	-12.24	231.18

7.15 Figures

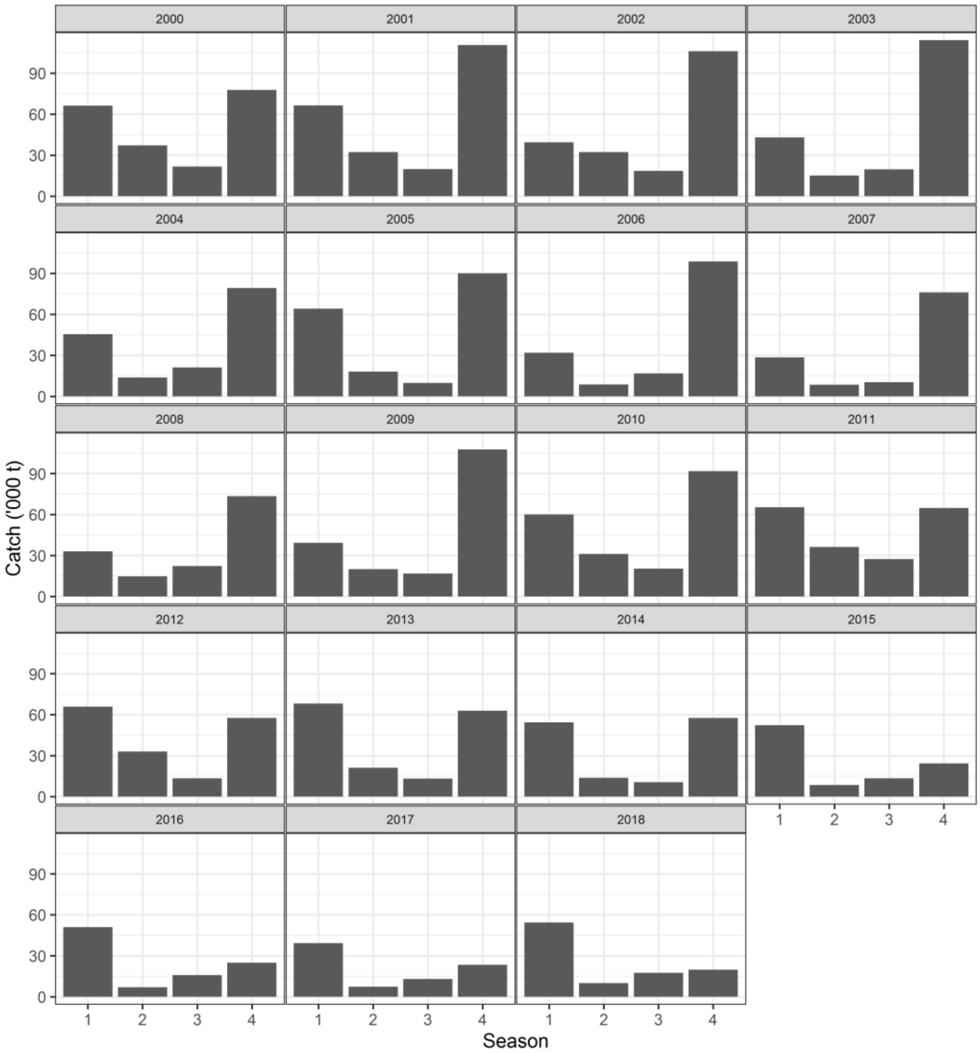


Figure 7.1.1.1: Western horse mackerel. Catch by quarter and year for 20002018

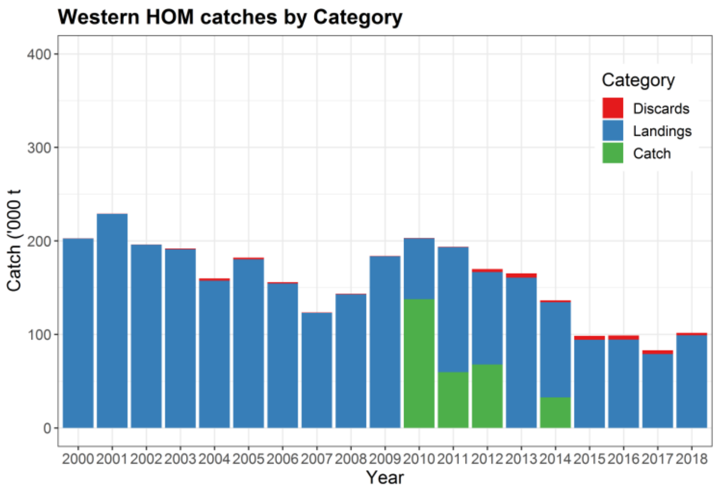


Figure 7.1.2.1. Western horse mackerel. Catch categories since 2000.

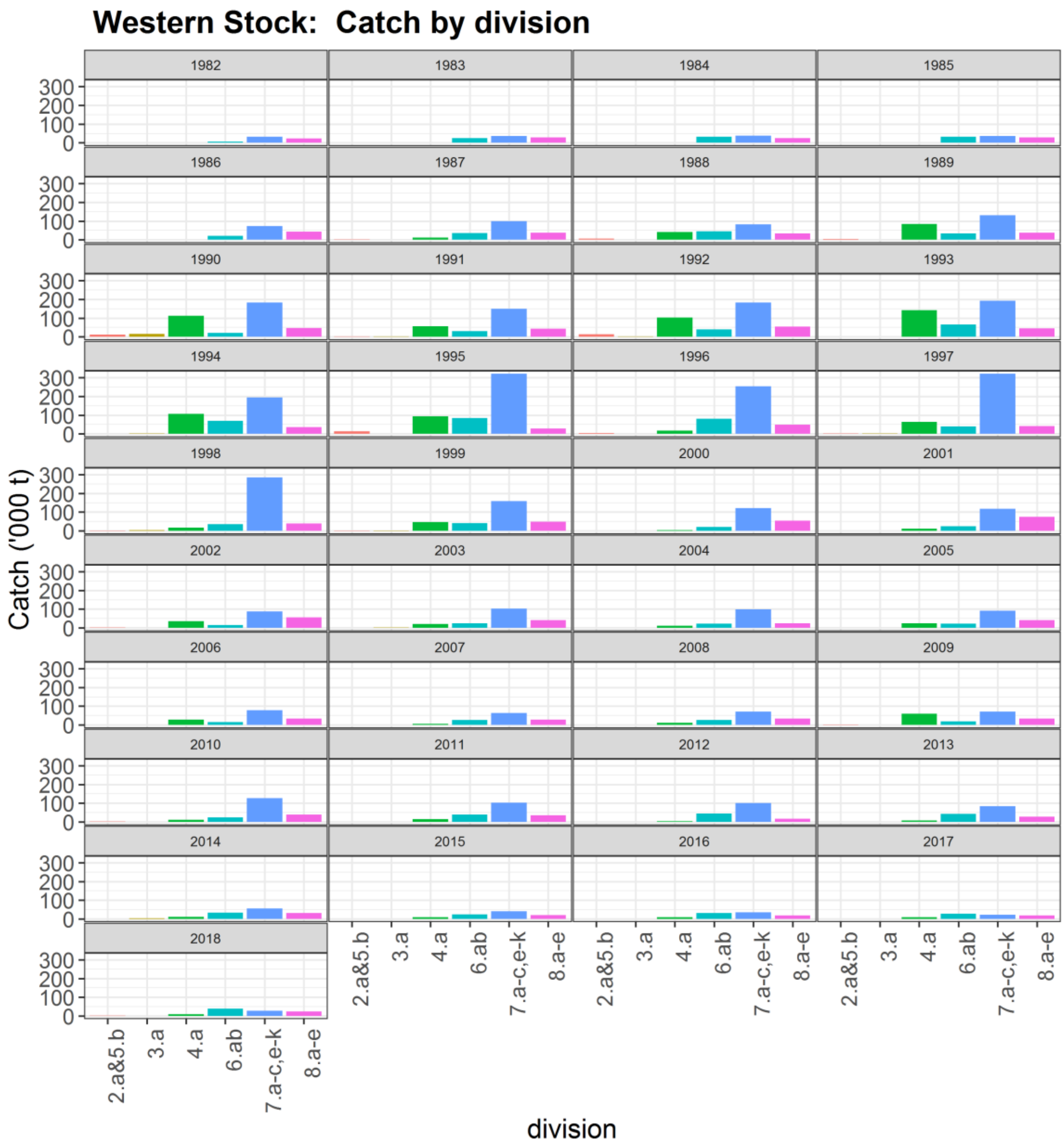


Figure 7.1.3.1: Western horse mackerel. Catch by ICES Division and year for 19822018

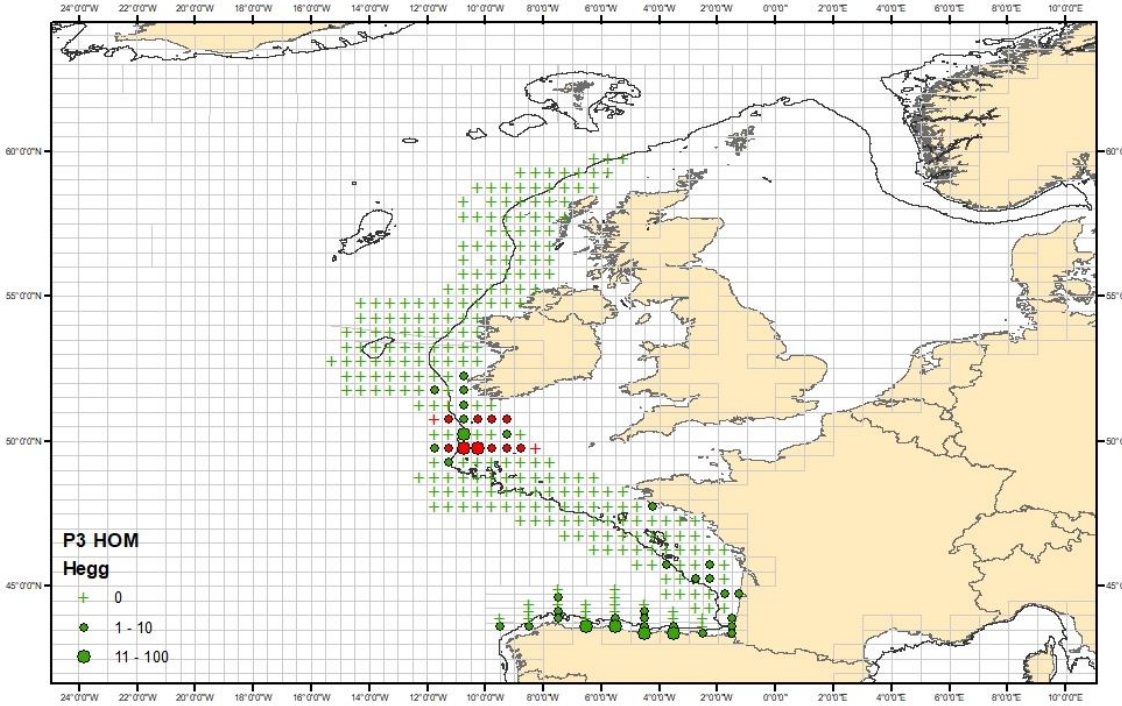


Figure 7.2.1.1: Western horse mackerel egg production by half rectangle for period 3 (March 4th – April 14th). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

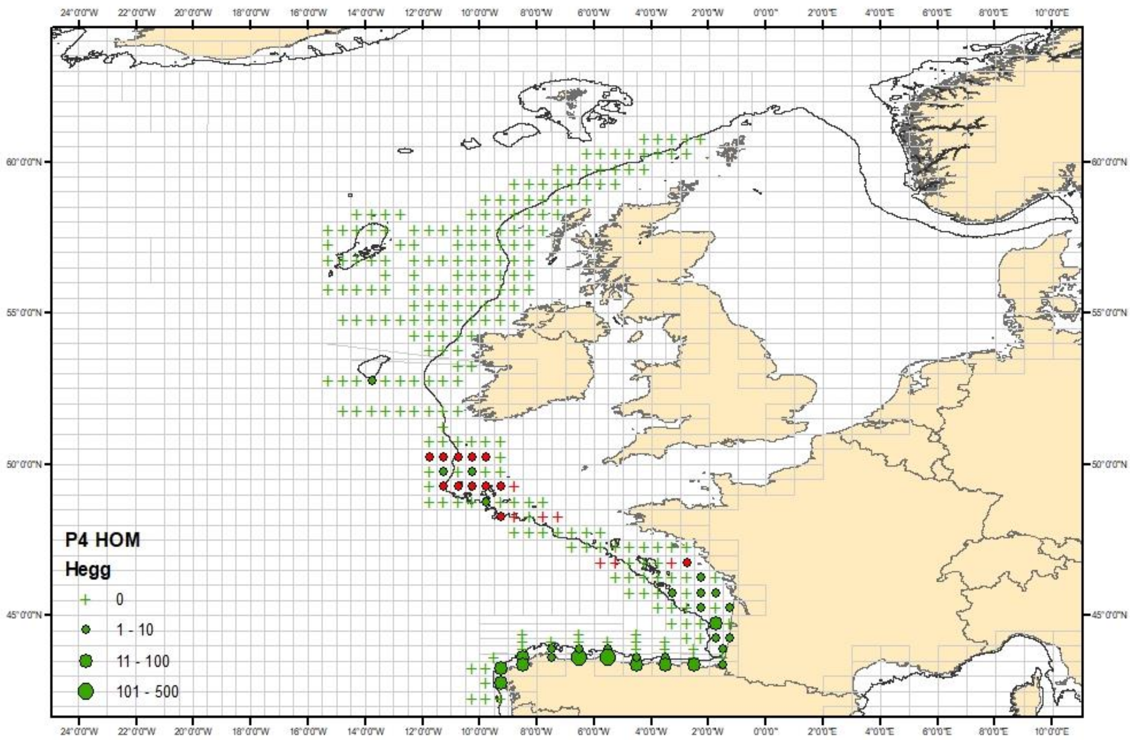


Figure 7.2.1.2: Western Horse mackerel egg production by half rectangle for period 4 (April 15th –May 3rd). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

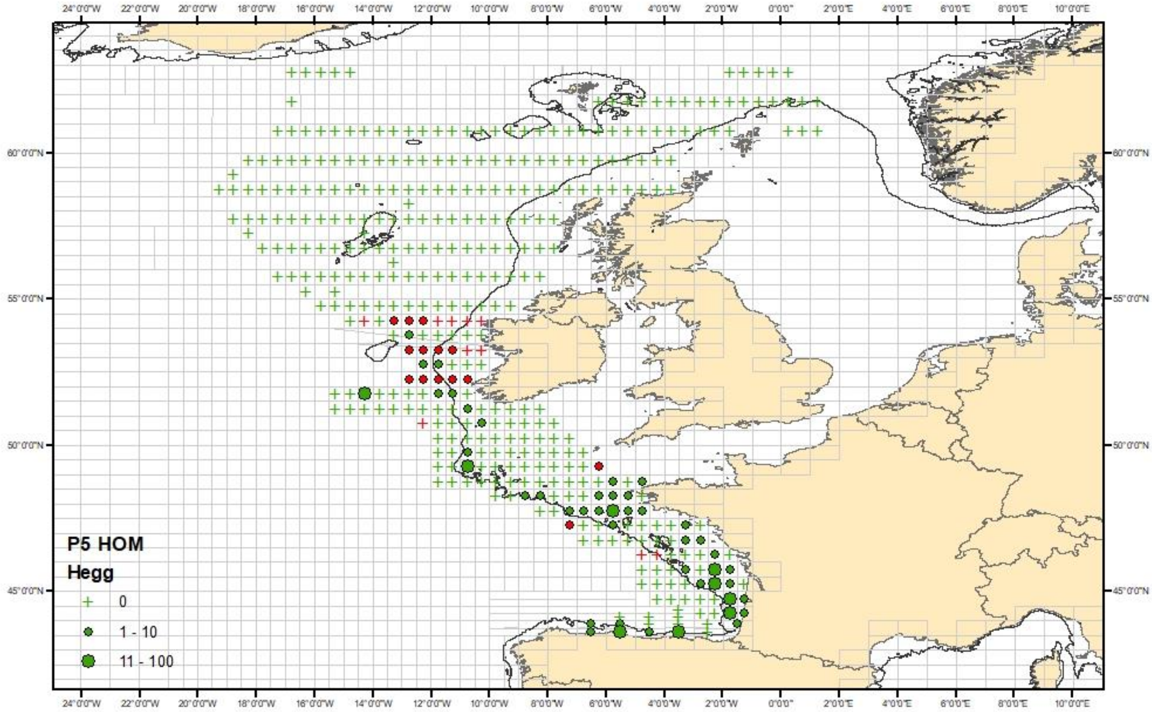


Figure 7.2.1.3: Western Horse mackerel egg production by half rectangle for period 5 (May 4thune 5th). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes

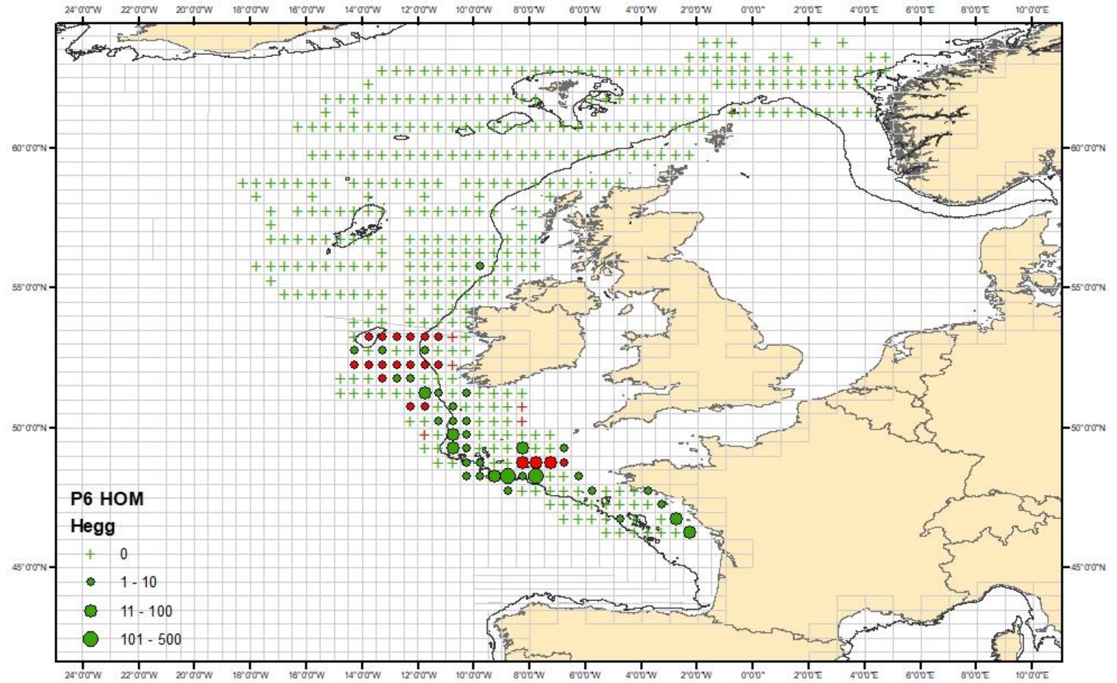


Figure 7.2.1.4: Western Horse mackerel egg production by half rectangle for period 6 (June 6th – 30th). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

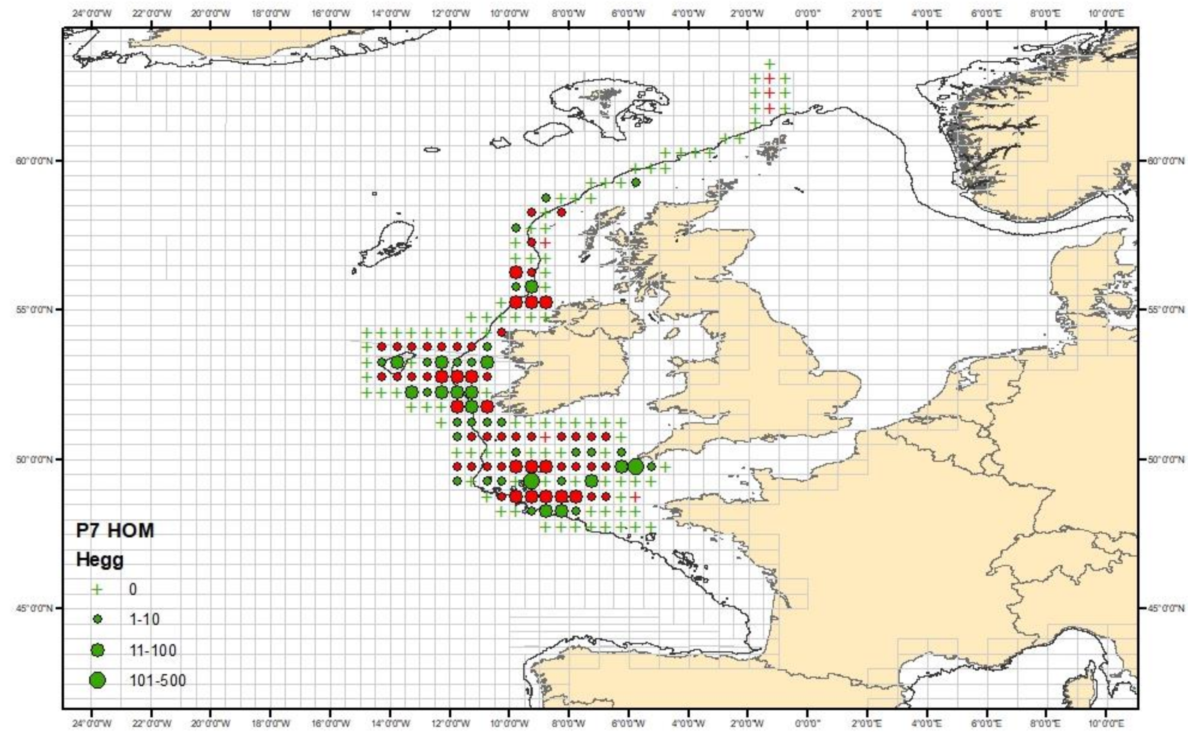


Figure 7.2.1.5: Western horse mackerel egg production by half rectangle for period 7 (July 1st –July 31st). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

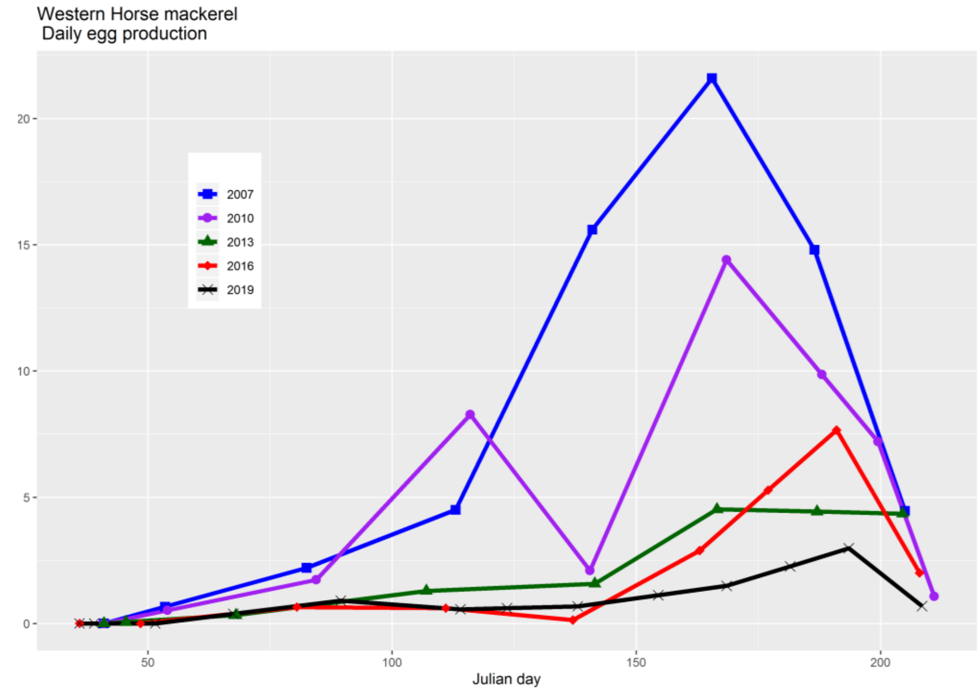


Figure 7.2.1.6: Provisional annual egg production curve for western horse mackerel for 2019. The curves for 2007, 2010, 2013, and 2016 are included for comparison. Production in numbers exponential 14.

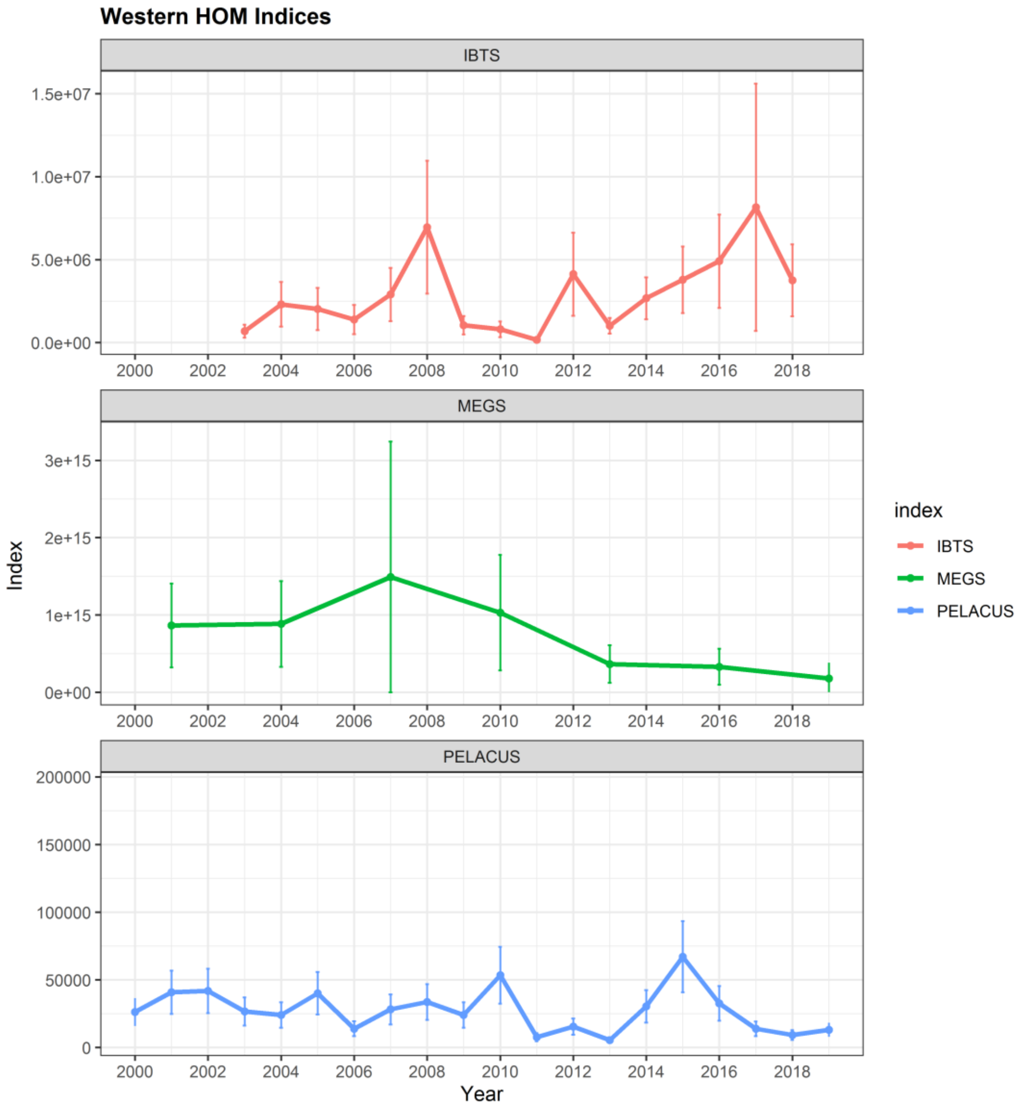


Figure 7.2.2.1: Western horse mackerel. Trend of the fisheries independent indices of abundance used in the assessment of Western Horse mackerel -- Plot on top: Spawning index from egg survey; plot in the middle: recruitment index from IBTS survey; plot at the bottom: biomass estimates from Pelacus acoustic survey. Confidence intervals are shown as well.

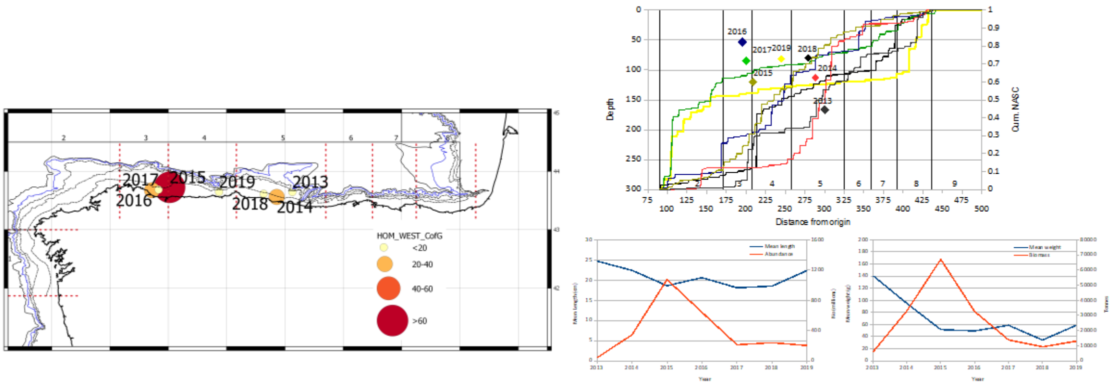


Figure 7.2.2.2: Left panel: western horse mackerel centre of gravity in 8c PELACUS 2013-19. Circle encompases the biomass estimated; right panel up: cumulative NASC values attributed to WHOM along the coast (numbers correspond to the areas of the left map); lower pannel abundance (million fish red line) and mean length (blue) and right biomass estimates (tonnes red line) and mean weight (blue).

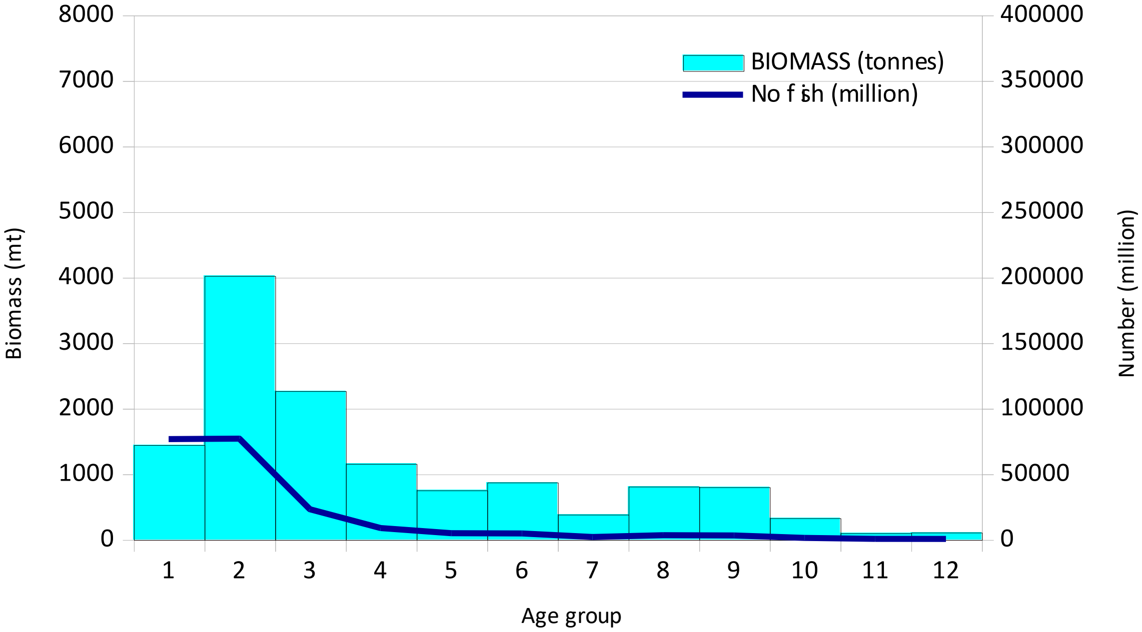


Figure 7.2.2.3: Western horse mackerel abundance and biomass estimates by age group in 8c during PELACUS 0319.

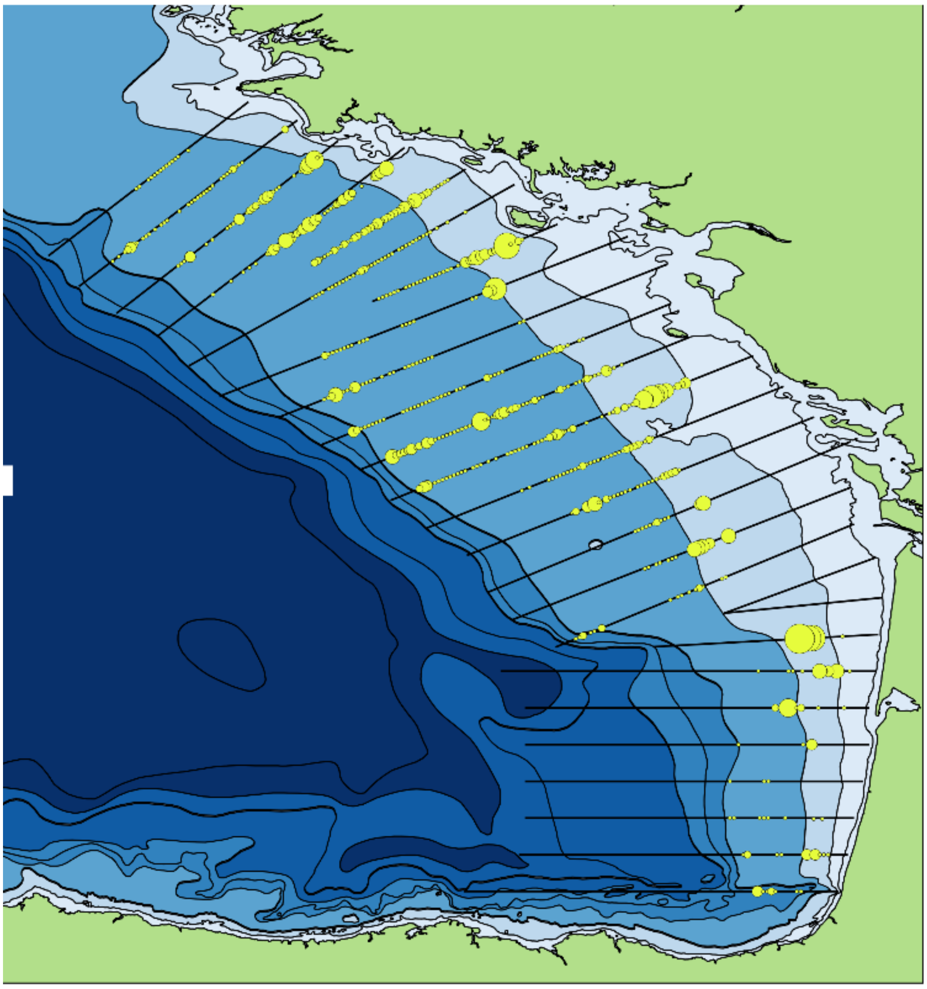


Figure 7.2.2.4: Western horse mackerel. Spatial distribution estimated during PELGAS 2019 (NASC values)

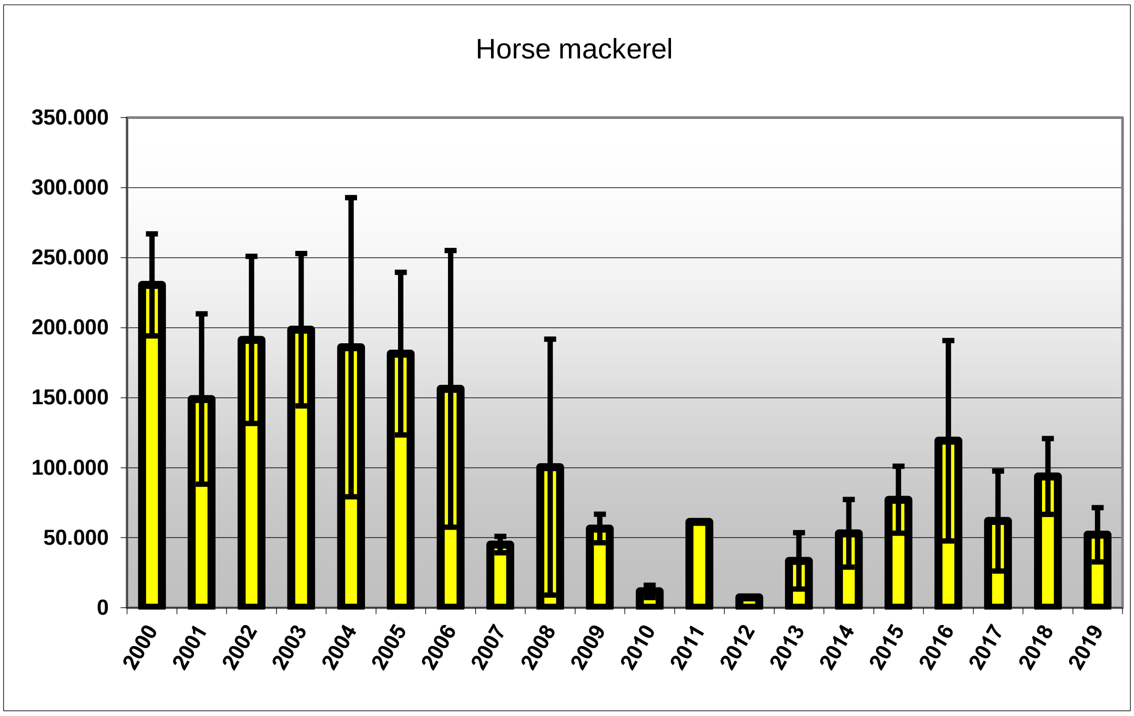


Figure 7.2.2.5: Western horse mackerel biomass estimates (20002019) during PELGAS

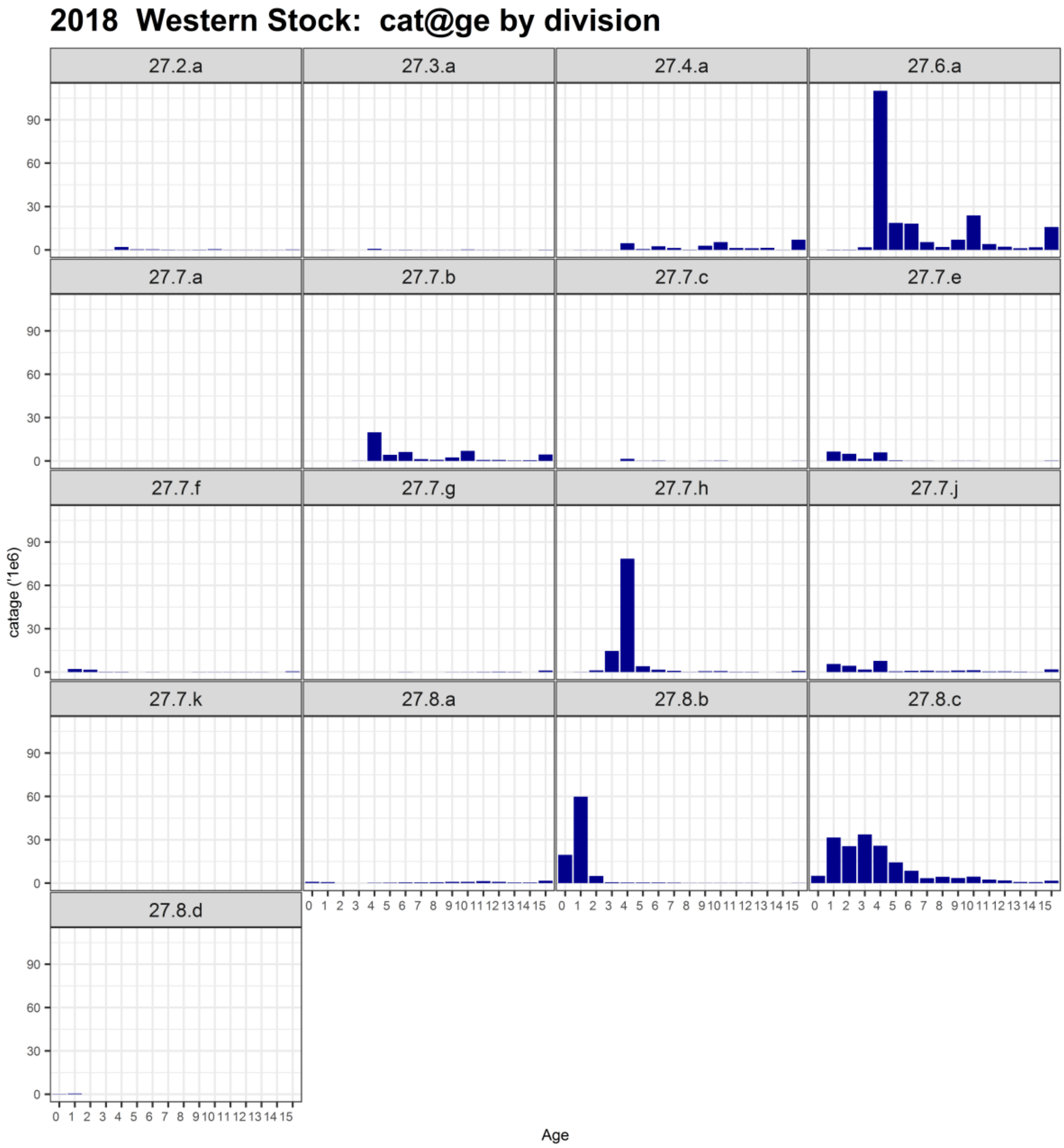


Figure 7.2.4.1: Western horse mackerel.. Catch-at-age matrix by division in 2018, expressed as numbers (millions)

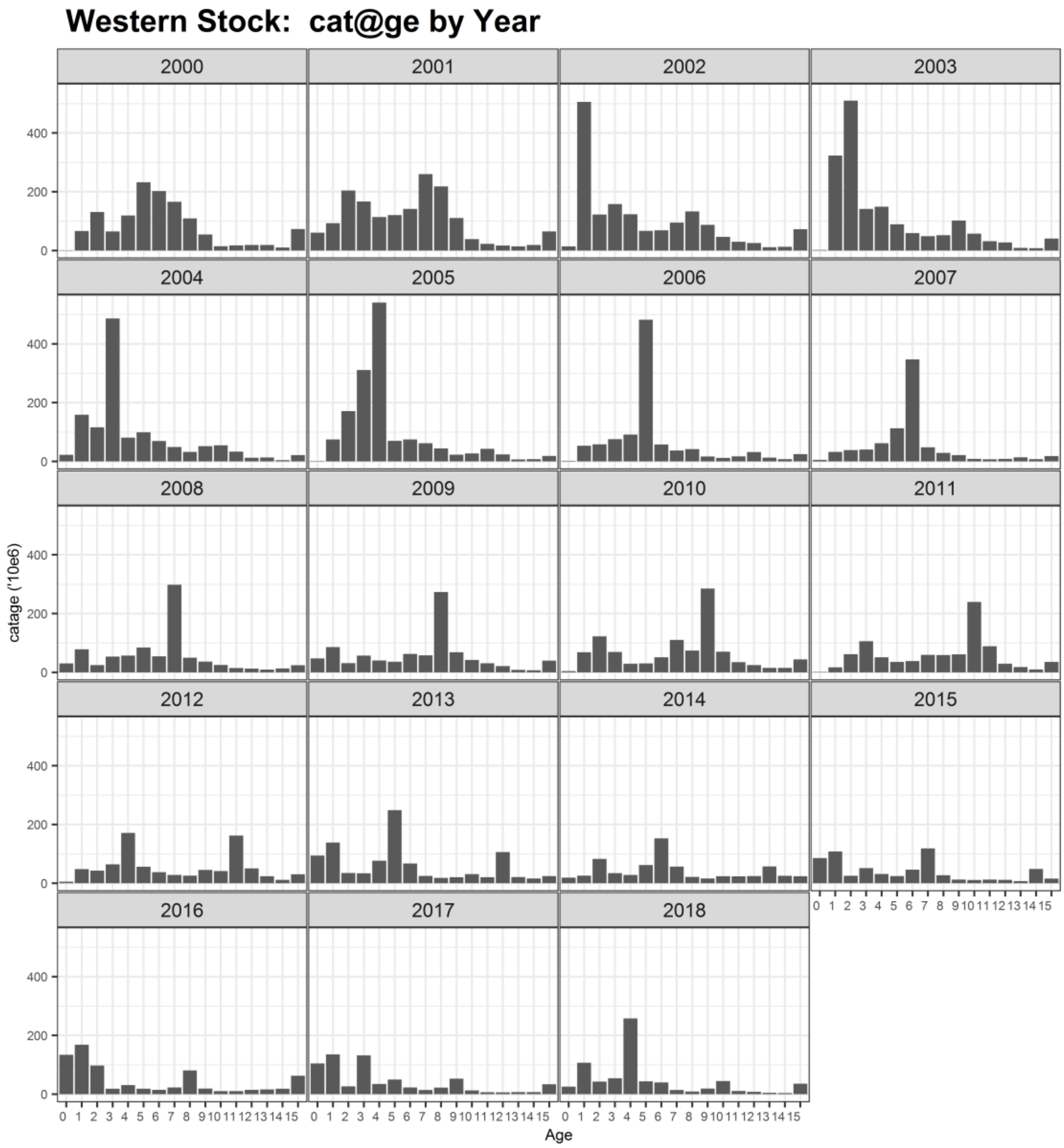


Figure 7.2.4.2: Western horse mackerel.. Catch-at-age matrix by year, expressed as numbers (millions).

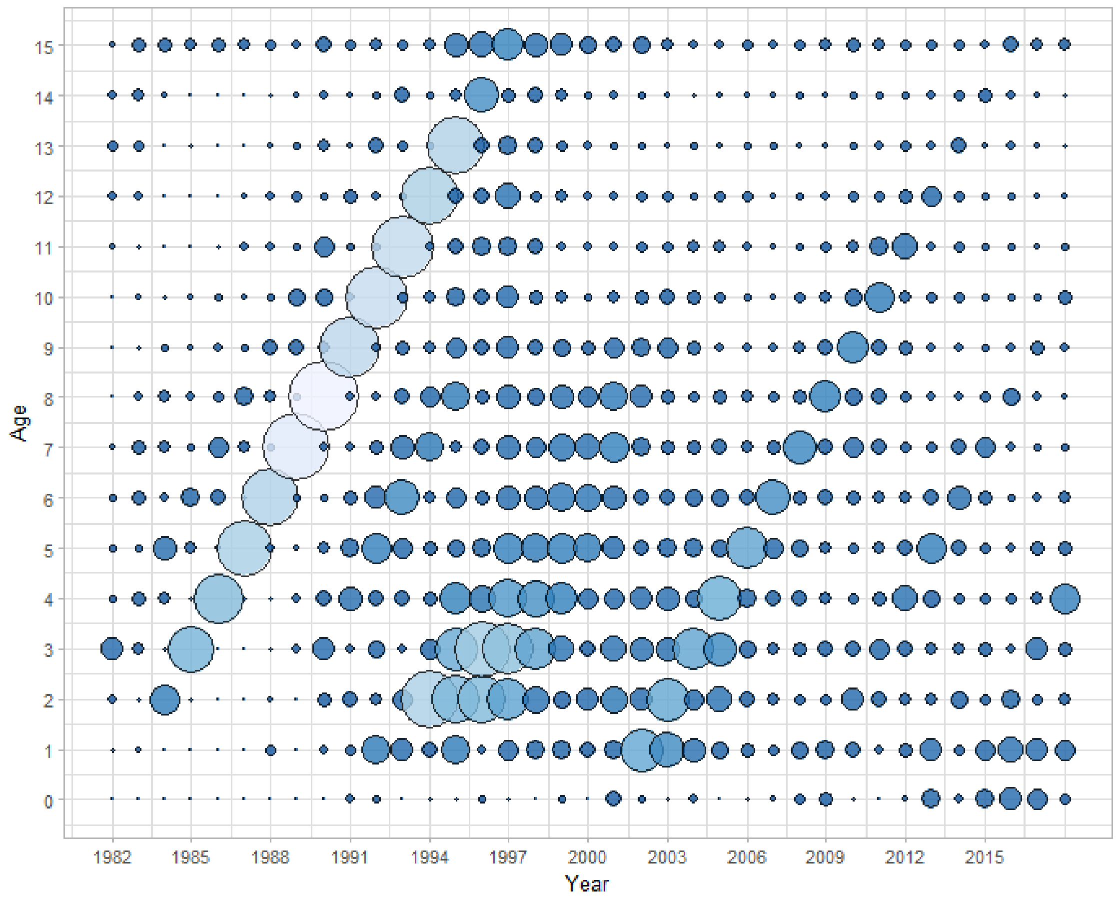


Figure 7.2.4.1: Western horse mackerel. Catch-at-age matrix, expressed as numbers. The area of bubbles is proportional to the catch number. Note that age 15 is a plus group.

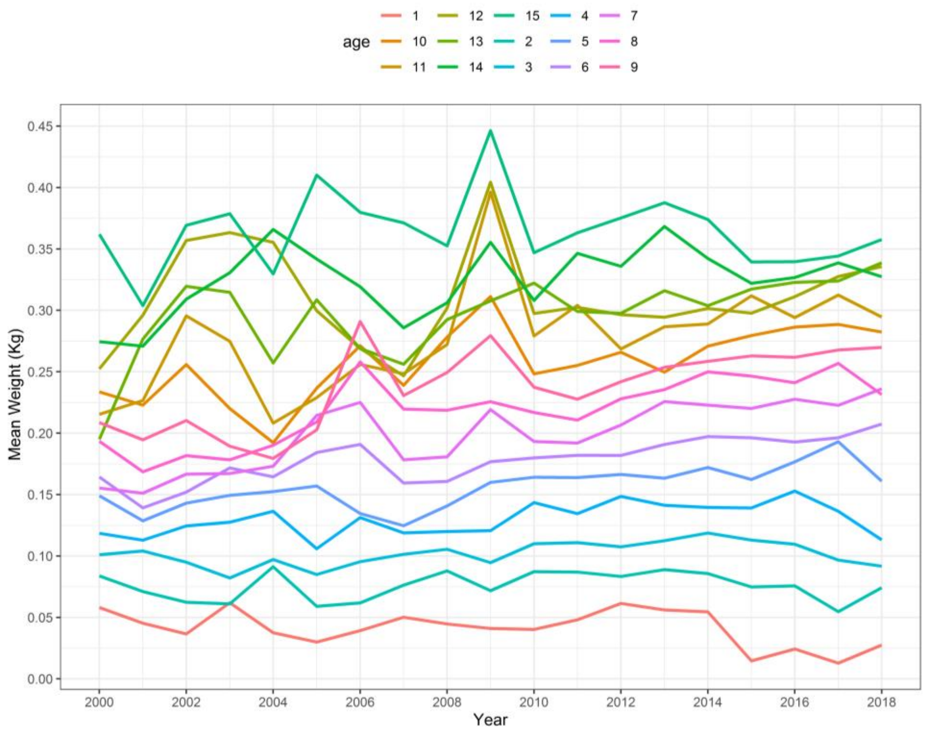


Figure 7.2.5.1: Western horse mackerel. Weight at age in the catch (kg) by year.

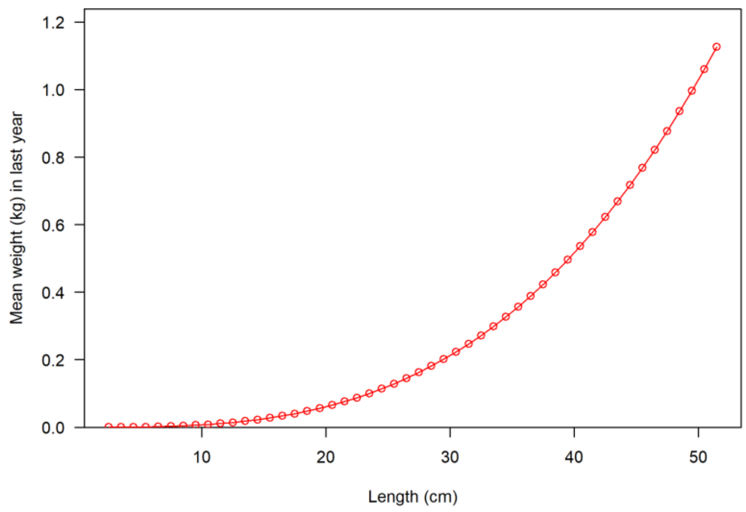


Figure 7.2.5.2: Western horse mackerel. Weight at length in the stock (kg) as estimated by SS.

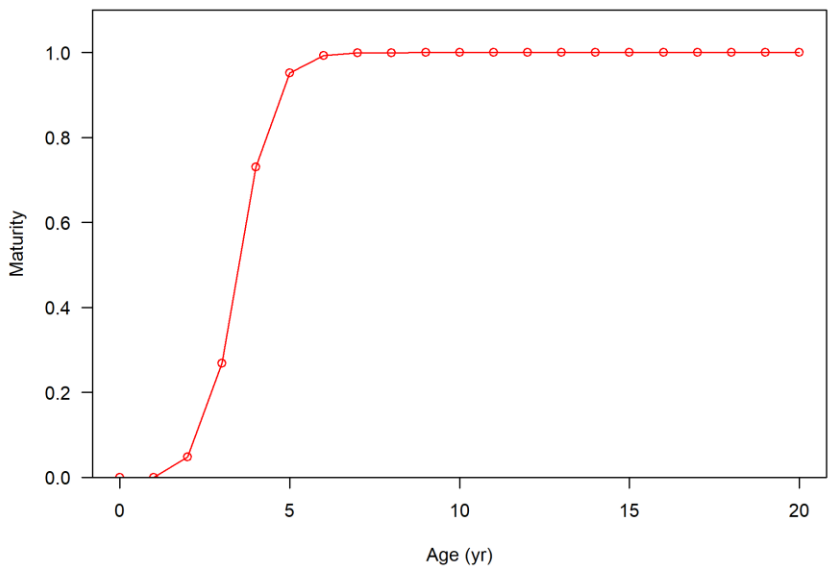


Figure 7.2.6.1: Western horse mackerel. Maturity at age as used in the assessment model.

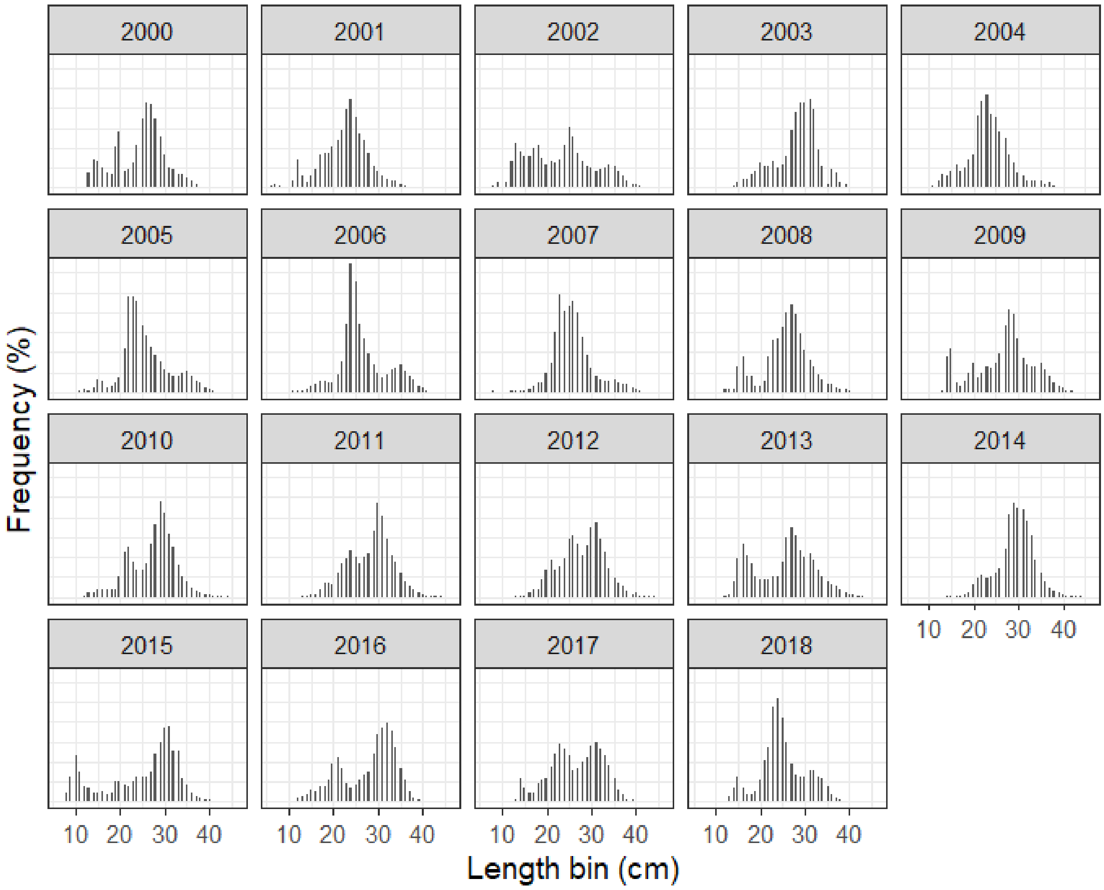


Figure 7.2.10.1: Western horse mackerel. Length frequency distribution of the catch data as used in the assessment model.

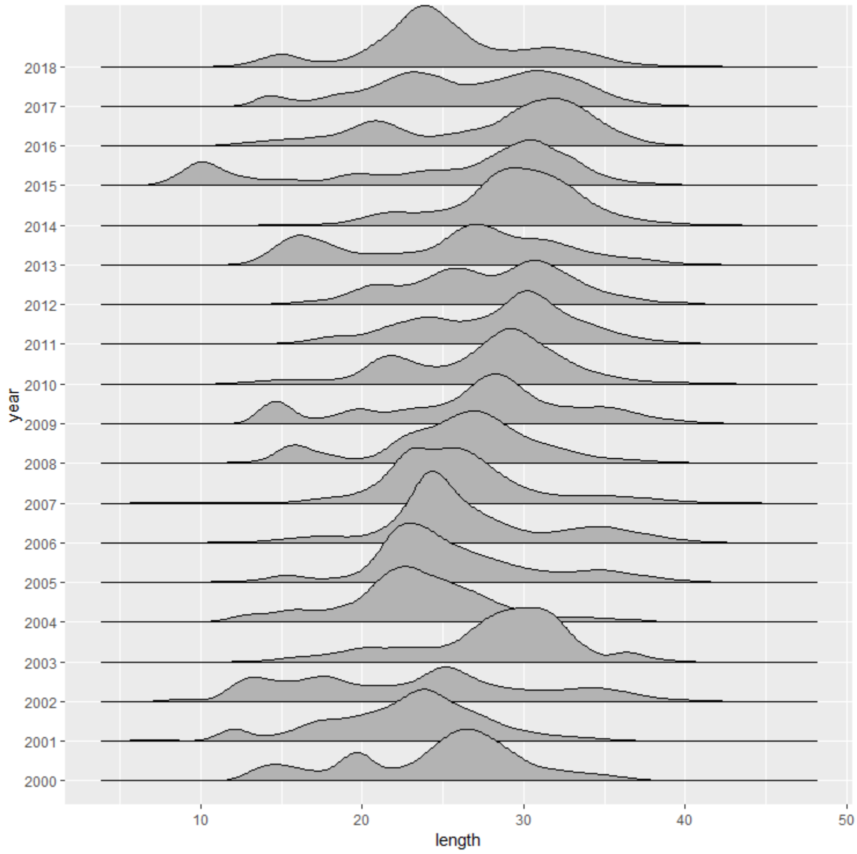


Figure 7.2.10.2: Western horse mackerel. Stacked length frequency distribution of the catch data as used in the assessment model.

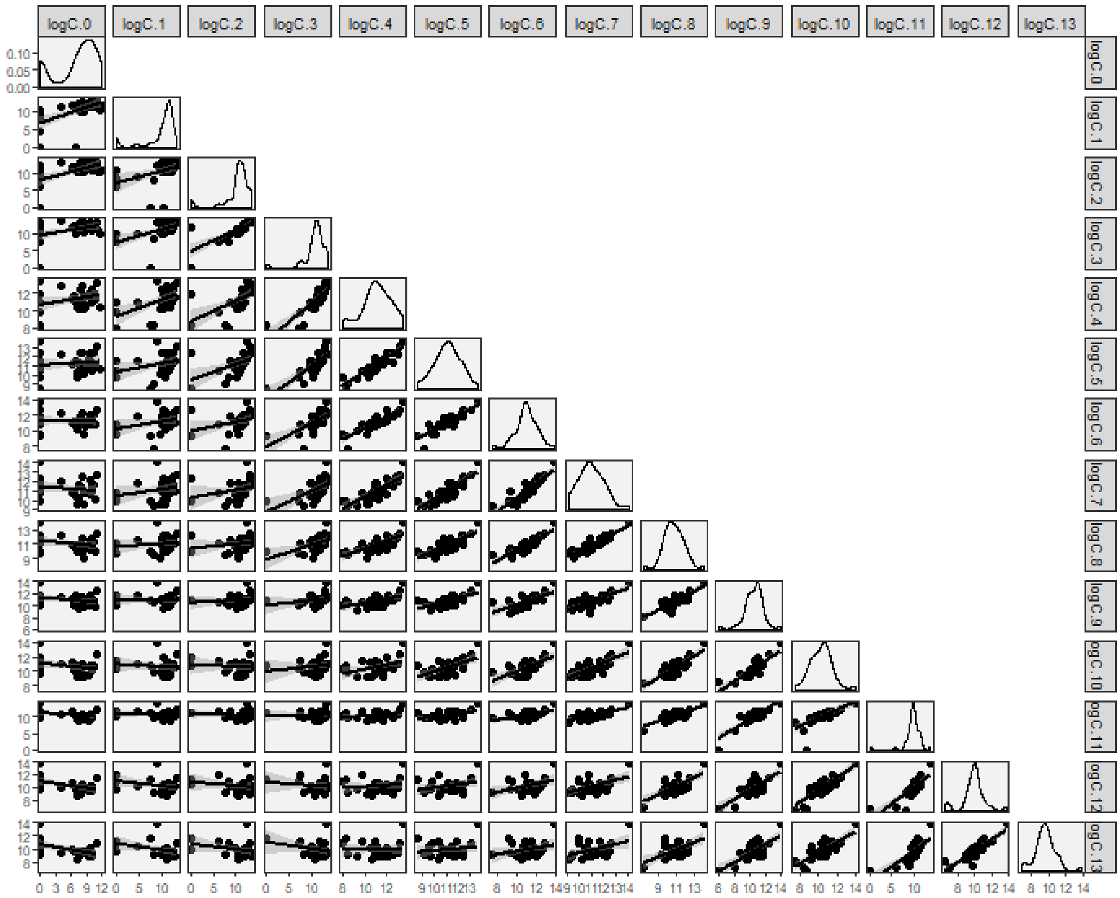


Figure 7.2.10.3: Western horse mackerel. Within-cohort consistency in the catch-at-age matrix, shown by plotting the log-catch of a cohort at a particular age against the log-catch of the same cohort at subsequent ages. Thick lines represent a significant (p<0.05) regression and the curved lines are approximate 95% confidence intervals.

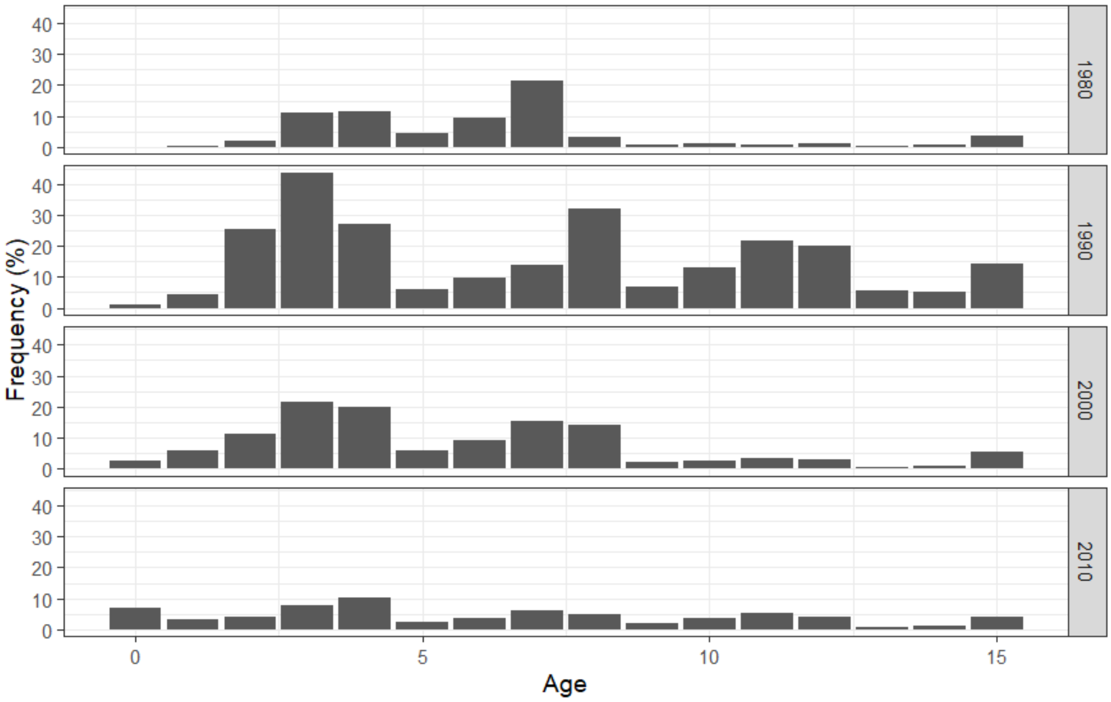


Figure 7.2.10.4: Western horse mackerel. Catch numbers at age composition by decade.

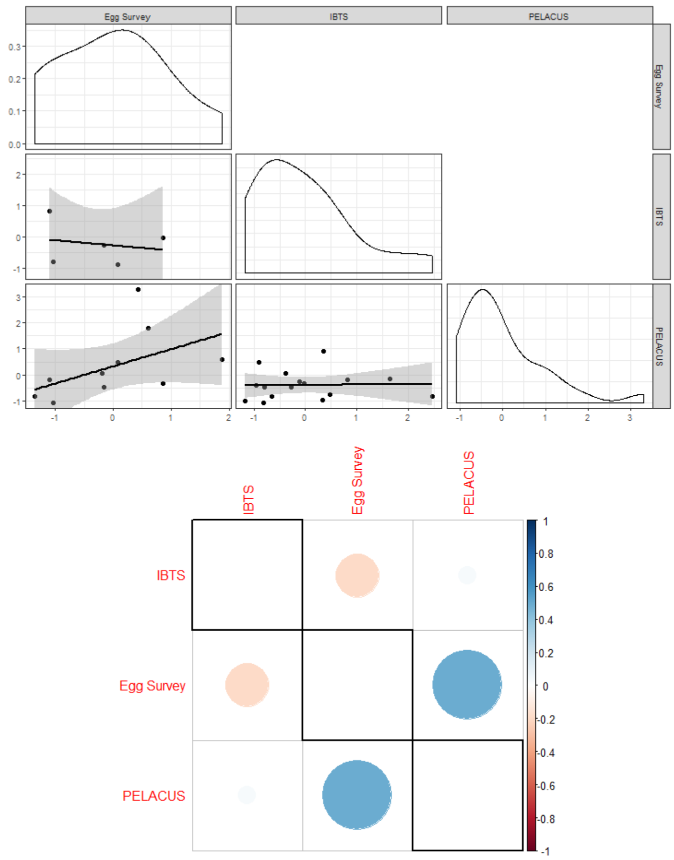


Figure 7.2.10.5: Western horse mackerel. Data exploration. Correlation plots between indices of abundance (including 2019 data points).

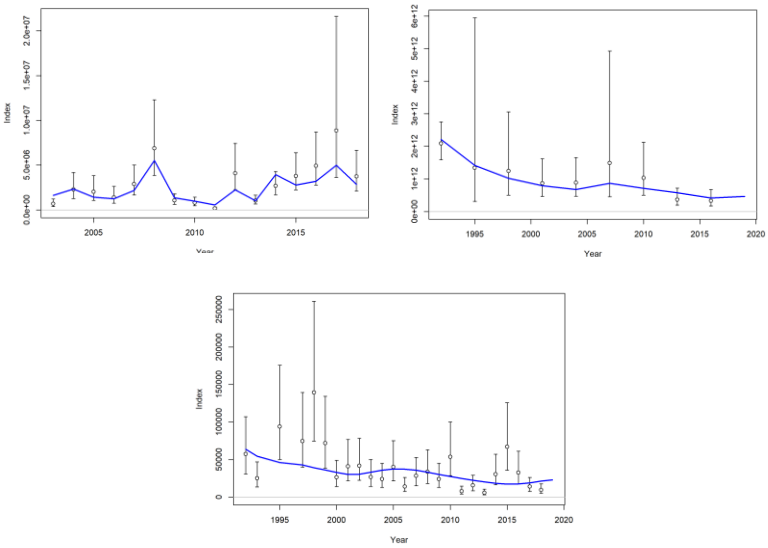


Figure 7.2.11.1: Western horse mackerel. Model fitting. Fitting of the model to the fisheries independent indices (2019 survey points excluded).

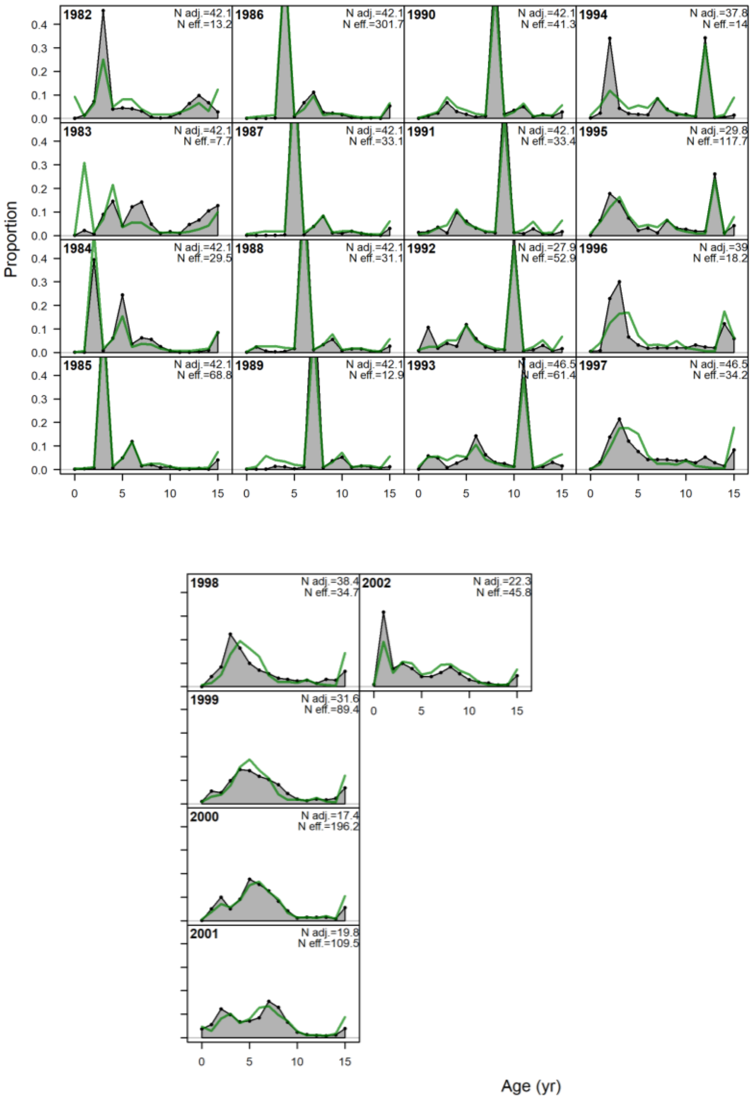


Figure 7.2.11.1 (cont'd): Western horse mackerel. Model fitting. Fitting of the model to the catch at age matrix from 1982 to 2002.

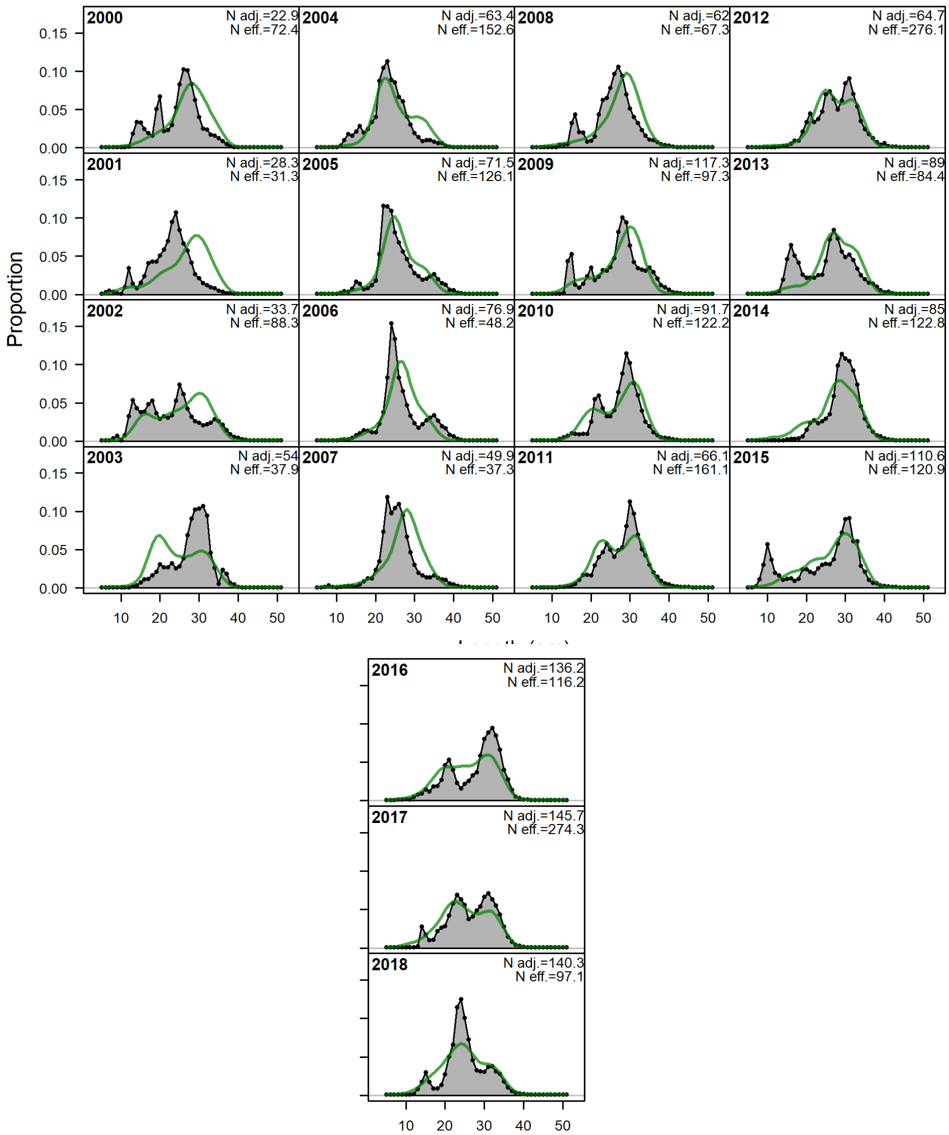
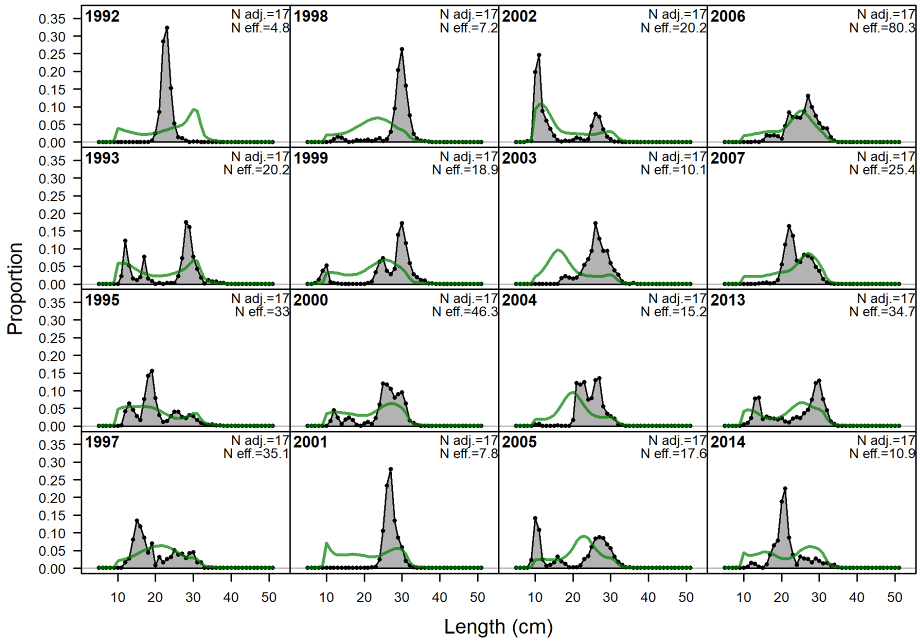


Figure 7.2.11.1 (cont'd): Western horse mackerel. Model fitting. Fitting of the model to the length composition of the catch data from 2002 to 2018.



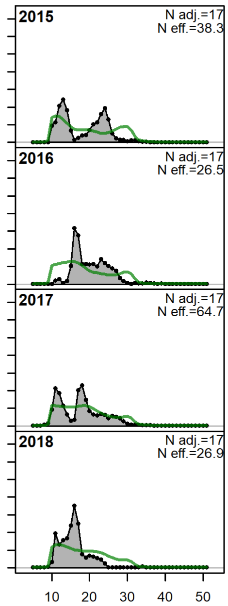


Figure 7.2.11.1 (cont'd): Western horse mackerel. Model fitting. Fitting of the model to the length composition of the acoustic survey.

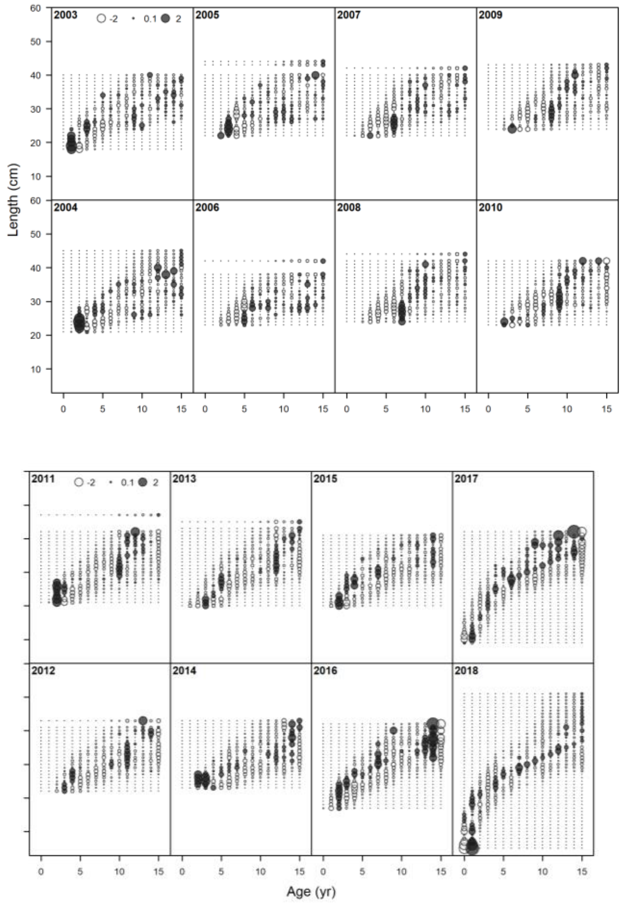


Figure 7.2.11.1 (cont'd): Western horse mackerel. Model fitting. Fitting of the model to the Age length comp of the catch.

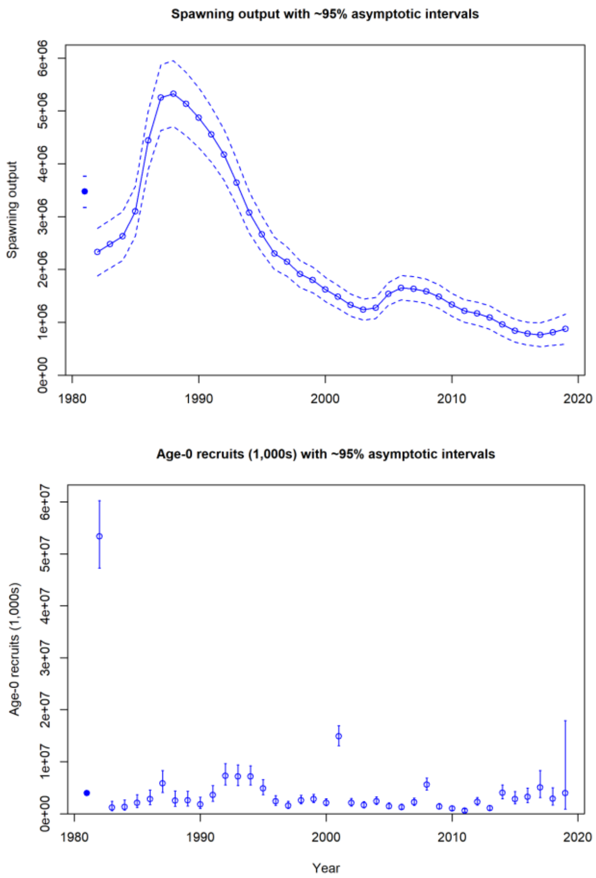


Figure 7.2.11.2:Western horse mackerel. Model results. Spawning stock biomass (0.5 of the overall SSB only is shown; plot on the left) and recruitment estimates (plot on the right) from the assessment model from 1982 to 2018. 95% CI are shown as well.

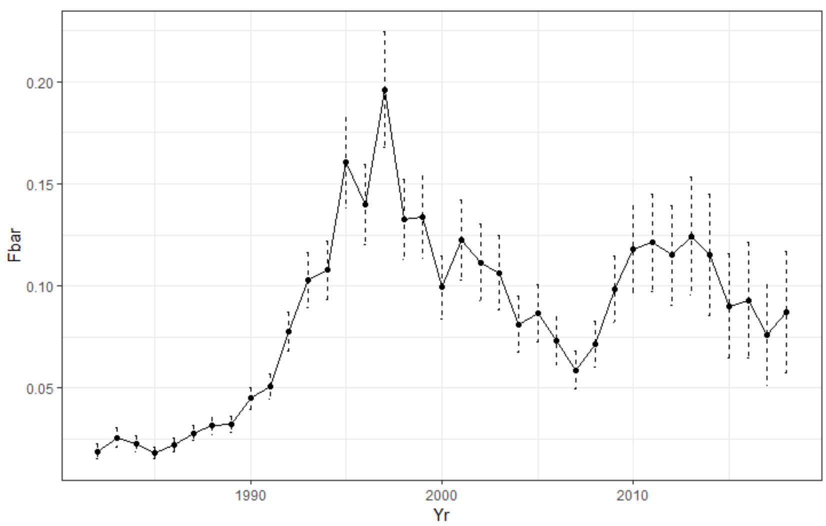


Figure 7.2.11.2 (cont'd): Western horse mackerel. Model results. Fishing mortality estimates (Fbar ages 1-10) from the assessment model from 1982 to 2018. 95% CI intervals are shown as well.

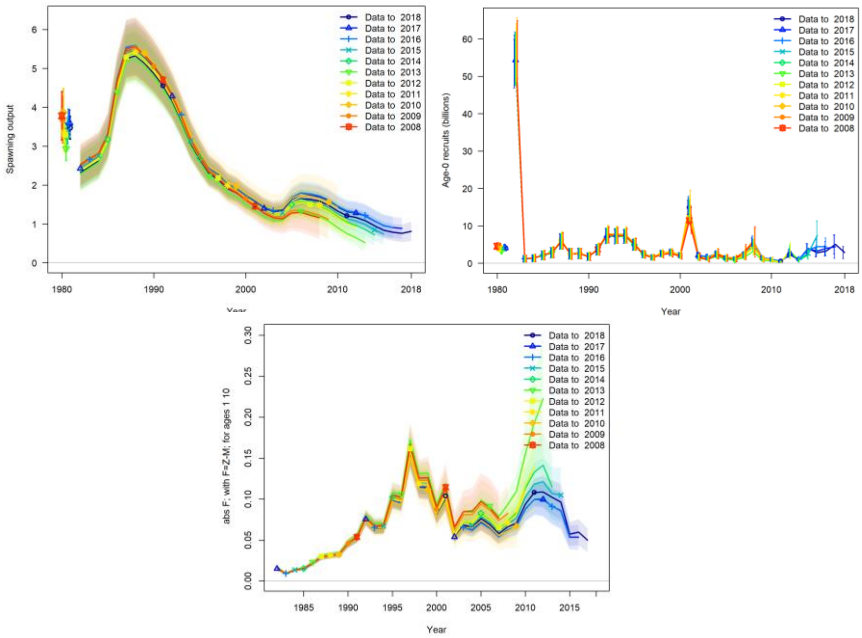


Figure 7.2.11.3: Western horse mackerel. Retrospective analysis. 10 years of retrospective analysis for SSB (left), Recruitment (middle), and F (right) (F is the weighted F_{bar} out of Stock Synthesis).

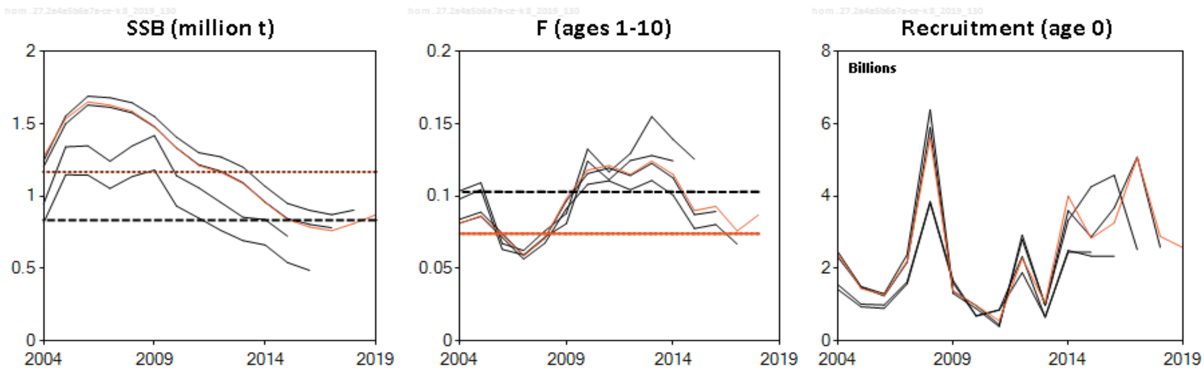


Figure 7.2.11.4: Western horse mackerel. Model results. Historical assessment results. Note: since the 2017 assessment, SSB is estimated on 1st of January. Prior to 2017 SSB has been estimated in May (spawning time).

8 Northeast Atlantic Mackerel

8.1 ICES Advice and International Management Applicable to 2018

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 has been reached among the Coastal States on the sharing of the mackerel quotas. In 2014, three of the Coastal States (EU, NO and FO) agreed on a Management Strategy for 2014 to 2018. In November 2018, the agreement from 2014 was extended for two more years until 2020. However, the total declared quotas for 2015 to 2019 all exceed the TAC advised by ICES. An overview of the declared quotas and transfers for 2019, as available to WGWIDE, is given in the text table below. Total removals of mackerel are expected to be approximately 835 000 t in 2019, exceeding the ICES advice for 2019 by about 65 000 t.

Estimation of 2019 catch	Tonnes	Reference
EU quota	324 195	European Council Regulation2019/124
Norwegian quota	146 832	NEAFC HOD 19/02
Inter-annual quota transfer 2018->2019 (NO)	-5 601	NEAFC HOD 19/02
Russian quota	108 840	Federal agencey for Fisheries, Russia
Inter-annual quota transfer 2018->2019 (RU)	6 152	Federal agencey for Fisheries, Russia
Discards	2 890	Previous years estimate
Icelandic quota	131 307	Icelandic regulation No. 605/2019
Faroese quota	82 339	Faroese regulation No. 176/2018
Greenland expected catch [1]	38 000	Ministry of Fisheries, Hunting and Agriculture in Greenland
Total expected catch (incl. discard) [2,3]	834 954	

[1] [1] Greenland quota for 2019 = 70 411 t.

[2] No guesstimates of banking from 2019 to 2020

[3] Quotas refer to claims by each party for 2019

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 2018

A description of the fleets operated by the major mackerel catching nations is given in Table 8.2.1.

The total fleet can be considered to consist of the following components:

Freezer trawlers. These are commonly large vessels (up to 150 m) that usually operate a single mid-water pelagic trawl, although smaller vessels may also work as pair trawlers. These vessels are at sea for several weeks and sort and process the catch on board, storing the mackerel in frozen 20 kg blocks. The Dutch, German and the majority of the French and English fleets consist of these vessels which are owned and operated by a small number of Dutch companies. They fish in the North Sea, west of the UK and Ireland and also in the English Channel and further south along the western coast of France. The Russian summer fishery in Division 2.a is also prosecuted by freezer trawlers and partly the Icelandic fishery in Division 5.a and in some years in 14.b.

Purse seiners. The majority of the Norwegian catch is taken by these vessels, targeting mackerel overwintering close to the Norwegian coastline. The largest vessels (> 20 m) used refrigerated seawater (RSW), storing the catch in tanks containing refrigerated seawater (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 singly whereas Ireland and Faroes 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 2018

The northern summer fishery in Subareas 2, 5 and 14 continued in 2018. Fishing in the North Sea and west of the British Isles followed a traditional pattern, targeting mackerel on their spawning migration from the Norwegian deep in the northern North Sea, westwards around the north coast of Scotland and down the west coast of Scotland and Ireland.

The Russian freezer trawler fleet operates over a wide area in northern international waters. This fleet targets herring and blue whiting in addition to mackerel. In the third and fourth quarter of 2018 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 with the majority of the catch taken in Division 2.a in 2018. In 2017 the majority of the Icelandic catch was taken in 5.a in waters south and south-east of Iceland. Catches were also taken to the east and west of Iceland.

In 2018, Iceland and Greenland targeted mackerel in Division 14.b, with 6% of the total catch coming from this area. Catches from Greenland have increased in 2018 to almost 63 kt from 46 kt in 2017 and 30 kt in 2016 but are still lower than the 78 kt caught in 2014 which was the biggest catch by this fleet to date.

Concerning the Spanish fisheries, no new regulations have been implemented since 2010 when a new control regime was enforced. Fishery has started as in previous years at the beginning of March.

8.2.3 Recent Changes in Fishing Technology and Fishing Patterns

Northeast Atlantic mackerel, as a widely distributed species, is targeted by a number of different fishing métiers. Most of the fishing patterns of these métiers have remained unchanged during the most recent years, although the timing of the spawning migration and geographical distribution can change from year to year and this affects the fishery in various areas.

The most important changes in recent years are related to the geographical expansion of the northern summer fishery (Subareas 2, 5 and 14) and changes in southern waters due to stricter TAC compliance by Spanish authorities.

As a result of this expansion, Icelandic vessels have increased effort and catch dramatically in recent years from 4 kt in 2006 to an average 160 kt annually since 2011. This fishery operates over a wide area E, NE, SE, S and SW off Iceland. Since 2011, there has been less fishing activity to the north and north-east and an increase in catches taken south and west of Iceland. Greenland has reported catches from Division 14.b since 2011, and reached the biggest catch by this fleet to date in 2014, with a catch of 78 kt.

In 2010, the Faroese fleet switched from purse-seining in Norwegian and EU waters to pair trawling in the Faroese area. The Faroese fleet used to catch their mackerel quota in Divisions 4.a and 6.a during September-October with purse-seiners. However, as no agreement has been reached between the Coastal States since 2009, the mackerel quota has been taken in Faroese waters during June-October by the same fleet using pair trawls. The mackerel distribution is more scattered during summer and pair trawls seem to be effective in such circumstances. However, since the agreement between the three of the Coastal States for the fisheries in 2015, parts of the Faroese quota will now again be taken with purse-seines in Divisions 5.a and 6.a. In recent years, up to 25% of the Faroese quota have been granted to smaller, traditionally demersal trawlers using pair trawls.

In Spain, part of the purse seiner fleet is using hand lines instead of nets. Although, neither the number of vessels and its evolution nor the reason for such change were deeply analysed, it seems market reasons are driving this shift.

8.2.4 Regulations and their Effects

An overview of the major existing technical measures, effort controls and management plans are given in Table 8.2.4.1. Note that there may be additional existing international and national regulations that are not listed here.

Between 2010 and 2018 no overarching Coastal States Agreement/NEAFC Agreement was in place and no overall international regulation on catch limitation was in force. Currently there is no agreement on a management strategy covering all parties fishing mackerel. In 2014, three of the Coastal States (The EU, Faroes and Norway) agreed on a Management Strategy for 2015 and the subsequent five years. However, the total declared quotas taken by all parties since 2015 have greatly exceeded the TAC advised by ICES (see Section 8.1).

Management aimed at a fishing mortality in the range of 0.15—0.20 in the period 1998—2008. The current management plan aims at a fishing mortality in the range 0.20—0.22. The fishing mortality realised during 1998—2008 was in the range of 0.27 to 0.46. Implementation of the management plan resulted in a reduced fishing mortality and increased biomass. Since 2008 catches have greatly exceeded those given by the plan.

The measures advised by ICES to protect the North Sea spawning component aim at setting the conditions for making a recovery of this component possible. Before the late 1960s, the North Sea spawning biomass of mackerel was estimated at above 3 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 zoo-plankton availability in the North Sea and increased wind-stress induced turbulence. These unfavourable environmental conditions probably led the mackerel to spawn in western waters instead of in the North Sea.

A review of the mackerel in the North Sea, carried out during WKWIDE 2017 (ICES, 2017b) concluded that Northeast Atlantic mackerel should be considered as a single population (stock) with individuals that show stronger or weaker affinity for spawning in certain parts of the spawning area. Management should ensure that fisheries do not decrease genetic and behavioural diversity, since this could reduce future production. Protection of mackerel that tend to spawn in the north-eastern parts of the spawning area is therefore still advisable to some extent.

In the southern area, a Spanish national regulation affecting mackerel catches of Spanish fisheries has been implemented since 2010. In 2015, fishing opportunity was distributed by region and gear and for the bottom trawl fleet, by individual vessel. This year, Spanish mackerel fishing opportunity in Divisions 8.c and 9.a was 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. 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 North East Atlantic (NEA) mackerel is summarised below:

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
1992	760000	85	920	77000	11800
1993	825000	83	890	80411	12922
1994	822000	80	807	72541	13360
1995	755000	85	1008	102383	14481
1996	563600	79	1492	171830	14130
1997	569600	83	1067	138845	16355
1998	666700	80	1252	130011	19371
1999	608928	86	1109	116978	17432
2000	667158	76	1182	122769	15923
2001	677708	83	1419	142517	19824
2002	717882	87	1450	184101	26146
2003	617330	80	1212	148501	19779
2004	611461	79	1380	177812	24173
2005	543486	83	1229	164593	20217
2006	472652	85	1604	183767	23467
2007	579379	87	1267	139789	21791
2008	611063	88	1234	141425	24350
2009	734889	87	1231	139867	28722
2010	869451	91	1241	124695	29462
2011	938819	88	923	97818	22817
2012	894684	89	1216	135610	38365
2013	933165	89	1092	115870	25178
2014	1394454	90	1506	117250	43475
2015	1208990	88	2132	137871	24283

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
2016	1094066	89	2200	149216	21456
2017	1155944	87	2183	151548	24104
2018	1026437	83	1858	139590	20703

Overall sampling effort in 2018 was similar to previous years with 83% 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 2018 sampling levels for countries with a WG catch of greater than 100 t are shown below.

Country	Official catch	% WG catch covered by sampling programme	No. Samples	No. Measured	No. Aged
Belgium	168	0%	0	0	0
Denmark	30708	95%	6	449	450
Faroe Islands	81079	99%	15	871	921
France	21471	0%	0	0	0
Germany	19883	34%	84	716	17233
Greenland	63024	0%	0	0	0
Iceland	168330	98%	78	1910	3400
Ireland	66747	100%	42	1593	8254
Netherlands	30392	83%	28	775	2242
Norway	187207	92%	71	2345	2345
Poland	4057	0%	0	0	0
Portugal	4565	19%	148	492	7187
Russia	118255	95%	145	1342	36468
Sweden	3987	0%	0	0	0
Spain	35173	87%	1161	7200	35379
UK (England & Wales)	20729	4%	47	1910	5234
UK (Northern Ireland)	14873	41%	1	53	203
UK (Scotland)	155380	99%	32	1047	4285

The majority of countries achieved a high level of sampling coverage. Belgian catches are 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. Greenland, with a WG catch of 63 kt did not provide any sampling information. Sweden and Poland did not supply sampling information in 2018. 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 83% and 34% respectively) is designed to provide complete coverage for the freezer trawlers operating under these national flags and also those of England and France. Catch sampling levels per ICES Division (for those with a WG catch of >100 t) are shown below.

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
2.a	316662	316662	216	39528	3508
3.a	552	552	2	50	50
4.a	338056	338056	121	8908	3805
4.b	2660	2660	4	340	161
4.c	838	838	0	0	0
5.a	65103	65103	31	1270	747
5.b	11034	11034	3	158	149
6.a	157275	157275	99	22006	1921
7.b	10130	10130	10	1824	256
7.d	5406	5406	3	192	154
7.e	1131	1131	14	1442	942
7.f	365	365	33	3792	968
7.g	159	159	0	0	0
7.h	209	209	0	0	0
7.j	8283	8283	10	1349	277
8.a	5966	5966	1	1	1
8.b	5002	5015	210	4414	303
8.c	22884	22884	401	10450	3122
8.c.E	8370	8749	186	16054	2320
8.d	113	113	2	2	2

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
9.a	855	855	148	7187	492
9.a.N	1881	1881	361	4458	1452
14.a	107	107	0	0	0
14.b	62834	62834	3	176	73

In general, areas with insufficient sampling have relatively low levels of catch. The exception is Division 7.d from which 5.5 kt (mainly French) was caught which was not sampled.

8.4 Catch Data

8.4.1 ICES Catch Estimates

The total ICES estimated catch for 2018 was 1 026 437 t, a decrease of 129 507 t on the estimated catch in 2017. Catches increased substantially from 2006—2010 and have averaged 1 081 kt since from 2011.

The combined 2018 TAC, arising from agreements and autonomous quotas, amounts to 998 000 t). The ICES catch estimate (1 026 437 t) represents an overshoot of this. The combined fishable TAC for 2019, as best ascertained by the Working Group (see Section 8.1), amounts to 834 954 t.

Catches reported for 2018 and in previous Working Group reports are considered to be best estimates. In most cases, catch information comes from official logbook records. Other sources of information include catch processors. Some countries provide information on discards and slipped catch from observer programs, logbooks and compliance reports. In several countries discarding is illegal. Spanish data is based on the official data supplied by the Fisheries General Secretary (SGP) but supplemented by scientific estimates which are recorded as unallocated catch in the ICES estimates.

The text table below gives a brief overview of the basis for the ICES catch estimates.

Country	**Official Log Book**	**Other Sources**	**Discard Information**
Denmark	Y (landings)	Y (sale slips)	Y
Faroe[1]	Y (catches)	Y (coast guard)	NA
France	Y (landings)		Y
Germany	Y (landings)		Y
Greenland	Y (catches)	Y (sale slips)	Y
Iceland[1]	Y (landings)		NA
Ireland	Y (landings)		Y
Netherlands	Y (landings)	Y	Y

Country	Official Log Book	Other Sources	Discard Information
Norway[1]	Y (catches)		NA
Portugal		Y (sale slips)	Y
Russia[1]	Y (catches)		NA
Spain	Y	Y	Y
Sweden	Y (landings)		N
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. Recent work has 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 up to 2007, total catch related removals were equivalent to 1.7 to 3.6 times the reported catch (Simmonds *et al.*, 2010).
- Reliance on logbook data from EU countries implies (even with 100% compliance) a precision of recorded landings of 89% from 2004 and 82% previous to this (Council Regulation (EC) Nos. 2807/83 & 2287/2003). Given that over reporting of mackerel landings is unlikely for economic reasons; the WG considers that the reported landings may be an underestimate of up to 18% (11% from 2004), based on logbook figures. Where inspections were not carried out there is a possibility of a 56% under reporting, without there being an obvious illegal record in the logsheets. Without information on the percentage of the landings inspected it is not possible for the Working Group to evaluate the underestimate in its figures due to this technicality. EU landings represent about 65% of the total estimated NEA mackerel catch.
- The accuracy of logbooks from countries outside the EU has not been evaluated by WGWIDE. Monitoring of logbook records is the responsibility of the national control and enforcement agencies.

The total catch as estimated by ICES is shown in Table 8.4.1.1. It is broken down by ICES area group and illustrates the development of the fishery since 1969.

Discard Estimates

With a few exceptions, estimates of discards have been provided to the Working Group for the ICES Subareas and Divisions 6, 7/8.a,b,d,e and 3/4 (see Table 8.4.1.1) since 1978. Historical discard estimates were revised during the data compilation exercise undertaken for the 2014 benchmark assessment (ICES, 2014). The Working Group considers the estimates for these areas are incomplete. In 2018, discard data for mackerel were provided by The Netherlands, France, Germany, Ireland, Spain, Portugal, Greenland, Denmark, England, Scotland and Sweden. Total discards amounted to 2 890 t from the southern area. The German, French, Dutch, Irish 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 data was limited but data available indicates that, in Divisions 8.a, 8.b and 8.c the majority of discarded fish were aged 0 to 3. In Division 9.a the majority of the discarded fish were 0 group.

Discarding of small mackerel has historically been a major problem in the mackerel fishery and was largely responsible for the introduction of the south-west mackerel box. In the years prior to 1994, there was evidence of large-scale discarding and slipping of small mackerel in the fisheries in Division 2.a and Sub-area 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, and maintained to the present. Of the total catch in 2018, Norway accounted for the greatest proportion (18%) followed by Scotland (15%), Iceland (16%), Russia (12%) and Faroe (8%). In the absence of an international agreement, Greenland, Iceland and Russia declared unilateral quotas in 2018. Russia and Iceland both had catches over 100 kt with Faroes catching 81 kt. Greenlandic catches increased to almost 63 kt. Scotland had catch in excess of 100 kt and Ireland caught almost 67 kt. The Netherlands, Spain and Denmark had catches of around 30 kt while Germany, France and England had catches of the order of 20 kt.

In 2018, catches in the northern areas (Subareas 2, 5, 14) amounted to 455 740 t (see Table 8.4.2.1), a decrease of 148 129 t on the 2017 catch. Icelandic, Norwegian and Russian catches were all over 100 kt. Catches from Division 2.a accounted for 31% of the total catch in 2018, a decrease from 40% in 2017. Almost all the Russian catch in 2018 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 2018 amounted to 342 147 t, an increase of 72 343 t from 2017. The majority of the catch is from Subarea 4 with small catches were also reported in Divisions 3.a-d.

Catches in the western area (Subareas 6, 7 and Divisions 8.a,b,d and e) decreased slightly to 194 180 t with most of the traditional fishing nations catching less mackerel in 2018 than 2017. 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 34 369 t represents an increase from 2017. The catch is close to the long-term average.

The distribution of catches by quarter (%) is described in the text table below:

Year	Q1	Q2	Q3	Q4	Year	Q1	Q2	Q3	Q4
1990	28	6	26	40	2005	46	6	25	23
1991	38	5	25	32	2006	41	5	18	36
1992	34	5	24	37	2007	34	5	21	40
1993	29	7	25	39	2008	34	4	35	27
1994	32	6	28	34	2009	38	11	31	20
1995	37	8	27	28	2010	26	5	54	15
1996	37	8	32	23	2011	22	7	54	17
1997	34	11	33	22	2012	22	6	48	24
1998	38	12	24	27	2013	19	5	52	24
1999	36	9	28	27	2014	20	4	46	30
2000	41	4	21	33	2015	20	5	44	31
2001	40	6	23	30	2016	23	4	44	29
2002	37	5	29	28	2017	24	3	45	28
2003	36	5	22	37	2018	20	3	40	37
2004	37	6	28	29					

The quarterly distribution of catch in 2018 is similar to recent years (since 2010) with the northern summer fishery in Q3 accounting for the greatest proportion of the total catch.

Catches per ICES statistical rectangle are shown in Figures 8.4.2.1 to 8.4.2.4. It should be noted that these figures are a combination of official catches and ICES estimates and may not indicate the true location of the catches or represent the location of the entire stock. These data are based on catches reported by all the major catching nations and represents almost the entire ICES estimated catch.

- First quarter 2018 (200 408 t – 20%)

The distribution of catches in the first quarter is shown in Figure 8.4.2.1. The quarter 1 fishery is similar to that in previous years 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. The Spanish fisheries also take significant catches along the north coast of Spain during the first quarter.

- Second quarter 2018 (34 125 t – 3%)

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 2018. The most significant catches where those in Division 8.c and at the start of the summer fishery in northern waters by Icelandic, Norwegian and Russian fleets.

- Third quarter 2017 (412 146 t – 40%)

Figure 8.4.2.3 shows the distribution of the quarter 3 catches. Large catches were taken throughout Divisions 2.a (Russian, Norwegian vessels), 4.a (Norwegian, Scottish vessels), 5.a (Icelandic vessels). Catch was also taken in Division 14.b in quarter 3.

- Fourth quarter 2017 (379 758 t – 37%)

The fourth quarter distribution of catches is shown in Figure 8.4.2.4. The summer fishery in northern waters has largely finished although there are substantial catches reported in the southern part of Division 2.a. The largest catches are taken by Norway, Scotland and Ireland around the Shetland Isles and along the north coast of Scotland. The pattern of catches is very similar to that reported in recent years.

ICES cannot split the reported mackerel catches into different stock components because there is no clear distinction between components upon which a split could be determined. Mackerel with a preference for spawning in the northeast area, including the North Sea, cannot presently be identified morphometrically or genetically (Jansen and Gislason, 2013). Separation based on time and area of the catch is not a precise way of splitting mackerel with different spawning preferences, because of the mixing and migration dynamics including inter-annual (and possibly seasonal) variation of the spawning location, combined with the post-spawning immigration of mackerel from the south-west where spawning ends earlier than in the North Sea.

8.4.3 Catch-at-Age

The 2018 catches in number-at-age by quarter and ICES area are given in Table 8.4.3.1. This catch in numbers relates to a total ICES estimated catch of 1 026 437 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 and Spain. There remain gaps in the age sampling of catches, notably from France (length samples were provided), Sweden, Poland and Greenland.

Catches for which there were no sampling data were converted into numbers-at-age using data from the most appropriate fleets. Accurate national fleet descriptions are required for the allocation of sample data to unsampled catches.

The percentage catch numbers-at-age by quarter and area are given in Table 8.4.3.2.

As in previous years almost 80% of the catch in numbers in 2018 consists of 3 to 8-year olds with all year classes between 2010 and 2014 contributing over 10% to the total catch by number.

There is a small presence of juvenile (age 0) fish within the 2018 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 lengths-at-age in the catch per quarter and area for 2018 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 2018 for 0 group mackerel (162 mm-254 mm) are higher than those in 2017 (131 mm-212 mm).The rapid growth of 0-group fish combined with variations in sampling (in recent years more juvenile fish have been sampled in northern waters whereas previously these fish were only caught in southern waters) will contribute to the observed variability in the observed size of 0-group fish. Growth is also affected by fish density as indicated by a recent study which demonstrated a link between growth of juveniles and adults (0—4 years) and the abundance of juveniles and adults (Jansen and Burns, 2015). A similar result was obtained for mature 3- to 8-year-old mackerel where a study over 1988—2014 showed declining growth rate since the mid-2000s to 2014, which was negatively related to both mackerel stock size and the stock size of Norwegian spring spawning herring (Ólafsdóttir *et al*., 2015).

Length distributions of the 2018 catches were provided by England, Faroes, France, Iceland, Ireland, Germany, Greenland, the Netherlands, Portugal, Russia, Scotland and Spain. The length distributions were available from most of the fishing fleets and account for over 90% of the catches. These distributions are only intended to give an indication of the size of mackerel caught by the various fleets and are used as an aid in allocating sample information to unsampled catches. Length distributions by country and fleet for 2018 catches are given in Table 8.5.1.2.

8.5.2 Weights at Age in the Catch and Stock

The mean weights-at-age in the catch per quarter and area for 2018 are given in Table 8.5.2.1. There is a trend towards lighter weights-at-age for the most age classes (except 0 to 2 years old) starting around 2005 is continuing until 2013 (Figure 8.5.2.1). This decrease in the catch mean weights-at-age seems to have stopped since 2013 and values for the last five 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 weights-at-age in the stock calculated as the average of the weights-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 weights-at-age in 2018 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 weights-at-age in the western spawning component. For the North Sea spawning component, mean weights-at-age in 2018 were calculated from samples of the commercial catches collected from Divisions 4.a and 4.b in the second quarter of 2017. Stock weights for the southern component, are based on samples from the Portuguese and Spanish catch taken in Divisions 8.c and 9.a in the 2nd quarter of the year. The mean weights in the three components and in the stock in 2018 are shown in the text table below.

As for the catch weights, the decreasing trend observed since 2005 for fish of age 3 and older seems to have stopped in 2013 and values in the last four years do not show any specific trend (except for weights of ages 2 to 5 which have been increasing, Figure 8.5.2.2).

	North Sea Component	Western Component	Southern Component	NEA Mackerel 2017
Age				Weighted mean
0				0.000
1			0.085	0.063
2	0.200	0.206	0.142	0.191
3	0.303	0.253	0.291	0.266
4	0.294	0.281	0.285	0.283
5	0.328	0.308	0.326	0.314
6	0.352	0.322	0.334	0.327
7	0.366	0.343	0.347	0.346
8	0.395	0.363	0.356	0.364
9	0.389	0.392	0.379	0.389
10	0.447	0.419	0.409	0.419
11	0.441	0.448	0.403	0.437
12+	0.465	0.490	0.490	0.488
Component Weighting	8.5%	68.1%	23.4%	
Number of fish sampled	98	658	736	

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 2018 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 collected during the first and second quarters (ICES, 2014 and Stock Annex). The 2018 maturity ogives for the three components and for the mackerel stock are shown in the text table below.

A trend towards earlier maturation (increasing proportion mature at age 2) has been observed from the around 2008 to 2015. A change in the opposite direction has been observed since then and the proportion of fish mature at age in 2018 are now markedly lower that in the previous years, at levels comparable with the one observed at the end of the 2000s (Figure 8.5.3.1).

Age	North Sea	Western Component	Southern Component	NEA Mackerel
0	0	0	0	0
1	0	0.12	0.02	0.09
2	0.37	0.44	0.54	0.46
3	1	0.92	0.70	0.88
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12+	1	1	1	1
Component Weighting	8.5%	68.1%	23.4%	

8.6 Fishery Independent Data

8.6.1 International Mackerel Egg Survey

The ICES Triennial Mackerel and Horse Mackerel Egg Survey for 2019 was carried out during January - August. Final results will be presented at the WGMEGS meeting in April 2020. The results have been used in the assessment for mackerel since 1977. Since 2004 and subsequent to demands for up-to-date data for the assessment, WGMEGS aims to provide a preliminary estimate of NEA mackerel biomass and western horse mackerel egg production in time for the assessment meetings within the same calendar year as the survey.

WGMEGS presents the preliminary results of the 2019 mackerel and horse mackerel egg survey provided for WGWIDE in August 2019. The final survey results will be available during the next WGMEGS meeting in April 2020. This is due to the extremely large numbers of plankton and fecundity samples to be analysed following the surveys as well as the tight deadline set by WGWIDE for delivering these estimates. A working document (O' Hea *et al*., 2019) with the preliminary results of the survey was presented to WGWIDE members on time.

The 2019 survey plan was split into 6 sampling periods. Maximum deployment of effort in the Western area was during periods three, four, five and six (ICES, 2018c). Historically these periods would have coincided with the expected peak spawning of both mackerel and horse mackerel. In recent years mackerel peak spawning has been taken place during periods 3 and 5. Due to the expansion of the spawning area which has been observed since 2007, the emphasis was even more focused on full area coverage and delineation of the spawning boundaries.

Analyses of the plankton and fecundity samples were carried out according to the sampling protocols as described in the ICES Survey Protocols SISP 5 and SISP 6 (ICES, 2019b, ICES, 2019c).

8.6.1.1 Data analysis for mackerel annual egg production

Egg counts were converted to stage 1 egg production, using data on the volume of water filtered. These values were then converted to egg production/day/m^2 using the development equations and water temperature at 20 m depth. Arithmetic means were used where more than one sample per rectangle per period was collected. Daily egg production values were interpolated into unsampled rectangles according to procedures described in the above report. Plots of the distribution of egg production for the western area are presented in Figures 8.6.1.1-8.6.1.6. Interpolated values are highlighted in red. The area coverage is described in detail in the working document from O' Hea *et al*. (2019) presented to WGWIDE.

Figure 8.6.1.7 presents the egg production curve for the western area for the 2019 survey, along with those for the previous surveys for comparison. 2010 provided an unusually large spawning event early in the spawning season, 2013 yielded an even larger spawning event indicating that spawning was probably taking place well before the nominal start date of 10th February (day 42). In 2016 the first survey commenced on February 5th which is five days prior to the nominal start date. The pattern in 2019 followed that of 2016 with no early peak spawning being recorded. This year however, peak spawning was found to have taken place in period 4, rather than period 5 as the case in 2016. Unlike 2016 when concern was expressed that survey coverage may have underestimated the total egg production estimate, area coverage in 2019 was much better. The expansion observed in western and north-western areas during periods 5 and 6 in 2016 was once again reported during 2019. However, egg numbers were not as large as in 2016 (Figures 8.6.1.4-5). During these periods it was not possible to fully delineate the northern and north-western boundaries. However, an analysis provided significant evidence that while some spawning has been missed the loss of egg abundance is not sufficiently large to significantly impact the SSB estimate.

The nominal end of spawning date of the 31st July is the same as was used during previous survey years and the shape of the egg production curve for 2019 does not suggest that the chosen end date needs to be altered. The provisional total annual egg production (TAEP) for the western area in 2019 was calculated as $1.22 * 10^{15}$. This is a 20% reduction on the 2016 TAEP estimate which was $1.55 * 10^{15}$.

Figure 8.6.1.8 shows the egg production curve for the southern area for the 2019 survey, along with those for previous surveys for comparison. The start date for spawning in the southern area was the 23rd January). The Portuguese period 1 survey in division 9.a was pushed back by around 1 week. The result being that the survey dates aligned more closely to period 2. It was subsequently re-classified within period 2 and survey period 1 was removed. Sampling in the Cantabrian Sea, where the majority of spawning occurs within the Southern area, commenced 6 days later than in 2016 on the 14th March. The same end of spawning date of the 17th July was used again this year and the spawning curve suggests that there is no reason for this to change. As in 2016 the survey periods were not completely contiguous, and this has been accounted for. The provisional total annual egg production (TAEP) for the southern area in 2019 was calculated as $4.19 * 10^{14}$. This is a 54% increase on the 2016 TAEP estimate which was $2.25 * 10^{14}$.

A comparison of the total annual egg production (TAEP) for the western and southern area over the last survey years is given below:

Year	Western TAEP	Southern TAEP
2019	$1.22 * 10^{15}$	$4.19 * 10^{14}$
2016	$1.55 * 10^{15}$	$2.25 * 10^{14}$
2013	$2.20 * 10^{15}$	$5.06 * 10^{14}$
2010	$1.92 * 10^{15}$	$4.59 * 10^{14}$
2007	$1.42 * 10^{15}$	$3.48 * 10^{14}$
2004	$1.36 * 10^{15}$	$1.38 * 10^{14}$
2001	$1.35 * 10^{15}$	$3.18 * 10^{14}$
1998	$1.54 * 10^{15}$	$4.79 * 10^{14}$

Total annual eggs production (TAEP) for both the western and southern components combined in 2019 is $1.63 * 10^{15}$. This is a decrease in production of 9% compared to 2016 (Figure 8.6.1.9).

8.6.1.2 Mackerel fecundity and atresia estimation

Estimates of fecundity are given as preliminary realised fecundity which is the potential fecundity minus the atresia rate (for details see O' Hea *et al.*, 2019). The analysis of potential fecundity is carried out by four different participating institutes. Preliminary results are based on a limited number (34) of samples from period 2 and 3. This number of samples have been lower than in 2016, when 66 samples were available for the preliminary potential fecundity. The preliminary relative potential fecundity in 2019 is 1224 oocytes/gram female slightly higher than preliminary estimate in 2016 (1215 oocytes/gram female). Due to time constraints no samples were analysed for atresia at the time of WGWIDE. For the preliminary estimation of the realised fecundity the mean atresia rate based on the last six survey years (6%) was used. This resulted in a preliminary realised fecundity estimate for 2019 of 1 142 oocytes/gram female fish.

8.6.1.3 Quality and reliability of the 2019 egg survey

The 2019 survey shows a good spatial and temporal coverage in each of the sampling periods.

The previous surveys in 2010 and 2013 have been dominated by the issue of early peak of western mackerel spawning and its close proximity to the nominal start date. Both the 2013 and 2016 surveys were determined to address this issue with the result that sampling in the western area during these years commenced 2 weeks earlier than the preceding survey in an effort to capture the start of spawning. The pattern in 2019 followed that of 2016 with no early peak spawning being recorded. This year, however, peak spawning for western component was found to have taken place in period 4 which in regard to its temporal position has been early that of 2016 (Figure 8.6.1.7). The bulk of the spawning activity reported during historical surveys resulted from several egg production hotspots on and around the continental shelf edge and usually around the Celtic Sea and Porcupine Bank region. During 2019, high levels of egg production were recorded close to the 200 m contour line in Cantabrian Sea, Bay of Biscay, Porcupine Bank and from Cape Wrath to Shetland. (Figures 8.6.1.2-8.6.1.5). As it was noted in 2016, a low to moderate egg production at westwards and northwards of North of 54°N was found. Although it was not possible to fully delineate the boundary in this region during periods 5 and 6. It was accepted that this north and north-westerly unaccounted egg production would contribute only a small proportion of the TAEP in the western area. WGMEGS is confident that this survey accurately reflects the spawning patterns and that the survey has been successful in capturing the bulk of spawning activity. Further analysis of the quality and reliability of the survey will be done by WGMEGS in April 2020.

8.6.1.4 Mackerel biomass estimates

Based on the total annual egg production (TAEP) for the western and southern component, a preliminary realized fecundity estimate of 1 142 oocytes/gr female, a sex ratio of 1:1 and a raising factor of 1.08, the preliminary total spawning stock biomass (SSB) was estimated as shown below:

$$SSB = \frac{TAEP}{F'} * s * cf$$

Where

F′ = realized fecundity,

s = 2 for a given sex ratio of 1:1,

cf = 1.08 (fixed raising factor to convert pre-spawning to spawning fish)

Giving

- 2.301 million tonnes for western component (2016: 3.077).
- 0.792 million tonnes for southern component (2016: 0.447).
- 3.092 million tonnes for western and southern components combined (2016: 3.524)

8.6.2 Demersal trawl surveys in October – March (IBTS Q4 and Q1)

The data and the model

An index of survivors in the first autumn-winter (recruitment index) was derived from a geostatistical model fitted to catch data from bottom trawl surveys conducted during autumn and winter. A complete description of the data and model can be found in Jansen *et al*. (2015) and the NEA mackerel Stock Annex.

The data were compiled from several bottom trawl surveys conducted between October and March from 1998—2019 by research institutes in (Denmark, England, France, Germany, Ireland, Netherlands, Norway, Scotland and Sweden). Surveys conducted on the European shelf in the first and fourth quarters are collectively known as the International Bottom Trawl Survey (IBTS), although several of the surveys use different names. All surveys sample the fish community on the continental shelf and upper shelf slope. IBTS Q4 covers the shelf from the Bay of Biscay to North of Scotland, excluding the North Sea, while IBTS Q1 covers the shelf waters from north of Ireland, around Scotland, the North Sea, Skagerrak and Kattegat.

Trawl operations during the IBTS have largely been standardized through the relevant ICES working group (ICES, 2013b). Furthermore, the effects of variation in wing-spread and trawl speed were included in the model (Jansen *et al*., 2015). Trawling speed was generally 3.5—4.0 knots, and trawl gear is also standardized and collectively known as the Grande Ouverture Verticale (GOV) trawl. Some countries use modified trawl gear to suit the particular conditions in the respective survey areas, although this was not expected to change catchability significantly. However, in other cases, the trawl design deviated more significantly from the standard GOV type, namely the Spanish BAKA trawl, the French GOV trawl, and the Irish mini-GOV trawl. The BAKA trawl had a vertical opening of only 2.1—2.2 m and was towed at only 3 knots. This was considered substantially less suitable for catching juvenile mackerel and, therefore, was excluded from the analysis. The French GOV trawl was rigged without a kite and typically had a reduced vertical opening, which may have reduced the catchability of pelagic species like mackerel. Catchability was assumed to equal the catchability of the standard GOV trawl because testing has shown that the recruitment index was not very sensitive to this assumption (Jansen *et al*., 2015). Finally, the Irish mini-GOV trawl, used during 1998—2002, was a GOV trawl in reduced dimensions which was accounted for by inclusion of the wing-spread parameter in the model.

All surveys in 2018 Q4 and 2019 Q1 were conducted according to standards. Figure 8.6.2.1 provides an overview of the distribution and number of samples.

A geostatistical log-Gaussian Cox process model (LGC) with spatiotemporal correlations was used to estimate the catch rates of mackerel recruits through space and time.

Results

The index of survivors in the first autumn-winter (recruitment index) was updated with data from surveys in 2018 Q4 and 2019 Q1. Parameter estimates and standard errors in the final model are listed in Table 8.6.2.1. The modelled average recruitment index (squared CPUE) surfaces were mapped in Figure 8.6.2.2. The timeseries 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 in IBPNEAMac (ICES, 2019a), but with the same interannual pattern ($p< 0.001$, $r = 0.9986$). This increase does not affect the stock assessment because it is used in the assessment as a relative abundance index. The estimated index value for the 2018 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; and (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 encourage studies of vertical distribution and catchability of age-0 mackerel in the Q4 and Q1 surveys, to evaluate if it is comparable in all areas (see acoustic information in Jansen *et al*., 2015).

8.6.3 Ecosystem surveys in the Nordic Seas in July-August (IESSNS)

The IESSNS was successfully conducted in the summer of 2019 (Figure 8.6.3.1). Six vessels sampled 309 predetermined surface trawl stations during the period from June 28 to August 5 which covered an area of 3.2 mill. km^2, 2.9 mill. km^2 excluding the North Sea, which was similar coverage to 2018 (Nøttestad *et al*., 2019). At each surface trawl station, a standardized trawl (Multpelt 832) is employed for 30-min according to a standardize operation protocol which is designed to catch mackerel. Additionally, abundance of herring and blue whiting was measured using acoustic methods, excluding the North Sea, and backscatter was verified by trawling on registrations as needed. The aim is to establish an index for blue whiting and herring abundance to be used in stock assessment in the future. The IESSNS 2019 cruise report is available as a working document to the current report (Nøttestad *et al*., 2019) and a detailed survey description is in the mackerel Stock Annex.

IESSNS provides an annual age-segregated index for mackerel abundance for age classes 1-14+ in Nordic Seas since 2010 and in the North Sea since 2018 (ICES, 2019a). In the current chapter, the North Sea mackerel data are reported separately from longer time series available from the Nordic Sea area. In Nordic Seas, total stock abundance (numbers) was estimated 26.4 billion and biomass was estimated 11.5 million tons which is compared to 2018 an increase of 56% and 85%, respectively (Table 8.6.3.1 and Figure 8.6.3.2a). Estimate stock abundance (billions) in 2019 is the second highest for the timeseries (Figure 8.6.3.2b), and in similar range as estimates for the period from 2013 to 2017 (Nøttestad *et al*., 2019). Catch curve analysis of cohort numbers for the period from 2010 to 2019 displays "a dip" for all age classes in 2018 (Figure 8.6.3.3), indicating annual effects in the survey (Nøttestad *et al*., 2019).

The most abundant year classes were 2011, 2010 and 2016 respectively presenting 14.8%, 14.5% and 14.4% of the total stock in numbers (Figure 8.6.3.4a, b). These cohorts were also abundant in 2018. Internal consistency of year classes is highly variable with correlation values ranging from 0.13 to 0.93 (Figure 8.6.3.5). There was a significant ($p < 0.05$) internal consistency for ages 1 to 5 years ($0.83 < r < 0.93$), it was not significant but fairly good for ages 6 to 7 and for ages 8 to 12 ($0.58 < r < 0.81$), and it was poor between ages 5 and 6 ($r = 0.31$) and ages 7 and 8 ($r = 0.13$) (Figure 8.6.3.5). Compared to 2018, internal consistency was similar for most ages except there was a noticeable decline for ages 5 - 6 and ages 7 - 8. It is worth noting that the internal consistency plots have seven data points each, hence one data point can have large influence on the correlation.

Mackerel density, per predetermined surface trawl station, ranged from 0 to 52 tonnes/km^2 with the highest densities recorded in the northern Norwegian Sea, south-east of Iceland, between Iceland and the Faroe Island, as well as south west of the Faroe Islands (Nøttestad *et al*., 2019). Mackerel geographical distribution began shifting eastward in 2018 compared to the period from 2010 to 2017 (Figure 8.6.3.6b). This eastward distributional shift continued in 2019 with limited amount of mackerel caught westward of longitude 27°W (Figure 8.6.3.6a) (Nøttestad *et al*., 2019). For comparison, the westward boundary of mackerel was at longitude 43°W in 2014 which is the year with the largest geographical distribution range.

For age classes 3-11, which are included in stock assessment (ICES, 2019a), increased in numbers was 98% compared to 56% for all age classes. This discrepancy is caused by age classes 1 and 2 being 70% lower in 2019 compared to 2018. The record high numbers of age 1 in 2018 resulted in below medium number at age 2 in 2019, and age 1 numbers in 2019 were among the lowest recorded (Figure 8.6.3.4a). The IESSNS is considered not cover the complete distribution range of youngest two-year classes, hence they are excluded from the assessment. However, the internal consistency between ages 1 - 3 suggests abundance at ages 1 and 2 gives an indication of year class size prior to recruitment into the survey at age 3 (Figure 8.6.3.5).

The North Sea (southward of latitude 60 °N) was included in the IESSNS for the second time in July 2019 with 38 predetermined surface trawl stations were sampled and survey area covering 0.28 mill. km^2 (Figure 8.6.3.6a). The mackerel abundance index was 1.0 billion and the biomass index was 0.2 million ton which was a decrease of 53% and 42% compared to 2018, respectively (Figure 8.6.3.6b) (Nøttestad *et al*., 2019).

8.6.4 Tag Recapture data

Steel-tags

The Institute of Marine Research in Bergen (IMR) has conducted tagging experiments on mackerel on annual basis since 1968, both in the North Sea and to the west of Ireland during the spawning season May–June. Information from steel-tagged mackerel tagged west of Ireland and British Isles was introduced in the mackerel assessment during ICES WKPELA 2014 (ICES, 2014), and data from release years 1980-2004, and recapture years 1986-2006 has been used in the update assessments after this. The steel tag experiments continued to 2009, with recaptures to 2010, but this part of the data was at the time considered less representative and was excluded.

What is used in the SAM stock assessment is a table of data showing numbers of steel tagged fish per year class in each release year, and the corresponding numbers scanned and recaptured of the same year classes in all years after release. The steel tag data and the corresponding trends in the data in terms of index of total biomass and year class abundance by year is described in (Tenningen *et al.*, 2011).

The steel tag methodology involved a whole lot of manual processes, demanding a lot of effort and reducing the possibility to scan larger proportions of the landings. The tags were recovered at metal detector/deflector gate systems installed at plants processing mackerel for human consumption. This system demanded external personnel to stay at the plants supervising the systems during processing. Among the typical 50 fish deflected, the hired personnel had to find the tagged fish with a hand-hold detector and send the fish to IMR for further analysis. It was decided in the end to go for a change in methodology to radio-frequency identification (RFID), which would allow for more automatic processes and increased proportion of scanned landings.

RFID tags

The RFID tagging project on NEA mackerel was initiated in 2011 by IMR, and the data was 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 tag itself is passive but information to the reader is released as it passes an electric field in the antenna system, and information is automatically updated in an IMR database. When tagging and releasing the fish, information is also synced to the IMR database regularly over internet.

There is a web-based software solution and database that is used to track the different scanning systems at the factories, import data on catch information, and biological sampling data of released fish and screened catches. Based on this information the system can 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. In the future it is planned that annual workshops should occur prior to the assessment, where more scientists go through the new data being updated from new tagging experiments, as well as recaptures from all previous experiments, undertake quality assurance of the data and other analyses of the trends in the data outside of the assessment model.

The RFID tagging technology is clearly a more cost-effective than the old steel tag technology. We are now scanning about 10 times more biomass than during the period with steel tags. An overview of the RFID tagging data in terms of numbers tagged, biomass scanned, and numbers recaptured is given in Tables 8.6.4.1-3, and geographical distributions of data in Figure 8.6.4.1.

During the period 2011— 1th September 2019 as many as 408 325 mackerel have been tagged with RFID (Table 8.6.4.1). This includes an experiment off the Norwegian Coast on young mackerel in September 2011 as well as five experiments carried out in August in Iceland 2015-2019, none of which are included as input data in the assessment. Data from the releases at the spawning grounds in May-June of Ireland and the Hebrides are the only data included in the assessment.

The 4 490 RFID-tagged mackerel recaptured up to 1th September 2019 came from 23 European factories processing mackerel for human consumption (Table 8.6.4.3). The project started with RFID antenna reader systems connected to conveyor belt systems at 8 Norwegian factories in 2012. Now there are 6 operational systems at 5 factories in UK (Denholm has 2 RFID systems) and 3 in Iceland. Norway has installed RFID systems at 8 more factories in 2017-2018, most of which with the purpose of scanning Norwegian spring spawning herring catches (IMR started tagging herring in 2016), but some also processing mackerel. More systems are also bought by Ireland (3), which up to now has been non-operational. The working document from Slotte (2019) presented to WGWIDE, describes potential problems with some of the factories that has led to the exclusion of the data for use in assessment, the data from factories used in the 2019 assessment is marked in Tables 8.6.4.2-3.

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, and it is illustrated in Tables 8.6.4.1-3 where subset data currently used are marked.

Figure 8.6.4.2 shows the relative distributions of year classes tagged per year and scanned/recaptured year 1 and 2 after release for the subset years used in current update assessment. The figure illustrates the problem that the tagged/recaptured fish are skewed towards older fish than scanned. Especially the large year classes 2010-2011 were tagged in low numbers at ages 2-4 compared with the scanned numbers. However, for the latest release used in the assessment (2017), it seems that this tendency is less pronounced.

During ICES WGWIDE 2018 (ICES, 2018d) the RFID tag data had high weight, and the SSB trend in the assessment showed a clear tendency to decrease from 2011-2016. This was also consistent with the observed trend in the data from various abundance index data from the RFID tag-recapture time series explored during ICES IBPNEAMac 2019 (ICES, 2019a). However, by using the current subset data this changed the trend in the RFID tag data significantly, which is demonstrated by comparing the index of abundance from RFID data using all data and the subset data (Figure 8.6.4.3). Here it is also obvious that adding one more year of release and recapture data results in increases abundance in release years 2011-2012, as well as a very clear downward trend to 2017. On the other hand, adding one more release year and recapture year in the subset data lifts the index in 2016 to same level as in 2017. The subset data indicate a weak increase in abundance from 2013-2017, rather than a decrease.

Estimates of year class abundance for the subset of RFID tag-recapture data used in the current assessment also show differences in year class levels and trends over time that seems reasonable with no clear year effects, and with a year class development following a total mortality of approximately Z=0.4 (Figure 8.6.4.4). These estimates of year class trends and trends in aggregated abundance over ages should be continued to be explored in next update assessments, as this is format that is easier to evaluate than the actual raw data used in the SAM model.

8.6.5 Other surveys

8.6.5.1 International Ecosystem survey in the Norwegian Sea (IESNS)

After the mid-2000s an increasing amount of NEA mackerel has been observed in catches in the Norwegian Sea during the combined survey in May during the International Ecosystem survey in the Norwegian Sea (IESNS) targeting herring and blue whiting (Rybakov *et al.*, 2016; 2017). The spatial distribution pattern of mackerel was reduced in 2019 compared to 2017 and 2018 (Rybakov *et al.*, 2017; ICES, 2018b; Salthaug *et al.*, 2019). Mackerel was caught within a more limited area and in fewer trawl stations of the Norwegian Sea in May 2019 compared to May 2017 and 2018 (Rybakov *et al.*, 2017; ICES, 2018b; Salthaug *et al.*, 2019). In 2019, the northernmost mackerel catch was at 66°N and the westernmost catch was at 2°W, whereas in 2018, the northernmost mackerel catch was at 70°N and the westernmost catch was similar at 2°W. Mackerel of age 3 dominated followed by age 5 in 2019, whereas there was found much less 1-year olds compared to last year (Salthaug *et al.*, 2019).

The IESNS survey provide valuable although limited quantitative information can be drawn. This acoustic based survey is not designed to monitor mackerel, and do not provide proper mackerel sampling in the vertical dimension and involve too low trawl speed for representative sampling of all size groups of mackerel. The trawl hauls are mainly targeting acoustical registrations of herring and blue whiting during the survey in May (IESNS) (Salthaug *et al.*, 2019).

8.6.5.2 Acoustic estimates of mackerel in the Iberian Peninsula and Bay of Biscay (PELACUS)

The northern Spanish waters (8.c and 9.a.N) were surveyed in PELACUS 0319 on board RV Miguel Oliver from 27th March till 19th April, using the methodology of the previous surveys.

The bulk of the mackerel distribution, as in previous years, was located just in the middle of the Cantabrian Sea (Cape Peñas), extending throughout the surveyed area (Figure 8.6.5.2.1). A total of 905 thousand tonnes, corresponding to 2 549 million fish were estimated, which represent an important increase from the 2018 estimates (557 thousand tonnes). Bigger fish (mainly age group 7) occurred in the westernmost part, while age group 5 in the rest of the area. (Figure 8.6.5.2.2, Tables 8.6.5.2.12).

Although biomass was higher, spawning area was lower than the one derived last year (246 positive egg stations of 367 this year; 364 of 373 in 2018), but probably due to the increase of the adult abundance, egg density was higher than that calculated last year (mean of 397 eggs per stations, corresponding to 36.21 eggs/m^3 this year and 248 egg per station -24 eggs/m^3- in 2018). It should be also noted the almost lack of spawning activity of mackerel in both Porcupine and the slope in 8.a (48ºN), with only a 7% and 33% of the stations being positives for mackerel eggs with an average of 20.67 and 2.29 egg counts/station corresponding to 2.29 and 0.2 eggs/m^3 respectively. On the contrary, in 8.b (45ºN) the spawning activity was really high, with 82% of the station being positives for mackerel eggs with the highest egg production too (1 181 eggs/station corresponding to 95.91 eggs/m^3) (Figure 8.6.5.2.3).

8.7 Stock Assessment

8.7.1 SAM assessment

8.7.1.1 Update assessment in 2019

During the 2019 interbenchmark process (ICES IBPNEAMac 2019; ICES, 2019a), a number of changes have been accepted for the NEA mackerel assessment. After identifying a number of potential biases in the RFID dataset, the decision was made to use a sub-set of the available data:

- Only fish recaptured 1 or 2 years after release are now used, in order to avoid the potential bias linked to tag loss or longer term post-tagging mortality.
- Fish tagged at a young age (4 and younger) are excluded from the data base, as they correspond to not fully mature ages, and therefore only a subcomponent of these age classes may be present on the spawning grounds were the tagging survey is carried out.
- The first 2 years of recapture in the tagging program are also excluded, as the volume of the catch scanned was much lower in these first years of the RFID program, and the catches only originates from a limited geographical area.

In addition to this, the SAM model configuration was modified in order to treat the young fish (ages 0 and 1) differently from the older fish. While in the previous assessment, there was one common observation variance parameter and one common F random walk variance parameter for all ages, the new assessment now estimates separate parameters for age 0, age 1 and for older ages.

The interbenchmark process was conducted using the data available for WGWIDE2018 (ICES, 2018d). The WGWIDE2019 assessment was therefore the first update assessment carried out with the new methodology. 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 is also available on the webpage stockassessment.org (assessment named MackWGWIDE2019v02).

The assessment model is fitted to catch-at-age data for ages 0 to 12 (plus group) for the period 1980 to 2018 (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 (1998-2018); and (3) the abundance estimates for ages 3 to 11 from the IESSNS survey (2010, 2012-2019). 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 2018 (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 ages 1-11.

The differences in the new data used in this assessment compared to the benchmark assessment were:

- update of the recruitment index until 2018.
- Addition of the preliminary 2019 SSB estimate from the egg survey
- Addition of the 2019 survey data in the IESSNS indices.
- Addition of the 2018 catch-at-age, weights-at-age in the catch and in the stock and maturity ogive, proportions of natural and fishing mortality occurring before spawning.
- The inclusion of the tag recaptures from 2018

Input parameters and configurations are summarized in Table 8.7.1.1.1. The input data are given in Tables 8.7.1.1.2 to 8.7.1.1.9. Given the size of the data base, the tagging data are not presented in this report, but are available on www.stockassessment.org in the data section (files named tag_steel.dat and tag_RFID.dat).

8.7.1.2 Model diagnostics

Parameter estimates

The estimated parameters and their uncertainty estimates are shown in Table 8.7.1.2.1 and Figure 8.7.1.2.1. The model now 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, 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 a 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 1.23, 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 0.86 for age 3 to 2.14 for age 7 and decreases slightly for older ages. 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 13%).

The process error standard deviation (ages 1-11) is moderate as well as the standard deviation of the F random walks.

The catchability parameters for the egg survey, recruitment index and post tagging survival appear to be estimated more precisely than other parameters (Table 8.7.1.2.1). 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 and for the recruitment index than for the other observations. Uncertainty on the overdispersion of the RFID tag data is high. The standard deviation on the estimate of process error is low, and the standard deviations for the estimates of F random walk variances of age 0 and 1 are both very high.

The estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11 has a high correlation between the errors of adjacent ages (r=0.73), then decreasing exponentially with age difference (Figure 8.7.1.2.2.). This high error correlation implies that the weight of this survey in the assessment in lower than for a model without correlation structure, which is also reflects in the high observation standard deviation for this survey.

There are some correlations between parameter estimates (Figure 8.7.1.2.3):

- Catchabilities are positively correlated (especially for the IESSNS age 4 to 11), and negatively correlated to the survival rate for the RFID tags. This simply represents the fact that all scaling parameters are linked, which is to be expected.
- The observation variance for the IESSNS age 4-11 is positively correlated to the autocorrelation in the errors for these observation. This implies that when the model estimates highly correlated errors between age-groups, the survey is considered more noisy.

Residuals

The "one step ahead" (uncorrelated) residuals for the catches did not show any temporal pattern (Figure 8.7.1.2.4) except for 2014 for which they were mainly positive for 2014 (modelled catches lower than the observed ones). This may result from the random walk that constraints the variations of the fishing mortality, which prevents the model from increasing the fishing mortality suddenly (which probably happened given the sharp increase in the catches in 2014). Residuals are of a similar size for all ages, indicating that the model configuration with respect to the decoupling of the observation variances for the catches is appropriate.

The residuals for the egg survey show a strong temporal pattern with large positive residuals for the period 2007-2010-2013, followed by large negative residuals in 2016 and 2019. This pattern reflects the fact that the model, based on all the information available, does not follow the recent trend present in the egg survey (with an historical low estimate for 2019) and considers those two last years as large negative observation errors. The strong increase in the observation variance for this survey (see Section 8.7.1.4.2) indicating a poorer fit with the egg survey is related to these two observations which point towards a very different direction as the other observations.

Residuals for the IESSNS indices show an alternation of positive, negative and positive residuals again in the years 2017-2018-2019, which reflect the fact that there is probably a negative year effect in 2018 in this survey. Residuals for the rest of the period year are more balanced.

Residuals to the recruitment index show no particular pattern, and appear to be relatively randomly distributed.

Finally, inspection of the residuals for the tag recaptures (Figure 8.7.1.2.5) did not show any specific pattern for the RFID data. For the steel tags, there is a tendency to have more positive residuals at the end of the period which could indicate that using a constant survival rate for this dataset may not be appropriate.

Leave one out runs

In order to visualise the respective impact of the different surveys on the estimated stock trajectories, the assessment was run leaving out successively each of the data sources (Figure 8.7.1.2.6).

The run without the RFID recaptures and the run without the recruitment index failed to converge. Making a small change in the model configuration (grouping the F random walk variance of age 1 with the one of the older ages, which did not have a noticeable effect on the stock trajectories for the run using all data source), it was possible to achieve converge for the run without RFID data, but not for the run without the recruitment index. It has therefore not been possible to assess the influence of this index on the assessment.

All leave out one runs showed parallel trajectories in SSB and F_{bar}. Removing the IESSNS resulted in lower SSB estimates and higher F_{bar} estimates for the period covered by the survey. On the opposite, removing the egg survey results in a larger estimated stock, exploited with a lower fishing mortality. In both cases, the estimated stock trajectories are well within the confidence interval of the assessment using all data sources. The final assessment seems to make a trade-off between the information coming from the IESSNS which leads to a more optimistic perception of the stock, and the information from the egg survey which suggests a more pessimistic perception of the stock. The run leaving out the RFID data gave a perception of the SSB very similar to the assessment using all data, and slightly higher fishing mortality over the last decade. This is a contrasting situation compared to the 2018 WGWIDE assessment, in which the RFID had a very strong influence on the assessment, and is the consequence of the changes made during the interbenchmark process and listed above. A closer inspection of the run without the RFID data (Figure 8.7.1.2.7) indicates that, although the inclusion of the RFID does not modify sensibly the

SSB trajectory, it does slightly reduce the uncertainty on the SSB estimates (slightly wider confidence bounds without the RFID data).

8.7.1.3 State of the Stock

The stock summary is presented in Figure 8.7.1.3.1 and Table 8.7.1.3.1. The stock numbers-at-age and fishing mortality-at-age are presented in Tables 8.7.1.3.2-3. The spawning stock biomass is estimated to have increase almost continuously from just above 2 million tonnes in the late 1990s and early 2000s to 5.2 million tonnes in 2014 and subsequently declined continuously to reach a level just above 4.3 million tonnes in 2018. The fishing mortality has declined from levels between F_{pa} (0.37) and F_{lim} (0.46) in the mid-2000s to levels just above F_{MSY} in 2018. The recruitment time series from the assessment shows a clear increasing trend since the late 1990s with a succession of large year classes (2002, 2005-2006, 2011 and 2016-2017). There is insufficient information to estimate accurately the size of the 2018 year class, estimate is very high but highly uncertain.

There is some indication of changes in the selectivity of the fishery over the last 30 years (Figure 8.7.1.3.2.). In the 1990s, the fishery seems to have had a steeper selection pattern (more rapid increase in fishing mortality with age). Between the end of the 1990s and the end of the 2000s, the selection pattern became less steep (decreasing selection on the ages2-5). After 2008, the pattern changed again towards a steeper selection pattern.

8.7.1.4 Additional exploratory runs

8.7.1.4.1 Excluding the 2018 estimates from the IESSNS survey

The residual plot for the IESSNS survey suggests a negative year effect in 2018 which is also visible in the survey index (Figure 8.6.3.3). A year effect in a survey corresponds to an anomaly in the catchability of the survey in a given year, that be caused by a range of different factors (poor weather, stock geographic distribution, fish behaviour ...). The reasons for this particular 2018 year effect have not been fully investigated yet. Nonetheless, it seemed worthwhile exploring the effect of removing this particular year from the IESSNS index used in the assessment.

This was done during WGWIDE and was found to make little difference in the outcome of the assessment. There was barely any difference in model parameters when the 2018 IESSNS index was removed (except a small reduction of the observation error variance for the age 3 in the IESSNS). This had no noticeable consequences for the estimated stock trajectories (Figure 8.7.1.4.1.1).

The SAM mackerel assessment includes a correlation structure for the errors in the IESSNS, which effectively means that the model is designed to cope with year effects in that survey (which correspond to errors correlated across age-classes). This results in more accurate estimates of model parameters (no bias due to invalid assumption that the errors are independently distributed). Amongst those parameters, the observation variance for the IESSNS survey are estimated at higher values once the correlation structure is used (ICES, 2017b), reflecting decreasing weight of this survey. A consequence is that the model is rather insensitive to the exclusion a single year of data, as already found in 2018 WGWIDE (ICES, 2018d), and confirmed by this analysis.

8.7.1.4.2 Excluding the 2016 and 2019 estimates from the egg survey index

Since 2010, the survey showed a very large expansion of the spawning area to the Northeast (into the Norwegian Sea), the North (south of Iceland) and West (on Hatton bank, see Figure 8.6.1.4). In 2016 and 2019, the survey could not cover the full extension of the spawning, probably leading to an underestimation of the total annual egg production. The areas that could not be covered are assumed to contain only low density of eggs and the conclusion of the MEGS group was that the bias on the SSB index should be rather small. Still, given the strong residual pattern found for this survey in the assessment (with 2 large negative residuals for 2016 and 2019), it seemed worthwhile investigating the sensitivity of the assessment to these 2 specific survey points.

The mackerel assessment run without the 2016 and 2019 egg survey estimates showed a much better overall fit to the egg survey index (strong decrease in the observation variance, Figure 8.7.1.4.2.1). However, a temporal pattern still remained in the residuals (Figure 8.7.1.4.2.2), which indicates that the assessment still did not completely match the temporal development in the egg survey index. The stock trajectories are slightly modified by the removal of these 2 years in the egg survey (upwards for SSB and downwards for F_{bar}, Figure 8.7.1.4.2.3). The difference on the final assessment year estimates is +10% for SSB and -7% for F_{bar}, but much smaller for the earlier years.

Considering the magnitude of the residuals for 2016 and 2019 - reflecting the discrepancy between the recent trend in the assessed SSB and the trend in the egg index - these two data only have a small overall effect on stock trajectories. This reflects the behaviour of the SAM model which automatically weights the data sources. In this case, the egg survey has been down-weighted as the new information became more contradictory with the rest of the assessment.

8.7.1.5 Quality of the assessment

Parametric uncertainty

Large confidence intervals are associated with the SSB in the years before 1992 (Figure 8.7.1.3.1 and Figure 8.7.1.5.1). 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 2018 is estimated with a precision of +/- 24% (Figure 8.7.1.3.1 and Table 8.7.1.3.1). There is generally also a corresponding large uncertainty on the fishing mortality, especially before 1995. The estimate of $F_{bar4\text{-}8}$ in 2018 has a precision of +/- 27%. The uncertainty on the recruitment is high for the years before 1998 (precision of on average +/- 45%). The precision improves for the years for which the recruitment index is available (+/- 30%) except for the most recent recruitments (+/- 40%).

Model instability

The retrospective analysis was carried out for 3 retro years, by fitting the assessment using the 2019 data, removing successively 1 year of data (Figure 8.7.1.5.2). There is a systematic retrospective pattern found in the SSB (which is revised upwards with each new year of data) and the opposite for F_{bar}. However, given that the RFID series in now composed for only 5 years of recapture data, retrospective instability is to be expected (and retrospective runs removing 4 or more years would be meaningless as only 1 recapture year or none would be available for model fitting).

Recruitment appears to be quite consistently estimated.

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 8.7.1.5.3) 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 8.7.1.5.4). 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 (19911994 and 2004 and 2006). For the years between 2008 and 2016, the biomass cumulated process error remains positive, and large (reaching in 2013 almost the weight of the catches). The reason for this misbehaviour of the model could not be identified. It should be noted, however, that the magnitude and autocorrelation of the biomass cumulated process error since 2016 is lower than in the previous year's assessment.

8.7.2 Exploratory assessments

8.7.2.1 Muppet model

Alternative model runs were done with the Muppet model that is a traditional separable catch at age model without any random effects. The model can use tagging data in the objective function and correlation of residuals in age disaggregated survey indices is modelled. The results are described in the working document from Björnsson (2019) presented to WGWIDE, but summarized shortly here.

The data used for tuning are the same as in the adopted assessment (i.e egg survey, pelagic survey, recruitment index and RFID tagging data).

The model setup before 2000 is based on using the catch in numbers data but estimate a scaling factor (1 number on the catches). This scaling factor is supposed to reflect average misreporting. For comparison the adopted assessment does not use the catch data before 2000 and the assessment is only based on tagging data where the level of misreporting depends on estimated tagging mortality.

The estimated "misreporting parameter" in the Muppet model depends on the selection pattern and is higher when selection is estimated separately for the early period.

Other differences between the Muppet and SAM model are:

- The recruitment model in Muppet is similar as if Beverton and Holt or Ricker were used in SAM (RTC3 type model).
- Constraints in fishing mortality (random walk) not implemented.

Different setup of the Muppet model lead to widely different results (Figure 8.7.2.1.1). The same setup as used in the adopted assessment leads to larger estimated stock compared to the adopted assessment. The preferred setup here is thought to use all the tagging data and implement tagloss. This setup leads to smaller stock compared to using limited subset of the tagging data as done in the adopted assessment. As shown in the IBPNEAMac report (ICES, 2019a) observed and predicted tagging data fit reasonably well with this model setup in Muppet.

Recruitment estimates from the Muppet model are very different from those in the assessment model (Figure 8.7.2.1.2) where large part of the recruitment is generated by subsequent deviations in M.

To summarize, the model does not lead to "one correct result", something that would be expected when tuning the model with as disparate and contradictory data as the data for NEA mackerel.

8.8 Short term forecast

The short-term forecast provides estimates of SSB and catch in 2020 and 2021, given assumption of the current year's (also called intermediate year) catch and a range of management options for the catch in 2020.

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 (2019) 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 (2018) 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 85 % (recruitment index) and 15 % (time tapered geometric mean), which leads to an expected recruitment of 7 259 millions.

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 2020.

Assuming catches for 2019 of 834 954 kt, F was estimated at 0.21 (below F_{MSY}) and SSB at 4.39 Mt (above B_{pa}) in spring 2019. If catches in 2020 equal the catch in 2019, F is expected to increase to 0.21 (above F_{lim}) in 2020 with a corresponding increase in SSB to 4.54 Mt in spring 2020. Assuming an F of 0.21 again in 2021, the SSB will remain at a similar level (4.47 Mt) in spring 2020.

Following the MSY approach, exploitation in 2020 shall be at F_{MSY} (0.23), this is equivalent to catches of 922 kt and an increase in SSB to 4.53 Mt in spring 2020 (3 % increase). During the subsequent year, SSB is predicted decrease with 3 % to 4.39 Mt in spring 2020.

8.9 Biological Reference Points

An Interbenchmark Workshop on the assessment of northeast Atlantic mackerel (IBPNEA-Mac) was conducted during 20182019 (ICES, 2019a) which resulted in the adoption of new reference points for NEA mackerel stock by ICES.

8.9.1 Precautionary reference points

B_{lim} - There is no evidence of significant reduction in recruitment at low SSB within the time series hence the previous basis for B_{lim} was retained. B_{lim} is taken as B_{loss}, the lowest estimate of spawning stock biomass from the revised assessment. This was estimated to have occurred in 2003; B_{loss} = 1 990 000 t.

F_{lim} - F_{lim} is derived from B_{lim} and is determined from the long-term equilibrium simulations as the F that on average would bring the stock to B_{lim}; F_{lim} = 0.46.

B_{pa} - The ICES basis for advice requires that a precautionary safety margin incorporating the uncertainty in actual stock estimates leads to a precautionary reference point B_{pa}, which is a biomass reference point with a high probability of being above B_{lim}. B_{pa} was calculated as $B_{lim} \cdot exp(1.645 \cdot \sigma)$ where $\sigma = 0.14$ (the estimate of uncertainty associated with spawning biomass in the terminal year in the assessment, 2017, as estimated in the 2019 intermediate benchmark assessment); B_{pa} = 2 500 000 t.

F_{pa} -The ICES basis for advice requires that a precautionary safety margin incorporating the uncertainty in actual stock estimates leads to a precautionary reference point F_{pa} .F_{pa} is the estimate of fishing mortality which is designed to ensure that the true F is above F_{lim} with a 95% probability. Its value is calculated based on F_{lim}, whilst taking the assessment uncertainty in F into consideration: F_{lim} * exp(1.645 σ) where σ = 0.14 was the estimated standard deviation of ln(F) in the final assessment year (2017), this leads to F_{pa} = 0.37.

8.9.2 MSY reference points

The ICES MSY framework specifies a target fishing mortality, F_{MSY}, which, over the long term, maximises yield, and also a spawning biomass, MSY $B_{trigger}$, below which target fishing mortality is reduced linearly relative to the SSB $B_{trigger}$ ratio.

Following the ICES guidelines (ICES, 2017a), long term equilibrium simulations indicated that F=0.23 would be an appropriate F_{MSY} target as on average it resulted in the highest mean yields in the long term, with a low probability (less than 5%) of reducing the spawning biomass below B_{lim}.

The ICES basis for advice notes that, in general, F_{MSY} should be lower than F_{pa}, and MSY $B_{trigger}$ should be equal to or higher than B_{pa}. Simulations indicated that potential values for MSY $B_{trigger}$ were below B_{pa}. Following the ICES procedure MSY $B_{trigger}$ was set equal to $B_{pa,}$ 2 500 000 t.

Updated ICES reference points for NEA mackerel			
Type		Value	Technical basis
MSY approach	MSY $B_{trigger}$	2.50 million tonnes	B_{pa} [1]
	F_{MSY}	0.23	Stochastic simulations [1]
Precautionary approach	B_{lim}	1.99 million tonnes	B_{loss} from 2019 interbenchmark assessment (2003) [1]
	B_{pa}	2.50 million tonnes	$B_{lim} \times \exp(1.654 \times \sigma)$, $\sigma_{SSB} = 0.14$ [1]
	F_{lim}	0.46	F that, on average, leads to B_{lim} [1]
	F_{pa}	0.37	$F_{lim} \times \exp(1.654 \times \sigma)$, $\sigma_F = 0.14$ [1]

[1] **20182019 benchmark assessment (ICES, 2019a)**

8.10 Comparison with previous assessment and forecast

The last available assessment used for providing advice was carried out in 2019 during the IBPNEAMac. The new 2019 WGWIDE assessment gives a slightly different perception of the recent development of the stock (Figure 8.10.1). The SSB trajectory since 2014 has been rescaled slightly upwards, while the estimated F_{bar} has been rescaled downwards. The estimated recruitment time series are very similar.

The differences in the 2017 TSB and SSB estimates between the previous and the present assessments are moderate, of 8.3 and 6.9% respectively. The upward revision of the 2017 fishing mortality estimate is larger, of -16%.

	TSB 2017	SSB 2017	Fbar4-8 2017
Values			
2019 IBPNEAMac	5329214	4387307	0.287
2019 WGWIDE	5773203	4692164	0.241
% difference	8.3%	6.9%	-16.0%

The addition of a new year of data has slightly modified the relative weight of the different data sources: the estimated observation standard deviation has increased (although not significantly) both for the IESSNS survey and for the egg survey. This decreasing influence of the 2 surveys on the assessment may be related to the increasing conflict between these two series, the IESSNS indicating record high biomass in 2019 (Figure 8.6.3.2a) while the egg survey index is at its lowest. These changes in the weight of the different data sources can partly explain the revision of stock trajectories. As a result of this change in perception of the stock, small differences are found in the estimated catchabilities for the surveys.

The uncertainty on the parameter estimates has decreased for some parameters (standard deviations of the F random walk for age 0, and the observation variance for the catches age 2-12, Figure 8.10.2), but increased for others (recruitment variance, and catchability of the IESSNS for ages 4-8). The uncertainty on SSB and $F_{bar4\text{-}8}$ in this year's assessment is in general larger than for the inter-benchmark assessment, especially for the period 2005-2015 (Figure 8.10.3).

The prediction of the mackerel catch for 2018 used for the short-term forecast in the advice given after the interbenchmark was very close to the actual 2018 catch reported for WGIWIDE 2019 and used in the present assessment (text table below). The new assessment produced an estimate of the SSB in 2018 which was just 2.2% lower than the 2019 IBPNEAMac forecast prediction (ICES, 2019a). The fishing mortality F_{bar4-8} for 2018 estimated at the WGWIDE 2019 is 14.2% lower than the value estimated by the short term forecast in the previous assessment. Most of this discrepancy is explained by the revision of the perception of F_{bar4-8} described above.

	Catch (2018)	SSB (2018)	F_{bar4-8} (2018)
2019 IBPNEAMac forecast	1 000 559 t	4 186 496 t	0.28
2019 WGWIDE assessment	1 026 424 t	4 279 185 t	0.24
% difference	2.6%	2.2%	-14.3%

8.11 Management Considerations

Details and discussion on quality issues in this year's assessment is given in Section 8.7 above.

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).

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 during the periods 1 January to 15 February and 1 September to 31 December. Up to 2010, 30% of the Western EU TAC of mackerel (MAC/2CX14-) could be taken in 4.a. From 2011 onwards, this percentage has been set at 40%, in 2015 at 60% and at 24% in 2018 and 2019.

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 historical basis for the setting of minimum landing sizes is described in a working document to WGWIDE in 2015 (Pastoors, 2015). 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. 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 North-east Atlantic mackerel and relevant observations are given in the Stock Annex. The discussion here is limited to recent features of relevance.

Production (recruitment and growth)

Mackerel recruitment (age 1) has been higher since 2001 compared to previous decades with several very large cohorts (Jansen, 2016). Increasing stock size was suggested to have an effect through density driven expansion of the spawning area into new areas with Calanus in oceanic areas west of the North European continental shelf (Jansen, 2016). There are several indications of a shift in spawning and mackerel recruitment/larvae and juvenile areas towards northern and north-eastern areas preceding the 2016 mackerel spawning (ICES, 2016; Nøttestad *et al.*, 2018). This northerly shift in spawning and recruitment pattern of NEA mackerel seem to have continued also in 2017 (Nøttestad *et al.*, 2018), but has reversed in 2018 (Figure 8.6.2.2).
The recruitment index indicates high recruitment in 2016, 2017 and 2018. For the two first year classes, this is confirmed by the IESSNS, where the incoming 2017-year class has the largest age-1 index value recorded in IESSNS and is 150% larger than the incoming age-1 cohort in 2017 (ICES, 2018a). In 2019 on the other hand, the incoming 2018-year class was one of the lowest in the entire IESSNS time series (Nøttestad *et al.*, 2019). This may reflect the more south-western distribution of the recruits from the 2018 year class as it was observed in the IBTS-surveys.

During the recent decade, mackerel length- and weight-at-age declined substantially for all ages (Jansen and Burns, 2015; Ólafsdóttir *et al.*, 2015). Growth of 0–3 years old mackerel decreased from 1998 to 2012. Mean length at age 0 decreased by 3.6 cm, however the growth differed substantially among cohorts (Jansen and Burns, 2015). For the 3-8 years old mackerel, the average size was reduced by 3.7 cm and 175 g from 2002 to 2013 (Ólafsdóttir *et al.*, 2015). The variations in growth of mackerel in all ages are correlated with mackerel density. Furthermore, the density dependent regulation of growth from younger juveniles to older adult mackerel, appears to reflect the spatial dynamics observed in the migration patterns during the feeding season (Jansen and Burns, 2015; Ólafsdóttir *et al.*, 2015). Growth rates of the juveniles were tightly correlated with the density of juveniles in the nursery areas (Jansen and Burns, 2015). For adult mackerel (age 3-8) growth rates were correlated with the combined effects of mackerel and herring stock sizes (Ólafsdóttir *et al.*, 2015). Conspecific density-dependence was most likely mediated via intensified competition associated with greater mackerel density.

The growth (mean weights per age group) have slightly increased during the last 34 years for several age groups (ICES, 2018c; ICES, 2019a). However, this does not include the 0-year olds which supports the finding of high abundance at age 0 (Figure 8.5.2.1.).

Spatial mackerel distribution and timing

In the mid-2000s, summer feeding distribution of Northeast Atlantic mackerel (*Scomber scombrus*) in Nordic Seas began expanding into new areas (Nøttestad *et al*., 2016). During 2007 - 2016 period mackerel distribution range increased three-fold and the centre-of-gravity shifted westward by 1650 km and northward by 400 km. Distribution range peaked in 2014 and was positively correlated to Spawning Stock Biomass (SSB).

After a mackerel stock expansion during the feeding season in summer from 1.3 million km^2 in 2007 to at least 2.9 million km^2 in 2014, mainly towards western and northern regions of the Nordic seas (Nøttestad *et al*., 2016), a slight decrease in distribution area of mackerel in the Nordic Seas was observed in 2017 and 2018 with 2.8 million square kilometres (Nøttestad *et al*., 2017; ICES, 2018a). The mackerel distribution slightly increased to 2.9 million km^2 in 2019 (Nøttestad *et al*., 2019). The mackerel was more patchily distributed within the survey area in 2019 and 2017 than in 2018. Mackerel had a more eastern distribution in 2019 and 2018 than in 20142017 (ICES, 2018a; Nøttestad *et al*., 2019). This difference in distribution primarily consists of a marked biomass decline in the west, and particularly in Greenland waters but also in Icelandic waters. Geographical distribution of the 2016 cohort at age 0 and 1 extended more to the north than normally, including latitude 6071°N along the coast and offshore areas of Norway based on various survey data and fishing data (Nøttestad *et a*l., 2018).

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. 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.
In the 2019 IESSNS a marked change in the spatial distribution of mackerel was observed with lower densities of mackerel in the western distribution areas (East Greenland and Iceland) as compared to 2017 (see Figures 8.6.3.6a and b). It is not clear what causes this distributional shift, but the SST were 1-2°C higher in the western and south-western areas as compared to a 20 years mean (19992009), and substantially lower zooplankton concentrations in Icelandic and Greenland waters in 2019 than 2018, might partly explain such changes (ICES, 2018a, Nøttestad *et al*., 2019).

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 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*., 2018). The spatio-temporal overlap between mackerel and herring was highest in the southern and south-western part of the Norwegian Sea in 2018 and 2019 (ICES, 2018a, Nøttestad *et al*., 2019). This is similar as seen in previous years (Nøttestad *et al*., 2016; 2017). A change was seen in the northern Norwegian Sea in 2019 where we had some overlap between mackerel and herring (mainly 2013- and 2016- year classes) (Nøttestad *et al*., 2019). There was, on the other hand, practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea in 2018 and previous years, mainly because of very limited amounts of herring in this area (ICES, 2018a).

There seem to be rather limited spatial overlap between marine mammals and mackerel during summers in the Nordic Seas (Nøttestad *et al*., 2019; Løviknes, 2019). There is spatial overlap between killer whales and mackerel in the Norwegian Sea, and killer whales are actively hunting for mackerel schools close to the surface during summer (Nøttestad *et al*., 2014). 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 (Nøttestad *et al*., 2017b; Boge, 2019). Additionally, the new situation of numerous 0- and 1-group mackerel in Norwegian coastal waters in 2018 (Bjørdal, 2019), have created favourable feeding possibilities for larger cod, saithe, marine mammals and seabirds in these waters. Repeated stomach samples from several species document that smaller sized mackerel is now eaten by different predators in northern waters (60-70°N) (Bjørdal, 2019). Although much fewer 1-groups of NEA mackerel was found along the coast in Norway during the IESSNS 2019 (Nøttestad *et al*., 2019), the Atlantic bluefin tuna are still indeed targeting schools of 1-group mackerel during their intense feeding migration in Norwegian waters.

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8.14 Tables

Table 8.2.1. 2018 Mackerel fleet composition of major mackerel catching nations.

Country	Len (m)	Engine power (hp)	Gear	Storage	No vessels
Denmark	57-88	407710469	Trawl	Tank	8
Faroe Islands	64-75	34605920 kw	Purse Seine/Trawl	RSW	2
	76-84	39208000 kw	Purse Seine/Trawl	RSW	4
	84	6005kw	Trawl	Freezer	1
	55-79	36007680 kw	Trawl/Pair trawl	RSW	5
	36-49	10291800 kw	Trawl	Clondyking	2
France		110529	Pair Trawl		56
		442400	Trawl		654
		6525	Nets		447
		7294	Lines		257
		22662	Other gears		245
Germany	90-140	380012000	Single Midwater Trawl	Freezer	4
Greenland	65 - 84	3 0029 517	Trawl	RSW, Freezer	14
	85 - 121	6 6899 517	Trawl	RSW, Freezer	9
Iceland	51-60	25024079	Single Midwater Trawl	RSW, Freezer	6
	61-70	20007507	Single Midwater Trawl	RSW, Freezer	17
	71-80	3200-11257	Single Midwater Trawl	RSW, Freezer	12
	>80	8051	Single Midwater Trawl	Freezer	1
Ireland	27m-65m	522-2720	Pair Midwater Trawl	RSW	14
	14m-45m	160-1119	Pair Midwater Trawl	Dryhold	23
	51m-71m	1007-3840	Midwater Trawl	RSW	7
Netherlands	55	2125	Pair Midwater Trawl	Freezer	1
	88-145	4400-10455	Single Midwater Trawl	Freezer	9
Norway	60-85 m		Purse seiner	RSW	78
	30-40 m		Purse seiner	Dryhold, RSW	16
	10-17 m		Purse seiner	Dryhold	178
	10-17 m		Hook and line/nets	Dryhold	169

Country	Len (m)	Engine power (hp)	Gear	Storage	No vessels
	10-17 m		PS/hooks/nets	Dryhold	200
	30-40 m		Trawl	Dryhold.Tankhold	17
Portugal	0-10		Other		94
	10-20		OTB		3
	10-20		Other		86
	20-30		OTB		27
	20-30		Other		16
	30-40		Trawl		7
Spain	12-18	80-294	Trawl	Dryhold	12
	18-24	96-344	Trawl	Dryhold	24
	24-40	191-876	Trawl	Dryhold	78
	40-	353	Trawl	Dryhold	2
	0-10	34-44	Purse Seine	Dryhold	1
	10-12	20-106	Purse Seine	Dryhold	11
	12-18	21-245	Purse Seine	Dryhold	97
	18-24	70-397	Purse Seine	Dryhold	100
	24-40	140-809	Purse Seine	Dryhold	94
	0-10	3-74	Artisanal	Dryhold	306
	10-12	12-118	Artisanal	Dryhold	207
	12-18	18-239	Artisanal	Dryhold	206
	18-24	59-368	Artisanal	Dryhold	42
	24-40	129-368	Artisanal	Dryhold	12

1 RSW = refrigerated seawater.

Table 8.2.4.1. Overview of major existing regulations on mackerel catches.

Technical measure	National/International level	Specification	Note
Catch limitation	Coastal States/NEAFC	2010-2018	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 2017 (EU, NO, FO agreement London 11. Oct. 2017)	European (EU, NO, FO)	If SSB >= 2.570.000t, F = 0.21 If SSB is less than 2.570.000t, F = 0.21 * SSB/2.570.000 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 years quota.	Not agreed by all parties
Minimum size (North Sea)	European (EU, NO, FO)	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, FO)	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 200m 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. Since 2016 is also partly in place for demersal fisheries.	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		
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

Table 8.4.1.1. NE Atlantic Mackerel. ICES estimated catches by area (t). Discards not estimated prior to 1978 (data submitted by Working Group members). Continued.

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
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

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		
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
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

Table 8.4.1.1. NE Atlantic Mackerel. ICES estimated catches by area (t). Discards not estimated prior to 1978 (data submitted by Working Group members). Continued.

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
2006	88077	6081	94158	66209	8642	74851	200929	8263	209192	46716		46716	52751	3607	56358	454587	26594	481181
2007	110788	2450	113238	71235	7727	78962	253013	4195	257208	72891		72891	62834	1072	63906	570762	15444	586206
2008	76358	21889	98247	73954	5462	79416	227252	8862	236113	148669	112	148781	59859	750	60609	586090	37075	623165
2009	135468	3927	139395	88287	2921	91208	226928	8120	235049	163604		163604	107747	966	108713	722035	15934	737969
2010	106732	2904	109636	104128	4614	108741	246818	883	247700	355725	5	355729	49068	4640	53708	862470	13045	875515
2011	160756	1836	162592	51098	5317	56415	301746	1906	303652	398132	28	398160	24036	1807	25843	935767	10894	946661
2012	121115	952	122067	65728	9701	75429	218400	1089	219489	449325	1	449326	24941	3431	28372	879510	15174	894684
2013	132062	273	132335	49871	1652	51523	260921	337	261258	465714	15	465729	19733	2455	22188	928433	4732	933165
2014	180068	340	180408	93709	1402	95111	383887	334	384221	684082	91	684173	46257	4284	50541	1388003	6451	1394454
2015	134728	30	134757	98563	3155	101718	295877	34	295911	632493	78	632571	36899	7133	44033	1198560	10431	1208990
2016	206326	200	206526	37300	1927	39227	248041	570	248611	563440	54	563494	32987	3220	36207	1088094	5971	1094066
2017	225959	151	226110	21128	1992	23119	269404	400	269804	603806	62	603869	32815	227	33042	1153112	2832	1155944
2018	157239	90	157329	35240	1611	36851	341527	620	342147	455689	51	455740	33851	518	34369	1023547	2890	1026437

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Subareas 1, 2, 5 and 14, 1984 – 2018 (Data submitted by Working Group members).

Country	1984	1985	1986	1987	1988	1989	1990	1991	1992
Denmark	11787	7610	1653	3133	4265	6433	6800	1098	251
Estonia									216
Faroe Islands	137				22	1247	3100	5793	3347
France		16				11		23	6
Germany Fed. Rep.			99		380				
Germany Dem. Rep.			16	292		2409			
Iceland									
Ireland									
Latvia									100
Lithuania									
Netherlands									
Norway	82005	61065	85400	25000	86400	68300	77200	76760	91900
Poland									
Sweden									
United Kingdom			2131	157	1413		400	514	802
USSR/Russia	4293	9405	11813	18604	27924	12088	28900	13361	42440
Misreported (Area 4.a)									
Misreported (Area 6.a)									
Misreported (Un-known)									
Unallocated									
Discards									
Total	98222	78096	101112	47186	120404	90488	118700	97819	139062

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Areas 1, 2, 5 and 14, 1984 – 2018. Continued.

Country	1993	1994	1995	1996	1997	1998	1999	2000
Denmark			4746	3198	37	2090	106	1375
Estonia		3302	1925	3741	4422	7356	3595	2673
Faroe Islands	1167	6258	9032	2965	5777	2716	3011	5546
France	6	5	5		270			
Germany								
Greenland				1				
Iceland				92	925	357		
Ireland							100	
Latvia	4700	1508	389	233				
Lithuania								2085
Netherlands				561			661	
Norway	100500	141114	93315	47992	41000	54477	53821	31778
Poland					22			
Sweden								
United Kingdom		1706	194	48	938	199	662	
Russia	49600	28041	44537	44545	50207	67201	51003	491001
Misreported (Area 4.a)		-109625	-18647			-177	-40011	
Misreported (Area 6.a)							-100	
Misreported (Unknown)								
Unallocated								
Discards								
Total	165973	72309	135496	103376	103598	134219	72848	92557

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Areas 1, 2, 5, and 14, 1984 – 2018. Continued.

Country	2001	2002	2003	2004	2005	2006	2007	2008
Denmark	7	1						
Estonia	219							
Faroe Islands	3272	4730		650	30		278	123
France				2	1			
Germany							7	
Greenland								
Iceland		53	122		363	4222	36706	112286
Ireland			495	471				
Latvia								
Lithuania								
Netherlands		569	44	34	2393		10	72
Norway	21971	22670	125481	10295	13244	8914	493	3474
Poland								
Sweden	8							
United Kingdom	54	665	692	2493				4
Russia	41566	45811	40026	49489	40491	33580	35408	32728
Misreported (Area 4.a)								
Misreported (Area 6.a)								
Misreported (Unknown)		-570		-553				
Unallocated			-44	32	-2393		-10	-18
Discards				9				112
Total	67097	73929	53883	62922	54129	46716	72891	148781

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Areas 1, 2, 5, and 14, 1984–2018. Continued.

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Denmark		4845	269		391	2345	4321	1	2	289
Estonia					13671		0			
Faroe Islands	2992	66312	121499	107198	142976	103896	76889	61901	66194	52061
France			2		197	8	36			733
Germany				107	74		2963	3499	4064	577
Greenland			621	74021	541481	875811	30351	36142	46388	62973
Iceland	116160	121008	159263	149282	151103	172960	169333	170374	167366	168330
Ireland			90			1725	6	2		
Latvia										
Lithuania						1082		1931		
Netherlands		90	178	5	1	5887	6996	8599	7671	2697
Norway	3038	104858	43168	110741	33817	192322	204574	153228	167739	46853
Poland										2
Sweden				4	825	3310	740	730	1720	910
United Kingdom					2	5534	7851	5240	4601	2009
Russia	414141	58613	73601	74587	80812	116433	128433	121614	138061	118255
Misreported (Area 4.a)										
Misreported (Area 6.a)										
Misreported (Unknown)										
Unallocated										
Discards		5	28	1	151	911	78	54	62	51
Total	163604	355729	398160	449326	465729	684173	632571	563315	603869	455740

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Subarea 4 and Division 3.a), 1988-2018 (Data submitted by Working Group members).

Country	1988	1989	1990	1991	1992	1993	1994	1995
Belgium	20	37		125	102	191	351	106
Denmark	32588	26831	29000	38834	41719	42502	47852	30891
Estonia					400			
Faroe Islands		2685	5900	5338		11408	11027	17883
France	1806	2200	1600	2362	956	1480	1570	1599
Germany Fed. Rep.	177	6312	3500	4173	4610	4940	1497	712
Iceland								
Ireland		8880	12800	13000	13136	13206	9032	5607
Latvia					211			
Lithuania								
Netherlands	2564	7343	13700	4591	6547	7770	3637	1275
Norway	59750	81400	74500	102350	115700	112700	114428	108890
Poland								
Romania							2903	
Sweden	1003	6601	6400	4227	5100	5934	7099	6285
United Kingdom	1002	38660	30800	36917	35137	41010	27479	21609
USSR (Russia from 1990)								
Misreported (Area 2.a)							109625	18647
Misreported (Area 6.a)	180000	92000	126000	130000	127000	146697	134765	106987
Misreported (Unknown)								
Unallocated	29630	6461	-3400	16758	13566			983
Discards	29776	2190	4300	7200	2980	2720	1150	730
Total	338316	281600	305100	365875	367164	390558	472397	322204

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Sub-area 4 and Division 3.a), 1988-2018. Continued.

Country	1996	1997	1998	1999	2000	2001	2002
Belgium	62	114	125	177	146	97	22
Denmark	24057	21934	25326	29353	27720	21680	343751
Estonia							
Faroe Islands	13886	32882	4832	4370	10614	18751	12548
France	1316	1532	1908	2056	1588	1981	2152
Germany	542	213	423	473	78	4514	3902
Iceland				357			
Ireland	5280	280	145	11293	9956	10284	20715
Latvia							
Lithuania							
Netherlands	1996	951	1373	2819	2262	2441	11044
Norway	88444	96300	103700	106917	142320	158401	161621
Poland							
Romania							
Sweden	5307	4714	5146	5233	49941	5090	52321
United Kingdom	18545	19204	19755	32396	58282	52988	61781
Russia		3525	635	345	1672	1	
Misreported (Area 2.a)				40000			
Misreported (Area 6.a)	51781	73523	98432	59882	8591	39024	49918
Misreported (Unknown)							
Unallocated	236	1102	3147	17344	34761	24873	22985
Discards	1387	2807	4753		1912	24	8583
Total	212839	229487	269700	313015	304896	339970	394878

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Subarea 4 and Division 3.a), 1988-2018. Continued.

Country	2003	2004	2005	2006	2007	2008	2009
Belgium	2	4	1	3	1	2	3
Denmark	275081	25665	232121	242191	252171	26716	23491
Estonia							
Faroe Islands	11754	11705	9739	12008	11818	7627	6648
France	1467	1538	1004	285	7549	490	1493
Germany	4859	4515	4442	2389	5383	4668	5158
Iceland							
Ireland	17145	18901	15605	4125	13337	11628	12901
Latvia							
Lithuania							
Netherlands	6784	6366	3915	4093	5973	1980	2039
Norway	150858	147068	106434	113079	131191	114102	118070
Poland			109				
Romania							
Sweden	4450	4437	3204	3209	38581	36641	73031
United Kingdom	67083	62932	37118	28628	46264	37055	47863
Russia			4				
Misreported (Area 2.a)							
Misreported (Area 6.a)	62928	23692	37911	8719		17280	1959
Misreported (Unknown)							
Unallocated	-730	-783	7043	171	2421	2039	-629
Discards	11785	11329	4633	8263	4195	8862	8120
Total	365894	317369	254374	209192	257208	236111	235049

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), 19882018. Continued.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018
Belgium	27	21	39	62	56	38	99	107	110
Denmark	36552	32800	36492	31924	21340	35809	21696	27457	22207
Estonia									
Faroe Islands	4639	543	432	25	42919	25672	18193	12915	15475
France	686	1416	5736	1788	4912	7827	3448	5942	6714
Germany	25621	52911	4560	5755	4979	6056	10172	11185	12091
Iceland									
Ireland	14639	15810	20422	13523	45167	34167	24437	35957	24567
Latvia									
Lithuania					8340		596		
Netherlands	1300	9881	6018	4863	24536	17547	11434	17401	13844
Norway	129064	162878	64181	130056	85409	36344	55089	51960	135715
Poland						24		0.721	4041
Romania									
Sweden	34291	32481	4560	2081	1112	3190	2933	1981	3056
United Kingdom	52563	69858	75959	70840	145119	129203	99945	104499	103707
Russia	696			4					
Misreported (Area 2.a)									
Misreported (Area 6.a)									
Misreported (Unknown)									
Unallocated	660								
Discards	883	1906	1089	337	334	34	559	400	620
Total	247700	303652	219489	261258	384221	295911	248611	269804	342147

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Sub-areas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2018 (Data submitted by Working Group members).

Country	1985	1986	1987	1988	1989	1990	1991	1992
Belgium								
Denmark	400	300	100		1000		1573	194
Estonia								
Faroe Islands	9900	1400	7100	2600	1100	1000		
France	7400	11200	11100	8900	12700	17400	4095	
Germany	11800	7700	13300	15900	16200	18100	10364	9109
Guernsey								
Ireland	91400	74500	89500	85800	61100	61500	17138	21952
Isle of Man								
Jersey								
Lithuania								
Netherlands	37000	58900	31700	26100	24000	24500	64827	76313
Norway	24300	21000	21600	17300	700		29156	32365
Poland								
Spain				1500	1400	400	4020	2764
United Kingdom	205900	156300	200700	208400	149100	162700	162588	196890
Misreported (Area 4.a)		-148000	-117000	-180000	-92000	-126000	-130000	-127000
Misreported (Unknown)								
Unallocated	75100	49299	26000	4700	18900	11500	-3802	1472
Discards	4500			5800	4900	11300	23550	22020
Total	467700	232599	284100	197000	199100	182400	183509	236079

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Sub-areas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2018 (Data submitted by Working Group members).

Country	1993	1994	1995	1996	1997	1998	1999	2000
Belgium								
Denmark		2239	1143	1271			552	82
Estonia			361					
Faroe Islands		4283	4284		24481	3681	4239	4863
France	2350	9998	10178	14347	19114	15927	14311	17857
Germany	8296	25011	23703	15685	15161	20989	19476	22901
Guernsey								
Ireland	23776	79996	72927	49033	52849	66505	48282	61277
Isle of Man								
Jersey								
Lithuania								
Netherlands	81773	40698	34514	34203	22749	28790	25141	30123
Norway	44600	2552			223			
Poland	600							
Spain	3162	4126	4509	2271	7842	3340	4120	4500
United Kingdom	215265	208656	190344	127612	128836	165994	127094	126620
Misreported (Area 4.a)	-146697	-134765	-106987	-51781	-73523	-98255	-59982	-3775
Misreported (Unknown)								
Unallocated		4632	28245	10603	4577	8351	21652	31564
Discards	15660	4220	6991	10028	16057	3277		1920
Total	248785	251646	270212	213272	196110	218599	204885	297932

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Sub-areas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2018 Continued.

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009
Belgium				1					1
Denmark	835		113				6	10	
Estonia									
Faroe Islands	2161	2490	2260	674		59	1333	3539	4421
France	18975	19726	21213	18549	15182	14625	12434	14944	16464
Germany	20793	22630	19200	18730	14598	14219	12831	10834	17545
Guernsey						10			
Ireland	60168	51457	49715	41730	30082	36539	35923	33132	48155
Isle of Man									
Jersey					9	8	6	7	8
Lithuania						95	7		
Netherlands	33654	21831	23640	21132	18819	20064	18261	17920	20900
Norway							7	3948	121
Poland					461	1368	978		
Russia									
Spain	4063	3483			4795	4048	2772	7327	8462
United Kingdom	139589	131599	167246	149346	115586	67187	87424	768821	109147
Misreported (Area 4.a)	-39024	-43339	-62928	-23139	-37911	-8719		-17280	-1959
Misreported (Unknown)									
Unallocated	37952	27558	5587	9714	13412	4783	10042	-952	490
Discards	1164	15191	7111	7696	20359	14723	10177	27351	6848
Total	280553	252620	233157	244432	190597	169009	192201	177662	230603

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Sub-areas 6 and 7 and Divisions 8.a,b,d,e), 1985 – 2018. Continued.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018
Belgium	2					14	44	21	58
Denmark	48	2889	8	903	18538	6741	19443	12569	8194
Estonia									
Faroe Islands	36	8			3421	5851	13173	20559	13543
France	10301	11304	14448	12438	16627	17820	16634	16925	13974
Germany	16493	18792	14277	15102	23478	19238	9740	9608	7214
Guernsey		10	5	9	9	4			12
Ireland	43355	45696	42627	42988	56286	54571	52087	48957	42181
Isle of Man	14	11	11	8	3		8	2	3
Jersey	6	7	8	8	7	3	3	0.003	3
Lithuania		23			176	554	13		
Netherlands	21699	18336	19794	16295	16242	15264	17896	18694	13851
Norway	30	2019	1101	734		1313	1035	2657	4639
Poland									14
Russia	1						30		
Spain	6532	1257	773	635	1796	951	1253	786	4471
United Kingdom	107840	111103	93775	92957	137195	110932	112268	116308	84309
Misreported (Area 4.a)									
Misreported (Unknown)									
Unallocated	4503	399	16	-144		34			13
Discards	7518	7153	10654	2105	1742	3185	2126	2142	1701
Total	218377	219007	197496	183857	275519	236475	245754	249229	194180

Table 8.4.2.4. NE Atlantic Mackerel. ICES estimated catch (t) in Divisions 8.c and 9.a, 1977–2018 (Data submitted by Working Group members).

Country	Div	1977	1978	1979	1980	1981	1982	1983	1984	1985
France	8.c									
Poland	9.a	8								
Portugal	9.a	1743	1555	1071	1929	3108	3018	2239	2250	4178
Spain	8.c	19852	18543	15013	11316	12834	15621	10390	13852	11810
Spain	9.a	2935	6221	6280	2719	2111	2437	2224	4206	2123
USSR	9.a	2879	189	111						
Total	9.a	7565	7965	7462	4648	5219	5455	4463	6456	6301
Total		27417	26508	22475	15964	18053	21076	14853	20308	18111

Country	Div	1986	1987	1988	1989	1990	1991	1992	1993	1994
France	8.c									
Poland	9.a									
Portugal	9.a	6419	5714	4388	3112	3819	2789	3576	2015	2158
Spain	8.c	16533	15982	16844	13446	16086	16940	12043	16675	21246
Spain	9.a	1837	491	3540	1763	1406	1051	2427	1027	1741
USSR	9.a									
Total	9.a	8256	6205	7928	4875	5225	3840	6003	3042	3899
Total		24789	22187	24772	18321	21311	20780	18046	19719	25045

Country	Div	1995	1996	1997	1998	1999	2000	2001	2002	2003
France	8.c									226
Poland	9.a									
Portugal	9.a	2893	3023	2080	2897	2002	2253	3119	2934	2749
Spain	8.c	23631	28386	35015	36174	37631	30061	38205	38703	17384
Spain	9.a	1025	2714	3613	5093	4164	3760	1874	7938	5464
Discards	8.c									531
Discards	9.a	3918	5737	5693	7990	6165	6013			
Total	9.a	27549	34123	40708	44164	43796	36074	4993	10873	8213
Total								43198	49575	26354

Table 8.4.2.4. NE Atlantic Mackerel. ICES estimated catch (t) in Divisions 8.c and 9.a, 1977–2018 (Data submitted by Working Group members). Continued.

Country	Div	2004	2005	2006	2007	2008	2009	2010	2011	2012
France	8.c	177	151	43	55	168	383	392	44	283
Poland	9.a									
Portugal	9.a	2289	1509	2620	2605	2381	1753	2363	962	824
Spain	8.c			43063	53401	50455	91043	38858	14709	17768
Spain	9.a			7025	6773	6855	14569	7347	2759	845
Discards	8.c	928	391	3606	156	73	725	4408	563	2187
Discards	9.a		405	1	916	677	241	232	1245	1244
Unallocated	8.c	28429	42851						4691	4144
Unallocated	9.a	3946	5107					108	871	1076
Total	9.a	6234	7021	9646	10293	9913	16562	10049	5836	3989
Total		35768	50414	56358	63906	60609	108713	53708	25843	28372

Country	Div	2013	2014	2015	2016	2017	2018
France	8.c	220	171	21	106	83	50
Portugal	8.c						3709
Portugal	9.a	254	618	1456	619	634	855
Spain	8.c	14617	33783	29726	26553	30893	27250
Spain	9.a	1162	2227	3853	2229	1206	1687
Discards	8.c	1428	2821	4724	2469	84	324
Discards	9.a	1027	1463	2409	751	143	194
Unallocated	8.c	-573	8795	11	1357		300
Unallocated	9.a	4053	662	1831	2123		
Total	9.a	6497	4308	9550	5722	1983	2736
Total		22188	45570	44033	36207	33042	34369

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2018. Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0	0	0	0	0	1267.7	0	3.07	0
1	4386.0	10.9	1.4	2.5	3.2	10822.8	364.2	96.7	0.0
2	43760.5	121.7	5.7	9.9	9.6	129923.4	3729.0	1055.1	1032.6
3	44149.5	43.8	4.9	8.3	3.1	53002.8	1700.4	450.3	3861.1
4	107902.8	235.6	7.3	12.3	3.9	136104.0	1990.2	578.9	18635.2
5	79566.3	108.9	3.9	6.3	2.6	79734.7	490.4	142.9	18278.4
6	73573.6	163.8	4.2	7.2	1.7	87574.7	221.6	113.0	24607.9
7	113671.1	208.9	2.3	3.9	0.6	142174.1	204.2	129.9	29419.7
8	96157.4	200.0	1.4	2.3	0.2	89309.3	67.9	91.8	24110.9
9	62313.7	108.1	1.2	2.1	0.2	45940.9	40.6	52.9	13139.8
10	54456.9	81.2	0.8	1.2	0.1	37487.6	34.6	36.8	8057.2
11	25324.4	61.2	0.8	1.2	0.1	25135.7	26.6	15.2	5255.1
12	13830.9	27.3	0.1	0.1	0.0	12045.6	8.4	9.8	1878.3
13	3966.2	8.3	0.0	0.0	0.0	3546.8	3.2	0.5	446.0
14	1953.6	10.9	0.1	0.1	0.0	2081.0	4.2	0.6	0.0
15+	569.1	5.2	0.0	0.0	0.0	1317.1	2.3	0.0	0.0
Catch	316662	552	12	20	8	338056	2660	838	65103
SOP	316681	551	12	20	8	338092	2664	839	65103
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0	0	0	1.29	120.3	682.6	48.3	0
1	0.5	108.8	0.1	6.0	0.3	18.7	2457.4	942.3	818.2
2	9809.0	19829.2	8.8	10.8	1949.3	29.2	3509.7	1273.7	808.8
3	625.2	20276.8	14.8	6.3	930.1	10.3	1515.6	327.1	124.0
4	4512.6	72579.1	35.5	9.5	5401.6	19.0	1751.2	460.6	140.0
5	1509.7	50059.3	38.5	9.6	2821.1	13.3	1744.0	293.3	42.2
6	1765.8	64007.3	38.5	6.5	3387.6	18.2	1613.5	295.2	16.3
7	3425.9	80083.2	0.9	4.4	4699.5	23.2	1329.9	180.6	0.1
8	3885.5	55339.0	1.0	2.2	5405.1	17.6	587.3	90.3	0.0
9	1477.1	37197.7	0.4	3.6	1686.5	12.5	996.5	182.0	0.1
10	2374.7	17448.5	0.6	1.8	1976.5	5.1	361.3	60.4	0.0
11	800.3	11976.9	0.2	0.1	909.1	3.7	216.9	94.8	0
12	846.3	6797.4	0.2	0.0	267.2	1.1	76.3	33.4	0
13	197.5	1005.9	0.1	0.0	58.3	0.3	34.1	14.9	0
14	0.1	318.1	0.0	0.0	3.5	0.2	34.1	14.9	0
15+	196.1	43.8	0.1	0.0	49.2	0.0	0.0	0.0	0
Catch	11034	157275	54	20	10130	51	5406	1131	365
SOP	11033	157285	54	20	10132	51	5442	1131	365
SOP%	100%	100%	100%	100%	100%	100%	99%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2018 (cont.). Q 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0.0	3.9	153.6	5.2	2235.0	1442.2	305.9	584.1
1	192.0	11.9	378.4	0.6	5808.4	1263.5	14909.6	1950.4
2	280.8	182.7	522.3	1.1	3500.8	2146.2	8791.3	311.0
3	47.7	77.0	536.2	0.5	1188.0	813.4	4179.3	539.1
4	75.1	175.8	3885.9	1.1	3177.7	2396.1	8518.4	2983.2
5	53.6	80.0	2208.3	0.9	1320.2	1215.6	4676.6	2293.9
6	34.8	57.6	4070.3	1.3	2145.6	1987.0	7338.3	3713.4
7	12.4	53.2	3149.6	1.7	2665.6	2512.9	9654.1	4940.7
8	7.0	22.3	2073.4	1.3	2026.5	1934.0	7592.3	3825.9
9	11.1	42.8	3080.7	0.9	1587.5	1465.2	7074.5	3092.3
10	5.4	12.4	1009.5	0.4	764.4	701.9	3709.7	1467.7
11	0.3	33.4	1992.7	0.3	503.7	462.3	2679.1	957.7
12	0.1	11.7	701.3	0.1	165.9	151.6	942.6	321.4
13	0.0	5.2	296.1	0.0	30.9	29.9	243.6	70.9
14	0.0	5.1	289.1	0.0	6.4	6.0	37.1	13.1
15+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Catch	159	209	8283	3	5966	5015	22884	8749
SOP	159	210	8287	3	5961	5009	22865	8748
SOP%	100%	99%	100%	100%	100%	100%	100%	100%

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	25.2	0.1	2574.3	0.0	0.0	9452.8
1	31.5	878.7	642.1	0.0	0.0	46106.9
2	20.4	1016.3	4774.9	0.8	473.5	238898.0
3	9.8	368.6	1006.1	3.0	1752.4	137575.2
4	38.3	255.5	714.8	9.6	5628.9	378239.8
5	27.2	124.5	140.3	18.2	10664.5	257688.9
6	45.6	99.7	197.5	31.3	18398.1	295536.9
7	61.4	48.1	448.2	45.6	26766.8	425922.4
8	49.2	57.9	210.5	41.8	24560.1	317671.2
9	41.5	65.5	108.0	32.0	18769.2	198527.0
10	20.3	17.9	87.9	18.0	10580.8	140781.4
11	13.7	23.1	35.5	11.1	6527.6	83062.8
12	4.6	0.0	24.0	5.8	3407.9	41559.6
13	0.8	0.0	4.3	3.6	2099.6	12066.8
14	0.2	0.0	0.0	0.0	0.0	4778.2
15+	0.0	0.0	0.0	0.0	0.0	2182.7
Catch	113	855	1881	107	62834	1026437
SOP	113	855	1880	107	62835	1026482
SOP%	100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2018 (cont.). Q1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	0.060					0.150	0.000	0.030	
2	0.770	1.850			0.020	13.810	0.050	1.030	
3	0.110	0.430	0.030	0.010	0.020	6.080	0.360	0.320	
4	1.830	7.700	0.070	0.030	0.060	53.520	0.840	2.250	
5	0.640	2.920	0.080	0.030	0.040	25.190	0.930	0.980	
6	0.780	5.780	0.080	0.030	0.050	41.880	0.930	1.710	
7	2.040	6.890			0.040	46.990	0.010	2.400	
8	1.780	7.420			0.040	46.790	0.010	2.310	
9	0.840	4.650			0.020	30.160	0.010	1.210	
10	0.770	2.630			0.010	16.510	0.010	0.890	
11	0.510	1.700			0.010	11.180	0.010	0.270	
12	0.230	0.480				3.420	0.010	0.290	
13	0.110	0.090				0.650	0.000	0.010	
14	0.050	0.040				0.290	0.000	0.020	
15+	0.030	0.000				0.040	0.000	0.000	
Catch	4.687	15.422	0.109	0.038	0.116	108.285	1.283	5.067	
SOP	4.683	15.302	0.105	0.041	0.114	107.636	1.280	5.068	
SOP%	100%	101%	103%	94%	102%	101%	100%	100%	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0							97.1		
1		106.9	0.1	1.0	0.0	7.7	349.6	206.3	143.1
2		19700.5	5.3	1.2	423.0	15.2	499.2	352.4	145.4
3		20230.2	0.3	0.2	307.6	3.9	233.4	101.1	19.2
4		71798.3	0.9	0.2	4199.4	9.6	447.4	216.1	17.8
5		49646.2	0.1	0.1	2340.5	3.4	309.0	104.4	5.9
6		63295.3	0.03	0.02	3326.3	2.7	448.2	153.6	0.9
7		79380.2			4463.7	2.8	262.4	79.9	
8		54826.6			5310.4	2.0	133.3	46.5	
9		36832.0			1654.5	1.6	272.3	109.7	
10		17171.0			1941.1	0.8	68.0	29.8	
11		11774.0			893.8	1.2	215.0	94.8	
12		6646.3			262.7	0.5	75.7	33.4	
13		939.9			57.4	0.2	33.8	14.9	
14		316.3			3.5	0.2	33.8	14.9	
15+		33.6			48.3	0.0	0.0	0.0	
Catch		155792	1	0.49	9109	12	1139	433	56
SOP		155800	1	0.49	9111	12	1175	434	56
SOP%		100%	100%	100%	100%	100%	97%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2018 (cont.). Q1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					677.1	244.6	0.0	0.0
1		10.3	228.2	0.0	1780.8	687.8	13158.0	1445.5
2	0.01	181.0	309.1	0.3	1422.0	1564.7	8192.3	279.6
3	0.02	75.8	474.1	0.1	484.3	564.7	3412.8	440.6
4	0.2	171.6	3703.0	0.3	1271.4	1570.7	5492.0	2404.2
5	0.1	74.7	2026.6	0.1	505.4	716.8	2249.4	1825.7
6	0.1	50.7	3853.9	0.1	812.9	1156.0	3415.1	2945.5
7	0.2	44.8	2959.9	0.1	988.7	1418.9	4562.1	3907.6
8	0.1	16.2	1946.2	0.0	739.7	1072.1	3530.2	3021.2
9	0.1	37.8	2935.1	0.1	532.5	727.9	3425.3	2397.3
10	0.04	10.3	951.1	0.0	251.8	336.4	1785.0	1120.2
11	0.02	32.6	1949.0	0.1	162.0	214.8	1345.2	727.7
12	0.01	11.5	687.0	0.02	52.1	67.7	470.2	241.5
13		5.1	290.5	0.01	11.0	16.0	153.1	54.8
14		5.1	284.3	0.01	1.9	2.5	18.0	9.9
15+						0.0	0.0	0.0
Catch	0	195	7793	0	2204	2877	13146	6859
SOP	0	196	7796	0	2205	2878	13126	6859
SOP%	100%	99%	100%	99%	100%	100%	100%	100%

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	5.9					1024.7
1	24.4	164.2	279.9			18594.2
2	12.5	175.3	2329.1			35625.4
3	4.5	182.0	22.6			26564.8
4	15.5	96.9	57.7			91539.7
5	8.3	33.7	10.5			59891.7
6	13.5	20.7	21.3			79568.1
7	17.6	25.4	30.9			98203.5
8	13.5	12.9	7.8			70736.9
9	11.2	24.9	3.5			49002.5
10	5.4	8.2	0.9			23700.9
11	3.6	13.6	0.9			17441.9
12	1.3	0.0	0.3			8554.4
13	0.3	0.0	0.0			1577.9
14	0.1	0.0	0.0			690.7
15+	0.0	0.0	0.0			82.0
Catch	36	259	361			200408
SOP	36	259	360			200425
SOP%	100%	100%	100%			100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2018 (cont.). Q2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	160.2	2.1	0.0	1.1	2.5	55.0	209.7	50.9	0.0
2	331.5	43.5	0.0	4.2	6.6	916.0	2698.7	718.6	0.1
3	1544.9	7.6	0.0	3.4	0.7	115.4	1111.7	289.7	0.3
4	1314.7	119.3	0.1	5.2	0.9	1104.8	1313.3	384.2	1.5
5	1937.6	41.2	0.1	2.6	0.4	419.2	267.1	83.5	1.4
6	785.5	78.2	0.1	3.0	0.4	397.1	99.3	65.1	1.9
7	2083.3	113.1	0.1	1.7	0.2	1026.3	111.2	94.6	2.3
8	1981.5	113.8	0.1	1.0	0.1	760.5	31.2	76.2	1.9
9	1868.7	66.8	0.0	0.9	0.1	394.7	26.6	39.8	1.0
10	1658.2	40.8	0.1	0.5	0.0	315.2	14.6	29.3	0.6
11	619.5	27.5	0.1	0.5	0.0	294.2	13.0	9.0	0.4
12	294.2	9.3	0.0	0.1		119.8	2.2	9.5	0.2
13	81.5	2.4	0.0	0.0		38.6	1.1	0.4	0.0
14	18.7	1.0	0.0	0.0		17.4	0.4	0.6	
15+	2.2	0.4	0.0	0.0		14.7	0.3		
Catch	6269.5	247.0	0.4	8.5	2.9	2338.1	1688.1	554.3	5.1
SOP	6269.2	246.4	0.3	8.5	2.9	2339.4	1690.2	554.5	5.1
SOP%	100%	100%	102%	100%	101%	100%	100%	100%	100%

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0									
1	0.0	0.2		1.2	0.2	3.4	0.0	7.3	3.9
2	339.3	74.8		1.7	1514.7	3.2	0.4	13.6	5.6
3	31.5	16.0		0.3	617.5	1.8	105.1	16.7	0.9
4	203.2	510.2		0.5	1186.8	8.9	316.2	49.1	1.4
5	99.2	280.2		0.4	473.1	9.8	524.9	83.0	0.9
6	124.3	516.6		0.3	55.3	15.4	421.0	70.8	0.5
7	193.8	513.9		0.0	226.6	20.3	420.2	54.8	0.1
8	195.8	373.9		0.0	85.3	15.6	210.2	27.4	0.0
9	84.8	270.0		0.0	29.0	10.8	420.5	54.8	0.1
10	102.4	208.0		0.0	31.9	4.3	209.9	27.4	0.0
11	41.1	149.8			13.8	2.5	1.2		
12	33.9	113.1			4.0	0.7	0.4		
13	7.9	50.4			0.9	0.2	0.2		
14		1.4			0.0	0.0	0.2		
15+	6.7	7.8			0.8				
Catch	547.3	1052.4		1.0	998.6	30.3	982.0	145.8	2.8
SOP	547	1053		1.01	999	30	982	146	3
SOP%	100%	100%		100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2018 (cont.). Q2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					1553.5	218.6		
1	191.95	1.3	142.1	0.3	4027.6	571.1	1734.4	504.9
2	280.74	1.4	203.3	0.3	2073.9	294.6	563.9	22.4
3	45.28	0.9	48.4	0.1	677.1	148.7	693.9	97.2
4	67.3	3.8	128.0	0.8	1760.7	573.6	3007.2	577.4
5	41.8	4.7	133.5	0.8	685.4	379.9	2419.5	467.5
6	24.9	6.5	150.6	1.2	1117.3	635.1	3918.3	766.8
7	2.1	7.9	145.2	1.6	1385.9	844.5	5086.2	1031.7
8	1.5	5.8	102.9	1.2	1053.5	672.5	4060.7	803.6
9	1.3	4.6	91.7	0.8	864.7	563.2	3646.5	694.1
10	0.59	1.9	39.4	0.4	421.6	281.1	1924.7	347.1
11	0.20	0.9	13.5	0.2	280.8	190.4	1333.9	229.7
12	0.07	0.2	3.8	0.06	93.9	63.4	472.3	79.8
13	0.01	0.1	0.8	0.02	16.3	10.6	90.5	16.1
14		0.0	0.1		3.7	2.6	19.1	3.3
15+								
Catch	136	13	345	3	3270	1566	9666	1870
SOP	136	13	346	3	3268	1560	9666	1869
SOP%	100%	100%	100%	100%	100%	100%	100%	100%

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	2.7					1774.8
1	7.0	590.8	54.2			8323.0
2	3.8	99.7	1837.5		7.5	12061.6
3	4.0	62.8	407.7		27.9	6077.4
4	20.0	96.6	576.0		89.6	13420.8
5	17.8	70.9	113.1		169.7	8729.1
6	30.1	72.5	165.8		292.8	9816.7
7	41.3	18.1	404.6		426.0	14257.4
8	33.7	43.9	199.6		390.9	11244.2
9	28.1	37.0	95.1		298.7	9594.4
10	13.7	9.7	87.0		168.4	5938.8
11	9.3	9.5	34.6		103.9	3379.4
12	3.0		23.4		54.2	1381.7
13	0.5		4.2		33.4	356.1
14	0.1					68.6
15+						32.9
Catch	70	315	998		1000	34125
SOP	70	315	997		1000	34120
SOP%	101%	100%	100%		100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2018 (cont.). Q3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58	0.00
1	3278.19	7.44	1.41	1.41	0.54	262.62	133.62	29.66	0.00
2	35269.91	67.08	5.48	5.41	2.15	4033.56	938.53	263.25	1030.57
3	40631.16	28.70	4.58	4.45	1.56	561.89	532.02	119.05	3853.53
4	93793.82	96.81	6.83	6.71	1.89	4553.67	607.42	139.45	18598.50
5	71557.17	57.43	3.47	3.34	1.36	1806.20	188.07	35.87	18242.40
6	66290.32	70.58	3.94	3.92	0.81	1645.94	102.02	24.33	24559.52
7	93461.43	82.77	2.13	2.15	0.25	3928.67	53.23	16.90	29361.86
8	80607.56	74.40	1.25	1.28	0.07	2940.16	23.76	6.18	24063.45
9	52814.30	34.08	1.15	1.18	0.05	1509.23	13.12	6.15	13113.97
10	44715.46	36.34	0.68	0.70	0.02	1245.84	13.57	3.09	8041.33
11	19799.06	30.91	0.68	0.70	0.02	1161.77	13.30	3.09	5244.78
12	11555.35	17.27	0.06	0.06	0.00	487.30	6.11	0.00	1874.63
13	2973.58	5.72	0.02	0.02	0.00	161.19	2.08	0.00	445.11
14	1680.19	9.80	0.04	0.04	0.00	97.77	3.80	0.00	0.00
15+	389.50	4.77	0.02	0.02	0.00	71.02	1.93	0.00	0.00
Catch	270554	265	11	11	3	9545	843	192	64975
SOP	270575	265	11	11	3	9546	844	192	64975
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0	0	0	1.29	106.4300	378.0	23.780	0
1	0.5	0.2	0.0	3.7	0.1	7.1	1360.4	468.0	213.6
2	100.3	4.6	3.5	7.7	0.8	10.3	1942.5	472.7	276.0
3	10.7	1.5	14.5	5.7	0.5	4.5	736.0	73.7	36.0
4	48.7	36.1	34.6	8.5	6.1	0.5	565.8	63.1	44.2
5	20.3	20.7	38.5	8.9	3.4	0.1	468.9	46.7	16.8
6	19.4	36.8	38.51	5.85	4.8	0.0	385.3	35.7	10.2
7	39.6	31.3	0.900	4.00	6.4	0.0	323.0	24.9	0.000
8	44.1	18.8	1.0	1.83	7.6	0.0	110.0	9.2	0.000
9	19.8	16.7	0.4	3.36	2.4	0.0	101.0	11.0	0.000
10	28.5	13.2	0.6	1.65	2.8	0.0	6.4	2.7	0.000
11	9.7	12.0	0.2	0.02	1.2	0.0	0.0	0.0	
12	9.3	8.5	0.2	0.00	0.4	0.0	0.0	0.0	
13	2.2	4.5	0.1	0.00	0.1	0.0	0.0	0.0	
14	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	
15+	2.0	0.7	0.1	0.00	0.1	0.0	0.0	0.0	
Catch	127	67	53	18.06	13	8	1898	268	120
SOP	127	67	53	18.09	13	8	1898	268	121
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2018 (cont.). Q3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0.00	3.9	84.8	5.2	0.0	332.4	5.5	169.2
1	0.00	0.3	5.7	0.4	0.0	1.6	2.9	0.0
2	0.00	0.4	8.1	0.5	1.6	104.3	23.0	2.8
3	0.01	0.2	13.5	0.2	13.6	35.4	55.4	0.5
4	0.0	0.2	54.5	0.0	80.4	86.6	15.9	0.8
5	0.1	0.3	47.8	0.0	79.3	39.8	6.5	0.3
6	0.1	0.3	65.3	0.0	134.9	65.9	4.4	0.5
7	0.1	0.3	44.2	0.0	186.0	84.0	5.1	0.7
8	0.0	0.1	24.2	0.0	153.0	64.4	1.3	0.5
9	0.1	0.3	53.7	0.0	128.0	57.6	2.4	0.4
10	0.02	0.1	18.9	0.0	62.2	28.0	0.0	0.2
11	0.00	0.0	30.0	0.0	42.5	18.9	0.0	0.1
12	0.00	0.0	10.6	0.00	13.9	6.6	0.1	0.0
13	0.00	0.0	4.7	0.00	2.2	1.1	0.0	0.0
14	0.00	0.0	4.7	0.00	0.6	0.3	0.0	0.0
15+	0.00	0.000	0.0000	0.00	0.0000	0.0	0.0	0.0
Catch	0	1	138	0	311	191	35	6
SOP	0	1	138	0	308	191	35	6
SOP%	102%	100%	100%	99%	101%	100%	100%	100%

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	0.0	0.1	1290.5	0.0	0.0	2402.7
1	0.0	86.9	276.7	0.0	0.0	6142.7
2	0.0	627.4	518.6	0.8	466.0	46187.6
3	0.1	93.1	305.8	3.0	1724.5	48865.4
4	0.0	43.1	48.5	9.6	5539.3	124491.5
5	0.0	0.3	15.2	18.2	10494.8	103222.3
6	0.0	3.2	9.7	31.3	18105.3	111658.9
7	0.0	3.3	11.7	45.6	26340.8	154061.2
8	0.0	0.0	2.7	41.8	24169.2	132367.9
9	0.0	3.6	8.7	32.0	18470.5	86404.9
10	0.0	0.0	0.0	18.0	10412.4	64652.6
11	0.0	0.0	0.0	11.1	6423.7	32803.8
12	0.0	0.0	0.2	5.8	3353.7	17350.0
13	0.0	0.0	0.0	3.6	2066.2	5672.3
14	0.0	0.0	0.0	0.0	0.0	1797.3
15+	0.0	0.0	0.0	0.0	0.0	470.1
Catch	0	215	335	107	61834	412146
SOP	0	215	335	107	61835	412163
SOP%	125%	100%	100%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers (‘000s) -at-age by area for 2018 (cont.). Q4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0	0.0	0.0	0.0	0.0	0.0	1267.7	0.0	1.5	0.0
1	947.5	1.4	0.0	0.1	0.1	10505.0	20.9	16.0	0.0
2	8158.3	9.3	0.2	0.3	0.8	124960.0	91.8	72.3	2.0
3	1973.3	7.0	0.3	0.4	0.9	52319.5	56.3	41.3	7.3
4	12792.5	11.8	0.3	0.4	1.0	130392.0	68.7	53.0	35.2
5	6070.9	7.4	0.2	0.3	0.8	77484.1	34.3	22.5	34.5
6	6497.0	9.3	0.1	0.2	0.4	85489.7	19.3	21.9	46.5
7	18124.4	6.1	0.0	0.1	0.1	137172.2	39.7	16.0	55.6
8	13566.6	4.3	0.0	0.0	0.0	85561.9	13.0	7.2	45.6
9	7629.9	2.5	0.0	0.0	0.0	44006.9	0.9	5.7	24.8
10	8082.5	1.4	0.0	0.0	0.0	35910.0	6.4	3.6	15.2
11	4905.3	1.1	0.0	0.0	0.0	23668.6	0.4	2.9	9.9
12	1981.1	0.2	0.0	0.0	0.0	11435.1	0.1	0.0	3.6
13	911.0	0.1	0.0	0.0	0.0	3346.3	0.1	0.0	0.8
14	254.6	0.0	0.0	0.0	0.0	1965.6	0.0	0.0	0.0
15+	177.3	0.0	0.0	0.0	0.0	1231.3	0.0	0.0	0.0
Catch	39834	24	0	1	2	326065	128	87	123
SOP	39834	24	0	1	2	326107	128	87	123
SOP%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0	0	0		0	0	13.8	207.5	24.510	0
1	0.0	1.5		0.2	0.0	0.49	747.5	260.7	457.6
2	9369.4	49.3		0.2	10.8	0.50	1067.6	435.0	381.7
3	583.0	29.1		0.0	4.5	0.06	441.1	135.6	67.9
4	4260.7	234.5		0.4	9.4	0.11	421.8	132.3	76.7
5	1390.3	112.2		0.1	4.0	0.04	441.2	59.1	18.6
6	1622.1	158.5		0.25	1.2	0.07	359.1	35.2	4.6
7	3192.6	157.8		0.34	2.7	0.08	324.4	20.9	
8	3645.5	119.7		0.36	1.8	0.05	133.9	7.1	
9	1372.5	78.9		0.23	0.7	0.06	202.7	6.5	
10	2243.8	56.4		0.13	0.7	0.03	77.0	0.4	
11	749.5	41.2		0.08	0.3	0.02	0.7	0.0	
12	803.1	29.5		0.02	0.1	0.01	0.2	0.0	
13	187.4	11.1		0.00	0.0	0.00	0.1	0.0	
14	0.0	0.3		0.00	0.0	0.00	0.1	0.0	
15+	187.4	1.6		0.00	0.0	0.00	0.0	0.0	
Catch	10359	364		0.78	9	1	1386	284	185
SOP	10359	367		0.77	9	1	1386	284	185
SOP%	100%	99%		101%	100%	103%	100%	100%	100%

Table 8.4.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2018 (cont.). Q4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0.02	0.02	68.8		4.4	646.7	300.4	414.9
1	0.00	0.00	2.48		0.0	2.9	14.4	0.0
2	0.02	0.00	1.89		3.2	182.7	12.1	6.2
3	2.34	0.06	0.13		13.0	64.7	17.2	0.8
4	7.6	0.17	0.38		65.2	165.2	3.3	0.8
5	11.7	0.29	0.28		50.1	79.1	1.2	0.4
6	9.8	0.23	0.41		80.5	130.0	0.5	0.6
7	10.1	0.23	0.26		105.1	165.4	0.7	0.8
8	5.3	0.12	0.13		80.4	125.0	0.2	0.6
9	9.6	0.23	0.28		62.3	116.6	0.3	0.4
10	4.78	0.12	0.10		28.9	56.5	0.0	0.2
11	0.10	0.00	0.16		18.5	38.1	0.0	0.1
12	0.04	0.00	0.05		6.1	13.8	0.0	0.0
13	0.00	0.00	0.02		1.3	2.3	0.0	0.0
14	0.00	0.00	0.02		0.3	0.6	0.0	0.0
15+								
Catch	23	1	7		181	381	37	14
SOP	23	1	7		181	381	37	14
SOP%	100%	100%	99%		100%	100%	100%	100%

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	16.6	0.0	1283.8			4250.6
1	0.1	36.8	31.3			13047.0
2	4.0	114.0	89.8			145023.3
3	1.3	30.6	270.1			56067.6
4	2.7	19.0	32.6			148787.9
5	1.2	19.6	1.5			85845.9
6	2.0	3.2	0.6			94493.3
7	2.6	1.4	1.0			159400.3
8	2.0	1.1	0.4			103322.3
9	2.3		0.8			53525.2
10	1.1		0.0			46489.2
11	0.8		0.0			29437.8
12	0.3		0.0			14273.4
13	0.0		0.0			4460.6
14	0.0		0.0			2221.6
15+			0.0			1597.7
Catch	7	65	188			379758
SOP	7	65	188			379804
SOP%	100%	100%	100%			100%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1%.

Quarters 14

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						0%		0%	
1	1%	1%	4%	4%	13%	1%	4%	3%	
2	6%	9%	17%	17%	38%	15%	42%	38%	1%
3	6%	3%	14%	14%	13%	6%	19%	16%	3%
4	15%	17%	22%	21%	15%	16%	22%	21%	13%
5	11%	8%	11%	11%	10%	9%	6%	5%	12%
6	10%	12%	12%	12%	7%	10%	2%	4%	17%
7	16%	15%	7%	7%	2%	17%	2%	5%	20%
8	13%	14%	4%	4%	1%	10%	1%	3%	16%
9	9%	8%	4%	4%	1%	5%	0%	2%	9%
10	8%	6%	2%	2%	0%	4%	0%	1%	5%
11	3%	4%	2%	2%	0%	3%	0%	1%	4%
12	2%	2%	0%	0%		1%	0%	0%	1%
13	1%	1%	0%	0%		0%	0%	0%	0%
14	0%	1%	0%	0%		0%	0%	0%	
15+	0%	0%				0%	0%		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0					0%	41%	4%	1%	
1	0%	0%	0%	10%	0%	6%	15%	22%	42%
2	31%	5%	6%	18%	7%	10%	21%	30%	41%
3	2%	5%	11%	10%	3%	4%	9%	8%	6%
4	14%	17%	25%	16%	18%	7%	10%	11%	7%
5	5%	11%	28%	16%	10%	5%	10%	7%	2%
6	6%	15%	28%	11%	11%	6%	10%	7%	1%
7	11%	18%	1%	7%	16%	8%	8%	4%	0%
8	12%	13%	1%	4%	18%	6%	3%	2%	0%
9	5%	9%	0%	6%	6%	4%	6%	4%	0%
10	8%	4%	0%	3%	7%	2%	2%	1%	0%
11	3%	3%	0%	0%	3%	1%	1%	2%	
12	3%	2%	0%	0%	1%	0%	0%	1%	
13	1%	0%	0%	0%	0%	0%	0%	0%	
14	0%	0%	0%	0%	0%	0%	0%	0%	
15+	1%	0%	0%	0%	0%	0%	0%	0%	

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarters 14

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		1%	1%	34%	8%	8%	0%	2%
1	27%	2%	2%	4%	21%	7%	18%	7%
2	39%	24%	2%	7%	13%	12%	11%	1%
3	7%	10%	2%	3%	4%	4%	5%	2%
4	10%	23%	16%	7%	12%	13%	11%	11%
5	7%	10%	9%	6%	5%	7%	6%	8%
6	5%	7%	17%	8%	8%	11%	9%	14%
7	2%	7%	13%	11%	10%	14%	12%	18%
8	1%	3%	9%	8%	7%	10%	9%	14%
9	2%	6%	13%	6%	6%	8%	9%	11%
10	1%	2%	4%	2%	3%	4%	5%	5%
11	0%	4%	8%	2%	2%	2%	3%	4%
12	0%	2%	3%	1%	1%	1%	1%	1%
13	0%	1%	1%	0%	0%	0%	0%	0%
14	0%	1%	1%	0%	0%	0%	0%	0%
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	6%	0%	23%			0%
1	8%	30%	6%			2%
2	5%	34%	44%	0%	0%	9%
3	3%	12%	9%	1%	1%	5%
4	10%	9%	7%	4%	4%	15%
5	7%	4%	1%	8%	8%	10%
6	12%	3%	2%	14%	14%	11%
7	16%	2%	4%	21%	21%	16%
8	13%	2%	2%	19%	19%	12%
9	11%	2%	1%	14%	14%	8%
10	5%	1%	1%	8%	8%	5%
11	4%	1%	0%	5%	5%	3%
12	1%		0%	3%	3%	2%
13	0%		0%	2%	2%	0%
14	0%					0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	1%	0%			0%	0%		0%	
2	7%	4%			6%	5%	2%	8%	
3	1%	1%	12%	10%	6%	2%	11%	2%	
4	17%	18%	27%	30%	19%	18%	26%	16%	
5	6%	7%	31%	30%	13%	8%	29%	7%	
6	7%	14%	31%	30%	16%	14%	29%	12%	
7	19%	16%			13%	16%	0%	17%	
8	17%	17%			13%	16%	0%	17%	
9	8%	11%			6%	10%	0%	9%	
10	7%	6%			3%	6%	0%	6%	
11	5%	4%			3%	4%	0%	2%	
12	2%	1%				1%	0%	2%	
13	1%	0%				0%	0%	0%	
14	0%	0%				0%	0%	0%	
15+	0%					0%	0%	0%	

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0							3%		
1		0%	2%	37%	0%	15%	10%	13%	43%
2		5%	79%	44%	2%	29%	14%	23%	44%
3		5%	5%	8%	1%	8%	7%	6%	6%
4		17%	13%	8%	17%	19%	13%	14%	5%
5		11%	1%	3%	9%	7%	9%	7%	2%
6		15%	0%	1%	13%	5%	13%	10%	0%
7		18%			18%	5%	8%	5%	
8		13%			21%	4%	4%	3%	
9		9%			7%	3%	8%	7%	
10		4%			8%	2%	2%	2%	
11		3%			4%	2%	6%	6%	
12		2%			1%	1%	2%	2%	
13		0%			0%	0%	1%	1%	
14		0%			0%	0%	1%	1%	
15+		0%			0%	0%	0%	0%	

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					7%	2%		
1		1%	1%		18%	7%	26%	7%
2	1%	25%	1%	24%	15%	15%	16%	1%
3	2%	10%	2%	11%	5%	5%	7%	2%
4	18%	24%	16%	24%	13%	15%	11%	12%
5	8%	10%	9%	11%	5%	7%	4%	9%
6	14%	7%	17%	7%	8%	11%	7%	14%
7	20%	6%	13%	6%	10%	14%	9%	19%
8	14%	2%	9%	2%	8%	10%	7%	15%
9	12%	5%	13%	5%	5%	7%	7%	12%
10	5%	1%	4%	2%	3%	3%	3%	5%
11	2%	4%	9%	5%	2%	2%	3%	3%
12	1%	2%	3%	2%	1%	1%	1%	1%
13		1%	1%	1%	0%	0%	0%	0%
14		1%	1%	1%	0%	0%	0%	0%
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	4%					0%
1	18%	22%	10%			3%
2	9%	23%	84%			6%
3	3%	24%	1%			5%
4	11%	13%	2%			16%
5	6%	4%	0%			10%
6	10%	3%	1%			14%
7	13%	3%	1%			17%
8	10%	2%	0%			12%
9	8%	3%	0%			8%
10	4%	1%	0%			4%
11	3%	2%	0%			3%
12	1%		0%			1%
13	0%					0%
14	0%					0%
15+	0%					0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	1%	0%	0%	4%	21%	1%	4%	3%	0%
2	2%	7%	3%	17%	56%	15%	46%	39%	1%
3	11%	1%	1%	14%	6%	2%	19%	16%	3%
4	9%	18%	15%	21%	7%	18%	22%	21%	13%
5	13%	6%	9%	11%	3%	7%	5%	5%	12%
6	5%	12%	8%	12%	3%	7%	2%	4%	17%
7	14%	17%	12%	7%	1%	17%	2%	5%	20%
8	13%	17%	15%	4%	1%	13%	1%	4%	16%
9	13%	10%	5%	4%	1%	7%	0%	2%	9%
10	11%	6%	9%	2%	0%	5%	0%	2%	5%
11	4%	4%	9%	2%		5%	0%	0%	4%
12	2%	1%	5%	0%		2%	0%	1%	1%
13	1%	0%	1%	0%		1%	0%	0%	0%
14	0%	0%	4%	0%		0%	0%	0%	
15+	0%	0%	1%	0%		0%	0%		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0									
1	0%	0%		26%	0%	3%	0%	2%	29%
2	23%	2%		38%	36%	3%	0%	3%	42%
3	2%	1%		6%	15%	2%	4%	4%	7%
4	14%	17%		11%	28%	9%	12%	12%	10%
5	7%	9%		10%	11%	10%	20%	21%	7%
6	8%	17%		8%	1%	16%	16%	17%	4%
7	13%	17%		1%	5%	21%	16%	14%	1%
8	13%	12%		0%	2%	16%	8%	7%	0%
9	6%	9%		1%	1%	11%	16%	14%	1%
10	7%	7%		0%	1%	4%	8%	7%	0%
11	3%	5%		0%	0%	3%	0%		
12	2%	4%		0%	0%	1%	0%		
13	1%	2%		0%	0%	0%	0%		
14	0%	0%		0%	0%	0%	0%		
15+	0%	0%		0%	0%	0%			

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					10%	4%		
1	29%	3%	12%	3%	25%	10%	6%	9%
2	43%	3%	17%	4%	13%	5%	2%	0%
3	7%	2%	4%	2%	4%	3%	2%	2%
4	10%	9%	11%	10%	11%	11%	10%	10%
5	6%	12%	11%	10%	4%	7%	8%	8%
6	4%	16%	13%	15%	7%	12%	14%	14%
7	0%	20%	12%	21%	9%	15%	18%	18%
8	0%	15%	9%	16%	7%	12%	14%	14%
9	0%	11%	8%	11%	5%	10%	13%	12%
10	0%	5%	3%	5%	3%	5%	7%	6%
11	0%	2%	1%	3%	2%	3%	5%	4%
12	0%	1%	0%	1%	1%	1%	2%	1%
13	0%	0%	0%	0%	0%	0%	0%	0%
14		0%	0%		0%	0%	0%	0%
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	1%					2%
1	3%	53%	1%			8%
2	2%	9%	46%		0%	11%
3	2%	6%	10%		1%	6%
4	9%	9%	14%		4%	13%
5	8%	6%	3%		8%	8%
6	14%	7%	4%		14%	9%
7	19%	2%	10%		21%	13%
8	16%	4%	5%		19%	11%
9	13%	3%	2%		14%	9%
10	6%	1%	2%		8%	6%
11	4%	1%	1%		5%	3%
12	1%		1%		3%	1%
13	0%		0%		2%	0%
14	0%					0%
15+						0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0								0%	
1	1%	1%	4%	4%	6%	1%	5%	5%	
2	6%	11%	17%	17%	25%	16%	36%	41%	1%
3	7%	5%	14%	14%	18%	2%	20%	18%	3%
4	15%	16%	22%	21%	22%	19%	23%	22%	13%
5	12%	9%	11%	11%	16%	7%	7%	6%	12%
6	11%	11%	12%	12%	9%	7%	4%	4%	17%
7	15%	13%	7%	7%	3%	16%	2%	3%	20%
8	13%	12%	4%	4%	1%	12%	1%	1%	16%
9	9%	5%	4%	4%	1%	6%	0%	1%	9%
10	7%	6%	2%	2%	0%	5%	1%	0%	5%
11	3%	5%	2%	2%	0%	5%	1%	0%	4%
12	2%	3%	0%	0%	0%	2%	0%		1%
13	0%	1%	0%	0%	0%	1%	0%		0%
14	0%	2%	0%	0%	0%	0%	0%		
15+	0%	1%	0%	0%	0%	0%	0%		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0					3%	83%	6%	2%	
1	0%	0%	0%	7%	0%	5%	21%	38%	36%
2	28%	2%	3%	15%	2%	8%	30%	38%	46%
3	3%	1%	11%	11%	1%	3%	12%	6%	6%
4	14%	18%	26%	17%	16%	0%	9%	5%	7%
5	6%	10%	29%	17%	9%	0%	7%	4%	3%
6	5%	18%	29%	11%	13%	0%	6%	3%	2%
7	11%	15%	1%	8%	17%	0%	5%	2%	
8	12%	9%	1%	4%	20%	0%	2%	1%	
9	6%	8%	0%	7%	6%	0%	2%	1%	
10	8%	6%	0%	3%	7%	0%	0%	0%	
11	3%	6%	0%	0%	3%				
12	3%	4%	0%	0%	1%				
13	1%	2%	0%	0%	0%				
14	0%	0%		0%					
15+	1%	0%	0%		0%				

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		61%	18%	83%		36%	4%	96%
1		4%	1%	6%		0%	2%	0%
2		6%	2%	8%	0%	11%	19%	2%
3	3%	4%	3%	4%	2%	4%	45%	0%
4	13%	3%	12%	0%	9%	9%	13%	0%
5	20%	5%	10%		9%	4%	5%	0%
6	17%	4%	14%		15%	7%	4%	0%
7	17%	4%	9%		21%	9%	4%	0%
8	7%	2%	5%		17%	7%	1%	0%
9	17%	4%	11%		14%	6%	2%	0%
10	7%	2%	4%		7%	3%		0%
11			6%		5%	2%		0%
12			2%		2%	1%	0%	0%
13			1%		0%	0%		0%
14			1%		0%	0%		
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0		0%	52%			0%
1		10%	11%			1%
2	13%	73%	21%	0%	0%	5%
3	63%	11%	12%	1%	1%	5%
4	13%	5%	2%	4%	4%	13%
5	13%	0%	1%	8%	8%	11%
6		0%	0%	14%	14%	12%
7		0%	0%	21%	21%	16%
8			0%	19%	19%	14%
9		0%	0%	14%	14%	9%
10				8%	8%	7%
11				5%	5%	3%
12			0%	3%	3%	2%
13				2%	2%	1%
14						0%
15+						0%

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						0%		1%	
1	1%	2%	3%	3%	3%	1%	6%	6%	
2	9%	15%	18%	18%	18%	15%	26%	27%	1%
3	2%	11%	21%	21%	21%	6%	16%	16%	3%
4	14%	19%	25%	25%	25%	16%	20%	20%	13%
5	7%	12%	19%	19%	19%	9%	10%	9%	12%
6	7%	15%	11%	10%	10%	10%	5%	8%	17%
7	20%	10%	2%	3%	3%	17%	11%	6%	20%
8	15%	7%	1%	1%	0%	10%	4%	3%	16%
9	8%	4%				5%	0%	2%	9%
10	9%	2%				4%	2%	1%	5%
11	5%	2%				3%	0%	1%	4%
12	2%	0%				1%	0%		1%
13	1%	0%				0%	0%		0%
14	0%	0%				0%	0%		
15+	0%	0%				0%	0%		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0						90%	5%	2%	
1	0%	0%		6%		3%	17%	23%	45%
2	32%	5%		10%	30%	3%	24%	39%	38%
3	2%	3%		2%	12%	0%	10%	12%	7%
4	14%	22%		16%	26%	1%	10%	12%	8%
5	5%	10%		5%	11%	0%	10%	5%	2%
6	5%	15%		11%	3%	0%	8%	3%	0%
7	11%	15%		15%	7%	1%	7%	2%	
8	12%	11%		15%	5%	0%	3%	1%	
9	5%	7%		10%	2%	0%	5%	1%	
10	8%	5%		6%	2%	0%	2%	0%	
11	3%	4%		3%	1%	0%	0%		
12	3%	3%		1%	0%	0%	0%		
13	1%	1%		0%	0%		0%		
14		0%		0%			0%		
15+	1%	0%			0%				

Table 8.4.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2018. Zeros represent values <1% (cont.).

Quarter 4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	0%	1%	91%		1%	36%	86%	97%
1	0%	0%	3%		0%	0%	4%	
2	0%	0%	3%		1%	10%	3%	1%
3	4%	4%	0%		2%	4%	5%	0%
4	12%	12%	1%		13%	9%	1%	0%
5	19%	20%	0%		10%	4%	0%	0%
6	16%	16%	1%		15%	7%	0%	0%
7	16%	16%	0%		20%	9%	0%	0%
8	9%	8%	0%		15%	7%	0%	0%
9	16%	16%	0%		12%	7%	0%	0%
10	8%	8%	0%		6%	3%		0%
11	0%		0%		4%	2%		0%
12	0%		0%		1%	1%	0%	0%
13			0%		0%	0%		
14			0%		0%	0%		
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	45%		75%			0%
1	0%	16%	2%			1%
2	11%	51%	5%			15%
3	3%	14%	16%			6%
4	7%	8%	2%			15%
5	3%	9%	0%			9%
6	5%	1%	0%			10%
7	7%	1%	0%			17%
8	5%	0%	0%			11%
9	6%		0%			6%
10	3%					5%
11	2%					3%
12	1%		0%			1%
13	0%					0%
14	0%					0%
15+	0%					0%

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018.

Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						225		254	
1	262	295	298	298	290	295	280	284	
2	309	306	315	315	295	313	305	304	343
3	315	337	330	329	340	343	320	316	345
4	341	341	334	332	350	347	342	338	347
5	349	356	351	349	365	360	352	346	358
6	358	360	347	345	364	362	362	353	360
7	360	365	359	358	374	367	375	365	363
8	366	370	365	365	370	372	372	368	365
9	369	378	368	368	372	379	371	379	375
10	373	385	374	373	374	384	384	384	376
11	383	384	373	373	373	386	380	381	380
12	389	396	393	393	401	387	392	391	384
13	390	395	390	390	397	391	390	405	394
14	392	388	385	385	388	395	386	410	
15+	397	410	410	410	410	402	409		

AGE	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0					170	175	254	254	
1	251	291	217	277	246	251	298	280	260
2	303	285	284	299	289	274	316	300	300
3	333	326	336	338	324	320	330	321	314
4	340	337	353	350	338	339	346	333	320
5	352	351	368	362	351	356	354	350	340
6	352	356	377	369	361	360	369	363	364
7	354	361	354	374	365	363	375	371	373
8	361	368	361	375	368	366	389	376	375
9	367	377	367	382	378	373	386	377	383
10	372	384	372	394	379	378	393	390	395
11	387	387	387	386	390	383	386	386	
12	380	393	380	407	396	389	390	390	
13	370	396	370	405	404	389	385	385	
14	400	397	409	405	385	386	385	385	
15+	390	404	390		421	421			

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarters 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		171	191	170	151	162	226	164
1	284	243	257	255	175	178	240	164
2	296	288	284	279	284	285	294	295
3	313	323	323	325	313	316	343	340
4	330	332	335	342	334	337	341	343
5	350	346	353	357	357	358	363	360
6	364	359	358	360	360	360	365	362
7	369	353	362	363	364	364	369	366
8	373	365	367	366	368	368	372	369
9	381	372	373	373	380	378	381	376
10	393	384	384	378	382	381	387	382
11	393	386	387	383	387	387	390	386
12	400	390	391	388	393	392	395	392
13	405	385	385	389	395	395	408	398
14	385	385	385	388	395	395	395	395
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	162	220	210			191
1	195	268	249			248
2	286	309	278	350	350	307
3	327	358	313	354	354	330
4	341	367	331	356	356	343
5	360	375	369	365	365	354
6	363	385	366	366	366	360
7	367	393	379	370	370	364
8	370	399	390	373	373	369
9	380	391	386	379	379	375
10	383	402	411	384	384	379
11	387	396	389	383	383	385
12	392		397	386	386	389
13	394		395	407	407	394
14	395					393
15+						400

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	300	300			288	301	280	277	
2	318	280			293	286	304	287	
3	335	309	337	337	338	320	335	311	
4	343	336	354	354	344	338	354	333	
5	353	355	369	369	364	356	369	353	
6	360	360	378	378	367	361	377	354	
7	367	363			364	363	359	361	
8	373	370			370	370	365	367	
9	378	377			377	376	370	380	
10	383	386			386	385	384	385	
11	388	386			386	386	378	387	
12	392	407				404	393	391	
13	396	406				403	390	405	
14	400	409				405	385	410	
15+	410					406	410		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0							254		
1		292	217	280		242	298	283	278
2		285	276	293	289	279	316	301	288
3		326	300	312	328	316	329	319	308
4		337	311	324	341	331	341	330	323
5		351	312	337	354	347	354	348	337
6		356	335	359	361	358	365	358	361
7		361			366	357	371	365	
8		368			368	367	384	365	
9		377			378	374	382	371	
10		384			379	382	385	385	
11		387			390	387	386	386	
12		393			396	392	390	390	
13		397			404	387	385	385	
14		397			385	385	385	385	
15+		406			421	421			

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					151	151		
1		242	242		176	180	236	164
2	301	288	277	289	284	285	292	294
3	326	323	323	323	312	314	342	340
4	336	331	335	331	334	335	338	343
5	353	346	353	345	356	357	364	360
6	355	358	357	358	359	359	365	362
7	359	351	362	351	363	363	369	366
8	368	365	367	365	367	366	373	368
9	376	371	373	371	378	377	383	376
10	383	385	384	385	380	379	389	381
11	393	386	387	386	387	387	392	386
12	400	390	391	390	393	393	396	391
13		385	385	385	397	398	414	398
14		385	385	385	395	395	395	395
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	151					161
1	200	259	237			225
2	286	346	261			286
3	322	364	329			328
4	337	359	333			337
5	359	381	359			352
6	362	376	355			357
7	366	389	356			362
8	369	410	368			368
9	378	394	378			377
10	383	400	382			383
11	388	396	385			388
12	393		386			393
13	402		395			396
14	395					391
15+						415

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	249	299	291	298	290	300	281	279	
2	301	298	315	316	291	314	304	303	343
3	305	319	347	328	324	329	316	314	345
4	332	336	346	331	329	340	339	338	347
5	342	353	357	347	343	349	344	346	358
6	351	358	357	344	341	356	358	356	360
7	354	364	357	358	355	363	374	365	363
8	363	370	365	365	360	369	369	367	365
9	365	377	370	368	362	375	372	380	375
10	368	385	384	373	370	379	377	385	376
11	380	387	378	373	370	384	381	386	380
12	389	401	393	393		388	388	391	384
13	393	401	390	390		392	389	405	394
14	399	403	385	385		396	393	410	
15+	410	411	410	410		406	407		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0									
1	254	244		284	240	240	280	287	284
2	303	285		297	289	273	301	303	296
3	337	312		314	322	342	325	324	313
4	342	335		330	329	348	345	343	329
5	355	351		352	339	360	355	356	350
6	356	357		365	361	361	365	365	365
7	357	362		373	347	364	372	373	373
8	362	367		375	368	366	375	375	375
9	370	377		383	378	373	382	383	383
10	373	384		395	379	377	395	395	395
11	385	389			390	382	386		
12	381	387			396	388	390		
13	374	386			405	391	385		
14	404	409			395	392	385		
15+	390	395			421	421			

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					151	151		
1	284	244	279	241	175	175	269	164
2	296	278	296	287	284	287	315	314
3	312	337	321	341	312	326	346	344
4	329	347	339	347	334	341	347	344
5	349	359	356	359	357	360	362	360
6	364	361	362	361	360	363	365	363
7	360	365	365	364	365	367	368	367
8	368	366	367	366	368	370	372	370
9	377	375	376	374	381	380	379	378
10	385	380	384	378	382	383	385	384
11	394	381	383	382	388	387	389	387
12	400	387	389	388	393	392	393	392
13	405	390	391	391	394	392	397	395
14		395	395		395	395	395	395
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	150					151
1	176	270	238			211
2	289	329	298		350	298
3	338	363	305		354	318
4	345	373	329		356	339
5	361	373	369		365	353
6	364	387	368		366	362
7	367	400	381		370	365
8	370	396	391		373	369
9	380	388	386		379	376
10	383	403	412		384	380
11	387	396	389		383	386
12	392		397		386	391
13	389		395		407	394
14	395					397
15+						401

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0								254	
1	254	294	298	298	290	298	278	287	
2	309	311	315	316	302	312	307	305	343
3	314	342	329	328	343	333	327	318	345
4	341	347	332	331	354	340	346	338	347
5	348	359	349	347	368	350	360	345	358
6	358	362	345	344	370	358	364	350	360
7	359	366	358	358	380	364	377	368	363
8	365	370	365	365	375	369	366	371	365
9	368	379	368	368	376	375	370	372	375
10	372	385	373	373	373	380	381	373	376
11	382	382	373	373	372	383	378	373	380
12	389	393	393	393	393	389	393		384
13	388	392	390	390	390	392	390		394
14	390	386	385	385	385	392	385		
15+	392	410	410	410	410	407	410		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0					170	170	254	254	
1	247	298	217	276	265	265	298	281	273
2	303	304	296	301	286	269	316	291	299
3	321	323	337	341	326	315	331	316	313
4	339	337	354	353	341	321	349	339	320
5	349	350	369	363	354	344	353	351	347
6	351	358	377	370	361	365	375	372	365
7	354	362	354	375	366	349	381	379	373
8	361	367	361	376	368	375	416	405	375
9	366	376	367	383	378	383	402	394	383
10	371	383	372	395	379	395	395	395	395
11	386	390	388	386	390				
12	381	387	380	407	396				
13	372	385	370	407	405				
14	399	396		409					
15+	390	395	390		421				

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		170	170	170		168	173	164
1		265	265	265		279	264	285
2		268	268	268	338	285	302	278
3	325	318	322	315	348	314	328	301
4	345	343	338	315	347	336	355	332
5	355	355	354		361	358	378	359
6	365	365	361		364	362	374	361
7	373	373	367		367	366	372	365
8	375	375	368		370	369	375	368
9	383	383	375		380	381	391	375
10	395	395	388		383	383		381
11			386		387	388		386
12			390		392	392	415	391
13			385		389	392		395
14			385		395	395		395
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0		220	218			209
1		262	262			269
2	306	298	279	350	350	310
3	327	352	311	354	354	319
4	353	376	344	356	356	342
5	377	410	375	365	365	352
6		381	371	366	366	360
7		381	368	370	370	362
8			375	373	373	367
9		400	400	379	379	372
10				384	384	374
11				383	383	382
12			415	386	386	388
13				407	407	396
14						390
15+						395

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						225		254	
1	294	294	288	288	288	294	282	294	
2	313	312	309	309	309	313	308	310	343
3	344	340	346	346	346	343	344	326	345
4	346	347	359	359	359	347	355	337	347
5	356	360	370	370	370	360	369	350	358
6	361	364	376	376	376	363	370	350	360
7	366	372	390	390	390	367	372	365	363
8	372	378	390	390	390	372	388	375	365
9	374	385	400	400	400	379	375	372	375
10	381	386				384	403	379	376
11	386	387				386	382	373	380
12	390	398				387	388		384
13	394	404				391	389		394
14	400	389				395	396		
15+	409	410				402	406		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0						210	254	254	
1	295	289		253		252	298	276	248
2	303	296		296	289	261	316	311	305
3	333	328		315	322	352	331	324	316
4	340	338		333	331	361	348	330	319
5	351	350		352	342	364	354	345	334
6	351	358		358	361	365	371	370	362
7	354	362		363	354	365	377	381	
8	361	369		370	368	371	393	416	
9	367	379		377	379	385	388	402	
10	372	386		386	380	385	395	395	
11	388	387		386	390	389	386		
12	380	392		407	396	393	390		
13	370	387		407	405		385		
14		410		409			385		
15+	390	395			421				

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2018 (cont.).

Quarter 4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	217	217	217		166	168	227	164
1	248	248	248		285	280	242	
2	311	257	257		324	285	277	276
3	325	325	345		342	316	325	290
4	344	345	345		343	336	344	334
5	355	355	355		359	359	376	359
6	364	365	361		361	362	374	361
7	371	373	367		365	366	369	365
8	374	375	368		368	369	379	368
9	382	383	375		376	382	390	375
10	394	395	388		381	384		381
11	394		386		386	388		386
12	400		390		391	392	415	391
13	405		385		395	394		395
14			385		395	395		
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	168		202			205
1	274	291	257			292
2	285	302	301			312
3	312	334	326			343
4	335	350	335			347
5	359	374	379			359
6	364	402	370			362
7	368	413	367			367
8	372	424	375			372
9	388		396			378
10	386					383
11	389					386
12	393		415			387
13	393					391
14	395					396
15+						401

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1%. Handline Fleet. UKE=UK England and Wales.

	UKE lines							
	7.e				7.f			
Length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
15								
16								
17				0%			0%	
18				0%			1%	0%
19				1%			3%	2%
20			0%	3%			2%	9%
21			0%	4%			0%	14%
22			0%	1%	0%	1%	0%	4%
23			1%	1%	0%	0%	0%	0%
24	1%		6%	0%	1%	5%	1%	0%
25	8%	1%	20%	0%	19%	5%	4%	1%
26	13%	4%	24%	2%	26%	10%	8%	2%
27	11%	3%	22%	8%	18%	10%	14%	7%
28	10%	7%	11%	10%	8%	20%	20%	14%
29	15%	8%	8%	20%	8%	17%	25%	20%
30	18%	7%	3%	22%	10%	8%	11%	17%
31	15%	4%	0%	17%	5%	7%	5%	6%
32	7%	9%	3%	7%	2%	6%	3%	3%
33	2%	12%	0%	1%	1%	5%	2%	1%
34	1%	12%	1%	1%	0%	2%	1%	0%
35	0%	16%	0%	1%	0%	1%	1%	0%
36	0%	10%	0%		0%	1%	0%	0%
37	0%	4%	0%			1%	0%	0%
38	0%	3%	0%			1%	0%	
39							0%	
40							0%	

	UKE lines							
	7.e				7.f			
Length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
41							0%	
42								
43								
44								
45								

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1% (cont.). Southern Fleets. ES=Spain.

	ES All fleets			
length cm	Q1	Q2	Q3	Q4
16				
17				1%
18			1%	4%
19			2%	19%
20	0%		5%	25%
21	4%		17%	11%
22	9%		19%	9%
23	6%		8%	7%
24	3%		1%	2%
25	5%	0%	4%	0%
26	8%	0%	9%	0%
27	4%	0%	7%	0%
28	3%	1%	3%	0%
29	1%	4%	4%	1%
30	2%	3%	5%	1%
31	2%	1%	4%	3%
32	3%	2%	3%	7%
33	3%	4%	1%	6%

	ES All fleets			
length cm	Q1	Q2	Q3	Q4
34	5%	10%	2%	2%
35	9%	15%	2%	0%
36	10%	18%	2%	0%
37	8%	17%	1%	0%
38	6%	14%	1%	0%
39	4%	7%	0%	0%
40	2%	3%	0%	
41	1%	1%	0%	
42	0%	0%	0%	
43	0%	0%		
44	0%	0%		
45	0%	0%		
46		0%		
47		0%		
48				

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1% (cont.). Southern Fleets (cont.). BQ=Basque

	BQ Purse Seine				**BQ Artisanal**		**BQ Trawl**	
length cm	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q1**	**Q2**
20								
21								
22								
23							1%	
24							1%	
25							1%	
26							4%	
27							15%	

	BQ Purse Seine				BQ Artisanal		BQ Trawl	
length cm	Q1	Q2	Q3	Q4	Q1	Q2	Q1	Q2
28					0%		12%	
29					0%		11%	
30	0%				0%		6%	
31	1%	1%			1%	0%	4%	
32	2%	1%		2%	2%	1%	4%	1%
33	6%	6%		6%	4%	4%	4%	3%
34	12%	14%		12%	9%	10%	5%	9%
35	22%	21%	33%	21%	18%	17%	7%	19%
36	25%	19%	39%	25%	24%	23%	8%	25%
37	17%	18%	28%	17%	22%	21%	7%	20%
38	9%	11%		10%	11%	13%	6%	12%
39	5%	6%		5%	6%	7%	2%	7%
40	1%	1%		1%	2%	2%	1%	4%
41	1%	1%			1%	1%		1%
42	0%	0%			0%	0%		1%
43	0%	0%			0%	0%		
44	0%				0%			
45					0%			
46								
47								
49								

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1% (cont.). Southern Fleets (cont.). PT=Portugal.

	PT All			
length cm	**Q1**	**Q2**	**Q3**	**Q4**
20				
21		0%		
22		1%		
23	1%	1%		
24	3%	1%	0%	
25	5%	2%	1%	0%
26	6%	12%	7%	1%
27	4%	19%	9%	10%
28	2%	9%	10%	23%
29	1%	4%	14%	16%
30	0%	3%	19%	9%
31	1%	1%	13%	9%
32	2%	0%	5%	8%
33	2%	2%	3%	2%
34	10%	1%	2%	1%
35	13%	2%	2%	3%
36	13%	7%	4%	3%
37	16%	11%	5%	5%
38	7%	9%	4%	6%
39	8%	7%	2%	1%
40	3%	4%	1%	1%
41	3%	2%		1%
42	0%	0%		0%
43	0%	0%		
44		0%		
45				
46		0%		

	PT All			
length cm	**Q1**	**Q2**	**Q3**	**Q4**
47				
49				

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1% (cont.). Pelagic Trawl Fleets. IE=Ireland, UKS=UK Scotland, IS=Iceland

	IE				**UKS**		**IS**		
	4.a	6.a	7.b	7.j	4.a	6.a	2.a	5.a	14.b
Length cm	Q4	Q1	Q1	Q1	Q4	Q1	Q3	Q3	Q3
15									
16									
17									
18									
19									
20									
21									
22									
23									
24		0%				0%			
25		0%				1%			
26	0%	1%				1%			
27	1%	1%			0%	1%			
28	1%	1%			1%	1%	0%		
29	2%	1%			2%	1%	1%		
30	4%	1%	0%	0%	3%	1%	1%		
31	2%	1%	0%	1%	4%	3%	2%	0%	
32	3%	5%	2%	5%	4%	6%	2%	0%	
33	4%	8%	6%	10%	7%	10%	6%	2%	1%
34	8%	10%	12%	15%	12%	17%	12%	8%	1%
35	15%	18%	22%	23%	17%	21%	19%	22%	10%

	IE				UKS		IS		
	4.a	6.a	7.b	7.j	4.a	6.a	2.a	5.a	14.b
Length cm	Q4	Q1	Q1	Q1	Q4	Q1	Q3	Q3	Q3
36	22%	19%	24%	21%	19%	17%	24%	26%	20%
37	18%	14%	15%	11%	16%	11%	17%	21%	23%
38	11%	10%	11%	7%	8%	8%	9%	12%	25%
39	7%	6%	5%	5%	5%	2%	4%	4%	14%
40	2%	2%	2%	1%	2%	1%	2%	2%	3%
41	1%	1%	1%	0%	0%	0%	1%	1%	2%
42	0%	0%	0%		0%	0%	0%	0%	1%
43	0%	0%				0%	0%		
44	0%	0%							
45		0%							
46		0%							

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1% (cont.). Pelagic Trawl Fleets. DK=Denmark, RU=Russia

	DK			RU	
	4.a	4.b	6.a	2.a	2.a
length cm	Q4	Q4	Q4	Q3	Q4
15					
16					
17					
18					
19					
20					
21					
22				0%	
23				0%	0%
24				0%	0%
25				0%	0%

	DK			**RU**	
	4.a	4.b	6.a	2.a	2.a
length cm	Q4	Q4	Q4	Q3	Q4
26		3%		0%	0%
27	1%	2%		0%	0%
28	1%	3%		0%	0%
29	3%	3%		2%	0%
30	4%	2%		3%	0%
31	3%	2%		3%	0%
32	3%	3%		3%	0%
33	5%	14%	4%	5%	1%
34	9%	9%	8%	12%	4%
35	13%	24%	19%	20%	18%
36	21%	12%	23%	22%	25%
37	18%	10%	15%	16%	23%
38	10%	7%	23%	8%	16%
39	6%	2%	8%	4%	9%
40	2%			1%	2%
41	1%			0%	0%
42				0%	
43				0%	0%
44				0%	
45				0%	

Table 8.5.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet in 2018. Zeros represent values <1% (cont.). Freezer Trawlers. NL=The Netherlands, DE=Germany,

	NL				**DE**	
	2.a,4.a,4.b,6.a,7.b,7.c				6.a	4.a
length cm	Q1	Q2	Q3	Q4	Q1	Q3
15						
16						
17						
18						
19						
20					0%	
21					0%	
22					0%	
23					0%	
24					0%	
25					1%	
26				0%	1%	0%
27	1%		2%	0%	1%	5%
28	3%		8%	5%	1%	12%
29	1%		15%	8%	1%	11%
30	3%	1%	13%	10%	1%	7%
31	3%	1%	10%	13%	2%	9%
32	9%	4%	12%	1%	4%	14%
33	16%	6%	14%	7%	7%	13%
34	22%	16%	11%	1%	14%	12%
35	16%	19%	4%	4%	20%	8%
36	11%	21%	5%	15%	17%	6%
37	7%	11%	3%	18%	14%	2%
38	4%	10%	3%	11%	9%	1%
39	2%	6%	1%	4%	4%	0%
40	2%	3%	0%	4%	2%	

	NL				DE	
	2.a,4.a,4.b,6.a,7.b,7.c				6.a	4.a
length cm	Q1	Q2	Q3	Q4	Q1	Q3
41	0%	1%	0%	0%	0%	
42	0%	0%			0%	
43	0%				0%	
44					0%	

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018

Quarters 1-4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						87		110	
1	156	225	237	238	217	220	188	200	
2	283	240	280	281	226	256	248	245	377
3	310	330	326	323	355	348	293	279	385
4	392	333	343	338	389	363	350	332	390
5	418	389	398	392	440	407	397	368	423
6	452	391	384	379	439	413	435	382	430
7	454	409	430	428	465	435	449	409	440
8	476	430	456	454	461	452	467	419	446
9	493	452	467	465	465	480	474	470	477
10	506	494	494	489	476	503	527	487	484
11	544	500	491	488	477	510	511	490	496
12	572	563	578	578	563	514	560	507	510
13	583	563	565	565	555	533	555	587	546
14	579	551	547	547	548	558	548	611	
15+	608	644	646	646	646	586	640		

AGE	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0					37	41	110	110	
1	131	211	65	160	110	117	205	165	135
2	234	173	177	211	161	148	253	209	208
3	321	270	301	337	245	241	295	261	244
4	343	297	362	367	291	276	338	289	260
5	384	344	433	396	326	314	359	336	322
6	383	361	448	403	356	323	409	366	403
7	392	377	391	405	369	329	432	392	386
8	417	402	416	429	379	338	505	432	428
9	442	436	441	423	412	360	462	410	420
10	459	461	458	455	415	375	451	445	455
11	527	475	527	454	451	395	423	423	
12	493	501	493	547	475	428	476	476	
13	452	525	451	529	502	406	390	390	
14	579	529	551	526	396	399	396	396	
15+	537	559	537		576	576			

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarters 1-4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		37	55	37	21	28	88	28
1	162	103	123	125	35	38	105	28
2	187	159	164	162	160	162	195	183
3	225	242	243	252	219	226	314	284
4	266	271	278	290	267	272	284	290
5	324	301	320	319	326	327	335	338
6	361	329	331	324	335	334	337	345
7	375	317	343	336	347	346	345	356
8	410	360	370	345	358	355	354	364
9	417	380	387	365	397	388	381	390
10	451	427	431	385	402	397	396	409
11	464	421	425	407	420	415	408	423
12	490	474	476	442	438	433	416	441
13	509	390	393	431	449	446	461	468
14	396	396	396	430	445	440	416	453
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	28	81	71			55
1	53	160	115			133
2	165	252	154	406	406	246
3	248	388	230	421	421	319
4	278	415	254	427	427	354
5	324	442	349	457	457	396
6	333	471	338	461	461	410
7	343	502	374	474	474	426
8	350	521	405	485	485	446
9	381	491	398	507	507	469
10	391	527	472	523	523	491
11	402	507	399	522	522	507
12	418		423	532	532	528
13	431		416	615	615	556
14	427					551
15+						587

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 1

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	238	230			205	233	190	183	
2	291	152			196	171	246	188	
3	350	220	303	303	327	252	301	249	
4	371	283	367	367	325	293	367	293	
5	407	345	434	434	406	360	434	357	
6	434	358	449	449	399	367	449	361	
7	455	367			371	371	444	388	
8	479	392			392	395	474	408	
9	503	416			417	420	490	465	
10	524	453			453	456	542	485	
11	545	456			455	461	520	493	
12	566	550			550	540	578	507	
13	582	542			541	539	565	587	
14	600	552			551	546	547	611	
15+	651	636				606	646		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0							110		
1		211	65	152		101	205	158	148
2		173	153	181	161	149	253	196	169
3		270	206	224	258	225	279	238	214
4		297	232	252	298	265	314	268	250
5		344	233	288	334	303	349	308	289
6		361	303	354	356	335	388	331	365
7		377			372	337	405	342	
8		403			379	374	477	367	
9		436			412	390	465	382	
10		461			415	423	435	435	
11		476			451	428	423	423	
12		502			475	473	476	476	
13		535			502	400	390	390	
14		528			396	396	396	396	
15+		606			576	576			

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 1

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					21	21		
1		101	101		36	40	97	28
2	188	159	149	161	161	161	192	181
3	249	242	243	243	218	222	318	282
4	277	270	277	271	267	270	279	289
5	325	300	319	300	326	328	341	338
6	332	330	330	330	334	334	337	345
7	343	314	342	314	347	346	348	356
8	374	367	371	367	358	356	357	364
9	401	382	387	382	395	390	391	388
10	427	435	432	435	402	400	403	407
11	462	423	426	423	425	424	417	422
12	489	475	477	476	444	445	420	440
13		390	393	390	460	465	482	472
14		396	396	396	451	451	416	453
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	21					30
1	58	145	95			88
2	165	342	124			175
3	239	394	248			275
4	273	382	254			294
5	331	455	316			342
6	339	434	305			357
7	351	479	308			373
8	360	560	340			395
9	390	499	367			426
10	404	520	379			448
11	419	506	387			460
12	436		388			492
13	472		416			494
14	443					458
15+						588

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 2

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0									
1	126	235	212	239	218	233	191	187	
2	264	212	299	282	218	265	246	242	377
3	280	273	375	321	309	317	279	273	385
4	372	296	407	334	326	342	339	329	390
5	399	348	441	388	372	372	369	359	423
6	432	359	442	376	365	396	419	374	430
7	441	382	445	427	416	422	440	398	440
8	467	404	474	454	435	444	456	408	446
9	482	429	491	465	442	465	472	465	477
10	492	464	542	489	477	485	495	485	484
11	540	474	520	488	477	503	509	493	496
12	575	547	578	578		522	526	507	510
13	625	552	565	565		539	542	587	546
14	582	565	547	547		555	553	611	
15+	651	636	646	646		606	613		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0									
1	138	107		164	99	99	190	168	162
2	235	171		190	161	144	229	201	187
3	341	233		227	239	276	263	258	224
4	354	270		266	266	288	318	311	263
5	403	315		328	287	318	343	346	321
6	407	317		366	355	320	353	357	365
7	411	348		386	313	328	386	386	386
8	426	374		428	379	334	428	428	428
9	456	405		420	411	355	420	420	420
10	464	416		455	416	365	455	455	455
11	517	414			451	379	423		
12	496	413			474	398	476		
13	465	379			508	412	391		
14	591	602			416	411	396		
15+	537	404			576	576			

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 2

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0					21	21		
1	162	104	156	102	35	35	163	28
2	187	153	187	184	160	165	244	225
3	223	271	242	277	217	245	301	294
4	261	292	282	299	266	277	293	293
5	319	325	328	322	326	323	328	339
6	365	326	338	324	336	332	336	348
7	345	333	341	337	349	342	341	359
8	376	339	351	344	360	351	352	368
9	403	365	380	363	403	381	373	396
10	430	382	404	383	405	390	389	416
11	464	376	386	402	422	402	399	426
12	490	394	409	431	439	418	411	444
13	510	406	415	454	447	419	425	455
14		416	416		446	427	416	453
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	21					21
1	36	164	100			84
2	169	297	183		406	207
3	268	389	198		421	266
4	283	425	246		427	304
5	321	423	342		457	351
6	329	475	339		461	354
7	338	522	378		474	373
8	345	505	407		485	392
9	374	476	389		507	413
10	383	532	473		523	437
11	393	508	399		522	446
12	408		422		532	469
13	402		416		615	499
14	417					509
15+						547

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 3

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0								110	
1	137	222	238	239	215	229	183	208	
2	288	258	281	282	242	259	254	249	377
3	309	343	324	321	365	330	314	284	385
4	394	379	338	334	405	346	369	338	390
5	419	417	393	388	449	379	426	374	423
6	454	425	379	376	458	404	448	396	430
7	456	446	428	427	487	425	461	440	440
8	478	472	454	454	495	448	466	480	446
9	495	499	465	465	492	469	478	486	477
10	505	530	489	489	487	490	526	486	484
11	548	525	488	488	486	505	514	486	496
12	577	572	578	578	578	528	573		510
13	588	567	565	565	565	542	562		546
14	578	549	547	547	547	552	548		
15+	596	645	646	646	646	615	644		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0					37	37	110	110	
1	123	239	65	162	142	142	205	167	157
2	234	224	213	221	159	149	253	191	206
3	303	277	303	348	258	241	303	261	240
4	344	265	365	380	299	254	360	323	260
5	387	303	433	401	334	303	380	366	348
6	387	306	449	408	356	353	477	448	409
7	398	328	391	408	372	319	498	478	386
8	422	347	416	436	379	428	656	599	428
9	451	377	441	423	412	420	610	530	420
10	464	386	458	455	416	455	455	455	455
11	529	402	527	455	452				
12	500	392	493	550	475				
13	468	374	451	541	509				
14	578	510		551					
15+	537	404	537		576				

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 3

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0		37	37	37		31	39	28
1		142	142	142		152	143	160
2		148	148	148	263	162	222	149
3	263	247	249	241	288	221	276	195
4	318	314	292	241	286	269	353	263
5	343	343	325		320	325	422	334
6	353	353	338		329	335	410	341
7	386	386	357		338	347	402	352
8	428	428	388		345	356	411	361
9	420	420	395		373	396	473	386
10	455	455	442		382	400		405
11			423		392	413		421
12			476		407	430	561	440
13			390		400	430		459
14			396		416	438		453
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0		81	79			70
1		144	138			161
2	224	223	168	406	406	282
3	273	393	236	421	421	318
4	346	481	322	427	427	393
5	419	639	415	457	457	422
6	407	499	399	461	461	449
7		500	389	474	474	455
8			411	485	485	473
9		588	502	507	507	494
10				523	523	505
11				522	522	533
12			561	532	532	559
13				615	615	593
14						576
15+						599

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 4

Age	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0						87		110	
1	226	223	205	205	205	220	191	224	
2	262	259	254	254	254	256	248	259	377
3	359	346	373	373	373	348	363	310	385
4	374	369	419	419	419	364	402	343	390
5	413	411	456	456	456	408	456	392	423
6	432	423	478	478	478	413	451	392	430
7	447	452	516	516	516	435	461	443	440
8	468	479	558	558	558	453	495	484	446
9	481	509	574	574	574	480	480	486	477
10	509	513				503	602	510	484
11	529	523				510	505	486	496
12	545	560				514	522		510
13	564	590				532	542		546
14	587	556				558	555		
15+	635	642				584	606		

Age	5.b	6.a	6.b	7.a	7.b	7.c	7.d	7.e	7.f
0						71	110	110	
1	225	203		130		122	205	168	120
2	234	193		199	161	134	253	240	225
3	321	266		249	240	342	300	279	254
4	342	278		275	270	363	349	298	262
5	383	315		332	295	372	364	348	308
6	382	334		350	356	374	426	451	402
7	391	357		366	336	376	447	499	
8	416	384		391	381	372	531	656	
9	441	419		416	414	423	472	610	
10	458	439		453	419	418	455	455	
11	527	433		455	452	432	423		
12	493	442		550	475	446	476		
13	451	393		541	509	449	390		
14		581		551		453	396		
15+	537	404			576				

Table 8.5.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2018 (cont.).

Quarter 4

Age	7.g	7.h	7.j	7.k	8.a	8.b	8.c	8.c.E
0	78	78	78		29	31	89	28
1	117	117	117		160	152	109	160
2	214	130	130		243	162	174	145
3	263	263	317		287	226	268	173
4	313	318	315		291	273	325	268
5	343	343	332		336	334	437	335
6	352	353	345		343	344	418	341
7	381	386	359		354	357	396	353
8	420	428	388		362	368	437	361
9	419	420	395		387	410	466	386
10	453	455	442		406	414		405
11	464		423		421	428		421
12	490		476		440	444	561	440
13	510		390		459	453		459
14			396		453	453		453
15+								

Age	8.d	9.a	9.a.N	14.a	14.b	All
0	31		63			66
1	145	206	131			214
2	161	233	217			254
3	218	338	270			347
4	270	384	292			364
5	336	484	428			408
6	351	598	396			414
7	365	657	385			436
8	377	714	411			453
9	430		488			479
10	422					502
11	433					513
12	446		561			517
13	449					535
14	453					562
15+						584

Table 8.6.2.1. Model parameter estimates and standard errors.

Symbol	Description	Unit	Estimate	Std.Error
T	Decorrelation time	year	2	0.4
H	Spatial decorrelation distance	km	486.3	97.81
WS	Log Wing spread	Nmi	-1.3	0.64
σ_N^2	Variance of the nugget effect	1	3.9	NA
σ_{xy}^2	Spatial variance parameter (year specific surfaces)	1	5.3	NA
$\sigma_x^{2^2}$	Spatial variance parameter (intercept surface)	1	5.6	NA

Table 8.6.3.1. Abundance index, mean weight-at-age, and biomass index for mackerel from the IESSNS in 2007 and from 2010 to 2019.

	2007			2010			2011			2012		
AGE	Number (billions)	W (g)	Biom. t (mil-lion)	Num-ber (bil-lions)	W (g)	Biom. t (mil-lion)	Num-ber (bil-lions)	W (g)	Biom. t (mil-lion)	Num-ber (bil-lions)	W (g)	Biom. t (mil-lion)
1	1.33	133	0.18	0.03	133	0	0.21	133	0.03	0.5	112	0.06
2	1.86	233	0.43	2.8	212	0.59	0.26	278	0.07	4.99	188	0.94
3	0.9	323	0.29	1.52	290	0.44	0.87	318	0.28	1.22	286	0.35
4	0.24	390	0.09	4.02	353	1.42	1.11	371	0.41	2.11	347	0.73
5	1	472	0.47	3.06	388	1.19	1.64	412	0.67	1.82	397	0.72
6	0.16	532	0.09	1.35	438	0.59	1.22	440	0.54	2.42	414	1
7	0.06	536	0.03	0.53	512	0.27	0.57	502	0.29	1.64	437	0.72
8	0.04	585	0.02	0.39	527	0.2	0.28	537	0.15	0.65	458	0.3
9	0.03	591	0.02	0.2	548	0.11	0.12	564	0.07	0.34	488	0.17
10	0.01	640	0.01	0.05	580	0.03	0.07	541	0.04	0.12	523	0.06
11	0.01	727	0.01	0.03	645	0.02	0.06	570	0.03	0.07	514	0.03
12	0	656	0	0.02	683	0.01	0.02	632	0.01	0.02	615	0.01
13	0.01	685	0.01	0.01	665	0.01	0.01	622	0.01	0.01	509	0
14+	0	671	0	0.01	596	0	0	612	0	0.01	677	0
TOTAL	5.65	512	1.64	13.99	469	4.89	6.42	467	2.69	15.91	426	5.09

	2013			2014			2015			2016		
AGE	Number (billions)	W (g)	Biom. t (mil-lion)	Num-ber (bil-lions)	W (g)	Biom. t (mil-lion)	Num-ber (bil-lions)	W (g)	Biom. t (mil-lion)	Num-ber (bil-lions)	W (g)	Biom. t (mil-lion)
1	0.06	96	0.01	0.01	228	0	1.2	128	0.15	<0.01	95	<0.01
2	7.78	184	1.43	0.58	275	0.16	0.83	290	0.24	4.98	231	1.15
3	8.99	259	2.32	7.8	288	2.24	2.41	333	0.8	1.37	324	0.45
4	2.14	326	0.7	5.14	335	1.72	5.77	342	1.97	2.64	360	0.95
5	2.91	374	1.09	2.61	402	1.05	4.56	386	1.76	5.24	371	1.95
6	2.87	399	1.15	2.62	433	1.14	1.94	449	0.87	4.37	394	1.72
7	2.68	428	1.15	2.67	459	1.23	1.83	463	0.85	1.89	440	0.83
8	1.27	445	0.56	1.69	477	0.8	1.04	479	0.5	1.66	458	0.76
9	0.45	486	0.22	0.74	488	0.36	0.62	488	0.3	1.11	479	0.53
10	0.19	523	0.1	0.36	533	0.19	0.32	505	0.16	0.75	488	0.37
11	0.16	499	0.08	0.09	603	0.05	0.08	559	0.04	0.45	494	0.22
12	0.04	547	0.02	0.05	544	0.03	0.07	568	0.04	0.2	523	0.1
13	0.01	677	0.01	0.02	537	0.01	0.04	583	0.02	0.07	511	0.04
14+	0.02	607	0.01	0	569	0	0.02	466	0.01	0.07	664	0.04
TOTAL	29.57	418	8.85	24.37	441	8.98	20.72	431	7.72	24.81	367	9.11

Table 8.6.3.1. Abundance index , mean weight-at-age, and biomass index for mackerel from the IESSNS in 2007 and from 2010 to 2018. Cont.

	2017			2018			2019		
AGE	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)	Number (billions)	W (g)	Biom. t (million)
1	0.86	86	0.07	2.18	67	0.15	0.08	153	0.01
2	0.12	292	0.03	2.5	229	0.57	1.35	212	0.29
3	3.56	330	1.18	0.5	330	0.16	3.81	325	1.24
4	1.95	373	0.73	2.38	390	0.93	1.21	352	0.43
5	3.32	431	1.43	1.2	420	0.5	2.92	428	1.25
6	4.68	437	2.04	1.41	449	0.63	2.86	440	1.26
7	4.65	462	2.15	2.33	458	1.07	1.95	472	0.92
8	1.75	487	0.86	1.79	477	0.85	3.91	477	1.86
9	1.94	536	1.04	1.05	486	0.51	3.82	490	1.87
10	0.63	534	0.33	0.5	515	0.26	1.50	511	0.77
11	0.51	542	0.28	0.56	534	0.3	1.25	524	0.65
12	0.12	574	0.07	0.29	543	0.16	0.58	564	0.33
13	0.08	589	0.05	0.14	575	0.08	0.59	545	0.32
14+	0.04	626	0.03	0.09	643	0.05	0.57	579	0.32
TOTAL	24.22	425	10.29	16.92	368	6.22	26.40	436	11.52

Table 8.6.4.1. Overview of numbers released in the different RFID tagging experiments, and numbers recaptured per year (year 2019 show update per 1th September to demonstrate ongoing process). Recaptures from experiments and recapture years used in 2019 stock assessment, based on decisions in the ICES IBPNEAMac 2019 (ICES, 2019) is 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 2019 (see Slotte, 2019 -WD12- and Tables 8.6.4.2-3). Note also that during tagging off Ireland 2018 two experiments were carried out on same vessel, where the one named Ireland2018-2 was based on fishing and handling mackerel in the same way as with the older steel tag time series (manual jigging and release directly at starboard side, instead of automatic jigging and release through pipes at port side as in rest of RFID time series) for comparison of recapture rates.

Survey	N-Released	2012	2013	2014	2015	2016	2017	2018	2019	All years
Iceland2015	806	0	0	0	6	2	3	0	0	11
Iceland2016	4884	0	0	0	0	59	48	28	13	148
Iceland2017	3890	0	0	0	0	0	28	27	3	58
Iceland2018	1872	0	0	0	0	0	0	5	6	11
Iceland2019	3614	0	0	0	0	0	0	0	0	0
Ireland 2011	18645	27	24	31	24	17	5	9	6	143
Norway2011	31253	9	31	24	34	26	16	20	3	163
Ireland 2012	32136	31	57	60	67	34	21	12	2	284
Ireland2013	22792	0	26	**89**	**109**	61	31	21	7	344
Ireland2014	55184	0	0	112	**321**	**277**	139	91	19	959
Ireland2015	43905	0	0	0	117	**219**	**177**	93	30	636
Ireland2016	43956	0	0	0	0	124	**326**	**185**	70	705
Ireland2017	56073	0	0	0	0	0	137	**344**	114	595
Ireland2018	33475	0	0	0	0	0	0	180	120	300
Ireland2018-2	4661	0	0	0	0	0	0	24	18	42
Ireland2019	51179	0	0	0	0	0	0	0	91	91
All surveys	408325	67	138	316	678	819	931	1039	502	4490

Table 8.6.4.2. Overview of numbers of tons scanned for RFID tags per factory per year. The biomass scanned which is used in 2019 stock assessment, based on decisions in the ICES IBPNEAMac 2019 (ICES, 2019) and evaluation of efficiency of the scanners (WD 12), is outlined and marked grey.

Factory	2012	2013	2014	2015	2016	2017	2018	All years
FO01 Vardin Pelagic	0	0	**10460**	**11565**	**7895**	**4844**	0	34763
GB01 Denholm Coldstore	0	0	0	**4377**	**4710**	**5365**	**7806**	22258
GB01 Denholm Factory	0	0	**14939**	**17509**	**18840**	**17913**	**13609**	82811
GB02 Lunar Freezing Peterhead	0	0	**22586**	**17830**	**16473**	**9745**	**9857**	76491
GB03 Lunar Freezing Fraserburgh	0	0	0	8797	14282	12684	**9452**	45215
GB04 Pelagia Shetland	0	0	**21436**	**41117**	**40200**	**26935**	**25350**	155038
GB05 Northbay Pelagic	0	0	0	0	0	0	**15353**	15353
IC01 Vopnafjord	0	0	**18577**	**18772**	**21716**	**22935**	**18869**	100869
IC02 Neskaupstad	0	0	0	**6288**	**21887**	**19558**	**16757**	64490
NO01 Pelagia Egersund Seafood	20930	21442	36724	14375	15905	0	**48373**	157748
NO02 Skude Fryseri	7546	8250	**16719**	**14172**	**8671**	**16760**	3108	75226
NO03 Pelagia Austevoll	6405	6134	10314	4203	2216	0	**7293**	36564
NO04 Pelagia Florø	9986	12838	**17379**	**12592**	**7749**	0	0	60544
NO05 Pelagia Måløy	13344	14632	**13942**	**21051**	**15762**	**22405**	**13341**	114477
NO06 Pelagia Selje	17731	26878	**39525**	**41209**	**29897**	**35416**	**28972**	219629
NO07 Pelagia Liavågen	9442	10968	**22395**	**18144**	**13911**	**19989**	**12398**	107249
NO08 Brødrene Sperre	14425	15048	**20182**	**34307**	**36736**	**18814**	33960	173473
NO09 Lofoten Viking	0	0	0	0	0	0	3380	3380
NO14 Nils Sperre	0	0	0	0	0	0	**28304**	28304
NO15 Grøntvedt Pelagic	0	0	0	0	0	0	6411	6411
NO16 Vikomar	0	0	0	0	0	0	12512	12512
All factories	99808	116190	265178	286310	276850	233363	315105	1592805

Table 8.6.4.3. Overview of numbers of RFID tagged mackerel recaptured per factory per year. The number of recaptures used in 2019 stock assessment, based on decisions in the ICES IBPNEAMac 2019 (ICES 2019) and evaluation of efficiency of the scanners (WD 12), is outlined and marked grey. Note that two factories, DK01 Sæby and IC03 Höfn, are shown in this table, but not in Table 8.6.4.2 with biomass scanned, to demonstrate that they have had a few recaptures although not functioning properly.

Factory	2012	2013	2014	2015	2016	2017	2018	All years
DK01 Sæby	0	0	0	20	0	0	0	20
FO01 Vardin Pelagic	0	0	**15**	**37**	**23**	**13**	0	88
GB01 Denholm Coldstore	0	0	0	**10**	**10**	**28**	**40**	88
GB01 Denholm Factory	0	0	**25**	**64**	**79**	**119**	**58**	345
GB02 Lunar Freezing Peterhead	0	0	**33**	**51**	**60**	**42**	**42**	228
GB03 Lunar Freezing Fraserburgh	0	0	0	9	16	7	**27**	59
GB04 Pelagia Shetland	0	0	**25**	**130**	**162**	**157**	**108**	582
GB05 Northbay Pelagic	0	0	0	0	0	0	**57**	57
IC01 Vopnafjord	0	0	24	**61**	**81**	**73**	**63**	302
IC02 Neskaupstad	0	0	0	**19**	**93**	**58**	**39**	209
IC03 Höfn	0	0	0	1	0	1	1	3
NO01 Pelagia Egersund Seafood	12	25	19	7	1	0	**148**	212
NO02 Skude Fryseri	6	8	**21**	**19**	**27**	**55**	17	153
NO03 Pelagia Austevoll	1	1	7	5	1	0	**29**	44
NO04 Pelagia Florø	6	19	**33**	**22**	**18**	0	0	98
NO05 Pelagia Måløy	6	19	**21**	**46**	**42**	**89**	**42**	265
NO06 Pelagia Selje	19	35	**38**	**77**	**59**	**102**	**100**	430
NO07 Pelagia Liavågen	10	13	**34**	**34**	**30**	**102**	**50**	273
NO08 Brødrene Sperre	7	18	**21**	**66**	**117**	**85**	58	372
NO09 Lofoten Viking	0	0	0	0	0	0	10	10
NO14 Nils Sperre	0	0	0	0	0	0	**117**	117
NO15 Grøntvedt Pelagic	0	0	0	0	0	0	11	11
NO16 Vikomar	0	0	0	0	0	0	22	22
All factories	67	138	316	678	819	931	1039	3988

Table 8.6.5.2.1. Biomass, abundance, mean length and mean weight at age of mackerel from the Spanish spring acoustics surveys (PELACUS) from 2001 to 2019.

	2001				2002				2003			
AGE	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)
1	29.0	25.9	126.2	3.7	621.4	23.3	80.5	50.0	5678.6	23.1	81.6	463.2
2	47.6	31.0	213.7	10.2	94.8	32.0	221.9	21.0	324.5	28.9	165.1	53.6
3	184.3	33.7	277.3	51.1	378.1	34.3	277.1	104.8	109.0	33.5	261.3	28.5
4	386.6	36.1	340.3	131.6	706.8	35.8	317.9	224.7	229.0	35.0	299.7	68.6
5	382.1	37.5	383.0	146.4	1065.9	36.8	348.0	370.9	265.2	37.1	359.1	95.2
6	393.6	38.0	397.7	156.5	604.6	38.2	390.9	236.3	230.1	38.0	385.7	88.8
7	202.7	39.5	446.7	90.5	674.5	39.1	419.2	282.8	94.3	39.8	443.4	41.8
8	143.5	40.0	464.5	66.7	191.4	39.9	447.2	85.6	88.5	40.1	454.6	40.2
9	83.7	40.5	481.7	40.3	158.4	40.3	461.4	73.1	19.6	41.5	505.1	9.9
10	17.0	40.2	469.3	8.0	100.2	41.0	490.2	49.1	10.0	41.9	519.9	5.2
11	26.3	42.1	541.4	14.2	54.0	41.4	504.0	27.2	14.0	42.6	549.6	7.7
12	12.3	41.9	533.8	6.5	12.4	43.5	586.7	7.3	3.8	41.5	503.1	1.9
13	1.9	41.5	517.1	1.0	0.0	0.0	0.0	0.0	3.7	43.1	566.9	2.1
14	6.1	43.5	596.5	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15+	9.4	42.8	568.1	5.3	2.9	45.5	676.9	2.0	2.0	43.3	578.1	1.2
TOTAL	1926.2	37.3	381.9	735.6	4665.3	35.5	329.0	1534.8	7072.1	25.5	128.4	907.8

	2004				2005				2006			
AGE	Number (mil-lions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)
1	195.2	25.0	114.6	22.4	43.4	24.8	112.1	4.6	83.7	20.8	58.5	4.9
2	952.4	28.3	164.5	156.6	106.5	29.2	181.8	19.0	9.3	29.7	177.2	1.7
3	599.3	32.8	258.1	154.7	229.1	32.3	245.4	56.1	57.3	31.9	223.1	12.8
4	227.5	37.5	377.8	86.0	259.6	36.5	349.4	92.4	230.7	33.5	262.7	60.6
5	425.6	38.1	395.5	168.3	82.6	38.3	403.4	34.2	104.7	36.7	345.0	36.1
6	336.7	39.1	428.4	144.2	163.8	38.8	417.6	70.4	34.2	38.5	398.1	13.6
7	181.5	40.1	461.7	83.8	114.9	39.5	438.4	52.0	22.2	39.2	420.5	9.3
8	106.1	40.8	483.2	51.3	63.8	39.8	451.7	29.8	7.6	40.9	483.3	3.6
9	76.5	41.0	492.5	37.7	33.6	41.0	493.9	17.2	2.0	41.9	513.6	1.0
10	31.1	42.3	538.0	16.7	15.3	42.3	535.4	8.5	3.4	41.3	495.1	1.7
11	18.9	42.2	533.9	10.1	13.7	41.8	518.8	7.4	1.4	42.7	545.7	0.8
12	13.5	43.3	573.8	7.7	6.6	42.0	526.6	3.6	0.5	42.8	551.1	0.3
13	3.2	43.9	599.8	1.9	11.3	42.5	544.1	6.4	0.1	43.8	590.7	0.1
14	0.0	0.0	0.0	0.0	5.1	43.8	592.6	3.2	0.0	0.0	0.0	0.0
15+	5.9	46.4	710.5	4.2	7.3	43.7	594.9	4.6	0.0	44.5	621.0	0.0
TOTAL	3173.2	33.8	298.0	945.6	1156.6	35.9	346.7	409.5	557.3	32.7	263.0	146.6

Table 8.6.5.2.1. Biomass, abundance, mean length and mean weight at age of mackerel from the Spanish spring acoustics surveys (PELACUS) from 2001 to 2019 (cont.).

	2007				2008				2009			
AGE	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)
1	182.2	21.5	64.1	11.7	407.1	24.4	100.4	40.9	7.5	24.3	98.5	0.7
2	34.6	25.6	110.5	3.8	100.5	27.1	135.2	13.6	65.1	29.3	176.1	11.5
3	22.1	33.4	254.5	5.6	327.4	29.8	180.7	59.1	148.4	30.0	189.4	28.1
4	129.6	34.9	291.7	37.8	125.8	33.5	261.9	32.9	201.7	32.5	248.1	50.0
5	189.4	36.1	324.0	61.4	233.6	36.2	328.2	76.5	86.8	35.0	314.3	27.3
6	117.5	38.1	379.7	44.6	277.5	36.3	328.5	91.0	148.8	36.9	370.0	55.0
7	31.9	39.8	435.9	13.9	131.0	37.9	374.1	48.9	180.8	37.7	394.7	71.3
8	20.5	39.7	431.5	8.8	25.2	39.5	423.4	10.6	93.0	39.5	454.8	42.2
9	4.8	41.2	484.0	2.3	20.1	39.5	422.7	8.5	32.6	40.2	484.7	15.7
10	6.1	40.7	464.7	2.8	20.5	40.2	443.6	9.0	14.9	40.7	500.8	7.5
11	1.5	41.4	490.3	0.8	9.2	41.1	474.8	4.4	4.6	41.6	537.0	2.4
12	4.7	44.5	608.6	2.8	7.3	41.8	500.0	3.6	3.5	42.2	561.9	2.0
13	0.7	43.5	567.6	0.4	2.4	43.4	561.4	1.3	4.1	42.4	569.2	2.3
14	2.6	44.0	591.5	1.5	1.1	44.6	607.1	0.7	0.0	0.0	0.0	0.0
15+	0.7	46.5	697.9	0.5	0.4	46.5	690.3	0.3	0.0	0.0	0.0	0.0
TOTAL	748.9	32.5	265.4	198.8	1689.2	31.7	238.0	401.4	991.8	34.8	319.0	316.2

	2010				2011				2012			
AGE	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)
1	431.8	23.6	89.2	38.6	1936.9	22.5	77.4	149.3	698.05	22.07	74.36	51.83
2	72.7	30.6	194.8	14.2	29.7	30.5	201.3	6.0	16.7	27.71	150.62	2.5
3	189.6	31.5	214.9	40.9	63.1	32.3	239.2	15.1	11.18	33.27	265.58	2.98
4	662.7	33.6	262.3	174.1	90.6	33.7	273.6	24.7	32.34	34.63	299.04	9.69
5	873.3	35.0	296.3	258.8	154.8	35.0	308.5	47.6	60.04	35.62	325.28	19.53
6	306.6	36.8	346.3	106.1	144.1	36.1	340.6	49.0	147.09	36.58	353.17	51.84
7	388.9	38.1	385.6	149.8	57.7	38.2	406.2	23.4	121.31	37.66	386.73	46.77
8	239.2	38.2	388.3	92.8	54.2	39.5	446.9	24.1	61.9	39.43	445.95	27.53
9	113.9	39.5	427.5	48.6	31.2	39.6	451.5	14.0	32.39	40.12	470.22	15.19
10	26.4	40.8	470.2	12.4	10.3	41.0	503.5	5.2	19.11	40.54	485.42	9.26
11	16.5	40.9	475.8	7.8	4.7	41.0	503.1	2.4	8.07	40.66	489.56	3.94
12	10.3	41.4	492.4	5.0	3.1	41.8	533.3	1.6	2.78	41.94	538.24	1.49
13	7.5	41.9	509.7	3.8	2.4	41.6	527.1	1.2	1.36	42.38	555.37	0.75
14	5.3	42.4	530.5	2.8	0.0	0.0	0.0	0.0	1.36	42.38	555.37	0.75
15+	3.0	43.1	557.7	1.7	0.0	0.0	0.0	0.0	1.19	44.53	649.03	0.78
TOTAL	3347.8	34.0	286.0	957.5	2582.9	25.8	141.2	363.7	1214.88	28.46	201.91	244.81

Table 8.6.5.2.1. Biomass, abundance, mean length and mean weight at age of mackerel from the Spanish spring acoustics surveys (PELACUS) from 2001 to 2019 (cont.).

	2013				2014				2015			
AGE	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)
1	99	24.5	93.0	9	68.1	22.5	71.5	5.1	101.38	22.34	69.55	7.50
2	653	26.5	119.1	81	42.8	32.0	217.4	9.1	11.91	31.88	214.66	2.60
3	123	28.6	152.4	20	157.4	32.3	223.7	34.6	43.16	32.69	232.42	10.20
4	114	34.2	267.6	31	340.4	33.3	245.5	81.9	112.36	34.05	264.52	29.81
5	228	35.3	296.0	68	675.8	34.5	275.3	181.7	299.50	35.09	290.94	86.92
6	235	36.2	322.3	76	581.1	36.1	318.0	179.5	348.66	36.40	326.84	112.95
7	178	36.7	335.3	60	502.4	36.6	333.9	163.0	344.06	37.03	345.17	117.63
8	64	37.6	361.4	23	246.9	36.7	335.2	80.4	164.59	37.02	344.84	56.24
9	11	38.1	378.2	4	84.5	38.2	381.8	31.3	71.17	38.37	386.31	27.15
10	8	40.0	439.4	4	33.1	39.2	414.3	13.3	29.50	39.17	412.51	12.00
11	3	40.8	470.1	1	34.7	39.4	420.9	14.2	29.95	39.24	414.69	12.25
12	2	41.2	490.3	1	34.7	39.4	420.9	14.2	29.95	39.24	414.69	12.25
13												0
14												0
15+												0
TOTAL	1718	31.2	200.2	379	2802.0	35.1	291.0	808.4	1586.20	35.40	299.24	487.49

	2016				2017				2018			
AGE	Number (millions)	L (cm)	W (g)	Bio-mass t ('000)	Num-ber (mil-lions)	L (cm)	W (g)	Bio-mass t ('000)	Num-ber (mil-lions)	L (cm)	W (g)	Bio-mass t ('000)
1	12.61	22.4	74.0	1.0	170.5	21.9	67.2	12.4		22.72	81.99	5.3
2	73.54	28.0	144.1	11.2	12.4	27.8	141.3	1.9		27.46	142.93	5.1
3	26.62	30.9	193.1	5.3	91.4	62.8	234.2	22.6		33.56	256.69	10.1
4	54.98	34.5	268.2	14.8	115.6	64.8	283.1	34.5		35.73	309.38	30.9
5	230.22	35.7	297.7	68.9	438.3	65.4	298.2	137.2		35.99	315.99	124.3
6	406.48	36.4	315.3	128.9	421.2	36.1	316.4	139.9		36.52	329.78	143.6
7	318.08	37.3	337.3	107.8	278.3	37.1	344.8	100.7		37.33	351.83	116.2
8	271.41	37.8	353.4	96.2	128.7	38.1	374.3	50.4		38.04	371.91	58.1
9	102.70	38.3	365.1	37.6	84.4	38.2	377.0	33.2		38.12	374.13	41.8
10	50.36	38.4	367.8	18.6	21.8	38.4	384.1	8.7		38.30	379.46	10.8
11	13.83	38.9	383.8	5.3	11.8	40.1	439.1	5.4		40.10	434.16	7.0
12	5.31	39.4	398.6	2.1	2.7	39.5	418.0	1.2		41.64	484.65	3.4
13		-	-	-								
14	-	-		-								
15+	´-	-	-	-								
TO-TAL	1566.14	36.3	311.7	497.7	1777.0	34.7	280.4	548.2		36.10	318.83	556.53

Table 8.6.5.2.1. Biomass, abundance, mean length and mean weight at age of mackerel from the Spanish spring acoustics surveys (PELACUS) from 2001 to 2019 (cont.).

	2019			
AGE	**Number (millions)**	**L (cm)**	**W (g)**	**Biomass t ('000)**
1	11	25.0	113.4	1
2	27	27.6	152.1	4
3	98	33.3	262.4	27
4	86	34.9	300.9	27
5	773	35.3	310.6	251
6	379	36.7	348.6	138
7	517	37.3	363.5	196
8	385	37.3	363.5	147
9	188	38.0	384.3	75
10	48	39.6	433.6	22
11	27	39.6	434.5	12
12	10	41.1	484.9	5
13				
14				
15+				
TOTAL	2549	36.3	338.0	905

Table 8.6.5.2.2. Mackerel abundance and biomass by ICES sub-divisions from Spanish spring acoustic surveys (PELACUS) from 2001 to 2018.

	ICES 9.a-N		ICES 8.c-W		8.c-EW		8.c-EE		TOTAL	
	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)
2001	0.02	7.4	0.31	120.1	1.23	489.1	0.36	119.1	1.93	735.7
2002	0.00	0.0	0.82	333.7	3.80	1191.1	0.04	10.0	4.67	1534.8
2003	4.58	376.6	1.07	184.4	0.88	202.5	0.54	144.3	7.14	907.8
2004	0.61	118.6	1.03	304.3	1.50	515.7	0.03	7.0	3.17	945.6
2005	0.16	45.6	0.23	13.0	0.60	228.6	0.16	32.3	1.06	409.5
2006	0.01	0.7	0.39	100.5	0.15	41.5	0.02	4.0	0.56	146.6
2007	0.16	11.2	0.22	77.4	0.36	108.4	0.01	1.8	0.75	198.8
2008	0.16	21.4	0.38	109.0	0.84	235.0	0.05	4.2	1.42	369.7
2009	0.06	11.8	0.04	10.1	0.57	220.2	0.33	74.1	0.99	316.2
2010	0.38	34.2	0.88	293.7	2.09	628.6	0.00	1.0	3.35	957.5
2011	1.42	109.2	0.51	39.4	0.65	212.4	0.01	2.7	2.58	363.7
2012	0.61	45.03	0.02	1.3	0.57	190.7	0.02	7.8	1.21	244.8
2013	0.00	00.00	0.46	58.0	1.06	270.9	0.19	49.7	1.72	378.6
2014*	0.02	2.4	0.03	3.0			2.75	803	2.80	808.4
2015*	0.21	73.6	0.3	7.4			1.36	410	1.57	483.3
2016*	0.00	0.2	0.09	13.7			1.48	484	1.57	498
2017*	.17	14.7	0.36	119.0			1.25	415	1.78	548.7
2018*	0.10	27.8	0.01	031			1.55	528*	1.64	556.5
2019	0.03	4.8	0.38	145.1			2.1	755	2.55	905.0

*** Without split between 8.c-EW and 8.c-EE.**

Table 8.7.1.1.1. 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 -2018		Yes
Catch-at-age in numbers	1980 -2018	0-12+	Yes
Weight-at-age in the commercial catch	1980 – 2018	0-12+	Yes
Weight-at-age of the spawning stock at spawning time.	1980 – 2018	0-12+	Yes
Proportion of natural mortality before spawning	1980 -2019	0-12+	Yes
Proportion of fishing mortality before spawning	1980 -2019	0-12+	Yes
Proportion mature-at-age	1980 -2019	0-12+	Yes
Natural mortality	1980 -2019	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)	1998-2018	Age 0
Survey (abundance index)	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)	2010, 2012-2019	Ages 3-11
Tagging/recapture	Norwegian tagging program	Steal tags : 1980 (release year)-2006 (recapture years) RFID tags : 2013 (release year) 2018 (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	No catchability parameter for the catches

	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	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 8.7.1.1.2. NE Atlantic Mackerel. CATCH IN NUMBER

Units : thousands

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	33101	56682	11180	7333	287287	81799	49983	7403	57644	65400
1	411327	276229	213936	47914	31901	268960	58126	40126	152656	64263
2	393025	502365	432867	668909	86064	20893	424563	156670	137635	312739
3	64549	231814	472457	433744	682491	58346	38387	663378	190403	207689
4	328206	32814	184581	373262	387582	445357	76545	56680	538394	167588
5	254172	184867	26544	126533	251503	252217	364119	89003	72914	362469
6	142978	173349	138970	20175	98063	165219	208021	244570	87323	48696
7	145385	116328	112476	90151	22086	62363	126174	150588	201021	58116
8	54778	125548	89672	72031	61813	19562	42569	85863	122496	111251
9	130771	41186	88726	48668	47925	47560	13533	34795	55913	68240
10	39920	146186	27552	49252	37482	37607	32786	19658	20710	32228
11	56210	31639	91743	19745	30105	26965	22971	25747	13178	13904
12	104927	199615	156121	132040	69183	97652	81153	63146	57494	35814

age \ year	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
0	23453	30429	23872	11325	62100	6732	716	28306	9453
1	78605	62708	66196	47020	43173	104019	45199	43458	46107
2	137101	115346	200167	235411	137788	124411	203753	87739	238898
3	303928	322725	214043	399751	669949	248852	257293	458301	137575
4	739221	469953	415884	370551	829399	579835	424843	351779	378240
5	611729	654395	456404	442597	564508	646894	589549	396862	257689
6	284788	488713	511270	429324	549985	450344	532890	503601	295537
7	143039	244210	323835	336701	503300	415107	340155	431014	425922
8	102072	113012	142948	188910	339538	355997	269962	261959	317671
9	45841	53363	69551	112765	141344	205691	170373	188950	198527
10	21222	25046	30619	45938	63614	107685	94778	138143	140781
11	6255	12311	11603	18928	21294	26939	33896	59211	83063
12	8523	10775	11678	17857	13136	22700	24420	51090	60587

Table 8.7.1.1.3. 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	0.127	0.154
2	0.263	0.268	0.197	0.215	0.222	0.213	0.221	0.231	0.187	0.234	0.232	0.242
3	0.323	0.306	0.307	0.292	0.292	0.283	0.291	0.282	0.285	0.277	0.282	0.294
4	0.400	0.366	0.357	0.372	0.370	0.331	0.331	0.334	0.340	0.336	0.324	0.320
5	0.419	0.434	0.428	0.408	0.418	0.389	0.365	0.368	0.375	0.360	0.362	0.351
6	0.485	0.440	0.479	0.456	0.444	0.424	0.418	0.411	0.401	0.386	0.395	0.392
7	0.519	0.496	0.494	0.512	0.497	0.450	0.471	0.451	0.431	0.406	0.422	0.420
8	0.554	0.539	0.543	0.534	0.551	0.497	0.487	0.494	0.469	0.431	0.444	0.443
9	0.573	0.556	0.584	0.573	0.571	0.538	0.515	0.540	0.503	0.454	0.468	0.465
10	0.595	0.583	0.625	0.571	0.620	0.586	0.573	0.580	0.537	0.472	0.482	0.489
11	0.630	0.632	0.636	0.585	0.595	0.599	0.604	0.611	0.538	0.493	0.523	0.522
12	0.684	0.655	0.689	0.666	0.662	0.630	0.630	0.664	0.585	0.554	0.583	0.560

	year		
age	2016	2017	2018
0	0.035	0.018	0.055
1	0.158	0.178	0.133
2	0.240	0.266	0.246
3	0.297	0.312	0.319
4	0.329	0.356	0.354
5	0.356	0.377	0.396
6	0.383	0.397	0.410
7	0.411	0.415	0.426
8	0.438	0.444	0.446
9	0.453	0.466	0.469
10	0.479	0.484	0.491
11	0.499	0.497	0.507
12	0.520	0.531	0.537

Table 8.7.1.1.4. NE Atlantic Mackerel. WEIGHTS AT AGE IN THE STOCK

Units : Kg

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	0.125	0.123	0.122	0.122	0.119	0.123	0.115	0.076	0.111	0.114	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	0.534	0.531	0.544	0.528	0.567	0.591	0.542	0.581	0.594	0.556	0.536	0.615

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	0.201	0.185	0.196	0.172	0.210	0.194	0.190	0.206	0.181
3	0.260	0.266	0.240	0.278	0.250	0.257	0.248	0.260	0.253	0.246	0.245	0.251
4	0.308	0.323	0.306	0.327	0.322	0.310	0.299	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	0.383	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	0.416	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	0.568	0.577	0.604	0.602	0.573	0.585	0.547	0.576	0.551	0.574	0.557	0.540

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	0.106	0.108	0.083	0.133	0.107	0.096	0.080	0.089	0.076	0.107	0.078
2	0.158	0.140	0.164	0.149	0.160	0.162	0.161	0.175	0.155	0.144	0.165	0.207
3	0.258	0.221	0.236	0.206	0.207	0.214	0.201	0.223	0.216	0.179	0.199	0.247
4	0.318	0.328	0.291	0.288	0.260	0.268	0.249	0.274	0.255	0.249	0.238	0.254
5	0.355	0.378	0.333	0.330	0.346	0.295	0.297	0.332	0.288	0.281	0.291	0.288
6	0.406	0.403	0.400	0.362	0.354	0.351	0.342	0.369	0.312	0.318	0.321	0.336
7	0.449	0.464	0.413	0.451	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	0.411	0.430	0.390	0.374	0.387	0.381
9	0.506	0.547	0.455	0.508	0.452	0.461	0.442	0.452	0.453	0.414	0.416	0.412
10	0.519	0.538	0.469	0.527	0.478	0.517	0.491	0.495	0.498	0.441	0.466	0.447
11	0.579	0.509	0.531	0.533	0.487	0.548	0.535	0.518	0.503	0.500	0.472	0.485
12	0.588	0.603	0.566	0.586	0.511	0.559	0.573	0.525	0.557	0.520	0.517	0.549

age	2016	2017	2018
0	0.000	0.000	0.000
1	0.059	0.058	0.063
2	0.183	0.204	0.191
3	0.240	0.237	0.266

4	0.282	0.278	0.283
5	0.299	0.308	0.314
6	0.335	0.308	0.327
7	0.364	0.338	0.346
8	0.382	0.377	0.364
9	0.403	0.394	0.389
10	0.427	0.426	0.419
11	0.441	0.430	0.437
12	0.469	0.494	0.488

Table 8.7.1.1.5. 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
0	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
2	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
4	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
6	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

8	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
10	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
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Table 8.7.1.1.6. NE Atlantic Mackerel. PROPORTION MATURE

	year											
age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.093	0.097	0.097	0.098	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
2	0.521	0.497	0.498	0.485	0.467	0.516	0.522	0.352	0.360	0.372	0.392	0.435
3	0.872	0.837	0.857	0.863	0.853	0.885	0.926	0.922	0.901	0.915	0.909	0.912
4	0.949	0.934	0.930	0.940	0.938	0.940	0.983	0.994	0.989	0.994	0.996	0.991
5	0.972	0.976	0.969	0.972	0.966	0.966	0.965	0.997	0.994	0.996	0.998	0.996
6	0.984	0.984	0.987	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996
7	0.990	0.987	0.985	0.984	0.975	0.976	1.000	1.000	1.000	1.000	1.000	1.000
8	1.000	0.999	0.999	0.999	0.999	0.999	0.991	0.992	0.991	0.993	0.995	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	year											
age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.102	0.102	0.102	0.102	0.102	0.097	0.097	0.097	0.104	0.104	0.104	0.106
2	0.520	0.534	0.621	0.599	0.586	0.621	0.688	0.669	0.692	0.675	0.710	0.690
3	0.928	0.934	0.938	0.931	0.936	0.880	0.886	0.876	0.909	0.909	0.937	0.940
4	0.996	0.996	0.994	0.993	1.000	0.993	0.994	0.989	0.989	0.987	0.992	0.988
5	0.997	0.997	0.997	0.994	1.000	0.998	0.999	0.999	0.998	0.998	1.000	1.000
6	0.994	0.994	0.993	0.987	0.994	0.999	0.999	0.999	0.999	0.999	1.000	1.000
7	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	0.999	1.000	0.999
8	1.000	1.000	1.000	1.000	1.000	0.994	0.995	0.996	0.997	0.997	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	year											
age	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.106	0.106	0.095	0.095	0.095	0.096	0.096	0.096	0.094	0.092	0.092	0.104
2	0.761	0.616	0.589	0.546	0.524	0.541	0.667	0.655	0.604	0.683	0.675	0.763
3	0.962	0.959	0.928	0.921	0.917	0.919	0.930	0.927	0.926	0.921	0.916	0.944
4	0.993	0.993	0.994	0.994	0.999	0.999	0.999	0.999	0.999	0.998	0.999	0.998
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
0	0.000	0.000	0.000
1	0.103	0.101	0.086
2	0.632	0.624	0.459
3	0.937	0.931	0.878
4	0.997	0.997	0.998
5	0.999	1.000	1.000
6	1.000	1.000	1.000
7	0.999	1.000	1.000
8	1.000	1.000	1.000
9	1.000	1.000	1.000
10	1.000	1.000	1.000
11	1.000	1.000	1.000
12	1.000	1.000	1.000

Table 8.7.1.1.7. 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	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.177	0.179
2	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.174	0.177	0.179
3	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.253	0.285
4	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.253	0.285
5	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
6	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
7	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
8	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
9	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
10	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
11	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403
12	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.381	0.392	0.403

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	0.181	0.216	0.252	0.287	0.250	0.212	0.175	0.179	0.183	0.187	0.201	0.216
2	0.181	0.216	0.252	0.287	0.250	0.212	0.175	0.179	0.183	0.187	0.201	0.216
3	0.316	0.318	0.321	0.323	0.328	0.334	0.339	0.364	0.390	0.415	0.408	0.400
4	0.316	0.318	0.321	0.323	0.328	0.334	0.339	0.364	0.390	0.415	0.408	0.400
5	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
6	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
7	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
8	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
9	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
10	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
11	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420
12	0.414	0.439	0.464	0.489	0.492	0.494	0.497	0.462	0.425	0.390	0.405	0.420

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	0.231	0.230	0.229	0.229	0.197	0.165	0.133	0.126	0.119	0.111	0.137	0.164
2	0.231	0.230	0.229	0.229	0.197	0.165	0.133	0.126	0.119	0.111	0.137	0.164

3	0.393	0.375	0.357	0.338	0.305	0.270	0.237	0.183	0.129	0.075	0.121	0.168
4	0.393	0.375	0.357	0.338	0.305	0.270	0.237	0.183	0.129	0.075	0.121	0.168
5	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
6	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
7	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
8	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
9	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
10	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
11	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183
12	0.434	0.402	0.368	0.336	0.305	0.272	0.241	0.232	0.223	0.214	0.199	0.183

	year		
age	2016	2017	2018
0	0.000	0.000	0.000
1	0.191	0.188	0.268
2	0.191	0.188	0.268
3	0.216	0.157	0.196
4	0.216	0.157	0.196
5	0.174	0.286	0.190
6	0.174	0.286	0.190
7	0.174	0.286	0.190
8	0.174	0.286	0.190
9	0.174	0.286	0.190
10	0.174	0.286	0.190
11	0.174	0.286	0.190
12	0.174	0.286	0.190

Table 8.7.1.1.8. 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
0	0.343	0.327	0.312
1	0.343	0.327	0.312
2	0.343	0.327	0.312
3	0.343	0.327	0.312
4	0.343	0.327	0.312
5	0.343	0.327	0.312
6	0.343	0.327	0.312
7	0.343	0.327	0.312
8	0.343	0.327	0.312
9	0.343	0.327	0.312
10	0.343	0.327	0.312
11	0.343	0.327	0.312
12	0.343	0.327	0.312

Table 8.7.1.1.9. NE Atlantic Mackerel. SURVEY INDICES

Some random text

103

SSB-egg-based-survey

1992 2019

1 1 0 0

-1 -1

1 3874476.93
1 -1
1 -1

```
1               3766378.516
1               -1
1               -1
1               4198626.531
1               -1
1               -1
1               3233833.244
1               -1
1               -1
1               3106808.703
1               -1
1               -1
1               3782966.707
1               -1
1               -1
1               4810751.571
1               -1
1               -1
1               4831948.353
1               -1
1               -1
1               3524054.85
1               -1
1               -1
1               3092415.70
R-idx(sqrt transf)

1998            2018

1               1               0               0

0               0

1               0.00537
1               0.008018
1               0.005652
1               0.008848
1               0.011184
1               0.005732
1               0.013097
1               0.016542
1               0.0152
1               0.00999
1               0.009151
1               0.006446
1               0.009707
1               0.016199
1               0.011892
1               0.013118
1               0.009979
1               0.010863
1               0.018963
1               0.019512
```

1 0.017155

Swept-idx

2010 2019

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			

Table 8.7.1.2.1. NE Atlantic Mackerel. SAM parameter estimates for the 2019 update.

	esti-mate	std.dev	confidence interval lower bound	confidence interval upper bound
observation standard deviations				
Catches age 0	0.97	0.19	0.66	1.42
Catches age 1	0.37	0.25	0.23	0.61
Catches age 2-12	0.11	0.17	0.08	0.15
Egg survey	0.32	0.26	0.19	0.54
Recruitment index	0.19	0.36	0.09	0.39
IESSNS age 3	0.62	0.26	0.37	1.06
IESSNS ages 4-11	0.34	0.15	0.25	0.46
Recapture overdispersion tags	1.23	0.25	1.37	1.14
random walk standard deviation				
F age 0	0.24	0.58	0.07	0.76
F age 1	0.17	0.48	0.07	0.45
F age 2+	0.12	0.20	0.08	0.17
N@age0	0.27	0.29	0.15	0.49
process error standard deviation				
N@age1-12+	0.20	0.09	0.17	0.24
catchabilities				
egg survey	1.23	0.11	0.98	1.55
recruitment index	0.00	0.11	0.00	0.00
IESSNS age 3	0.86	0.24	0.53	1.40
IESSNS age 4	1.27	0.16	0.92	1.75
IESSNS age 5	1.67	0.16	1.21	2.30
IESSNS age 6	2.00	0.16	1.45	2.78
IESSNS age 7	2.14	0.17	1.54	2.98
IESSNS age 8	2.04	0.17	1.46	2.85
IESSNS age 9	2.07	0.17	1.48	2.88
IESSNS ages 10-11	1.77	0.16	1.28	2.44

post tagging survival steal tags	0.40	0.11	0.35	0.45
post tagging survival RFID tags	0.13	0.11	0.11	0.16

Table 8.7.1.3.1. NE Atlantic Mackerel. STOCK SUMMARY. Low = lower limit and High = higher limit of 95% confidence interval.

Year	Recruitment Age 0 thousands	High	Low	SSB tonnes	High	Low	Total Catch tonnes	F Ages 4-8 per year	High	Low
1980	5811487	2993662	11281629	4133735	1978488	8636782	734950	0.225	0.149	0.341
1981	5081028	2931698	8806106	3619938	1955059	6702587	754045	0.225	0.151	0.335
1982	3613849	2041350	6397678	3493680	2105977	5795789	716987	0.226	0.154	0.330
1983	3372139	1876687	6059250	3731743	2507647	5553376	672283	0.227	0.158	0.325
1984	4359034	2642350	7191015	4010169	2874270	5594970	641928	0.228	0.162	0.322
1985	4140770	2570310	6670781	3978339	2973239	5323213	614371	0.231	0.167	0.320
1986	4128829	2615106	6518751	3562706	2718570	4668953	602201	0.235	0.173	0.320
1987	4388517	2797577	6884198	3528345	2695161	4619100	654992	0.240	0.179	0.321
1988	3762477	2436833	5809274	3473395	2718784	4437452	680491	0.246	0.187	0.323
1989	3573130	2312000	5522172	3257928	2592729	4093792	585920	0.254	0.197	0.329
1990	3214451	2046045	5050081	3327951	2692831	4112868	626107	0.265	0.208	0.337
1991	3346363	2174251	5150345	3226517	2637787	3946646	675665	0.277	0.220	0.348
1992	3456082	2244504	5321666	2968248	2448778	3597914	760690	0.290	0.233	0.362
1993	3112788	2034941	4761538	2648332	2199450	3188824	824568	0.302	0.244	0.374
1994	2943059	1928161	4492155	2329018	1947957	2784623	819087	0.310	0.252	0.380
1995	2792843	1818532	4289157	2303399	1941410	2732882	756277	0.310	0.256	0.376
1996	2994638	1932217	4641226	2185774	1848588	2584463	563472	0.306	0.256	0.365
1997	2926988	1936803	4423402	2148580	1839814	2509165	573029	0.304	0.257	0.360
1998	2977574	2171685	4082521	2118079	1810296	2478192	666316	0.310	0.264	0.364
1999	3528098	2547705	4885760	2302099	1973069	2685997	640309	0.322	0.276	0.374
2000	2952146	2112975	4124594	2283798	2001413	2606025	738606	0.336	0.294	0.383
2001	4749644	3452779	6533612	2172227	1907342	2473899	737463	0.363	0.315	0.419
2002	5646271	4025264	7920072	2066525	1792202	2382837	771422	0.386	0.330	0.451

Year	Recruitment Age 0 thousands	High	Low	SSB tonnes	High	Low	Total Catch tonnes	F Ages 4-8 per year	High	Low
2003	3696698	2502549	5460662	2001924	1734279	2310873	679287	0.400	0.337	0.476
2004	5397194	3828829	7607994	2623839	2236181	3078701	660491	0.375	0.318	0.442
2005	7070591	4816015	10380629	2356722	2003961	2771579	549514	0.315	0.272	0.365
2006	6866257	4799793	9822401	2154446	1833349	2531780	481181	0.296	0.256	0.344
2007	5176997	3756146	7135318	2282022	1954818	2663993	586206	0.324	0.280	0.376
2008	4658201	3364249	6449832	2651098	2237447	3141224	623165	0.317	0.272	0.368
2009	4188877	2840952	6176341	3272629	2755301	3887090	737969	0.294	0.252	0.344
2010	5507435	3939474	7699466	3650817	3094848	4306662	875515	0.288	0.245	0.338
2011	7152461	4951329	10332115	4115518	3480137	4866903	946661	0.286	0.241	0.338
2012	5944485	4300959	8216050	3780926	3174452	4503266	892353	0.270	0.225	0.325
2013	5795704	4157315	8079781	4185895	3493207	5015939	931732	0.273	0.226	0.330
2014	5807466	4177963	8072513	5229726	4368401	6260879	1393000	0.278	0.229	0.338
2015	5273724	3777291	7362995	5195560	4304180	6271543	1208990	0.265	0.215	0.325
2016	7454724	4935333	11260215	4896846	4021132	5963271	1094066	0.241	0.193	0.302
2017	8514386	5650073	12830766	4692164	3801919	5790867	1155944	0.241	0.191	0.305
2018	8417954	5641595	12560625	4279185	3368975	5435312	1026437	0.238	0.182	0.310

*** Time-tapered weighted mean of recruitment estimates for 1990-2016.**

**** Geometric mean 1990–2016.**

***** Estimated value from the forecast.**

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Table 8.7.1.3.2. NE Atlantic Mackerel. ESTIMATED POPULATION ABUNDANCE

Units : Thousands

age	1980	1981	1982	1983	1984	1985	1986	1987
0	5811487	5081028	3613849	3372139	4359034	4140770	4128829	4388517
1	5066727	5336916	4836475	2678222	2430810	4350004	3431733	3400436
2	2356914	4207417	4775209	4488699	1942279	1717024	4228815	2785062
3	971920	1900616	3509680	4414944	4431183	1366235	1220034	4105793
4	1667214	745535	1428708	2919746	3904993	4079146	1023220	837081
5	3532918	1227527	534141	981668	2204394	3127743	3167500	798035
6	2720078	2458671	871816	388128	669736	1619976	2258697	2167274
7	796744	1809490	1633840	583783	268768	459718	1072754	1506920
8	295072	543030	1235375	1113115	394745	190838	306700	750523
9	817621	201096	369765	843094	756721	271045	133121	203735
10	219293	557548	136989	251506	574522	513448	187494	90283
11	321051	149463	379660	93279	170967	390066	346585	126377
12	670122	676226	562212	639426	496779	452475	567162	611101

age	1988	1989	1990	1991	1992	1993	1994	1995
0	3762477	3573130	3214451	3346363	3456082	3112788	2943059	2792843
1	4227661	3033117	3129422	2538719	2880073	3168710	2592044	2507014
2	2746398	3976245	2392196	2673416	1960756	2421052	2834665	2103094
3	2197614	2369434	3922898	2125376	2540241	1623864	1980696	2397052
4	3742417	1693417	1845461	3033097	1519690	2021591	1095526	1427841
5	532325	2963250	1092446	1258271	1921266	987028	1382143	686011
6	603519	344106	1958216	775256	937460	1149156	587857	963596
7	1407812	457354	213861	1210712	471761	563756	643823	346178
8	1032219	1044471	341785	136533	727737	308354	336294	287197
9	523307	710921	707747	240048	88068	413582	183596	179611
10	134667	353719	460208	477409	154452	53056	221677	111076
11	60869	86834	234273	289782	300008	94909	30336	135809
12	491084	365448	296881	344108	403220	438340	326376	215920

age	1996	1997	1998	1999	2000	2001	2002	2003
0	2994638	2926988	2977574	3528098	2952146	4749644	5646271	3696698
1	2237518	2681714	2442259	2639368	3164303	1831918	5225586	6546657
2	2082761	1747234	2340997	1985763	2287288	2633917	1162604	4838263
3	2165772	1936746	1257137	2362967	1849592	1763267	2517487	798499
4	1811766	1783097	1634555	1259527	1840505	1314230	1545782	1564105
5	977367	1212140	1503291	1262108	1034238	1244403	985542	912708
6	494593	727191	859452	904037	857830	676977	802017	575099
7	571367	323932	478737	609850	613375	598927	411157	379253
8	216439	345325	261064	308331	371112	406402	345210	241512
9	141874	151886	210019	178440	188868	236538	227586	194314
10	95846	88654	101606	129476	111914	126110	127014	117130
11	64806	51494	54473	62675	69292	67734	62863	66410
12	213886	173268	142706	125678	120876	125587	111456	81303

age	2004	2005	2006	2007	2008	2009	2010	2011
0	5397194	7070591	6866257	5176997	4658201	4188877	5507435	7152461
1	2782018	4115431	6257389	5837497	4253706	4050708	3931871	5468140
2	6903746	2366385	3456976	4928830	4914299	3467381	3889809	3248914
3	3935453	5359600	1688164	2468583	4407270	4959973	3324633	3582565

4	748161	1855893	3137021	1441641	1932829	3865976	4564342	2973954
5	995776	530813	1013461	2037647	1201501	1553094	2895012	3260361
6	474183	472969	366991	731893	1080211	875286	1202387	2022930
7	265787	228543	275871	250053	412211	668360	543054	865890
8	183896	132749	129095	180661	173670	255774	360937	392261
9	116257	86043	71915	92813	99590	106161	162364	197104
10	91785	61559	51620	46423	57232	51047	71441	89927
11	47235	30896	31318	33550	21592	27854	24443	43745
12	56812	39794	37692	38940	30660	19938	30667	37263

	year							
age	2012	2013	2014	2015	2016	2017	2018	2019
0	5944485	5795704	5807466	5273724	7454724	8514386	8417954	8417954
1	6764044	4660042	4364061	5887265	3554837	6253009	6665681	7219298
2	5483351	6641401	3731239	3369114	5208571	2251622	5663515	5558268
3	2629623	5116627	6744045	2874181	2655377	4415613	1454336	4466194
4	2877283	2339308	4850744	4459795	2616745	2057688	2837967	1065094
5	2310697	2357877	2251610	3382451	3169647	2011058	1396565	1838158
6	2243752	2017883	2105139	1747398	2503277	2421971	1311630	1155087
7	1268941	1476690	1805233	1627215	1372480	2088658	1908878	766610
8	559947	786322	1205200	1333183	1175988	1082969	1499558	1329015
9	249717	374251	541573	850072	785497	924875	882297	1133087
10	117817	153492	243436	407131	465747	569871	605599	565355
11	49392	75314	83145	120934	200296	311841	407462	460681
12	46190	63107	57208	89478	118166	226285	296018	460899

units: NA

Table 8.7.1.3.3. NE Atlantic Mackerel. ESTIMATED FISHING MORTALITY

	year						
age	1980	1981	1982	1983	1984	1985	1986
0	0.0079637	0.0079821	0.0079918	0.0080282	0.0081053	0.0080973	0.0080419
1	0.0318048	0.0317035	0.0316022	0.0315436	0.0314226	0.0312491	0.0311197
2	0.0590627	0.0589670	0.0588420	0.0588308	0.0589727	0.0589586	0.0589003
3	0.1143646	0.1144215	0.1143559	0.1146084	0.1155079	0.1171984	0.1189421
4	0.1852804	0.1855727	0.1861833	0.1863764	0.1872804	0.1896991	0.1933297
5	0.2126300	0.2128668	0.2134704	0.2151041	0.2165622	0.2191039	0.2226244
6	0.2593009	0.2597709	0.2606091	0.2617647	0.2644178	0.2681483	0.2723270
7	0.2336101	0.2338513	0.2341282	0.2347044	0.2357387	0.2387384	0.2431078
8	0.2336101	0.2338513	0.2341282	0.2347044	0.2357387	0.2387384	0.2431078
9	0.2336101	0.2338513	0.2341282	0.2347044	0.2357387	0.2387384	0.2431078
10	0.2336101	0.2338513	0.2341282	0.2347044	0.2357387	0.2387384	0.2431078
11	0.2336101	0.2338513	0.2341282	0.2347044	0.2357387	0.2387384	0.2431078
12	0.2336101	0.2338513	0.2341282	0.2347044	0.2357387	0.2387384	0.2431078

	year						
age	1987	1988	1989	1990	1991	1992	1993
0	0.0079613	0.0079592	0.0079186	0.0078394	0.0077524	0.0077054	0.0076400
1	0.0310186	0.0309753	0.0309986	0.0310071	0.0309902	0.0309350	0.0308831
2	0.0590065	0.0590752	0.0592226	0.0595768	0.0600065	0.0606068	0.0612113
3	0.1203655	0.1226368	0.1250483	0.1276805	0.1304954	0.1330712	0.1360127
4	0.1984633	0.2025169	0.2084142	0.2134091	0.2183330	0.2220026	0.2247438
5	0.2262146	0.2317444	0.2364785	0.2409026	0.2464809	0.2544704	0.2603452
6	0.2773143	0.2825125	0.2923300	0.3016604	0.3105762	0.3186741	0.3257536
7	0.2487956	0.2561388	0.2672094	0.2836643	0.3049666	0.3276275	0.3496797
8	0.2487956	0.2561388	0.2672094	0.2836643	0.3049666	0.3276275	0.3496797
9	0.2487956	0.2561388	0.2672094	0.2836643	0.3049666	0.3276275	0.3496797
10	0.2487956	0.2561388	0.2672094	0.2836643	0.3049666	0.3276275	0.3496797
11	0.2487956	0.2561388	0.2672094	0.2836643	0.3049666	0.3276275	0.3496797
12	0.2487956	0.2561388	0.2672094	0.2836643	0.3049666	0.3276275	0.3496797

	year						
age	1994	1995	1996	1997	1998	1999	2000
0	0.0075786	0.0075085	0.0074455	0.0073612	0.0072515	0.0071007	0.0069145
1	0.0308493	0.0307299	0.0305944	0.0303518	0.0300827	0.0297624	0.0294683
2	0.0617987	0.0624223	0.0632962	0.0643490	0.0652014	0.0663590	0.0677509
3	0.1382657	0.1402508	0.1423662	0.1451665	0.1489544	0.1551726	0.1621972
4	0.2274085	0.2284119	0.2295167	0.2302798	0.2348751	0.2422538	0.2539412
5	0.2637545	0.2684914	0.2756808	0.2866376	0.3008093	0.3144050	0.3314492
6	0.3292134	0.3307539	0.3311059	0.3337611	0.3391175	0.3509724	0.3682325
7	0.3636306	0.3611378	0.3464510	0.3348470	0.3379247	0.3501930	0.3620875
8	0.3636306	0.3611378	0.3464510	0.3348470	0.3379247	0.3501930	0.3620875
9	0.3636306	0.3611378	0.3464510	0.3348470	0.3379247	0.3501930	0.3620875
10	0.3636306	0.3611378	0.3464510	0.3348470	0.3379247	0.3501930	0.3620875
11	0.3636306	0.3611378	0.3464510	0.3348470	0.3379247	0.3501930	0.3620875
12	0.3636306	0.3611378	0.3464510	0.3348470	0.3379247	0.3501930	0.3620875

	year						
age	2001	2002	2003	2004	2005	2006	2007
0	0.0064504	0.0060630	0.0054441	0.0049533	0.0047164	0.0047473	0.0045190
1	0.0280298	0.0274159	0.0239256	0.0197643	0.0181384	0.0181156	0.0166957
2	0.0670692	0.0665897	0.0654018	0.0666868	0.0611811	0.0535286	0.0447764
3	0.1572967	0.1573937	0.1435419	0.1458268	0.1348009	0.1149774	0.1062388
4	0.2619204	0.2587623	0.2364095	0.2233034	0.1983572	0.1842172	0.1784182

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  5  0.3234447 0.3281295 0.3233877 0.3124659 0.2823805 0.2593185 0.2658818
  6  0.4022376 0.4006351 0.4043449 0.3863956 0.3499205 0.3382625 0.3349733
  7  0.4135473 0.4709529 0.5185751 0.4759785 0.3725255 0.3500767 0.4215319
  8  0.4135473 0.4709529 0.5185751 0.4759785 0.3725255 0.3500767 0.4215319
  9  0.4135473 0.4709529 0.5185751 0.4759785 0.3725255 0.3500767 0.4215319
  10 0.4135473 0.4709529 0.5185751 0.4759785 0.3725255 0.3500767 0.4215319
  11 0.4135473 0.4709529 0.5185751 0.4759785 0.3725255 0.3500767 0.4215319
  12 0.4135473 0.4709529 0.5185751 0.4759785 0.3725255 0.3500767 0.4215319
    year
age  2008      2009      2010      2011      2012      2013      2014
  0  0.0043309 0.0040697 0.0038012 0.0035126 0.0031951 0.0028520 0.0025915
  1  0.0154370 0.0142991 0.0144289 0.0133007 0.0124674 0.0121304 0.0120714
  2  0.0397398 0.0378851 0.0385101 0.0390073 0.0395508 0.0395536 0.0404353
  3  0.1036988 0.1029883 0.1019253 0.0995995 0.0950419 0.0947216 0.1036332
  4  0.1776054 0.1835016 0.1855085 0.1825708 0.1772060 0.1824536 0.1853439
  5  0.2601412 0.2525970 0.2512682 0.2444012 0.2397071 0.2393082 0.2584703
  6  0.3134106 0.3106012 0.2974811 0.2935257 0.2833848 0.2772942 0.2972979
  7  0.4157745 0.3624106 0.3529844 0.3537624 0.3257843 0.3326300 0.3244693
  8  0.4157745 0.3624106 0.3529844 0.3537624 0.3257843 0.3326300 0.3244693
  9  0.4157745 0.3624106 0.3529844 0.3537624 0.3257843 0.3326300 0.3244693
  10 0.4157745 0.3624106 0.3529844 0.3537624 0.3257843 0.3326300 0.3244693
  11 0.4157745 0.3624106 0.3529844 0.3537624 0.3257843 0.3326300 0.3244693
  12 0.4157745 0.3624106 0.3529844 0.3537624 0.3257843 0.3326300 0.3244693
    year
age  2015      2016      2017      2018      2019
  0  0.0021519 0.0018347 0.0018630 0.0018175 0.0018175
  1  0.0123229 0.0114141 0.0101151 0.0095777 0.0095778
  2  0.0411522 0.0425606 0.0434984 0.0450707 0.0450748
  3  0.1029212 0.1085399 0.1125820 0.1100668 0.1100927
  4  0.1713103 0.1823056 0.1849752 0.1689698 0.1692441
  5  0.2376831 0.2287867 0.2301573 0.2255009 0.2266378
  6  0.2943613 0.2694109 0.2626977 0.2693035 0.2660935
  7  0.3098142 0.2626654 0.2642959 0.2630290 0.2595995
  8  0.3098142 0.2626654 0.2642959 0.2630290 0.2595995
  9  0.3098142 0.2626654 0.2642959 0.2630290 0.2595995
  10 0.3098142 0.2626654 0.2642959 0.2630290 0.2595995
  11 0.3098142 0.2626654 0.2642959 0.2630290 0.2595995
  12 0.3098142 0.2626654 0.2642959 0.2630290 0.2595995
```

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
2019								
0	4486293	0.15	0.000	0.000	0.327	0.000	0.002	0.036
1	6236961	0.15	0.097	0.216	0.327	0.060	0.010	0.156
2	5558268	0.15	0.572	0.216	0.327	0.193	0.044	0.251
3	4466194	0.15	0.915	0.190	0.327	0.248	0.110	0.309
4	1065094	0.15	0.997	0.190	0.327	0.281	0.179	0.346
5	1838158	0.15	1.000	0.217	0.327	0.307	0.228	0.376
6	1155087	0.15	1.000	0.217	0.327	0.323	0.267	0.397
7	766610	0.15	1.000	0.217	0.327	0.349	0.263	0.417
8	1329015	0.15	1.000	0.217	0.327	0.374	0.263	0.443
9	1133087	0.15	1.000	0.217	0.327	0.395	0.263	0.463
10	565355	0.15	1.000	0.217	0.327	0.424	0.263	0.485
11	460681	0.15	1.000	0.217	0.327	0.436	0.263	0.501
12+	460899	0.15	1.000	0.217	0.327	0.484	0.263	0.529
2020								
0	4486293	0.15	0.000	0.000	0.327	0.000	0.002	0.036
1	-	0.15	0.097	0.216	0.327	0.060	0.010	0.156
2	-	0.15	0.572	0.216	0.327	0.193	0.044	0.251
3	-	0.15	0.915	0.190	0.327	0.248	0.110	0.309
4	-	0.15	0.997	0.190	0.327	0.281	0.179	0.346
5	-	0.15	1.000	0.217	0.327	0.307	0.228	0.376
6	-	0.15	1.000	0.217	0.327	0.323	0.267	0.397
7	-	0.15	1.000	0.217	0.327	0.349	0.263	0.417
8	-	0.15	1.000	0.217	0.327	0.374	0.263	0.443
9	-	0.15	1.000	0.217	0.327	0.395	0.263	0.463
10	-	0.15	1.000	0.217	0.327	0.424	0.263	0.485
11	-	0.15	1.000	0.217	0.327	0.436	0.263	0.501
12+	-	0.15	1.000	0.217	0.327	0.484	0.263	0.529

	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	4486293	0.15	0.000	0.000	0.327	0.000	0.002	0.036
1	-	0.15	0.097	0.216	0.327	0.060	0.010	0.156
2	-	0.15	0.572	0.216	0.327	0.193	0.044	0.251
3	-	0.15	0.915	0.190	0.327	0.248	0.110	0.309
4	-	0.15	0.997	0.190	0.327	0.281	0.179	0.346
5	-	0.15	1.000	0.217	0.327	0.307	0.228	0.376
6	-	0.15	1.000	0.217	0.327	0.323	0.267	0.397
7	-	0.15	1.000	0.217	0.327	0.349	0.263	0.417
8	-	0.15	1.000	0.217	0.327	0.374	0.263	0.443
9	-	0.15	1.000	0.217	0.327	0.395	0.263	0.463
10	-	0.15	1.000	0.217	0.327	0.424	0.263	0.485
11	-	0.15	1.000	0.217	0.327	0.436	0.263	0.501
12+	-	0.15	1.000	0.217	0.327	0.484	0.263	0.529

Table 8.8.3.2. NE Atlantic Mackerel. Short-term prediction: Multi-option table for 834 954 t catch in 2019 and a range of F-values in 2020.

2019			
TSB	**SSB**	**F_{bar}**	**Catch**
5665055	4389601	0.206	834954

2020				2021		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
5680185	4696388	0	0	6136310	5287640	-100.0%
-	4688846	0.01	43964	6099423	5243867	-94.7%
-	4681320	0.02	87553	6062857	5200562	-89.5%
-	4673808	0.03	130768	6026610	5157720	-84.3%
-	4666311	0.04	173614	5990679	5115335	-79.2%
-	4658828	0.05	216095	5955060	5073402	-74.1%
-	4651360	0.06	258214	5919751	5031915	-69.1%
-	4643907	0.07	299974	5884749	4990869	-64.1%
-	4636468	0.08	341379	5850050	4950259	-59.1%
-	4629044	0.09	382432	5815652	4910081	-54.2%
-	4621635	0.10	423136	5781552	4870328	-49.3%
-	4614240	0.11	463496	5747747	4830995	-44.5%
-	4606859	0.12	503514	5714234	4792079	-39.7%
-	4599493	0.13	543193	5681010	4753574	-34.9%
-	4592141	0.14	582537	5648072	4715475	-30.2%
-	4584803	0.15	621549	5615418	4677778	-25.6%
-	4577480	0.16	660233	5583045	4640477	-20.9%
-	4570172	0.17	698590	5550950	4603568	-16.3%
-	4562877	0.18	736624	5519131	4567047	-11.8%
-	4555597	0.19	774340	5487584	4530909	-7.3%
-	4548331	0.20	811738	5456308	4495149	-2.8%
-	4541079	0.21	848823	5425299	4459764	1.7%

2020				2021		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change
						in the catch
-	4519408	0.24	958226	5333853	4355808	14.8%
-	4512212	0.25	994086	5303889	4321876	19.1%
-	4505031	0.26	1029648	5274181	4288296	23.3%
-	4497864	0.27	1064913	5244725	4255066	27.5%
-	4490710	0.28	1099885	5215518	4222180	31.7%
-	4483571	0.29	1134566	5186560	4189634	35.9%
-	4476445	0.30	1168959	5157847	4157425	40.0%
-	4469333	0.31	1203068	5129377	4125550	44.1%
-	4462236	0.32	1236894	5101148	4094003	48.1%
-	4455151	0.33	1270440	5073157	4062781	52.2%
-	4448081	0.34	1303710	5045402	4031880	56.1%
-	4441025	0.35	1336704	5017881	4001297	60.1%
-	4433982	0.36	1369427	4990591	3971029	64.0%
-	4426953	0.37	1401881	4963531	3941070	67.9%
-	4419938	0.38	1434068	4936698	3911418	71.8%
-	4412936	0.39	1465991	4910091	3882070	75.6%
-	4405948	0.40	1497652	4883706	3853021	79.4%
-	4398973	0.41	1529053	4857541	3824268	83.1%
-	4392012	0.42	1560198	4831596	3795809	86.9%
-	4385065	0.43	1591089	4805867	3767639	90.6%
-	4378131	0.44	1621727	4780352	3739755	94.2%
-	4371210	0.45	1652115	4755050	3712153	97.9%
-	4364303	0.46	1682257	4729958	3684832	101.5%
-	4357410	0.47	1712153	4705075	3657787	105.1%
-	4350530	0.48	1741806	4680398	3631015	108.6%
-	4343663	0.49	1771219	4655926	3604513	112.1%
-	4336809	0.50	1800394	4631656	3578279	115.6%

2020				2021		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	4309528	0.54	1914754	4536564	3475949	129.3%
-	4302741	0.55	1942771	4513279	3451005	132.7%
-	4295966	0.56	1970562	4490185	3426309	136.0%
-	4289205	0.57	1998130	4467281	3401860	139.3%
-	4282457	0.58	2025477	4444564	3377654	142.6%
-	4275723	0.59	2052605	4422033	3353690	145.8%
-	4269001	0.60	2079517	4399686	3329963	149.1%
-	4262292	0.61	2106213	4377522	3306472	152.3%
-	4255596	0.62	2132696	4355539	3283213	155.4%
-	4248913	0.63	2158969	4333734	3260185	158.6%
-	4242243	0.64	2185032	4312107	3237384	161.7%
-	4235586	0.65	2210889	4290656	3214808	164.8%
-	4228942	0.66	2236540	4269379	3192454	167.9%
-	4222311	0.67	2261988	4248274	3170320	170.9%
-	4215693	0.68	2287234	4227340	3148403	173.9%
-	4209087	0.69	2312281	4206575	3126701	176.9%
-	4202494	0.70	2337131	4185978	3105212	179.9%
-	4195914	0.71	2361784	4165546	3083932	182.9%
-	4189347	0.72	2386244	4145280	3062861	185.8%
-	4182792	0.73	2410511	4125176	3041994	188.7%
-	4176250	0.74	2434588	4105233	3021331	191.6%
-	4169720	0.75	2458476	4085451	3000868	194.4%
-	4163204	0.76	2482177	4065827	2980604	197.3%
-	4156699	0.77	2505693	4046360	2960537	200.1%
-	4150208	0.78	2529025	4027048	2940663	202.9%
-	4143728	0.79	2552176	4007890	2920981	205.7%
-	4137262	0.80	2575146	3988885	2901489	208.4%

2020				2021		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change
						in the catch
-	4130808	0.81	2597937	3970031	2882184	211.1%
-	4124366	0.82	2620552	3951327	2863066	213.9%
-	4117937	0.83	2642991	3932771	2844130	216.5%
-	4111520	0.84	2665257	3914363	2825376	219.2%
-	4105115	0.85	2687350	3896099	2806801	221.9%
-	4098723	0.86	2709273	3877981	2788404	224.5%
-	4092343	0.87	2731027	3860005	2770182	227.1%
-	4085975	0.88	2752614	3842170	2752133	229.7%
-	4079620	0.89	2774034	3824476	2734256	232.2%
-	4073277	0.90	2795290	3806921	2716549	234.8%
-	4066946	0.91	2816384	3789504	2699009	237.3%
-	4060627	0.92	2837315	3772223	2681636	239.8%
-	4054321	0.93	2858087	3755078	2664426	242.3%
-	4048026	0.94	2878701	3738066	2647378	244.8%
-	4041744	0.95	2899157	3721187	2630491	247.2%
-	4035474	0.96	2919457	3704440	2613763	249.7%
-	4029216	0.97	2939604	3687822	2597191	252.1%
-	4022969	0.98	2959597	3671334	2580775	254.5%
-	4016735	0.99	2979439	3654974	2564512	256.8%
-	4010513	1.00	2999131	3638740	2548401	259.2%
-	4004303	1.01	3018674	3622632	2532440	261.5%
-	3998105	1.02	3038070	3606649	2516627	263.9%
-	3991918	1.03	3057319	3590788	2500962	266.2%
-	3985744	1.04	3076424	3575050	2485441	268.5%
-	3979581	1.05	3095386	3559433	2470064	270.7%
-	3973430	1.06	3114205	3543936	2454829	273.0%
-	3967291	1.07	3132884	3528557	2439735	275.2%

2020				2021		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change**
						in the catch
-	3961164	1.08	3151422	3513296	2424779	277.4%
-	3955049	1.09	3169823	3498152	2409961	279.6%

Table 8.8.3.3. NE Atlantic Mackerel. Short-term prediction: Management option table for 834 954 t catch in 2019 and a range of catch options in 2020.

Rationale	Catch (2020)	F_{bar} (2020)	SSB (2020)	SSB (2021)	% SSb change	% catch change	% advice change
MSY AR	922064	0.23	4526617	4390097	-3.0%	10.4%	19.7%
F = 0	0	0.00	4696388	5287640	12.6%	-100.0%	-100.0%
F = Fpa	1401881	0.37	4426953	3941070	-11.0%	67.9%	82.0%
F = Flim	1682257	0.46	4364303	3684832	-15.6%	101.5%	118.4%
SSB(2021) = MSY Btrigger = Bpa	3058502	1.03	3991537	2500000	-37.4%	266.3%	297.0%
SSB(2021) = Blim	3705781	1.42	3760134	1990000	-47.1%	343.8%	381.0%
F = F2019	835665	0.21	4543657	4472310	-1.6%	0.1%	8.5%
Catch(2020) = Catch(2019) −20%	667963	0.16	4576011	4633032	1.2%	-20.0%	-13.3%
Catch(2020) = Catch (2019)	834954	0.21	4543796	4472988	-1.6%	0.0%	8.4%
Catch(2020) = Catch(2019) +25%	1043693	0.26	4502182	4275053	-5.0%	25.0%	35.5%
F = 0.20	811738	0.20	4548331	4495149	-1.2%	-2.8%	5.4%
F = 0.21	848823	0.21	4541079	4459764	-1.8%	1.7%	10.2%
F = 0.22	885597	0.22	4533841	4424748	-2.4%	6.1%	15.0%
F = 0.24	958226	0.24	4519408	4355808	-3.6%	14.8%	24.4%
F = 0.25	994086	0.25	4512212	4321876	-4.2%	19.1%	29.0%
F = 0.26	1029648	0.26	4505031	4288296	-4.8%	23.3%	33.7%
F = 0.27	1064913	0.27	4497864	4255066	-5.4%	27.5%	38.2%
F = 0.28	1099885	0.28	4490710	4222180	-6.0%	31.7%	42.8%
F = 0.29	1134566	0.29	4483571	4189634	-6.6%	35.9%	47.3%

8.15 Figures

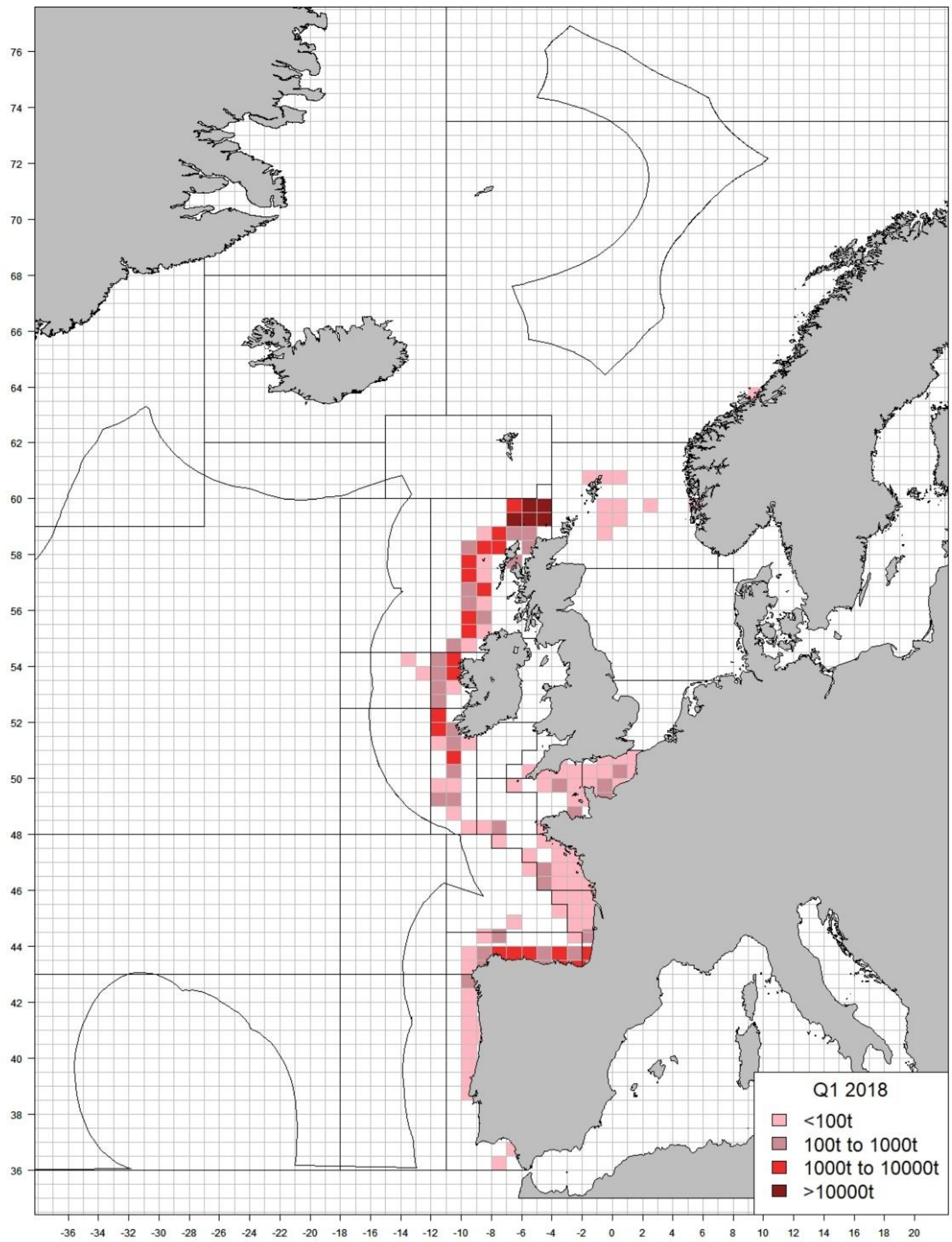

Figure 8.4.2.1. NE Atlantic Mackerel. Commercial catches in 2018, quarter 1.

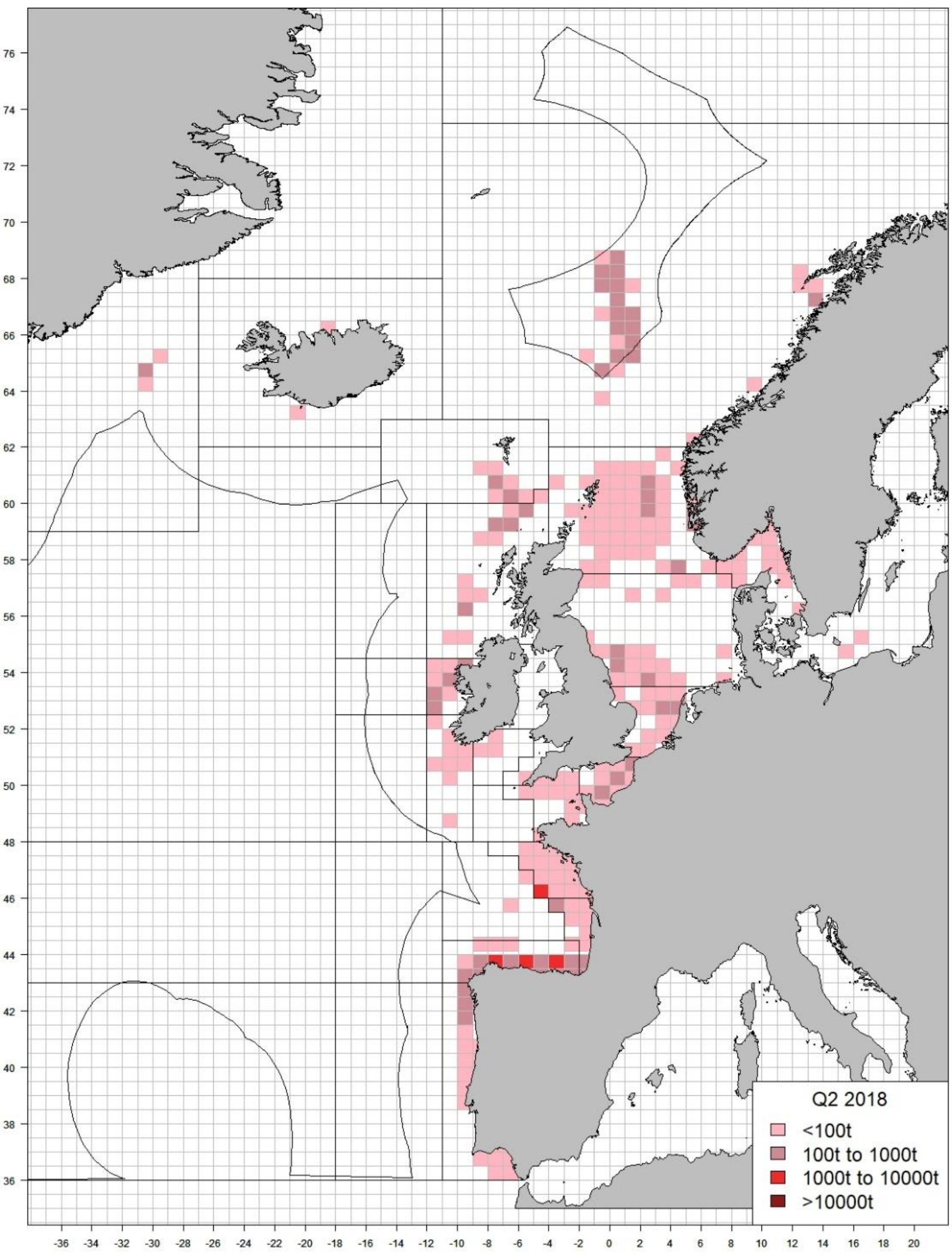

Figure 8.4.2.2. NE Atlantic Mackerel. Commercial catches in 2018, quarter 2.

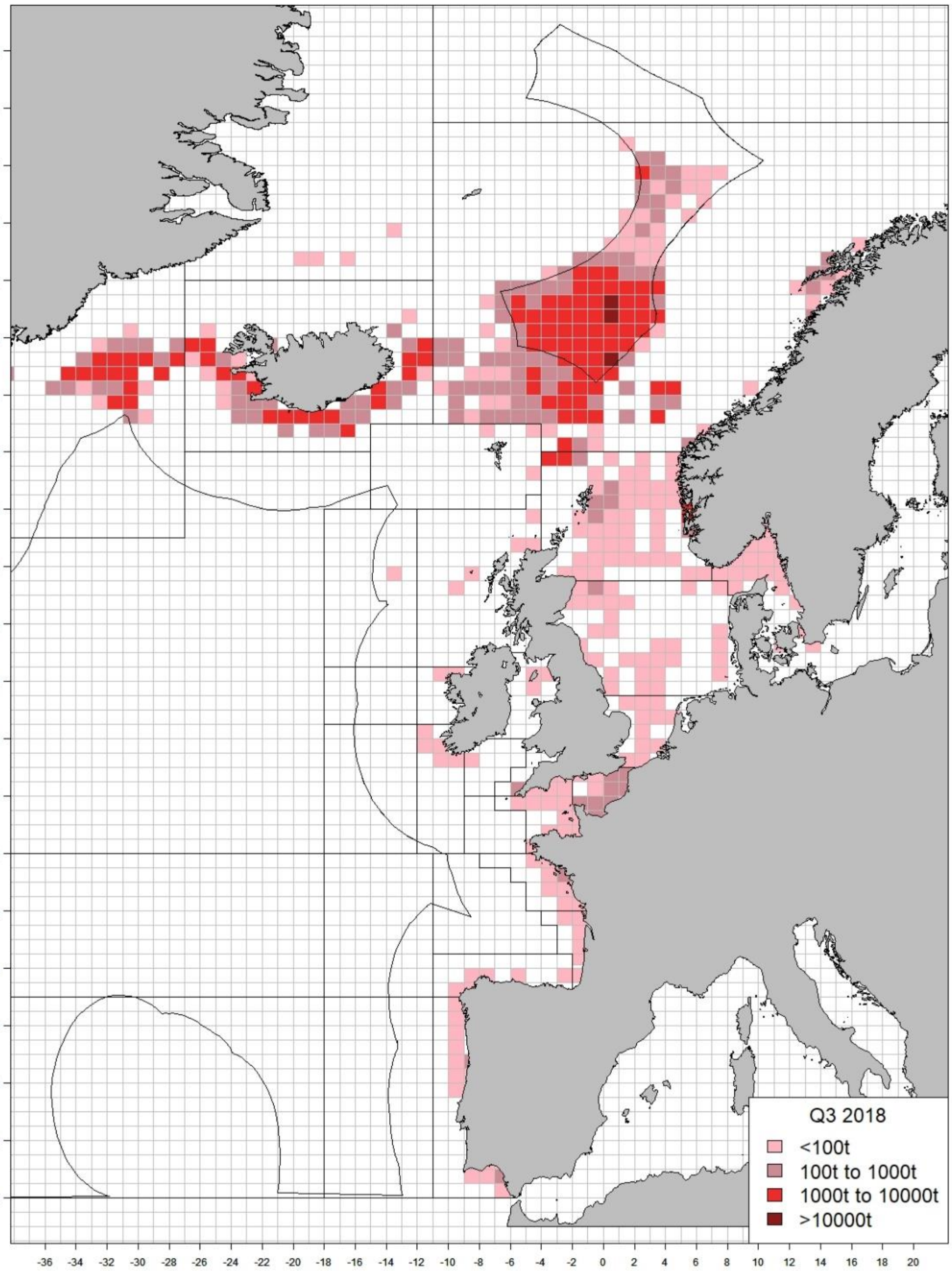

Figure 8.4.2.3. NE Atlantic Mackerel. Commercial catches in 2018, quarter 3.

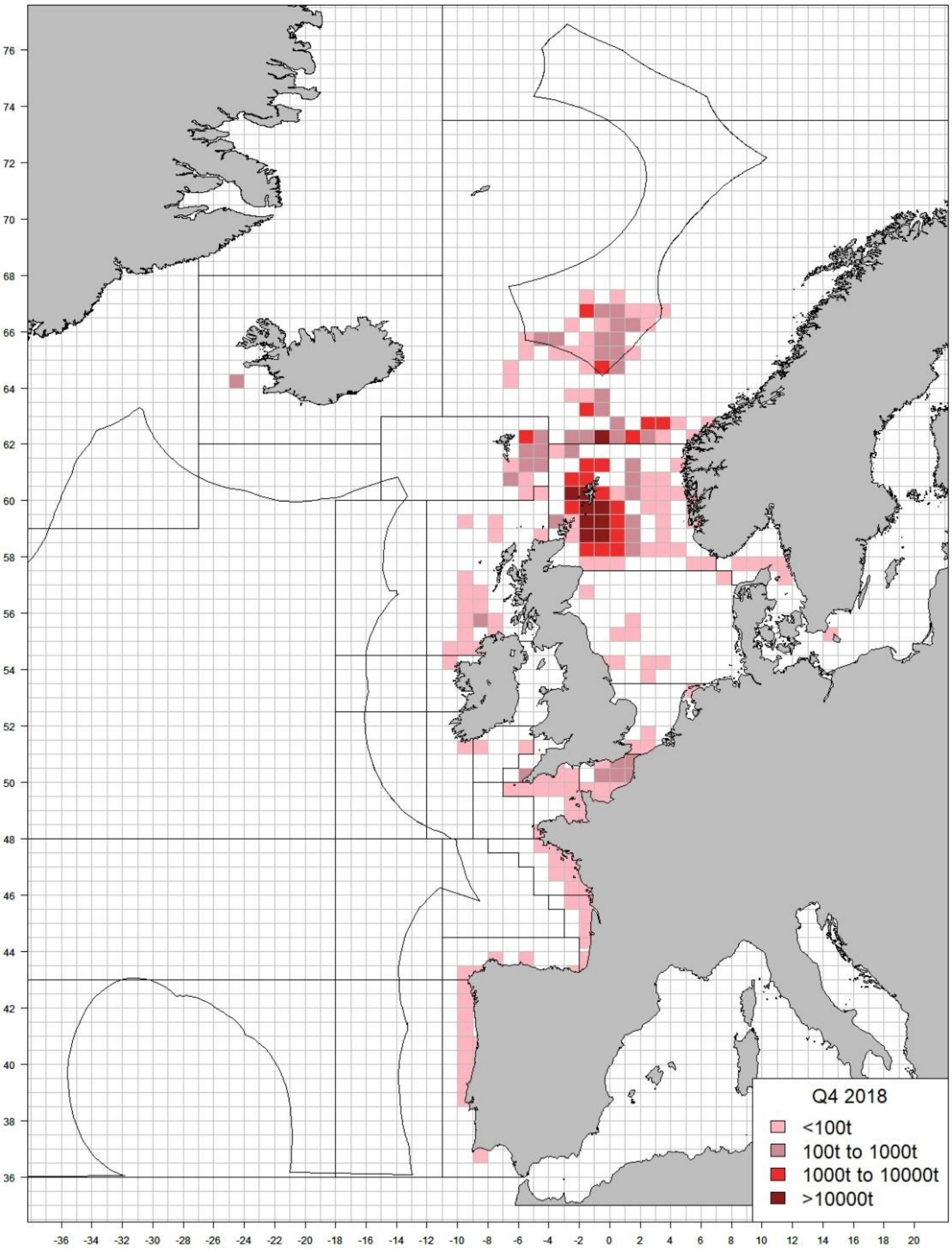

Figure 8.4.2.4. NE Atlantic Mackerel. Commercial catches in 2018, quarter 4.

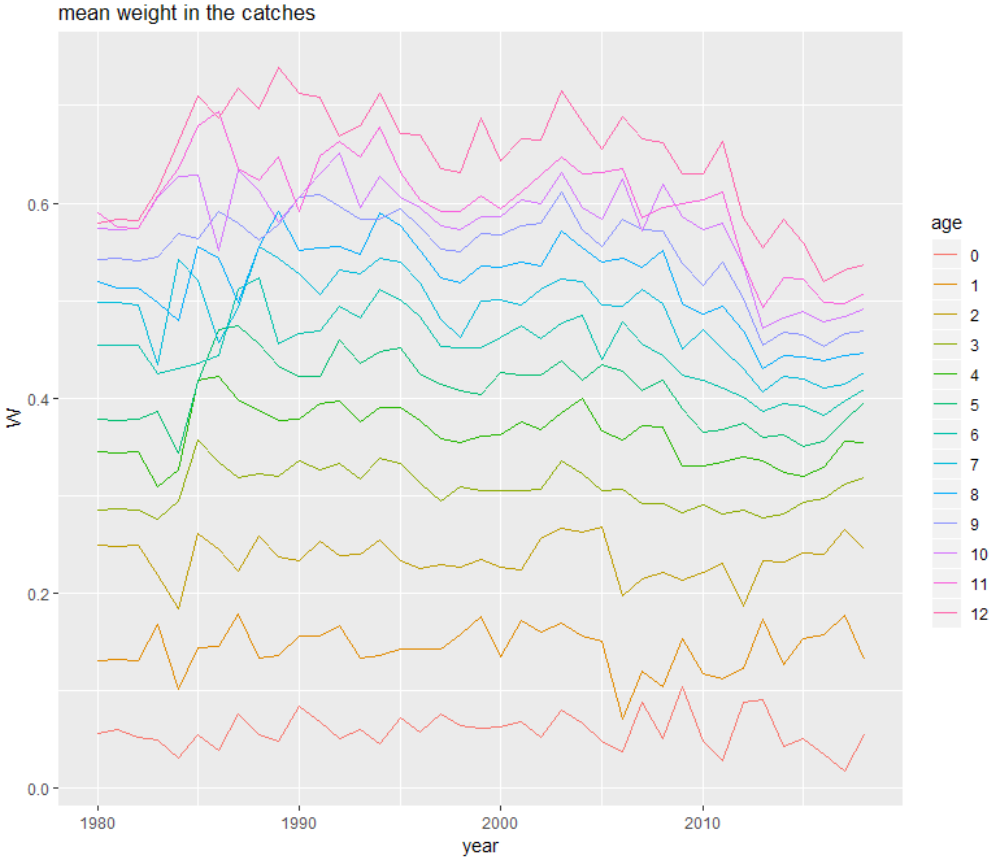

Figure 8.5.2.1. NE Atlantic mackerel. Weights-at-age in the catch.

Figure 8.5.2.2. NE Atlantic mackerel. Weights-at-age in the stock.

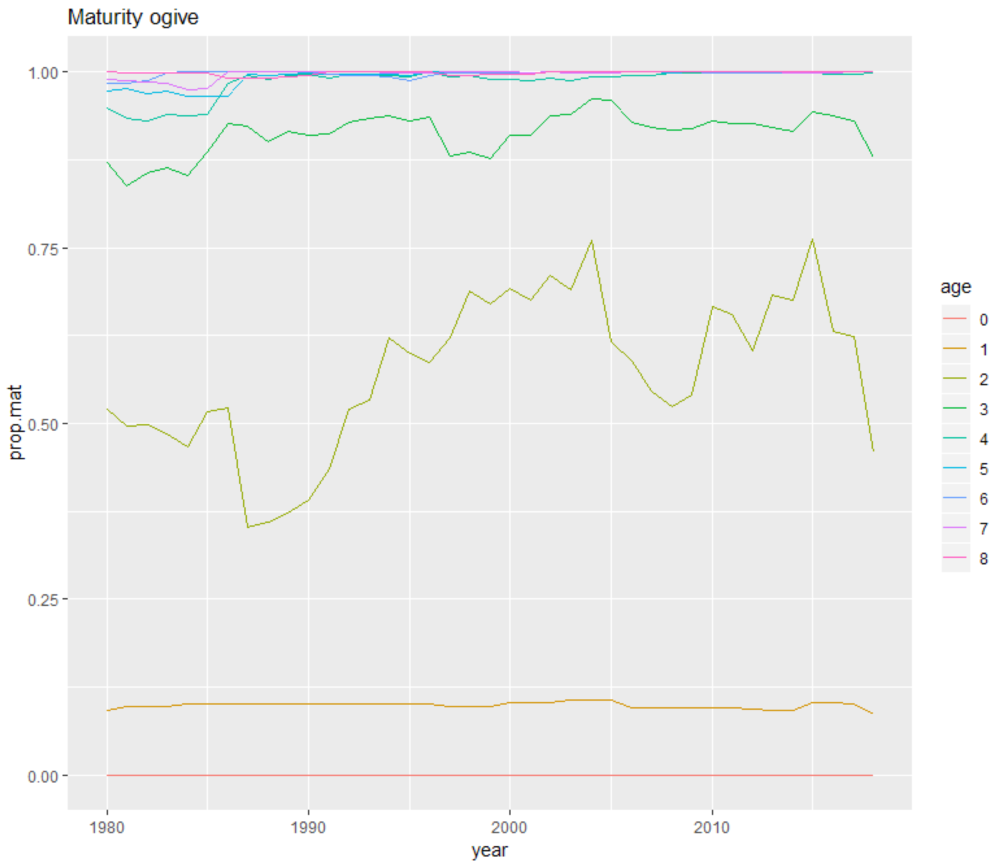

Figure 8.5.3.1. NE Atlantic mackerel. Proportion of mature fish at age.

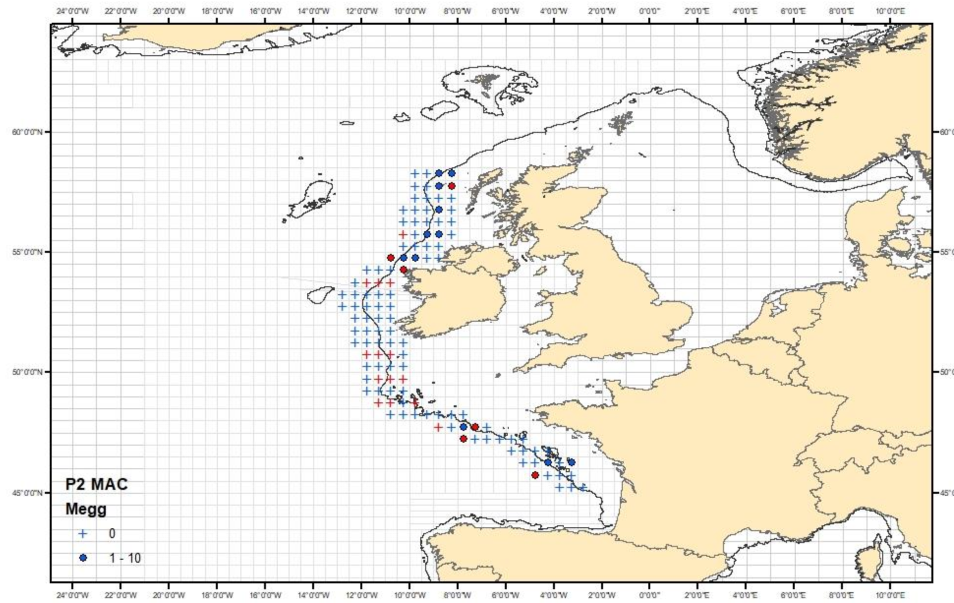

Figure 8.6.1.1. Mackerel egg production by half rectangle for period 2 (Feb 5th – Mar 3rd). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

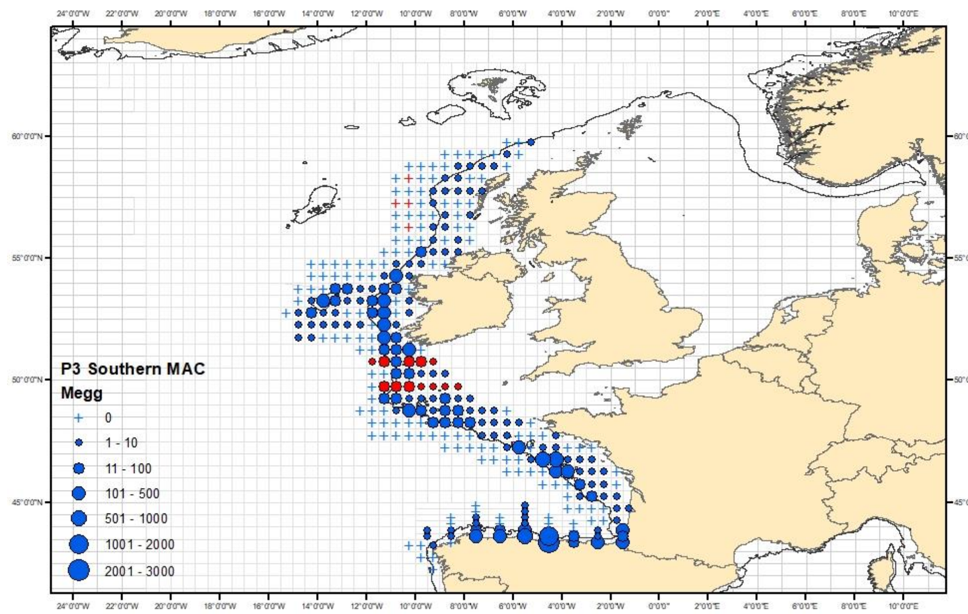

Figure 8.6.1.2. Mackerel egg production by half rectangle for period 3 (Mar 4th – Apr 12th). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

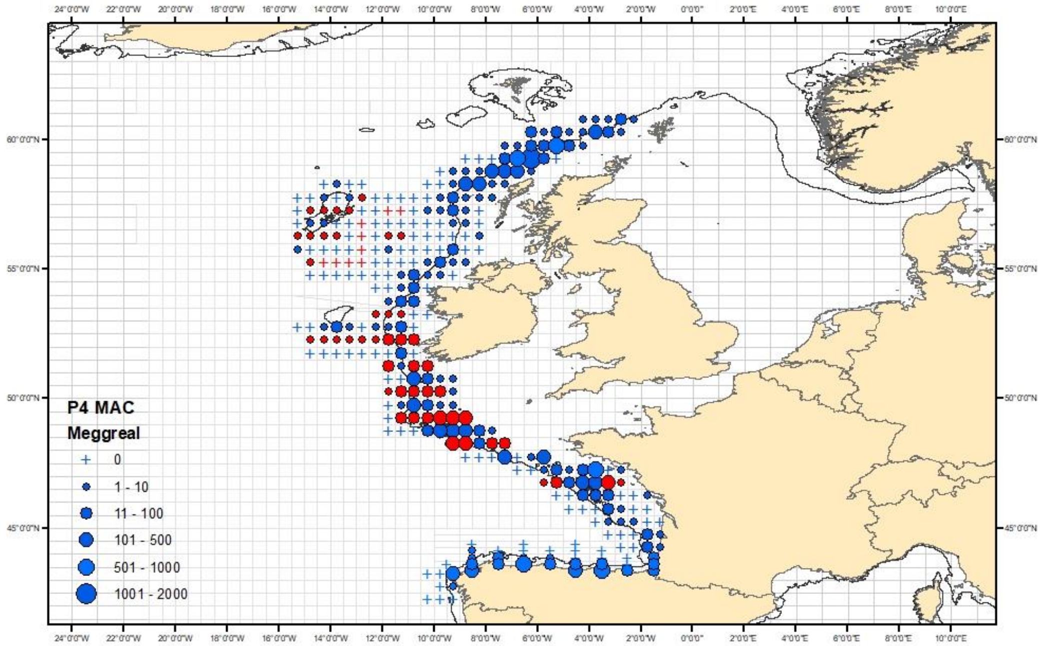

Figure 8.6.1.3. Mackerel egg production by half rectangle for period 4 (Apr 13th – May 3rd). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

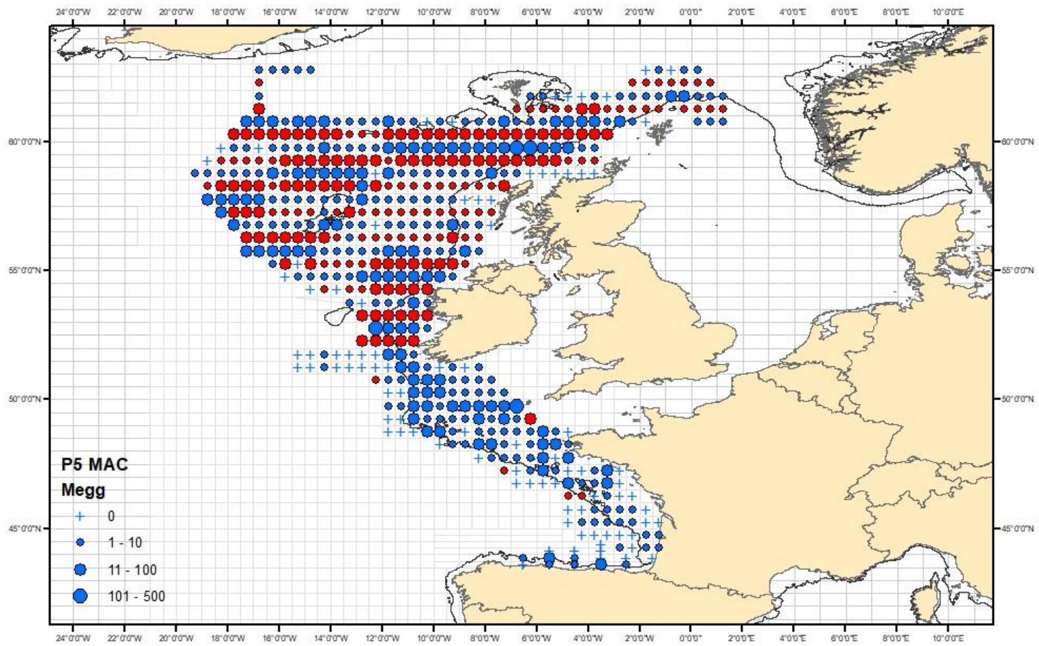

Figure 8.6.1.4. Mackerel egg production by half rectangle for period 5 (May 4th – June 5th). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

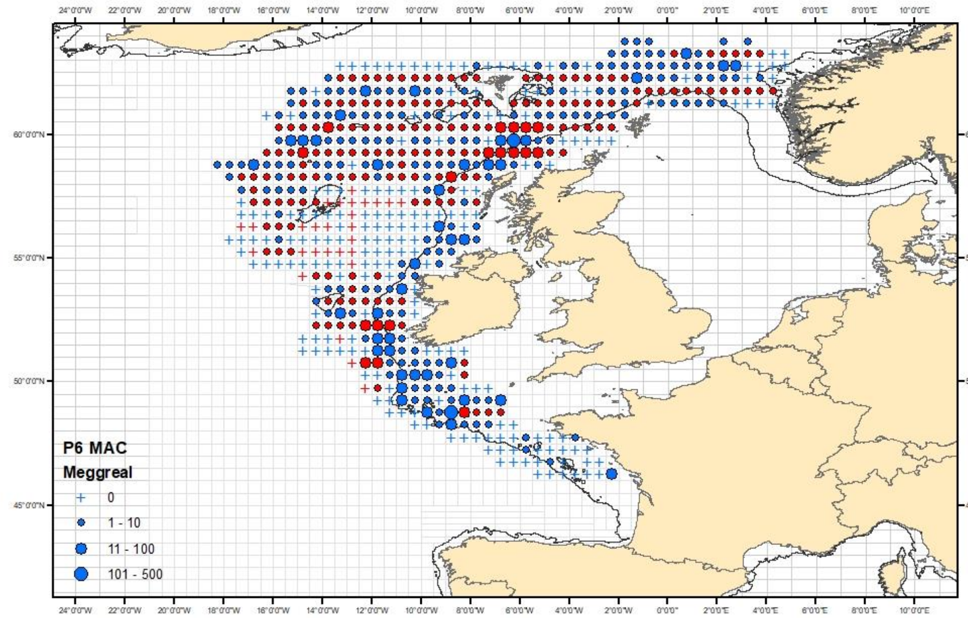

Figure 8.6.1.5. Mackerel egg production by half rectangle for period 6 (June 6th – 30th). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

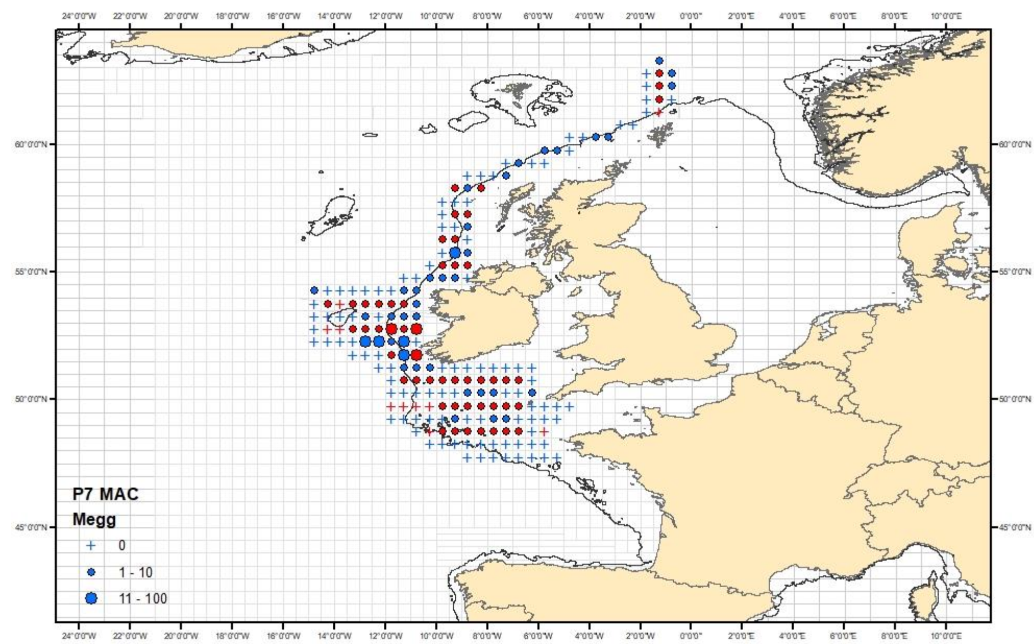

Figure 8.6.1.6. Mackerel egg production by half rectangle for period 7 (July 1st – 31st). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

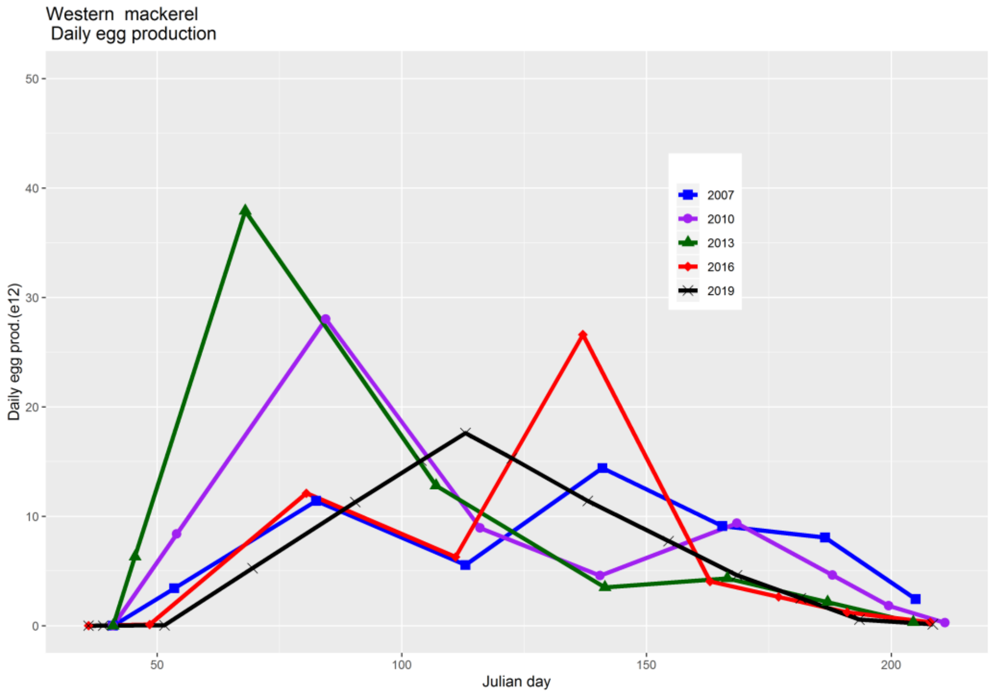

Figure 8.6.1.7. Provisional annual egg production curve for mackerel in the western spawning component. The curves for 2007, 2010 2013 and 2016 are included for comparison.

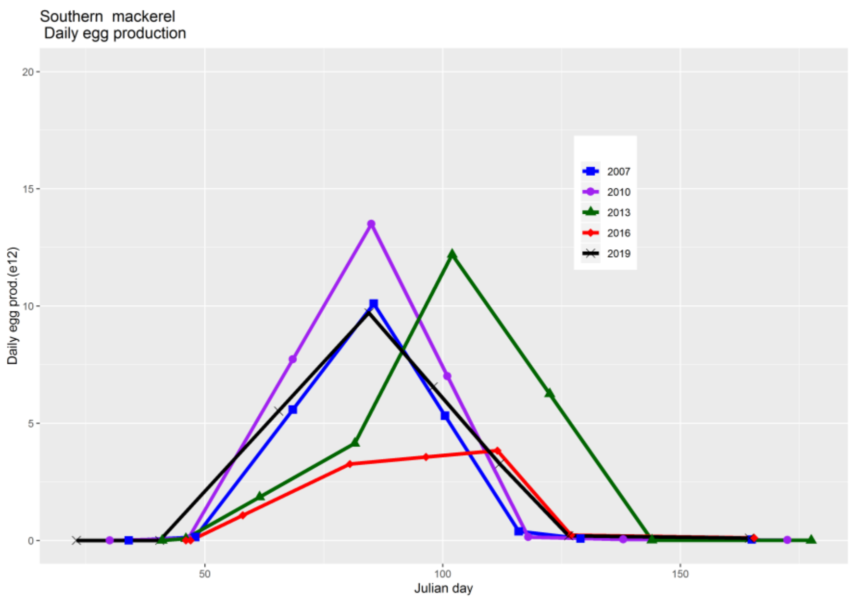

Figure 8.6.1.8. Provisional annual egg production curve for mackerel in the southern spawning component for 2019. The curves for 2007, 2010, 2013 and 2016 are included for comparison.

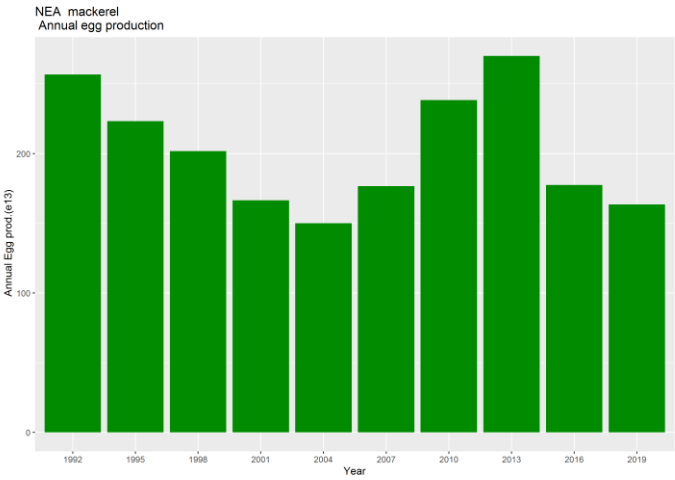

Figure 8.6.1.9. Combined mackerel TAEP estimates (*10^{13}) - 1992 – 2019.

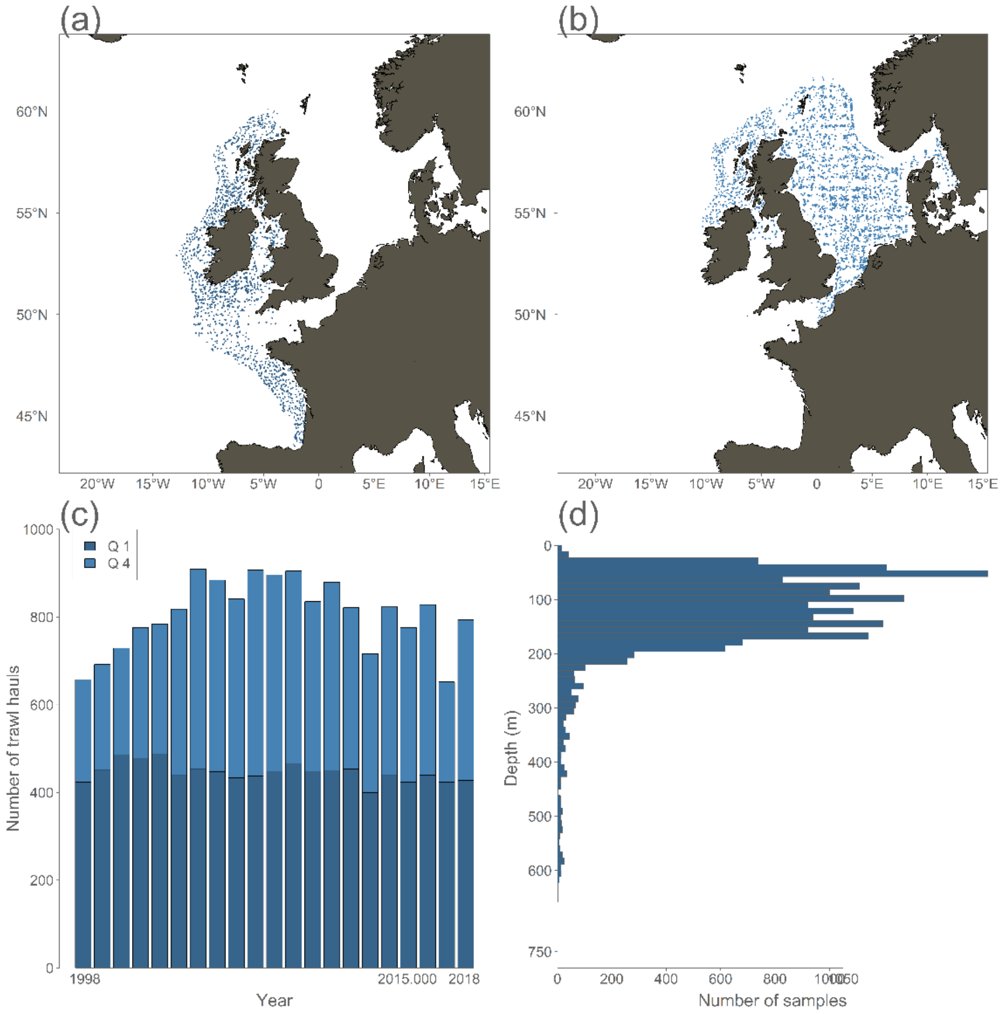

Figure 8.6.2.1. Demersal trawl survey data used to derive the abundance index of age-0 mackerel. (a) Trawl sample locations in the fourth quarter (Q4, October - November, blue dots); (b) trawl sample locations in the first quarter (Q1, January - March, light blue dots); (c) number of samples by year and quarter; and (d) depth.

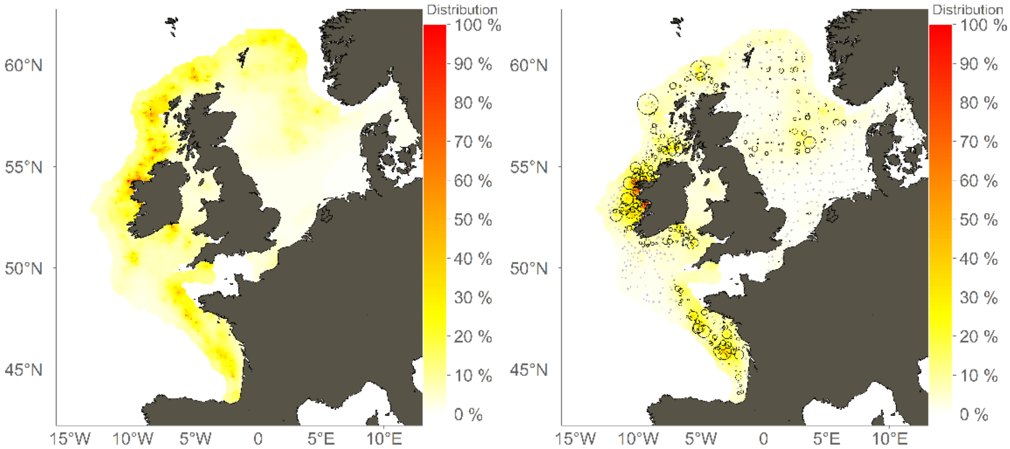

Figure 8.6.2.2. Spatial distribution of mackerel juveniles at age 0 in October to March. Left) average for cohorts from 19982018; and Right) 2018 cohort. Mackerel squared catch rates by trawl haul (circle areas represent catch rates in kg/km2) overlaid on modelled squared catch rates per 10 x 10 km rectangle. 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.

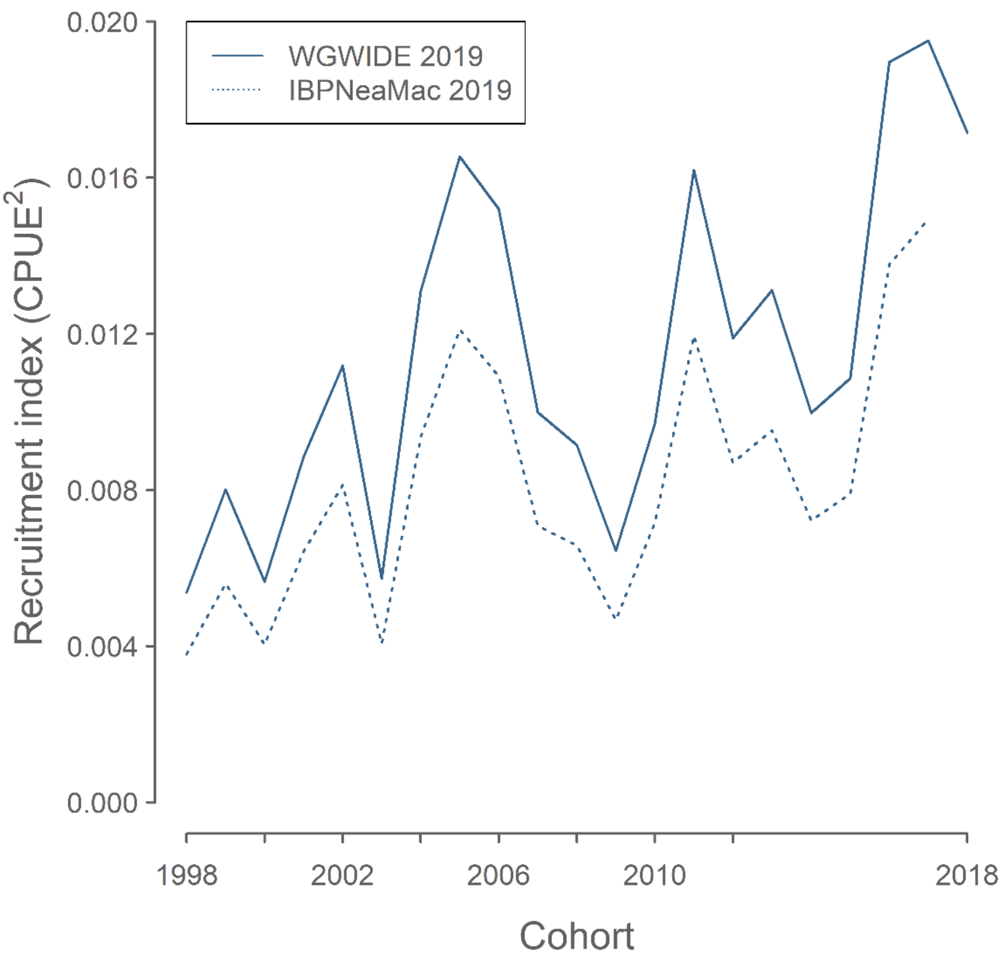

Figure 8.6.2.3. Index of mackerel juveniles at age 0 in October to March proxied by annual integration of square root of expected catch in demersal trawl surveys (Blue lines). See Jansen *et al.* (2015) for details.

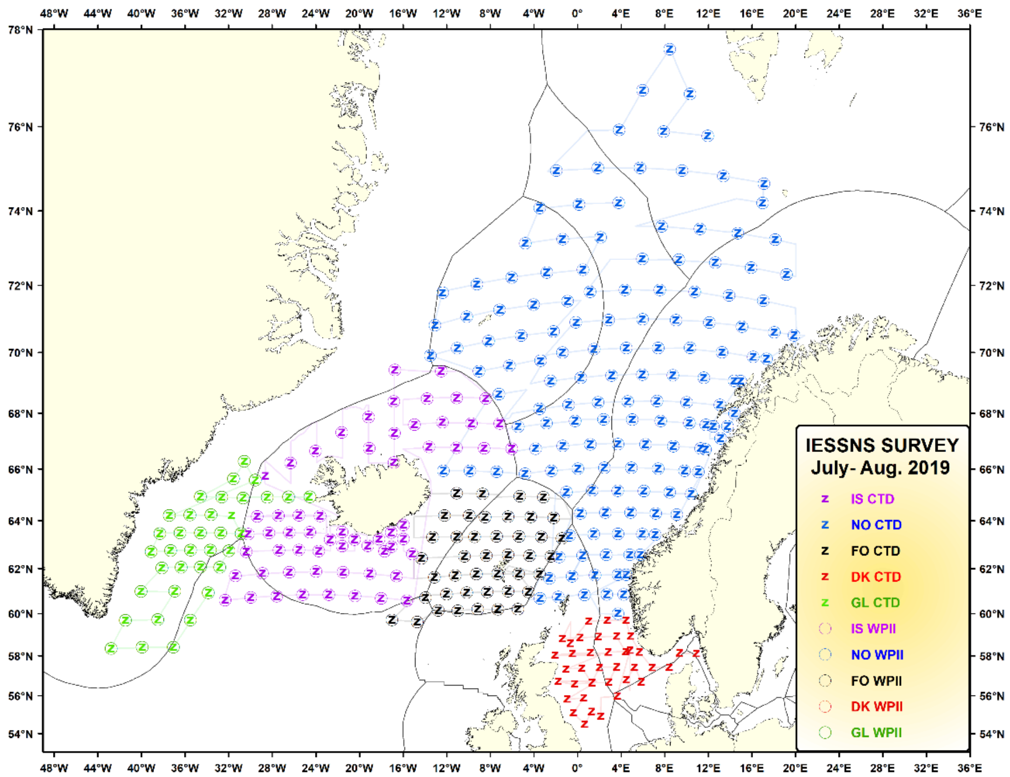

Figure 8.6.3.1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 28th June – 5th August 2019. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) were performed. The colour codes, Árni Friðriksson (purple), Finnur Fríði (black), Kings Bay and Vendla (blue), Eros (green) and Ceton (red).

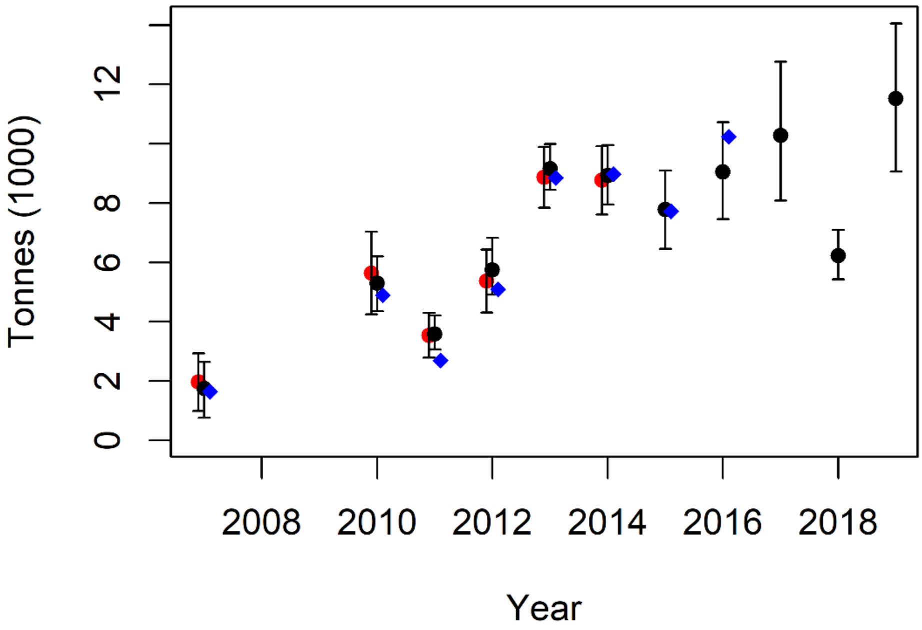

Figure 8.6.3.2a. Estimated total stock biomass (TSB) of mackerel from StoX (black dots), Nøttestad et al. (2016) (red dots) and IESSNS cruise reports (blue diamonds) 2007-2019. The error bars represent approximate 90 % confidence intervals.

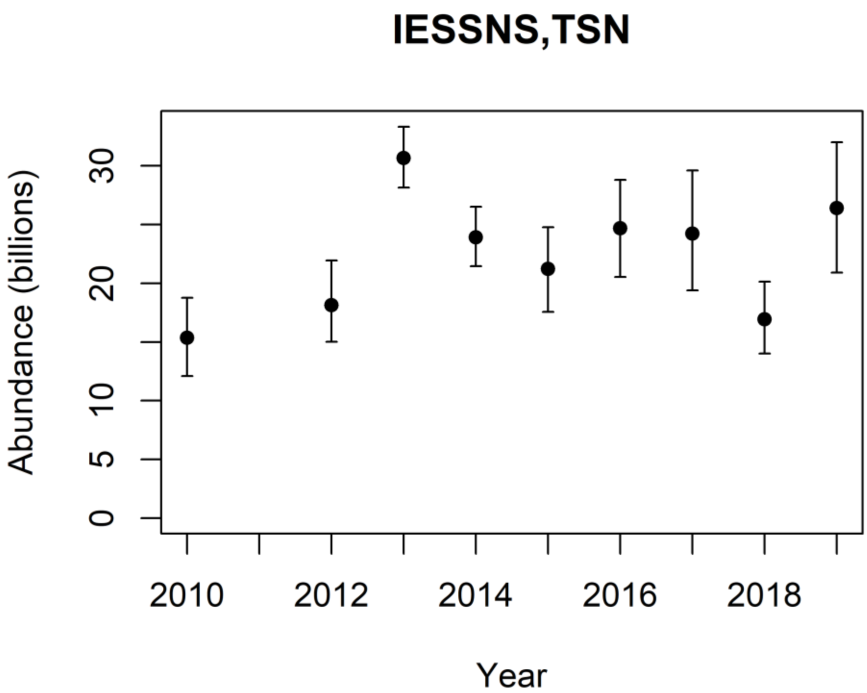

Figure 8.6.3.2b. Estimated total stock numbers (TSN) of mackerel from StoX (black dots) for the years 2010, 20122019. The error bars represent approximate 90 % confidence intervals

Figure 8.6.3.3. Catch curves. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

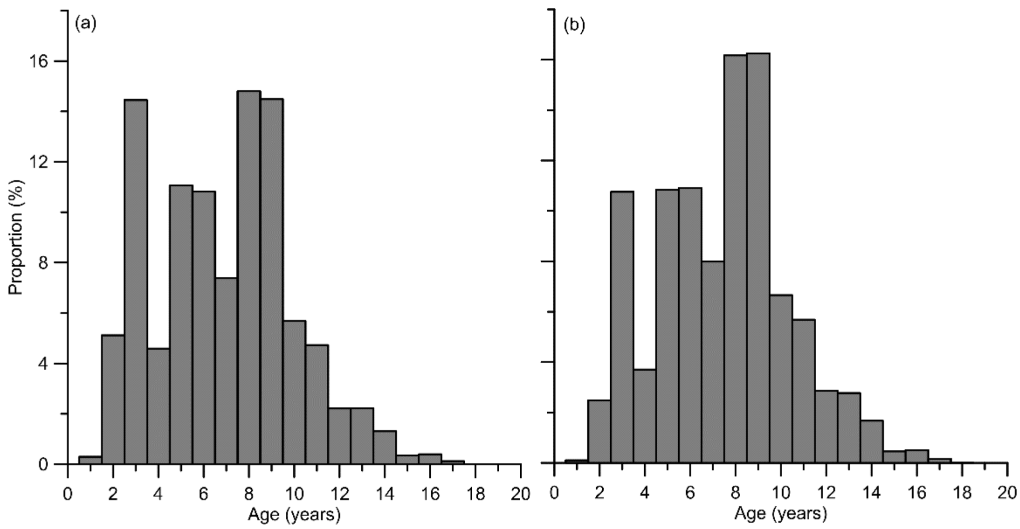

Figure 8.6.3.4a. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2019.

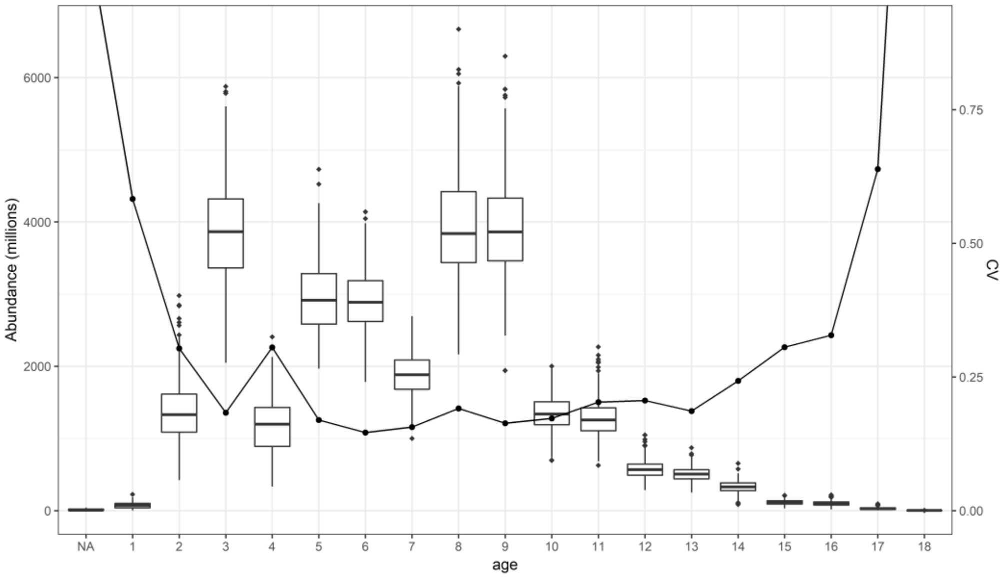

Figure 8.6.3.4b. Mackerel numbers by age from the IESSNS survey in 2019, excluding North Sea. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software (http://www.imr.no/forskning/prosjekter/stox/nb-no).

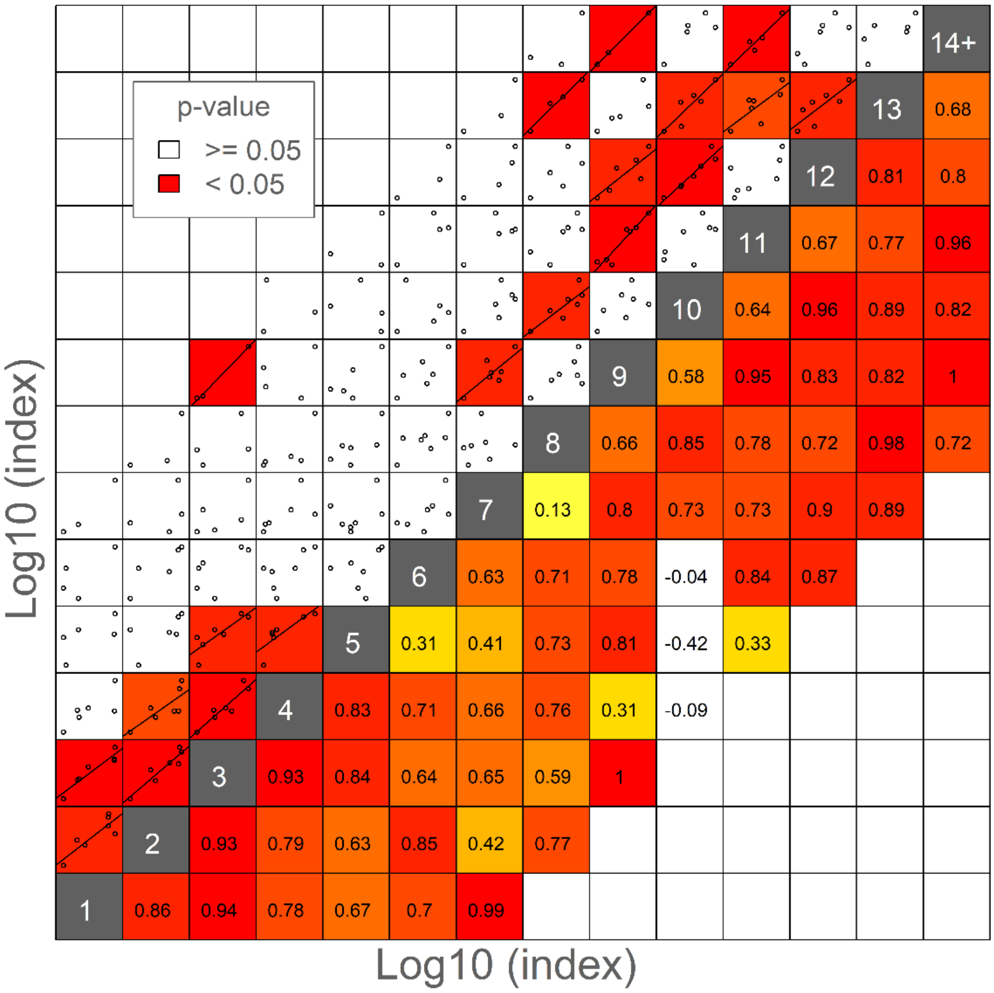

Figure 8.6.3.5. Internal consistency of the mackerel abundance index from the IESSNS surveys including data from 2012 to 2019, excluding North Sea in 2019. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

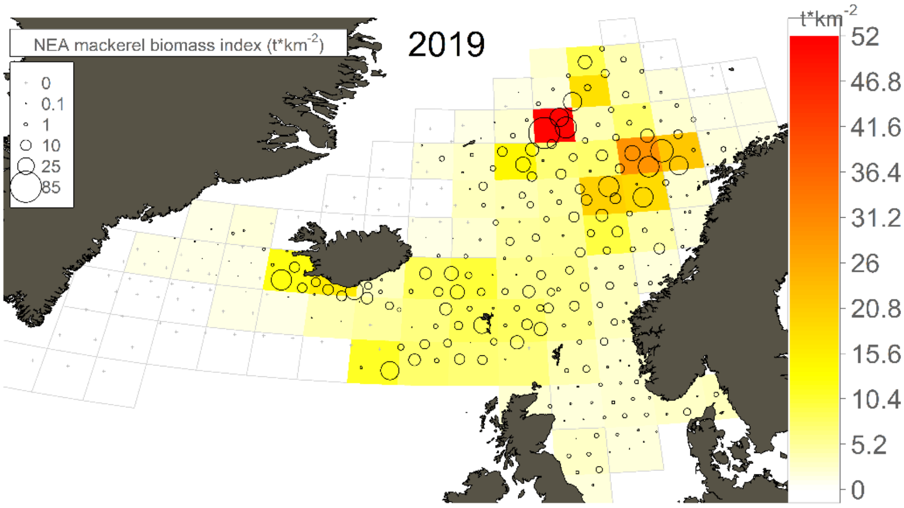

Figure 8.6.3.6a. Mackerel catch rates from surface trawl hauls (circle size represents catch rate in kg/km2) overlaid on mean catch rate per standardized rectangle (1° lat. x 2° lon.) from the IESSNS survey in 2019.

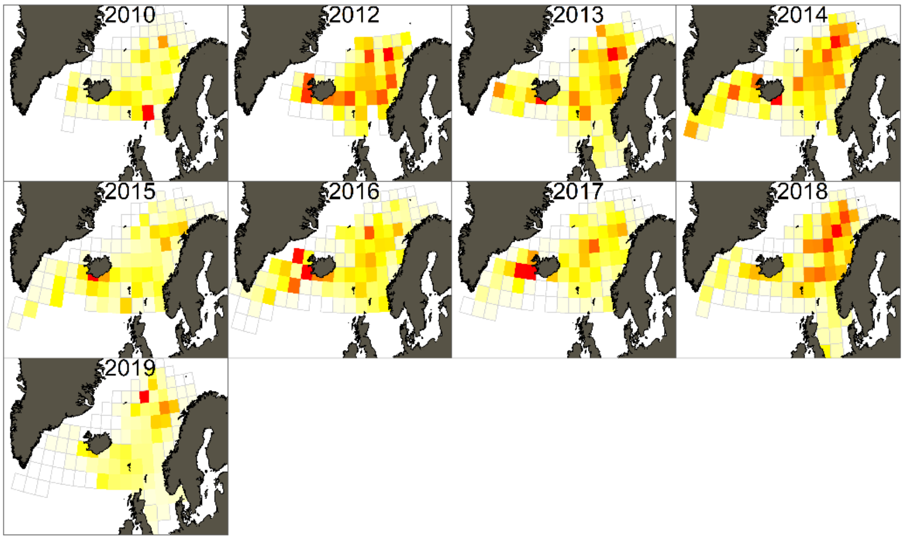

Figure 8.6.3.6b. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the given year).

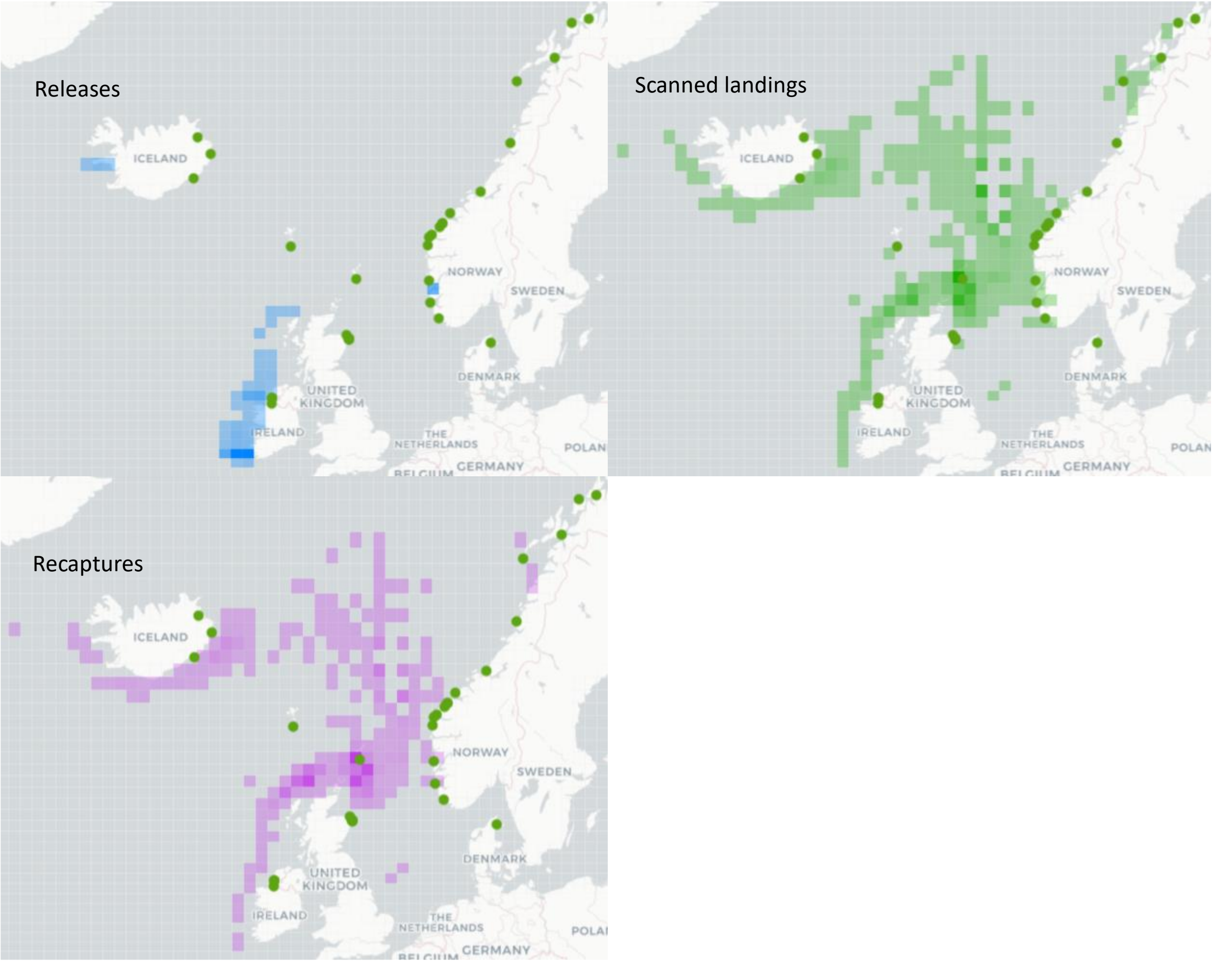

Figure 8.6.4.1. Distribution (per ICES rectangle) of RFID tagged mackerel (20112019), catch biomass scanned for RFID tagged mackerel (2012-2018) and corresponding numbers of recaptured mackerel (20122018). Darker colours mean higher density. Note that the maps give an overview of the total material, whereas details on actual data used on the stock assessment is given in Tables 8.4.6.13. Positions of factories with RFID scanners are shown as green dots on map (Irish scanners are not operational).

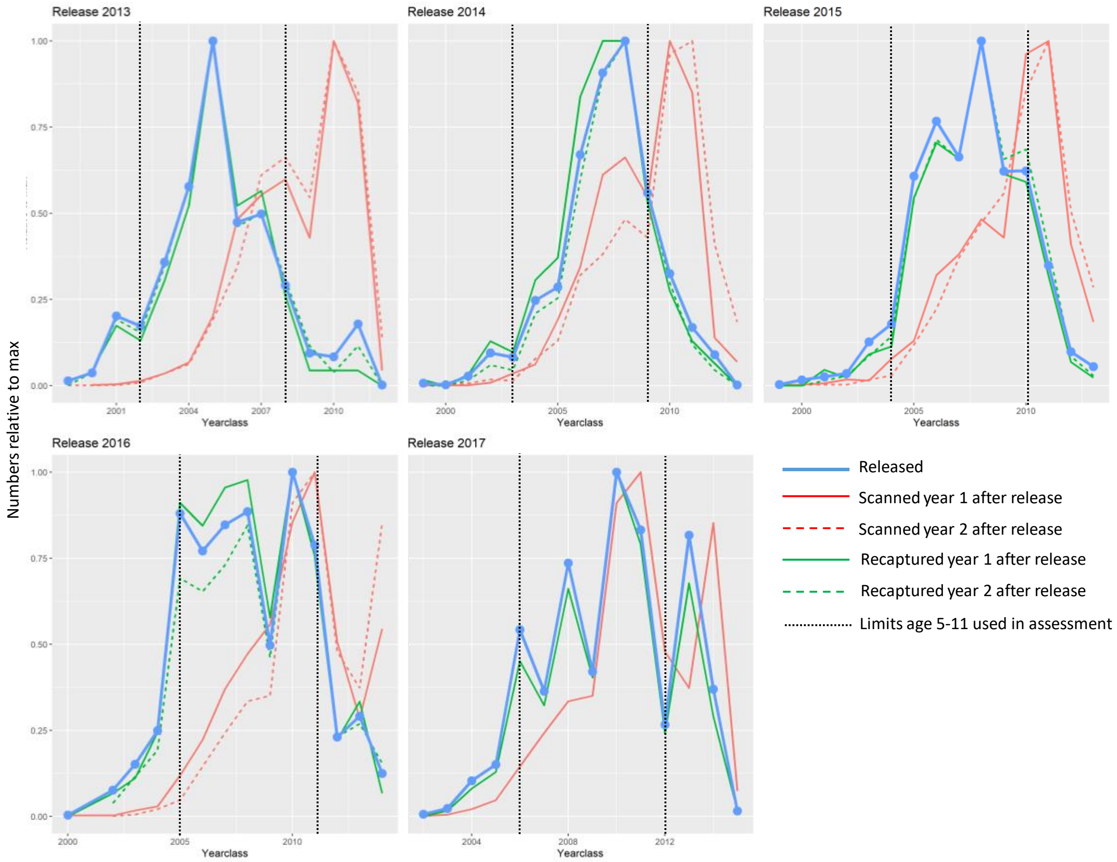

Figure 8.6.4.2. Overview of the relative year class distribution among RFID tagged mackerel per release year, compared with the numbers scanned and recaptured in year 1 and 2 after release of the same year classes. Only release years used in the mackerel assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES, 2019a) are shown. Not that it was also decided to only use ages 511 in updated assessments, and limits for this age span is marked for each release year.

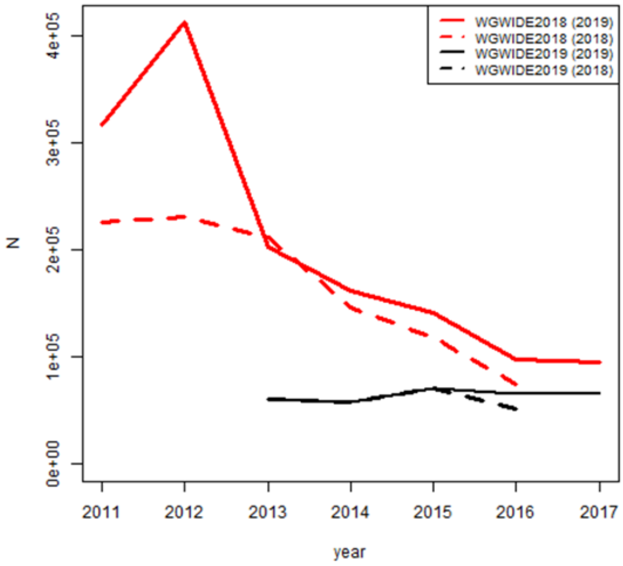

Figure 8.6.4.3. Trends in aggregated abundance index from RFID tag-recapture data. Comparison between the subset used in WGWIDE 2018 (release year 2011+, all recapture years, ages 211) versus the subset used in the updated WGWIDE 2019 assessment (release year 2013+, only recapture year 1 and 2 after release, ages 5-11), and the change using these subsets but the 2019 updated tag data set (updated with 2017 release data, and recaptures in 2018 from 2016 and 2017 releases). Method used is Chapman Lincoln-Peterson estimator described in IBPNEAMac 2019 report (ICES, 2019a).

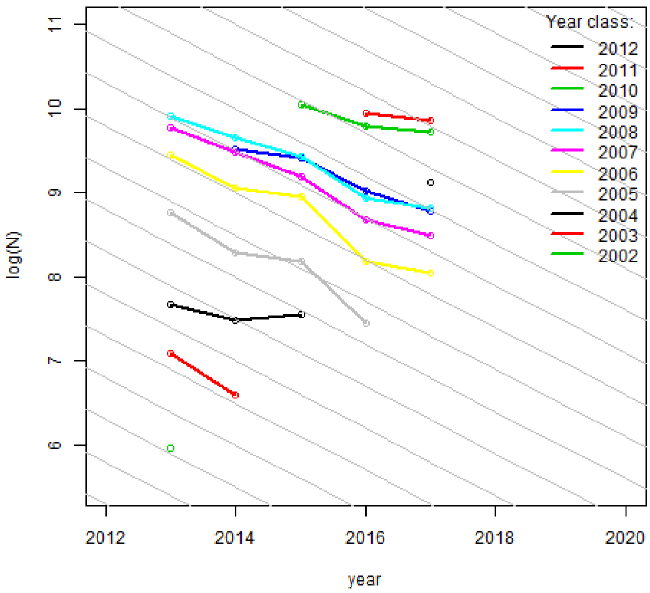

Figure 8.6.4.4. Trends in year class abundance from RFID tag-recapture data. Method used is Chapman Lincoln-Peterson estimator described in IBPNEAMac 2019 report (ICES, 2019a). Shown is only the subset data used in current assessment; release year 2013+, recapture year 1 and 2 after release and ages 5-11.

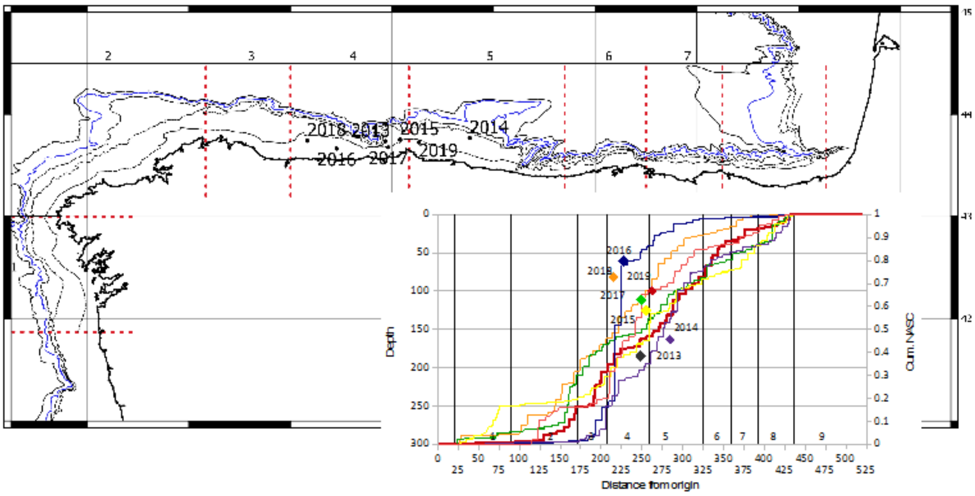

Figure 8.6.5.2.1. Centre of gravity for mackerel acoustic distribution from PELACUS 0313-19. The plot is showing the relative cumulative NASC distribution starting in the southern part and ending at the inner part of the Bay of Biscay.

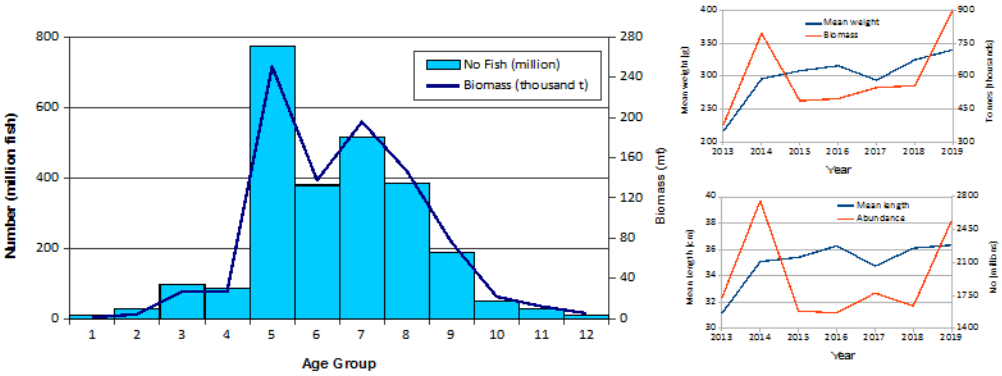

Figure 8.6.5.2.2: Mackerel abundance and biomass estimates by age group in ICES Divisions 8c. and 9.a during PELACUS 0319 (left). Upper right panel: mackerel mean weight (grams, blue line) and total biomass (thousand tonnes red line) estimated in PELACUS 201319; lower right: mackerel mean length (cm, blue line) and total abundance (million fish, red line) estimated in PELACUS 201319.

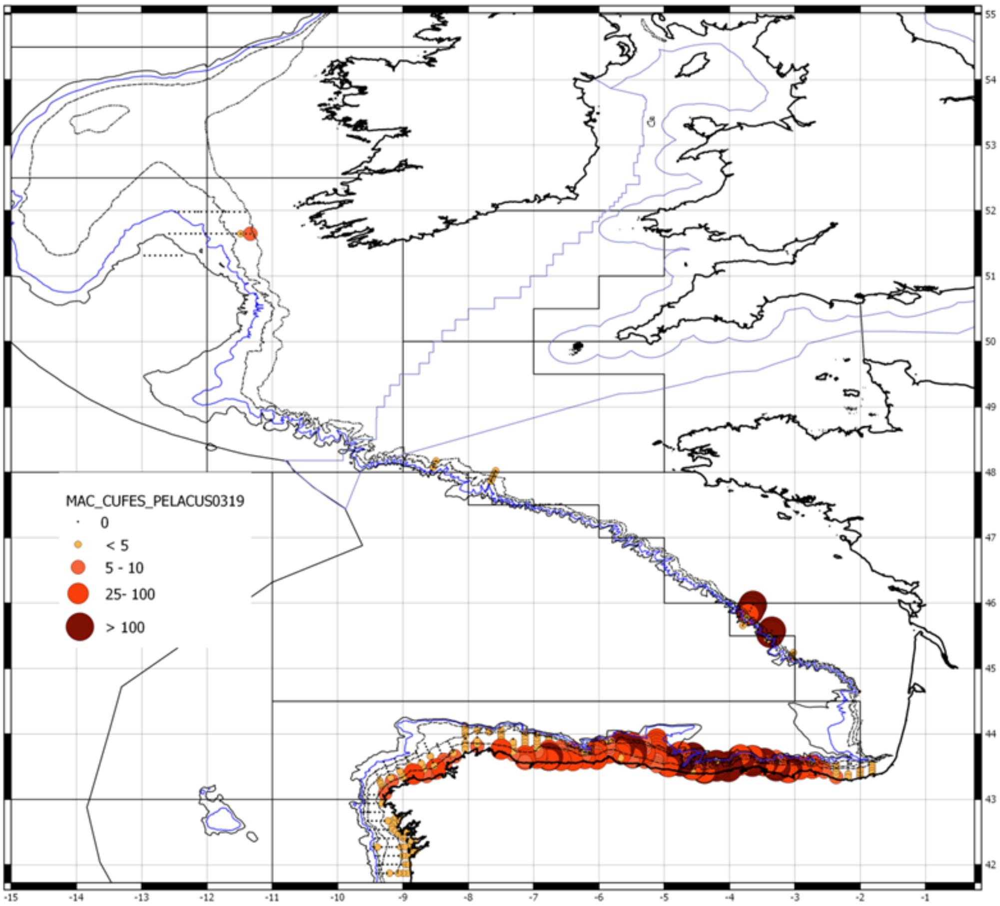

Figure 8.6.5.2.3: Mackerel subsurface egg distribution (no eggs/m³) as recorded by CUFES during PELACUS 0319.

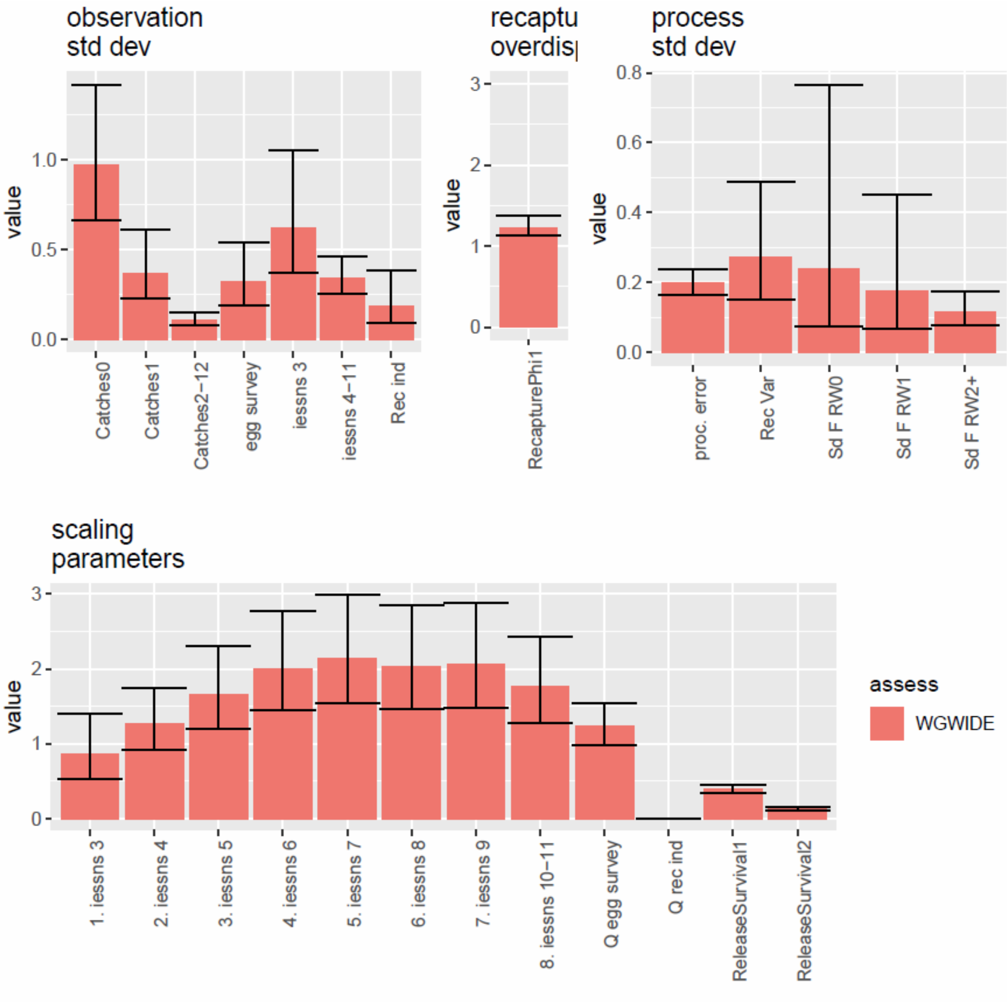

Figure 8.7.1.2.1. NE Atlantic mackerel. Parameter estimates from the SAM model (and associated confidence intervals) for the WGWIDE 2019 update assessment. top left: estimated standard deviation for the observation errors, top centre: estimated overdispersion for the errors on the tag recaptures, top right: standard deviation for the processes, bottom: survey catchabilities and post-release survival of tagged fish.

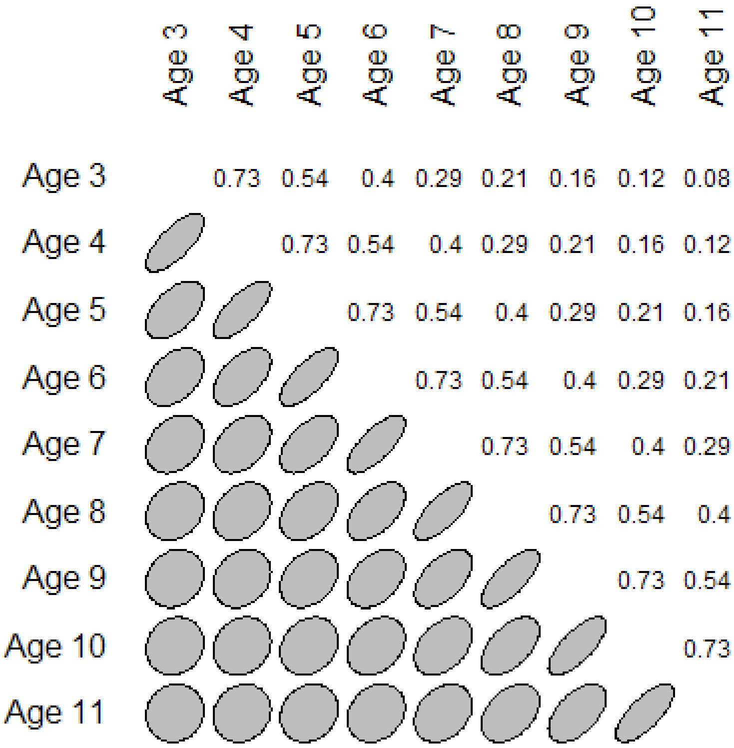

Figure 8.7.1.2.2. NE Atlantic mackerel. Estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11.

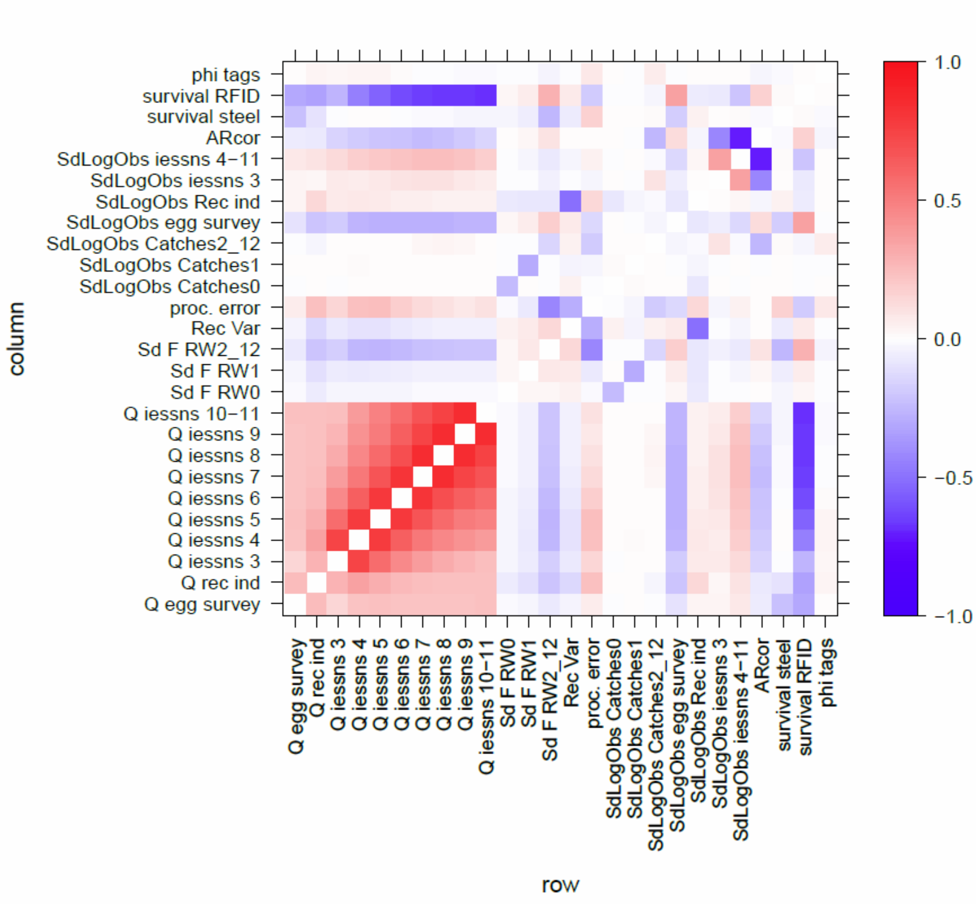

Figure 8.7.1.2.3. NE Atlantic mackerel. Correlation between parameter estimates from the SAM model for the WGWIDE 2018 update assessment

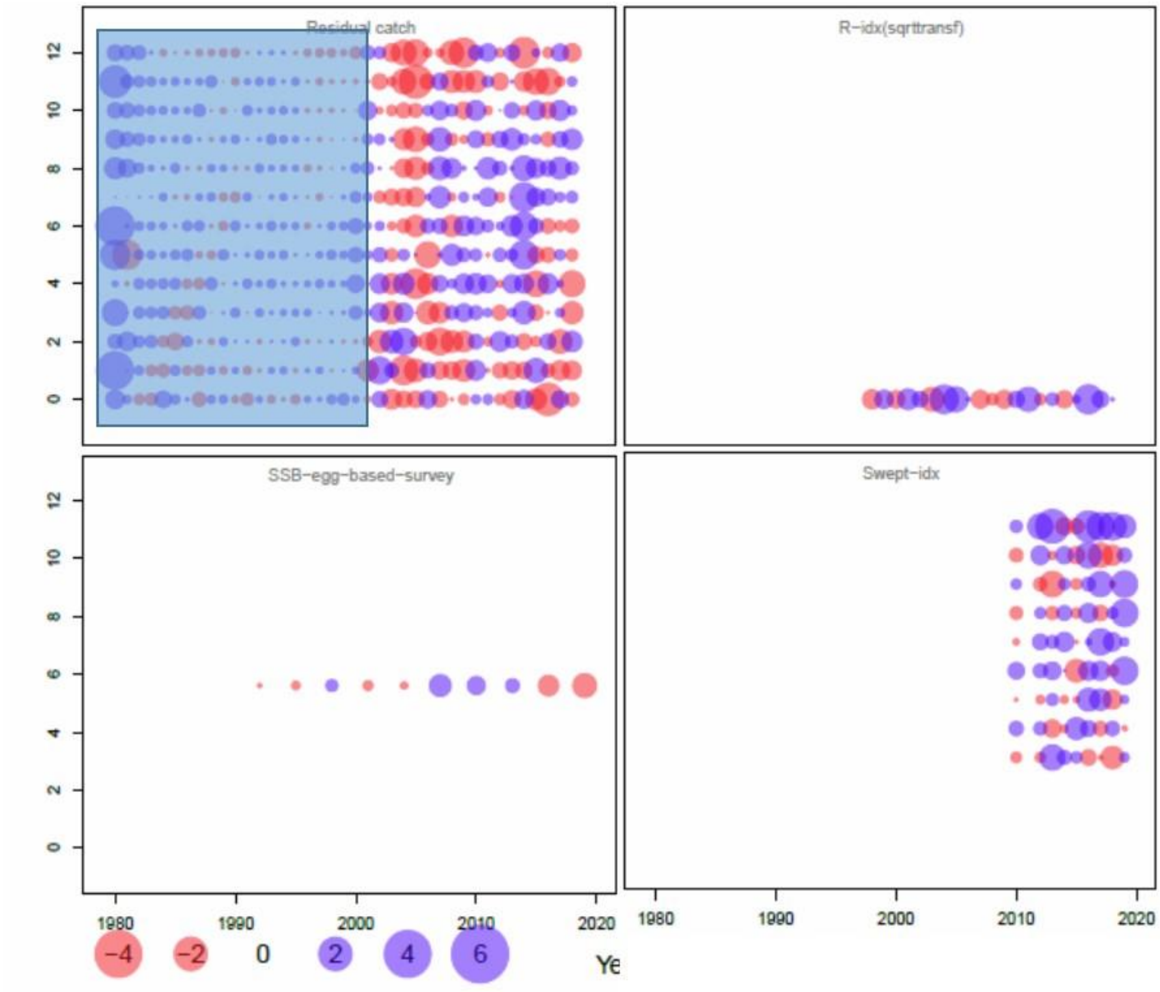

Figure 8.7.1.2.4. NE Atlantic mackerel. One Step Ahead Normalized residuals for the fit to the catch data (catch data prior to 2000 in blue rectangle were not used to fit the model). Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

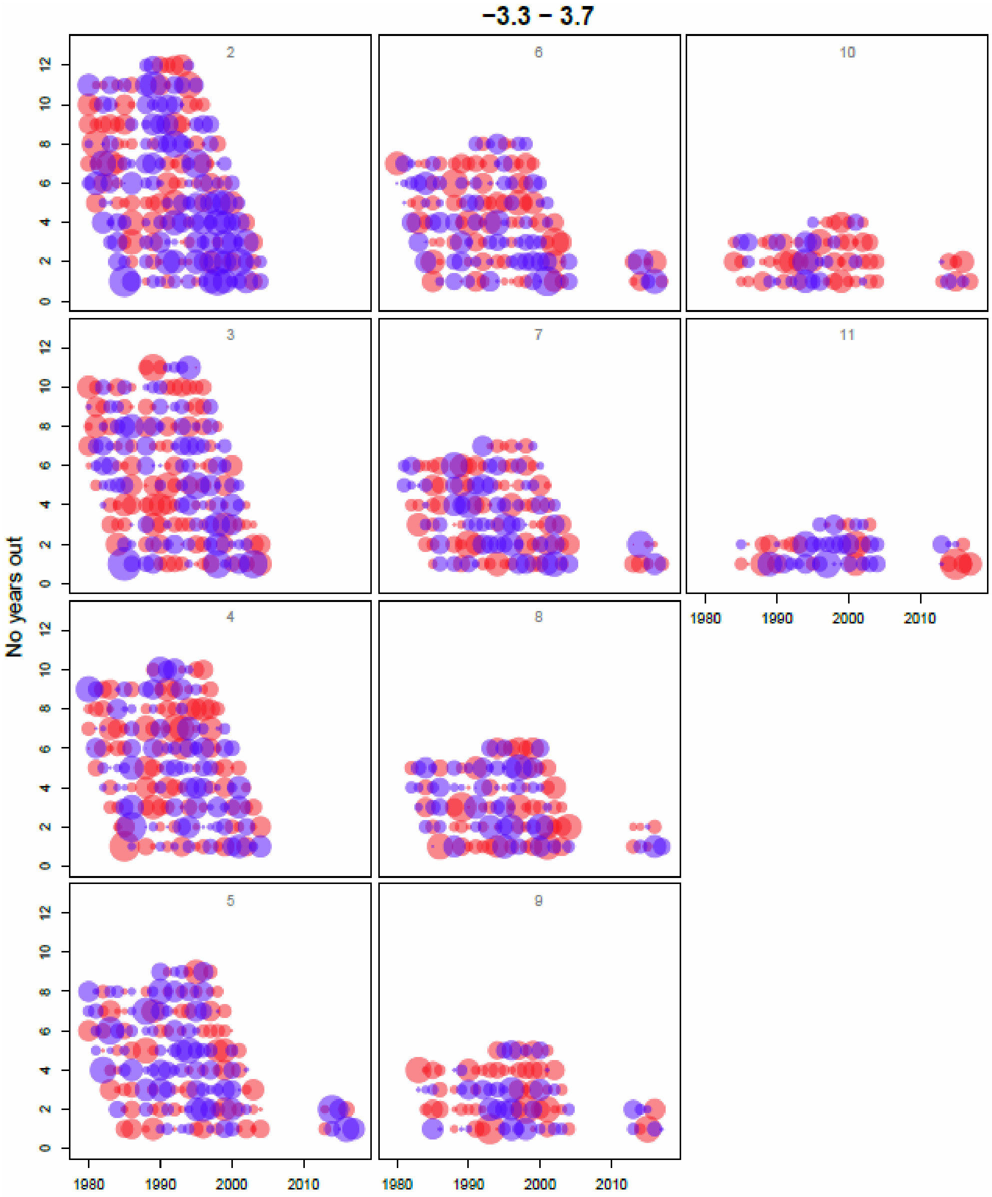

Figure8.7.1.2.5. NE Atlantic mackerel. One step ahead residuals for the fit to the recaptures of tags in the final assessment. The x-axis represents the release year, and the y-axis is the number of years between tagging and recapture. Each panel correspond to a given age at release. Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

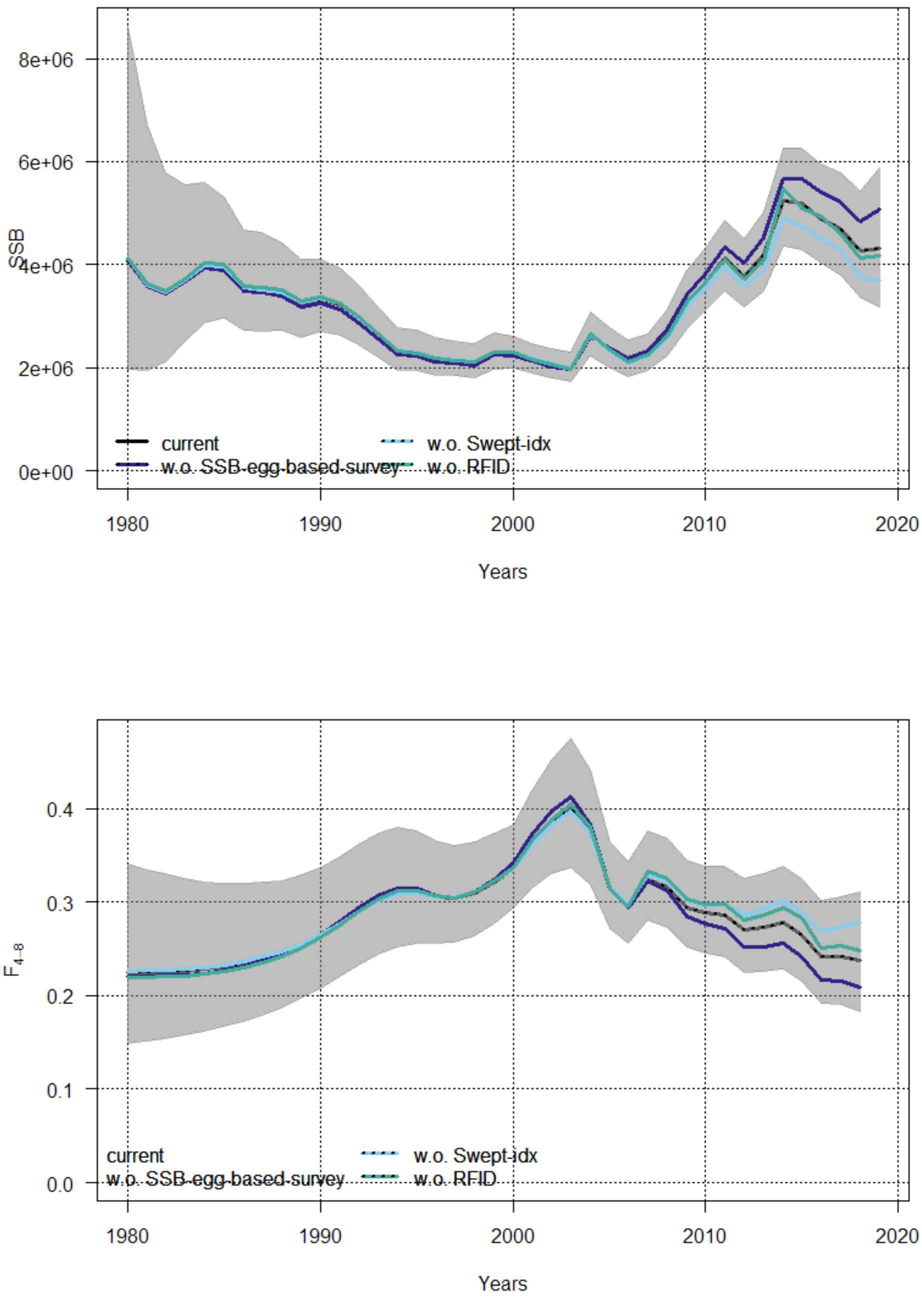

Figure 8.7.1.2.6. NE Atlantic mackerel. Leave one out assessment runs. SAM estimates of SSB and F_{bar}, for assessments runs leaving out one of the observation data sets.

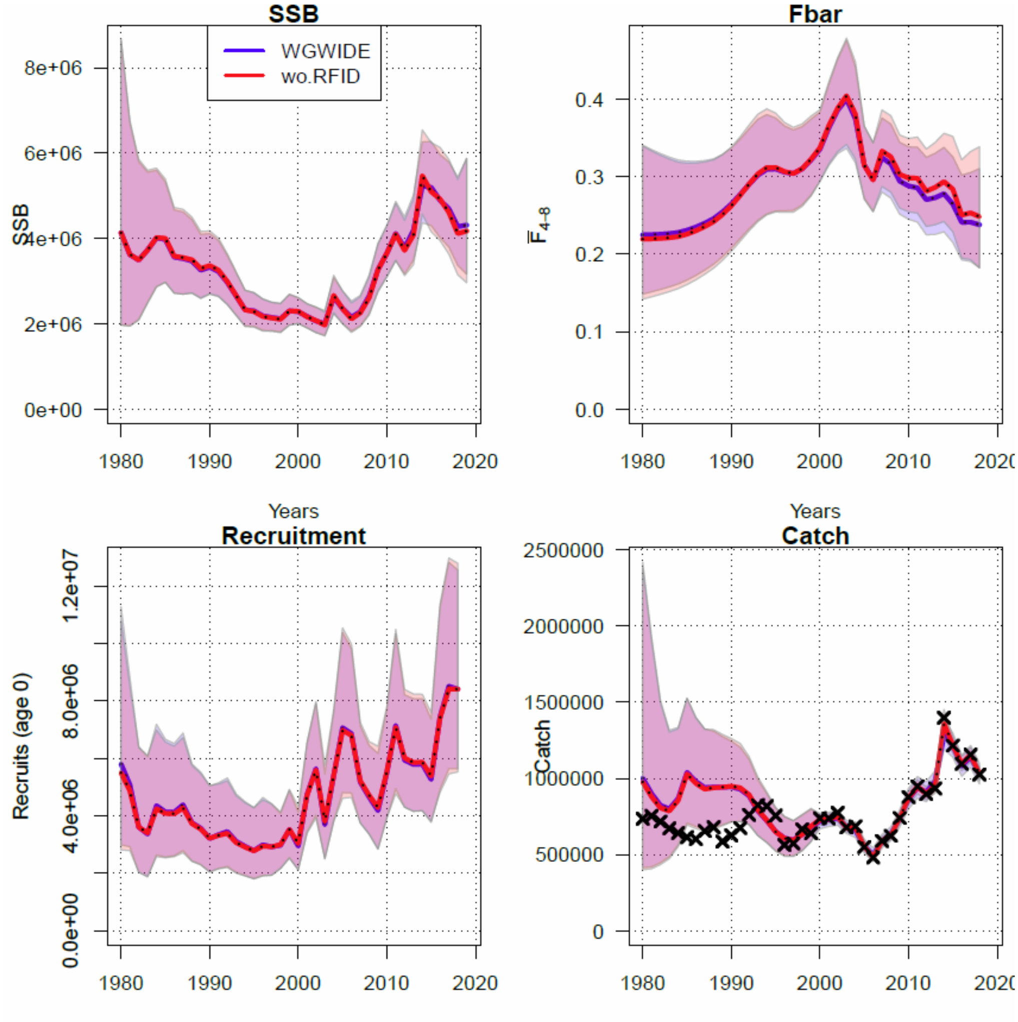

Figure 8.7.1.2.7. NE Atlantic mackerel. Leave one out assessment run excluding the RFID tagging data with confidence intervals for both runs (WGWIDE assessment in blue, run with RFID in red, overlap between both confidence intervals in purple).

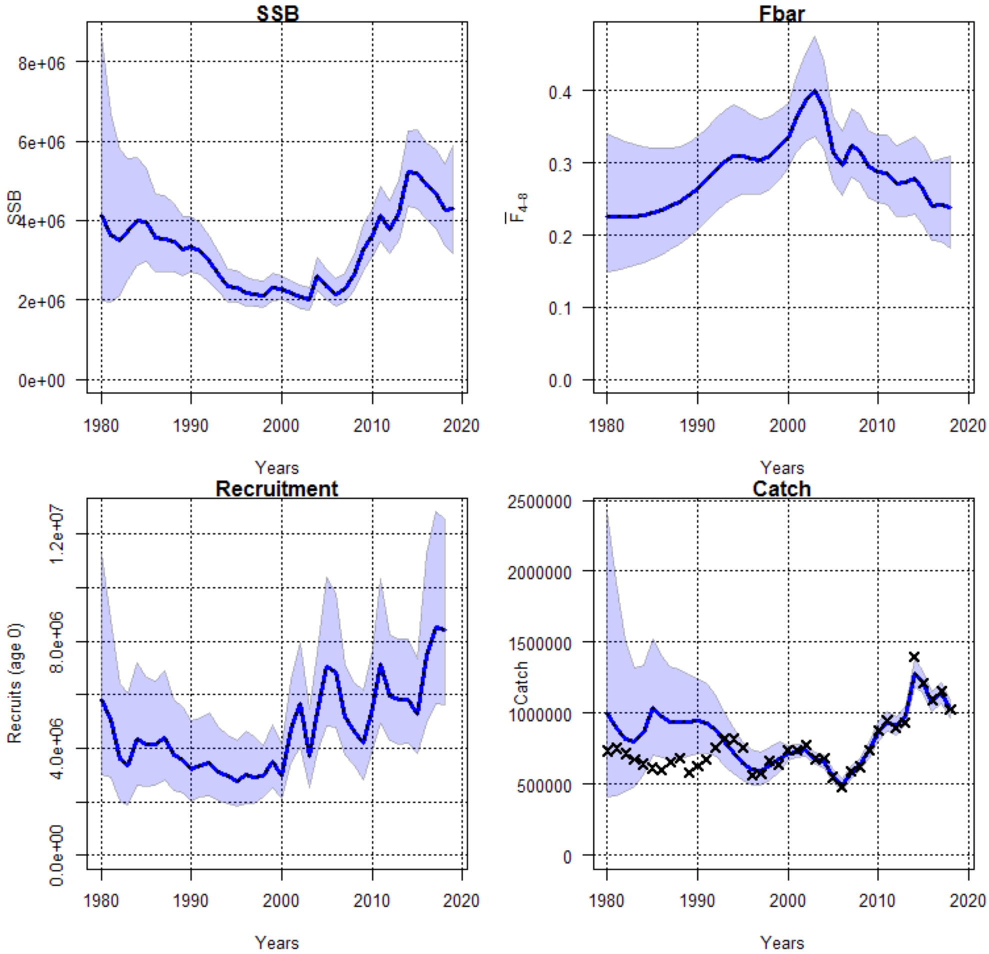

Figure 8.7.1.3.1. NE Atlantic mackerel. Perception of the NEA mackerel stock, showing the SSB, F_{bar}4-8 and recruitment (with 95% confidence intervals) from the SAM assessment.

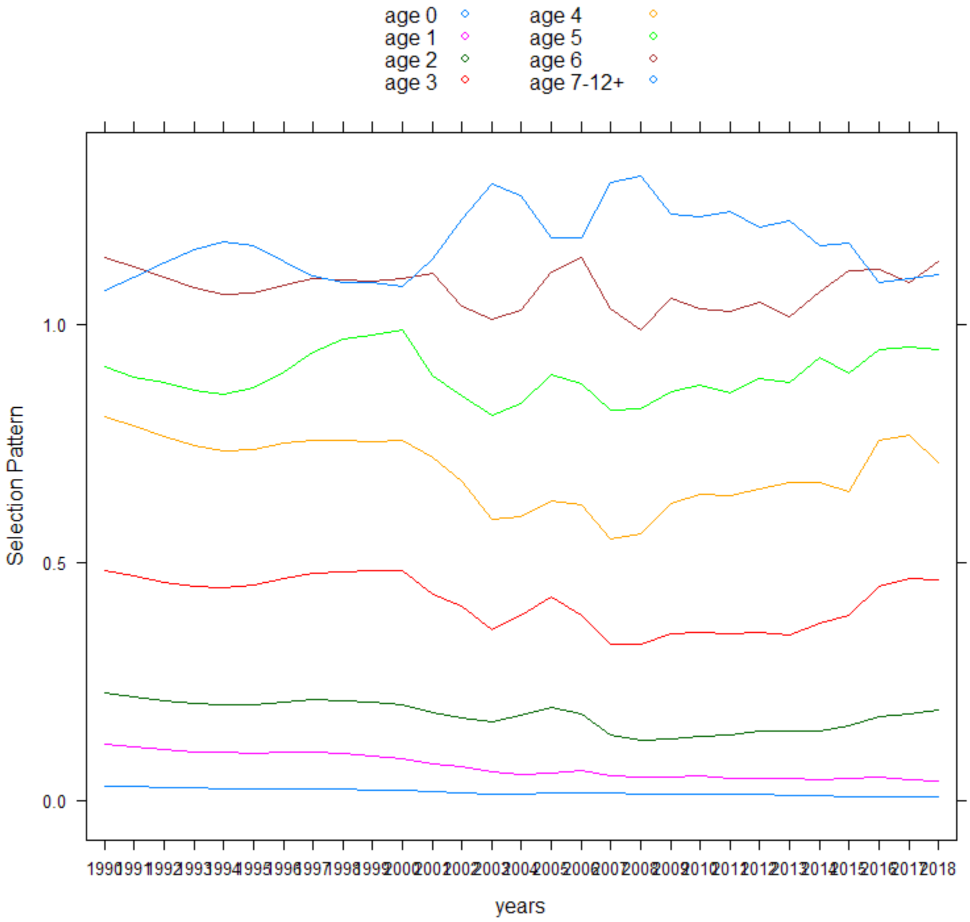

Figure 8.7.1.3.2. NE Atlantic mackerel. Estimated selectivity for the period 1990 to 2018, calculated as the ratio of the estimated fishing mortality-at-age and the F_{bar}48 value in the corresponding year.

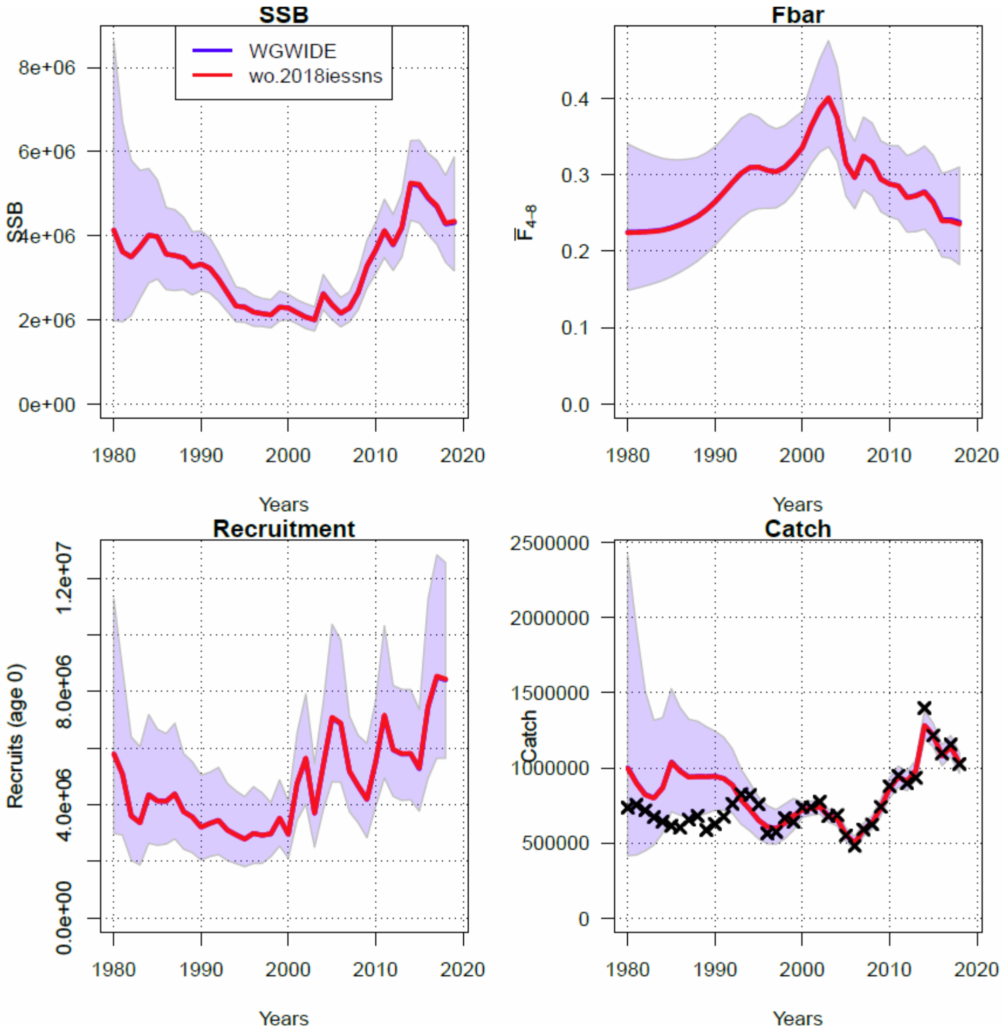

Figure 8.7.1.4.1.1. NE Atlantic mackerel. Influence of the 2018 IESSNS survey on the output of the assessment. Comparison of stock estimates from the 2019 WGWIDE assessment, the 2019 WGWIDE assessment without the 2018 IESSNS index.

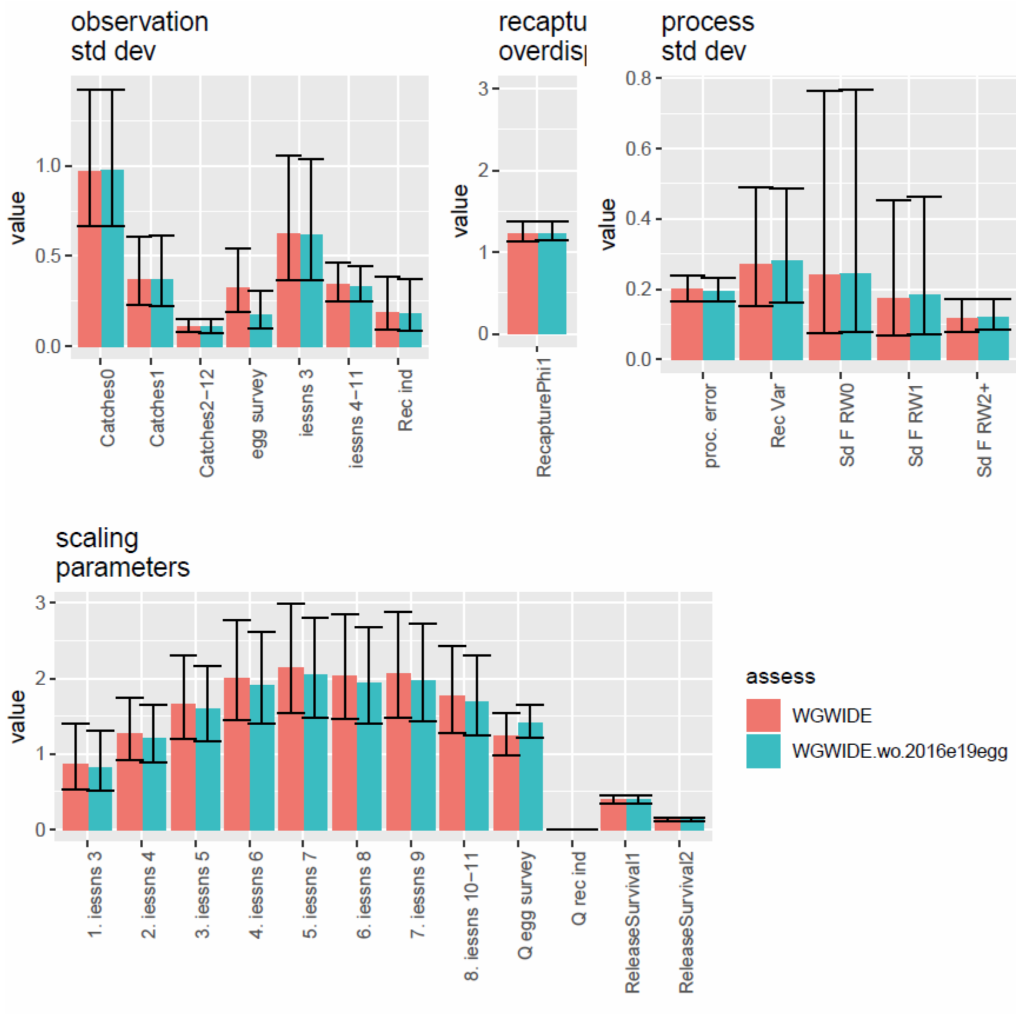

Figure 8.7.1.4.2.1. NE Atlantic mackerel. Comparison of estimated model parameters for the WGWIDE 2019 update assessment and the same assessment performed excluding the 2016 and 2019 egg survey indices.

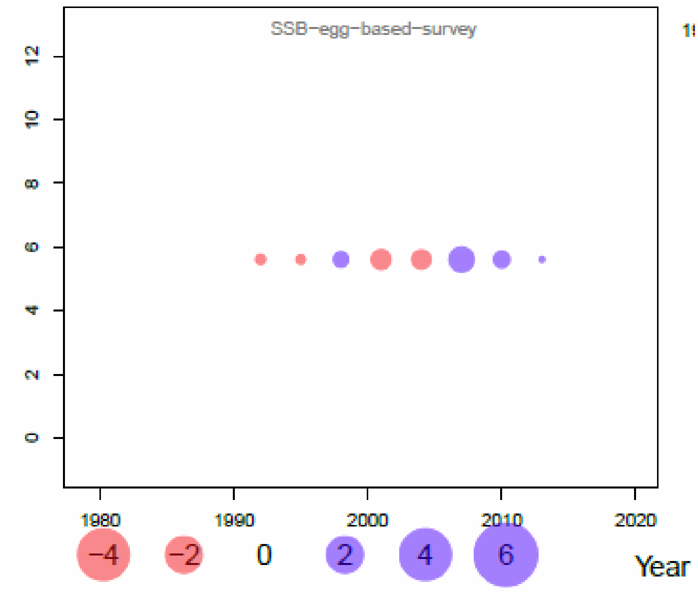

Figure 8.7.1.4.2.2. NE Atlantic mackerel. Residuals for the egg survey index in the assessment run excluding the 2016 and 2019 egg survey estimates.

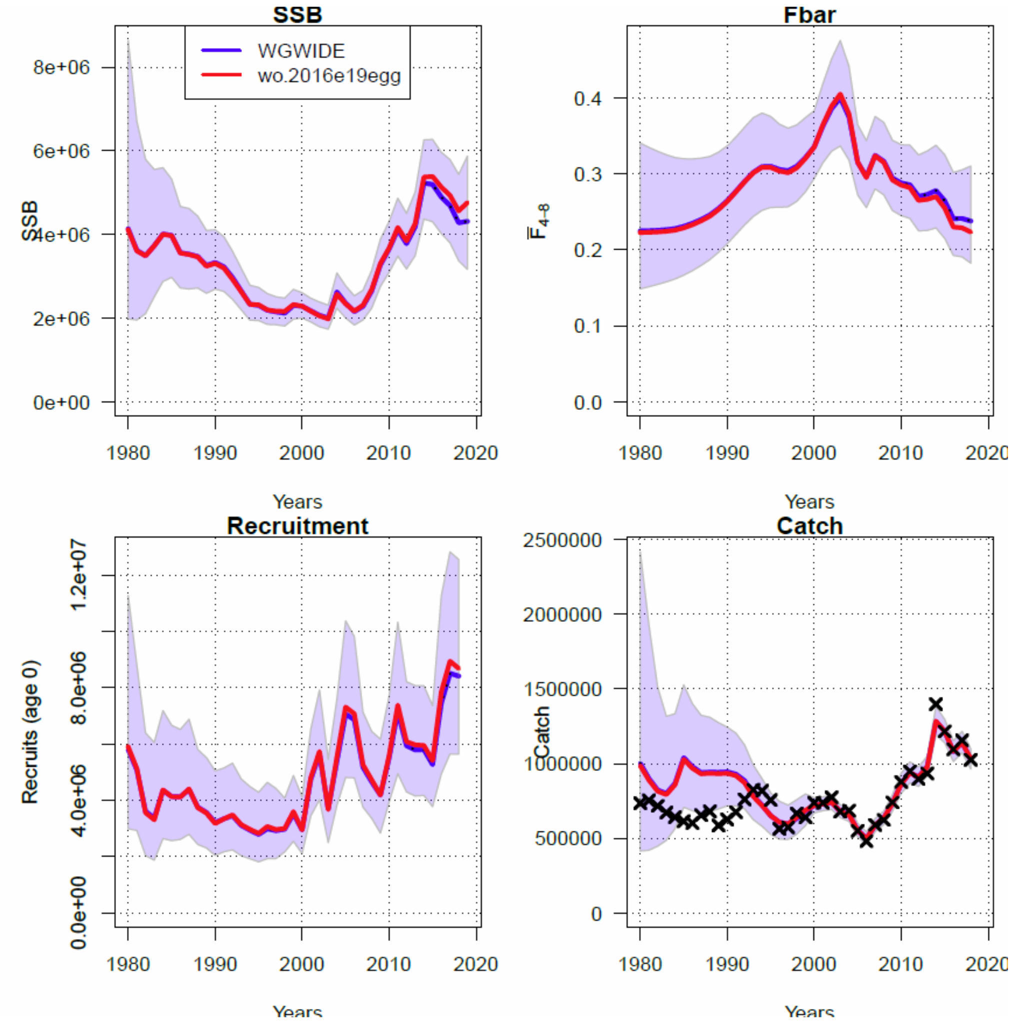

Figure 8.7.1.4.2.3. Influence of the 2016 and 2019 egg survey estimates on the output of the assessment. Comparison of stock estimates from the 2019 WGWIDE assessment, the 2019 WGWIDE assessment without the 2016 and 2019 egg indices.

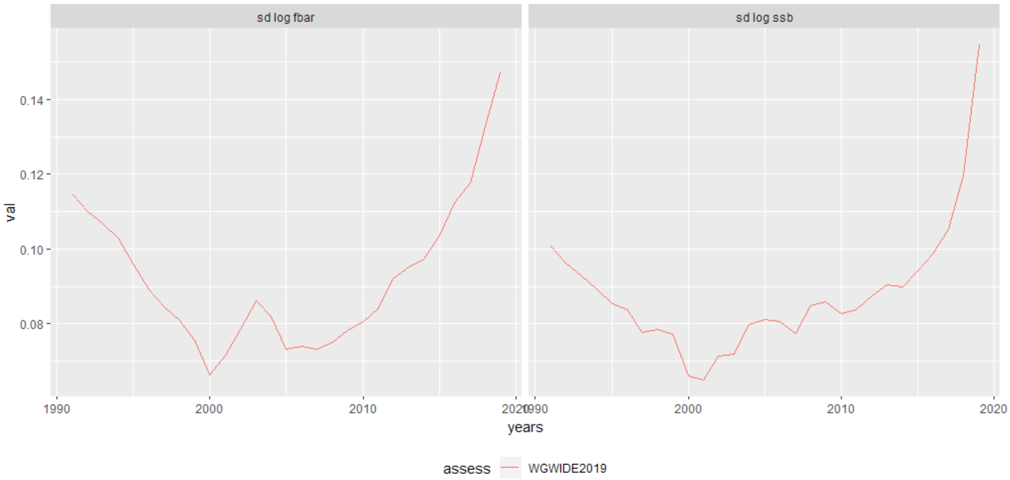

Figure 8.7.1.5.1. NE Atlantic mackerel. Uncertainty (standard deviation of the log values) of the estimates of SSB and F_{bar} from the SAM for the 2018 WGWIDE assessment.

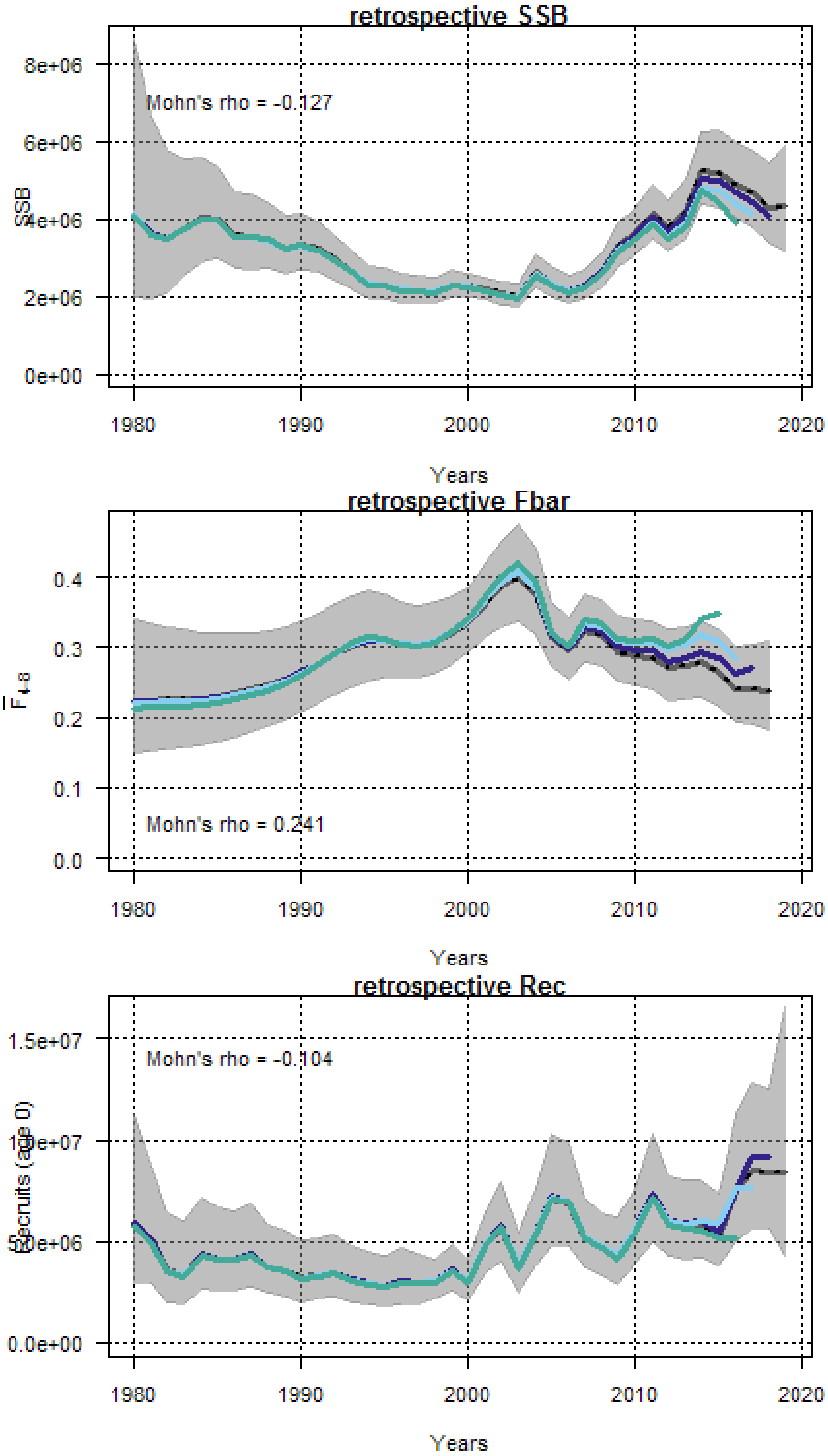

Figure 8.7.1.5.2. NE Atlantic mackerel. Analytical retrospective patterns (3 years back) of SSB, F_{bar}48 and recruitment from the WGWIDE 2018 update assessment.

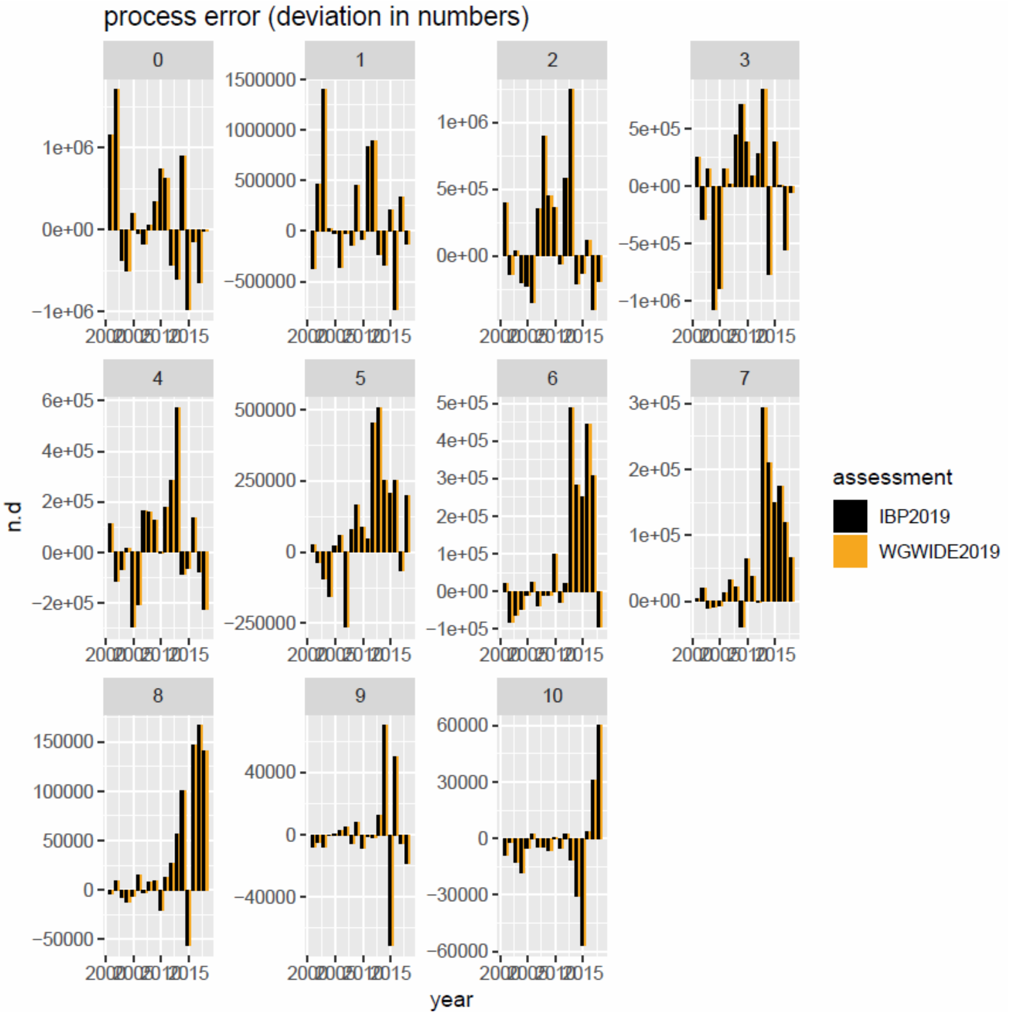

Figure 8.7.1.5.3. NE Atlantic mackerel. Process error expressed as annual deviations of abundances at age, for the 2019 WGWIDE assessment and from the 2019 interbenchmark assessment.

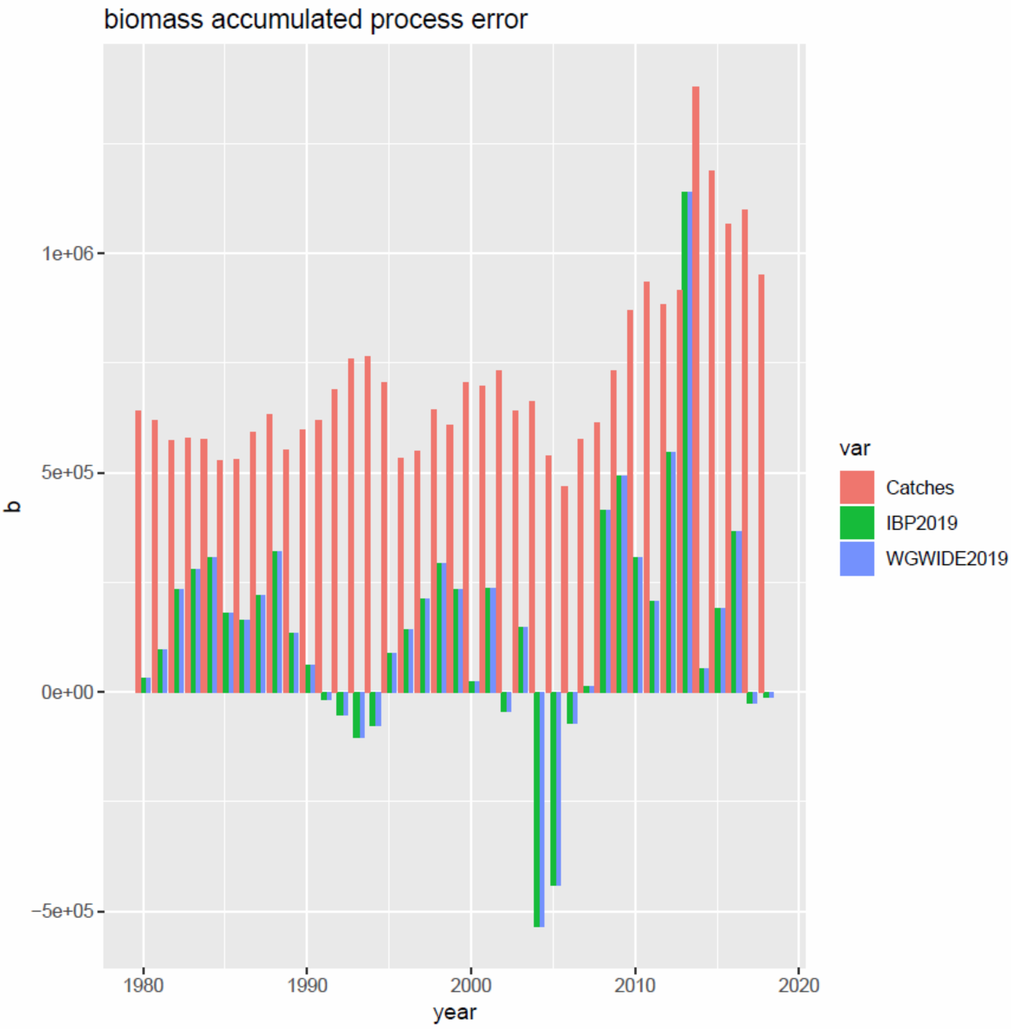

Figure 8.7.1.5.4. NE Atlantic mackerel. Model process error expressed in biomass cumulated across age-group for the 201 WGWIDE assessment and for the 2019 interbenchmark assessment.

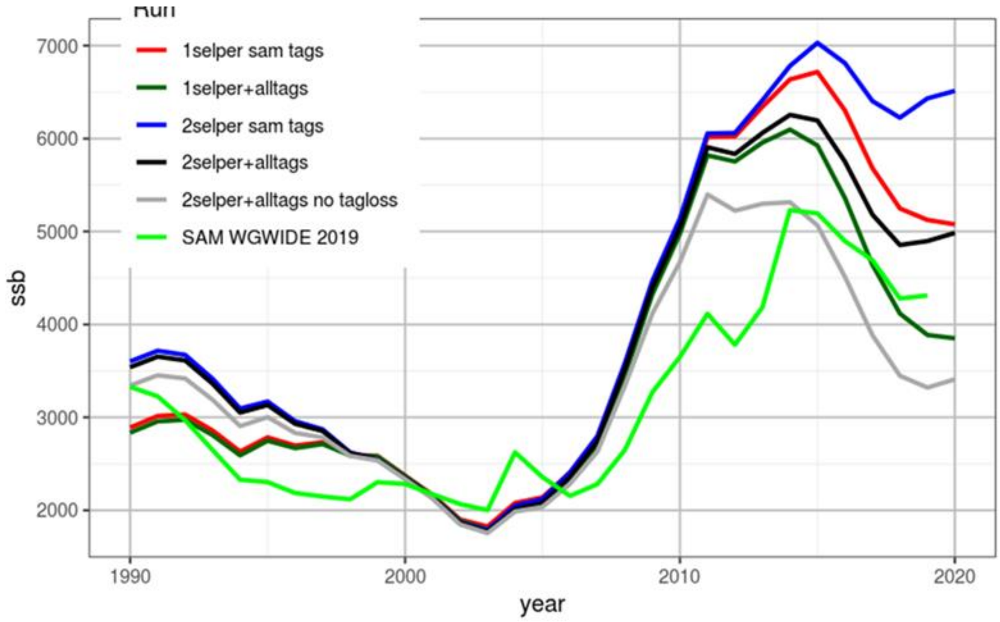

Figure 8.7.2.1.1. Development of spawning stock from different configurations of the Muppet model compared to the adopted SAM setup from WGWIDE 2019.

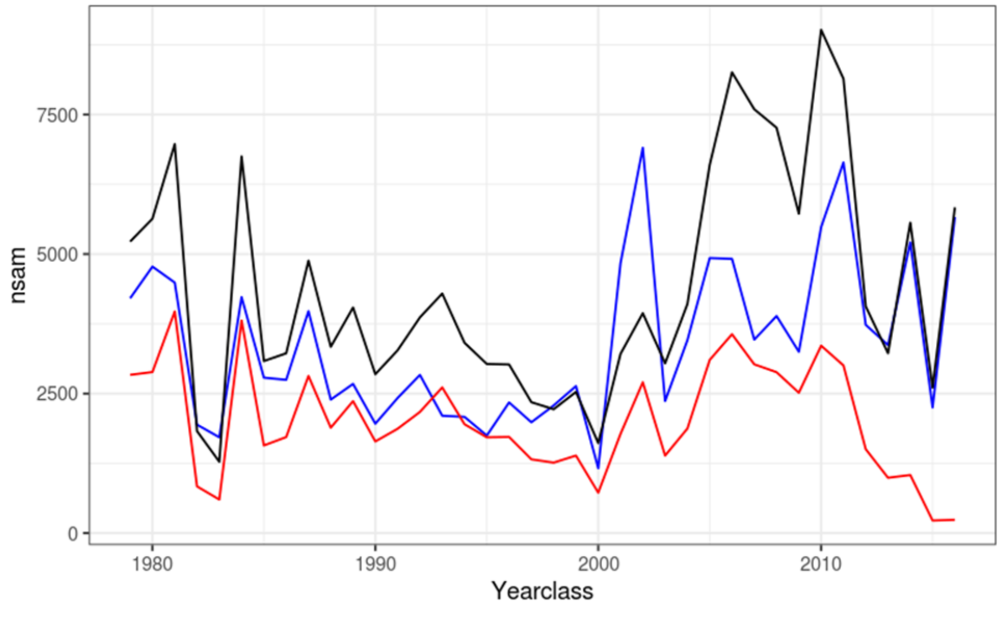

Figure 8.7.2.1.2. Estimated number of age 2 fish from SAM (blue), muppet (black) and catch of the year-class at age 2 to 11 (red).

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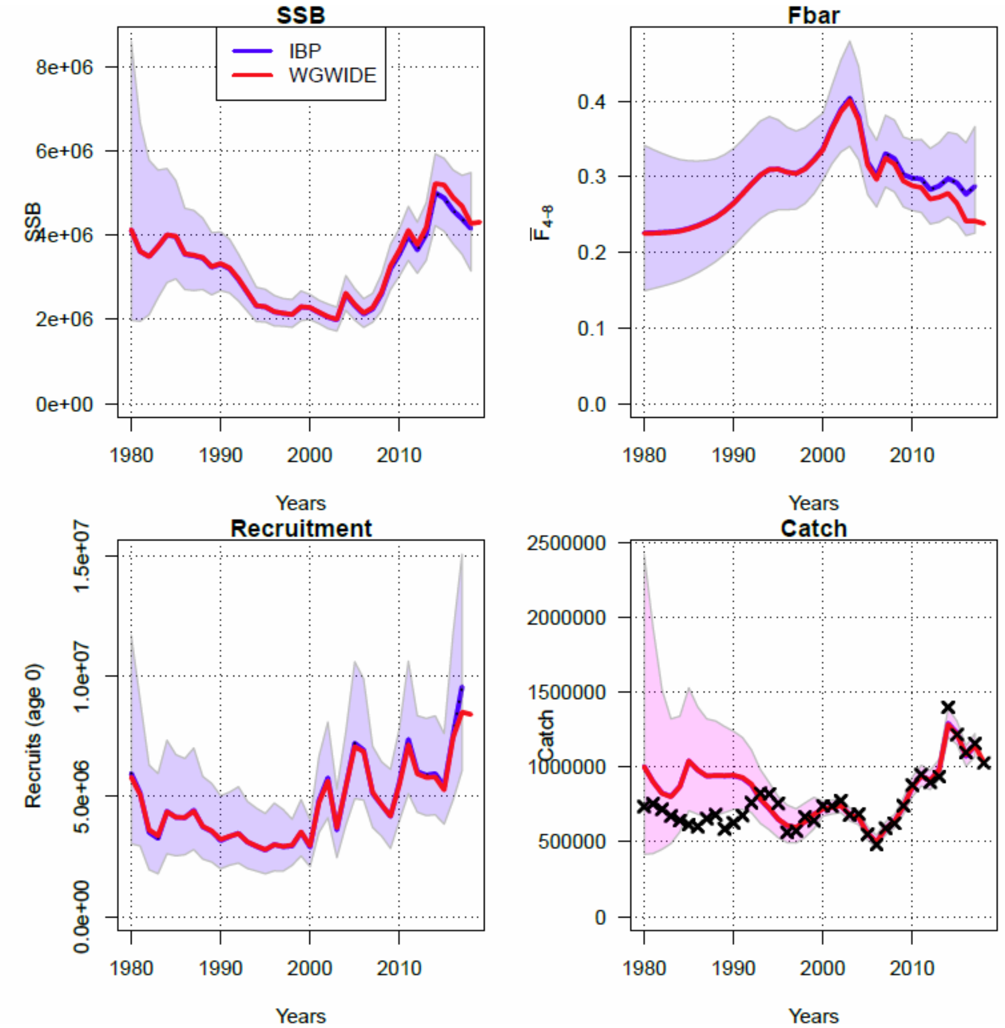

Figure 8.10.1. NE Atlantic mackerel. Comparison of the stock trajectories between the 2019 WGWIDE assessment and the 2019 IBPNEAMac (ICES, 2019a).

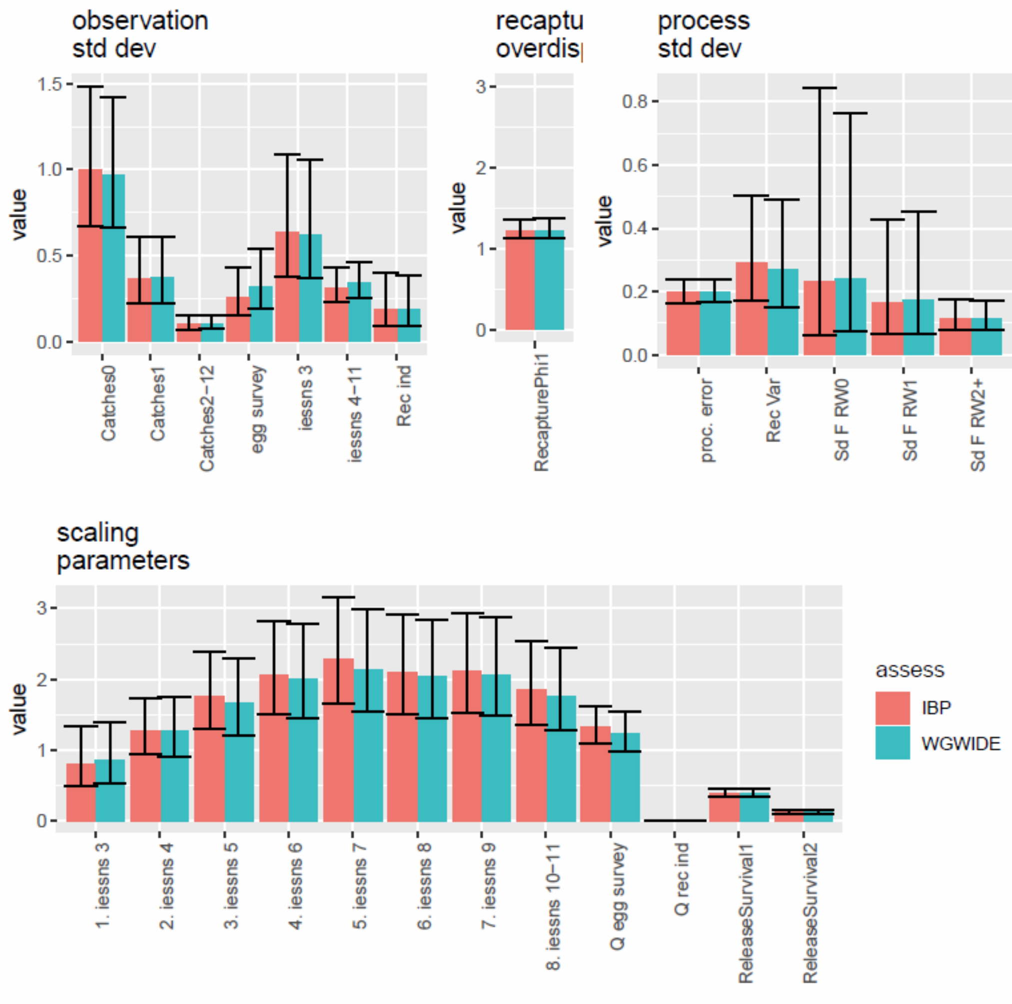

Figure 8.10.2. NE Atlantic mackerel. Comparison of model parameters and their uncertainty for the 2019 WGWIDE and the 2019 IBPNEAMac (ICES, 2019a).

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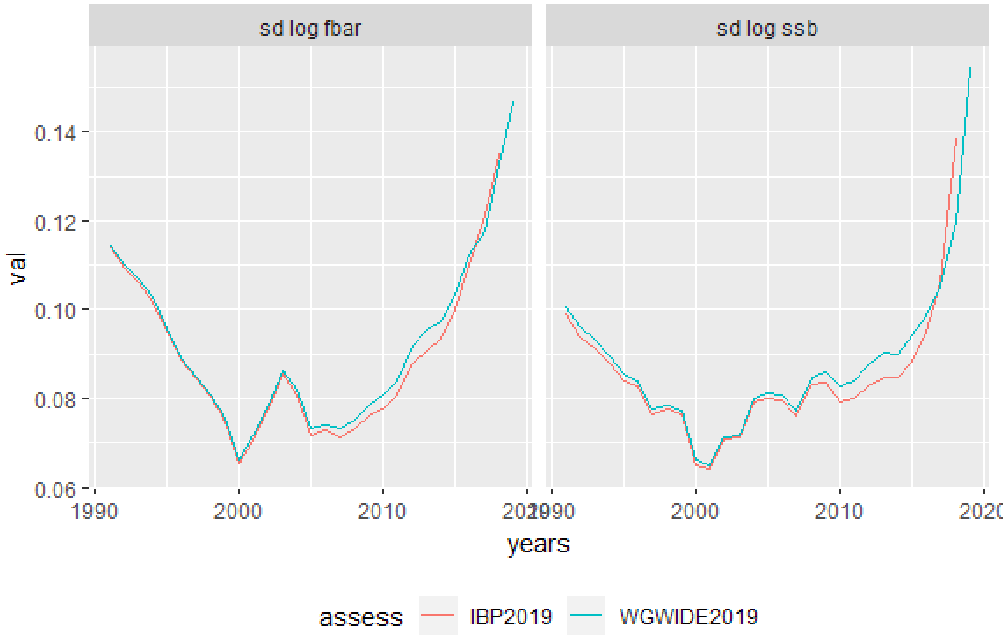

Figure 8.10.3. NE Atlantic mackerel. Comparison of the uncertainty on estimates of SSB and F_{bar} for the WGWIDE 2019 update assessment and the 2019 IBPNEAMac (ICES, 2019a).

9 Red gurnard in the Northeast Atlantic

9.1 General biology

The main biological features known for red gurnard (*Aspitrigla (Chelidonichthys) cuculus*) are described in the stock annex. This species is widely distributed in the North-east Atlantic from South Norway and North of the British Isles to Mauritania on grounds between 20 and 250 m. This benthic species is abundant in the Channel (7de) and on the shelf West of Brittany (7h, 8a), living on gravel or coarse sand. In the Channel, the size at first maturity is ~25cm at 3 years old (Dorel, 1986).

9.2 Stock identity and possible assessments areas

A compilation of datasets from bottom-trawl surveys undertaken within the project 'Atlas of the marine fishes of the northern European shelf' has produced a distribution map of red gurnard. Higher occurrences of red gurnard with patchy distribution have been observed along the Western approaches from the Shetlands Islands to the Celtic Seas and the Channel.

A continuous distribution of fish crossing the Channel and the area West of Brittany does not suggest a separation of the Divisions 7d from 7e and 7h. Therefore a split of the population between the Ecoregions does not seem appropriate. Similar temporal signals observed in NS-IBTS and SCO-WCIBTS surveys, which are not seen in other survey series, may suggest a linkage between subareas 4 and 6. Further investigations are needed to progress on stocks boundaries such as morphometric studies, tagging and genetic population studies.

9.3 Management regulations

There is currently no technical measure specifically applied to red gurnard or other gurnard species. The exploitation of red gurnard is submitted to the general regulation in the areas where they are caught. There is no minimum landing size set.

9.4 Fisheries data

Red gurnard is mainly landed as bycatch by demersal trawlers in mixed fisheries, predominantly in Divisions 7d, 7e and 7h (Figure 9.1). High discard rates and lack of resolution at a species level make interpretation of spatial trends in catches in other areas problematic.

9.4.1 Historical landings

Official landings reported at ICES are available in Table 9.1 and Table 9.2. Before 1977, red gurnard was not specifically reported. Landings of gurnards are still not always reported at a species level, but rather as mixed gurnards. For those countries who do report landings at a species level, only Portugal has presented information on how this is achieved. This makes interpretations of the records of official landings difficult.

International landings have fluctuated between 3452 5171 tonnes since 2006. France is the main contributor of 'red gurnard' landings, with around 80% of landings coming from ICES Subarea 7d-h (Celtic Sea/English Channel). In the North Sea red gurnard landings are variable, but roughly evenly distributed between Divisions 4a,b and c. Landings from the west of Scotland and Ireland, and the Irish Sea (ICES Subarea 6a-b, 7a-c, 7j) and Bay of Biscay (ICES Division 8) have been consistently low.

9.4.2 Discards

Discard data for red gurnard has been provided for 2015 - 2018 through Intercatch (Table 9.3). For those countries which provided data, discard rates ranged between from 48% and 91% of catch in 2017, and 21% and 95% in 2018 (Table 9.4).

9.5 Survey data

Information on gurnard abundance are available in DATRAS for the IBTS-Q1 survey in the North Sea, Scottish West Coast Groundfish Survey (WCGFS), Irish Groundfish Survey (IGFS) and the French EVHOE-WIBTS-Q4 survey in the Celtic Sea and Bay of Biscay and CGFS-Q4 in Division 7d. Each of these surveys covers a specific area of red gurnard distribution. Lengths at age are available from CGFS-Q4 in and IGFS-Q4

- NS- IBTS-Q1 series. Before 1990, red gurnard was scarce in North Sea and the abundance index was close to 0. The abundance index of red gurnard has trended generally upwards between 1994 – 2013, before declining somewhat, although it remains well above long-term average values. This change reflects an increase of the abundance in the northern and central North Sea (4a-b). It is interesting to contrast these trends with the apparent very low abundances in the NS-IBTS-Q3 series.
- SCO-WCGFS series. Before 1996, red gurnard was also scarce on the west of Scotland. The abundance index trended strongly upwards after 1997, reaching a peak in 2013, before declining to around the series average in recent years.
- IGFS series. The abundance index of red gurnard in the IGFS series has varied around the series mean without trend between 2002 and 2018.
- CGFS-Q4 series. Over the time-series 1988—2011, the abundance index has fluctuated, peaked in 1994, reached a low in 2011, but is above long term mean in 2016.
- EVHOE-WIBTS-Q4 series. Over the period 1997—2011, the abundance index in Nb or kg/hr has increased over time. Age reading of red gurnards caught during EVHOE survey has been carried out in 2006 and routinely since 2008. They indicate that the individuals caught are mainly of age 1 and 2.
- Survey abundance information was provided via DATRAS for the first time for the Spanish Porcupine and Northern Spanish groundfish surveys (SP-PORC and SP-NSGFS). Both survey indices are variable, but show an overall upwards trend over time in numbers and weight per tow.

9.6 Biological sampling

Number at length information was provided by French and Portuguese landings and discards. There remains a lack of regular sampling for red gurnard in commercial landings and discarding to provide series of length or age compositions usable for a preliminary analytical assessment.

9.7 Biological parameters and other research

There is no update of growth parameters and available parameters from several authors are summarized in the Stock Annex. They vary widely. Available length–weight relationships are also shown in Stock Annex. Natural mortality has not been estimated in the areas studied at this Working Group.

9.8 Analyses of stock trends

In the North Sea, the appearance of red gurnard in the index of the IBTS Survey since 1990 is in line with an increase of the abundance in 4a. In Eastern Channel, the abundance index of the CGFS-Q4 survey has widely fluctuated, with a weak decline. The EVHOE-WIBTS-Q4 survey has slightly increased since its beginning in the 1990s.

9.9 Data requirements

Gurnards are still not always reported by species, but rather as mixed gurnards. This makes interpretations of the records of official landings difficult. Extending the studied area by a survey in 7e and collecting length and age data of red gurnard in the main area of production should help in better understanding the biology and dynamics of this species.

9.10 References

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.

9.11 Tables

Table 9.1. Red gurnard in the Northeast Atlantic official landings by country in tonnes.

Year	Bel-gium	Spain	France	Jer-sey	Guern-sey	Ire-land	IM	Nether-lands	Portugal	UK	Total
2006	313	0	4552	0	10	0	0	57	125	115	5172
2007	328	0	4494	1	4	0	0	66	127	156	5176
2008	352	0	4045	0	8	0	0	92	112	166	4775
2009	227	0	3310	0	6	0	1	160	150	263	4117
2010	237	0	3437	0	2	0	0	251	115	362	4404
2011	306	0	3176	1	2	0	1	295	134	257	4172
2012	306	0	2706	3	4	26	0	329	148	257	3779
2013	288	576	3154	3	9	16	2	267	113	329	4757
2014	263	399	3782	3	6	0	5	241	108	283	5090
2015	187	91	2919	2	3	0	0	210	122	341	3875
2016	238	87	2598	3	2	9	1	224	106	381	36469
2017	265	105	2396	0	1	9	4	226	114	335	3455
2018*	313	89	2968	0	0	13	1	305	114	342	4145
2018**	308	65	2952			14	1	301		342	3983

***Preliminary Data,**

****Intercatch Data**

Table 9.2. Red gurnard in the Northeast Atlantic official landings by area in tonnes.

Year	4a	4b	4c	5b	6a	6b	7a	7b	7c	7d	7e	7f	7g	7h	7j	7nk	8a	8b	8c	8d	9a	9nk	10a	10nk	14a	Total
2006	13	83	64	0	32	1	11	9	12	1101	2803	229	16	446	5	1	153	60	1	5	9	115	0	1	0	5171
2007	12	120	55	2	21	0	7	7	15	1229	2674	246	15	437	4	0	139	59	3	2	125	0	0	2	0	5174
2008	34	64	54	0	28	3	5	7	16	1236	2451	249	9	408	5	0	66	24	3	1	109	0	3	0	0	4775
2009	58	59	92	0	94	2	4	8	6	1293	1557	112	22	510	7	0	98	40	1	3	148	0	1	0	0	4115
2010	79	63	86	0	101	46	13	8	10	1531	1608	132	23	433	9	0	100	33	0	2	114	0	0	1	0	4392
2011	66	29	51	0	69	54	13	5	6	1295	1753	124	20	372	9	0	112	46	1	3	133	0	1	0	1	4163
2012	83	71	78	0	51	7	8	2	5	1244	1441	145	53	294	2	0	83	50	8	1	136	4	1	0	1	3768
2013	88	109	60	0	47	0	10	2	6	1193	1692	170	58	477	2	0	79	72	532	1	155	0	2	0	0	4755
2014	102	52	68	0	47	3	7	1	2	1294	1642	115	19	1069	1	0	82	75	363	3	139	0	3	0	0	5087
2015	133	102	53	0	58	1	4	3	1	790	1553	87	6	703	1	0	95	70	81	2	128	0	2	0	0	3873
2016	112	83	117	0	76	1	11	3	1	906	1268	114	16	608	1	0	87	63	56	1	120	0	1	0	0	3645
2017	53	44	90	0	27	1	14	1	0	874	1424	83	38	473	3	0	78	48	59	1	142	0	1	0	0	3454
2018*	106	39	113	0	41	0	9	0	0	902	1793	164	28	631	4	0	80	42	61	2	125	0	1	0	0	4141

***Preliminary Data**

Table 9.3. Red gurnard in the Northeast Atlantic, discards (t) by country, 2015 – 2018.

Country	2015	2016	2017	2018
France	1323	2249	2232	770
Ireland	10	147	93	251
Portugal				0
Spain		286	272	189
UK (ENG)	74	30		207
UK (SCO)	649	411	198	512
Total	2056	3123	2795	1929

Table 9.4. Discarding of Red gurnard in the Northeast Atlantic, as a percentage of catch, by country, in 2017-18.

Country	Discard rate (%)	
	2017	2018
France	48	21
Ireland	91	95
Spain	72	68
UK (SCO)	68	92

9.12 Figures

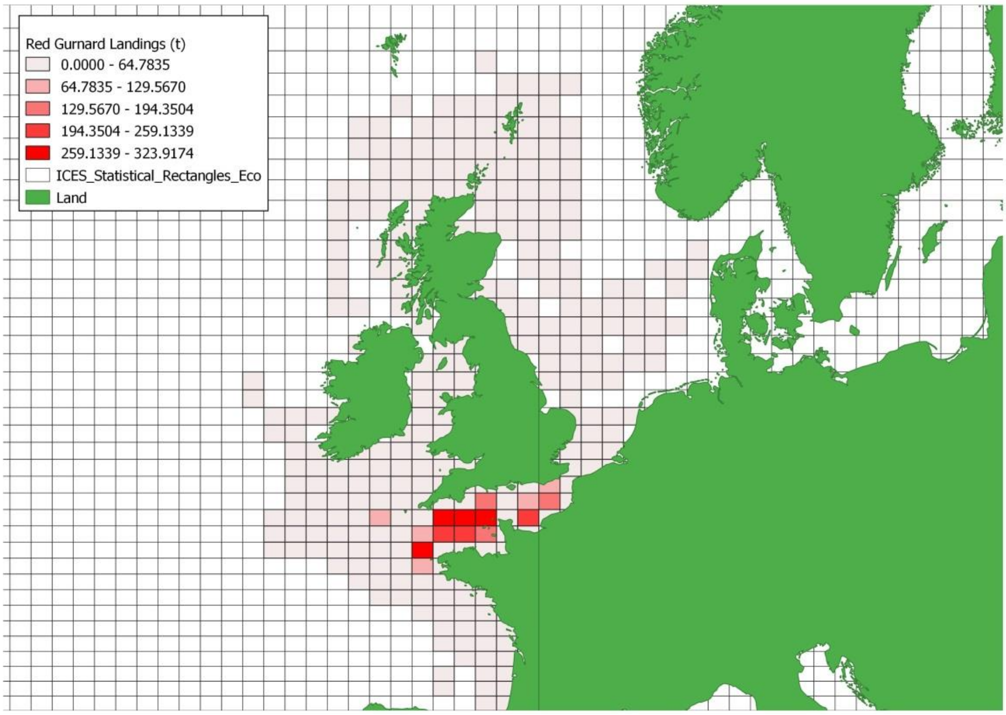

Figure 9.1. Red gurnard in the Northeast Atlantic. Landings in 2018, by statistical rectangle, from BEL, FRA, IRE, UK(E&W), UK(IoM) & UK(SCO).

10 Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a

10.1 General biology

Striped red mullet (*Mullus surmuletus*) is a predominantly benthic species found along the coasts of Europe, southern Norway and northern Scotland (northern Atlantic, Baltic Sea, North Sea and the English Channel), up to the Northern part of West Africa, in the Mediterranean Basin, and in the Black Sea (Hureau, 1986; Mahé *et al.*, 2005). Young fish are distributed in lower salinity coastal areas, while adults have a more offshore distribution.

Adult red mullet feed on small crustaceans, annelid worms and molluscs, using their chin barbels to detect prey and search the mud. As a consequence, striped red mullet are typically found on sandy, gravelly and shelly sediments where they can excavate sediment with their barbels and dislodge the small invertebrates. The main natural predators of striped red mullet are sea basses, pollacks, barracudas, monkfish, congers and sharks (Caill-Milly *et al.*, 2017).

Sexual maturity is reached at the beginning of the second year for males, followed by a marked decrease in growth rates, and at the end of the second or beginning of the third year for females which therefore continue their rapid growth a little longer (Déniel, 1991). In the English Channel, this species matures at approximately 16 cm (Mahé *et al.*, 2005), while in the Bay of Biscay, the sizes of first sexual maturity are given by Dorel (1986) as: males 16 cm, females 18 cm and a length at which 50% of the individuals are mature (the distinction between the two sexes is not mentioned) of 22cm.

Spawning occurs in the spring and early summer (May to June according to Desbrosses, 1935) with a spawning peak in June in the northern Bay of Biscay (N'Da & Déniel, 1993). Eggs and larvae average 2.8mm and are pelagic (Sabates *et al.*, 2015). The hatching takes place after three days at 18°C and after eight days at a temperature of 9°C (Quéro & Vayne, 1997). After metamorphosis juveniles become first demersal then benthic. At the age of one month, they measure about 5cm and weigh 0.9 to 1.6g. They show rapid growth during their first four months of life between July and October. Increases in length and mass are about 7cm and 25g on average during this period (N'Da & Déniel, 2005). The rate of growth declines sharply in October due to the cooling of water and the scarcity of trophic resources in the environment. These conditions contribute to the initiation of migration of red mullets to greater depths offshore. Until the age of two, there is no significant difference in size between males and females; they then measure 20-23cm. Sexual dimorphism is observed from the age of first maturity due to growth rates that will then differ between the two sexes. From age three, females exceed males in length by 4 cm on average and 7cm beyond 5 years (N'Da & Déniel, 2006).

The maximum reported age of the striped red mullet is 11 years (Quéro & Vayne, 1997; ICES, 2012), while the maximum length given is 44.5cm in the Bay of Biscay (Dorel, 1986) and 40cm elsewhere (Hureau, 1986; Bauchot, 1987). The maximum reported mass is 1kg (Muus and Nielsen, 1999).

10.2 Management regulations

Prior to 2002, France enforced a minimum landing size of 16cm. Since this minimal size requirement has been removed, immature individuals (< 14cm) have been recorded in landings. There is no TAC for this stock.

10.3 Stock ID and possible management areas

In 2004 and 2005, a study using fish geometrical morphometry was carried out in the Eastern English Channel and the Bay of Biscay. It pointed out a morphological difference on striped red mullets between those from the Eastern English Channel and those from the Bay of Biscay.

Benzinou *et al.* (2013) conducted stock identification studies based on otolith and fish shape in European waters and showed that striped red mullet can be geographically divided into three zones:

- The Bay of Biscay (Northern Bay of Biscay – NBB, and Southern Bay of Biscay - SBB)
- A mixing zone composed of the Celtic Sea and the Western English Channel (CS + WEC)
- A northern zone composed of the Eastern English Channel and the North Sea (EEC + NS)

The distinction between the putative Biscay and Western Channel/Celtic Sea populations is supported by the distribution of landings at a statistical rectangle level (Fig. 10.1). 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 (Figure 10-1). Landings are mainly taken from Subarea 7 and 8 (Table 10.1) and France accounts for the majority of removals. 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 15 m; the seiners are by far the largest and the oldest vessels (Caill-Milly *et al.*, 2017).

The French activity on this species differs between the area composed by West Scotland/Celtic sea (including West Channel) and the area comprising the Bay of Biscay. In the first one, landings are mainly taken by bottom trawlers, followed by gillnet. In the second one, they are mainly done by bottom trawls, seine and nets. French activity in the Atlantic Iberian waters remains limited. The Spanish activity is located in the north (8.a,b) and the south (8.c) of the Bay of Biscay.

Prior to 2015 this species was not recorded as being discarded by French or Portuguese vessels and was infrequent in Spanish sampling. Discarding represented between 9% and 68% of UK catches in 2014 - 17 (Table 10.3), however there are concerns about how these discards have been estimated – the 2016 figure is based on a sample of 2 fishes. French discard estimates for 2017 represented 7% of catch. For French demersal trawls (70-99mm mesh size), discards are essentially composed of individuals measuring between 8 and 17cm (Figure 10.2).

10.5 Survey data, recruit series

Exchange data is available in Datras during 1997-2018 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. Standardised catch rates in the EVHOE survey are variable around the series mean between 1997 – 2011, before falling to a lower level thereafter. Similarly, catch rates in the PT-IBTS are at a low level in 2005, peak in 2010, before falling back to near the series mean in recent years (Fig. 10.3).

Abundance indices per size class during EVHOE-WIBTS-Q4 show mainly fish between 8 and 17 cm (TL).

Data was provided separately for the northern Spanish groundfish survey (SP-NSGFS), showing a similar variable trend to the EVHOE survey in the early part of the series, followed by a decline to lower levels in recent years (Figure 10-4).

10.6 Biological sampling

In the Bay of Biscay sexual maturity and length measures were taken in 2009 by AZTI. French samplings started in 2004 in the Eastern Channel and in the south North Sea, and since 2008 in the Bay of Biscay.

10.7 Biological parameters and other research

Since 2004, data (age, length, sexual maturity) are usually collected by France for the Eastern English Channel and the southern North Sea. France started to collect data for 8a,b at the end of 2007. In 2007—2008, the striped red mullet otolith exchange had for goal to optimize age estimation between countries.

In 2011, an Otolith Exchange Scheme was carried out, which was the second exercise for the Striped red mullet (*Mullus surmuletus*). Four readers of this exchange interpreted an images collection coming from the Bay of Biscay, the Spanish coasts and the Mediterranean coasts (Spain and Italy). A set of *Mullus surmuletus* otoliths (N=75) from the Bay of Biscay presented highest percentage of agreement (82%). On 75 otoliths, 34 were read with 100% agreement (45%) and thus a CV of 0%. Modal age of these fishes was comprised between 0 and 3 years (Mahé *et al.*, 2012).

10.8 Analysis of stock trends/ assessment

Currently, an age structured analytical stock assessment has not been developed due to a short time-series of available data.

10.9 Data requirements

Regular sampling of biological parameters of striped red mullet catches must be continued under DCF. Sampling in the Celtic Sea and in the Bay of Biscay started in 2008. In 2010 and 2011, sampling for age and maturity data was reduced compared to 2009, due to the end of the Nespman project. Since 2009, a concurrent sampling design carried out, should provide more data (length compositions) than in recent years.

10.10 References

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10.11 Tables

Table 10.1. Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a official landings by country in tonnes.

Year	Belgium	Spain	France	Guernsey	Ireland	Jersey	Netherlands	Portugal	UK	Total
2006	33	379	1937	8	15	1	115	11	170	2669
2007	43	390	1926	9	17	1	148	222	193	2949
2008	26	379	1384	9	17	0	165	169	164	2313
2009	20	490	1539	5	10	0	110	199	131	2504
2010	20	465	1725	5	5	0	128	276	132	2756
2011	21	504	1722	0	5	0	130	245	154	2781
2012	37	328	1318	0	4	1	125	217	122	2152
2013	28	245	925	5	3	0	50	187	70	1513
2014	12	265	914	5	2	0	1	221	53	1473
2015	23	248	1207	5	3	0	110	282	102	1980
2016	28	194	1166	15	4	0	69	204	83	1763
2017	35	152	988	0	10	0	16	150	64	1415
2018*	36	178	880	0	9	0	93	154	66	1416
2018**	37	321	896		0		95	122	67	1538

*** Preliminary Data**

**** Intercatch Data**

Table 10.2. Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a official landings by area in tonnes.

Year	6a	6b	7a	7b	7c	7e	7f	7g	7h	7j	7k	8a	8b	8c	8d	8e	9a	Total
2006	0	0	1	1	0	869	50	24	103	5	0	1023	468	71	14	0	39	2668
2007	1	0	1	1	1	1047	54	22	104	12	0	861	473	90	16	0	267	2950
2008	0	0	1	1	0	880	46	16	73	13	0	639	246	87	18	0	296	2316
2009	2	0	1	2	1	592	25	9	74	17	0	879	460	156	44	0	243	2505
2010	2	0	1	3	1	642	26	10	59	16	1	1033	467	146	19	0	331	2757
2011	1	1	1	0	0	665	20	10	55	6	0	970	513	214	17	0	310	2783
2012	0	0	0	0	0	493	23	7	34	4	0	696	387	200	27	0	280	2151
2013	0	0	0	1	0	232	23	7	36	2	0	473	328	166	6	0	241	1515
2014	1	0	0	0	0	192	15	3	40	1	0	523	240	151	12	0	297	1475
2015	0	0	0	1	0	595	10	2	35	1	0	506	327	127	7	0	369	1980
2016	0	0	0	2	0	432	21	7	35	3	0	549	311	117	10	0	277	1764
2017	0	0	0	1	0	279	26	21	36	3	0	505	244	96	5	0	198	1414
2018*	0	0	0	0	0	358	26	16	41	2	0	437	219	75	2	0	244	1420
2018**	1	0	0	0	0	361	26	7	40	1	0	453	276	144	3	0	226	1538

*** Preliminary Data**

**** Intercatch Data**

Table 10.3. Striped red mullet in Subareas and Divisions 6, 7a–c, e–k, 8, and 9a discards (t) by country in 20122018.

Country	2012	2013	2014	2015	2016	2017	2018
BE						2	3
ES			4	5	8	0	2
FR				115	213	74	34
IE						0	0
NL							0
PT	0	0	0		0	0	0
UK	2	1	5	77	171	11	1
Total	2	1	9	197	392	87	40

10.12 Figures

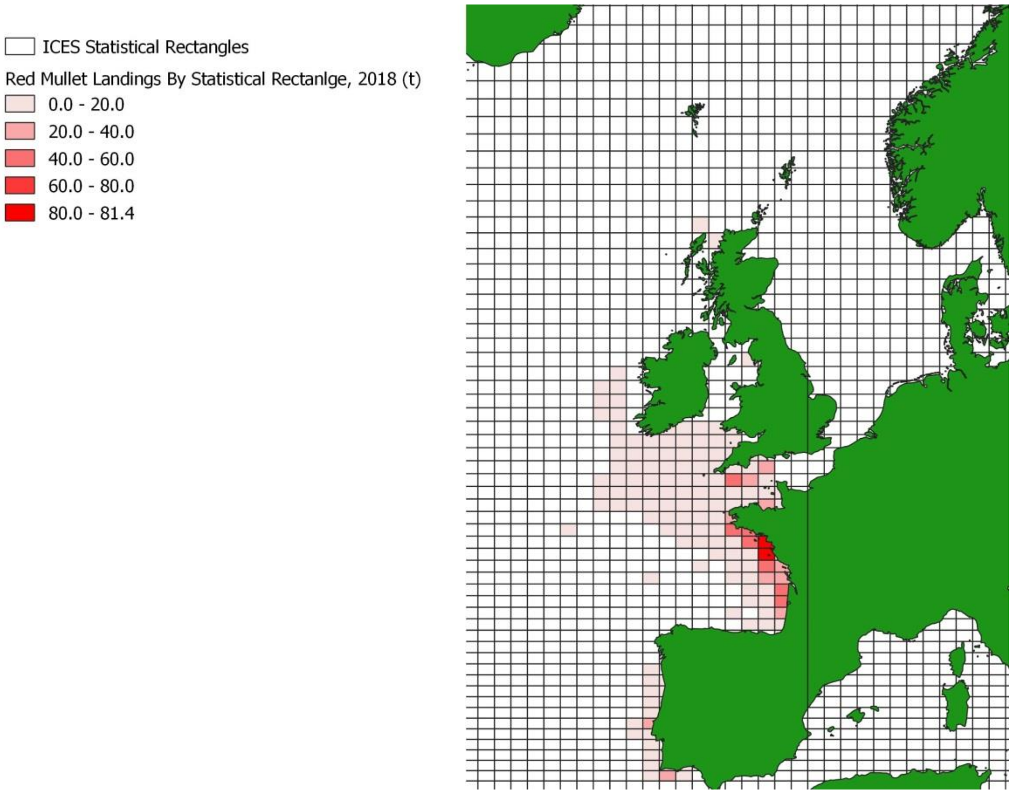

Figure 10.1. Striped red mullet in Subareas and Divisions 6, 7a-c, e-f, 8 and 9a. Landings by statistical rectangle for BEL, FRA, IRE, PT, UK (E&W), UK (SCO).

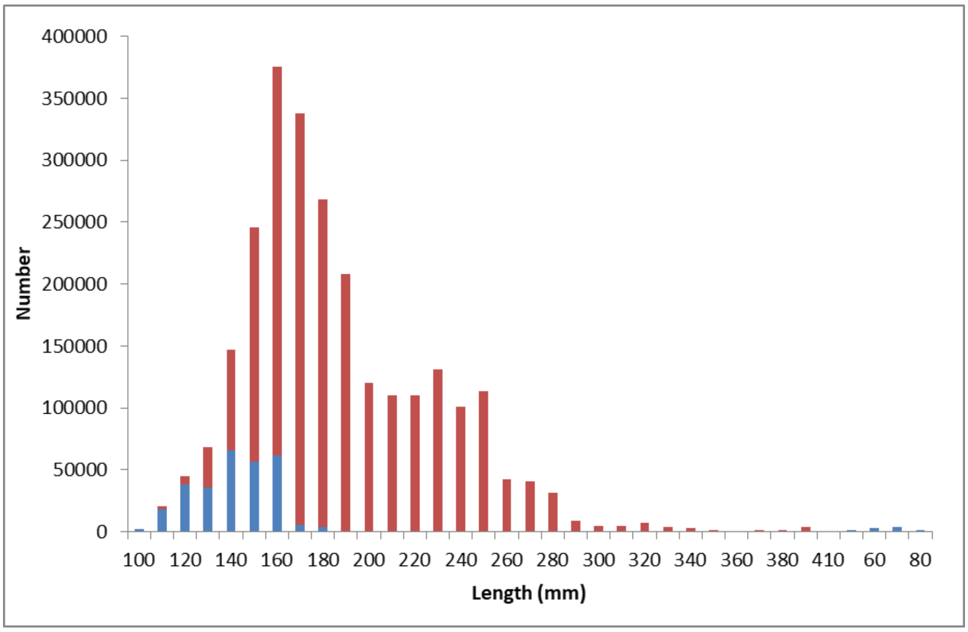

Figure 10.2. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Length distribution in 2018 of French catches from OTB_DEF_>=70 (landings – red, discards – blue).

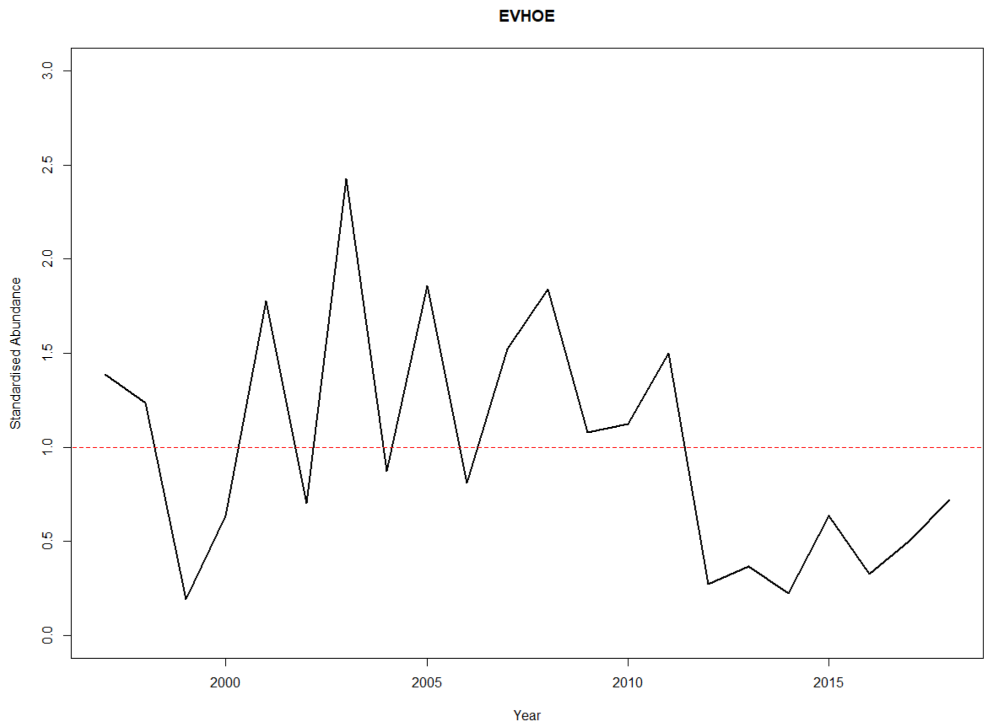

Figure 10.3. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Standardised survey abundances for French Southern Atlantic Bottom Trawl (EVHOE) survey, 1997 – 2017.

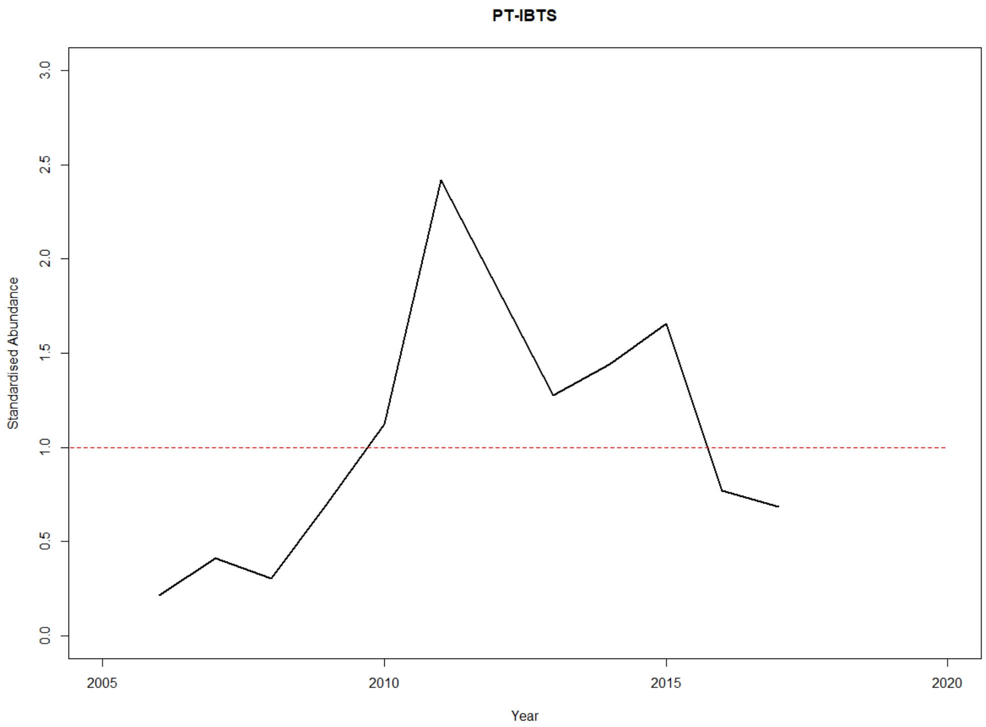

Figure 10.4. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Standardised survey abundances for Portuguese International Bottom Trawl Survey (PT-IBTS), 20062017.

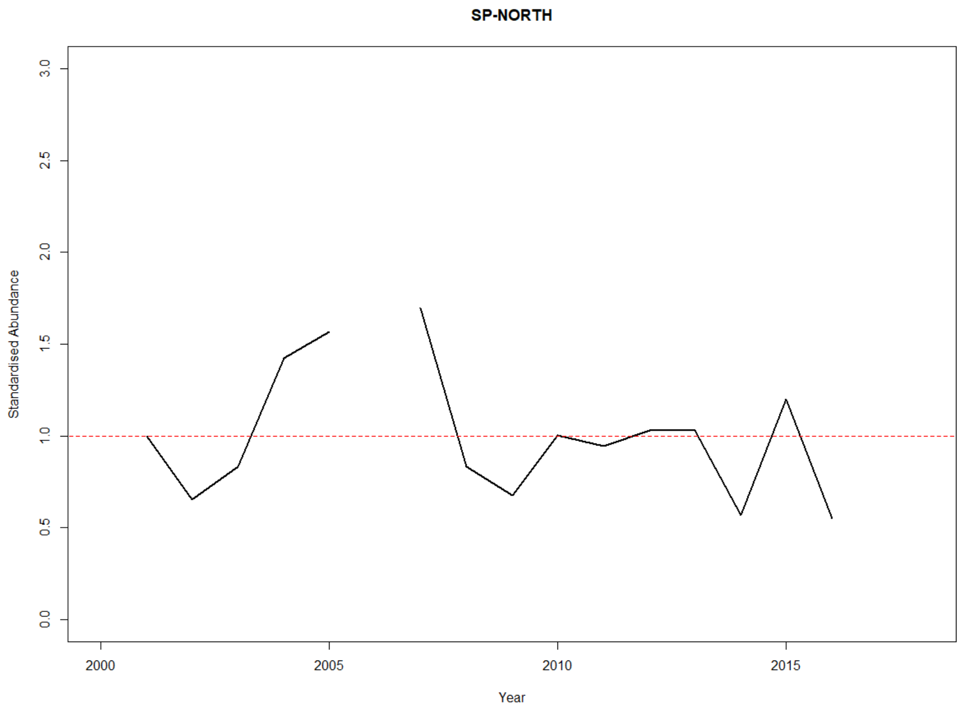

Figure 10.5. Striped red mullet in Subareas and Divisions 6, 7a-c, e-k, 8 and 9a. Standardised survey abundances for Spanish North Coast Bottom Trawl Survey (SP-NORTH). 20012016.

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Annex 2: Recommendations

Recommendations to WGWIDE 2019

There were no recommendations to WGWIDE 2019.

Recommendations from WGWIDE 2019

Recommendations from WGWIDE 2019 are listed in the table below. Background information for the recommendations is in the relevant chapters for the respective species.

All recommendations have been uploaded to the ICES Recommendation database.

Recommendation	Recipient:
1. WGWIDE recommends that an age reading workshop on blue whiting must be conducted in the next years. Therefore it is important that the planned age-reading workshop for blue whiting will take place. Background is described in section 2.13	WGBIOP
2. It is recommended that WGBIOP provides WGWIDE with the variance-covariance matrix for results of the age-reading by species (NSS herring, blue whiting NEA mackerel), for use in exploration of effects of ageing-errors on the assessments.	WGBIOP
3. It is recommended that a method is developed to calculate and provide uncertainty estimates around the SSB-estimate from the mackerel egg survey.	WGMEGS
4. It is recommended to undertake feasibility study with regard to surveys conducted in summer south of 60N to potentially extend swept area coverage outside the southern boundary of the current IESSNS-survey.	WGIPS
5. It is recommended to increase the spatial coverage of NS-IBTS Q1 or very late Q4 to include the south-western Norwegian shelf and shelf edge in proximity to the Norwegian trench. The IBTS has observed high catch rates in some years at the north-eastern edge of the survey area (towards the Norwegian trench) in winter. It is therefore possible that some recruits are also overwintering on the other side of the trench along the south western shelf edge of Norway. This relates to section 8.6.2	IBTSWG

Annex 1: Resolutions

2019 Terms of Reference

WGWIDE– Working Group on Widely Distributed Stocks

2018/2/FRSG17 The **Working Group on Widely Distributed Stocks** (WGWIDE), chaired by Gudmundur J. Óskarsson, Iceland, will meet in Tenerife, Spain, 28 August – 3 September 2019 to:

a) Address generic ToRs for Regional and Species Working Groups.

b) Prepare a draft plan for a scoping workshop on the management needs for Atlantic mackerel

c) An RFID tag data preparation group should be established for mackerel and Norwegian spring spawning herring to:

i) Carry out quality assurance of the tag-recapture data for use in stock assessment
ii) Explore potential sources of bias in the tag-recapture data that may affect the stock assessment
iii) Explore the trends (indexes of abundance by age and biomass) in the tag data outside stock assessment
iv) Explore the basis for the low survival rate estimated for the tagged mackerel when scaling the data in the SAM stock assessment

The RFID tag data preparation group will be chaired by Aril Slotte, Norway, and meet in spring on an annual basis and report to WGWIDE members no later than one month prior the WGWIDE meeting.

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting. Material and data relevant for the meeting must be available to the group no later than 14 days prior to the starting date.

WGWIDE will report by 10 September 2019 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

2020 Terms of Reference

WGWIDE–Working Group on Widely Distributed Stocks (WGWIDE)

2019/2/FRSGxx

The **Working Group on Widely Distributed Stocks (WGWIDE)** chaired by Andrew Campbell (Ireland), will meet at ICES headquarters, Copenhagen, Denmark 26 August–1 September 2020 to:

a) Address generic ToRs for Regional and Species Working Groups

WGWIDE will report by 8 September 2020 for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group

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 2018	boc.27.6-8_SA
gur.27.3-8	Red gurnard (*Chelidonichthys cuculus*) in subareas 3–8 (Northeast Atlantic)	March 2012	gur.27.3-8
her.27.1-24a514a	Herring (*Clupea harengus*) in subareas 1, 2, and 5, and in divisions 4.a and 14.a, Norwegian spring-spawning herring (the North-east Atlantic and Arctic Ocean)	March 2016	her.27.1-24a514a_SA
hom.27.3a4bc7d	Horse mackerel (*Trachurus trachurus*) in divisions 3.a, 4.b-c, and 7.d (Skagerrak and Kattegat, southern and central North Sea, eastern English Channel)	March 2017	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 2017	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 2019	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 2019	whb.27.1-91214_SA

Annex 1: Audits

Audit of North Seas Horse mackerel stock (hom.27.3a4bc7d)

Date: 10. September 2019
Auditor: Gitte Høj Jensen

General

The advice sheet and report was well written and well documented., however the majority of the Stock Annex is missing, which make it difficult to check if the assessment is done according to this.

For single stock summary sheet advice:

1) **Assessment type:** update
2) **Assessment**: Survey trends based assessment (Category 3)
3) **Forecast**: not presented
4) **Assessment model**: Hurdle model
   Formed by two sub-models
   - Modelling probability of zeroes (GLM binomial)
     - With Year + Survey
   - Modelling count data (GLM negative binomial)
     - With Year * Survey

   Weighting factors (based on survey area and wingspread of gears):
   - 0.86 * IBTS survey index estimate
   - 0.24 * CGFS survey index estimate
5) **Data issues:**
   Data is available, but:
   - Bad catch sampling coverage
   - Discard information is considered to be incomplete, and discard numbers from earlier years have not been submitted to ICES.
6) **Consistency**:
   - Mistake found in the calculation of CPUE in the last assessment for 2016 and 2017, however the 2017 advice would have resulted in the same catch advice
7) **Stock status**:
   No reference points, but
   - Still low abundance index with no sign of recovery
   - F/Fmsy slightly above 1
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 majority of the Stock Annex is missing, which make it difficult to check if the assessment is done according to this.

Conclusions

The assessment has been performed correctly

Audit of North Seas Horse mackerel stock (hom.27.3a4bc7d)

Date: 6th September 2019
Auditor: Gersom Costas

General

In 2012 the North Sea horse mackerel (NSHM) was classified as a category 5 stock, based on the ICES approach to data-limited stocks (DLS). Since then, a progressive reduction of TAC was advised by ICES.

In 2017, this stock was benchmarked and the North Sea International Bottom Trawl Survey (NS-IBTS) and the Channel Ground Fish Survey (CGFS) indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHM stock was upgraded to category 3. In 2018, the index remained at a similar levels in 2016 and 2017. The application of the HCR 3.1resulted in an index ratio (mean index value of two most recent years (A) over mean index value of three preceding years (B); A/B ratio) of 0.39, meaning that an 80% uncertainty cap was applied. Length Based DLS methods indicated that the F in 2018 was slightly above the F_{MSY} proxy, and stock size relative to reference points was unknown. However, since the precautionary buffer was already applied to the advice in 2017, the precautionary buffer was not applied this time. This resulted in a catch advice for 2020 and 2021 of 14014 tonnes. Considering the 5.05% discards rate, the corresponding wanted catches are advised to be 13305 tonnes

For single stock summary sheet advice:

9) **Assessment type: update**
10) **Assessment**: category 3 (survey based method)
11) **Forecast**: not presented
12) **Assessment model**: No analytical stock assessment model. Data Limited Stock approach (Category 5 stock) based on survey data (IBTS and CGFS)
13) **Data issues:** a mistake was discovered in the calculation for the years 2016 and 2017 indices for CFGS survey. A new estimate for combined index 2016 and 2017 was estimed
    Catch at age data questionable due to low sampling coverage
    index area did not sufficiently cover the distribution area of the stock
    discard information is considered to be incomplete
14) **Consistency**: In 2019 an error was identified in the code that was used to generate the assessment of this stock in 2017. The error was in the calculation of CPUE for the year 2016. This lead to the high estimates of biomass in the 2017 assessment. The error has now been corrected, which resulted in a substantially lower estimate of biomass in 2016. The resulting 2017 advice without error would have resulted in the same catch advice because of the uncertainty cap. d
15) **Stock status**: no reference points for stock size have been defined
16) **Management Plan**: There is no agreed management plan for this stock

General comments

The section was well documented and ordered. Exploratory indices were well described and the results presented clearly. The conclusions regarding advice are appropriate given the index trends and the high levels of uncertainty

Technical comments

(The assessment is done according to decisions taken during benchmark in 2017 and according to the stock annex)

Section 6.4.1: should be"provide complete data for the 1992 to 2007 cohorts"

Conclusions

The updated assessment has been performed correctly. Stock advice for NSHM is biennial

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Audit of WHB

Date: 10 September 2019
Auditor: Nikolay Timoshenko

General

The WG suggests that catches in 2019 should be no more than 1,444,301 tons. The assessment is based on knowledge of the level and structure of catch in the main fishing period of the current year. The practice of recent years shows this approach as acceptable. Application of IBWSS indexes for the main age groups is a proven way to fit the cohort programs. In general, the assessment is satisfactorily provided by the input data

For single stock summary sheet advice:

The evaluation methodology was described in the previous reports of WGWIDE.

1) **Assessment type: update/SALY**
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: SAM, (in addition TISVPA and XSA as optional models for checking purposes).
5) **Data issues:** The data for 2018 presented completely in the report. Data for 2019 are preliminary, but applied in the models.
6) **Consistency**: The view of the WG was this year's assess should be accepted.
7) **Stock status**: B is clearly more than Bpa. F>Fpa. R seems to be increasing the last years, but still low.

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. 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.

Technical comments

The data provided in the tables are sufficient to repeat the simulations. Although, it would not be superfluous to give more detailed explanation of the coincidence of the results of the IBWSS regarding the plus group in 2017-2019.

The Mohn's-Rho values in respect of SSB are small in all models applied, and the shape of the trajectories is similar. The reasons for the differences in recruitment estimates in the terminal year are indicated.

Conclusions

The assessment has been performed correctly according to the stock Annex.

Assessment type: update Western horse mackerel (hom.27.2a4a5b6a7a-ce-k8) – data audit

Date: 3. September 2019

Auditor: Leif Nøttestad

General

The Western horse mackerel assessment has been carried out using Stock Synthesis 3.30 since after the benchmark in 2017. This audit only focuses on the data that is being used for the assessment.

When auditing the input and output data to this assessment, it was noticed that the tracking of the data throughout the assessment process is quite challenging as also pointed out last year. Input datafiles are prepared specifically in the format required by Stock Synthesis, however the link between the basic input data and the input file for the assessment needs to be better documented and explained. Ideally, the input data should be available in standard readable formats so that other assessment models than Stock Synthesis could also be deployed.

The assessment itself is consistent with the assessment carried out in 2017, although the retrospective upward revision of biomass and downward revision of fishing mortality has occurred both in 2018 and 2019. The model rescales the absolute level of SSB and F.

Summary

- **Assessment type**: Update
- **Assessment**: Analytical
- **Forecast**: Presented
- **Assessment model**: Stock Synthesis 3.30
- **Data issues:** The main issue with the data for this assessment is the difficult in tracking the different sources of input data and how they lead to the Stock Synthesis input file. It is recommended to provide a detailed step-by-step documentation how the data is being worked up. In the current situation it is not feasible to completely check derivation of the input data to the stock assessment from the raw data files. This was also the situation in 2018.
- **Consistency**: The view of the WG was that the assessment should be accepted. An interbenchmark (IBP) on updated reference points was conducted in 2019 by correspondence. The new suggested biomass reference points which were estimated at the interbenchmark in 2019 and presented and discussed at the WGWIDE meeting, suggest substantial changes in the biomass reference points from 2018 to 2019. However, the IBP final report from the external reviewers are not yet available.
- **Stock status**: Fishing pressure on the stock is above F_{MSY} and between F_{pa} and F_{lim}. Spawning stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.
- **Management plan**: There is no agreed precautionary management plan in 2019 for this area.

General comments

The report is well documented and contains relevant explanations and references in line with the reports of previous years. The assessment has been used with new updated reference points as the basis for the advice. Given that this was an update assessment, in the end the stock annex was followed which resulted in the advice that is in the draft advice document. The data been used as specified in the stock annex although, as mentioned above, the documentation of the input data is difficult to track. Reliable stock indicators remain an important challenge for the assessment, since there is only the egg survey (every three years and last one in 2019), a recruitment index and a biomass and length-frequency index from the southern part of the distribution area.

Technical comments

Only one model (Stock Synthesis) has been applied to this stock as specified in the stock annex. However, the model does not follow the stock annex for the intermediate year. Catch advice for 2020 is 42% lower than that for 2019. This is due to both an update of the reference points and a downward revision in the perception of the stock biomass from the assessment, including new input data series. There was only a 5% advice change in 2019 when comparing with the existing 2018 reference points. The Stock Annex needs to be updated due to the substantial changes in the reference points for western horse mackerel.

The data file contains a specification of the data sources that are being used and the actual data series. Data series that are not used in the model but instead are calculated (e.g. maturity, weight, fecundity), are not included in the data file even though that data may be available in the underlying data sources.

SSB is around the lowest of the time series but recruitment appears to have been a bit higher over the past few years. Nevertheless, recruitment is very small the last few years compared to the 2001-year class and particularly the 1982-year class. ICES assess that fishing pressure on the stock is above F_{MSY} and between F_{pa} and F_{lim}; and spawning stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}. The retrospective revisions of the stock estimates have been a feature of the western horse mackerel assessment for several years. Unfortunately, the Stock Synthesis model does not until now seem to have remedied that situation.

Conclusions

The assessment has primarily been performed according to the specifications in the Stock Annex. The updated reference points provide a substantial change in the biomass reference points from 2018 to 2019, strongly influencing the abundance estimation and stock advice for western horse mackerel.

The documentation and transparency of the input data for the assessment needs to be improved.

Audit of Boarfish – input data and assessment

Date: 3.September 2019
Auditor: Sólvá Káradóttir Eliasen

General

In general, the input data and stock assessment were well arranged and easily accessible.

For single stock summary sheet advice:

17) **Assessment type:** update
18) **Assessment**: trends
19) **Forecast**: not presented
20) **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.
21) **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" and running the scripts gives the same results as those presented in the report.

    As pointed out in the audit for 2018, there are inconsistencies between assessment input in landings/discards/catch-data (catch.data.xlsx) and landings/discards/catch-data in table 3.1.2.1. This is still the case.

22) **Consistency**: The assessment from 2019 is, as it also was in 2018, accepted.
23) **Stock status**: There are no reference points defined for this stock.
24) **Management Plan**: A management strategy has been proposed by the Pelagic AC. ICES provides advice for this stock following the standard procedures which conforms to the proposed strategy from the Pelagic AC.

General comments

In general, the input data and stock assessment were well arranged and easily accessible.

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
- Have the data been used as specified in the stock annex?
    - yes
- Is there any **major** reason to deviate from the standard procedure for this stock?
    - no

Audit of boarfish in subareas 6–8

Date: 06.09.2019

Auditor: Alessandro Orio (Auditing of text and numbers in the report and the advice sheet)

For single stock summary sheet advice:

25) **Assessment type: update**
26) **Assessment**: trends – Category 3 stock
27) **Forecast**: not presented
28) **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
29) **Data issues:** The catches of 2018 seem incomplete. .
30) **Consistency**: Update assessment. If the catches of 2018 are incomplete a new assessment has to be run.
31) **Stock status**: ICES cannot assess the stock and exploitation status relative to MSY and PA reference points because the reference points are undefined
32) **Management Plan**: A management strategy has been proposed by the Pelagic AC. ICES provides advice for this stock following the standard procedures which conforms to the proposed strategy from the Pelagic AC

General comments

This was a well documented and well ordered section. It includes many tables that help the audit. There seem to be an inconsistency in the landings of 2018 (missing landings from Spain) has been found but need to be checked by the stock assessor and coordinator.

Conclusions

If the catches in 2018 are incomplete a new assessment has to be performed.

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 catches of 2018 needs to be checked
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
  Yes but catches of 2018 needs to be checked
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
  No
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?
  Yes if the catches of 2018 are correct.

Audit of Red gurnard

Date: 06.09.2019

Auditor: Alexander Pronyuk

General

The landings data are not species-specific in the fisheries and there are currently no technical measures specifically for managing the fishery. There is need for regular sampling of red gurnard in commercial landings and discarding to provide series of length or age compositions to conduct analytical assessment.

For single stock summary sheet advice:

1) **Assessment type:** update
2) **Assessment**: not presented
3) **Assessment model**: NA
4) **Data issues:** landings data are not species-specific, lack of biological sampling in commercial landings and discarding
5) **Consistency**: NA
6) **Stock status**: Uncertain
7) **Management Plan**: NA

General comments

No update report

Technical comments

No final update advice

Conclusions

The assessment has been performed correctly.

Audit of Red gurnard

Date: 09.09.2019

Auditor: Patrícia Gonçalves

General

Information on gurnard abundance are available in DATRAS for the IBTS-Q1 survey in the North Sea, Scottish West Coast Groundfish Survey (WCGFS), Irish Groundfish Survey (IGFS) and the French EVHOE-WIBTS-Q4 survey in the Celtic Sea and Bay of Biscay and CGFS-Q4 in Division 7d. Each of these surveys covers a specific area of red gurnard distribution. Lengths at age are available from CGFS-Q4 in and IGFS-Q4.

In the North Sea, the appearance of red gurnard in the index of the IBTS Survey since 1990 is in line with an increase of the abundance in 4a. In Eastern Channel, the abundance index of the CGFS-Q4 survey has widely fluctuated, with a weak decline. The EVHOE-WIBTS-Q4 survey has slightly increased since its beginning in the 1990s.

The landings data are not species-specific in the fisheries and there are currently no technical measures specifically for managing the fishery. There is need for regular sampling of red gurnard in commercial landings and discarding to provide series of length or age compositions to conduct analytical assessment.

For single stock summary sheet advice:

1) **Assessment type:** updated
2) **Assessment**: not presented
3) **Assessment model**: NA
4) **Data issues:** landings data are not species-specific, lack of biological sampling in commercial landings and discarding
5) **Consistency**: NA
6) **Stock status**: Unknown
7) **Management Plan**: NA

General comments

This is a well-documented section.

Technical comments

None.

Conclusions

The assessment has been performed correctly.

Audit of striped red mullet

Date: 09/09/2019
Auditor: Laurent Dubroca

General

Assessment of this stock is not possible due to the short time-series of the data provided to this group. However, it seems that these data have been collected for several years by some countries and that it would be appropriate to request them as part of a benchmark.

For single stock summary sheet advice:

1) **Assessment type:** no assessment due to lack of age structured analytical input data provided to the WG.
2) **Assessment**: limited data available to evaluate stock trends.
3) **Forecast**: not presented.
4) **Assessment model**: none.
5) **Data issues:** general lack of sampling and time series data available for this WG.
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.

Technical comments

Annual total in tables 10.1 (years 2006, 2008, 2011, 2013, 2014 and 2018) and 10.2 (years 2007 to 2014, 2016 and 2017) presents minor error due to rounding. Consequently the annual totals between these tables are not equal. Two references are not in the references list: Jones 1972 and Russel 1976.

Conclusions

The absence of assessment has been performed correctly, but has to include some minor corrections on the landings tables.

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

Date: 11/09/2019

Auditor: Afra Egan and Anna Olafsdottir

General

The WG accepted the update assessment as a basis for advice for 2020.

For single stock summary sheet advice:

1) **Assessment type:** Update assessment. Benchmarked in 2012 and went through an inter benchmark in 2016.
2) **Assessment**: Age based analytical assessment
3) **Forecast**: Presented
4) **Assessment model**: SAM assessment with catch data from 1981-2019 (preliminary figures used for 2019) and a single tuning series – the International Blue whiting spawning stock survey (IBWSS) from 2004-2019, excluding 2010.
5) **Data issues:** Data used in the assessment are described in the stock annex and are available on SharePoint. Source code for the SAM model and all scripts are available at https://www.stockassessment.org.

   In previous years the assessment used mean weights at age in the "preliminary year" which were calculated as a 3-year average, because the preliminary mean weight data were considered too uncertain to use for the full year. Due to a decrease in mean weight at age for ages 4-8, this average becomes consistently higher than the "final" mean weight at age. This gives a tendency to overestimate SSB and underestimate F. At the 2019 working group it was decided to use the preliminary mean weights (for 2019) from the sampling data submitted to the working group.
6) **Consistency**: The assessment shows the same trend as last year but there is an upward revision in SSB and a downward revision in F. This is mainly due to higher than expected survey indices mainly for the large 2014 year class. The advised catch is 2% higher than last year.
7) **Stock status**: SSB has decreased but is well above MSY $B_{trigger}$, F has also decreased and is slightly above F_{msy} but is below F_{pa} and F_{lim}. Low recruitment is estimated in 2017, 2018 and 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.

General comments

This was a well-documented, well ordered, concise chapter and is easy to follow and interpret. There are some minor corrections outlined below.

Technical comments

- The preliminary catch figure for 2019 Q1 and Q2 in Table 2.3.2.1. and 2.3.2.2. is 1,251,841 and in Table 2.3.2.3.is 1,257,762 t.
- Section 2.3.1.2. Figure should be 2.3.1.2.1 (Two figures are labelled 2.3.1.2)
- Table 2.3.7.1.1. and Table 2.3.7.1.2 have the same data. Perhaps the data used in the assessment (ages 1-8) could be highlighted in Table 2.3.7.1.1 instead of repeating the same information twice.

- In text Section 2.8.2.2. Output – The catch reduction should read 19.6% and not 16.9%
- In 2.10 Quality considerations paragraph 1 – the assessment comparison should be Figure 2.4.1.1 and the comparison years should be 2015-2019.
- In 2.10 quality considerations paragraph 3 does this refer to the Faroese catch at age data in 2018 (not 2017)? Figure label should be 2.3.1.2.1.
- Section 2.13 Regulations and their effects second paragraph estimated catch of 1.444 mil tonnes should be 2019 (not 2018).
- Figure 2.9.1: Text should read comparison of the 2015-2019 assessment as there are 5 years in the plot and not 2010-2019.
- Report text chapter 2.5, 2nd paragraph: replace "with catch data up to 2018" instead of "with catch data up to 2017".
- Advice sheet, table 3, subheading ***: “2019 relative to 2019”. Should this be “2020 relative to 2019”?

Conclusions

The assessment has been performed according to the stock annex.

Audit of **Norwegian spring-spawning herring (her.27.1-24a514a)**

Date: 03.09.2019
Auditor: Are Salthaug

General

The Norwegian spring spawning herring is carried out using the XSAM model. This audit focuses on input data and assessment.

For single stock summary sheet advice:

33) **Assessment type: update/SALY**
34) **Assessment**: analytical
35) **Forecast**: presented
36) **Assessment model**: XSAM (3 survey fleets)
37) **Data issues:** data are available as described in the stock annex
38) **Consistency**: This years' assessment is consistent with last years' assessment and the WG accepted the assessment.
39) **Stock status**: The fishing pressure on the stock is below FMSY, FMGT, Fpa and Flim; spawning-stock size is above MSY Btrigger,Bpa, and Blim.
40) **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.
41) **General comments** The input data and assessment are documentet as described in the stock annex.

Technical comments

There is a downward revision of the 2016 year class in this years' assessment compared to last year, however, estimates of recent year classes are generally very uncertain.

Conclusions

The assessment has been performed correctly

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Audit of NEA Mackerel (WGWIDE 2018)

Date: 3. September 2019
Auditor: Jan Arge Jacobsen

General

The WG accepted the update assessment as a basis for advice for 2020.

For single stock summary sheet advice:

42) **Assessment type: update (benchmarked late 2018/early 2019)**
43) **Assessment**: analytical
44) **Forecast**: presented
45) **Assessment model**: SAM, modified to utilise tag/recapture dataset.
46) **Data issues:** New survey input data for the assessment, as described in the stock annex, were available for the IESSNS, tagging-recapture data from the Norwegian tagging program and the 2019 egg survey. In addition, the IBTS recruitment index was updated to include data up to 2018 (last updated in 2016).
47) **Consistency**: Last year's assessment was accepted, but should perhaps have been rejected (see last years audit by J.A. Jacobsen and A. Campbell). An interbenchmark exercise in 2018-19 resulted in a revised perception of the stock and an updated catch advice for 2019 was released in early 2019 (more than twice the 2018 advice). The WGWIDE2019 update assessment is consistent with the interbenchmark assessment.
48) **Stock Status:** Fishing mortality is above F_{MSY} and below F_{pa} and F_{lim}; and spawning-stock size is above MSY $B_{trigger}$.
49) **Management Plan**: Since not all fishing parties have an agreed management strategy, ICES advice is based on the MSY approach. EU, NO and FO agreed in 2014 on an *ad hoc* management plan for the years 2015-2018, and have extended the plan until 2020 (in 2018). The *ad hoc* Management Plan was evaluated by ICES in 2017 after the benchmark, and was adjusted accordingly for the updated reference points by the three parties for the 2018 advice (refer to Table 8.2.4.1 in the 2019 WG report).

General comments

The report sections were well ordered, however not all were completed by the time of the audit although this did not affect the main conclusions. The interbenchmark addressed most of the issues raised during the WG in 2018. Although the diverging signals is the survey datasets persist, the 2019 update assessment is consistent with that conducted at the interbenchmark.

Technical comments

The technical issues that were raised by WGWIDE in 2018 were dealt with by the interbenchmark in 2018/2019. For 2019, a new egg survey data point is available, continuing the downward trend in stock size indicated by this survey. This remains in conflict with the IESSNS trawl survey, resulting in lower weight for both these surveys in the assessment. There remains concern that the accumulation of tag recapture data will, over time, lead to similar issues that were identified in 2018 as the number of data points for this index increases more rapidly than for the other surveys (addressed by the interbenchmark through the identification of subset of the tagging data for input).

There are indications of over parameterization of the assessment model with some strong correlations between parameters in the model. Also of concern are some diverging retrospective patterns, some false convergenmce in the retrospective patterns, and serially correlated process errors.

Conclusions

The assessment has been performed correctly and gives a valid basis for advice.

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Annex 1: Working Documents

Annex 06 Working Documents to WGWIDE 2019

1. Blue Whiting stock assessment by means of TISVPA. **Authors**: Dimitry Vasilyev. 6 pp.
2. Norwegian Spring Spawning Herring stock assessment by means of TISVPA. **Authors**: Dimitry Vasilyev. 5 pp.
3. Utilizing the full time-series of catch by rectangle. **Authors**: Martin Pastoors. 8 pp.
4. Vertical distribution of herring from sonars during international ecosystem survey in Nordic seas (IESNS) in May 2019. **Authors**: Rolf Korneliussen, Héctor Peña and Arne Johannes Holmin. 8 pp.
5. Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 28th of June – 5th of August 2019. **Authors**: Leif Nøttestad, Valantine Anthonypillai, Sindre Vatnehol, Are Salthaug, Åge Høines, Anna Heiða Ólafsdóttir, James Kennedy, Eydna i Hömrum, Leon Smith, Teunis Jansen, Søren Post, Kai Weiland, Per Christensen, and Søren Eskildsen. 51 pp.
6. PFA self-sampling report for WGWIDE, 2015-2019. **Authors**: Martin Pastoors. 26 pp.
7. Evaluation of Current and Alternative Harvest Control Rules for Blue Whiting Management using Hindcasting. A report commissioned by the Pelagic Advisory Council. **Authors**: L.T. Kell and P. Levontin. 57 pp.
8. 2019 Mackerel and Horse Mackerel Egg Survey. Preliminary Results. Authors: Brendan O' Hea, Finlay Burns, Gersom Costas, Maria Korta, and Anders Thorsen. 37 pp.
9. Distribution and abundance of Norwegian springspawning herring during the spawning season in 2019. Survey report for MS Eros, MS Kings Bay MS Vendla 13-25 Feb. 2019. **Authors**: Aril Slotte, Are Salthaug, Erling Kåre Stenevik, Sindre Vatnehol and Egil Ona. 58 pp.
10. NEA mackerel. Alternative assessment. Authors: Höskuldur Björnsson. 7 pp.
11. Cruise report on the International ecosystem survey in Nordic Seas (IESNS) in May – June 2019. **Authors:** Are Salthaug, Erling Kåre Stenevik, Åge Høines, Valantine Anthonypillai, Kjell Arne Mork, Cecilie Thorsen Broms, Øystein Skagseth, Evgeny Sentyabov, Karl-Johan Stæhr, Serdar Sakinan, Mathias Kloppmann, Sven Kupschus, Guðmundur J. Óskarsson, Hildur Pétursdóttir, Eydna í Homrum, Ebba Mortensen, Leon Smith, and Pavel Krevoshey. 33 pp.
12. Issues regarding updated version of RFID-tag data 2019. Authors: Aril Slotte. 7 pp.
13. Cruise report on the International blue whiting spawning stock survey (IBWSS) spring 2019. **Authors**: Jan Arge Jacobsen, Leon Smith, Jens Arni Thomassen, Poul Vestergaard, Bram Couperus, Dirk Burggraaf, Felix Muller, Steven O'Connell, Thomas Pasterkamp, Kyle Sweeney, Dirk Tijssen, Michael O'Malley, Graham Johnston, Eugene Mullins, Ciaran O'Donnell, Åge Høines, Valantine Anthonypillai, Ørjan Sørensen, Ståle Kolbeinson, Justine Diaz, Pablo Carrera, Urbano Autón, and Ana Antolínez. 32 pp.
14. Direct assessment of small pelagic fish by the PELGAS acoustic survey focus on horse mackerel in recent years (2018-2019). Authors: Erwan Duhamel and Mathieu Doray. 9 pp.

Blue Whiting stock assessment by means of TISVPA

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Russian Federal Research Institute of Fisheries and Oceanography (VNIRO),
17, V.Krasnoselskaya St., 107140, Moscow, Russia

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 somewhat changed in comparison to those used at WGWIDE 2018: 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 surveys the measure of closeness of fit was the median (MDN) of the distribution of squared logarithmic residuals, and for catch-at-age data – the absolute median deviation 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 2018 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 2018, if to consider the second (corresponding to higher SSB) local minimum for catch-at-age/.

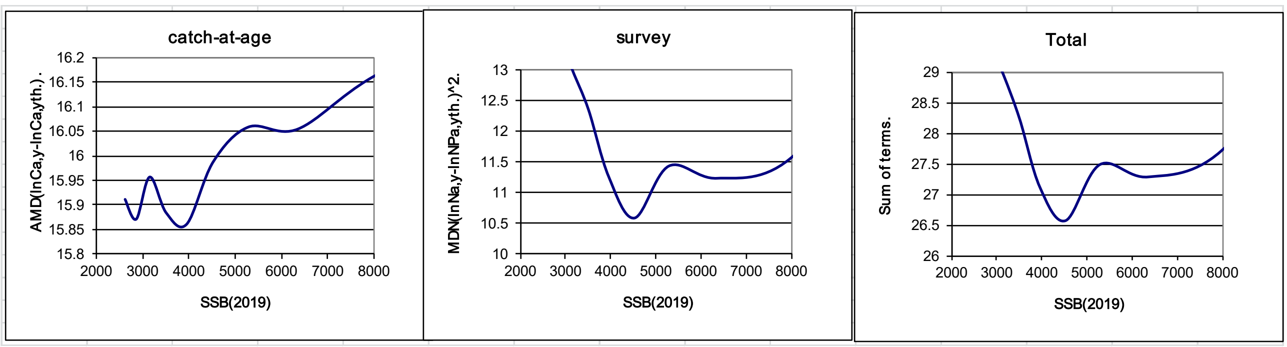

Figure 1. Profiles of the components of the TISVPA objective function

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.

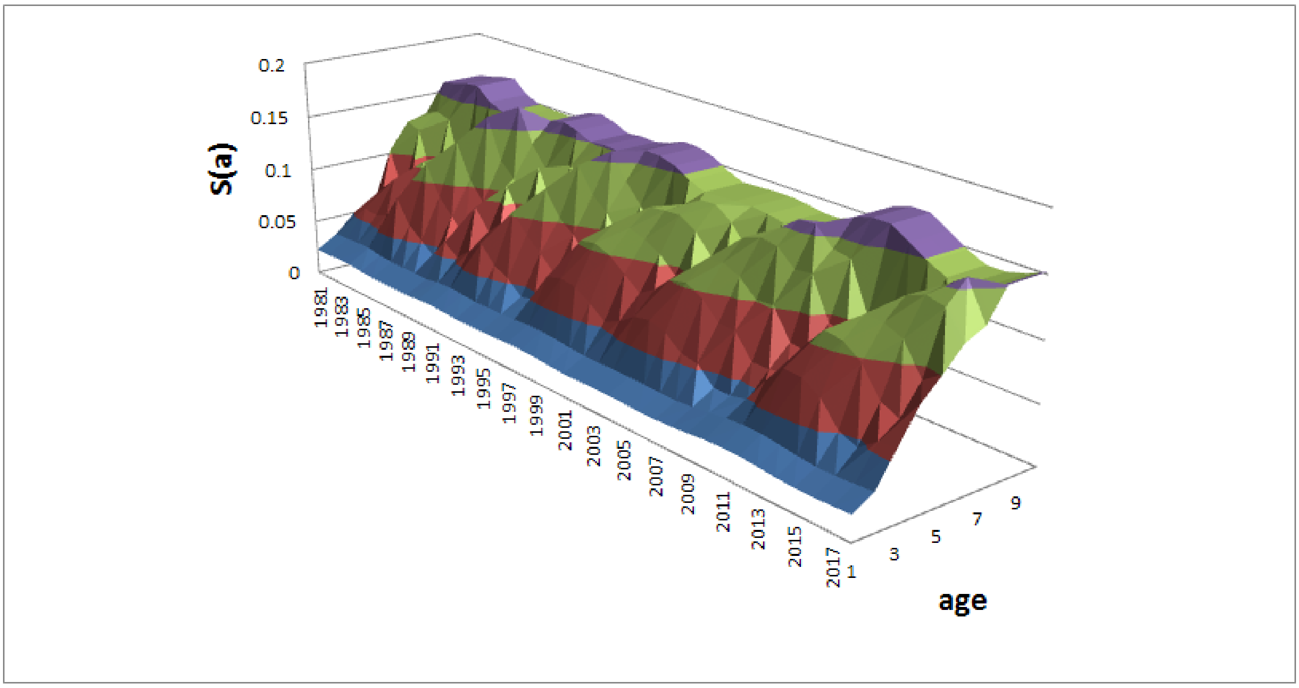

Figure 2. TISVPA-derived selection pattern

Figure 3 represents the results of retrospective analysis. The estimates of biomass 5 years ago jumped up, and there is also an upward correction from 2016 to 2017.

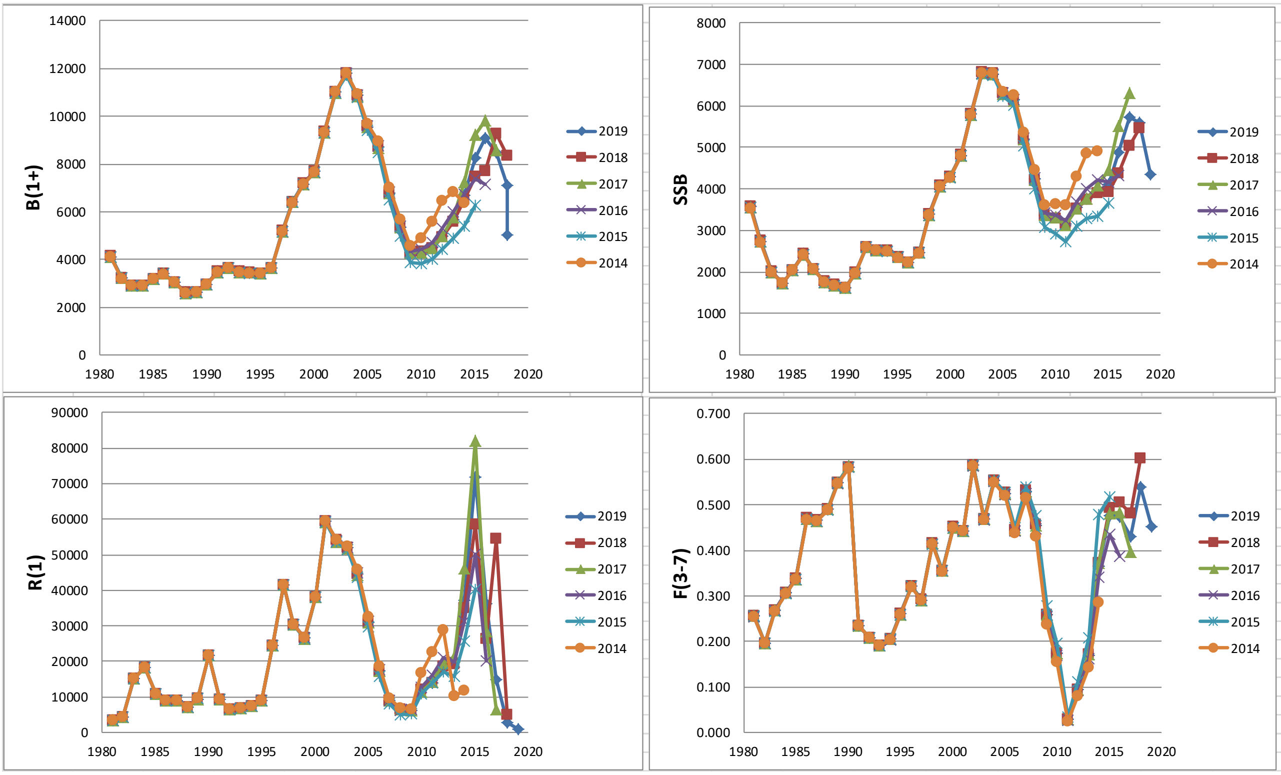

Figure 3. Retrospective runs for TISVPA

The residuals of the model approximation of catch-at-age and survey are presented in Figure 4. For the survey some year-dependent peculiarities in abundance-derived residuals are apparent for final 3 years.

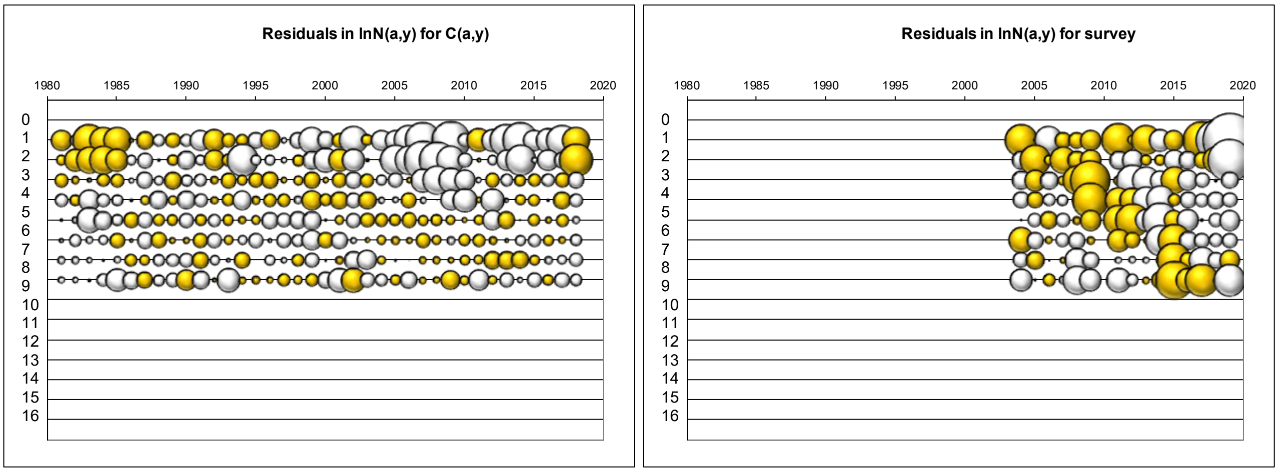

Figure 4. Residuals of the TISVPA data approximation.

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.

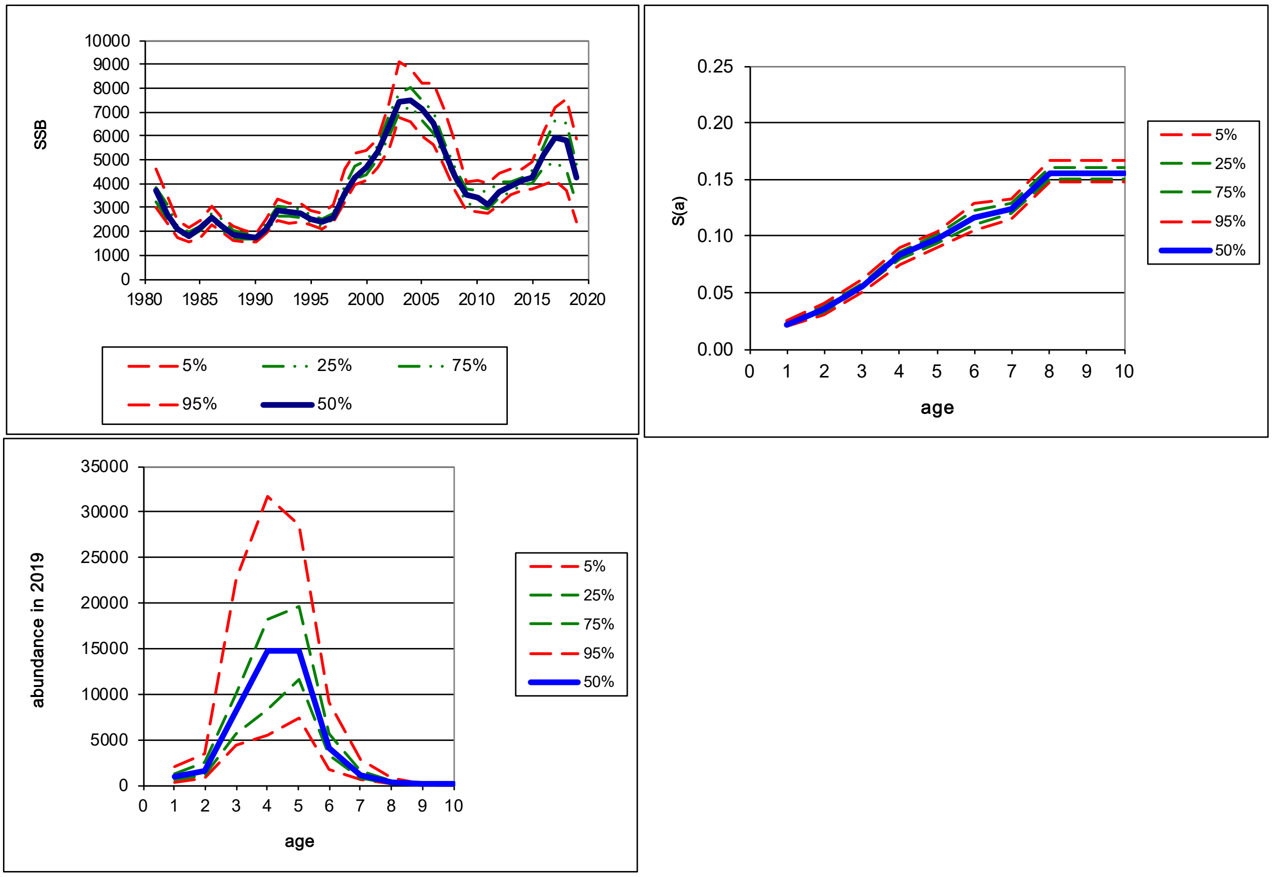

Figure 5. Bootstrap- estimates of uncertainty in the results.

The results of the assessment are presented in the Tables 1-3.

year	B(1+)	SSB	R(1)	F(3-7)
1981	4122	3578	3588	0.256
1982	3225	2739	4354	0.196
1983	2920	2005	15101	0.268
1984	2924	1733	18280	0.307
1985	3192	2042	10926	0.337
1986	3406	2434	9061	0.470
1987	3060	2073	8949	0.466
1988	2616	1764	7169	0.491
1989	2642	1690	9458	0.548
1990	2949	1619	21718	0.583
1991	3488	1977	9255	0.234
1992	3659	2603	6483	0.207
1993	3488	2530	6698	0.191
1994	3445	2514	7452	0.205
1995	3409	2357	9058	0.260
1996	3635	2228	24500	0.321
1997	5192	2462	41535	0.291
1998	6401	3387	30332	0.416
1999	7159	4074	26532	0.355
2000	7680	4295	38096	0.452
2001	9342	4809	59444	0.443
2002	11008	5799	53945	0.588
2003	11789	6796	51886	0.468
2004	10865	6774	44462	0.553
2005	9557	6300	31090	0.525
2006	8714	6144	17274	0.445
2007	6787	5202	9080	0.530
2008	5370	4233	6508	0.455
2009	4288	3377	6246	0.259
2010	4352	3318	12187	0.174
2011	4524	3170	13996	0.028
2012	4973	3557	18402	0.094
2013	5663	3766	20340	0.169
2014	6699	3963	37306	0.365
2015	8234	4124	71962	0.477
2016	9084	4890	36088	0.474
2017	8500	5729	14820	0.431
2018	7093	5594	2842	0.539
2019	5041	4347	899	0.452

Table 1. Blue whiting. The results of the assessment by TISVPA

	1	2	3	4	5	6	7	8	9	10
1981	3587.58	4183.83	5426.73	3556.17	2547.43	2190.36	1863.66	2051.69	1764.87	4457.99
1982	4353.67	2746.28	3136.35	3870.74	2560.19	1572.99	1256.96	1060.97	1057.47	2505.9
1983	15101.38	3414.08	2061.36	2272.76	2692.53	1838.89	999.46	765.29	604.14	896.82
1984	18280.27	11070.61	2440.21	1436.87	1490.42	1763.62	1206.52	538.83	357.89	592.62
1985	10925.53	13487.37	7664.74	1610.33	899.77	874.37	995.05	741.44	232.02	646.17
1986	9060.8	8110.1	9665.26	4647.64	1004.87	541.88	454.07	561.62	357.83	818.47
1987	8948.94	6817.95	5874.58	6117.96	2169.02	504.8	269.08	201.41	218.68	414.01
1988	7168.94	6674.86	4989.1	3980.81	3333.3	941.08	256.04	128.6	69.36	105.09
1989	9458.46	5432.66	4826.18	3472.46	2438.89	1616.38	288.8	121.41	49.45	75.17
1990	21718.16	7035.36	3862.71	2903.65	2140.11	1268.43	674.18	83.97	43.94	154.6
1991	9254.62	16089.29	4986.51	2467.28	1456.74	1179.7	512.69	218.54	16.09	32.18
1992	6483.2	7242.41	12206.07	3547.77	1697.97	876.77	751.89	294.8	120.3	45.11
1993	6697.92	5016.62	5463.18	8508.07	2391.1	1162.4	547.62	504.56	167.04	74.73
1994	7452	5262.02	3860.66	3964.75	5626.85	1598.19	781.42	345.67	320.47	125.75
1995	9058.17	5837.55	4114.66	2835.9	2774.27	3504.27	1025.84	499.53	201.3	140.91
1996	24500.37	7085.58	4443.83	3018.86	1905.54	1721.18	1979.45	599.7	265.57	224.92
1997	41535.01	18624.2	5296.19	3137.34	2017.3	1191.27	932.09	937.09	279.79	454.66
1998	30332.21	31954.98	13873.71	3505.63	2077.04	1331.7	698.25	488.34	423.92	171.97
1999	26531.88	22974.52	22756.13	8219.17	1829.14	1251.02	750.86	313.78	165.71	338.63
2000	38096.32	20520.61	17105.41	14021.7	4206.36	994.41	766.12	448.86	128.43	310
2001	59443.95	29105.94	15256.86	10817	7223.46	1991.3	406.46	424.7	188.41	161.49
2002	53944.9	45076.04	20804.47	10067.63	5921.59	3605.84	950.43	180.43	203.07	281.94
2003	51885.86	41229.35	32989.76	13238.68	5754.95	2831.14	1337.13	349.47	45.68	61.67
2004	44462.34	39243.7	30133.12	20013.26	7129.82	3040.11	1282.95	583.43	149.52	73.76
2005	31090.45	33768.94	28186.47	17810.31	9840.41	3275.49	1356.33	472.65	211.1	116.1
2006	17274.15	23715.09	25170.14	17509.92	8864.17	4245.35	1415.52	617.11	170.61	92.83
2007	9079.67	13422.44	17941.88	16740.81	9403	4160.34	1899.1	680.45	289.84	198.43
2008	6508.12	7034.79	10151	12198.04	9602.1	4325.2	1515.46	709.15	266.05	299.01
2009	6246.26	4951.25	5334.75	7409.91	7242.35	5049.38	1837.03	576.71	293.4	161.53
2010	12187.09	4935.55	3817.94	4038.7	5318.56	4503.81	2978.94	960.69	285.45	179.43
2011	13996.21	9603.96	3815.92	2925.73	3011.76	3756.68	2831.07	1817.62	558.15	279.07
2012	18401.78	11345.18	7772.69	3062.31	2345.64	2403.66	2976.36	2210.71	1419.22	1057.72
2013	20339.5	14752.79	8959.19	5810.4	2309.36	1789.1	1784.4	2151.62	1490.01	1663.26
2014	37305.85	16183.49	11489.08	6437.65	3902.76	1524.02	1256.2	1212.41	1324.34	1669.28
2015	71961.84	29101.45	12266.93	7348.92	3493.22	2007.11	824.37	730.34	544.03	1024.33
2016	36087.84	55228.07	21272.12	7948.05	3877.63	1574	886.49	388.33	310.47	682.55
2017	14820.11	27834.3	41154.54	14272.75	4711.78	1918.5	641.95	379.52	158.54	369.1
2018	2842.33	11491.98	20723.44	27048.94	8216.36	2572.16	869.97	269.77	177.15	320.83
2019	899.12	2057.12	8507.94	13313.51	14808.29	3989.6	1127.25	298.54	89.15	172.08

Table 2. Blue whiting. Estimates of abundance-at-age

1	2	3	4	5	6	7	8	9	10
0.05536	0.08062	0.12748	0.13699	0.28102	0.35905	0.37466	0.47275	0.47275	0.47275
0.04517	0.06562	0.11896	0.15462	0.13365	0.26815	0.30478	0.36951	0.36951	0.36951
0.0632	0.0922	0.15954	0.25749	0.27014	0.22704	0.42524	0.5593	0.5593	0.5593
0.07339	0.10732	0.20188	0.28592	0.37476	0.38599	0.28665	0.68311	0.68311	0.68311
0.06819	0.09959	0.27959	0.28575	0.32302	0.41682	0.38095	0.61815	0.61815	0.61815
0.08334	0.12217	0.26082	0.56543	0.44523	0.49771	0.57833	0.81949	0.81949	0.81949
0.08062	0.11809	0.20882	0.3924	0.69016	0.52337	0.51637	0.78041	0.78041	0.78041
0.08147	0.11937	0.16793	0.32552	0.49543	0.89049	0.5747	0.79246	0.79246	0.79246
0.08679	0.12732	0.27126	0.27409	0.43357	0.66555	1.09436	0.87106	0.87106	0.87106
0.10653	0.15703	0.26132	0.54737	0.4266	0.69451	0.98729	1.22707	1.22707	1.22707
0.05246	0.07634	0.14867	0.18603	0.2931	0.23021	0.31323	0.44237	0.44237	0.44237
0.04473	0.06497	0.15684	0.18944	0.19011	0.29379	0.20691	0.36524	0.36524	0.36524
0.03813	0.0553	0.10909	0.19992	0.19344	0.19039	0.26295	0.30338	0.30338	0.30338
0.04138	0.06007	0.10391	0.17848	0.26656	0.25249	0.22252	0.33346	0.33346	0.33346
0.05026	0.0731	0.10024	0.19136	0.26856	0.40232	0.33761	0.41985	0.41985	0.41985
0.0626	0.09131	0.13072	0.18916	0.297	0.41761	0.57184	0.55246	0.55246	0.55246
0.06307	0.09201	0.20941	0.19865	0.23178	0.36102	0.45443	0.55786	0.55786	0.55786
0.08582	0.12587	0.31201	0.46365	0.34086	0.39432	0.56735	0.85624	0.85624	0.85624
0.07093	0.10366	0.25251	0.39411	0.45905	0.33068	0.33987	0.65192	0.65192	0.65192
0.07717	0.11295	0.25463	0.43581	0.54643	0.63007	0.39203	0.73288	0.73288	0.73288
0.06957	0.10165	0.19598	0.35229	0.47959	0.59065	0.59647	0.63508	0.63508	0.63508
0.08709	0.12778	0.27884	0.38917	0.57825	0.80637	0.88642	0.87568	0.87568	0.87568
0.07472	0.10931	0.27747	0.36614	0.40291	0.58663	0.70816	0.70043	0.70043	0.70043
0.08609	0.12628	0.34002	0.5195	0.54228	0.58846	0.77648	0.86038	0.86038	0.86038
0.0811	0.11882	0.29834	0.50635	0.60876	0.62137	0.59081	0.78723	0.78723	0.78723
0.06779	0.099	0.20475	0.38093	0.50808	0.59632	0.53363	0.61334	0.61334	0.61334
0.07662	0.11213	0.22157	0.36258	0.55305	0.7441	0.76961	0.72553	0.72553	0.72553
0.0724	0.10586	0.14539	0.32116	0.42035	0.63671	0.75039	0.67054	0.67054	0.67054
0.05117	0.07444	0.09505	0.15204	0.26629	0.33821	0.44195	0.42914	0.42914	0.42914
0.04116	0.05974	0.07666	0.11315	0.14604	0.25009	0.28284	0.3314	0.3314	0.3314
0.00769	0.01108	0.02036	0.02067	0.02452	0.03069	0.04566	0.05507	0.05507	0.05507
0.02487	0.03597	0.0835	0.0991	0.08141	0.09533	0.1086	0.18853	0.18853	0.18853
0.0387	0.05615	0.13938	0.19931	0.19087	0.15254	0.16162	0.30865	0.30865	0.30865
0.06754	0.09864	0.23825	0.39554	0.46276	0.43076	0.29904	0.61039	0.61039	0.61039
0.07498	0.1097	0.22126	0.41892	0.56316	0.65342	0.52952	0.70387	0.70387	0.70387
0.07191	0.10512	0.21353	0.32609	0.49711	0.66203	0.67205	0.66427	0.66427	0.66427
0.06869	0.10034	0.20453	0.31264	0.38161	0.5776	0.6772	0.62426	0.62426	0.62426
0.08724	0.128	0.25379	0.41517	0.51529	0.63007	0.88295	0.87803	0.87803	0.87803
0.08264	0.12112	0.23928	0.37194	0.46225	0.568	0.61658	0.80929	0.80929	0.80929

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

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 2018.

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 2018: 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 and 5 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 catch-at-age data the measure of fit was the median (MDN) of the distribution of logarithmic squared residuals in catch-at-age.

Profiles of the components of the TISVPA loss function with respect to SSB in 2019 are shown in Figure 1. The minima are clear for catch-at-age and all surveys.

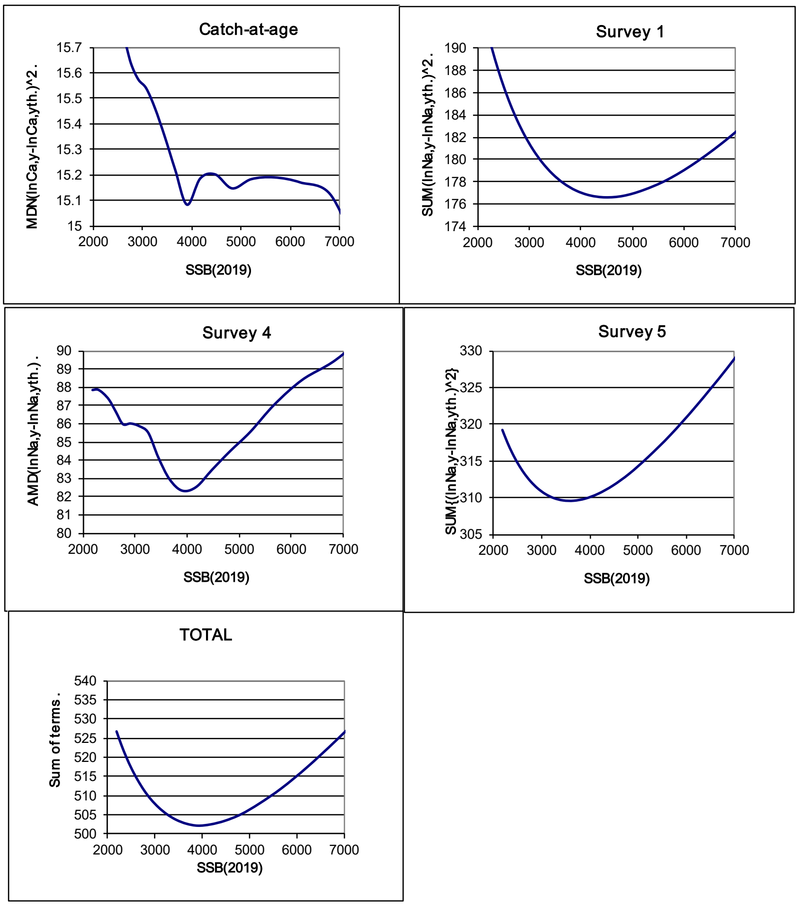

Figure 1. Profiles of the components of the TISVPA objective function.

The estimated selection pattern is given in Figure 2 (selection-at-age in the TISVPA model is normalized to SUM=1 for each year).

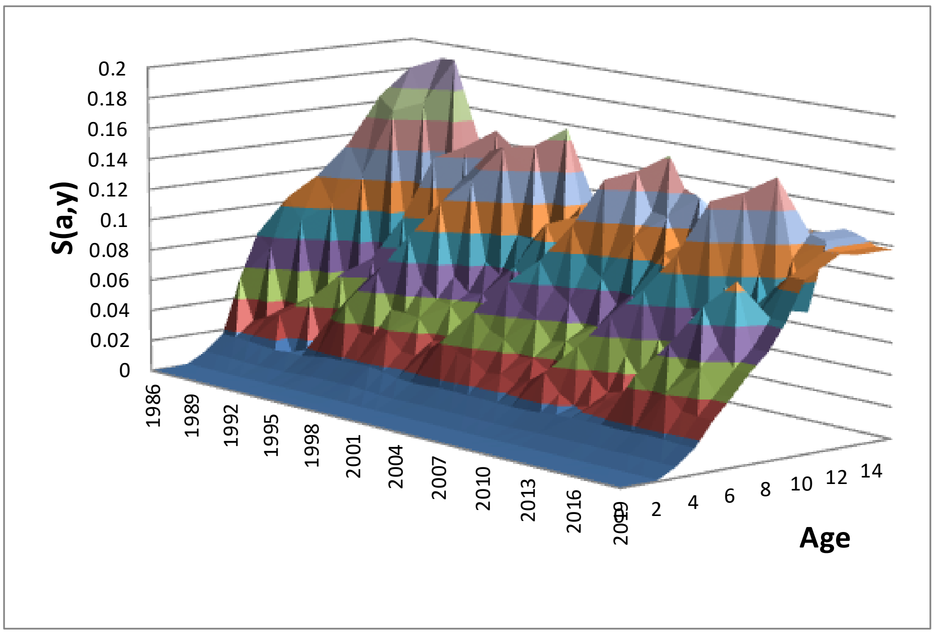

Figure 2. TISVPA – derived selection pattern.

Figure 3 represents the results of retrospective runs.

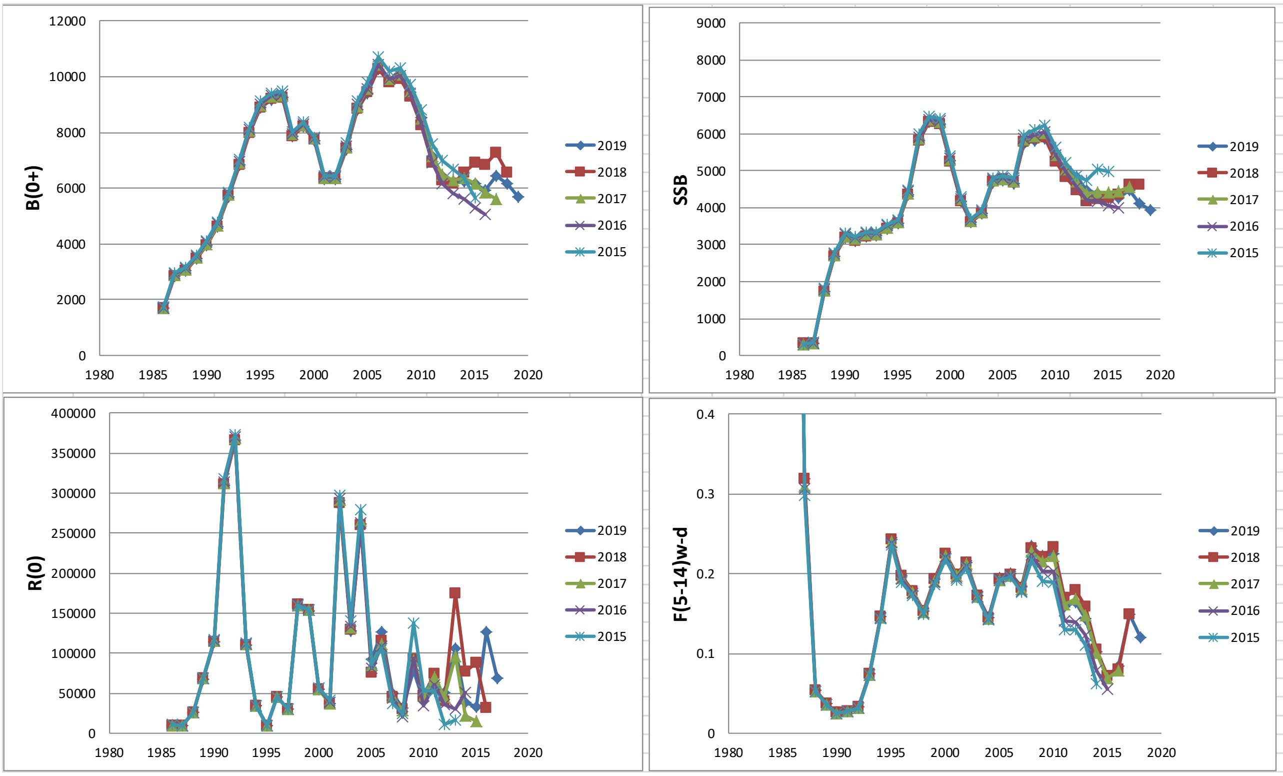

Figure 3. TISVPA retrospective runs

The residuals of the model approximation of the data are presented below.

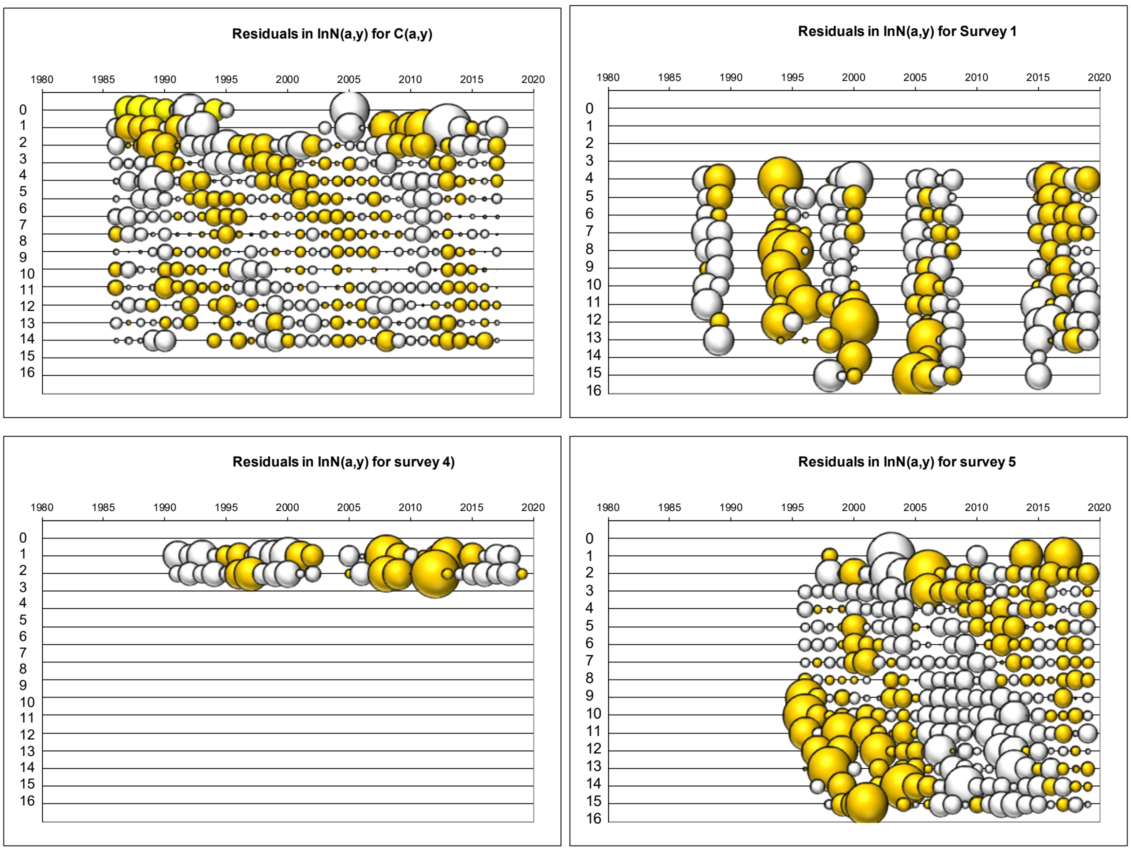

Figure 4. Residuals of the TISVPA data approximation.

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.

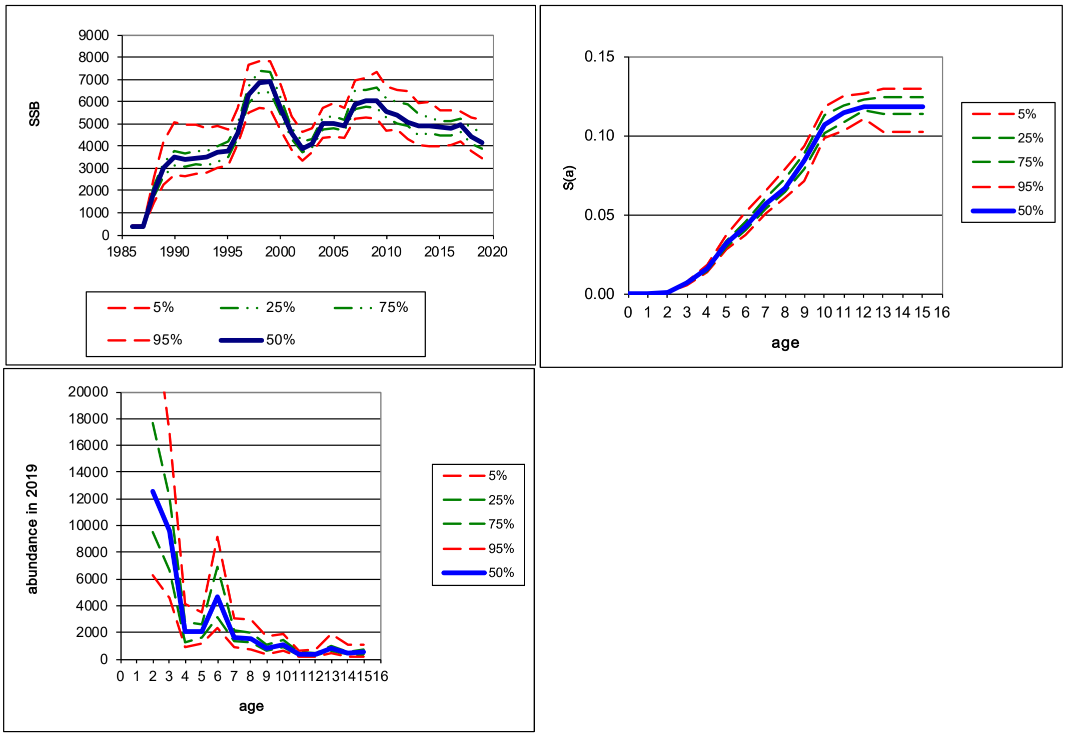

Figure 5. Bootstrap- estimates of uncertainty in the results.

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	322	10170	1.156
1987	2866	335	9139	0.319
1988	3034	1747	25681	0.054
1989	3492	2678	68212	0.037
1990	3966	3196	114510	0.026
1991	4632	3117	310107	0.028
1992	5706	3237	366289	0.033
1993	6846	3245	110066	0.075
1994	7977	3438	34434	0.147
1995	8891	3574	10368	0.244
1996	9180	4350	45000	0.197
1997	9241	5808	30107	0.178
1998	7859	6312	159708	0.153
1999	8212	6272	152725	0.193
2000	7716	5267	55151	0.225
2001	6327	4189	37291	0.199
2002	6330	3613	284941	0.214
2003	7400	3843	128614	0.173
2004	8804	4687	260923	0.146
2005	9396	4734	92889	0.195
2006	10281	4648	126360	0.201
2007	9870	5738	49194	0.184
2008	10065	5825	31842	0.234
2009	9463	5880	78064	0.222
2010	8547	5360	39799	0.225
2011	7149	5090	60978	0.159
2012	6452	4845	51709	0.165
2013	6207	4478	105683	0.144
2014	6261	4393	38177	0.102
2015	6176	4256	32979	0.072
2016	5916	4281	126075	0.084
2017	6454	4467	69487	0.149
2018	6185	4104		0.120
2019	5683	3939		

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	10170	21708	1672	18144	169	47	62	213	134	64	78	40	111	101	0	3
1987	9139	4131	8824	677	14969	129	26	27	116	42	28	22	14	11	10	1
1988	25681	3711	1678	3570	562	11998	94	15	11	75	15	15	13	6	3	1
1989	68212	10436	1508	678	2993	453	9285	70	8	4	50	4	10	7	2	0
1990	114510	27731	4242	606	580	2549	379	7635	57	6	3	39	3	8	6	5
1991	310107	46556	11274	1720	512	494	2179	313	6300	47	4	2	32	2	6	10
1992	366289	126079	18927	4582	1475	438	424	1863	262	5247	39	3	1	27	0	0
1993	110066	148921	51260	7694	3933	1250	373	364	1593	219	4341	32	3	1	0	0
1994	34434	44747	60546	20833	6594	3318	1022	314	310	1347	174	3416	27	2	1	17
1995	10368	13999	18193	24603	17848	5574	2619	779	258	261	1126	124	2472	21	2	3
1996	45000	4215	5692	7391	21025	14989	4389	1849	527	207	213	910	60	1522	0	0
1997	30107	18296	1714	2304	6295	17431	11739	3170	1253	360	164	175	720	35	783	1
1998	159708	12241	7439	690	1896	5111	13139	8299	2058	680	197	110	128	530	15	281
1999	152725	64932	4977	2998	556	1480	4026	9618	5882	1386	381	102	71	103	303	219
2000	55151	62094	26400	2020	2496	452	1165	3103	6920	4111	928	205	62	39	70	215
2001	37291	22423	25245	10717	1684	1850	351	892	2293	4736	2638	564	95	32	18	118
2002	284941	15161	9116	10257	9126	1358	1344	272	691	1745	3401	1843	404	59	23	33
2003	128614	115848	6164	3686	8658	7396	996	914	198	501	1230	2145	1175	259	36	28
2004	260923	52290	47098	2503	3118	7187	5814	734	647	146	364	861	1374	791	178	76
2005	92889	106082	21259	19126	2133	2612	5867	4512	552	457	105	268	615	903	534	66
2006	126360	37766	43128	8631	16143	1763	2098	4545	3209	380	287	61	175	408	534	184
2007	49194	51374	15353	17506	7335	13302	1431	1635	3344	2169	247	163	31	106	244	220
2008	31842	20001	20885	6234	14846	6028	10208	1109	1206	2344	1425	155	97	16	67	168
2009	78064	12946	8121	8478	5288	12183	4534	7110	787	806	1485	779	83	38	2	154
2010	39799	31738	5262	3266	7109	4332	9370	3041	4526	530	457	802	356	29	20	85
2011	60978	16181	12883	2119	2716	5760	3445	6759	1757	2514	289	190	326	96	11	19
2012	51709	24792	6544	5160	1761	2183	4545	2634	4623	867	1266	135	60	119	33	9
2013	105683	21023	10078	2654	4296	1452	1738	3582	2010	3243	469	706	74	24	55	13
2014	38177	42967	8547	4089	2245	3527	1189	1402	2862	1565	2372	287	486	48	14	58
2015	32979	15522	17469	3473	3493	1888	2839	977	1140	2311	1240	1764	190	362	33	62
2016	126075	13408	6310	7099	2973	2959	1574	2301	806	926	1865	987	1359	141	273	70
2017	69487	51258	5451	2564	6067	2517	2443	1279	1816	647	733	1463	773	1025	97	214
2018	0	28251	20839	2210	2163	4999	2045	1874	953	1266	467	510	1034	565	675	194
2019	0	0	11486	8461	1879	1808	4065	1625	1451	722	926	325	350	699	383	459

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	0.002	0.000	0.002	0.032	0.115	0.393	0.305	0.726	0.882	1.149	3.627	0.709	0.979	1.755	0.000	2.207
1987	0.002	0.002	0.005	0.031	0.036	0.164	0.153	0.316	0.292	0.359	0.433	0.237	0.856	0.920	1.285	1.285
1988	0.001	0.001	0.007	0.019	0.048	0.049	0.112	0.297	0.798	0.229	0.952	0.212	0.330	0.713	0.839	0.839
1989	0.000	0.000	0.022	0.004	0.001	0.013	0.037	0.054	0.108	0.188	0.072	0.399	0.079	0.043	0.158	0.000
1990	0.000	0.000	0.005	0.033	0.005	0.005	0.031	0.032	0.024	0.293	1.180	0.066	0.246	0.028	0.116	0.116
1991	0.000	0.000	0.000	0.005	0.006	0.003	0.007	0.030	0.037	0.057	0.129	0.071	0.023	0.053	0.053	0.053
1992	0.000	0.000	0.000	0.003	0.024	0.012	0.003	0.007	0.023	0.046	0.070	0.206	0.189	0.048	0.000	0.000
1993	0.000	0.000	0.000	0.004	0.029	0.076	0.024	0.010	0.020	0.093	0.104	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.000	0.000	0.002	0.018	0.122	0.185	0.053	0.028	0.029	0.241	0.220	0.114	0.275	0.143	0.143
1995	0.000	0.000	0.000	0.002	0.021	0.124	0.294	0.372	0.065	0.066	0.067	1.231	0.487	0.229	0.229	0.229
1996	0.000	0.000	0.007	0.005	0.036	0.116	0.254	0.261	0.230	0.029	0.037	0.079	0.368	0.856	0.000	0.000
1997	0.000	0.000	0.017	0.061	0.046	0.114	0.196	0.289	0.318	0.195	0.137	0.216	0.141	0.842	0.682	0.682
1998	0.000	0.000	0.015	0.113	0.144	0.078	0.151	0.174	0.216	0.223	0.256	0.276	0.029	0.251	0.517	0.517
1999	0.000	0.000	0.001	0.049	0.070	0.100	0.118	0.192	0.232	0.248	0.344	0.161	0.884	0.076	0.365	0.365
2000	0.000	0.000	0.001	0.044	0.268	0.084	0.105	0.147	0.219	0.309	0.280	0.453	0.324	0.955	0.429	0.429
2001	0.000	0.000	0.000	0.010	0.105	0.276	0.122	0.119	0.145	0.205	0.224	0.147	0.302	0.123	0.218	0.218
2002	0.000	0.000	0.009	0.020	0.077	0.219	0.293	0.122	0.153	0.173	0.228	0.214	0.147	0.250	0.385	0.385
2003	0.000	0.000	0.001	0.022	0.040	0.109	0.204	0.213	0.129	0.169	0.204	0.324	0.217	0.170	0.266	0.266
2004	0.000	0.000	0.001	0.010	0.031	0.065	0.138	0.172	0.252	0.213	0.164	0.230	0.365	0.326	0.180	0.180
2005	0.000	0.000	0.001	0.025	0.047	0.071	0.122	0.243	0.263	0.331	0.478	0.295	0.270	0.510	0.286	0.286
2006	0.000	0.000	0.001	0.009	0.048	0.050	0.089	0.183	0.290	0.280	0.330	0.731	0.424	0.419	0.327	0.327
2007	0.000	0.000	0.001	0.014	0.054	0.153	0.119	0.169	0.259	0.283	0.223	0.178	0.718	0.278	0.325	0.325
2008	0.000	0.003	0.001	0.006	0.040	0.124	0.268	0.209	0.251	0.304	0.317	0.222	0.494	0.553	0.501	0.501
2009	0.000	0.000	0.018	0.024	0.030	0.108	0.237	0.334	0.211	0.415	0.355	0.385	0.850	0.292	0.653	0.653
2010	0.000	0.003	0.015	0.033	0.031	0.047	0.127	0.281	0.398	0.423	0.531	0.588	0.746	0.612	0.953	0.953
2011	0.000	0.010	0.026	0.031	0.041	0.043	0.066	0.124	0.390	0.311	0.395	1.029	0.573	0.672	1.047	1.047
2012	0.000	0.000	0.003	0.044	0.030	0.059	0.067	0.110	0.185	0.477	0.351	0.530	1.513	0.832	0.508	0.508
2013	0.000	0.000	0.003	0.024	0.070	0.053	0.070	0.086	0.135	0.212	0.475	0.242	0.436	0.634	0.203	0.203
2014	0.000	0.000	0.000	0.007	0.027	0.079	0.045	0.055	0.074	0.104	0.184	0.360	0.132	0.327	0.145	0.145
2015	0.000	0.000	0.000	0.005	0.017	0.029	0.058	0.037	0.062	0.073	0.091	0.127	0.108	0.143	0.154	0.115	0.115
2016	0.000	0.000	0.000	0.007	0.015	0.040	0.059	0.078	0.070	0.087	0.103	0.108	0.148	0.336	0.135	0.135
2017	0.000	0.000	0.004	0.027	0.054	0.049	0.112	0.143	0.183	0.174	0.211	0.221	0.157	0.255	0.277	0.277
2018	0.000	0.000	0.001	0.012	0.029	0.057	0.080	0.106	0.128	0.162	0.213	0.227	0.241	0.237	0.237	0.237

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

Working document xx, WGWIDE 2019

Utilizing the full time-series of catch by rectangle

Martin Pastoors, 25/08/2019

Introduction

WGWIDE and its precursors WGMHSA and WGNPBW have been publishing catch per rectangle plots in their reports for many years already. Catch by rectangle has been compiled by WG members and generally provide a WG estimate of catch per rectangle. In most cases the information is availalble by quarter whereas most recently, the data has been requested by month. So far, the catch by rectangle has only been presented for one single year in the WG reports. Here, we collated all the catch by rectangle data that is available for herring, blue whiting, mackerel and horse mackerel for as many years as available.

** Results **

An overview of the available catches by 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	(all)
0	993001	819755	684723	461383	328679	383081	715545	0	4386167
252455	211305	181505	220870	141685	108136	113592	122009	118276	3300243
861394	936099	874986	920066	1374495	1166138	1083641	1151726	0	15454213
0	103861	377079	616511	1139737	1389447	1175687	1540077	0	6342399

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
BE	0	0	0	0	0	0	0	0	0	0	0	0
BQ	0	0	0	0	0	0	0	0	0	0	0	0
DE	21490	19956	22977	25323	26532	24059	23368	19123	16599	18221	15503	22703
DK	28157	30208	32693	31133	32180	27198	25311	22921	24230	24877	26726	23228
EE	0	0	0	0	0	0	0	0	0	0	0	0
ES	44607	45914	38320	44143	31845	23858	34968	53192	54569	63235	64785	114141
FO	11229	11620	21023	24004	19768	14014	13029	9769	12066	13393	11289	14061
FR	0	0	0	0	0	0	0	0	15968	14997	15454	9740
GL	0	0	0	0	0	0	0	0	0	0	0	0
GY	0	0	0	0	0	0	0	0	0	0	0	0
IC	0	0	0	0	0	0	0	0	4220	36496	112220	116157
IE	69171	59578	71226	70443	72173	63588	58929	42530	38563	46675	44318	61086
IM	0	0	0	0	0	0	0	0	0	0	0	0
JY	0	0	0	0	0	0	0	0	0	0	7	7
LT	0	0	0	0	0	0	0	0	0	0	0	0
NL	46127	28070	32403	49815	42254	34263	35680	41432	24007	23912	19933	23355
NO	158179	160728	174098	180595	184291	163404	157363	119680	121981	131697	121470	121225
PL	0	0	0	0	0	0	0	0	0	977	0	0
PT	2846	1981	2253	3049	2934	2749	2143	1479	2591	2598	2367	1742
RU	67837	51348	50772	41568	45811	40026	49489	39922	33462	35408	32728	41413
SE	5146	5233	4995	5099	0	4447	4437	3202	3210	3858	3660	7303
UKE	26694	19403	0	25868	26082	24446	21806	14676	7725	14653	2299	2973
UKN	8030	0	0	0	0	0	10933	8037	8369	5544	1797	2735
UKS	144984	139918	164069	163941	165017	146129	141988	129987	79721	113487	109848	151302
(all)	634497	573957	614829	664981	648887	568181	579444	505950	447281	550028	584404	713171

Table: Table continues below

2010	2011	2012	2013	2014	2015	2016	2017	(all)
0	0	38	60	0	51	142	128	419
0	0	0	0	10509	0	8165	0	18674
19055	24082	18974	20933	28451	28207	23411	24857	443824
41045	29213	36503	33261	41903	45015	40655	37899	634356
0	0	0	1366	0	0	0	0	1366
53350	23988	17735	13069	33734	33744	21426	34425	845048
70987	122049	107629	143001	150419	107993	93266	99499	1070108
12108	12393	17859	14642	21695	0	20171	22920	177947
0	162	5319	52796	78672	30410	36194	46498	250051
0	0	0	8	8	4	0	0	20
122337	159008	149584	151326	172960	169257	170374	166601	1530540
57993	63188	63058	56611	103178	88738	76523	84914	1292483
0	11	0	7	3	4	7	0	32
0	6	0	0	6	2	2	0	30
0	0	0	0	0	553	2539	0	3092
25062	34500	32554	21159	46665	39807	37752	43765	682515
233941	208077	176031	164602	277724	242233	210569	222397	3530285
0	0	0	0	0	0	0	0	977
2355	938	821	253	636	928	619	633	35915
59310	73601	74578	80756	116086	128292	121336	138077	1321820
3428	3247	4563	2906	4421	3930	3662	3700	80447
17722	20041	19186	16542	26562	32260	23699	26421	369058
4293	11344	14945	12347	20351	12597	2302	16887	140511
138403	150243	135602	134412	240503	202104	190817	182096	3024571
861389	936091	874979	920057	1374486	1166129	1083631	1151717	15454089

Table 1: Catch of mackerel (tonnes) included in the rectangle data by year and country

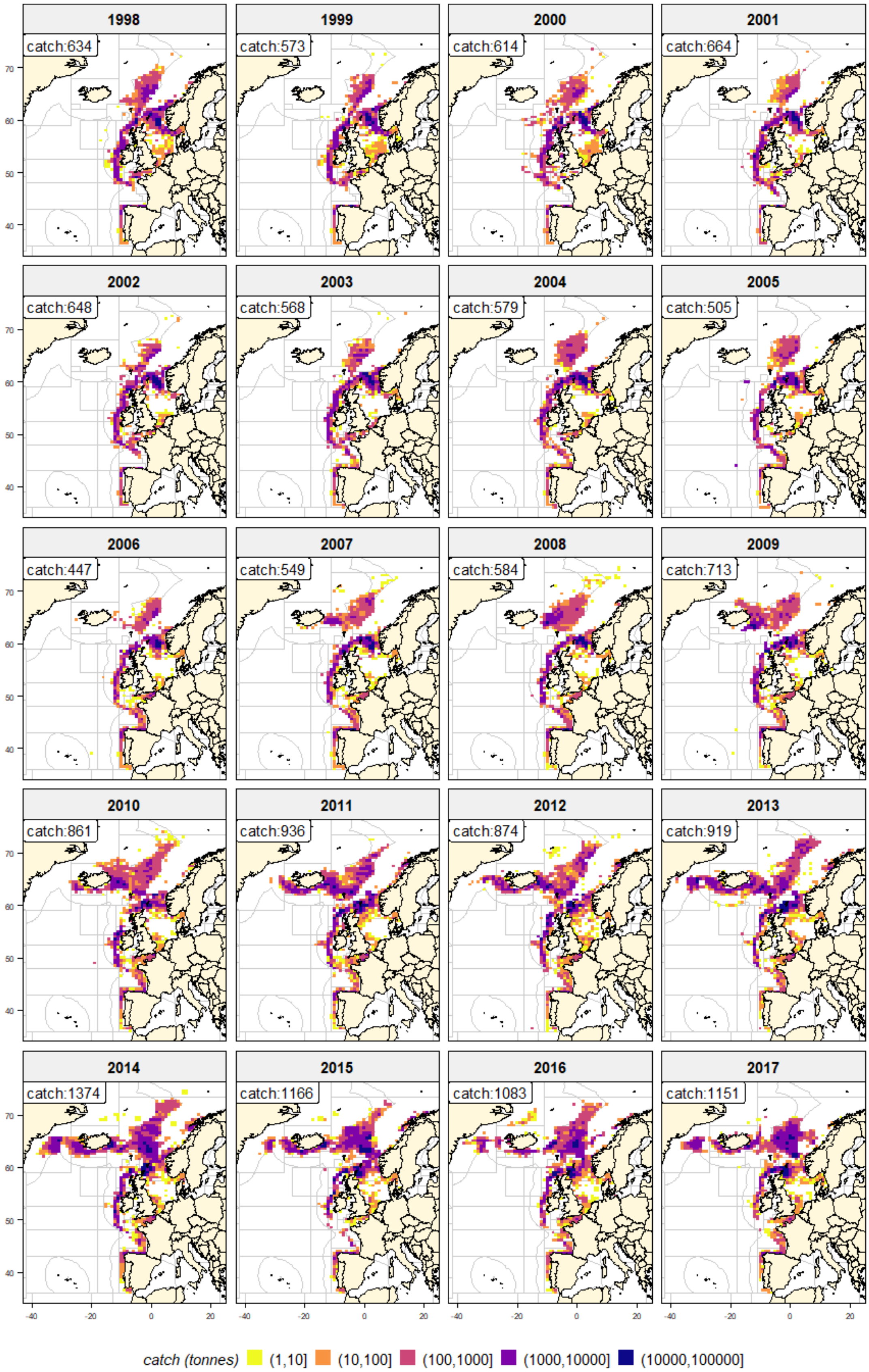

Figure 1: Catch of mackerel (tonnes) by year and rectangle

Horse Mackerel

country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	(all)
BEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	0	67	44	174
DNK	0	12478	14636	20256	14135	9794	7885	0	6097	5935	6100	4674	0	0	0	0	0	0	101990
ENG	10430	8294	6405	10251	7418	0	12404	4425	16209	14604	13466	13057	45306	9197	0	0	0	0	171466
ESP	34688	34258	32926	27947	26435	23829	27319	34169	36722	54230	32942	12373	39507	32907	37896	32851	33860	37109	591968
FAR	0	0	808	3846	3695	0	477	477	0	0	0	0	0	0	0	0	50	0	9353
FRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5785	3443	9228
GER	12510	15925	18762	22792	18978	12453	5871	12882	16420	21482	21114	22588	27959	19056	10061	13293	8121	8121	288388
IRL	52212	36482	35854	26432	35359	28856	30091	36508	40779	44475	38464	45306	35783	32660	21647	27606	23559	25347	617420
NIRL	0	0	0	0	426	223	0	0	0	0	0	0	2325	1578	0	0	0	0	4552
NLD	103349	59585	86162	68733	73130	64413	61433	0	60459	85042	71981	78552	62519	29975	28150	27685	19906	19906	1000980
NOR	7992	36689	20515	10749	25115	27225	5425	12247	72615	12500	13770	3378	6791	14658	9560	11184	11184	10742	312339
POR	13759	14269	10571	11874	13307	14607	10380	9278	10840	11726	0	0	0	0	0	0	19473	13370	153454
SCO	8028	2907	0	1524	0	769	1403	1082	1417	2459	13466	1574	675	1650	737	970	0	190	38851
SWE	0	0	0	0	0	0	0	0	0	0	0	0	1	1	18	0	0	0	20
(all)	242968	220887	226639	204404	217998	182169	162688	111068	261558	252453	211303	181502	220866	141682	108132	113589	122005	118272	3300183

Table: Table continues below

Table 2: Catch of horse mackerel (tonnes) included in the rectangle data by year and country

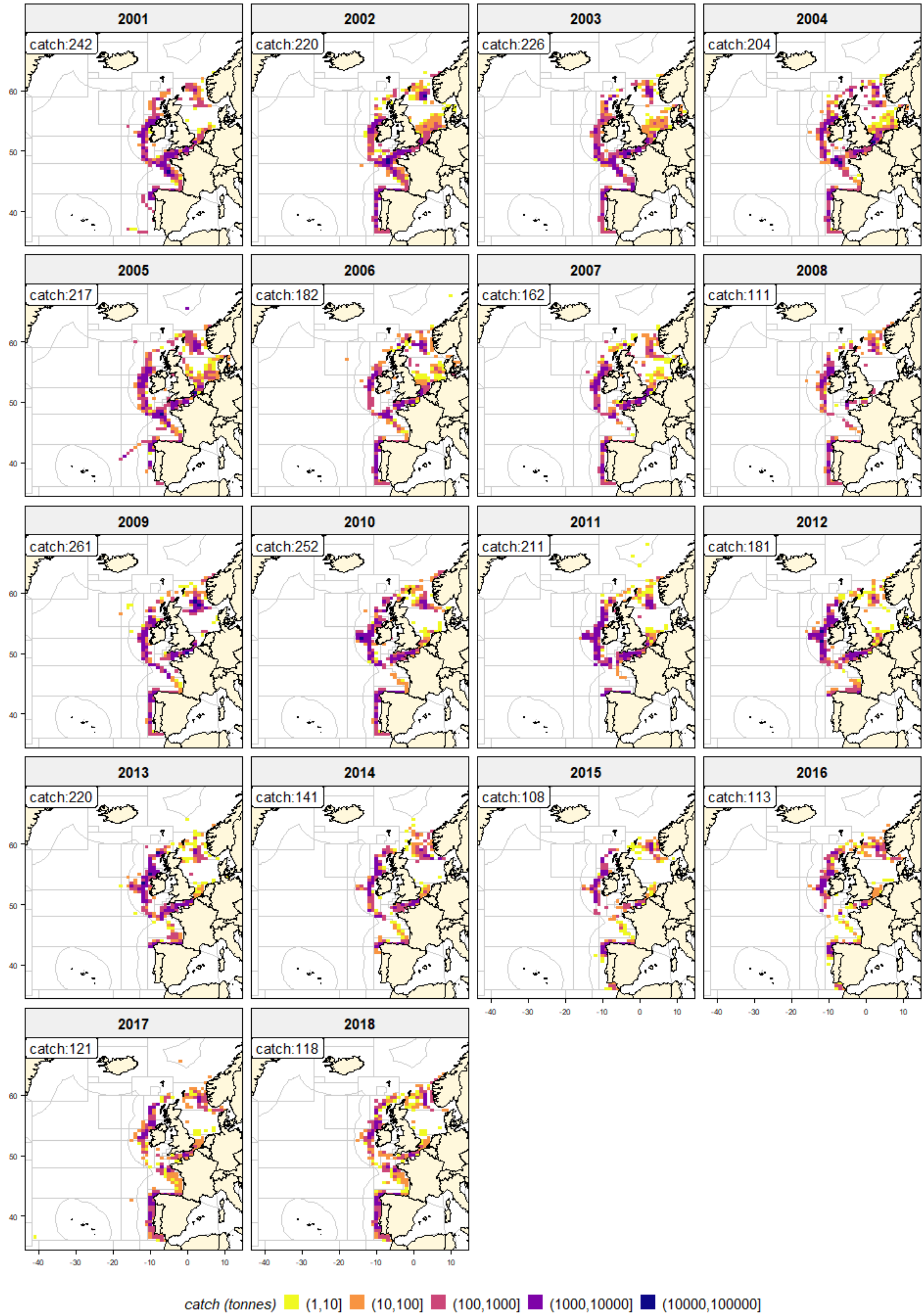

Figure 2: Catch of horse mackerel (tonnes) by year and rectangle

Blue whiting

country	2011	2012	2013	2014	2015	2016	2017	(all)
ALL	0	377079	0	0	0	0	0	377079
DEU	266	0	11528	24487	24106	20024	0	80411
DNK	0	0	0	27945	45047	39134	60866	172992
ESP	2416	0	13388	25140	24967	27493	27433	120837
FRA	4337	0	8978	10410	9657	10345	13221	56948
FRO	16404	0	85767	224699	282477	282364	356501	1248212
GER	0	0	0	0	0	0	45555	45555
GRL	0	0	0	0	0	0	20212	20212
IRL	1194	0	13205	21467	24785	26329	43237	130217
ISL	5887	0	104912	182873	214868	186907	228934	924381
LTU	0	0	0	4718	0	1129	5299	11146
NLD	4595	0	51634	38524	56397	58148	81155	290453
NOR	20539	0	196246	399520	489438	310412	399363	1815518
PRT	0	0	2014	1303	1429	1429	1625	7800
RUS	46888	0	120669	151810	185763	173655	188449	867234
SCO	0	0	8166	0	0	36896	64690	109752
SWE	0	0	0	1	0	42	89	132
UK	0	0	0	0	0	1374	0	1374
UKEW	0	0	0	0	0	0	3442	3442
UKN	0	0	0	2205	0	0	0	2205
UKS	1331	0	0	24630	30508	0	0	56469
(all)	103857	377079	616507	1139732	1389442	1175681	1540071	6342369

Table 3: Catch of blue whiting (tonnes) included in the rectangle data by year and country

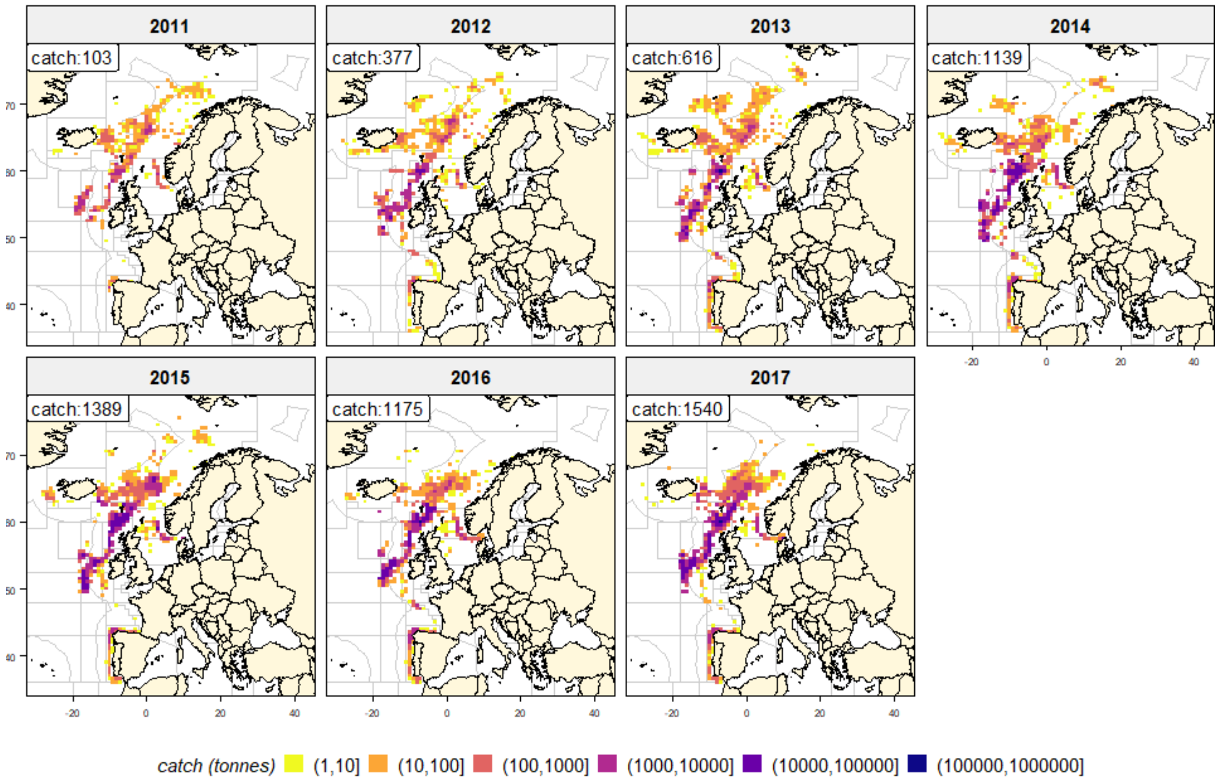

Figure 3: Catch of blue whiting (tonnes) by year and rectangle

Atlanto-scandian herring

country	2011	2012	2013	2014	2015	2016	2017	(all)
ALL	0	819755	0	0	0	0	0	819755
DEU	13295	0	4243	668	2660	2582	5201	28649
DNK	26732	0	17159	12513	9105	10384	17373	93266
FRO	53270	0	105037	38527	33030	44726	98170	372760
GRL	3426	0	11787	13187	12434	17507	12569	70910
IRL	5738	0	3814	705	1399	2048	3494	17198
ISL	151078	0	90729	58827	42626	50457	90400	484117
NLD	8348	0	5625	9175	5248	3519	6678	38593
NOR	572637	0	359458	263252	176321	197500	389383	1958551
RUS	144429	0	78501	60291	45853	50454	91119	470647
SCO	14045	0	0	0	0	0	0	14045
SWE	0	0	23	0	0	0	1155	1178
UK	0	0	0	4233	0	3899	0	8132
UKS	0	0	8342	0	0	0	0	8342
(all)	992998	819755	684718	461378	328676	383076	715542	4386143

Table 4: Catch of Atlanto-scandian herring (tonnes) included in the rectangle data by year and country

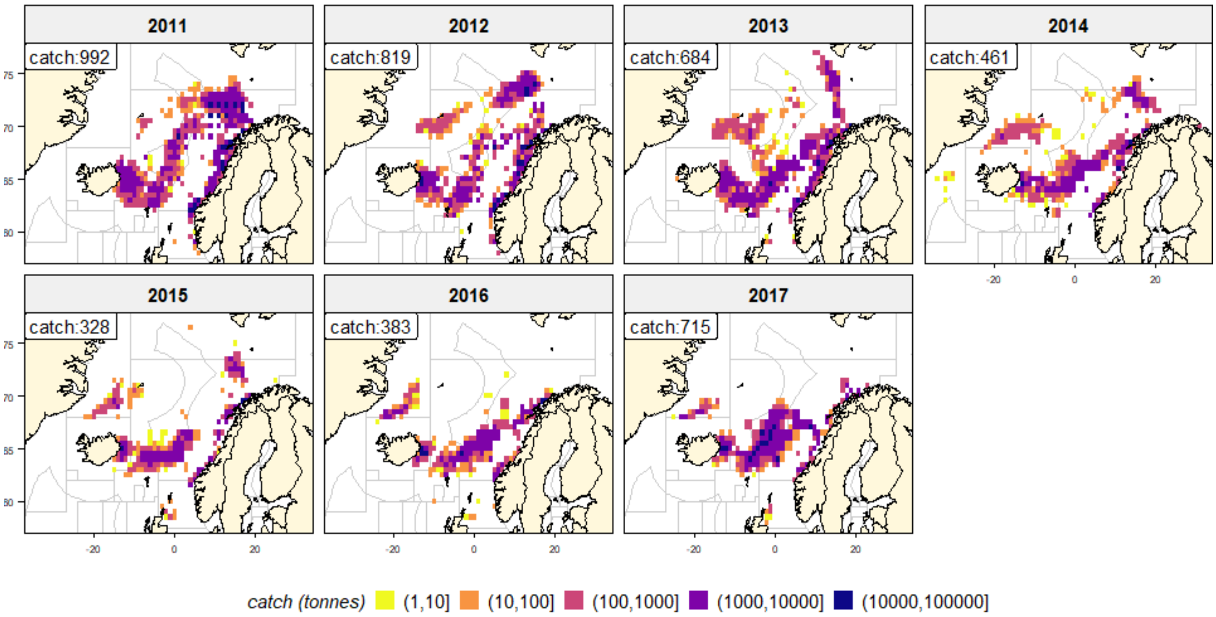

Figure 4: Catch of Atlanto-scandian herring (tonnes) by year and rectangle

Vertical distribution of herring from sonars during international ecosystem survey in Nordic seas (IESNS) in May 2019

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Introduction

The biomass estimation method using hull mounted echosounders only have at least two sources of bias related to the collection of the acoustic backscattering of the pelagic target species: i) fish present in the echosounder blind zone close to the sea surface, and ii) fish avoidance to the surveying vessel. Horizontally oriented sonars can potentially provide data to investigate those biases.

During the last three years, the collection and scrutinizing of sonar data has been an additional activity in the IESNS survey carried out by the Institute of Marine Research (IMR). Experience gained will help to evaluate feasibility and benefits of using sonar in a routine basis during acoustic pelagic trawling surveys.

Two classes of sonars were used; an omnidirectional fisheries sonar (SU90), and a scientific matrix sonar (MS70). The SU90 sonar can be run in two modes: either by measuring in a 360 degrees dish, or in a vertical slice. The SU90 is similar to sonars common on many fishing vessels and has the advantage of being available on many fishing vessels, while MS70 is currently only available onboard RV "G.O. Sars". The MS70 points port and use 500 beams covering 60 degrees (horizontally) by 45 degrees (vertically). Thus, the MS70 sonar has a better spatial resolution, but a poorer horizontal coverage than SU90. MS70 provides data both at horizontal ranges from the ship and also vertically.

The main goal of the present study was to use the sonars onboard RV "G. O. Sars" to quantify the fraction of NSS herring in the upper depths of 60 m during the IESNS survey in the Nordic seas. SU90 can cover the upper 60 m, and MS70 was used to investigate the upper 200 m. The vertical distribution of fish abundance by means of SU90 and MS70 will be compared with the distribution from echo sounder.

Methods

The sonars onboard RV "G.O. Sars" were calibrated in April 2018. The SU90 sonar was calibrated at 26 kHz frequency, FM normal transmission mode and narrow beam. The MS70 was calibrated at the survey operation mode with (for the first time) the highest frequency in the top fan.

The SU90 omnidirectional fishery sonar

Setup

During the survey, the sonar was set up to achieve a high ping rate operating at a range of 600 m. The sonar was synchronized with the EK80 echo sounder and MS70 scientific sonar to avoid interference, which resulted in a ping rate of the near-horizontal beams between 4 to 5 seconds.

A tilt of 5 deg was set for the near-horizontal beams with a theoretical upper depth of the beam of 8 m at 50 m range and lower depth of the beam of 90 m at the maximum operational range. Experienced showed that shallower tilt angles (i.e. 1 or 2 deg) can affect severely data acquisition, which is subject to noise produced by air bubbles swept down by waves, that in high winds (>25 knots) can reach up to 50 m below the surface. The vessel roll contained in the echo sounder data was used as an indicator of bad sonar conditions (high wind and high waves), not processing sonar data with absolute roll angles larger than 2.5 deg.

The 180° vertical beam fan was set perpendicular to the vessel track with a horizontal range of 600 m and a vertical range of 600 m.

All the sonar filters (AGC, RCG, Ping to ping) were set to the default values, except for the "Noise filter", which was disabled because it alters the values of exported raw data.

LSSS-PROFOS settings

The Processing system for omni directional fisheries sonar (PROFOS) module of the LSSS software was used for the data replay and school segmentation. The automatic school detection functionality was used, with a posterior manual quality control of the segmented school. The segmentation settings most commonly used were: 12 dB above the background level, minimum area of 100 m^2, maximum area of 7000 m^2, two missing pings, at least 7 pings schools, and a ratio of 10 between length and school width. The output from LSSS contained school descriptors and vessel navigation information for each ping de the school was detected.

Vertical distribution of fishey sonar and echo sounder

School descriptors from fishey sonar data were used to compute the nautical area scattering coefficient (S_A, m^2 nmi^{-2}) by 1 nmi distance and depth channels of 10 m, from surface up to 60 m. Similar integration criteria was used with the echo sounder data resulted from the official survey scrutiny. Data was sorted by transects and vertical distributions of S_A were generated.

Because different ensonification angle of the two instruments used (vertical for echo sounder and near-horizontal for sonar) the S_A values are not directly comparable, and a conversion factor was used to upscale the lower sonar S_A values to facilitate the visual comparison. The conversion factor used was 2.5, corresponding to the a 4 dB difference between horizontal and vertical mean target strength.

The MS70 scientific matrix sonar

Setup

MS70 was set up to cover a horizontal distance of 250 m (i.e. range 410 m) and to ping at least every second EK80 ping (1 ping per 2 seconds). The highest frequency (112 kHz) closest to the surface with centre of beams parallel to the surface, and the lowest beams (75 kHz) was pointing 45 degrees down. The highest frequencies were used at the top to have the narrowest beams in the vertical direction in order to get as close to the surface as possible. The MS70 transducer were mounted on a protrudable instrument keel, with the centre of the transducer at 7.5 m below the sea surface.

Data preprocessing

The MS70 data were preprocessed by means of LSSS-PROMUS (Processing system for advanced multibeam sonar). A brief description of the preprocessing is as follows:

1) Spatial and temporal spikes were detected and replaced median of the surrounding data.
2) Ambient noise were estimated for each of the 500 beams and then each sample was corrected for ambient noise.
3) Data were collected to a range of 410 m. Data closer to the ship than 20 m were removed. Data at larger horizontal range from the ship than 250 m were removed.
4) Data closer to the surface than 2.5 m were removed. This implies that at least the two uppermost fans were cut at ranges where the upper edge of beam is closer to the surface than 2.5 m. The vertical extent of the fans is a source of uncertainty: we used the nominal vertical beamwidth multiplied by 1.65.
5) Data were thresholded, so that all S_v-samples weaker than -70 dB and stronger than -5 dB were removed (set to -120 dB).
6) Data were compressed by removing data where 20 samples in a row were weaker than -70 dB. This reduced the data volume by 85%.

Pre-scrutiny

School-candidates were automatically detected from preprocessed data according to specified criteria. The most important of those were:

1) The school seed-point needed to be between -30 and -60 dB.
2) The maximum grow-depth of the centre of the beam was 150 m (although the lower edge of the beam could be deeper). This means that at depths deeper than 150 m, the data are not trusthworthy.
3) The minimum grow-depth depended on the weather. It mostly varied between 2.5 and 15 m below the sea surface, but it could be as deep as 25 – 30 m.

Data interpretation

The EK80 data were scrutinized by the cruise leader and the chief instrument engineer some hours after the data were collected. The MS70 data were scrutinized by a single scientist. MS70-data collected after May 15 were scrutinized a few hours after the EK80 data. Data collected from May 1 were scrutinized after May 15. All scrutiny finished by the end of the survey.

MS70 data were scrutinizing by first removing outliers of the school-candidates. Then the school-candidates were scrutinized in pretty much the same way as the EK80 data, i.e. by considering scattering strength, shape of school (in 4 dimensions), biological samples, and by conferring the results of the EK80-data scrutiny. Scrutinization of 24 hours of MS70 data took typically 20 minutes.

Data were stored in a database as volume backscattering data and were exported to files to be processed in external systems. The data were averaged to over the same distance (1 nmi) as the EK80 data, and in range-cells of 10 m, and at its native beam resolution. Thus, each database cell is an average of typically 4500 MS70-samples. Note that MS70-data and database storage cells are natively shaped as sphere-sectors, and that the data used here are converted to cartesian coordinates.

Scrutinization of the fishery sonar and MS70 sonar differ from that of the echosounder in that they consider schools of a minimuma size (e.g., minimum area of 100 m^2 for the fishery sonar). This represents a potential source of bias in the comparison between the instruments, as a layer of small schools or individual fish can contribute significantly to the echosounder NASC while being excluded from the sonar NASC.

Results

The sum of the herring NASC from 0 to 70 m depth by transects for the fishery sonar showed a similar spatial distribution as the NASC from the echo sounder (Figure 1, left versus right panel). The majority of the herring was observed in transects T8, T10 and T11, for both fishery sonar and echo sounder. We selected these transects for further analysis.

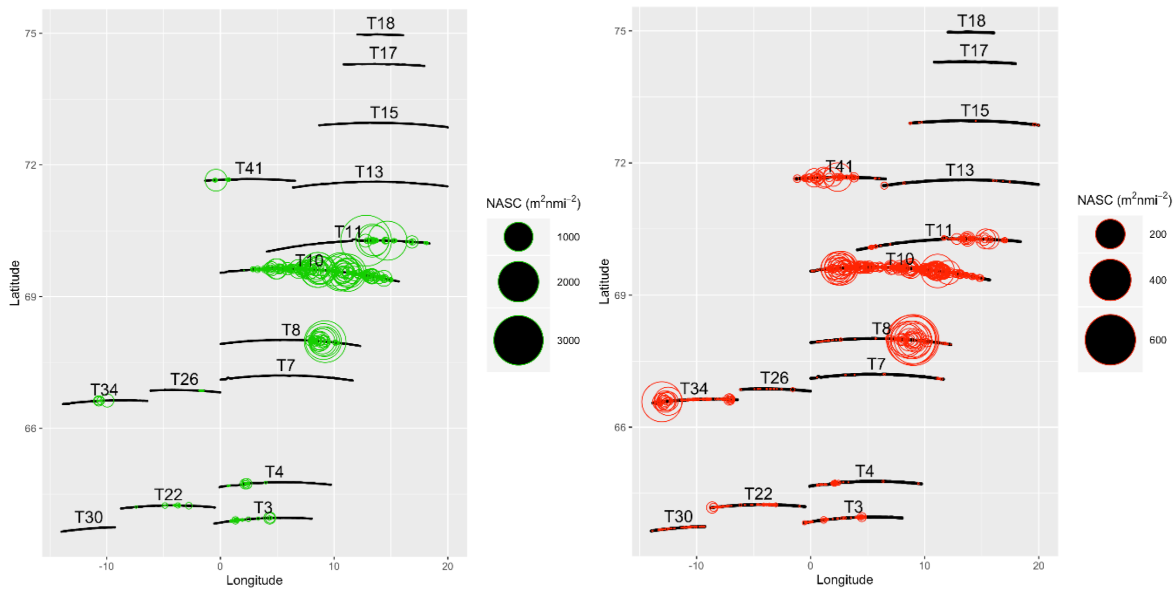

Figure 1. Herring NASC from 0 to 70 m by transects for echo sounder (left panel) and fishery sonar (right panel).

Herring schools measured with fishery sonar showed similar sizes in transects T10 and T11, with maximum length about 25 m. In transect T8, many schools were also in the same size range, with addition of larger schools between 40 and 100 m size (Figure 2).

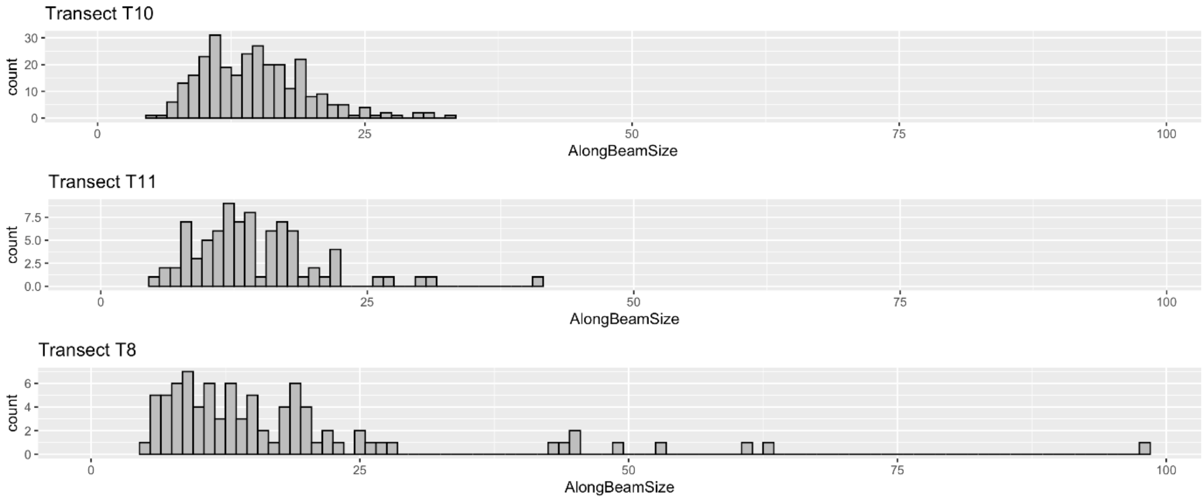

Figure 2. Length of herring schools (m) measured with fishery sonar for transects 10, 11 and 8.

The difference between school sizes in transect T8 versus transects T10 and T11 is further illustrated in Figure 3. In the upper panel, taken from transect T8, some 6 larger schools are visible in the echogram (upper frame) between 20 and 70 m depth, and the sonar is densely populated by detected schools. In the lower panel, taken from transect T10 there are only 2 smaller schools, and only a few schools are detected by the sonar.

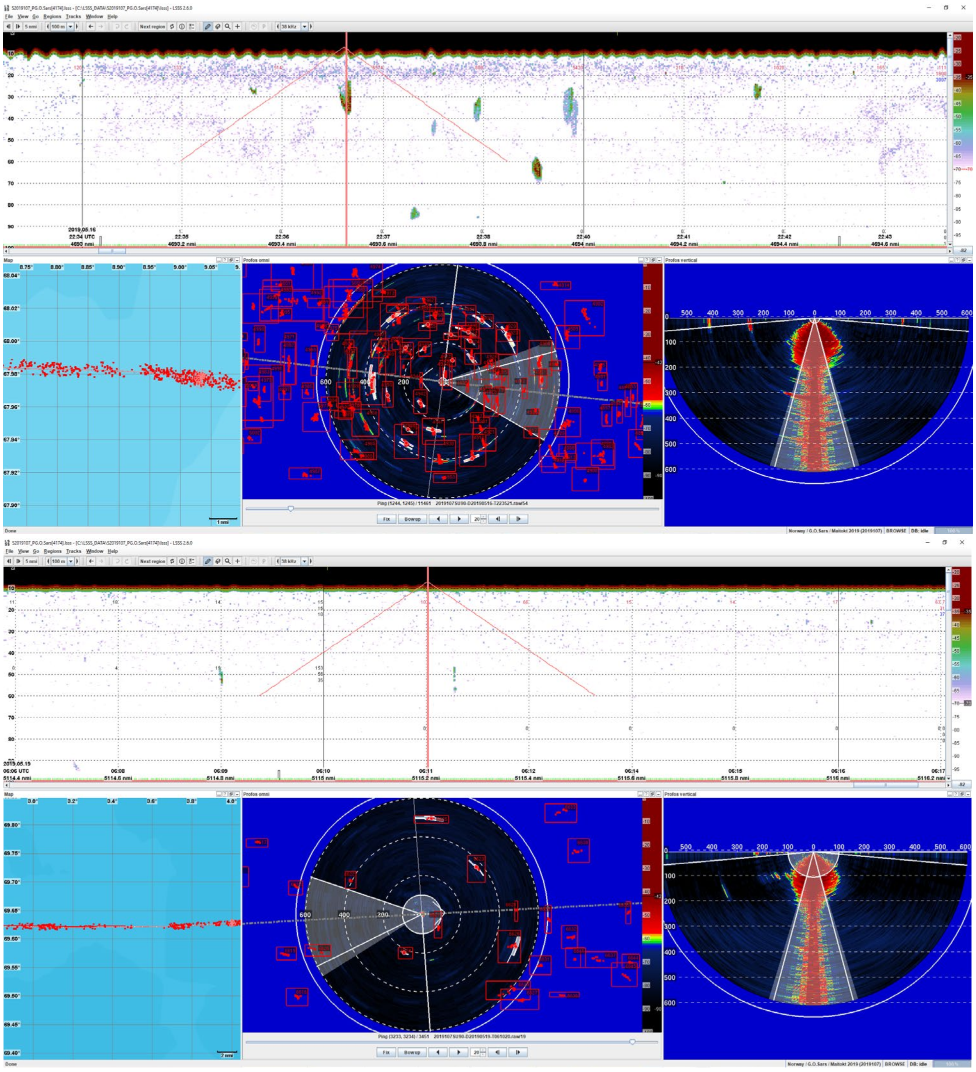

Figure 3. Image of Profos display showing typical herring aggregations in transect T10 (lower panel) and transect T8 (upper panel from echo sounder and fishery sonar near-horizontal and vertical beams.

The vertical distribution of herring in the three transects with the higher NASC values are shown for echosounder, fishery sonar and MS70 sonar in Figure 4. The vertical distribution from the echosounder shows a peak in all three transects, indicating a layer of herring between 20 and 40 meters. This peak is present in transect T8 for the two sonars as well, and to some degree in transects T10 and T11.

In transect T8 the levels of the vertical distributions are fairly similar, whereas the sonars are largely underestimating the NASC of the echosounder in transects T10 and T11. This could be related to rough weather conditions in those transects. As shown in Figure 5, the surface noise on the MS70 sonar propagates below 20 m depth in transect T10 (red layer in the lower panel, frame "MS70-Phantom"), intersecting with the large peak in the vertical distribution of the echosounder. In transect T8 the surface noise is negligible.

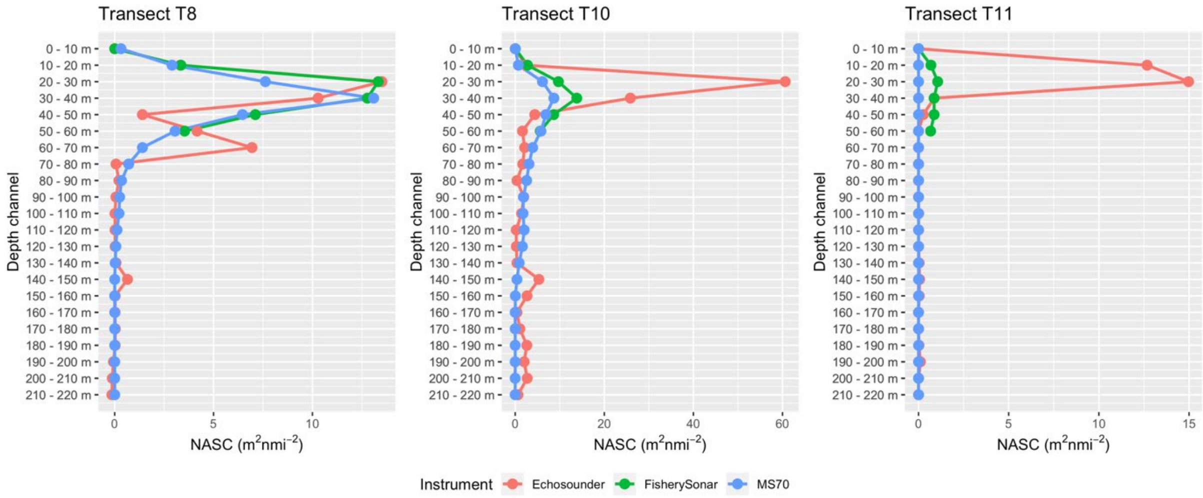

Figure 4. Vertical distribution of herring NASC values from echo sounder (red), fishery sonar (green) and MS70 sonar (blue) for transects 8 (left panel), 10 (middle panel), 11 (right panel).

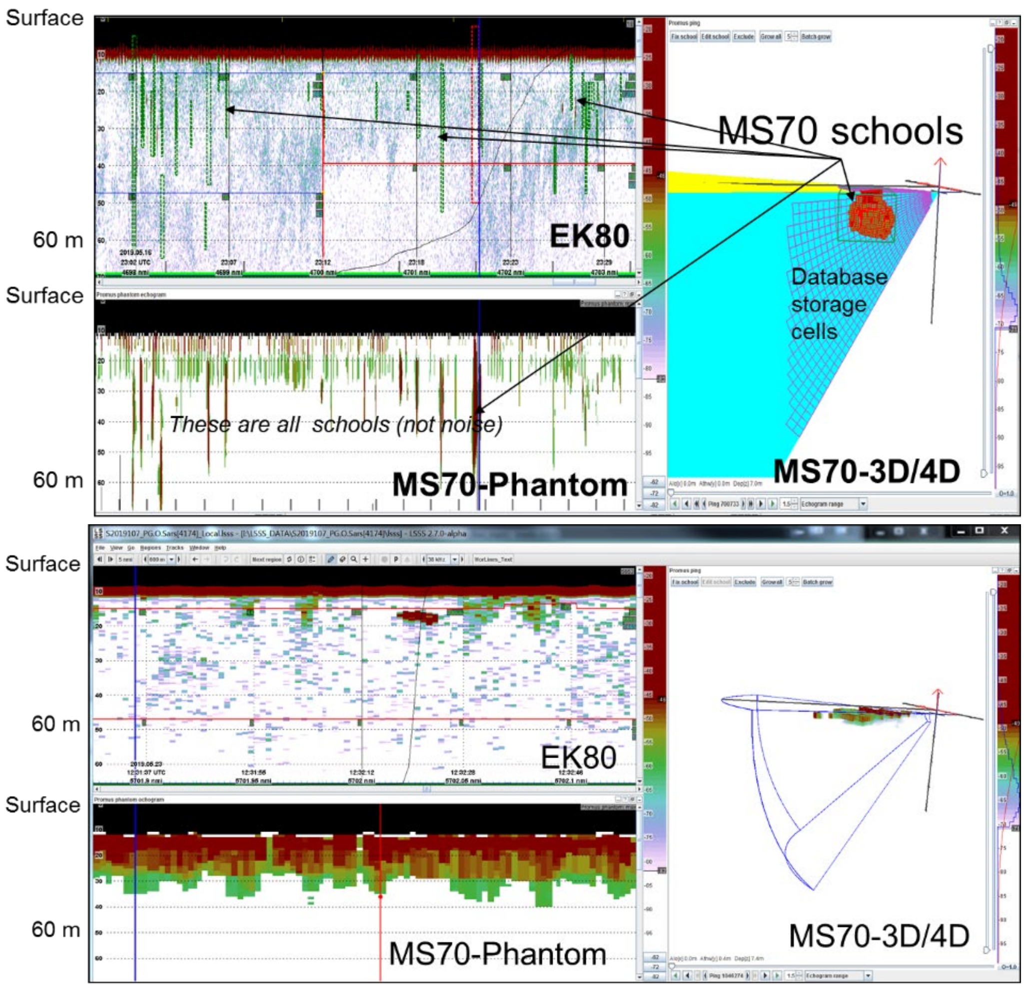

Figure 5. Screen dump from the Large Scale Survey System (LSSS), showing echosounder echogram (upper left frame), MS70 phantom echogram (lower left frame) and 3-D view of the MS70 sonar (right frame) of transect T8 (upper panel) and T10 (lower panel). In T8 there were some schools found in EK80, and many in MS70 (some "onto" the surface). In T10, the weather was bad, so the upper school detection depth was 20m. In T10, the weather was very bad, which explains very few detections of MS70.

Discussion

The vertical distribution from echosounder and the fishery sonar and MS70 sonar showed discrepancies in the level depending on the transects. For transect T8, where the weather was calm, all three instruments shows a peak of NASC between 20 and 40 m depth. In transects T10 and T11, where the weather was rougher, the sonars fail to return a peak at the same level as the echosounder. This discrepancy illustrates a fundamental issue with sonar data, which is related to the width of the sonar beams. When observing a near surface school, separation of school and surface noise can be challenging, which could result in exclusion of these schools from the vertical distribution. In the case of transect T10 and T11 the rough weather seems to result in a *sonar blind zone* that exceeds the echosounder blind zone.

The sonar data were scrutinized in terms of schools of a required size. The echosounder data can in contrast include all data down to single targets, as long as the data are categorized in acoustic categories representing species. If there are aggregations of individual fish and small schools at certain depths, this difference in post-processing can lead to bias in the vertical distribution from the sonars. This can in particular be a problem close to the surface, where small schools are more likely to be excluded from the sonar scrutinization than larger schools.

In transect T8 the vertical distribution from the echosounder shows a more rugged profile than those of the sonars. This could possibly reflect the potentially higher variance echosounder data when the number of schools encountered by the echosounder beam is relatively low.

The vertical distribution from the echosounder did not show any strong signs of avoidance to the vessel in this survey, with a peak in the vertical distribution starting at 10 m depth and reaching a maximum in the interval 20 to 30 m depth. As such, these data serve as a useful example to comparing vertical distribution from the different instruments, as the avoidance, which is generally unknown, will not affect the comparison. Given that the echosounder performs equally well or better than the sonars as indicator of biomass in the upper 30 meters, there is no strong cause for using sonar to assist the survey estimation. Note, however, that the school depths found by the sonars are estimated from the centre of the beam. Although this is a good estimate of depth for most beams, it also prevents registering schools at the shallowest depths. For MS70, the two uppermost beams were cut at some range, so that a school on the surface 150 m from the transducer would be registered at 20 m depth. Results from calmer weather during this survey showed that MS70 could in fact measure schools onto the surface. Thus, methods to visualize shallow schools need to be developed.

The methods presented in this study for estimating vertical distribution from sonars can be applied to other surveys where reactions to the research vessel may be stronger than in the IESNS survey from 2019 used in this study. In calm weather the sonars appear to compare well to the echosounder in terms of vertical distribution. In rough weather scrutinization of sonar can however be challenging, and further development should focus on improving separation of fish and noise in these conditions.

Working Document to

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Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 28th June – 5th August 2019

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1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from June 28th to August 5th in 2019 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 ICES mackerel benchmark. 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 mackerel index increased by 85% for biomass and 56 % for abundance (numbers of individuals) compared to the 2018 index. In 2019, the most abundant year classes were 2011, 2010, 2016, 2014 and 2013, respectively. Overall, the cohort internal consistency remained good and was similar to 2018.

The survey coverage area was 2.9 million km^2 which is similar as in 2017 and 2018. Furthermore, 0.3 million km^2 was surveyed in the North Sea. Distribution zero boundaries were found in majority of the survey area with a notable exception of high mackerel abundance at the survey boundary south-west of Faroe Island and in the northern Norwegian Sea. The mackerel were more north-easterly distributed in 2019, compared to the period from 2012 to 2018. This was specifically apparent in Greenland waters, where the catch was the lowest for the time series.

The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2019 was 15.2 billion and the total biomass index was 4.78 million tonnes, which is slightly higher compared to 2018. The herring stock is dominated by 6-year old herring (year class 2013) in terms of numbers and biomass. This year class is now distributed in all areas with herring in the survey compared to last year when it was mainly found in the north-eastern part. It contributes 23% and 22% to the total biomass and total abundance, respectively.

The total biomass of blue whiting registered during IESSNS 2019 was 2.0 million tons, which is the same compared to 2018. The stock estimate in number for 2019 is 16.2 billion compared to 16.3 billion of age groups 1+ in 2018. The age group five is dominating the estimate (36% and 30% of the biomass and by numbers, respectively). A good sign of recruiting year class (0-group) was also seen in the survey this year.

As in previous years, the spatio-temporal overlap between mackerel and NSSH was highest in the southern and south-western parts of the Norwegian Sea. There was practically no overlap between mackerel and NSSH in the central part of the Norwegian Sea, whereas we had some overlap between mackerel and herring in the northern part of the Norwegian Sea. Herring distribution was mostly limited to the area east and north of Iceland and the southern Norwegian Sea. However, NSSH was also found in the central northern part for the first time in many years, dominated by the 2013- and 2016- year classes.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 73% of surface trawl stations distributed across the surveyed area from Cape Farwell, Greenland, to western part of the Barents Sea. Abundance was greater north of latitude 66 °N compared to southern areas. A total of 58 North Atlantic salmon were caught, mainly in central and northern part of the Norwegian Sea. More salmon was caught in western regions compared to previous years.

Sea surface temperature (SST) was 1-2°C warmer in Icelandic and Greenland waters in July 2019 compared to the long-term average (20-year mean), but similar to the long-term average in eastern part of the

Norwegian Sea. This contrasts with the situation in 2018 when SST was 1-2°C colder than the average in Icelandic and Greenland waters. The SST in the entire Norwegian Sea in July 2019 was similar to July 2018.

The overall average zooplankton index in 2019 declined substantially compared to 2018. In 2019, the index decreased in both Greenland and Icelandic waters, whereas the index increased in the Norwegian Sea compared to 2018.

2 Introduction

During approximately five weeks of survey in 2019 (28th of June to 3rd of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Finnur Fridi" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland, the M/V "Eros" operating in Greenland waters and M/V "Ceton" operating in the North Sea by Danish scientists, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS).

The main aim of the coordinated IESSNS have been to collect data on abundance, distribution, migration and ecology of Northeast Atlantic mackerel (*Scomber scombrus*) during its summer feeding migration phase in Nordic Seas, used as tuning series in stock assessment of mackerel at the annual meeting of ICES working group of widely distributed stocks (WGWIDE). Since 2016, systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) have also been conducted. This objective was initiated to provide an additional abundance index for these two stocks because the current indices used in the stock assessments by ICES have shown some unexplained fluctuations (ICES 2016). It was considered that a relatively small increase in survey effort would accommodate a full acoustic coverage of the adult fraction (spawning stock biomass (SSB)) of both species during their summer feeding distribution in the Nordic Seas (Utne et al. 2012; Trenkel et al. 2014; Pampoulie et al. 2015). The pelagic trawl survey was initiated by Norway in the Norwegian Sea in the beginning of the 1990s. Faroe Islands and Iceland have participated in the joint mackerel-ecosystem survey since 2009, Greenland since 2013 and Denmark for the first time in 2018.

Opportunistic whale observations were conducted onboard the Norwegian vessels Kings Bay and Vendla, and the Icelandic R/V Arni Fridriksson, predominantly from the bridge. The major objectives were to collect data on distribution, aggregation and behaviour of marine mammals in relation to potential prey species and the physical environment.

Swept-area abundance indices of mackerel from IESSNS have been used for tuning in the analytical assessment by ICES WGWIDE, since the benchmark assessment in 2014 (ICES 2014). In the benchmark process in 2017 methodological and statistical changes were made to calculation of the index (ICES 2017).

The North Sea was included in the survey area again in 2019, 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 38 stations (CTD and fishing with the pelagic Multipelt 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 results).

3 Material and methods

Coordination of the IESSNS 2019 was done during WGWIDE 2018 meeting in August-September 2018 in Torshavn, Faroe Islands, and at the WGIPS meeting in January 2019 in Santa Cruz, Tenerife, Canary Islands, and by correspondence in spring and summer 2019. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calm with good survey conditions for all six vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. There were sporadic windy periods in Greenland waters. The weather was good and calm for the two Norwegian vessels and the Icelandic and Faroese vessels operating in the central and northern part of the Norwegian Sea and in Icelandic and Faroese waters The chartered vessel Ceton encountered some bad weather in the North Sea, without influencing the swept area trawling.

During the IESSNS, the special designed pelagic trawl, Multpelt 832, has now been applied by all participating vessels since 2012. This trawl is a product of cooperation between participating institutes in designing and constructing a standardized sampling trawl for the IESSNS. The work was lead by trawl gear scientist John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway (Valdemarsen et al. 2014). The design of the trawl was finalized during meetings of fishing gear experts and skippers at meetings in January and May 2011. Further discussions on modifications in standardization between the rigging and operation of Multpelt 832 was done during a trawl expert meeting in Copenhagen 17-18 August 2012, in parallel with the post-cruise meeting for the joint ecosystem survey, and then at the WKNAMMM workshop and tank experiments on a prototype (1:32) of the Multpelt 832 pelagic trawl, conducted as a sequence of trials in Hirtshals, Denmark from 26 to 28 February 2013 (ICES 2013a). The swept area methodology was also presented and discussed during the WGISDAA workshop in Dublin, Ireland in May 2013 (ICES 2013b). The standardization and quantification of catchability from the Multpelt 832 pelagic trawl was further discussed during the mackerel benchmark in Copenhagen in February 2014. Recommendations and requests coming out of the mackerel benchmark in February 2014, were considered and implemented during the IESSNS survey in July-August 2014 and in the surveys thereafter. Furthermore, recommendations and requests resulting from of 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 2019. 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	3/7-29/7	5500	69/61	61	60
Finnur Fríði	28/6- 12/7	3150	47/40	42	41
Eros	19/7-3/8	2881	27/27	27	27
Ceton	2/7-12/7	1870	38/38	38	-
Vendla	4/7-5/8	5933	91/66	71	71
Kings Bay	4/7-5/8	5639	88/77	76	76
Total	28/6-5/8	24873	360/309	315	275

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Árni Friðriksson was equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. Finnur Fríði was equipped with a mini SEABIRD SBE 25+ CTD sensor, Kings Bay and Vendla were both equipped with SAIV CTD sensors. Eros used a SEABIRD 19+V2 CTD sensor. Ceton used a Seabird SeaCat 4 CTD. The CTD-sensors were used for recording temperature, salinity and pressure (depth) from the surface down to 500 m, or to the bottom when at shallower depths.

Zooplankton was sampled with a WP2-net on 5 of 6 vessels, Ceton did not take any plankton samples. Mesh sizes were 180 µm (Kings Bay and Vendla) and 200 µm (Árni Friðriksson, Finnur Fríði and Eros). The net was hauled vertically from a depth of 200 m (or bottom depth at shallower stations) to the surface at a speed of 0.5 m/s. All samples were split in two, one half preserved for species identification and enumeration, and the other half dried and weighed. Detailed description of the zooplankton and CTD sampling is provided in the survey manual (ICES 2014a).

Not all planned CTD and plankton stations were taken due to bad weather. The number of stations taken by the different vessels is provided in Table 1.

3.2 Trawl sampling

All vessels used the standardized Multpelt 832 pelagic trawl (ICES 2013a; Valdemarsen et al. 2014; Nøttestad et al. 2016) for trawling, both for fixed surface stations and for trawling at greater depths to confirm acoustic registrations. Standardization of trawl deployment was emphasised during the survey as in previous years (ICES 2013a; ICES 2014b). Effective trawl width (actually door spread) and trawl depth was monitored live by scientific personnel and/or the captain and stored on various sensors on the trawl doors, headrope and ground rope of the Multpelt 832 trawl. The properties of the Multpelt 832 trawl and rigging on each vessel is reported in Table 2.

Trawl catch was sorted to the highest taxonomical level possible, usually to species for fish, and total weight per species recorded. The processing of trawl catch varied between nations as the Norwegian, Icelandic and Greenlandic vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting. Sub-sample size ranged from 60 kg (if it was clean catch of either herring or mackerel) to 100 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).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 28th June to 5th August 2019. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Kings Bay**	**Árni Friðriksson**	**Vendla**	**Ceton**	**Finnur Fríði**	**Eros**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynex	Dynema – 30 mm	Dynex-34 mm	+
Warp length during towing	350	350	350	350	350-360	340-347	0
Difference in warp length port/starb. (m)	2-10	16	2-10	10	0-10	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×400	2×500	0
Setback (m)	6	14	6	6	6	6	+
Type of trawl door	Seaflex 7.5 m^2 adjustable hatches	Jupiter	Seaflex 7.5 m^2 adjustable hatches	Thybron type 15	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	1970	2000	2000	+
Area trawl door (m^2)	7.5 with 25% hatches (effective 6.5)	6	7.5 with 25% hatches (effective 6.5)	7	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	4.8 (4.3-5.3)	4.9 (4.1-5.2)	4.5 (3.8-5.6)	4.8 (4.8-5.5)	4.5 (3.8-5.3)	4.9 (4.1-5.9)	+
Trawl height (m) mean (min-max)	28-40	35.3 (27.4-41.0)	28-37	32 (25-41)	42.7	-	+
Door distance (m) mean (min-max)	115-120	103 (91 - 116)	118-126	119 (114-128)	102.8	118 (113-121)	+
Trawl width (m)*	66.8	60.4	67.3	67.4	58.5	66.5	+
Turn radius (degrees)	5-10	5	5-12	5-10	5-10 BB turn	6-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	5-15, 7-18	4-21, 4-17	6-22, 8-23	4-28	3-12, 4-19	(11.4-11)	+
Headline depth (m)	0-1	0	0-1	0	0	0-1	+
Float arrangements on the headline	Kite with fender buoy +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite with fender buoy +2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite + 1 buoy on each wingtips	Kite + 1 buoy on each wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	All weighed	All weighted	+

* calculated from door distance

Table 3. Protocol of biological sampling during the IESSNS 2019. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Greenland	Iceland	Norway	Denmark
Length measurements	Mackerel	100	100/50*	150	100	≥ 75 (as appropriate)
	Herring	100	100/50*	200	100	
	Blue whiting	100	100/50*	100	100	
	Lumpfish	10	All	all	all	all
	Salmon	all	All	all	all	-
	Other fish sp.	100	25/25	50	25	As appropriate
Weight, sex and maturity determination	Mackerel	25	25	50	25	***
	Herring	25	25	50	25	0
	Blue whiting	50	25	50	25	0
	Lumpfish	10		1^	25	0
	Salmon	1		0	25	0
	Other fish sp.	0	0	0	0	0
Otoliths/scales collected	Mackerel	25	25	25	25	***
	Herring	25	25	50	25	0
	Blue whiting	50	25	50	25	0
	Lumpfish	0	0	1	0	0
	Salmon	1	0	0	0	0
	Other fish sp.	0	0	0	0	0
Fat content	Mackerel Herring Blue whiting	0 0 0	50 0 50	10** 10** 10	0 0 0	0 0 0
Stomach sampling	Mackerel	5	20	10**	10	***
	Herring	5	20	10**	10	0
	Blue whiting	5	20	10	10	0
	Other fish sp.	1	0	0	10	0
Tissue for genotyping	Mackerel	0	0	0	0	0
	Herring	0	0	0	0	0

*Length measurements / weighed individuals
**Sampled at every third station
*** One fish per cm-group from each station was weighed, aged, stomachs were sampled from each second station.
^All live lumpfish were tagged and released, only otoliths taken from fish which were dead when brought aboard

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 and 5 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and possible escapement from the cod end and through meshes. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. No light source was employed with cameras; hence, recordings were limited to day light hours. Some recordings were also taken during nighttime when there was midnight sun and good underwater visibility. Video recordings were collected at 65 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 4th July and 6th August 2019 onboard M/V "Kings Bay" and M/V "Vendla", respectively. Opportunistic marine mammal observations were also done on R/V Árni Friðriksson from the bridge between 3rd and 29th July 2019 by crew members and by one student between 3rd July and 15th July.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson" and M/V "Eros" 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 estimate the latitude and longitude of the release location.

3.5 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 3rd July 2019 for 18, 38 and 200 kHz. Árni Friðriksson was calibrated in May 2019 for the frequencies 18, 38, 120 and 200 kHz. Finnur Fríði was calibrated on 27th June 2019 for 38 kHz. Calibration of the acoustic equipment onboard Eros was done after the cruise on the 5th of August. All frequencies were calibrated successfully. Ceton did not conduct any acoustic data collection because no calibrated equipment was available. All the other vessels used standard hydro-acoustic calibration procedure for each operating frequency (Foote 1987). CTD measurements were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

Acoustic recordings were scrutinized to herring and blue whiting on daily basis using the post-processing software (LSSS or Echoview, 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 2019.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Finnur Fríði	M/V Ceton *	Eros
Echo sounder	Simrad EK80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad ES 80	Simrad EK80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 120, 200	18, 38, 70, 120, 200	38,120, 200	38	18, 38, 70, 120, 200
Primary transducer	ES38B	ES38B	ES38B	ES38B		ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull		Hull
Transducer depth (m)	9	8	9	8		8
Upper integration limit (m)	15	15	15	Not used		15
Absorption coeff. (dB/km)	9.6	10.0	9.1	9.8		9.3
Pulse length (ms)	1.024	1.024	1.024	1.024		1.024
Band width (kHz)	2.43	2.43	2.43	2.43		2.43
Transmitter power (W)	2000	2000	2000	2000		2000
Angle sensitivity (dB)	21.90	21.9	21.90	21.9		21.9
2-way beam angle (dB)	-20.7	-20.81	-20.6	-20.3		-20.7
TS Transducer gain (dB)	24.33	24.36	24.56	26.67		25.63
s_A correction (dB)	-0.58	-0.58	-0.69	-0.58		-0.6
alongship:	7.01	7.28	7.03	7.16		6.86
athw. ship:	7.00	7.23	7.09	7.22		7.05
Maximum range (m)	500	500	500	500		750 for 18 and 38 kHz 500 for 70, 120 and 200 kHz
Post processing software	LSSS v.2.5.1	LSSS v.2.3.0	LSSS v.2.5.1	Sonardata Echoview 10.x		LSSS v.2.5.1

* No acoustic data collection

Multibeam sonar

M/V Kings Bay was 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. M/V Vendla was equipped with the Simrad fisheries sonar SX93 (frequency range: 20-30 kHz). Acoustic multibeam sonar data was stored continuously onboard Kings Bay and Vendla for the entire survey.

Cruise tracks

The six participating vessels followed predetermined survey lines with predetermined surface trawl stations (Figure 1). Calculations of the mackerel index are based on swept area approach with the survey area split into 13 strata, permanent and dynamic strata (Figure 2). Distance between predetermined surface trawl stations is constant within stratum but variable between strata and ranged from 35-90 nmi. The survey design using different strata is done to allow the calculation of abundance indices with uncertainty estimates, both overall and from each stratum in the software program StoX (see Salthaug et al. 2017). Temporal survey progression by vessel along the cruise tracks in July-August 2019 is shown in Figure 3. The cruising speed was between 10-12 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

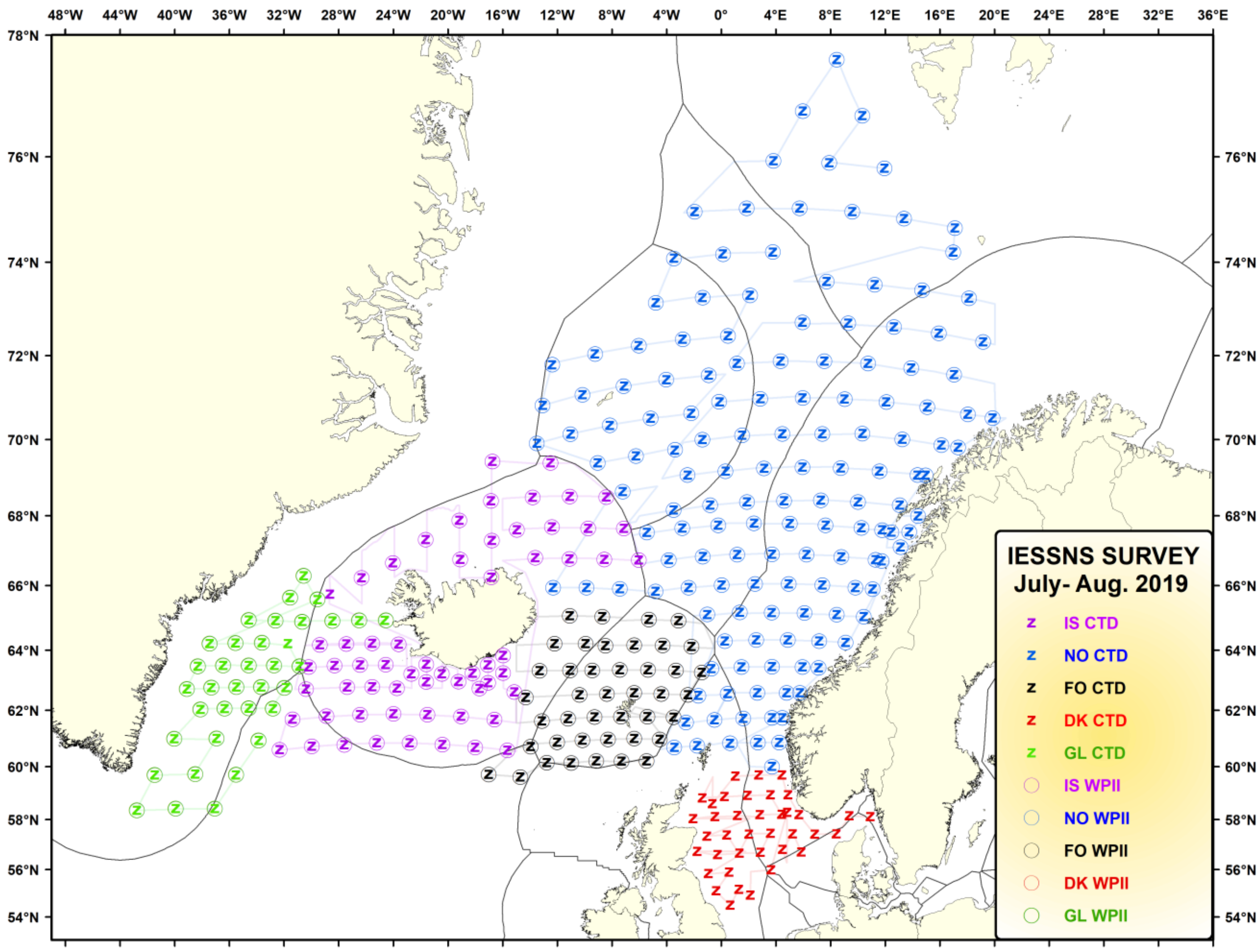


Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 28th June – 5th August 2019. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Finnur Fríði (black), Kings Bay and Vendla (blue), Eros (green) and Ceton (red).

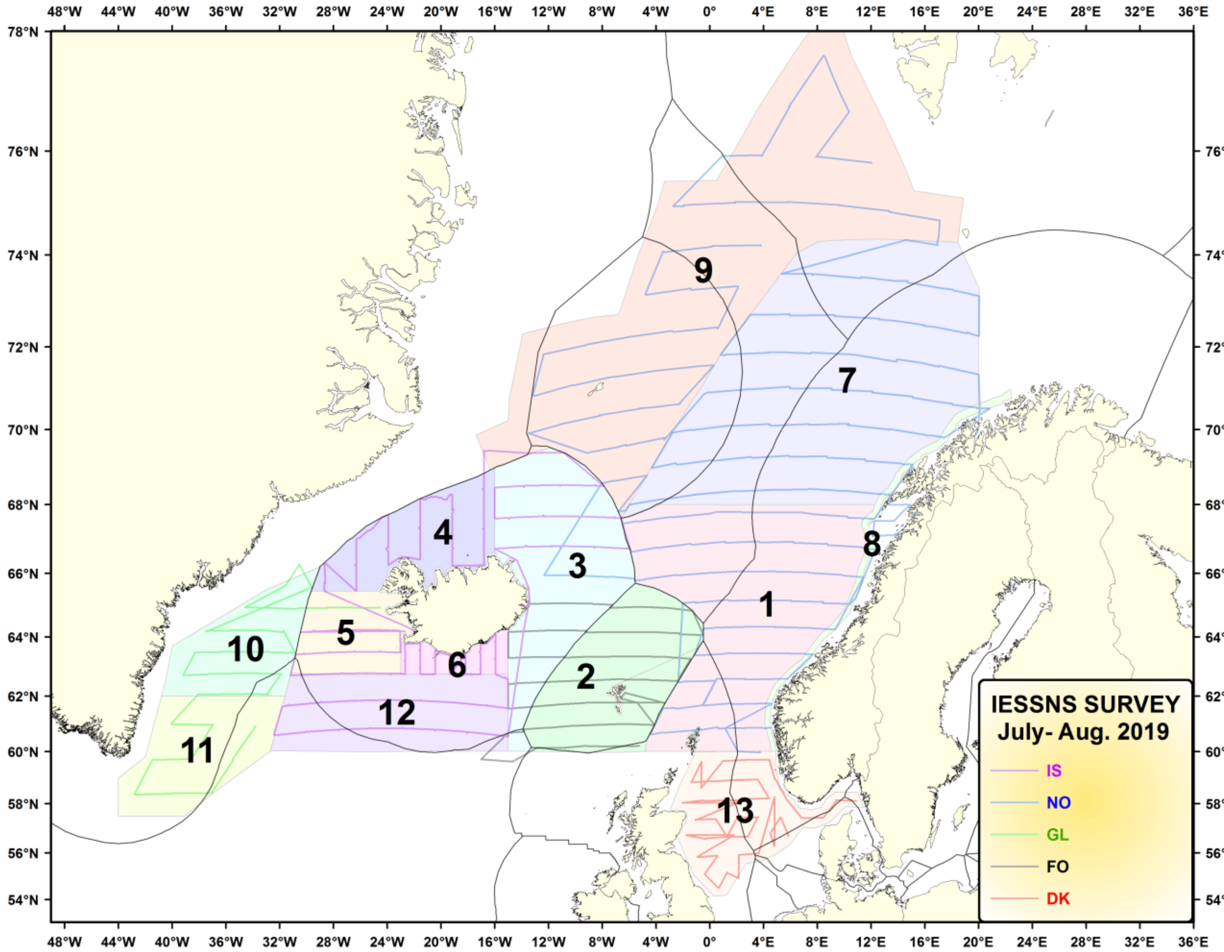


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2019. The dynamic strata are: 4, 9 and 11.

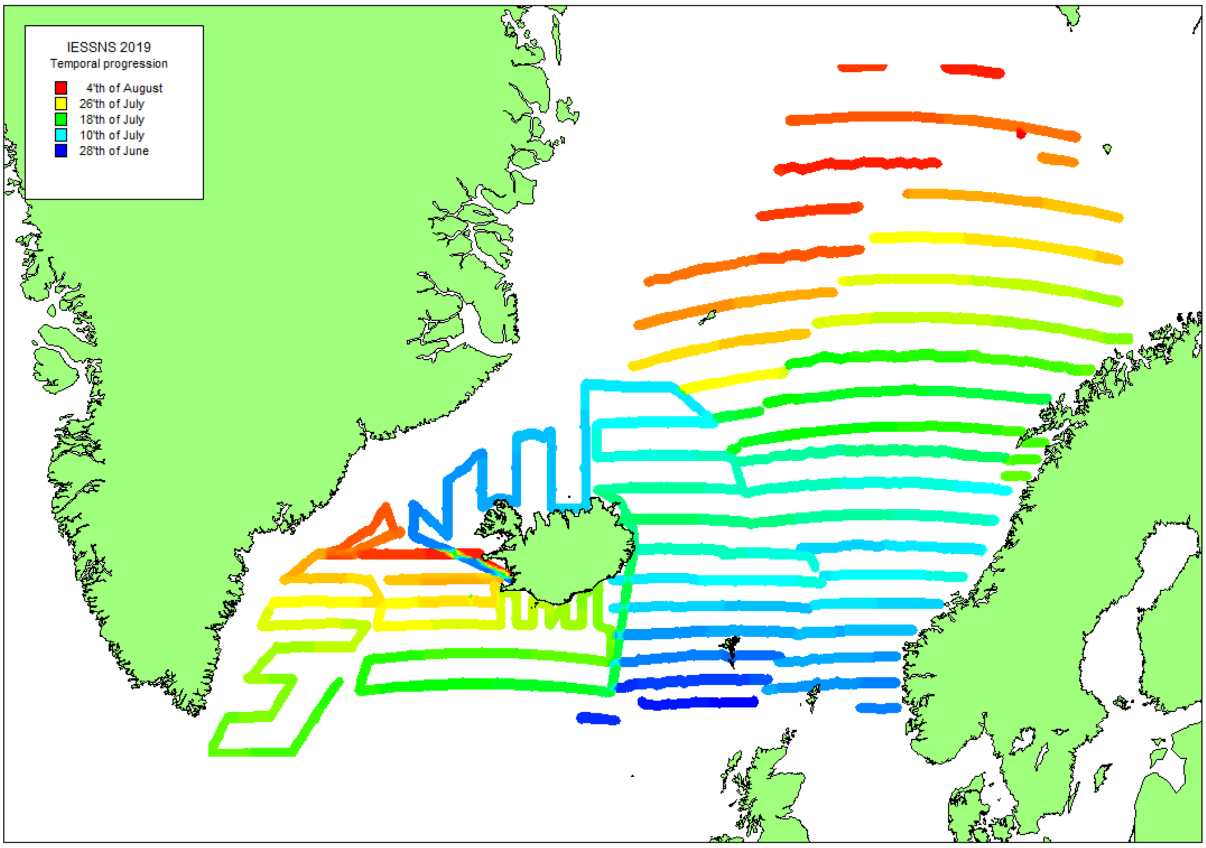


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2019: blue represents effective survey start (28th of June) progressing to red representing the effective end of the survey (4th of August). Ceton is not included in the survey progression map for the North Sea, due to no acoustic recordings.

3.6 StoX

StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The software, with examples and documentation, can be found at: http://www.imr.no/forskning/prosjekter/stox/nb-no. The program is a stand-alone application built with Java for easy sharing and further development in cooperation with other institutes. The underlying high-resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high-resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990) is implemented. Mackerel, herring and blue whiting indices were calculated using the StoX software package (version 2.7).

3.7 Swept area index and biomass estimation

The swept area age segregated index is calculated separately for each stratum (see stratum definition in Figure 2). Individual stratum estimates are added together to get the total estimate for the whole survey area which is approximately defined by the area between 57°N and 78°N and 44°W and 20°E in 2019.

Average density (Mac_D; kg km^{-2}) is calculated for each trawl haul with the following formula;

Mac_D = h * d * c

where h (km) is the horizontal opening of the trawl, d is distance trawled (km) and c is the total mackerel catch (kg). 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).

Table 5. Descriptive statistics for trawl door spread, vertical trawl opening and tow speed for each vessel. 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).

	Finnur Fríði	RV Árni Friðriksson	Kings Bay	Vendla	Eros	Ceton
Trawl doors horizontal spread (m)						
Number of stations	39	60	68	57	27	38
Mean	102.8	103	119	126	119	119
max	111	116	120	130	127	128
min	97	91	115	117	113	114
st. dev.	3.3	6.7	1.5	4.2	3.1	4.9
Vertical trawl opening (m)						
Number of stations	40	61	68	57	27	38
Mean	42.7	35.3	37.8	34.2	34.7	32
max	47	41.0	40	36	39.0	41
min	35	27.4	30	28	31.5	25
st. dev.	2.5	2.5	3.6	2.6	2.0	4.5
Horizontal trawl opening (m)						
mean	58.5	60.4	66.8	67.3	66.5	67.4
Speed (over ground, nmi)						
Number of stations	42	61	68	57	27	38
mean	4.45	4.9	4.6	4.2	4.9	4.8
max	5.3	5.2	5.3	5.6	5.9	5.5
min	3.8	4.1	4.3	3.8	4.1	4.1
st. dev.	0.41	0.2	0.41	0.7	0.3	0.3

Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (Table 6). The estimates in the formulae were based on flume tank simulations in 2013 (Hirtshals, Denmark) where formulas were developed from the horizontal trawl opening as a function of door spread, for two towing speeds, 4.5 and 5 knots:

Towing speed 4.5 knots: Horizontal opening (m) = 0.441 * Door spread (m) + 13.094

Towing speed 5.0 knots: Horizontal opening (m) = 0.3959 * Door spread (m) + 20.094

Table 6. Horizontal trawl opening as a function of trawl door spread and towing speed. Relationship based on simulations of horizontal opening of the Multpelt 832 trawl towed at 4.5 and 5 knots, representing the speed range in the 2014 survey, for various door spread. See text for details. In 2017, the towing speed range was extended from 5.0 to 5.2.

	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

4 Results and discussion

4.1 Hydrography

Satellite measurements of sea surface temperature (SST) in the eastern part of the Norwegian Sea in July 2019 was similar to the average for July 1990-2009 based on SST anomaly plot (Figure 4). Surface temperature in the western part of the Norwegian Sea in July 2019 was slightly higher (1°C) compared to the average (Figure 4). The SST situation in the entire Norwegian Sea in July 2019 is very similar to July 2018. In Icelandic and Greenland waters, on the other hand, the SST was 1-2°C warmer than the average in July 2019 (Figure 4). This contrasts with the situation in 2018 when SST was 1-2°C colder than the average in Icelandic and Greenland waters. Sea Surface Temperature in July 2019 was most like the situation in July 2010 and partly in July 2012, whereas quite different than most other years for the time series from 2010 to 2019.

It must be mentioned that the NOAA SST are sensitive to the weather condition (i.e. wind and cloudiness) prior to and during the observations and do therefore not necessarily reflect the oceanographic condition of the water masses in the areas, as seen when comparing detailed *in situ* features of SSTs between years (Figures 5-8). However, since the anomaly is based on the average for the whole month of July, it should give representative results of the surface temperature.

The upper layer (< 20 m depth) was 1.0-2.0°C warmer in 2019 compared to 2018 in most of Icelandic and Greenland waters (Figure 5). The temperature in the upper layer was higher than 8°C in most of the surveyed area, except along the north-western fringes of the surveyed areas north of Iceland, west of Jan Mayen and Svalbard where it was lower. In the deeper layers (50 m and deeper; Figure 6-8), the hydrographical features in the area were similar to the last four years (2014-2018). At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

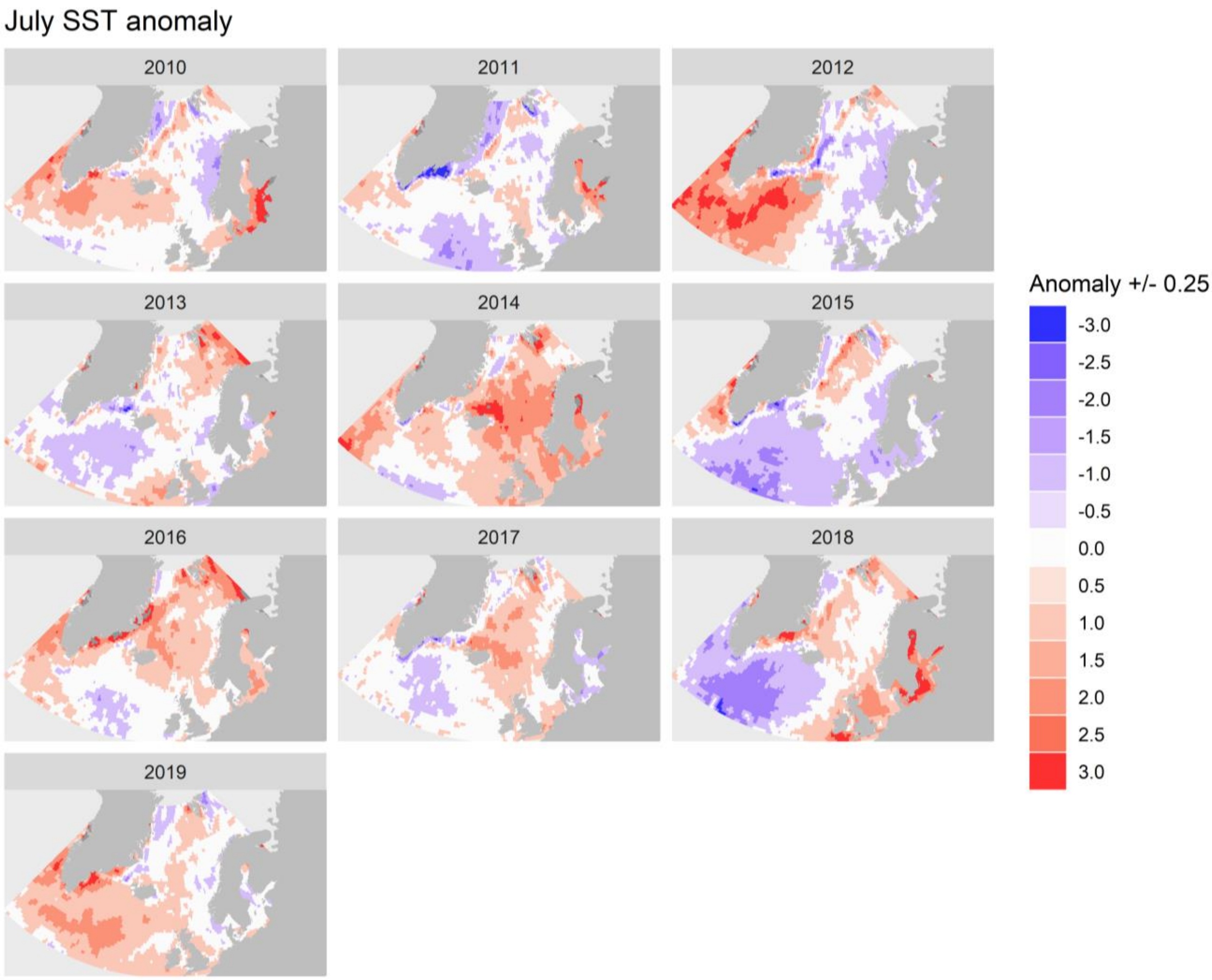


Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2019 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

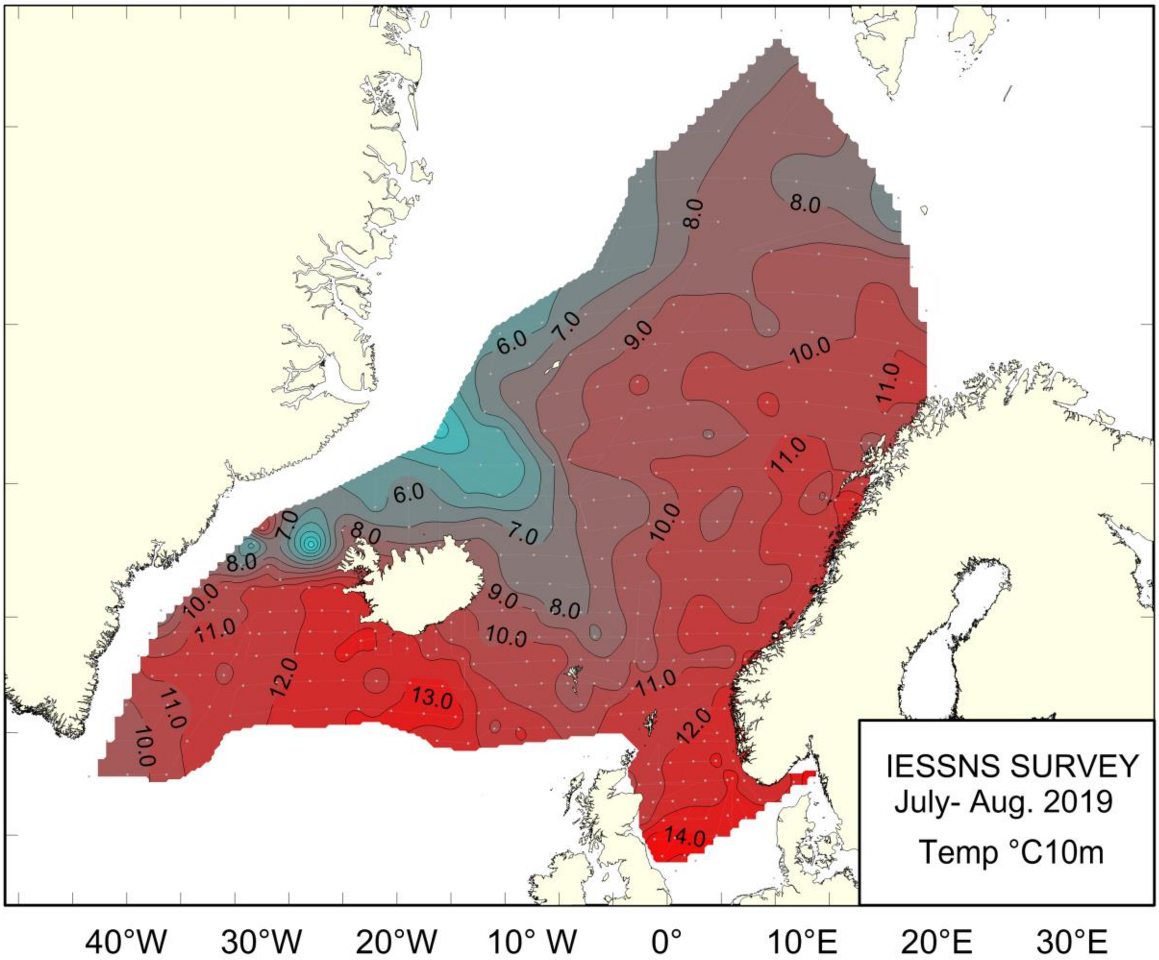


Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2019.

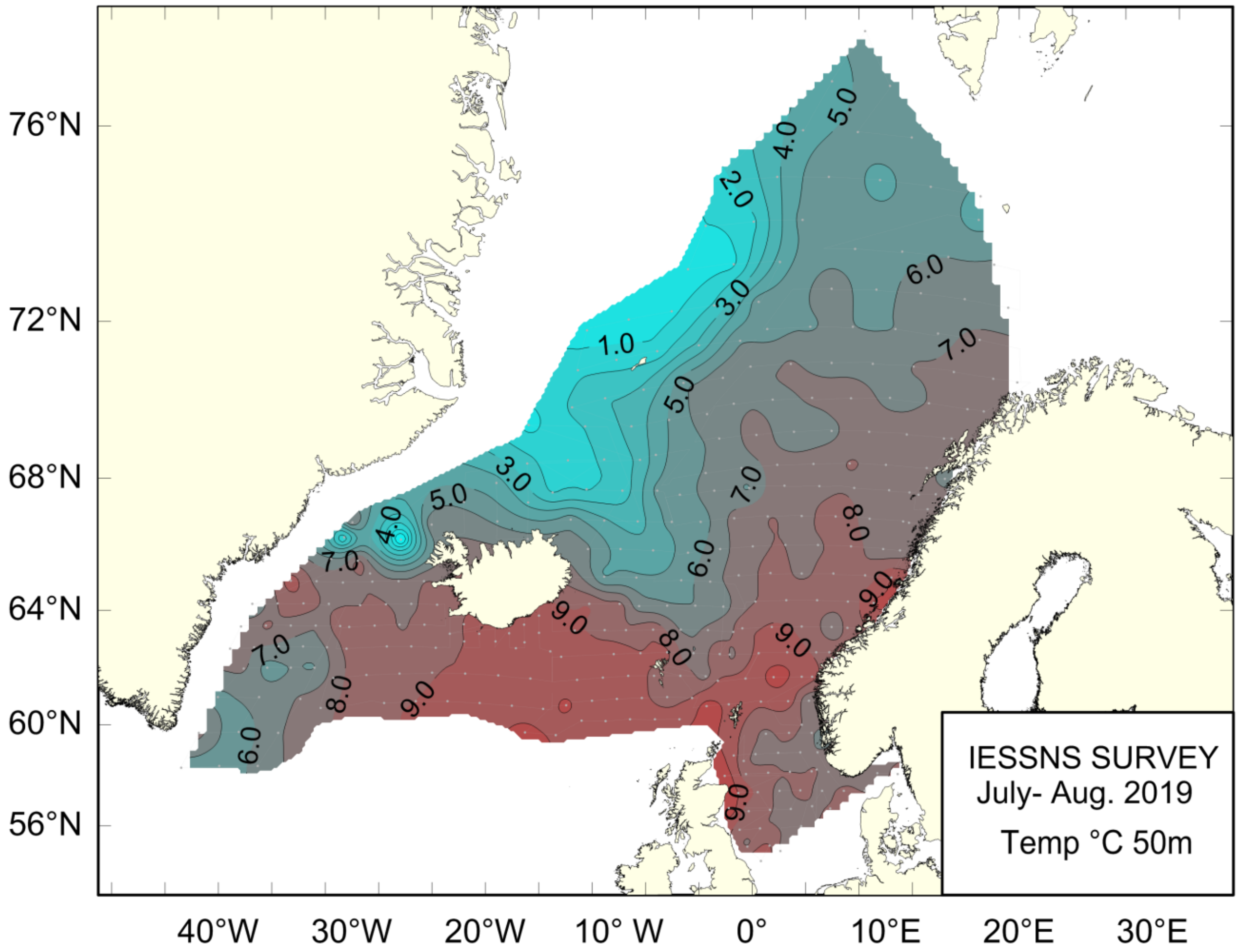


Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2019.

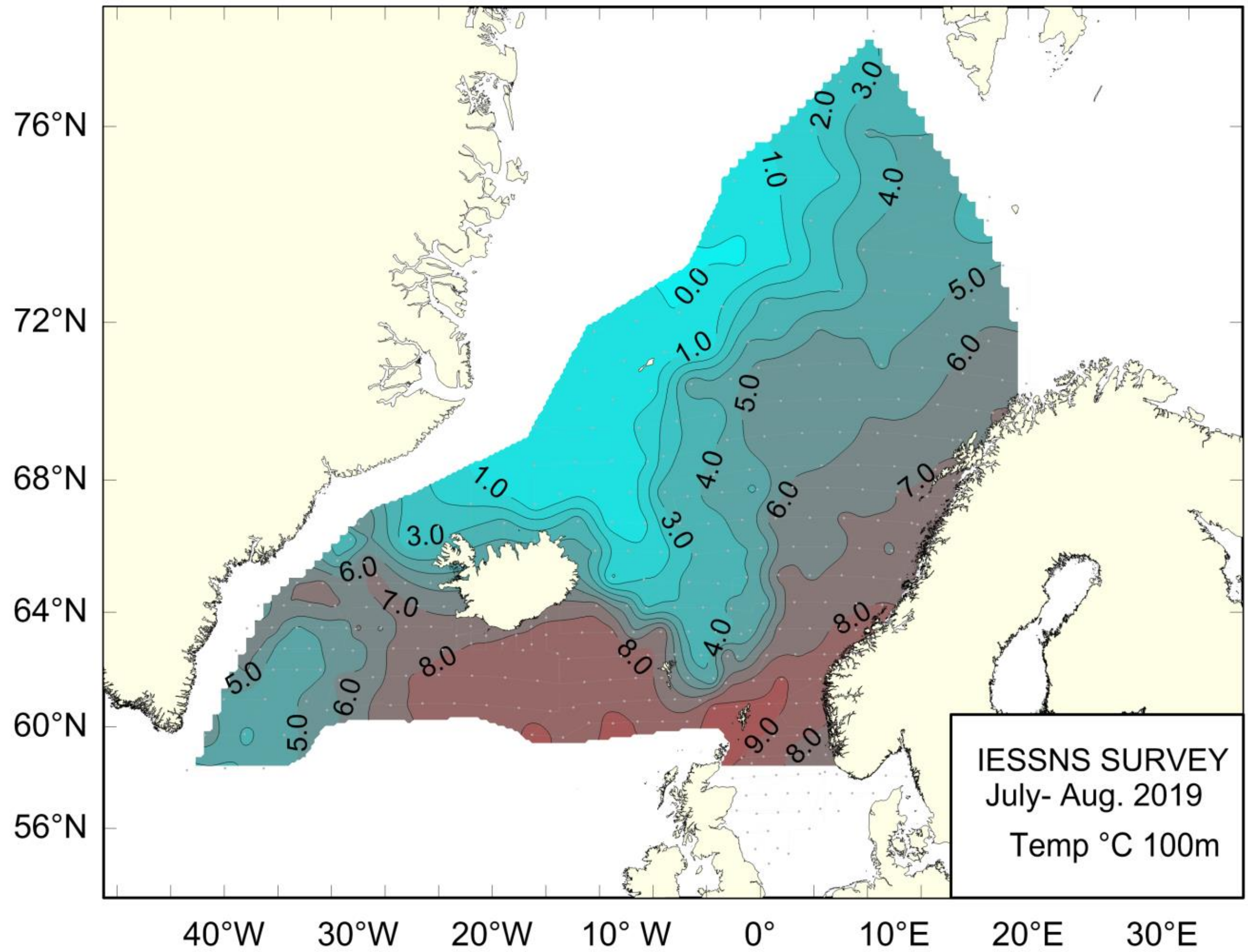


Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2019.

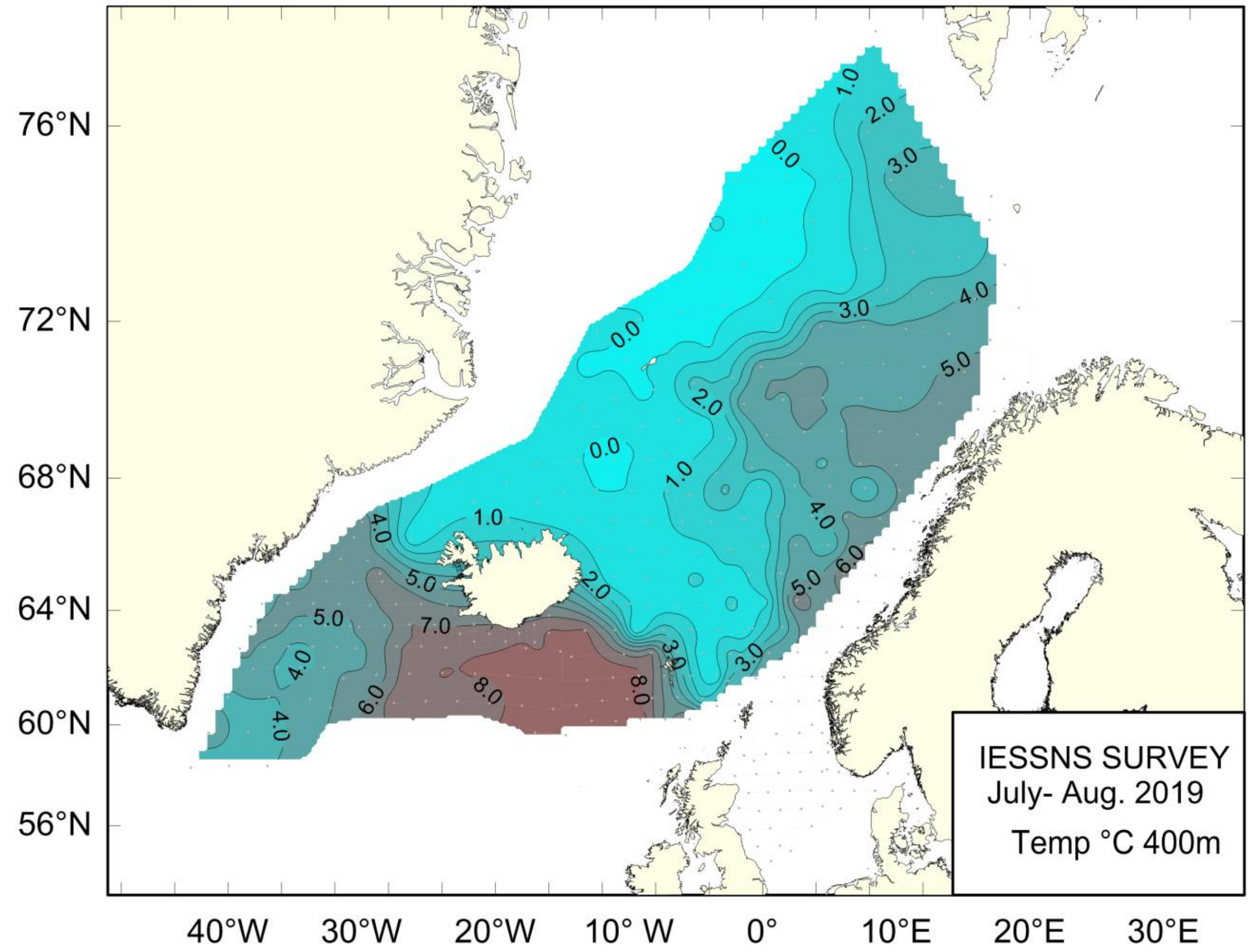
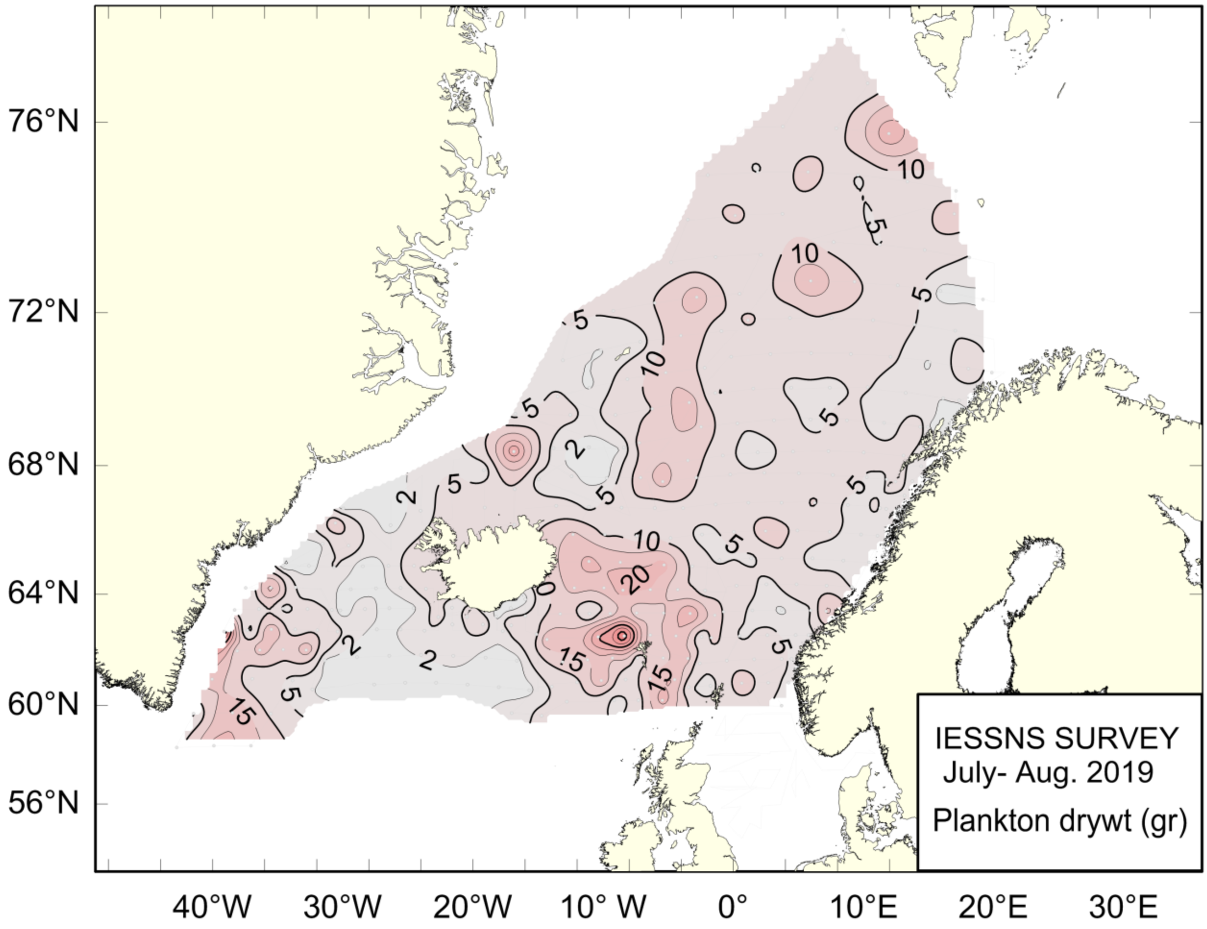


Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2019.

4.2 Zooplankton

Average zooplankton index for the survey area declined quite substantially from 2019 compared to both 2017 and 2018. Zooplankton biomass varied between areas and was highest in Greenland waters (Figure 9a). In 2019, the average had decreased in Greenland (10.1 g m^{-2}; n=27) and Icelandic waters (7.0 g m^{-2}; n=60), while it had increased in the Norwegian Sea (8.7 g m^{-2}; n=173) compared to 2018. There was a sharp decline by more than 30% of zooplankton in Greenland waters (eastward of longitude 30 °W) compared to both 2017 and 2018. There was also a decline in Icelandic waters from 2018 to 2019. This relatively short time-series show much more pronounced fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea. Zooplankton in Iceland and Greenland waters are highly variable from year to year and statistically correlated (r=0.83). These plankton indices, however, needs to be treated with some care due as it is only a snapshot of the standing stock biomass, not of the actual production in the area, which complicates spatio-temporal comparisons.


76°N
72°N
68°N
64°N
60°N
56°N
40°W
30°W
20°W
10° W
0°
10°E
20°E
30°E
IESSNS SURVEY
July- Aug. 2019
Plankton drywt (gr)

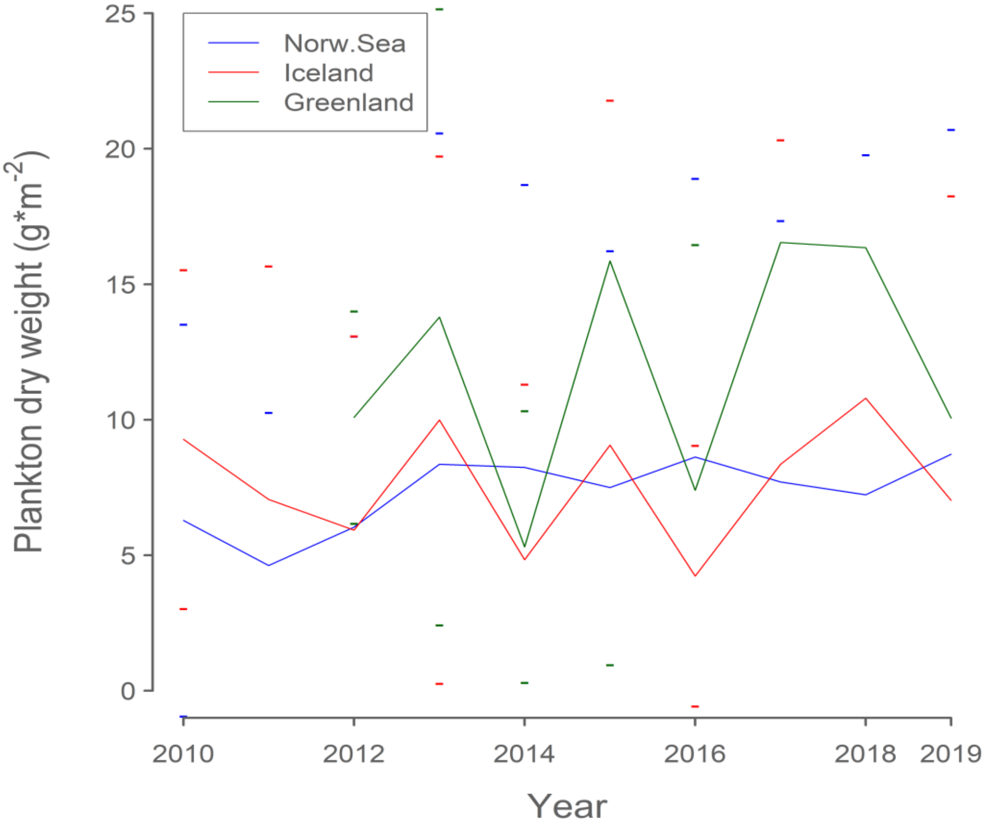


Figure 9. Zooplankton biomass indices (g dw/m², 0-200 m) (a) in Nordic Seas in July-August 2019 and (b) time-series of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W).

4.3 Mackerel

The mackerel biomass index i.e. catch rates by trawl station (kg/km²) measured at predetermined surface trawl stations is presented in Figure 10 together with the mean catch rates per 1*2° rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 52 tonnes/km² (mean = 3.9). High density areas were found in the northern Norwegian Sea, south-east of Iceland, between Iceland and the Faroe Island, as well as south west of the Faroe Islands. The mackerel were more north-easterly distributed in 2019, compared to the years between 2012 and 2018 (Figure 11 & 12). This was apparent in Greenland waters, where the catch was the lowest in the time series.

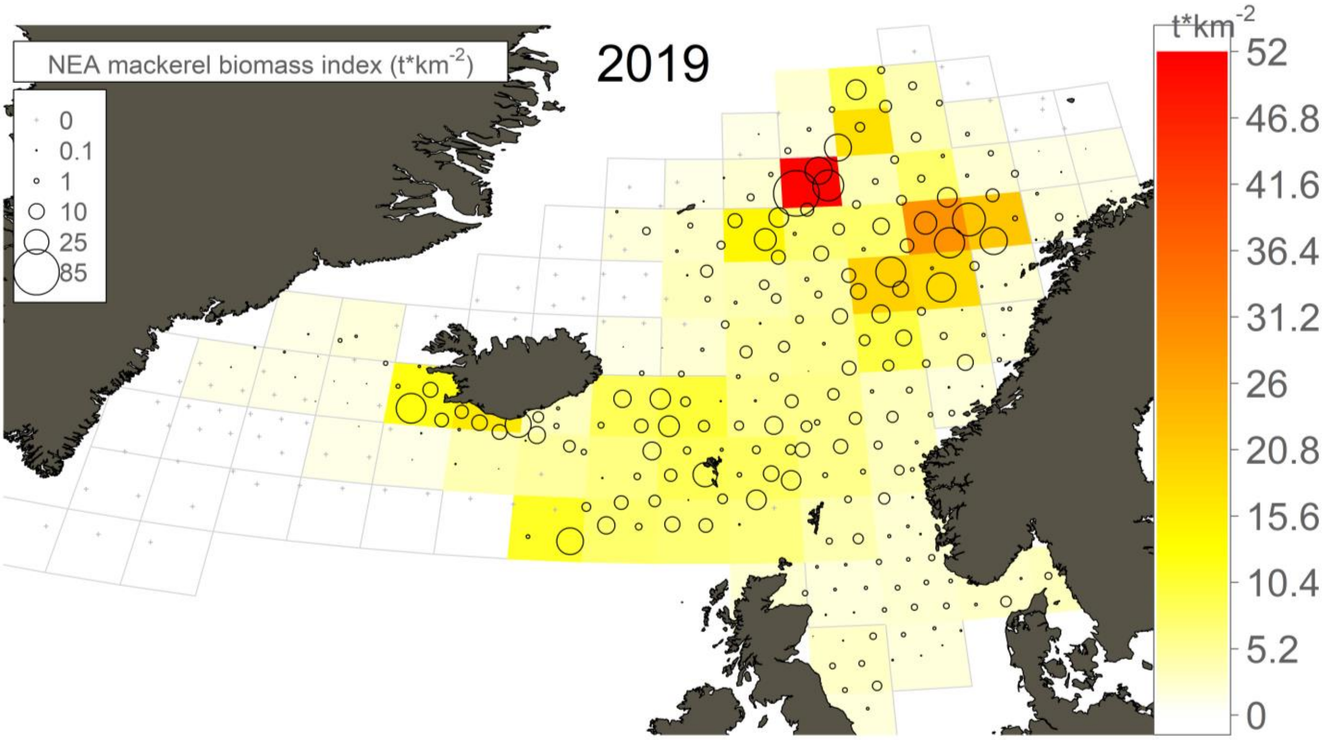


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

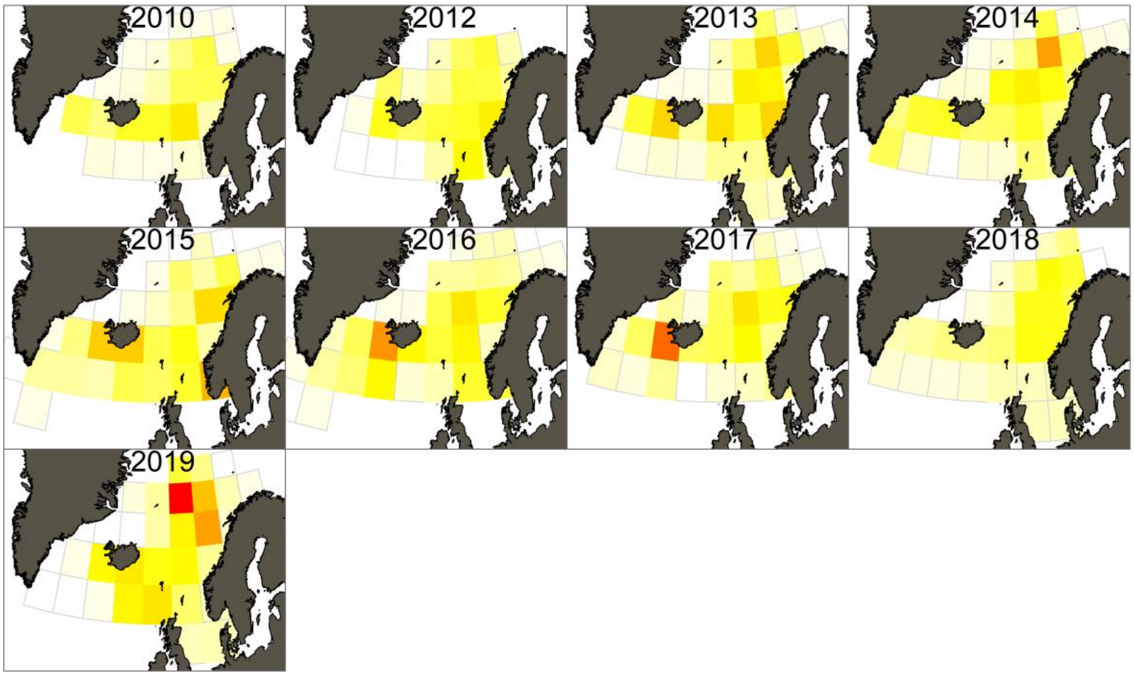


Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (4° lat. x 8° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Color scale goes from white (= 0) to red (= maximum value for the highest year).

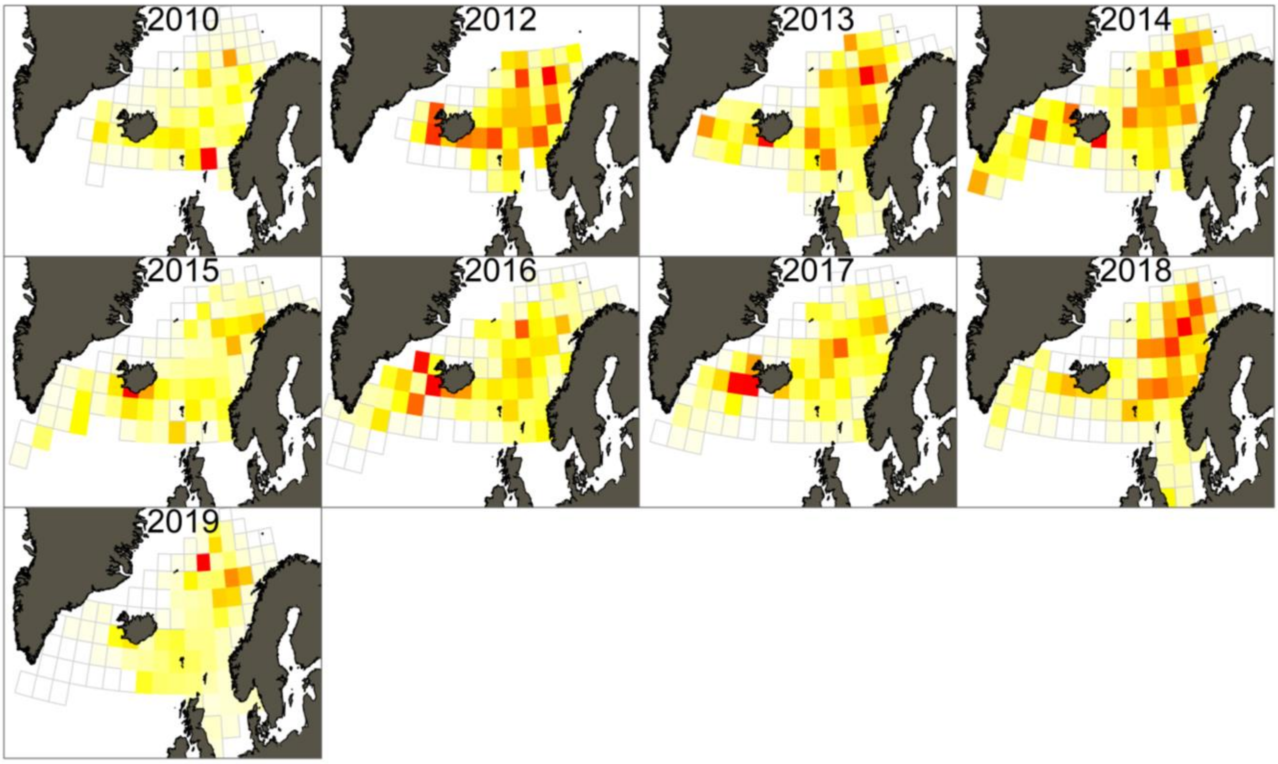


Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Color scale goes from white (= 0) to red (= maximum value for the given year).

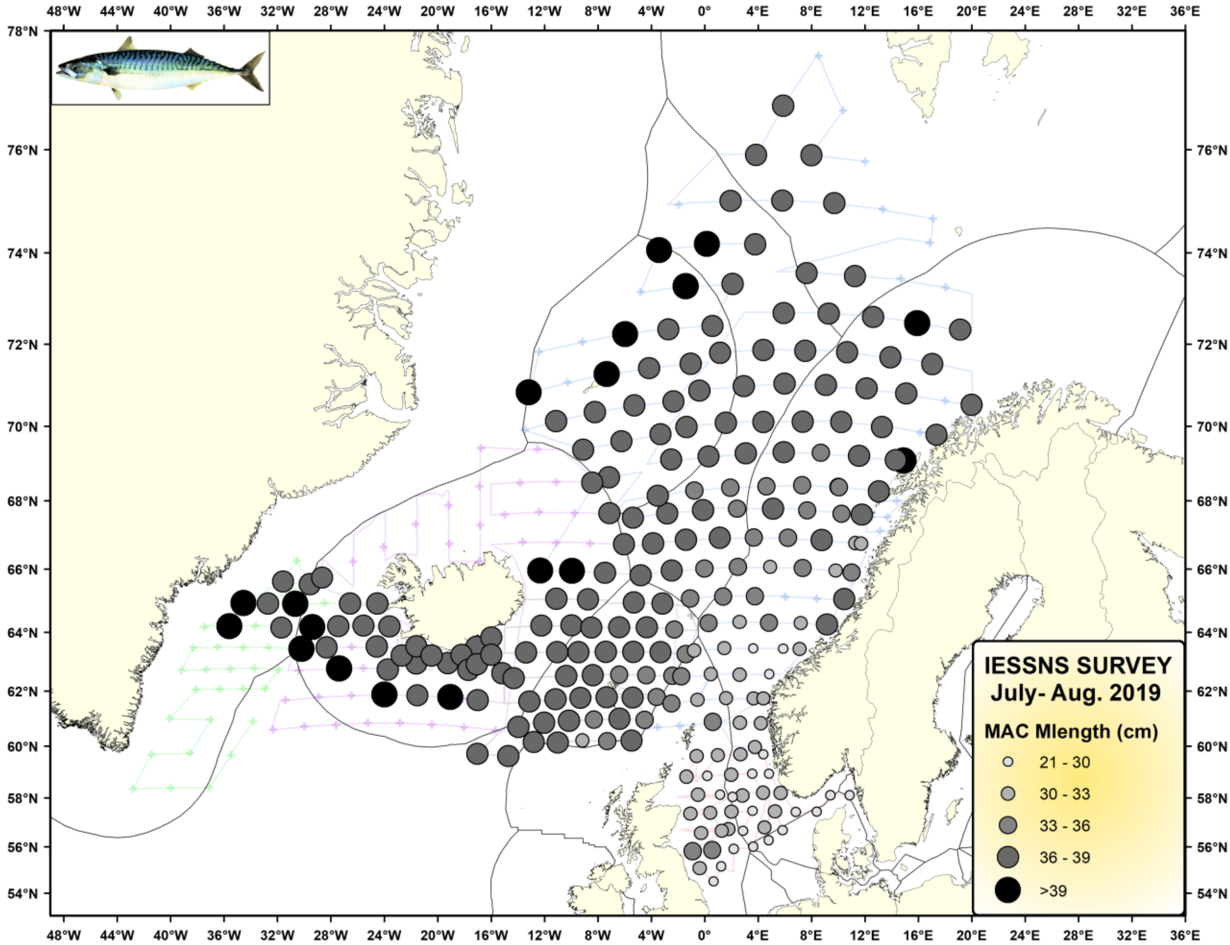


Figure 13. Average length of mackerel at predetermined surface trawl stations during IESSNS 2019.

Mackerel caught in the pelagic trawl hauls onboard the six vessels varied from 25.2 to 41.0 cm in length, with an average of 35.0 cm. Individuals in length range 30–37 cm dominated in numbers and biomass. The mackerel weight (g) varied between 192 to 641 g with an average of 422 g. Mackerel length distribution followed the same pattern as previous years in the Norwegian Sea, with increasing size towards the distribution boundaries in the north and the north-west. In the west (Iceland-Greenland waters), the largest mackerel were again found towards south and west, however, with the restricted western distribution this does appear slightly different (Figure 13). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon (*Salmo salar*), lumpfish) in 2019 according to the catches are shown in Figure 14.

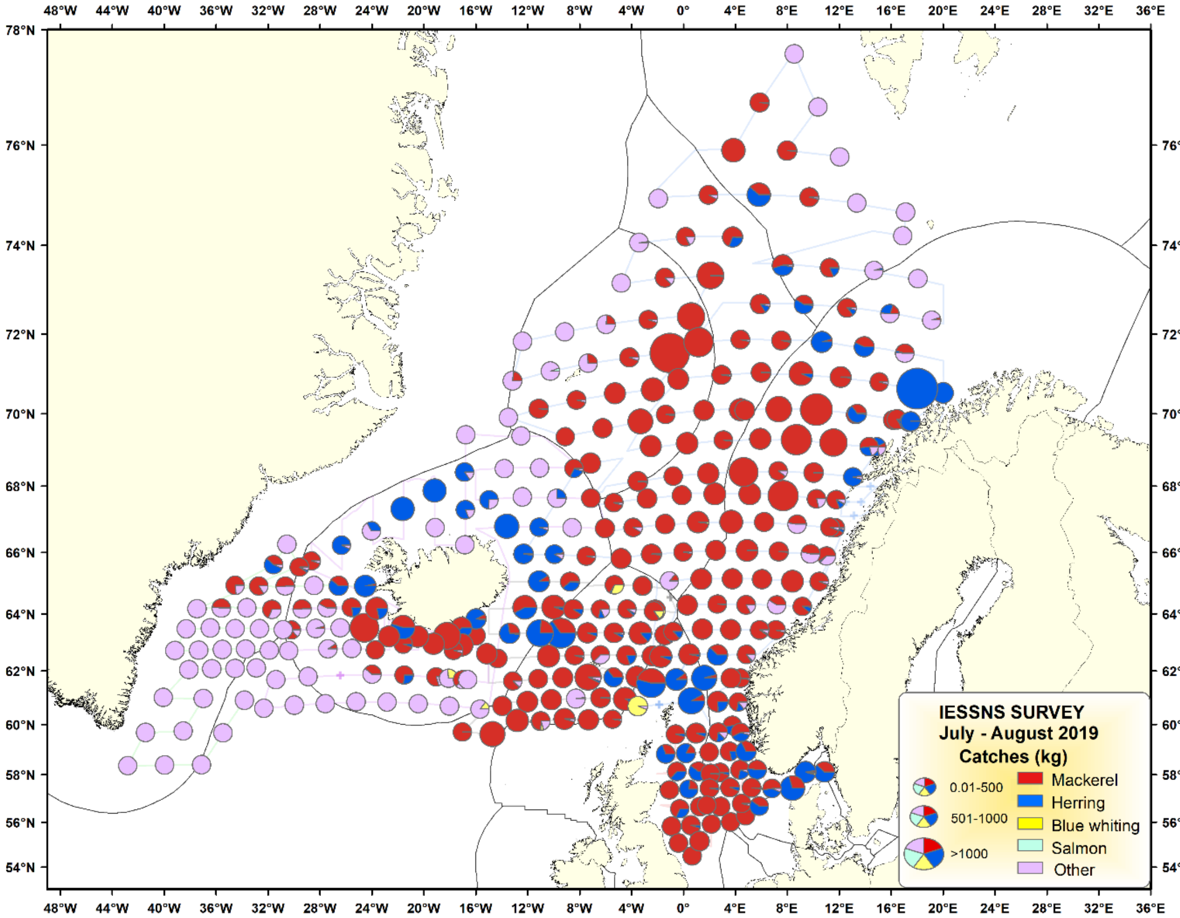


Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, lumpfish (other)) in 2019 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2019 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX. Mackerel biomass index and abundance index was the highest in the time series that started in 2010 (Table 7, Figure 15). Comparing the 2019 estimate to the 2018 estimate shows a 56 % increase in abundance and 85 % increase in biomass. The survey coverage area (excl. the North Sea, 0.3 million km^2) was 2.9 million km^2 in 2019, which is similar to 2018 and 2017. The most abundant year classes were 2011, 2010, 2016, 2014 and 2013 (Figure 16). Mackerel of age 2 and to some extent also age 3 are not completely recruited to the survey (Figure 18, bottom). Therefore, the results suggest that the incoming 2016- and 2017- year classes are large. Variance in age index estimation is provided in Figure 17.

The internal consistency plot for age-disaggregated year classes is similar to last year (Figure 18, top). There is a strong internal consistency for ages 1 to 5 years ($0.83 < r < 0.93$), it is poor ($0.13 < r < 0.31$) between age 5 and 6 as well as 7 and 8, and it is a fair/good internal consistency for ages 5 to 11 years ($0.58 < r < 0.81$).

Mackerel index calculations from the catch in the North Sea (stratum 13 in Figure 2) were excluded from the index calculations presented in the current chapter to facilitate comparison to previous years and because the 2017 mackerel benchmark stipulated that trawl stations south of latitude 60 °N be excluded from index calculations (ICES 2017). Results from the mackerel index calculations for the North Sea are presented in Appendix 1.

The indices used for NEA mackerel stock assessment in WGIWIDE are the number-at-age indices for age 3 to 11 year (Table 7).

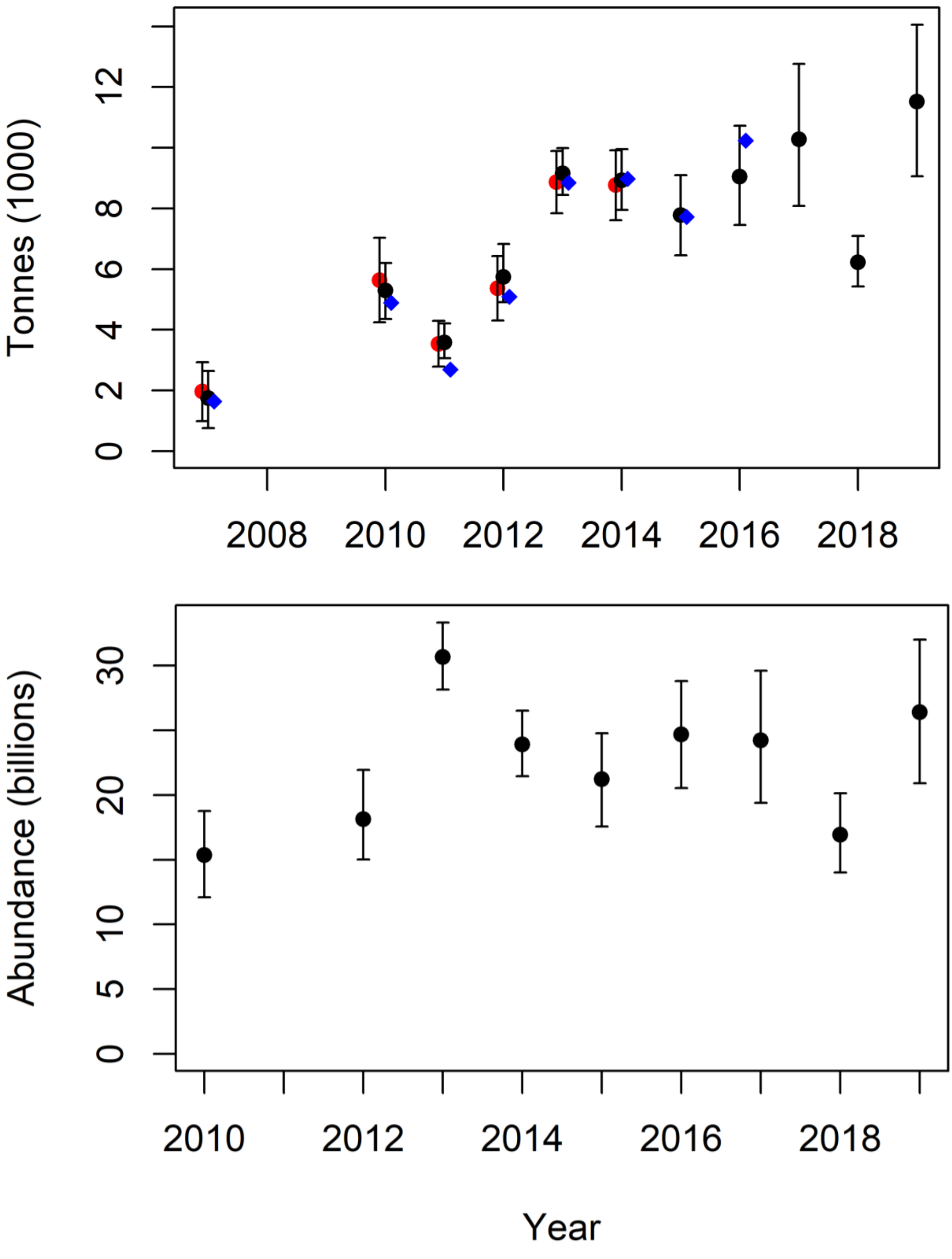


Figure 15. Estimated total stock biomass (TSB) of mackerel from StoX (black dots), Nøttestad et al. (2016) (red dots) and IESSNS cruise reports (blue diamonds) (top) and estimated total stock numbers (TSN) of mackerel from StoX (black dots) (bottom), The error bars represent approximate 90 % confidence intervals.

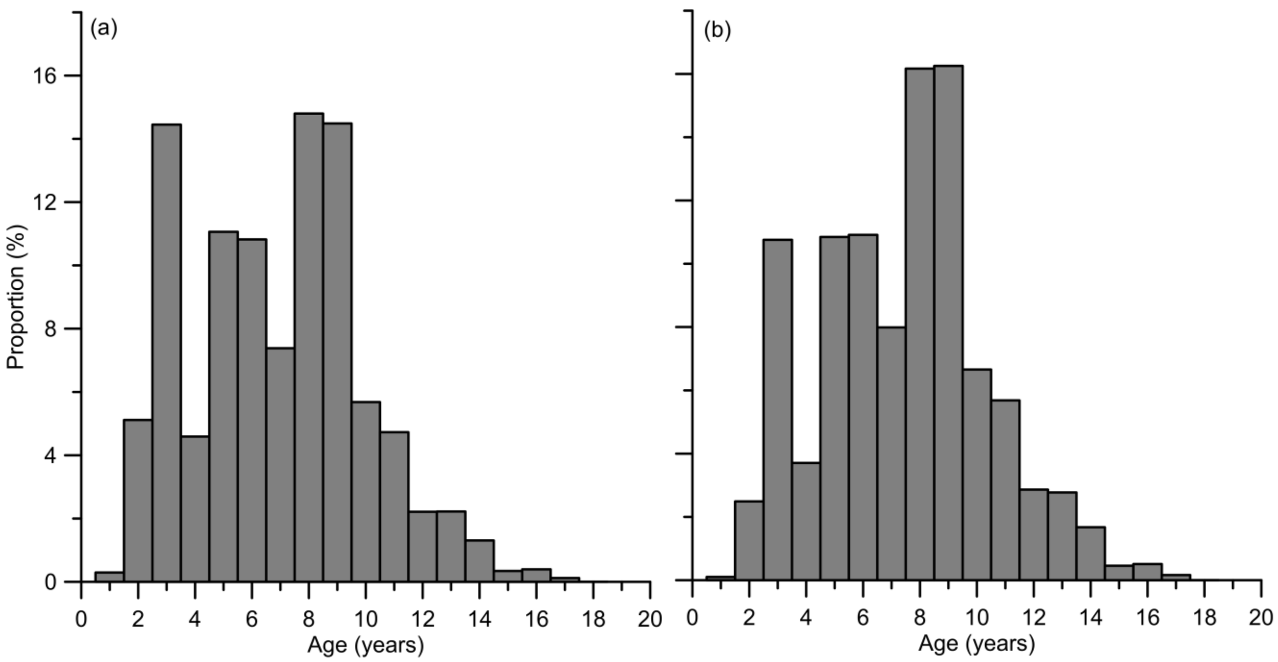


Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2019.

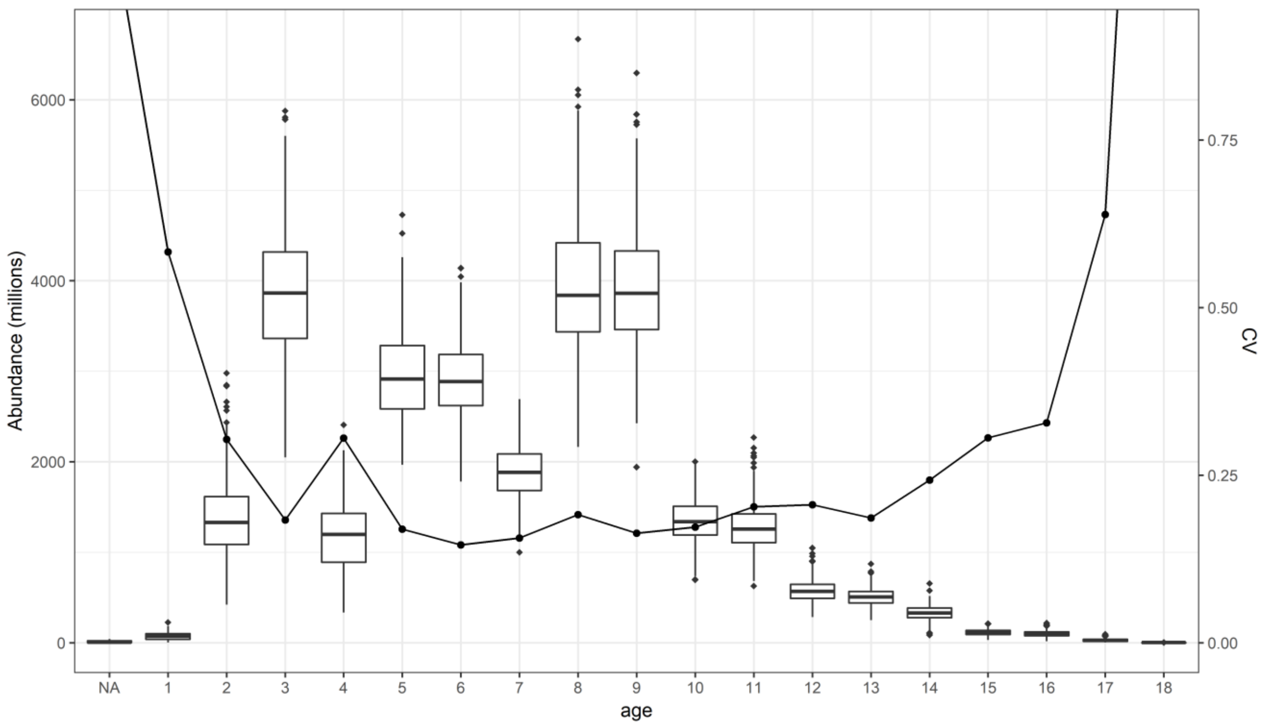


Figure 17. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-c) Time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (g) per age and (c) estimated biomass at age (million tonnes) from 2007 to 2019. d) Output from StoX

a)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot N
2007	1.33	1.86	0.90	0.24	1.00	0.16	0.06	0.04	0.03	0.01	0.01	0.00	0.01	0.00	5.65
2010	0.03	2.80	1.52	4.02	3.06	1.35	0.53	0.39	0.20	0.05	0.03	0.02	0.01	0.01	13.99
2011	0.21	0.26	0.87	1.11	1.64	1.22	0.57	0.28	0.12	0.07	0.06	0.02	0.01	0.00	6.42
2012	0.50	4.99	1.22	2.11	1.82	2.42	1.64	0.65	0.34	0.12	0.07	0.02	0.01	0.01	15.91
2013	0.06	7.78	8.99	2.14	2.91	2.87	2.68	1.27	0.45	0.19	0.16	0.04	0.01	0.02	29.57
2014	0.01	0.58	7.80	5.14	2.61	2.62	2.67	1.69	0.74	0.36	0.09	0.05	0.02	0.00	24.37
2015	1.20	0.83	2.41	5.77	4.56	1.94	1.83	1.04	0.62	0.32	0.08	0.07	0.04	0.02	20.72
2016	<0.01	4.98	1.37	2.64	5.24	4.37	1.89	1.66	1.11	0.75	0.45	0.20	0.07	0.07	24.81
2017	0.86	0.12	3.56	1.95	3.32	4.68	4.65	1.75	1.94	0.63	0.51	0.12	0.08	0.04	24.22
2018	2.18	2.50	0.50	2.38	1.20	1.41	2.33	1.79	1.05	0.50	0.56	0.29	0.14	0.09	16.92
2019	0.08	1.35	3.81	1.21	2.92	2.86	1.95	3.91	3.82	1.50	1.25	0.58	0.59	0.57	26.4

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

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

Table 7d) Estimates of abundance, mean weight and mean length of mackerel based on calculation in StoX for IESSNS 2019.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	45.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1335	60.6	45.42
19-20	55.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2296	126.9	55.27
20-21	60.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3428	206.7	60.31
21-22	-	69.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	575	39.9	69.27
22-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	91.0	74	6.8	91.00
23-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.6	555	55.9	100.58
24-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	114.9	1142	131.2	114.88
25-26	145.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22012	3208.5	145.76
26-27	156.9	161.6	155.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65967	10477.9	158.84
27-28	159.0	175.1	189.7	175.1	165.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290352	50983.2	175.59
28-29	201.5	194.7	195.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	374768	73101.1	195.06
29-30	-	217.2	214.2	226.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	393319	85397.0	217.12
30-31	-	241.4	247.9	249.7	251.3	266.0	-	-	255.9	-	-	-	-	-	-	-	-	-	-	609333	149809.7	245.86
31-32	-	266.6	274.8	291.6	292.5	-	-	285.3	278.6	-	-	-	-	-	-	-	-	-	-	967693	269885.1	278.90
32-33	-	313.0	306.2	325.5	290.7	290.4	314.5	-	-	-	-	-	-	-	-	-	-	-	-	1237341	382196.0	308.89
33-34	-	312.3	339.2	338.0	327.4	327.7	-	-	-	-	-	-	-	-	-	-	-	-	-	1066369	359974.7	337.57
34-35	-	320.0	375.4	379.4	366.9	359.1	-	424.3	390.9	-	-	-	-	-	-	-	-	-	-	1291109	483425.5	374.43
35-36	-	412.0	418.3	411.0	409.7	406.6	400.6	423.9	423.5	387.3	359.7	-	379.6	-	-	-	-	-	-	2777412	1143483.2	411.71
36-37	-	-	362.2	443.3	444.7	437.7	443.2	445.5	452.2	455.2	456.9	429.4	428.0	-	-	-	-	-	-	4638338	2061271.9	444.40
37-38	-	-	487.1	475.7	474.0	480.4	468.7	477.2	475.9	474.9	480.0	468.6	455.4	460.0	492.1	442.5	-	-	-	5599575	2664028.8	475.76
38-39	-	-	508.8	504.0	516.9	506.6	520.3	499.1	512.1	516.5	509.4	528.2	511.3	527.3	494.4	487.8	-	-	-	3751183	1915605.3	510.67
39-40	-	-	528.0	588.5	551.4	589.5	547.5	545.4	554.4	543.9	534.8	552.5	520.8	540.0	561.8	535.5	546.0	-	-	2050873	1115916.2	544.12
40-41	-	-	-	584.0	533.7	641.9	567.3	607.9	576.9	576.4	586.5	599.8	554.4	586.3	579.3	572.7	591.7	-	-	847185	490784.8	579.31
41-42	-	-	650.0	-	-	745.9	686.6	542.0	605.4	630.8	619.6	612.1	639.3	625.1	604.9	682.9	-	-	-	335134	209209.4	624.26
42-43	-	-	-	-	756.1	-	655.1	-	659.7	665.2	697.5	710.4	657.9	699.5	685.8	663.3	-	-	-	67784	45665.2	673.69
43-44	-	-	-	-	-	802.0	772.0	-	-	-	725.6	663.1	699.5	713.3	708.0	-	-	606.4	-	6667	4717.5	707.59
44-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	707.7	471	333.4	707.66
45-46	-	-	-	-	-	-	-	-	-	-	-	-	688.0	-	833.3	-	-	-	-	860	648.1	753.97
TSN(1000)	77213	1350193	3814661	1211770	2920591	2856932	1948653	3906891	3824410	1499778	1248160	584066	586585	344601	90489	104106	31589	219	2243	26403151	-	-
TSB(1000 kg)	11778.9	286752.2	1239274.6	426846.0	1249678.7	1257274.0	920393.4	1862667.6	1872447.6	767051.0	654542.4	329619.0	319405.9	192633.1	52432.8	58693.2	18600.1	132.9	527.3	-	11520750.7	-
Mean length (cm)	25.83	28.89	32.69	33.35	35.76	36.17	37.02	37.18	37.45	38.11	38.56	39.34	39.43	39.31	40.06	39.66	39.94	43.08	28.22	-	-	-
Mean weight (g)	152.55	212.38	324.87	352.25	427.89	440.08	472.32	476.76	489.60	511.44	524.41	564.35	544.52	559.00	579.44	563.79	588.81	606.42	235.06	-	-	436.34

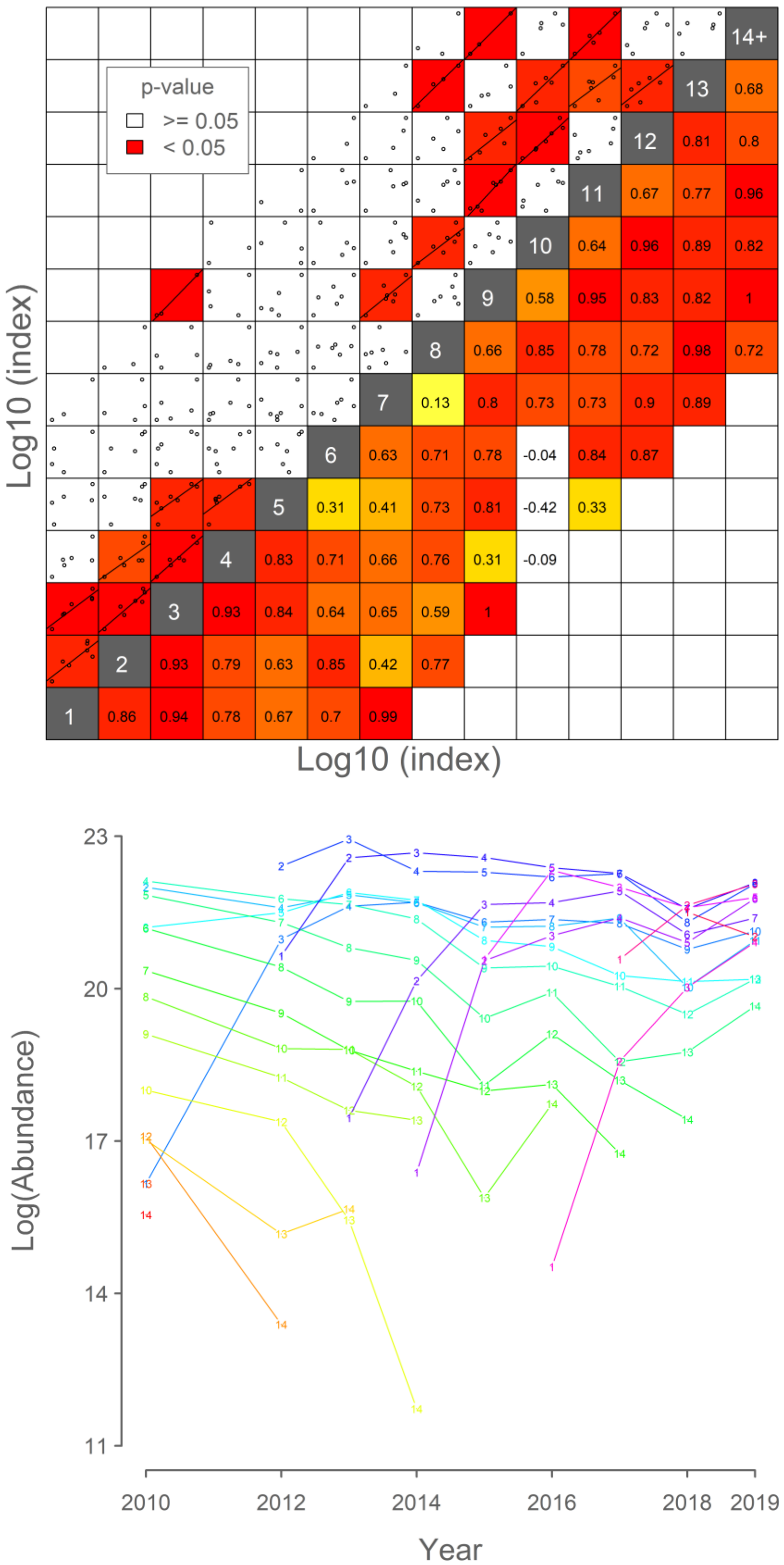


Figure 18. Diagnostics of the of mackerel density index from 2012 to 2019. Internal consistency (top), Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half. Catch curves (bottom). Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

Distribution zero boundaries were found in majority of survey area with a notable exception of high mackerel abundance at the survey boundary south-west of Faroe Island. Low densities were found in a single location at the north-western boundary west of Jan-Mayen, and high densities towards the Fram Strait west of Svalbard.

The mackerel appeared more patchily distributed within the survey area and more northerly and north-westerly distributed in 2019 compared to in 2017 and 2018. This difference in distribution primarily consists of a marked biomass decline in the west and a marked increase in the north and northwest. Furthermore, there was also a westward shift in distribution within the Norwegian Sea.

The marked decrease in the western areas since 2017 may have several causes, importantly; it reflects that the 2017 estimate was driven by few exceptionally large catches. Statistical methods that account for trawl catch distributions with over-dispersion has successfully been applied to mackerel trawl data before (Jansen et al. 2015; Nikolioudakis et al. 2019). In 2019 there were practically no mackerel in Greenland waters during the survey. The marked increase of mackerel in the Norwegian Sea, could partly be explained by improved feeding conditions from average estimates in the Norwegian Sea in 2019 compared to previous years and more mackerel migrating into the surveyed area compared to in 2018. Furthermore, there are indications that there has been strong recruitment during the last two years from 2016-2017, based on results from the mackerel recruitment index used in the assessment. Both vertical and horizontal distribution and patchiness and avoidance behaviour of mackerel may have affected the catch rates and catchability from the swept area trawling in surface waters differently in 2018 compared to 2019 and 2017. There are indications from results at Rockall bank and other areas at the IBTS surveys, that a larger fraction of the mackerel stock may have been distributed south of our survey coverage at 60°N in July-August 2018 compared to in July-August 2019. This also indicate that it would be beneficial to have an additional future survey participation by other countries covering the southwestern waters south of 60°N. We see a strong year effect for all age groups in the results from 2019 compared to 2018. However, the biomass and abundance indices of mackerel in 2019 were much more in line with the results from 2017.

As in previous years, the spatio-temporal overlap between mackerel and NSSH was highest in the southern and south-western parts of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSSH in the central part of the Norwegian Sea, whereas we had some overlap between mackerel and herring in the northern part of the Norwegian Sea. Herring distribution was mostly limited to the area east and north of Iceland and the southern Norwegian Sea. However, NSSH was also found in the central northern part for the first time in many years, dominated by the 2013- and 2016- year classes.

The swept-area estimate was, as in previous years, based on the standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 58.5-67.4m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

Results from the survey expansion southward into the North Sea is analysed separately from the traditional survey grounds north of latitude 60°N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017). We have now available IESSNS survey data from 2018 and 2019 for the North Sea.

This year's survey was well synchronized in time and was conducted over a relatively short period (5 weeks) given the large spatial coverage of around 3 million km^2 (Figure 1). This was in line with recommendations put forward in 2016 that the survey period should be around four weeks with mid-point around 20. July. The main argument for this time period, was to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southern (north of the Faroes and east and north of Iceland) and north-eastern part of the Norwegian Sea basin (Figure 19). The fish in the northeast consisted of young adults (mainly 3- and 6- year olds) while the fish further southwest are a range of age groups, mainly from 6 to 14 years old. Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring while the herring closer to the Faroes south of 62°N were Faroese autumn spawners. Also, herring to the west in Icelandic waters (west of 14°W south of Iceland and west of 24°W north of Iceland, not shown on the map) were allocated to a different stock, Icelandic summer-spawners. The abundance of NSSH in the eastern and north-eastern part of the area surveyed were lower and consisted mainly of younger and smaller fish than in the western part. The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. However, the second most abundant year class in the survey estimate, the 2016- year class (3- year olds) are not fully covered in this survey. Most of this young year class is still located in the Barents Sea based on results from the ecosystem surveys in the Barents Sea.

The NSSH stock is dominated by 6-year old herring (year class 2013) in terms of numbers and biomass (Table 8). This year class is now distributed in all areas with herring in the survey compared to last year when it was mainly found in the north-eastern part. It contributes 23% and 22% to the total biomass and total abundance, respectively. The total number of herring recorded in the Norwegian Sea was 15.2 billion and the total biomass index was 4.78 million tonnes in 2019, in comparison to 13.6 billion and a total biomass index of 4.46 million tonnes in 2018. This means that the biomass index was slightly higher in 2019 than in 2018. Number by age, with uncertainty estimates, for NSSH is shown in Figure 20. The group considered the acoustic biomass estimate of herring to be of good quality in the 2019 IESSNS as in the previous survey years.

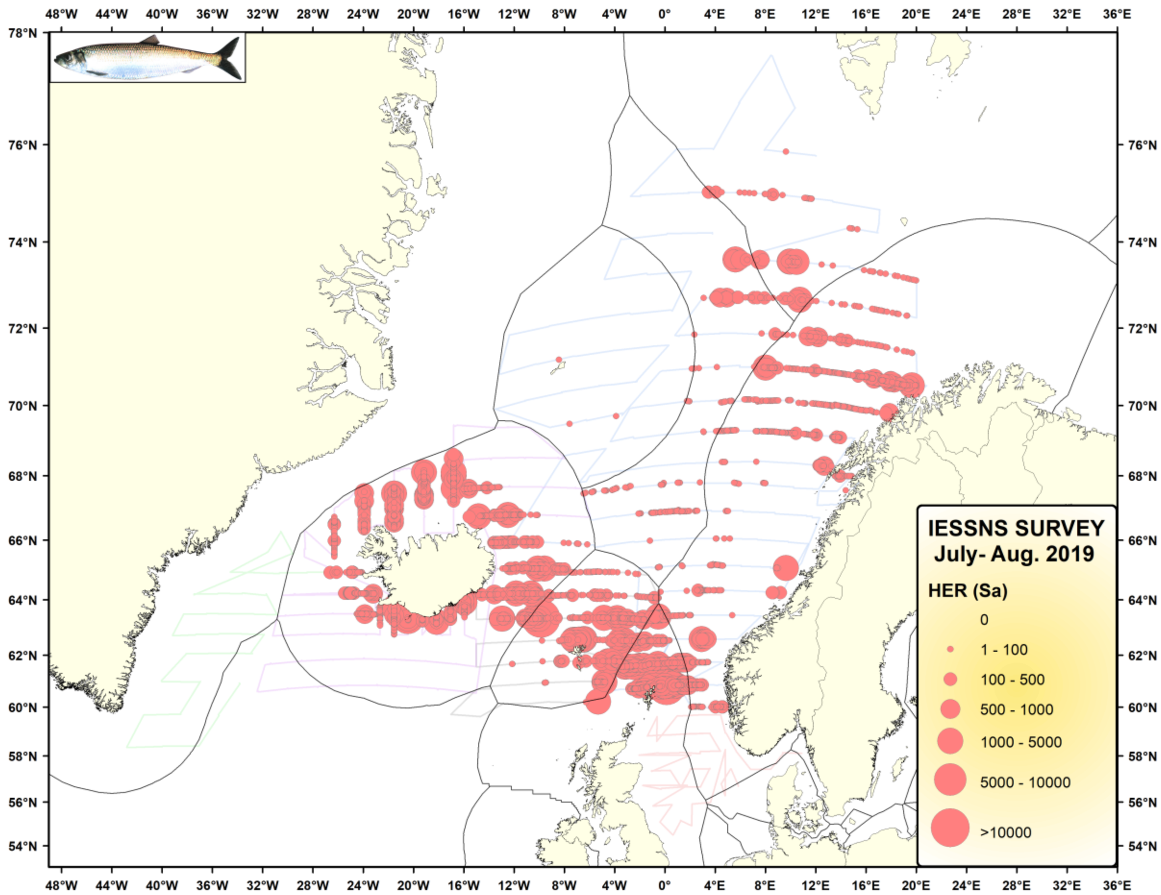


Figure 19. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2019. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

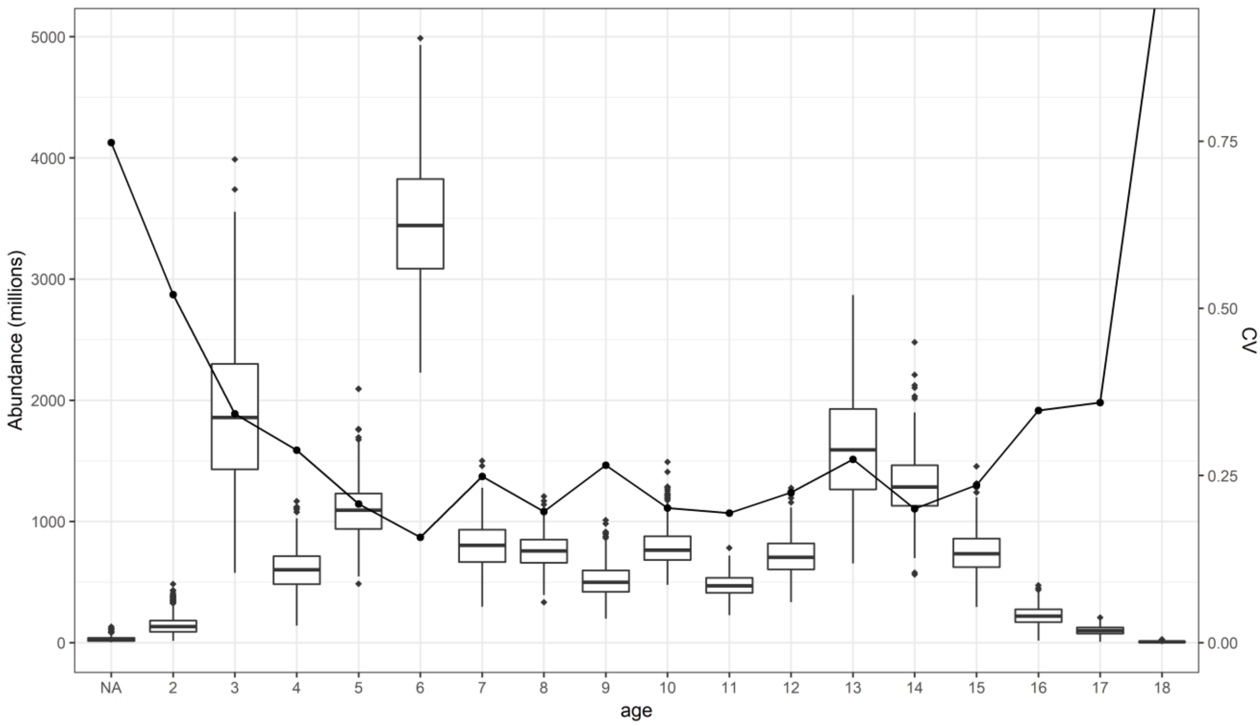


Figure 20. Number by age for Norwegian spring-spawning herring during IESSNS 2019. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 8. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2019.

	age																				
LenGrp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
14-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1893	1893	45.4	24.00
15-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1893	1893	68.1	36.00
18-19	11828	15977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27805	1119.9	40.28
19-20	6860	6860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13721	699.8	51.00
20-21	20818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20818	1311.5	63.00
21-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19762	19762	1665.9	84.30
22-23	44947	4731	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49678	4951.3	99.67
23-24	23089	-	5772	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28861	2978.4	103.20
24-25	20818	26495	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	47313	5859.2	123.84
25-26	24221	206376	9634	-	8808	-	-	-	-	-	-	-	-	-	-	-	-	-	249040	36659.0	147.20
26-27	-	420933	49037	21019	6433	-	-	-	-	-	-	-	-	-	-	-	-	-	497422	81005.6	162.85
27-28	-	518195	87141	13858	41574	3465	11319	-	-	-	-	-	-	-	-	-	-	-	675552	121158.7	179.35
28-29	-	376825	54678	59549	76814	11652	11652	2913	-	-	-	-	-	-	-	-	-	-	594082	120467.3	202.78
29-30	-	119725	71307	52850	125882	51911	-	78021	10263	16420	11146	-	-	-	-	-	-	-	537525	125525.3	233.52
30-31	-	91309	116543	254855	74004	38696	54681	12879	25538	11039	-	5520	21283	-	-	-	-	-	706348	179615.4	254.29
31-32	-	44136	131284	356156	427881	12239	10158	20316	20877	25676	49793	201390	-	10158	-	-	-	-	1310064	366915.2	280.07
32-33	-	25564	25442	229417	1297150	56852	62946	37773	62953	-	-	104911	-	-	-	-	-	-	1903010	571454.1	300.29
33-34	-	12427	33420	50212	1035752	215875	72592	30266	14503	17788	-	17788	-	-	-	-	-	-	1500623	477060.2	317.91
34-35	-	-	6145	24940	337328	352310	138168	36308	18744	-	20285	30240	-	-	-	-	-	-	964468	324725.7	336.69
35-36	-	-	-	4326	43394	74490	210462	180324	236500	66665	253222	148104	140479	48253	-	12978	-	-	1419196	511294.8	360.27
36-37	-	-	-	-	-	41430	111055	76055	119294	102076	229777	670420	348972	145974	86442	6950	-	-	1938443	729270.4	376.21
37-38	-	-	-	-	-	-	19015	40381	107311	179345	169450	419279	397974	303175	73501	52682	-	-	1762115	701554.4	398.13
38-39	-	-	-	-	-	-	-	3488	84472	43980	16075	122152	240545	233647	37842	8647	6976	-	797825	338056.4	423.72
39-40	-	-	-	-	-	-	-	1598	-	-	-	4869	83485	16253	15179	18974	-	-	140358	64743.4	461.28
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	11446	11446	-	-	-	22891	11647.0	508.80
TSN(1000)	152581	1869554	590404	1067181	3475021	858919	702048	520323	700455	462990	749748	1724672	1232738	768907	224410	100231	6976	23547	15230704	-	-
TSB(1000 kg)	15035.9	344119.4	136410.1	289293.0	1039849.0	275970.4	233783.4	173825.2	254428.6	168740.1	276301.0	635219.1	485525.1	312828.8	93800.0	39752.0	3192.1	1779.4	-	4779852.4	-
Mean length (cm)	22.42	27.33	29.53	31.00	32.30	33.40	34.03	33.86	35.28	35.75	35.59	35.55	36.77	37.05	37.14	37.20	38.00	20.20	-	-	-
Mean weight (g)	98.54	184.06	231.05	271.08	299.24	321.30	333.00	334.07	363.23	364.46	368.53	368.31	393.86	406.85	417.99	396.61	457.55	75.57	-	-	313.83

4.5 Blue whiting

Blue whiting was distributed throughout the entire survey area with exception of the area north of Iceland influenced by the cold East Icelandic Current and in the East Greenland area. The highest s_A-values were observed in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands as well as south of Iceland and the distribution in 2019 is similar to the 2018 distribution. The main concentrations of older fish were observed in connection with the continental slopes, both in the eastern and the southern part of the Norwegian Sea (Figure 21). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during IESSNS 2019 was 2.0 million tons (Table 9), which is the same compared to 2018. The stock estimate in number for 2019 is 16.2 billion compared to 16.3 billion of age groups 1+ in 2018. The age group five is dominating the estimate (36% and 30% of the biomass and by numbers, respectively). A good sign of recruiting year class (0-group) was also seen in the survey this year.

Number by age, with uncertainty estimates, for blue whiting during IESSNS 2019 is shown in Figure 22.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2019 IESSNS as in the previous survey years.

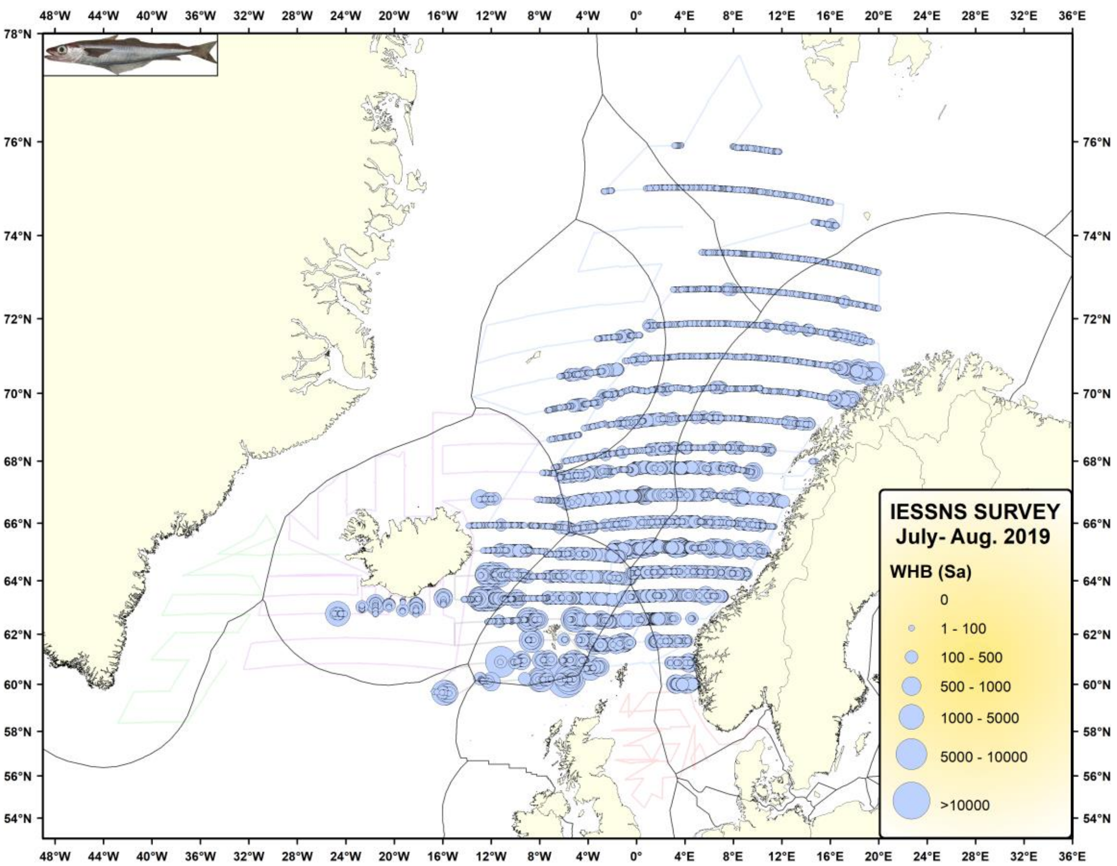


Figure 21. The s_A/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2019.

Table 9. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2019.

LenGrp	age 0	1	2	3	4	5	6	7	8	9	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
9-10	-	-	-	-	-	-	-	-	-	-	-	41290	41290	-	-
10-11	179782	-	-	-	-	-	-	-	-	-	-	-	179782	1078.7	6.00
11-12	245276	-	-	-	-	-	-	-	-	-	-	-	245276	2136.9	8.71
12-13	742161	-	-	-	-	-	-	-	-	-	-	-	742161	7639.2	10.29
13-14	419538	-	-	-	-	-	-	-	-	-	-	-	419538	6041.0	14.40
14-15	431653	-	-	-	-	-	-	-	-	-	-	-	431653	7593.6	17.59
15-16	122387	-	-	-	-	-	-	-	-	-	-	-	122387	2697.5	22.04
16-17	12091	-	-	-	-	-	-	-	-	-	-	-	12091	290.2	24.00
17-18	-	-	-	-	-	-	-	-	-	-	-	3807	3807	83.8	22.00
18-19	-	13326	-	-	-	-	-	-	-	-	-	-	13326	342.7	25.71
19-20	-	58448	-	-	-	-	-	-	-	-	-	-	58448	2069.4	35.41
20-21	-	45689	81842	-	-	-	-	-	-	-	-	-	127531	6116.0	47.96
21-22	-	96286	249072	-	-	-	-	-	-	-	-	-	345358	20098.2	58.20
22-23	-	183118	363974	-	-	-	-	-	-	-	-	-	547092	36303.9	66.36
23-24	-	161561	443693	6176	-	-	-	-	-	-	-	-	611431	45728.6	74.79
24-25	-	63431	220678	-	19330	38660	-	-	-	-	-	-	342098	29877.7	87.34
25-26	-	315	238986	201293	197353	135844	6442	-	-	-	-	-	780234	77108.6	98.83
26-27	-	17527	73113	660792	687115	534868	81213	-	79485	-	-	-	2134114	231058.0	108.27
27-28	-	-	180484	567017	1286928	1341078	150141	37237	72998	-	-	-	3635883	428875.5	117.96
28-29	-	-	50015	461404	976222	1272180	305664	55484	31523	-	-	-	3152492	415762.7	131.88
29-30	-	-	22264	230403	667792	1007146	259856	33174	-	2160	-	-	2222795	324328.9	145.91
30-31	-	-	8736	49959	407292	670400	138264	9181	3768	654	-	-	1288253	211455.6	164.14
31-32	-	-	-	2295	81907	304294	92257	22691	21262	-	-	-	524705	94821.9	180.71
32-33	-	-	-	-	16676	80874	55580	8605	10445	-	6453	-	178633	35779.9	200.30
33-34	-	-	-	-	5926	47431	11451	36124	-	-	-	-	100932	21537.6	213.39
34-35	-	-	-	-	1261	1261	38534	6271	-	-	-	-	47327	10867.8	229.63
35-36	-	-	-	-	-	315	5611	-	6012	2004	2004	-	15945	4219.0	264.59
36-37	-	-	-	-	-	-	5510	-	-	-	-	-	5510	1816.8	329.71
37-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38-39	-	-	-	-	-	-	-	-	-	-	-	1904	1904	552.1	290.00
39-40	-	-	-	-	-	-	-	-	3607	-	-	-	3607	1222.7	339.00
TSN(1000)	2152887	639702	1932857	2179339	4347802	5434350	1150524	208766	229101	4817	8457	47001	18335603	-	-
TSB(1000 kg)	27477.1	41410.4	160751.9	263617.9	563266.3	734895.2	172044.0	32177.7	28457.9	938.6	1831.4	635.8	-	2027504.3	-
Mean length (cm)	12.79	22.16	23.76	27.23	27.90	28.38	29.12	29.79	28.13	31.63	32.96	11.17	-	-	-
Mean weight (g)	12.76	64.73	83.17	120.96	129.55	135.23	149.54	154.13	124.22	194.83	216.54	111.33	-	-	110.83

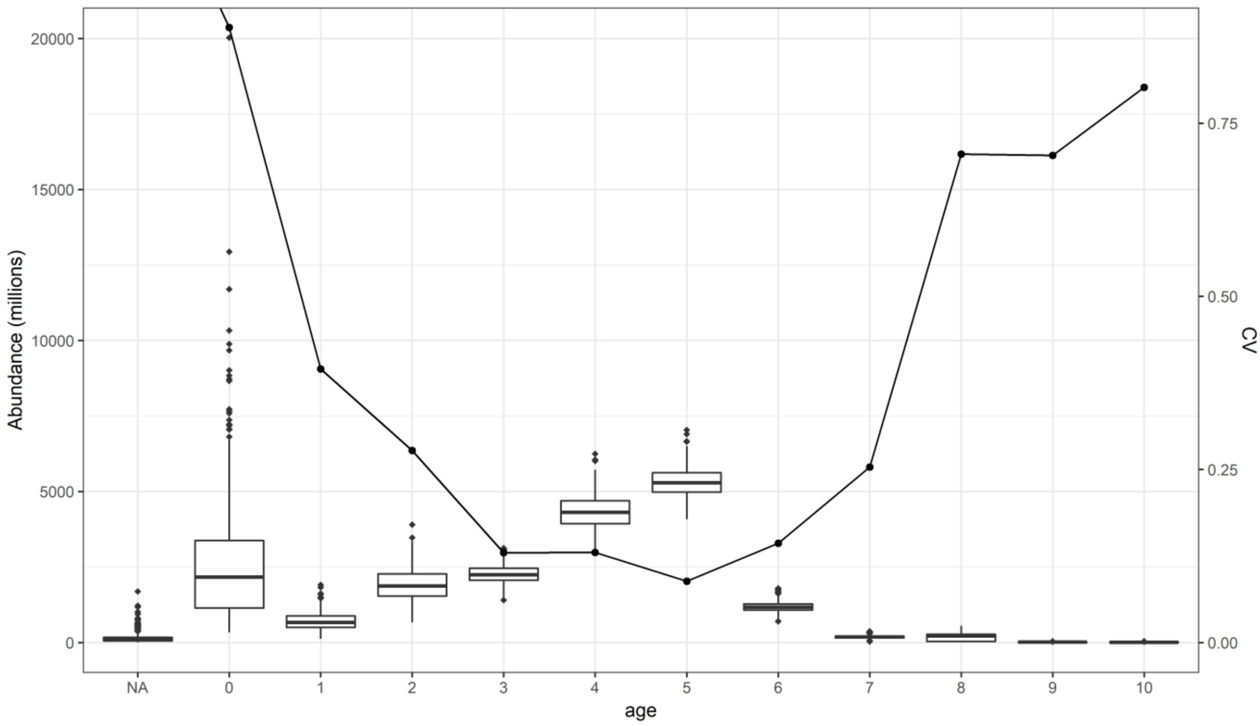


Figure 22. Number by age with uncertainty for blue whiting during IESSNS 2019. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 73% of trawl stations across the six vessels (Figure 23) and where lumpfish was caught, 98% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Of note, total trawl catch at each trawl station were processed on board R/V ”Árni Friðriksson", M/V “Kings Bay”, M/V “Vendla” and M/V “Eros”, whereas a subsample of 50 kg to 200 kg was processed onboard M/V “Finnur Fríði” in Faroese waters. Therefore, small catches (<10 kg) of lumpfish might be missing from the survey track of M/V “Finnur Fríði” (black crosses in Figure 23). However, it is unlikely that larger catches of lumpfish would have gone unnoticed by crew during sub-sampling of catch.

Abundance was greatest north of 66°N, and lower south of 65°N south of Iceland, in Faroese waters and northern UK waters. 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 51 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 24). For fish ≥20 cm in which sex was determined, the males exhibited a unimodal distribution with a peak around 25-27 cm. The females also exhibited a unimodal distribution but with a peak around 27-30 cm which was positively skewed. Aboard the Norwegian vessels, the ratio of males to females was approximately 1:1. Generally, the mean length and mean weight of the lumpfish was highest in the coastal waters and along the shelf edges in southwest, west, and northwest, and lowest in the central Norwegian Sea.

A total of 472 fish (217 by R/V “Árni Friðriksson” and 255 by M/V “Eros”) between 13 and 46 cm were tagged during the survey (Figure 25).

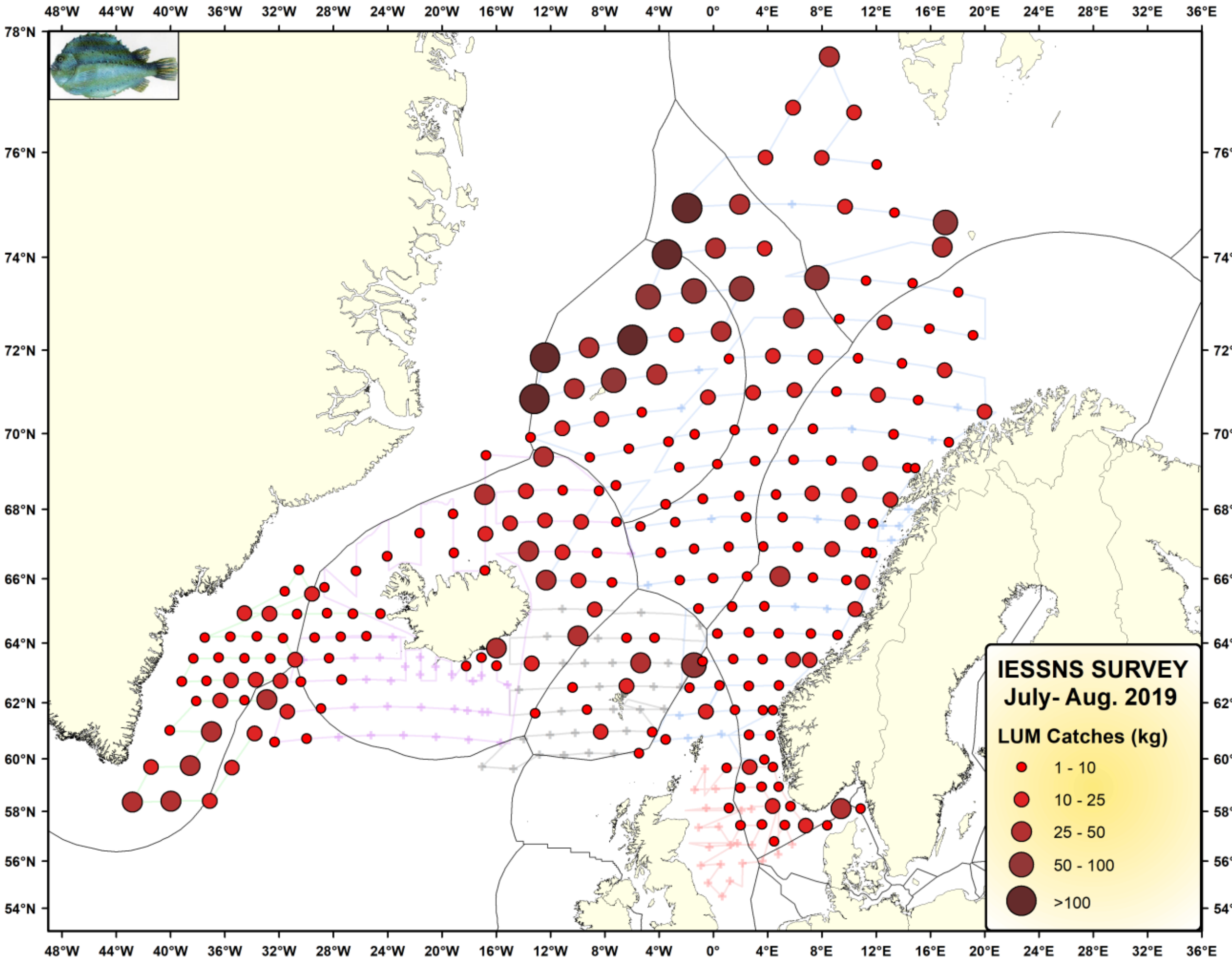


Figure 23. Lumpfish catches at surface trawl stations during IESSNS 2019.

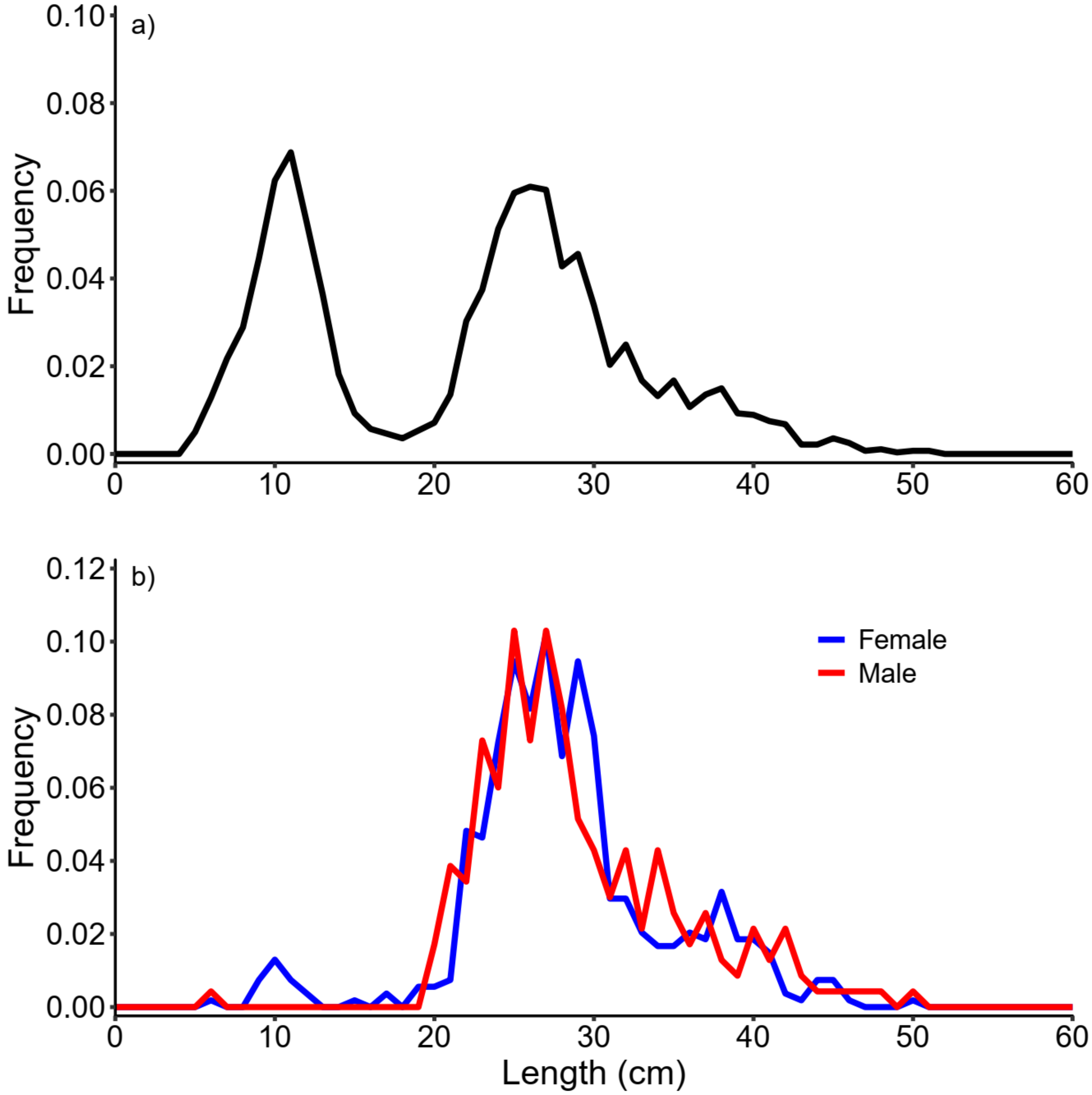


Figure 24. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

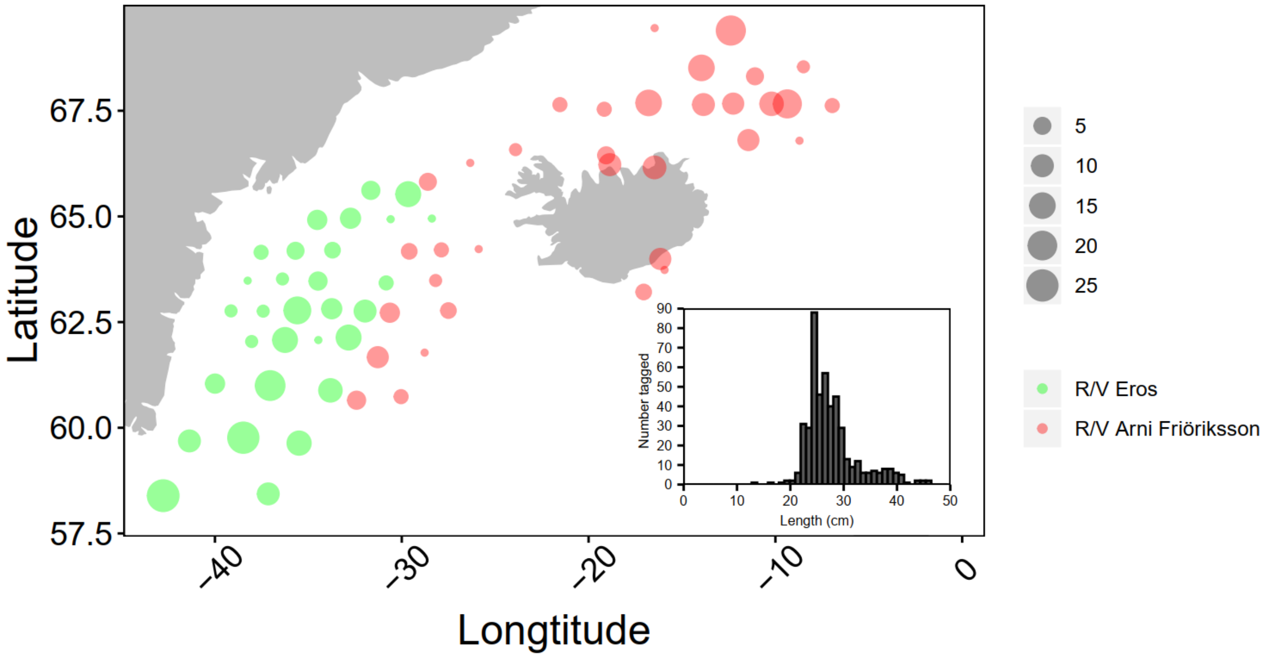


Figure 25. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 58 North Atlantic salmon were caught in 37 stations both in coastal and offshore areas from 62°N to 74°N in the upper 30 m of the water column during IESSNS 2019 (Figure 24). The salmon ranged from 0.08 kg to 2.5 kg in weight, dominated by postsmolt weighing 80-200 grams. The length of the salmon ranged from 20 cm to 62 cm, with a large majority of the salmon <30 cm in length. The general impression was that postsmolt was distributed more westerly in 2019 compared to in 2017 and 2018.

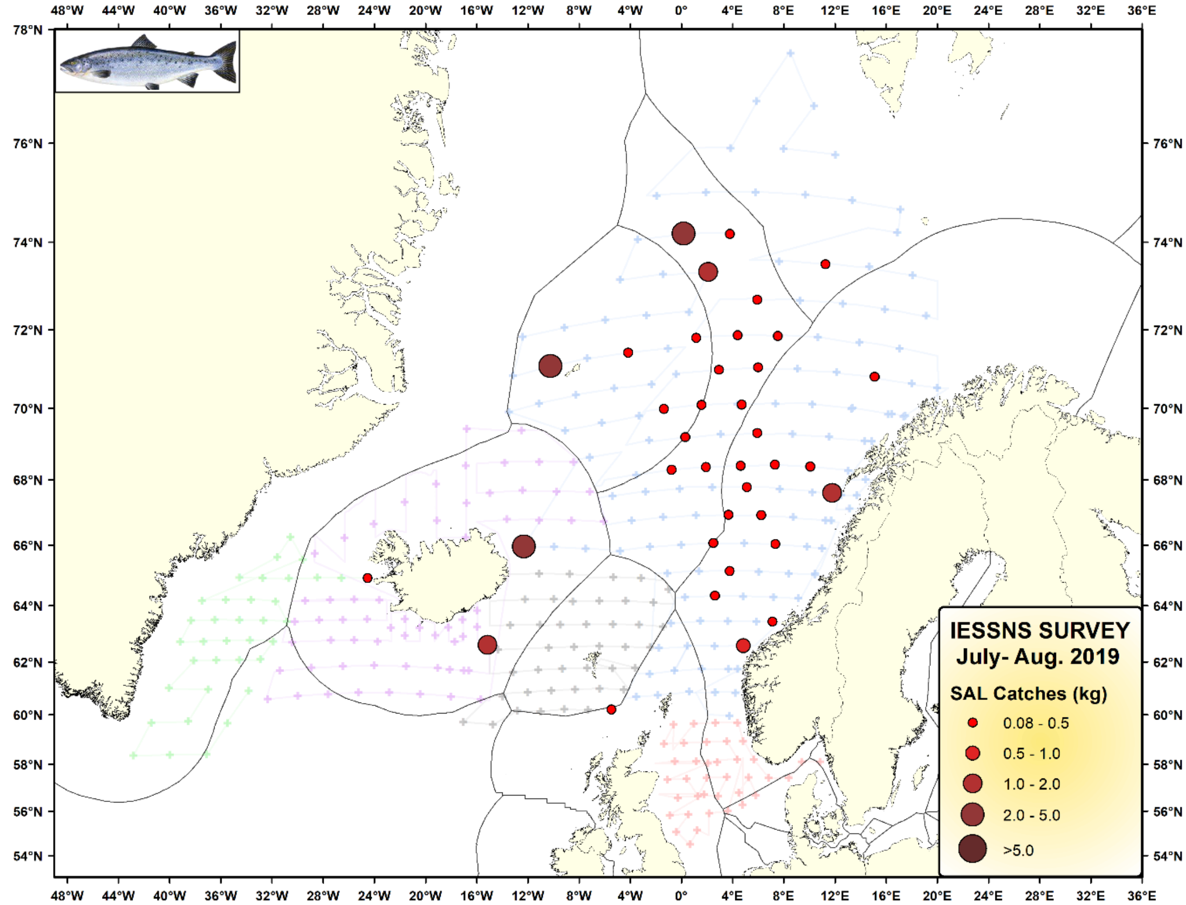


Figure 26. Catches of salmon at surface trawl stations during IESSNS 2019.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 29 stations along the cold front in SE Greenland, Denmark Strait, North of Iceland, West and North of Jan Mayen and at the entrance to the Barents Sea around Bear Island (Figure 27).

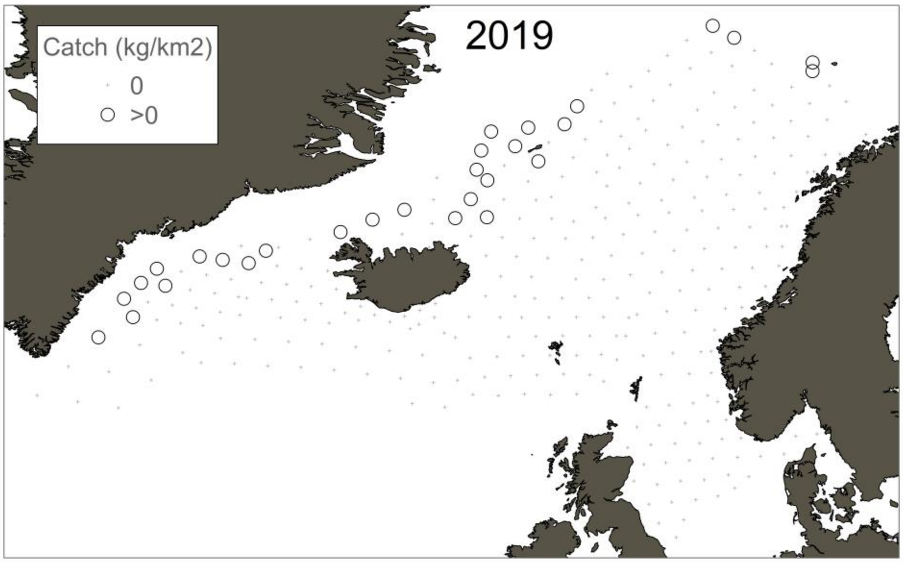


Figure 27. Presence of capelin in surface trawl stations during the IESSNS survey 2019.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Kings Bay" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland in 2019 (Figure 28). Overall, 521 marine mammals of 10 different species were observed, which was a reduction from 600+ in 2018 and 700+ in 2017 observed individuals. This could partly be explained by reduced observation effort on R/V "Árni Friðriksson" as in 2017 dedicated whale observers were onboard which was not the case in 2018 and 2019. Kings Bay had several days with fog and very reduced visibility in the north-western region (Jan Mayen area), possibly influencing the low number of marine mammals observed on this vessel during IESSNS 2019. Vendla experienced mainly good to excellent visibility during the entire survey period except for some limited periods between Bear Island and Svalbard, while Arni Fridriksson had occasional periods with fog north of Iceland. The species that was observed included; fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*), sei whales (*Balaenoptera borealis*) pilot whales (*Globicephala sp.*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), white beaked dolphins (*Lagenorhynchus albirostris*) and harbour porpoise (*Phocoena phocoena*). The dominant number of marine mammal observations were along the continental shelf between the north-eastern part of the Norwegian Sea and western part of the Barents Sea. Fin whales (n=63, group size = 1-4) and humpback whales (n=73, group size = 1-10) dominated among the large whale species, and they were particularly abundant from Norwegian coast outside Finnmark stretching north/northwest via Bear Island to southwest of Svalbard. Killer whales (n=55, group size = 1-10) dominated in the southern and eastern part of the Norwegian Sea, mostly overlapping and feeding on mackerel. White beaked dolphins (n=78, group size = 1-15) were present in the northern part of the Norwegian Sea. There were more observations made of marine mammals in the central Norwegian Sea in 2019 compared to previous years.

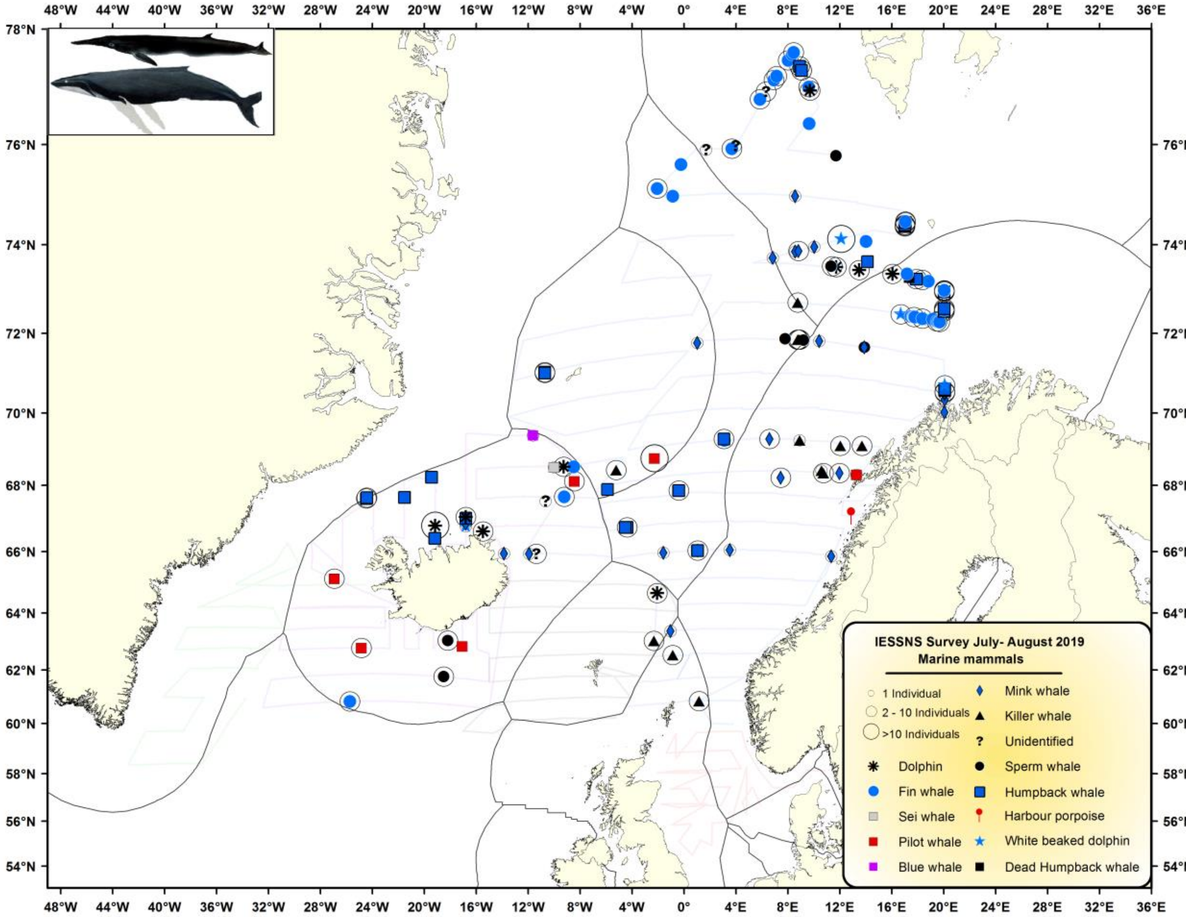


Figure 28. Overview of all marine mammals sighted during IESSNS 2019.

5 Recommendations

Recommendation	To whom
WGIPS recommends that the IESSNS extension to the North Sea should continue for establishing a time series suitable for assessing the part of the NE Atlantic Mackerel stock in the North Sea. The surveys conducted by Denmark in 2018 and 2019 have demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak for the area is deeper than 50 m. The survey provides essential fishery-independent information on the stock during its feeding migration in summer and WGIPS recommends that the Danish survey should continue as a regular annual survey.	WGWIDE, RCG NANSEA

6 Action points for survey participants

Action points
The guidelines for trawl performance should be revised to reflect realistic manoeuvring of the Multpelt832 trawl.
Criteria and guidelines should be established for discarding substandard trawl stations using live monitoring of headline, footrope and trawl door vertical depth, and horizontal distance between trawl doors. As 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 weighted. If predetermined trawl hauls are not satisfactory according to criteria the station will be excluded from mackerel index calculations, i.e. treated as it does not exist, but not as a zero mackerel catch station.
Tagging of lumpfish should be initiated or continue on all vessels.
We recommend that observers collect sighting information of marine mammals and birds on all vessels.

7 Survey participants

M/V "Vendla":
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Land based coordinator: Teunis Jansen, Greenland Institute of Natural Resources, Nuuk, Greenland

M/V "Ceton"
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Per Christensen, National Institute of Aquatic Resources, Denmark
Søren Eskildsen, National Institute of Aquatic Resources, Denmark

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1 Appendix 1:

Denmark joined the IESSNS in 2018 for the first time extending the original survey area into the North Sea. The commercial fishing vessels “Ceton S205” was used, and in total 39 stations (CTD and fishing with the pelagic Multipelt 832 trawl) had successfully been conducted. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths larger 50 m and no plankton samples were taken.

Denmark joined the IESSNS again in 2019 using the same vessel. 38 station 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 20019 was lower than in 2018 (1009 compared to 1743 kg/km2). The length and age composition indicate a relative low amount of small (< 25 cm) individuals (Tab. A.1) whereas the abundance of older (≥ age 6) mackerel was higher in 2019 than in 2018 (Fig. A.1.), and the mean individual weight increased from 204 in 2018 to 220 g in 2019.

Table A1. StoX estimate of age segregated and length segregated mackerel index for the North Sea in 2019. Also provided is average length and weight per age class.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20-21	2314	-	-	-	-	-	-	-	-	-	-	-	2314	149.0	64.36
21-22	1469	-	-	-	-	-	-	-	-	-	-	-	1469	111.8	76.09
22-23	13171	-	-	-	-	-	-	-	-	-	-	-	13171	1133.7	86.08
23-24	33414	745	-	-	-	-	-	-	-	-	-	-	34159	3096.2	90.64
24-25	50228	-	-	-	-	-	-	-	-	-	-	-	50228	5557.8	110.65
25-26	62325	209	-	-	-	-	-	-	-	-	-	-	62534	8172.5	130.69
26-27	88071	17616	-	-	-	-	-	-	-	-	-	-	105686	14967.0	141.62
27-28	66712	24203	674	-	-	-	-	-	-	-	-	-	91588	15526.3	169.52
28-29	24663	81243	-	-	-	-	-	-	-	-	-	-	105906	20070.9	189.52
29-30	3405	90274	2644	-	-	-	-	-	-	-	-	-	96323	19671.7	204.23
30-31	759	54156	45081	346	-	-	-	-	-	-	-	-	100342	24027.1	239.45
31-32	-	27383	25019	27464	-	-	-	-	-	-	-	-	79865	21511.4	269.35
32-33	-	4929	42869	16616	400	-	-	-	-	-	-	-	64814	17876.5	275.81
33-34	-	6714	22531	34224	7627	-	-	-	-	-	-	-	71097	21182.0	297.93
34-35	-	-	9371	22922	15351	15109	-	113	-	-	-	-	62866	20863.7	331.88
35-36	-	-	965	7597	11034	5520	3715	1054	-	-	-	-	29885	10414.4	348.48
36-37	-	-	-	978	6236	3733	3227	2409	1527	-	-	-	18110	6920.1	382.11
37-38	-	-	-	-	713	4068	3654	2651	1369	-	-	-	12455	5191.8	416.85
38-39	-	-	-	-	-	658	2329	2498	1012	1166	-	-	7662	3461.5	451.77
39-40	-	-	-	-	-	261	-	1463	1082	725	-	466	3996	1957.4	489.81
40-41	-	-	-	-	-	-	-	442	404	462	10	19	1337	696.8	521.08
41-42	-	-	-	-	-	-	-	490	129	97	13	13	742	458.7	618.09
42-43	-	-	-	-	-	-	-	-	-	-	64	-	64	42.8	672.00
43-44	-	-	-	-	-	-	-	-	-	80	-	-	80	51.2	638.00
TSN(1000)	346531	307470	149154	110147	41361	29349	12925	11119	5522	2530	87	499	1016695	-	-
TSB(1000 kg)	46889.3	63754.6	40510.5	33331.5	14102.1	10336.8	5369.5	4753.4	2485.9	1270.9	55.9	251.9	-	223112.3	-
Mean length (cm)	25.40	28.88	31.45	32.72	34.43	34.99	36.36	37.35	37.63	38.93	41.61	39.09	-	-	-
Mean weight (g)	135.31	207.35	271.60	302.61	340.95	352.20	415.44	427.52	450.16	502.30	639.96	505.26	-	-	219.45

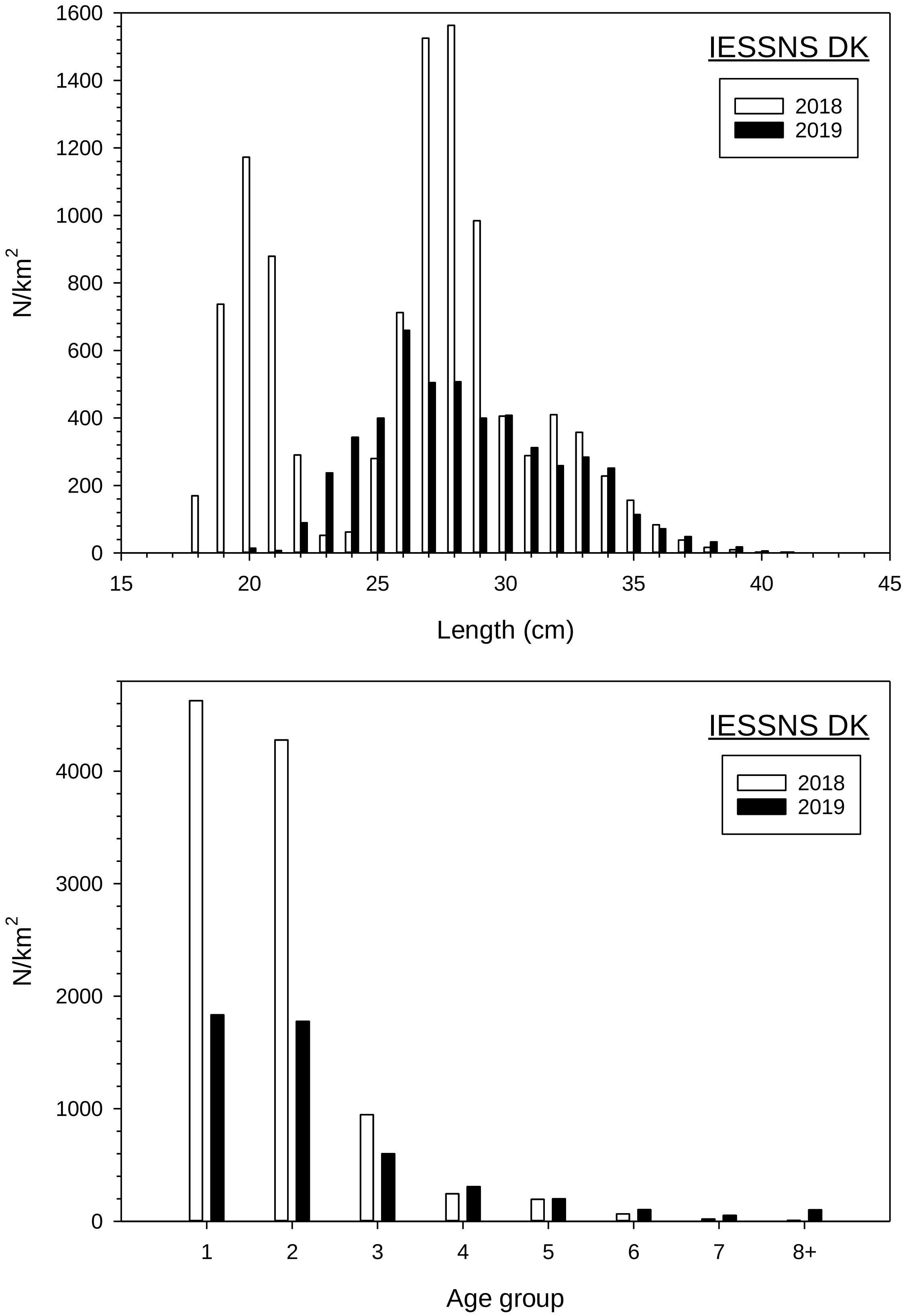


Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018 and 2019.

2 Annex 2:

The mackerel index is calculated on all valid surface stations. That means, that invalid and potential extra surface stations and deeper stations need to be excluded. Below is the exclusion list used when calculating the mackerel abundance index for IESSNS 2019.

Table A2-1: Trawl station exclusion list for IESSNS 2019 for calculating the mackerel abundance index.

Vessel	Country	Exclusion list	
		Cruise	Stations
Kings Bay	Norway	2019837	29,38,47,52,55,70,74,77,79,81,82,86,92,98
Vendla	Norway	2019838	37,41,49,52,57,64,67,70,73,76,77,78,83,86,88,89,90,91,93,97,100,104,109,112,113
Árni Friðriksson	Iceland	A8-2019	342,344,347,361,365,366,375,383
Finnur Fríði	Faroe Islands	1952	9, 33,50,73,82,1081,1084 *
Eros	Greenland	CH-2019-01	87
Ceton	EU (Denmark)		North Sea data were not used in the combined index in IESSNS 2019

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceeded by 1952 (e.g. ‘19520009’)

Working document xx, WGWIDE 2019, 28 August-3 September 2019, Santa Cruz de Tenerife, Spain

PFA self-sampling report for WGWIDE, 2015-2019

Martin Pastoors, 28/08/2019 21:55:29

1 Introduction

The Pelagic Freezer-trawler Association (PFA) is an association that has nine member companies that together operate 19 freezer trawlers in five European countries (www.pelagicfish.eu). In 2015, the PFA has initiated a self-sampling programme that expands the ongoing monitoring programmes on board of pelagic freezer-trawlers by the specialized crew of the vessels. The primary objective of that monitoring programme is to assess the quality of fish. The expansion in the self-sampling programme consists of recording of haul information, recording the species compositions per haul and regularly taking random length-samples from the catch. The self-sampling is carried out by the vessel quality managers on board of the vessels, who have a long experience in assessing the quality of fish, and by the skippers/officers with respect to the haul information. The scientific coordination of the self-sampling programme is carried out by Martin Pastoors (PFA chief science officer) with support of Floor Quirijns (contractor).

2 Material and methods

The PFA self-sampling programme has been implemented incrementally on many vessels that belong to the members of the PFA. The self-sampling programme is designed in such a way that it follows as closely as possible the working practices on board of the different vessels and that it delivers relevant information for documenting the performance of the fishery and to assist stock assessments of the stocks involved. The following main elements can be distinguished in the self-sampling protocol:

- haul information (date, time, position, weather conditions, environmental conditions, gear attributed, estimated catch, optionally: species composition)
- batch information (total catch per batch=production unit, including variables like species, average size, average weight, fat content, gonads y/n and stomach fill)
- linking batch and haul information (essentially a key of how much of a batch is caught in which of the hauls)
- length information (length frequency measurements, either by batch or by haul)

The self-sampling information is collected using standardized Excel worksheets. Each participating vessel will send in the information collected during a trip by the end of the trip. The data will be checked and added to the database by Floor Quirijns and/or Martin Pastoors, who will also generate standardized trip reports (using RMarkdown) which will be sent back to the vessel within one or two days. The compiled data for all vessels is being used for specific purposes, e.g. reporting to expert groups, addressing specific fishery or biological questions and supporting detailed biological studies. The PFA publishes an annual report on the self-sampling programme.

A major feature of the PFA self-sampling programme is that it is tuned to the capacity of the vessel-crew to collect certain kinds of data. Depending on the number of crew and the space available on the vessel, certain types of measurements can or cannot be carried out. That is why the programme is essentially tuned to each vessel separately. And that is also the reason that the totals presented in this report can be somewhat different dependent on which variable is used. For example the estimate of total catch is different from the sum of the catch per species because not all vessels have supplied data on the species composition of the catch.

Because the self-sampling programme has been under development over the years, different numbers of vessels have been participating in the programme over different years. Results should not be interpreted as a census of the PFA fleet, but rather as an indicator of relative distributions and samples of catch and catch compositions.

In order to supply relevant information to WGWIDE 2019, the PFA self-sampling data has been filtered using the following approach. First, all catches per vessel, trip and species have been summed by week. For each vessel-trip-species-week combination, the proportion of the species in the catch were calculated. Then the following filter criteria have applied to the weekly data:

- for horse mackerel: latitude > 45, proportion in the catch > 10%, catch > 10 tonnes

- for mackerel : latitude > 45, proportion in the catch > 10%, catch > 10 tonnes
- for blue whiting : latitude > 50, proportion in the catch > 10%, catch > 10 tonnes
- for herring : division = 27.2.a, proportion in the catch > 10%, catch > 10 tonnes

Data have been processed up to 27 August 2019.

3 Results

3.1 General

An overview of all the selected self-sampling hauls between 2015 and (August) 2019 is shown in Table 3.1.

year	nvessels	ntrips	ndays	nhauls	catch	nlength	catch/trip	catch/day	catch/haul
2015	6	29	443	1,009	77,364	80,904	2,667	174	76
2016	9	57	748	1,771	154,044	76,026	2,702	205	86
2017	12	73	974	2,159	207,719	101,727	2,845	213	96
2018	16	104	1,484	3,385	317,981	192,988	3,057	214	93
2019	14	66	927	2,069	174,265	88,684	2,640	187	84
(all)	.	329	4,576	10,393	931,373	540,329	.	.	.

Table 3.1.1: PFA selfsampling summary of hauls in widely distributed pelagic fisheries with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort) by year

Number of self-sampled hauls in widely distributed pelagic fisheries by year and area

division	2015	2016	2017	2018	2019	all
27.2.a	52	148	264	250	1	715
27.4.a	212	387	339	754	295	1,987
27.4.b	33	25	67	78	0	203
27.4.c	5	12	22	20	1	60
27.5.b	28	57	66	82	1	234
27.6.a	256	425	669	1,268	989	3,607
27.6.b	0	0	2	50	10	62
27.7.b	50	98	140	88	171	547
27.7.c	32	87	255	242	252	868
27.7.d	107	213	232	243	34	829
27.7.e	47	142	48	32	65	334
27.7.f	3	0	0	4	1	8
27.7.g	21	10	0	9	0	40
27.7.h	5	25	29	96	24	179
27.7.j	84	62	20	61	128	355
27.7.k	56	77	3	59	17	212
27.8.a	15	2	1	41	72	131
27.8.b	3	0	0	6	4	13
27.8.c	0	0	0	0	1	1
27.8.d	0	1	2	2	3	8
(all)	1,009	1,771	2,159	3,385	2,069	10,393

Table 3.1.2: PFA selfsampling summary of number of hauls per division in widely distributed pelagic fisheries

Catch compositions in widely distributed pelagic fisheries by year and species

species	englishname	scientificname	2015	2016	2017	2018	2019	all
whb	blue whiting	Micromesistius poutassou	16,472	37,882	49,220	137,226	81,237	322,037
mac	mackerel	Scomber scombrus	26,720	28,537	51,925	58,540	36,929	202,651
her	herring	Clupea harengus	17,622	25,117	29,803	56,064	15,011	143,617
hom	horse mackerel	Trachurus trachurus	9,634	14,791	12,541	28,031	25,060	90,057
arg	argentines	Argentina spp	2,210	997	977	3,117	3,859	11,160
pil	pilchard	Sardina pilchardus	1,132	2,552	414	946	72	5,116
spr	sprat	Sprattus sprattus	682	104	16	264	0	1,065
hke	hake	Merluccius merluccius	204	61	62	215	205	746
boc	boarfish	Capros aper	121	63	74	161	238	657
ane	anchovy	Engraulis encrasicolus	251	192	8	23	0	474
oth	NA	NA	574	119	108	165	175	1,142
(all)	(all)	(all)	75,623	110,416	145,148	284,751	162,786	778,723

Table 3.1.3: PFA selfsampling catch per species in widely distributed pelagic fisheries. OTH refers to all other species that are not the main target species

Haul positions

An overview of all self-sampled hauls in PFA widely distributed fisheries.

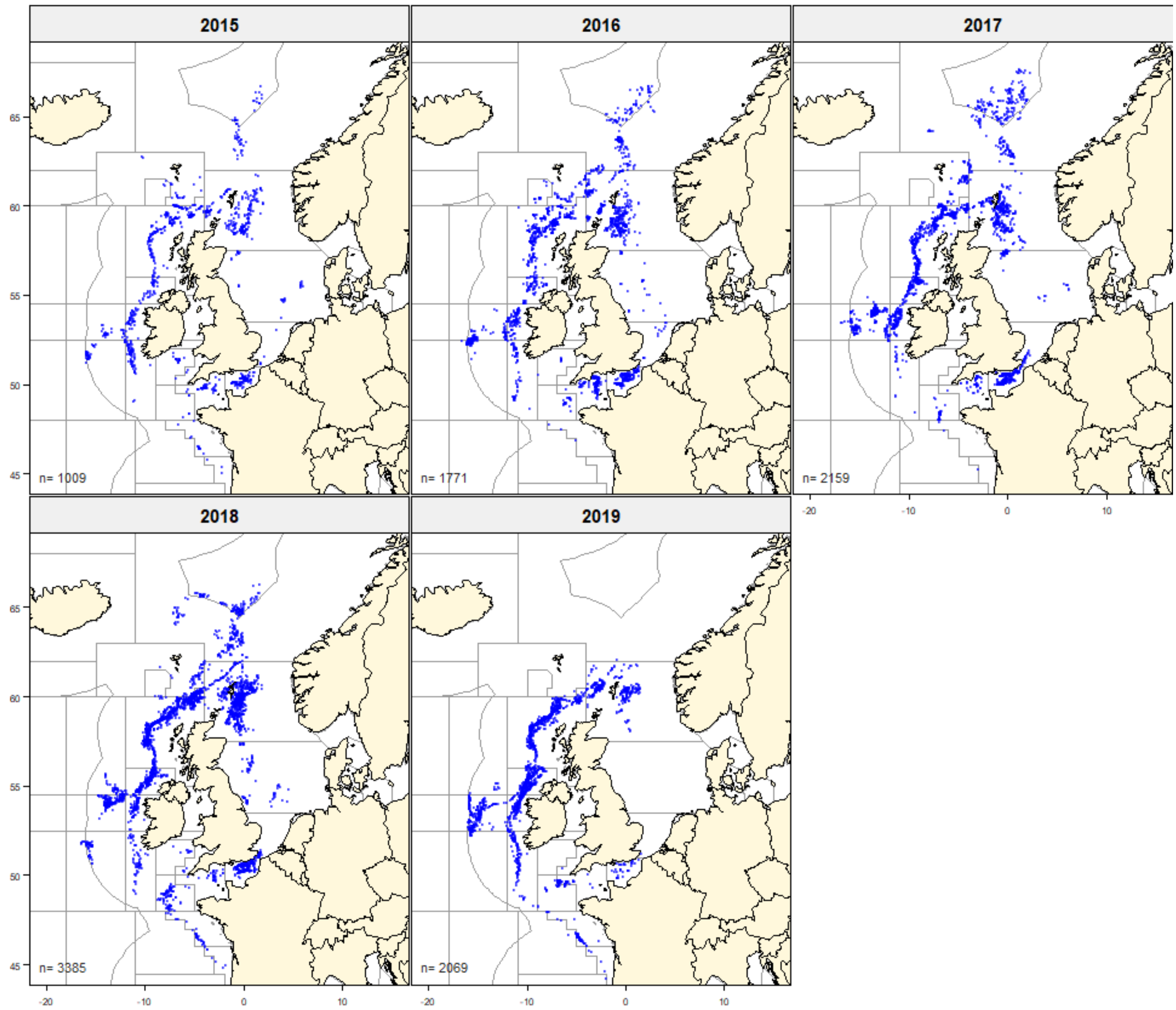


Figure 3.1.1: Haul positions in PFA self-sampled widely distributed pelagic fisheries. N indicates the number of hauls.

Catch rates for the main target species

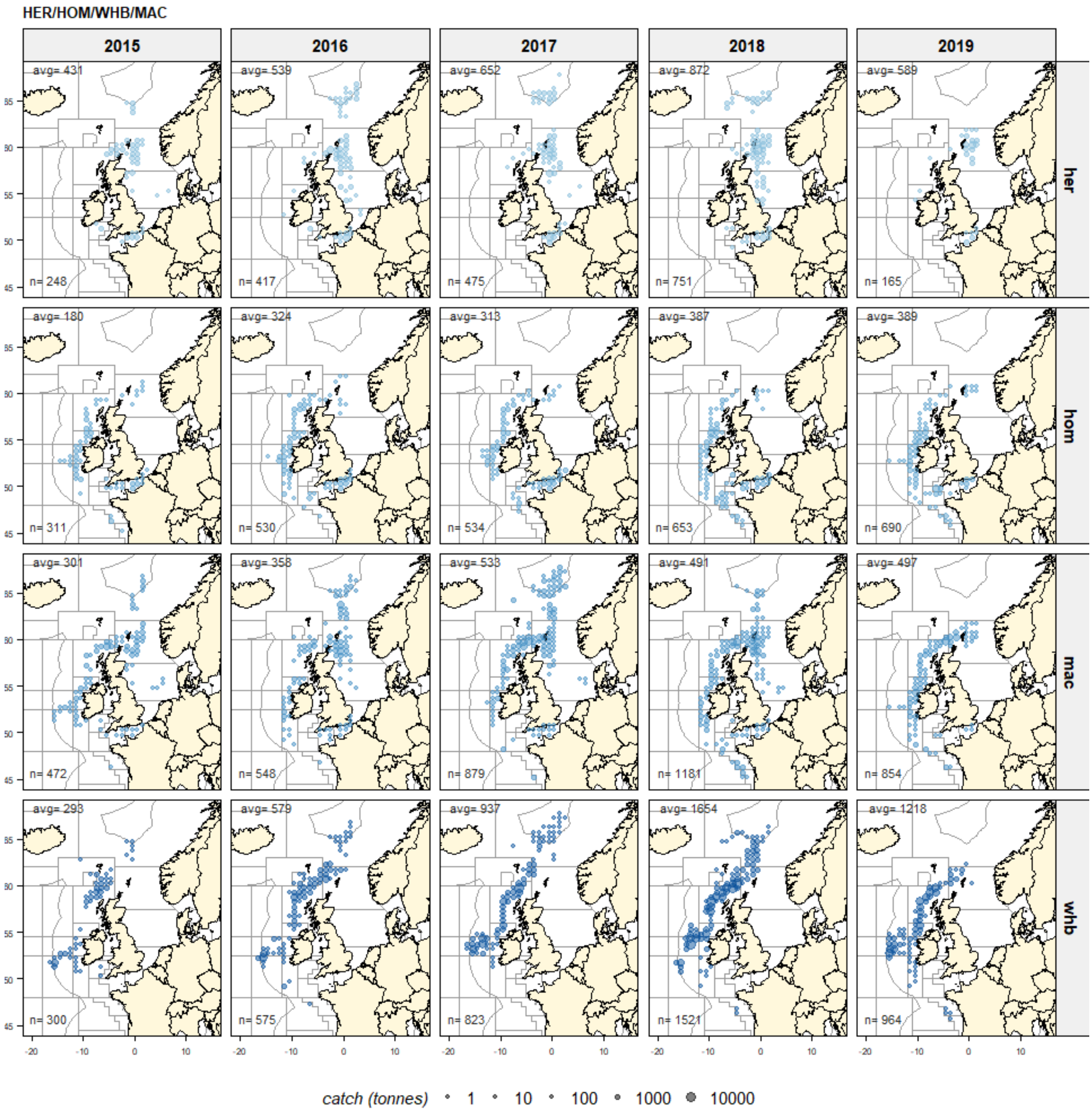


Figure 3.1.2: Catch per haul of the main target species in PFA self-sampled widely distributed pelagic fisheries

3.2 Mackerel (Scomber scombrus)

species	year	nvessels	ntrips	ndays	nhauls	catch	catch/trip	catch/day
mac	2015	6	26	237	473	26,820	1,031	113
mac	2016	9	51	318	554	34,838	683	109
mac	2017	11	65	490	889	64,599	993	131
mac	2018	16	80	690	1,191	59,018	737	85
mac	2019	14	55	477	858	38,838	706	81
mac	(all)	.	277	2,212	3,965	224,113	.	.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	nlength
mac	27.2.a	2015	3	3	18	35	2,040	1,643
mac	27.2.a	2016	6	7	48	98	7,441	2,611
mac	27.2.a	2017	6	9	81	164	13,019	1,948
mac	27.2.a	2018	5	7	38	67	4,870	9
mac	27.2.a	2019	0	0	0	0	0	1
mac	27.4.a	2015	5	11	74	157	14,545	4,787
mac	27.4.a	2016	9	19	104	173	16,062	1,847
mac	27.4.a	2017	9	23	132	248	17,937	5,058
mac	27.4.a	2018	14	39	263	491	29,426	6,456
mac	27.4.a	2019	11	15	94	196	9,195	5,393
mac	27.4.b	2015	2	3	10	15	90	32
mac	27.4.b	2016	3	4	6	9	99	1
mac	27.4.b	2017	3	4	14	32	396	96
mac	27.4.b	2018	4	5	19	37	77	176
mac	27.4.c	2016	1	1	1	1	0	0
mac	27.4.c	2018	1	1	1	1	0	0
mac	27.5.b	2016	1	1	2	2	5	0
mac	27.5.b	2017	4	5	8	11	81	43
mac	27.6.a	2015	4	8	45	84	7,936	1,698
mac	27.6.a	2016	6	15	56	94	8,689	2,293
mac	27.6.a	2017	10	25	156	264	28,287	4,861
mac	27.6.a	2018	16	31	238	393	18,005	7,804
mac	27.6.a	2019	12	35	251	416	20,689	8,509
mac	27.7.b	2015	2	4	19	34	810	79
mac	27.7.b	2016	5	7	35	68	185	66
mac	27.7.b	2017	6	9	51	98	3,639	276
mac	27.7.b	2018	6	9	33	51	1,111	37
mac	27.7.b	2019	12	22	73	124	5,364	2,024
mac	27.7.c	2015	2	4	14	25	512	0
mac	27.7.c	2016	1	1	3	3	0	0
mac	27.7.c	2017	3	3	5	7	0	9
mac	27.7.c	2019	3	3	4	4	54	34
mac	27.7.d	2015	4	7	12	15	64	165
mac	27.7.d	2016	5	14	36	56	695	267
mac	27.7.d	2017	6	14	30	42	368	117
mac	27.7.d	2018	8	11	38	60	432	304
mac	27.7.d	2019	2	3	4	5	51	693
mac	27.7.e	2015	3	3	7	10	36	128
mac	27.7.e	2016	3	5	13	20	211	13
mac	27.7.e	2017	3	6	7	10	118	0
mac	27.7.e	2018	3	6	7	8	69	0
mac	27.7.e	2019	2	3	4	4	4	153
mac	27.7.f	2015	1	1	1	1	0	0
mac	27.7.f	2018	1	1	1	1	0	0
mac	27.7.g	2015	1	1	2	7	0	0
mac	27.7.g	2018	1	2	5	8	21	0
mac	27.7.h	2017	1	1	1	1	0	0
mac	27.7.h	2018	4	4	7	8	235	3

mac	27.7.h	2019	1	1	2	2	242	8
mac	27.7.j	2015	4	7	33	69	763	686
mac	27.7.j	2016	3	6	20	29	1,413	61
mac	27.7.j	2017	3	4	6	11	495	170
mac	27.7.j	2018	8	11	27	39	2,661	314
mac	27.7.j	2019	8	11	47	89	2,348	2,112
mac	27.7.k	2015	3	3	10	18	18	0
mac	27.7.k	2019	1	1	1	1	0	0
mac	27.8.a	2015	1	1	2	3	0	0
mac	27.8.a	2016	1	1	1	1	33	0
mac	27.8.a	2018	3	3	18	21	1,509	428
mac	27.8.a	2019	3	3	12	16	887	702
mac	27.8.b	2018	2	2	3	4	364	211
mac	27.8.b	2019	1	1	1	1	0	270
mac	27.8.d	2017	1	1	1	1	253	0
mac	27.8.d	2018	2	2	2	2	233	319
mac	(all)	2015		56	247	473	26,814	9,218
mac	(all)	2016		81	325	554	34,833	7,159
mac	(all)	2017		104	492	889	64,593	12,578
mac	(all)	2018		134	700	1,191	59,013	16,061
mac	(all)	2019		98	493	858	38,834	19,899
mac	(all)	(all)		473	2,257	3,965	224,087	64,915

Table 3.2.1: Mackerel self-sampling summary in widely distributed pelagic fisheries with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). Top: by year. Bottom: by year and division.

Mackerel catch by rectangle

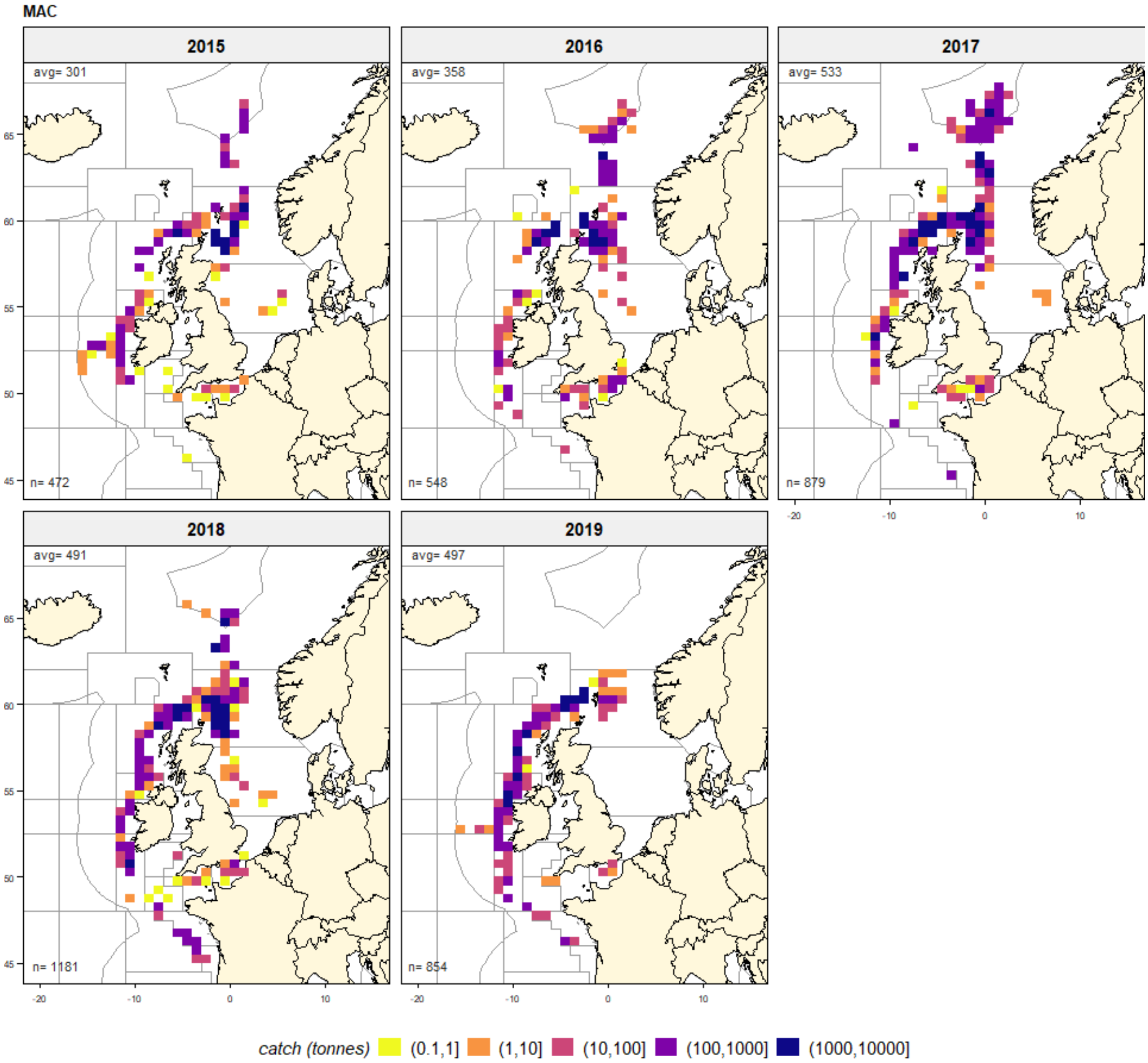
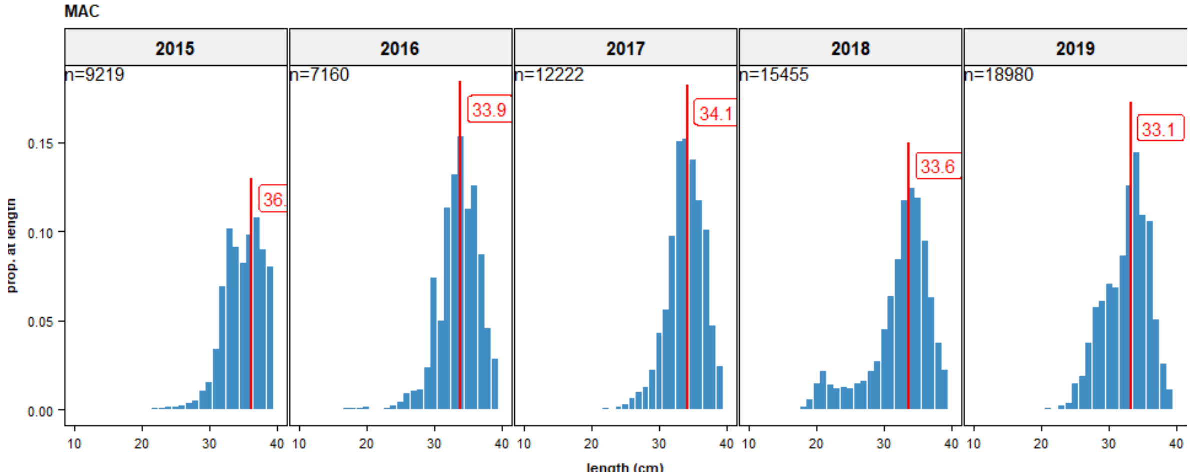


Figure 3.2.1: Mackerel catch per per square in PFA self-sampled widely distributed pelagic fisheries

Mackerel length distributions



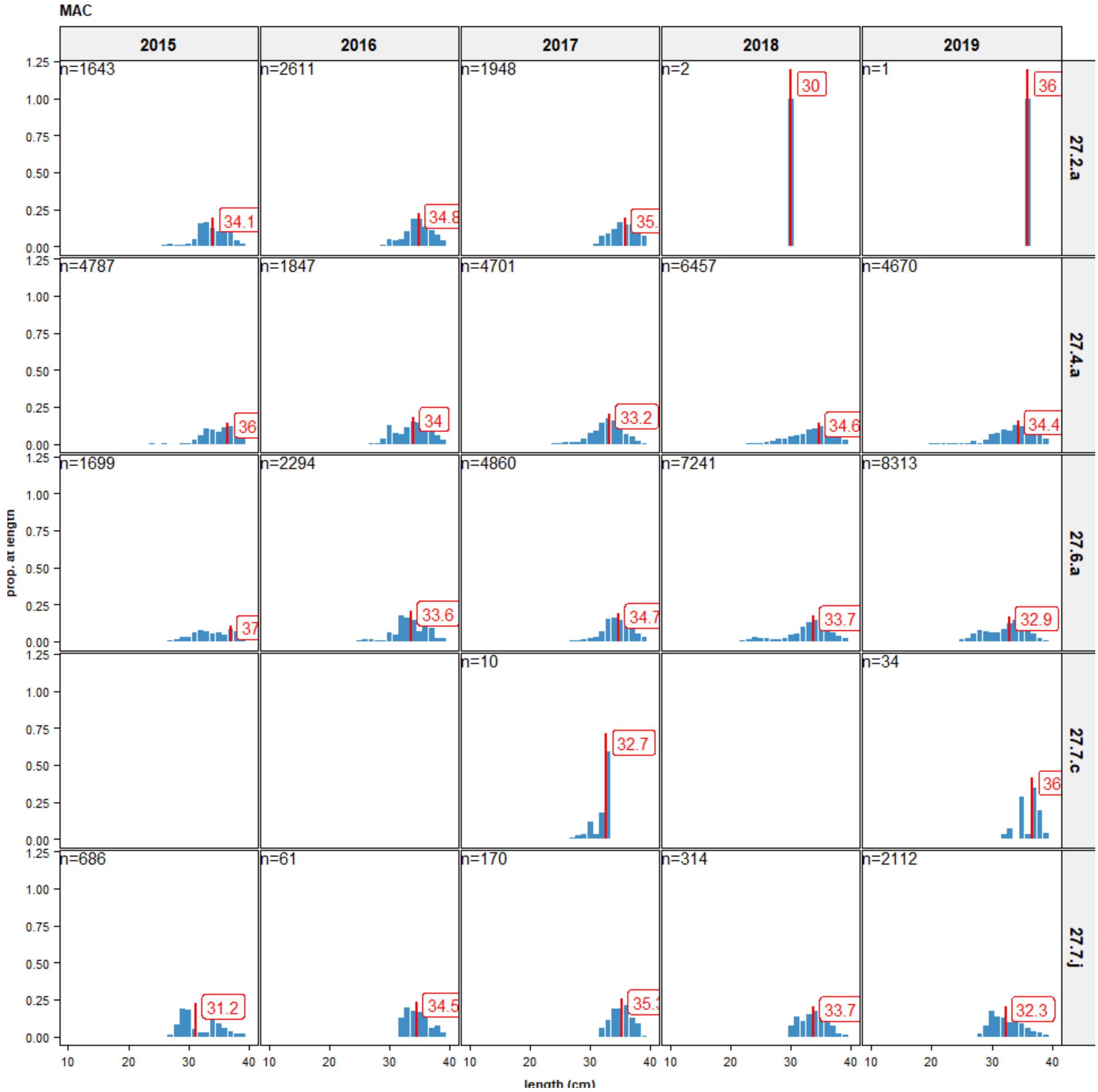


Figure 3.2.2: Mackerel length distributions by year (top) and by year and division (bottom) in PFA self-sampled widely distributed pelagic fisheries

Mackerel fishing depth

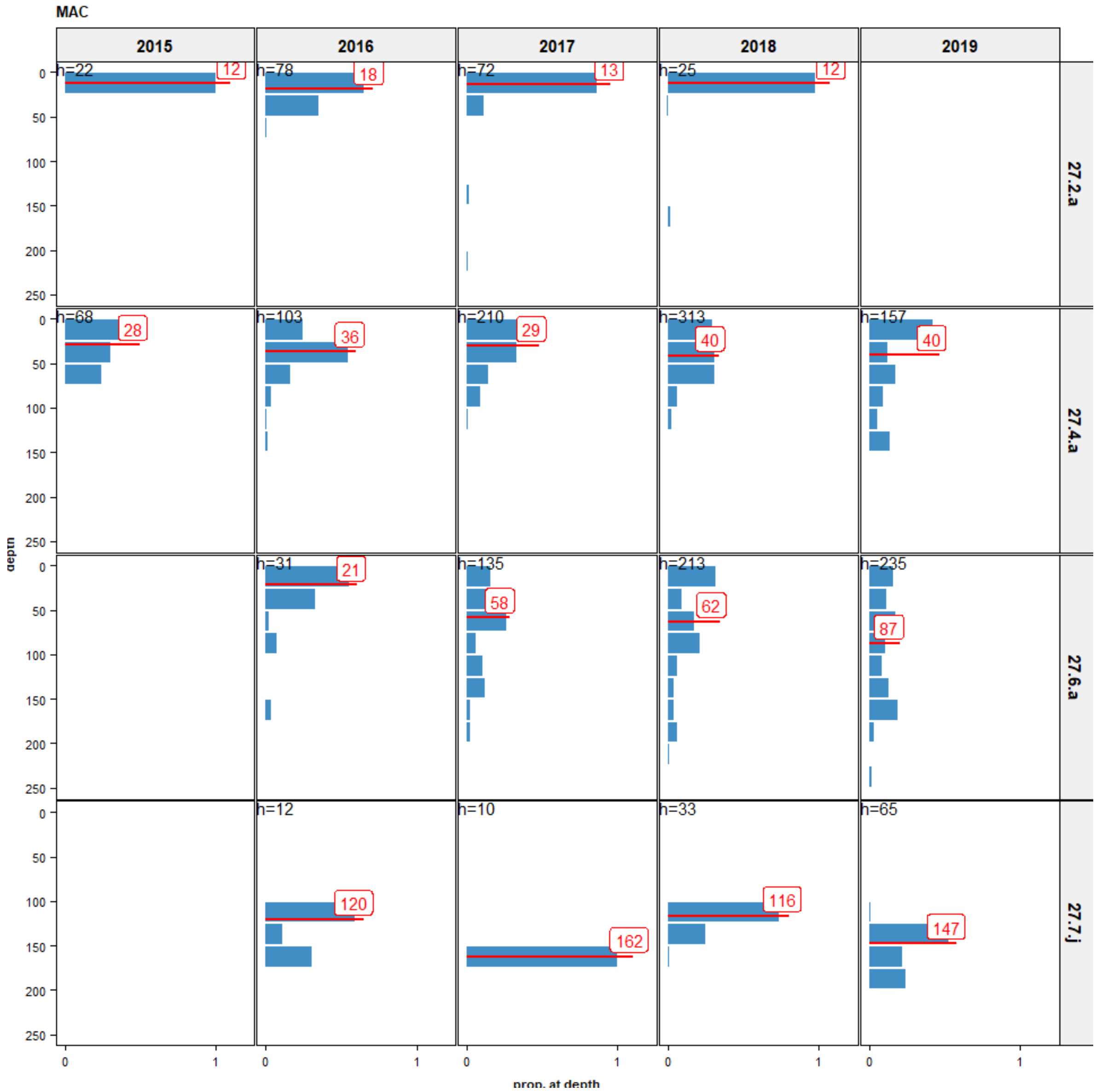


Figure 3.2.3: Mackerel depth distribution of catches by year and division in PFA self-sampled widely distributed pelagic fisheries. Median depth indicated in red. Number of hauls in black.

3.3 Horse mackerel (Trachurus trachurus)

species	year	nvessels	ntrips	ndays	nhauls	catch	catch/trip	catch/day

hom	2015	6	21	163	312	10,638	506	65
hom	2016	9	43	304	550	23,074	536	75
hom	2017	10	41	285	535	21,384	521	75
hom	2018	14	48	374	656	30,280	630	80
hom	2019	14	44	394	699	27,695	629	70
hom	(all)	.	197	1,520	2,752	113,071	.	.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	nlength
hom	27.2.a	2016	1	1	6	19	0	0
hom	27.4.a	2015	4	5	7	10	7	85
hom	27.4.a	2016	6	6	21	28	115	52
hom	27.4.a	2017	5	5	10	12	30	5
hom	27.4.a	2018	4	4	11	18	5	69
hom	27.4.a	2019	5	5	22	33	36	85
hom	27.4.c	2015	1	2	2	2	110	0
hom	27.4.c	2016	1	1	1	1	0	0
hom	27.4.c	2017	2	3	10	18	1,370	0
hom	27.4.c	2018	2	3	7	9	853	451
hom	27.6.a	2015	3	6	39	66	2,745	2,233
hom	27.6.a	2016	6	16	92	152	4,750	3,994
hom	27.6.a	2017	8	13	82	159	5,302	4,337
hom	27.6.a	2018	13	23	125	235	11,983	12,014
hom	27.6.a	2019	10	23	154	262	10,676	4,876
hom	27.7.b	2015	4	6	27	48	1,482	563
hom	27.7.b	2016	5	7	45	89	4,301	2,043
hom	27.7.b	2017	6	12	57	104	4,728	3,459
hom	27.7.b	2018	9	11	39	60	2,273	1,663
hom	27.7.b	2019	11	23	77	127	4,220	2,600
hom	27.7.c	2015	2	3	12	23	350	136
hom	27.7.c	2016	4	4	18	35	2,067	878
hom	27.7.c	2017	6	8	19	28	612	999
hom	27.7.c	2019	4	4	5	5	133	62
hom	27.7.d	2015	4	6	32	52	2,063	3,864
hom	27.7.d	2016	5	16	77	131	7,225	6,313
hom	27.7.d	2017	7	19	84	154	7,339	1,016
hom	27.7.d	2018	6	14	73	141	6,289	3,898
hom	27.7.d	2019	3	4	13	17	1,380	913
hom	27.7.e	2015	5	7	10	15	328	258
hom	27.7.e	2016	5	9	18	22	217	80
hom	27.7.e	2017	3	6	8	13	368	0
hom	27.7.e	2018	4	5	13	18	394	0
hom	27.7.e	2019	6	9	29	61	3,849	6,672
hom	27.7.f	2015	1	1	2	2	50	0
hom	27.7.f	2018	2	2	4	4	276	0
hom	27.7.g	2015	1	1	1	1	0	0
hom	27.7.g	2018	1	1	4	7	401	77
hom	27.7.h	2016	1	1	8	16	1,297	5,043
hom	27.7.h	2017	2	4	17	29	1,326	0
hom	27.7.h	2018	9	13	50	89	6,311	7,804
hom	27.7.h	2019	6	6	13	21	983	2,663
hom	27.7.j	2015	4	6	35	79	3,081	4,595
hom	27.7.j	2016	4	8	29	55	3,091	709
hom	27.7.j	2017	3	5	7	13	159	463
hom	27.7.j	2018	7	10	31	46	813	519
hom	27.7.j	2019	10	14	58	110	4,871	1,617
hom	27.7.k	2015	2	2	2	3	104	390
hom	27.7.k	2017	2	2	3	3	94	101
hom	27.7.k	2019	1	1	1	1	0	0
hom	27.8.a	2015	1	1	3	10	313	0
hom	27.8.a	2016	2	2	2	2	7	0
hom	27.8.a	2017	1	1	1	1	30	0
hom	27.8.a	2018	3	3	19	25	670	0

hom	27.8.a	2019	5	9	36	57	1,527	341
hom	27.8.b	2015	1	1	1	1	0	0
hom	27.8.b	2018	1	1	2	3	2	0
hom	27.8.b	2019	1	1	2	2	4	0
hom	27.8.d	2017	1	1	1	1	21	0
hom	27.8.d	2018	1	1	1	1	3	0
hom	27.8.d	2019	1	1	2	3	9	56
hom	(all)	2015		47	173	312	10,633	12,124
hom	(all)	2016		71	317	550	23,070	19,112
hom	(all)	2017		79	299	535	21,379	10,380
hom	(all)	2018		91	379	656	30,273	26,495
hom	(all)	2019		100	412	699	27,688	19,885
hom	(all)	(all)		388	1,580	2,752	113,043	87,996

Table 3.3.1: Horse mackerel self-sampling summary in widely distributed pelagic fisheries with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). Top: by year. Bottom: by year and division.

Horse mackerel catch by rectangle

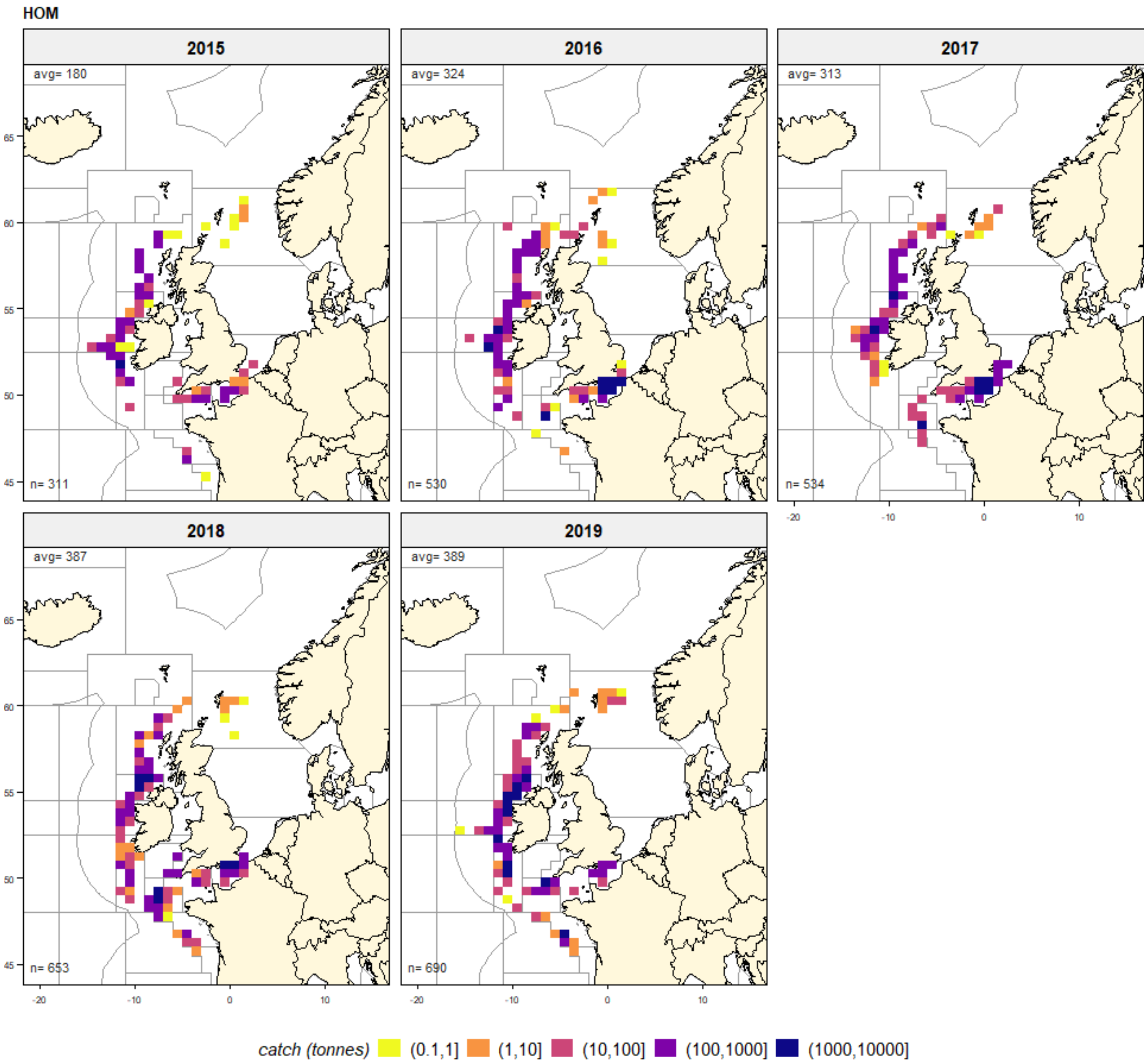
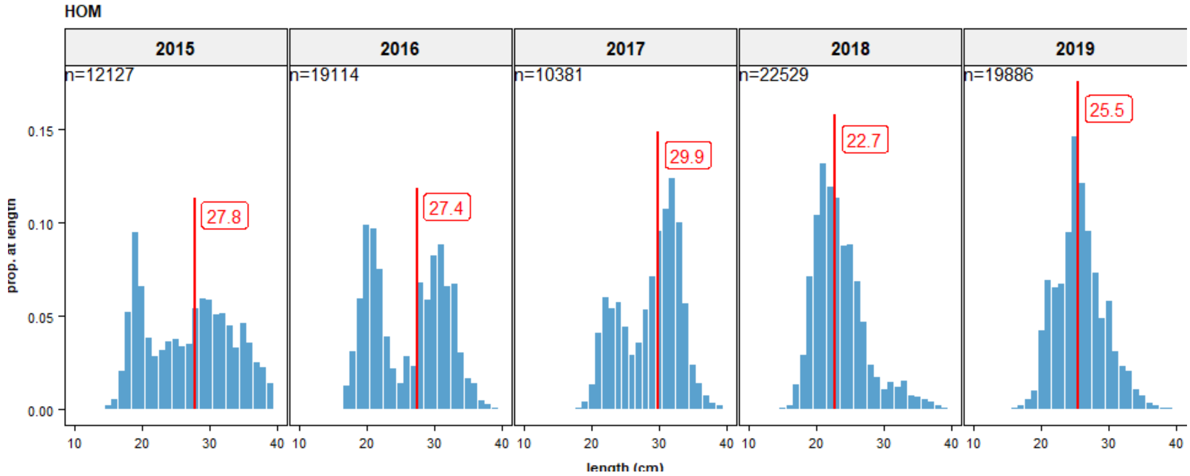


Figure 3.3.1: Horse mackerel catch per per square in PFA self-sampled widely distributed pelagic fisheries

Horse mackerel length distributions



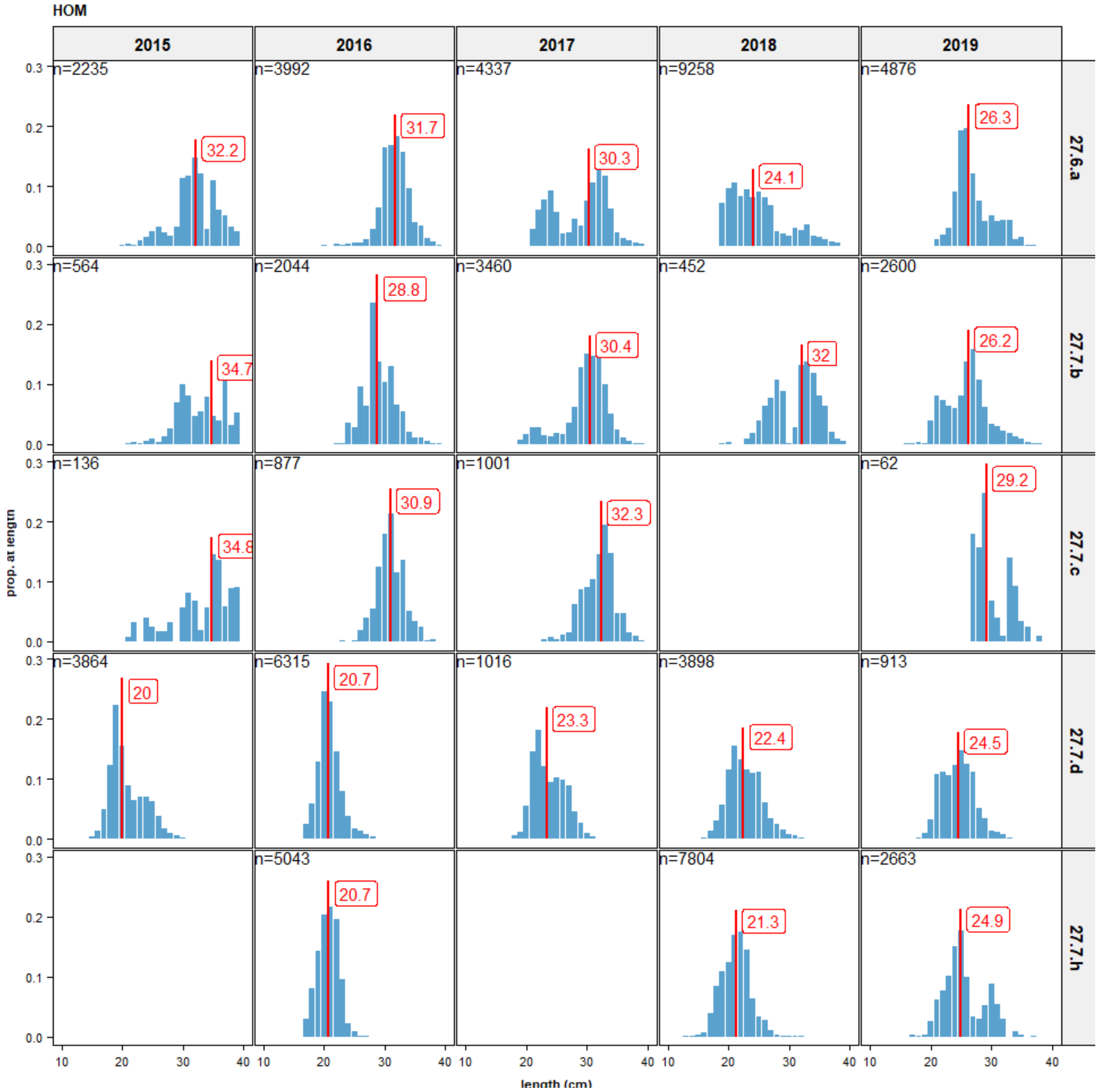


Figure 3.3.2: Horse mackerel length distributions by year (top) and by year and division (bottom) in PFA self-sampled widely distributed pelagic fisheries

Horse mackerel fishing depth

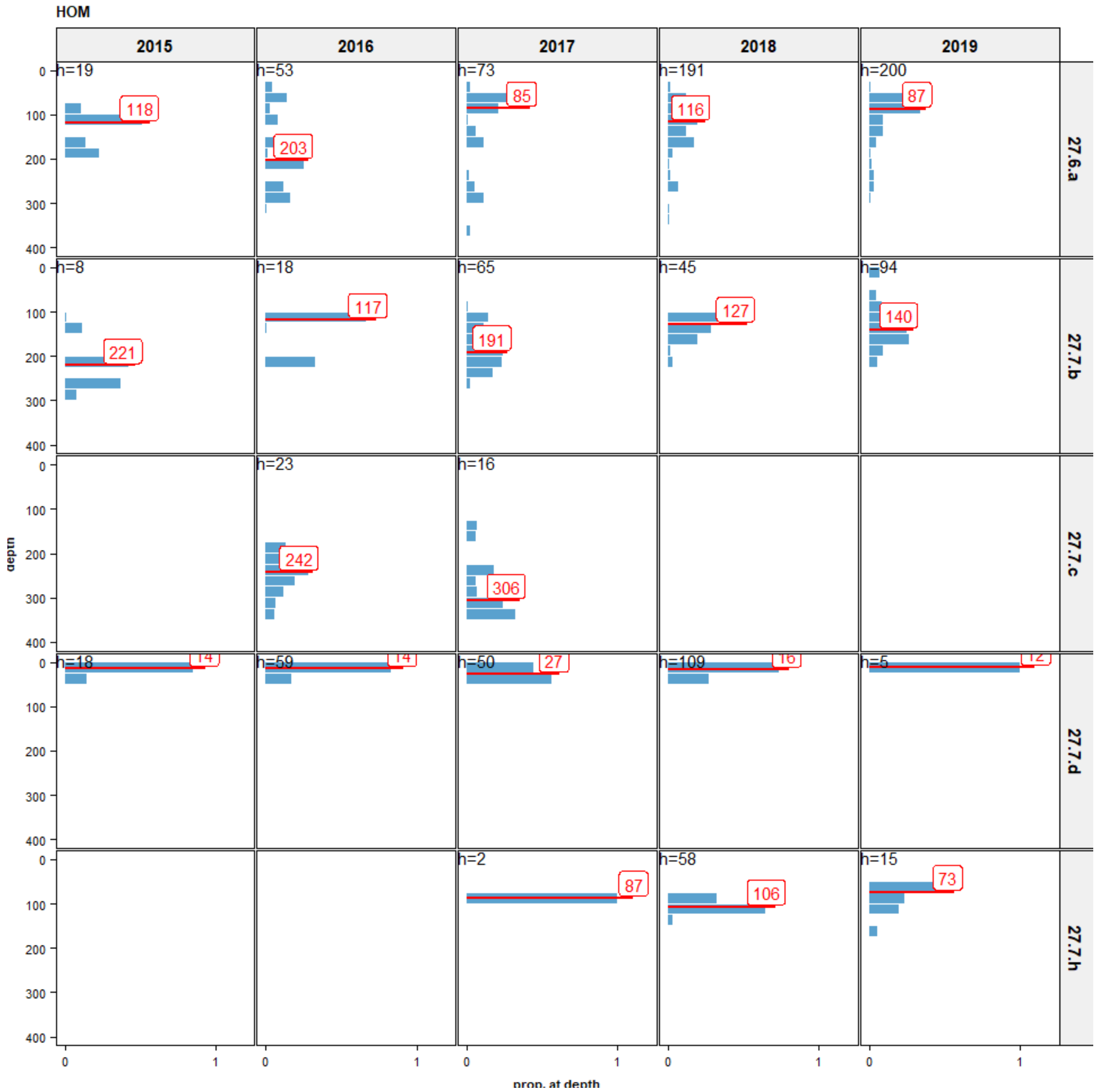


Figure 3.3.3: Horse mackerel depth distribution of catches by year and division in PFA self-sampled widely distributed pelagic fisheries. Median depth indicated in red. Number of hauls in black.

3.4 Blue whiting (Micromesistius poutassou)

species	year	nvessels	ntrips	ndays	nhauls	catch	catch/trip	catch/day
whb	2015	5	18	147	305	15,545	863	105
whb	2016	9	24	252	578	49,411	2,058	196
whb	2017	8	34	386	840	78,792	2,317	204
whb	2018	15	49	610	1,525	162,405	3,314	266
whb	2019	13	41	413	969	87,871	2,143	212
whb	(all)	.	166	1,808	4,217	394,024	.	.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	nlength
whb	27.2.a	2015	3	3	11	20	96	573
whb	27.2.a	2016	6	6	32	62	2,345	1,369
whb	27.2.a	2017	5	9	56	92	2,587	2,597
whb	27.2.a	2018	6	8	91	158	12,032	12,352
whb	27.2.a	2019	1	1	1	1	14	77
whb	27.4.a	2015	1	1	1	1	0	0
whb	27.4.a	2016	4	5	35	73	7,791	6,614
whb	27.4.a	2017	2	2	5	7	726	352
whb	27.4.a	2018	9	10	27	55	2,946	6,359
whb	27.4.a	2019	5	5	24	45	1,829	3,585
whb	27.5.b	2015	2	3	20	28	1,872	9,970
whb	27.5.b	2016	3	4	29	57	5,577	4,685
whb	27.5.b	2017	5	6	40	64	7,959	8,226
whb	27.5.b	2018	5	7	52	82	7,927	4,560
whb	27.5.b	2019	1	1	1	1	68	84
whb	27.6.a	2015	3	7	55	127	7,376	15,149
whb	27.6.a	2016	4	11	93	210	20,327	12,244
whb	27.6.a	2017	7	16	163	378	39,084	36,330
whb	27.6.a	2018	12	29	338	861	91,577	72,775
whb	27.6.a	2019	12	25	238	581	55,600	25,450
whb	27.6.b	2017	1	1	2	2	158	0
whb	27.6.b	2018	6	6	22	49	7,634	3,211
whb	27.6.b	2019	3	3	6	10	604	69
whb	27.7.b	2015	2	4	9	12	115	0
whb	27.7.b	2016	3	3	14	21	27	0
whb	27.7.b	2017	5	6	31	57	51	86
whb	27.7.b	2018	3	3	6	11	1,941	531
whb	27.7.b	2019	10	11	17	29	813	1,768
whb	27.7.c	2015	2	4	13	22	888	0
whb	27.7.c	2016	4	8	37	66	5,471	5,358
whb	27.7.c	2017	6	10	96	230	28,219	16,945
whb	27.7.c	2018	6	9	76	235	30,575	21,392
whb	27.7.c	2019	10	16	99	246	26,403	10,726
whb	27.7.d	2017	1	1	2	3	0	0
whb	27.7.e	2015	1	1	1	1	0	0
whb	27.7.f	2015	1	1	1	1	152	0
whb	27.7.g	2015	1	1	1	1	5	0
whb	27.7.j	2015	4	6	21	36	64	0
whb	27.7.j	2016	3	4	6	11	376	0
whb	27.7.j	2017	2	2	4	7	4	139
whb	27.7.j	2018	5	5	10	12	123	174
whb	27.7.j	2019	6	7	20	25	132	35
whb	27.7.k	2015	3	3	24	56	4,972	8,784
whb	27.7.k	2016	3	3	29	77	7,488	4,845
whb	27.7.k	2018	3	3	20	59	7,645	3,077
whb	27.7.k	2019	4	4	11	17	2,025	401
whb	27.8.a	2018	1	1	2	3	1	0

whb	27.8.a	2019	3	3	8	12	284	1,305
whb	27.8.b	2019	1	1	2	2	93	0
whb	27.8.d	2016	1	1	1	1	6	0
whb	(all)	2015		34	157	305	15,540	34,476
whb	(all)	2016		45	276	578	49,408	35,115
whb	(all)	2017		53	399	840	78,788	64,675
whb	(all)	2018		81	644	1,525	162,401	124,431
whb	(all)	2019		77	427	969	87,865	43,500
whb	(all)	(all)		290	1,903	4,217	394,002	302,197

Table 3.4.1: Blue whiting self-sampling summary in widely distributed pelagic fisheries with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). Top: by year. Bottom: by year and division.

Blue whiting catch by rectangle

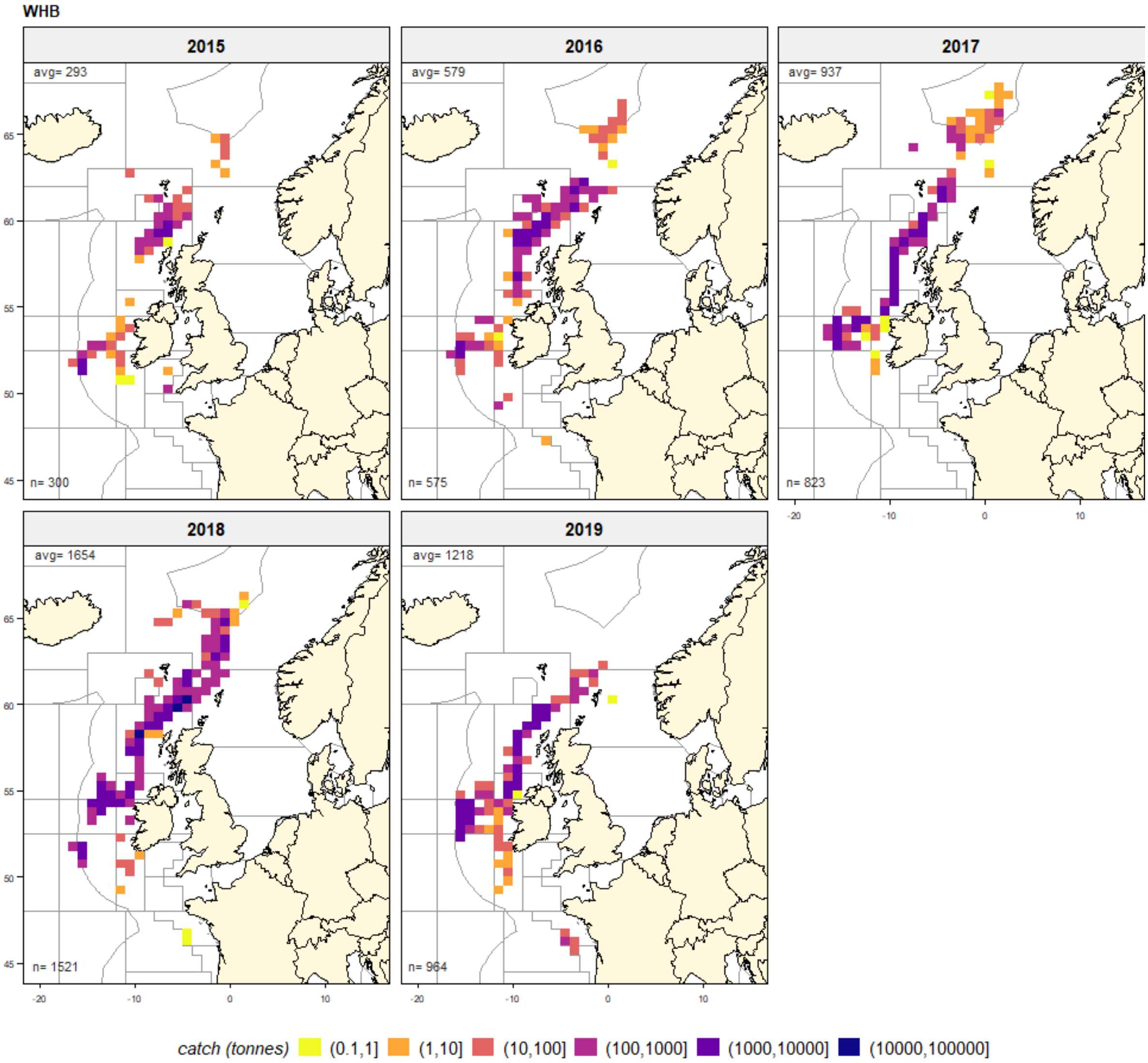
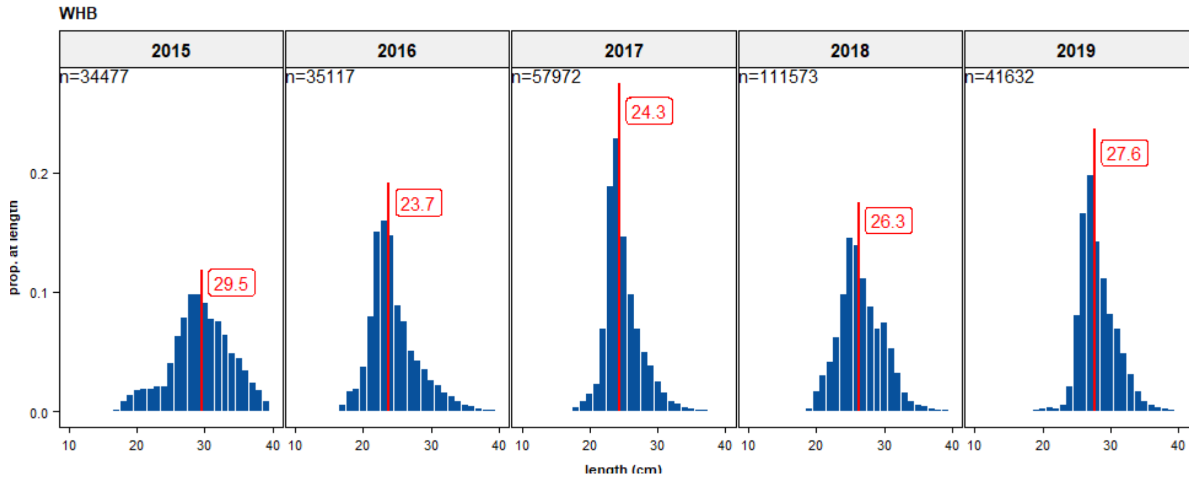


Figure 3.4.1: Blue whiting catch per per square in PFA self-sampled widely distributed pelagic fisheries

Blue whiting length distributions



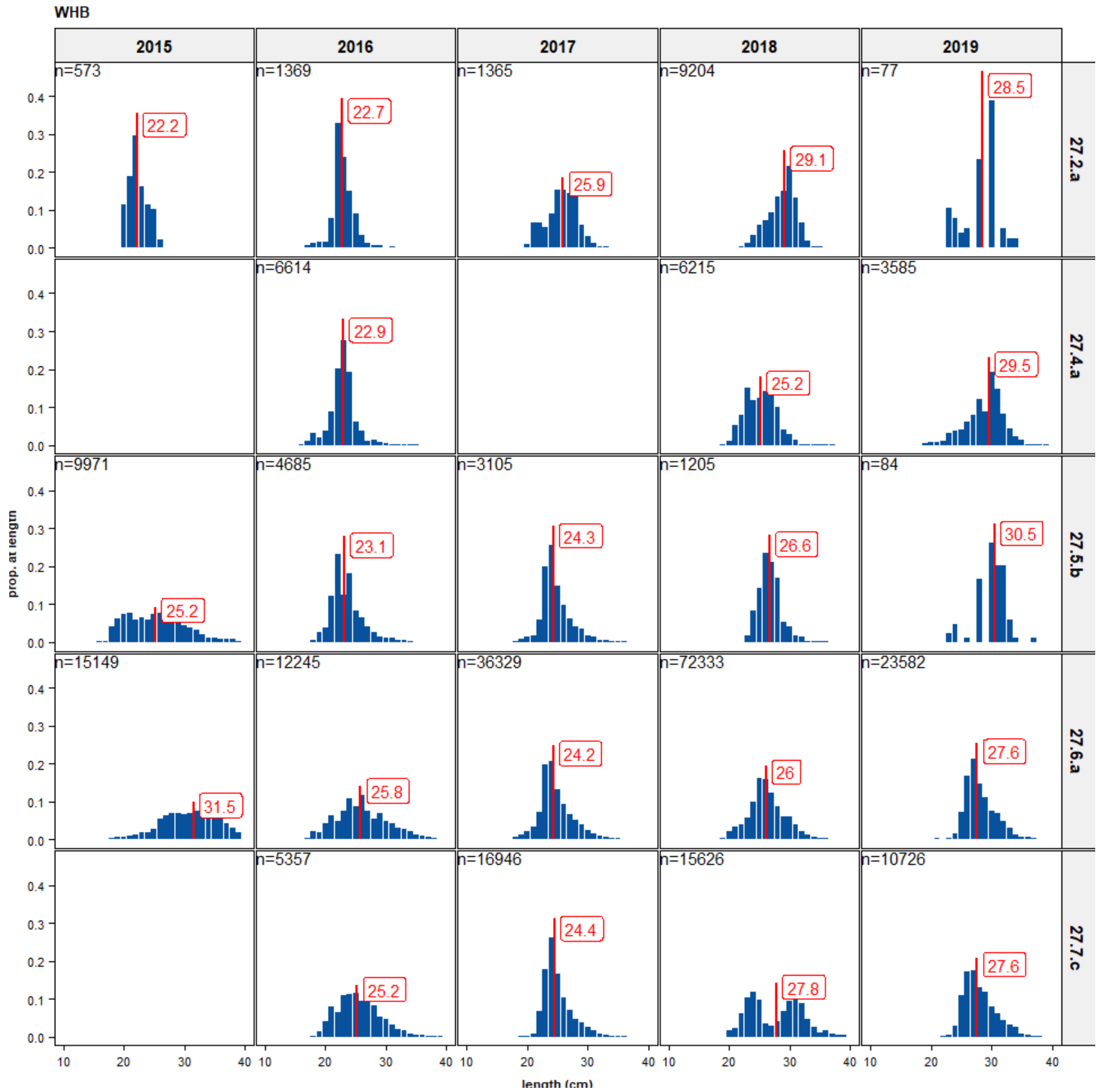


Figure 3.4.2: Blue whiting length distributions by year (top) and by year and division (bottom) in PFA self-sampled widely distributed pelagic fisheries

Blue whiting fishing depth

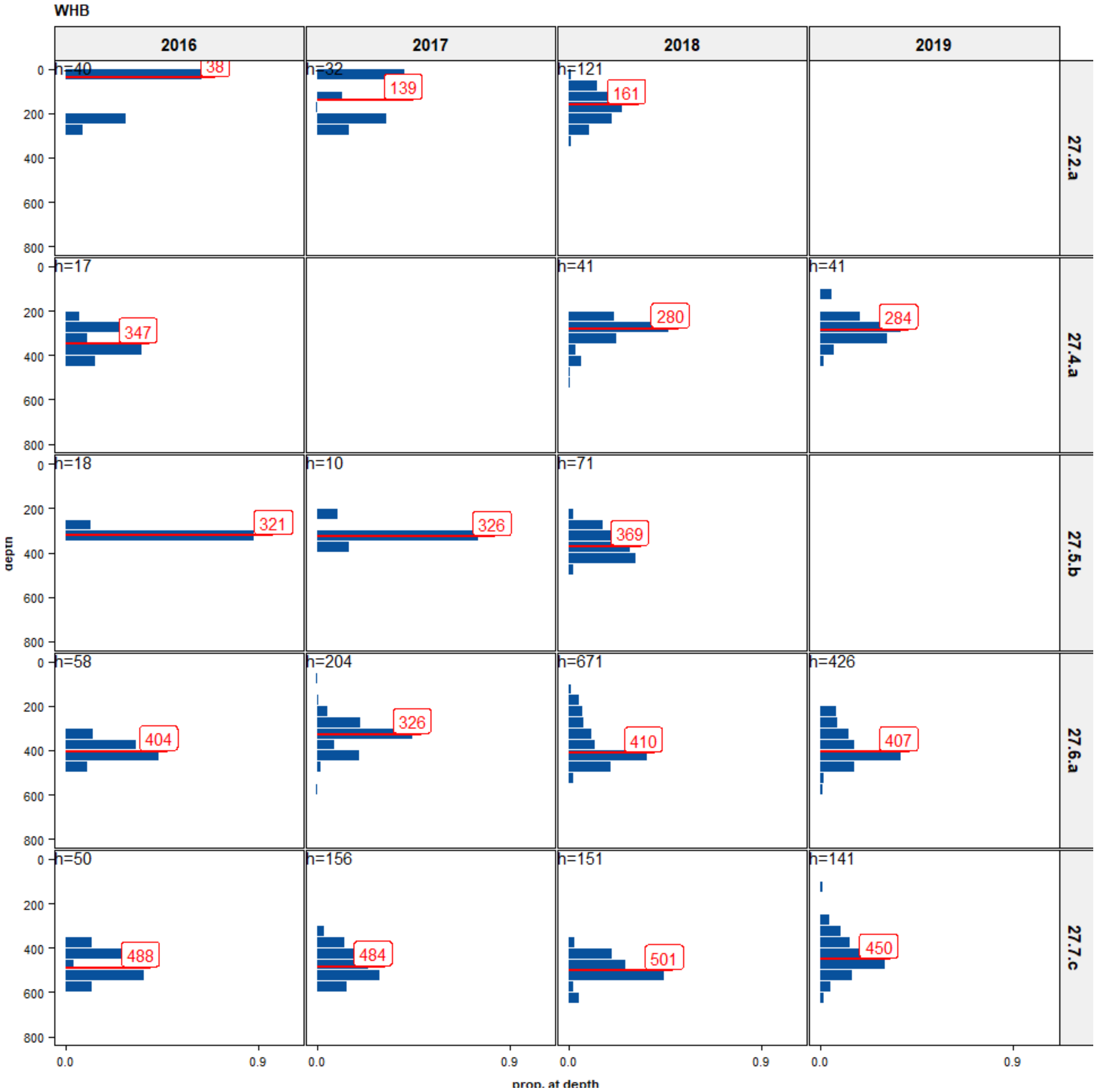


Figure 3.4.3: Blue whiting depth distribution of catches by year and division in PFA self-sampled widely distributed pelagic fisheries. Median depth indicated in red. Number of hauls in black.

3.5 Herring (Clupea harengus)

Here we selected only hauls north of 62 degrees, to get the catches of Atlanto-scandian herring. Therefore this gives another impression that the earlier catch tables in which some North Sea herring may have been included south of 62 degrees.

species	year	nvessels	ntrips	ndays	nhauls	catch	catch/trip	catch/day
her	2015	2	2	9	18	1,369	684	152
her	2016	6	7	40	85	3,362	480	84
her	2017	4	7	42	83	7,950	1,135	189
her	2018	4	5	36	68	5,277	1,055	146
her	(all)	.	21	127	254	17,958	.	.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	nlength
her	27.2.a	2015	2	2	9	18	1,369	1,260
her	27.2.a	2016	6	7	40	85	3,362	1,206
her	27.2.a	2017	4	7	42	83	7,950	2,210
her	27.2.a	2018	4	5	36	68	5,277	490
her	other	2015	5	16	105	234	17,379	23,821
her	other	2016	9	31	137	335	32,243	13,429
her	other	2017	10	35	165	398	30,543	11,878
her	other	2018	13	53	285	685	55,064	25,506
her	other	2019	8	17	72	169	14,731	5,399
her	(all)	2015		18	114	252	18,748	25,081
her	(all)	2016		38	177	420	35,605	14,635
her	(all)	2017		42	207	481	38,493	14,088
her	(all)	2018		58	321	753	60,341	25,996
her	(all)	2019		17	72	169	14,731	5,399
her	(all)	(all)		173	891	2,075	167,918	85,199

Table 3.5.1: Herring self-sampling summary in widely distributed pelagic fisheries with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort). Top: by year. Bottom: by year and division.

Herring catch by rectangle

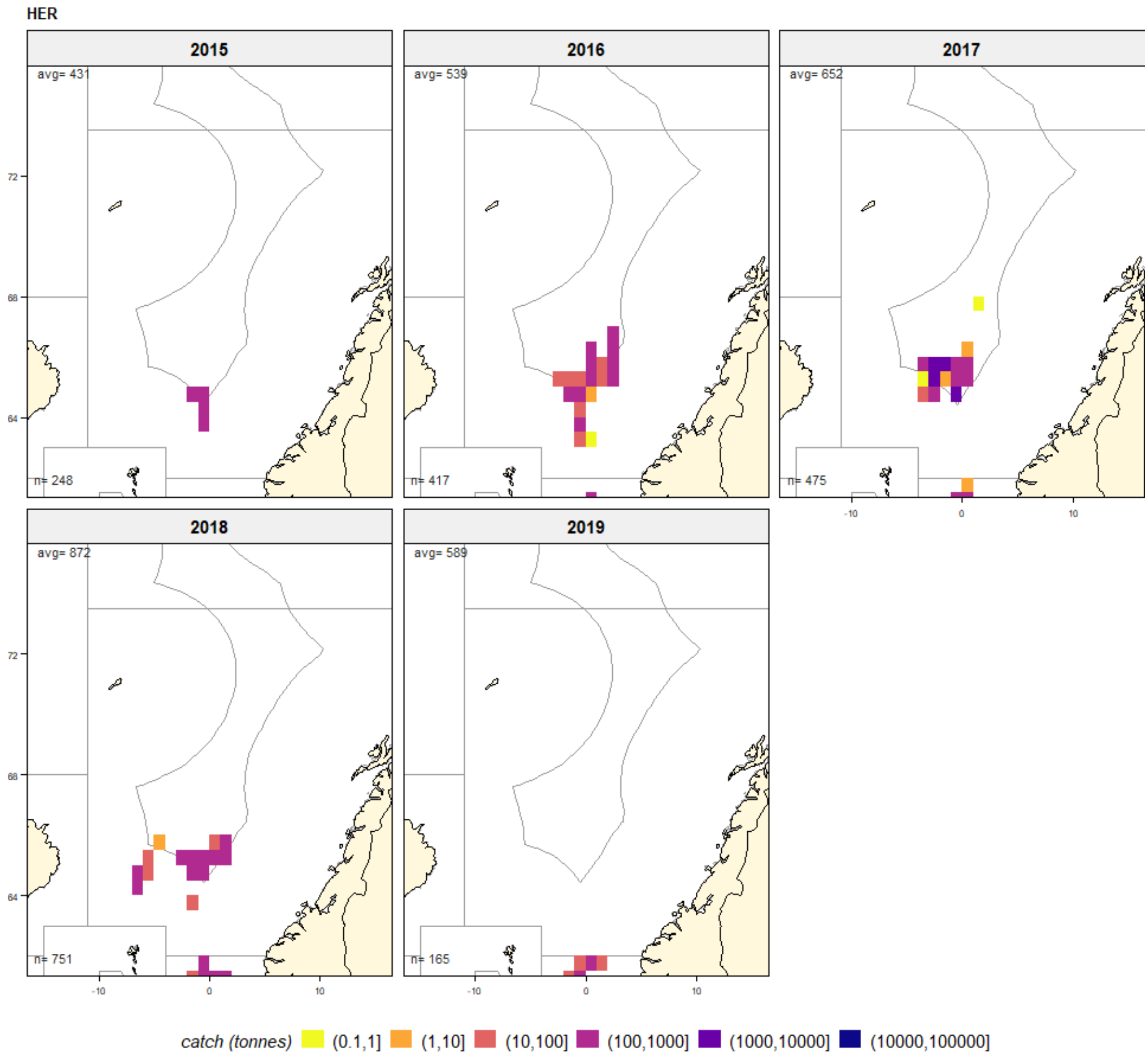


Figure 3.5.1: Herring catch per per square in PFA self-sampled widely distributed pelagic fisheries

Herring length distributions (27.2.a only)

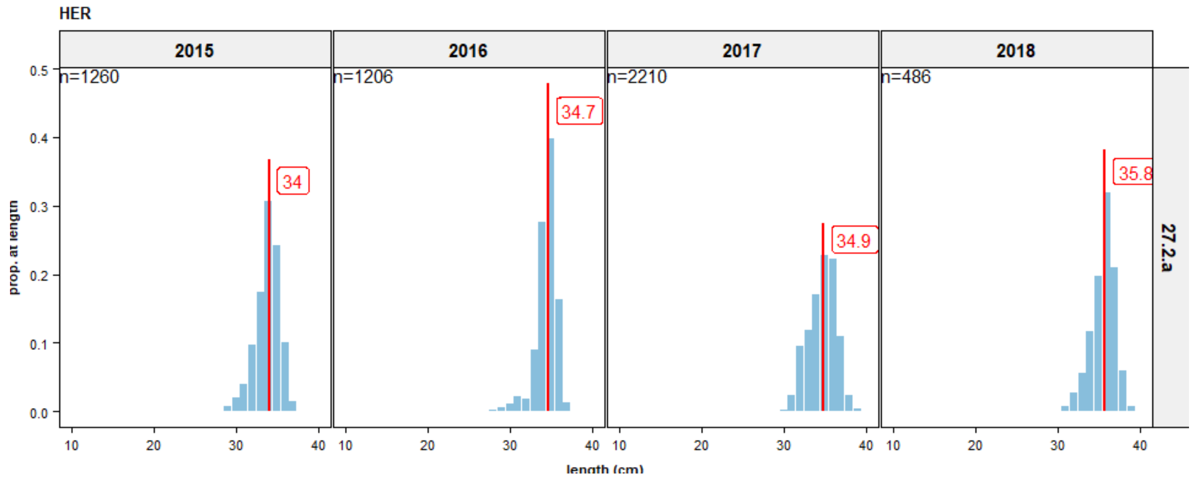


Figure 3.5.2: Herring length distributions by year (top) and by year and division (bottom) in PFA self-sampled widely distributed pelagic fisheries

Herring fishing depth

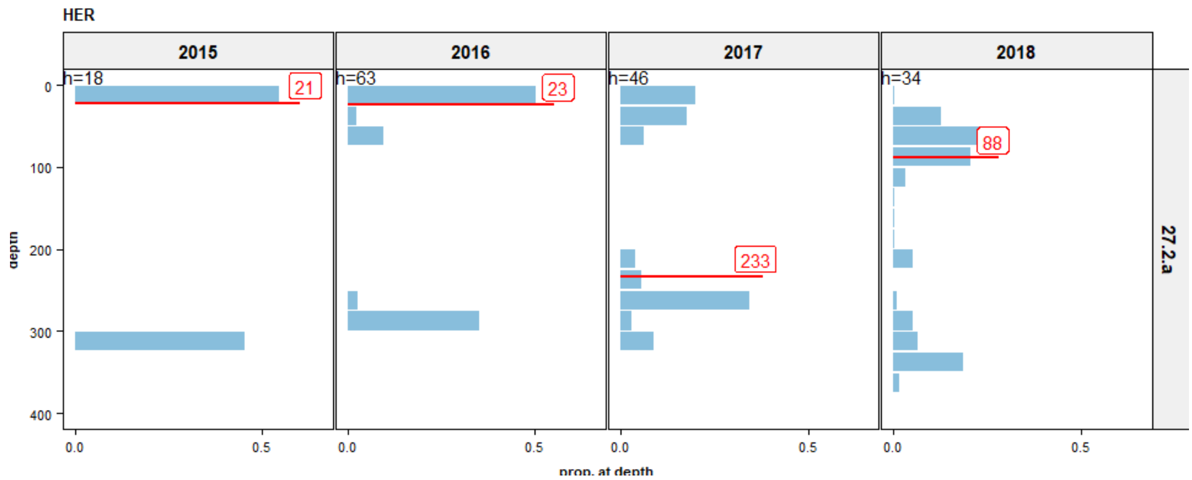


Figure 3.5.3: Herring depth distribution of catches by year and division in PFA self-sampled widely distributed pelagic fisheries. Median depth indicated in red. Number of hauls in black.

4 Discussion and conclusions

The definition of what constitutes 'a fishery' for a certain species is not well specified. In this report we selected all combination of vessel-trip-week where hauls were taken in a certain area and where the catch composition consisted of a minimum percentage of certain species and a minimum catch of 10 tons. Although for herring we aimed to select only trips for Atlanto-scandian herring (in division 27.2.a) some trips with North Sea herring will probably also have been included.

5 Acknowledgements

The skippers, officers and the quality managers of many of the PFA vessels have put in a lot of effort to make the PFA the self-sampling work. Without their efforts, there would be no self-sampling.

6 More information

Please contact Martin Pastoors (mpastoors@pelagicfish.eu) if you would have any questions on the PFA self-sampling programme or the specific results presented here. Detailed length compositions (e.g. CSV files) can also be made available on request.

Evaluation of Current and Alternative Harvest Control Rules for Blue Whiting Management using Hindcasting

A report commissioned by the Pelagic Advisory Council

L.T. Kell, P. Levontin

20 August 2019

[Sea++](Sea++)

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Executive summary

The Pelagic Advisory Council commissioned Laurie Kell and Polina Levontin of Sea++ to carry out a hindcast evaluation for blue whiting to assess the potential implications that different types of harvest control rules would have had given the observed dynamics of the stock. Managing the blue whiting stock has two major challenges: 1) shifts between different recruitment regimes, and 2) unstable assessments because of strong year-to-year variations in survey results.

A simulation framework was developed in R using FLR (Kell, et al., 2007) designed to build simulation models representing alternative hypotheses about stock and fishery dynamics. Code is available on the GitHub repository

An Operating Model (OM) was developed to run simulations of the stock under the different HCRs. The OM was conditioned on the current ICES stock assessment (ICES. 2018). A Beverton and Holt stock recruitment relationship with a steepness of 0.9 was assumed so that simulated recruitments were similar to those observed historically but if the stock crashed recruitment would also be impaired.

Two HRCs were implemented and simulation tested, namely

- HCR-I: The Standard ICES MSY rule using an Fmsy= 0.32 and an MSYBtrigger of 2.25 Mt
- HCR=II: The two-tier approach with the following parameters:
  - A lower bound of Fmin= 0.05 below Blim = 1.5 Mt;
  - A linear sliding scale with slope a1 =2.0 starting at B lim and ending at B1 Trigger = 2.25 Mt;
  - A standard level between Trigger B1 and Trigger B2 at F 0.1 =0.22;
  - A linear sliding scale with slope a2 =2.0 above B2 Trigger where B2 Trigger is 4.0 Mt;
  - An upper bound at higher stock sizes at F MSY =0.32

Both scenarios were executed with and without a stability mechanism of 20% down and 25% up when the stock is assessed to be above MSY Btrigger. Simulations start in the initial year (2000) and then the stock is projected forward using either of the two alternative HCRs and with or without bounding the variability in TACs. Uncertainty in stock assessments was taken at 0.3, derived from the retrospective analysis of the SAM assessment

Overall, the two-tier HCR (II) performed similar to the standard HCR (I), the main difference is the additional level of safety provided by HCR II which reduced F and catch at low biomass, i.e. in 2010-2015.

On the other hand, introducing bounds on the amount of change in TACs if the stock is above MSY Btrigger did lead to stock collapses, as the large reductions in stock biomass seen were driven by recruitment and the bounds resulted in F not being reduced quickly enough. In addition, the bounds prevented the TAC from being increased as the stock recovered. A

deterministic example of the working of the TAC bounds, showed that in 2010 the stock was still estimated above MSY Btrigger and therefore the bound on TAC decrease still applied. This resulted in a high fishing mortality for that year. The next year, the stock was below MSY Btrigger, so the bounds did no longer apply and the TAC was reduced substantially. In 2012 the stock was again above MSY Btrigger but because the bounds applied again, the catches remained low for a number of years. This demonstrates that the use of bounds in mitigating changes in TACs may have counter-intuitive and unwanted consequenses.

The simulations only considered historical conditions to ensure that a HCR is robust in practice, i.e. after implementation it will be necessary to simulate a range of hypotheses, e.g. about stock and recruitment and the relative importance of fishing versus environment on resource dynamics.

Introduction

A long-term management strategy was agreed for the North East Atlantic blue whiting stock by the European Union, the Faroe Islands, Iceland, and Norway in 2016 (Anon, 2016). ICES has evaluated the strategy and found it to be precautionary (ICES, 2016a). In addition the Pelagic Advisory Council (PELAC) has had a long involvement in the development of harvest control rules for blue whiting.

Managing the stock has two major challenges: namely 1) shifts between quite different recruitment regimes, and 2) unstable assessments because of strong year-to-year variations in survey results. The objective of this work is to carry out an evaluation of alternative harvest control rules (HCRs) that could have been applied to the blue whiting stock in the past in order to identify future management measures that are both precautionary and economically advantageous. Where a HCR determines the target F for setting a total allowable catch (TAC) based on an assessment of stock status and precautionary and limit reference points (Figure 1).

The HCRs are evaluated by conducting simulations using a hindcast with the most recent ICES stock assessment. In a hindcast the most recent years in the assessment are removed and the stock projected under a candidate HCR. The performance of the alternative HCRs can then be compared with the historical outcomes, allowing stakeholders to evaluate the relative performance of alternative HCRs for multiple management objectives.

During development of the simulation framework example results will be presented to stakeholders, following feedback on the procedure used, the relevance of the results and the analysis conducted the simulations and the report will be finalised.

Material and Methods

An Operating Model (OM) was developed to run simulations of the stock under the different HCRs. Where the OM is a mathematical model used to describe resource dynamics in simulation trials and was conditioned on the current ICES stock assessment (ICES. 2018). The assessment provides values for the assumed biological parameters (weights at age, natural mortality, and maturity-at-age), estimates of historical fishing mortality and numbers-at-age, and historical recruitment and selection patterns. Uncertainty in the historical estimates and starting conditions are generated from the stock assessment variance-covariance matrix.

Uncertainty

Recent applications for Marine Stewardship Certification for blue whiting[1] raised the usual questions about the reliability of the assessment, especially when it comes to estimation of SSB. These may stem from uncertainty about ageing and assumptions about stock structure. There is also concern that recruitment estimates, which depend on survey estimates, are strongly affected

1 https://fisheries.msc.org/en/fisheries/faroese-pelagic-organization-north-east-atlantic-blue-whiting/@@assessments

by observation error. It is also suggested that exploitation in recent decades may have contributed to recruitment variability as theoretical models predict that at higher exploitation levels boom and bust recruitment cycles are more common. The assessment therefore may only account for a limited number of sources of uncertainty, particularly since there are relatively large updates to the estimates of F and SSB as new data becomes available (Figure 2).

Previous HCR Evaluations

A number of HCRs have been evaluated for blue whiting. In 2012 Skagen (2012ab) evaluated HCRs for objectives related to economic viability and stability of catches while making sure that the risk to the stock is low, defined by the probability of falling below B_{lim} at least once over a period of 10 years during a 30 year simulation period. Simulations showed that a two tier HCR (figure 3) could achieve management objectives with the following parameters $B_{trigger1}$ = 4.0 million tonnes, $B_{trigger2}$ = 5.0 million tonnes, the fist slope in the HCR = 1.5 and the second = 4, while the maximum F is 0.12 or a TAC in the range of 400 - 500 thousand tonnes.

Following a request from NEAFC similar HCRs were evaluated (Figure 4) but with updated reference points. A Multistage HCR was shown to contribute to inter annual variability in catches. In this evaluation the maximum F was set to the new target of F_{MSY} = 0.3 and the first biomass trigger point was reduced to 2.35 million tonnes with the second trigger point at 4 million tonnes. This rule was found to be precautionary, even though it would not have been seen as ‘precautionary’ a year ago even though risk criteria had not changed.

Both exercises calculated the probability of falling below the same absolute threshold of B_{lim} of 1.5 million tonnes of biomass and the risk acceptance level was similar - less than 5% of falling below B_{lim} in simulations over a 10 year period.

Again the 2016 evaluation of HCRs identified variability in recruitment and the limitations in our ability to know the state of the stock at the time of making a decision due to imprecision in the assessments. The evaluations in 2016 used past advice uncertainty (i.e. by comparing the updated assessment and historical estimates) rather than model derived estimates to parametrise assessment error. This is particularly relevant to the two tier HCR, since in order to decide which segment of the rule is relevant one needs to know whether the stock is at a high or low productivity regime.

Even though a simple HCR with B_{lim}, $B_{trigger}$ and F_{MSY} (1.5 mt, 2.25 mt and 0.32) was found precautionary, a reviewer raised questions over the ICES definition of F_{MSY} and the simplified stock recruitment relationship used in the evaluation, alerting the Workshop on Blue Whiting Long Term Management Strategy Evaluation (WKBWMSE, ICES, 2016a) group to the possibility that this HCR may expose the stock to higher levels of risk than the modelling suggests. In particular, yield per recruit analysis suggests that F_{MSY} of 0.32 is at the upper limit of the estimated range, the lower limit is 0.19 and notes that the current precautionary management reference points (F_{pa} = 0.58) have greater than 5% chance of SSB falling below Blim.

The difficulty in estimating and modelling stock recruitment relationship was also noted, this has implications for reference points and MSE evaluation approach more generally. Given that modelling relies heavily on the assumption of stock recruitment relationship and that this relationship is the key unknown raises the question whether simulation exercises of this type are the right approach to help formulate a risk based management system.

Perception that recruitment is largely independent of biomass and henceforth for the most part fishing pressure makes it tempting to exploit the stock in adaptive ways, riding the waves of recruitment bounty. However, not being able to reliable tell whether one is at the top of the wave or the bottom makes such surfing a potentially precarious proposition not just for the stock but the fishery. There are associated costs of keeping a potential redundancy in the fishing capacity and adjusting to sudden expansion and downsizing of catch opportunities. Additionally, other economic and social concerns might be relevant too. Will the lack of stability inherent in a bimodal management strategy have impacts on employees in the fishery or the profitability of the industry through price fluctuations? Further, there seems to be little information on whether there are other species dependent on the boom and bust cycles of blue whiting and what dampening those cycles through fishing might cause in the wider ecosystem.

It was noted (ICES 2016a) 'The TAC advice for blue whiting has fluctuated significantly in recent years. Reductions of more than 90% have been followed by increases exceeding 800%. Such instability negatively affects the economic viability of fisheries targeting this stock (if the advice is implemented), and increases the scepticism amongst stakeholders about the scientific basis for the advice. The cause of this variability can be sourced to the large year effects in the acoustic survey estimates of abundance. This lack of precision in assessment, leading to highly variable advice, demands a management solution that counteracts this variability and dampens-down the between year fluctuations.'

Methods

An MSE framework was developed based on the ICES assessment. The OM was condition on the last assessment, an aged based state space analytical assessment (SAM; Berg and Nielsen, 2016) that uses catch-at-age for both the historical assessment and the forecast.
All coding was done in R using FLR (Kell, et al., 2007) designed to build simulation models representing alternative hypotheses about stock and fishery dynamics. Code will be made available on the GitHub repository and the stock assessment will be based on the blue whiting assessment at .

Harvest Control Rules

The two HRCs were implemented and simulation tested, namely

HCR-I: The Standard ICES MSY rule using an Fmsy= 0.32 and an $MSY_{Btrigger}$ of 2.25 Mt

HCR=II: The two-tier approach with the following parameters:

i. A lower bound of $\boldsymbol{F_{min}}$= 0.05 below $\boldsymbol{B_{lim}}$ = 1.5 Mt;
ii. A linear sliding scale with slope $\boldsymbol{a_1}$=2.0 starting at $\boldsymbol{B_{lim}}$ and ending at $\boldsymbol{B^1_{Trigger}}$ = 2.25 Mt;
iii. A standard level between Trigger $\boldsymbol{B^1_{Trigger}}$ and $\boldsymbol{B^2_{Trigger}}$ at $\boldsymbol{F_{0.1}}$=0.22;
iv. A linear sliding scale with slope a_2=2.0 above $\boldsymbol{B^2_{Trigger}}$ where $B^2_{Trigger}$ is 4.0 Mt; and
v. An upper bound at higher stock sizes at $\boldsymbol{F_{MSY}}$=0.32. The upper bound was taken as $\boldsymbol{B^2_{Trigger}}$ + 30%, i.e. 5.2 Mt

Both scenarios will be executed with and without a stability mechanism of 20% down and 25% up when the stock is assessed to be above $\boldsymbol{B_{lim}}$. When the stock is below $\boldsymbol{B_{lim}}$, no stability mechanism will be used.

Since 2016, the assessment has used a preliminary estimate of catch-at-age in the year in which the assessment is carried out to supplement information from the acoustic survey conducted in the spring. In most recent years more than 90% of the annual catches of the age 3+ fish are consistently taken in the first half of the year, which makes it reasonable to estimate the total annual catch-at-age from preliminary first semester data. This is expected to provide an assessment that is more robust to the year effects sometimes observed in the survey index from the International Blue Whiting Spawning Stock Survey (IBWSS). The HCR was therefore simulation tested using as input the value of SSB in the "current" year to set the TAC in the next year. The reference points in the HCR were those agreed on the long-term management strategy was agreed by the European Union, the Faroe Islands, Iceland and Norway in 2016 (Anon, 2016) and evaluated by (ICES, 2017)

OM Conditioning

Operating Model exploring uncertainty in assessment

In the simulations in each year historical assessment errors is used to scale biomass to mimic uncertainty in the assessment. A total allowable catch (TAC) was then set according to the HCR under evaluation and the stock projected forward using the OM. In other words, we simulate annual assessments based on the ‘true’ state of the stock with assessment error rather than mimic assessment procedure itself which would require simulating data using an Observation Error Model (OEM) and conducting an assessment model to estimate inputs to the HCR.

Simulations start in an initial year (2000) and then the stock is projected forward using either of the two alternative HCRs. In addition, a simple projection is made at the F_{MSY} level for comparison and to check that the model is set up correctly.

The time series from the assessment are shown in figure 5, these include estimation error from the SAM covariance matrix. The values of mass, M and maturity-at-age assumed in and selectivity-at-age estimated by the assessment are shown in Figure 6. M was fixed at 0.2 and maturity was not assumed to vary over time. Changes have been seen, however, in both mass-at-age and selection pattern. Figure 7 shows the time series of stock mass-at-age and selectivity-at-age. There appears to have been an increase in selectivity for older and a decrease for younger ages.

To understand the nature of the age dynamics the relative catch and stock numbers-at-age (i.e. number-at-age scaled by the mean number for that age) are plotted in figures 8 and 9 respectively. These show that the population tends to be dominated by strong year classes, for example around 2000 there were a number of strong age-classes. The strong year class in 1989, suggest that there may be an ageing problem from age 6 onwards.

Cross-correlation is used to separate the influence of recruitment on SSB from the influence of SBB on recruitment. If recruitment estimates are lagged to the year of fertilisation, the correlation at zero lag represents the influence of SBB on recruitment. Negative lags represent the influence of recruitment 1,2,3,. . . years in the past on the current year's SSB If the influence of recruitment on SRP is much larger than the influence of SSB on recruitment, it is possible that recruitment is environmentally driven, even if there is an apparent stock–recruit relationship (Gilbert 1997). Therefore, only if SSB has a larger and significant influence on recruitment than recruitment does on SSB, then the existence of a stock–recruitment relationship is unequivocal. The cross correlations are plotted in Figure 10 and the negative lags suggest that SSB is driven by recruitment.

Cross-correlation were also explored for exploitable biomass and recruitment (Figure 11), the largest correlation is seen for a lag of 1 showing that catches are dominated by recent year classes.

Stock Recruitment Relationship

Two forms of stock recruitment relationships were fitted to the stock assessment estimates, i.e. and segmented regression (Figure 12) and Beverton and Holt, in the case of the Beverton and Holt two fits were made where steepness was estimated and fixed at 0.9 (Figures 13 and 14 respectively). Although low recruitment is more likely to occur when the biomass is low, it can occur even when biomass is above 5 million tonnes.

The residuals about the fitted functional forms are shown in figures 15, 16 and 17. Changes in recruitment regimes were identified (i.e boxes) using a sequential t-test algorithm for regime shifts (Rodionov 2004). The regimes are similar in all cases.

Figure 18 shows the autocorrelation in the recruitment deviates from the Beverton and Holt relationship, while figure 19 shows an example of a simulated time series of recruitment.

Productivity

Combining the stock recruitment relationship fitted above with the biological parameters and selection patterns allows the expected dynamics and corresponding reference points to be derived; Figures 20, 21 and 22 show equilibrium SSB and catch against F and recruitment and yield against SSB. The maxima of the Yield v SSB curve provides an estimate of Maximum Sustainable Yield (MSY).

Changes in recruitment, growth and selection pattern will cause changes in productivity and hence reference points. As an exploration of the impact on reference points $F_{0.1}$ scaled by mean recruitment was calculated using a 3 year window for recruitment and mass and selection-at-age. The resulting time series are shown in figure 23.

$F_{0.1}$ is based on a yield/spawner-per-recruit analysis, where yield and SSB are scaled by the average recruitment therefore the level of yield and SSB are driven by recruitment and vary by a factor of four. The value of $F_{0.1}$ is determined by the selection pattern and mass-at-age (since M and maturity-at-age are assumed not to vary over time).

Assessment Error

A feature of the blue whiting assessment is unstable stock estimates because due to strong year-to-year variations in survey results. Assessment error was therefore explored by conducting a retrospective analysis and projection based on the 2018 stock assessment. The assessment was performed in each year from 2009 through to 2018, assessments prior to 2009 did not converge. Then the stock was projected through to 2018 based on the values of recruitment estimated in 2018 and the reported catches. The time series of catch, recruitment, spawning stock biomass and fishing mortality are shown in Figure 24.

The error in F and SSB values were simulated assuming a multivariate lognormal distribution. There is a strong correlation between the error in SSB and F, as seen in figure 25.

Scenarios

Only a single OM was evaluated, namely

- Selection pattern, M, mass and maturity-at-age were derived from the 2018 assessment
- Stock recruitment was modelled as a Beverton and Holt functional form estimated from the 2018 assessment with a steepness fixed at 0.9.
- Recruitment in the HCR simulations were derived from the fitted stock recruitment relationship plus the recruitment deviate estimated in the year being simulated.

A number of scenarios were run for the HCR; namely

- HCR with a F_{MSY} target
- HCR with a F_{MSY} target and assessment error
- HCR I with assessment error
- HCR II with assessment error
- HCR I with TAC bounds of [0.8, 1.25] with observed recruitment deviates and assessment error
- HCR II with TAC bounds of [0.8, 1.25] with observed recruitment deviates and assessment error

In addition a projection at F_{MSY}=0.32 was run for reference

All simulations started in 2000, with the HCR being applied first in 2001.

Results

First the time series are summarised, the behaviour of HCR is explored and then summary statistics presented.

Summary statistics includes

i. Median total catch over the whole time period
ii. Median interannual variability over the whole time period
iii. Median stock size by year (and variability)
iv. Median recruitment by year (and variability)
v. Median catch by year (and variability)
vi. The number of years when the stability mechanism was applied
vii. The median Inter-Annual Variability per iteration

The results are also stored in relational database form so that additional analysis can be conducted.

Time Series

As a benchmark the ICES assessment was projection from 2001 onwards at the F_{MSY} level and compared to an example simulation of the HCR with an F target (F_{tar}) of F_{MSY} with no biomass triggers and no assessment error for a deterministic HCR (i.e. with no assessment error and with actual recruitment estimates) in Figure 26.

Fishing mortality in the past has been higher than F_{MSY} apart from a period from 2009 to 2013. Catches under the F_{MSY} projection have correspondingly been above and below the reported catches and projected SSB has followed recruitment. Under the HCR with only F_{MSY} (i.e. without biomass triggers) F is shows slight variability due to setting the TAC via a short-term projection.

Figure 27 compares the results from the stochastic (1000 realisations) and the deterministic HCRs, and shows the large impact of assessment error on the results.

Next the performance of the different HCRs are evaluated; figure 28 compares the two HCRs without TAC bounds, and Figures 29 and 30 compares HCR I & II respectively with and without TAC bounds.

The performance of the four HCRs are summarised in Figure 31. The main points are that HCR II reduces F during periods of low recruitment and that bounds can cause stock collapse due to shifts in recruitment.

HCRs

The behaviour of the HCRs are examined by plotting F against SSB for by year. First in Figure 32 the values of F and SSB from the assessment and HCR are plotted to ensure the simulations are behaving as expected; each value of SSB should result in a value of F consistent with the HCR. Next the values of F and SSB from the OM are overlaid on the values from the assessment and the HCR (Figure 33). The red line indicates the values of F set by the HCR for any particular value of SSB. The reason for the uncertainty (i.e. the scatter of points) is due to the F being using in a short-term projection to set the TAC.

Figures 34 and 35 then show the results of HCR I and IIs run with assessment error for each year. The main difference between the performance of the HCRs is as a result of a low recruitment period. Therefore Figures 36 and 37 show the results from 2012, when the stock was at a low level and F was reduced by the HCR. It can be seen that HCR II reduces the target F and hence catch due to the low stock size.

Summary Statistics

Figure 38 summarise total catch, and the AAV and variance in total catch over the simulated period for HCR I and II with and without bounds. The “violins” show the actual distributions and the box plots the first and third quartiles (the 25th and 75th percentiles), while the upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the box edges (where IQR is the inter-quartile range, or distance between the first and third quartiles).

Figure 39 summaries AAV for SSB, F and catch, while Figure 40 shows the percentage in each year when the stability mechanism was applied for the HCR with bounds. Finally Figure 41 shows the probability that SSB falls below Bpa and Figure 42 the probability it falls below Blim.

Figure 43 shows the time series from a simulation of HCR I for a single Monte Carlo run without assessment error both with and without bounds; the horizontal line shows the Bpa level. Figure 44 demonstrates the effects of applying bounds on TAC change when the stock falls below Bpa. The effect of the bounds is first seen in 2007 when the TAC is prevented falling below 80% of the previous years TAC. This causes SSB to fall below Bpa in 2010, at which point the bounds are no longer applied and the TAC is based on the F set by the HCR. This results in a much reduced TAC and a recovery of the stock above Bpa in 2012, at which point the bounds are reapplied and preventing catches from increasing to the level seen for HCR I without bounds even though SSB has recovered. The simulations are therefore important in showing unintended consequences that are difficult predicted in advance.

Figure 45 is an example of a comparison of historical stock trends with an escapement harvesting strategy (take all biomass>Bpa) and an F cap of 0.6. This is presented as a potential different type of HCR compared to the standard F based HCRs.

The 4 HCR scenarios are summarised in table 2 and compared to the historical time series and an idealised projection at F_{MSY}.

Discussion and conclusions

Managing the blue whiting stock has two major challenges: 1) shifts between different recruitment regimes, and 2) unstable assessments because of strong year-to-year variations in survey results.

- A Beverton and Holt stock recruitment relationship with a steepness of 0.9 was assumed so that recruitments in the projections were similar to those observed historically but if the stock crashed recruitment would also be impaired.
- A large assessment error without any particular bias, was assumed in stock estimates when setting HCR.
- It is likely that assessment error will vary depending on a number of factors, e.g. if F varies, the strength of incoming year classes and serial correlation in assessment datasets. To model these would require a MSE with a management procedure, i.e. that models the data and assessment processes as well as the HCR.
- HCR II performed similarly to HCR I, the main difference is the additional level of safety provided by HCR II which reduced F and catch at low biomass, i.e. in 2010-2015
- The bounds evaluated caused stock collapse, as the large reductions in stock biomass seen were driven by recruitment and the bounds resulted in F not being reduced quickly enough.
- After a stock collapse the use of bounds prevented the TAC being increased as the stock recovered.
- Dynamics largely driven by incoming year-classes, i.e. catches are high for up to 3 years following a large recruitment.
- M was fixed at 0.2 in all years and at all ages. It may be expected that M would vary between ages and years in a stock that exhibits large variations in recruitment and density.

- The assumptions about M will also have important impacts on the stock dynamics, e.g. due to density dependence and resonant cohort effects.
- The simulations only considered historical conditions to ensure that a HCR is robust in practice, i.e. after implementation it will be necessary to simulate a range of hypotheses, e.g. about stock and recruitment and the relative importance of fishing v environment on resource dynamics.
- If dynamics are recruitment driven what are appropriate reference points?
- Could use STARS algorithm to detect regime shifts, but how to make it part of a HCR?
- Appropriate MPs also depend on the data, to evaluate this

More sources of uncertainty and a range of alternative HCRS could be evaluated. Further, a stakeholder communication strategy could be developed using an interactive visualization tool such as the shiny app that Sea++ had developed for North Atlantic Swordfish ().

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Tables

Table 1. Reference points, values, and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	2250000 t	B_{pa}	ICES (2013a, 2013b, 2016a)
	F_{MSY}	0.32	Stochastic simulations with segmented regression stock–recruitment relationship	ICES (2016a)
Precautionary approach	B_{lim}	1500000 t	Approximately B_{loss}	ICES (2013a, 2013b, 2016a)
	B_{pa}	2250000 t	B_{lim} exp(1.645 × σ), with σ = 0.246	ICES (2013a, 2013b, 2016a)
	F_{lim}	0.88	Equilibrium scenarios with stochastic recruitment: F value corresponding to 50% probability of (SSB < B_{lim})	ICES (2016a)
	F_{pa}	0.53	Based on F_{lim} and assessment uncertainties. F_{lim} exp(-1.645 × σ), with σ = 0.299	ICES (2016a)
EU–Faroes–Iceland–Norway long-term management strategy	SSB_{MGT_lower}	1500000 t	B_{lim}	Anon (2016)
	SSB_{MGT}	2250000 t	B_{pa}	
	F_{MGT_lower}	0.05	Arbitrary low F	
	F_{MGT}	0.32	F_{MSY}	

Table 2. Summary of HCR scenarios and comparison to the historical and an idealised F_{MSY} projection.

Median Catch

Scenario	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
FMSY	1412	1151	1359	1643	1734	1766	1839	1535	1283	1045	880	721	614	627	712	855	970	1141	1359	22645
HCR I	1412	1772	1341	1671	1897	1816	1816	1566	1118	814	575	556	498	602	734	961	1202	1379	1338	23069
HCR I with Bounds	1412	1772	1417	1685	1695	1772	1841	1771	1537	1249	907	185	119	209	299	395	495	619	773	20151
HCR II	1412	1772	1119	1691	1971	1868	1850	1624	1079	605	440	445	404	463	569	750	1019	1467	1466	22014
HCR II with Bounds	1412	1772	1417	1685	1649	1772	1823	1772	1542	1259	907	158	107	167	228	290	363	454	566	19341
Historical	1412	1772	1557	2365	2401	2018	1956	1612	1252	635	540	104	376	614	1148	1391	1181	1555	1713	25601

Median SSB

Scenario	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FMSY	4241	4589	5901	7287	7571	7455	7247	5803	4563	3599	3061	2678	2606	2854	3136	3771	4725	5474	5685
HCR I	4241	4608	5576	6952	7210	6847	6483	5030	3743	2858	2511	2471	2601	2970	3306	3917	4740	5232	5114
HCR I with Bounds	4241	4608	5576	6789	7180	7048	6778	5368	3961	2719	2007	1811	2180	2769	3354	4352	5596	6722	7561
HCR II	4241	4608	5576	7137	7414	7051	6674	5179	3853	3045	2838	2837	2955	3332	3705	4388	5224	5721	5617
HCR II with Bounds	4241	4608	5576	6792	7242	7110	6889	5487	4038	2804	2076	1851	2212	2826	3467	4540	5894	7086	8028
Historical	4241	4608	5410	6867	6749	5979	5828	4686	3632	2788	2716	2713	3433	3711	3920	4055	4631	5536	5493

Median F

Scenario	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FMSY	0.48	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
HCR I	0.48	0.47	0.34	0.35	0.38	0.38	0.37	0.40	0.37	0.33	0.25	0.26	0.25	0.29	0.31	0.35	0.41	0.42	0.37
HCR I with Bounds	0.48	0.47	0.40	0.34	0.34	0.35	0.35	0.42	0.49	0.56	0.44	0.12	0.07	0.10	0.11	0.11	0.12	0.12	0.11
HCR II	0.48	0.47	0.28	0.35	0.38	0.38	0.37	0.40	0.33	0.22	0.16	0.17	0.17	0.18	0.19	0.22	0.30	0.40	0.36
HCR II with Bounds	0.48	0.47	0.40	0.34	0.34	0.34	0.34	0.42	0.48	0.55	0.43	0.09	0.06	0.08	0.08	0.08	0.08	0.08	0.08
Historical	0.48	0.47	0.47	0.50	0.54	0.51	0.46	0.46	0.40	0.26	0.18	0.05	0.11	0.20	0.39	0.52	0.47	0.47	0.45

Annual Average Variation in Catch

Scenario	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
FMSY	-19%	19%	21%	5%	2%	4%	-16%	-17%	-18%	-16%	-19%	-14%	2%	13%	20%	14%	17%	20%	14%
HCR I	25%	-24%	27%	13%	-4%	0%	-11%	-27%	-28%	-32%	-9%	-10%	20%	21%	31%	28%	15%	0%	18%
HCR I with Bounds	25%	-20%	6%	20%	10%	10%	-8%	-20%	-20%	-20%	-20%	10%	25%	25%	25%	25%	25%	25%	19%
HCR II	25%	-37%	40%	18%	-6%	-1%	-14%	-35%	-35%	-27%	-1%	-6%	16%	26%	38%	35%	23%	0%	21%
HCR II with Bounds	25%	-20%	3%	22%	12%	11%	-5%	-20%	-20%	-20%	-20%	7%	25%	25%	25%	25%	25%	25%	19%
Historical	25%	-12%	52%	1%	-16%	-3%	-18%	-22%	-49%	-15%	-81%	262%	63%	87%	21%	-15%	32%	10%	44%

Figures

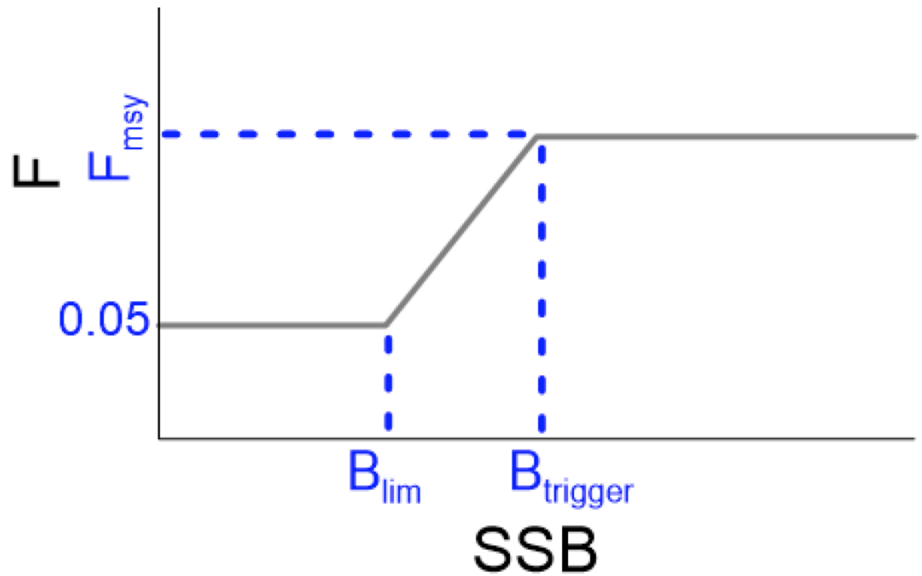

Figure 1. HCR I evaluated during this study (based on the 2016 NEAFC request to ICES)

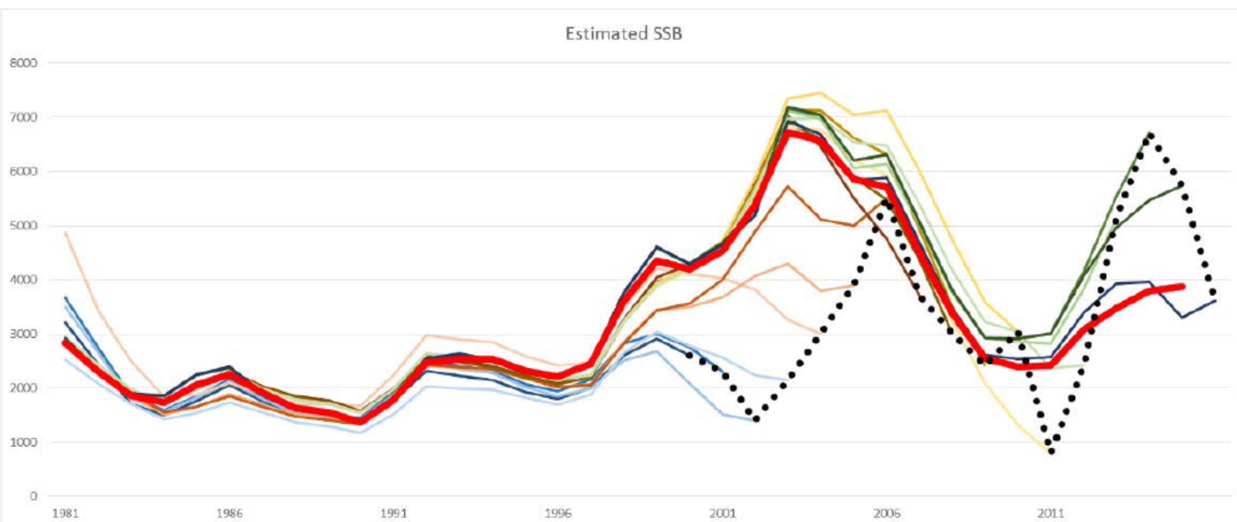

Figure 2. Blue whiting SSB as estimated by the last 18 assessments of the stock (conducted in 1999-2015, plus IBPBLW 2016). Time series include forecasted values for y+1 (except for IBPBLW). Prior to 2006 SSB was not estimated for Jan 1. Dotted line = forecasted SSB values from each assessment (i.e. what advice was based on); Red line = IBPLW_2016 assessment (i.e. current 'best' estimate; ICES, 2016a).

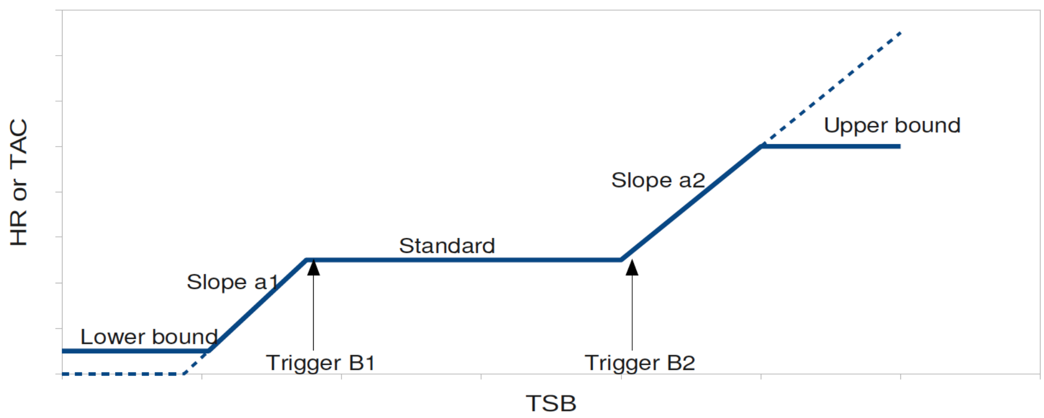
HR or TAC
Upper bound
Slope a2
Standard
Slope a1
Lower bound
Trigger B1
Trigger B2
TSB

Figure 3. From Skagen (2012), who evaluated a two tier HCR and found it to be precautionary with roughly these parameters: Trigger B1 = 4 Mt, Trigger B2 = 5 Mt and Upper bound F = 0.12 or TAC of about 500 thousand tonnes.

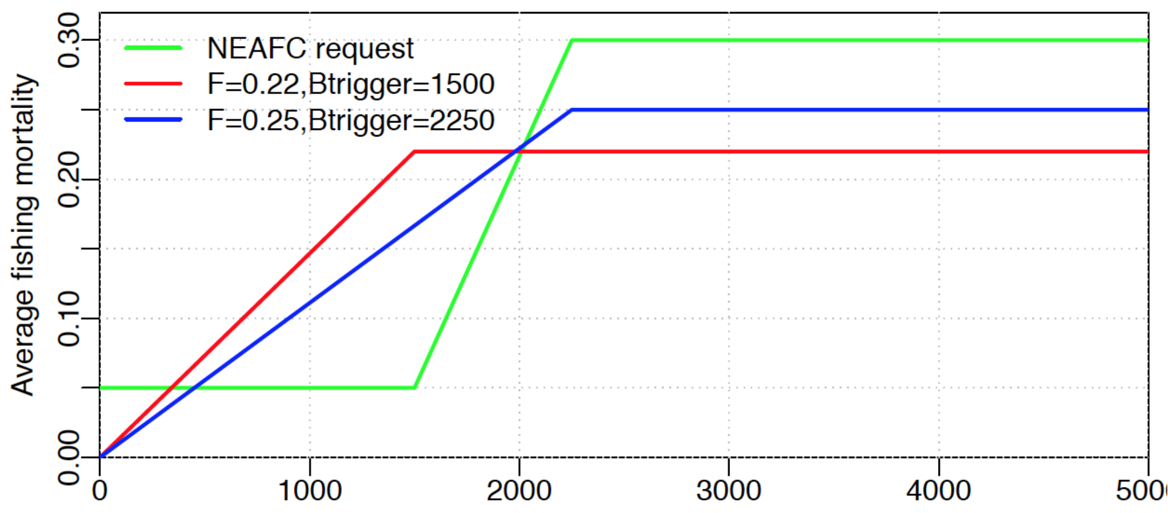

Figure 4. Alternative HCRs evaluated as part of MSE of long term management plans in 2016 (WKBMS 2016).

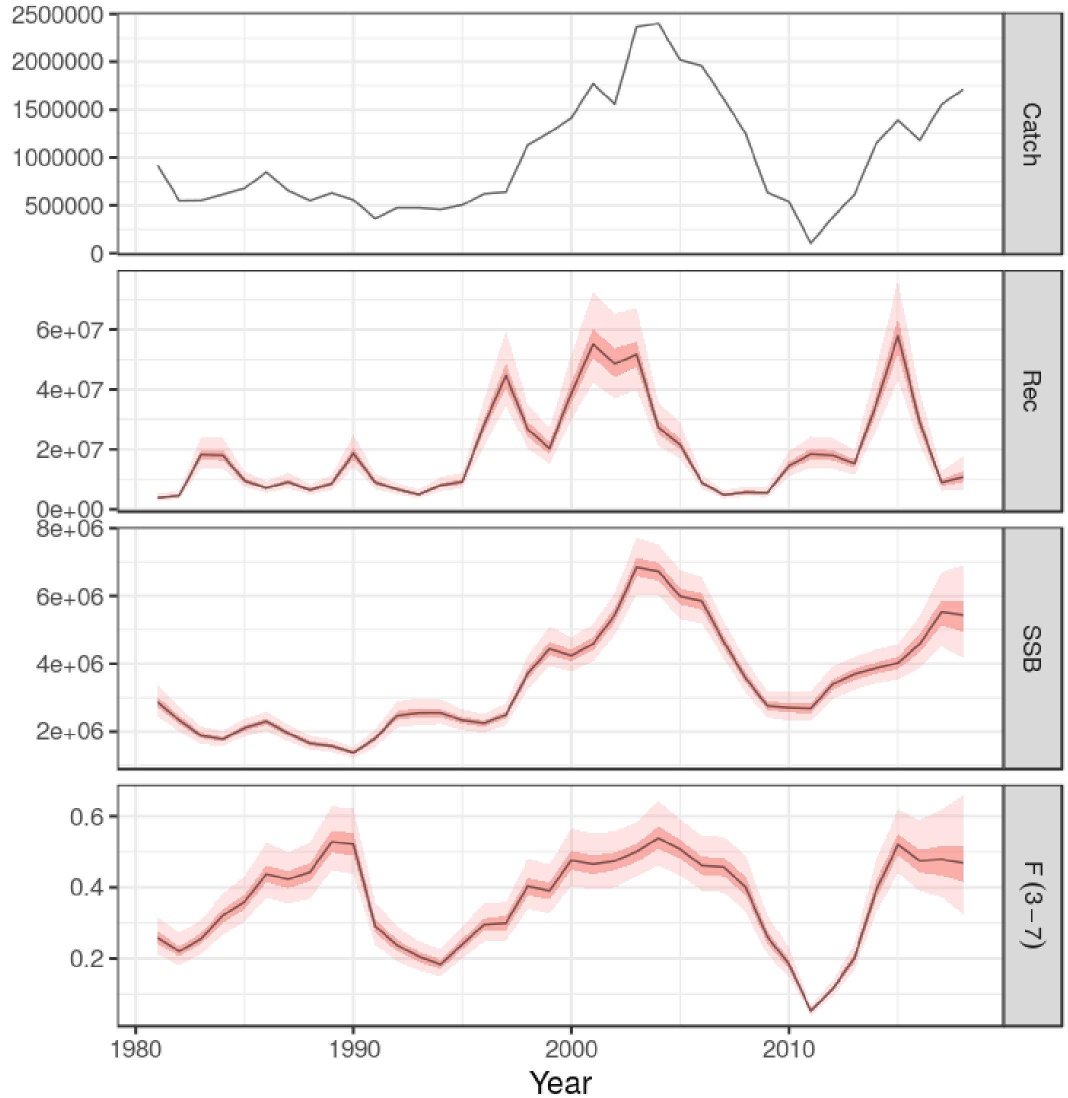

Figure 5 Time series estimates of catch, recruitment, spawning stock biomass and fishing mortality from the 2018 stock assessment.

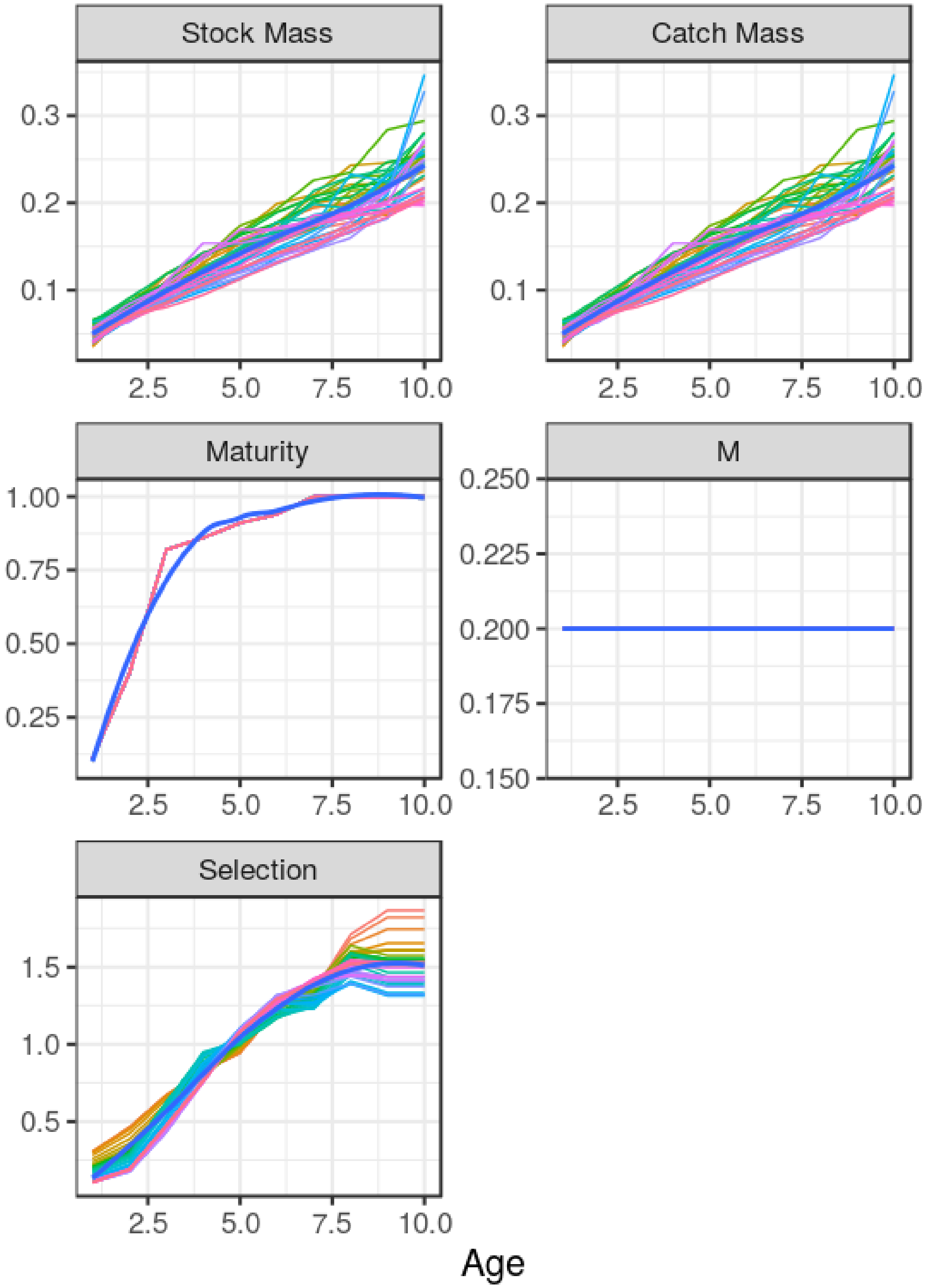

Figure 6 Stock mass, catch mass, maturity, natural mortality and selection pattern at-age

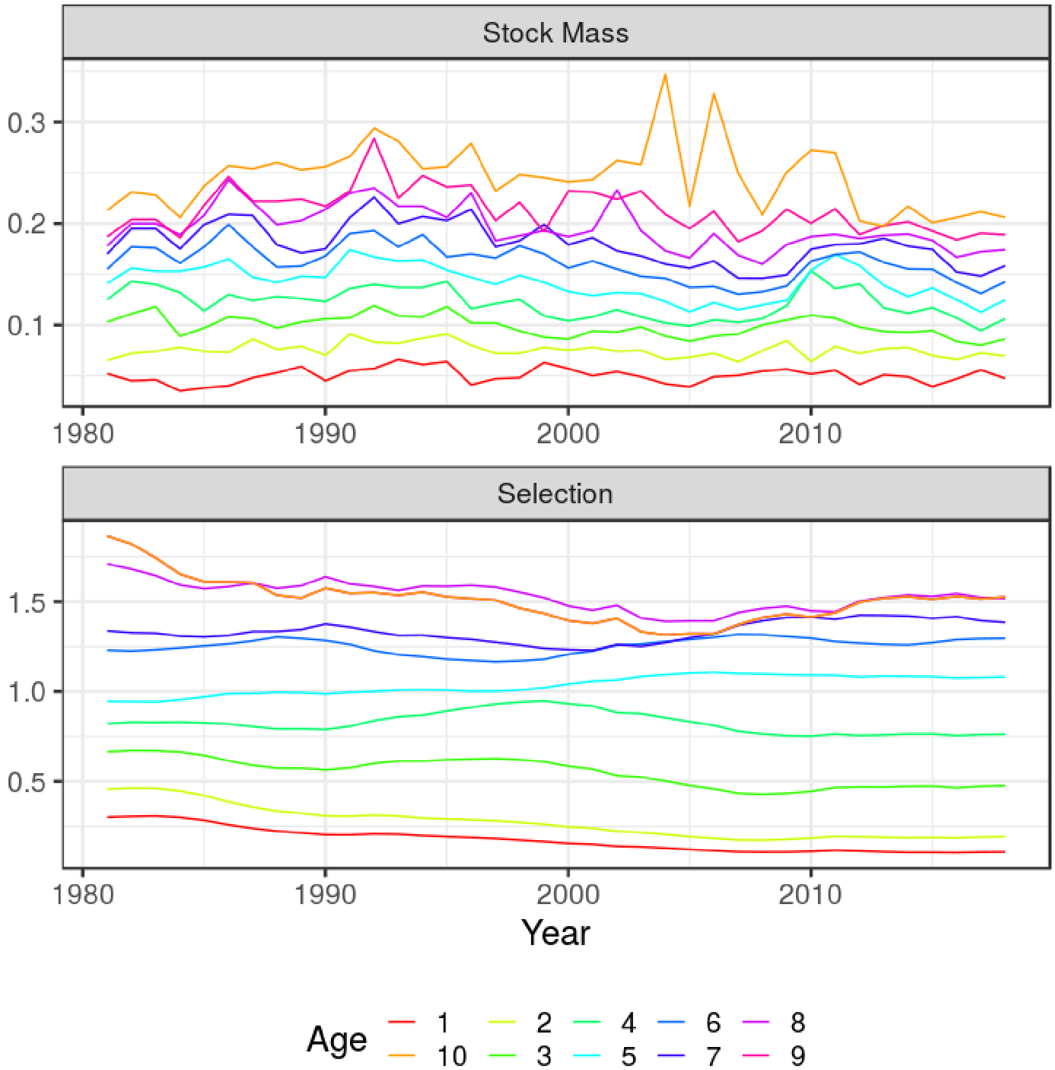

Figure 7 Stock mass, catch mass, maturity, natural mortality and selection pattern at-age

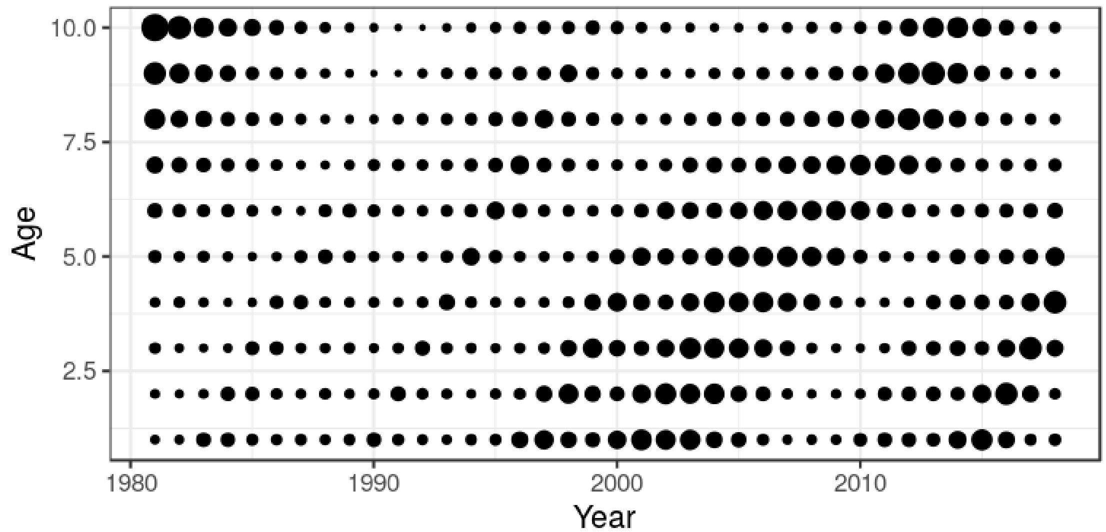

Figure 8 Relative stock numbers-at-age, i.e. numbers at an age scaled by mean numbers

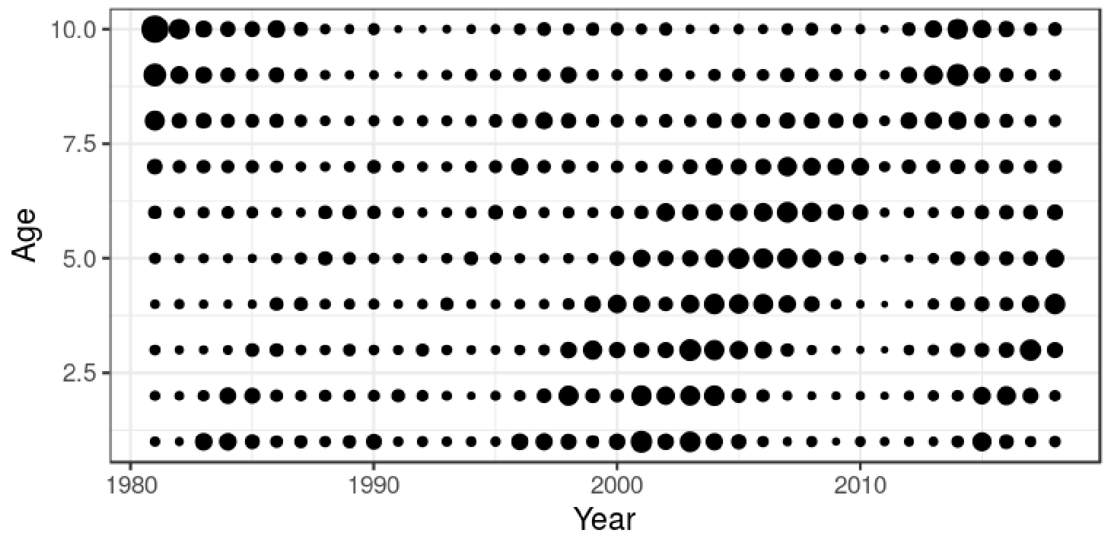

Figure 9 Relative catch numbers-at-age, i.e. numbers at an age scaled by mean numbers

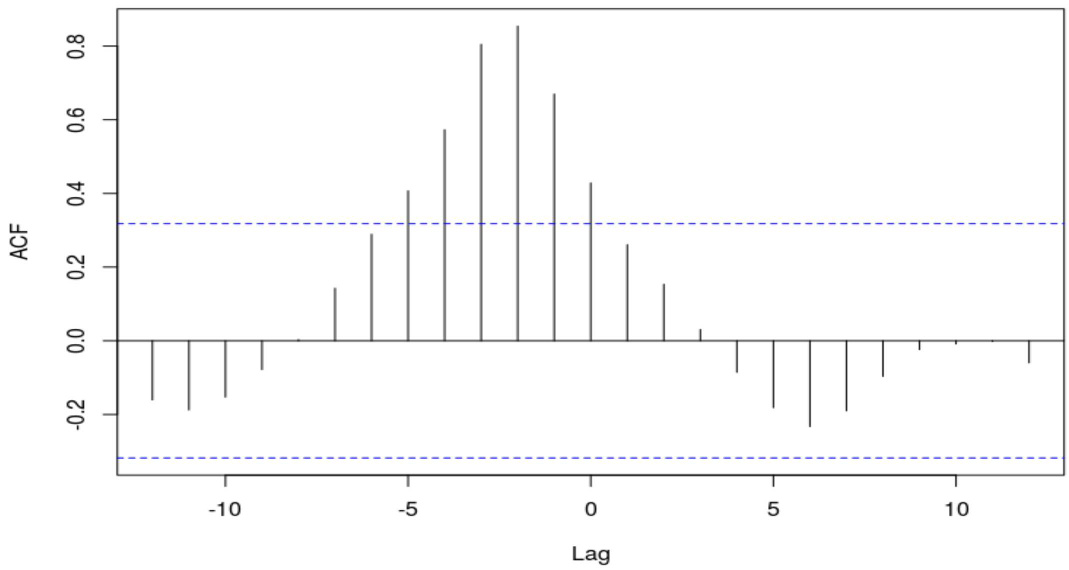

Figure 10 Cross correlations between **SSB** and **recruitment at age 1**, a positive lag of 1 would indicate the presence of a stock recruitment relationship, while a negative lag indicates that SSB is determined by past recruitment

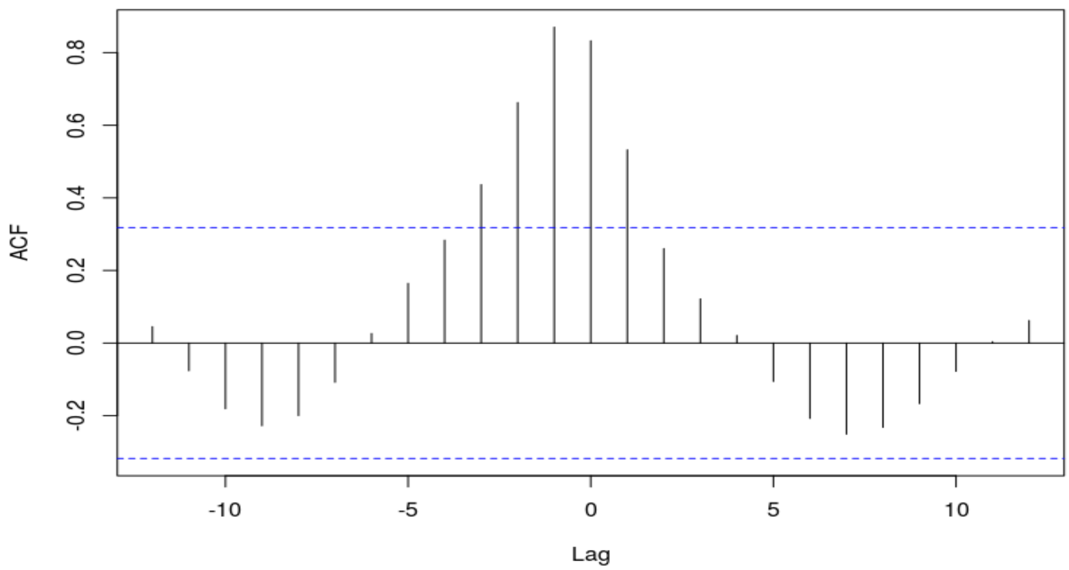

Figure 11 Cross correlations between **exploitable biomass** and **recruitment at age** 1, a positive lag of 1 would indicate the presence of a stock recruitment relationship, while a negative lag indicates that SSB is determined by past recruitment

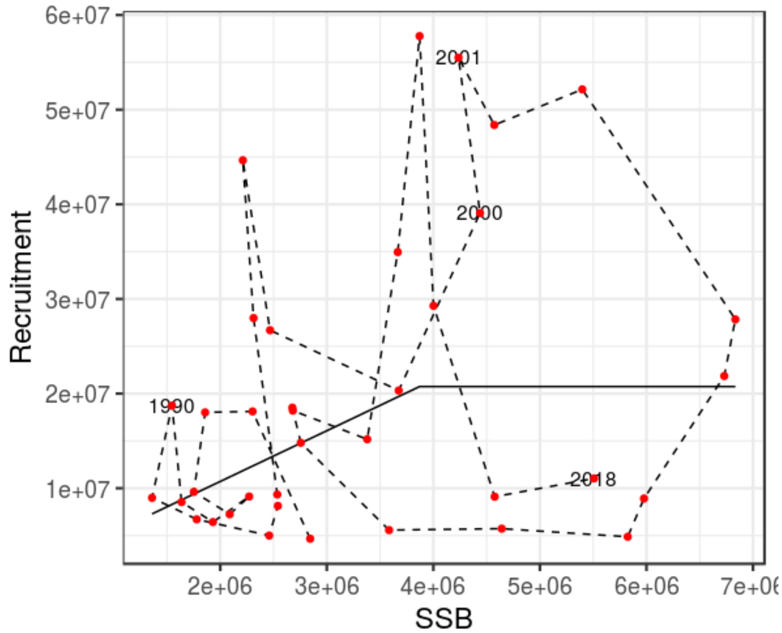

Figure 12 Estimates of SSB and recruitment with fitted segmented regression stock recruitment relationship

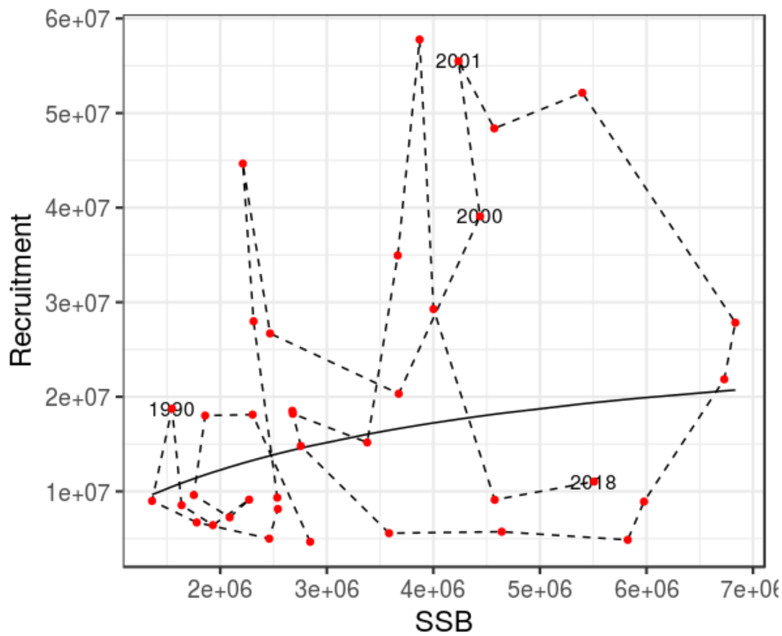

Figure 13 Estimates of SSB and recruitment with fitted Beverton and Holt stock recruitment relationship.

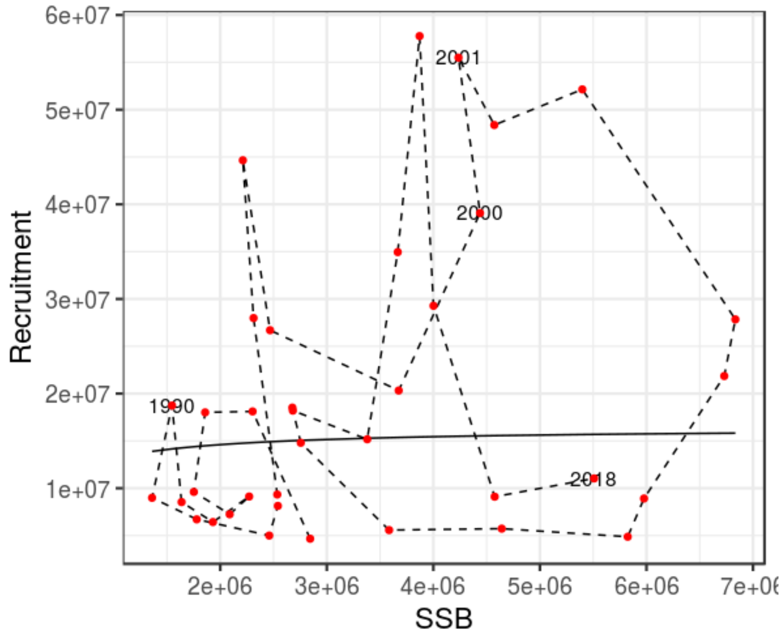

Figure 14 Estimates of SSB and recruitment with fitted Beverton and Holt stock recruitment relationship with a fixed steepness of 0.9

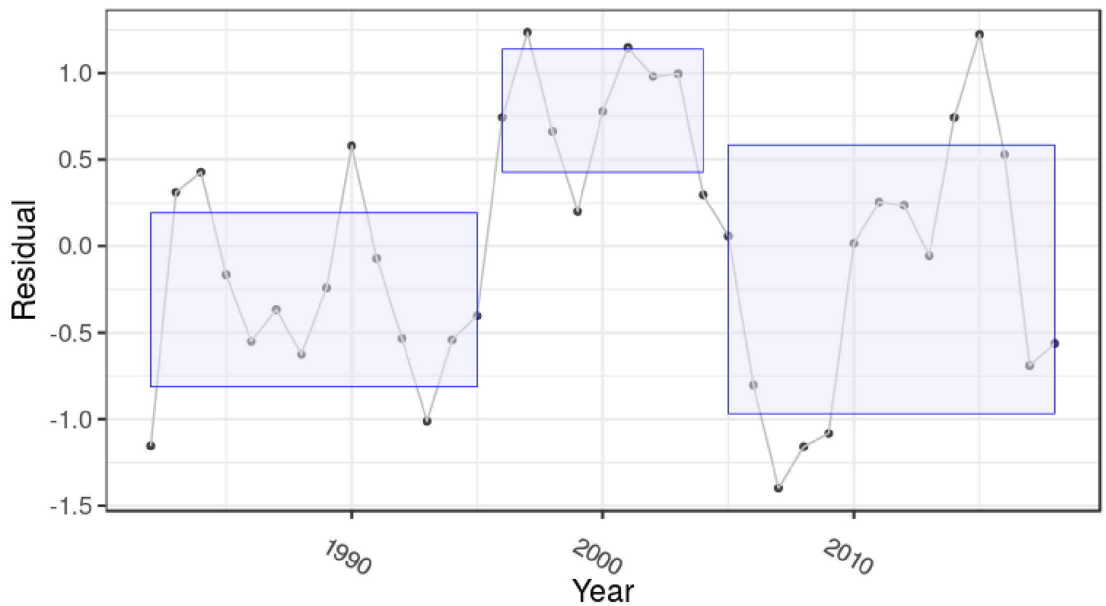

Figure 15 Recruitment deviates for Beverton and Holt stock recruitment relationship, with regimes estimated by STARS algorithm showing changes in mean and variance.

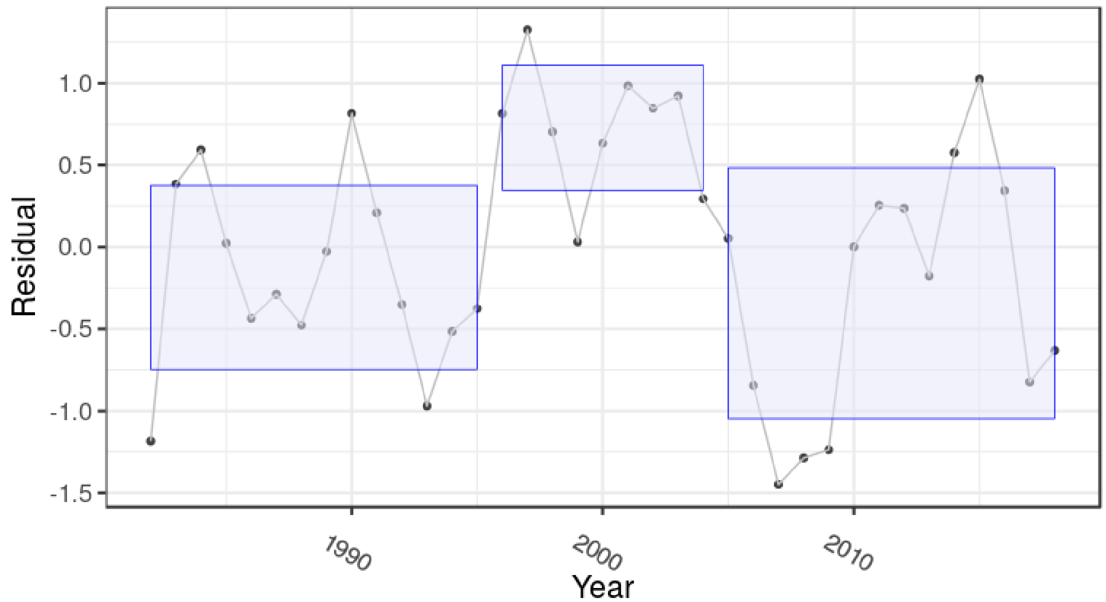

Figure 16 Recruitment deviates for segmented regression stock recruitment relationship, with regimes estimated by STARS algorithm showing changes in mean and variance.

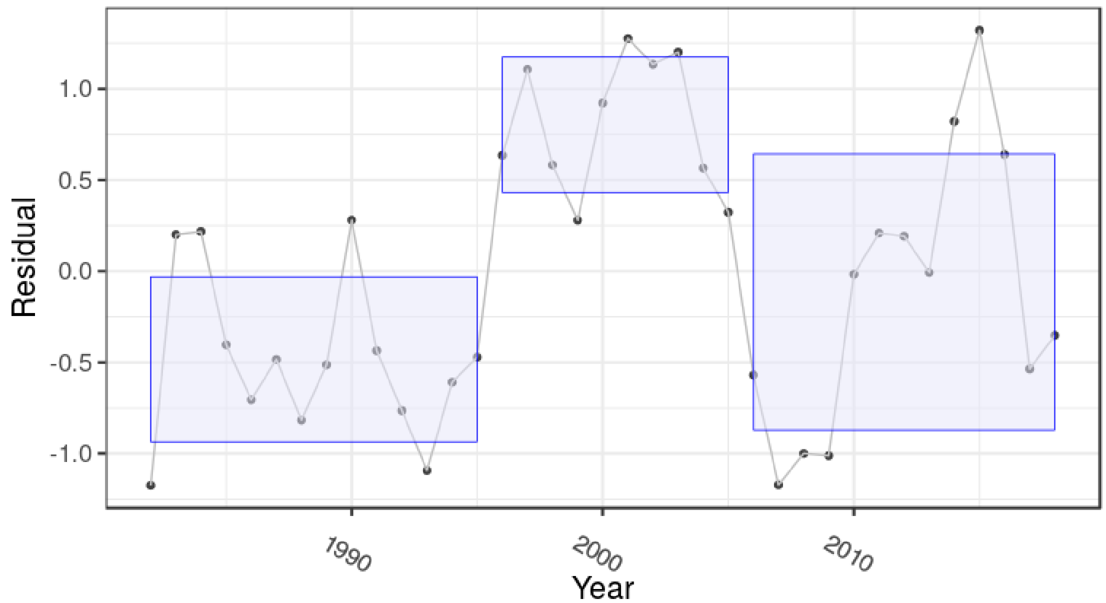

Figure 17 Recruitment deviates for Beverton and Holt stock recruitment relationship with steepness fixed at 0.9, with regimes estimated by STARS algorithm showing changes in mean and variance.

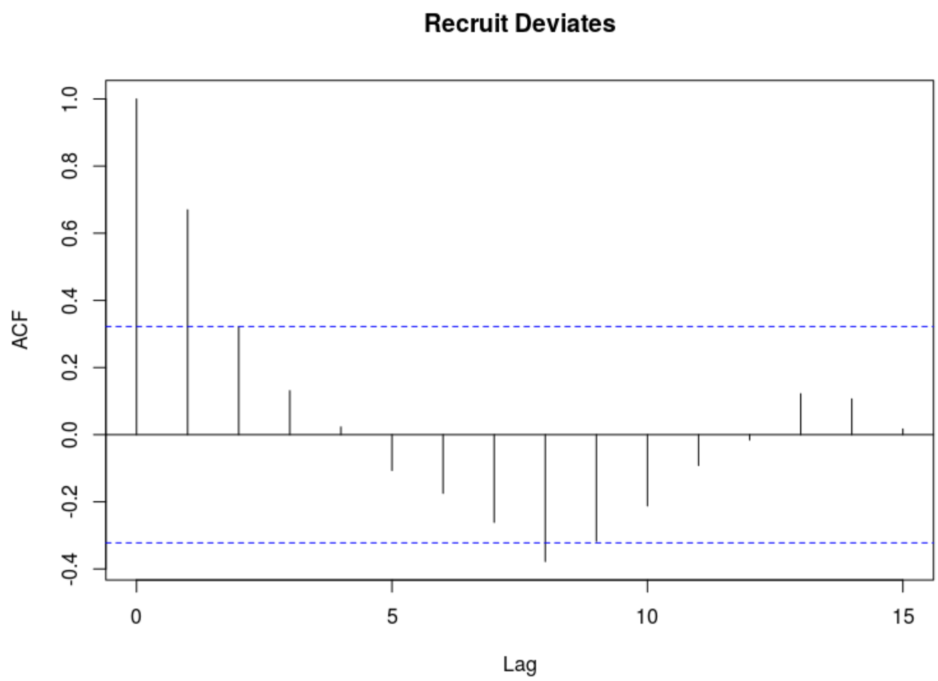

Figure 18 Autocorrelation in recruitment deviates.

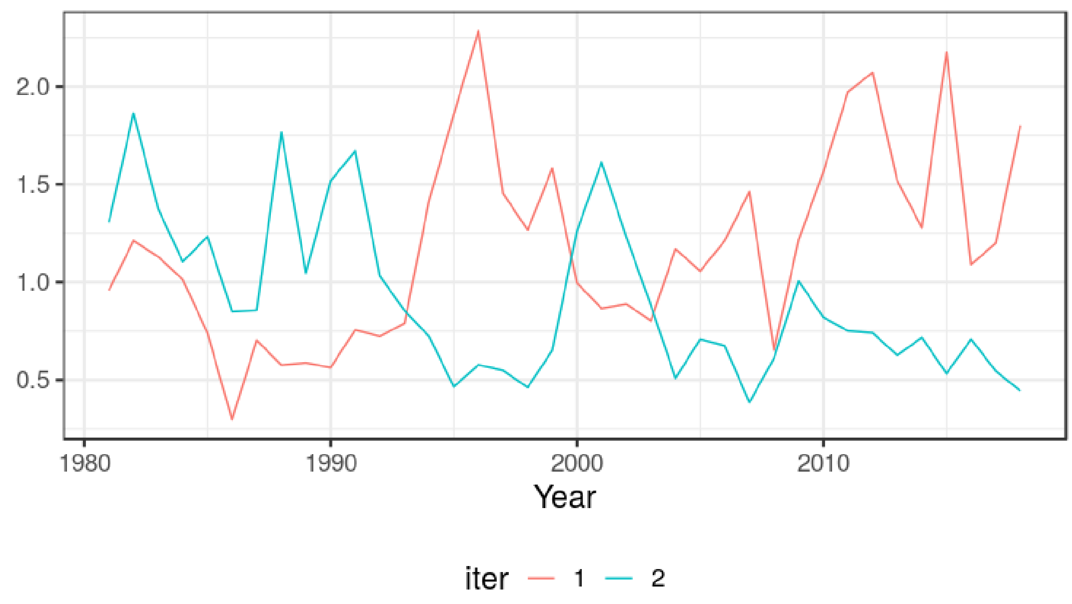

Figure 19 An example of simulated recruitment deviates with autocorrelation.

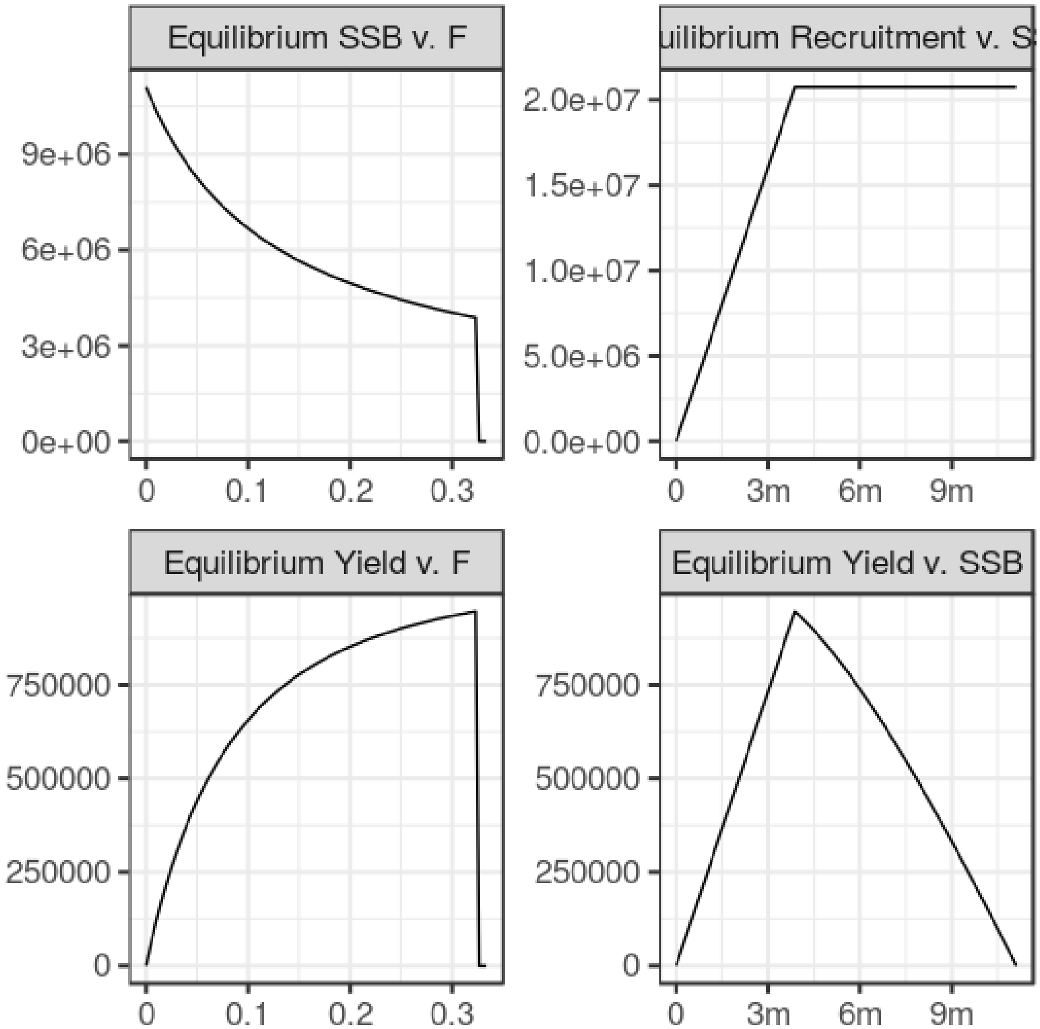

Figure 20 Biological reference points based on the Beverton and Holt stock recruitment relationship.

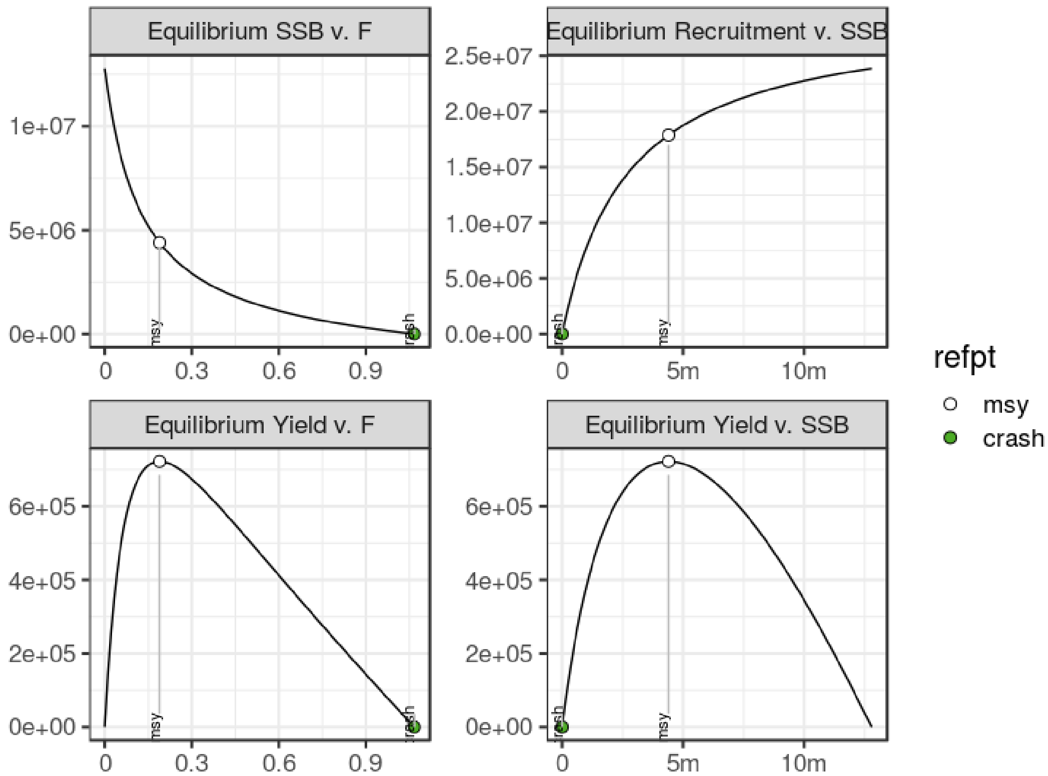

Figure 21 Biological reference points based on the fitted segmented regression stock recruitment relationship.

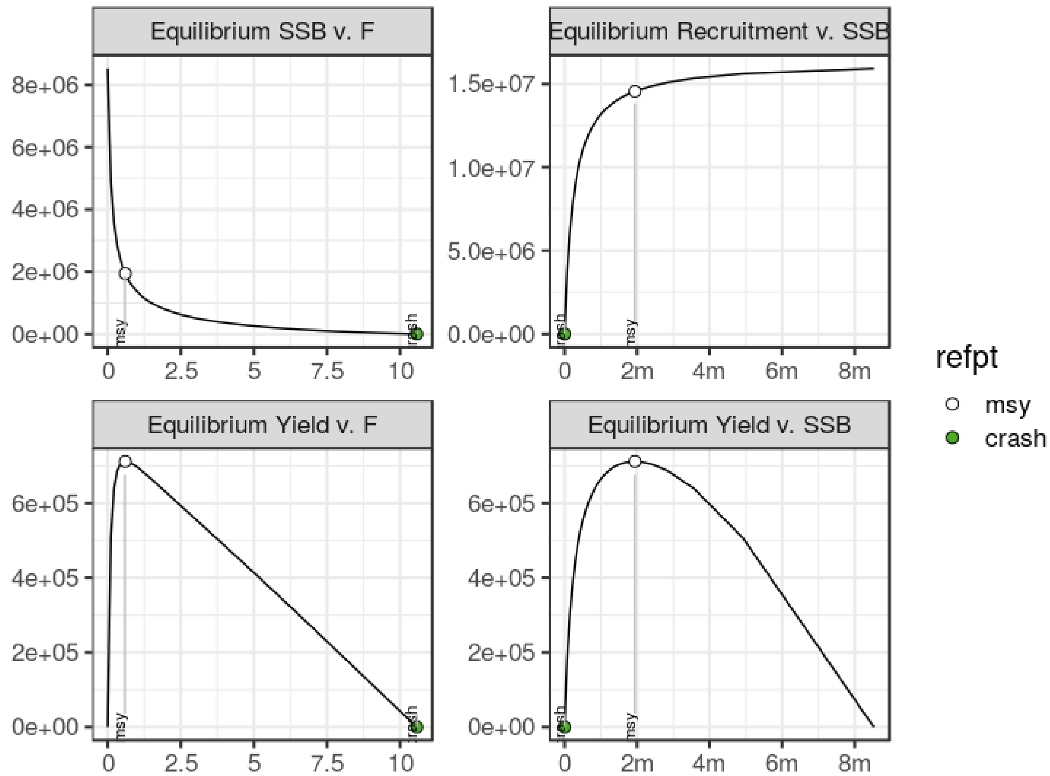

Figure 22 Biological reference points based on the Beverton and Holt stock recruitment relationship with steepness fixed at 0.9.

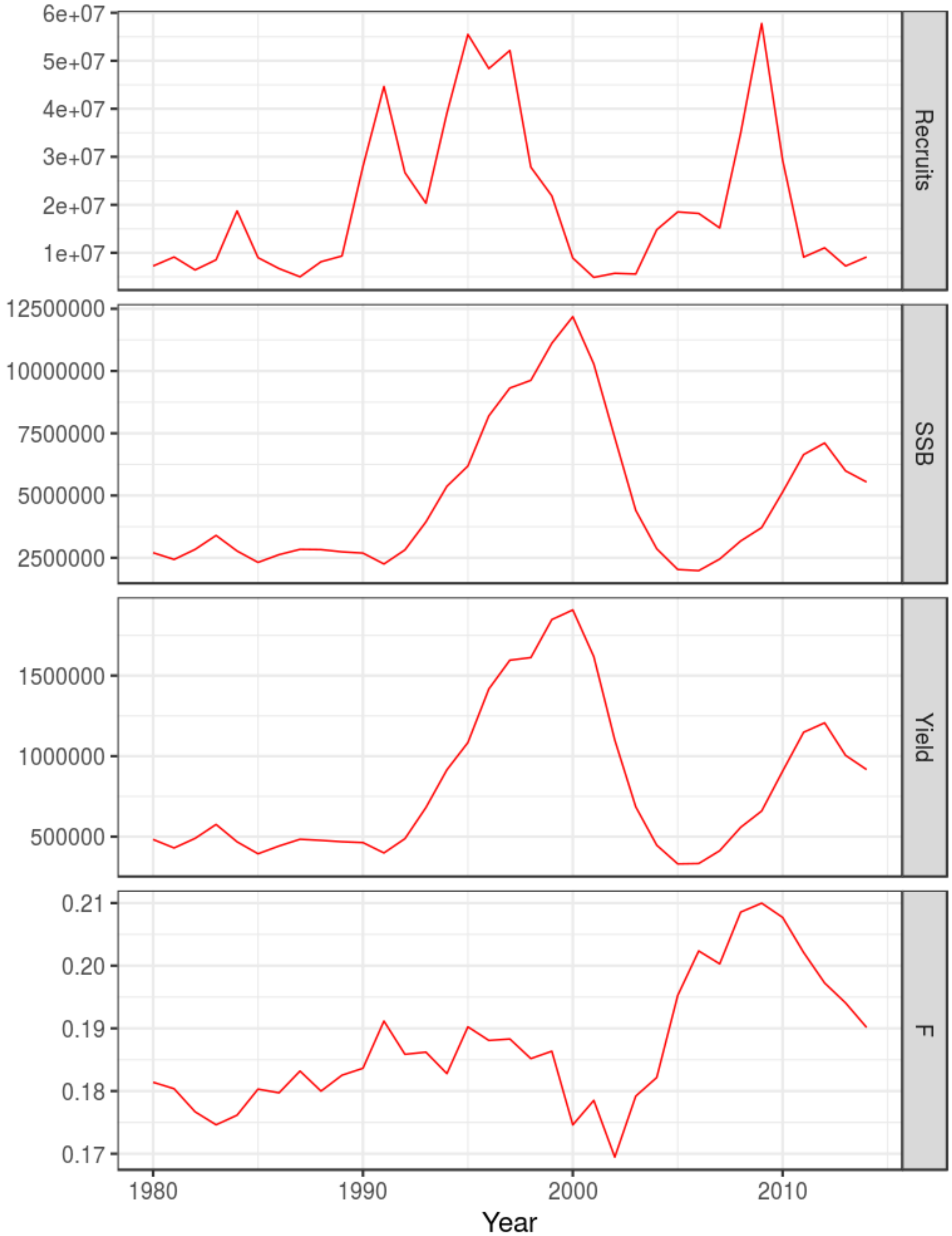

Figure 23 F0.1 proxy for Fmsy reference point calculated with a three year moving window

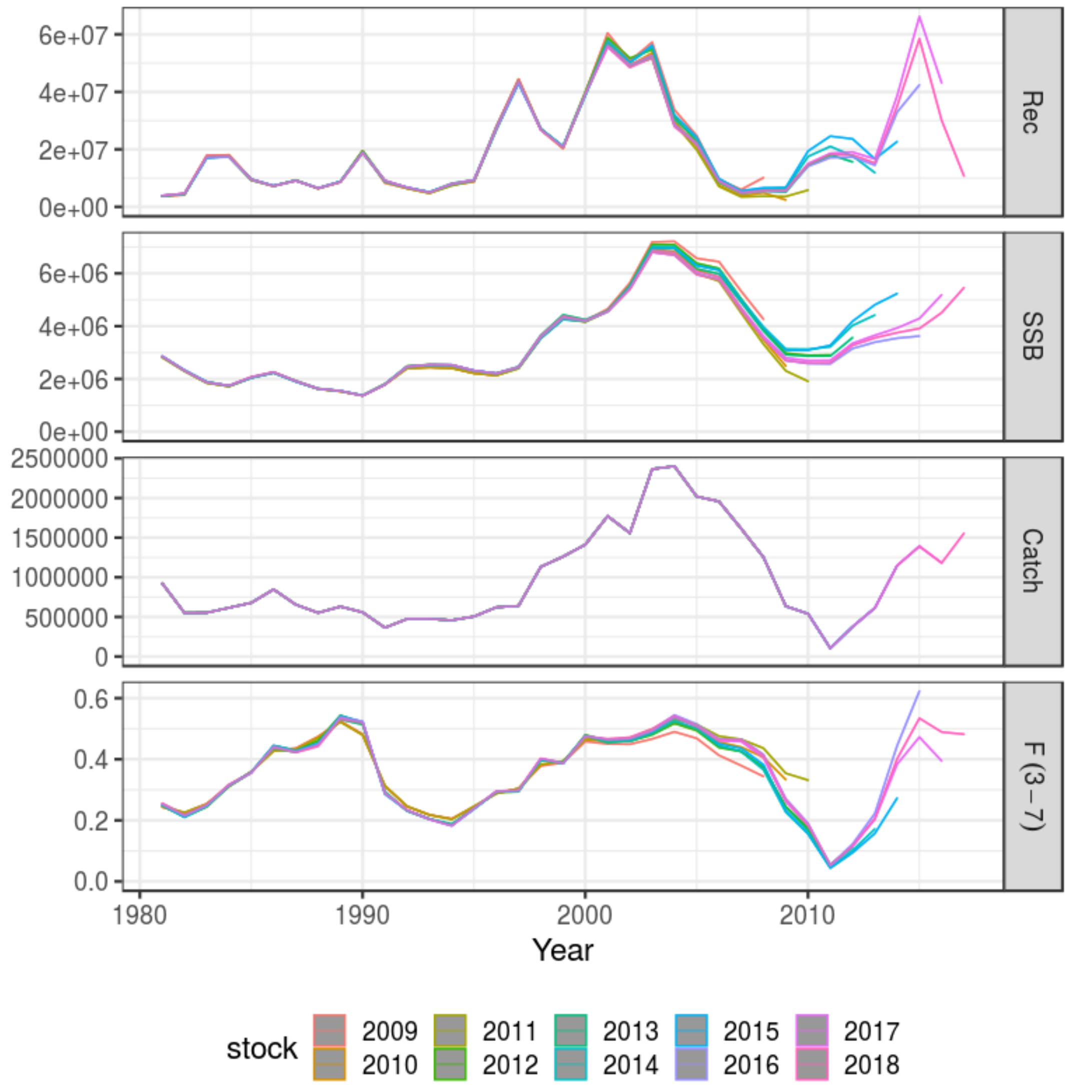

Figure 24 Retrospective estimates of time series of catch, recruitment, spawning stock biomass and fishing mortality from the 2018 stock assessment.

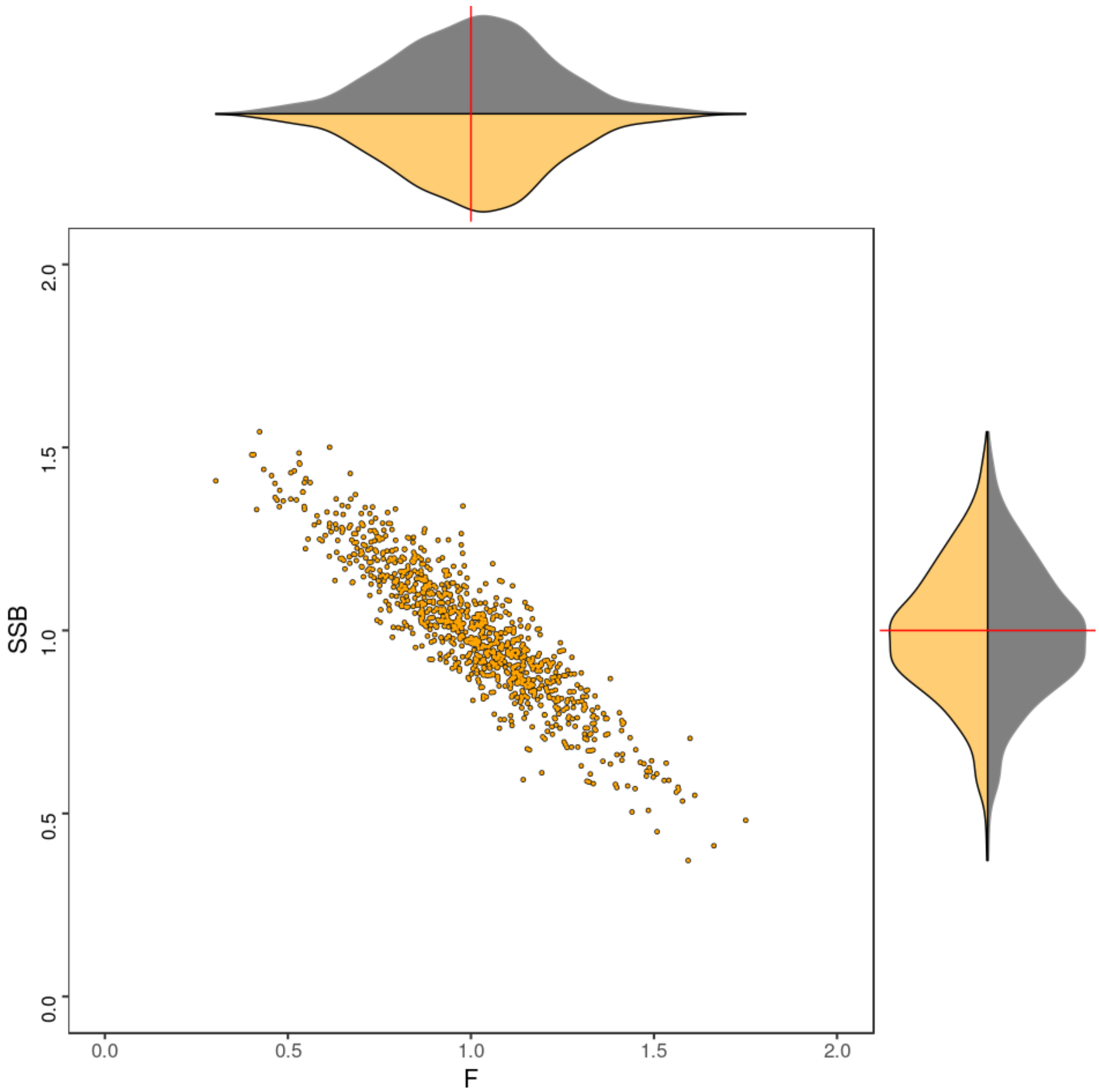

Figure 25 Assessment error in SSB and F derived from the retrospective runs.

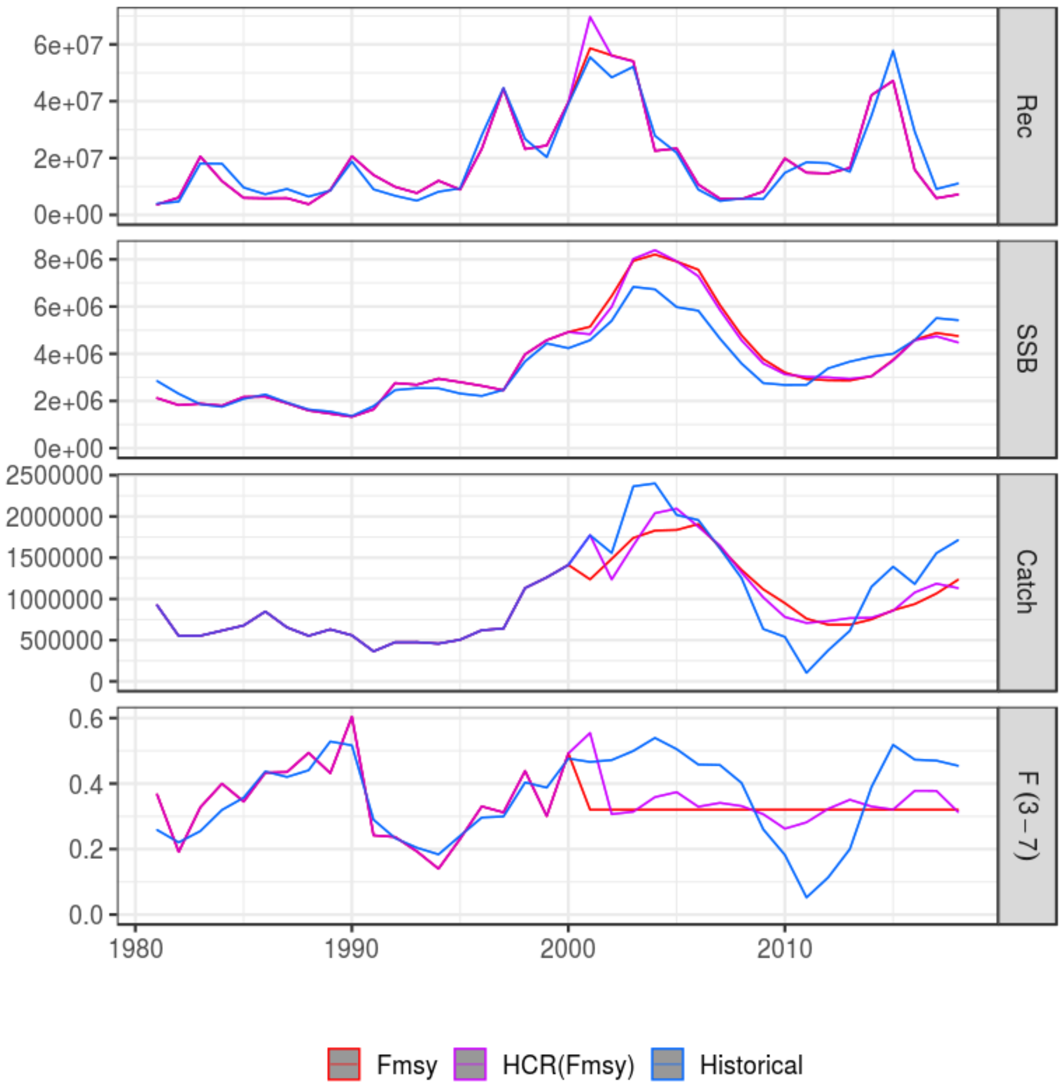

Figure 26 Comparison between historical assessment estimates, and a single Monte Carlo realisation for a projection at Fmsy, and HCR1 without assessment error.

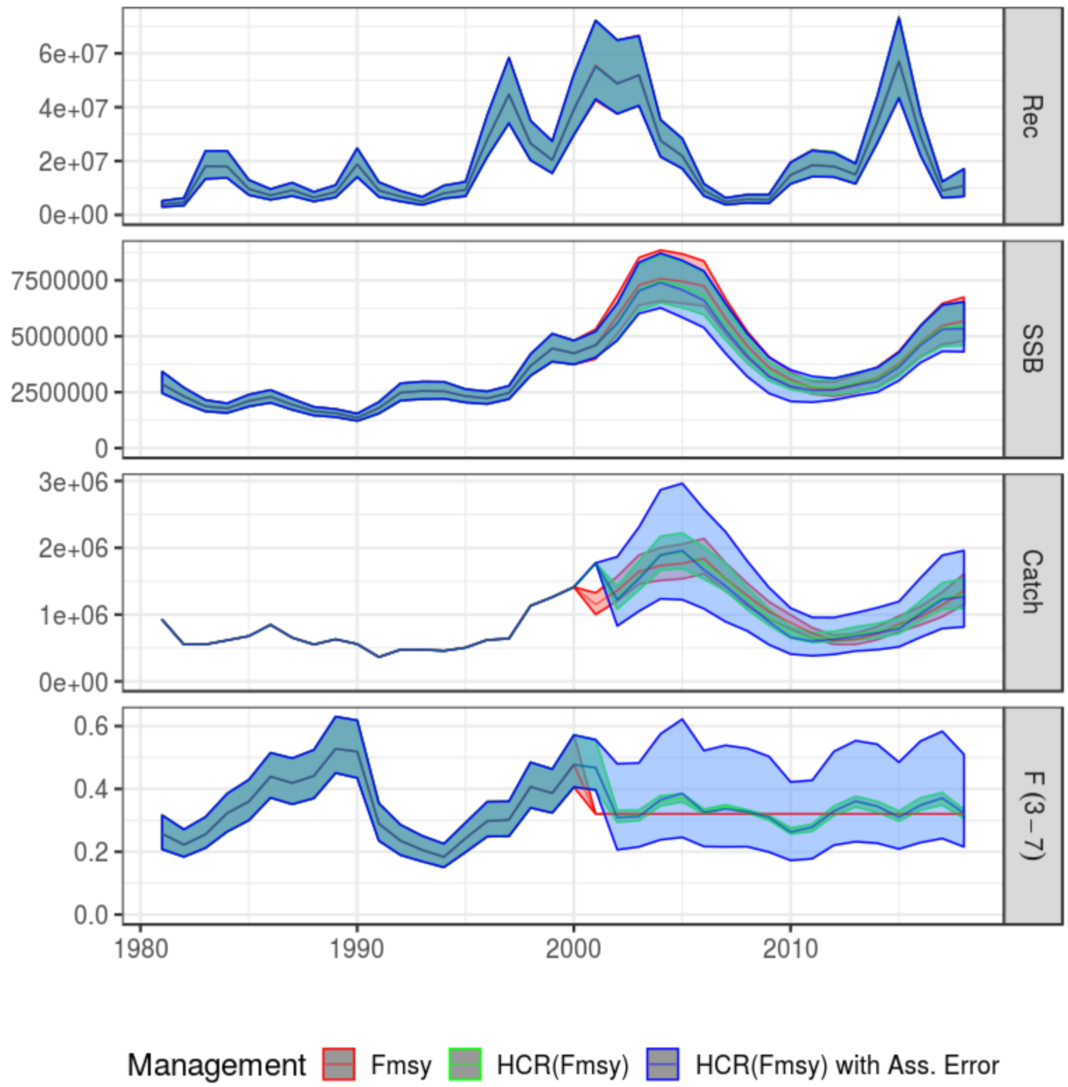

Figure 27 HCR with and without assessment error compared to historical estimates; with median and 10 and 90 percentiles, the hatched line is a single Monte Carlo realisation.

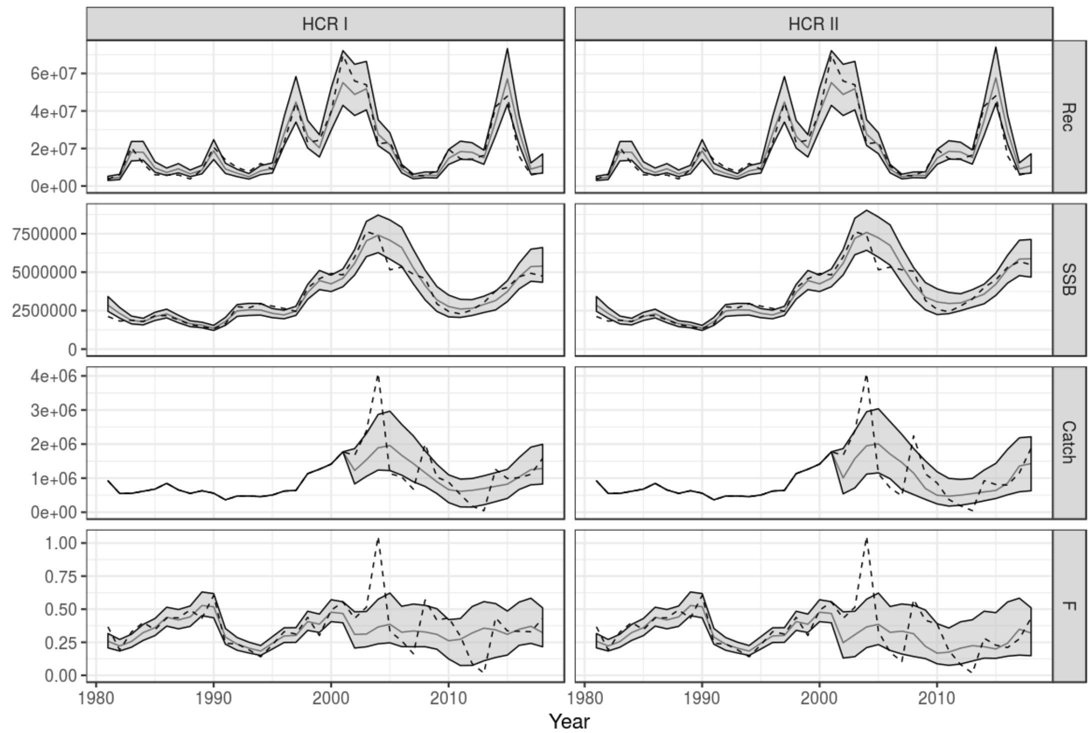

Figure 28 Comparison between HCR I & II with assessment error; shown with median and 10 and 90 percentiles, the hatched line is a single Monte Carlo realisation.

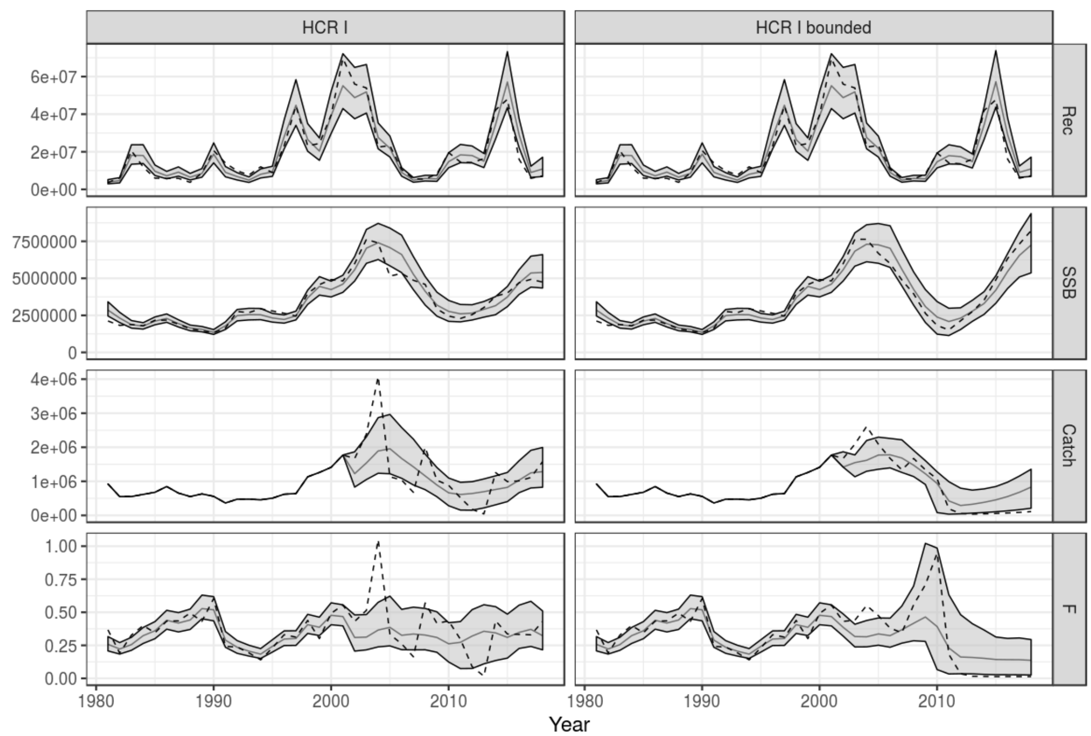

Figure 29 Comparison between HCR I without and with bounds; shown with median and 10 and 90 percentiles, the hatched line is a single Monte Carlo realisation.

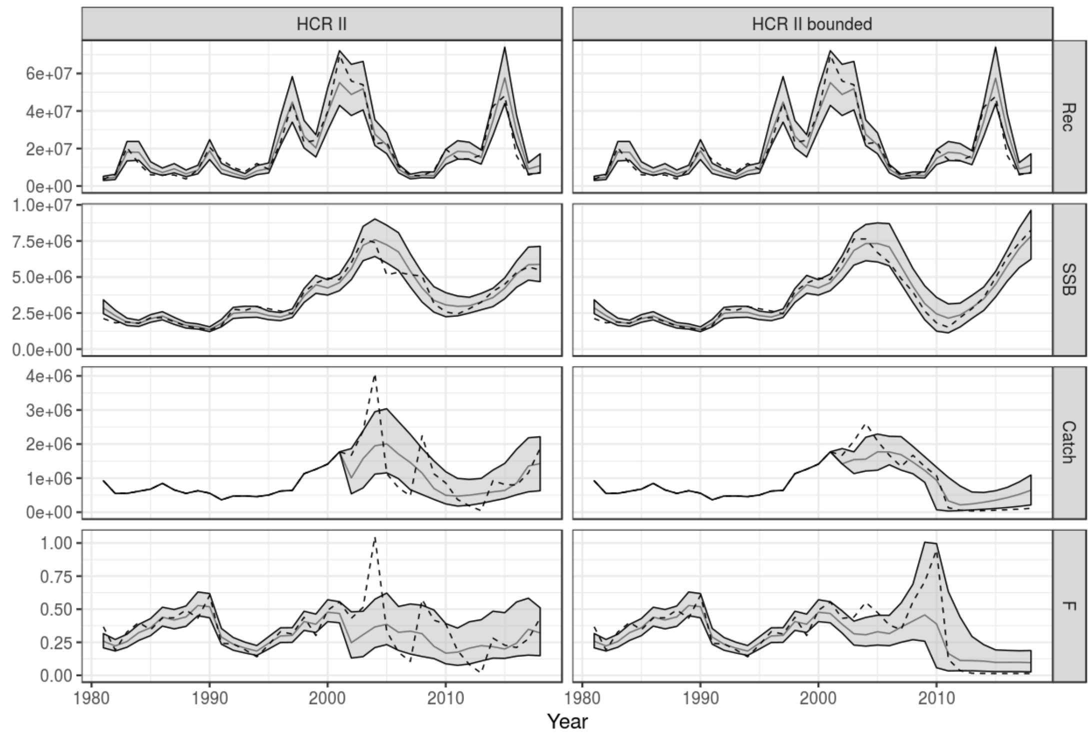

Figure 30 Comparison between HCR II without and with bounds; shown with median and 10 and 90 percentiles, the hatched line is a single Monte Carlo realisation.

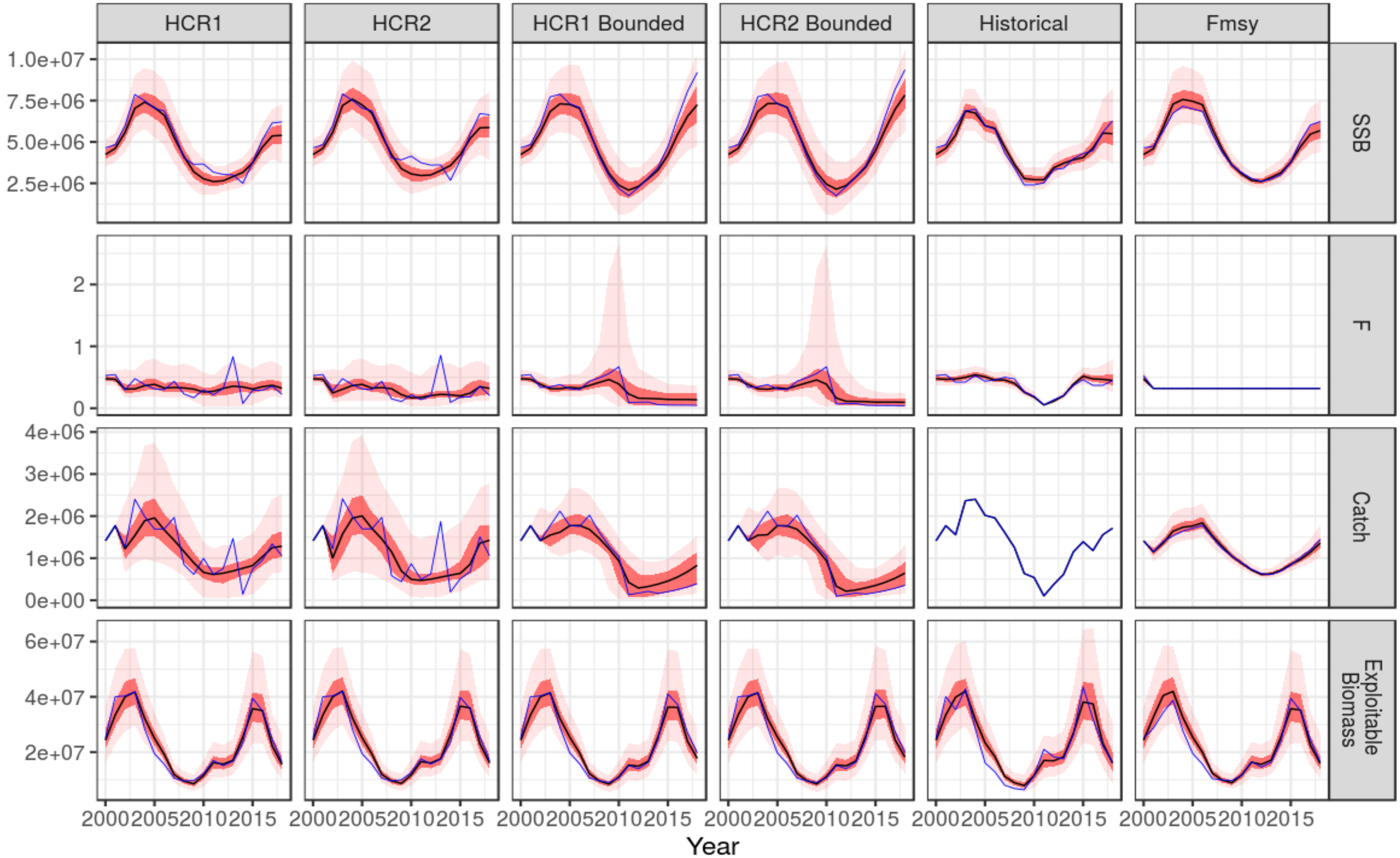

Figure 31 Summary of HCR performance.

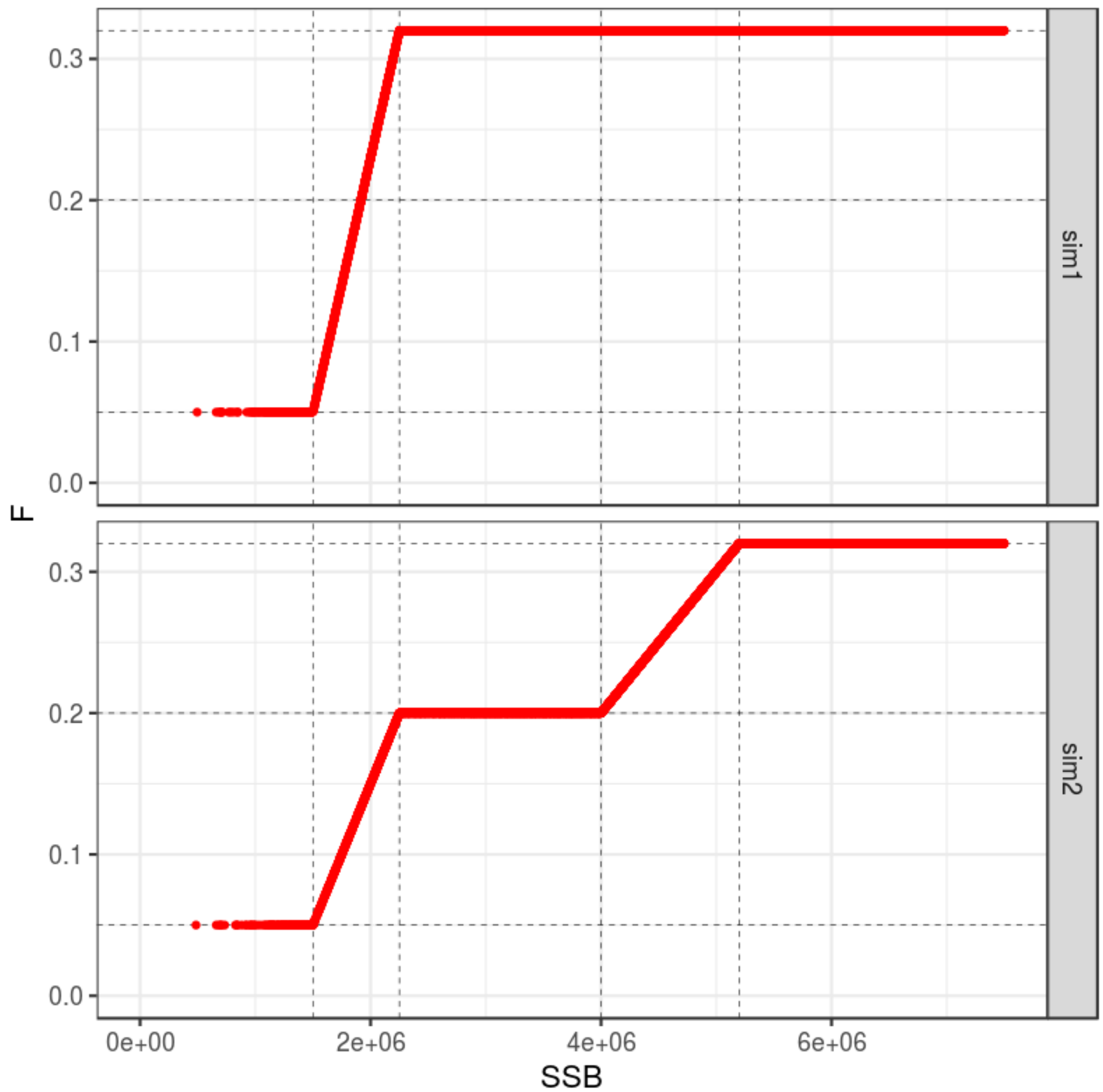

Figure 32 Values of F for assessed SSB from the HCR, as a check that the HCR is working as expected

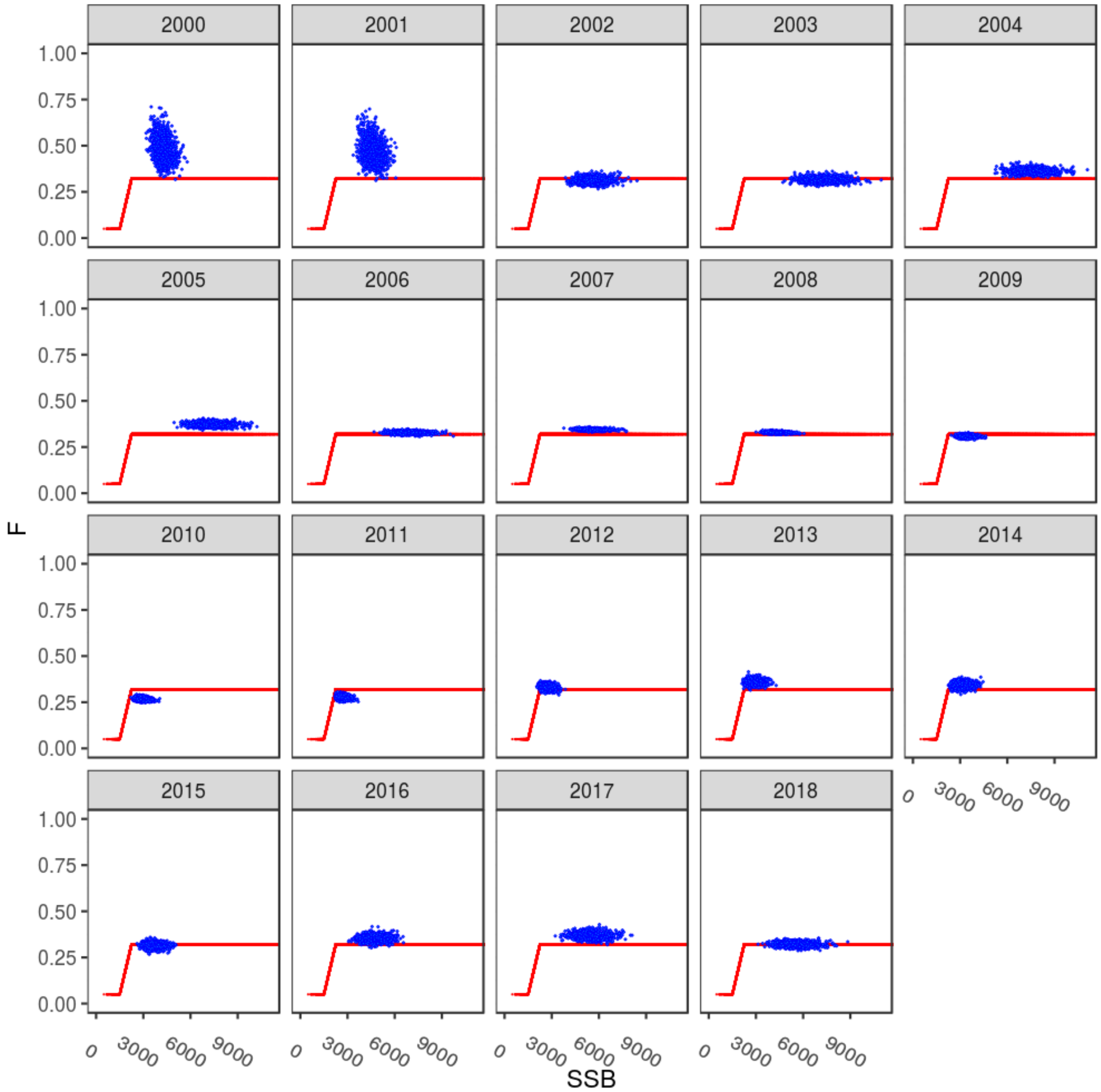

Figure 33 Plot of F v SSB for HCR I without assessment error.

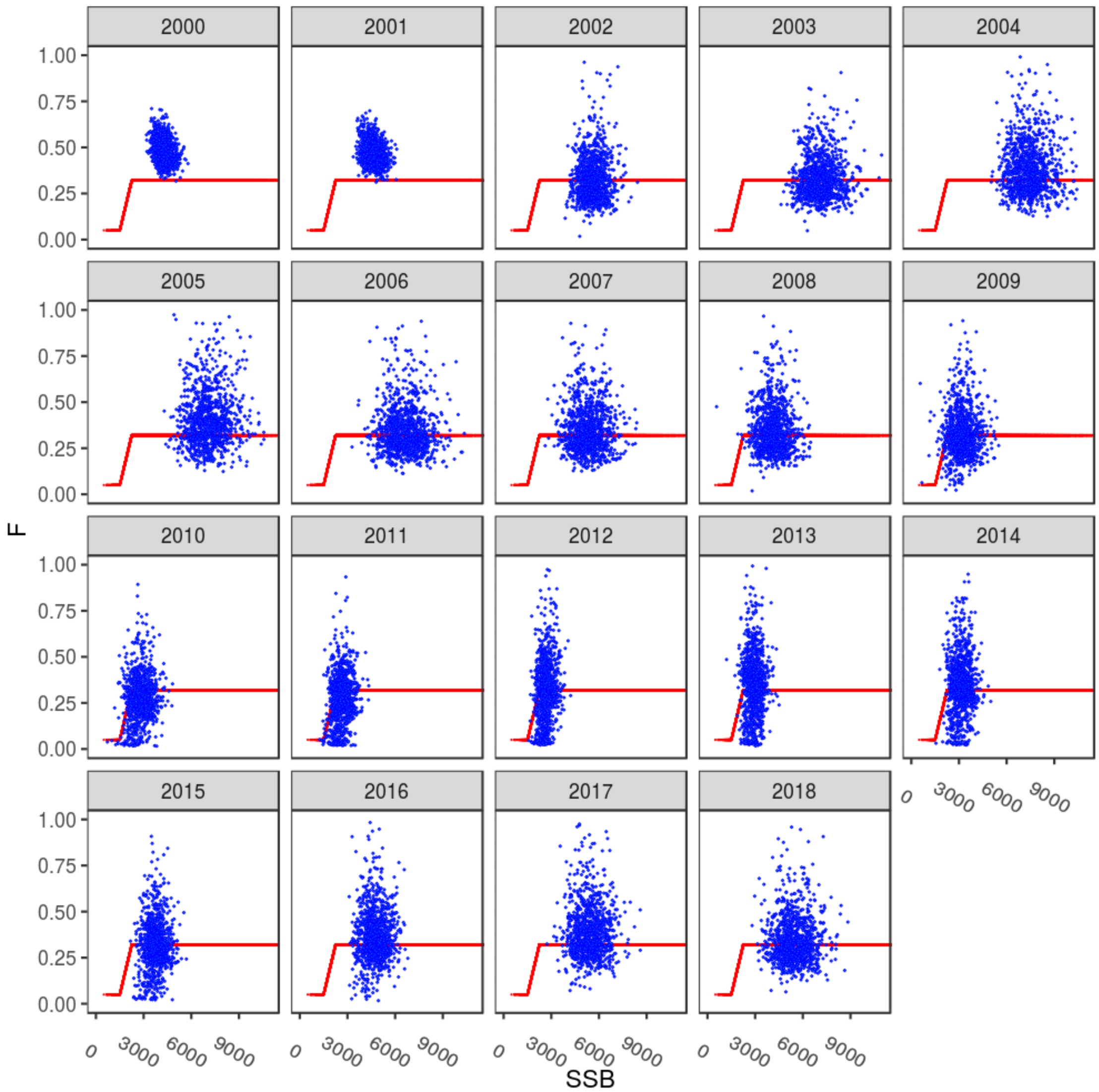

Figure 34 Plot of F v SSB for HCR I.

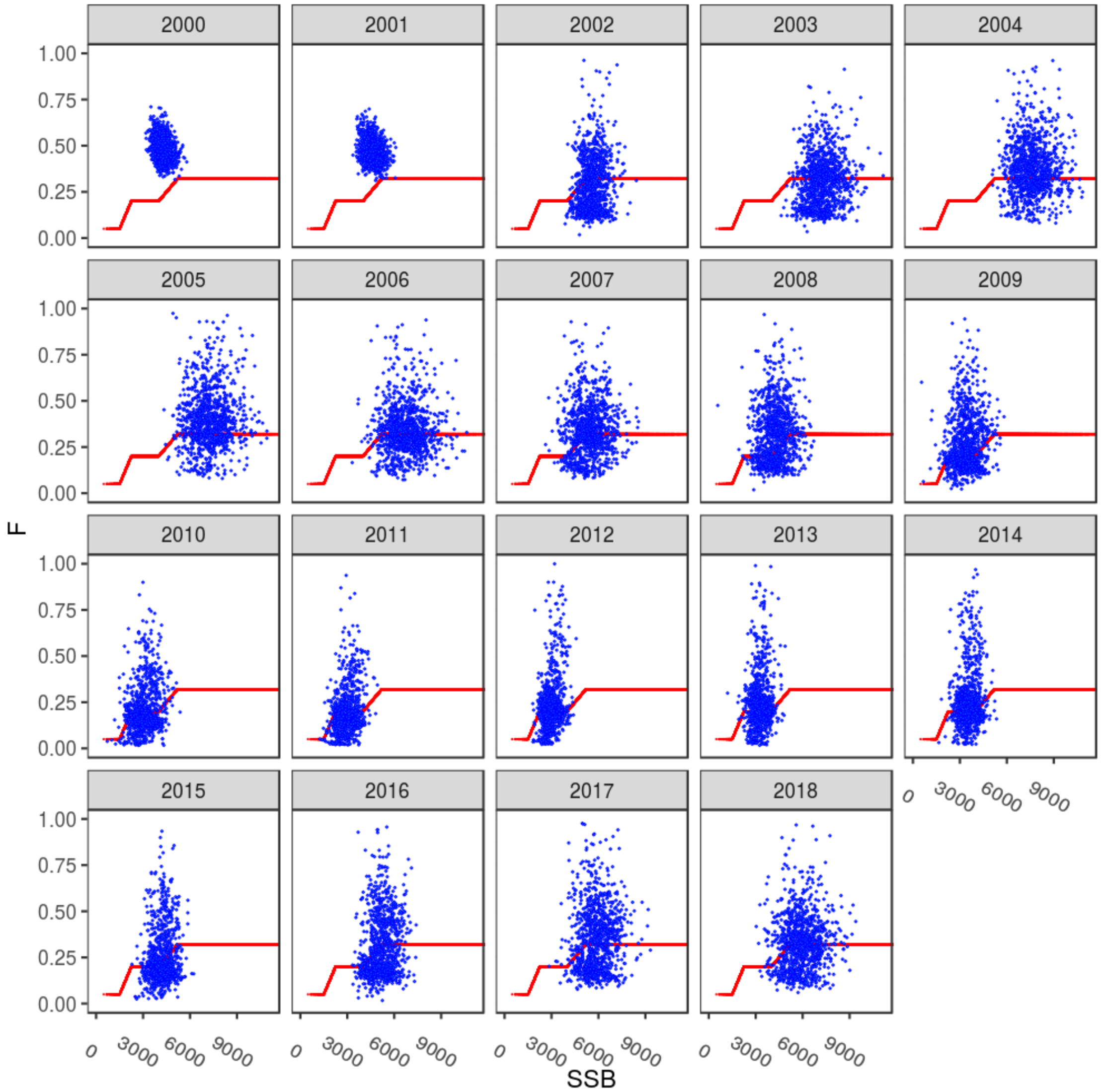

Figure 35 Plot of F v SSB for HCR II.

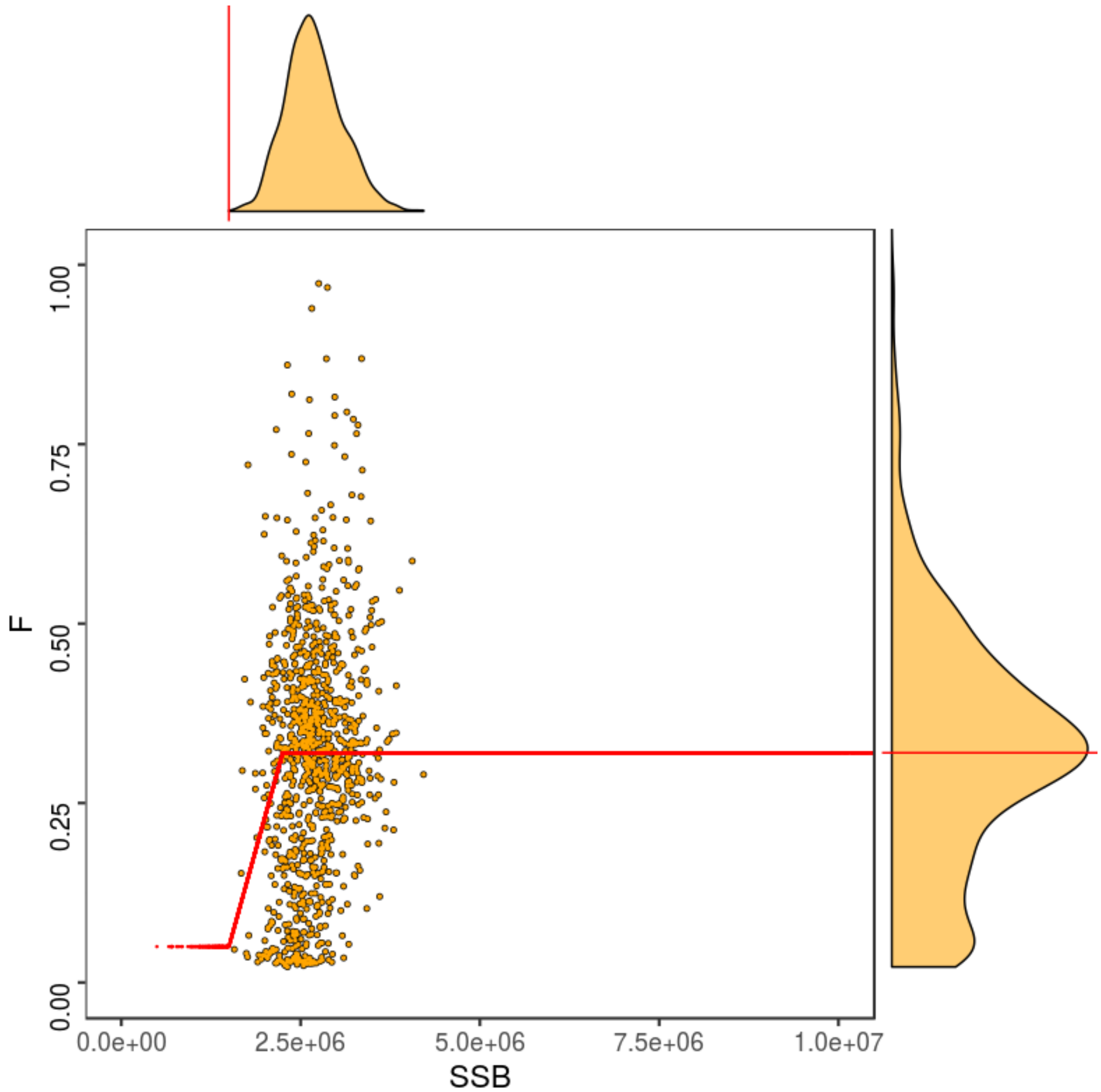

Figure 36 HCR I plot of F v SSB for 2012 with marginal densities

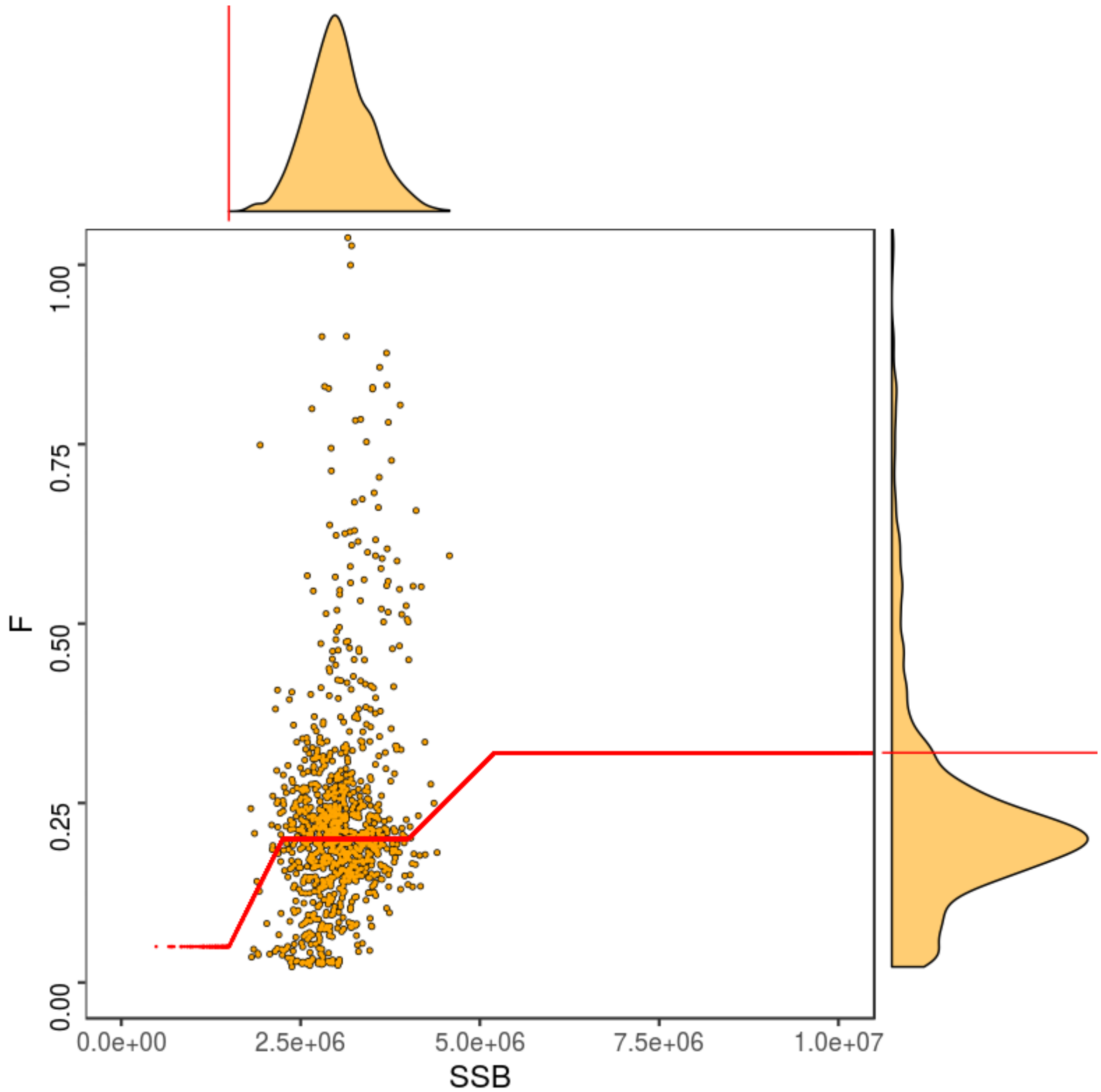

Figure 37 HCR II plot of F v SSB for 2012 with marginal densities

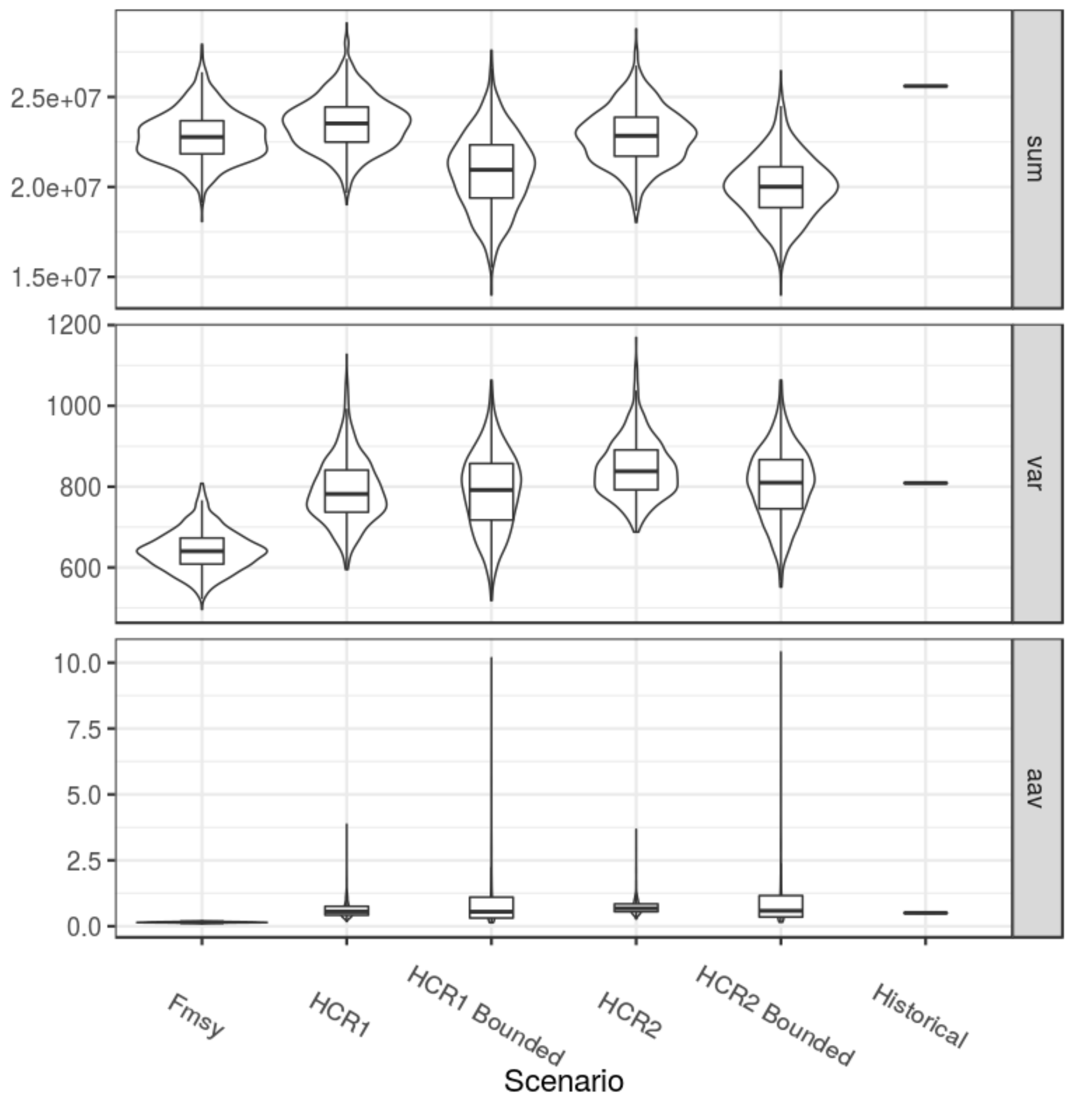

Figure 38 Catch summary, total catch and AAV by iteration over simulated period

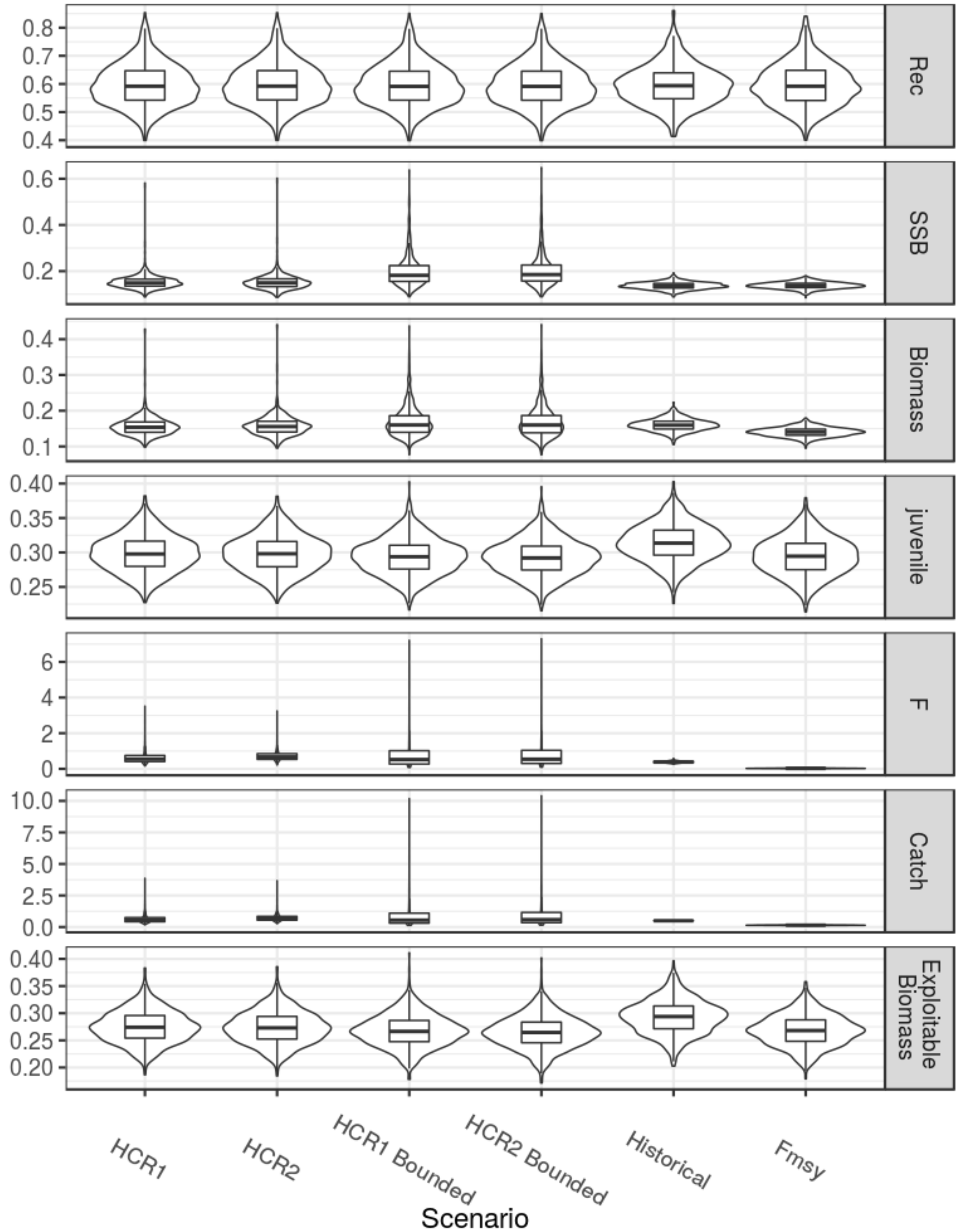

Figure 39 Mean Interannual Annual Absolute Variation over time series by iteration.

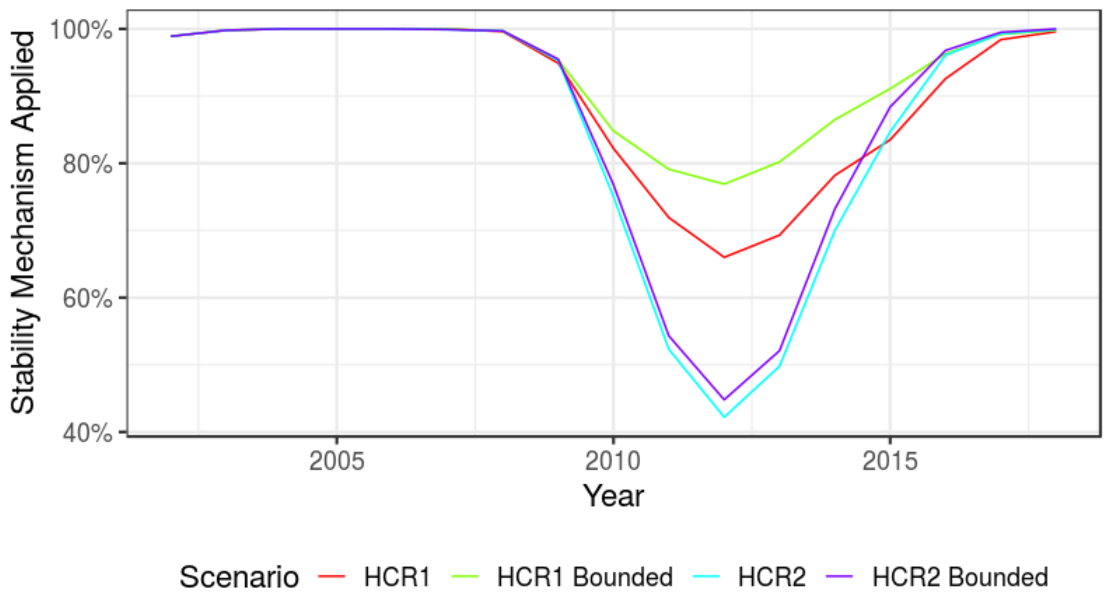

Figure 40 The percentage by year when the stability mechanism was applied.

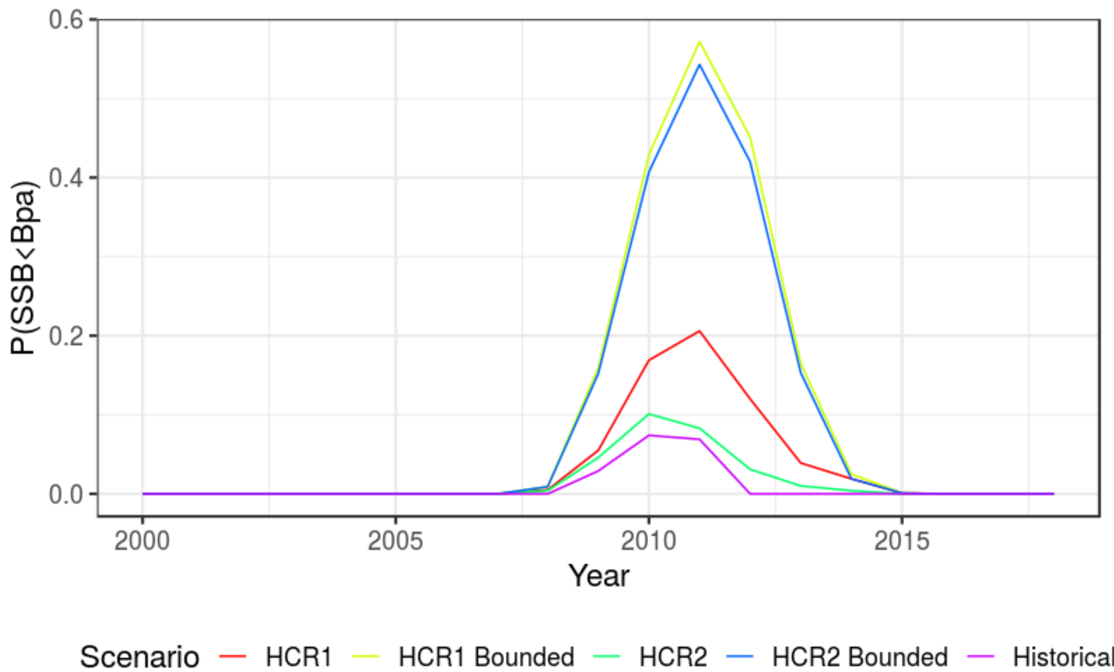

Figure 41 Probability that SSB falls below Bpa

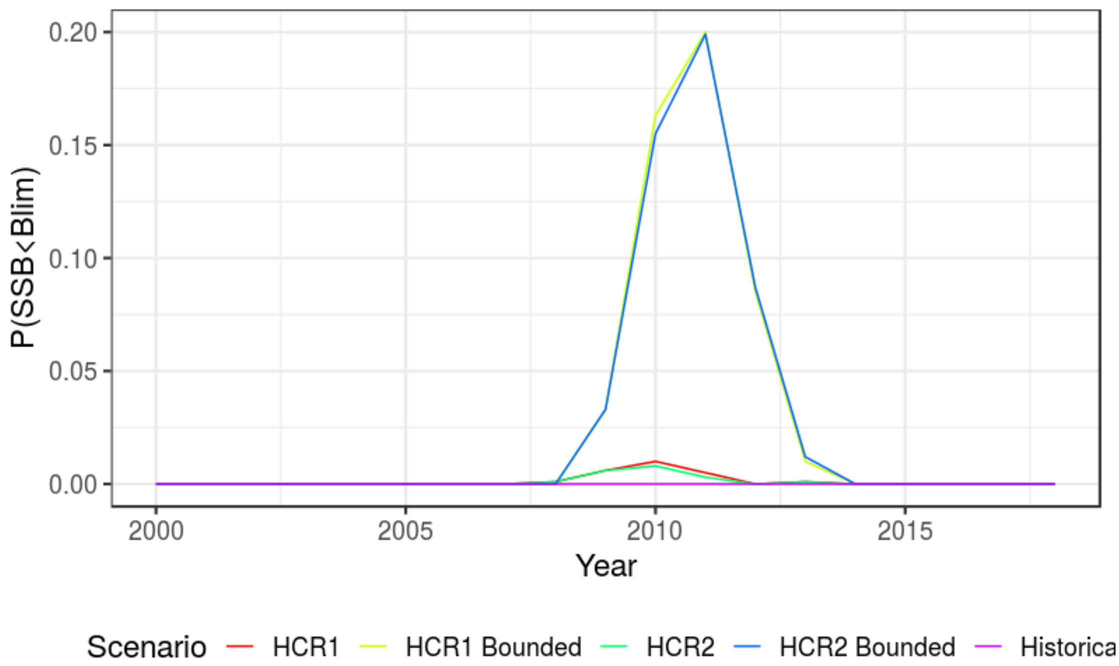

Figure 42 Probability that SSB falls below BLim.

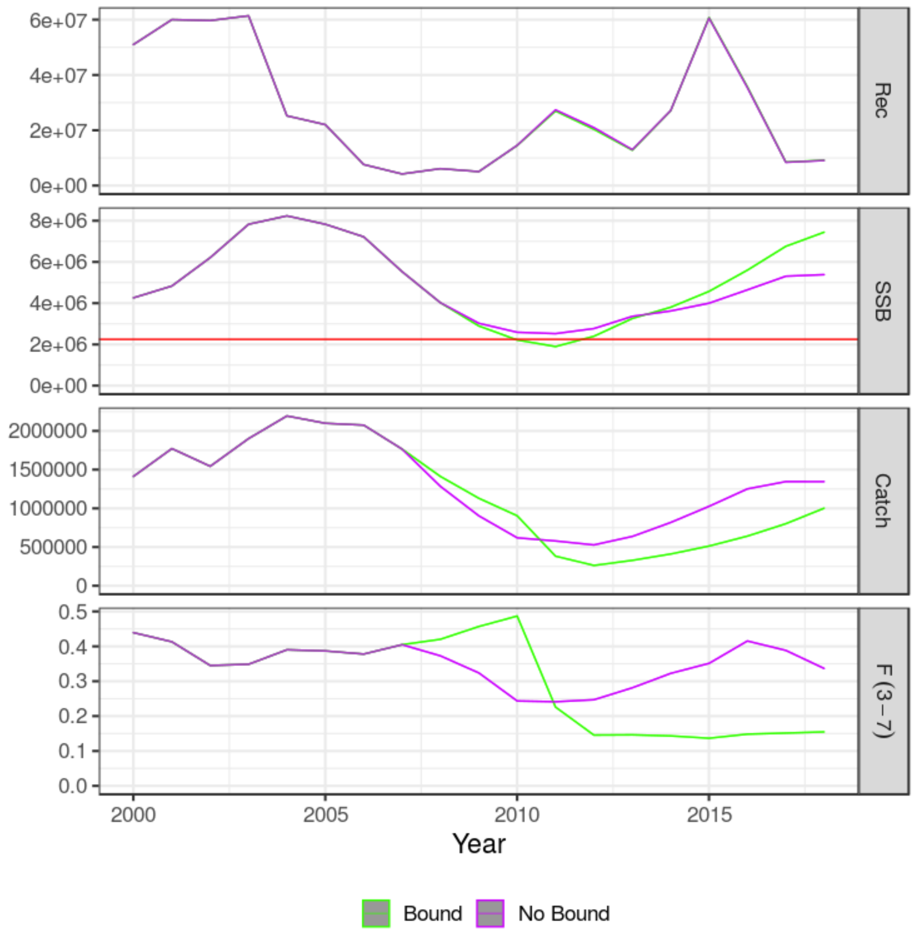

Figure 43. Simulation of HCR I for a single Monte Carlo run without assessment error and with and without bounds. The horizontal line shows the Bpa level and the verticle line the year when the bounds are turned off.

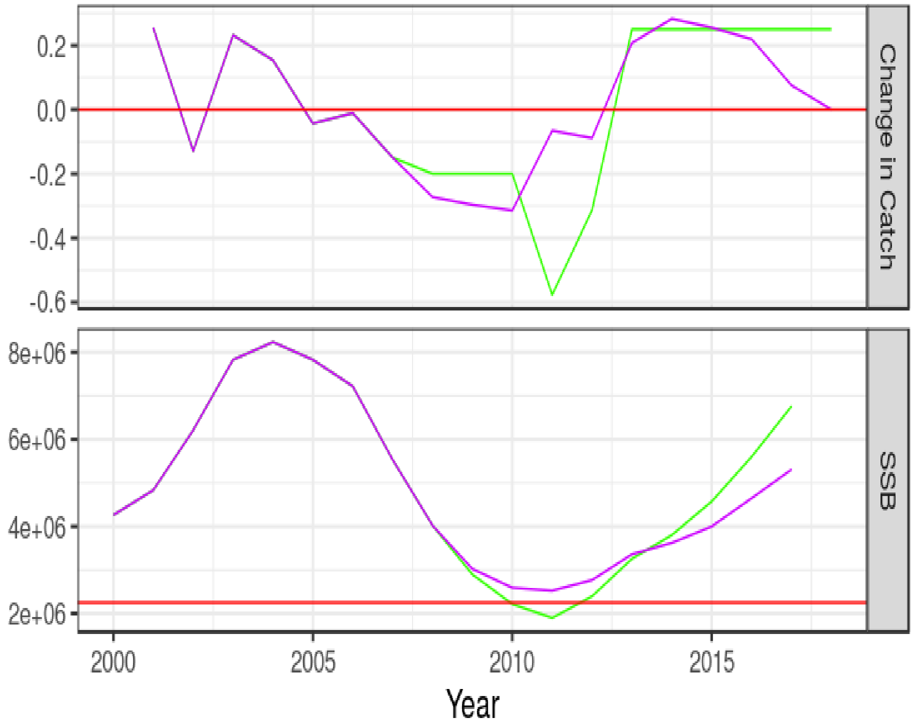

Figure 44. Simulation of HCR I for a single Monte Carlo run without assessment error and with (green) and without (purple) bounds. The horizontal line shows the Bpa level.

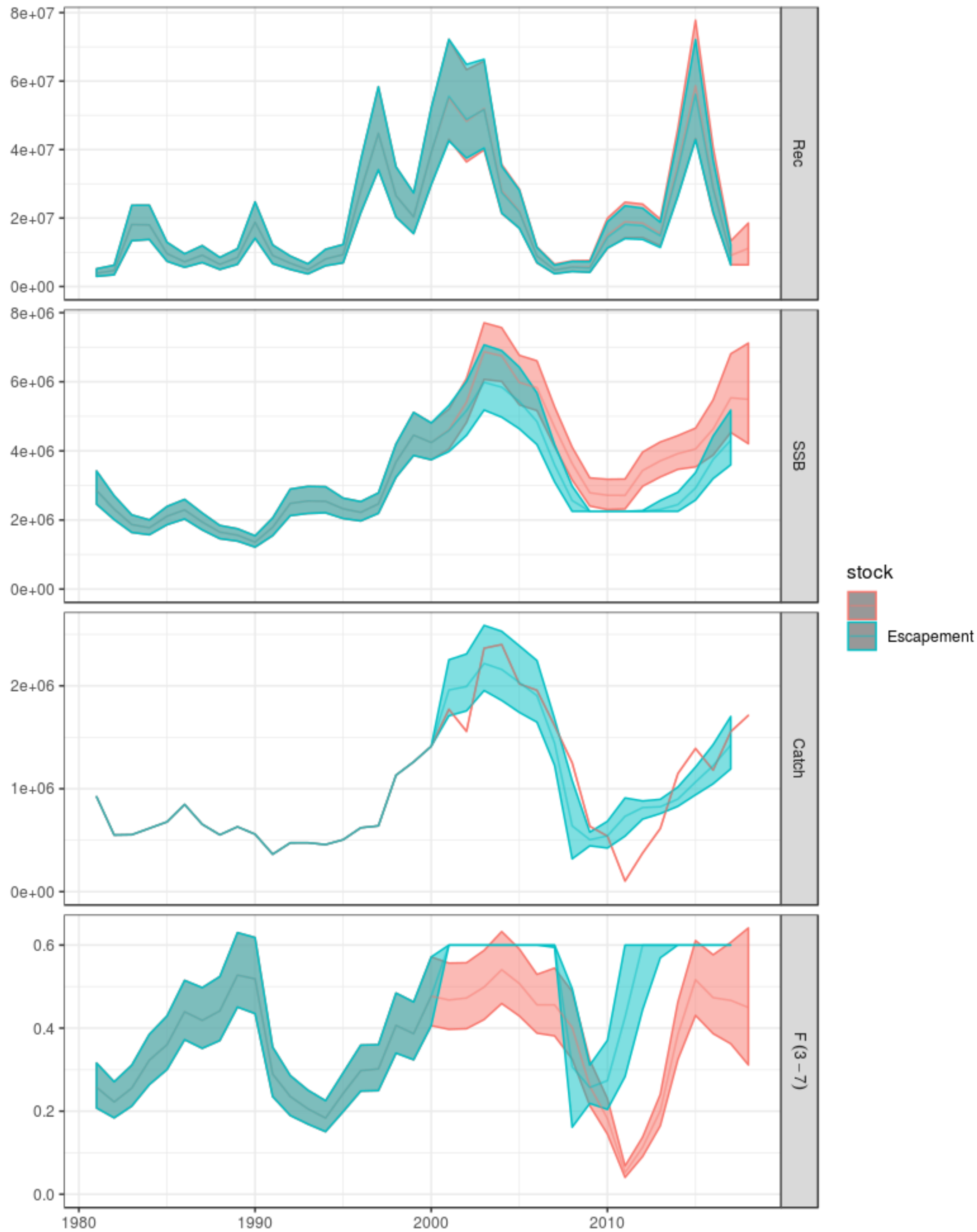

Figure 45. Comparison of historical stock trends and an escapement harvesting strategy (take all biomass>Bpa) and an F cap of 0.6

Review

Blue whiting technical meeting, 7 August 2019, WTC Schiphol

Participants: Esben Sverdrup, Gerard van Balsfoort, Laurie Kell, Polina Levontin, Martin Pastoors

The objective of the meeting was to review the preliminary results of the blue whiting hindcast evaluation, to identify whether additional work needed to be done and to prepare for the final presentation of results for the blue whiting focus group on 21 August and the ICES WGWIDE starting on the 28th of August.

Laurie Kell and Polina Levontin of Sea++ explained the results of the hindcast evaluation that they carried out for blue whiting. The basic approach has been as follows:

All coding was done in R using FLR (Kell, et al., 2007) designed to build simulation models representing alternative hypotheses about stock and fishery dynamics. Code will be made available on the GitHub repository

An Operating Model (OM) was developed to run simulations of the stock under the different HCRs. The OM was conditioned on the current ICES stock assessment (ICES. 2018)

Two HRCs were implemented and simulation tested, namely

- HCR-I: The Standard ICES MSY rule using an Fmsy= 0.32 and an MSYBtrigger of 2.25 Mt
- HCR=II: The two-tier approach with the following parameters:
    - A lower bound of Fmin= 0.05 below Blim = 1.5 Mt;
    - A linear sliding scale with slope a1 =2.0 starting at B lim and ending at B1 Trigger = 2.25 Mt;
    - A standard level between Trigger B1 and Trigger B2 at F 0.1 =0.22;
    - A linear sliding scale with slope a2 =2.0 above B2 Trigger where B2 Trigger is 4.0 Mt;
    - An upper bound at higher stock sizes at F MSY =0.32

Both scenarios were executed with and without a stability mechanism of 20% down and 25% up when the stock is assessed to be above Blim .

Simulations start in the initial year (2000) and then the stock is projected forward using either of the two alternative HCRs and with or without bounding the variability in TACs.

Uncertainty in stock assessments was taken at 0.3, derived from the retrospective analysis of the SAM assessment

Evaluation of results

Overall, the participants from PELAC were happy with the results that were presented in the sense that it was clearly outlined what had been done and that the diagnostics were well explained. Laurie and Polina were complimented for providing a comprehensive analysis for blue whiting. Because the results are based on a hindcast with a fixed recruitment pattern it was relatively easy to see the performance of different HCRs under different recruitment regimes). A remarkable (and erroneous) outcome was that when a TAC bound was applied for stocks higher than Blim, the stocks would tend to crash at some stage and finding it difficult to recover. This was thought to be caused by the lack of a 'break'-effect of a declining F in the HCR which was 'overwritten' by the stability clause, meaning that the catches would not go down quickly enough when the stock was rapidly going down.

It was suggested that possibly the best HCR rule would be an escapement rule with an Fcap of e.g. 0.5. However, this option has not been presented in the report.

There a number of issues that would need to be modified or changed prior to a final product being delivered:

[X] Add years (and colours) to the stock and recruitment plot of blue whiting

[X] In the simulation (and contract) it was specified that below Blim no bounds should be used. However, in fact this should apply below Btrigger. The results need to be redone with bounds only being applied when the stock is above Btrigger.

[X] When the stock has declined to a low level and the catches are set close to zero, the HCR does not allow for rapid increases in catch based on the bounds on TAC change. In such a situation a different element of the HCR would need to be included. It is not foreseen to carry out such an analysis prior to the 21st of August, because of timing issues. do you do when the TAC has been set to almost zero. This needs a change in the HCR approach.

[X] The results were based on almost no uncertainty in recruitment. It is recommended to use uncertainty estimates for recruitment from the 1000 replicated assessments and the estimated SRR relationships therein.

[ ] It is important to make a list of the uncertainties that have been included in the simulation.

[ ] Idea: explore the management approach for Southern bluewhiting fishery (New Zealand); MP

[ ] Idea: Make a plot of recruitment data from surveys; MP

[X] Plan a skype meeting on friday 9 August or Monday 12 August to start preparing the presentation for 21 august and WGIDE (LK, PL, CS, MP).

2019 Mackerel and Horse Mackerel Egg Survey

Preliminary Results

by

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Maria Korta[4], Anders Thorsen[5]

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Introduction

The mackerel and horse mackerel egg survey is an ICES-coordinated international study in the north east Atlantic conducted during the first half of 2019. This study is a combined plankton and fishery investigation formed by a series of individual surveys which have taken place triennially since the late 1970s and is coordinated by the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS).

The main objective of this series of individual cruises from January until July is to produce both an index and a direct estimate of the biomass of the north east Atlantic mackerel stock and an index for the southern and western horse mackerel stocks. The results have been used in the assessment for mackerel since 1977 and from 1992 for horse mackerel. The mackerel and horse mackerel egg survey is still the main source of data providing fisheries independent information for these stocks.

The general method is to quantify the freshly spawned eggs in the water column on the spawning grounds. To be able to establish a relationship between eggs and biomass of the spawning stock, the fecundity of the females must also be determined. This is undertaken by sampling ovaries before and during spawning. The potential fecundity is counted from whole mount volumetric subsamples using a dissecting microscope while atresia is counted histologically from slides. Realised fecundity is estimated as potential fecundity minus atresia. The realised fecundity is used in combination with the calculated number of freshly spawned eggs in the water to estimate the spawning stock biomass.

To provide reliable estimates of spawned eggs and fecundity an extensive coverage of the spawning area is required both in time and space. The spawning of the southern horse mackerel stock and mackerel starts in late December off the Portuguese coast. Spawning proceeds further north along the continental shelf edge as water temperature increases during late winter and spring. In the past peak spawning of mackerel has normally occurred in April-May in the area of the Sole Banks with an extension to the Porcupine Bank. Whilst the distribution and timing of peak western horse mackerel spawning has remained fairly stable during recent surveys the same cannot be said for NEA mackerel. Recent surveys in 2010 and 2013 saw peak mackerel spawning in February – March with 2013 also demonstrating a shift in the geographical centre of spawning further south within the southern Biscay region. Away from these areas mackerel spawning is now observed over a large region of the Northeast Atlantic both on and off the continental shelf, ranging as far west as Hatton Bank and as far north as Iceland and the Faroe Islands as well as the Shetland Islands and the Norwegian coast in the Northeast.

This survey report presents the preliminary results of the 2019 mackerel and horse mackerel egg survey provided for WGWIDE in August 2019. The survey report and the analysis will be finalized during the next WGMEGS meeting in April 2020. Although every effort was made to ensure that WGWIDE were provided with the most recent and accurate data-set, WGMEGS cannot guarantee that there will not be changes prior to the analysis being finalised. This is due to the extremely large numbers of plankton and fecundity samples to be analysed following the surveys as well as the tight deadline set by WGWIDE for delivering these estimates. This has resulted in a very limited time within which to process the 2019 MEGS data.

Survey effort

As a consequence of the long spawning period and the large survey area involved, the mackerel and horse mackerel egg surveys have always relied on broad international participation. In 2019 a total of 18 individual cruises were carried out with a total of 352 survey days, with the contribution of Spain (IEO: 51 days at sea, AZTI: 30 days), Scotland (80 days), the Netherlands (39 days), Ireland (42 days), Portugal (39 days), Germany (36 days), Norway (21 days) and the Faroe Islands (14 days). In 2019 Iceland unfortunately had to withdraw from the MEGS surveys but the group were very happy to welcome the return of Norway. Denmark who had expressed an interest in joining the surveys were eventually not in a position to participate in 2019.

Survey design

The aim of the triennial egg survey is to determine the annual egg production (AEP). This is calculated using the mean daily egg production rates per pre-defined sampling period for the complete spawning area of the Northeast Atlantic Mackerel and Horse Mackerel Stocks. To achieve this, one plankton haul per each half rectangle (separated by approximately 15 nm) is conducted on alternating transects covering the complete spawning area. The 2019 egg survey was designed in order to maximise both the spatial and temporal coverage in each of the sampling periods. Given the very large area to be surveyed this design minimises the chances of under/overestimation of the egg production (ICES 2008).

The 2019 survey plan was split into 6 sampling periods (Table 1). Originally Portugal were assigned a Period 1 survey which would extend into Period 2. Due to a delay in the start of their survey it was decided to modify the start date of period 2 in the southern area and include the survey into period 2. No sampling was scheduled to take place in division 9.a after Period 2. Sampling of the western area commenced in period 2, and included coverage of the west of Scotland, west of Ireland and Biscay. Surveying in the Cantabrian sea ended at the end of period 5. In periods 6 and 7 the surveys were designed to identify a southern boundary of spawning and to survey all areas north of this boundary.

Maximum deployment of effort in the western area was during periods three, four, five and six. Historically these periods would have coincided with the expected peak spawning of both mackerel and horse mackerel. Recent years have seen mackerel peak spawning taking place during periods 3 and 5.

Due to the expansion of the spawning area which has been observed since 2007 the emphasis was even more focused on full area coverage and delineation of the spawning boundaries. Cruise leaders had been asked to cover their entire assigned area using alternate transects and then use any remaining time to fill in the missed transects.

Table 1. Participating countries, vessels, areas covered, dates and sampling periods of the 2019 surveys.

Country	Vessel	Area	Dates	Period
Portugal	Noruega	Portugal	Jan 23rd – Feb 26th	2
Ireland	Celtic Explorer	West of Ireland, Celtic sea, Biscay,	February 8th – 28th	2
	Corystes	West of Ireland, west of Scotland	June 9th – 29th	6
Scotland	Scotia	West of Scotland	February 24th – Mar 1st	2
	Altaire	West of Scotland, west of Ireland	March 19th – Apr 1st	3
	Altaire	West of Scotland	April 16th – 29th	4
	Scotia	West of Scotland, west of Ireland	May 8th – 30th	5
	Altaire	West of Scotland, west of Ireland, Celtic sea, Biscay	July 1st – 23rd	7
Spain (IEO)	Vizconde de Eza	Cantabrian sea, Galicia, southern Biscay	March 14th – April 5th	3
	Vizconde de Eza	Cantabrian sea, Galicia, Biscay	April 9th – May 4th	4
Spain (AZTI)	Ramon Margalef	Northern Biscay	March 19th – 30th	3
	Ramon Margalef	Biscay, Cantabrian sea	May 3rd - 25th	5
Germany	Dana	Celtic sea, west of Ireland	March 29th – April 12th	3
	Dana	Celtic sea, west of Ireland, west of Scotland	April 15th – 30th	4
Netherlands	Tridens	Northern Biscay, Celtic sea	May 4th – 24th	5
	Tridens	Biscay, Celtic sea	June 5th – 23rd	6
Norway	Brennholm	Faroes & Norway	June 9th – 29th	6
Faroes	Magnus Heinason	Faroes, Iceland	May 23rd – June 5th	5

Processing of samples

The analysis of the plankton and fecundity samples were carried out according to the sampling protocols as described in the WGMEGS Survey Manual (ICES, 2019a) & Fecundity manual (ICES, 2019b).

A total of 1780 plankton samples were collected and sorted. Mackerel and horse mackerel eggs were identified and the egg development stages determined. Depending on the vessel facilities and the experience of the participants this was done either during the cruise or back in the national institutes.

Double micropipette samples and slices from ovaries of mackerel were taken during each survey. Additional samples were collected during periods 3 and 4 by participants in an effort to carry out DEPM analysis. Fecundity sampling for horse mackerel only took place during the expected peak spawning periods, 6 and 7. After each survey the ovary screening and fecundity samples were sent to different European research institutes for histological and whole mount analysis to determine the realised fecundity (potential fecundity minus atresia). Fecundity samples have to be analysed in the laboratory upon return from sea and the procedures for analyses are time consuming. The last samples were collected in July and because of the narrow time frame only a selection of the fecundity samples have been analysed up to this date. Samples were therefore only analysed from sampling periods 2 and 3 for the preliminary estimate.

Horse mackerel is considered to be an indeterminate spawner and therefore since 2007 IPMA has adopted the DEPM methodology for horse mackerel in the southern area. The egg survey design in the western area is directed at the AEP method for mackerel which produces an estimate of SSB. Fecundity samples for horse mackerel were taken during the survey in the western areas in order to develop a modified DEPM approach for estimating the biomass of the horse mackerel stocks.

None of the DEPM ovary samples have been analysed yet.

Survey coverage and mackerel egg production by period

Period 2 – Portugal started the 2019 survey series on January 23rd. This DEPM survey is mainly targeting the southern horse mackerel stock and is designed for this purpose, but it provides mackerel egg samples as well. The survey is usually undertaken between Cadiz and the Galicia and is confined to ICES IXa. Period 2 also marks the commencement of the western area surveys. In the west MEGS once again started sampling earlier in February than would have been the case prior to the 2010 and 2013 surveys. Sampling was undertaken by Ireland (West of Scotland, west of Ireland, Celtic Sea, Biscay), and Scotland (West of Ireland and West of Scotland) (Fig. 1.1 & Annex 1). This year the mackerel migration appears to have been similar to that noted in 2016 and as a consequence only very low levels of spawning were found. The eggs that were recorded were close to the 200m contour line. Despite some very poor weather at the start of February survey coverage was good with 101 stations sampled, only 20 interpolations, and 14 replicate samples.

Period 3 – In period 3 the German vessel was operating to the West of Ireland, Celtic Sea and northern Biscay with Northwest Ireland and the West of Scotland being covered by Scotland. The Bay of Biscay, Cantabrian Sea and Galicia were covered by Spain (IEO and AZTI). Egg numbers were quite low to the west of Scotland, however further south large numbers of eggs were found close to the 200m contour line and the Porcupine bank (Fig. 1.2 & Annex 1). In Biscay and the Cantabrian Sea IEO and AZTI recorded a number of stations with large egg numbersThis was much higher than that recorded in 2016 for this area and time period. 362 stations were sampled and there were only 16 interpolations. There were 68 replicate samples with the majority being completed in the Cantabrian Sea.

Period 4 – This period was covered by three surveys. Denmark had intended to survey West of Scotland but were forced to withdraw. Scotland was subsequently able to mobilise an additional survey to cover this area. Germany surveyed west of Ireland, Celtic sea and northern Biscay while IEO completed the survey coverage in southern Biscay and the Cantabrian Sea (Fig. 1.3 & Annex 1). Once again moderate levels of eggs were recorded throughout the area, with the highest concentrations still being found close to the 200m contour line. The exception this year was a number of stations with high counts recorded by Scotland along the 200m contour from Cape Wrath to Shetland. 319 stations were sampled and there were 55 interpolations. 50 replicate samples were taken and these were collected from the Cantabrian Sea.

Period 5 – In period 5, the entire spawning area from the Cantabrian sea to the West of Scotland, and up to Faroese waters at around 61°N was planned to be surveyed by AZTI, the Netherlands, Scotland, Faroes and Iceland. Due to the withdrawal of Iceland, Faroes agreed to cover the whole of the northern area on alternate transects. Extra stations were also added to the east of Faroes where very high mackerel counts had been recorded by Scotland in period 4. Several stations with significant numbers of stage 1 eggs were recorded in the Cantabrian Sea but throughout Biscay and into the southern Celtic sea numbers were generally low to moderate (Fig. 1.4 & Annex 1). This pattern continued west of Ireland to around 54°N, with spawning remaining on and around the Shelf edge. North of this however, and similar to that noted in 2016, spawning activity fanned out greatly both westwards and northwards. Due to the large area Scotland had to survey their vessel was forced to restrict exploration of the western boundary to the SW of Rockall Bank. In this area significant numbers of eggs were found and consequently it was not possible to fully delineate theboundary in this region. North of this the Faroese survey completed stations North of Hatton Bank and up towards the Icelandic coast before bad weater curtailed sampling and ended the survey. In total 409 stations were sampled and there were 184 interpolations. 22 replicate samples taken

Period 6 – During period 6 northern Biscay, from 46°N and also the Celtic sea were covered by the Netherlands while Ireland covered west of Ireland and also west of Scotland. Norway surveyed the area north of 59°N from the south of Iceland to the Norwegian coast. Low levels of spawning were observed all along the survey area from Biscay in the south to the West of Ireland and Porcupine bank (Fig. 1.5 & Annex 1). In contrast to the period 5 survey very few mackerel eggs were found between 54°N and 58°N, apart from close to the 200m line. West of the Faroes Norway secured the northern boundary at 63°N, while to the east of the Faroes small numbers of eggs were observed right up to survey boundary at 64°N. 422 stations were sampled with 210 interpolations. Six replicate station was completed.

Period 7 – This period was covered entirely by Scotland sampling on alternate transects in the area from 47°15N in the South (Fig. 1.6 & Annex 1). Due to the lack of eggs encountered the Scottish survey adhered very closely to the 200m contour. As a result the survey followed this contour line as far as Shetland before heading north to reach 63.15°N. 145 stations were sampled with 60 interpolations. Only 1 replicate station was completed. Only very low levels of spawning were observed and these were confined to the continental shelf and shelf edge with all spawning boundaries being delineated successfully.

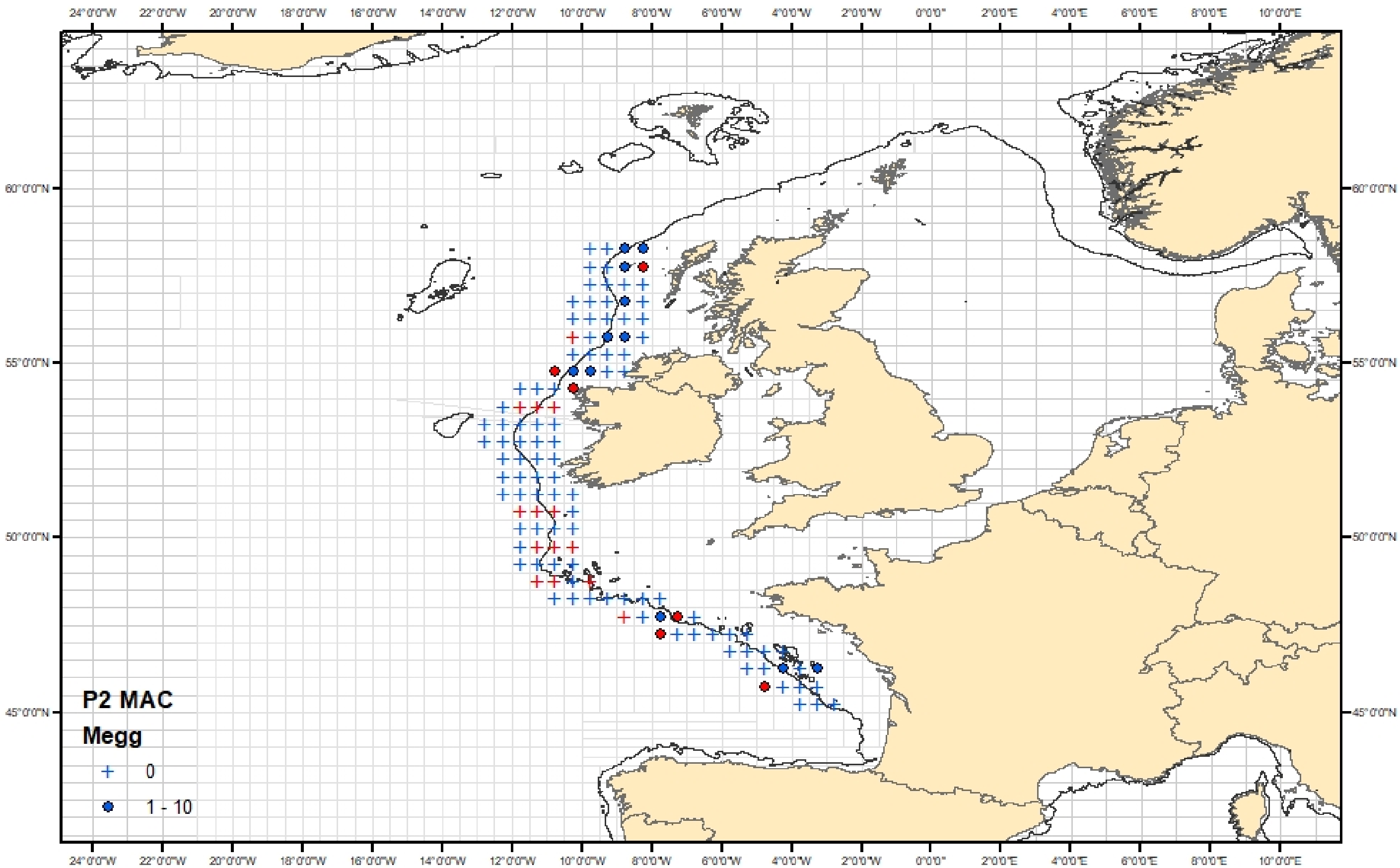

Figure 1.1: Mackerel egg production by half rectangle for period 2 (Feb 5th – Mar 3rd). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

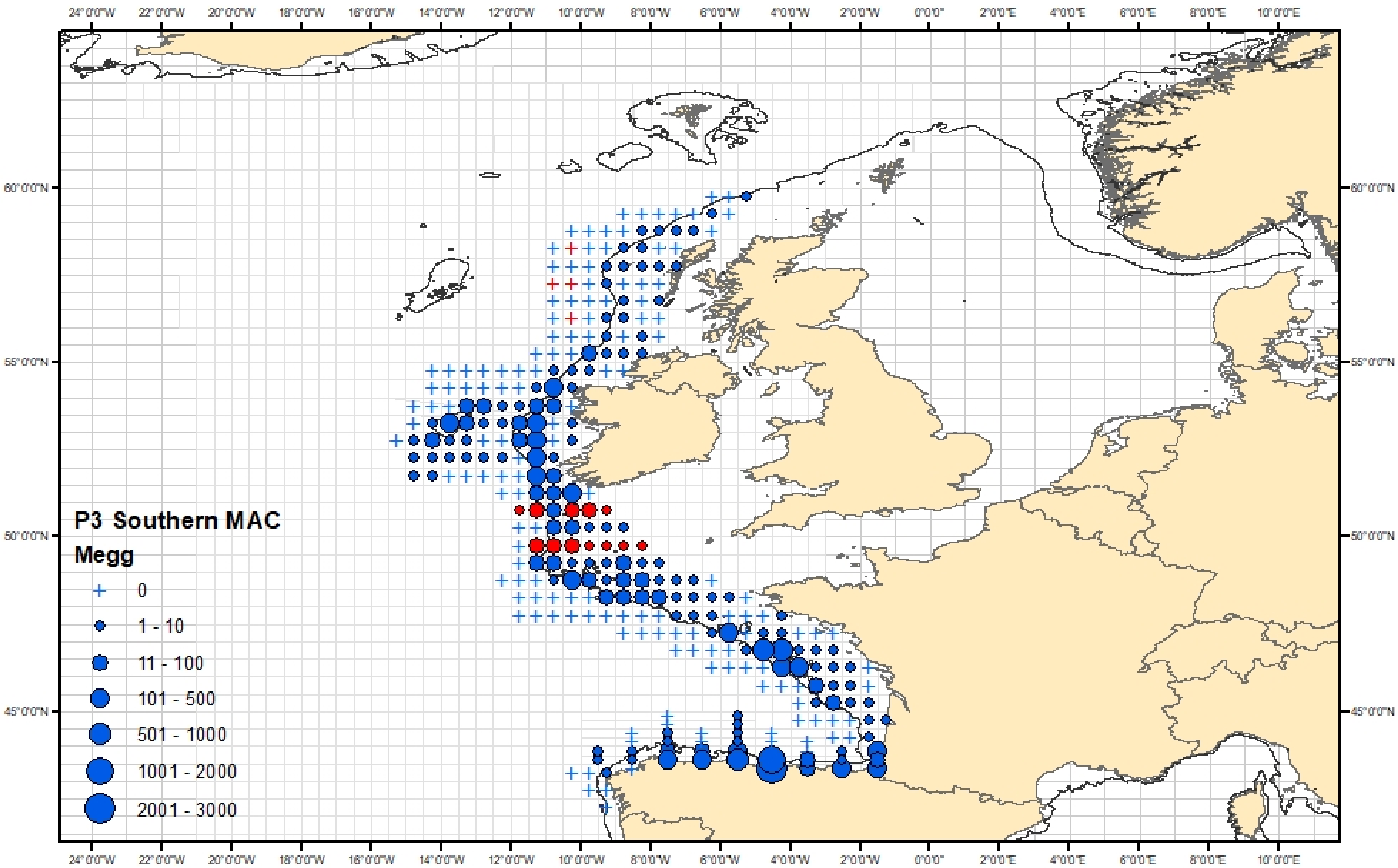

Figure 1.2: Mackerel egg production by half rectangle for period 3 (Mar 4th – Apr 12th). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

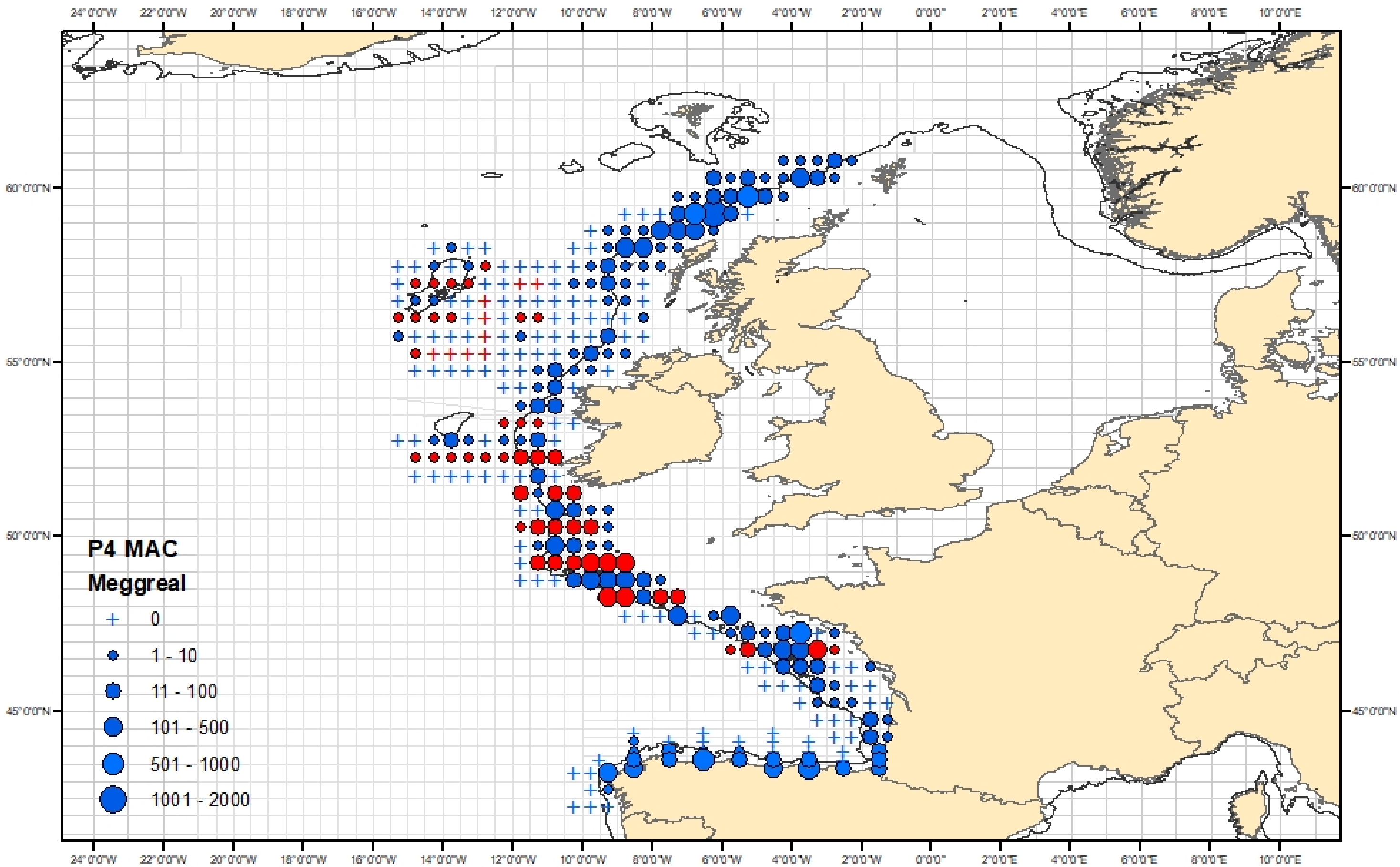

Figure 1.3: Mackerel egg production by half rectangle for period 4 (Apr 13th – May 3rd). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

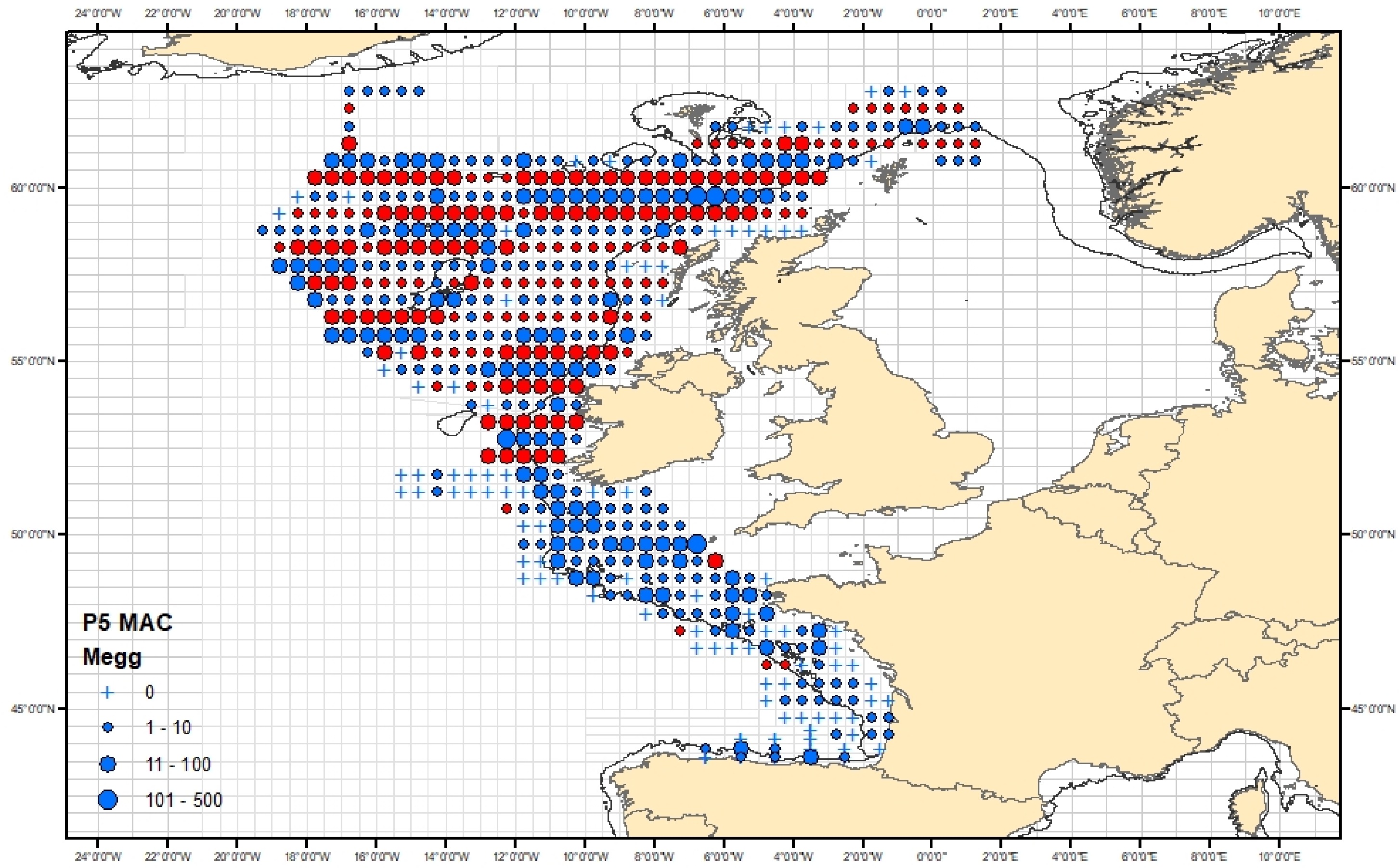

Figure 1.4: Mackerel egg production by half rectangle for period 5 (May 4th – June 5th). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

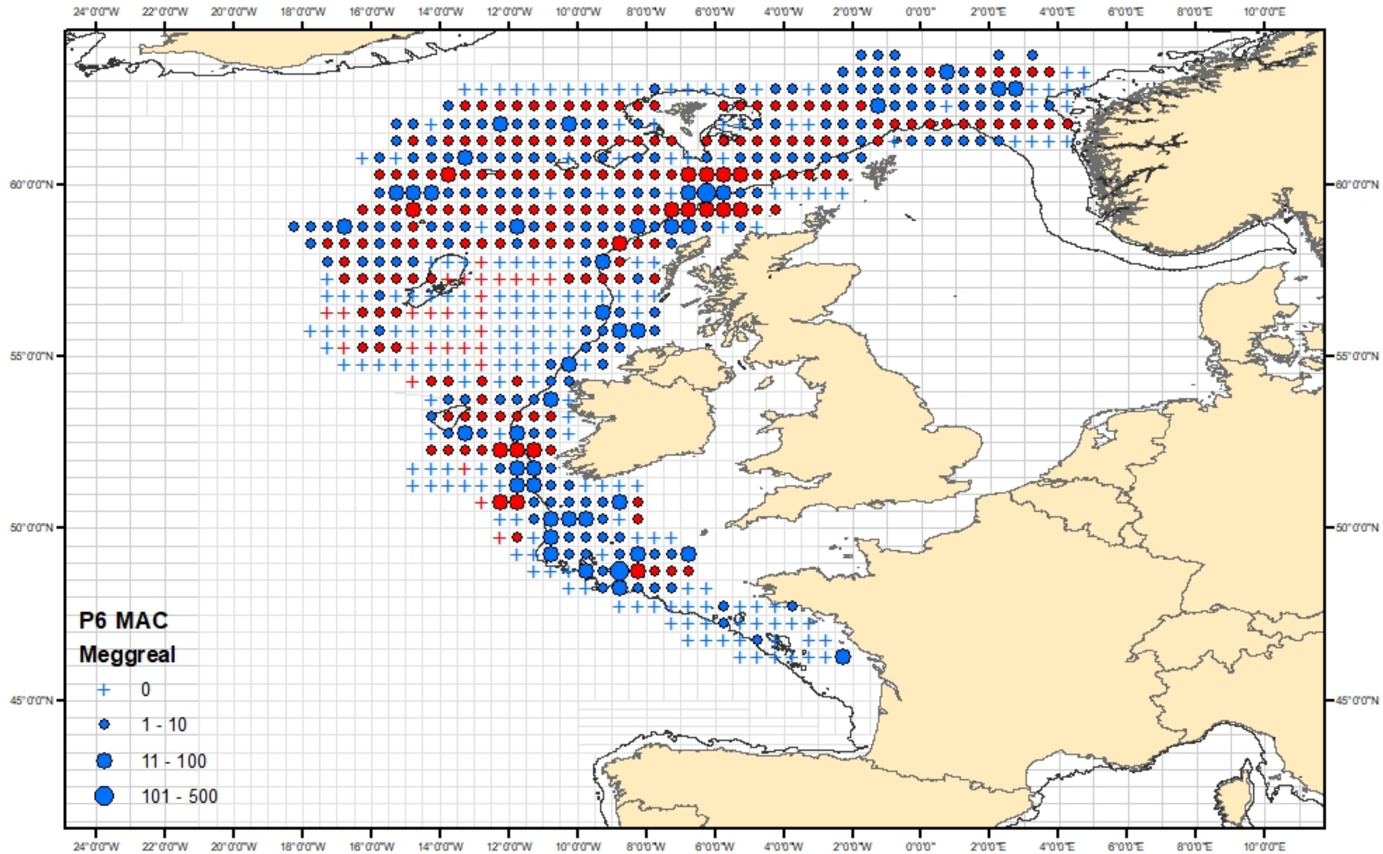

Figure 1.5: Mackerel egg production by half rectangle for period 6 (June 6th – 30th). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

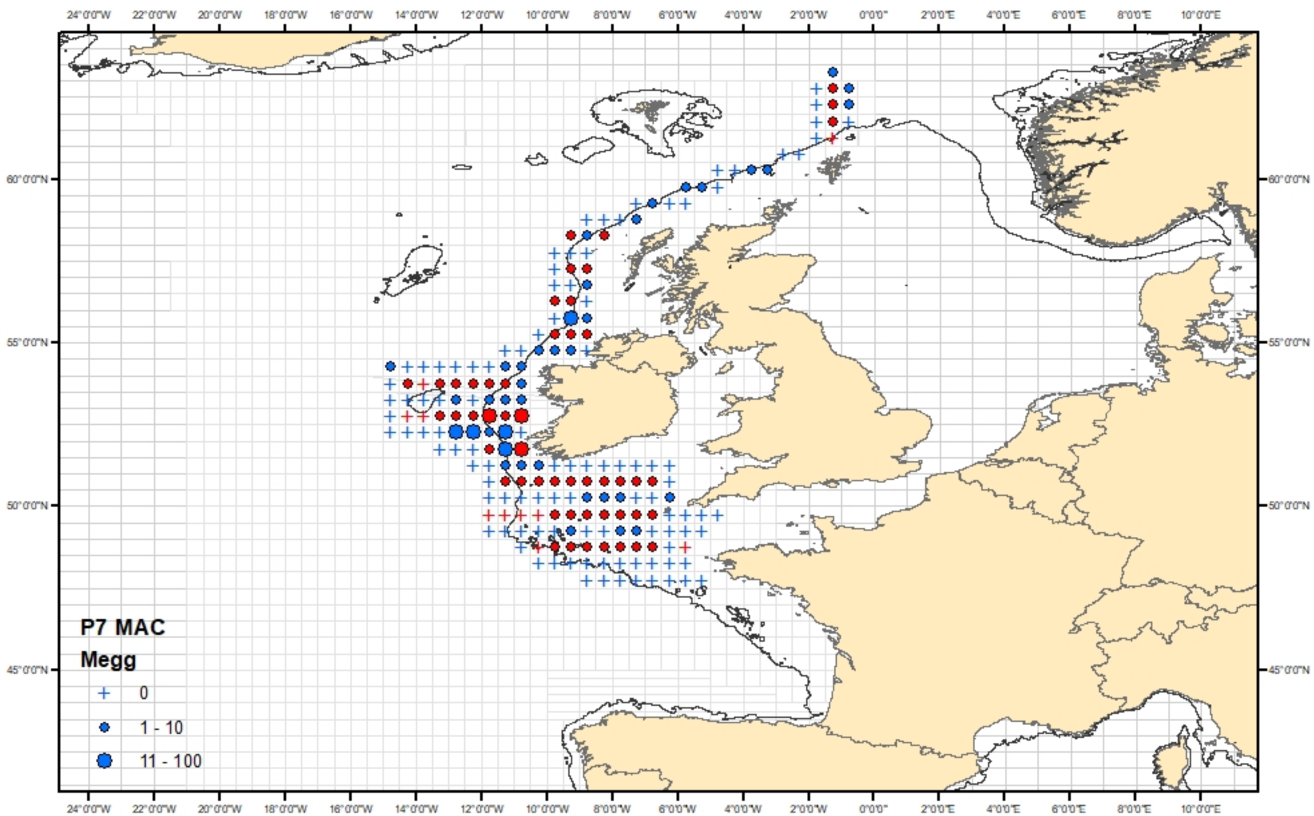

Figure 1.6: Mackerel egg production by half rectangle for period 7 (July 1st – 31st). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes, red crosses interpolated zeroes.

Results - MACKEREL

Stage 1 Egg production in the Western Areas

2010 provided an unusually large spawning event early in the spawning season, 2013 yielded an even larger spawning event indicating that spawning was probably taking place well before the nominal start date of 10th February (day 42) (Fig. 2.1). In 2016 the first survey commenced on February 5th which is five days prior to the nominal start date. That year however mackerel migration was later and slower than that recorded in the previous two surveys. The pattern in 2019 followed that of 2016 with no early peak spawning being recorded (Fig. 2.1 & Table 2). This year however peak spawning was found to have taken place in period 4, rather than period 5 as the case in 2016. Unlike 2016 when concern was expressed that survey coverage may have underestimated the total egg production estimate, area coverage in 2019 was much better. The expansion observed in western and northwestern areas during periods 5 and 6 in 2016 was once again reported during 2019, however egg numbers were not as large as in 2016. During period 5the northern and northwestern boundaries were once again not delineated, however the exploratory egg surveys carried out in this region during both 2017 and 2018 provide significant evidence that while some spawning has been missed the loss of egg abundance is not sufficiently large to significantly impact the SSB estimate.

The nominal end of spawning date of the 31st July is the same as was used during previous survey years and the shape of the egg production curve for 2019 does not suggest that the chosen end date needs to be altered. The provisional total annual egg production (TAEP) for the western area in 2019 was calculated as **1.22 * 10^{15}** (Table 2). This is a 20% reduction on the 2016 TAEP estimate which was 1.55 * 10^{15}.

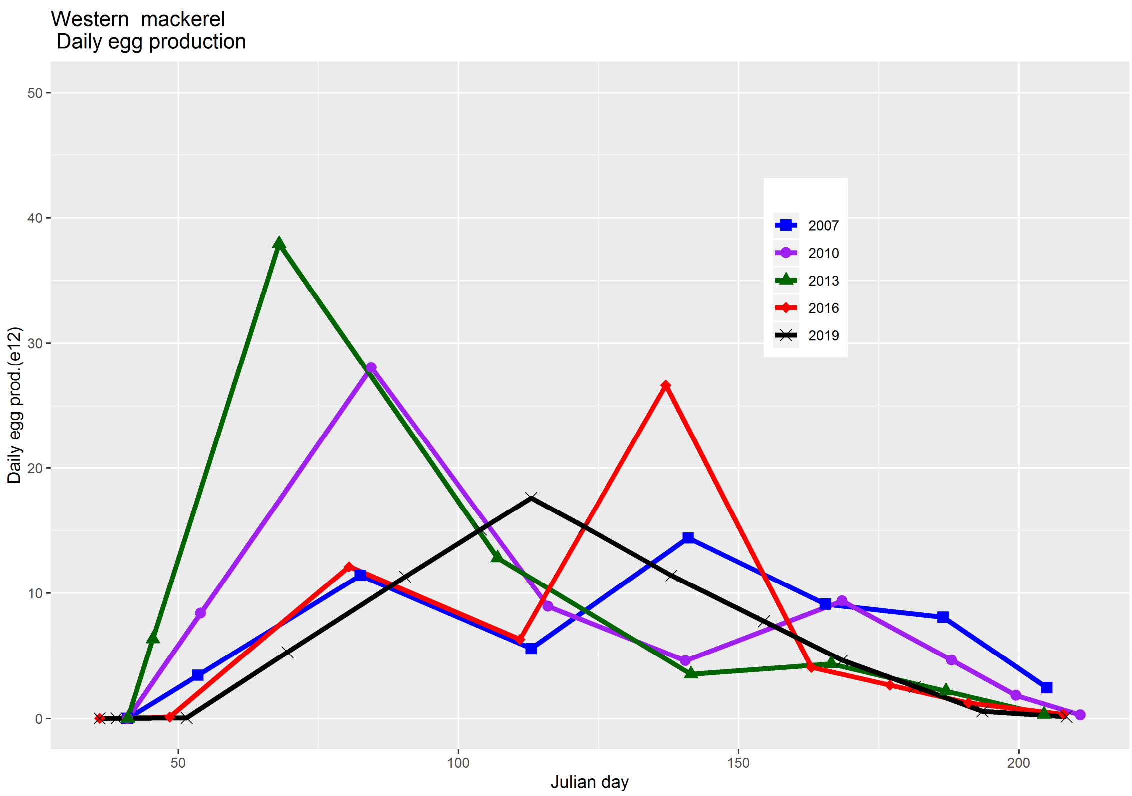

Figure 2.1: Provisional annual egg production curve for mackerel in the western spawning component. The curves for 2007, 2010 2013 and 2016 are included for comparison.

Table 2. Western estimate of mackerel total stage I egg production by period using the histogram method for 2019.

Dates	Period	Days	Annual stage I egg production * 10^{15}
	Pre 2		0
Feb 11th – Mar 1st	2	25	0.0007
Mar 2nd – 18th	2 - 3	17	.09
Mar 19st – April 12th	3	25	0.28
Apr 13th – 14th	3 - 4	2	.03
Apr 15th – April 30th	4	16	0.28
May 1st – 3rd	4 - 5	3	.05
May 4th – May 31st	5	28	0.32
Jun 1st – 5th	5 - 6	5	0.04
Jun 6th – June 28th	6	23	0.11
June 29th – July 1st	6 – 7	3	0.008
June 2nd – July 22nd	7	21	0.01
Total			1.22
CV			20%

Stage 1 Egg production in the Southern Areas

The start date for spawning in the southern area was the 23rd January (Table 3). The Portuguese period 1 survey in subarea 9a was pushed back by around 1 week. The result being that the survey dates aligned more closely to period 2. It was subsequently reclassified within period 2 and survey period 1 was removed. Sampling in the Cantabrian Sea where the majority of spawning occurs within the Southern area commenced 6 days later than in 2016 on the 14th March. The same end of spawning date of the 17th July was used again this year and the spawning curve suggests that there is no reason for this to change (Fig. 2.2). As in 2016 the survey periods were not completely contiguous and this has been accounted for (Table 3). The provisional total annual egg production (TAEP) for the southern area in 2019 was calculated as **4.19 * 10^{14}** (Table 3). This is a 54% increase on the 2016 TAEP estimate which was 2.25 * 10^{14} (Fig. 2.2)

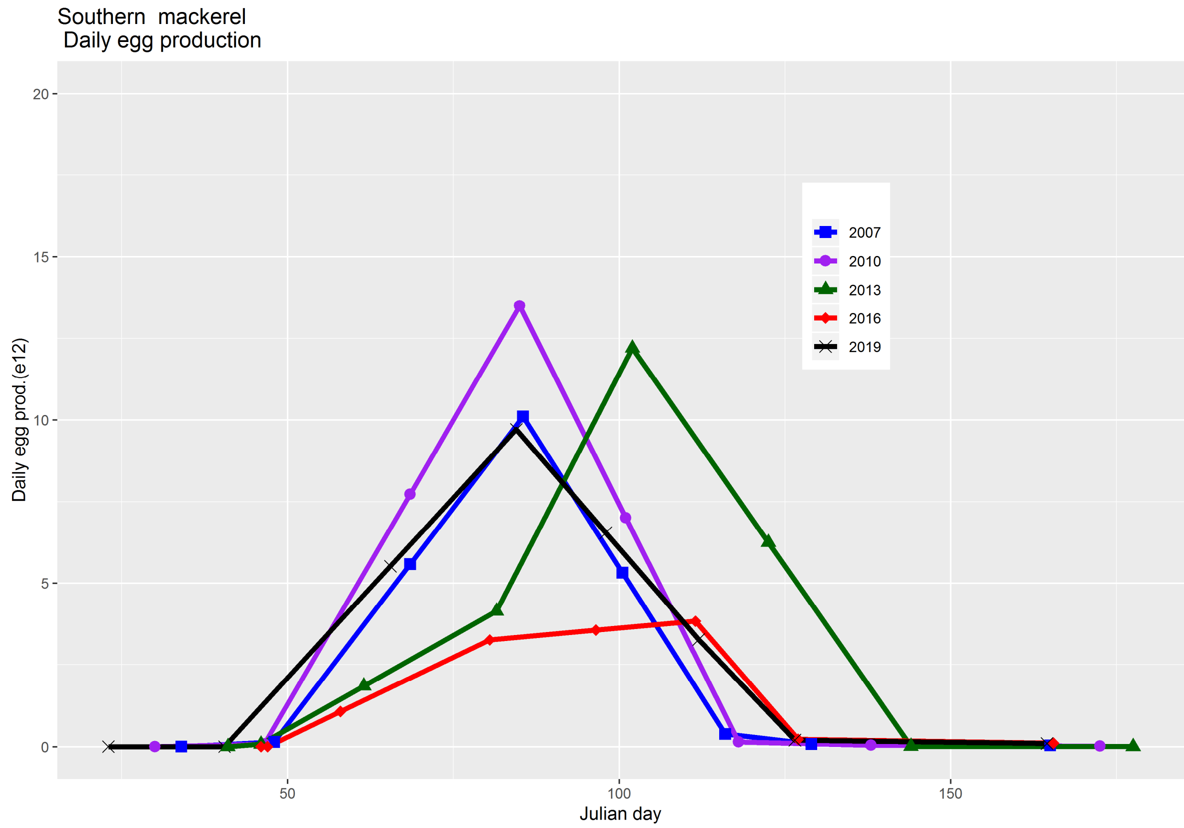

Figure 2.2: Provisional annual egg production curve for mackerel in the southern spawning component for 2019. The curves for 2007, 2010, 2013 and 2016 are included for comparison.

Table 3: Southern estimate of mackerel total stage I egg production by period using the histogram method for 2016.

Dates	Period	Days	Annual stage I egg production x 10^{14}
	1	No sampling	
Jan 23rd – Feb 26th	2	35	0
Feb 27th –Mar 13th	2 - 3	15	0.83
March 14th – April 5th	3	23	2.23
April 6th – April 9th	3 - 4	4	0.26
April 10th – May 3rd	4	24	0.79
May 4th – May 8th	5	5	0.01
May 9th –July 17th	Post 5	71	0.07
Total			4.19
CV			99%

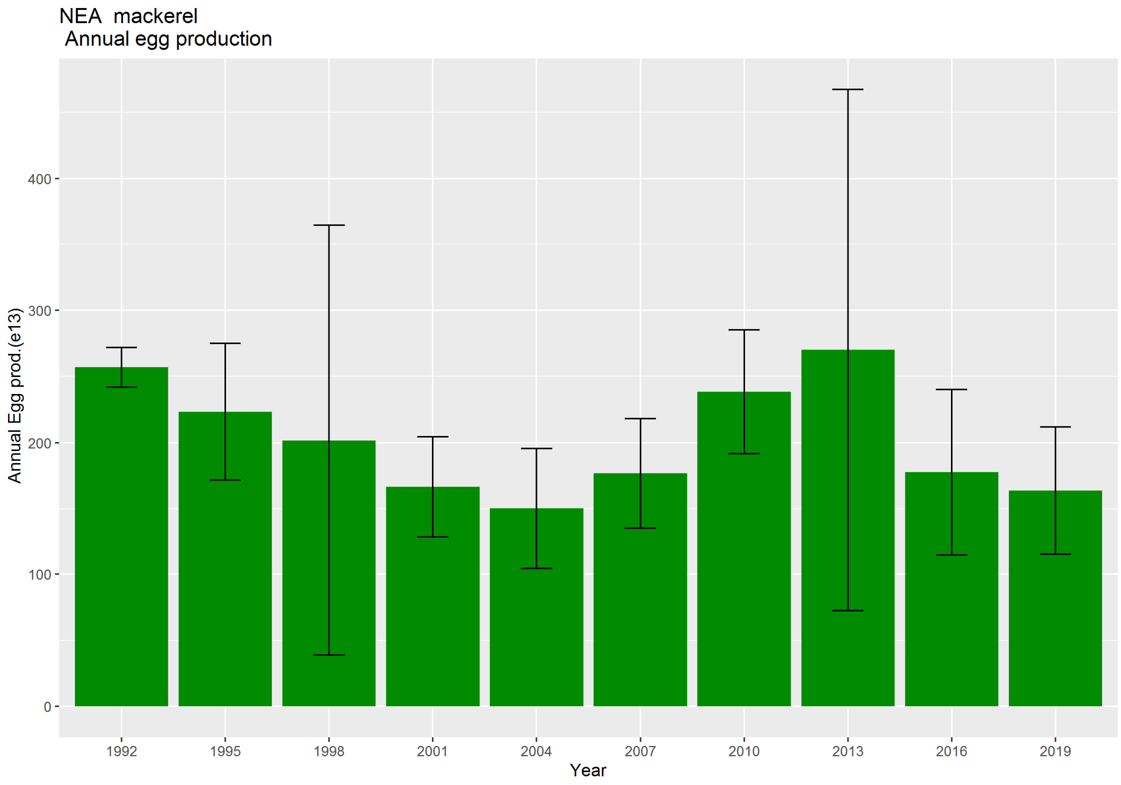

Figure 2.3: Combined mackerel TAEP estimates (*10^{15}) - 1992 – 2019.

Total egg production

Total annual eggs production (TAEP) for both the western and southern components combined in 2019 is **1.63*10^{15}**. (Fig. 2.3). This is a decrease in production of **9%** compared to 2016 (Fig. 2.3).

Fecundity estimates

Preliminary Results Mackerel AEPM - Fecundity

Adult Parameters

Fecundity Sample distribution

Atlantic mackerel fecundity samples were collected during periods 2-5 spread over an area within a bounding box of 59.22N 6.78W - 4399N 1.82W. Eight institutes participated in the collection. The histological screening of samples was performed by four Institutes while fecundity was analysed by six. As for earlier years, this preliminary fecundity estimate is based on samples from period 2 and 3 only. Samples from the periods 4-5 did not arrive at the participating laboratories with sufficient time to process them before the ICES WGWIDE 2019 meeting. Results of those samples will, however, be included in the finalized results in April 2020.

Screening

Potential fecundity counts were based on whole mount samples taken from maturing females which had not started spawning. To select these samples, a histological screening procedure was used followed by a screening procedure on the selected whole mount samples.

A total of 904 samples were screened, of which 707 were from periods 2 and 3 (
Table **1**). Of those, 565 samples showed spawning markers, i.e. migratory nucleus stage (MIG), hydrated oocytes, eggs, and post ovulatory follicles (POFs). Both MIG and POF stages are difficult to detect on whole mount samples and therefore they are looked for only in the histological screening.

Table 1. Number of samples collected and analysed by period. The column *Fecundity Histology* shows the number of samples that were qualified by histological screening for fecundity analysis. *Fecundity Whole Mount* shows the number of samples that qualified for fecundity analysis after the whole mount screening that came afterwards. *Atresia presence* means the number of samples in which early alpha atresia was found.

Period	Screened	Spawning Markers	POFs	Fecundity Histology	Fecundity Whole mount	Atresia Presence
2	32	24	21	2	2	3
3	675	541	494	38	33	156
4	191	173	165	2	1	32
5	6	4	4	1	1	0

Results from previous surveys showed that POF scoring could vary considerably between periods. At WKFATHOM2 (ICES 2018) this issue was discussed and more detailed criteria for POF staging were elaborated. Looking at screening results from 2019, POFs were identified more frequently than in 2016 for periods 2 and 3, i.e. 74 % vs 59% (Table 2).

Table 2. POF scoring using histology by periods 2-3.

Period	No POF	POF	%POF	%POF 2016
2	11	21	66	16
3	178	494	74	75
2-3	189	515	74	59

A total of 159 samples from periods 2-3 showed presence of atresia without considering those that were classified as "spent" or having "massive atresia" (Table 1).

Considering that most of the samples in periods 2-3 were at MIG or hydrated oocyte stage (n = 596) and that only 66 were in vitellogenic oocyte stage, potential fecundity samples were reduced to 39 individuals. The whole mount evaluation allows identifying whether there is any mismatch between the histological and whole mount reading of the samples selected for fecundity analysis. In general, both readings agreed. However, five samples classified as fecundity samples in histology were reclassified in whole mount screening due to presence of hydrated oocytes (n = 2), eggs (n = 1) or being early vitellogenic (n=1) or spent (n = 1). These samples were dropped from the first pull of potential samples and the final number of fecundity samples reduced to 34.

Potential fecundity

For the 2019 preliminary estimate of potential fecundity, 34 samples were available, which represents 5% of all samples screened for periods 2 and 3. This number was lower than in 2016, when 66 samples were available for the preliminary report.

For the 2013 and 2016 surveys, the median was used for relative fecundity estimation while the mean was used previously. The reason for the change is related to the fact that that unlike the mean, the median is not influenced by extreme values. A posterior analysis showed that the median for relative potential fecundity was close to the arithmetic mean in most years. The largest difference was in 2013, but even then, the median was within the confidence interval of the potential fecundity arithmetic mean. During WGMEGS 2018 (ICES 2018) we discussed whether we should use the trimmed mean instead of the median for the potential fecundity estimate. A trimmed mean is preferred for calculation of confidence intervals. However, until the time-series data is reanalyzed in the near future, it was decided that the relative fecundity estimate should still be based on the median rather than the mean, as for 2013 and 2016. (Figure 1).

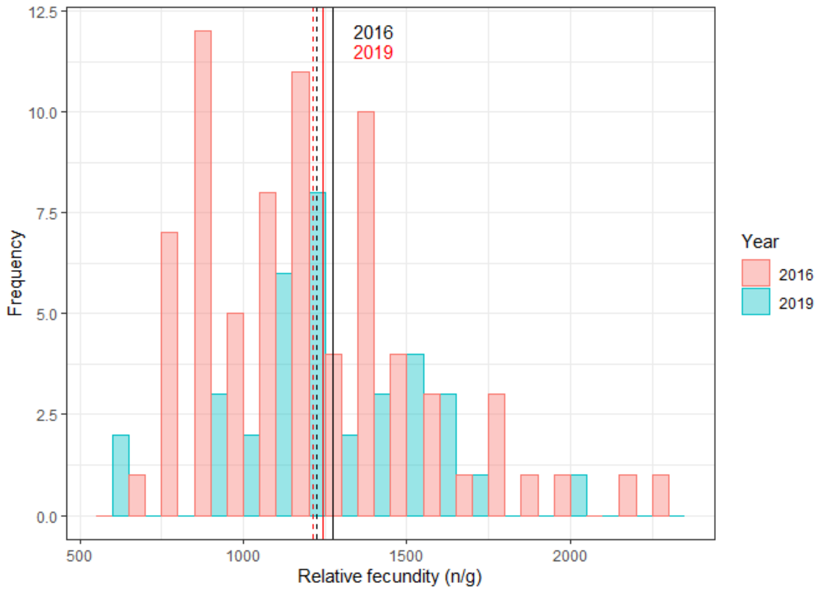

Figure 1. Relative fecundity preliminary estimation in 2016 and 2019. Median: dashed line, Mean: solid line.

The preliminary relative potential fecundity in 2019 was slightly higher than in 2016 (1215 and 1224, respectively) (

Figure **2**). This difference was however not significant (Kruskal-Wallis U-test, p > 0.05).

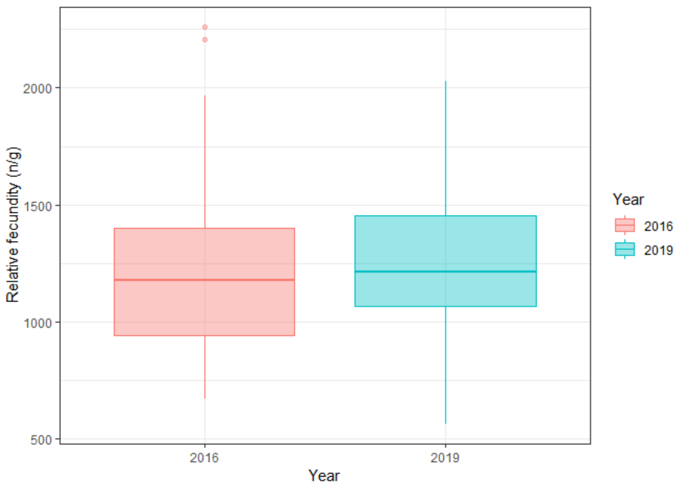

Figure 2. Relative fecundity preliminary estimation in 2016 and 2019.

Table 3. Estimate of relative fecundity (n/g fish) and statistics.

N	Median	Mean	sd	Max	Min	95%CI
34	1215	1263	285	2029	564	1163-1362

Biological data of fish samples to fecundity

Mean length, weight and ovary weight of fish analyzed for fecundity were higher in 2019 than in previous survey (Figure 3).

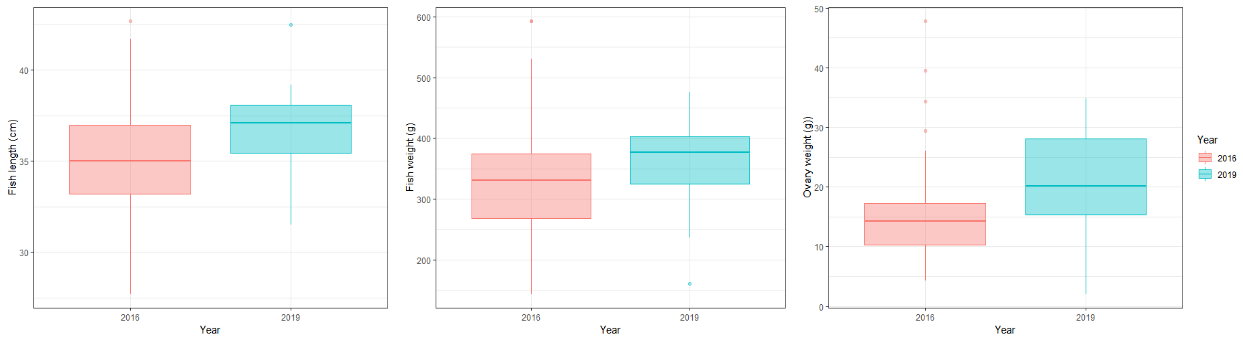

Figure 3. Fish length ad weight, and ovary weight of individuals analysed for fecundity.

Fish condition (Fulton K) and gonadosomatic index (GSI) were used to evaluate any change in the distribution pattern compared to 2016 (Figure 4). In this sense, condition factor is slightly lower while the GSI is higher for the same period in 2019 than in 2016.

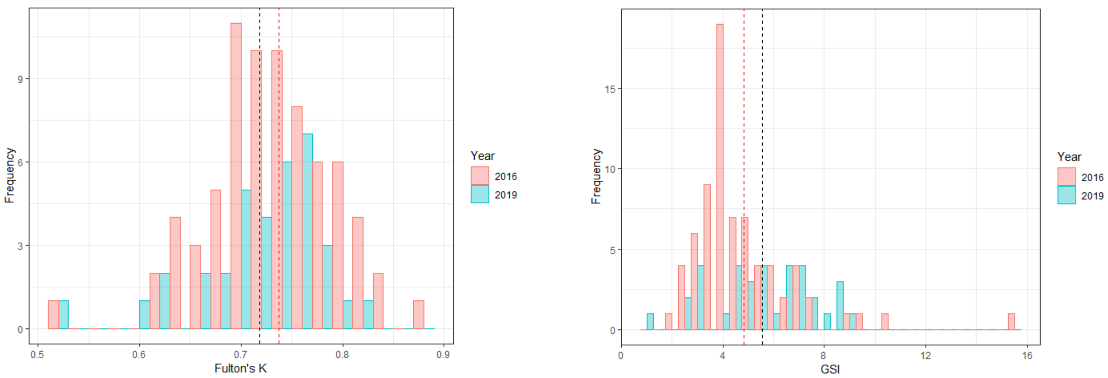

Figure 4. Fulton's K and GSI of individuals analysed for fecundity in both 2016 and 2019. Dashed lines are the means in 2016 (red) and 2019 (black) for each factor and index respectively.

Atresia

Atresia is the loss of oocytes by reabsorption before spawning and must be subtracted from the potential fecundity (whole mount fecundity counting) to estimate the realised fecundity. In this preliminary report, intensity of atresia will not be presented due to the time consumed for the histology screening.

The prevalence of atresia estimated by histological screening may however be a good indicator of the level of atresia. Prevalence of atresia is defined as the percentage of spawning fish which have early stage atresia (early alpha-atresia). Among the 507 samples considered (Table 4) the prevalence of atresia estimated was 31 % (fish from period 2-3, excluding spent fish and fish with massive atresia).

Realised fecundity

Realised fecundity is defined as the potential fecundity minus the loss by atresia. The loss by atresia is a function of both intensity of atresia and prevalence of atresia. The intensity of atresia for 2019 is still unavailable, therefore the loss was calculated from the average loss from the surveys since 2001 (Table 4). The relative loss by atresia from this period (2001-2016) ranged from 6-9% (average 6%).

Based on this, the preliminary realised fecundity-estimate for 2019 was 1142 oocytes/gram female. The working group acknowledges that the number of fecundity samples this year is very small (n = 34) but the estimate is, however, well within the observed range of realized fecundity (1002-1209, average 1066 egg per gram female) from all previous surveys back to 1998 (Table 4). For the three most recent surveys, realized fecundity varied between 1070 and 1209 eggs per gram female (average 1122).

Table 4. Summary table of mackerel fecundity and atresia by survey year.

	Assessment year							
	1998	2001	2004	2007	2010	2013	2016	**2019 Prel.**
Fecundity samples (n)	96	187	205	176	74	132	97	34
Prevalence of atresia (n)	112	290	348	416	511	735	713	507
Intensity of atresia (n)	112	290	348	416	511	56	66	
Relative potential fecundity (n/g)	1206	1097	1127	1098	1140	1257*	1159*	1215*
Prevalence of atresia	0.55	0.2	0.28	0.38	0.33	0.22	0.3	0.31
Geometric mean intensity of atresia (n/g)	46	40	33	30	26	27	30	
Potential fecundity lost per day (n/g)	3.37	1.07	1.25	1.48	1.16	0.8	1.2	
Potential fecundity lost (n/g)	202	64	75	89	70	48	72	
Relative potential fecundity lost (%)	17	6	7	9	6	4	6	
Realised fecundity (n/g)*	1002	1033	1052	1009	1070	1209	1087	1142

*Median not mean relative potential fecundity.

Biomass estimation

Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 1142 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass of:

- 2.301 million tonnes for western component (2016: 3.077).
- 0.792 million tonnes for southern component (2016: 0.447).
- 3.092 million tonnes for western and southern components combined (2016: 3.524)

Results – HORSE MACKEREL

Horse mackerel egg production by period

Period 2 – No horse mackerel eggs were found in this period (Fig. 4.1).

Period 3 – In period 3 horse mackerel spawning starts in the Cantabrian, but numbers of eggs found are very low. Some spawning also took place west of Ireland (Fig. 4.2).

Period 4 – Horse mackerel was spawning continues in the Cantabrian Sea, extending into southern Biscay. Small numbers of eggs were found in the Celtic Sea (Fig. 4.3).

Period 5 – Horse mackerel spawning continues in the Cantabrian Sea, Celtic Sea and northern Bay of Biscay, but in low numbers around the 200m depth contour. Some eggs were also found south and west of Ireland (Fig. 4.4).

Period 6 –Spawning was confined to the Celtic sea with very few eggs being found outside this area, apart from some stations close to the French coast (Fig. 4.5).

Period 7 – Eggs are found from the Celtic Sea to west of Scotland (Fig. 4.6) In general egg numbers were low but occasional stations with high counts were found. Peak spawning took place in this period High egg numbers are found in the Celtic Sea and Rockall (Fig. 4.6).

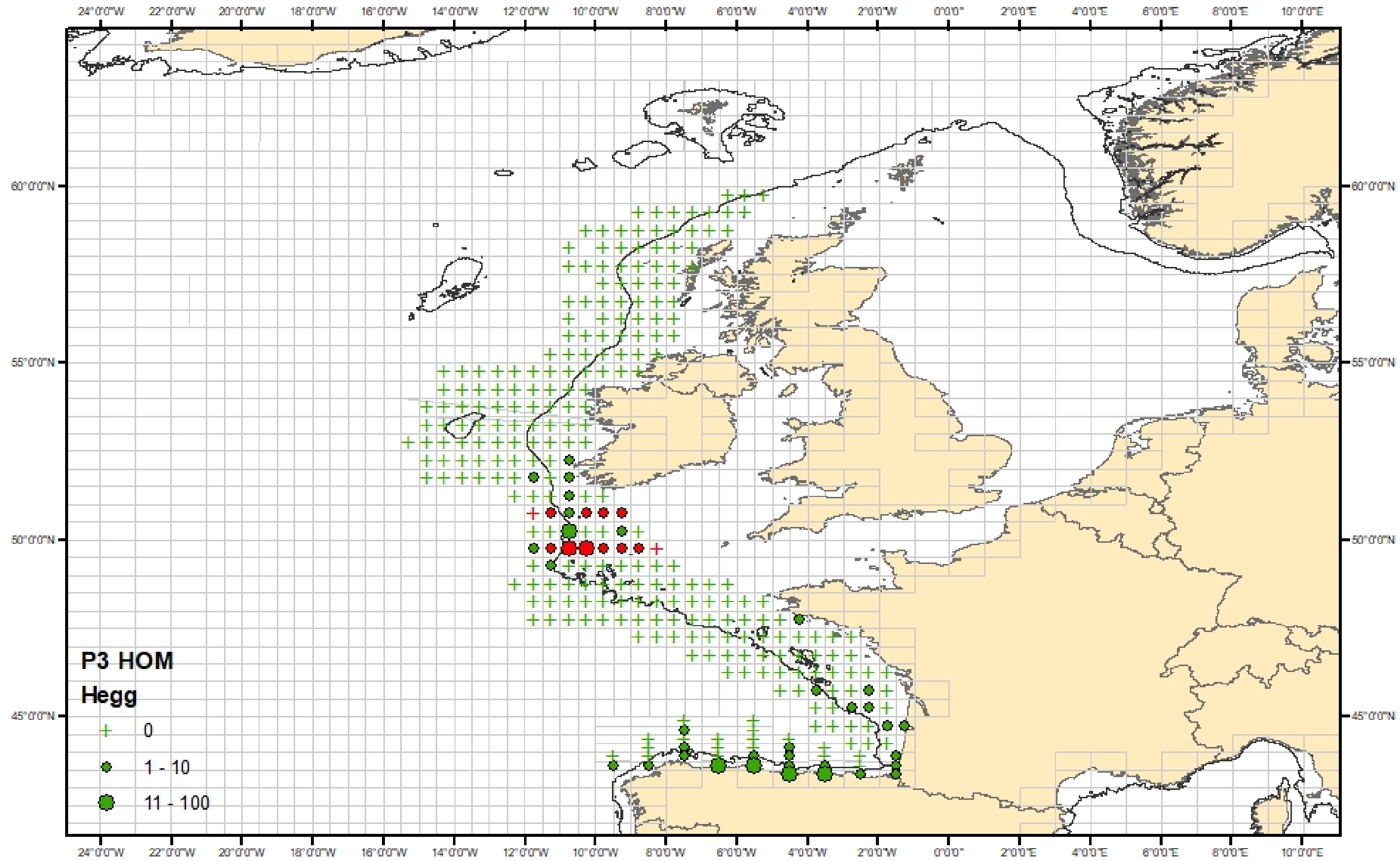

Figure 4.2: Horse mackerel egg production by half rectangle for period 3 (March 4th – April 14th). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

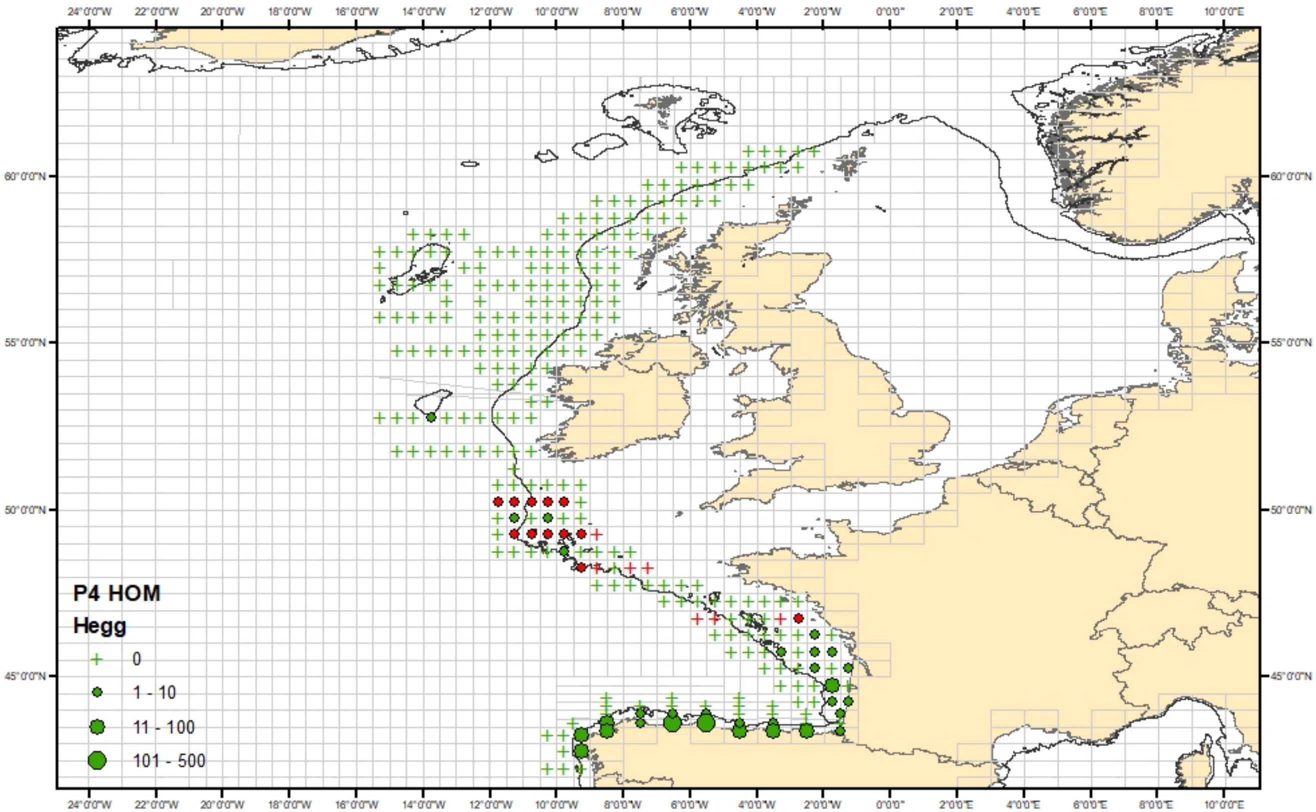

Figure 4.2: Horse mackerel egg production by half rectangle for period 4 (April 15th –May 3rd). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

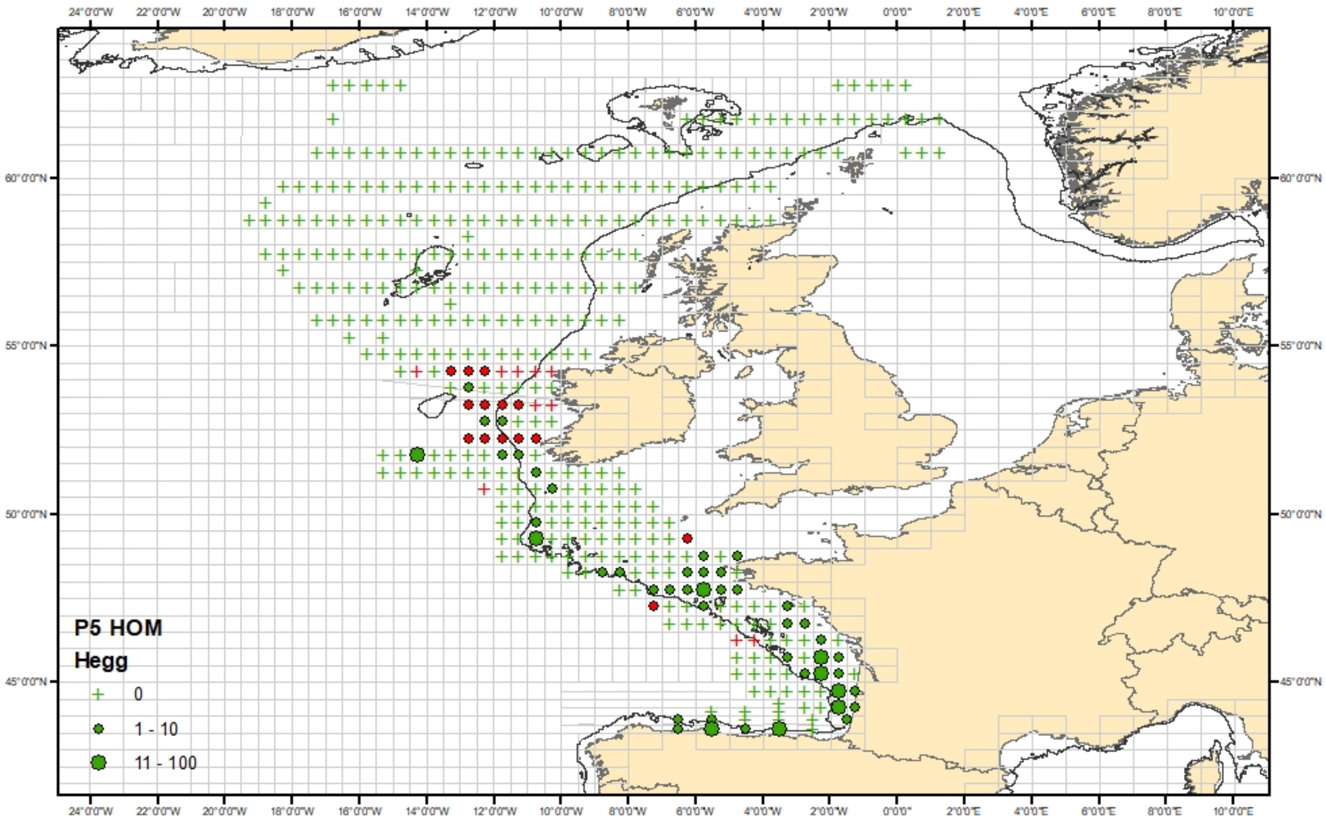

Figure 4.3: Horse mackerel egg production by half rectangle for period 5 (May 4th – June 5th). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

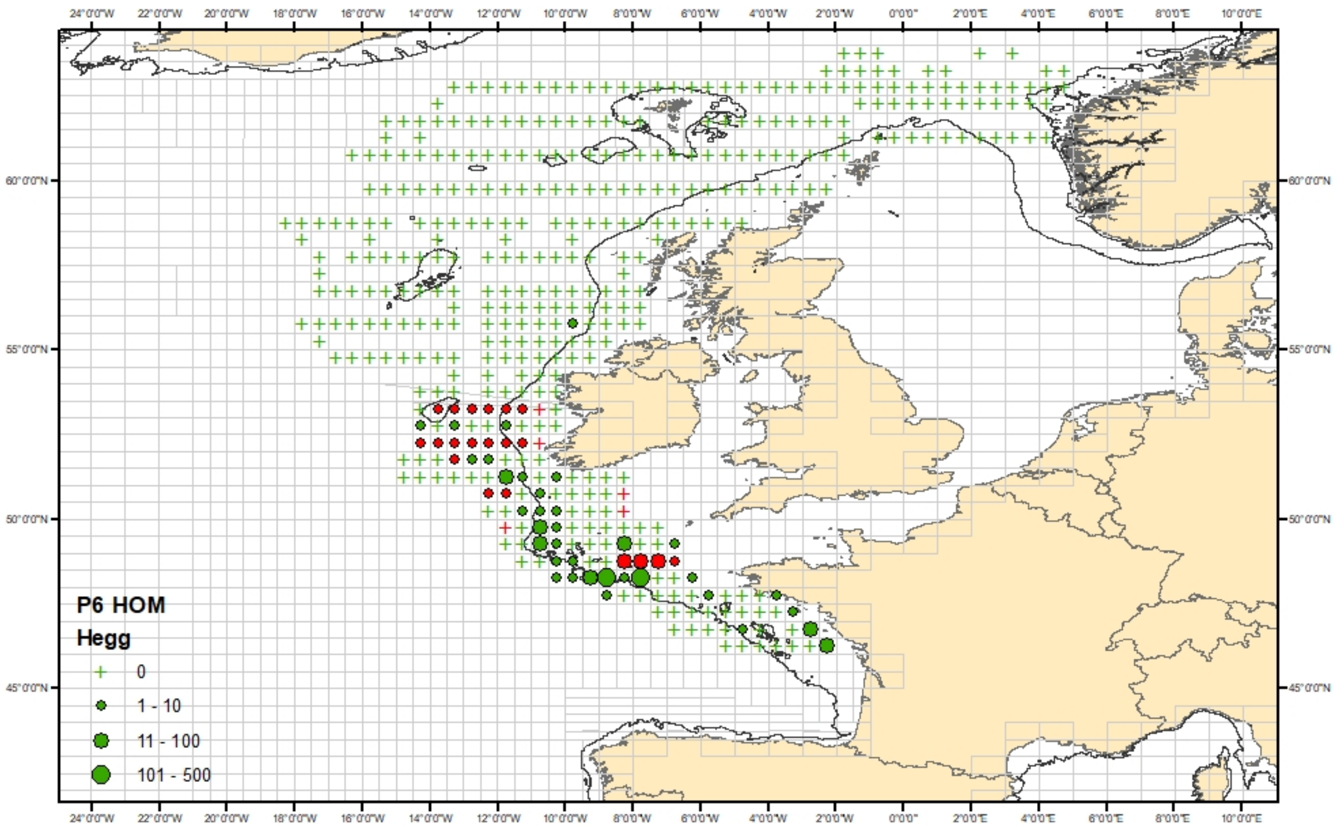

Figure 4.4: Horse mackerel egg production by half rectangle for period 6 (June 6th – 30th). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

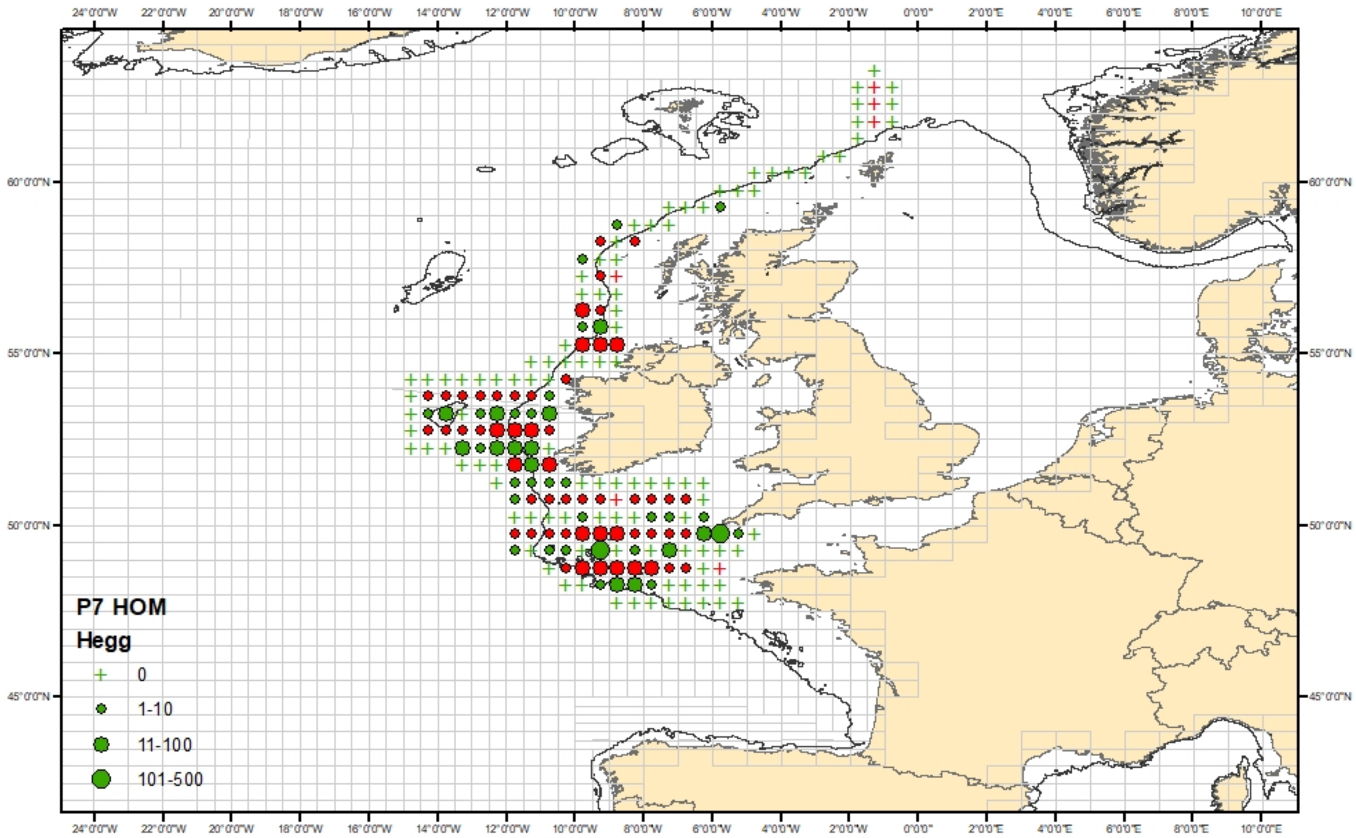

Figure 4.5: Horse mackerel egg production by half rectangle for period 7 (July 1st – July 31st). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes, red crosses interpolated zeroes.

TAEP results – Western Horse Mackerel

Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning (Table 6). The shape of the egg production curve does not suggest that those dates should be altered for 2019 (Fig. 5.1). The total annual egg production was estimated at 1.78 **x 10^{14}**. This is a decrease of almost **53%** on 2016 which was 3.31 × 10^{14} and is the lowest estimate of annual egg production ever recorded for this species.

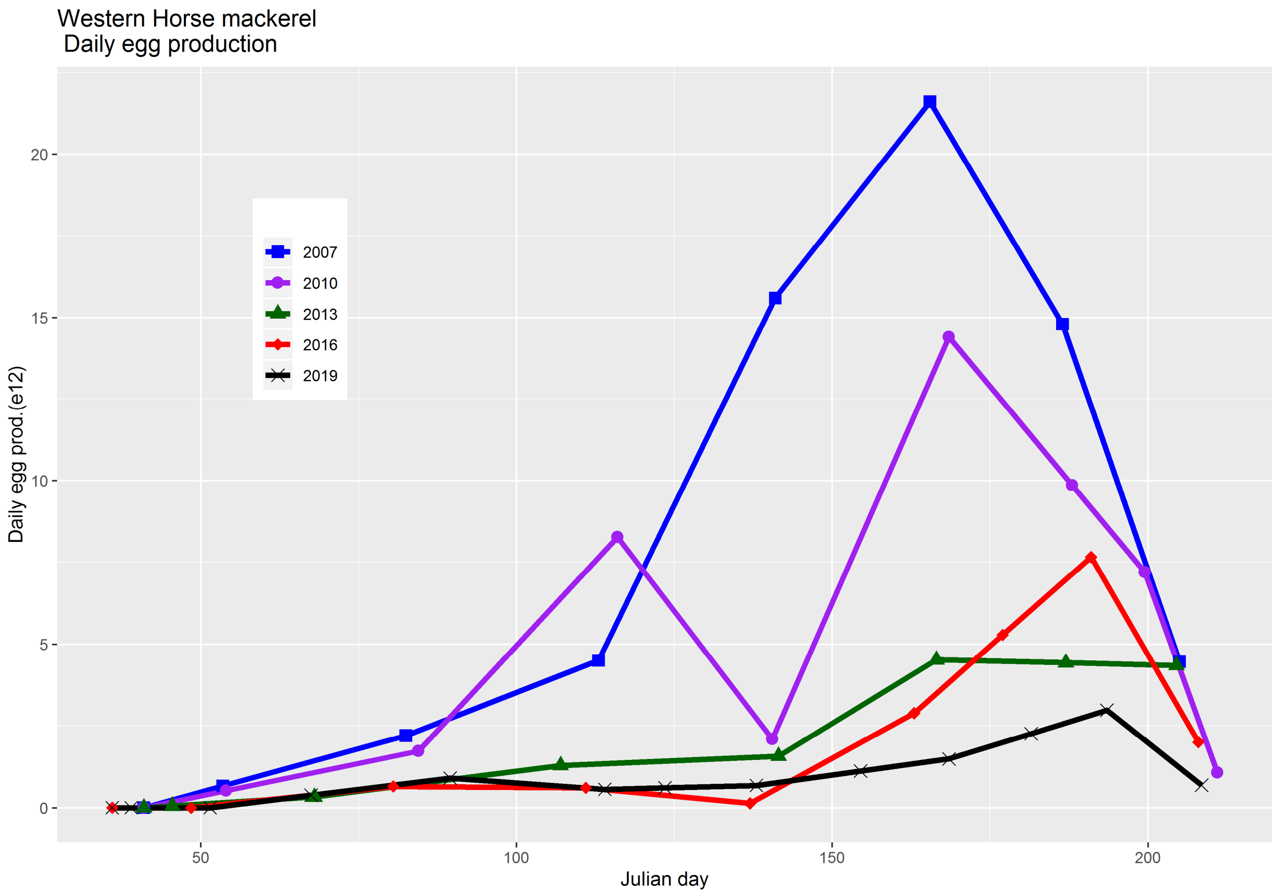

Figure 5.1: Provisional annual egg production curve for western horse mackerel. The curves for 2007, 2010, 2013, and 2016 are included for comparison.

Table 6: Western estimate of horse mackerel total stage I egg production by period using the histogram method for 2016

Dates	Period	Days	Annual stage I egg production * 10^{15}
	Pre 2		0
Feb 11th – Mar 1st	2	25	0
Mar 2nd – 14th	2 - 3	13	.005
Mar 15th – April 14th	3	31	0.03
Apr 15th – May 2nd	4	18	0.01
May 3rd	4 - 5	1	.0006
May 4th – May 31st	5	28	0.02
Jun 1st – 5th	5 - 6	5	0.006
Jun 6th – June 28th	6	23	0.034
June 29th – July 1st	6 – 7	3	0.007
June 2nd – July 22nd	7	21	0.06
July 23rd – 31st	Post 7	9	0.007
Total CV			0.178 57%

Fecundity investigations

This year for horse mackerel only DEPM ovary samples were collected in periods 6 and 7, during peak of spawning. Since horse mackerel fecundity is at this moment not used for estimating the spawning stock biomass the focus of the fecundity analysis has been on mackerel. Therefore, at this time no horse mackerel fecundity results are ready to be presented. All samples will be analysed and results presented at the 2020 WGMEGS meeting.

DEPM results –Western Horse Mackerel

The horse-mackerel egg data of the DEPM survey are still under revision. Data are expected to be analyzed and results will be presented at the 2020 WGMEGS meeting.

Discussion

Since 2004 and subsequent to demands for up-to-date data for the assessment, WGMEGS has endeavored to provide an estimate of NEA mackerel biomass and western horse mackerel egg production within the same calendar year as the survey and in time for the assessment meetings taking place. This report represents the preliminary results of the 2019 egg survey. WGMEGS cannot guarantee that there will be no changes prior to the presentation of the final survey results at WGMEGS in April 2020. However, despite the tight deadline nearly all plankton samples were analyzed for mackerel (southern and western area) and horse mackerel (western stock only) stage 1 eggs. Portugal still have to supply data for their Period 2 survey in ICES division 9a. Historically not many mackerel are caught during this survey therefore only negligible changes in the total egg production values are to be expected

As with 2016 no fecundity samples from period 1 were available, instead samples from periods 2 and 3 were included in the potential fecundity estimate. For the final fecundity estimate the later periods will also be included, as was done for the 2016 survey. No estimate of loss by atresia is yet available for 2019. The realised fecundity estimate is therefore based on the average atretic loss found in the period from 2001-2016. Since the atretic loss has always been a small number compared to the potential fecundity, using this average value will likely not give a large error. The prevalence of atresia for 2016 (31%) is comparable to previous survey estimates,it is thus highly likely that the atretic loss will also be at the same level. Atretic loss will however be analysed and included in the final fecundity estimate at the WGMEGS meeting in 2020.

Previous surveys in 2010 and 2013 were dominated by the issue of the early peak of western mackerel spawning and its close proximity to the nominal start date. In 2016 peak spawning reverted to May / June, a time that would traditionally be considered it’s normal timing. In 2019, peak spawning in the western area was found to have occurred slightly earlier in period 4. During 2016, high levels of spawning were recorded over a large area of the Northeast Atlantic with a large number of the stations being reported over deepwater and well away from the continental shelf. Moderate to high numbers of stage 1 eggs were recorded on most of these northerly and western boundary stations. This expansion was repeated in 2019 during periods 5 and 6, however spawning densities recorded in these areas were significantly lower than 2016. Available surveys deployed during these periods were unable to fully delineate all boundaries however WGMEGS are satisfied that significant additional egg production is not being missed in these northern and western areas.

Western horse mackerel continues its decline with an even lower egg production estimate than was observed in 2016 and at the time that was the lowest recorded estimate for this survey.

The MEGS group is confident that this survey accurately reflects the spawning patterns as exhibited by both species as it is presented in this working document. Despite the inability to secure a northern spawning boundary for western mackerel during periods 5 and 6 the survey group is confident that the resulting fraction of spawning missed is a minor one and that the survey has indeed been successful in capturing the bulk of spawning activity.

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ICES, 2019a. Manual for mackerel and horse mackerel egg surveys, sampling at sea. Series of ICES Survey Protocols SISP 6. 82pp. 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

Annex

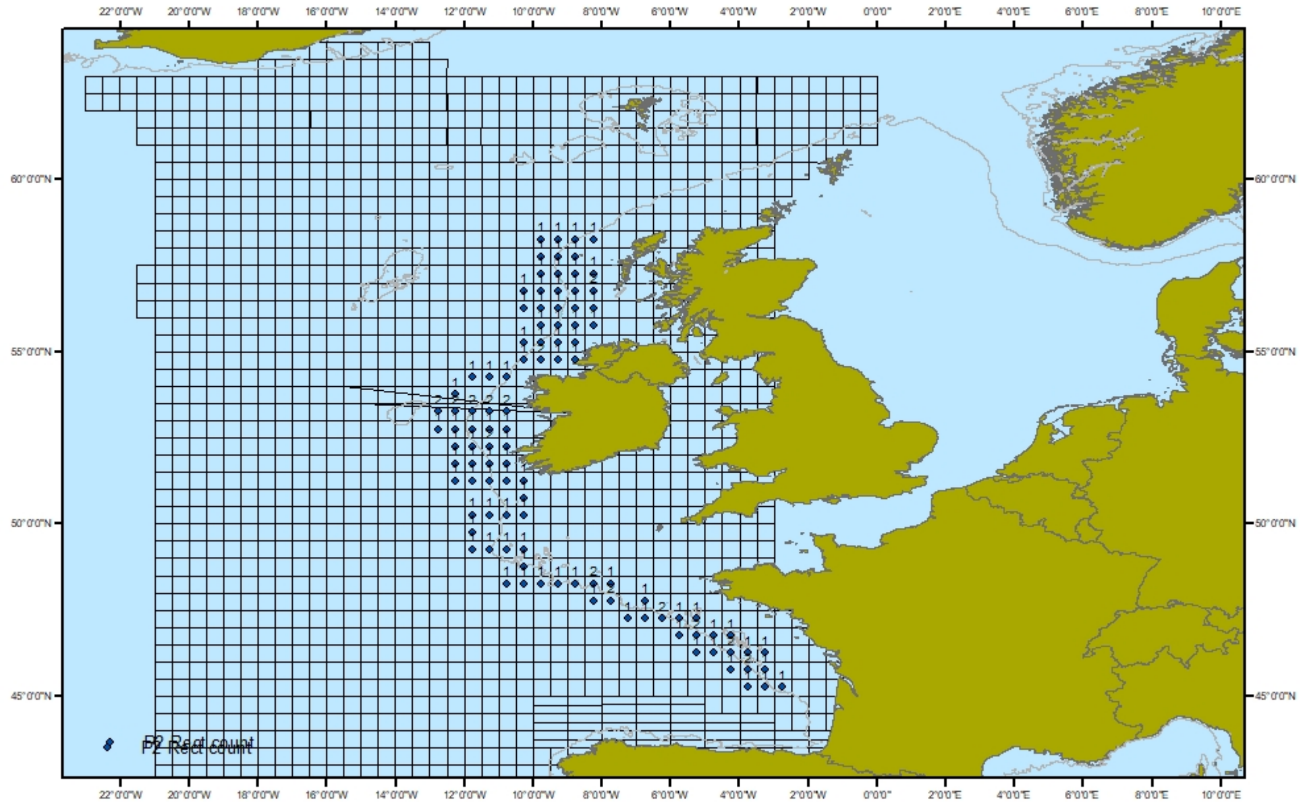

Figure 1.1: Number of observations per rectangle in period 2 (Feb 5th to Mar 3rd)

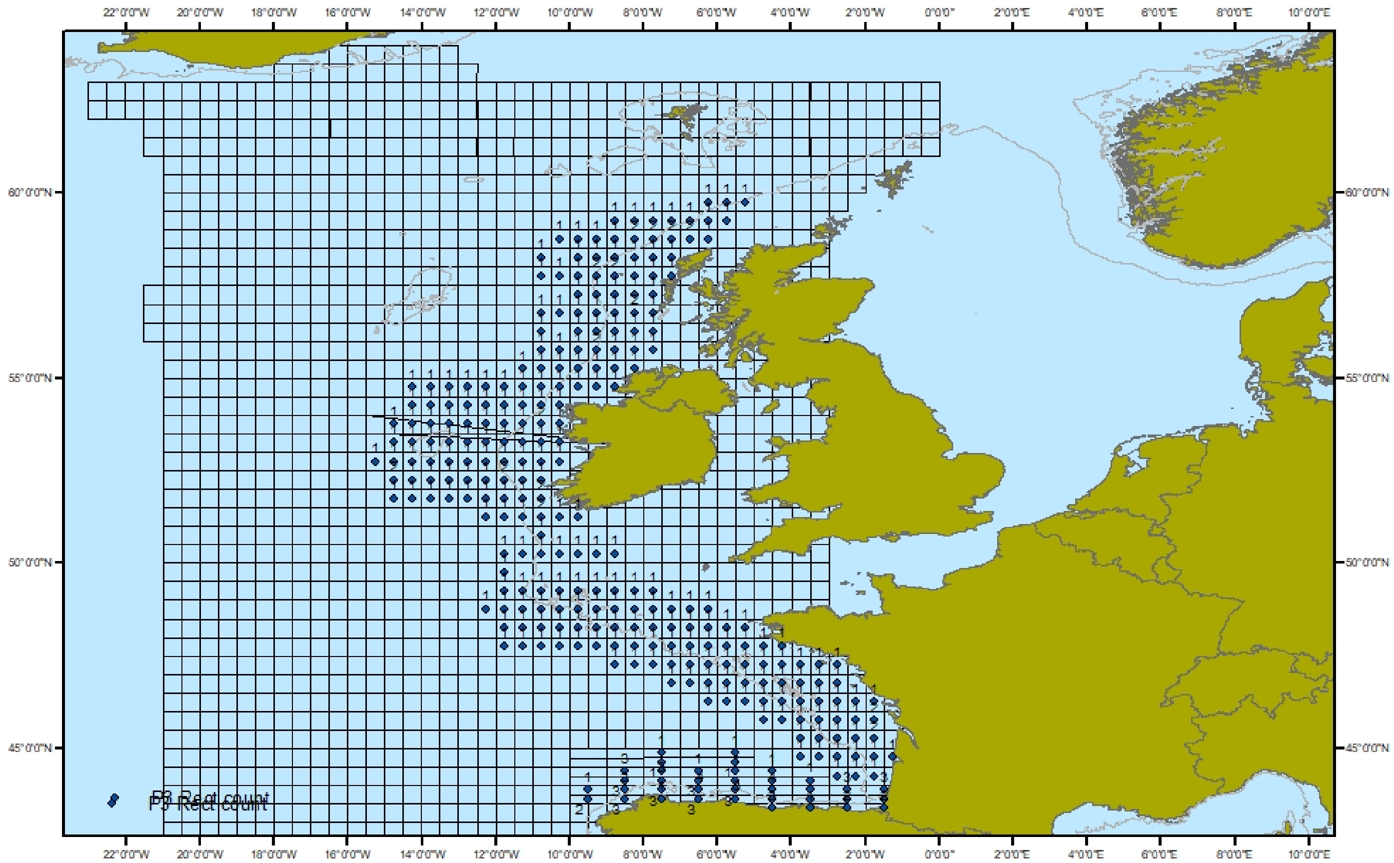

Figure 1.2: Number of observations per rectangle in period 3 (March 4th – April 12th)

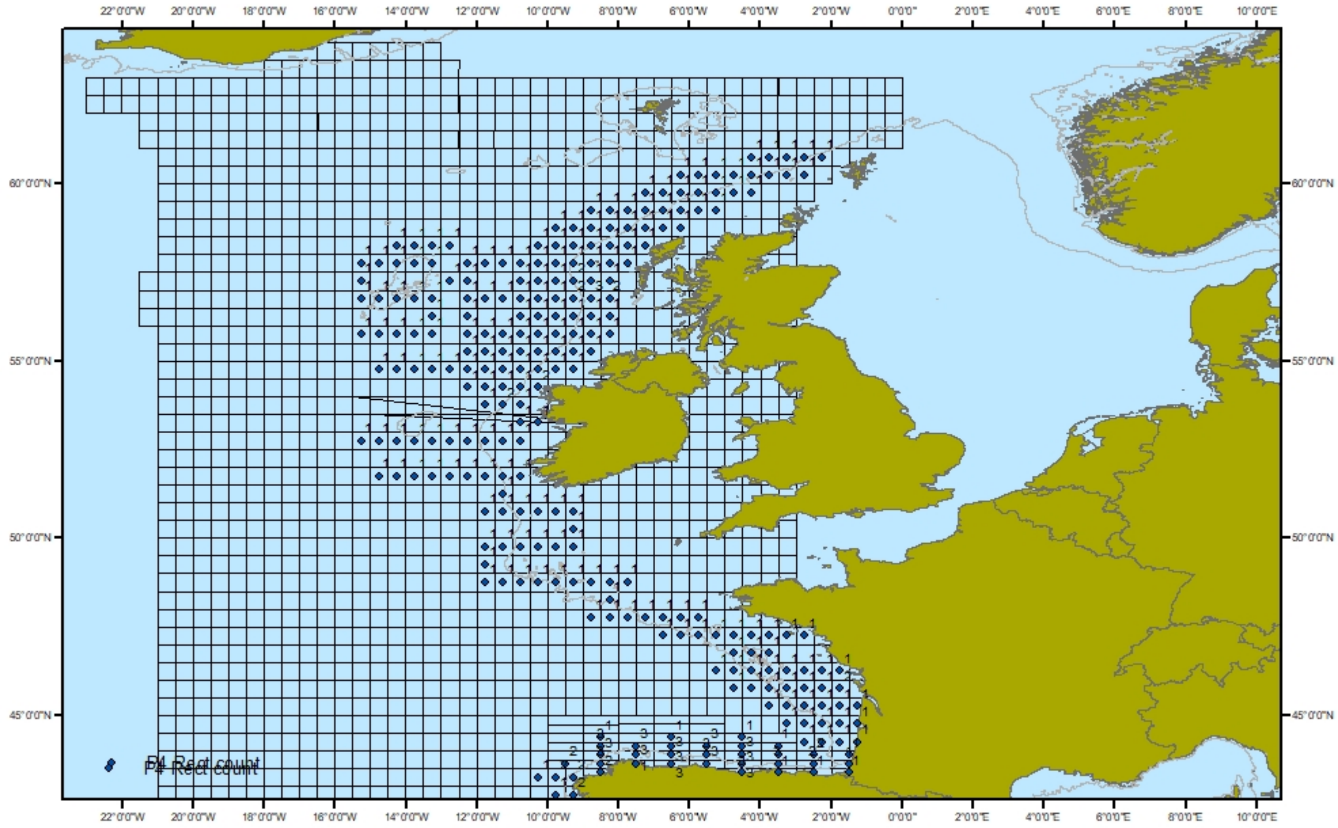

Figure 1.3: Number of observations per rectangle in period 4 (April 13th – May 3rd)

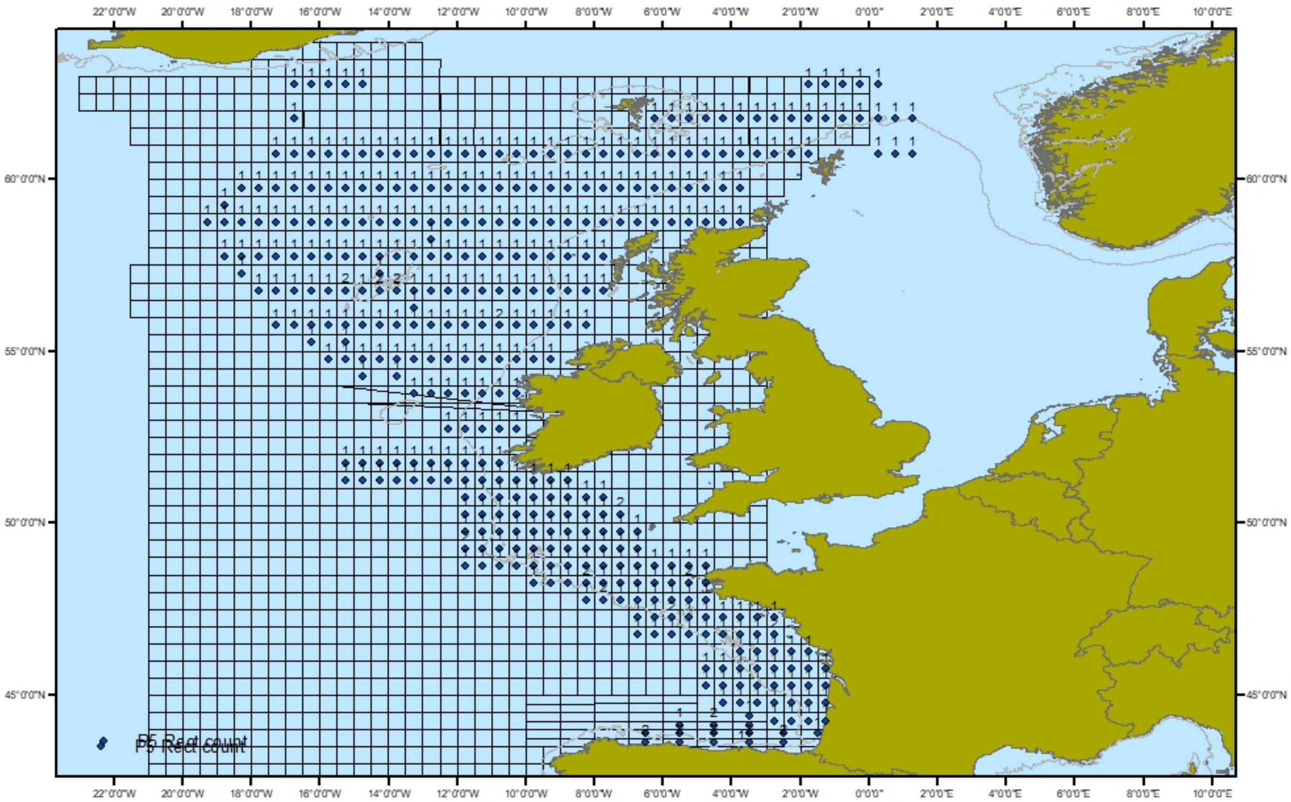

Figure 1.4: Number of observations per rectangle in period 5 (May 4th – June 5th)

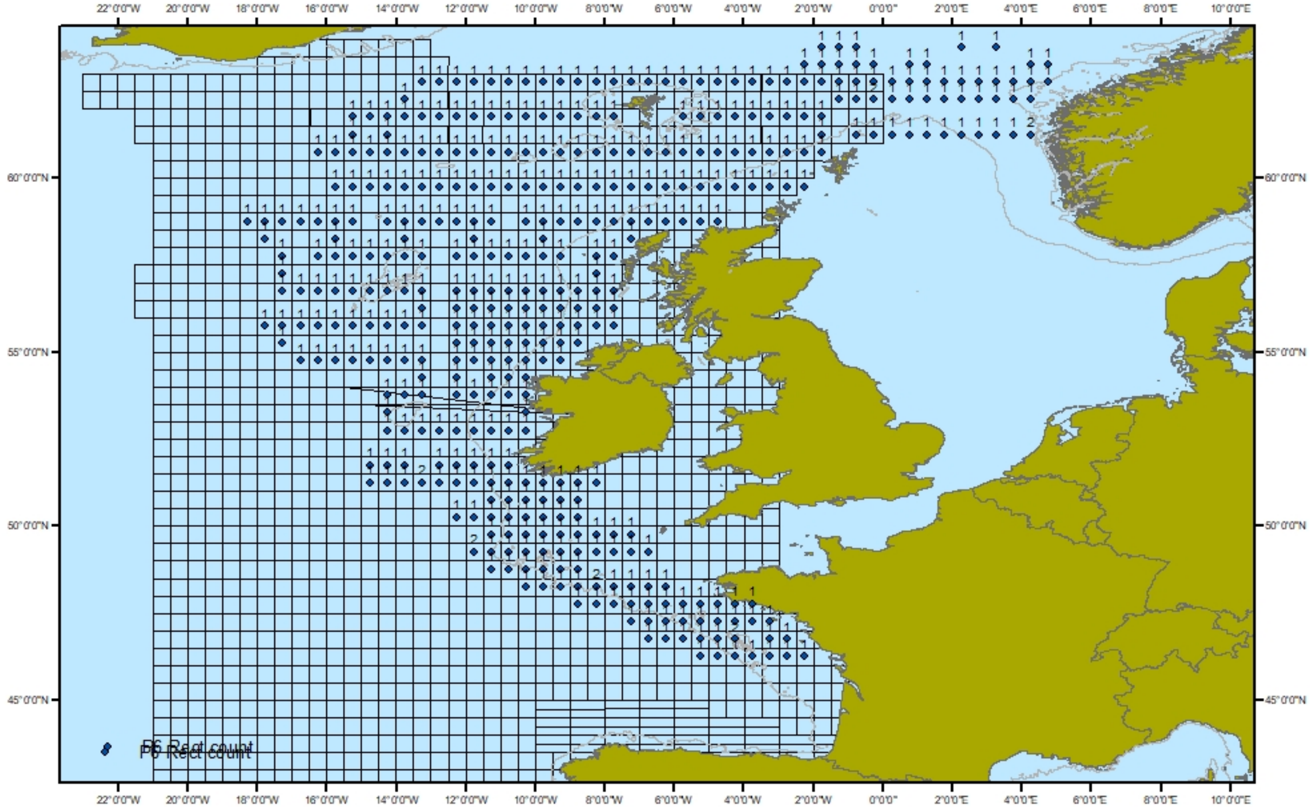

Figure 1.5: Number of observations per rectangle in period 6 (June 6th – 30th)

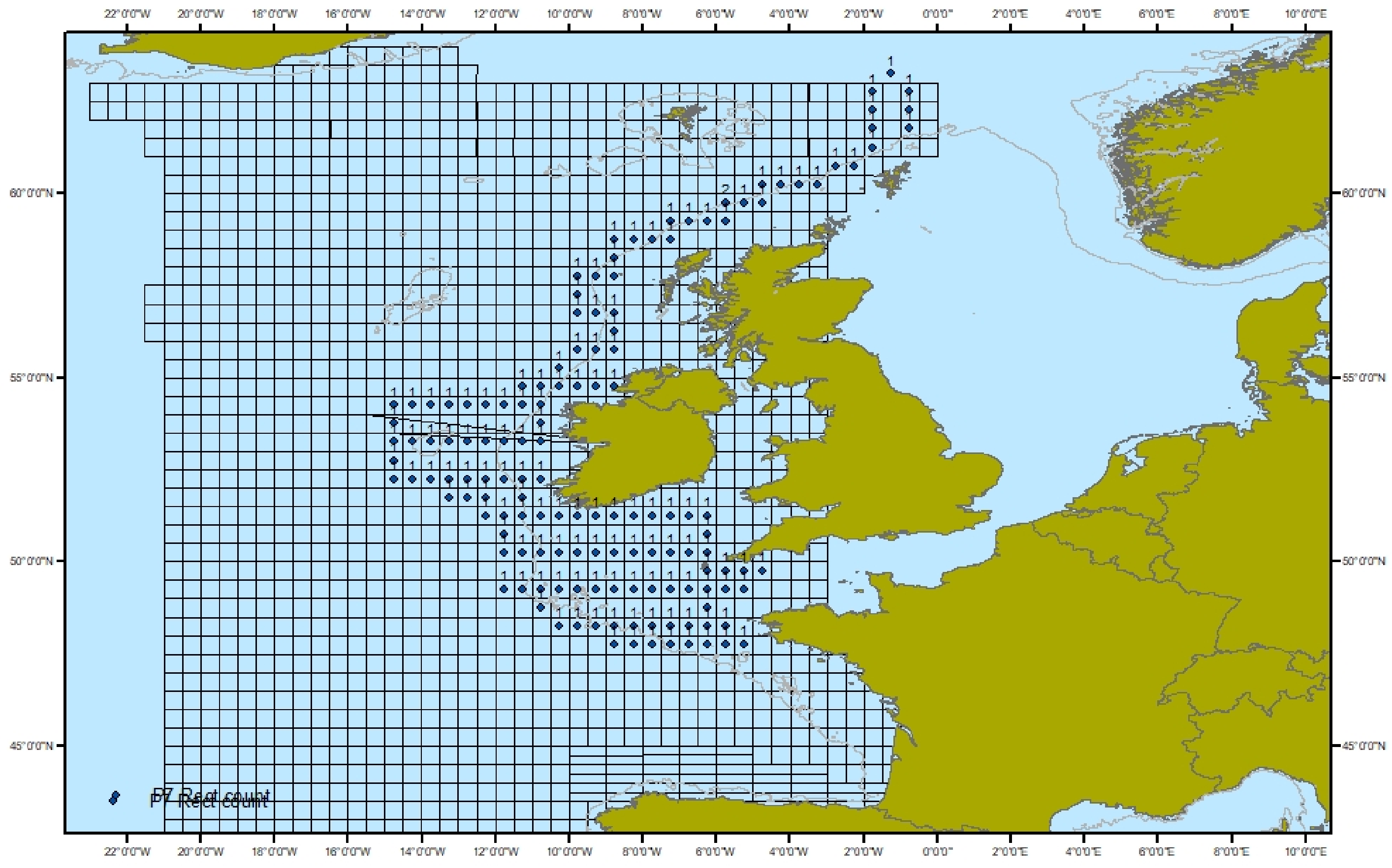

Figure 1.6: Number of observations per rectangle in period 7 (July 1st – 31st)

Toktrapport/Havforskningsinstituttet/ISSN 15036294/Nr. 2–2019

Survey report

MS *Eros*, MS *Kings Bay* MS *Vendla* 13.-25.02.2019

Distribution and abundance of Norwegian spring-spawning herring during the spawning season in 2019

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Contents

Summary

During the period 13-25th of February 2019 the spawning grounds of NSS herring from Møre (62ºN) to the borderline Troms-Finnmark at Tromsøflaket (71º) were covered acoustically by the commercial vessels MS *Eros,* MS *Kings Bay* and MS *Vendla.* The survey was carried out under variable weather conditions; very rough conditions in the beginning, improving over the survey, yet with very few days with good conditions. This lead to some problems with acoustic registrations, to a degree that some corrections of data due to air-bubble attenuation was necessary. The trawling for verification of acoustic registrations and for sampling of herring was also to some degree hindered by the rough weather during the survey. Still, the data recorded during the survey were considered to be of adequate quality. As in 2018, most of the herring in 2019 were distributed in deep layers from 150-300 m depth. In addition, sonar investigations indicated that that echo sounder biomass estimations were not seriously biased by unaccounted fraction of herring in the upper layers (i.e. vessel avoidance and/or distribution of fish in the blind zone between the surface and the echo sounder transducer). The estimated biomass index of 4.25 was a 30% increase from 2018, but with a bit higher (yet still low) uncertainty of CV=10.0% compared with the very low CV=7.4 % in 2018. The increase in the biomass index from last year seems to be a general result of more fish being captured by the survey across ages in 2019 than in 2018 (indication of a year effect), but the largest increase in biomass was for the 2013 year class, a 60 % increase which also was attributed to body growth. The 2013 year class was clearly the most abundant year class in the survey contributing with 26 % in numbers, but fish from older year classes 2006 and 2004 were still present in relatively high numbers contributing with 13 % each. The first significant herring observations was recorded north on the Møre shelf at Buagrunnen 63°N, and from here and northwards the herring was distributed along the coast and observed on most of the transects as far as south of Tromsøflaket 70°30N. About 69 % of the biomass was found between 63° and 67°30N, and the rest was found up to 71°N. The presence of the 2013 year class clearly increased northwards, predominating north of 67°N. The subjective scaling of maturation and GSI (% gonad weight relative to total weight) was quite similar over the survey area, indicating that the herring were still maturing and that timing of main spawning event was after the survey.

Survey participants 13-25.02.2019:

<u>MS *Eros*</u>	
Aril Slotte	Survey leader
Jan Frode Wilhelmsen	Instrument/Acoustics
Sindre Vatnehol	Scientist/Acoustics
Ståle Kolbeinson	Biology
Jostein Røttingen	Biology
<u>MS *Kings Bay*</u>	
Erling Kåre Stenevik	Survey coordinator
Egil Ona	Head of acoustics
Jarle Kristiansen	Instrument/Acoustics
Guosong Zhang	Instrument/Acoustics
Stine Karlson	Biology
Ørjan Sørensen	Biology
<u>MS *Vendla*</u>	
Are Salthaug	Survey leader
Reidar Johannesen	Instrument/Acoustics
Kåre Tveit	Instrument/Acoustics
Valantine Anthonypillai	Biology
Adam Custer	Biology

Introduction

Acoustic surveys on NSS herring during the spawning season has been carried out regularly since 1988, with some breaks (in 1992-1993, 1997, 2001-2004 and 2009-2014). In 2015 the survey was initiated again partly based on the feedback from fishermen and fishermen's organizations that IMR should conduct more surveys on this commercially important stock. Since then this has continued with a survey design using three commercial vessels, and IMR has contracted the same vessels to run this survey during the period 2017-2020. The ICES WKPELA benchmark in 2016 decided to use the data from this time series as input to the stock assessment, together with the ecosystem survey in the Norwegian Sea in May in addition to catch data, meaning that the results of the survey have significant influence on quota advice.

Hence, the objective of the NSS spawning survey 2019 was to continue the index for use in the ICES WGWIDE stock assessment, more specifically to estimate indices of abundance at age and biomass during the period of spawning migration from wintering areas at/off the northern

Norwegian coast and in the Norwegian Sea towards the coastal spawning ground further south. Finally, it was also a purpose that the results of the survey should be compared with recent surveys with comparable effort and design during 2015-2019.

Material and methods

Survey design

During the period 13-25th of February 2019 (exact same period as in 2017-2018) the spawning grounds from Møre (62ºN) to Troms (71ºN) were covered acoustically by the commercial fishing vessels *MS Eros, MS Kings Bay* and MS *Vendla*.

The survey was planned based on the information we hels from the distribution of the fishery during the autumn 2018 up to the survey start 13. February 2019 (Figure 1). The fishery prior to the survey start in 2019 was indicating that the herring wintering in the Norwegian Sea were entering the coast in the Træna deep south of Røst and following the eastern shelf edge 200 m depth southwards from Træna as also observed in 2016-2018. This information also suggested that smaller and younger herring recruiting to the spawning stock initiated their spawning migration from wintering grounds further north of 70ºN west of Tromsøflaket and in Kvænangen fjord area, which was the basis for the planned survey coverage this far north. As seen from Figure 1, the fishery had already started at Buagrunnen (63°N) at the onset of survey 13 February in 2018, whereas in 2019 the fishery did not start in this area until a couple of days after the survey started. It was discussed among fishermen that the herring they were fishing at Buagrunnen came directly from the Norwegian Sea from the west, not following the southward migration along the shelf from Røst. This is difficult to disprove, but the recordings from the survey (both biomass and size of herring) suggest that herring observed from Buagrunnen and northwards clearly may have attributed to the fishery developing at Buagrunnen after the survey passed the area.

The survey design followed a standard stratified design (Jolly and Hampton 1990), where the survey area was stratified before the survey start according to the expected density and age structures of herring (Figure 2). With exception of stratum 14, all strata this year was covered with a zig zag design instead of parallel west-east transects each (Figure 3). The introduction of a zig-zag design started in 2018, and it was based on the wish to reduce the uncertainty related to stock coverage, using more of the survey time on transects and thereby increasing the survey coverage. In 2015-2017, a significant part of the survey time was used as transport between transects, whereas in 2018-2019 insignificant time was used on transport. Each straight line in the zig-zag design were considered as transects and primary sampling units (Simmonds and MacLennan 2008), with uniform coverage of strata and a random starting position.

Biological sampling

Trawl sampling was carried out on a regular basis during the survey to confirm the acoustic observations and to be able to give estimates of abundance for different size and age groups. The positions of the trawl hauls are shown in Figure 3. The following variables of individual herring were analysed for each station with herring catch: Total weight (W) in grams and total length (L_T) in cm (rounded down to the nearest 0.5 cm) of up to 100 individuals per sample. In addition, age from scales, sex, maturity stage, stomach fullness and gonad weight (W_G) in grams were measured in up to 50 individuals per sample. The maturation stages were determined by visual inspection of gonads as recommended by ICES (Anon. 1962): immature = 1 and 2, early maturing = 3, late maturing = 4, ripe = 5, spawning = 6, spent = 7 and resting/recovering = 8. Data from the subjective evaluation of maturation stages were used to split between immature and mature herring in the estimation of spawning stock biomass (SSB), as well as to demonstrate spatial differences in maturation. The gonadosomatic index (GSI=gonad weight/total weight x100) was also used to demonstrate spatial differences in maturation along the coast.

Environmental sampling

CTD casts (using Seabird 911 systems) were taken by MS Eros and Vendla, spread out in the survey area (Figure 3).

Echo sounder data

Multifrequency (18, 38, 70, 120, 200 kHz) acoustic data were recorded with a SIMRAD EK 60 echo sounder and echo integrator on board Eros and Vendla, and SIMRAD EK 80 on board Kings Bay. All three vessels were calibrated at the tip of the fishing pier in Ålesund prior to the survey according to standard methods (Foote et al., 1987), adjusted for split beam methods as described in Ona (1999) and (Demer et al., 2015). The calibration reports of each vessel are shown in Annex 1. The low frequency sonars were not calibrated. The intension was only to use the sonar data for studies of potential issues with herring in blind zone close to the surface or avoidance, not for biomass estimations of schools. Hence, a new calibration of the sonars was not considered necessary. For details on the use of sonar and data storage, see sonar report in Annex 2.

LSSS, Large Scale Survey System (Korneliussen et al., 2006) was applied for the interpretation of the multi-frequency data. The recorded area echo abundance, i.e. the nautical area backscattering coefficient (NASC) (MacLennan et al., 2002), was interpreted and distributed to herring and ‘other’ species at 38 kHz. Various characteristics of the acoustic recordings like frequency response (Korneliussen & Ona, 2002) and visual appearance were used to identify herring from other targets.

In 2019 the survey suffered from relatively bad weather conditions compared with 2018. During conditions where the vessels had to survey against strong winds, acoustic registrations on some transects were significantly influenced by air bubble attenuation. This was corrected for during the scrutinization of the data in LSSS, and the problems and methods used to adjust is described in Annex 3, see also Annex 5 for more examples of echograms with bubble attenuation problems.

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. 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:

$$\hat{S}_i = \frac{1}{n_i} \cdot \sum_{i=1}^{n_i} w_{it} s_{it} \qquad (1)$$

where $w_{it} = L_{it} / \overline{L}_t$ (t= 1,2,.. n_i) are the lengths of the n_i sample transects, and

$$\overline{L}_i = \frac{1}{n_i} \sum_{t=1}^{n_i} L_{it} \qquad (2)$$

The final mean NASC is given by weighting by stratum area, A;

$$\hat{S} = \frac{\sum_i A_i \hat{S}_i}{\sum_i A_i} \qquad (3)$$

Variance by stratum is estimated as:

$$\hat{V}\left(\hat{S}_i\right) = \frac{n}{n_i - 1} \sum_{t=1}^{n} w_{it}^2 \left(s_t - \bar{s}\right)^2 \quad \text{with } \bar{s}_i = \frac{1}{n_i} \cdot \sum_{t=1}^{n_i} s_t \qquad (4)$$

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

$$\hat{V}(\hat{S}) = \frac{\sum_i A_{i=1}^2 \hat{V}(\hat{S})}{\left(\sum_i A\right)^2} \qquad (5)$$

The global relative standard error of NASC

$$RSE = 100 \sqrt{\frac{\hat{V}(\hat{S})}{N}} \Big/ \hat{S} \qquad (6)$$

where N is number of strata.

In order to verify acoustic observations and to analyse year class structure over the surveyed area, trawling was carried out regularly along the transects (Figure 3). All trawl stations with herring were used to derive a common length distribution for all transect within the respective strata. All stations had equal weight.

Relative standard error by number of individuals by age group was estimated by combining Monto Carlo selection from estimated NASC distributions by stratum with bootstrapping techniques of the assigned trawl stations.

The acoustic estimates presented in this report use the 38 kHz NASC, and the mean was calculated for data scrutinized as herring and collected along the transects (acoustic recordings taken during trawling, and for experimental activity are excluded). The number of herring (*N*) in each length group (*l*) within each stratum (*i*) is then computed as:

$$N_l = \frac{f_l \cdot \hat{S}_i \cdot A_i}{\langle \sigma \rangle}$$

Where

$$f_l = \frac{n_l L_i^2}{\sum_{l=1}^{m} n_l L_l}$$

is the ”acoustic contribution” from the length group L_l to the total energy and <s_i>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 ICES WGWIDE 2019 as another year in the time series. However, as in the 2016-2018, special measurements were made from MS Kings Bay for investigating if the mean target strength of herring during spawning is different from non-spawning herring. See Annex 4 for information regarding these experiments which at a later stage will be used to develop a new depth dependent TS, which could be used to re-estimate all years of this survey. This will be a more realistic mean target strength for spawning herring, measured in situ, expected to remove potential bias from variable depth distribution between surveys and survey areas (see Figure 6).

The StoX software developed by IMR were used in the abundance estimation in 2019, just as in 2015-2018. StoX is an open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application build with Java for easy sharing and further development in cooperation with other institutes. The underlying high resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Accessing StoX from external software may be an efficient way to process time series or to perform boot-strapping on one dataset, where for each run, the content of the parameter dataset is altered. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990)[i] is implemented.

Sonar data and analyses

Data from Simrad low-frequency sonars were logged onboard 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 extend of these biases are presently being developed. See Annex 2 for more information on sonar logging and data.

Results and discussion

Spatial distribution and acoustic densities

The distribution and densities of herring in the area covered in 2019 was quite similar to that observed in 2018, relatively evenly distributed along the coast 63-71ºN, yet with some high density areas around Halten/Sklinna banks (64°30-66°N) and south western part of Vesterålen banks (67°30N-68°30N) (Figures 4 and 5).

Depth distribution

As in 2018 most of the herring in 2019 were distributed in deep acoustic layers at 150-300 m depth south of 67°N, whereas further north along the western part of the Vesterålen shelf area and northwards along the coast high densities were also observed closer to the surface during periods of darkness (Figure 6). Several examples of acoustic registrations of herring in the survey area using EK80 echo sounder are given in Annex 5.

Estimated biomass index

The estimate of a total stock biomass index using StoX, to be treated as a relative one, was 4.25 in 2019 (Table 1) with a reasonably low uncertainty (CV = 10.0%). A 33 % bulk of the herring biomass was found in the area Halten and Sklinna (64°30-66°N), but also 32% was found along Vesterålen and further rnord (north of 67°30N) (Figure 7, Table 2), suggesting that these areas were also important for spawning. The biomass index in 2019 was a 30% increase from 2018 when it was estimated to be 3.3 with a very low uncertainty (CV = 7.5%). The trends in the total abundance and biomass index since 2015 shows a decline until 2017, after which a flattening in 2018 and an increase in 2019 (Figure 8).

Estimated abundance index by age

The 2013 year class was clearly the most abundant year class in the survey in 2019 contributing with 26 % in numbers, but fish from older year classes (2006 and 2004) were still present in relatively high numbers contributing with 13% each (Figure 9, Table 3). The estimated abundance index by age appeared with low uncertainty and CVs mostly ranging between 15-20 % for ages 4-15, whereas the estimates were less precise with CVs above 25% for younger and older fish (Figure 9, Table 3). This CV pattern is quite normal since few very old and very young fish are caught.

Trends in biomass index and abundance index by age 2015-2018

A more detailed inspection of the trends in number of fish per year class over all surveys 2015-2018 clearly demonstrate a steady decrease in exploited year classes with time, but from 2018 to 2019 we see a minor increase for most year classes (Figure 10). The estimated trends in year class abundance over time is considered a sign of quality or consistency; i.e. if you see a steady decrease as a result of exploitation and natural mortality after a year class is fully recruited to the spawning stock. This is indicating that the survey captures quite well the relative trends in abundance. Still, so-called year effects (unexpected drops or increases over all year classes) in such survey indices are quite normal. The increase in biomass index from 2018 to 2019 seems to be a general result of more fish being captured by the survey across ages than in 2018. However, the largest increase in biomass was for the 2013 year class; a 60 % increase that also may be attributed to the fact that it was fully recruited to the spawning stock in 2019 and to body growth since 2018. The trends in the year classes over 2015-2019 (Figure 10) also signifies that there does not seem to be any new significant recruitment after the 2013 year class, and that 2013 is a moderate size year class compared to the 2004 year class having dominated in the spawning stock for many years.

When year classes are fully recruited to the spawning stock, the abundance indices from the survey in the Norwegian Sea in May and the following spawning survey in February should show comparable numbers. A comparison between the May survey 2018 and February survey 2019 demonstrates that the two surveys are showing the same signal in terms of present year class strengths (Figure 11).

Geographical variation in biomass and abundance index by age

The age and size of the herring was relatively stable all over the area 63-67ºN, but further north size and age of the herring decreased (Figures 12-14). North of 67ºN the 2013 year class predominated, and north of 69ºN to especially west of Tromsøflaket in Stratum 18 the 2016 year class (3 year olds) started to contribute in high numbers (Figure 12, Table 2). This year class is expected to be the largest year class since 2004 based on surveys in the Barents Sea in recent years. The first real test to verify if this prediction is true is the 2019 ecosystem survey in May in the Norwegian Sea. Based on the results from the spawning survey, it seems that this year class already is migrating out of the Barents Sea and should be captured by the ecosystem survey in May.

The observed size dependent distribution pattern in 2019 is similar to what was observed in 2015-2018 (Slotte et al 2015, 2016, 2017, 2019). It is also in accordance with the observations in earlier years, which has been thoroughly discussed in Slotte and Dommasnes, 1997, 1998, 1999, 2000; Slotte, 1998*b*; Slotte, 1999*a*, 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, 1999*b*). 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).

Maturation status

No real clear geographical trends in the maturation of the herring were observed during the survey coverage and biological sampling based on subjective scaling of gonads, and by looking at the gonadosomatic index (GSI = gonad weight × 100/total weight) (Figure 15). The herring seemed to be less ripe than observed in 2018, when more herring was spawning or close to spawning (Slotte et al. 2018), suggesting a later main spawning event in 2019. In 2018 there was also quite evident that herring in the northern part of the distribution tended to be less ripe (Slotte et al. 2018). This is in accordance with a general perception that the first time spawners tend to spawn later in the season, in a second wave (Slotte 2001, Slotte et al. 2000). However, in 2019 very few fish were recruit spawners, the dominating year class 2013 was fully recruited, so there were no clear indications of a second spawning wave in the north. An interesting observation was that in the area 65-67°N, herring with resting gonads (stage 8) considered to be summer spawners were present also at the coast. This was also apparent in 2018 (Slotte et al. 2018), and a possible reason is that these fish followed the main mass of spring-spawners to the coast from the wintering area in the Norwegian Sea. Alternatively, that they already were present in the area, when the spring spawners arrived. These areas along Helgeland, Lofoten and Vesterålen is believed to the main spawning area of the summer spawners.

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, clearly colder close to the surface (Figure 16). At typical spawning depths of herring 100-200 m temperature did not vary much along the coast, being rather stable at 7°-8°C as also observed in 2017-2018 (Slotte et al. 2017, 2018).

Quality of the survey for abundance estimation

In 2019 all vessels were equipped with multifrequency equipment on a drop keel. Weather conditions this year were not good, and strong wind led to periods with problems doing acoustic surveying, especially in the beginning of the survey. Hence, the acoustic data recorded was of lower quality from all three vessels than in 2018, when the surveying conditions were close to perfect (Slotte et al. 2018). The weather conditions in 2019 did not allow for a survey speed of 10 knots for the whole survey period, especially for transects running up against the wind, the vessel speed wasreduced to 3-5 knots for some periods.

Even at reduced reducing survey speed there was significant bubble attenuation. Still, given the survey coverage needed to ensure a full estimate with low uncertainty of the herring in the area, and the time available, it was decided to continue the survey during the bad weather conditions. This decision is especially linked to the potential bias in the estimates a break in the survey may lead to when covering in the direction against the migration direction of the herring. This bias was considered a larger problem than reduced quality of the acoustic data themselves, which it was possible to correct for. In Annex 3 the acoustic problems and the adjusting of bubble attenuation is described in more details.

During the survey, there was special focus on potential blind zone problems and fish avoidance, and the sonar was monitored at the same time as the echo sounder (Annex 2). The main conclusion is that we did not have a significant bias in the survey related to these factors. The main part of the estimated biomass (about 70 %) (Figure 7, Table 2) was found south of Vesterålen distributed very deep in layers both during day and night, mostly at 150-300 m depth close to the bottom, not expecting to avoid the vessels (Figure 6). However, further north along Vesterålen and Troms at night time some strong registrations of young herring were observed close to the surface at 20-40 m depth (Figure 6). The echo sounder data suggested that they were not in the blind zone closer to the surface, as they were located 10-30 m below the transducer, and this was also supported by observations from the sonars. Still, in these northernmost strata we may have had some avoidance of these herring registrations close to the surface during night, and hence some underestimation. During daytime, however, the fish in this area were also registered very deep, typically at 200 m and deeper along the shelf edge (Figure 6), where avoidance was not expected to be a problem.

In 2019 all vessels were able to trawl, but the weather conditions also to some degree prevented trawling at acoustic registrations for verification of species or for sampling of herring in the survey area. This resulted in less sampling on acoustic registrations than in 2018, which may have resulted in a lower quality of the scrutiny process into herring and other targets, as well as lower quality on estimation of abundance index by age. Still, the scrutinizing and biological sampling was considered to be of an acceptable quality.

With regard to coverage, and potential herring outside the covered area, there were no data suggesting that this may have been a potential bias in the survey. In 2018 very few schools were registered westwards in the off-shelf wintering area (Slotte et al. 2018), where the fishery on Norwegian spring spawning herring took place prior to the survey in January. This year (2018) the herring in this area contributed with only 0.2% of the total biomass index, and it was pre-dominated by 91% summer spawners. It was concluded that the spring spawning herring by the time of the survey coverage in 2018 already had left the wintering areas and entered the survey area. Based on the experience from 2018 as well as the experience from the earlier years 2016-2017 (Slotte et al. 2016, 2017) surveying this area, it was decided to skip this area in 2019. Instead focus was put on an area that previously has not been covered, the Trænabank area (Stratum 16), where 5% of the biomass was found (Figure 7, Table 2). This is an area that herring potentially may migrate through during the southward migration, rather than taking the main route closer to the coast along, so this is an area that should be surveyed also next years.

In summary, the acoustic and biological data recorded in 2019 were of satisfactory quality, and the distribution of the herring was wide spread leading to a good spatial coverage with many transects in a zig-zag design and a low CV of 10.0%. Hence, the index can be recommended used for stock assessment purposes.

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Tables

Table 1. Estimated total index of abundance (TSN), total biomass (TSB) and spawning stock biomass (SSB) of Norwegian spring-spawning herring during the spawning season 13-25. February 2019.

									Age											Total		
Length (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Unknown	Number	Biomass	MeanW
12-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2681	2681	32	12.0
13-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-15	50698	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50698	807	15.9
15-16	47832	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	47832	939	19.6
16-17	11038	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11038	235	21.3
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1769	1769	64	36.0
19-20	-	1769	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1769	60	34.0
20-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3539	3539	163	46.0
21-22	-	-	5308	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5308	319	60.0
22-23	-	-	28738	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28738	1881	65.5
23-24	-	-	70719	5409	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76128	5580	73.3
24-25	-	-	88608	3599	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	92207	7968	86.4
25-26	-	-	64180	31798	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	95978	9618	100.2
26-27	-	-	73604	8197	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81801	9365	114.5
27-28	-	-	28356	38165	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66521	8856	133.1
28-29	-	-	-	82204	65931	14877	-	-	-	-	-	-	-	-	-	-	-	-	-	-	163012	25598	157.0
29-30	-	-	-	60258	172562	41328	-	-	-	-	-	-	-	-	-	-	-	-	-	-	274148	50371	183.7
30-31	-	-	-	17847	199745	416182	10868	7203	-	-	-	-	-	-	-	-	-	-	-	-	651845	137721	211.3
31-32	-	-	-	31375	209474	1084824	171863	60323	-	-	-	-	-	-	-	-	-	-	-	-	1557859	370659	237.9
32-33	-	-	-	12636	92998	1237598	154025	54932	2246	-	-	-	-	-	-	-	-	-	-	-	1554435	403545	259.6
33-34	-	-	-	12878	150416	588053	282398	183675	22891	5898	-	8075	-	-	-	-	-	-	-	-	1254285	356338	284.1
34-35	-	-	-	-	19714	224539	135829	323226	184160	170866	90854	19871	13483	-	48120	-	13797	-	-	-	1244459	387379	311.3
35-36	-	-	-	-	6868	47869	41512	215577	313561	405496	268816	143811	514970	43578	353049	13614	32187	-	-	-	2400907	812245	338.3
36-37	-	-	-	-	5898	-	2297	43675	114752	361122	235740	150784	779176	121072	764077	36533	101625	3238	4784	-	2724772	982660	360.6
37-38	-	-	-	-	15516	-	-	6986	6767	72617	130412	25977	457362	30323	578281	-	83804	-	-	-	1408045	537134	381.5
38-39	-	-	-	-	-	-	-	-	-	17760	13973	46032	79673	13758	112611	2253	13058	-	2253	-	301370	123389	409.4
39-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17462	-	14481	-	-	-	31943	13874	434.4
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5898	-	-	-	5898	2654	450.0
TSN (1000)	109567	1769	359512	304367	939122	3655271	798791	895597	644377	1033758	739795	394548	1844663	208732	1873599	52400	264850	3238	7037	7988	14138984	-	-
TSB (t)	1981	60	33475	50448	210703	932892	221570	276212	215805	355400	261755	139988	665160	75834	684486	18548	101122	1049	2708	259	-	4249454	-
Mean L (cm)	14.9	19.0	24.7	28.6	31.1	32.0	32.9	34.1	35.1	35.6	35.9	36.0	36.3	36.3	36.4	36.1	36.7	36.5	37.0	17.3	-	-	-
Mean W (g)	18.1	34.0	93.1	165.8	224.4	255.2	277.4	308.4	334.9	343.8	353.8	354.8	360.6	363.3	365.3	354.0	381.8	324.0	384.8	32.4	-	-	300.6
% mature	0	0	22	89	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	-	-	-	-
SSB (t)	0	0	7364	44833	210703	932892	221570	276212	215805	355400	261755	139988	665160	75833	684486	18548	101122	1049	2708	-	-	4215428	-

Table 2. Estimated index of abundance (TSN), total biomass (TSB) and spawning stock biomass (SSB) of Norwegian spring-spawning herring by the strata covered during the spawning season 13-25. February 2019.

	Stratum														
Age	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**	**18**	**Total**
1	0	0	15	26	28	11	0	0	12	1	7	0	9	0	110
2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
3	0	0	0	0	0	8	7	12	15	0	9	0	0	308	360
4	0	0	2	4	14	27	0	41	74	2	39	0	7	95	304
5	3	16	39	82	92	59	118	167	190	9	78	0	31	56	939
6	18	124	155	260	184	317	968	803	480	22	199	0	70	54	3655
7	1	5	57	89	103	165	173	129	33	1	9	0	34	0	799
8	8	47	57	123	156	170	69	188	20	0	6	0	49	3	896
9	8	83	100	186	90	48	21	77	0	0	0	0	32	0	644
10	17	135	161	268	200	53	0	109	17	1	6	0	64	3	1034
11	2	21	198	279	80	44	0	83	0	0	0	0	33	0	740
12	5	26	85	164	31	32	0	29	10	1	3	0	10	0	395
13	38	259	296	510	333	53	7	218	10	1	8	0	113	0	1845
14	9	57	22	33	39	5	0	30	0	0	0	0	15	0	209
15	25	207	285	495	344	88	21	268	15	2	5	0	116	3	1874
16	0	0	11	15	16	2	0	3	0	0	0	0	5	0	52
17	12	57	41	71	49	2	0	10	5	0	0	0	18	0	265
18	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
19	0	0	0	0	4	2	0	0	0	0	0	0	1	0	7
TSN (millions)	146	1035	1524	2604	1764	1086	1383	2171	880	38	370	0	607	531	**14139**
B (1000 tons)	52	372	517	883	582	316	341	635	195	9	82	0	200	66	**4249**
% Mature	100	100	100	100	100	99	100	99	98	100	99	0	100	48	**98**
SSB (1000 tons)	52	372	517	883	581	314	341	631	191	9	80	0	200	32	**4153**

Table 3. Uncertainty estimates in the abundance index of Norwegian spring-spawning herring during the spawning season 13 -25 February 2019. Uncertainty estimates are from 500 boostrap replicates in StoX. See also Figure 10 for graphical presentation of data.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
1	0.0	90.9	189.2	80.7	69.5	0.86
2	0.0	1.7	5.0	1.9	1.7	0.91
3	119.8	353.4	745.8	377.1	188.3	0.50
4	216.7	304.1	415.2	309.3	61.3	0.20
5	701.1	917.5	1207.0	932.3	149.9	0.16
6	2594.7	3746.4	5010.1	3752.7	761.7	0.20
7	506.1	730.2	1051.1	749.9	169.5	0.23
8	716.2	883.8	1071.5	883.2	106.9	0.12
9	479.7	646.9	884.9	660.9	125.0	0.19
10	846.6	1048.7	1313.3	1060.8	143.1	0.13
11	549.0	732.5	985.8	747.6	133.9	0.18
12	290.4	406.0	570.6	416.2	88.1	0.21
13	1385.5	1790.1	2425.6	1836.6	324.1	0.18
14	104.9	178.6	276.1	182.8	53.1	0.29
15	1428.8	1811.6	2298.6	1838.5	266.1	0.14
16	7.2	48.3	91.2	48.7	24.8	0.51
17	174.4	273.3	415.3	281.9	72.9	0.26
18	0.0	4.4	18.9	5.8	6.4	1.11
19	0.0	8.4	18.8	8.4	6.3	0.76

Figures

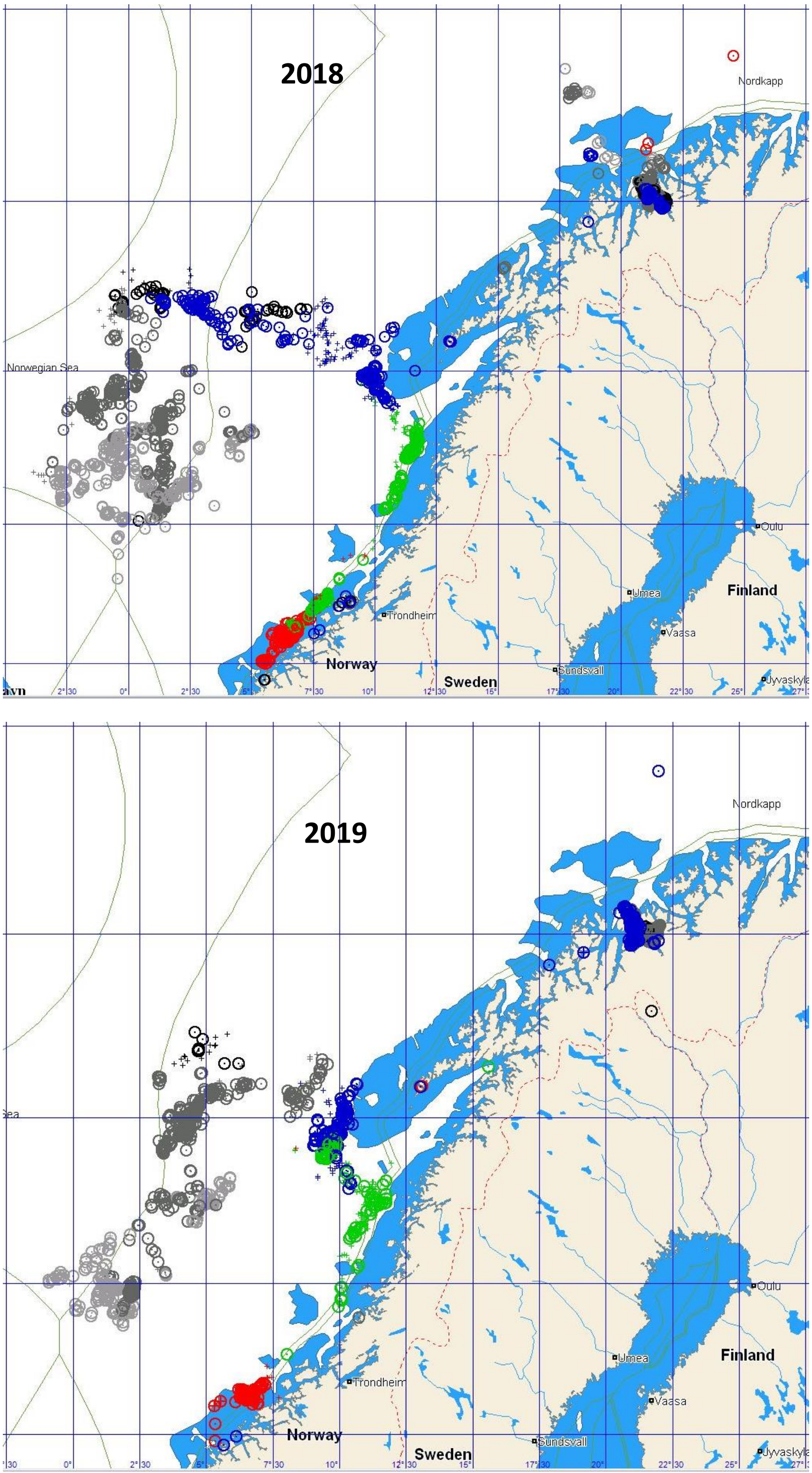

Figure 1. Monthly distribution of catches of Norwegian Spring spawning herring from October until February, based on electronic logbooks. Each point represent one catch, only catches larger then 5 tonnes are shown. Small crosses=trawl catches, circles (with dot inside)=purse seine, light grey=October, dark grey=November, black=December, blue=January, green=February 1-12, red=February 13-28 (overlapping with survey period).

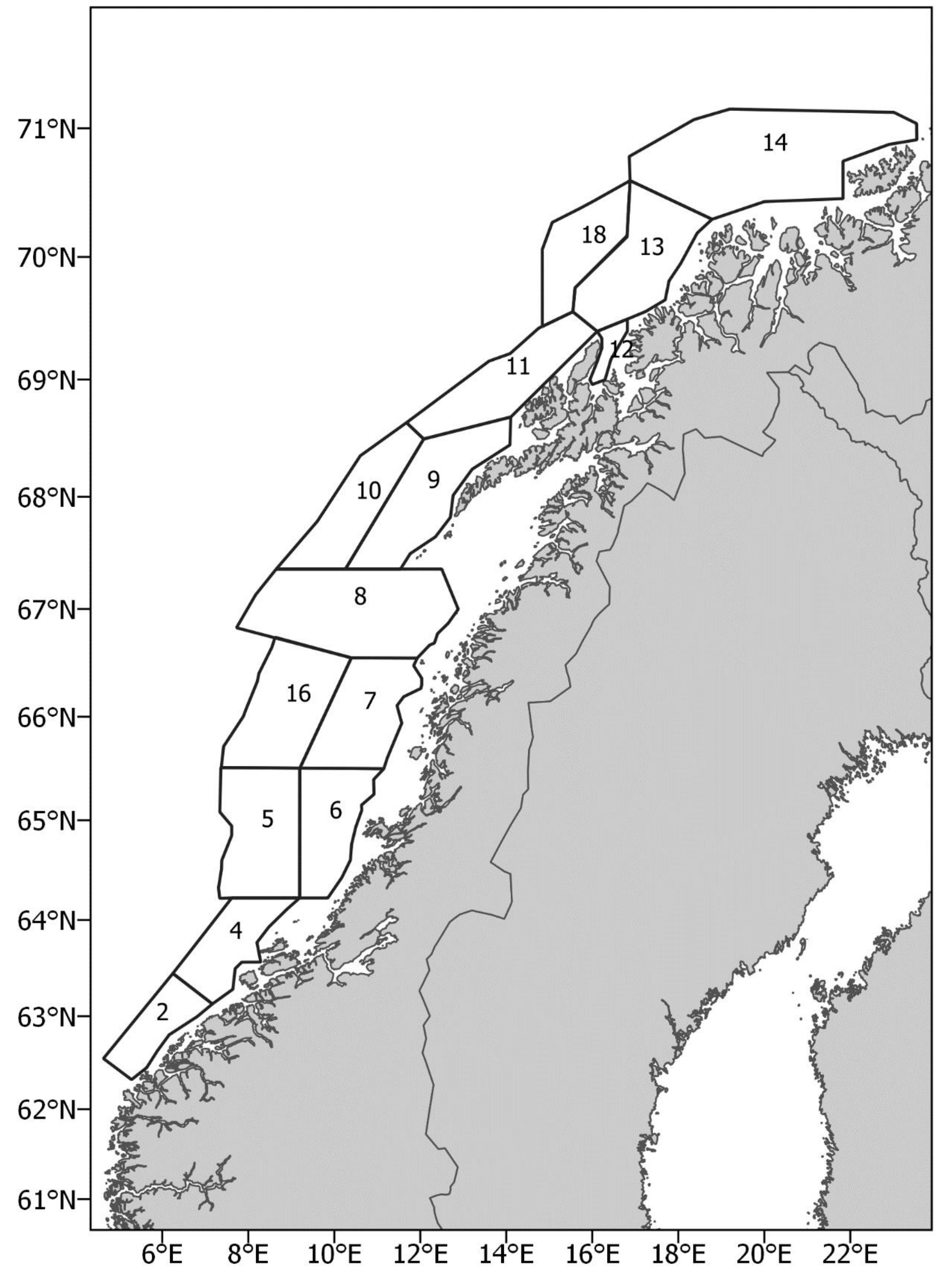

Figure 2. Strata covered during 13-25. February 2019 with MS *Eros, Kings Bay* and *Vendla*

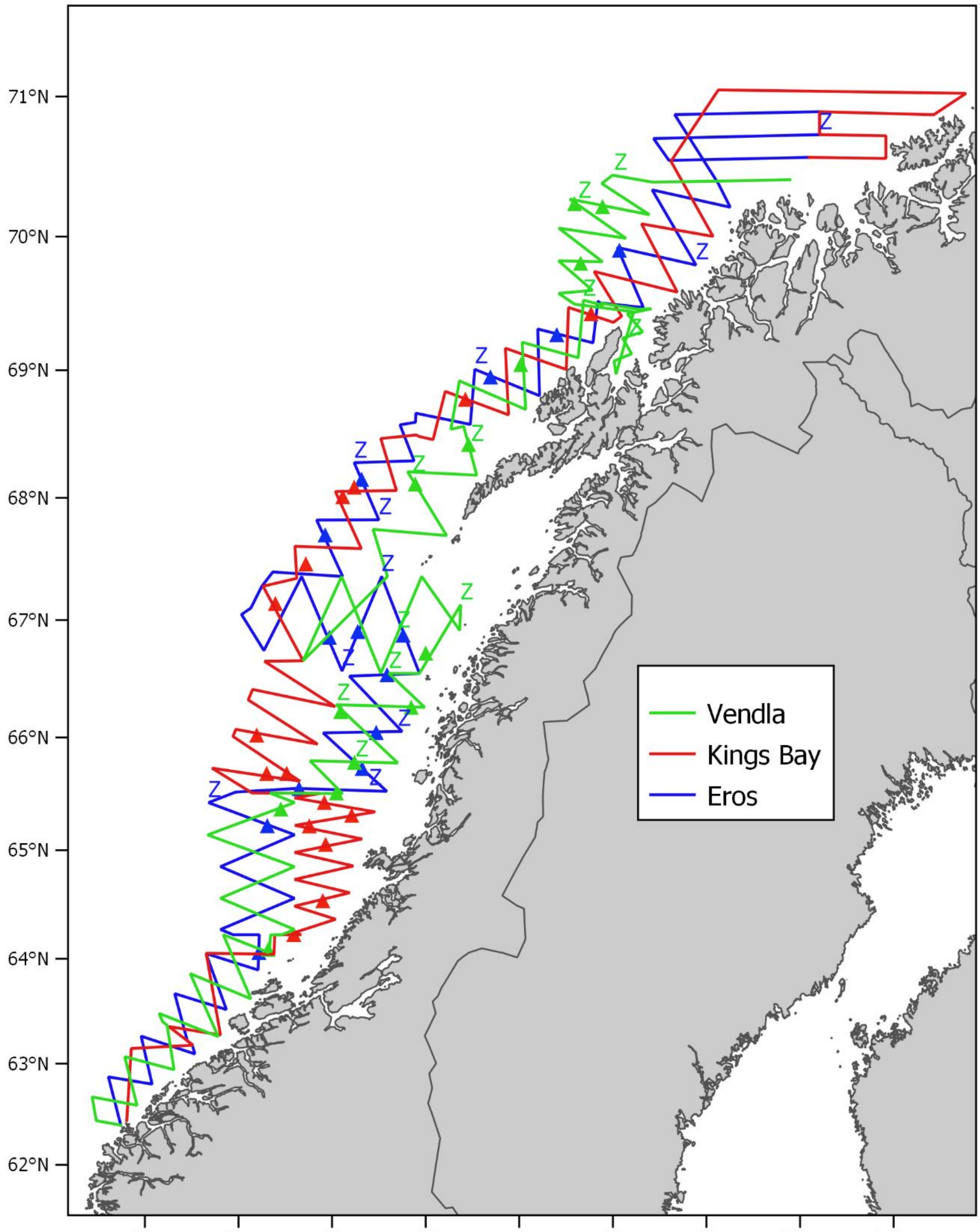

Figure. 3. Acoustic transects, pelagic trawl stations (triangles), and CTD stations (Z) covered with *Eros*, *Kings Bay* and *Vendla* 13-25 February 2019.

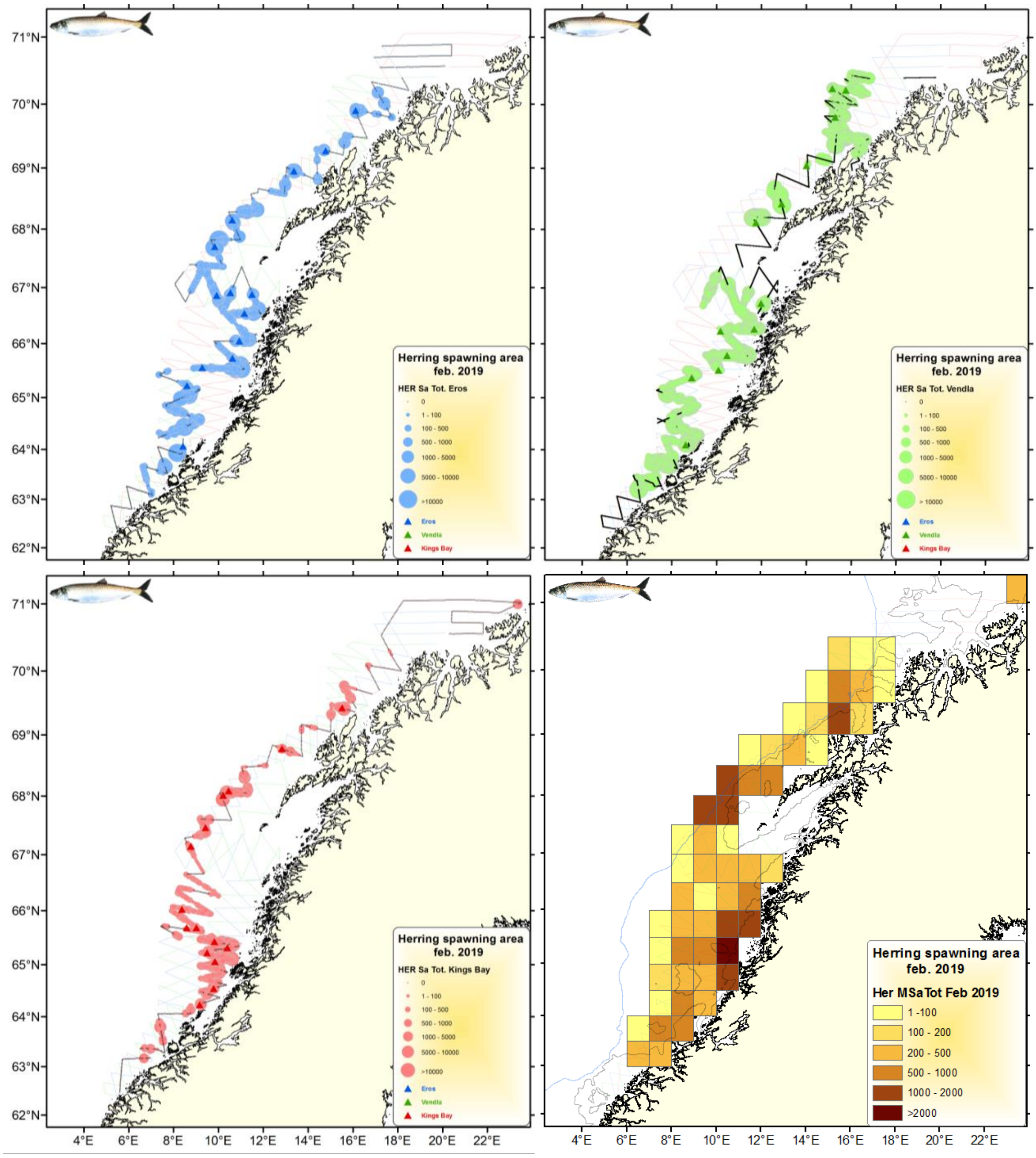

Figure 4. Acoustic density (NASC) of herring recorded during 13-25. February 2019. Bubbles represent 0.1 nm NASC values shown per vessels (*Eros*, *Kings Bay* and *Vendla*). Also shown is mean NASC within geographical rectangles using data from all vessels (bottom right). See Annex 5 for examples of acoustic registrations in the survey area from *Kings Bay*.

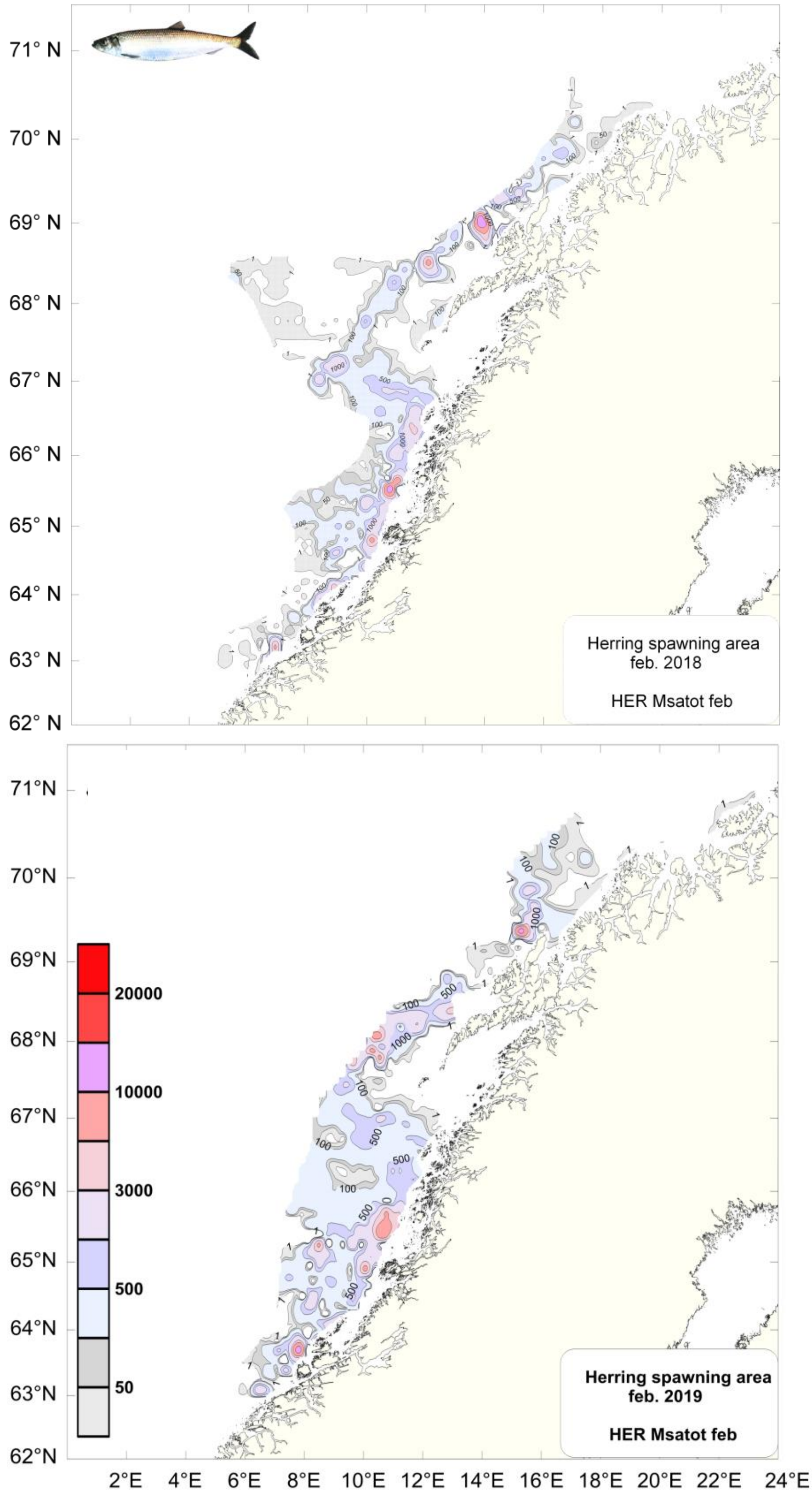

Figure 5. Distribution and acoustic densities (NASC) of herring recorded during 13-25. February 2019 (bottom), compared with the situations in 2018 (top).

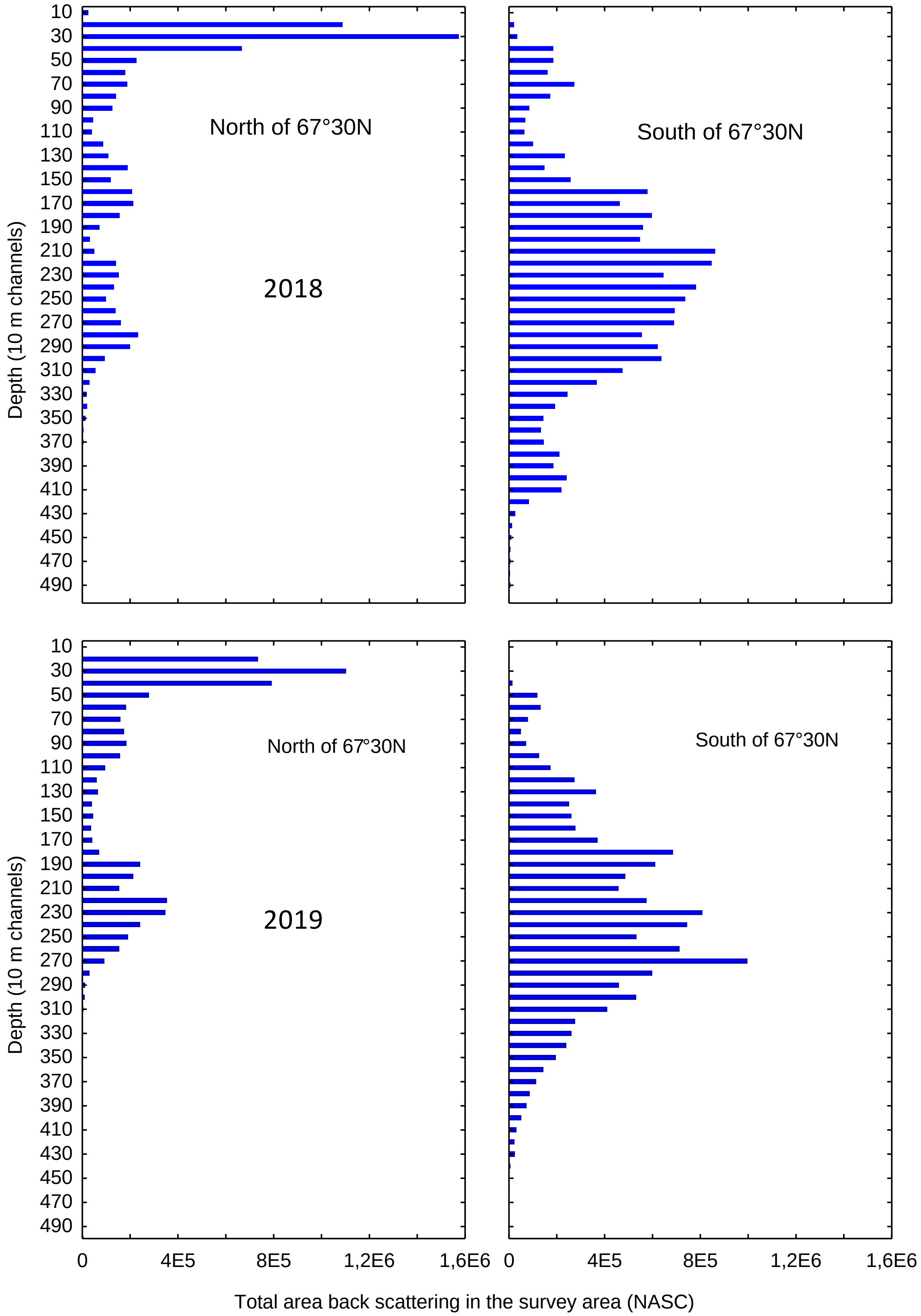

Figure 6. Total acoustic back scattering (NASC) by 10 m depth channels in the survey area during 13-25.February. Comparison between areas to the south and north of 67°N, and between the surveys in 2018 and 2019.

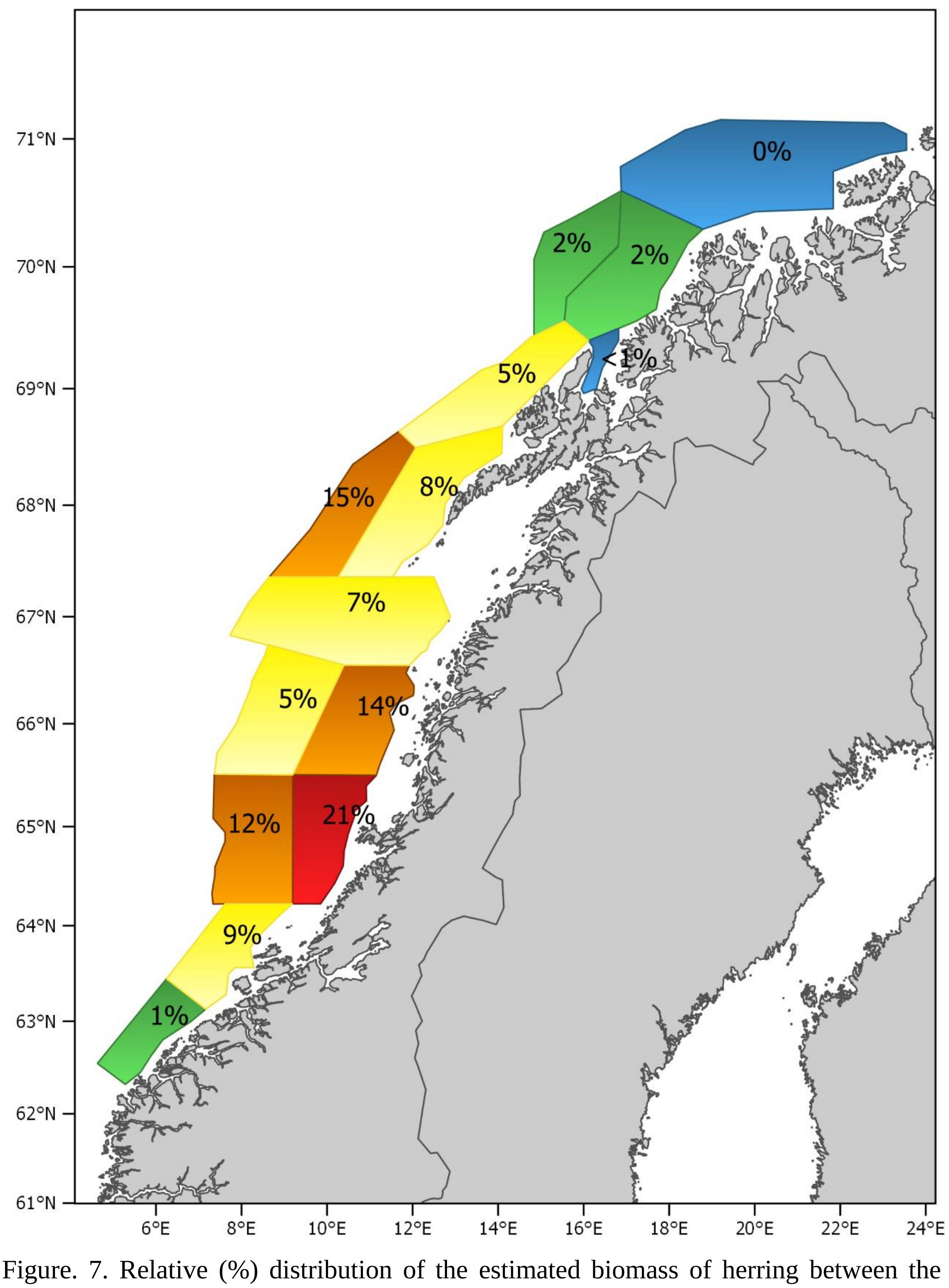

Figure. 7. Relative (%) distribution of the estimated biomass of herring between the strata covered by *Eros, Kings Bay* and *Vendla* 13-25 February 2019. See Table 3 for details on the estimates from each strata.

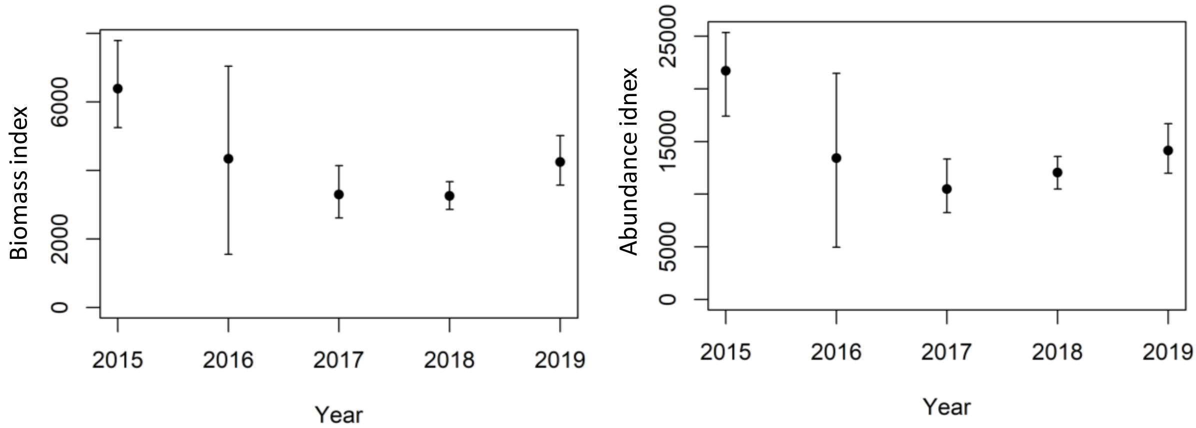

Figure 8. Index of total biomass and abundanceestimated from the Norwegian spring-spawning herring spawning surveys 2015-2019 (the error bars represent 90% confidence intervals).

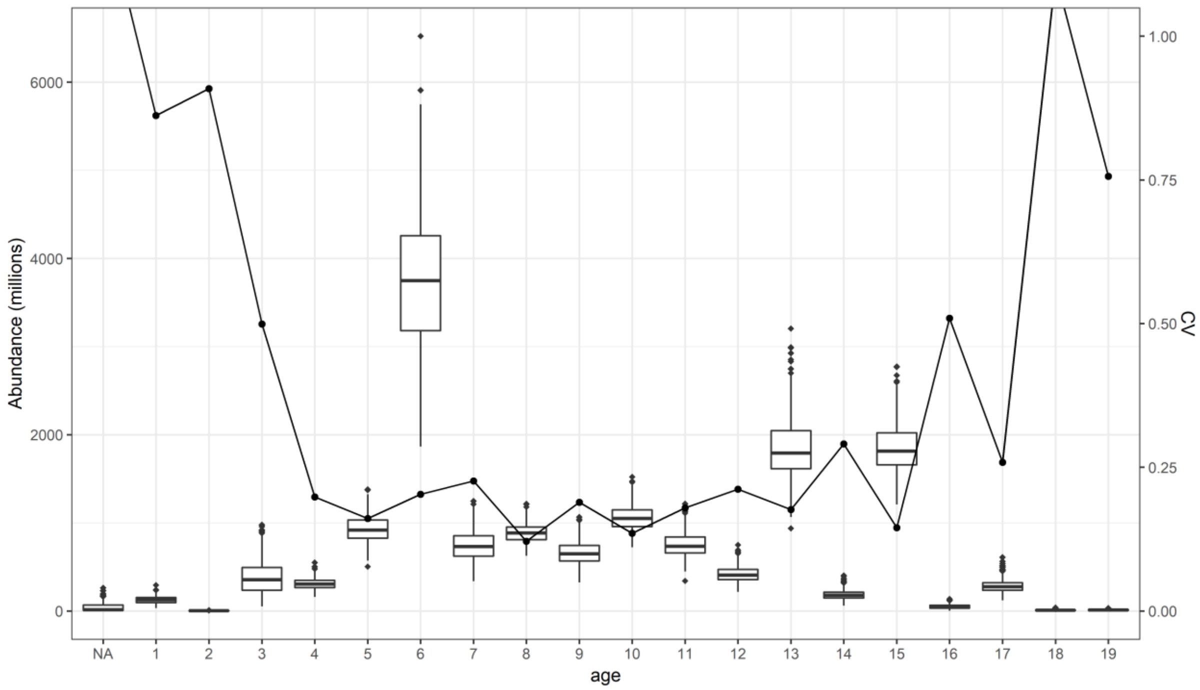

Figure 9. Standard box plot of abundance index by age with uncertainty as estimated during 13-25. February 2019. The Uncertainty estimates were based on 500 bootstrap replicates in StoX. See Table 2 for details on the data presented.

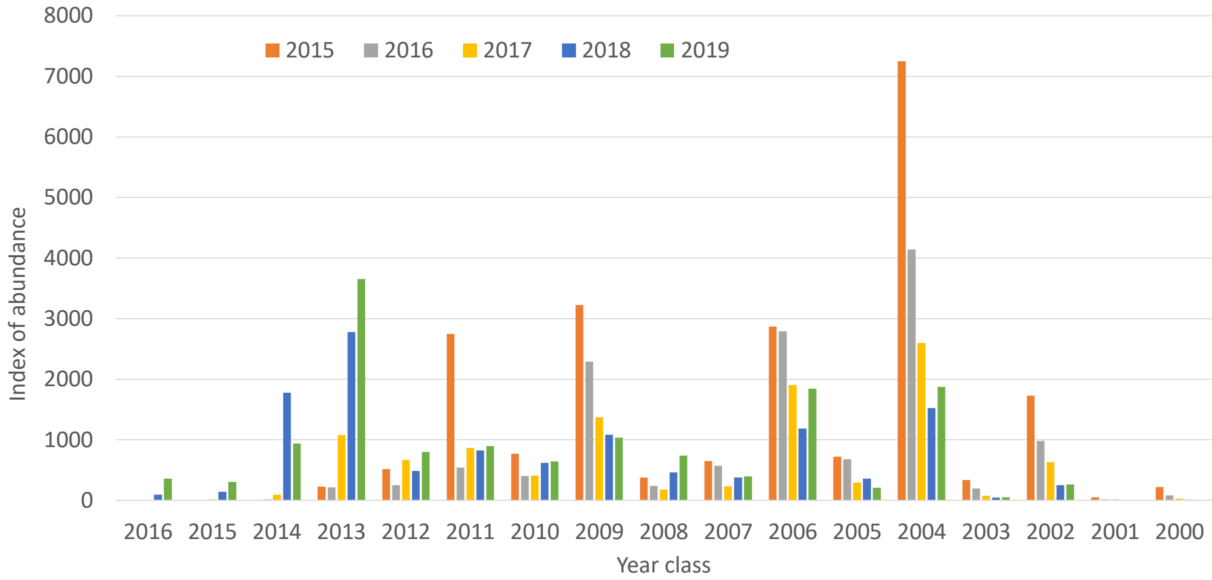

Figure 10. Abundance index by year class estimated during the Norwegian spring-spawning herring surveys 2015-2019.

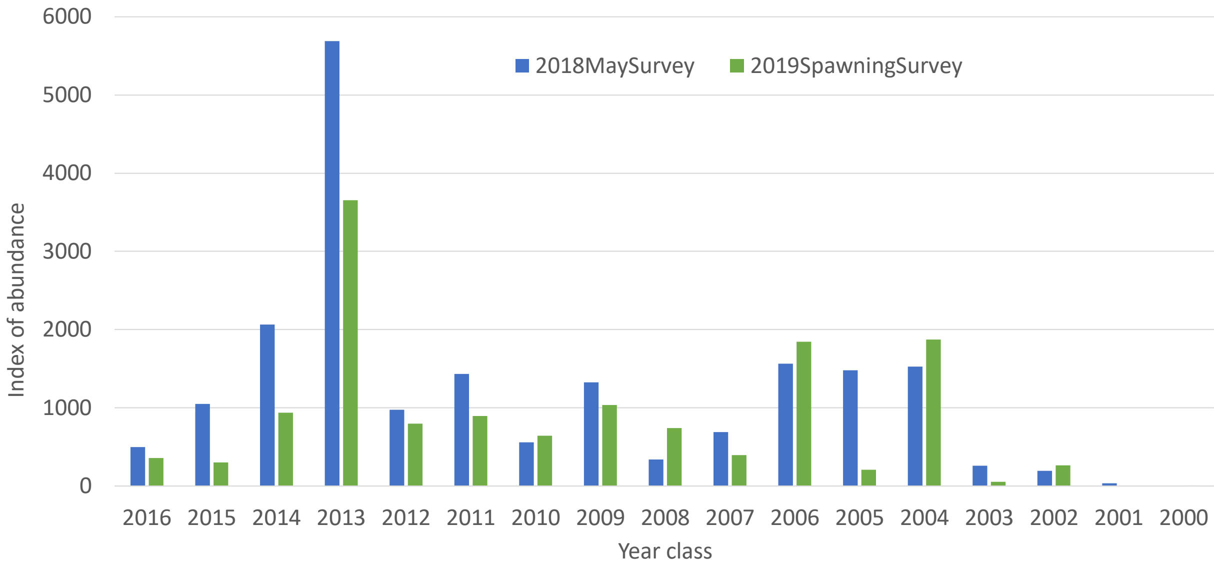

Figure 11. Comparison of abundance index by year class between the Norwegian spring-spawning herring survey 2019 with the index from the international ecosystem survey in the Norwegian Sea in May 2018 (IESNS).

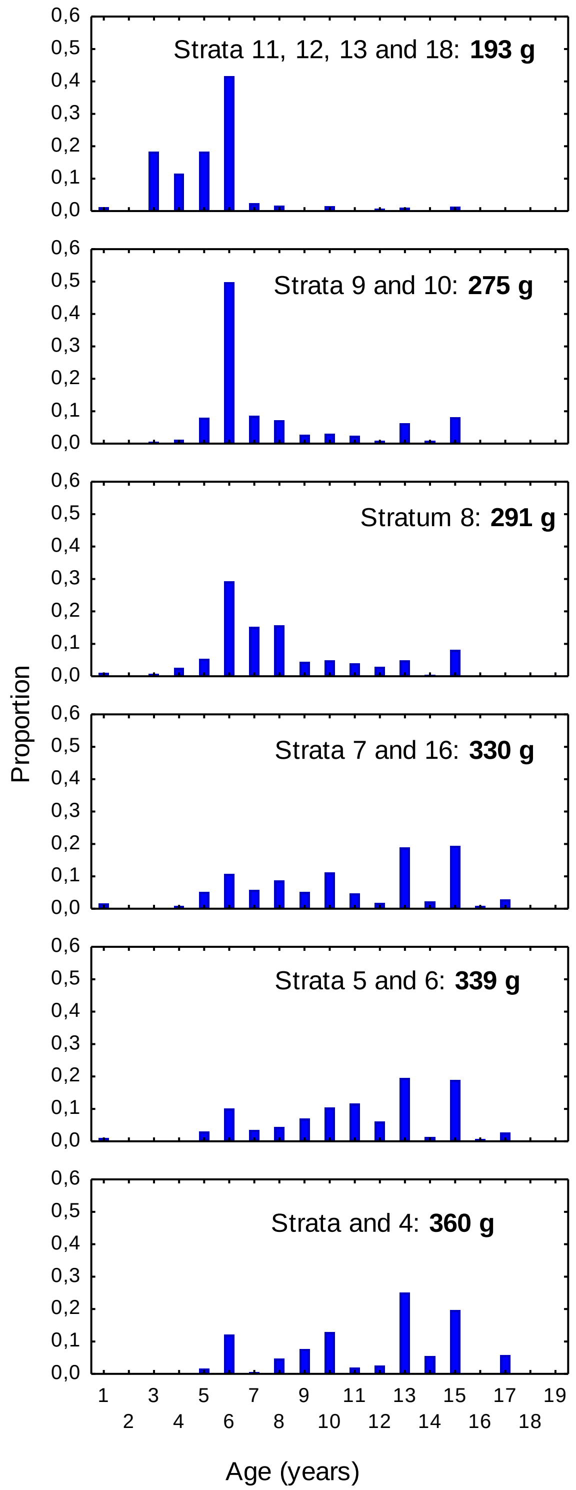

Figure 12. Comparison of age composition (%) and mean weight (bold) estimated in different strata covered during 13-25. February 2019. Se Figure 1 for spatial distribution of strata.

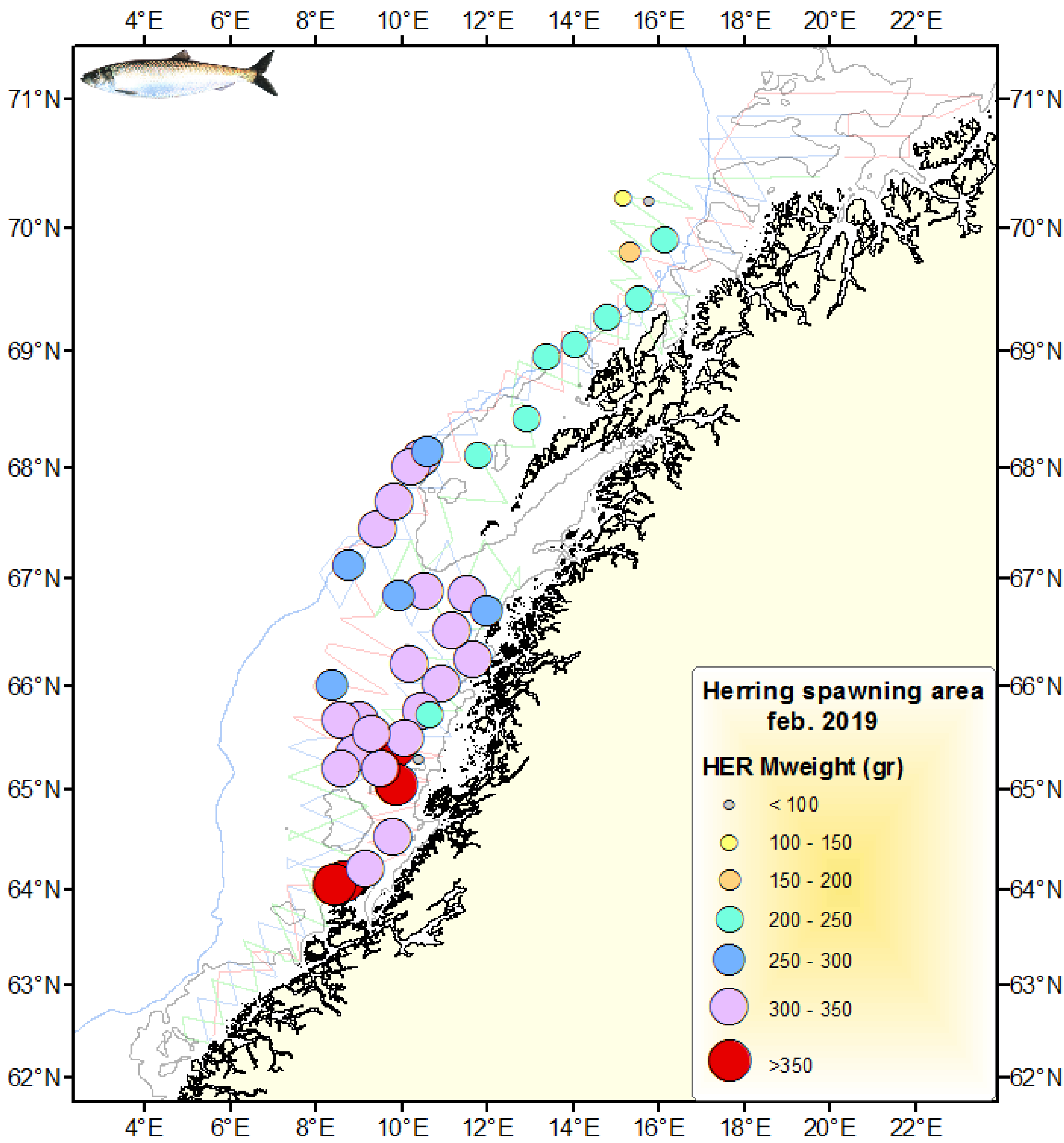

Figure 13. Spatial differences in mean herring weight (g) during the Norwegian spring-spawning herring survey13-25. February 2019.

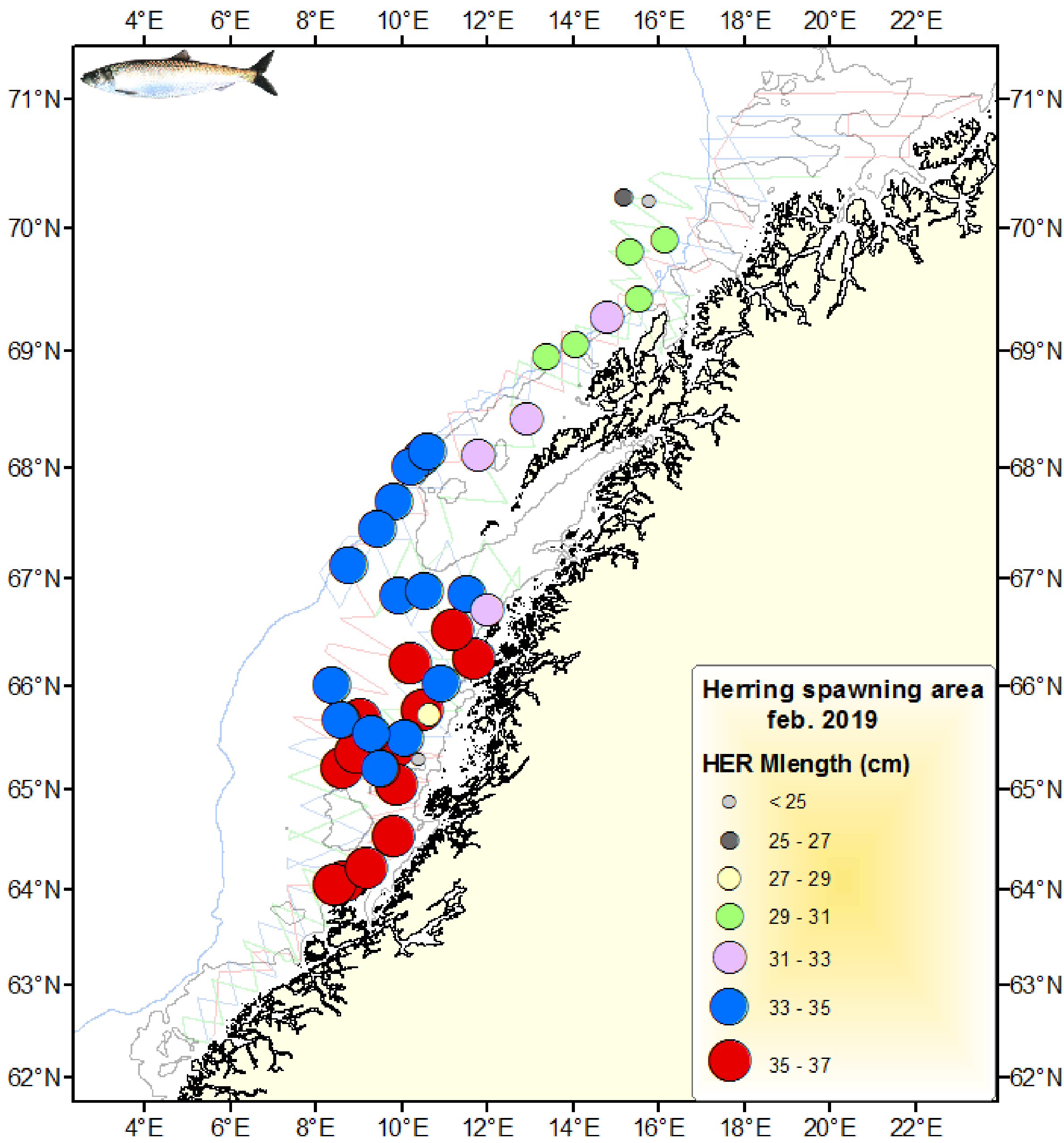

Figure 14. Spatial differences in mean herring body length (cm) during the Norwegian spring-spawning herring survey 13-25. February 2019.

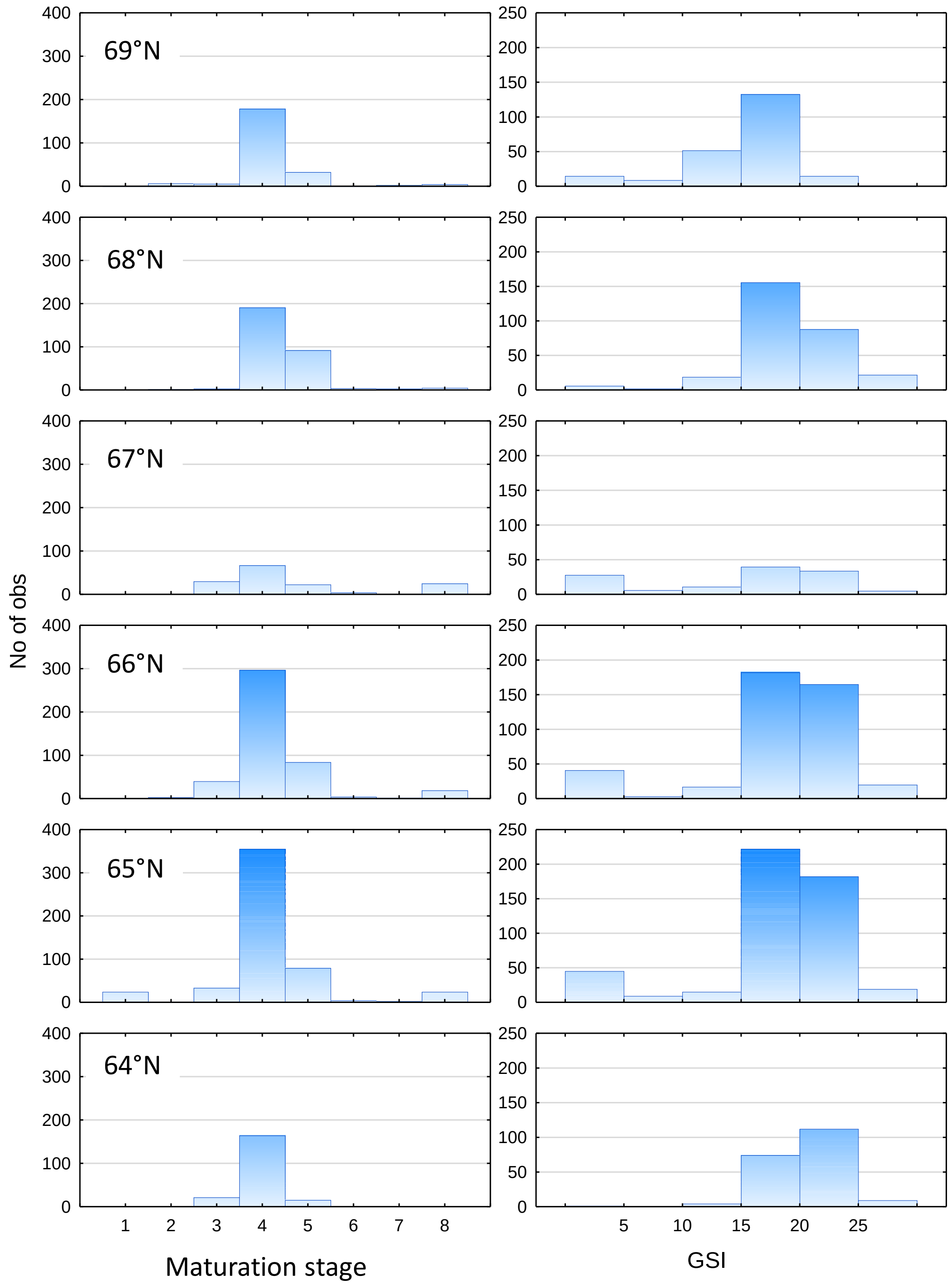

Figure 15. Latitudinal variation in maturation during the Norwegian spring-spawning herring survey13-25.February 2019. Data are not weighted by acoustics, simply frequency of fish analysed. Shown is maturation stage on a subjective scale, where 1-2= immature, 3=early maturing, 4=late maturing, 5=ripe, 6=spawning, 7=spent, 8=resting stages, as well as GSI (gonadosomatic index; % gonad weight relative to total weight).

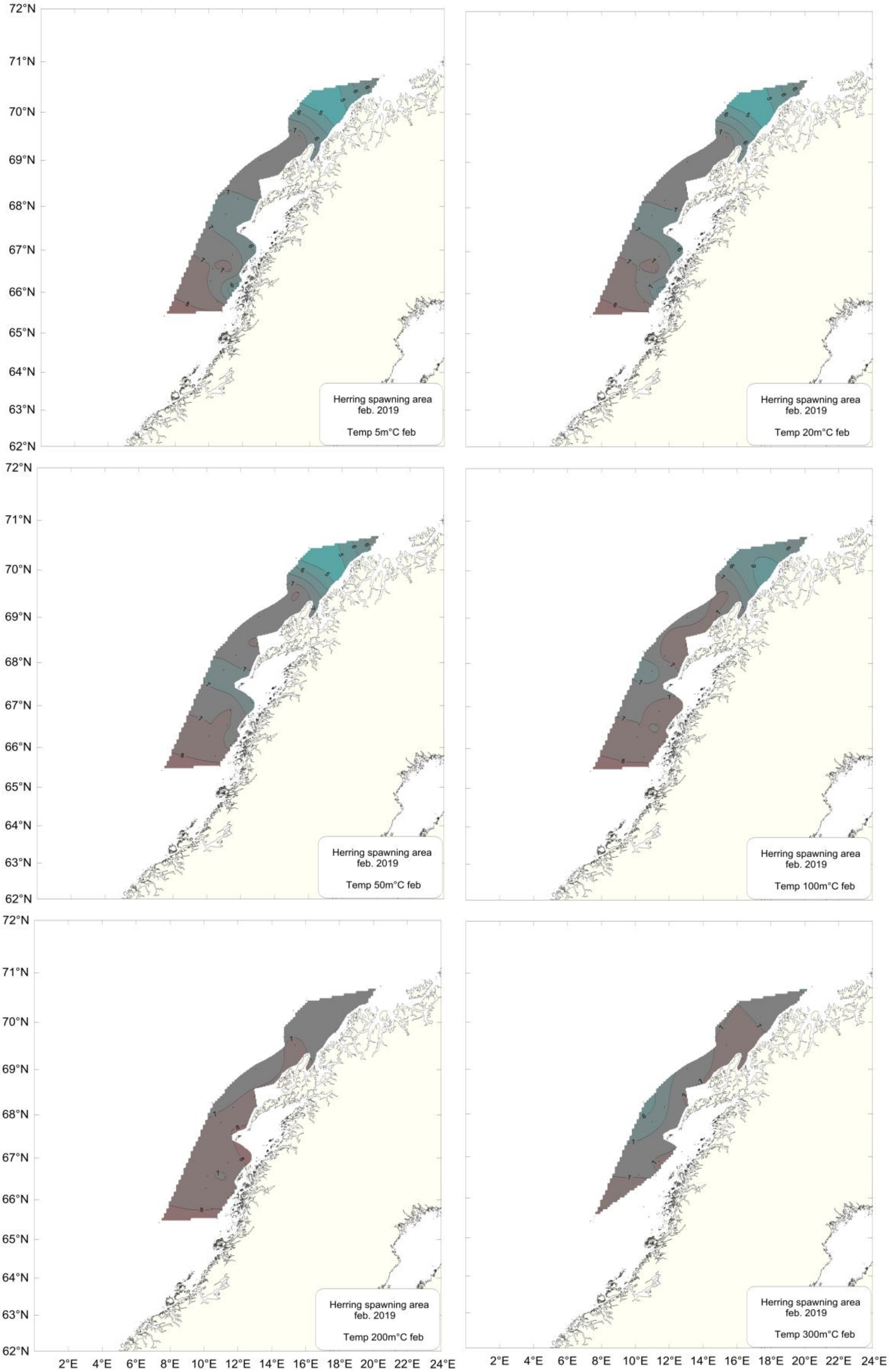

Figure 16. Temperature at 5, 20, 50, 100, 200, 300 m in the area covered during the Norwegian spring-spawning herring survey13-25. February 2019.

Annex 1. Calibration results and settings

Table 1. Calibration data and parameter settings of the five Simrad EK80 WBT's the five EK60 GPT split-beam echo sounders mounted on respectively on Kings Bay, Vendla and Eros as used during the survey. The new WC57.2 calibration sphere was as target for all frequencies when calibration at the fishery pier in Ålesund, with tabulated values for the sphere TS on EK60, and with the internally computed by the calibration program in EK80. An error in the calibration program of the EK80 at 18 and 38 kHz was discovered during the survey in 2017 and corrected for in postprocessing. The error was corrected in the EK80 software version 1.12.2. For the two other vessels, using Simrad EK60, the calibration data below was used, as measured in Aalesund February 13. 2018. The validity of the WC 57.2 calibration sphere against the CU60 was previously done on G.O.Sars in November 2018 with good results. The echo sounders calibration showed very good stability compared to 2017, while the 200 kHz transducer on Kings Bay was defect and not used.

MS Kings Bay, Simrad EK80					
Parameter	Survey data sample 20190213 02: Simrad EK80, narrow-band				
Transducer type	ES18	ES38B	ES70-7C	ES120-7C	ES200-7C
Transmission frequency [kHz]	18	38	70	120	200
Transmission power [W]	2000	2000	750	250	150
Pulse duration [ms]	1.024	1.024	1.024	1.024	1.024
TS Transducer Gain [dB]	23.04	23.9	27.77	26.91	Defect (not used)
Sa Correction (dB)	0.001	0.005	0.13	0.08	
Equivalent beam angle [dB]	-17.0	-20.7	-20.7	-20.7	-20.7
Absorption coefficient [dB km^{-1}]	2.9	10.1	20.9	31.8	52.15
Half power beam widths (along/athwart ship) [deg]	11.08/9.77	7.1/7.23	6.7/6.72	6.34/6.46	6.67/6.43
Transducer angle sensitivity (along ship and athwart ship)	15.5	23.0	23.0	23.0	23.0
Sound speed [m s^{-1}]	1475	1475	1475	1475	1474

M/S Vendla, Simrad EK60					
Parameter	Calibration 20190218 Simrad EK60, CW narrow-band				
Transducer type	ES18	ES38B	ES70-7C	ES120-7C	ES200-7C
Transmission frequency [kHz]	18	38	70	120	200
Transmission power [W]	2000	2000	750	250	120
Pulse duration [ms]	1.024	1.024	1.024	1.024	1.024
TS Transducer Gain [dB]	22.83	25.58	26.51	27.18	27.48
Sa Correction (dB)	-0.57	-0.66	-0.31	-0.32	-0.26
Equivalent beam angle [dB]	-17.0	-20.6	-20.7	-21.0	-20.7
Absorption coefficient [dB km^{-1}]	2.8	9.6	20.3	31.3	44.5
Half power beam widths (along/athwart ship) [deg]	10.61/10.88	7.15/7.04	6.61/6.59	6.44/6.56	6.27/6.21
Transducer angle sensitivity (along ship and athwart ship)	15.5	23.0	23.0	23.0	23.0
Sound speed [m s^{-1}]	1475	1475	1475	1475	1475

M/S EROS, Simrad EK60					
Parameter	Calibration 20180218, Simrad EK60, CW narrow-band				
Transducer type	ES18	ES38B	ES70-7C	ES120-7C	ES200-7C
Transmission frequency [kHz]	18	38	70	120	200
Transmission power [W]	2000	2000	375	150	90
Pulse duration [ms]	1.024	1.024	1.024	1.024	1.024
TS Transducer Gain [dB]	22.13	26.05	26.86	26.61	25.98
SaCorrection (dB)	-0.78	-0.66	-0.36	-0.31	-0.30
Equivalent beam angle [dB]	-17.0	-20.6	-20.7	-21.0	-20.7
Absorption coefficient [dB km^{-1}]	2.8	9.7	20.6	31.6	44.9
Half power beam widths (along/athwart ship) [deg]	10.98/10.80	7.04/6.90	6.61/6.60	6.46/6.51	6.41/6.22
Transducer angle sensitivity (along ship and athwart ship)	15.5	23.0	23.0	23.0	23.0
Sound speed [m s^{-1}]	1475	1475	1475	1475	1474

Annex 2. Sonar report

By Sindre Vatnehol

Purpose for using sonar

Fish in the echo sounder's blind zone and avoidance behaviour of fish, caused by the presence of the vessel, are often referred to as potential sources of bias when developing annual indices (Løland et al. 2007). Horizontally observing equipment, such as scientific and fisheries sonars, may have the potential to measure the presence and magnitude of these measurement biases and if these have changed between years/areas. Data from calibrated fisheries sonars have been collected from all participating vessels since 2015. Methods to quantify or evaluate the extend of these biases are presently being developed.

Sonar preparation:

The low-frequency sonars, either the Simrad SX90 or the Simrad SU90, were not calibrated as these have already been calibrated on other surveys. Given the considerable size of the data stream from 64 beams, all sonar data was stored directly to a 2TB external hard drive. Backup was daily made by IMR's personnel on each vessel.

We used the same sonar setting that has been used since 2015.

- The horizontal beam fan was slightly tilted to 8 degree below the horizon (Horizontal mode)
- For vertical mode, the fan of beams was set to observe perpendicular to the vessel's heading direction.
- Frequency of 30 kHz
- Range of 600 meter
- Noise-filter was switched off as this filter corrupts the data.

Visual interpretation of the data

Methods for evaluating the extension of the biases are still being developed; hence, no temporarily estimates will be presented here. However, some remarks of what was observed is made.

For most of the transects, most of the fish were observed by the echo-sounder to be close to the seabed, hence not within the sonar detection volume.

In the northern strata the fish was distributed closer to the sea surface and was thus also recorded by the sonar. Some of these registrations originated from relatively young herring.

References:

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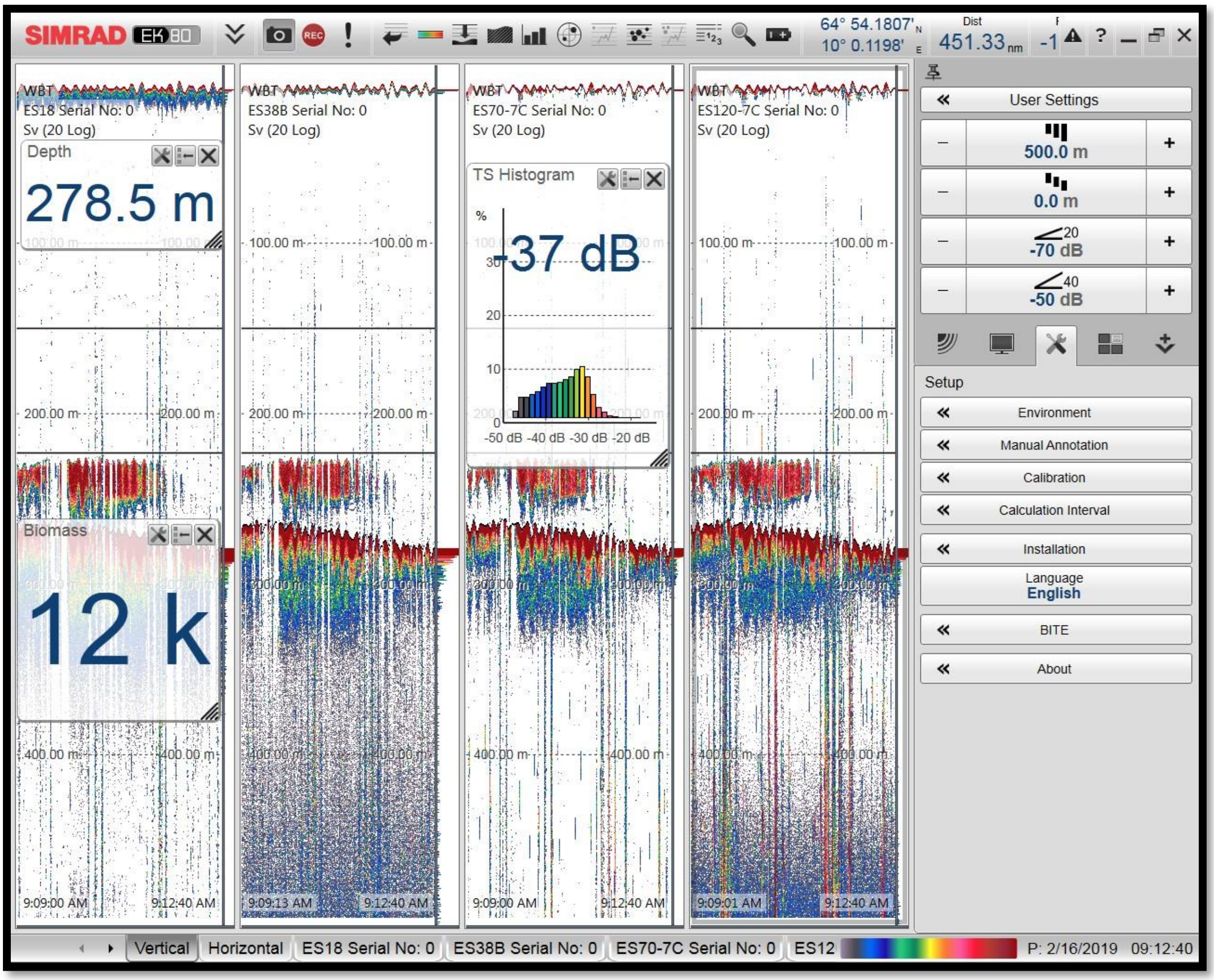
Løland, Anders, Magne Aldrin, Egil Ona, Vidar Hjellvik, and Jens Christian Holst. 2007. "Estimating and Decomposing Total Uncertainty for Survey-Based Abundance Estimates of Norwegian Spring-Spawning Herring." *ICES Journal of Marine Science* 64 (7): 1302–12. doi:10.1093/icesjms/fsm116.

Annex 3. Corrections for air bubble attenuation on keel-mounted echo sounders

By
Egil Ona IMR



Air bubble sound attention in fisheries acoustic surveys is a well-known problem (Urick, 1967: Dalen and Hovem, 1981), while the main portion of the problem was solved by mounting transducers on a drop keel (Ona & Traynor, 1990), extending up to 3 meters below the hull of the vessel. In very strong wind and wave conditions, however, also bubble attenuation may occur on keel mounted systems. The three fishing vessels used in the survey had nearly identical echo sounder equipment during the survey, with very similar ship design and transducer mountings, all on drop keels.

Several Simrad split beam transducer were mounted in a close packing arrangement (Fig 1.), and all vessels were using the keel in maximum extension, 2.85 m outside the vessel hull. The transducers where was installed with a draft of 8.5 meters, making a large difference in attenuation compared to hull mounted systems (see Novarani & Bruno 1982).

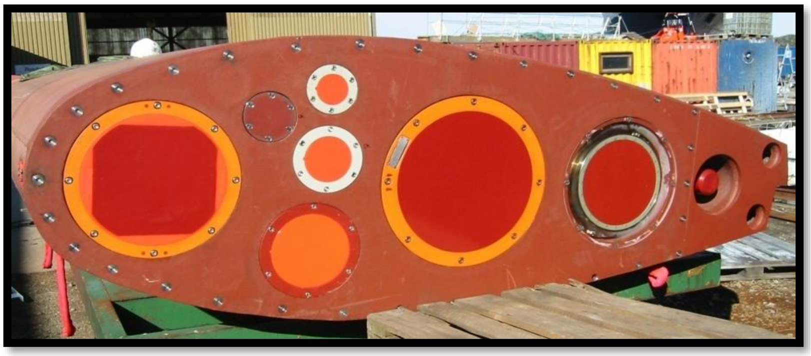


Figure 1. Drop keel system of the fishing vessels used. (Example)

In very bad weather, especially with little or no herring registrations in the survey area, we adopted a procedure for air bubble attenuation like the one suggested for 38 kHz by Shabangu et al, (2014), using F/F Kings Bay as the reference vessel. Integrated backscattering from the air bubble layer in front of the transducer was used as an index for air bubble attenuation, which previously have been found to be a good proxy, and well correlated with the air bubble attenuation (Ona, 1991; Ona & Traynor 1990). A permanent integrator layer from 5 m in front of the transducer, well out of the transducer ringing zone, and outside the transducer near field, to about 25 meters were used as a scaling factor. Two factors are then estimated and corrected for;

1. Constant and variable air bubble layers brought down with wind, waves and vessel
2. Lost transmission power, blocking, or reception, appearing as or “white” pings in the echogram.

Earlier investigations have used either the number of lost pings as a proxy, or the frequency of “bad” or weak bottom echo returns.

If the post processing system are reporting these, or are systematically removing pings with blocking, like the IMR ND10 integrator, used before 1990, (See Blindheim et al., 1981; Ona & Mamylov 1988), the correction factors for air bubble attenuation will be lower, then needing to only correct for the air bubble layer itself. The comparison to the Soviet echo integrator system revealed this difference in the 1970-1990 cooperative Barents Sea surveys. Modern echo integrators, like LSSS and others, does presently not measure the fraction of weak or lost pings, and this correction may therefore be of the same order as for the air bubble attenuation alone.

The magnitude of this dropouts has been tried estimated with special experiments where the vessel first is going into the waves, measuring dropouts, and then turning with the wind and measuring the difference in backscattering of the bottom echo. Monitoring of the vessel heave, pitch and roll were also conducted during these experiments.

Especially vessel pitch, where the bulb of the vessel is pulled out of the water, and then knocked down through the waves again, seemed to cause deep air bubble clouds, as earlier documented with camera on the drop keel of G.O.Sars by Knudsen (2012).

Comparative measurements against the backscattering from the bottom echo over some nautical miles with and without air bubble attenuation will then give estimates for the total attenuation, or data for establishing a correction factor, just like applied in a more sophisticated comparative manner with two multiplexed transducers in Shabangu et al, (2014). On two transects in the present survey, F/F Kings Bay sailed first against the wind and waves, and then returned on the same transect with the wind and waves, with practically no air bubble attenuation. Data from these comparisons of the bottom echo backscattering, averaged over 1 nautical mile bins are shown in Figure 1. The wind speed was measured by the weather station onboard, and the vessel speed subtracted by the Olex system, giving real wind speed and direction. The wave height was not recoded scientifically, but visually estimated by the captain, while the vessel movement was logged to the echo sounder raw files for each ping.

In really bad weather conditions, at 30 – 35 ms^{-1} wind speed and 7-8 meter waves, the nautical area scattering coefficient, NASC, in the air bubble layer exceed 1000 m^2nmi^{-2}, and the backscattering from the bottom was 50% lower compared to the backscattering when sailing in opposite direction. Successive data on two transects were used to establish the curve, using the shape indicated in Shabangu et al. (2014), fitting the data to a y=c+ a*x^b relationship, nonlinear regression methods, yielding parameter estimates for c, a and b, with asymptotic estimates for the parameter standard deviations, and confidence intervals for the parameter estimates.

It is suggested that the correction factor is realized in a stepwise manner, like indicated in Fig.2

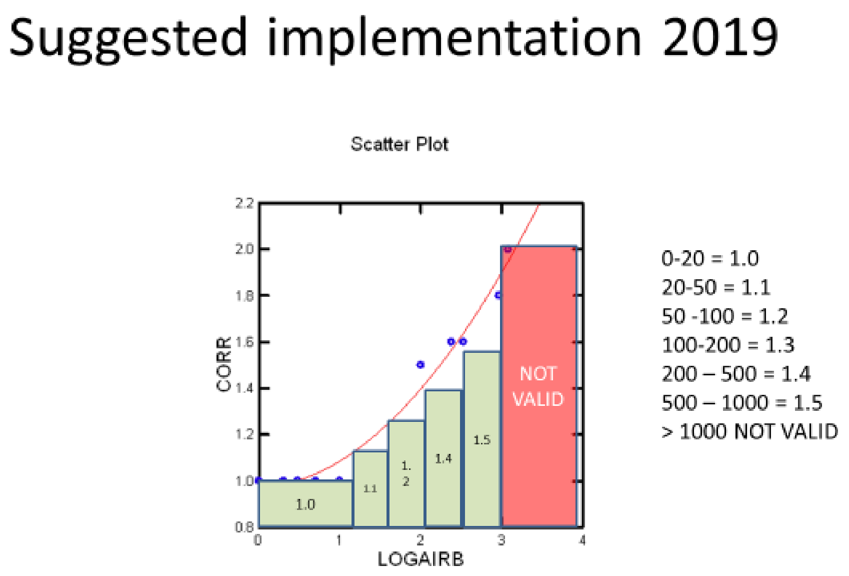


Figure 2. Suggested correction curve for air bubble attenuation during the herring survey February 2019, realized in stepwise manner, using Table to the right for the figure.

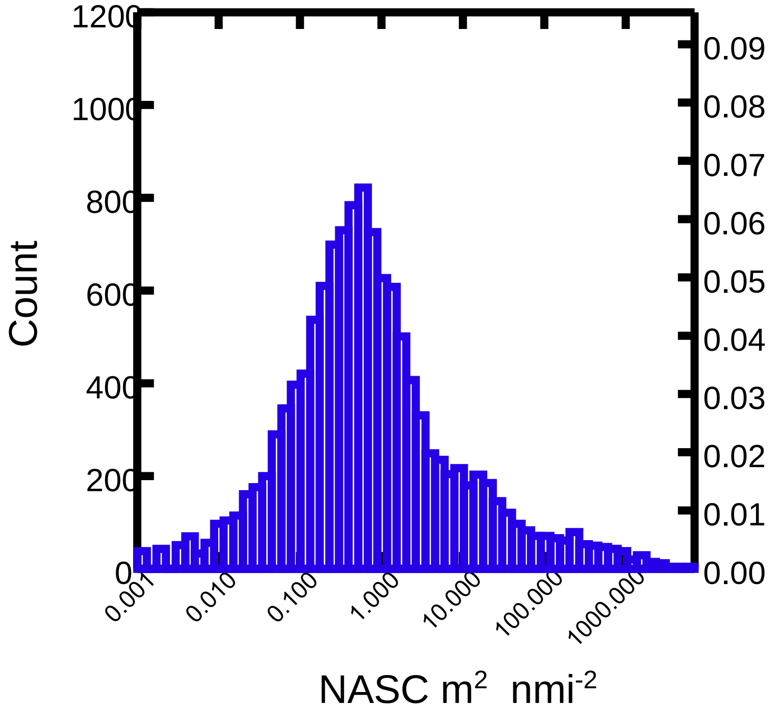
Procedure during interpretations.

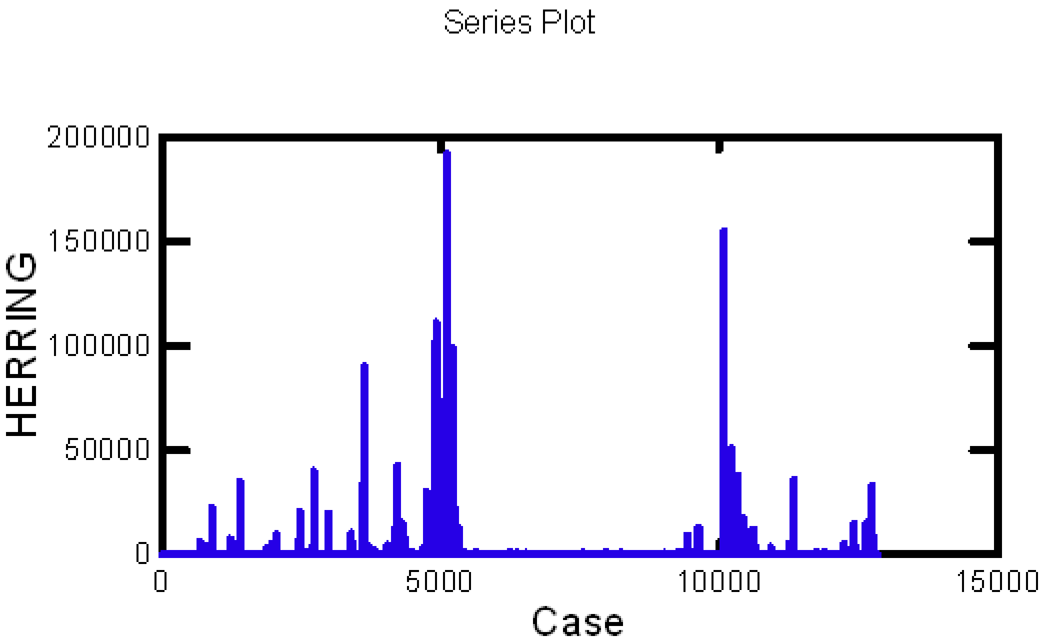
1. Estimate the indicator for air bubble attenuation = Mean NASC for layer 5 – 25 meters, being sure that no pings from transmit pulse goes into the layer.
2. Scrutinize like normal, isolating herring aggregations on echogram and allocate the NASC to herring.

3. Move the air bubble correction button for the whole 5 nmi section to for example 1.2 if you want to correct the entire file, and pull the allocation percentage to full scale 120%, which now is possible.
4. Similarly, if you will correct only for LOST PINGS:
    a. Evaluate the % of lost pings visually, by inspecting the integrator line, and then evaluate how much of the concentration which have been lost by lost pings.
    b. Use the MAXUMUM ALLOCATION BUTTON under the air bubble correction factor button in the interpretation window, and scale the NASC to the correct value, for example 20% = 1.2, WHEN YOU NOW CAN ALLOCATE MORE THAN 100% OF THE MEASURED VALUE.
5. In the case of lost pings, at least for Kings Bay, there is sometimes one single noise stripe, following one or several lost pings. This noise probably comes from the propeller cavitation when the propeller lose pressure when the bow is going down into a wave.
6. The backscattering from this noise stripes sometimes compensates for the lost pings, and less correction may then be given. Detailed inspection of this phenomena may be studies in the data but was not prioritized here. The correlation between wind speed, heave, roll and especially pitch and this phenomenon was, however clear.

The accuracy of the correction is evaluated to be ± 10% when using corrections below 1.5, and the most applied correction in the start of the survey with low densities of herring was 1.1 and 1.2. Even if the weather was quite rough in the start of the survey, the extra uncertainty will disappear in the total uncertainty, as relatively low fraction of the data is corrected for air bubble attenuation. The probability density function for measured NASC for the observations made before February 22 is shown in Fig. 3.

Figure 3. Air bubble NASC in the upper layer from 5 to 25 m for the survey between 13. February and 22 February, using ESU of 0.1 nmi. The data where air bubble attenuation was applied is from 10 to 1000 in this figure. As apparent, only a fraction of the data has been corrected.





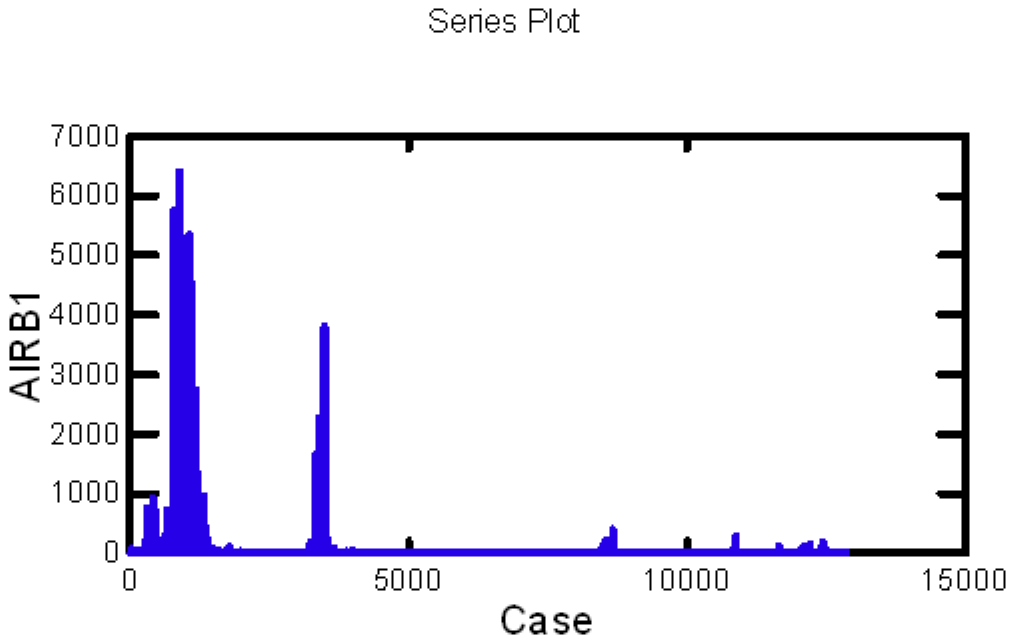


Figure 4. Time series plots of HERRING NASC (upper) and AIRB NASC, showing that it was in the start of the survey, with low Herring backscattering that the bubble attenuation was large, and therefore have insignificant effect on the survey results.

Egil Ona
Kings Bay 23.02 2019

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Annex 4. TS measurements

As in the 2016, 2017, and 2018 special investigations were made from MS Kings Bay in order to investigate the mean target strength, TS, of herring during the spawning migration. At two locations, detailed TS measurements was collected from the vessel transducers, by resetting the echo sounder to ping at 5 Hz to 100 meters without bottom detectors. (see echogram).

At one location, a Simrad WBAT, portable EK80 using a 38 khz and a 70 Khz split beam transducer were lowered into a layer of spawning herring at about 50 to 100 m depth, transmitting alternate series of 100 pings at each frequency at high PRF over two hours. The WBAT system was hanging from a surface buoy with positional devices and was left on drift by the vessel. Trawling and surveying the layer was conducted at 2-4 nautical miles distance from the buoy until the measurement were finalized. Results from these TS measurements will be analyzed on a later stage and is not included in the report. The idea behind these investigations is that a new depth dependent TS will be developed and used to re-estimate all years of this survey. This will be a more realistic TS and the depth term is also expected to remove potential bias related to variable depth distribution of the herring. The WBAT system was calibrated in Tromsø February 24, 2019.

Fig 1. WBAT system lowered into schools

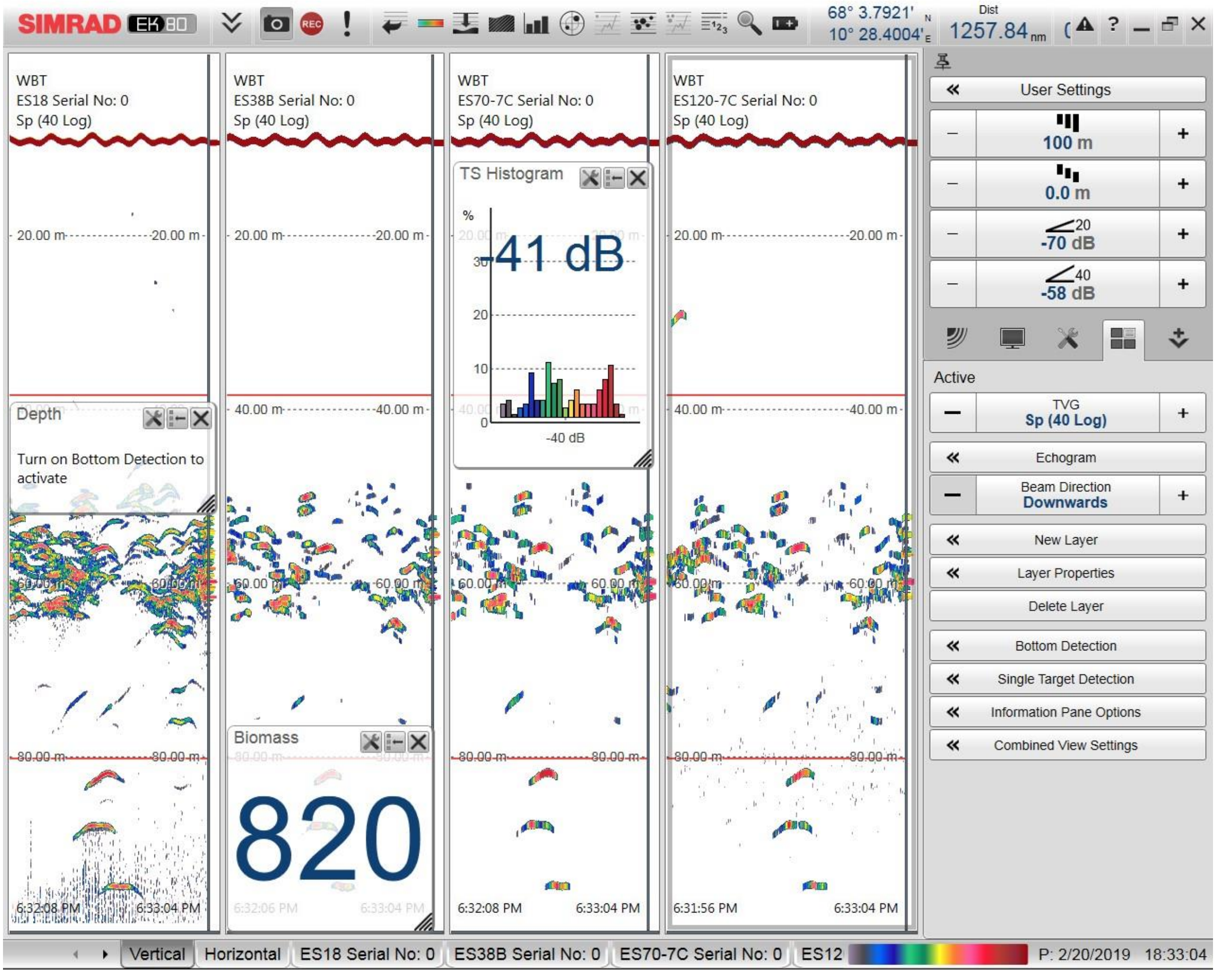
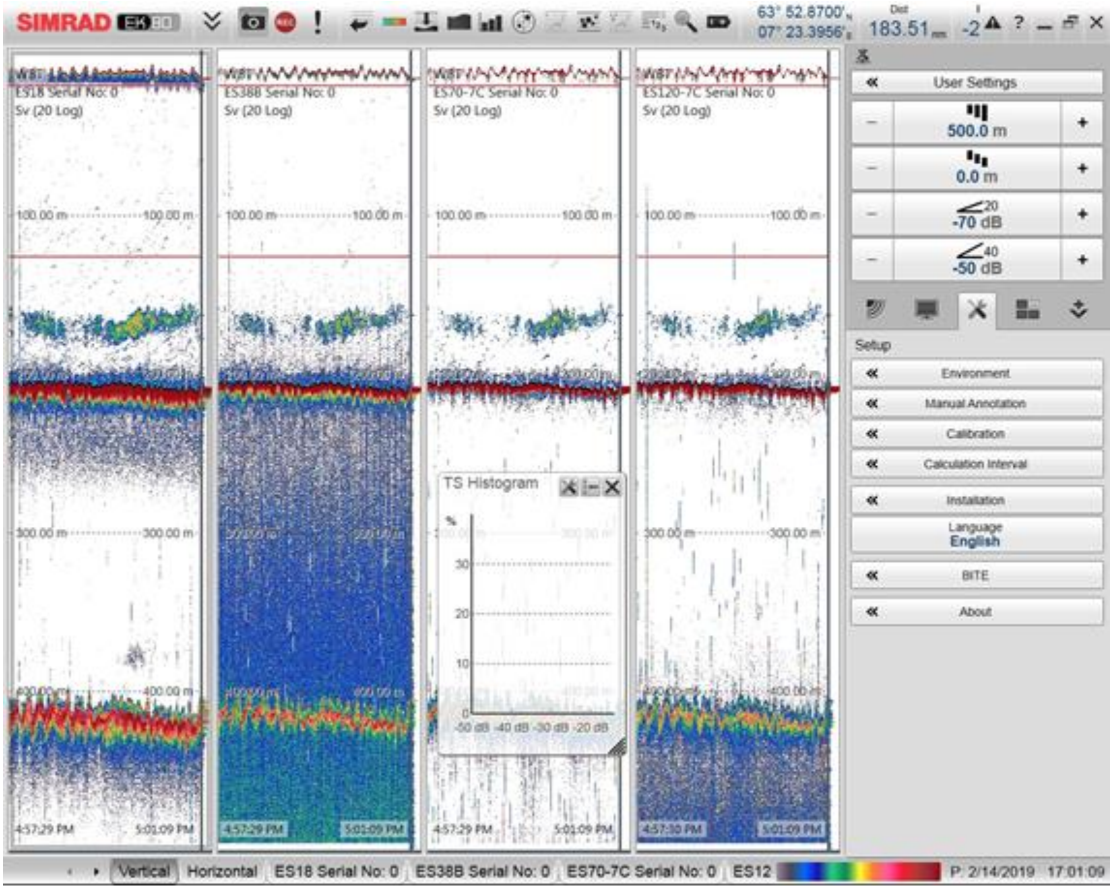
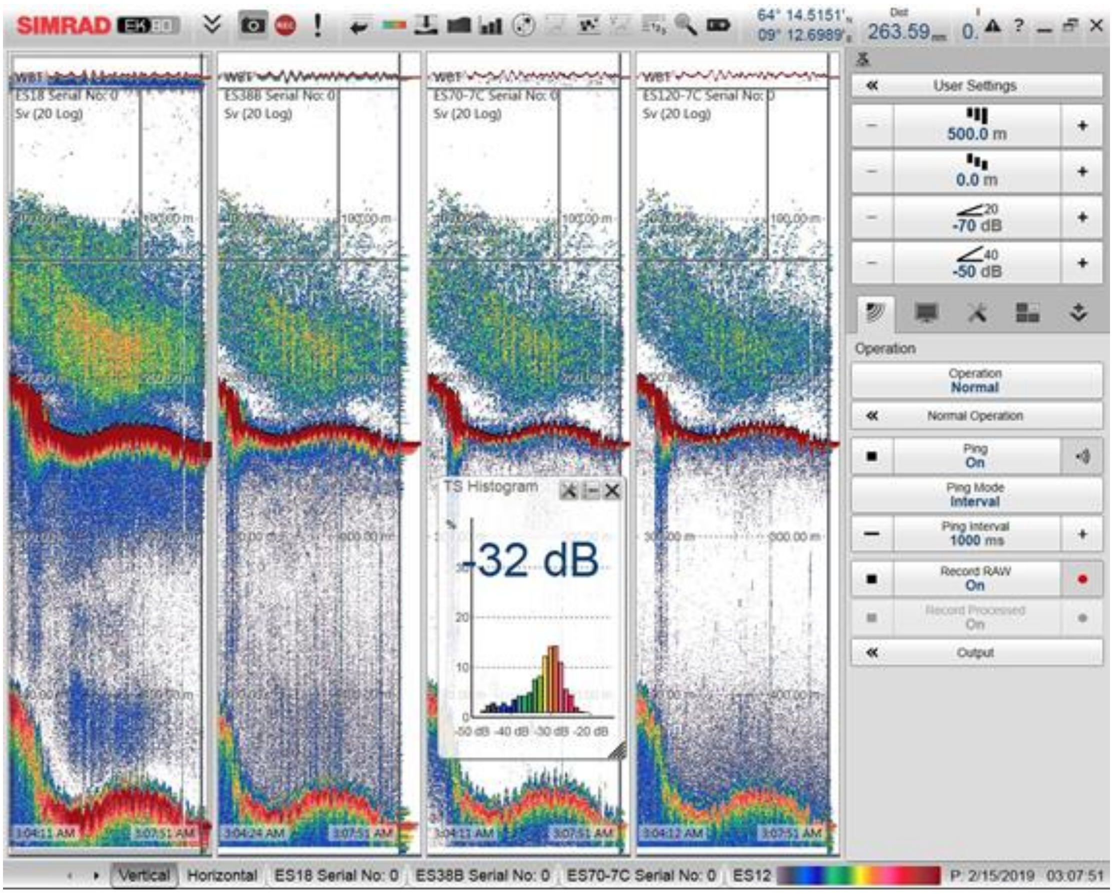
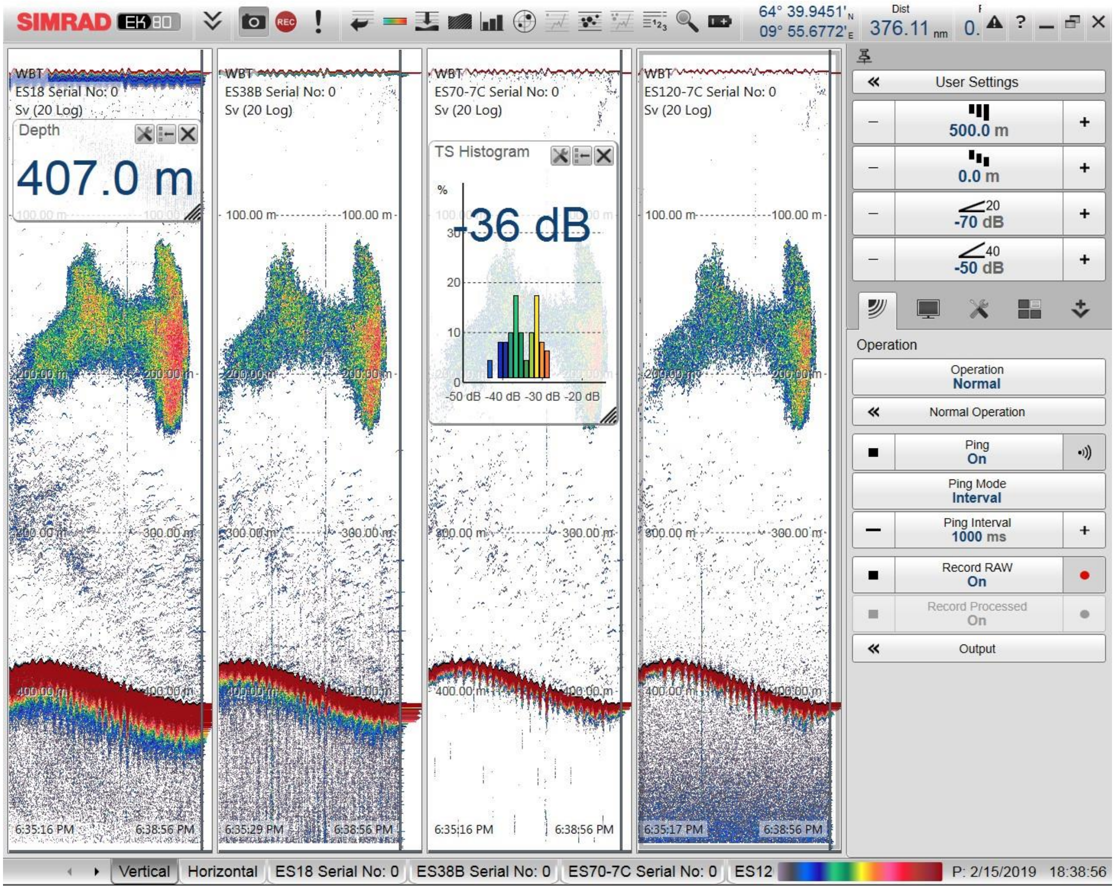


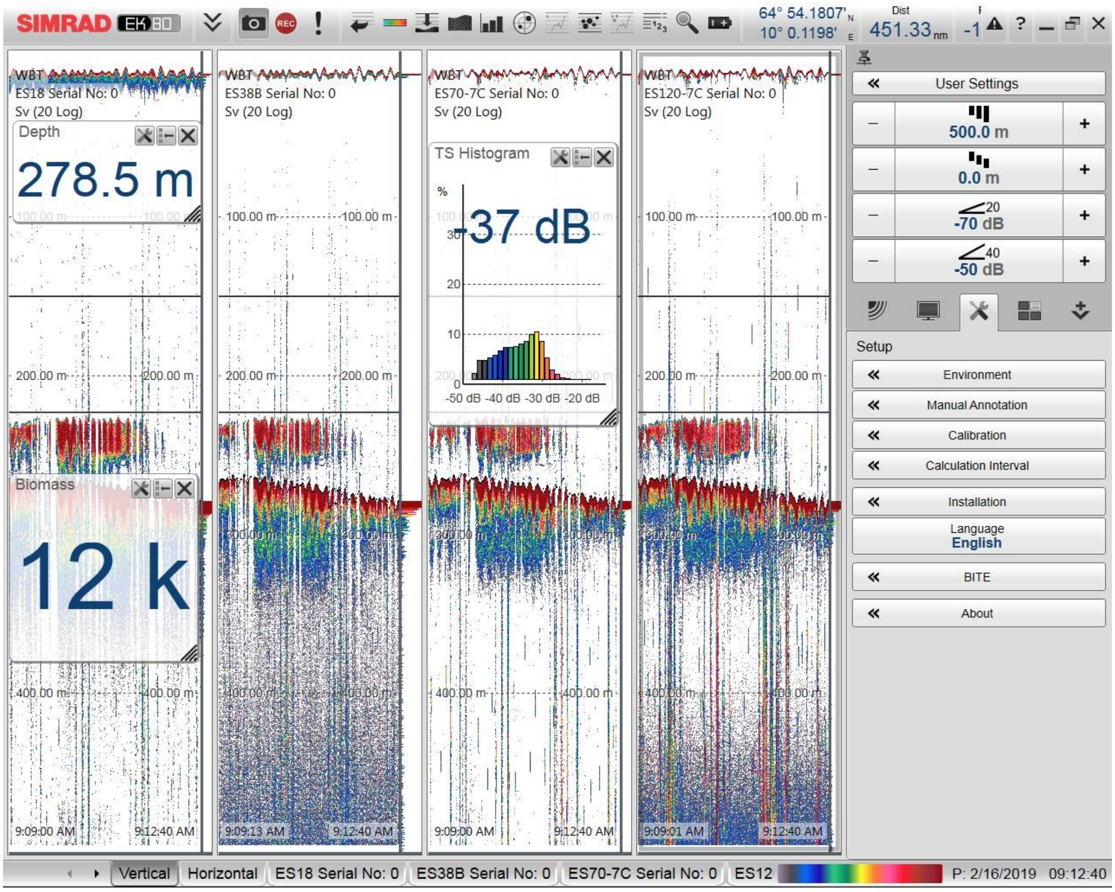
Fig. 2 TS measurements from vessel at 18, 38, 70 and 120 kHz

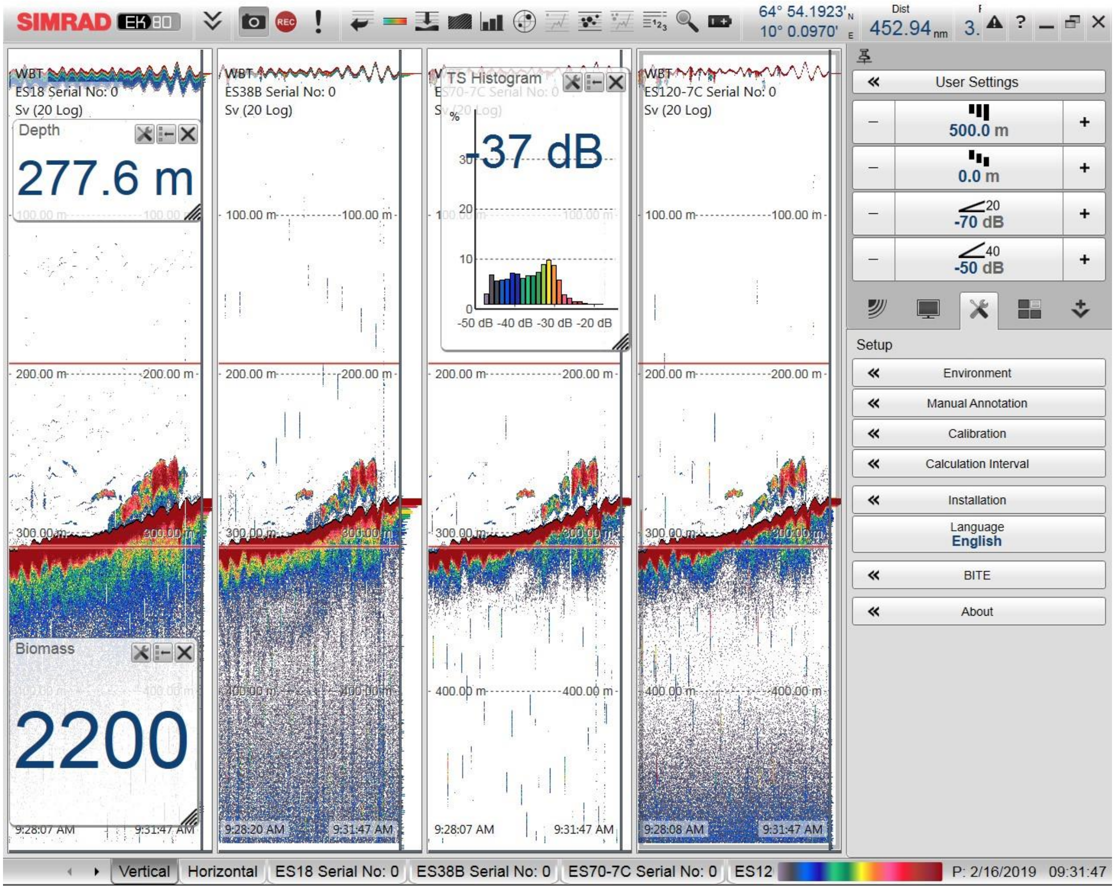
Annex 5. Examples of acoustic registrations with EK80 at Kings Bay

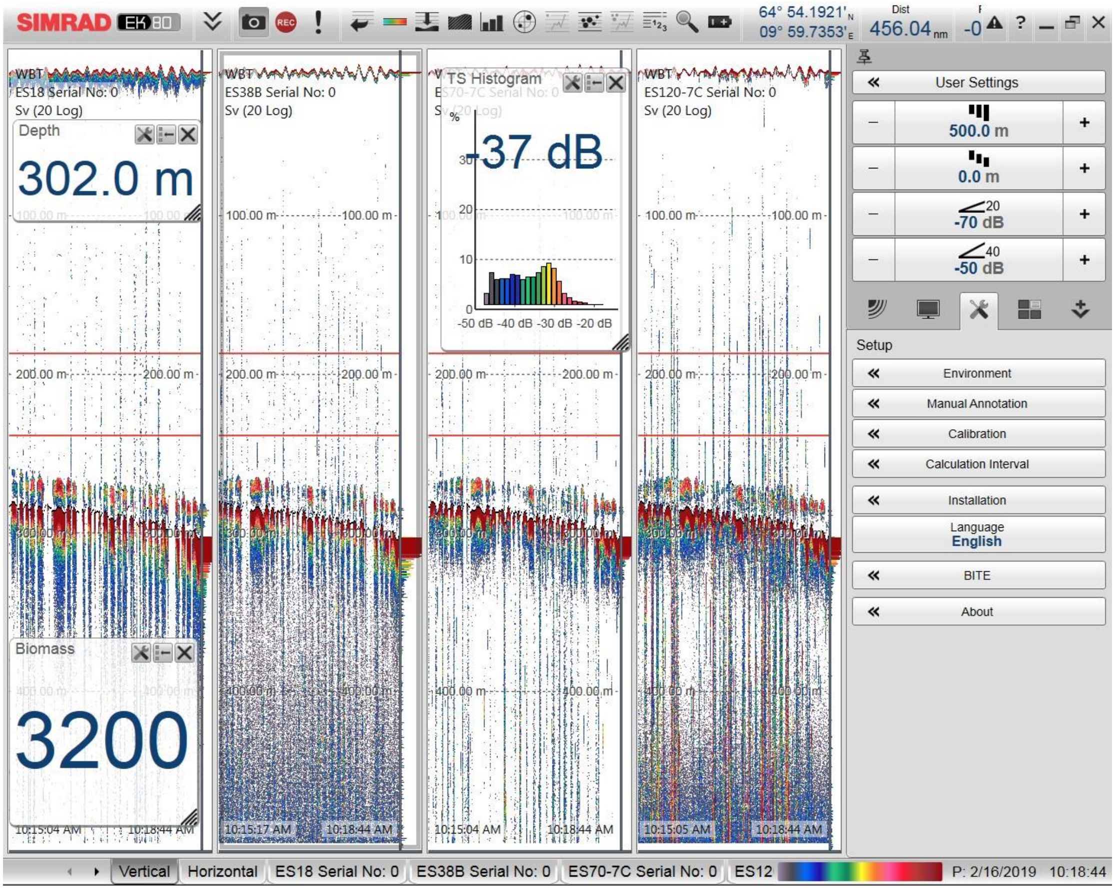


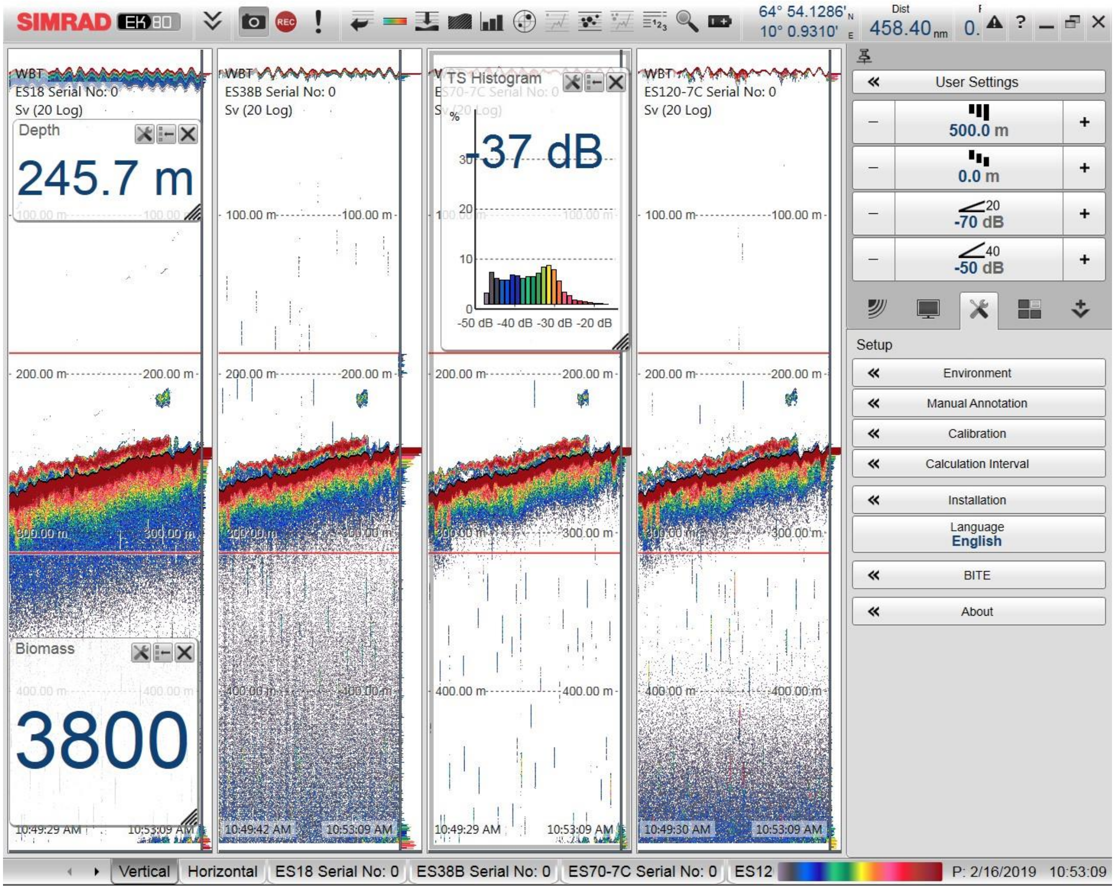


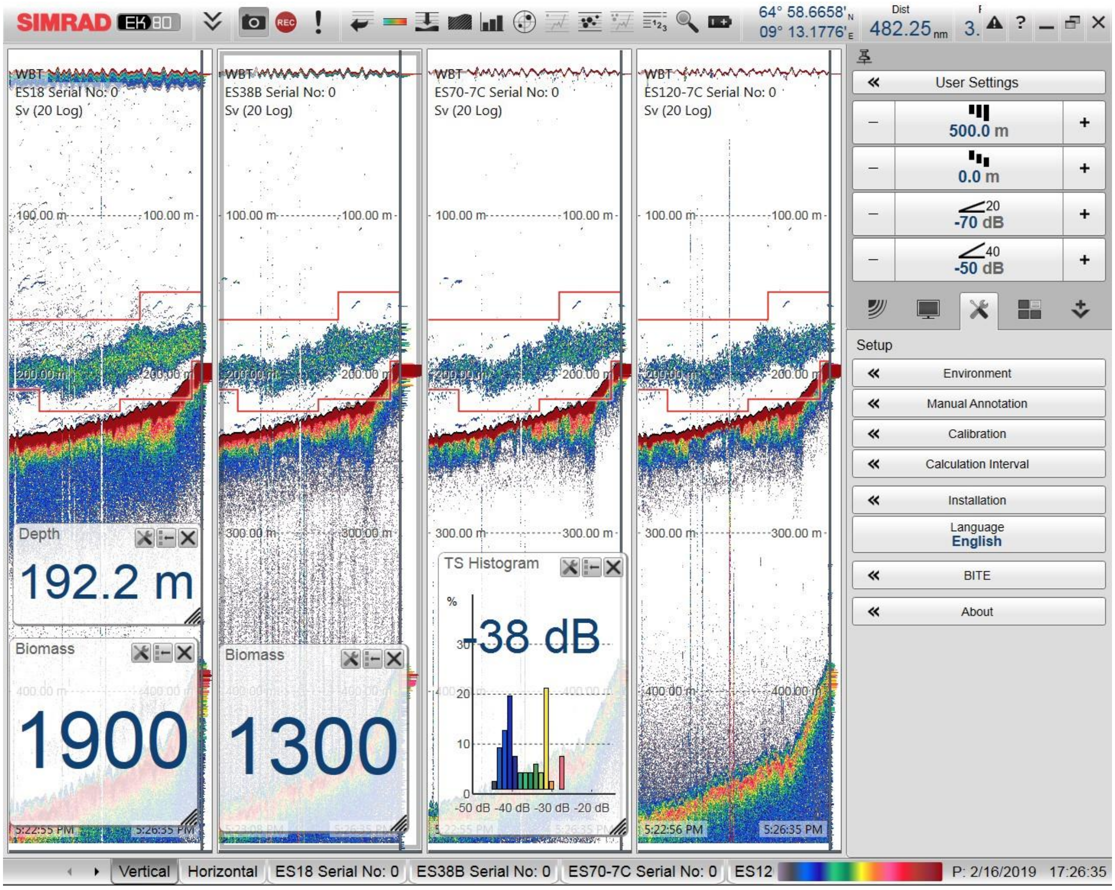

SIMRAD EK80
64° 39.9451' N
09° 55.6772' E
Dist
376.11 nm
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1000 ms
Record RAW On
Record Processed On
Output
ES18 Serial No: 0
Sv (20 Log)
Depth
407.0 m
ES38B Serial No: 0
ES70-7C Serial No: 0
TS Histogram
-36 dB
ES120-7C Serial No: 0
Vertical
Horizontal
P: 2/15/2019 18:38:56

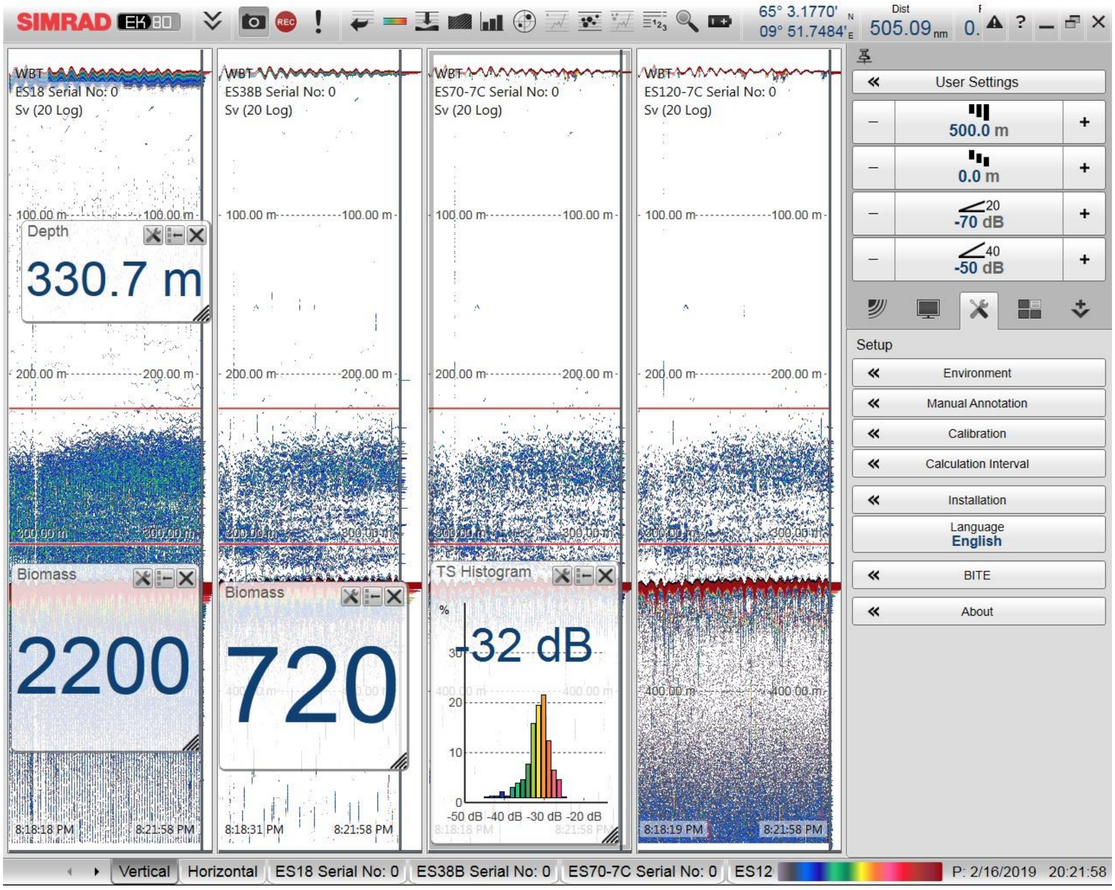

SIMRAD EK80
64° 54.1807' N
10° 0.1198' E
Dist
451.33 nm
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language English
BITE
About
ES18 Serial No: 0
Sv (20 Log)
Depth
278.5 m
Biomass
12 k
ES38B Serial No: 0
ES70-7C Serial No: 0
TS Histogram
-37 dB
ES120-7C Serial No: 0
Vertical
Horizontal
P: 2/16/2019 09:12:40

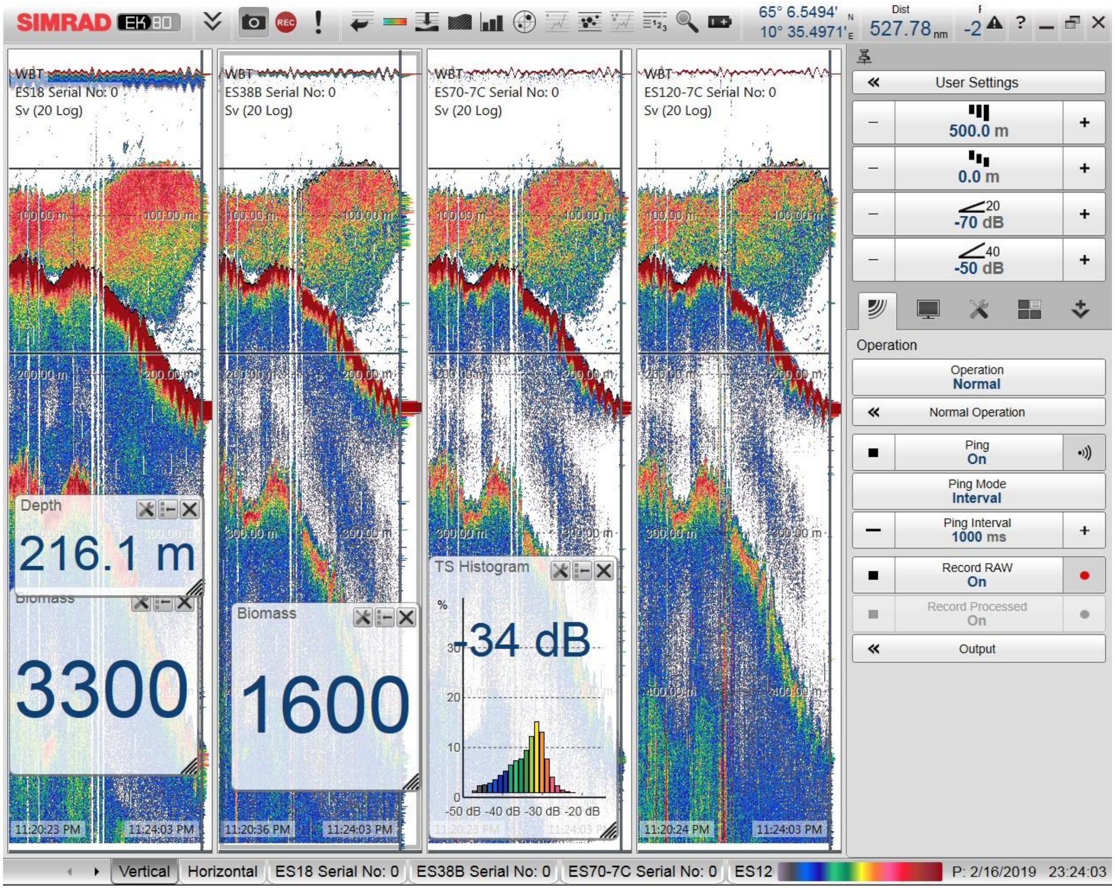

SIMRAD EK80
64° 54.1923' N
10° 0.0970' E
Dist
452.94 nm
ES18 Serial No: 0
Sv (20 Log)
Depth
277.6 m
ES38B Serial No: 0
Sv (20 Log)
TS Histogram
-37 dB
-50 dB -40 dB -30 dB -20 dB
ES120-7C Serial No: 0
Sv (20 Log)
Biomass
2200
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language
English
BITE
About
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
P: 2/16/2019 09:31:47

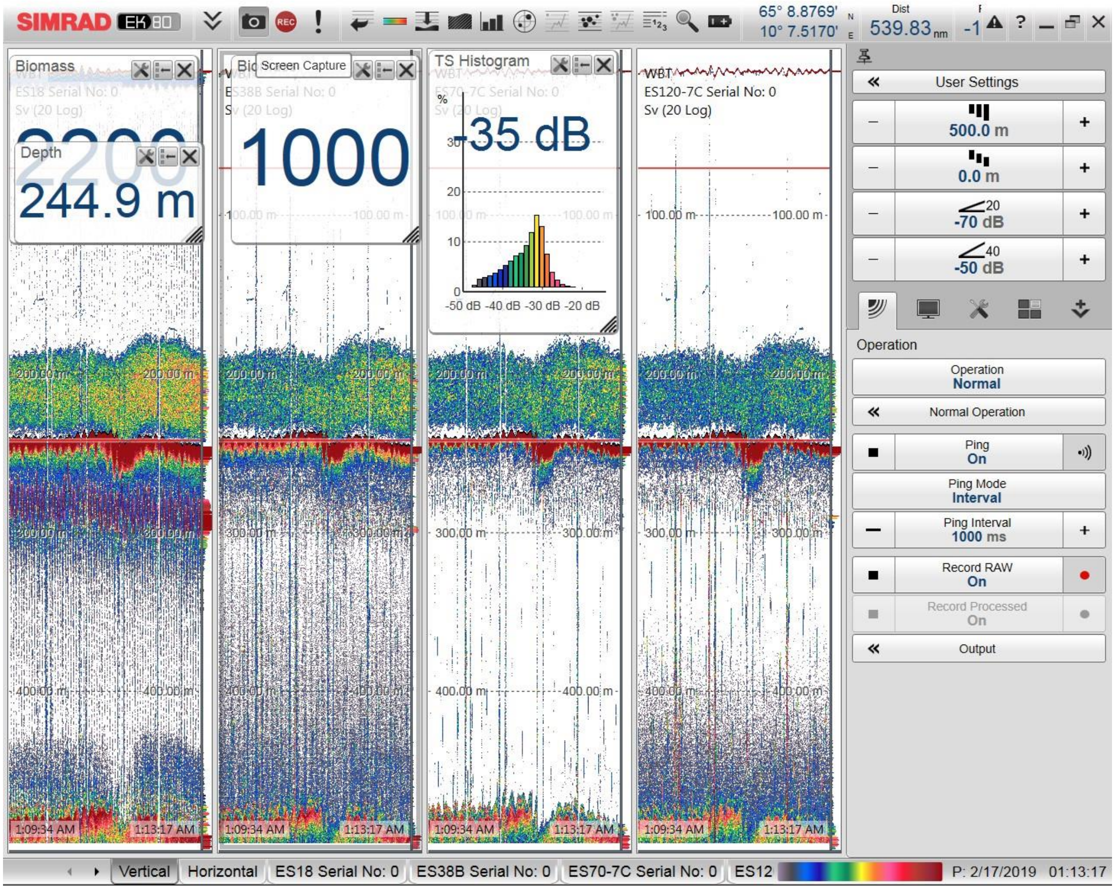

SIMRAD EK80
64° 54.1921' N
09° 59.7353' E
Dist
456.04 nm
ES18 Serial No: 0
Sv (20 Log)
Depth
302.0 m
ES38B Serial No: 0
Sv (20 Log)
TS Histogram
-37 dB
-50 dB -40 dB -30 dB -20 dB
ES120-7C Serial No: 0
Sv (20 Log)
Biomass
3200
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language
English
BITE
About
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
P: 2/16/2019 10:18:44

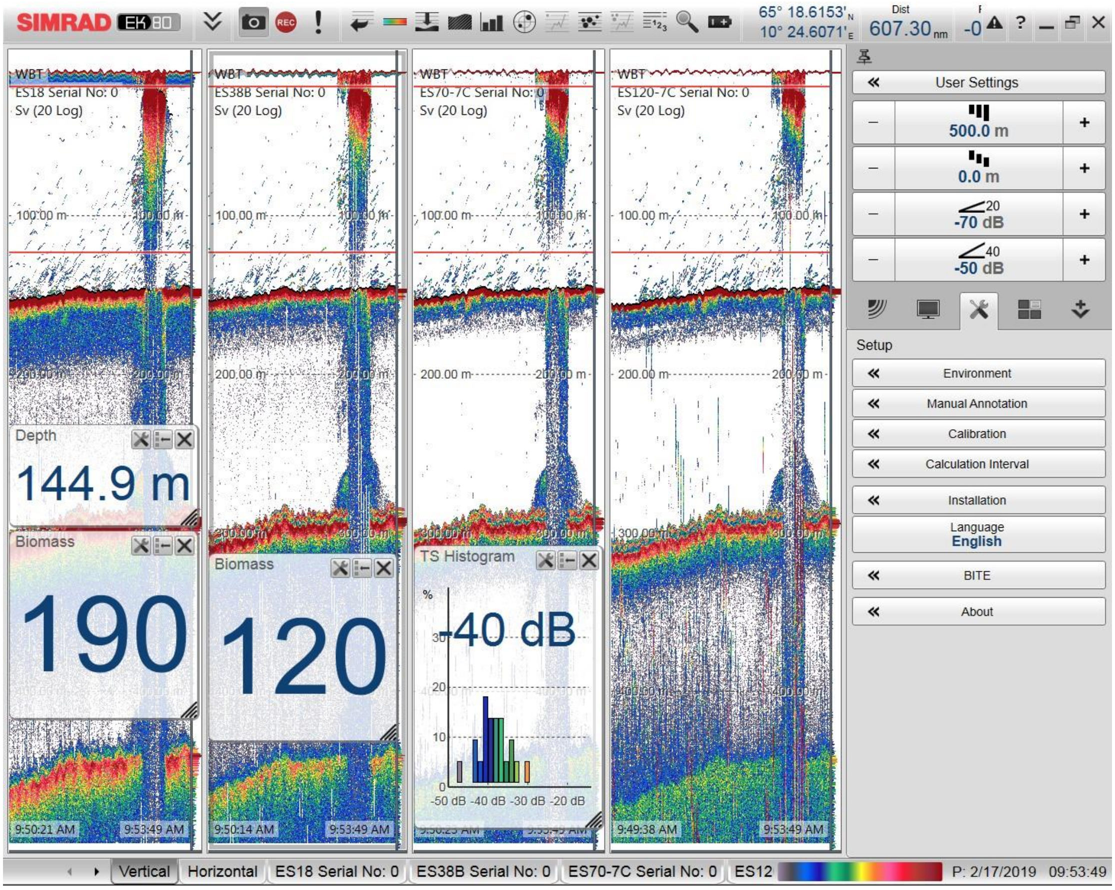

SIMRAD EK80
64° 54.1286' N
10° 0.9310' E
Dist
458.40 nm
WBT
ES18 Serial No: 0
Sv (20 Log)
Depth
245.7 m
ES38B Serial No: 0
TS Histogram
-37 dB
-50 dB -40 dB -30 dB -20 dB
ES120-7C Serial No: 0
Biomass
3800
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language
English
BITE
About
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
P: 2/16/2019 10:53:09

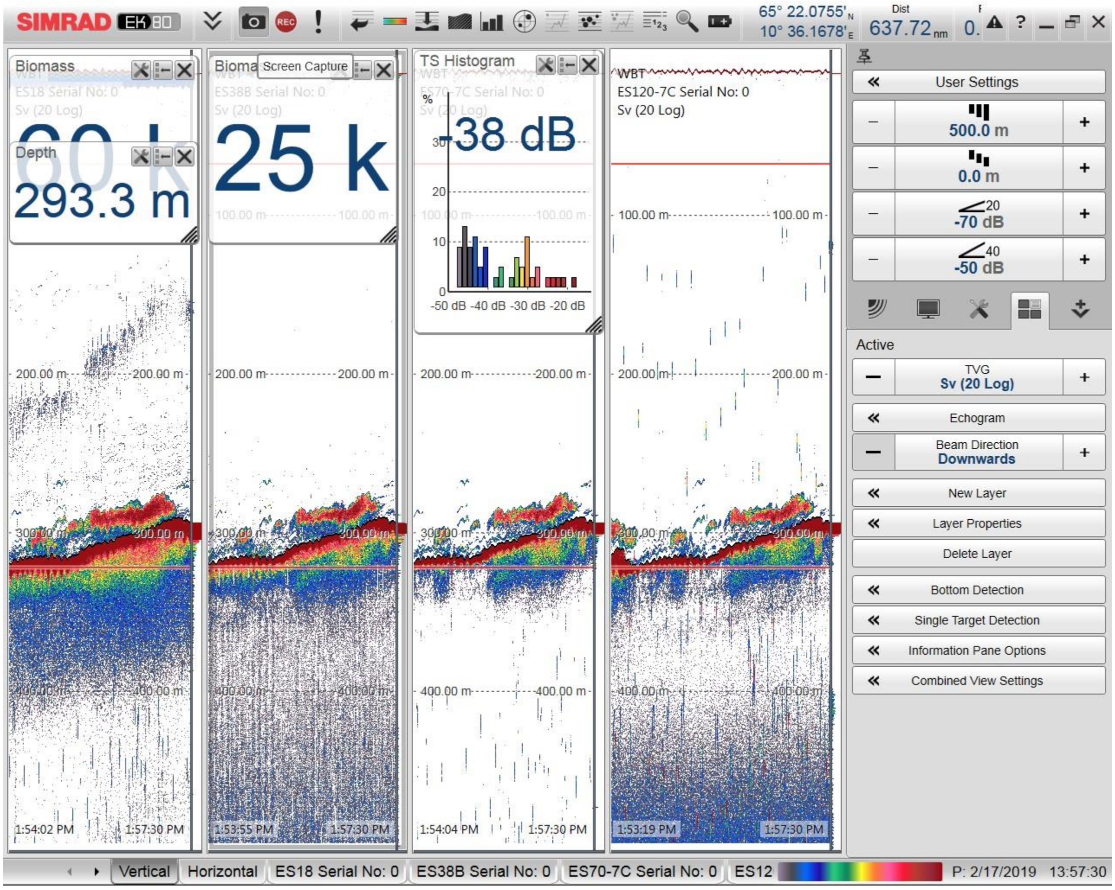

SIMRAD EK80
64° 58.6658' N
09° 13.1776' E
Dist
482.25 nm
WBT
ES18 Serial No: 0
Sv (20 Log)
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
Depth
192.2 m
TS Histogram
-38 dB
-50 dB -40 dB -30 dB -20 dB
Biomass
1900
1300
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language
English
BITE
About
Vertical
Horizontal
P: 2/16/2019 17:26:35

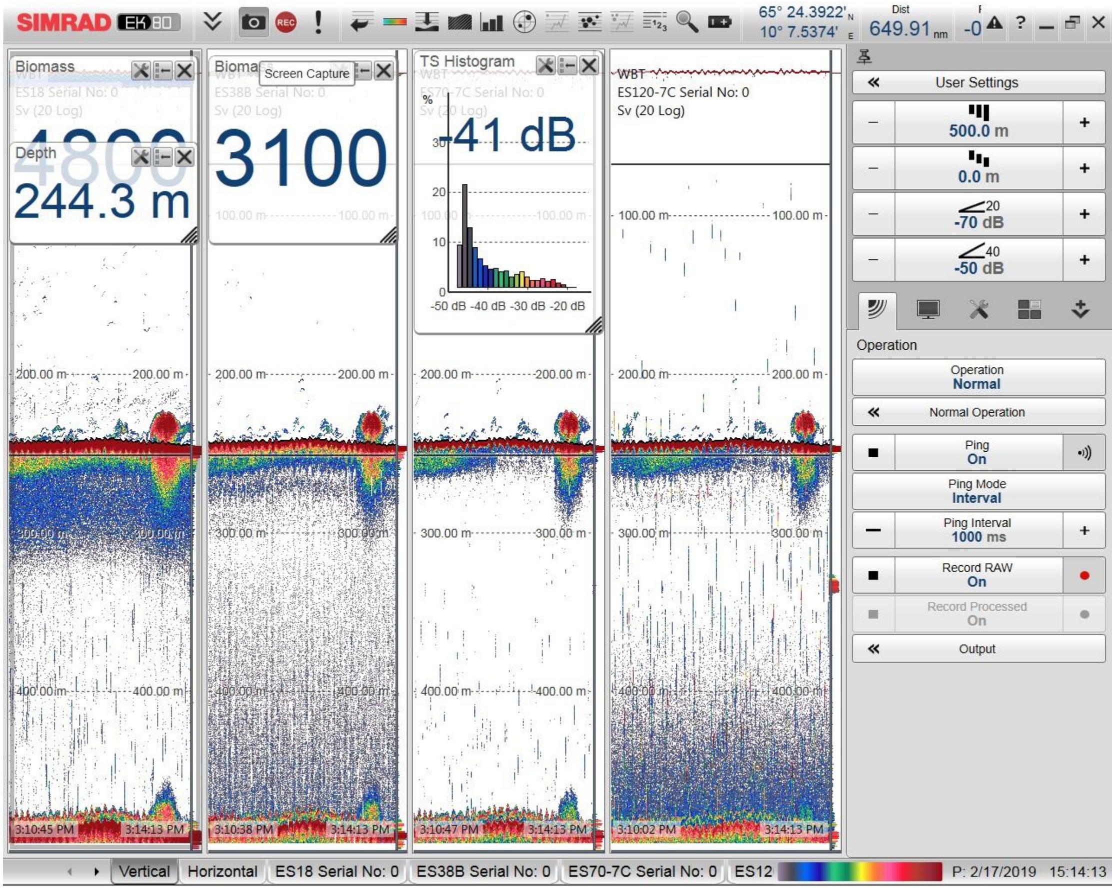

SIMRAD EK80
65° 3.1770' N
09° 51.7484' E
Dist
505.09 nm
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language
English
BITE
About
WBT
ES18 Serial No: 0
Sv (20 Log)
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
Depth
330.7 m
Biomass
2200
720
TS Histogram
-32 dB
-50 dB -40 dB -30 dB -20 dB
8:18:18 PM
8:21:58 PM
8:18:31 PM
8:18:19 PM
Vertical
Horizontal
P: 2/16/2019 20:21:58

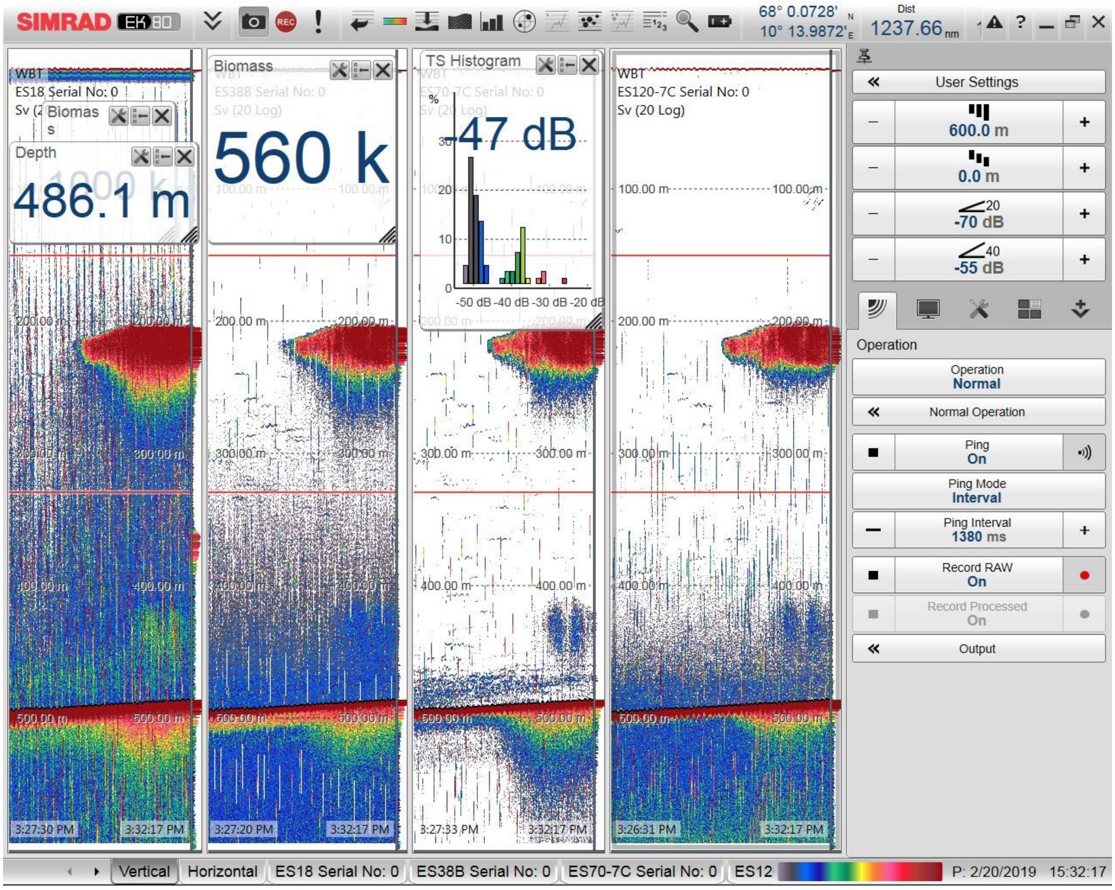

SIMRAD EK80
65° 6.5494' N
10° 35.4971' E
Dist
527.78 nm
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Operation
Operation
Normal
Normal Operation
Ping
On
Ping Mode
Interval
Ping Interval
1000 ms
Record RAW
On
Record Processed
On
Output
WBT
ES18 Serial No: 0
Sv (20 Log)
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
Depth
216.1 m
Biomass
3300
1600
TS Histogram
-34 dB
-50 dB -40 dB -30 dB -20 dB
11:20:23 PM
11:24:03 PM
11:20:36 PM
11:20:24 PM
Vertical
Horizontal
P: 2/16/2019 23:24:03

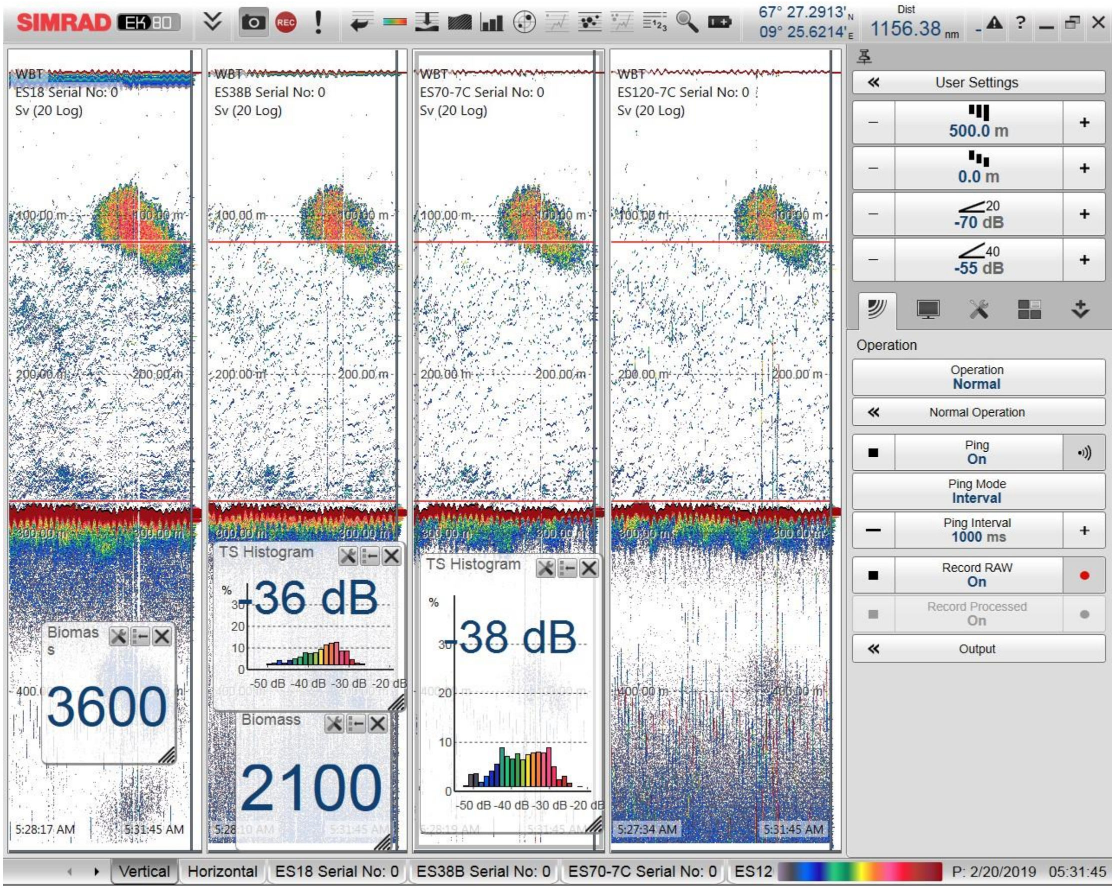

SIMRAD EK80
65° 8.8769' N
10° 7.5170' E
Dist
539.83 nm
Biomass
ES18 Serial No: 0
Sv (20 Log)
Depth
244.9 m
Screen Capture
ES38B Serial No: 0
1000
TS Histogram
ES70-7C Serial No: 0
-35 dB
-50 dB -40 dB -30 dB -20 dB
WBT
ES120-7C Serial No: 0
Sv (20 Log)
100.00 m
200.00 m
300.00 m
400.00 m
1:09:34 AM
1:13:17 AM
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1000 ms
Record RAW On
Record Processed On
Output
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/17/2019 01:13:17

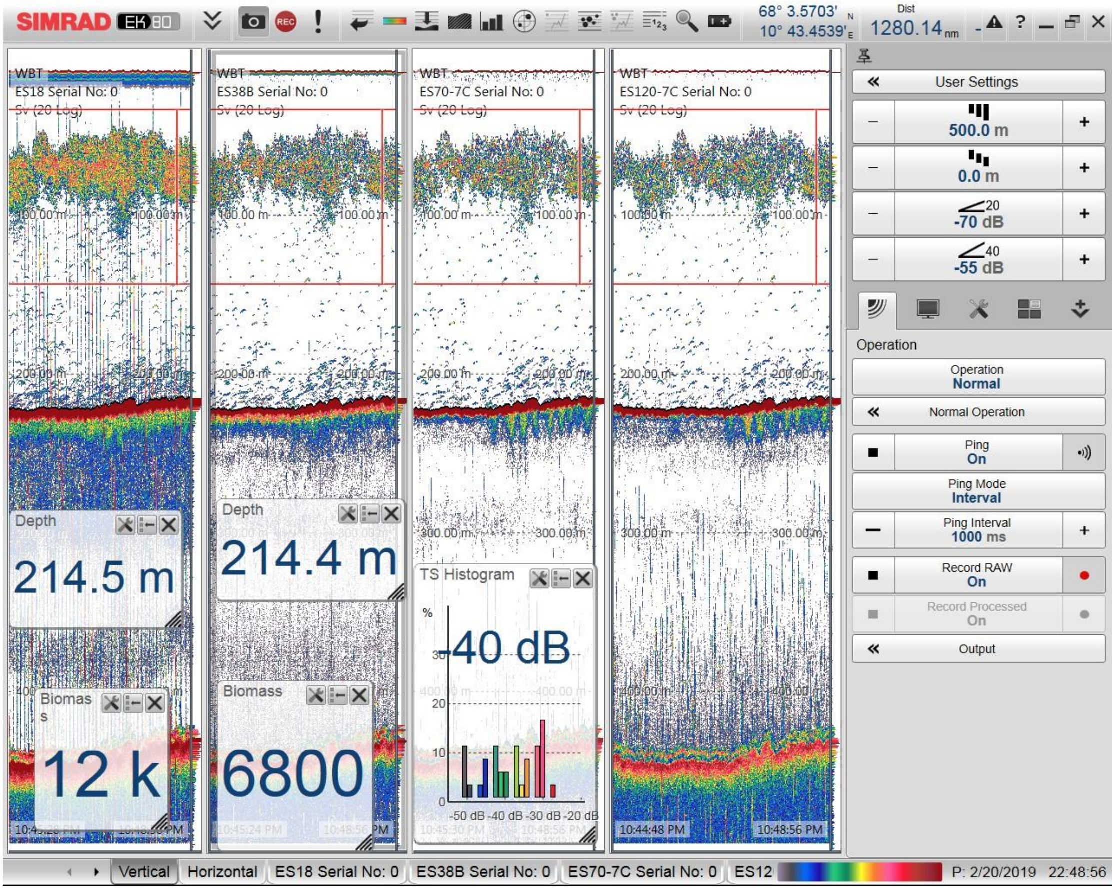

SIMRAD EK80
65° 18.6153' N
10° 24.6071' E
Dist
607.30 nm
WBT
ES18 Serial No: 0
Sv (20 Log)
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
100.00 m
200.00 m
300.00 m
Depth
144.9 m
Biomass
190
120
TS Histogram
-40 dB
-50 dB -40 dB -30 dB -20 dB
9:50:21 AM
9:53:49 AM
9:50:14 AM
9:49:38 AM
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Setup
Environment
Manual Annotation
Calibration
Calculation Interval
Installation
Language English
BITE
About
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/17/2019 09:53:49

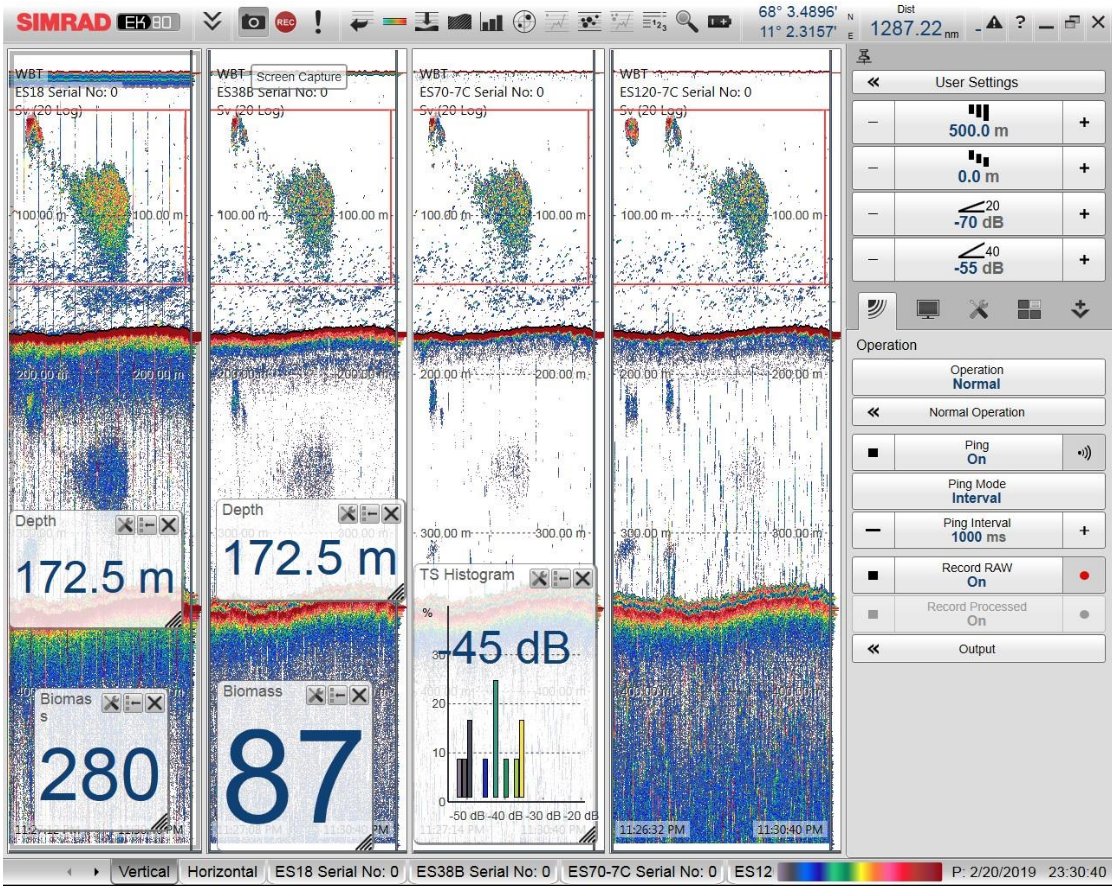

SIMRAD EK80
65° 22.0755' N
10° 36.1678' E
Dist
637.72 nm
Biomass
Depth
293.3 m
Screen Capture
25 k
TS Histogram
-38 dB
-50 dB -40 dB -30 dB -20 dB
WBT
ES120-7C Serial No: 0
Sv (20 Log)
100.00 m
200.00 m
300.00 m
400.00 m
1:54:02 PM
1:57:30 PM
1:53:55 PM
1:54:04 PM
1:53:19 PM
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Active
TVG
Sv (20 Log)
Echogram
Beam Direction
Downwards
New Layer
Layer Properties
Delete Layer
Bottom Detection
Single Target Detection
Information Pane Options
Combined View Settings
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/17/2019 13:57:30

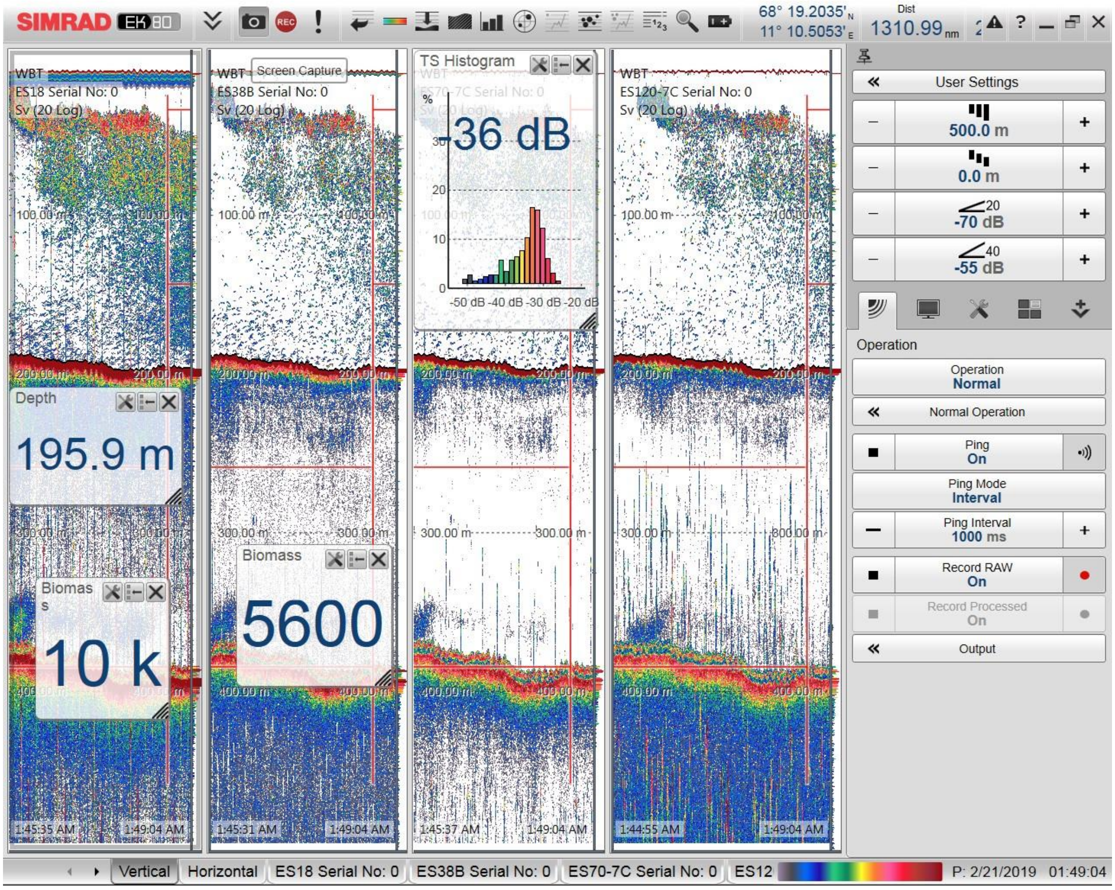

SIMRAD EK80
65° 24.3922' N
10° 7.5374' E
Dist
649.91 nm
Biomass
Depth
244.3 m
Screen Capture
3100
TS Histogram
-41 dB
-50 dB -40 dB -30 dB -20 dB
WBT
ES120-7C Serial No: 0
Sv (20 Log)
100.00 m
200.00 m
300.00 m
400.00 m
3:10:45 PM
3:14:13 PM
3:10:38 PM
3:10:47 PM
3:10:02 PM
User Settings
500.0 m
0.0 m
-70 dB
-50 dB
Operation
Operation
Normal
Normal Operation
Ping
On
Ping Mode
Interval
Ping Interval
1000 ms
Record RAW
On
Record Processed
On
Output
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/17/2019 15:14:13


SIMRAD EK80
68° 0.0728' N
10° 13.9872' E
Dist
1237.66 nm
ES18 Serial No: 0
Depth
486.1 m
Biomass
560 k
TS Histogram
-47 dB
-50 dB -40 dB -30 dB -20 dB
ES120-7C Serial No: 0
Sv (20 Log)
User Settings
600.0 m
0.0 m
-70 dB
-55 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1380 ms
Record RAW On
Record Processed On
Output
3:27:30 PM
3:32:17 PM
3:27:20 PM
3:27:33 PM
3:26:31 PM
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/20/2019 15:32:17


SIMRAD EK80
67° 27.2913' N
09° 25.6214' E
Dist
1156.38 nm
WBT
ES18 Serial No: 0
Sv (20 Log)
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
TS Histogram
-36 dB
-38 dB
-50 dB -40 dB -30 dB -20 dB
Biomass
3600
2100
User Settings
500.0 m
0.0 m
-70 dB
-55 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1000 ms
Record RAW On
Record Processed On
Output
5:28:17 AM
5:31:45 AM
5:27:34 AM
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/20/2019 05:31:45


SIMRAD EK80
68° 3.5703' N
10° 43.4539' E
Dist 1280.14 nm
WBT
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
Sv (20 Log)
Depth
214.5 m
214.4 m
TS Histogram
40 dB
Biomass
12 k
6800
-50 dB -40 dB -30 dB -20 dB
10:44:48 PM
10:48:56 PM
User Settings
500.0 m
0.0 m
-70 dB
-55 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1000 ms
Record RAW On
Record Processed On
Output
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/20/2019 22:48:56


SIMRAD EK80
68° 3.4896' N
11° 2.3157' E
Dist 1287.22 nm
WBT
Screen Capture
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES120-7C Serial No: 0
Sv (20 Log)
Depth
172.5 m
172.5 m
TS Histogram
45 dB
Biomass
280
87
-50 dB -40 dB -30 dB -20 dB
11:26:32 PM
11:30:40 PM
User Settings
500.0 m
0.0 m
-70 dB
-55 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1000 ms
Record RAW On
Record Processed On
Output
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/20/2019 23:30:40


SIMRAD EK80
68° 19.2035' N
11° 10.5053' E
Dist
1310.99 nm
WBT
ES18 Serial No: 0
Sv (20 Log)
Screen Capture
ES38B Serial No: 0
TS Histogram
-36 dB
-50 dB -40 dB -30 dB -20 dB
ES120-7C Serial No: 0
Depth
195.9 m
Biomass
10 k
5600
100.00 m
200.00 m
300.00 m
400.00 m
1:45:35 AM
1:49:04 AM
1:45:31 AM
1:45:37 AM
1:44:55 AM
User Settings
500.0 m
0.0 m
-70 dB
-55 dB
Operation
Operation Normal
Normal Operation
Ping On
Ping Mode Interval
Ping Interval 1000 ms
Record RAW On
Record Processed On
Output
Vertical
Horizontal
ES18 Serial No: 0
ES38B Serial No: 0
ES70-7C Serial No: 0
ES12
P: 2/21/2019 01:49:04

NEA mackerel

Alternative assessment

Working Document #10 for WGWIDE 2019.

Höskuldur Björnsson

August 31st 2019

1 Introduction

The Mackerel assessment this year has all potential to become very difficult. It is as before based on 5 data sets.

1. Catch in numbers
2. Triannual Egg survey 1992-2019
3. Recruitment index from bottom trawl surveys in the north sea and west of Ireland and Scotland.
4. Pelagic trawl survey
5. Tagging data

Obvious problem this year is new egg survey with record low values and very high values from the pelagic trawl survey. The recruitment index has been at very high level 2016-2018 and high since 2003 compared to the time before that. As data on younger agegroups are scarse this index can have substantial effect on adviced TAC. The index changed somewhat in March 2019 but the main features are though the same (figure 1)

Quick look at the DATRAS database does not lead to the same trends as observed in this recruitment index. This could be caused by mistakes by the author of this paper and his DATRAS teacher. Reworking the index could though be useful, a common problem in recent years is that the cohort are much larger at age 0 and 1 compared to ages 3-4.

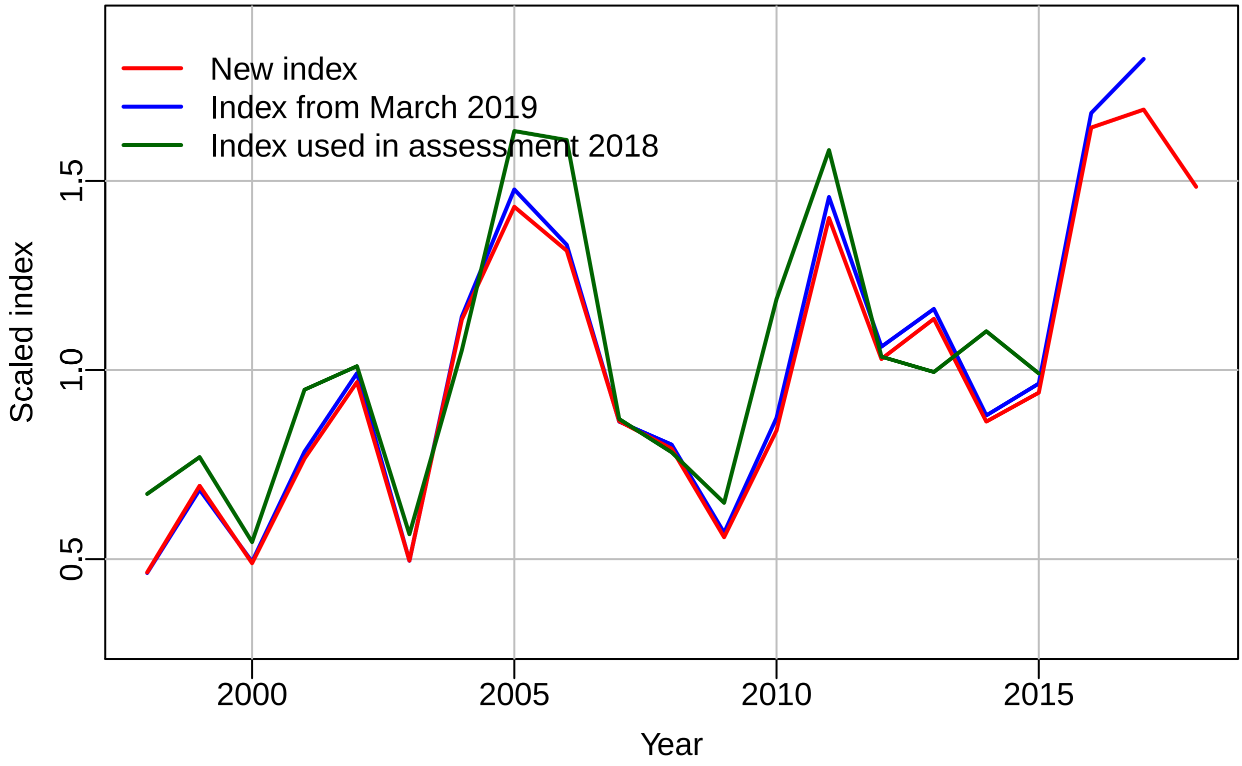


Figure 1: Recruitment index used in recent years, all values scaled to average of 1

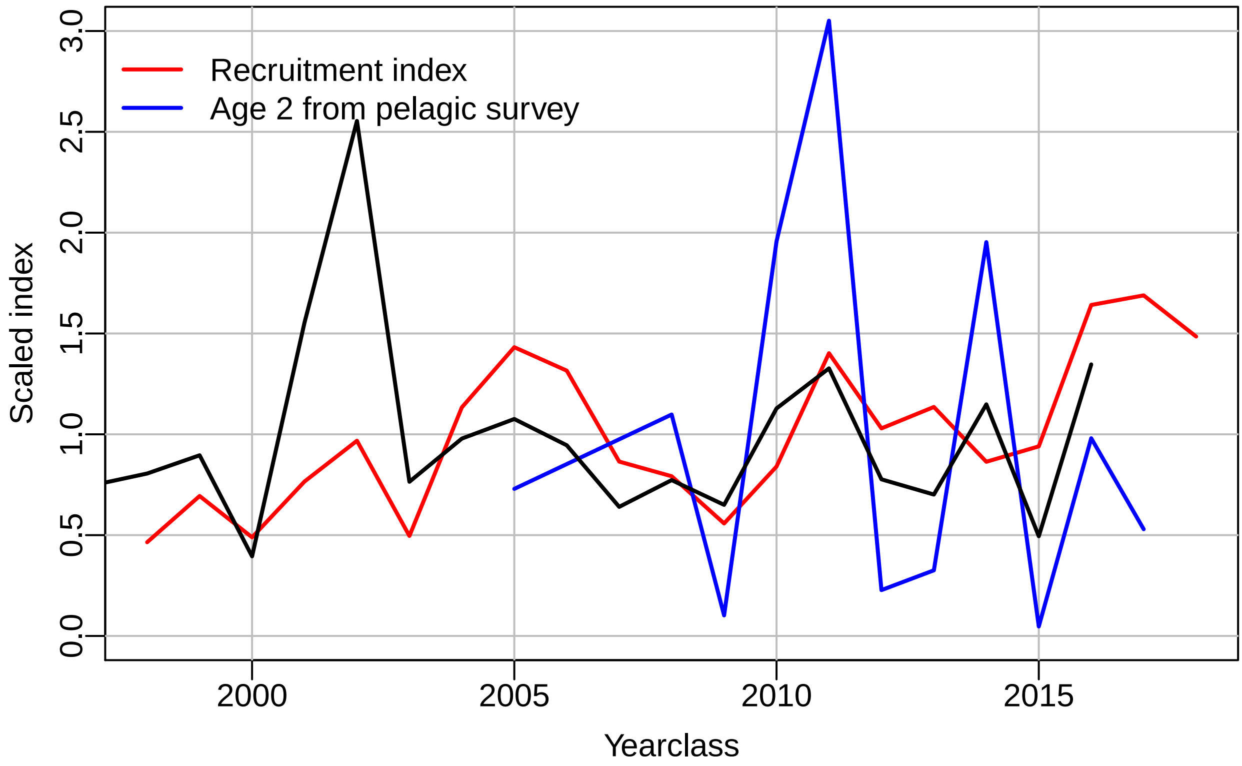


Figure 2: Recruitment index, age 2 from the pelagic survey and catches 2 years later.

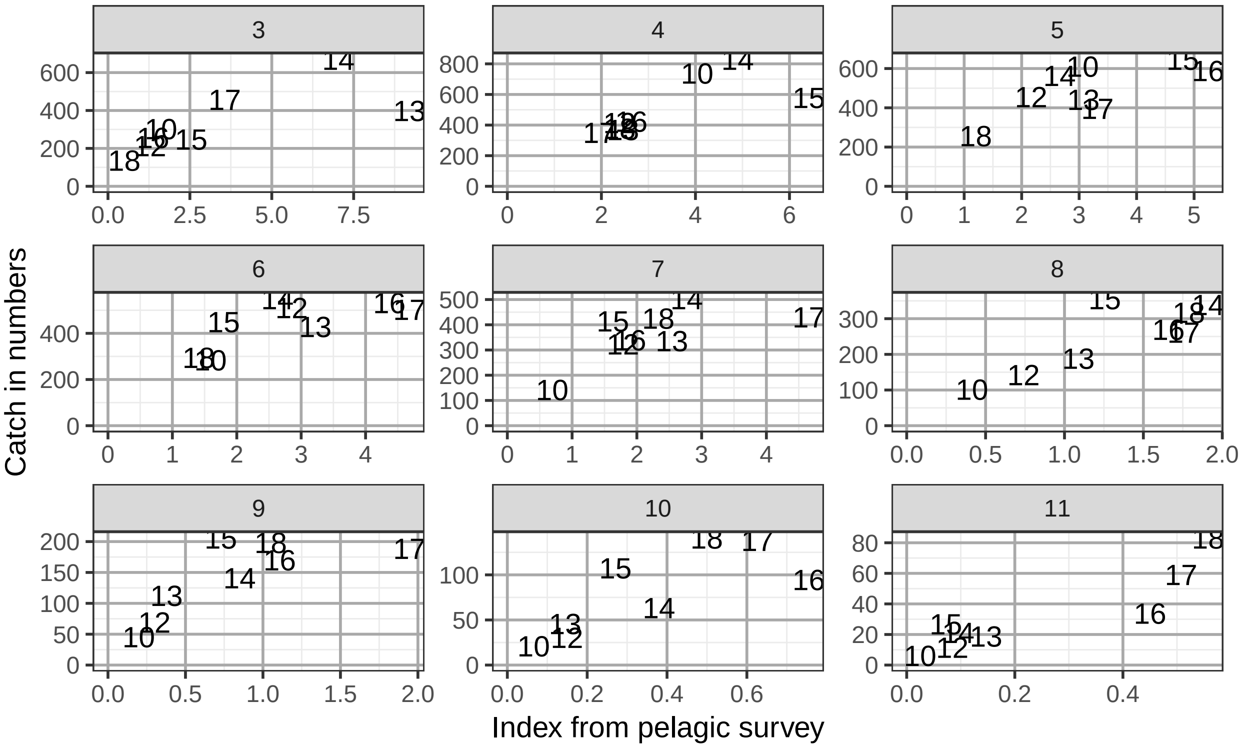


Figure 3: Catch in numbers by age vs indices from the Pelagic survey for the years 2010 and 2012:2017.

Catch in numbers and index from the pelagic survey fit well for the older age groups but not as well for the younger age groups where contrast in data is less, especially in the catches.

2 Assessment

Initially 4 different runs of Muppet were done and the results compared to the adopted SAM assessment. The configurations are.

1. 1 selection period, same tag subset as in the adopted sam run.
2. 1 selection period, all tags.
3. 2 selection periods, same tag subset as in the adopted sam run.
4. 2 selection periods, all tags.
5. 2 selection periods, all tags, tagloss not estimated.

When 2 selection periods are used the selection is allowed to change in 1996. 1 vs 2 selection periods affects historical stock size (figure 4) but a multiplier on catches before 1999 is estimated and that multiplier is higher when the selection is allowed to change. One vs 2 selection pattern does also affect recent estimate of spawning stock as "geometric mean" affects the most recent cohorts in a similar way as in the RCT3 model. Comparable feature is included in SAM when using Beverton and Holt or Ricker functio,n which is not done in the adopted assessment. SAM seems to start by believing the recruitment index, gradually finding out that it is too high, therefore applying process error to reduce the number in recent cohorts.

SSB before 1998 does also affect current SSB through the egg survey.

Tagloss is estimated when all tags are used but not when the subset used in SAM is selected.

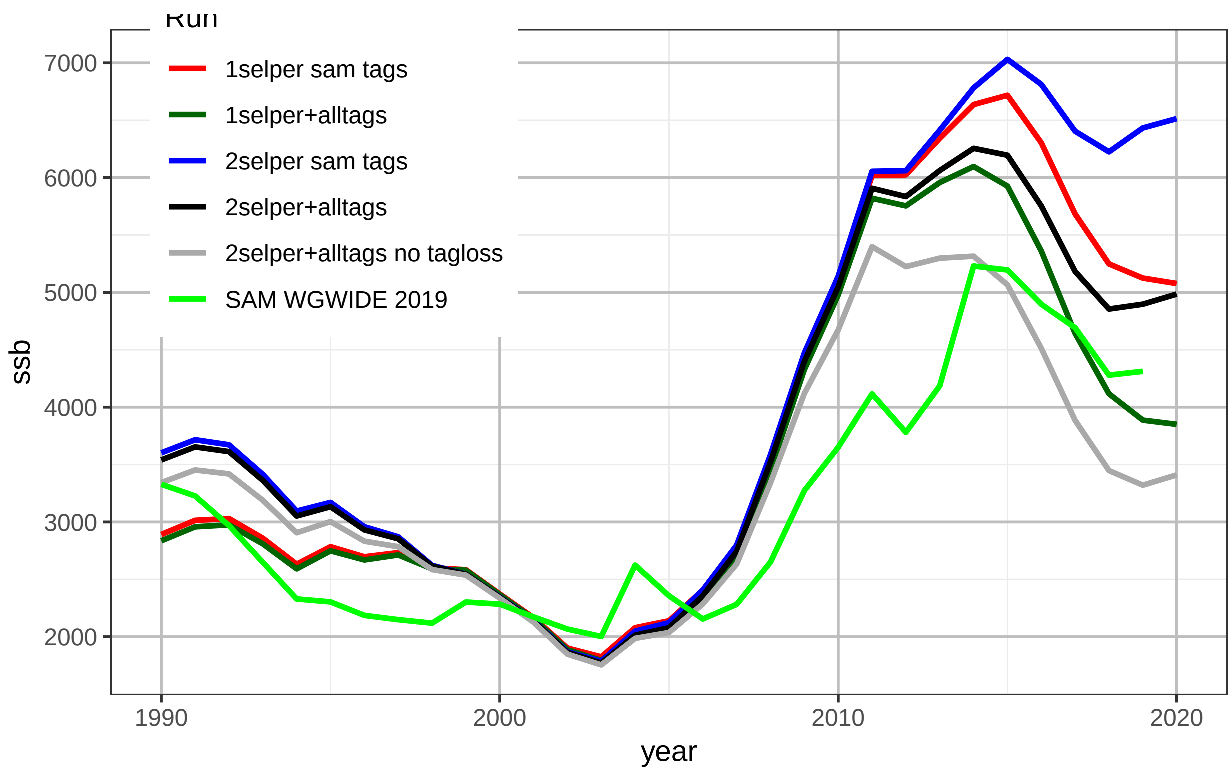


Figure 4: Spawning stock for the 4 model settings and from SAM (black)

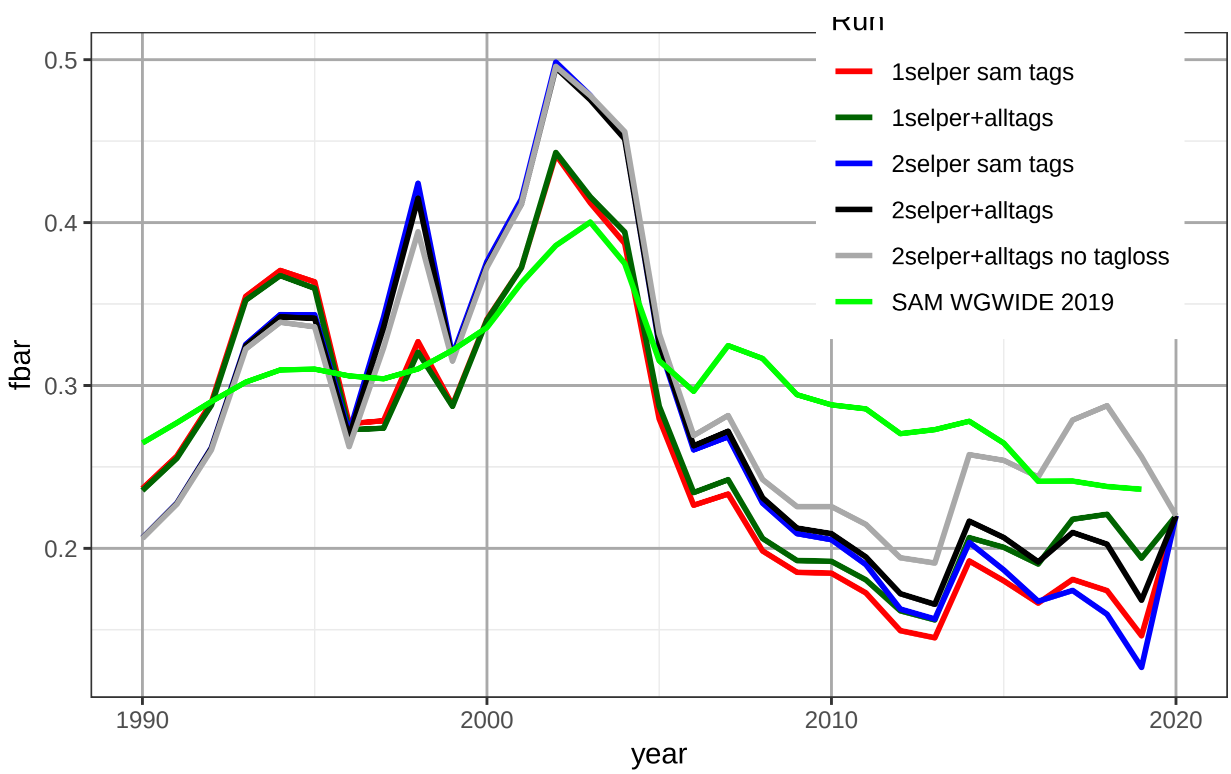


Figure 5: Average Fishing mortality for the 4 Muppet settings and SAM (grey)

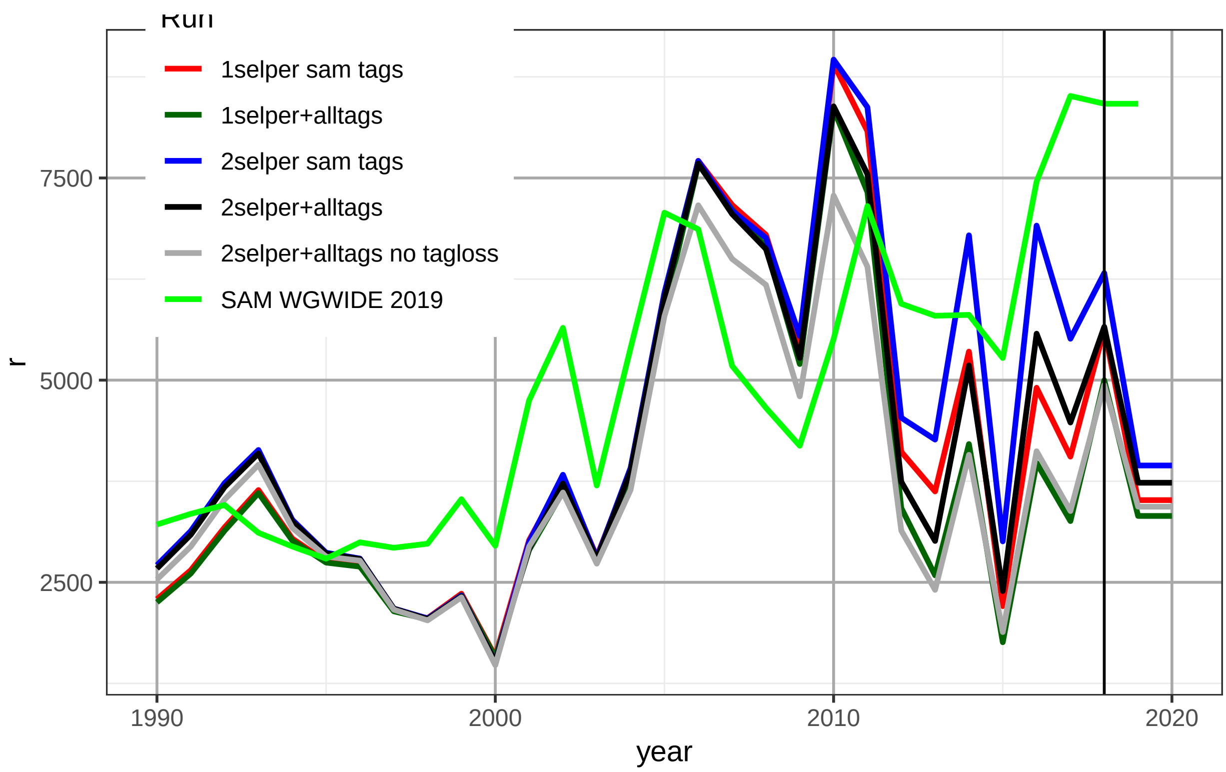


Figure 6: Recruitment age 0 for the 4 Muppet settings and SAM (grey)

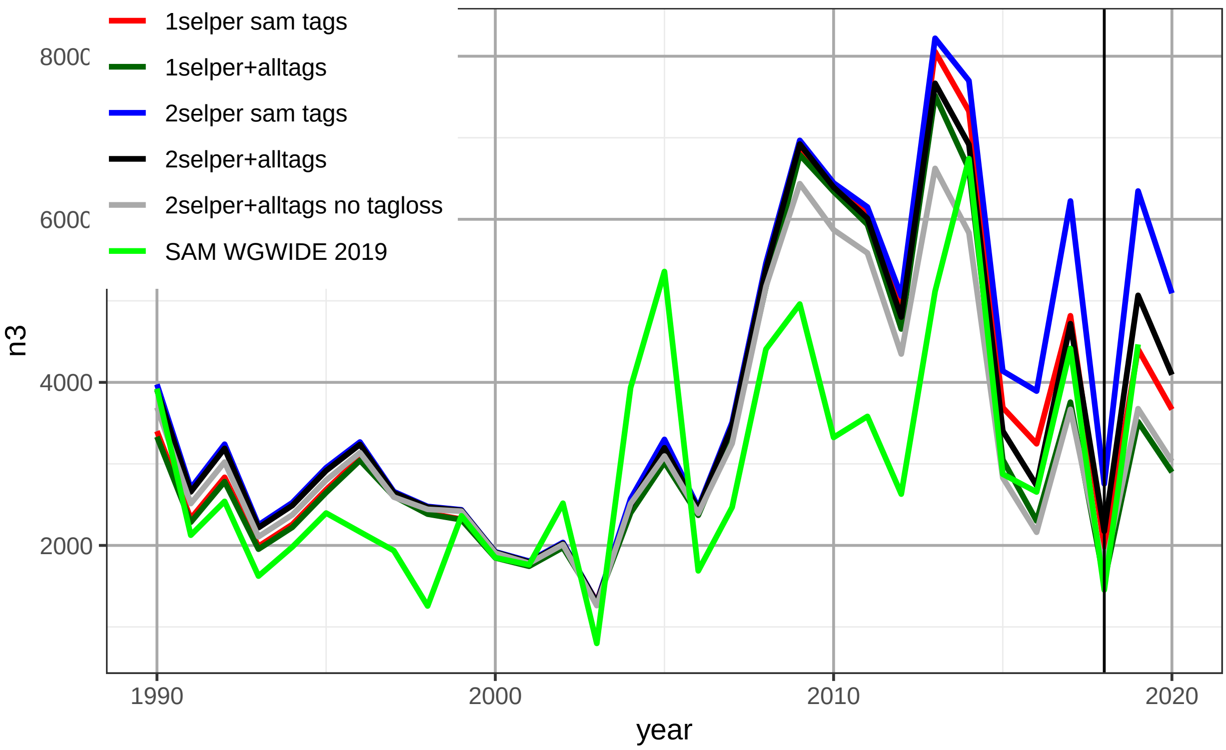


Figure 7: Recruitment at age 3 for the 4 Muppet settings and SAM (grey)

Comparison of the results (figures 4 to 7) show that most of the Muppet runs indicate higher SSB last 10 years compared to SAM. F_{4-8} has according to SAM been higher and much more stable. Stability in F is not surprising as the fishing mortality is modelled as uncorrelated random walk with $\sigma \approx 0.11$, a number that is of course estimated from the data. Recruitment at age 0 from SAM has been higher than in Muppet since 2012 at least when looking at age 0 (figure 6. Looking at age 3 shows lower recruitment in SAM compared to the

Muppet results (figure 7). Strange recruitment from the SAM model can be seen in figure 10 where number caught at ages 2-11 are often 85 or higher percentage of number in stock at age 2.

The run showing the lowest biomass is the run using all the tagging data but not implementing tagloss. Advice in September 2018 was based on those settings but implementing tagloss (one parameter) leads to large change in perception of the stock and much better fit (change in objective function is 30 for 1 parameter.)

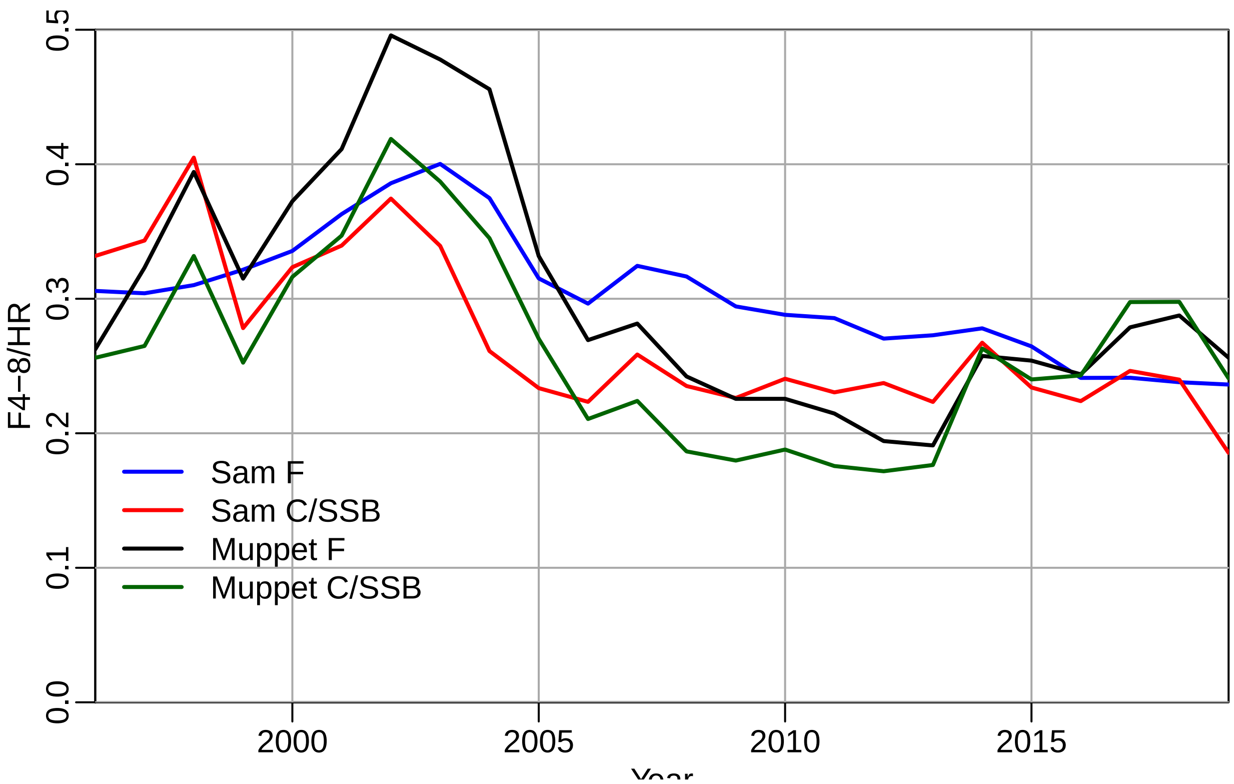


Figure 8: Comparison of different measures of fishing mortality in SAM and SEP not using the pelagic survey.

Figure 8 shows that the measures C/SSB and F develop in a similar way according to the Muppet model but quite different way in sam wher F has been decreasing while C/SSB has been similar. This discrepancy could be caused by gradual change in selection and difference between observed and predicted catches in SAM.

The settings of the assessment can have quite large effect on the advice. The runs shown in figures figures 4 to 7 lead to TAC_{2020} between 600 and 1380 thous. tonnes (assuming $F_{4-8}) = 0.22$.

Finally some aggregated residuals from the surveys are shown in figure 9. The fit is very poor, recruiemtne index too high ub last 4 years, 3 last egg surveys below prediction and huge year factor in the Pelagic survey. Correlation of residuals in the pelagic survey in the same year is modelled by a first order AR model with estimated correlation between adjacent age groups 0.77. The modelling of the correlation could be improved from what is done now. The year 2018 does look like an outlier and one WD presented indicated more southerly distribution of the stock in 2018. The question is then if the same applies to 2010 and 2012 that are the reference values where assessment has converged.

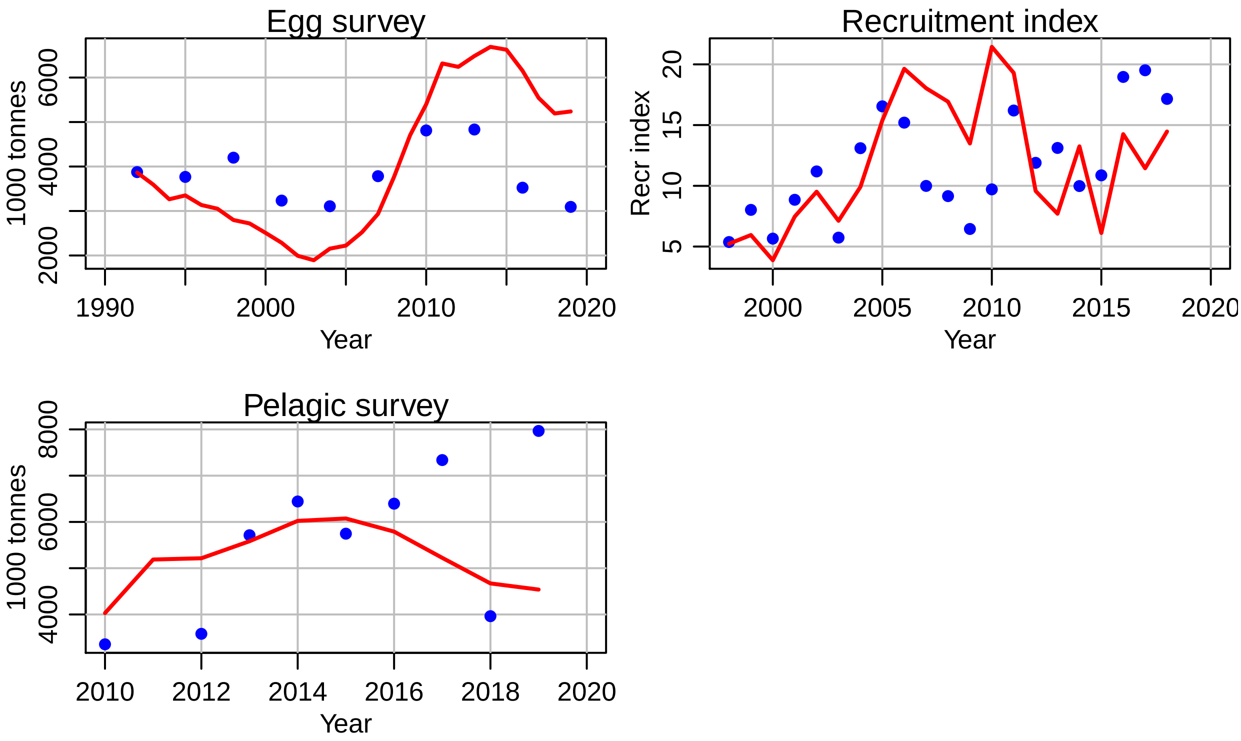


Figure 9: Observed and predicted survey indices from the Mackerel assessment. (2 selection period using all tags, modelling tagloss)

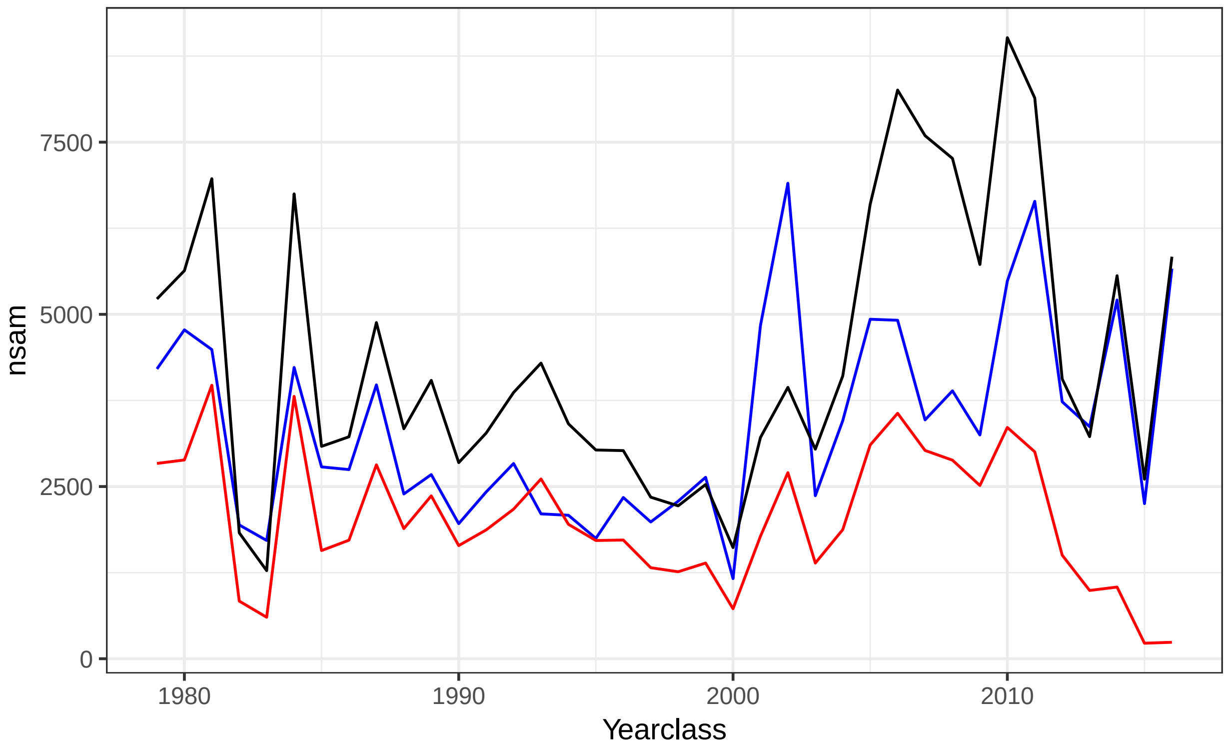


Figure 10: Estimated number of age 2 fish from sam (blue), muppet (black) and catch of the yearclass at age 2 to 11 (red).

Working Document to

Working Group on International Pelagic Surveys (WGIPS)
Bergen, Norway, 13 - 17 January 2020
and
Working Group on Widely distributed Stocks (WGWIDE)
Santa Cruz, Tenerife, Spain, 28 August - 3 September 2019

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2019

Post-cruise meeting, Reykjavik, Iceland, 18-20 June 2019

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Introduction

In May-June 2019, five research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherlands, Sweden and UK), R/V Magnus Heinason, Faroe Islands, R/V Árni Friðriksson, Iceland, R/V G.O. Sars, 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 biomass of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 also the EU participated (except 2002 and 2003) and from 2004 onwards it was more integrated into an ecosystem survey. This report represents analyses of data from this International survey in 2019 that are stored in the PGNAPES database and supported by national survey reports from each survey (Dana: Staehr, Sakinan, Kloppmann, Kupschus 2019, Magnus Heinason: Homrum et al, FAMRI 1918-2019, Árni Friðriksson: Óskarsson et al. 2019).

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2019 and by correspondence. Planning of the acoustic transects and hydrographic stations and plankton stations were carried out by using the recently developed survey planner function in the r-package Rstox version 1.11 (see www.imr.no/forskning/prosjekter/stox). The survey planner function generates the survey plan (transect lines) in a cartesian coordinate system, and transforms the positions to the geographical coordinate system (longitude, latitude) using the azimuthal equal distance projection, which ensures that distances, and also equal coverage, if the method used is designed with this prerequisite, are preserved in the transformation. Figure 1 shows the planned acoustic transects and hydrographic and plankton stations in each stratum. Only parallel transects were used this year, however, the transects now follow great circles instead of a constant latitude as before, so they appear bended in a Mercator projection. The participating vessels together with their effective survey periods are listed in the table below:

Vessel	Institute	Survey period
Dana	Danish Institute for Fisheries Research, Denmark	02/5-31/5
G.O. Sars	Institute of Marine Research, Bergen, Norway	29/4-03/6
Vilnyus	PINRO, Russia	03/6-19/6
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	02/5- 14/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	08/5-19/5

Figure 2 shows the cruise tracks, Figure 3a the hydrographic and plankton stations and Figure 3b the pelagic trawl stations. Survey effort by each vessel is detailed in Table 1. Frequent contacts were maintained between the vessels during the course of the survey, primarily through electronic mail. The temporal progression of the survey is shown in Figure 4.

In general, the weather condition did not affect the survey even if there were some days that were not favourable and prevented for example WP2 and Multinet sampling at some stations. The survey was based on scientific echosounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote *et al*., 1987) prior to the survey. Salient acoustic settings are summarized in the text table below.

Acoustic instruments and settings for the primary frequency (boldface).

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason	Vilnyus
Echo sounder	Simrad EK 60	Simrad EK 80	Simrad EK60	Simrad EK60	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 120, 200	**38**,200	**38,** 120
Primary transducer	ES38BP	ES 38B	ES38B	ES38B	ES38B
Transducer installation	Towed body	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	5	8.5	8	3	4.5
Upper integration limit (m)	5	15	15	7	10
Absorption coeff. (dB/km)	10	10.1	10	10.1	10
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	1.573	2.43	2.425	2.425	2.425
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)	-20.5	-20.7	-20.81	-20.8	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.32	26.07	24.36	25.64	25.76
s_A correction (dB)	-0.56	-0.15	-0.58	-0.66	-0.64
3 dB beam width (dg)					
alongship:	6.8	6.48	7.28	7.02	7.09
athw. ship:	6.8	6.22	7.23	7.00	7.01
Maximum range (m)	500	500	500	500	500
Post processing software	LSSS1	LSSS	LSSS	Sonardata Echoview 9.1	LSSS

Post-processing software differed among the vessels but all participants used the same post-processing procedure, which is according to an agreement at a PGNAPES scrutinizing workshop in Bergen in February 2009 (ICES 2009), and "Notes from acoustic Scrutinizing workshop in relation to the IESNS", Reykjavík 3.-5. March 2015 (Annex 4 in ICES 2015).

Generally, acoustic recordings were scrutinized on daily basis and species identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms. All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason	Vilnyus
Circumference (m)		496	832	640	500
Vertical opening (m)	25-35	25-30	30–35	45–55	50
Mesh size in codend (mm)	16	24	40	40	16
Typical towing speed (kn)	3.5-4.0	3.0–4.5	3.6–4.5	3.0–3.5	3.3–4.5

Catches from trawl hauls were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. Normally, a subsample of 30–100 herring, blue whiting and mackerel were sexed, aged, and measured for length and weight, and their maturity status was estimated using established methods. For the Norwegian, Icelandic and Faroese vessel, a smaller subsample of stomachs was sampled for further analyses on land. An additional sample of 70–300 fish was measured for length.

Acoustic data were analysed using the StoX software package which has been used for some years now for WGIPS coordinated surveys. A description of StoX can be found here: www.imr.no/forskning/prosjekter/stox. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). This method requires pre-defined strata, and the survey area was therefore split into 6 strata with pre-defined acoustic transects as agreed during the WGIPS in January 2019. Within each stratum, parallel transects with equal distances were used. The distance between transects was based on available survey time, and the starting point of the first transect in each stratum was randomized. This approach allows for robust statistical analyses of uncertainty of the acoustic estimates. The strata and transects used in StoX are shown in Figure 1. All trawl stations within a given stratum with catches of the target species (either blue whiting or herring) were assigned to all transects within the stratum, and the length distributions were weighted equally within the stratum. The following target strength (TS)-to-fish length (L) relationships were used:

Blue whiting: $TS = 20 \log(L) - 65.2$ dB (ICES 2012)

Herring: $TS = 20.0 \log(L) - 71.9$ dB

The target strength for herring is the traditionally one used while this target strength for blue whiting was first applied in 2012 (ICES 2012).

The hydrographical and plankton stations by survey are shown in Figure 3a. Most vessels collected hydrographical data using a SBE 911 CTD. Maximum sampling depth was 1000 m. Zooplankton was sampled by a WPII on all vessels 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 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.

Results and Discussion

Hydrography

The temperature for selected depths in the Norwegian Sea is shown in Figure 5. 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 6-8. The temperatures in the surface layer (0-50 m) ranged from below 0°C in the Greenland Sea to 9°C in the southern part of the Norwegian Sea (Figure 6). The Arctic front was encountered south of 65°N east of Iceland extending eastwards towards about 2° West where it turned northeastwards to 65°N and then almost straight northwards. This front was well-defined at 200-500 m depth while shallower it was unclear. Further to west at about 8° West another front runs northward to Jan Mayen, the Jan Mayen Front, that was distinct throughout the observed water column. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures >7 °C to 69° N in the surface layer.

Relative to a 23 years long-term mean, from 1995 to 2017, the temperatures at 0-50 m and 50-200 m over the western Norwegian Sea, roughly west of the 0 meridian, were higher in 2019 compared to the long-term mean (Figures 6-7). Relative warmest water was in the south- and northwestern Norwegian Sea where the temperatures in some regions were 1.0 °C higher than the mean. In the eastern area of the Norwegian Sea, the temperatures were instead lower than normal, where temperatures in few areas were 0.5 °C lower than the mean. At 200-500 m depth, both higher and lower temperatures than the long-term mean can be observed in whole region.

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in May 2019 are shown in Figure 9. Atlantic water is lying over the colder and fresher intermediate layer and reach down to 500 m at the shelf edge and shallower westward. The warmest water 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. Relative to a long-term mean, from 1978 to 2007, the temperatures in 2019 were substantial higher in the western part (west of 2.5° E) where temperatures were 3.0 °C higher than the mean between 200 m and 400 m depth. In the eastern part the temperatures were in general lower than long-term mean.

Two main features of the circulation in the Norwegian Sea, where the herring stock is grazing, are the Norwegian Atlantic Current (NWAC) and the East Icelandic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the southwestern Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is only in the last three decades that a similar layer has been observed all over the Norwegian Sea.

This circulation pattern creates a water mass structure with warm Atlantic Water in the eastern part of the area and more Arctic conditions in the western part. The NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward. The western branch of the NWAC reaches the area of Jan Mayen at about 71°N. Further northward in the Lofoten Basin the lateral extent of the Atlantic water gradually narrows again, apparently under topographic influence of the mid-ocean ridge. It has been shown that atmospheric forcing largely controls the distribution of the water masses in the Nordic Seas. Hence, the lateral extent of the NWAC, and consequently the position of the Arctic Front, that separates the warm North Atlantic waters from the cold Arctic waters, is correlated with the large-scale distribution of the atmospheric sea level pressure. The local air-sea heat flux in addition influence the upper layer and it is found that it can explain about half of the year to year variability of the ocean heat content in the Norwegian Sea.

Zooplankton

The zooplankton biomass (g dry weight m^{-2}) in the upper 200 m is shown in Figure 10. Sampling stations were evenly spread over the area, covering Atlantic water, Arctic water, and the Arctic frontal zone. The Svinøy transect was not included in this survey but covered in a separate survey. The highest zooplankton biomasses were not concentrated in a specific area but spread over several locations covering the entire sampling area, except from the southernmost part and especially the area south-east of Iceland which contained low biomasses. High biomasses were found in an area around Lofoten/Vesterålen and north and northwest of that area, and in the Norwegian Sea basin.

Figure 11 shows the zooplankton index given for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional difference in the biomass, the total area were divided into 4 subareas 1) Southern Norwegian Sea including the Norwegian Sea Basin, 2) The Northern Norwegian Sea including the Lofoten Basin, 3) Jan Mayen Arctic front, and 4) East of Iceland. The mean index of subarea 1 and 2 is also given. The zooplankton biomass index for the Norwegian Sea and nearby areas was in 2019 10.8 g dry weight m^{-2}, which is an increase from last year. A similar increase was observed in all sub-areas, except from East of Iceland.

The zooplankton biomass index for the Norwegian Sea in May has been estimated since 1995. For the period 1995-2002 the plankton index was relatively high even if varying between years. From 2003-2006, the index decreased continuously and was at lower levels for several years, but since 2010 there has been an increasing trend. For the period 2003-2019 the mean was 7.9 g, compared to 11.5 for the period 1995-2002. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea. In 2019 the biomass index for the Norwegian Sea was comparable to the high-biomass period. The zooplankton biomass at the Jan Mayen Arctic front was high until 2007 but has since then been at the same level as the Norwegian Sea. The zooplankton biomass East of Iceland was in general higher compared with the other sub-areas until 2015.

The reason for this fluctuation in the zooplankton biomass is not obvious to us. The unusually high biomass of pelagic fish feeding on zooplankton has been suggested to be one of the main causes for the reduction in zooplankton biomass. However, carnivorous zooplankton and not pelagic fish are the main predators of zooplankton in the Norwegian Sea (Skjoldal *et al.,* 2004), and we do not have good data on the development of the carnivorous zooplankton stocks. Timing effects, as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. It is also worth noting that the period with lower zooplankton biomass coincides with lower-than-average heat contents in the Norwegian Sea (ICES 2019). More ecological and environmental research to reveal inter-annual variations and long-term trends in zooplankton abundance are recommended. Quantitative research on carnivorous zooplankton stocks (such as krill and amphipods) across the whole survey area, is an important step in that direction and needs a further effort by all participating countries.

Norwegian spring-spawning herring

The zero-line was not fully reached in the north western part of the distribution area of the adult NSS herring. However, based on the zero-line reached south and east of this area, the vast majority of the NSS herring stock is believed to be contained within the survey area. It is therefore recommended that the results from IESNS 2019 can be used for assessment purpose. The herring was primarily (~2/3) distributed in the south western Norwegian Sea (Figure 12) but a third of the biomass was distributed between 69°N and 72°N and this was still primarily the 2013 year class but also the 2014 and 2016 year classes were numerous. This year the amount of herring in the eastern part of the Barents Sea was significant.

As in previous years the size and age of herring were found to increase towards west and south in the Norwegian Sea (Figure 13). Correspondingly, it was mainly older herring that appeared in the southwestern areas. The 2013 year class (age 6) was observed across most of the survey area.

Six year old herring (year class 2013) dominated both in terms of number and biomass (24 %) on basis of the StoX estimations for the Norwegian Sea (Table 2). Its number at age 6 (Table 2) is higher than for the 2009 year class at same age, but only half the size of the large 2004 year class (Figure 14), which puts the size of the 2013 year class into perspective. The large 2004 year class, which has dominated the stock together with the 2002 year class, has contributed significantly to the biomass of older age-groups (see paragraph on issues with age determination below). Herring aged 12-15 years old thus comprised 19% of the numbers and 25% of the biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 15.

The total estimate of herring in the Norwegian Sea from the 2019 survey was 19.7 billion in number and the biomass 4.87 million tonnes. This estimate is 0.17 million tonnes (3 %) decrease from the 2018 survey estimate. 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. Although there is only little change in total abundance and biomass, there is a gradual shift in age and size composition with the 2013 and 2014 year classes becoming more dominant than the old 2004 year class. The 2016 year class had started to enter the Norwegian Sea.

In the Barents Sea, herring was distributed widely in the area and in large concentrations in the eastern part of the survey area, where the zero line concentration was not reached. The abundance estimates of herring by age and length in the Barents Sea (Stratum 6) are shown in Table 3. The herring at age 3 was in the highest number (17 billions, mean length 22.1 cm and mean weight 67 g). This is the second largest observation of age 3 herring in the Barents Sea since the start of this survey in 1991, only slightly lower than the estimate in 1994 (the strong 1991 year class). Age 2 herring was also in significant amount (2.3 billions, mean length 16.7 cm and mean weight 28.5 g). The abundance of age 1 herring was low (0.1 billions, mean length 12.0 and mean weight 11.2 g). The survey estimates of age 1, 2 and 3 from the period 1991-2019 are shown in Figure 17. The year class from 2016 was also relatively numerous at age 1 in 2017 and the 5th largest on record as 2 year olds in 2018. This gives good indications that the 2016 year class is a good year class, which will probably recruit to the adult stocks over the coming two-three years. The zero-line was not fully covered to north and east, but the main aggregations were more southerly distributed and probably most of the juvenile herring was covered by the survey.

In the last 5 years there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences – particularly older specimens appear to have uncertain ages. A scale and otolith exchange has been ongoing for some period, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop was planned in the spring 2018 to discuss the results. This workshop was postponed indeterminately. The survey group emphasizes the necessity of having this workshop before next year's survey takes place.

With respect to age-reading concerns in the recent years, the comparison between the nations in this year's survey showed a similar difference as observed in recent years (Figure 21). For example, the 2004 year class was in higher proportion by the Norwegian readers than the Faroese and the Icelandic readers in Stratum 3 and 4, which had higher proportions of the 2005 and 2006 year classes. These three year classes are in the plus group in the analytical assessment (age 12+).

In the IESNS survey in 2019 there was good agreement in the acoustic scrutinizing results between any neighbouring vessels.

Blue whiting

The spatial distribution of blue whiting in 2019 was similar to the years before, with the highest abundance estimates in the southern and eastern part of the Norwegian Sea, along the Norwegian continental slope. The main concentrations were observed in connections with the continental slopes of Norway and along the Scotland – Iceland ridge (Figure 18). Blue whiting was distributed similar as last year and not as far west into the Norwegian Sea as in the years before. 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 2019 was 0.53 million tonnes, which is a 6 % increase from the biomass estimate in 2018 (0.50). The abundance index for 2019 was 6.2 billion, which is 41 % higher than in 2018. The main reason for this is the incoming 2018 year class. Ages 4, 1 and 5 are dominating the acoustic estimate (71 % of the biomass and 80% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20.

In this year's IESNS survey, one-year old blue whiting was more numerous as compared to IESNS 2017 and 2018. The survey group compared age and length distributions by vessel and strata (Figure 22 and 23) and no clear differences were found.

Mackerel

Trawl catches of mackerel is shown in Figure 24. This shows that mackerel was present in the southern part of the Norwegian Sea in the beginning of May. No further quantitative information can be drawn from these data as this survey is not designed to monitor mackerel.

Vertical profile across the Norwegian Sea

Two "transects" were carried out by G.O. Sars across the southern part of the Norwegian Sea (Figure 25). Herring was distributed mainly to the west of 2 - 3° W, in the temperature range 0 - 4 °C. The largest aggregations of older herring were observed acoustically between 6 and 10° W in the high-gradient thermal zone near the border of the cold East Icelandic Current in a layer from 150 to 400 m. The blue whiting, as in previous years, was distributed in Atlantic waters, preferring a layer between 300 and 400 m. Its schools were registered mainly in areas with high temperature gradients from the "warm side" of the frontal zone between the Atlantic and Arctic waters and in the bottom layer above the shelf and continental the slope of Norway. Some blue whiting were observed in the southwestern area to south from Faroe-Iceland Ridge in layer 350-450 m under temperature 6-7 °C.

General recommendations and comments

Recommendation	Adressed to
1. Continue the methodological research in distinguishing between Herring and blue whiting in the interpretation of echograms.	WGIPS
2. It is recommended that a workshop based on the ongoing otolith and scale exchange will take place before next year's IESNS survey.	WGBIOP, WGWIDE
3. It is recommended that the WGIPS meeting in 2020 includes a workshop on how to deal with stock components of herring in the IESNS-survey.	WGIPS
4. It is recommended that the WGIPS meeting in 2020 discusses whether cruise-planning with zig-zag transects in some strata is a possibility for the IESNS survey in order to optimise survey coverage.	WGIPS
5. It is recommended that the WGIPS meeting in 2020 discusses the possible implementation of sonar observations in IESNS and other acoustic surveys.	WGIPS

Next year's post-cruise meeting

We will aim for next meeting in Copenhagen 16-18 June 2020. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2019 at 0-200 m depth was above long-term mean (1995-2017) in the western and central Norwegian Sea but below the mean in the eastern and southern areas of the Norwegian Sea.
- The 2019 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters increased a bit from last year and is comparable to the mean of the earlier high-biomass period, but is still relatively low in the westernmost areas.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 4.87 million tonnes, which is a 3 % decrease from the 2018 survey estimate. The survey followed the pre-planned protocol and the survey group recommends using the abundance estimates in the analytical assessment.
- The 2013 year class dominated in the survey indices both in numbers and biomass (24 %). Despite relatively high number at age 6 of this year class, it is half the size of the large 2004 year class at the same age.
- The estimated number at age 3 (2016 year class) of NSSH in the Barents Sea in 2019 was the highest observed since 1994. Although uncertainty around the estimates are high, this indicates that the 2016 year class will recruit strongly to the adult stock over the next two-three years.
- The biomass of blue whiting measured in the 2019 survey increased by 6 % from last year's survey and 41 % in terms of numbers.
- Ages 4, 1 and 5 (2015, 2018 and 2014 year classes) of blue whiting are dominating the acoustic estimate (71 % of the biomass and 80 % by numbers).

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Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2018.

Data for Vilnyus will be updated for final report in August 2019.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	06/05-26/05	2058	20	38	473	1559	38
Magnus Heinason	2/5-12/5	1496	12	19	349	554	19
Árni Fridriksson	8/5-19/5	2320	13	35	914	2515	34
G.O.Sars	01/5-31/5	4887	53	55	564	1680	54
Vilnyus	03/6-19/6	2770	17	45	556	2955	45
Total		**10761**	**98**	**147**	**2300**	**6308**	**145**

Table 2. IESNS 2019 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	-	-	-	24512	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24512	713.3	29.10
17-18	-	55317	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55317	2012.6	36.38
18-19	6030	18091	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24121	978.7	40.58
19-20	-	4923	4923	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9846	537.9	54.63
20-21	-	19696	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19696	1288.0	65.39
21-22	-	19967	54564	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	74531	5233.6	70.22
22-23	-	27108	275402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	302510	24142.4	79.81
23-24	-	-	640302	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	640302	59839.0	93.45
24-25	-	-	592054	7461	-	-	-	-	-	-	-	-	-	-	-	-	-	-	599515	61842.0	103.15
25-26	-	19111	290836	23889	-	-	-	-	-	-	-	-	-	-	-	-	-	-	333836	39115.4	117.17
26-27	-	-	401494	3375	3375	-	-	-	-	-	-	-	-	-	-	-	-	-	408244	54944.1	134.59
27-28	-	3180	177549	80370	85869	3180	6361	-	-	-	-	-	-	-	-	-	-	-	356510	54080.0	151.69
28-29	-	-	143631	118774	217920	141779	13128	-	18379	13128	-	-	-	-	-	-	-	-	666739	115694.5	173.52
29-30	-	-	5557	205671	456082	392370	66183	2364	33091	7091	7091	-	-	-	-	-	-	-	1175500	220984.3	187.99
30-31	-	-	9045	153768	409969	488625	177890	69347	106231	15075	3015	-	9045	-	-	-	-	-	1442012	299482.5	207.68
31-32	-	-	-	21795	539092	780021	99941	76904	108269	86403	49970	-	-	-	-	-	-	-	1762397	394334.4	223.75
32-33	-	-	-	5894	263760	1499818	198994	152871	23574	67810	42406	5894	36986	-	-	-	-	-	2298006	562165.2	244.63
33-34	-	-	-	45209	110186	931985	274370	223970	60198	21066	1289	-	-	-	-	-	-	-	1668273	437728.9	262.38
34-35	-	-	-	-	40303	307932	302795	233985	123268	215323	30847	55462	53724	28961	6806	-	-	-	1399405	404735.9	289.22
35-36	-	-	-	-	28359	196578	70759	331745	208858	309430	198001	198257	200157	174175	44490	35448	-	-	1996256	620313.0	310.74
36-37	-	-	-	-	3566	33763	13372	72161	198850	350525	261806	224979	548152	264010	254163	2674	-	-	2228021	723676.3	324.81
37-38	-	-	-	-	11522	9048	22708	44157	41219	198577	206531	147545	404944	371497	261547	54879	5027	-	1779201	615561.3	345.98
38-39	-	-	-	-	-	-	8613	-	-	10179	3915	51722	108650	82144	90090	18009	-	-	373323	137998.6	369.65
39-40	-	-	-	-	-	-	-	-	-	-	-	-	19045	17102	3420	33866	-	-	73433	28858.9	393.00
40-41	-	-	-	-	-	-	-	-	-	-	-	2750	-	-	-	5499	-	-	8249	3737.3	453.06
41-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8306	8306	3584.1	431.50
TSN(1000)	6030	167393	2595359	690716	2170003	4785101	1255113	1207504	921939	1294606	804871	686609	1380702	937888	660516	150376	5027	8306	19728061	-	-
TSB(1000 kg)	253.3	10528.0	288485.2	124080.6	461558.3	1146871.7	322436.5	342043.3	258763.5	394139.7	254213.4	224025.6	453514.2	312166.5	222575.8	52598.7	1743.5	3584.1	-	4873582.1	-
Mean length (cm)	18.00	20.09	24.60	28.68	30.49	31.90	32.62	33.81	33.73	34.98	35.47	36.04	36.22	36.45	36.76	37.27	37.00	41.00	-	-	-
Mean weight (g)	42.00	62.89	111.15	179.64	212.70	239.68	256.90	283.26	280.67	304.45	315.84	326.28	328.47	332.84	336.97	349.78	346.85	431.50	-	-	247.04

Table 3. IESNS 2019 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	Number (1E3)	Biomass (1E3kg)	Mean W (g)
11-12	44590	-	-	-	44590	412.5	9.25
12-13	57958	38639	-	-	96596	1197.8	12.40
13-14	9441	28323	-	-	37764	561.7	14.88
14-15	-	146810	-	-	146810	2695.4	18.36
15-16	-	464859	-	-	464859	10005.3	21.52
16-17	-	594723	11894	-	606617	15673.9	25.84
17-18	-	419589	18243	-	437832	12967.7	29.62
18-19	-	330068	123076	-	453145	16237.7	35.83
19-20	-	198315	637012	-	835328	35684.7	42.72
20-21	-	84062	1921406	-	2005468	100276.4	50.00
21-22	-	-	3692469	-	3692469	215843.3	58.46
22-23	-	-	5473191	-	5473191	377116.2	68.90
23-24	-	-	4352376	22827	4375204	342148.5	78.20
24-25	-	-	956706	-	956706	86193.3	90.09
25-26	-	-	122087	-	122087	12114.0	99.23
26-27	-	-	6381	-	6381	638.1	100.00
TSN(1000)	111989	2305387	17314842	22827	19755046	-	-
TSB(1000 kg)	1252.1	65629.6	1161355.4	1529.4	-	1229766.6	-
Mean length (cm)	11.99	16.72	22.05	23.00	-	-	-
Mean weight (g)	11.18	28.47	67.07	67.00	-	-	62.25

Table 4. IESNS 2019 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
15-16	-	-	-	-	-	-	-	-	-	-	-	1414	1414	-	-
16-17	201748	-	-	-	-	-	-	-	-	-	-	-	201748	4521.1	22.41
17-18	401046	-	-	-	-	-	-	-	-	-	-	-	401046	10793.4	26.91
18-19	728972	-	-	-	-	-	-	-	-	-	-	-	728972	24964.6	34.25
19-20	928754	-	-	-	-	-	-	-	-	-	-	-	928754	36072.1	38.84
20-21	522045	1388	-	-	-	-	-	-	-	-	-	-	523433	24431.9	46.68
21-22	220569	-	-	-	-	-	-	-	-	-	-	-	220569	12334.4	55.92
22-23	99456	-	-	13369	-	-	-	-	-	-	-	-	112825	7075.0	62.71
23-24	38055	6732	-	-	-	-	-	-	-	-	-	-	44787	3167.4	70.72
24-25	-	36494	61170	18643	4460	-	-	-	-	-	-	-	120766	10226.7	84.68
25-26	12528	61556	87524	86038	11008	-	-	-	-	-	-	-	258654	25551.0	98.78
26-27	-	109246	146840	177200	41030	9914	-	4265	-	-	-	-	488496	53790.1	110.11
27-28	3427	-	225124	245039	152288	32593	1940	-	2397	-	-	-	662808	83509.6	125.99
28-29	-	-	25770	274957	216755	66846	4182	1835	-	-	-	-	590344	83894.2	142.11
29-30	-	-	37072	121687	270425	75085	17977	-	-	-	-	-	522247	79843.0	152.88
30-31	-	-	47156	41705	104185	39331	6605	3642	-	-	-	-	242625	40925.2	168.68
31-32	-	-	-	33566	21461	29717	1989	32377	-	-	-	-	119110	21843.1	183.39
32-33	-	-	-	-	8489	6589	4237	2909	970	-	997	-	24191	4666.4	192.90
33-34	-	-	-	-	-	10386	1888	-	-	3944	-	-	16218	3382.1	208.54
34-35	-	-	-	-	-	-	-	-	4543	-	-	-	4543	1065.6	234.58
35-36	-	-	-	-	1058	2115	-	-	-	-	-	-	3173	928.0	292.47
36-37	-	-	-	-	-	-	-	5123	2115	-	-	-	7239	1912.6	264.22
TSN(1000)	3156598	215417	630655	1012205	831158	272577	38819	50152	10025	3944	997	1414	6223961	-	-
TSB(1000 kg)	123807.7	22738.5	74785.7	131456.3	122102.7	41704.6	6033.0	9147.8	2094.0	826.0	201.2	-	-	534897.5	-
Mean length (cm)	18.86	25.28	26.70	27.46	28.57	29.22	29.75	31.17	32.92	33.00	32.00	15.00	-	-	-
Mean weight (g)	39.22	105.56	118.58	129.87	146.91	153.00	155.41	182.40	208.87	209.46	201.75	-	-	-	85.96

Figures

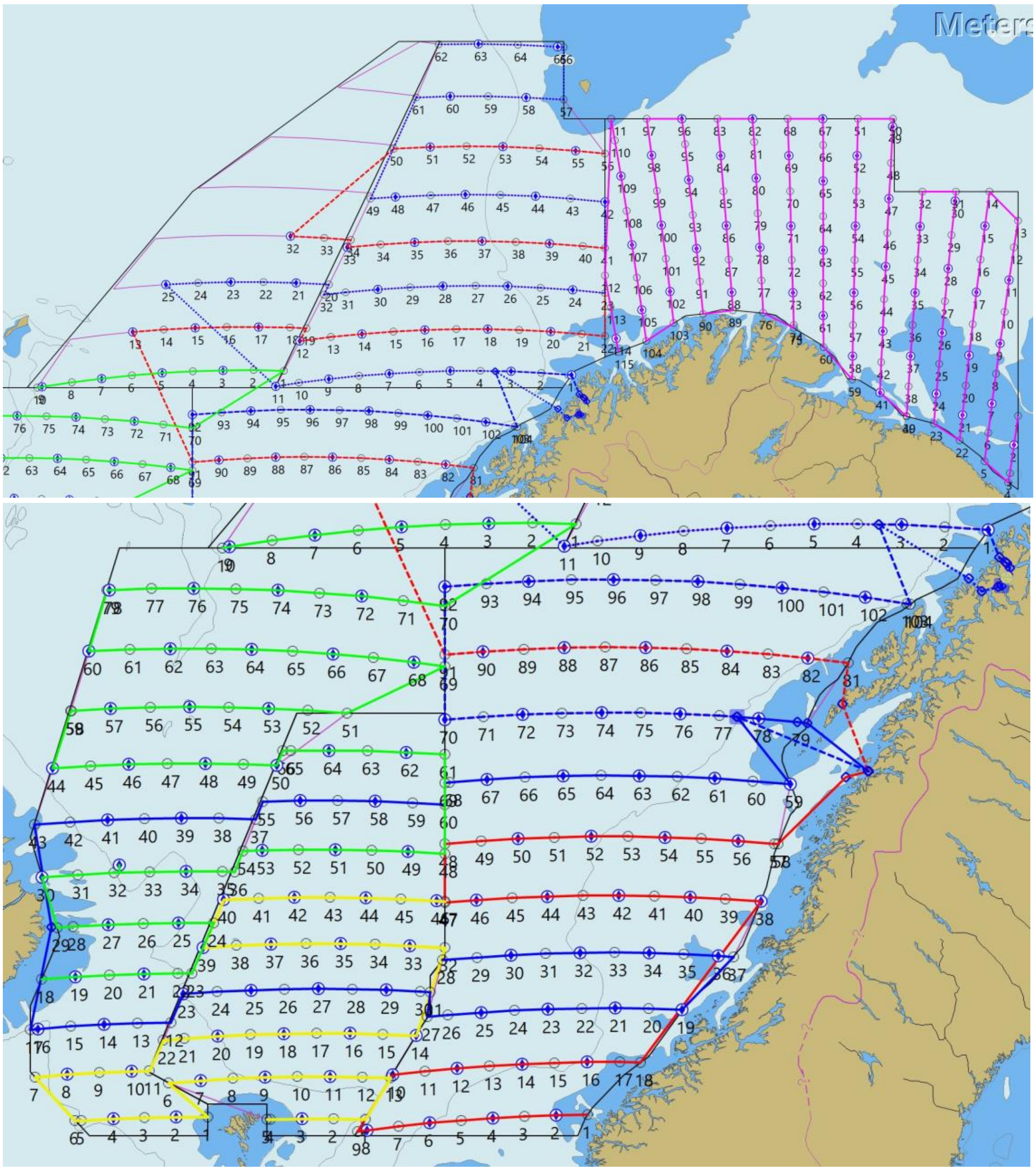


Figure 1. The pre-planned strata and transects for the IESNS survey in 2019 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends.

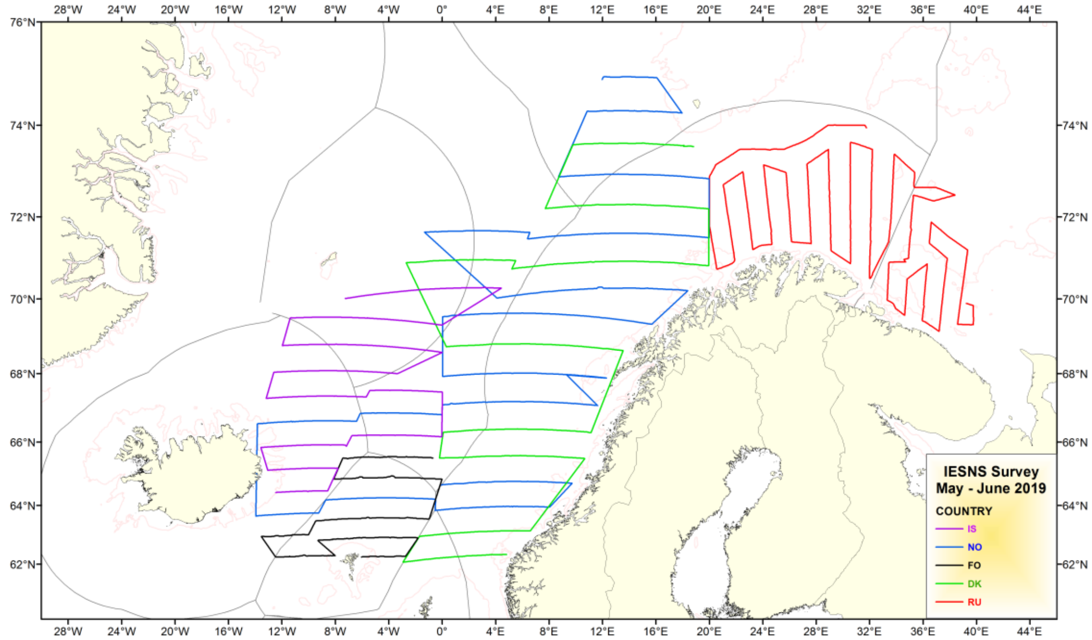


Figure 2. Cruise tracks for the IESNS survey in May 2019.

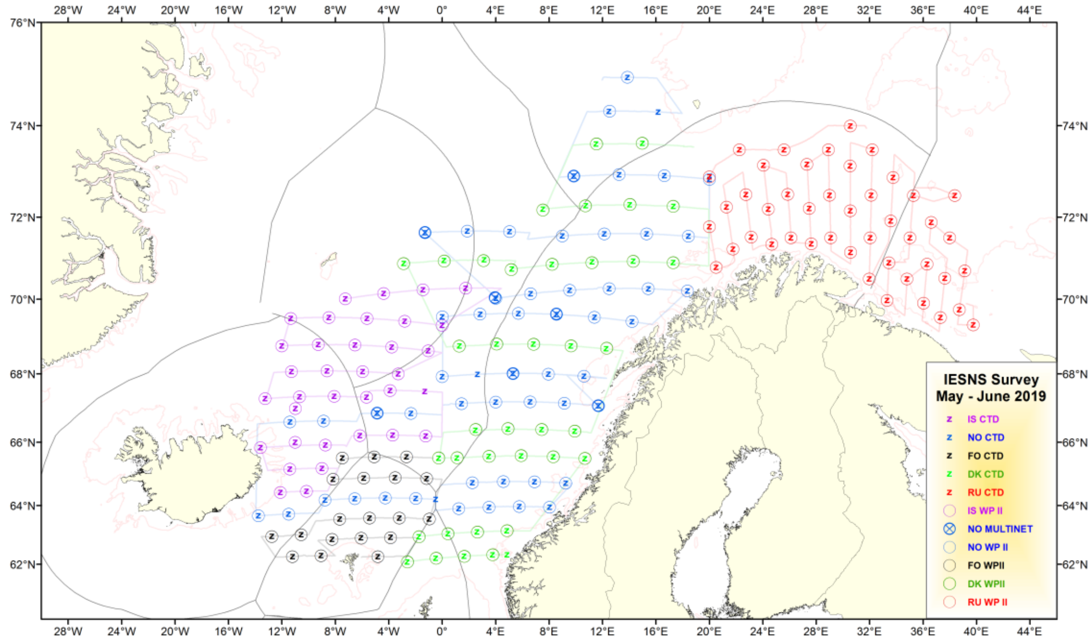


Figure 3a. IESNS survey in May 2019: location of hydrographic and plankton stations.

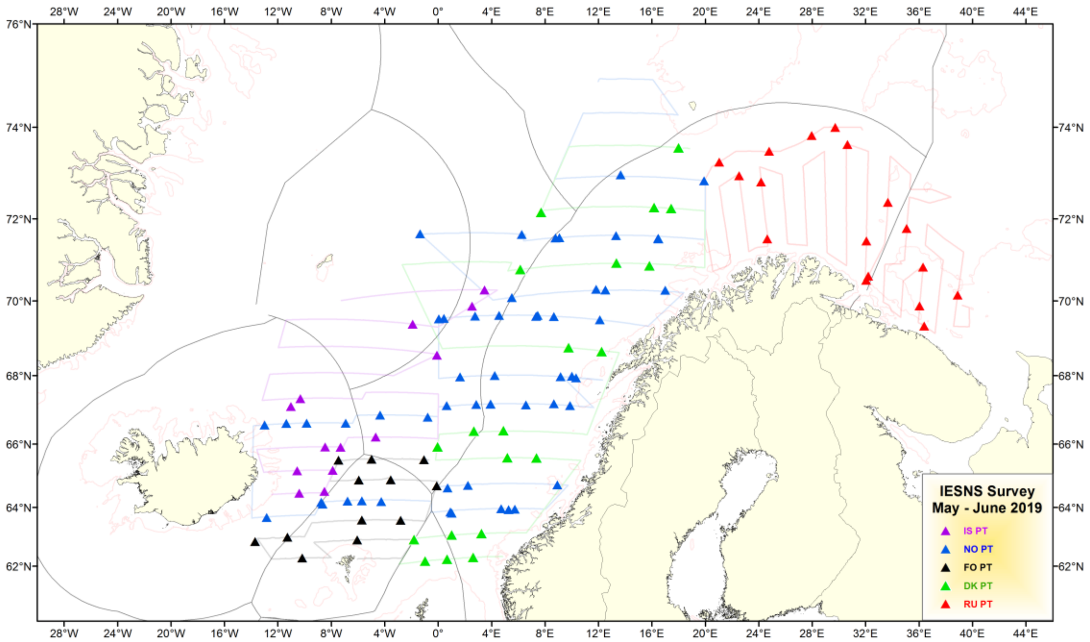


Figure 3b. IESNS survey in May 2019: location of pelagic trawl stations.

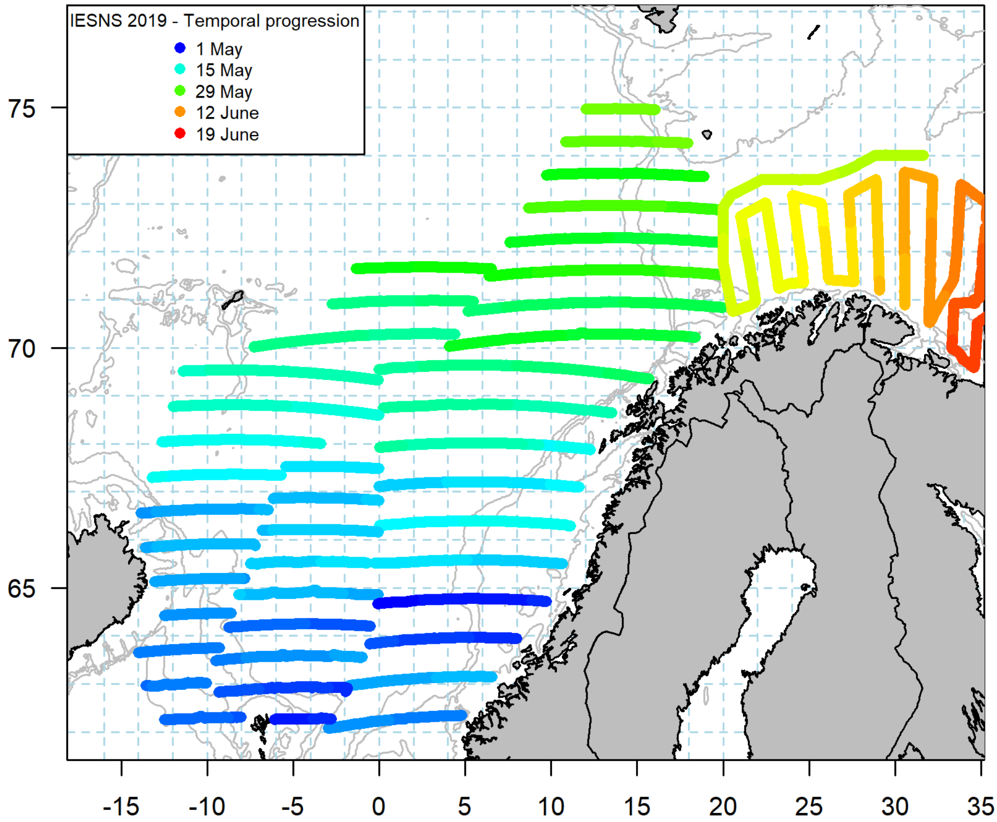


Figure 4. Temporal progression IESNS in May-June 2019.

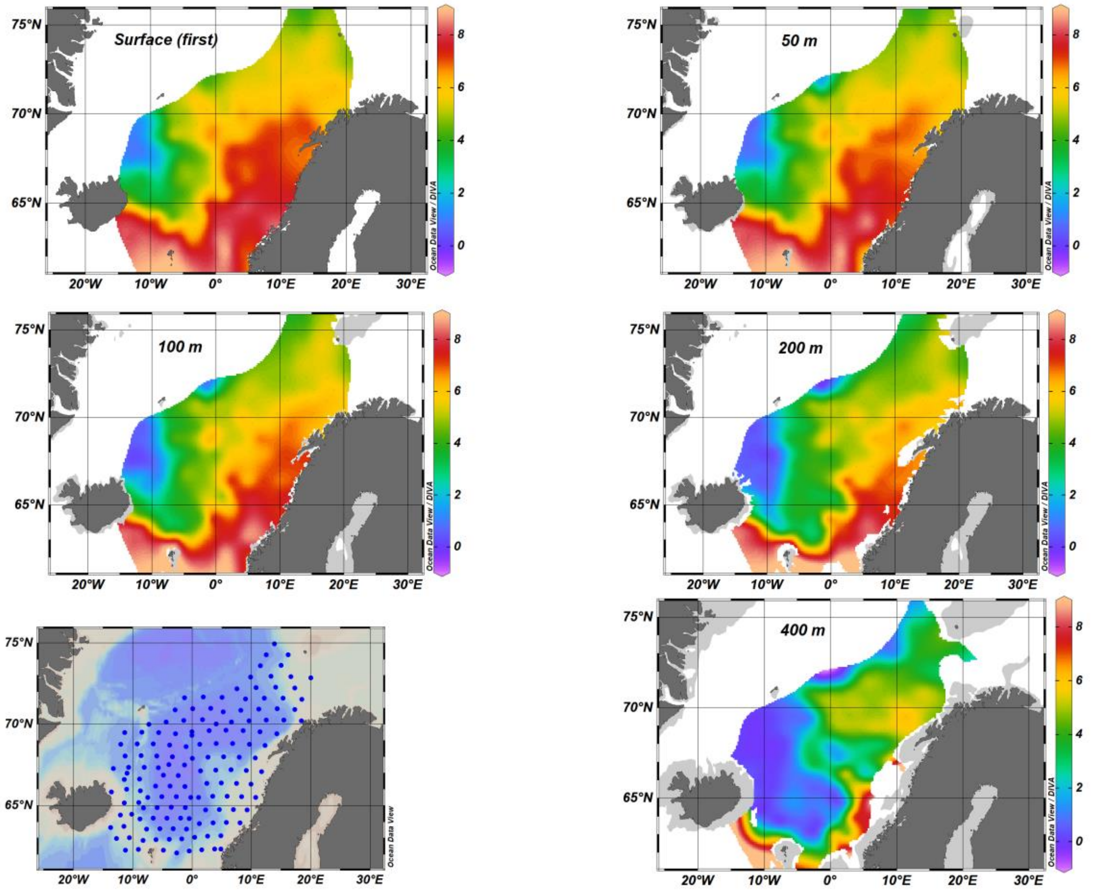


Figure 5. The horizontal distribution of temperatures (°C) at surface, 50m, 100m, 200m and 400m depth in IESNS in May-June 2019.

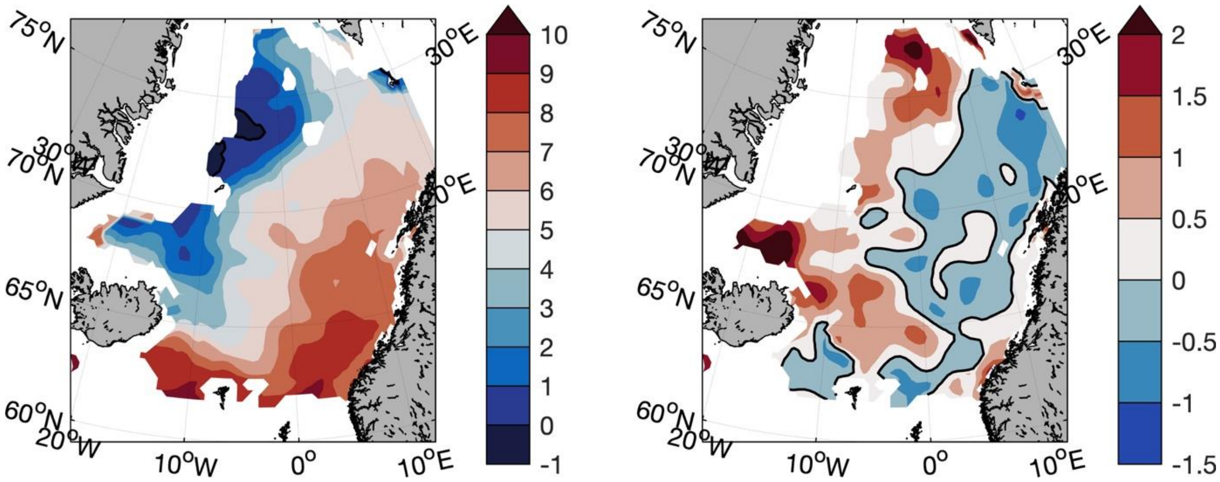


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

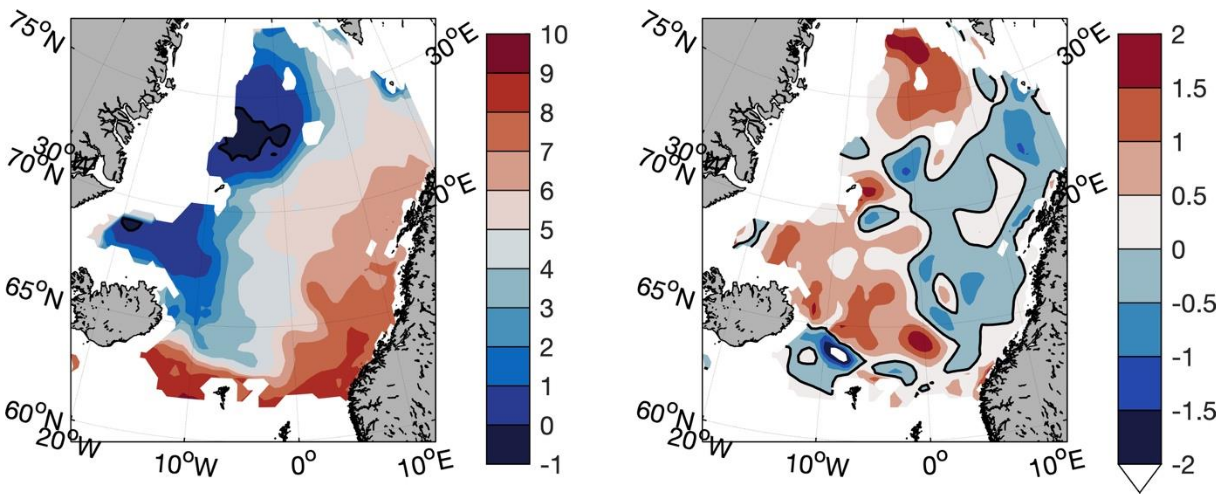


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

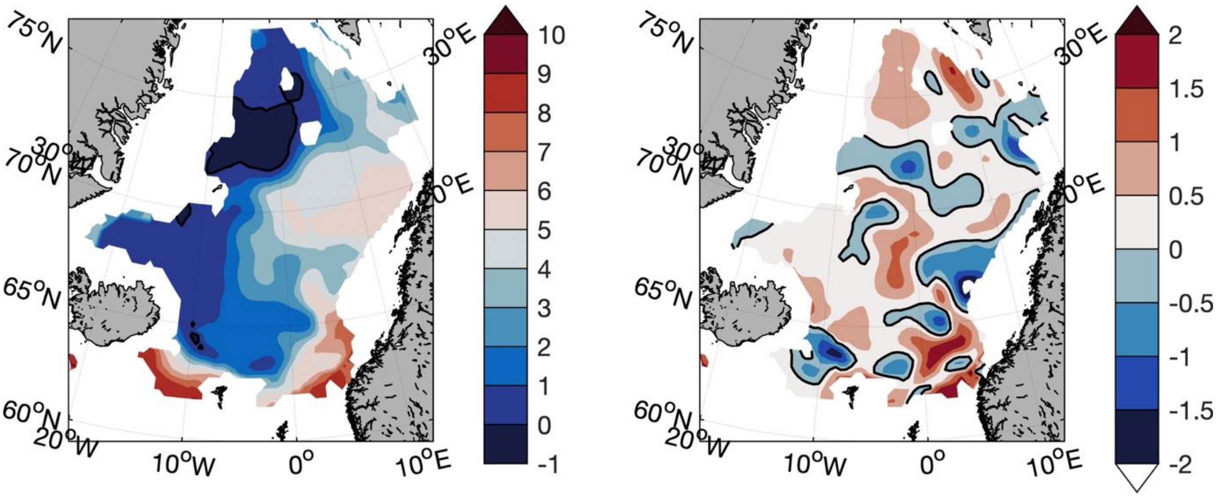


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

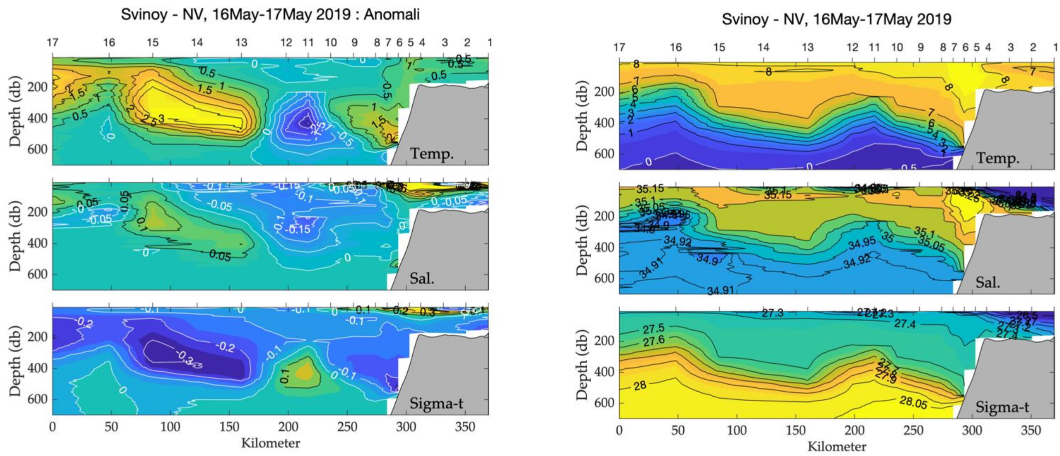


Figure 9. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinøy section, May 2019. Anomalies are relative to a 30 years long-term mean (1978-2007).

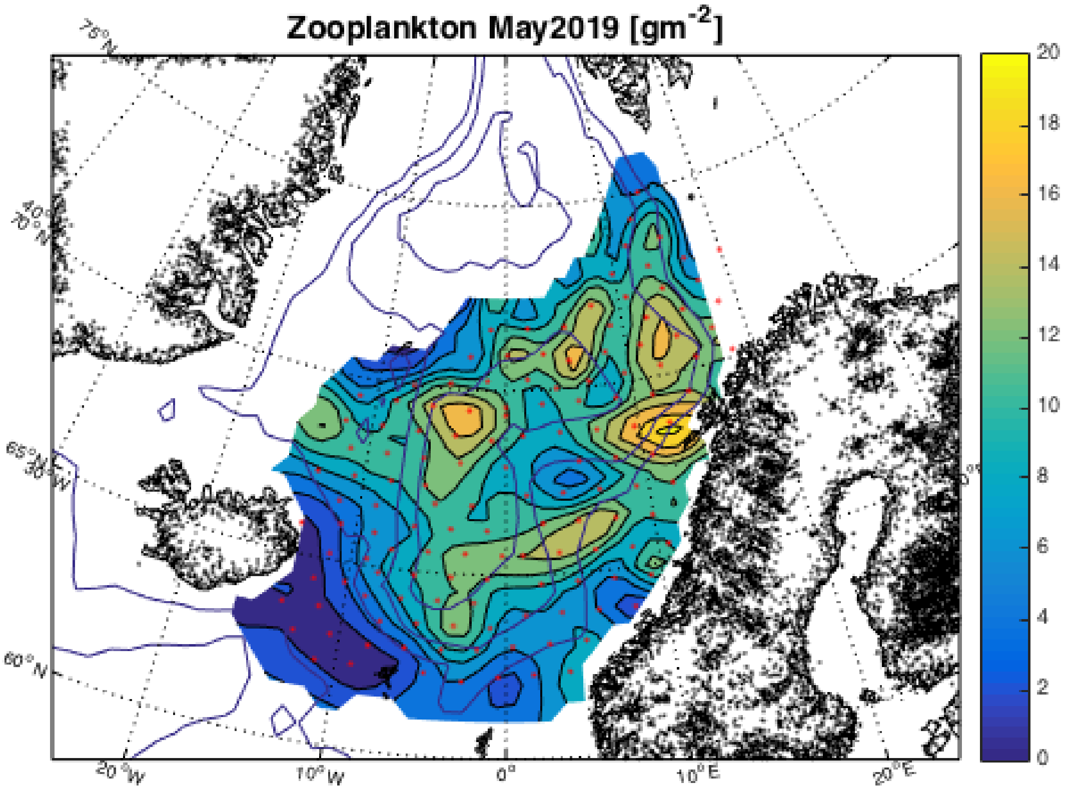


Figure 10. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May 2019.

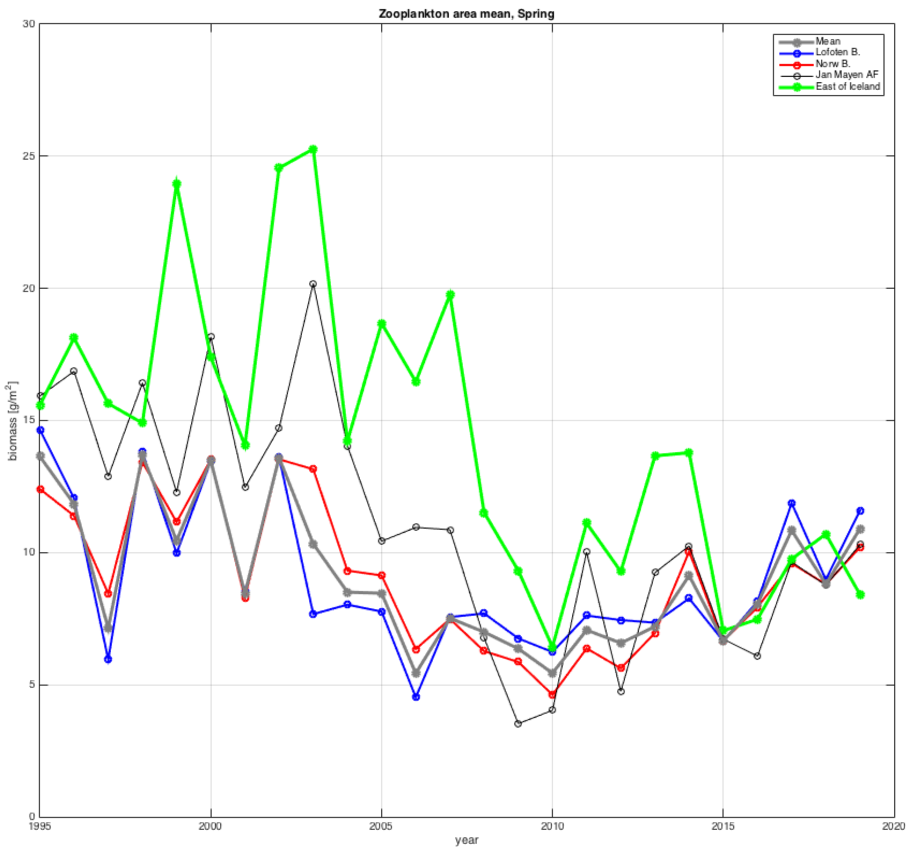
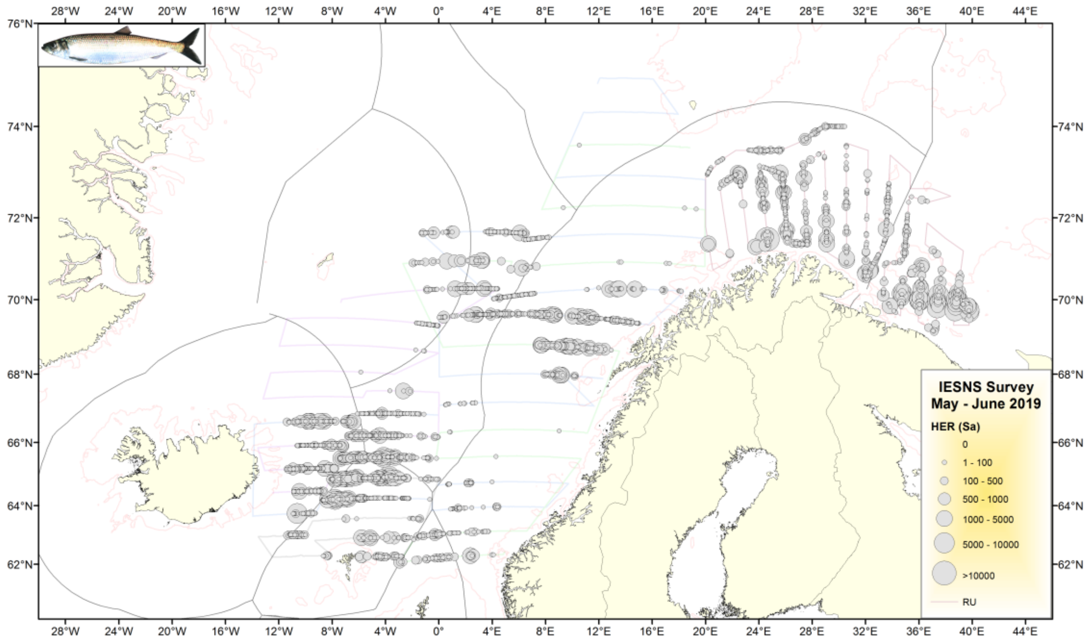


Figure 11. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

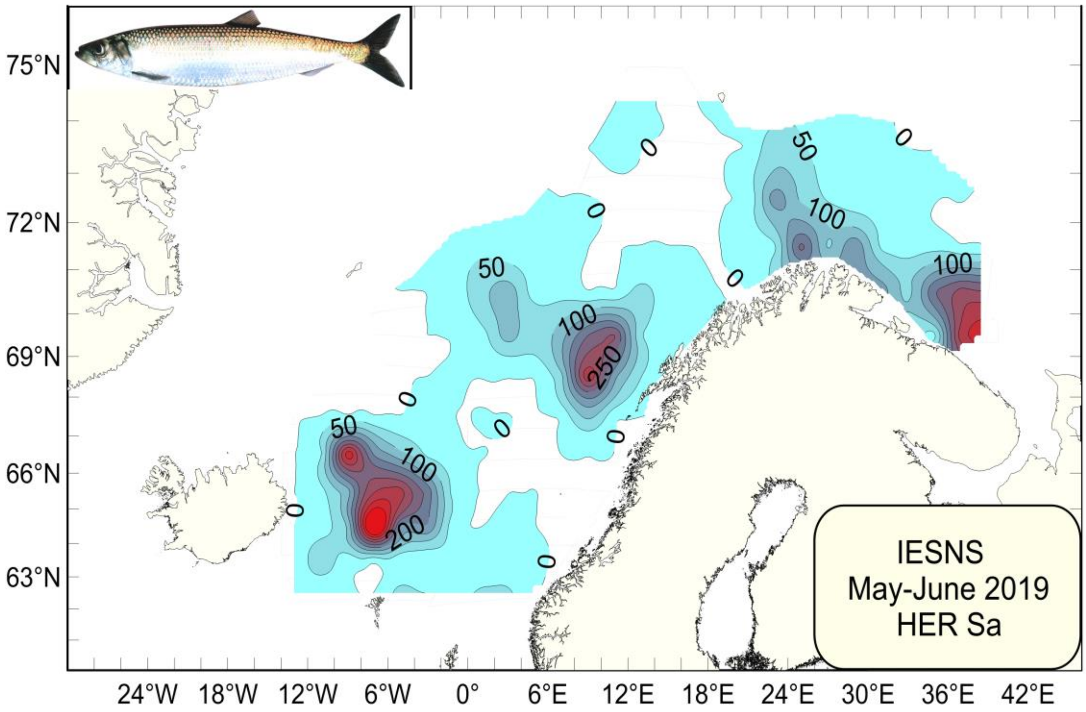


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2019 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile and (b) represented by a contour plot.

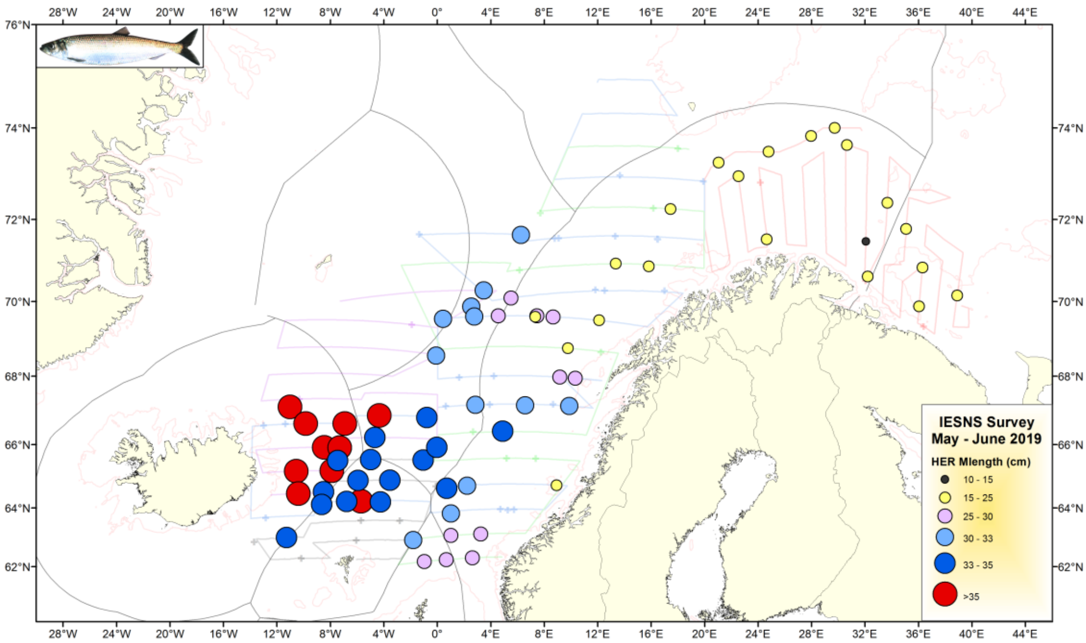


Figure 13. Mean length of Norwegian spring-spawning herring in all hauls in May 2019.

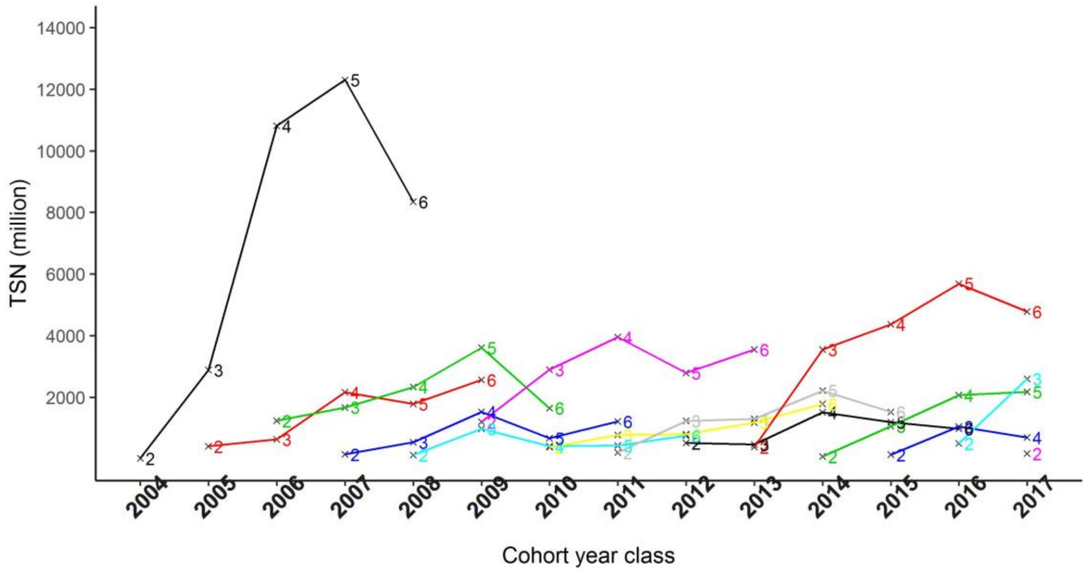


Figure 14. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

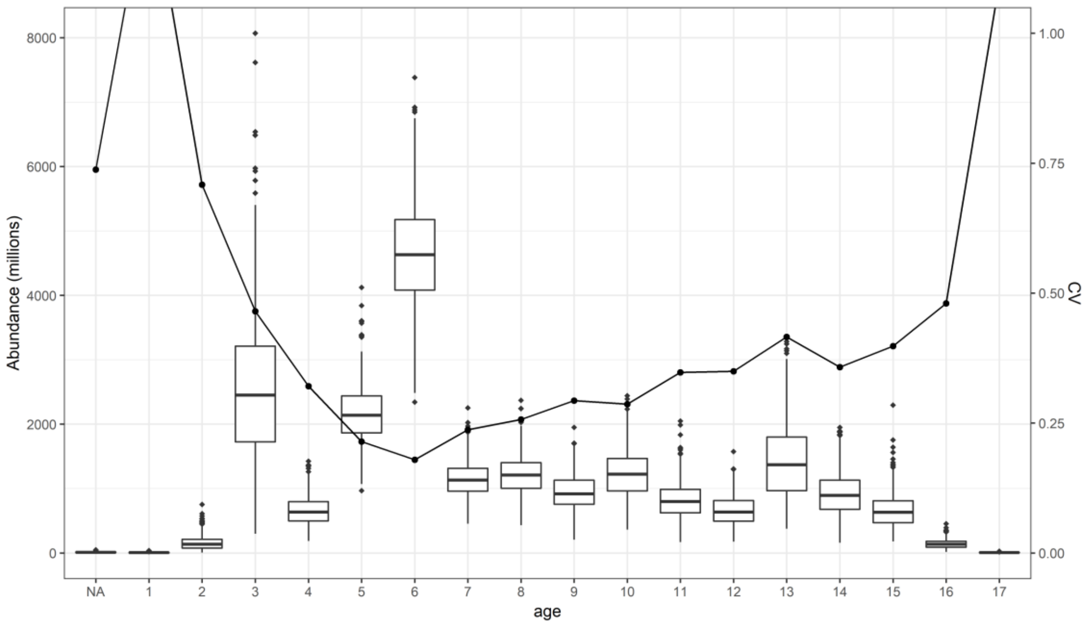


Figure 15. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

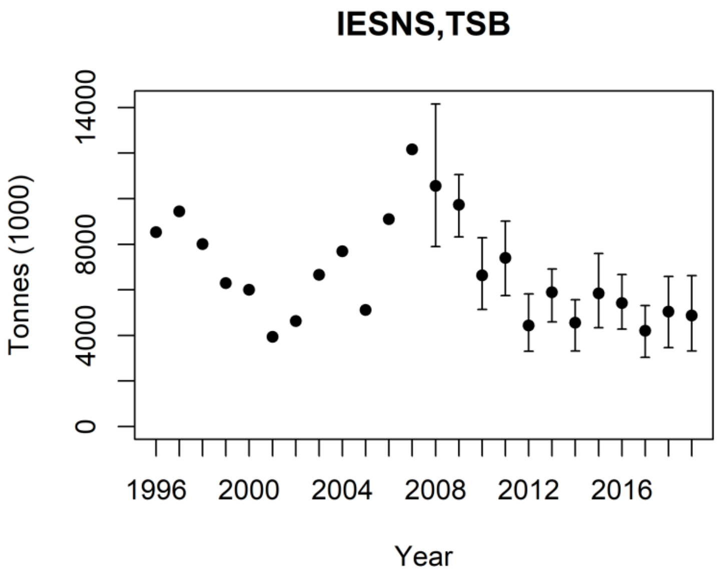


Figure 16. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2019 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2019; with 90% confidence interval; calculated on basis of standard stratified transect design).

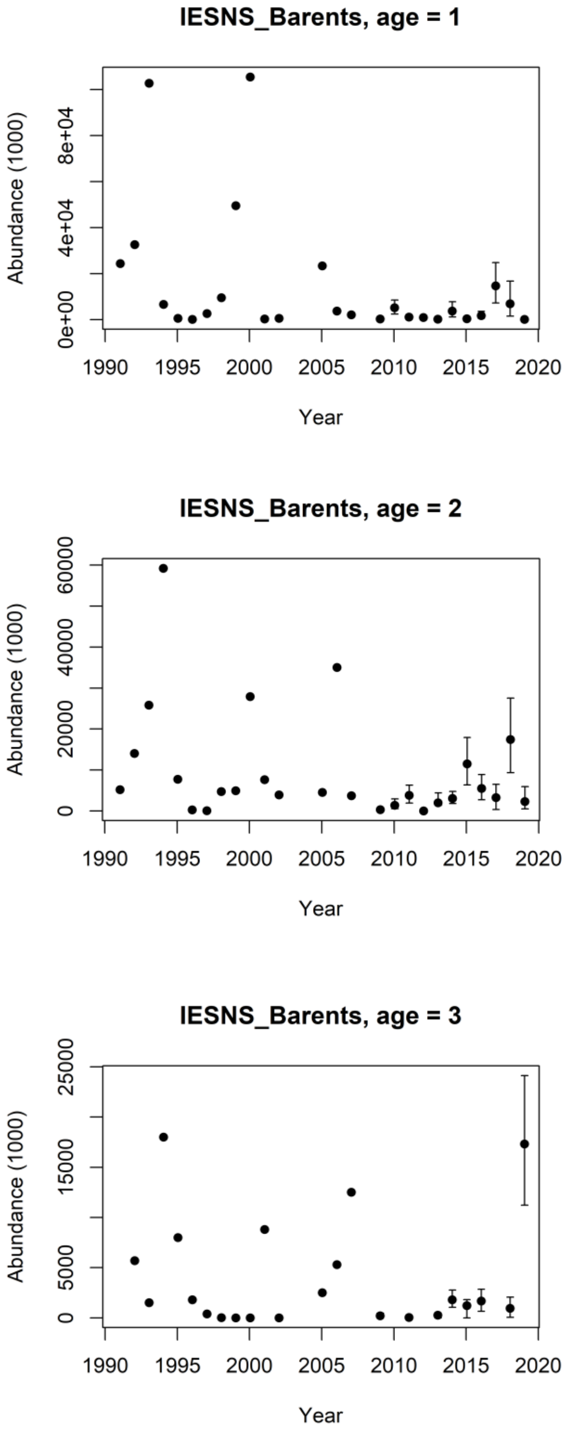
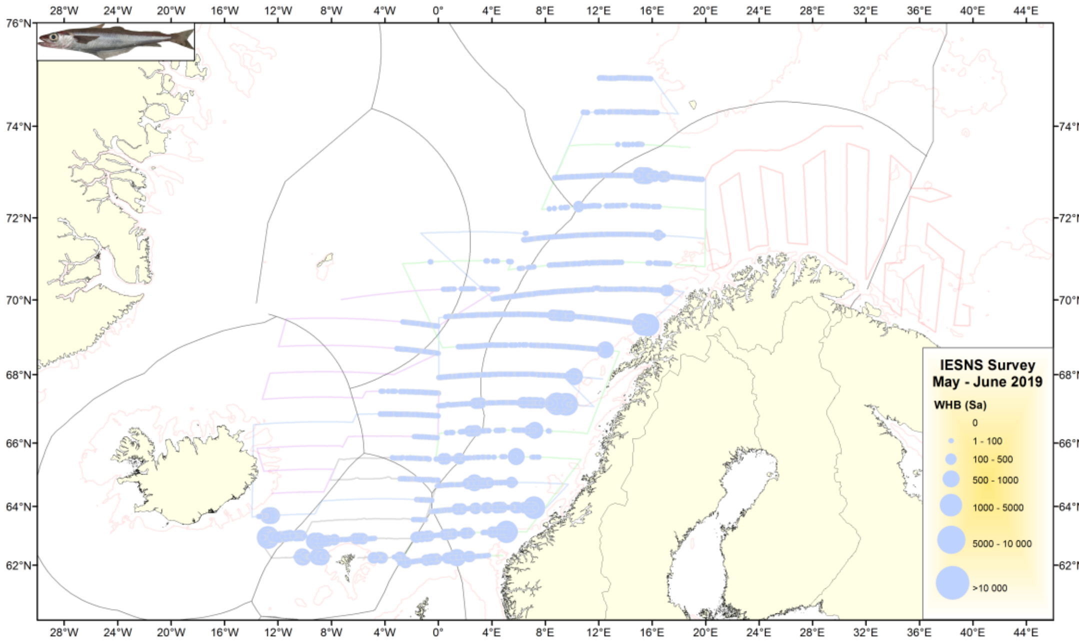


Figure 17. Numbers at age 1-3 herring in the Barents Sea in April-June. From 2009 onwards StoX has been used and the error bars indicates 90% confidence intervals.

(a)



(b)

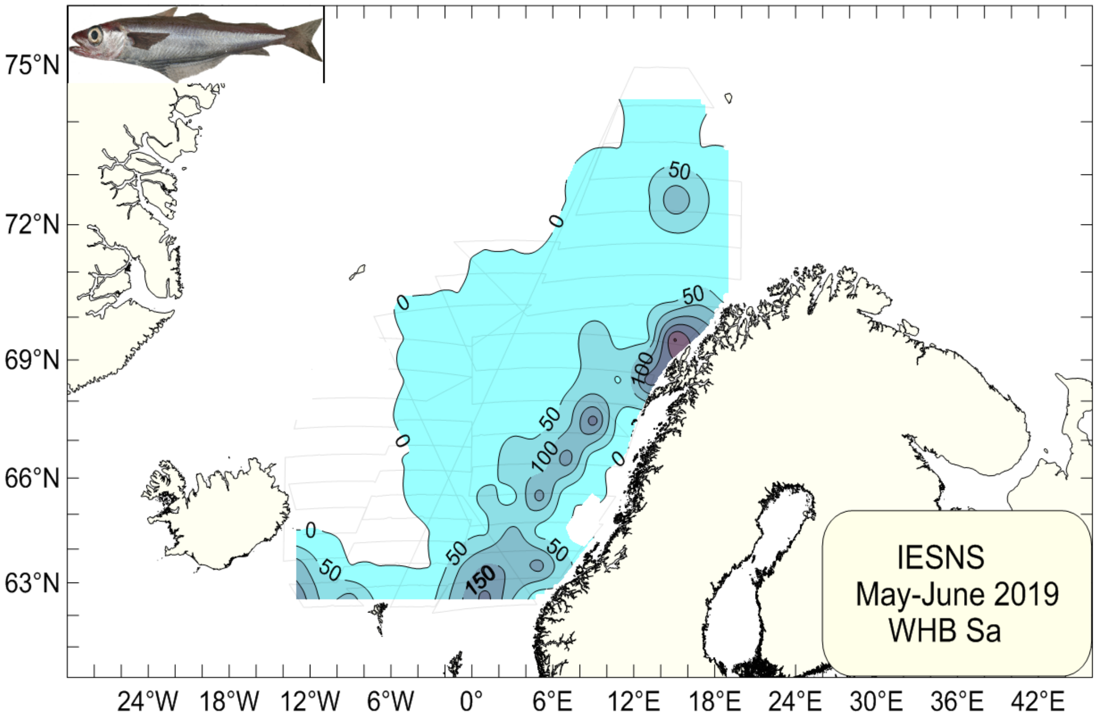


Figure 18. Distribution of blue whiting as measured during the IESNS survey in May 2019 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. Note that the coverage in the Barents Sea is not included in b.

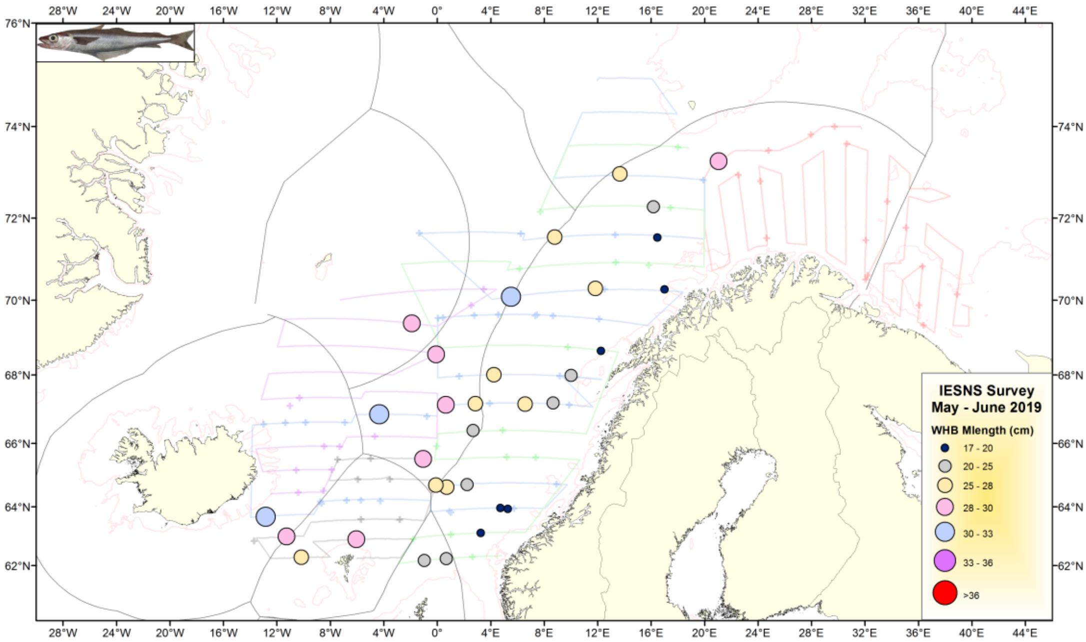


Figure 19. Mean length of blue whiting in all hauls in IESNS 2019.

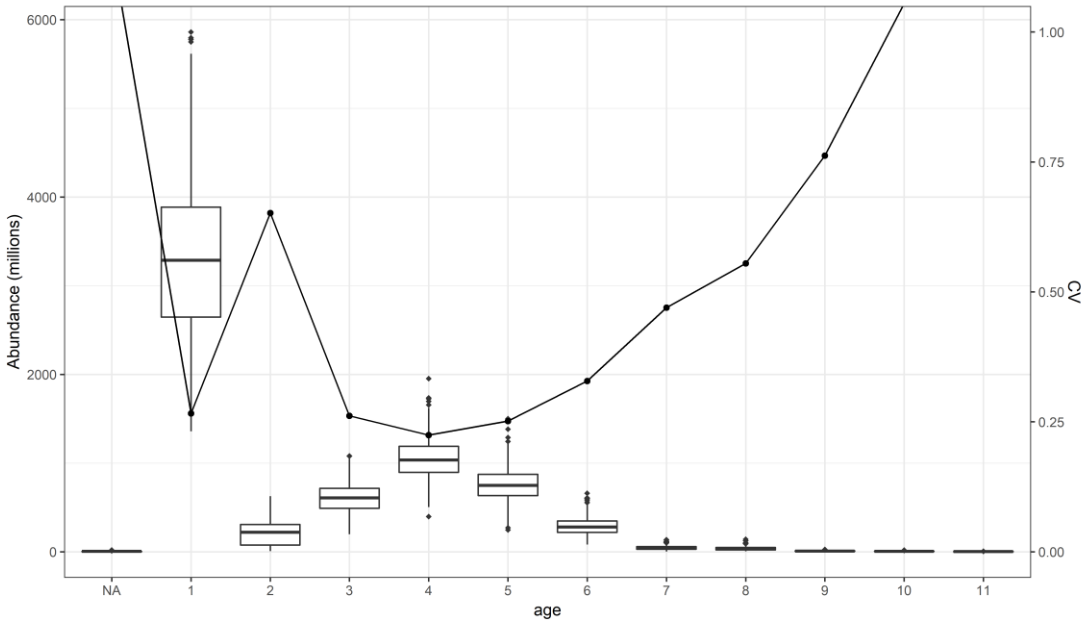


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

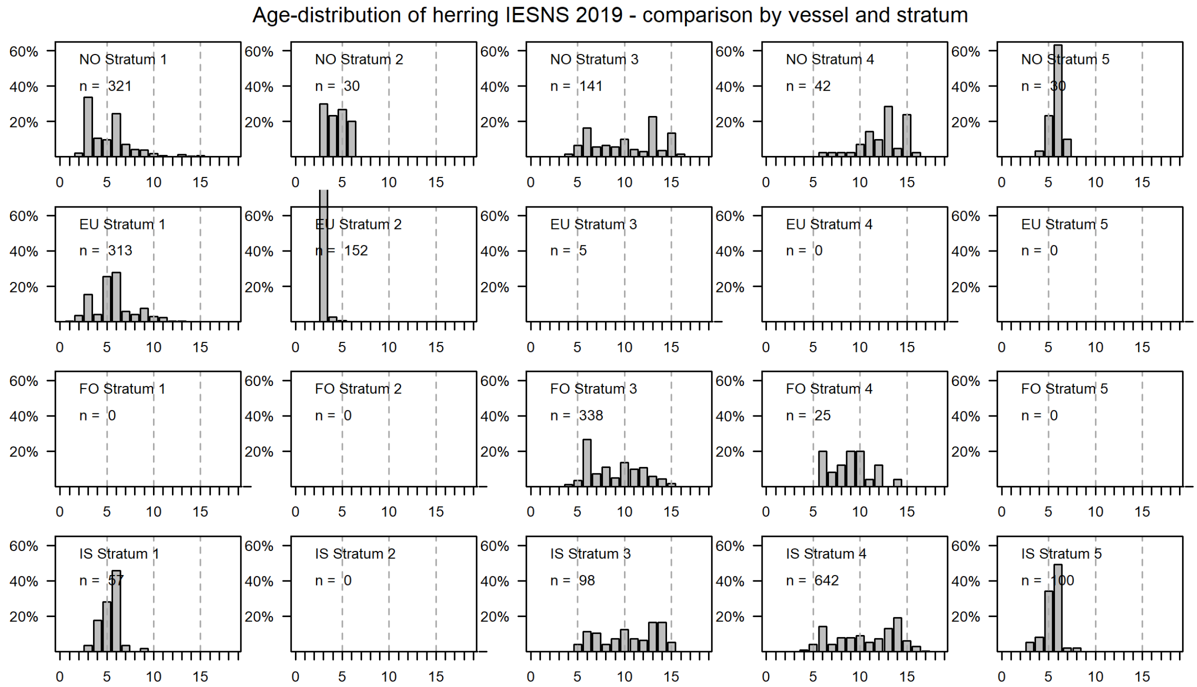


Figure 21. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2019. The strata are shown in Figure 3.

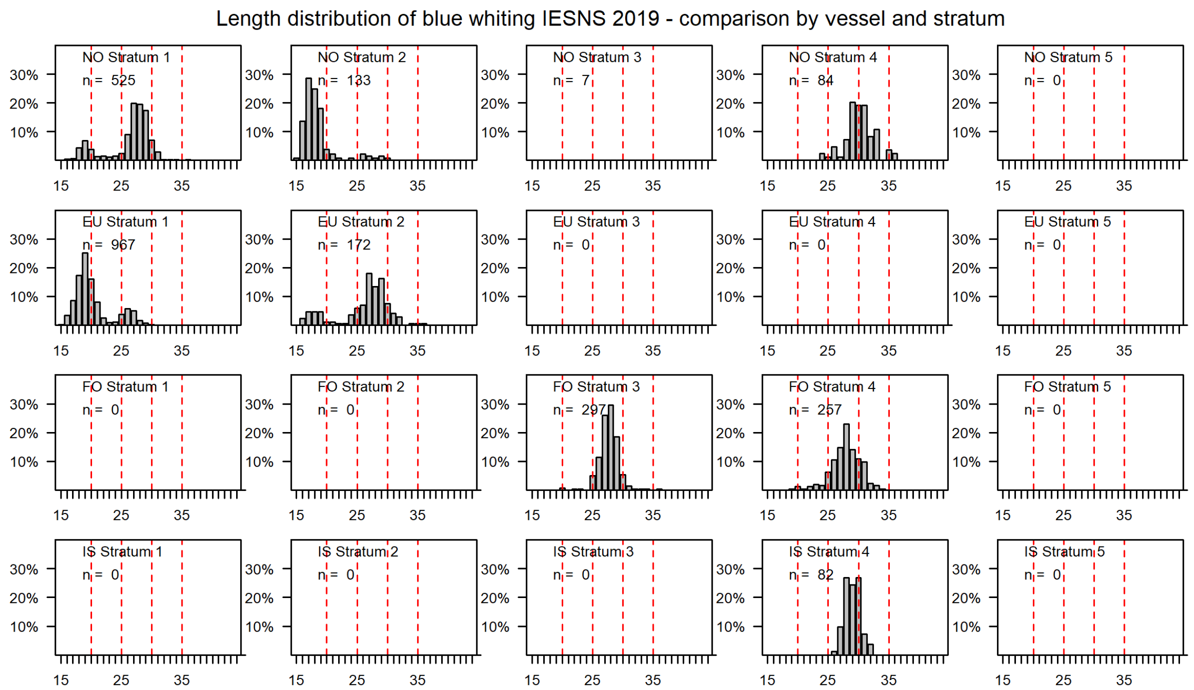


Figure 22. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2019. The strata are shown in Figure 3.

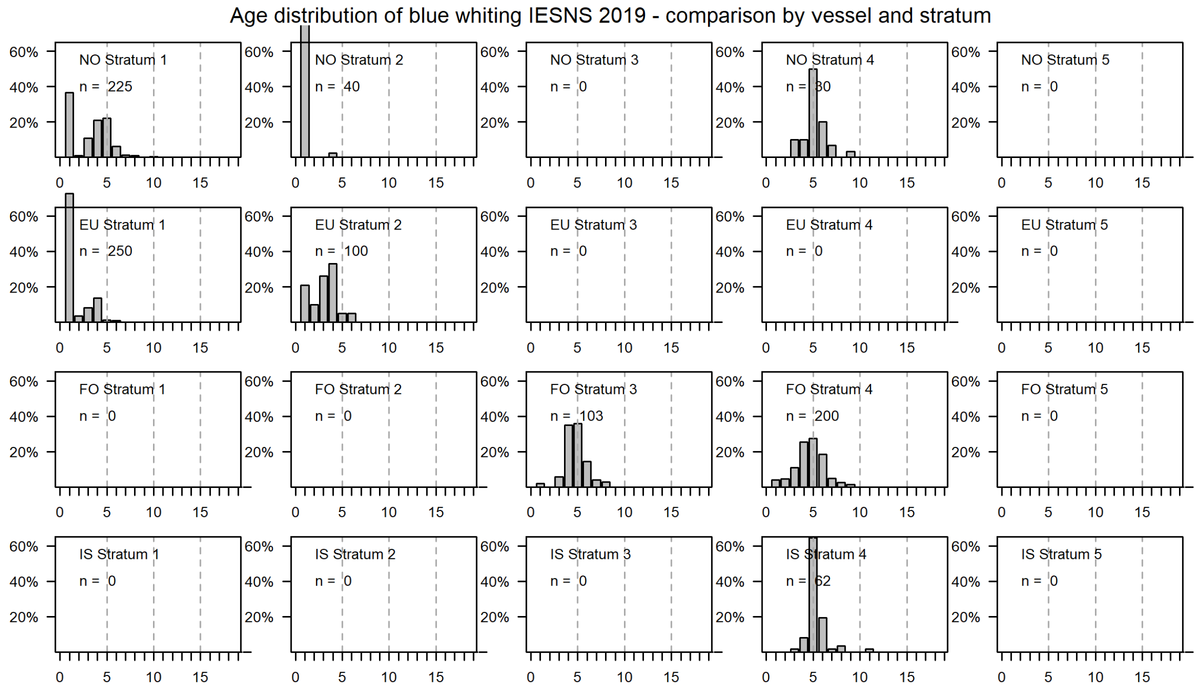


Figure 23. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2019. The strata are shown in Figure 3.

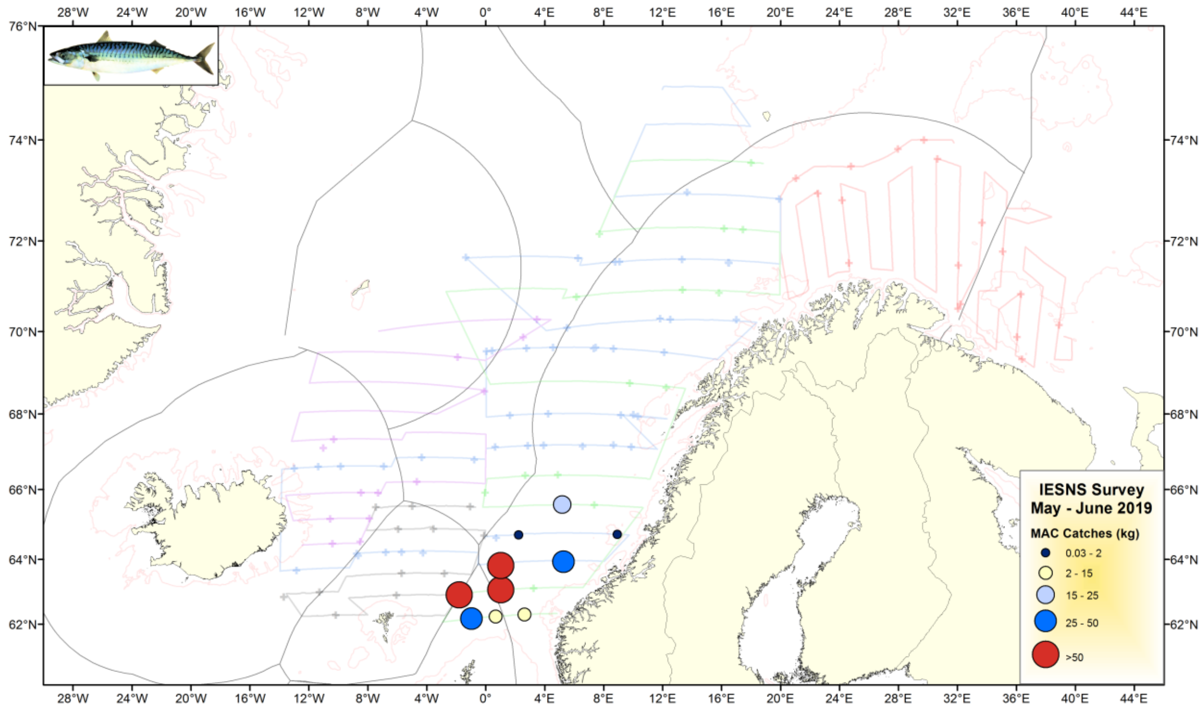


Figure 24. Pelagic trawl catches of mackerel in IESNS 2019.

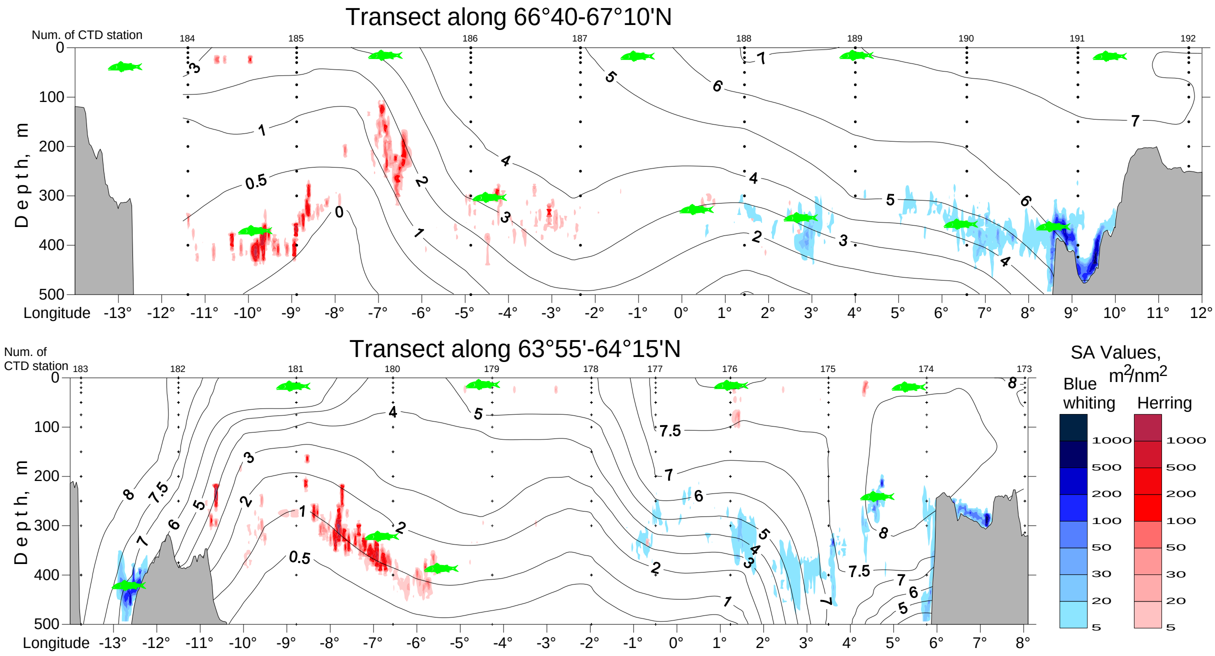


Figure 25. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2019, covered by "G.O. Sars".

WGWIDE 2019

Issues regarding updated version of RFID-tag data 2019

By Aril Slotte

Background and objectives

The RFID tagging started in 2011, the first factories with RFID antennas started working in 2012. Since then there has been a development in both the distribution of factories with RFID antenna systems scanning mackerel landings, but also a development in software solutions to monitor the factories. This WD is describing data excluded from the estimation of the tag table going into the assessment, and the reasoning behind it. It is also describing the differences in recapture rates between factories over the time series. In the 2019 intermediate benchmark it was decided to exclude release data from release years 2011-2012, and hence recaptures from 2012-2013 entirely from the stock assessment. This was due to observed bias in recaptures with number of years after release. This subset of data used in the model has, however, no effect on the tag table itself. This still includes data from all years to be able to keep studying the bias with the objective to perhaps treat the bias within the model and include all data at a later stage.

Exclusions of experiments and factories having issues with efficiencies in estimation of tag file

Experiments excluded from the assessment are 1 off the Norwegian coast in 2011, only targeting young mackerel, mostly the 2010 year class. Also excluded are all experiments in Iceland 2015-2017.

Factories excluded from the time series due to very low efficiency in WGWIDE 2018 were:

- Pelagia Austevoll 2012-2017
- Pelagia Egersund 2014-2017
- Lunar Freezing Fraserburgh 2014-2017

These three factories were included again in 2018 scannings due to high efficiency in the large scale testing (Table 1), and normal recapture rates (Figure 8)

In autumn 2018 a large scale test program were initiated, where each factory got a test material of 100 tags, 10 tests of 10 tags and a tagging gun. They got instructions to do 10 different tests where they tagged 10 fish and released them into the RSV tanks of the vessel landing the catch. In Table 1 these tests are summarized. Based on these tests it was decided to exclude 4 factories from 2018:

- Brødrene Sperre
- Vikomar (new factory)
- Grøntved Pelagic (new factory)
- Lofoten Viking (new factory)

After excluding these factories, the mean efficiency was estimated to 93%, which is an acceptable efficiency. However, one cannot be sure this efficiency has been the same backwards in time for all factories, there has been some services etc. There are 3 factories that a not touched, fixed or serviced after initiation, and that still had high efficiencies in the test, these are Vopnafjord at Iceland, Pelagia Shetland in Scotland, Pelagia Liavaagen in Norway. This is something one may have in mind when comparing recapture rates between factories back in time.

Differences in recapture rates between factories

In Figure 1 is given an overview of the recaptures rate (in terms of number of tons scanned per recaptured fish) development at the different factories over the time series, here including recaptures from all experiments. The figure suggests a potential problem in 2012, with very variable recapture rates compared with the other years; a solution may be to exclude this year from the data. The more detailed figures per year 2012-2018 (Figures 2-8) indicate that there still is variability also in years 2013-2018, but at a level perhaps more acceptable. The variability may be due to differences in efficiencies like shown in Table 1, but also differences in year classes scanned, this is not addressed when looking more roughly at recapture rates.

Corrections in numbers scanned in the updated RFID data for interbenchmark

Over the time series there has been development int the software used to monitor all the factories. In autumn 2013 one decided to store conveyor belt tag data for those factories having tags incorporated into the conveyor belt. The idea was that one would follow the production making sure the system was operating during a landing by looking at how many times the tag in the conveyor belt was passing the antenna. It turned out that the software solution, a web solution to monitor the factories could cope properly with all the data produced, also there were other issues with slow processes between data going in and out of database and all analyses and estimation need for producing the tag table going into the assessment. Therefor a process with development of new quicker web solutions was started, and the new solutions was ready in 2018. This solution handles all conveyor belt statistics very well, and there for the interbenchmark process these data were looked at with the purpose of finding mis-match, or discrepancies in the data. Factories that seemed to have comparatively lower recapture rates than others were looked at and landing data corrected. For all figures 1-8, data shown is based on an update data set where some discrepancies have been fixed.

What has been done is as follows. In factories with conveyor belt tags, if there were periods where the conveyor tag was not detected, unstable, and where no recaptures were coming in, but landing data had been reported, then landing data were removed from the database. This counts for the following years and factories and will reduce the numbers scanned in tag table:

- 2013, Skude Factory, landings removed from 8-28.1, in total 4410 t
- 2014, Brødrende Sperre, landings removed from 23.2 and 30.9-22.10, in total 11495 t
- 2014, Pelagia Måløy, landings removed from 3-4.2 and 27.8-24.9, in total 9793 t
- 2015, Pelagia Florø, landings removed from 25.10-18.11, in total 6318 t
- 2015, Skude Factory, landings removed from 30.10-20.11, in total 2204 t
- 2016, Pelagia Selje, landings removed from 10-16.1, in total 2827 t
- 2016, Vardin, landings removed from 16.9-6.10, in total 2200 t
- 2017, Brødrene Sperre, 10-25.1, and 12.9-16.10, in total 21433 t

Use of age samples to estimate numbers scanned by year class in landings

Up to now Icelandic biological samples with age data has been used to allocate to the landings in the estimation of numbers scanned per year class in their landings. Same for Faroes, the nation's own biological data. However, Scottish biological data have not been available in right format yet, and Norwegian biological data from same area and period has been allocated to both landings at Scottish factories and Norwegian. In the future we aim to use Scottish biological data to allocate to the Scottish landings in Scotland.

Table 1. Overview of tests of efficiency of RFID antenna systems. Red, not included due to issues with antenna systems. Green not included, mainly herring landings.

Factory	N-tests	Efficienc	Potential problem
DK01 Sæby	0		Not online -not included
FO01 Vardin Pelagic	0		Burned down
GB01 Denholm Coldstore	10	84,0	Some issues with noise -unstability - still included
GB01 Denholm Factory	9	95,6	
GB02 Lunar Freezing Peterhead	10	99,0	
GB03 Lunar Freezing Fraserburgh	8	91,3	Not included up to 2017 - included from 2018
GB04 Pelagia Shetland	10	99,0	
GB05 Northbay Pelagic	10	88,0	Some issues with noise -unstability
IC01 Vopnafjord	10	98,0	
IC02 Neskaupstad	5	74,0	Increased production speed with 36% in 2018, some detection problems, still included
IC03 Höfn	0		Antenna problems -not included
NO01 Pelagia Egersund Seafood	1	91,0	
NO02 Skude Fryseri	1	10,0	New engine prior to Q3-4 create noise problem, include only Q1
NO03 Pelagia Austevoll	10	96,0	
NO04 Pelagia Florø	0		Closed down
NO05 Pelagia Måløy	10	93,0	
NO06 Pelagia Selje	10	97,0	
NO07 Pelagia Liavågen	8	98,8	
NO08 Brødrene Sperre	2	50,0	Unstable - New noise problems autumn 2018, not included
NO09 Lofoten Viking	5	22,0	Unstable - New factory - noise problems autumn 2018, herring focus, not included
NO10 Pelagia Træna	10	96,0	New factory 2018 - high effectivity - focus on herring - not included
NO11 Nergård Sild Senjahopen	0		
NO12 Pelagia Lødingen	2	30,0	New factory - noice problems detected
NO13 Pelagia Tromsø	0		
NO14 Nils Sperre	10	97,0	New factory 2018 - high effectivity - included
NO15 Grøntvedt Pelagic	2	15,0	Noise problems detected, not included
NO16 Vikomar	6	68,3	One of two ring antennas has stopped working 2018, not included
Mean efficiency		**93,0**	

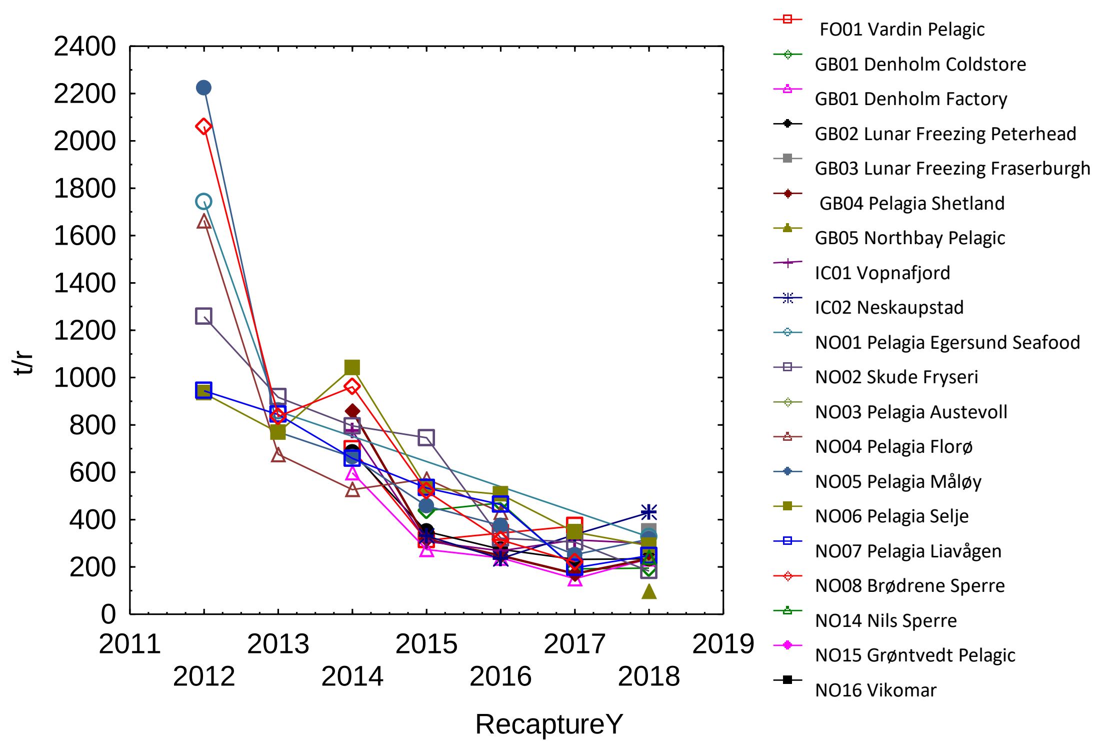


Figure 1. Number of tons scanned per recaptured mackerel (regardless of release year and areas), per recapture year and factory, see Figures 2-8 for details.

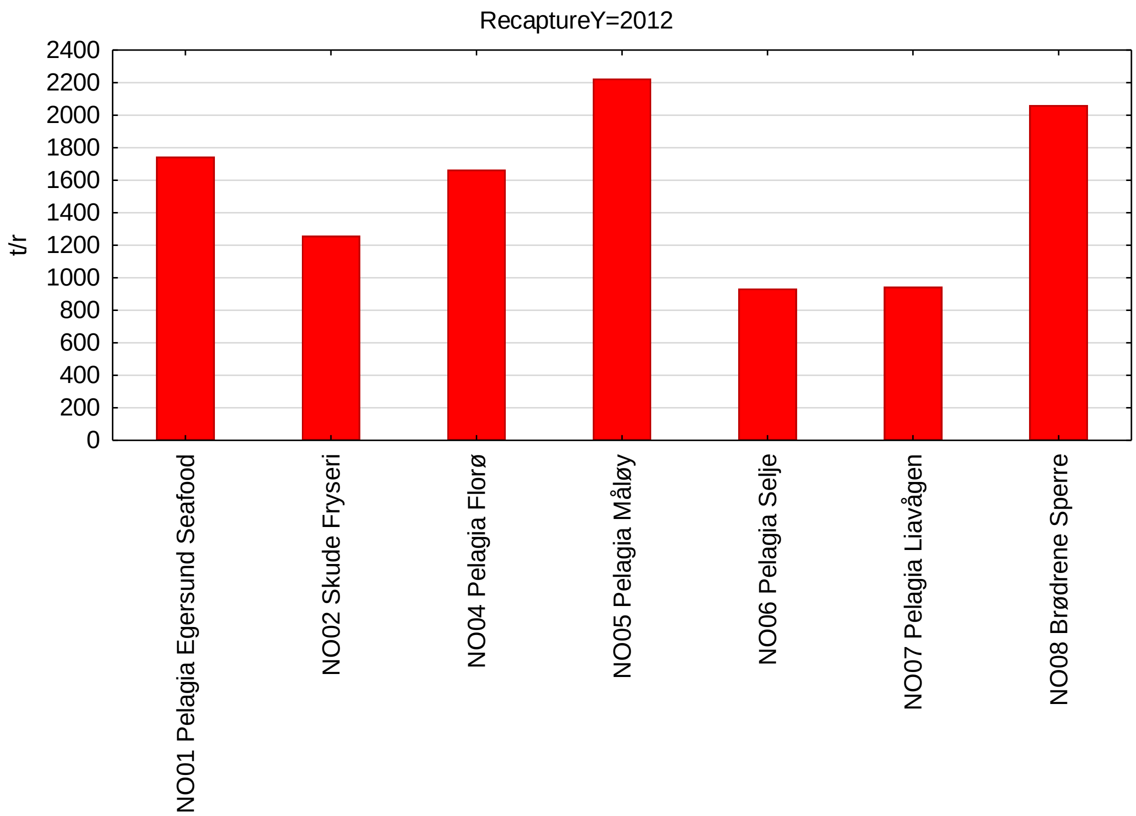


Figure 2. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2012.

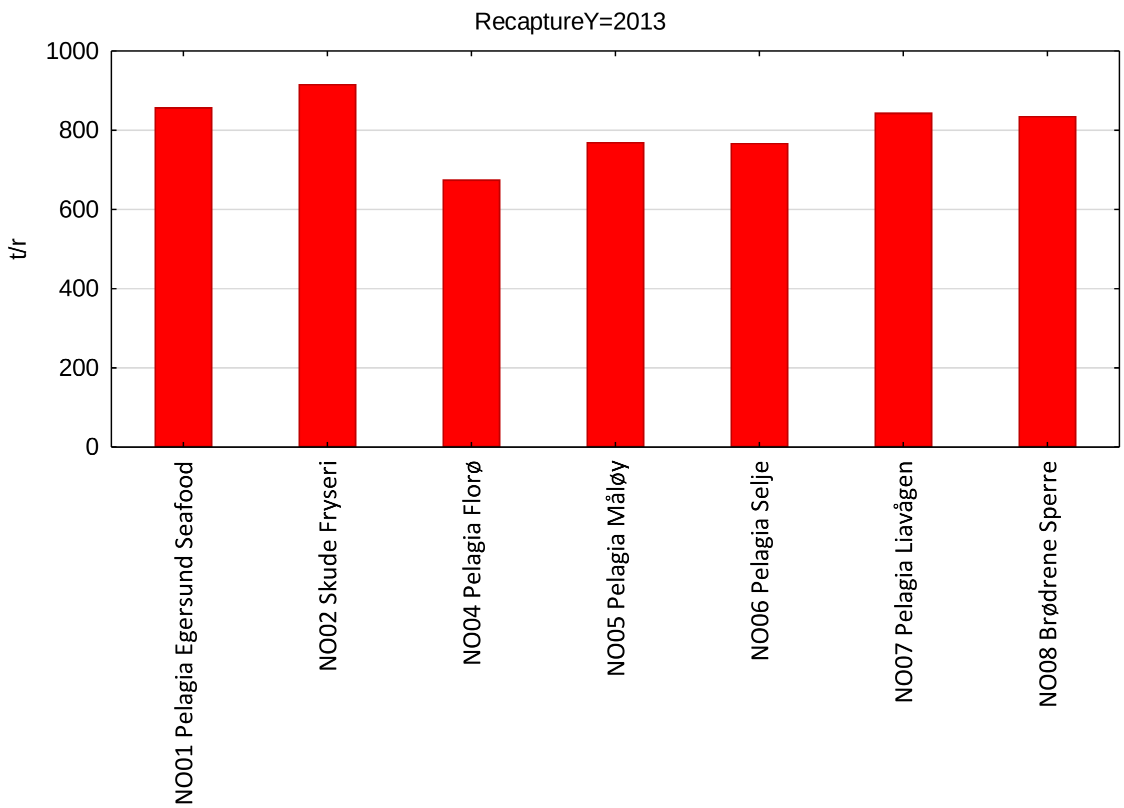


Figure 3. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2013.

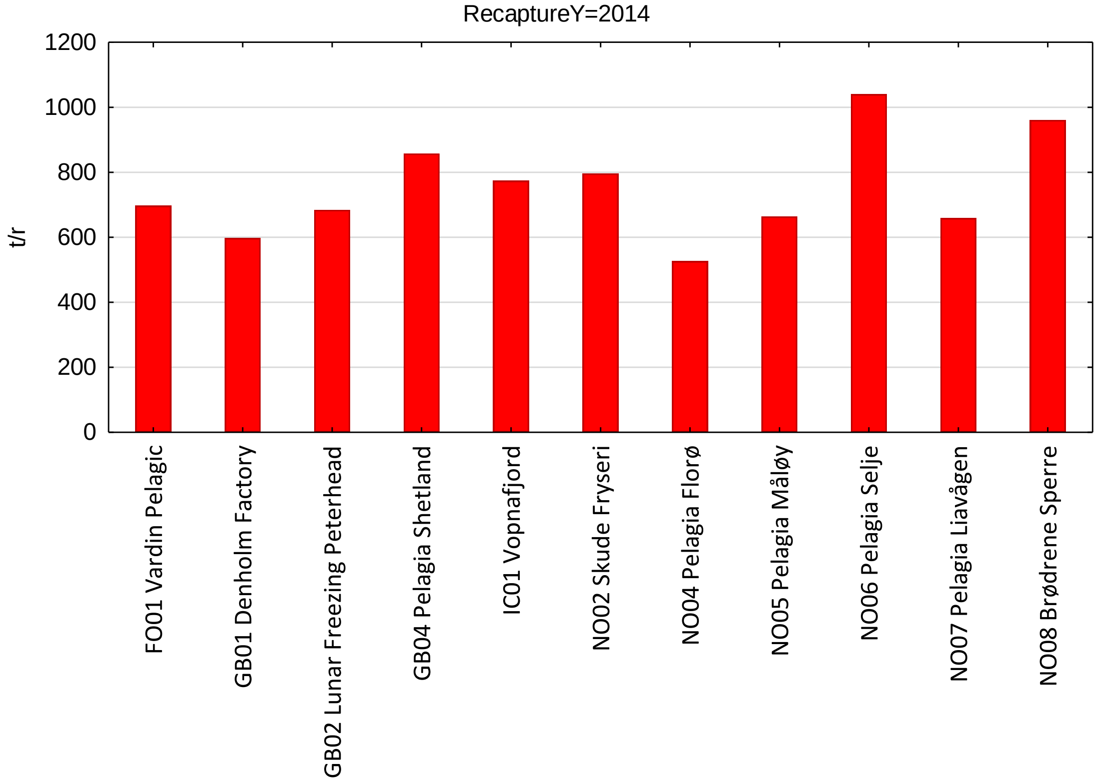


Figure 4. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2014.

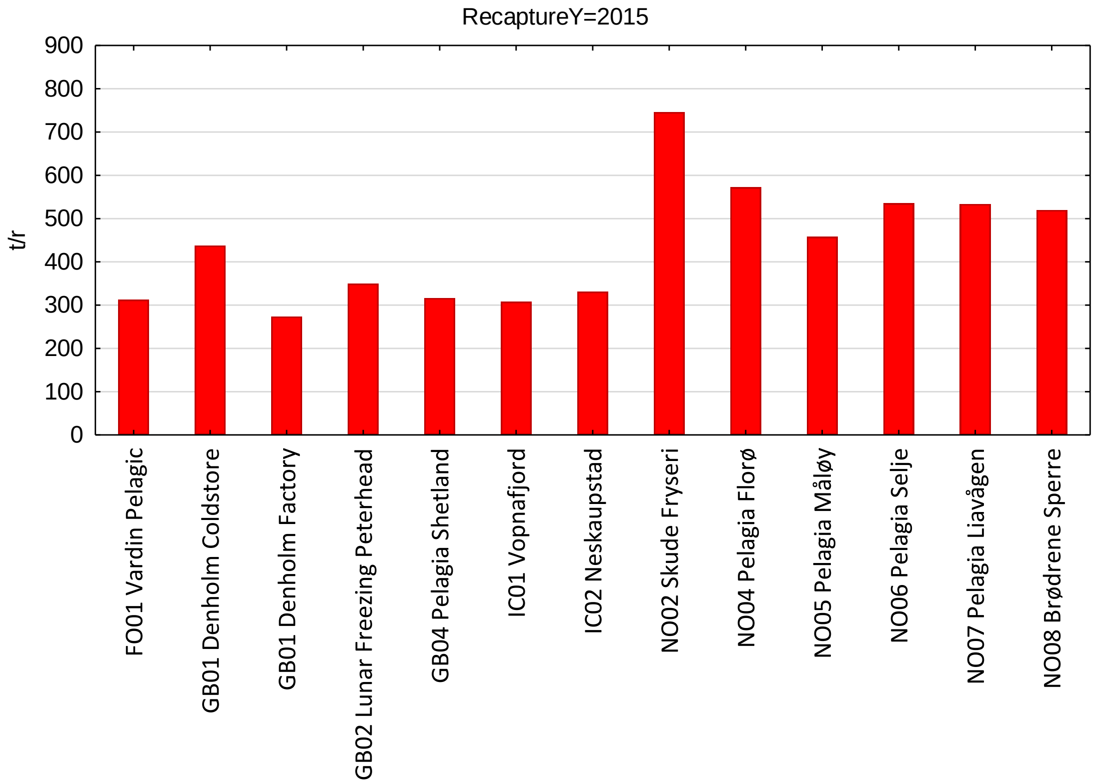


Figure 5. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2015.

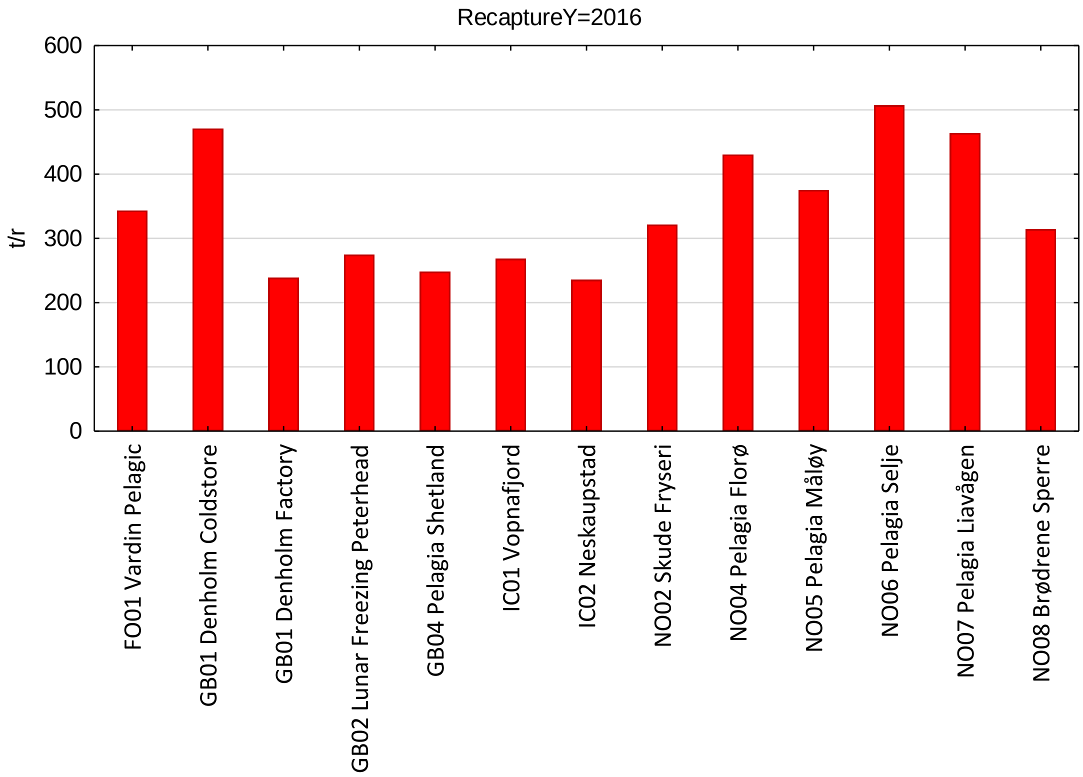


Figure 6. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2016.

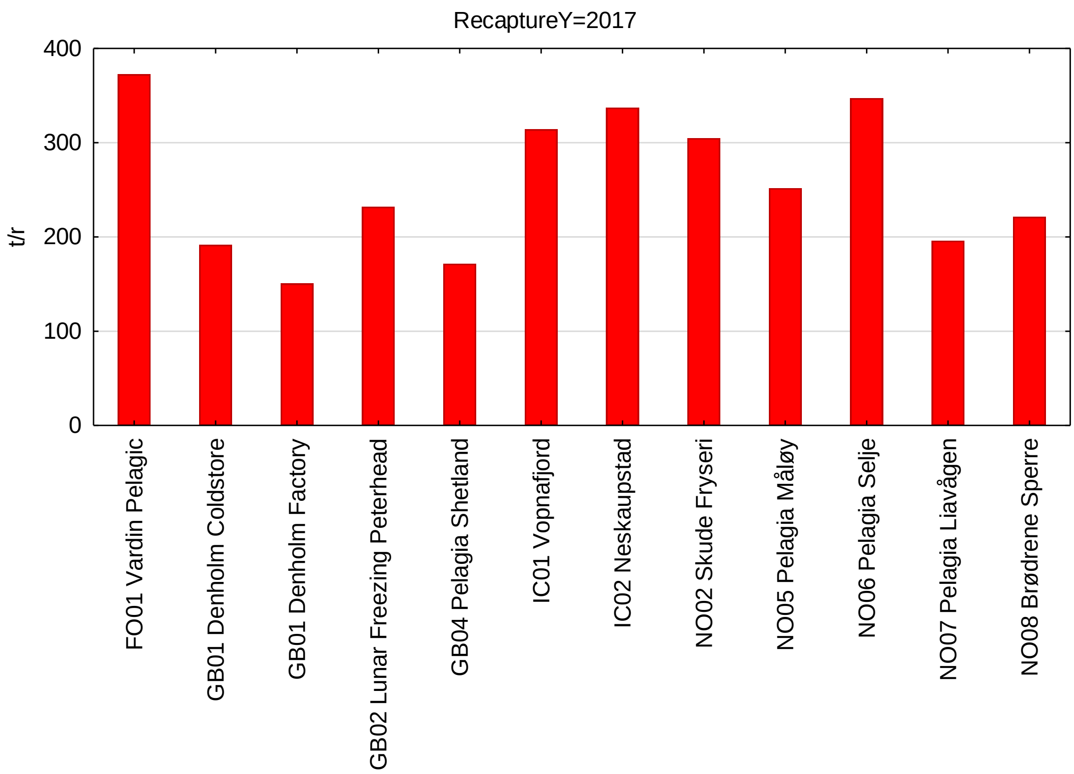


Figure 7. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2017.

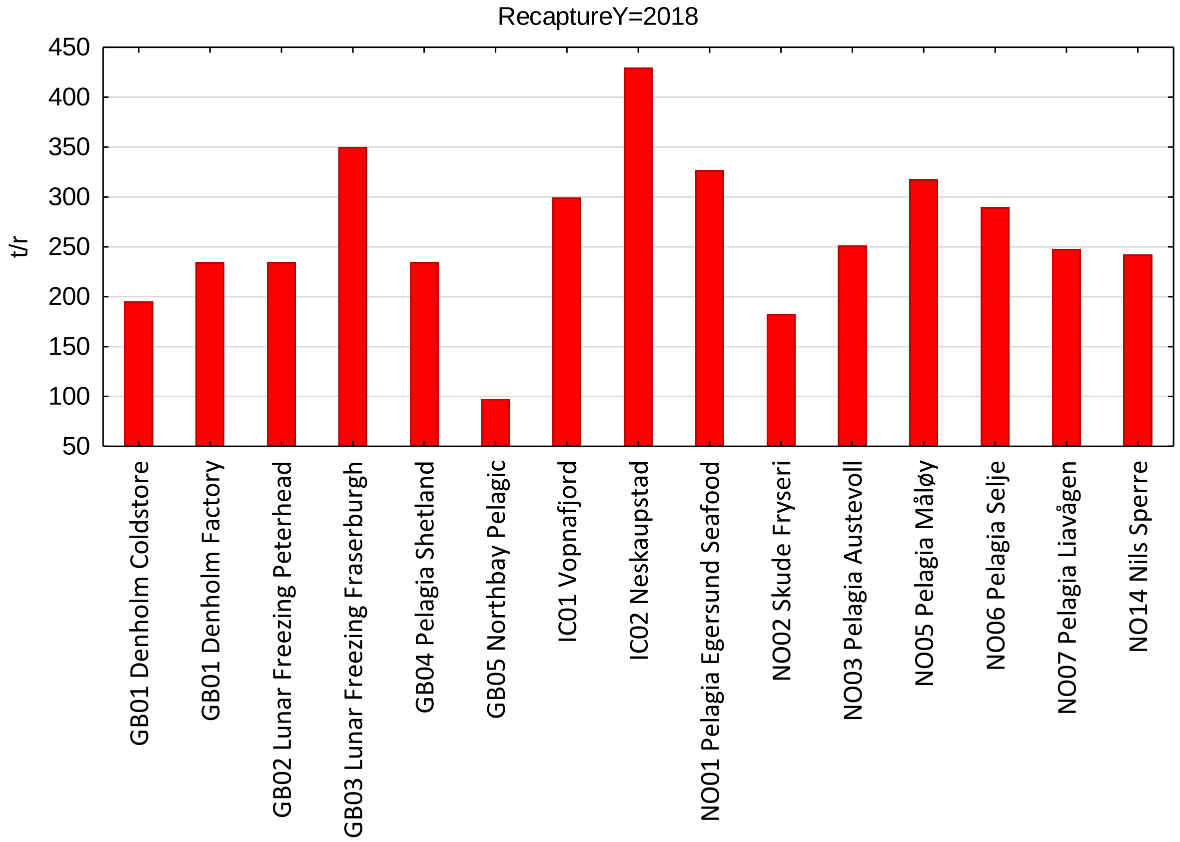
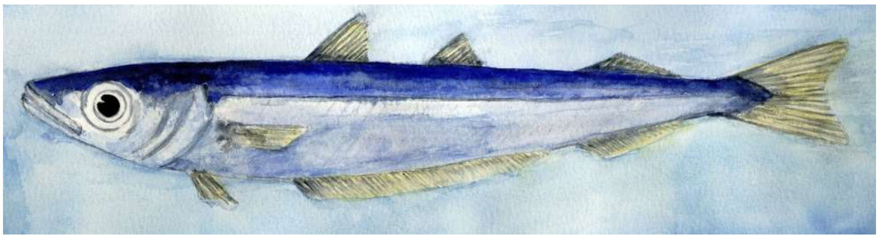


Figure 8. Number of tons scanned per recaptured mackerel (regardless of release year and areas) by factory in 2018.

Working Document

Working Group on International Pelagic Surveys
Bergen, Norway, January 2020

Working Group on Widely Distributed Stocks
Tenerife, Spain, August 2019



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2019

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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 2019 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	28/3 – 11/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	29/3 – 08/4
Tridens	Wageningen Marine Research, the Netherlands	19/3 – 02/4
Kings Bay	Institute of Marine Research, Norway	25/3 – 07/4
Miguel Oliver	Spanish Institute of Oceanography, Spain	18/3 – 21/3

The survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Overall weather conditions were mixed with periods of poor and good weather. All vessels experienced some downtime due to poor weather conditions. The entire survey was completed in 26 days, above the 21-day target threshold. However, the survey start was delayed by almost one week compared to 2018 and included additional effort by the Spanish survey in the Porcupine Sea bight.

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. All vessels worked in a northerly direction with the exception of the Faroes (Figure 4). 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.

Sampling equipment

Vessels employed a 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. The level of biological sampling by vessel is shown 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. 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 Magnus Heinason (FO) to a depth of 200 m (Table 3).

Acoustic data processing

Echogram scrutinisation was carried out by experienced personnel, with the aid of trawl composition information. Post-processing software and procedures differed among the vessels;

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using EchoView (V 9.0) post-processing software for the previous days work. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species (daylight only) and blue whiting.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside and mesopelagic species, blue whiting and krill (krill/mesopelagics). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

On Tridens, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.5.0) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On Kings Bay, the acoustic recordings were scrutinized using LSSS (V. 2.5.0) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On Miguel Oliver, acoustic data were scrutinised every 24 hrs on board using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: Müeller's pearlside, blue whiting and mesopelagic layer (mainly composed by krill and other mesopelagic fish species). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V 2.7), as the standard adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning /prosjekter/stox/nb-no. 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 2018 (Figure 1). The strata and transects used 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:

$$TS = 20 \log 10 (L) - 65.2$$

In StoX a 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 2019 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 (RStoX V1.11) randomly replaces transects and trawl stations within a stratum on each successive run. The output of all the runs is stored in a RData-file, which is used to calculate the relative sampling error.

Results

Distribution of blue whiting

In total 7,610 nmi (nautical miles) of survey transects were completed across six strata, relating to an overall geographical coverage of 121,397 nmi² (Figure 1, Tables 3). The acoustic sampling effort area increased in 2019 to include the Porcupine sea bight area. Otherwise area coverage was comparable to 2018 (Table 7). 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 2019 was located in the 3 strata that covers the shelf edge area (Strata 1, 2 and 3) accounting for 95% of total biomass (Table 4). The Rockall Trough area alone (strata 3) accounted for 61% of the overall survey estimate; this is at a similar level to the two previous years. The Porcupine Bank (strata 2) increased by 57% and contained 21% of the stock compared to 13% in 2018. The three strata outside the core shelf edge area (stratum 4, 5, and 6) collectively decreased from around 12% in 2018 to 5% in 2019 (Table 4). The Rockall and Hatton Bank area (strata 5) contributed just 0.7% of the overall biomass of blue whiting in 2019, down from 4% in 2018. A decrease in salinity and temperature observed in 2017 persists through 2018 and 2019 (see next section).

The two northernmost strata (South Faroes (strata 4) and Shetland Channel (strata 6) accounted for the remaining 4.1% of the biomass (Table 4).

The highest s_A value (98,698 m²/nmi² - sampling unit: one nautical mile) observed in the survey in 2019 was recorded by FV *Kings Bay* on the northern slope of Porcupine Bank in strata 2 (Figure 8a). An example of a typical high density layer of blue whiting observed in the Rockall Trough strata is shown in Figure 8b. A weak layer of blue whiting from the Rockall Bank strata is shown in Figure 8c. Juvenile blue whiting were mainly observed in the northern stratum (South Faroes and Faroe – Shetland Channel) and an example echogram is shown in Figure 8d. High density blue whiting registrations were observed in the Porcupine Sea bight by the RV *Miguel Oliver* (Figure 8e & 8f).

The vertical distribution of blue whiting observed in 2019 did not extend deeper than 750 m as observed in 2018. However, schools in the Porcupine sea bight were observed down to a depth of 600 m.

Stock size

The estimated total biomass of blue whiting for the 2019 international survey was 4.2 million tonnes, representing an abundance of 36.9×10^9 individuals (Table 4). Spawning stock was estimated at 4.17 million tonnes and 35.8×10^9 individuals (Table 5).

Stock composition

Individuals of ages 1 to 13 years were observed during the survey.

The main contribution (82%) to the spawning stock biomass were the age groups 4, 5 and 6 with the five year olds (2014 year-class) being most abundant (47%), followed by the 2015 year-class (24%) and 2013 year-class (11%) (Table 5).

The highest mean weights of blue whiting were caught in the northern part of the Rockall Trough stratum 3 (Figures 9 and 10). Highest mean weight in 2019 was in strata 3 representing 121g.

Five year olds (the 2014 year-class) were dominant in all strata with the exception of strata 4 (south Faroes) and strata 6 (Faroe/Shetland Channel), where 1 year olds ranked highest (Figure 12). The proportion of 1 and 2-year-old fish was low in the total estimate in 2019 (Figure 13).

An uncertainty estimate at age based on a comparison of the abundance estimates was calculated for IBWSS for years 2017, 2018 and 2019 using StoX (Figure 11). By comparing the estimates of young year classes from 2017 to 2019 it appears that good cohort tracking is achieved in the survey for some year classes. For example, the relative abundance of two year olds in 2016 (2014-year class) was high; the strong abundance of this cohort is also seen in 2017 as three year olds, in 2018 as four year olds, and in 2019 as five year olds. Similarly, the 2015 year-class were picked up as two year olds in 2017, and subsequently the three and four year olds in 2018 and 2019 respectively are relatively strong. The CV of the abundant age groups 3 to 6 was below 0.25 in 2019 (Figure 11).

The CV of the total estimate of both biomass and abundance were 0.17, which is higher than last year (0.125) and slightly higher than the years before when the CV varied around 0.16.

The survey time series (2004-2019) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A total of 118 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 and temperature observed in 2017 persists through 2018 and 2019. This is thought to limit the western extent of the blue whiting spawning distribution on the Rockall and Hatton Bank areas (Hátún *et al.* 2009).

Concluding remarks

Main results

- Weather conditions were mixed with both good and bad periods. All vessels experienced poor weather conditions at some point during the survey, resulting in slower transect speeds.
- The total area surveyed was comparable but lower than in 2018. Corresponding acoustic sampling effort (transect miles) increased. Reduced area coverage can be accounted by the lack of blue whiting in western peripheral areas (stratum 5- Rockall). Acoustic sampling increased due to the presence of the RV *Miguel Oliver* and her coverage of the Porcupine sea bight. Coverage in the sea bight can be considered a new extension of the total survey area and is necessary to contain the stock in its southern boundary.
- Overall, biological sampling saw an increased number of measured fish but a lower number of aged individuals compared to 2018.
- The International Blue Whiting Spawning Stock Survey 2019 shows an increase in total stock biomass of 4% with a corresponding decrease in total abundance of 9% when compared to the 2018 estimate.
- The survey was carried out over 26 days, above the 21-day time window target. These additional days can be accounted for the by the delayed start of the RV *Celtic Explorer* compared to previous years.
- Estimated uncertainty around the total stock biomass was higher than last year, CV=0.17 compared to 0.13.
- The stock biomass within the survey area was dominated by 4, 5 and 6-year-old fish contributing 82% of total stock biomass.
- There was no evidence of blue whiting below 750 m
- Immature fish (1-year-old) represent 0.7% of the TSB and 2.9% of TSN.

Interpretation of the results

- The group considers the 2019 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.
- Total stock biomass observed in 2019 is the highest in the overall time series (2004-present). Representing an increase in TSB of 4% compared to 2018 (4.0 mt and 4.2 mt respectively). The 2014-year class (5 year old fish) accounts for approximately 46% of the TSB and almost 2 million tons. This year class is the largest observed in the survey time series.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and up to the Hebrides.
- The Northern migratory stock and the Porcupine sea bight; Spatio-temporal survey data and biological data from trawl hauls (RV *Tridens* and RV *Miguel Oliver*) 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.
- The group recommends that the process of producing output reporting tables, figures and maps from StoX outputs files is standardised through scripting routines and developed by WGIPS for wider use.
- To facilitate the above process, we request that StoX developers look into the possibility of fixing the format of output tables of biomass and abundance to aid this process. Currently zero values in biomass and abundance tables (age and lengths) are omitted.
- Current XML file formats generated from ICES or PGNAPES data repositories are not cross compatible for combined use in StoX due to differences in formatting. As the group diverges from using PGNAPES as the sole data repository to using the ICES acoustic database members need to be clear during the planning phase on which repository they intend to use going forward. This issue requires attention during WGIPS in 2020 so as not to disrupt the process of global abundance estimation in 2020.
- It is recommended that all participants produce files types in both ICES and PGNAPES file formats for the 2020 post cruise meeting to facilitate cross compatibility testing within StoX.

Achievements

- The Porcupine sea bight was covered synoptically, in close temporal progression by two survey vessels.
- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable to 2018.

References

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Table 1. Country and vessel specific details, IBWSS March-April 2019.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay	Miguel Oliver
Trawl dimensions					
Circumference (m)	768	640	860	832	752
Vertical opening (m)	50	42-45	30-70	45	30
Mesh size in codend (mm)	20	40	40	40	20
Typical towing speed (kn)	3.5-4.0	3.2-3.6	3.5-4.0	3.5-4.0	3.5-4.0
Plankton sampling	-	16	-	-	
Sampling net	-	WP2 plankton net	-	-	
Standard sampling depth (m)	-	200	-	-	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25
Standard sampling depth (m)	1000	1000	1000	900	520

Table 2. Acoustic instruments and settings for the primary frequency, IBWSS March-April 2019.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay	Miguel Oliver
Echo sounder	Simrad EK 60	Simrad EK60	Simrad EK 60	Simrad EK 80	Simrad EK 60
Frequency (kHz)	**38**, 18, 120, 200	**38**, 200	18, **38**, 70, 120, 200, 333	18, **38**, 70	**38**, 18, 70, 120, 200
Primary transducer	ES 38B	ES 38B	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Hull	Drop keel	Drop keel	Hull
Transducer depth (m)	8.7	3	8	8.5	6.5
Upper integration limit (m)	15	7	15	15	15
Absorption coeff. (dB/km)	9.9	10.1	9.5	9.59	9.2
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	23	21.9
2-way beam angle (dB)	-20.6	-20.8	-20.6	-20.7	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.85	25.64	26.52	24.06	24.68
s_A correction (dB)	-0.64	-0.66	-0.76	0.008	-0.54
3 dB beam width (dg)					
alongship:	6.87	7.02	6.79	7.0	6.90
athw. ship:	6.91	7.00	6.81	7.0	7.10
Maximum range (m)	750	750	750	750	1000
Post processing software	Echoview	Echoview	LSSS	LSSS	Echoview

Table 3. Survey effort by vessel, IBWSS March-April 2019.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling WP2-net	Aged fish	Length-measured fish
Celtic Explorer	28/3-11/4	2282	7	24	-	350	3001
Magnus Heinason	29/3-8/4	1400	6	19	17	300	668
Kings Bay	25/3- 7/4	2185	11	27	-	330	1,091
Tridens	19/3-2/4	1473	10	28	-	798	800
Miguel Oliver	18/3-21/3	270	4	20	-	160	668
Total	28/3-11/4	7610	38	118	17	1938	6228

Table 4. Abundance and biomass estimates of blue whiting by strata in 2019 and 2018. IBWSS March-April 2019.

Strata	Name	2019 TSB (10^3 t)	2019 TSN (10^9)	2019 % TSB	2019 % TSN	2018 TSB (10^3 t)	2018 TSN (10^9)	2018 % TSB	2018 % TSN	Difference 2019-2018 TSB	Difference 2019-2018 TSN
1	Porcupine Bank	870	8,350	20.7	22.6	534	5,519	13.2	13.6	57%	66%
2	N Porcupine Bank	572	5,692	13.6	15.4	521	5,599	12.9	13.8	6%	12%
3	Rockall Trough	2,555	21,116	60.9	57.2	2,475	24,708	61.4	60.9	-1%	-6%
4	South Faroes	125	1,039	3.0	2.8	164	1,604	4.1	4.0	-27%	-29%
5	Rockall Bank	29	272	0.7	0.7	179	1,835	4.4	4.5	-85%	-84%
6	Faroe/Shetland Ch.	47	448	1.1	1.2	162	1,336	4.0	3.3	-72%	-63%
	Total	4,198	36,918	100	100	4,035	40,602	100	100	4%	-9%

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2019.

					Age in years (year class)						Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2018	2017	2016	2015	2014	2013	2012	2011	2010		(10^6)	(10^6 kg)	(g)	
16-17	11										11	0.3	28	0
17-18	50										50	1.6	31	0
18-19	184										184	6.1	33	50
19-20	233										233	8.2	35	16
20-21	291										291	13.5	46	23
21-22	173										173	8.8	51	21
22-23	82	19	4								104	6.5	62	46
23-24	81	89	2								172	11.6	67	59
24-25	35	380	113								528	38.3	73	95
25-26		475	467	281	638	101					1,962	164.0	84	100
26-27		146	948	2,125	2,069	209					5,497	506.0	92	100
27-28		43	1,038	2,589	3,514	574					7,759	787.1	101	100
28-29		14	421	2,348	4,765	406	31	7			7,991	889.8	111	100
29-30		3	182	921	2,853	666	28		7		4,660	579.3	124	100
30-31			150	862	1,651	669	103	37			3,473	480.0	138	100
31-32				380	758	257	170				1,564	244.7	156	100
32-33			144	63	442	79	40	195		18	982	181.9	185	100
33-34				20	97	336	47	114			614	113.2	184	100
34-35					109	86	26	42		5	269	57.5	214	100
35-36					68	2		65		2	137	32.6	238	100
36-37							15		74	12	101	21.8	215	100
37-38						22		41	11	6	80	21.9	274	100
38-39					14	18		13			46	10.0	218	100
39-40							24				24	7.7	316	100
40-41											0		-	100
41-42						8					8	3.1	372	100
43-44									6		6	2.4	397	100
TSN(mill)	1,129	1,169	3,468	9,590	16,979	3,434	484	513	99	144	36,918			
TSB(1000 t)	51.7	94.4	358.2	1,025.1	1,962.1	463.3	81.4	131.4	20.6	38.2	4,197.6			
Mean length(cm)	20.1	25.0	27.1	27.9	28.4	29.5	31.7	33.4	36.2					
Mean weight(g)	46	81	103	107	116	135	168	256	209					
% Mature	8	99	98	100	100	100	100	100	100	100				
SSB (1000kg)	4.3	93.4	349.5	1024.5	1961.4	463.3	81.4	131.4	20.6	38.2	4168.0			
SSN (mill)	93	1156	3384	9584	16973	3434	484	513	99	144	35862.1			

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
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

*Survey discarded.

Table 7. Survey effort in the IBWSS.

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

* End of Russian participation.

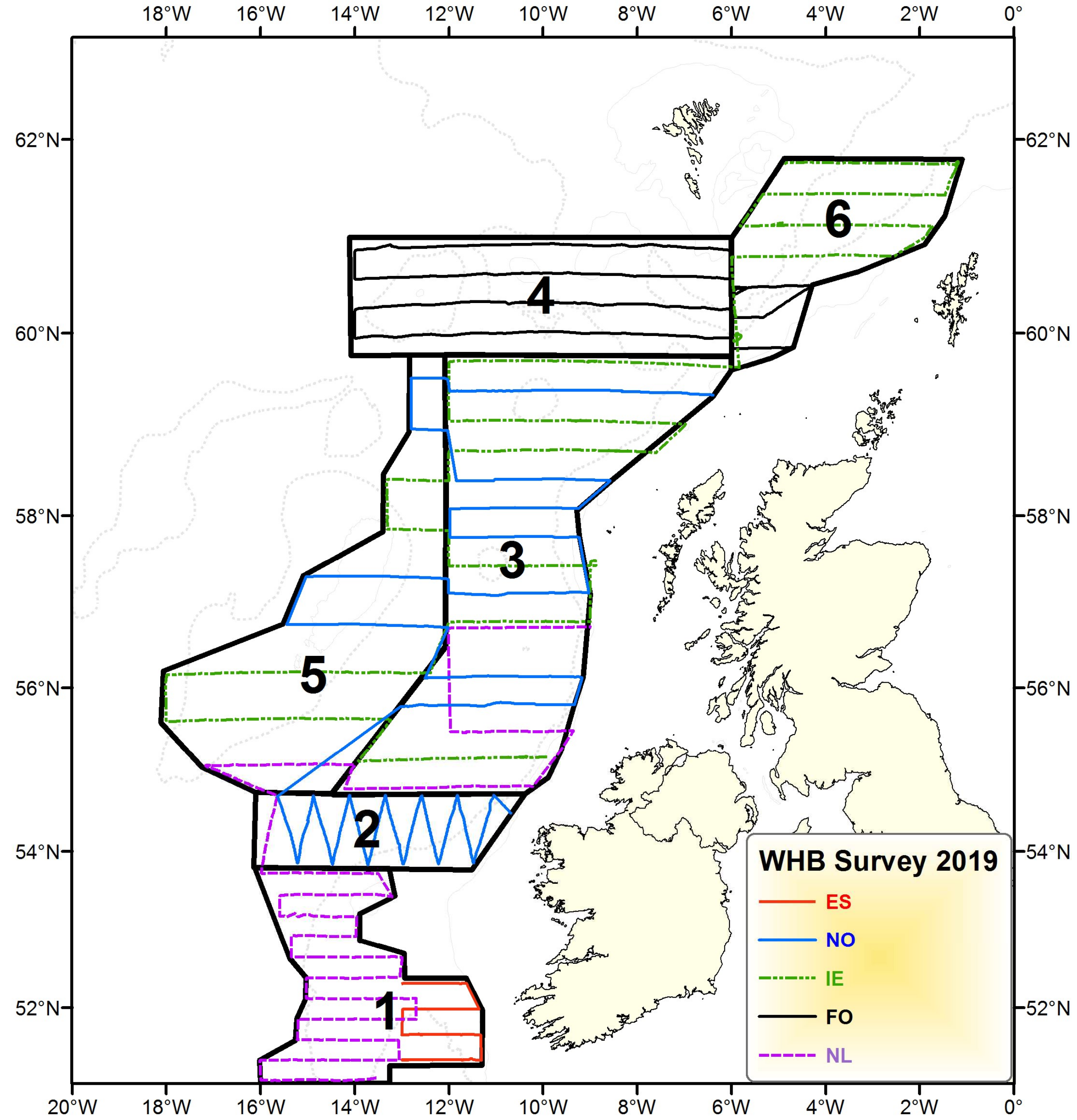


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

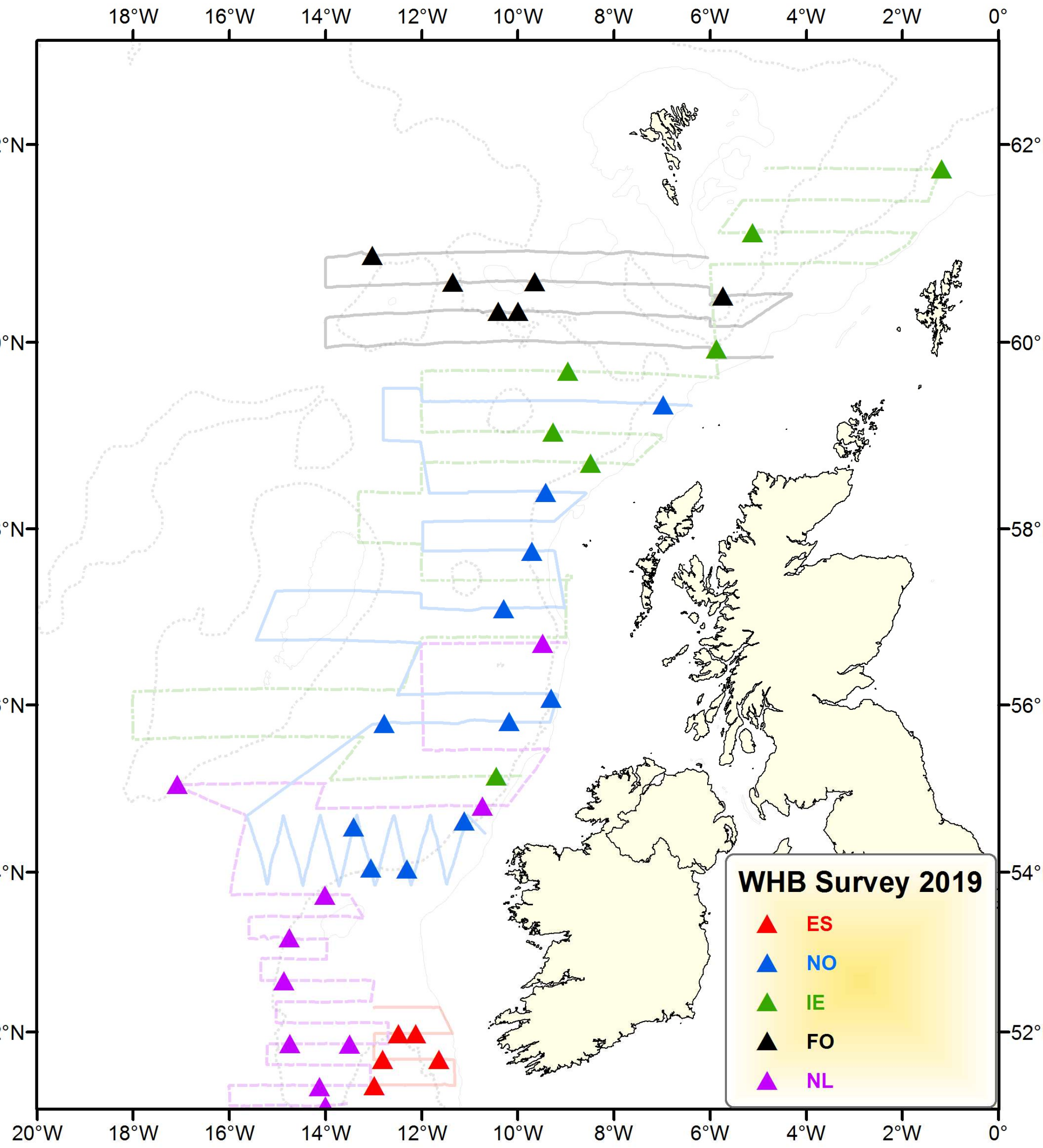


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019. IE: Ireland (RV *Celtic Explorer*); FO: Faroe Islands (RV *Magnus Heinason*); NL: Netherlands (RV *Tridens*); NO: Norway (FV *Kings Bay*); ES: Spain (RV *Miguel Oliver*).

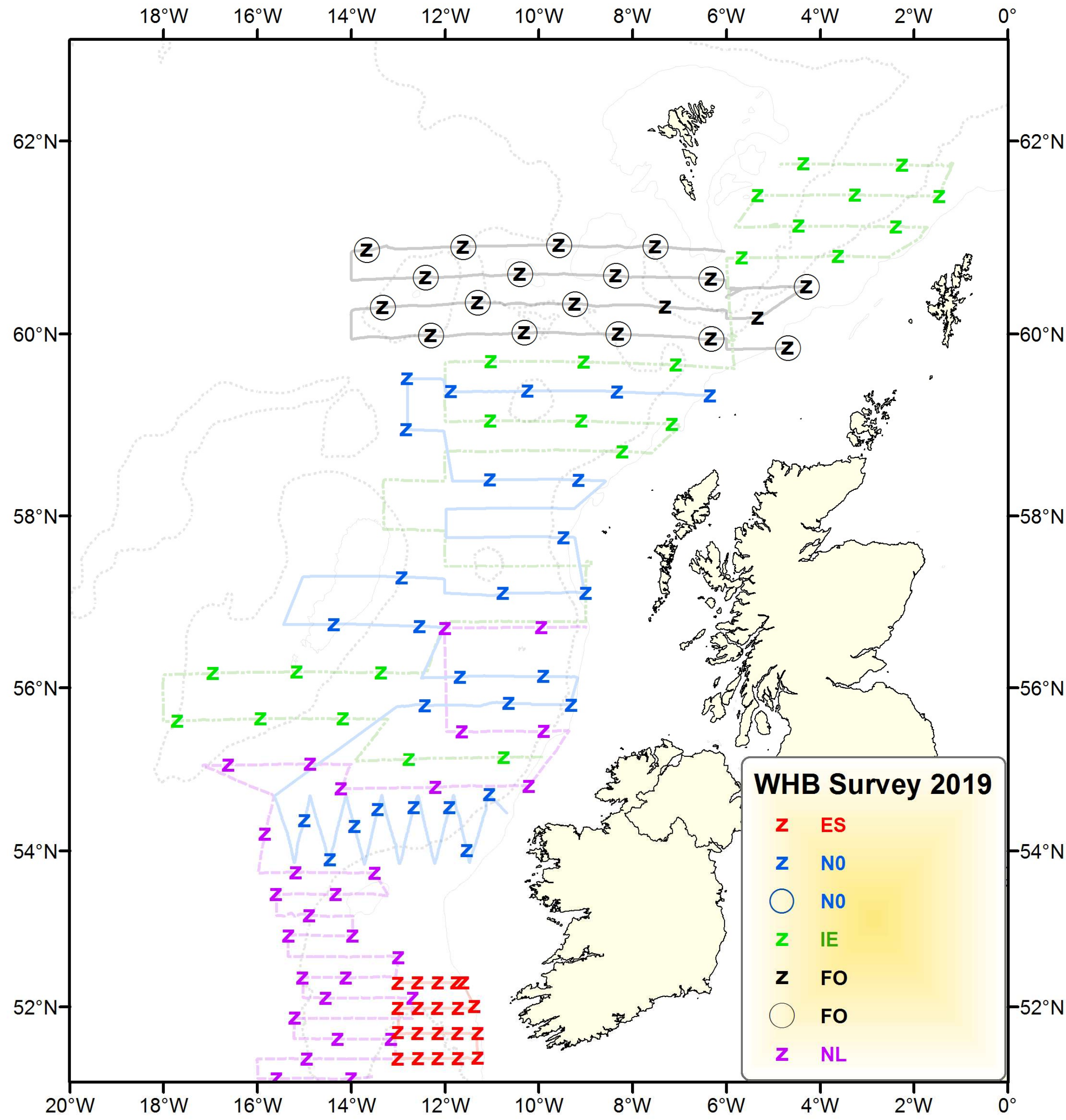


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019. Colour coded by vessel.

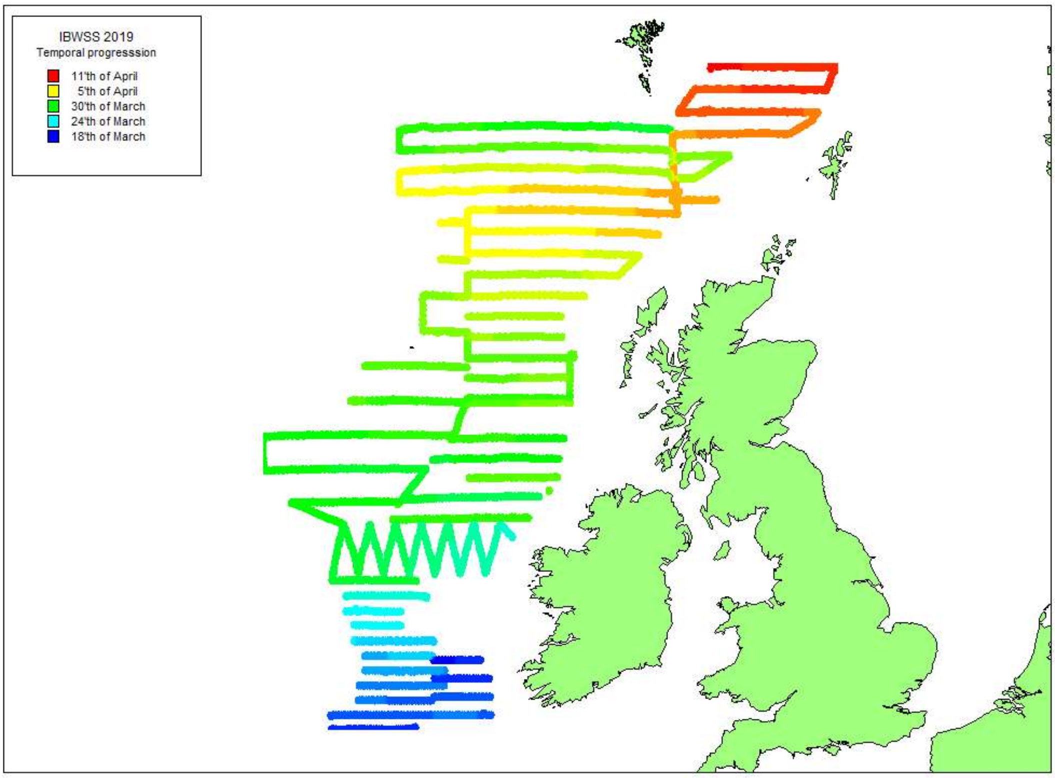


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

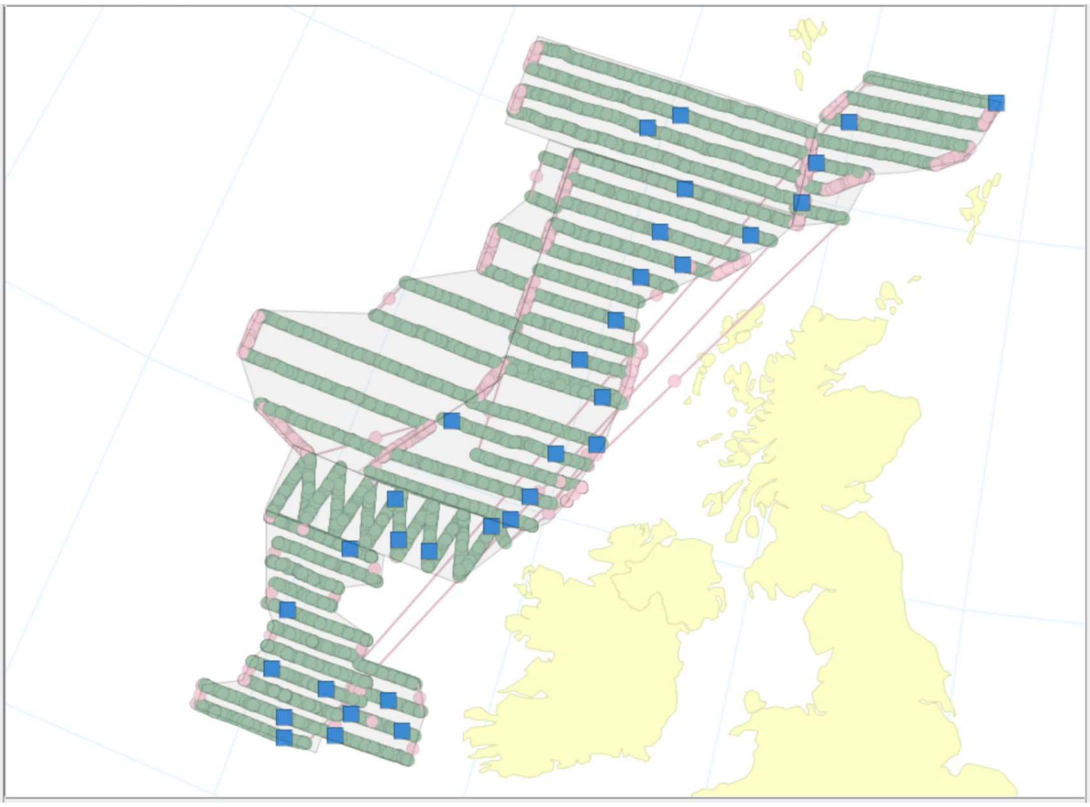


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (blue squares) used in the StoX abundance estimation. IBWSS March-April 2019.

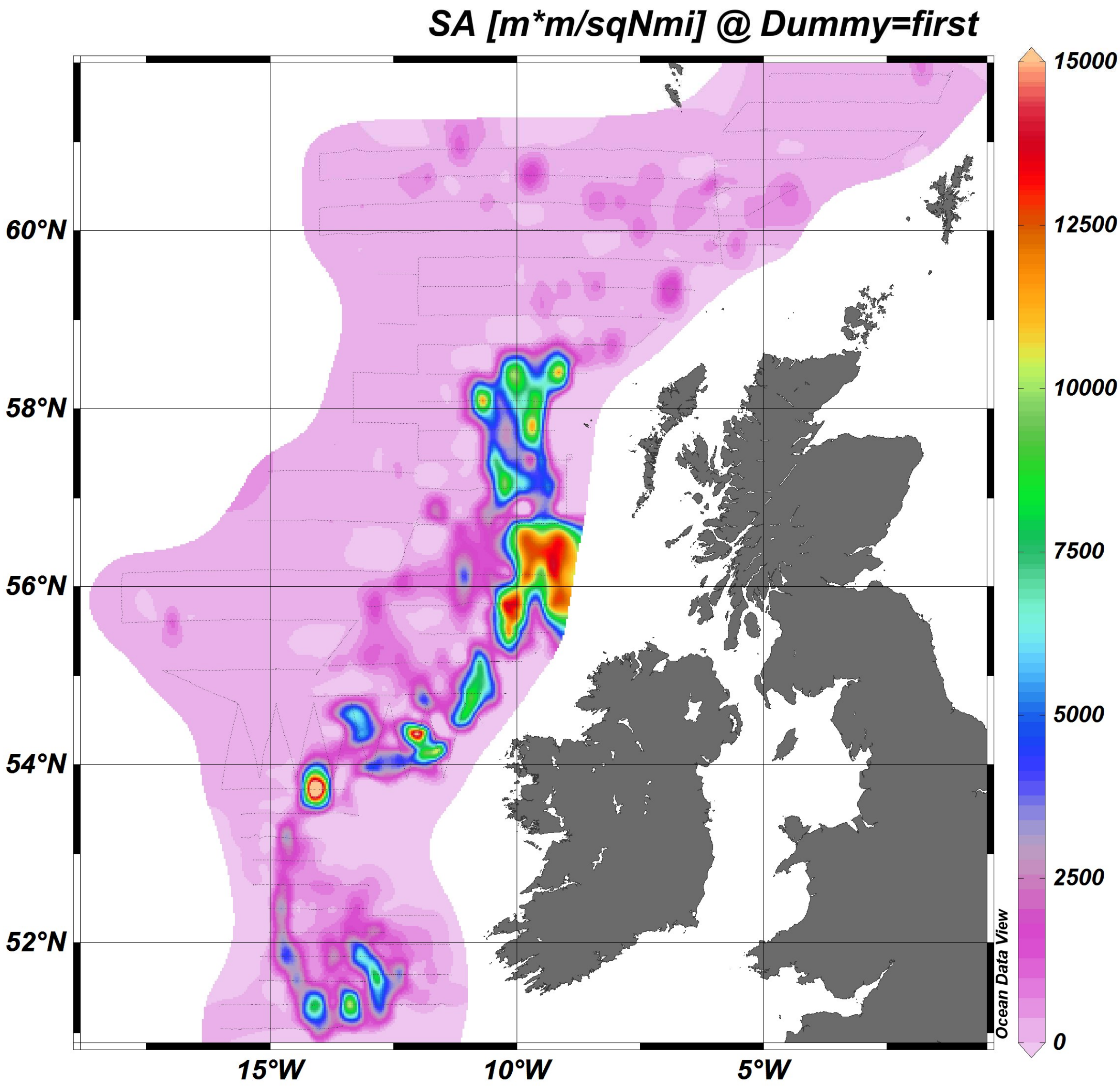


Figure 6. Map of acoustic density (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

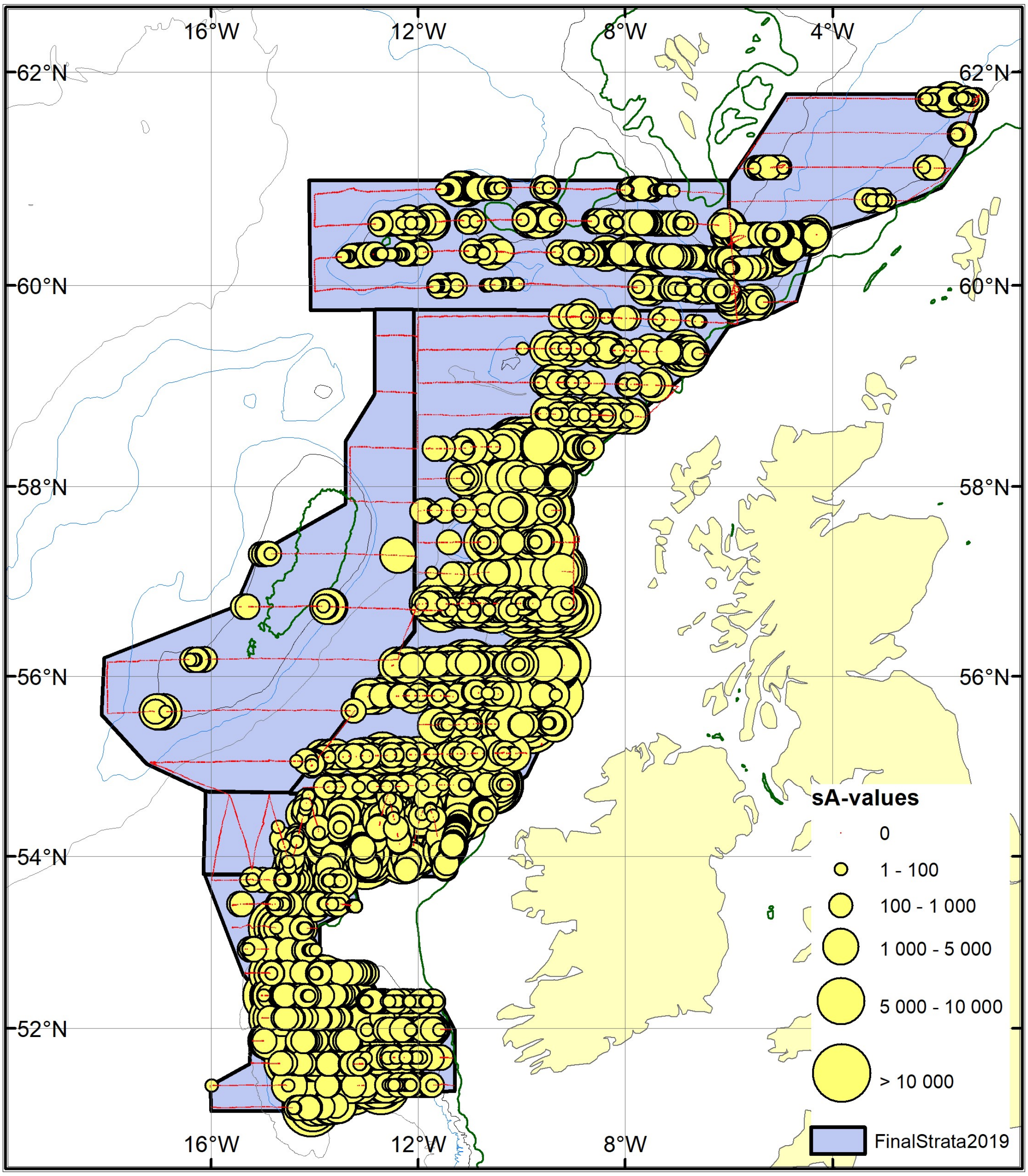
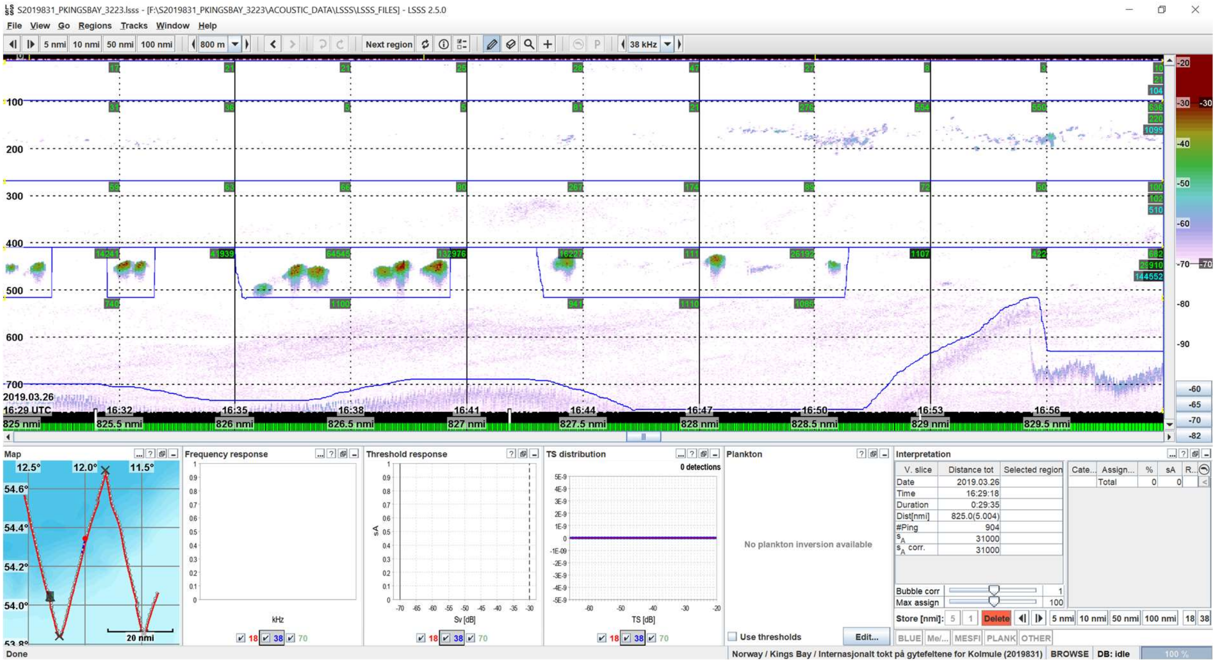
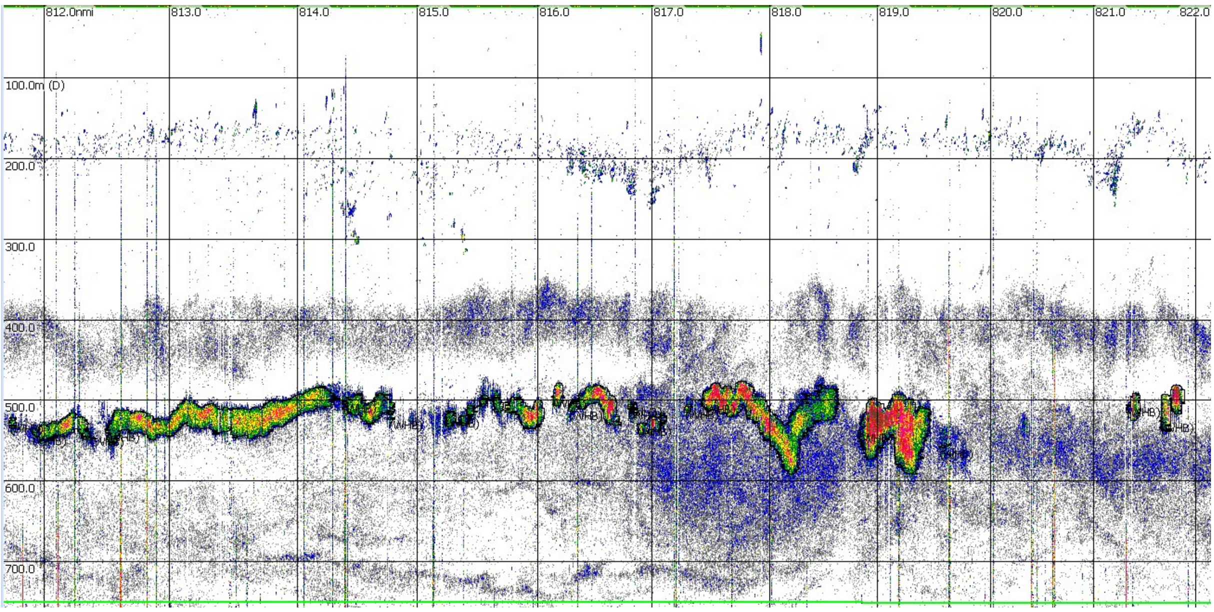


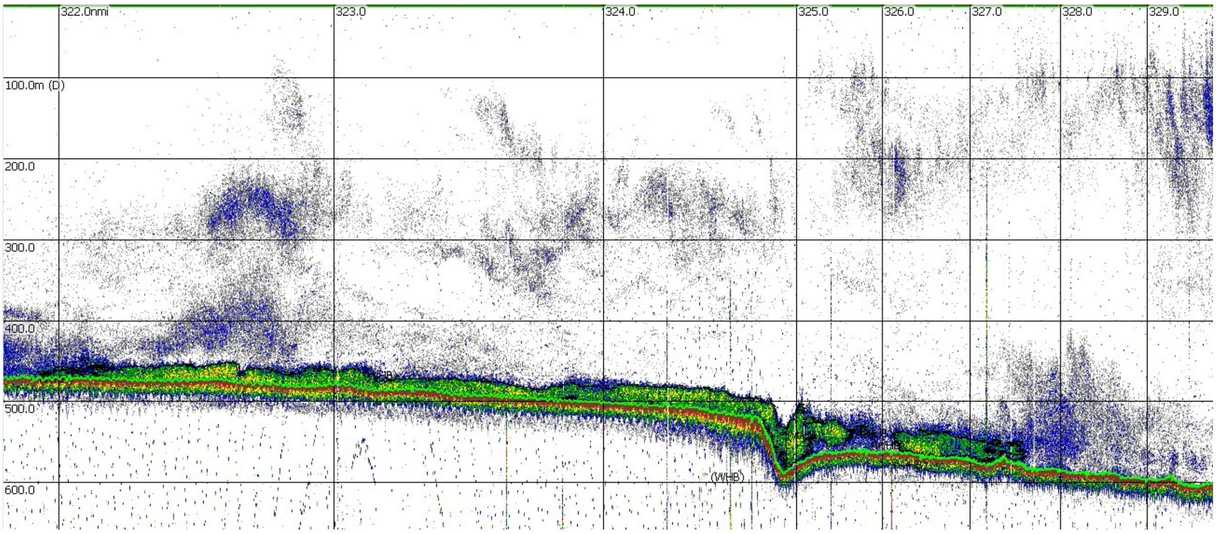
Figure 7. Map of acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi (circle scaled by acoustic density). IBWSS March-April 2019.



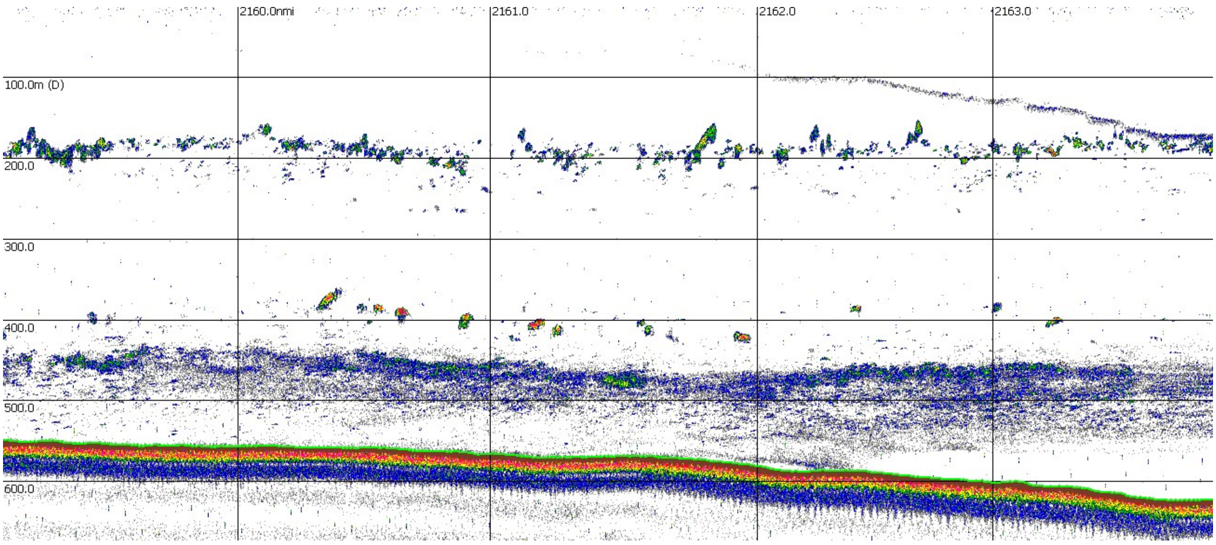
a) High density blue whiting registrations recorded on western Porcupine Bank area (strata 2) FV *Kings Bay*, Norway.



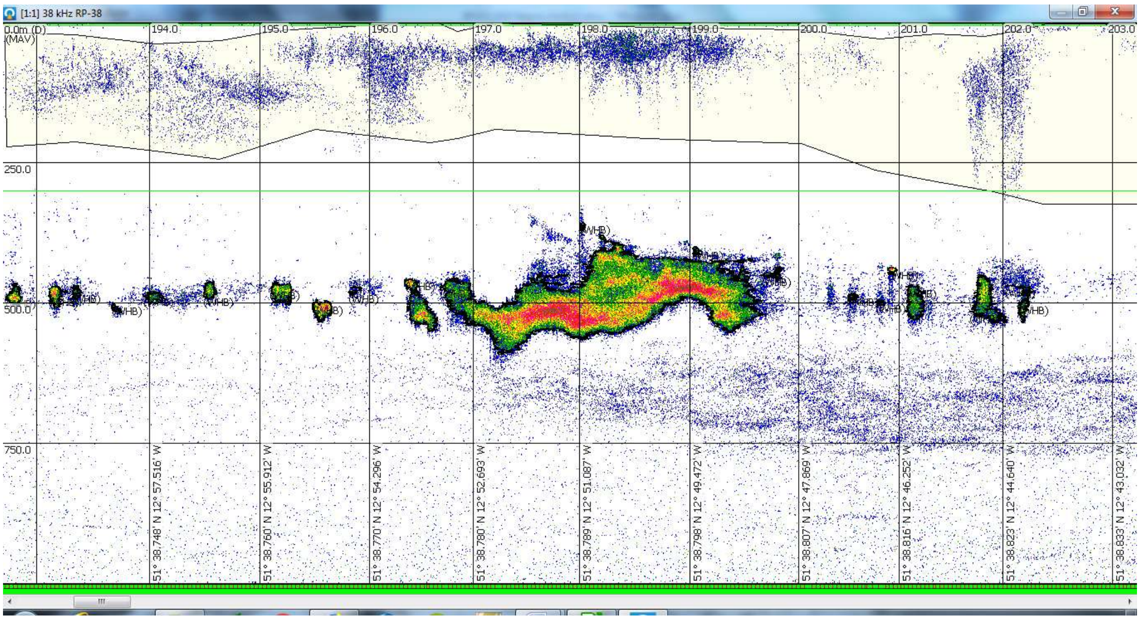
b) High density blue whiting layer per 1 nmi log interval at 500- 600 m recorded by the RV *Celtic Explorer* in the Rockall Trough area (strata 3).



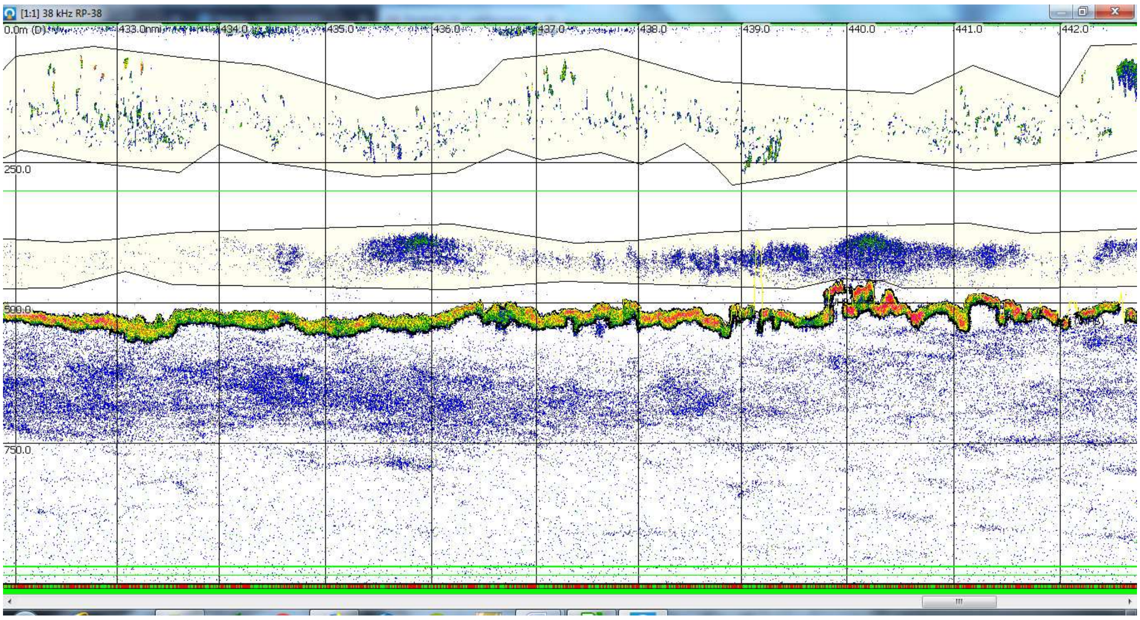
c) Low density blue whiting layer per 1nmi log interval close to the bottom at 450 – 550 m recorded by the RV *Celtic Explorer* in the Rockall Bank area (strata 5).



d) Juvenile and adult blue whiting marks per 1nmi log interval at 400 m depth. A layer of mesopelagic fish is also evident at 150 – 200 m. Recorded by the RV *Celtic Explorer* in the Faroe – Shetland channel area (strata 6).



e) High density blue whiting schools-like at 500- 600 m recorded by the RV *Miguel Oliver* at night in the Porcupine Sea bight area (stratum 7).



f). High density day time blue whiting layer at 500- 600m recorded by the RV *Miguel Oliver* the Porcupine Sea bight area (stratum 7).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2019. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU), vertical binning at 50 m intervals. All echograms presented at 38 kHz.

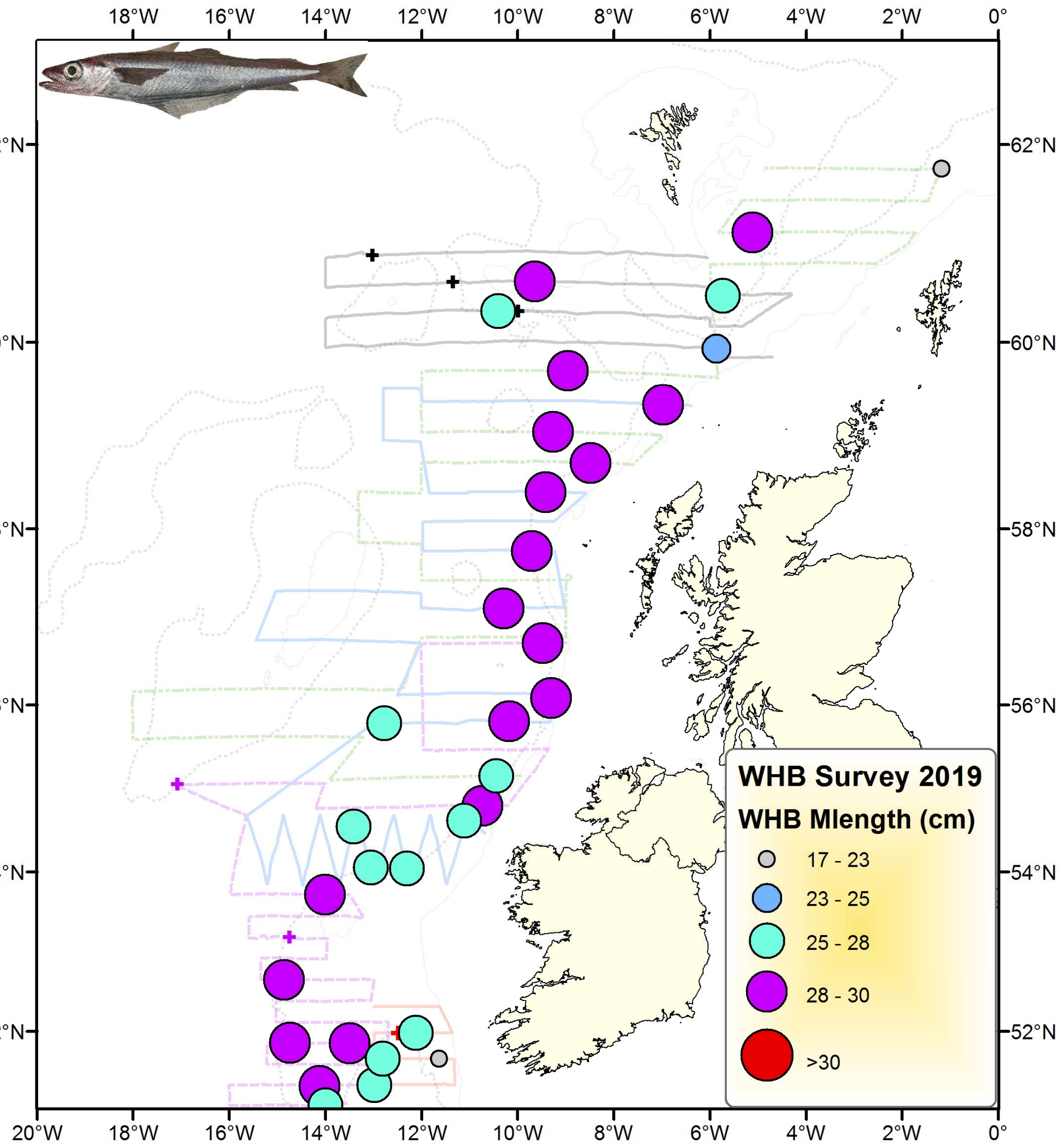


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2019. Crosses indicate hauls with zero blue whiting catches.

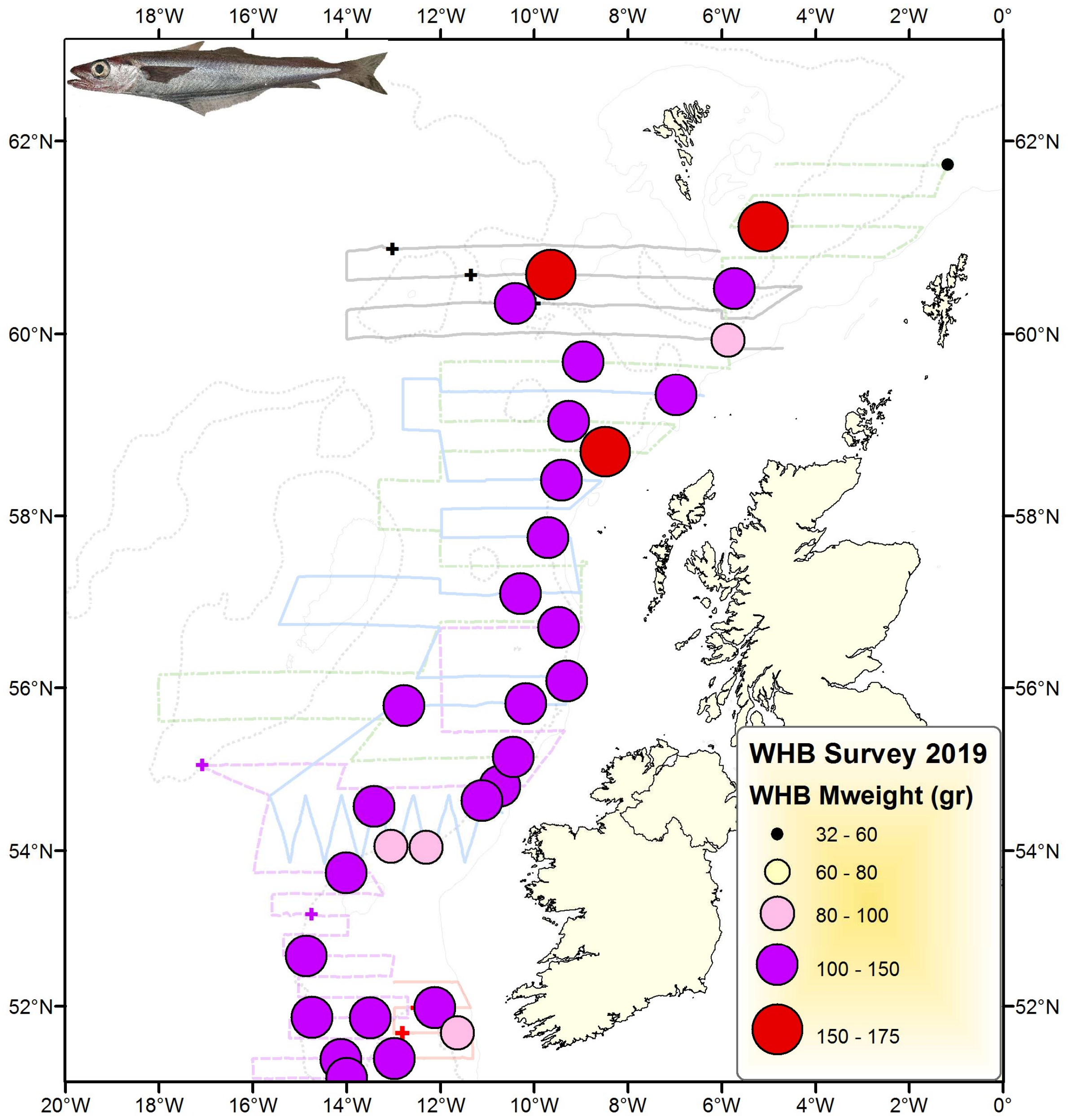


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2019. Crosses indicate hauls with zero blue whiting catches.

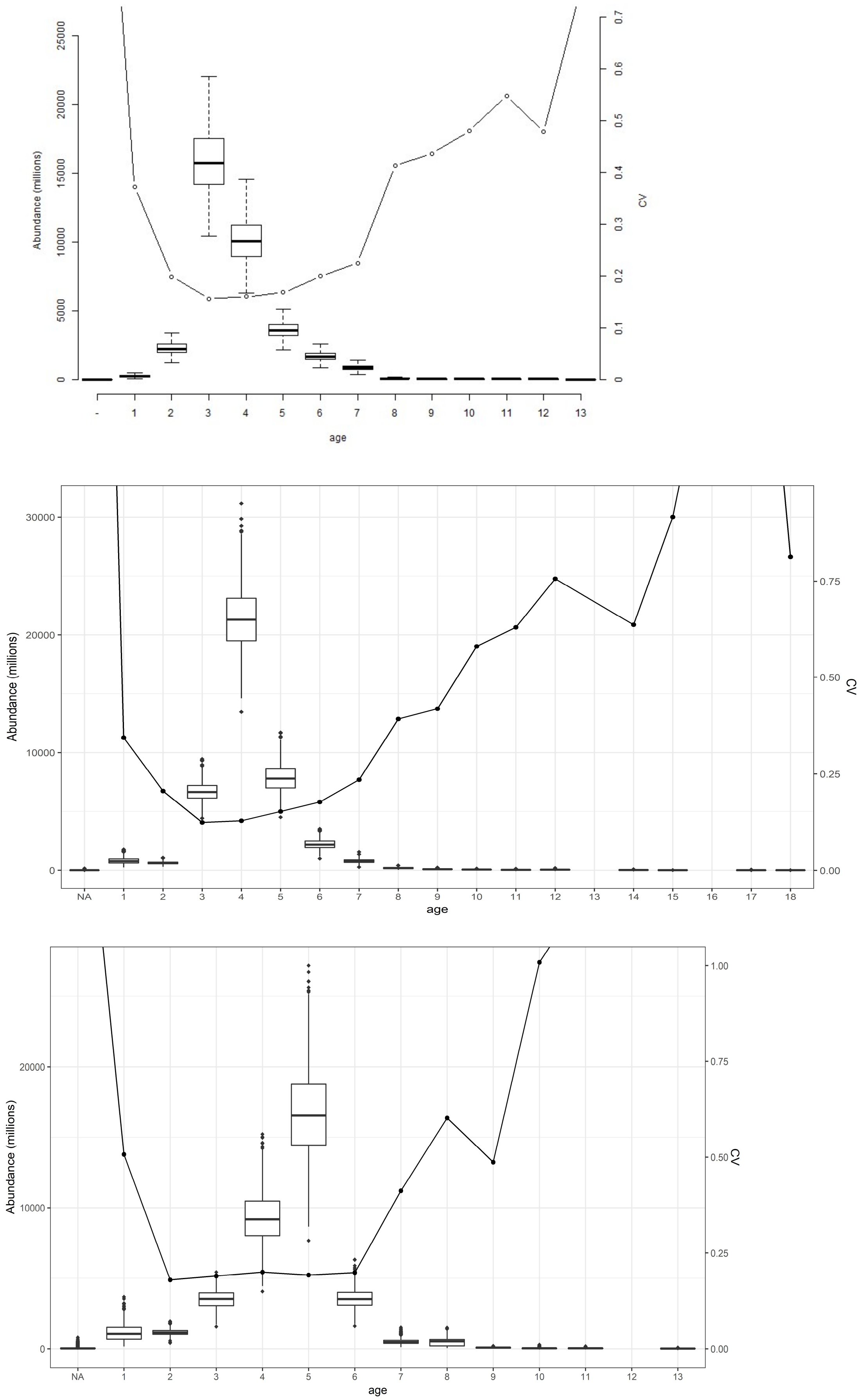


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2017 (top panel), 2018 (middle panel) and 2019 (lower panel). From StoX.

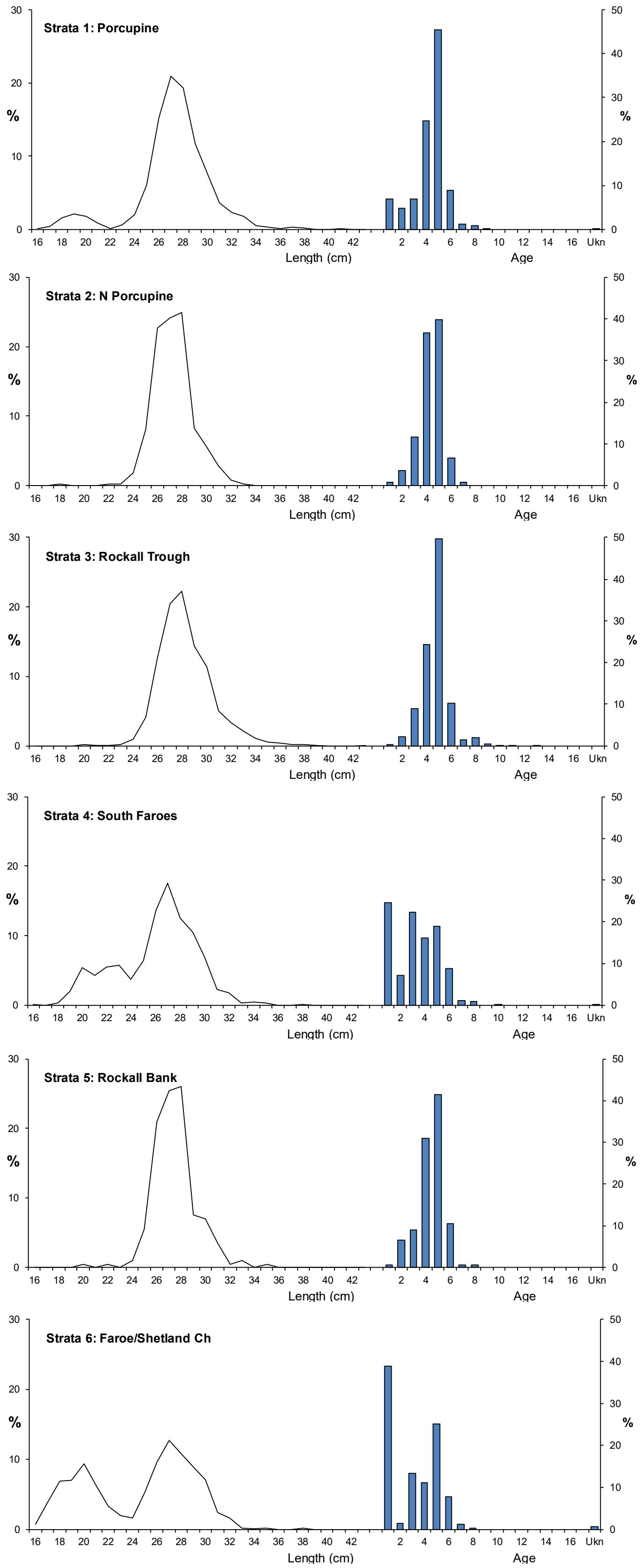


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2019.

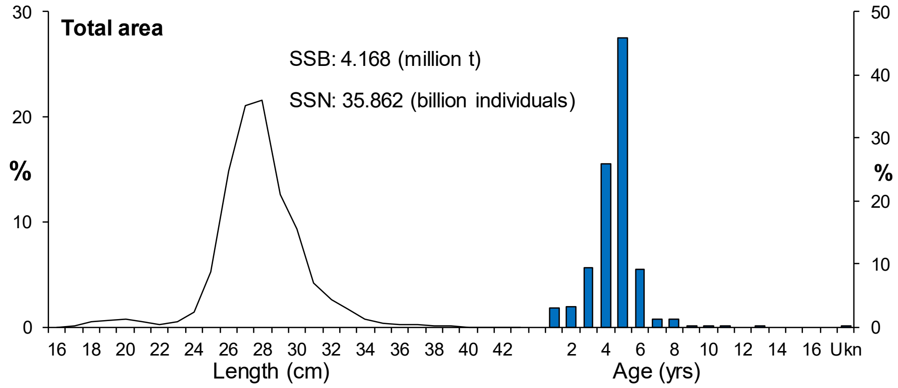


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2019.

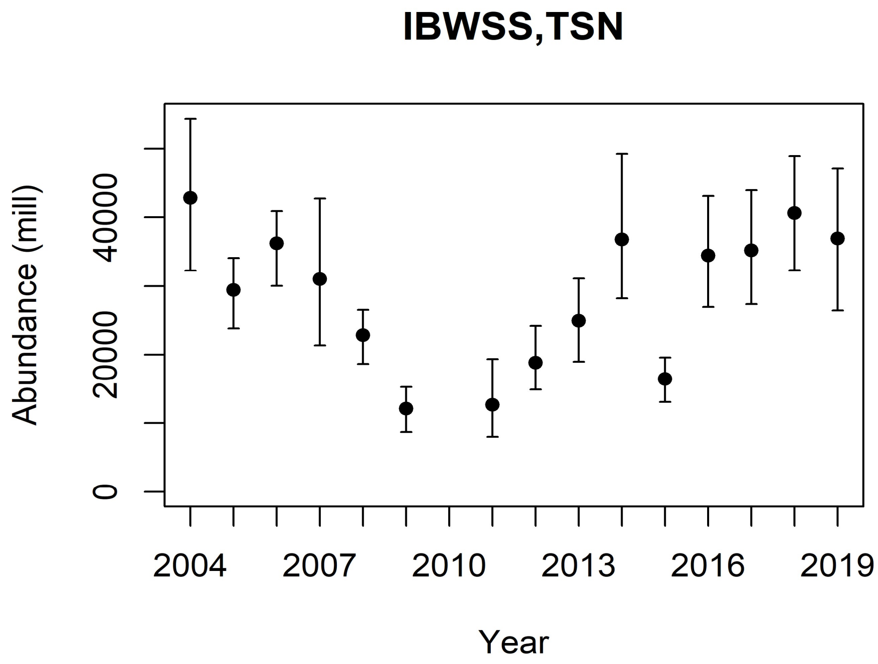


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2019, excluding 2010 due to data problems.

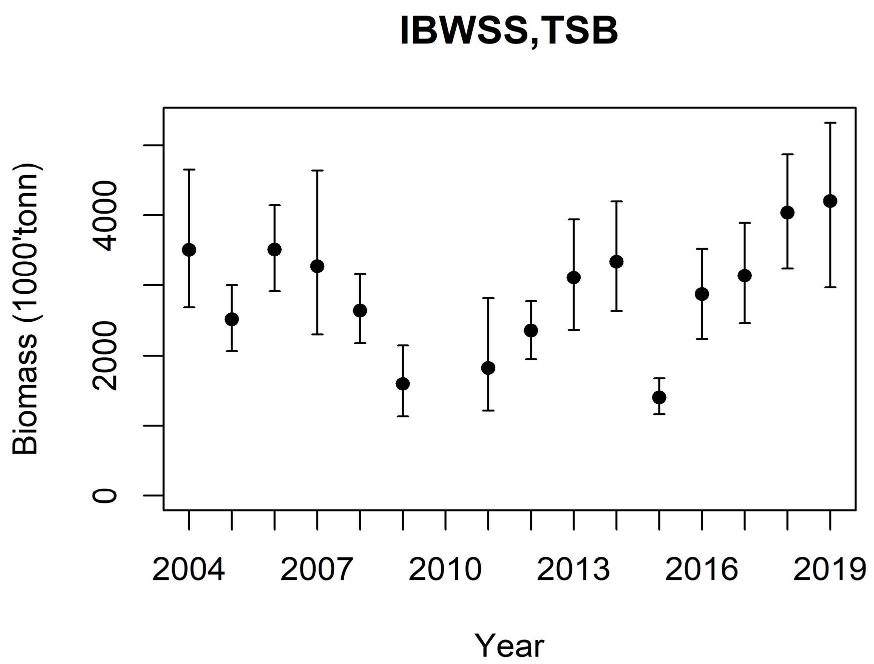


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2019, excluding 2010 due to data problems.

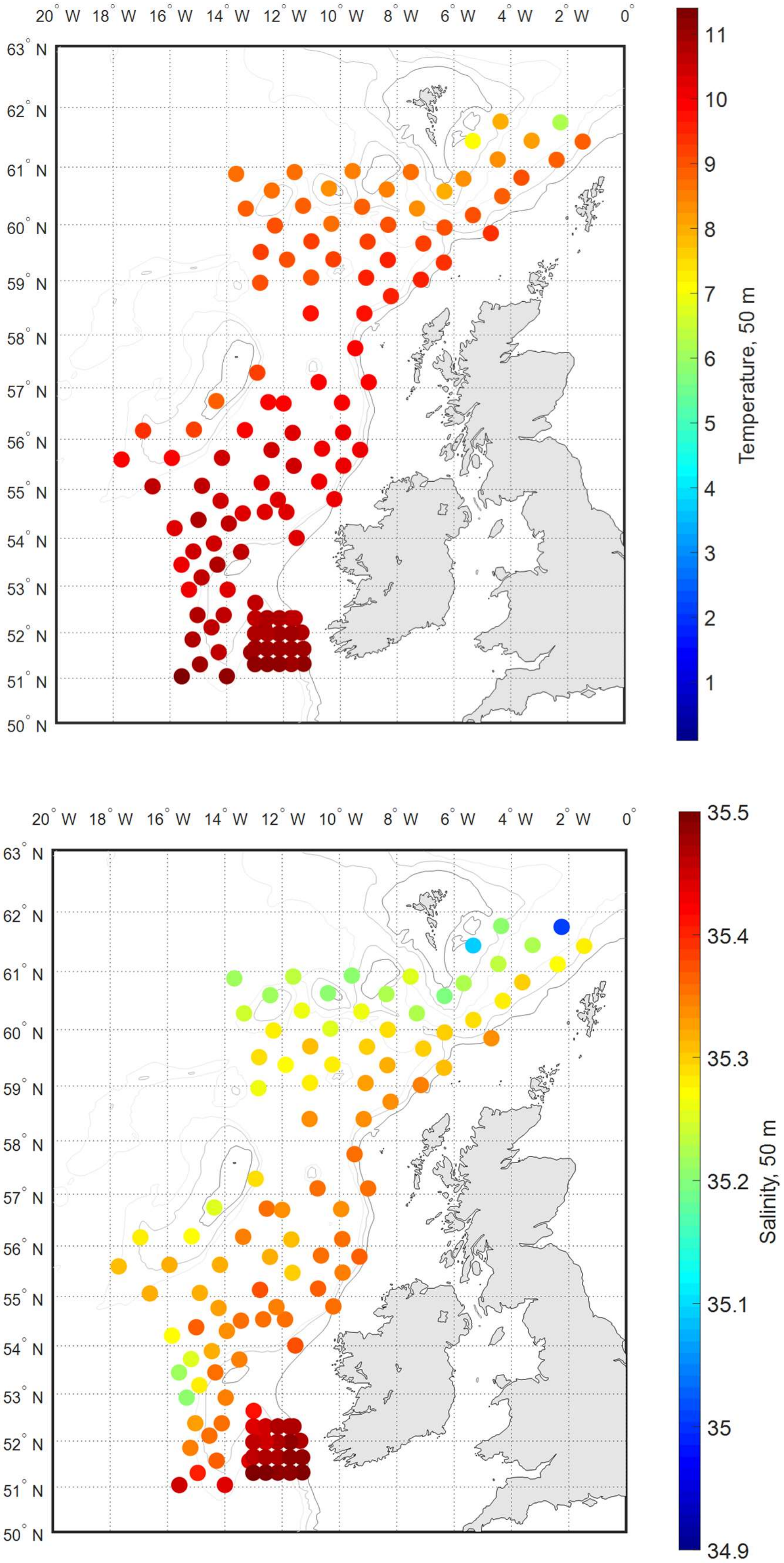


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

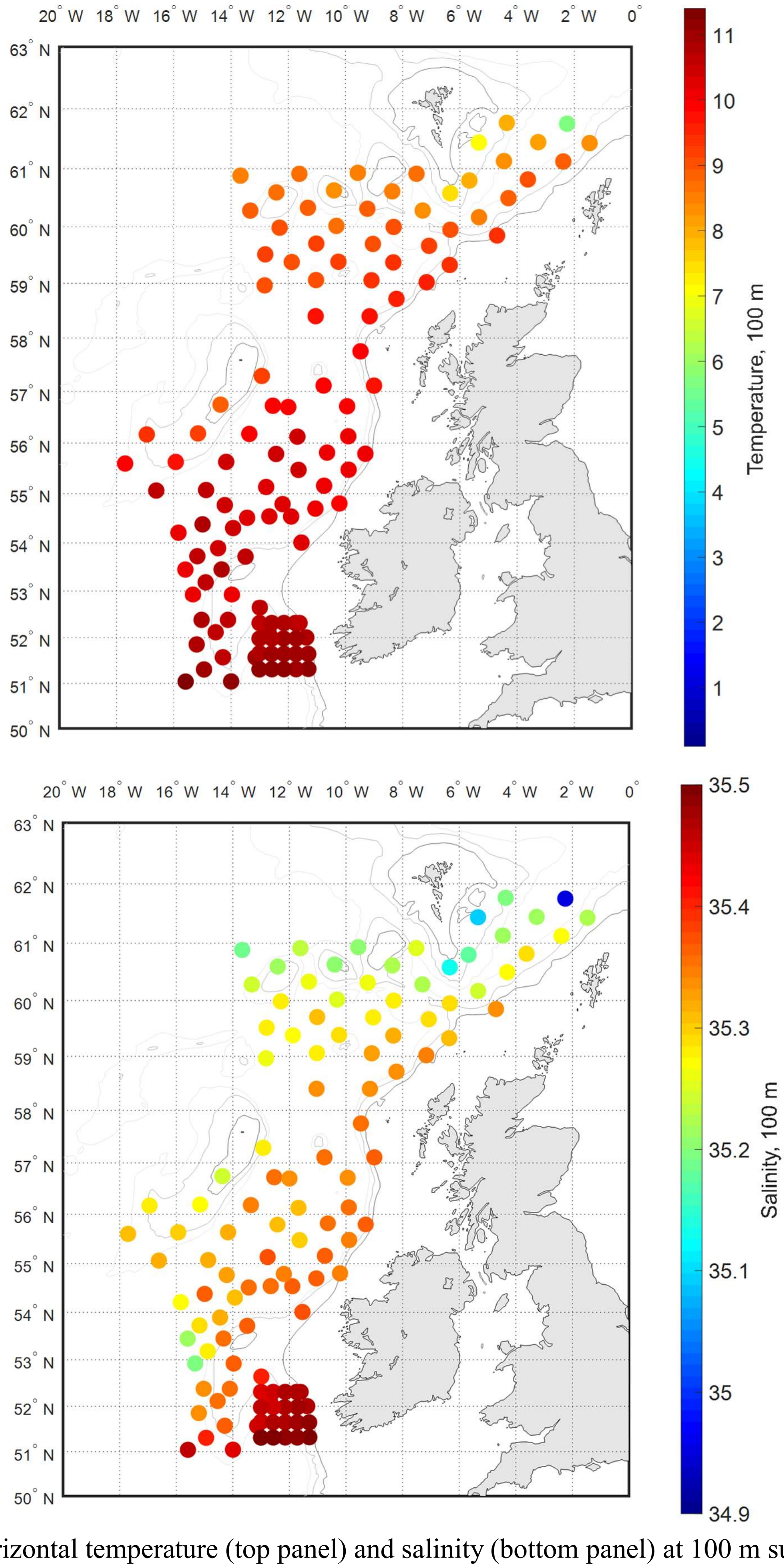


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

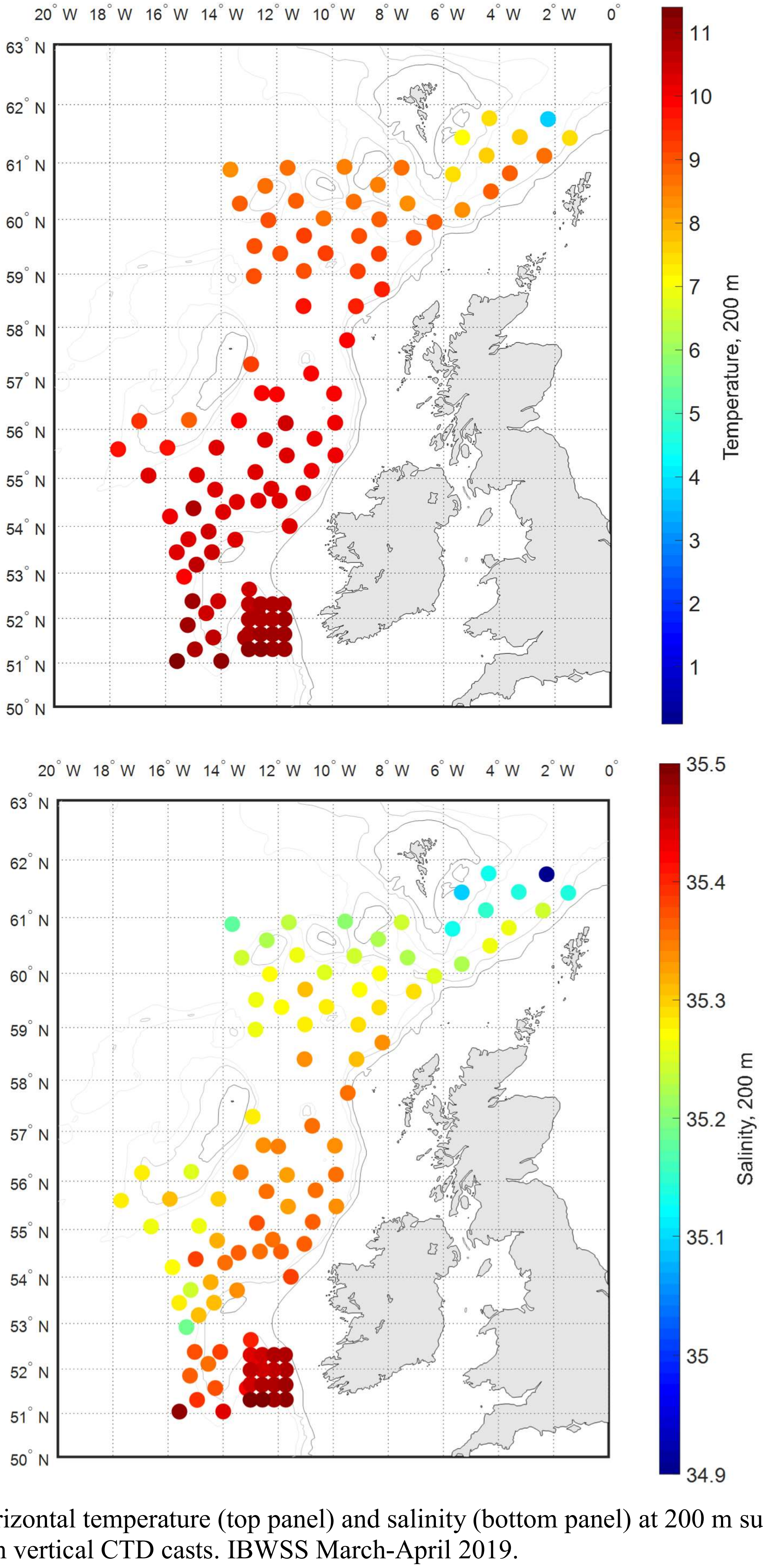


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

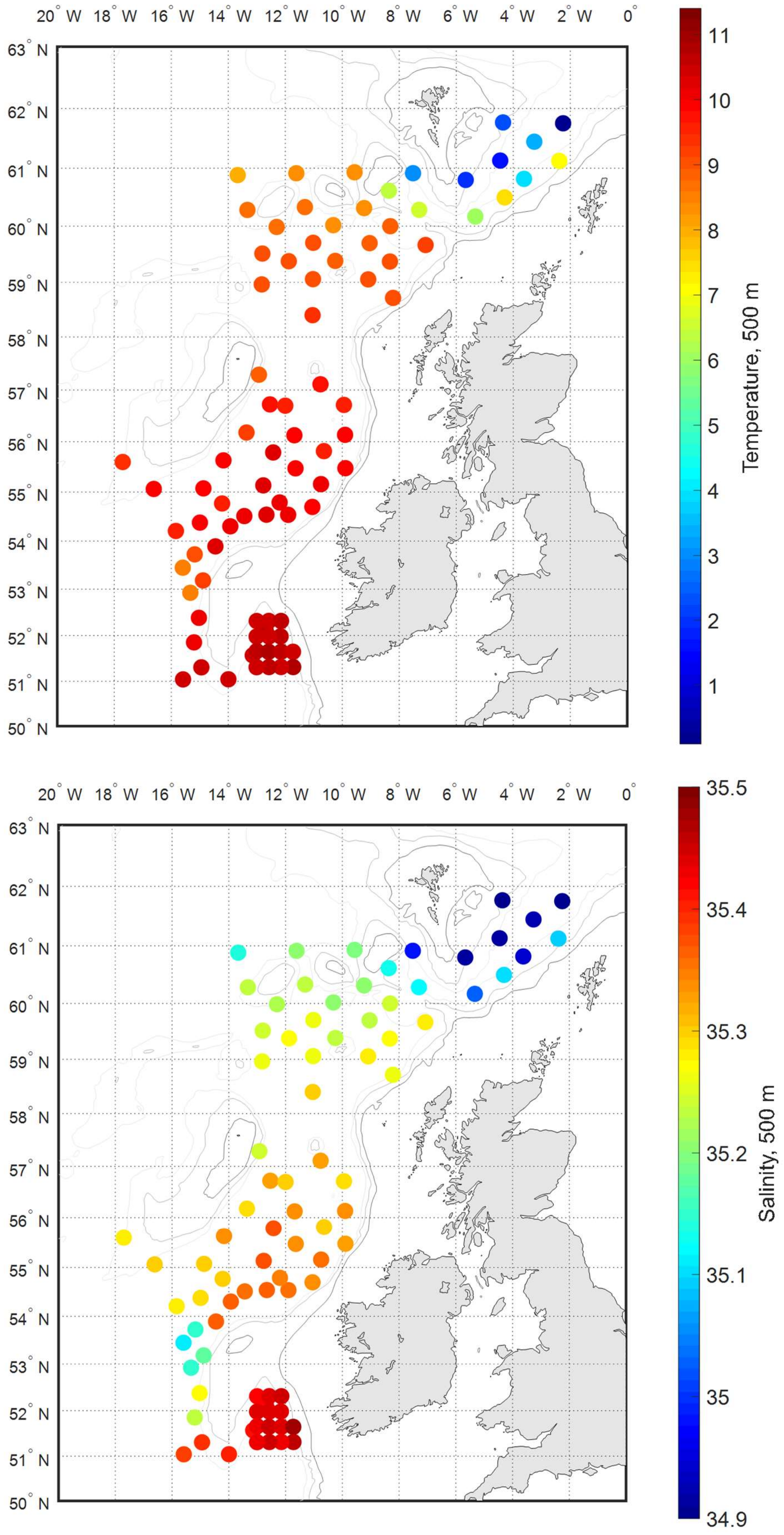


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

Direct assessment of small pelagic fish by the PELGAS acoustic survey
- focus on horse mackerel in recent years (2018-2019) -

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Introduction

The PELGAS survey (Doray et al., 2014) aims at monitoring the Bay of Biscay pelagic ecosystem, in order to provide scientific data for the implementing of an ecosystemic management of Biscay living resources. The spatial and temporal dynamics of small pelagic fish populations are specifically monitored, with a focus on anchovy populations. The cruise hence takes place in spring, during anchovy spawning, to allow for the assessment of both eggs and adult stages.

The PELGAS ecosystemic cruise aims at collecting data at each level of the Biscay trophic chain. Data are collected continuously along parallel transects covering the whole Bay of Biscay, in order to thoroughly characterize the horizontal and vertical structures of the pelagic ecosystem. Multibeam and multifrequency echosounders provide real time information on the spatial patterns and abundance of pelagic organisms ranging from plankton to fish. Simultaneously, a Continuous Fish Egg Sampler provide complementary data on small pelagic fish eggs. The presence and abundance of seabirds and marine mammals are also continuously recorded.

Acoustic targets are adaptatively identified by fishing (pelagic trawling and plankton nets) and/or using video (trawl camera, Remotely Operated Vehicle EROC, plankton video profiler). CTD stations are actually performed over the whole Bay of Biscay to provide hydrological information. In situ measurements are compared to satellite and hydrodynamic models outputs.

The PELGAS cruise is part of the "Fisheries Information System" implemented by the "Biological and Environmental Resources" Ifremer department. Data are collected within the EU Data Collection Regulation framework and are used to assess the anchovy and sardine stocks within the ad-hoc International Council for the Exploration of the Sea (ICES) working group WGHANSA. The sea cruise is internationally coordinated with Spanish, Portuguese and English cruises within the ICES WGACEGG working group. The survey also collects data on nutrients useful for descriptor D5 of the Marine Strategy Framework Directive. The numerous parameters collected during the PELGAS sea cruises will actually provide indicators to assess the good ecological state of the Biscay pelagic ecosystem, within the framework of the new EU directive.

This document briefly describes the methods used to derive abundance and biomass estimates from fisheries acoustic data collected during PELGAS, and particularly results concerning horse mackerel, as answered by the WGWIDE data call.

2- Material and methods

2.1. PELGAS sampling

Acoustic data are collected along systematic parallel transects perpendicular to the French coast (Figure 1), from the Northern French coast to Spain, over a linear total distance of about 6 000 nautical miles (NM, 1 NM = 1 852 m). The transects are uniformly spaced every 12 nautical miles (22 km).

The survey design allows for the coverage of the whole Biscay continental shelf (about 23 000 NM²), from 25 m depth to the shelf break (>200 m depth). The nominal sailing speed is 10 knots (1 knot = 1 852 m.s-1), the speed being reduced to 4 knots on average during fishing operations. This speed allows to sample the whole Biscay shelf in about 30 days.

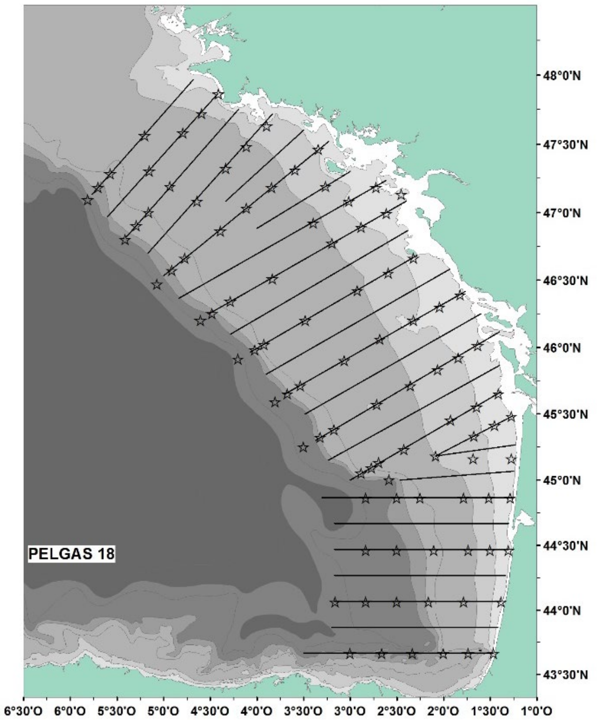


Figure 1. Bay of Biscay map and PELGAS survey design. Lines: acoustic transects; stars : hydrological stations

A total amount of around 2000 nautical miles is usable for assessment purpose.

2.2 acoustic data processing

In 2018 and 2019, as in previous surveys (since 2009), three modes of acoustic observations were used:

- 1 SIMRAD ME70 multi-beam echo-sounder (21 2 to 7°beams, from 70 to 120 kHz) used essentially for visualisation and observing the behaviour and shapes of fish schools during the whole survey. Nevertheless, only echoes stored on the vertical echo-sounder were used for abundance index calculation.
- 1 horizontal echo-sounder on the starboard side for surface echo-traces
- These two recent years, the broadband echosounder EK80 was installed and used

Energies and samples provided by all sounders were simultaneously visualised and stored using the MOVIES3D software and stored at the same standard HAC format.

The calibration method was the same that the one described for the previous years (see WD 2001) and was performed at anchorage near Brest, in the West of Brittany, in good meteorological conditions at the end of the survey.

2.3 – species identification by trawling

The identification of species and size classes comprising fish echotraces (ICES, 2000) heavily depends on identification via trawl hauls performed by R/V Thalassa using a 2 doors, headline: 76 m foot rope: 70 m (or 57 m x 52 m) pelagic trawls. Echograms are scrutinized in real time and trawl hauls are performed as often as possible. Rationale for performing an identification haul include:

• observation of numerous fish echotraces over several elementary sampling units (ESDUs) or of very dense fish echotraces in one ESDU;

• changes in the echotrace characteristics (morphology, density or position in the water column);

• observation of an echotrace type fished on previous transects, but never fished on the current transect.

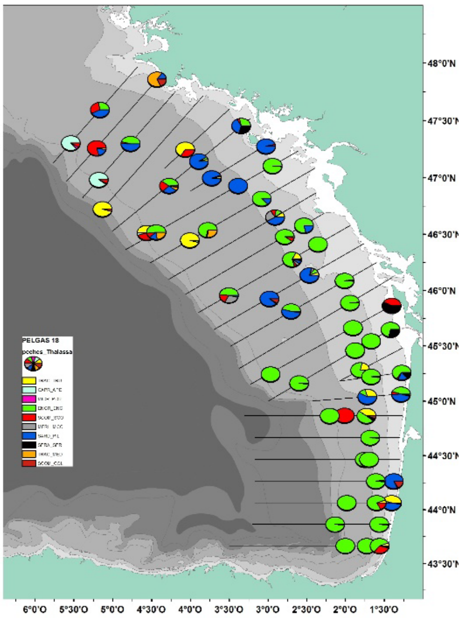
A consort survey is routinely organised since 2007 with French commercial vessels during 18 days. This approach is in identical to last year's surveys, using the commercial vessel's hauls were for echoes identification and biological parameters to complement hauls made by the R/V Thalassa.

Four commercial vessels (two pairs of pelagic trawlers) participate to each PELGAS survey.

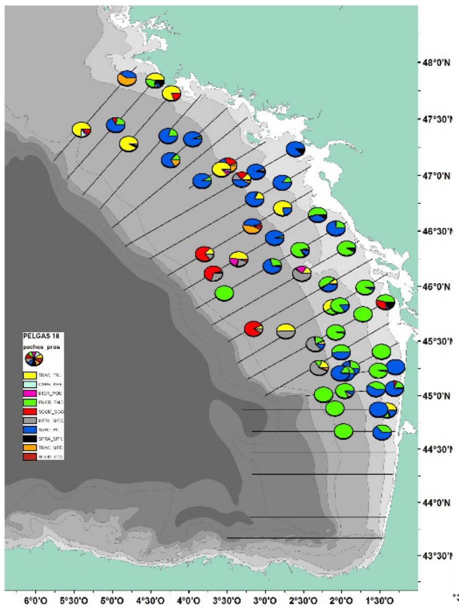
Their pelagic trawl was up to 25 m vertical opening and the mesh of their codend was similar to the on uses by the R/V Thalassa (12 mm).

A scientific observer was on board the commercial vessel to control every fishing operation, and to collect biological data. The fishing operations were systematically agreed after a radio contact with Thalassa in order to confirm their usefulness. In some occasions, these fishing operation were used to check the spatial extension of species already observed and identified by Thalassa (and therefore the spatial distribution); in others the objective was to enlarge the vertical distribution description by stratified catches. Globally, a great attention was given on a good distribution of samples to avoid over-sampling on some situations. Catches and biological data were used to complement the sampling made on board the R/V Thalassa.

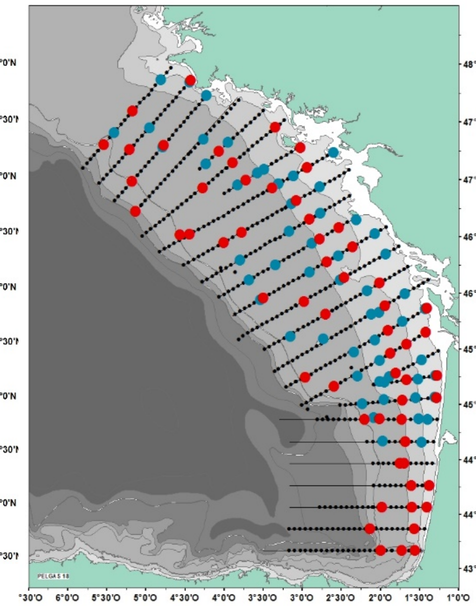
A total of an average of 120 hauls are carried out during the whole survey



a) Thalassa (nb :60)



b) Commercial vessels (nb : 61)



c) all fishing hauls (nb :121) Thalassa in red and commercial in blue

Figure 1.2.2 : fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS18

2.4. Pelagic fish biomass assessment by acoustic

Biscay fish population biomass is assessed during Pelgas cruise using an 'expert' methodology to combine acoustic and fishing data. The data processing procedure produces the following outputs:

• Overall biomass and abundance per species, with estimation error;

• Biomass and abundance per species per 1NM Elementary Sampling Distance Unit (ESDU);

• Biomass and abundance at size per species per 1NM Elementary Sampling Distance Unit (ESDU);

• Biomass and abundance at age per 1NM Elementary Sampling Distance Unit (ESDU) for anchovy and sardine;

The methodology used is described in details in Doray et al. (2010).

3- Results

3.1 Horse mackerel biomass estimate

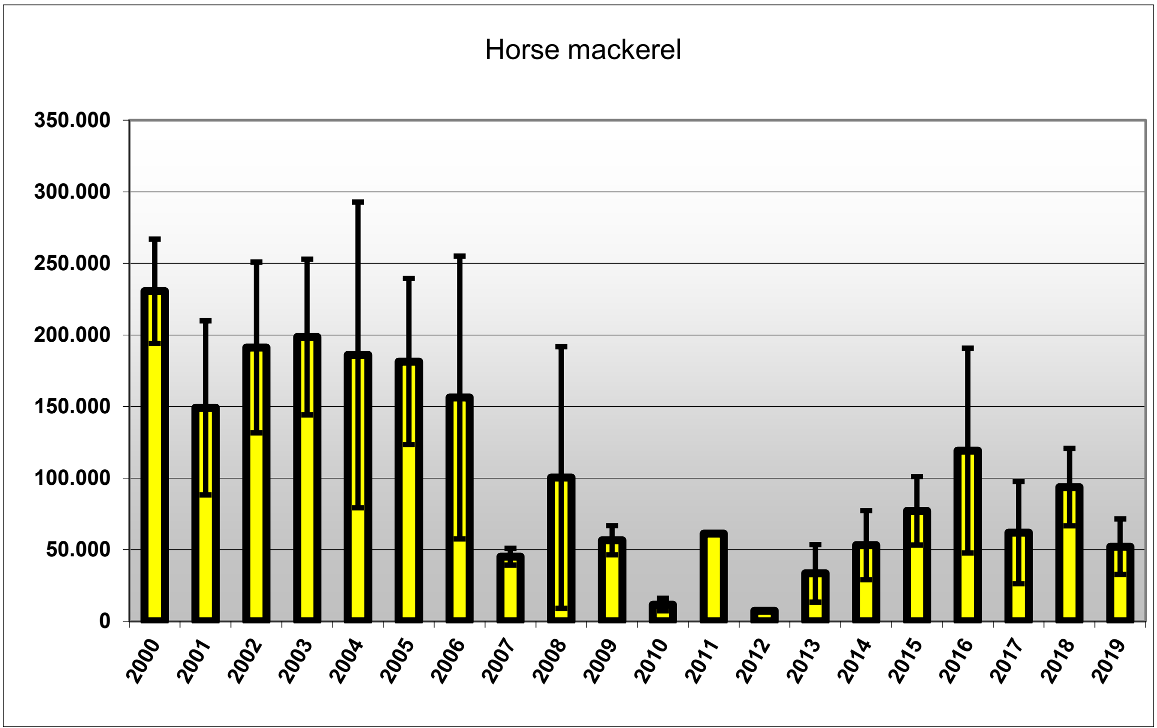


Fig 3.1 : horse mackerel abundance index serie.

In these recent years, it seems that horse mackerel showed a kind of stability of the biomass reaching a medium/low level since 2014 in the bay of Biscay. The decrease of the abundance was strong from the beginning of the pelgas serie until 2012.

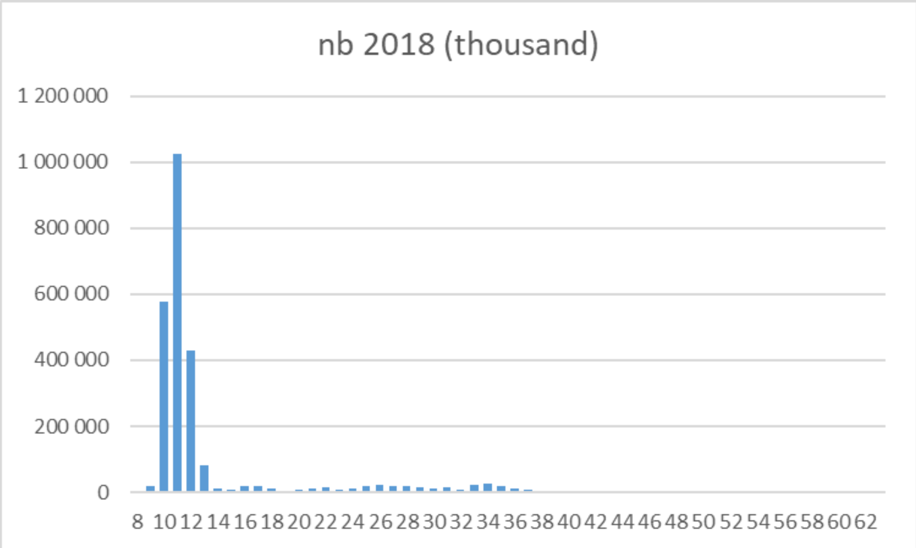
Biomass indices and associated CV are showed in table 3.1.

Table 3.1. serie of biomass indices for horse mackerel during pelgas serie

year	HOM index	*CV HOM*
2000	230 530	0.08
2001	149 053	0.20
2002	191 258	0.16
2003	198 528	0.14

2004	186 046	0.29
2005	181 448	0.16
2006	156 300	0.32
2007	45 098	0.07
2008	100 406	0.46
2009	56 593	0.09
2010	11 662	0.19
2011	61 237	
2012	7 435	
2013	33 471	0.30
2014	53 154	0.23
2015	77 142	0.15
2016	119 230	0.30
2017	61 919	0.29
2018	93 728	0.14
2019	52 101	0.19

3.2. size distribution in 2018 and 2019



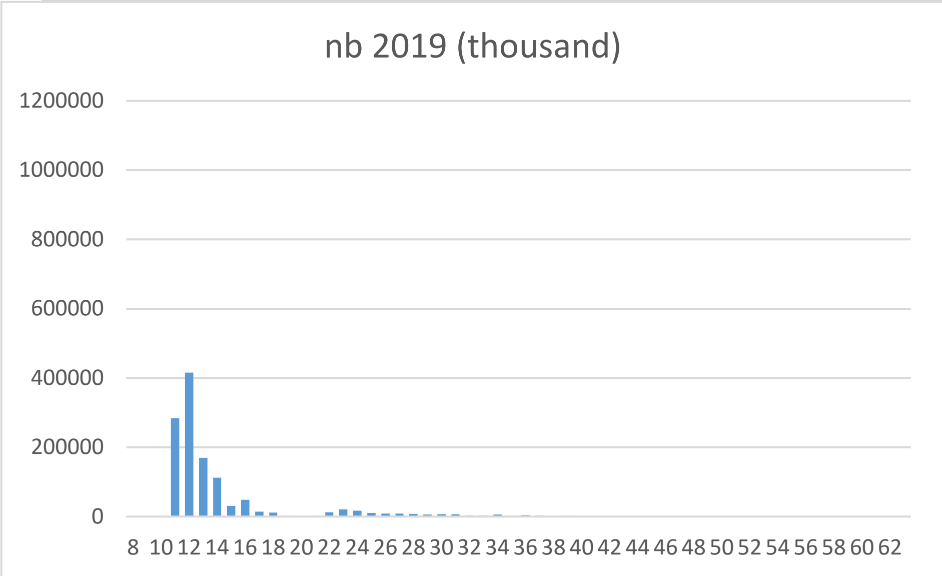


Fig 3.2 : abundance of horse mackerel for each length class in 2018 and 2019

length	nb 2018 (thousand)	nb 2019 (thousand)
8	0	
9	19 919	
10	577 165	321
11	1 022 986	283 907
12	429 646	415 835
13	83 005	169 584
14	9 861	112 387
15	8 178	30 479
16	17 577	48 135
17	19 036	14 121
18	9 774	11 641

19	3 834	1 872
20	7 156	312
21	10 556	2 518
22	14 630	12 362
23	5 907	20 306
24	11 684	16 873
25	16 869	10 517
26	22 886	8 838
27	17 143	8 711
28	18 786	7 668
29	14 179	6 014
30	10 563	6 665
31	15 657	6 355
32	7 701	3 227
33	23 829	2 917
34	25 426	5 559
35	17 943	1 985
36	12 481	4 024
37	8 981	3 184
38	1 986	1 391
39	834	2 509
40	174	431
41	2 158	46
42		71
43		129
44	7	17
45	7	106
46		23
47		6
48		83
49		23
50		35
51		46
52		6
53		29
54		95
55		
56		6
57		
58		6
59		12
60		
61		
62		
63		23

The small horse mackerel is predominant in the bay of Biscay. It appears in schools sometimes very dense, or mixed with sardine and/or anchovy in coastal waters. More offshore, the large horse mackerel is scattered on the shelf, in low density or mixed with mackerel, blue whiting or hake. It appears also sometimes closed to the surface, particularly in the Northern part of the bay of Biscay.

3.3 spatial distribution

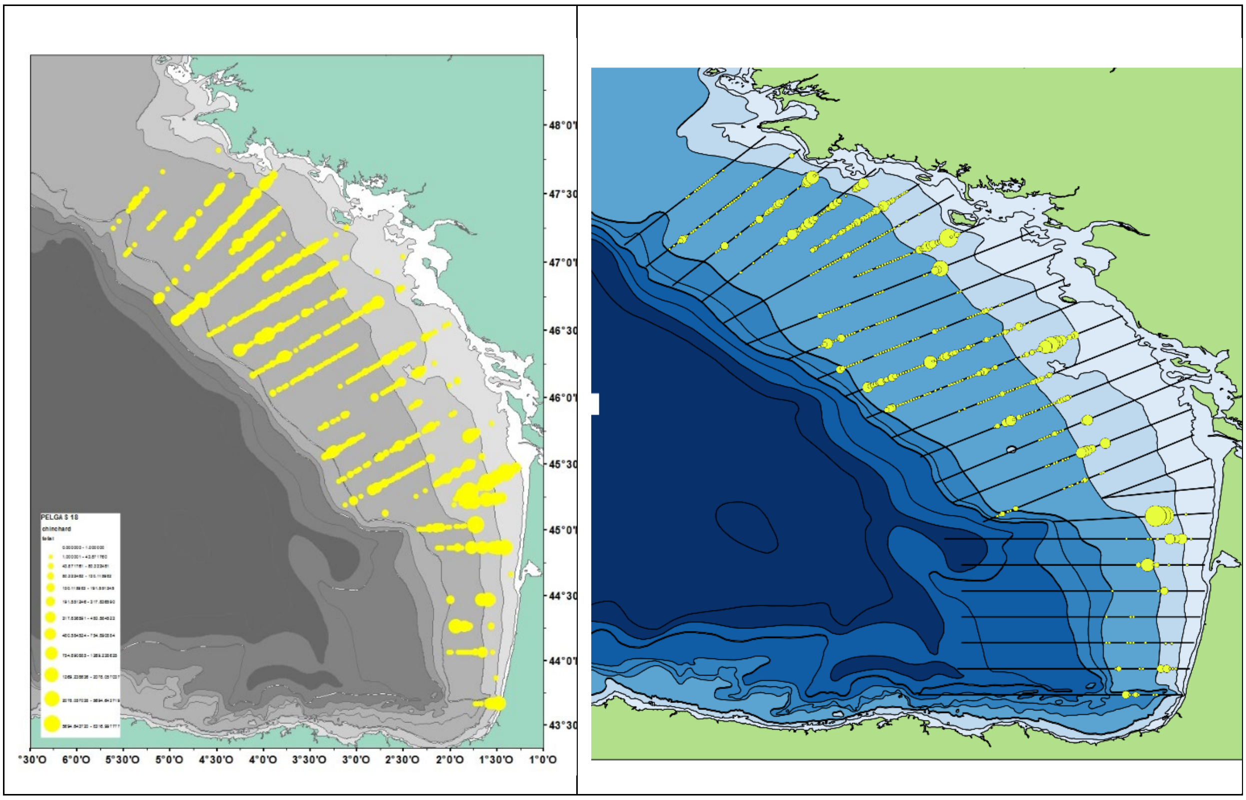


Fig 3.3. spatial distribution of horse mackerel as observed during spring 2018 (left) and 2019 (right).

4. Conclusion

At least, it must be noticed that during surveys the two species of horse mackerel *(trachurus trachurus* and *trachurus mediterraneus*) are well identified. This is not the case in the sales, when some mixing or false identification occurred more or less significantly.

Annex 7: European Commission, DG MARE, request for assessing the risk on sustainable management of limiting the TAC for Boarfish to areas 6 and 7

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Request

Details of the request

> *ICES is requested to analyse for Boarfish in subarea 8b and 8c (TAC currently covering subareas 6, 7 and 8) the role of the Total Allowable Catch instrument. It is asked to assess the risks of limiting the TAC for Boarfish to areas 6 and 7 in light of the requirement to ensure that the stock concerned is exploited sustainably in the short and medium term.*
>
> *ICES is further requested to assess the potential contribution of the application of other conservation tools in absence of TACs for Boarfish in subarea 8b and 8c to the requirement that the stocks concerned are managed in a sustainable manner.*

ICES asked this request to be addressed by answering the following series of six questions:

1. *Was the TAC restrictive in the past?*
2. *Is there a targeted fishery for the stock or are the species mainly discarded?*
3. *Is the stock of large economic importance or are the species of high value?*
4. *How are the most important fisheries for the stock managed?*
5. *What are the fishing effort and stock trends over time?*
6. *What maximum effort of the main fleets can be expected under management based on FMSY (ranges) for the target stocks, and has the stock experienced similar levels of fishing effort before?*

A concluding section is provided.

Upon clarification with DGMARE:

It is asked to assess the risks of limiting the TAC for Boarfish to areas 6, 7 and 8a and d.

General

The boarfish (*Capros aper*) is a deep bodied, laterally compressed, pelagic shoaling species. It is widely distributed at depths of up to 600m - the most recent data suggests that a single stock exists in subareas 4,5,6,7,8 and the northern part of 9.a – broader than the current management area of subareas 6,7 and 8.

Boarfish reach a maximum length of approximately 18cm with growth most rapid in the first 2-3 years and a maximum age of 31 has been recorded. Boarfish mature at 5-6 years, and is a batch spawner, spawning in June–July. All indications are that boarfish is an indeterminate spawner.

Latest advice

The most recent advice for Boarfish in subareas 6-8 was published in September 2017. Advice for 2018 and 2019, based on the precautionary approach (framework for category 3 stocks), was for annual catches of no more than 21,830t.

1. Was the TAC restrictive in the past?

The first landings of boarfish were reported in 2001 and were relatively small (<1kt) up until 2007 after which the fishery expanded rapidly. A TAC for European Union vessels in Union and International waters of ICES subareas 6, 7 and 8 was set for the first time for 2011. Prior to this the fishery was unregulated. There was full uptake of the TAC in 2011 and 2012. However, since 2013, the TAC has not restricted catch levels although the most recent TAC is of the order of recent catches. Figure 1 and table 1 show the history of landings, discard estimates and the TAC (black line).

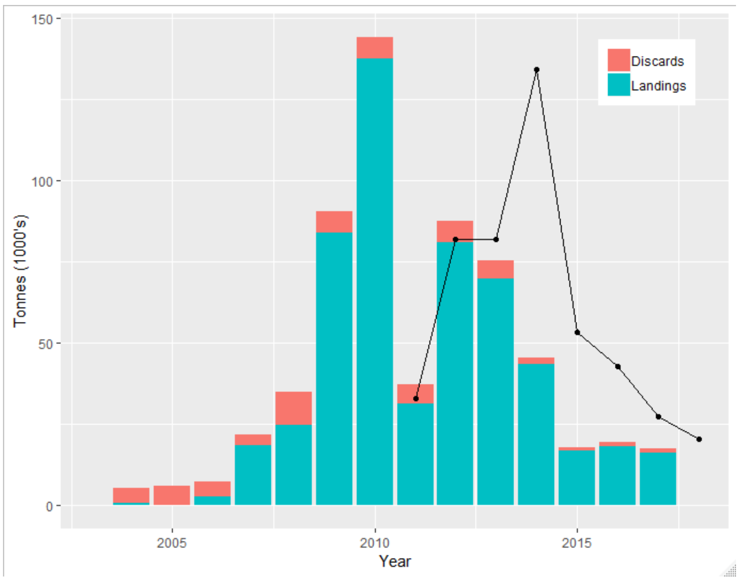

Figure 1: History of landings, discards and TAC for Boarfish in subareas 6, 7, and 8.

Table 1: Discards, WG Catch (Data provided by working group members) and TAC 2001–2018.

Year	Discards	WG Catch	TAC	Year	Discards	WG Catch	TAC
2001		120	-	2010	6,544	144,047	-
2002		91	-	2011	5,802	37,096	33,000
2003	10,929	11,387	-	2012	6,634	87,355	82,000
2004	4,476	5,151	-	2013	5,598	75,409	82,000
2005	5,795	5,959	-	2014	1,813	45,231	133,957
2006	4,365	7,137	-	2015	929	17,766	53,296
2007	3,189	21,576	-	2016	1,284	19,315	47,637
2008	10,068	34,751	-	2017	1,173	17,388	27,288
2009	6,682	90,370	-	2018			20,380

2. Is there a targeted fishery for the stock or are the species mainly discarded?

Prior to the mid-2000s, the majority of boarfish catches were discarded. It was an unwanted bycatch in both pelagic and whitefish fisheries. Dutch, English and German reported catches in recent years are bycatch by their pelagic freezer trawler fleet. It is estimated that boarfish may have accounted for up to 5% of the total catch of the Dutch Freezer trawler fleet during 2002-2005 (Borges *et al* 2008).

With the development of pumping and processing technology facilitating the expansion of a targeted fishery, discards account for a relatively minor proportion (approx. 5%) of the total catch since 2008. Ireland has the majority of the quota (69%) with Scottish (6%) and Danish (25%) vessels also participating although not since 2015. Landings by country are shown in figure 2.

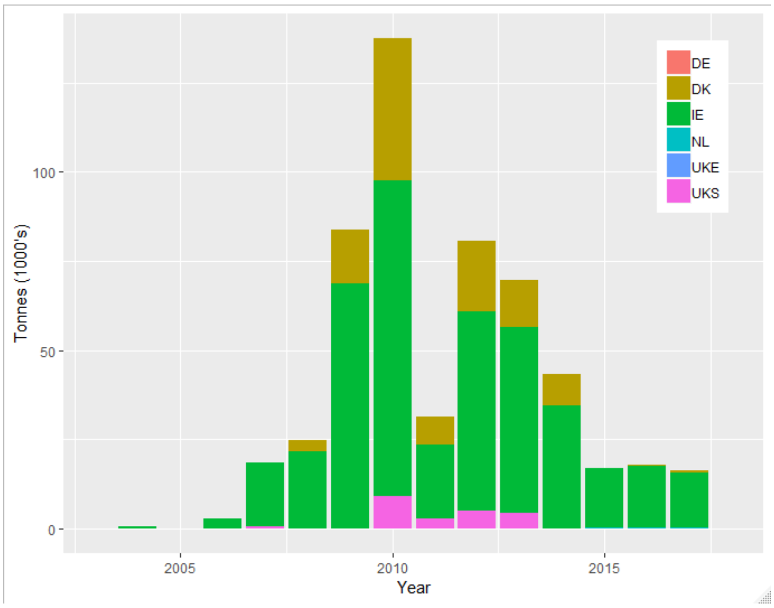

Figure 2 – National landings of Boarfish 2003–2017 (data supplied to WG)

The Irish fishery is prosecuted by pelagic trawlers including a relatively small number of large RSW vessels. Irish catches by ICES division are shown in figure 3, disaggregated by gear type (OTM – single trawl, PTM – pair trawl).

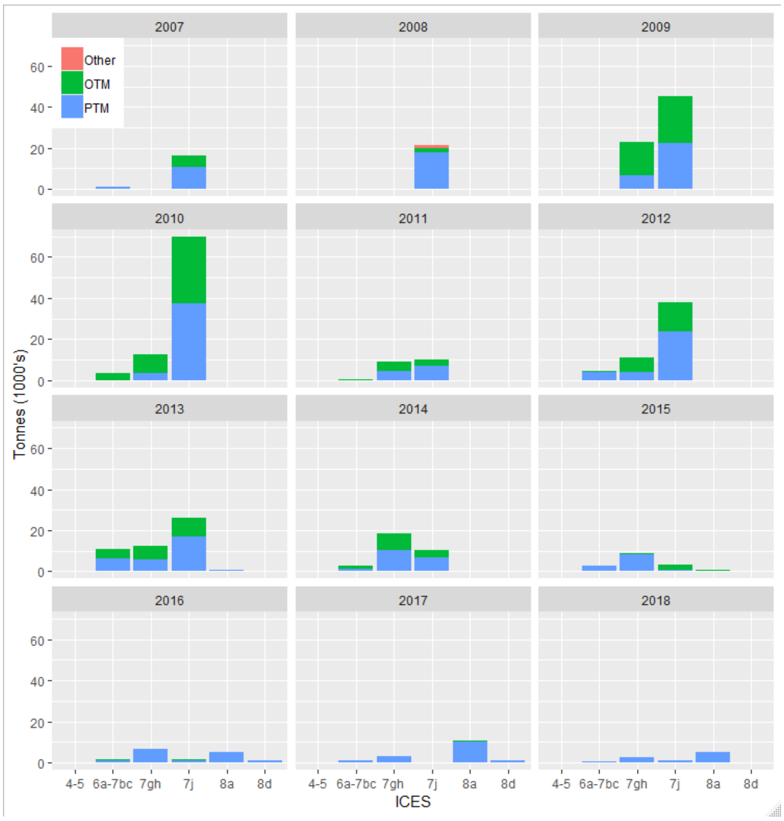

Figure 3. Boarfish catches by ICES division and gear type for Irish vessels.

During the period of expansion, the majority of Irish catch was taken in ICES divisions 7h, j & k by a combination of single and pair trawls. In recent years' catches have been lower, mostly taken by pair trawlers and increasingly further south with an increasing proportion from division 8a. Since 2015, catches from 7j represent a relatively minor proportion of the total, in contrast to

2007-2013 when it accounted for the largest proportion. For the Irish fleet, over 85% of catches were taken on trips when boarfish accounted for over 90% of the total landings from the trip (by weight). Average trip length has increased in recent years.

3. Is the stock of large economic importance or are the species of high value?

Boarfish catches are used in the fishmeal and fish oil industries and prices depend on the relative availability of other species used for reduction. Although minor when compared to other pelagic species, the value of landings to the Irish fleet is of the order 2-5 million euro per annum (figure 4).

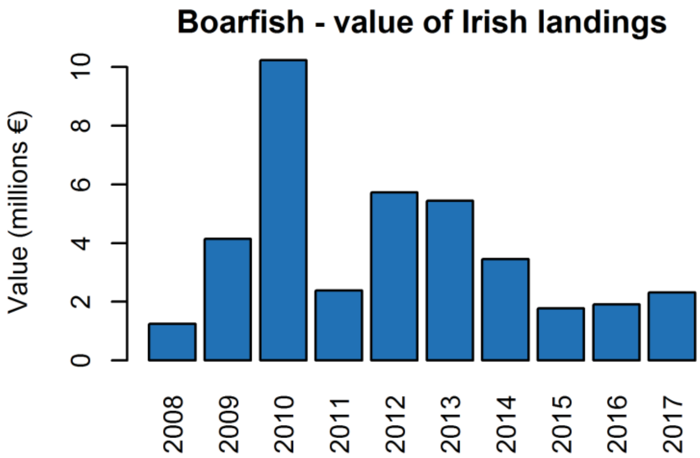

Figure 4: Value of Irish landings of Boarfish, 2008–2017

4. How are the most important fisheries for the stock managed?

Management of this stock is by Total Allowable Catch (TAC) set for sub-areas 6, 7 and 8. The first TAC was established for 2011, Prior to this, the fishery was unregulated, during which time the largest annual catches were recorded (2010).

A number of provisions including a closed season and area specific closures, along with a moving on regulation at statistical rectangle level exist in Irish law to avoid mixed catches (mackerel, herring).

5. What are the fishing effort and stock trends over time?

Since 2007 an average of 83% of the total annual landings have been by Irish vessels. The number of vessels participating in the fishery increased rapidly in 2010-2013 and average landings per trip fell during this time. Since 2013 there has been a decline in the number of vessels targeting boarfish. Linked to availability of fish, market conditions and national quota administrative processes. Figure 5 shows the average landings per trip along with the number of vessels, trip and average trip length for the Irish fleet targeting boarfish.

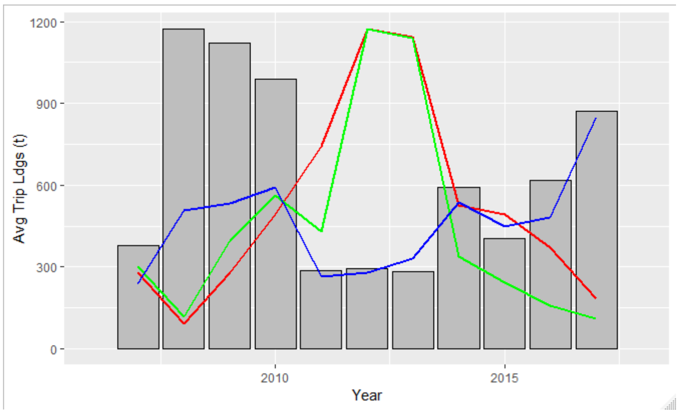

Figure 5: Average landings per trip (grey bars) and trends in number of vessels (red), number of trips (green) and trip length (blue) for the Irish fleet, 2007–2017.

Following the introduction of the TAC a large number of vessels (35) participated in the fishery (2011-2013). A relatively large number of trips were undertaken with an average of 300t landed per trip. In subsequent years the number of vessels has reduced with only larger (RSW) vessels participating undertaking fewer but longer trips. Catches were taken further south than previously adding to trip length. Uptake has been influenced by the availability of alternative, more profitable opportunities.

The assessment for this stock is conducted using a Bayesian Schaefer surplus production model. The assessment output is considered indicative of trends in total stock biomass and is used within the ICES framework for category 3 stocks. The assessment is informed by total catch, six IBTS surveys and an acoustic survey that has been conducted since 2011.

The biomass trend results from the 2017 stock assessment are shown in figure 6.

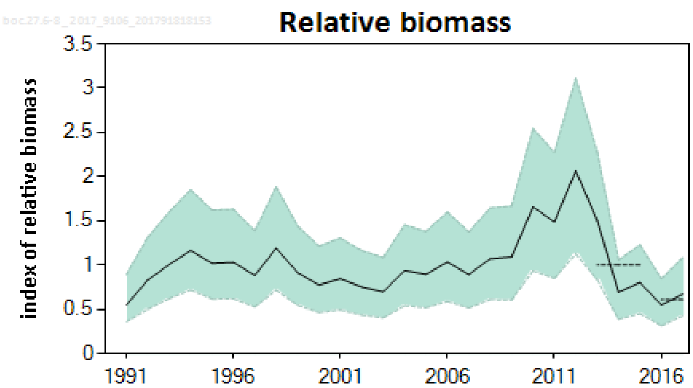

Figure 6: Output from the most recent assessment conducted for the provision of catch advice (ICES, 2017)

The relative stock biomass was stable until 2009, then increased in 2010–2012 before declining rapidly in 2013 and 2014. Since 2014, relative biomasses have been stable but lower than previously observed.

6. What maximum effort of the main fleets can be expected under management based on FMSY (ranges) for the target stocks, and has the stock experienced similar levels of fishing effort before?

Advice for this stock is given using the precautionary approach and no reference points are defined. An estimate of F_{MSY} is available from the exploratory surplus production model (r/2). In

2018, F_{MSY} was estimated at 0.185 which was exceeded in 2009-10 when effort and catches were high and in 2014. $MSYB_{trigger}$ (K/4) is estimated as 165,420kt. Estimated biomass has been greater than this throughout the period of the fishery.

Effort by the fleet targeting boarfish has not been TAC limited in the recent past rather, it is determined by a combination of factors including the availability of fishable aggregations, external economic conditions and other pelagic, more profitable opportunities.

Conclusion

Recent data suggests that the proportion of boarfish caught in southern areas is increasing. Figure 7 compares the average annual catch between 2003 and 2017 with that from 2017.

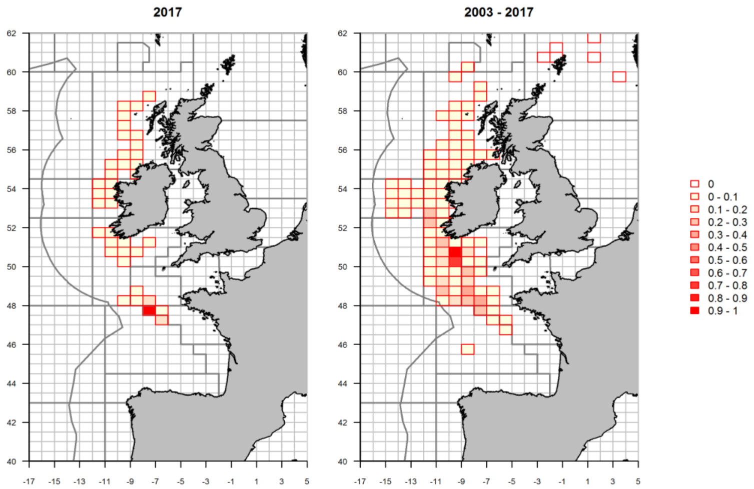

Figure 7: Distribution of catch, 2017 (left) and 2003–2017 (right).

While no catches have been reported from subareas 8b and 8c (which would be removed from the TAC area under the proposal), these subareas are considered to be part of the stock distribution area, following a dedicated genetic study on population structure (Farrell *et al.* 2016).

Groundfish (IBTS) surveys in 8b and 8b regularly encounter boarfish and are an important source of information for the assessment. In addition, boarfish is regularly discarded by both pelagic and demersal fleets operating where the species is present. Discard estimates are included in the assessment.

The surplus production model assessment output used as an index of stock development has high uncertainty, as the catch and acoustic survey stock size estimate time series are relatively short. Longer time series are available from the IBTS surveys from which a biomass indices are extracted using a delta-lognormal method given the high proportion of zero hauls although confidence intervals are wide.

The assessment output is heavily influenced by the acoustic survey (BFAS) which was first conducted in 2011 and was redesigned in 2017. The acoustic estimates of stock size are considered to be reliable within the survey area although stock containment at transect edges has not been achieved in all survey years. The most recent assessment output and time series of input data are shown in figure 8.

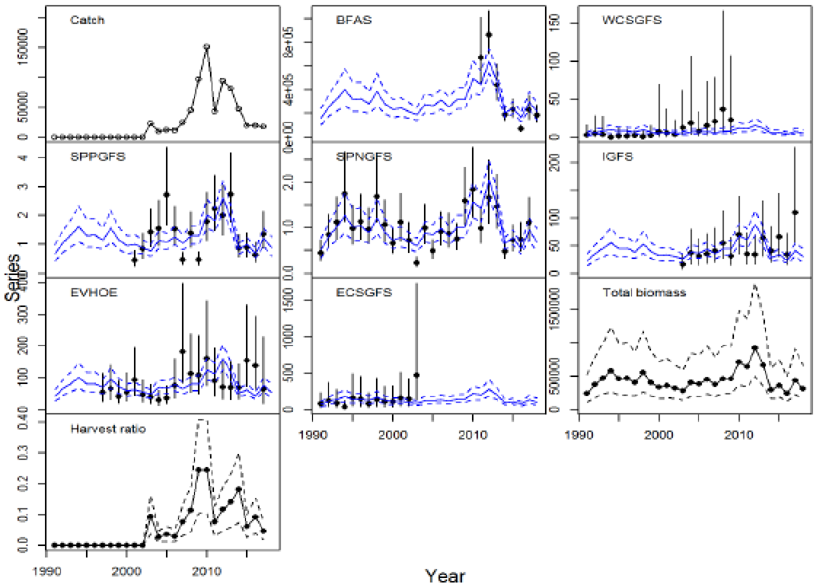

Figure 8: Trajectories of IBTS indices, acoustic index (BFAS), stock size and harvest ratio (total catch divided by estimated biomass)

Overall, several elements linked to this stock are of concern with respect to this request. The level of uncertainty associated with the current assessment and supporting data is high. The stock also lacks defined reference points. In addition, recent changes in fishing pattern and reductions in the TAC to a level close to recent catches are observed. Under precautionary considerations, it is thus not considered appropriate to remove subareas 8b and 8c from the current TAC area.

References

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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.

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Reviews

Review 1: Stage 4 Species: Stock by Stock Impression of whether the summary of the questions and data *provide a solid background to say Y/N to lifting TAC.*

1. *Has the species/stock/group (hereafter referred to as stock) got characteristics that places it at high relative risk?*

In terms of its general biology e.g. aggregating, sex change, long lived, low productivity, forage fish, ecosystem important

In terms of its catchability e.g. degree of population overlap with key fisheries, presence of refuges, ability to be directly targeted

Greater silver smelt is slow growing and relatively log-lived (>20 years). It is a forage species – prey for species such as hake and other deepwater fish. It is an aggregating species, forming shoals that can be detected using acoustic gear. It can therefore be targeted by pelagic trawls. The stock structure is unknown. The assessment stock definition was changed in 2015 – subarea 7 fell into one of four stocks, while most of the present fisheries fall within the other stocks.

There is no dedicated effort on the species, but catches were discarded in fisheries for other species such as hake and monkfish i.e. trawl fisheries.

2. *Is the present TAC/management influenced by past unsustainable practices?*

If yes, are those fisheries still active?

Was the stock targeted?

There is no targeting of the species in this sub-area and larger past catches may have been confounded with other species and market driven. The management of this species is mainly through TACs and quotas. Past landings figures are confounded by being lumped together with other species.

A survey biomass index based on the Spanish survey on Porcupine bank showed increases in biomass between 2014 and 2016, and recent declines. The current level of biomass in subarea 7 in unknown. An assessment is also not available.

The report finds that a value of 500t is likely to be sustainable but the basis for this is unclear. The report also does not include the TACs over time which would be useful.

3. *Can these or new unsustainable practices return if the TAC is removed?*

Can they be targeted with present fleet?

Are they heavily discarded?

Is the stock valuable?

In the past decade the stock was not targeted and was largely discarded until the landings obligation commenced. It is a bycatch species in this subarea. The stock is of low to moderate value, but this value has increased in the last decade as processed food products were developed.

These species can be targeted using pelagic trawls as has been shown in subareas 1,2,5 and 6. If shoals appear in subarea 7, then a targeted fishery could develop and, as such, active management would be required.

4. *Are there alternatives to a TAC to manage this stock?*

Can they be managed as companion species through target TACs (if applicable)?

Can they be spatially managed?

Any other mechanism? E.g. Multi-Year TACs (MYTAC).

The report clearly states that removal of the TAC of greater silver smelt in subarea 7 would require a monitoring process to rapidly re-introduce TACs if a targeted fishery develops (which is possible). It proposes a maximum proportion of bycatch per fishing operation as well as in the total catch be considered. Bycatch of greater silver smelt in other fisheries should also be kept to a minimum.

5. *Conclusion*

The report provides adequate information to make a decision about the risks associated with removing the TAC, including advice as to what alternatives should be put in place of a TAC. These conclusions are reasonable given the information provided, although the justification of the 500t sustainable catch value needs a bit more justification. It would also be helpful if the TACs are also included in the table.

Review 2: Special request by EC (DG MARE) to assess the risk on sustainable management of limiting the TAC for boarfish to areas 6 and 7′

The methodology used by to address this request followed closely the approach, which was applied before for similar requests to evaluate TAC as a management tool (e.g. for dab and flounder, ICES 2017). Six questions with regard to the main fisheries and the stock were examined:

1. *Was the TAC restrictive in the past?*
2. *Is there a targeted fishery for the stock or are the species mainly discarded?*
3. *Is the stock of large economic importance or are the species of high value?*
4. *How are the most important fisheries for the stock managed?*
5. *What are the fishing effort and stock trends over time?*
6. *What maximum effort of the main fleets can be expected under management based on F_{MSY} (ranges) for the target stocks, and has the stock experienced similar levels of fishing effort before?*

General comments

The defined questions were clearly answered and supported with sufficient and conclusive information. The fishery targeting boarfish for reduction purpose just developed in the early 2000s and is currently mainly conducted by Irish trawlers. In the beginning of the catch time series high discard rates were observed, but these declined over the time when the processing and fishery further developed. A TAC was first introduced in 2011. This TAC was only restrictive in 2011 and 2012. After these two years, the quota was never fully utilized, although the TAC was reduced continuously from 2015 to 2018. The stock trend was stable until 2009, then increased from 2010 to 2012 and declined again in 2013 and 2014. Since 2014, the stock trend has stabilized but on a lower level compared to earlier years.

Given the high uncertainties in the data and the assessment, and a change in fishing pattern to more southern areas in the most recent years the authors conclude that lifting the TAC from area 8b and 8c is not in line with the precautionary approach. However, from the presented data it seems that no catches were taken from areas 8b and 8c in the period 2003-2017. How likely is it that a target fishery will develop in these areas? Is anything known about bycatch in other fisheries in these areas? What is known about the stock abundance and distribution in these areas? If possible, these issues should be further examined to support the conclusion.

Specific comments

1. *Was the TAC restrictive in the past?*

Working group name should be given at least in the caption of figure 1.

2. *Is there a targeted fishery for the stock or are the species mainly discarded?*

What is the reason that no Danish vessel participate in the fishery anymore?

3. *Is the stock of large economic importance or are the species of high value?*

Figure 4: Would it be possible to display also the market price over time?

4. *How are the most important fisheries for the stock managed?*

No further comments.

5. *What are the fishing effort and stock trends over time?*

Figure 5: Maybe it would be possible to add y-axis for the line plots (number of vessels, number of trips, and length of trips).

Does the number of 35 vessels participating in the fishery relates to the whole fleet or just the Irish fleet?

6. *What maximum effort of the main fleets can be expected under management based on FMSY (ranges) for the target stocks, and has the stock experienced similar levels of fishing effort before?*

Is the boarfish bycatch of other fleets known and is it a problem?

Conclusion

Figure 7: What is the unit of the legend? Please better describe what is exactly displayed here (mean values 2003-2017?). The ICES areas should be labelled.

Would it be possible to show also distribution patterns of IBTSurveys for boarfish abundance and to display the overlap with the fishing activities?

Are the mentioned discards by other fleets included in figure 1? If so, they seem to be negligible, at least for the most recent years. How are these discards are estimated? I assume that there are fleets which do not land boarfish at all (zero landings, but possibly high discards) and it would not be possible to raise something by applying a discard rate?

"*Longer time series are available from the IBTS surveys from which biomass indices are extracted using a delta-lognormal method given the high proportion of zero hauls although confidence intervals are wide*." Second part of the sentence is not clear…maybe reformulate.