1 Introduction

1.1 Terms of References (ToRs)

The Working Group on Widely Distributed Stocks (WGWIDE), chaired by Andrew Campbell, Ireland, met virtually from 25-31 August 2021. A virtual meeting replaced the planned physical meeting at ICES Headquarters due to restrictions resulting from the COVID-19 emergency. The terms of reference for the meeting were the generic ToRs for Regional and Species Working Groups:

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

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

   i) descriptions of ecosystem impacts on fisheries

   ii) descriptions of developments and recent changes to the fisheries

   iii) mixed fisheries considerations, and

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

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

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

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

   iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area), estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2020.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.1.1 The WG work 2021 in relation to the ToRs

The WG considered updates for all eight stocks within its remit. Based upon these assessments and associated short term forecasts, the group produced draft advice sheets for Northeast Atlantic mackerel, Blue Whiting, Norwegian spring spawning herring, Western horse mackerel, North Sea horse mackerel, boarfish and red gurnard. 2021-23 catch advice for striped red mullet was issued in 2020. All draft advice sheets were agreed in plenary. Advice sheets, report sections and assessments were audited with 3 working group members assigned to each stock. In addition, six stock annexes were updated and the productivity audit was completed for each stock.

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

1.2 Participants at the meeting

WGWIDE 2021 was attended by 46 delegates from the Netherlands, Ireland, Spain, Norway, Germany, Portugal, Iceland, UK (England and Scotland), Faroe Islands, France, Denmark, Greenland, Russia and Sweden. The full list of participants, all of whom are authors of this report is given in Annex 1.

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

1.3 Overview of stocks within the WG

Eight stocks are assessed by WGWIDE. In 2021, the group drafted 2022 advice sheets for 7 stocks. 2022 advice for striped red mullet was issued in 2020 the relevant data series and stock assessments were updated and considered at WGWIDE 2021. A summary of the WGWIDE stocks, current data category and assessment method and advice frequency is given in the table below:

Stock	ICES code	Data Category	Assessment method	Assessment Frequency	Last Assessment
Boarfish	boc.27.6-8	3.2	Bayesian Schafer surplus production model	2	2019
Red gurnard	gur.27.3-8	3.2	Survey trends based	2	2019
Norwegian spring-sp. herring	her.27.1-24a514a	1	XSAM	1	2020
Western horse mackerel	hom.27.2a4a5b6a7a-ce-k8	1	Stock Synthesis	1	2020

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

1.4 Quality and Adequacy of fishery and sampling data

1.4.1 Sampling Data from Commercial Fishery

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

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

1.4.2 Catch Data

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

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

1.4.3 Discards

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

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

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

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

1.4.4 Age-reading

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

1.4.4.1 Mackerel

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

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

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

A further, small scale exchange on NE A mackerel otoliths is scheduled for the 4th quarter 2020 and the results are currently being analysed.

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

1.4.4.2 Horse mackerel

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

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

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

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

1.4.4.3 Norwegian Spring-spawning Herring

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

There are several topics to cover in the recommended work.

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

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

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

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

1.4.4.4 Blue Whiting

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

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

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

During the workshop some of the otoliths from the exercise were polished, to help readers in the cases were the first age ring were not so evident, completely absent, or showing a growth pattern different from the expected. The polishing results revealed to be useful on the ring interpretation and to help in cases here the visible first ring size presents a size higher than the expected and the readers have doubts if an inner first ring are there. The hypothesis of the existence of a non-visible first ring has been described in the otoliths from the adult fish as the otolith becomes thicker and wider.

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

1.4.4.5 Boarfish

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

1.4.4.6 Striped red mullet

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

1.4.4.7 Red gurnard

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

1.4.5 Current methods of compiling fisheries assessment data

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

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

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

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

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

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

1.4.6 Quality of the Input data

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

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

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

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

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

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

Stock	Data Problem	How to be addressed in	By who
Northeast Atlantic Mackerel	Submission of data	Data submissions must include all the data outlined in the data call and be submitted by the deadline. Data should include length distributions split by area and quarter. Should the data submitter be unavailable after the data has been submitted (e.g. vacation) an alternative contact should be available who can be contacted in the event of any queries.	National laboratories
Northeast Atlantic Mackerel	Discard and slippage information	Discard and slippage information is incomplete. All fleets, including demersal fleets should be monitored and sampled for discards and slipping. Data should be supplied to the coordinator by the submission deadline, accompanied by documentation describing the sampling protocol.	National laboratories, RCG NA, RCG NS&EA
Northeast Atlantic Mackerel	Sampling deficiencies–general	All countries involved should provide sampling information. Increased cooperation between countries would help reduce redundancy and increase coverage.	National laboratories, RCG NA, RCG NS&EA
Northeast Atlantic Mackerel	Sampling of foreign vessels	Any information available from the sampling of foreign vessels should be forwarded to the appropriate person in the national laboratory in order that they may use this information when compiling the data submission.	National laboratories; RCG NA, RCG NS&EA
Horse Mackerel – Western Stock	Missing sampling data for some parts of the distribution area (e.g. 27.2a, 7e)	Fishing nations to Sample age and length Distributions from commercial fleets	National Institutes
Horse Mackerel – North Sea Stock	Incomplete report of discards by non-pelagic fleet.	Reporting of discards by national institutes.	National Institutes
Horse Mackerel – North Sea Stock	Lack of maturity ogive both by age or length	Collection of information about maturity stage during regular biological sampling (otoliths) in commercial and survey fleets	National institutes
Horse Mackerel – North Sea Stock	Lack of length distributions in the discarded component	Sampling of length distribution of discarded individuals	National institutes
Horse Mackerel – North Sea Stock	Low contribution of countries to the estimation of the age and length distribution of catches	To ensure the sampling of age and length information from all catch fractions and all areas and within all quarters from all commercial fleets with a distribution of sampling effort over the year and areas in the North Sea	National institutes
Norwegian Spring-spawning Herring	Low sampling effort on some nations	Sampling effort should be increased by nations with little or no samples.	National laboratories; RCG NS&EA
Red gurnard	Species level catch reporting and sampling	Red gurnard catches should be reported to species level and with the appropriate codification. Where reported as mixed gurnards, this should be accompanied by documented procedures for estimating the proportion of red gurnard.	National laboratories
Red gurnard	Discard and slippage information	Discard rates for this species can be very high (up to 100% of catch at a trip level). Alternative data sources	National laboratories

Stock	Data Problem	How to be addressed in	By who
		and methods for estimation (e.g. CCTV systems) should be investigated.	
Red gurnard	Stock area	Red gurnard is found all along the Iberian continental shelf. There are no records of catches of red gurnards in SA5, and this area could be removed from the data call.	
Northeast Atlantic Blue whiting	Submission of data	Data submissions must include all the data outlined in the data call and be submitted by the deadline. Should the data submitter be unavailable after the data has been submitted (e.g. vacation) an alternative contact should be available who can be contacted in the event of any queries.	National laboratories

1.4.7 Quality control of data and assessments, auditing

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

1.4.8 Information from stakeholders

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

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

A recent development that started around 2014 involves fishing industry organizations taking initiatives on their own, to collect additional information that is contributed to the expert groups. In many cases these research activities are undertaken in close cooperation with research institutes. In WGWIDE 2021, the following contributions from fishing industry research activities have been reported to the working group:

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

1.4.8.1 PFA self-sampling report 2016-2021 (WD01)

The Pelagic Freezer-trawler Association (PFA) initiated a self-sampling programme in 2015, aimed at expanding and standardizing ongoing fish monitoring programmes by the vessel quality managers on board of the vessels. An overview of the self-sampling in widely distributed pelagic fisheries from 2017 onwards is presented in the text table below.

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

***incomplete**

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

The horse mackerel fishery takes place from October through to March of the subsequent year. Overall, the self-sampling activities for the horse mackerel fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 243 fishing trips with 3 446 hauls, a total catch of 141 548 t and 153 307 individual length measurements. The main fishing areas are ICES divisions 27.6.a, 27.7.b and 27.7.d. Horse mackerel have a wide range in the length distributions in the catch. Median lengths in divisions 27.6.a, 27.7.b and 27.7.j have fluctuated between 26.2 and 31.3 cm (with one low median length of 23.3 cm in 27.6.a in 2018). In ICES divisions 27.7.d and 27.7.h, median lengths in the catch are smaller and fluctuated between 21.3 and 24.6 cm.

The blue whiting fishery takes place from February through to May although some minor fisheries for blue whiting may remain over the other months. Overall, the self-sampling activities for the blue whiting fisheries during the years 2017 - 2021 (up to 27/07/2021) covered 240 fishing trips with 6 560 hauls, a total catch of 650 604 t and 507 481 individual length measurements. The main fishing areas are ICES divisions 27.6.a, 27.7.c and 27.7.k. Compared to the previous years, blue whiting in the catch in 2021 have been relatively large with a median length of 27.9 cm compared to 24.2-27.2 cm in the preceding years. Also, the median weight has been somewhat higher at 137 g compared to 85-120 g in the preceding years.

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

1.4.8.2 Gonad sampling for mackerel and horse mackerel

Working Document 08 presented to WGWIDE 2020 summarized the status of the industry-science collaboration aimed at improving the knowledge on gonad development of mackerel and horse mackerel. The work was based on samples taken by the fishing industry (PFA vessels) on both targeted and by-catches of mackerel and/or horse mackerel. The overall aim of the Year of the Mackerel project was to gain insight in the gonad development of female and male mackerel throughout the year in order to gain improved understanding of the spawning strategy. For horse mackerel, the aim was to investigate the period during which spawning occurred in 2020 for the Western horse mackerel. Unfortunately, the final report on the analyses was not available for WGWIDE 2021 although it is expected to be ready soon. Gonad sampling for mackerel has been restarted again from the beginning of 2021.

1.5 Comment on update and benchmark assessments

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

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

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

1.6 Planning future benchmarks

Two of the WGWIDE stocks are yet to be benchmarked; Boarfish for which an exploratory surplus production model is used and Striped red mullet for which there is no assessment in place. The WG considers that the Boarfish should be benchmarked. Ongoing sampling of the commercial catch, an expanded acoustic survey time series and advances in modelling techniques *e.g.* VAST should be explored with a view to improving the current assessment. A number of research projects are underway for Striped red mullet - findings will be presented to the working group when available and will inform any proposed future benchmark.

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

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

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

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

1.7.1 General overview of management system

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

1.7.2 Management plans

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

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

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

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

1.7.3 Comparison of advice, TAC and catches

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

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

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

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

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

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

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

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

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

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

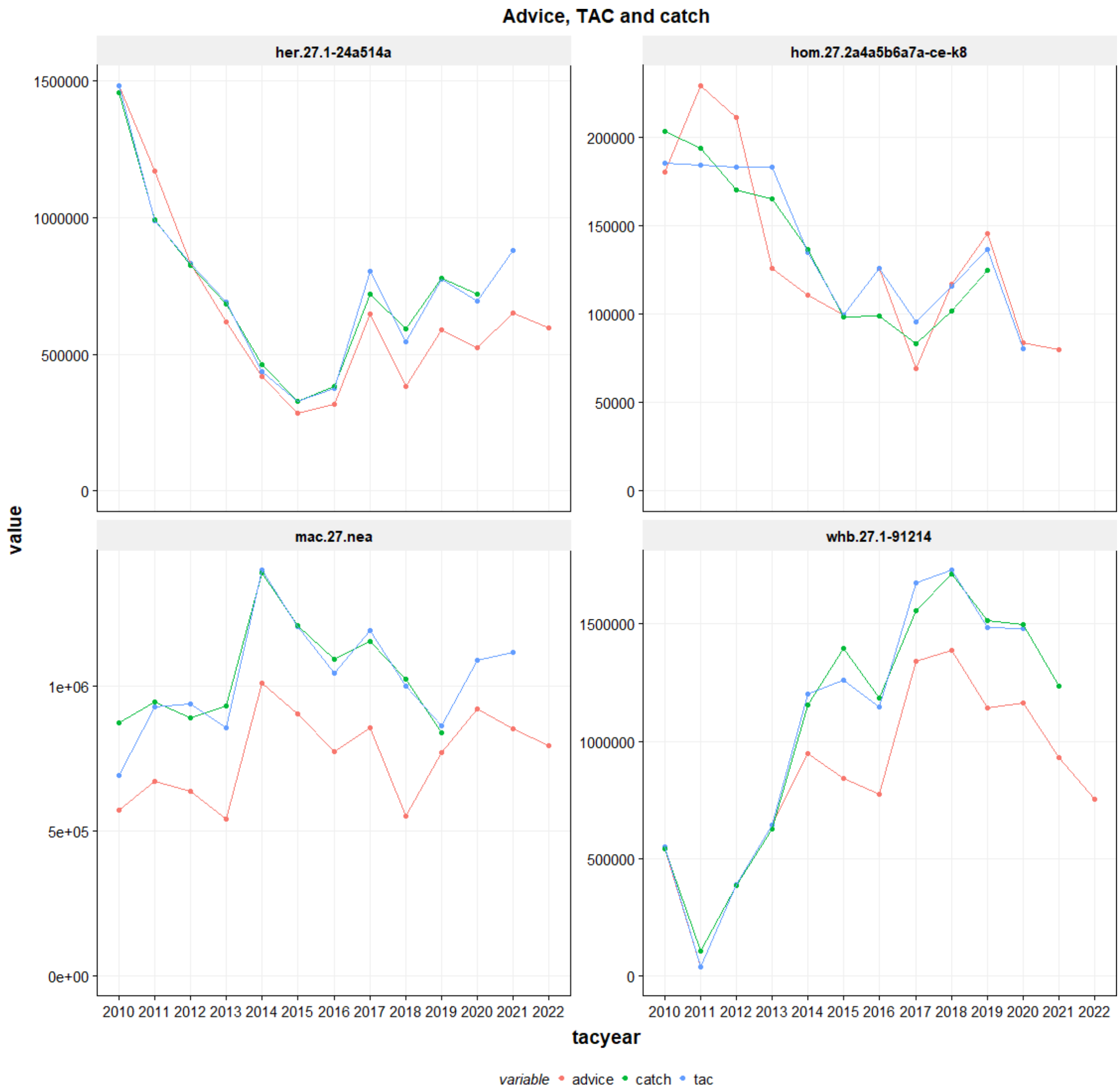

Figure 1.10.1.a: Overview of scientific advice, agreed TAC (or sum of unilateral quota) and catch

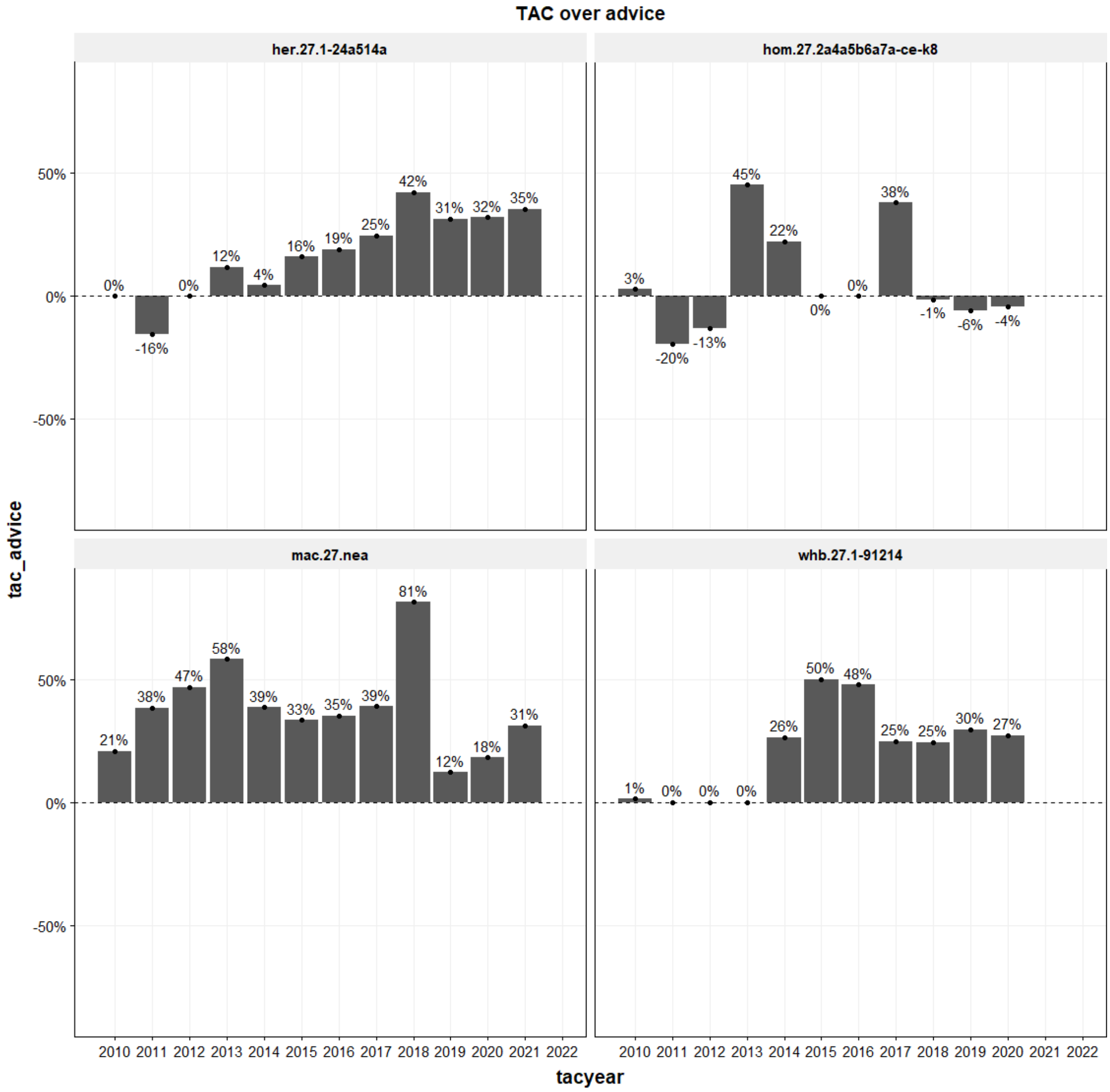

Figure 1.10.2: Overview of TAC (or sum of unilateral quota) over advice

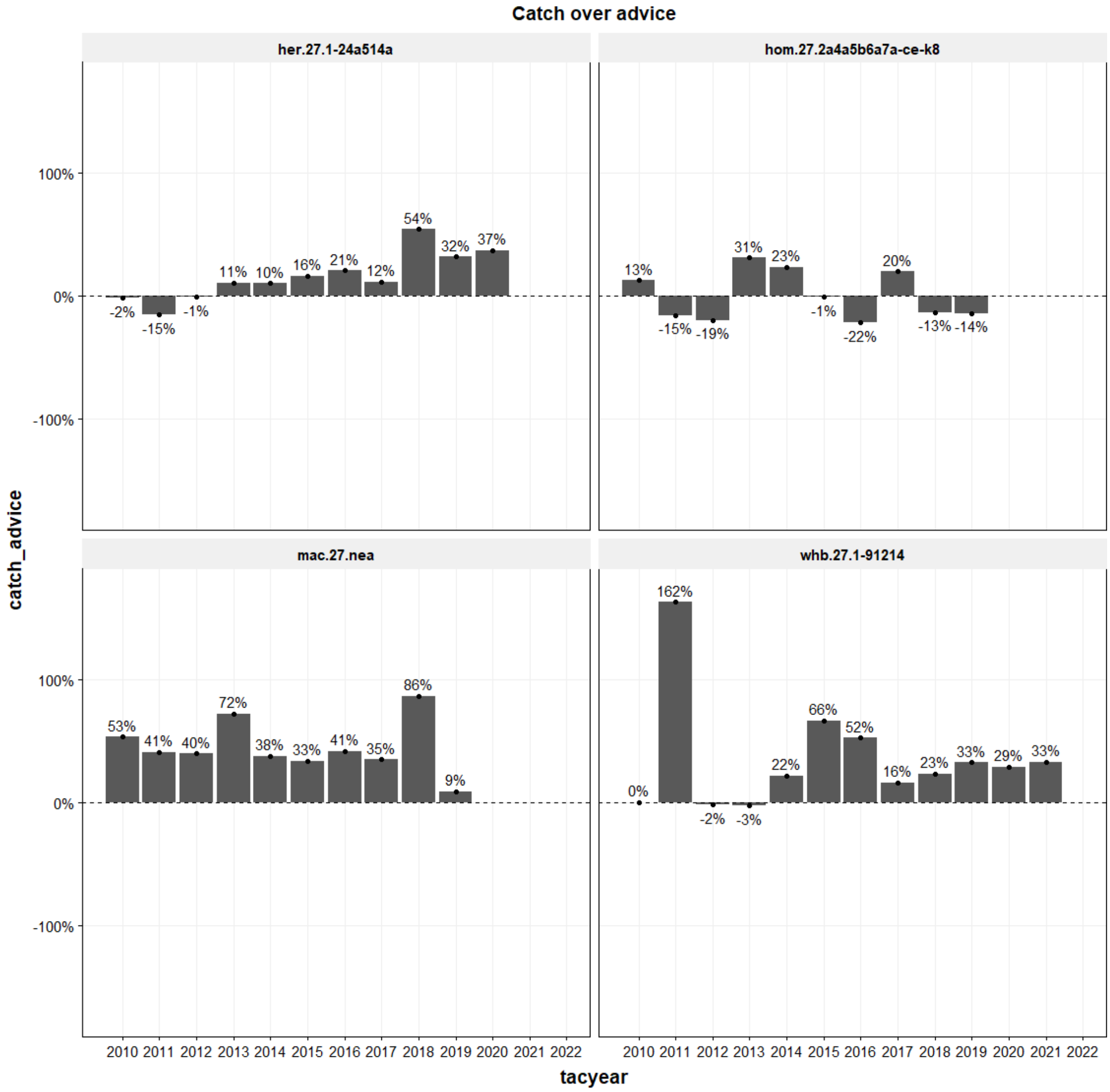

Figure 1.10.3: Overview of catch over advice

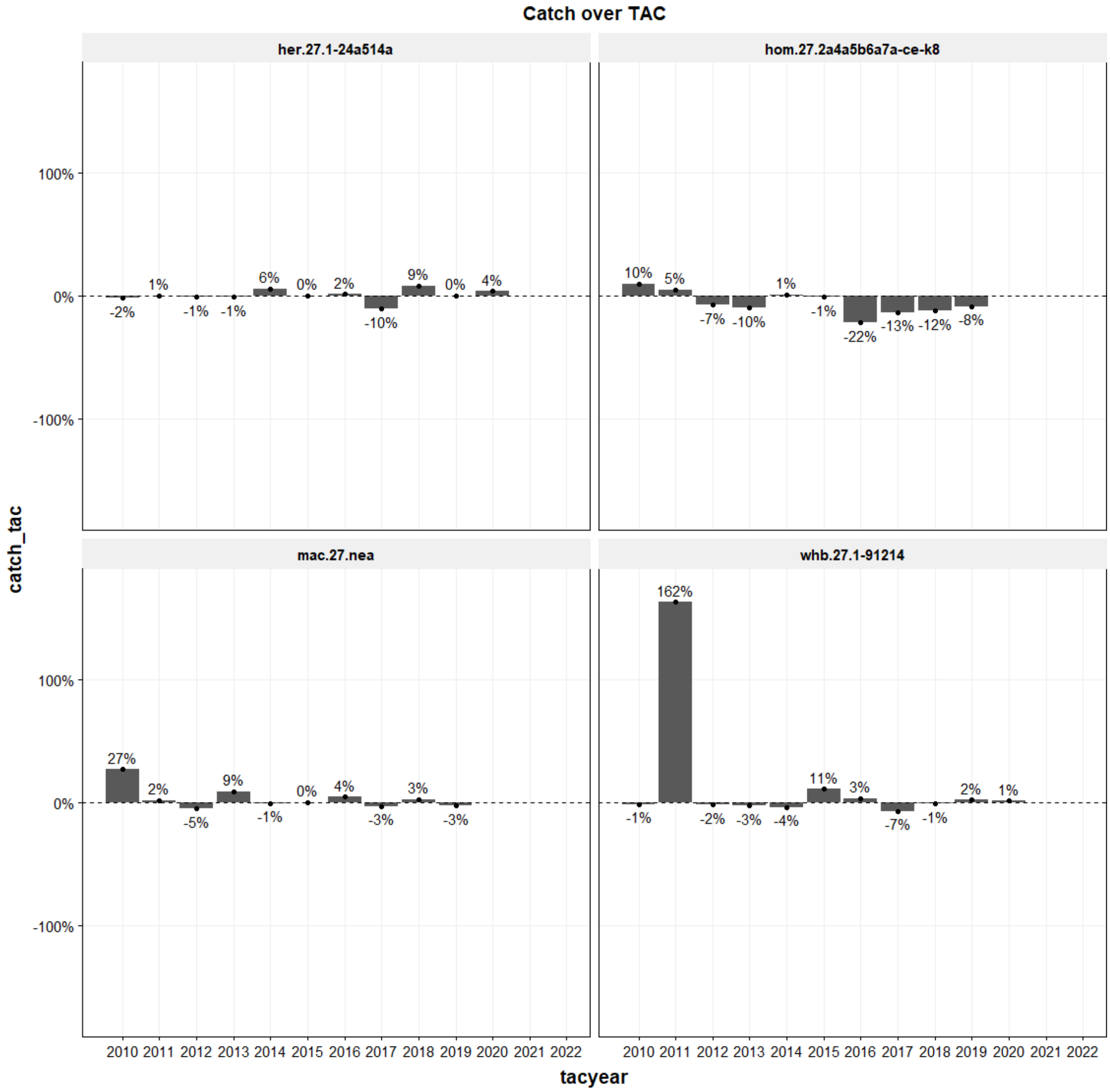

Figure 1.10.4: Overview of catch over TAC (or sum of unilateral quota)

1.8 General stock trends for widely distributed and migratory pelagic fish

WGWIDE 2021 has carried out the stock assessments of the following widely distributed and migratory pelagic species: boarfish, red gurnard, Norwegian spring spawning herring, Western horse mackerel, North Sea horse mackerel, Northeast Atlantic mackerel, Striped red mullet and Blue whiting.

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

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

The time series of the combined catch of these four stocks since 1988 is shown in Figure 1.10.1. The highest combined catch (approx. 4 million tonnes) for these four species was been taken in

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

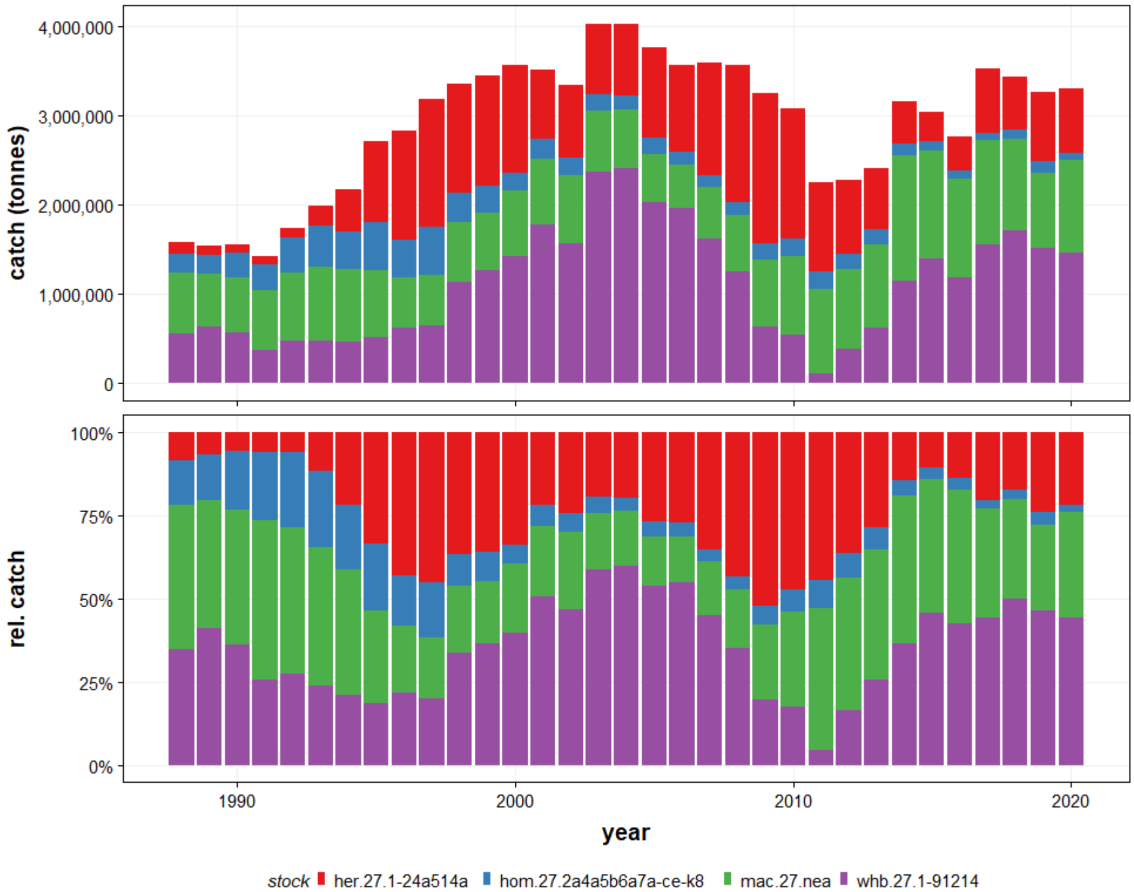

Figure 1.10.1: Catch of blue whiting, mackerel, western horse mackerel and Norwegian spring spawning herring

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

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

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

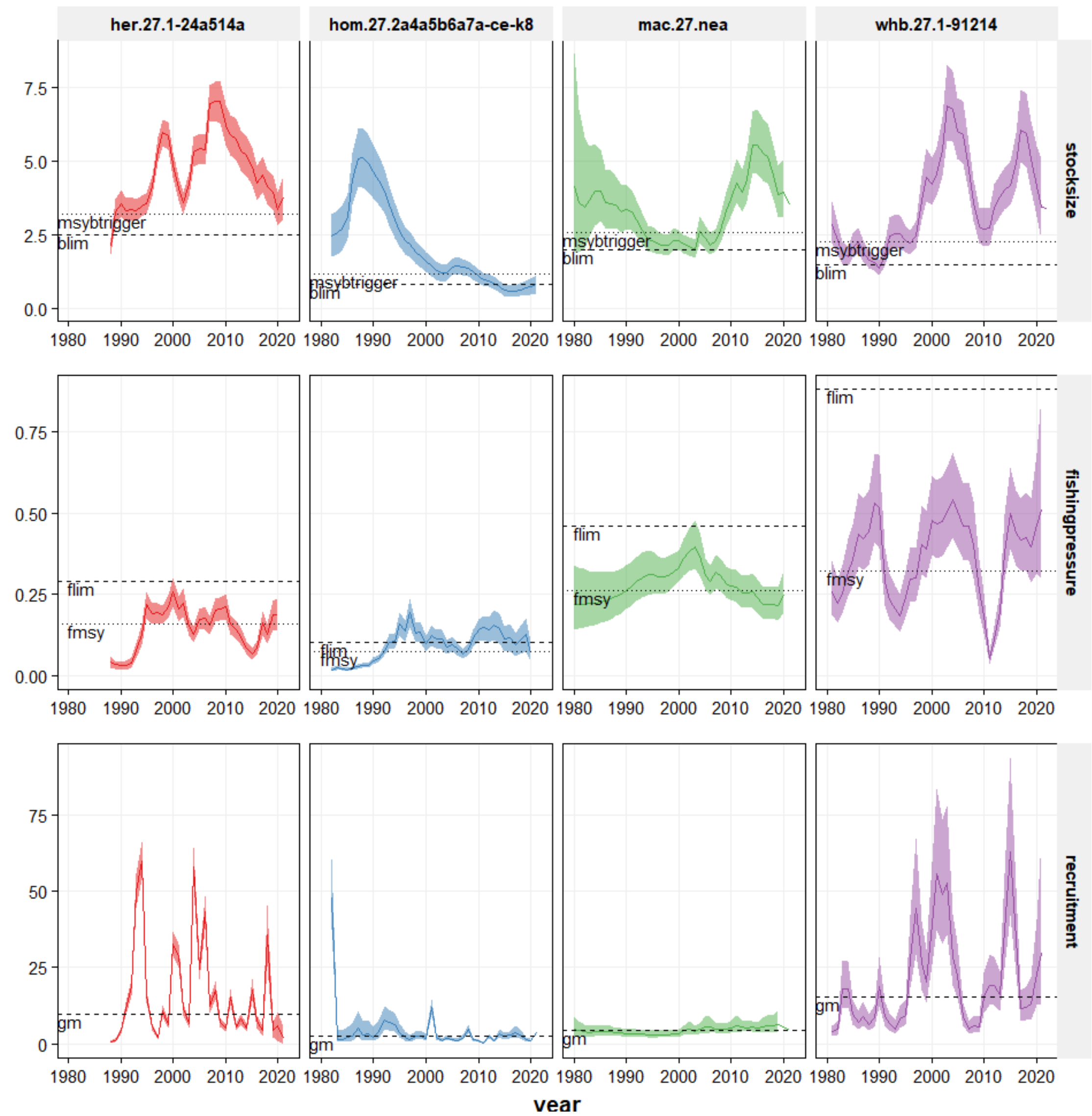

Figure 1.10.2: top - SSB (million tons), middle - fishing pressure and bottom - recruitment (billions) of Norwegian spring spawning herring, western horse mackerel, Northeast Atlantic mackerel and blue whiting.

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

For mackerel, a decline in weight at age started around 2005 for most ages. In more recent years, this has ceased with increases for younger fish noted since 2012.

Weight-at-age of blue whiting shows substantial fluctuations over time. For most ages, a decline in weight at age has been observed from 2010 although this appears to have ceased and, for some ages reversed in the most recent years.

Figure 1.10.3: Stock weight-at-age of NEA mackerel

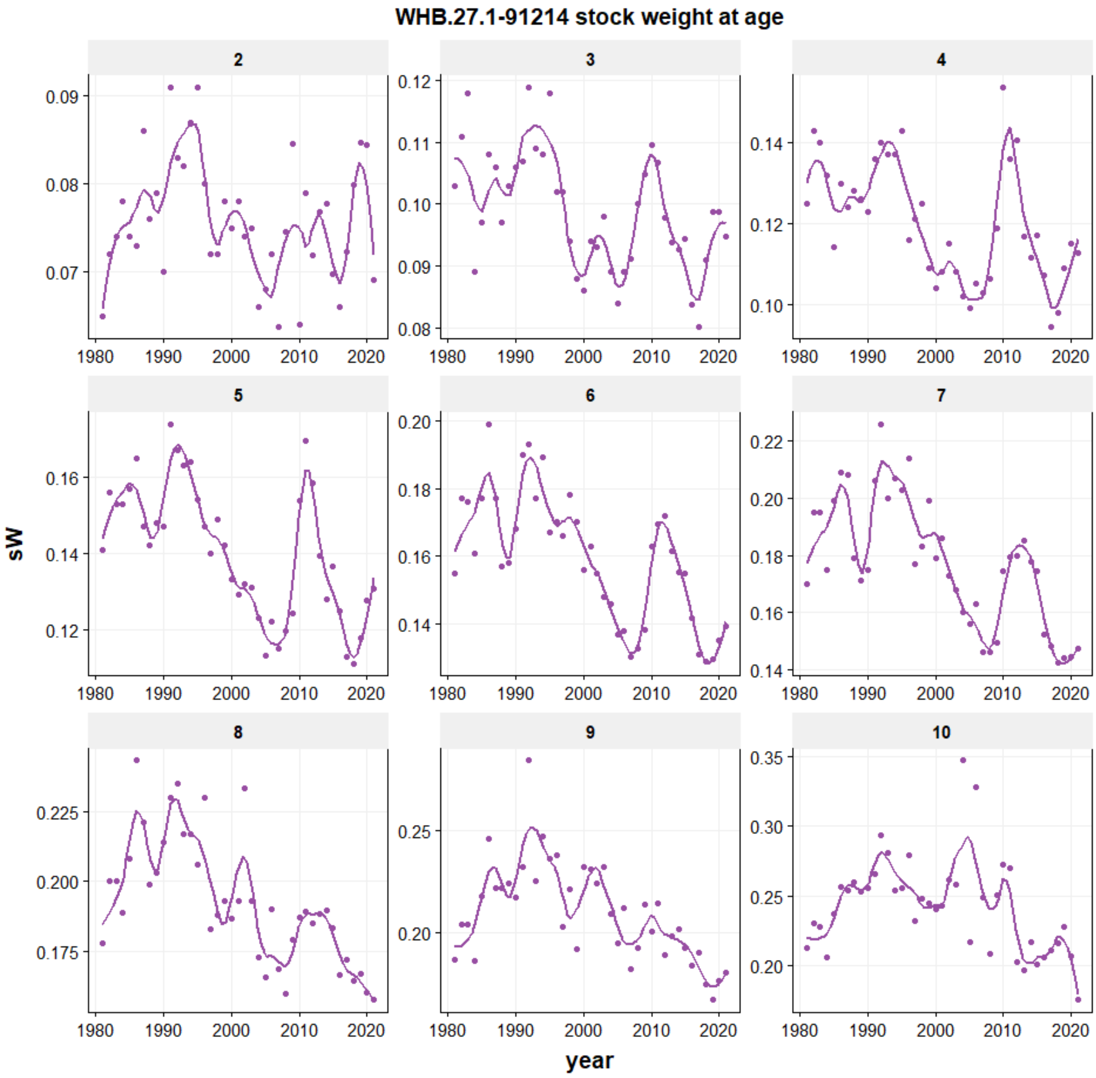

Figure 1.10.4: Stock weight at age of blue whiting

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

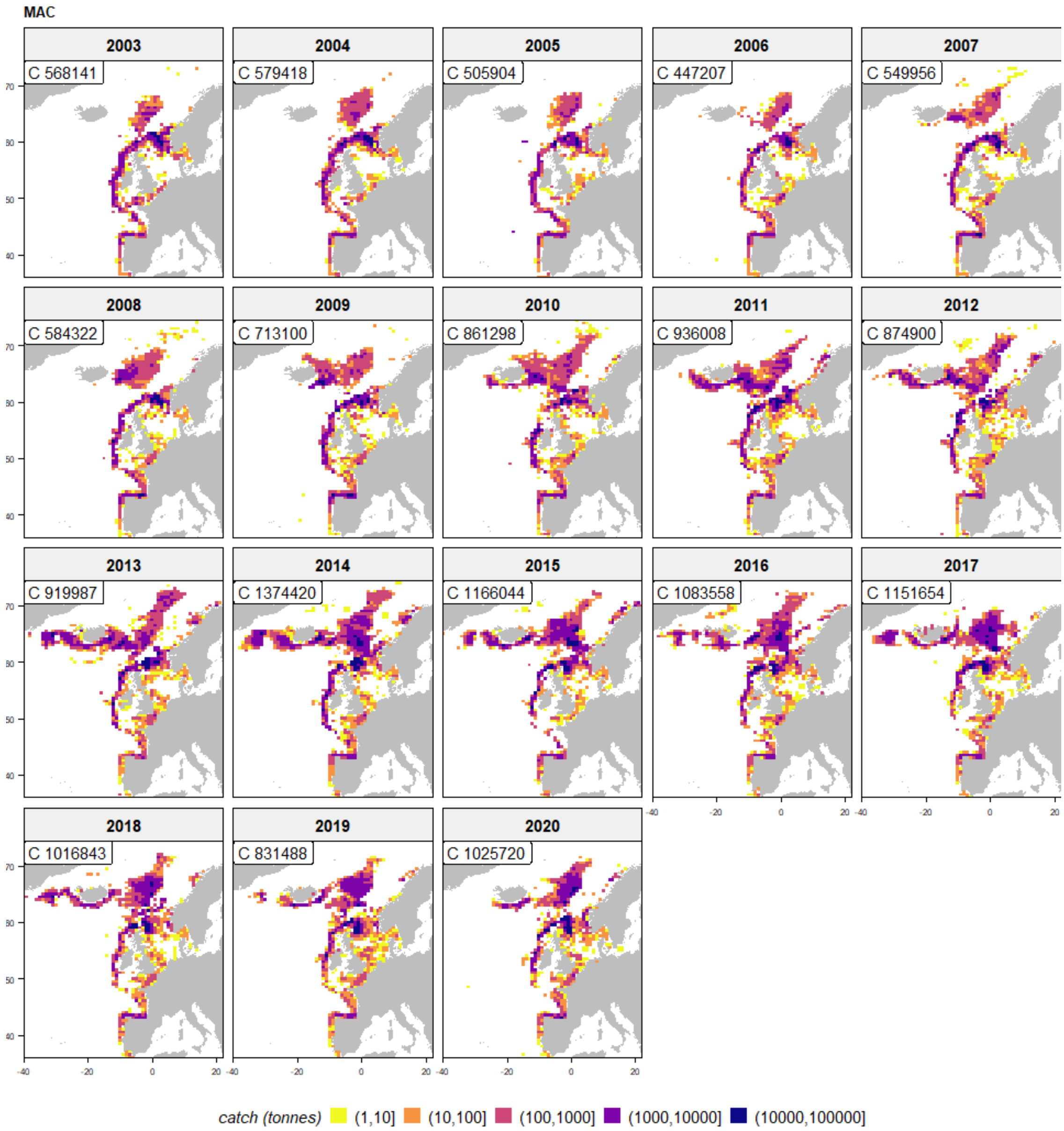

Figure 1.10.5: Catch of mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

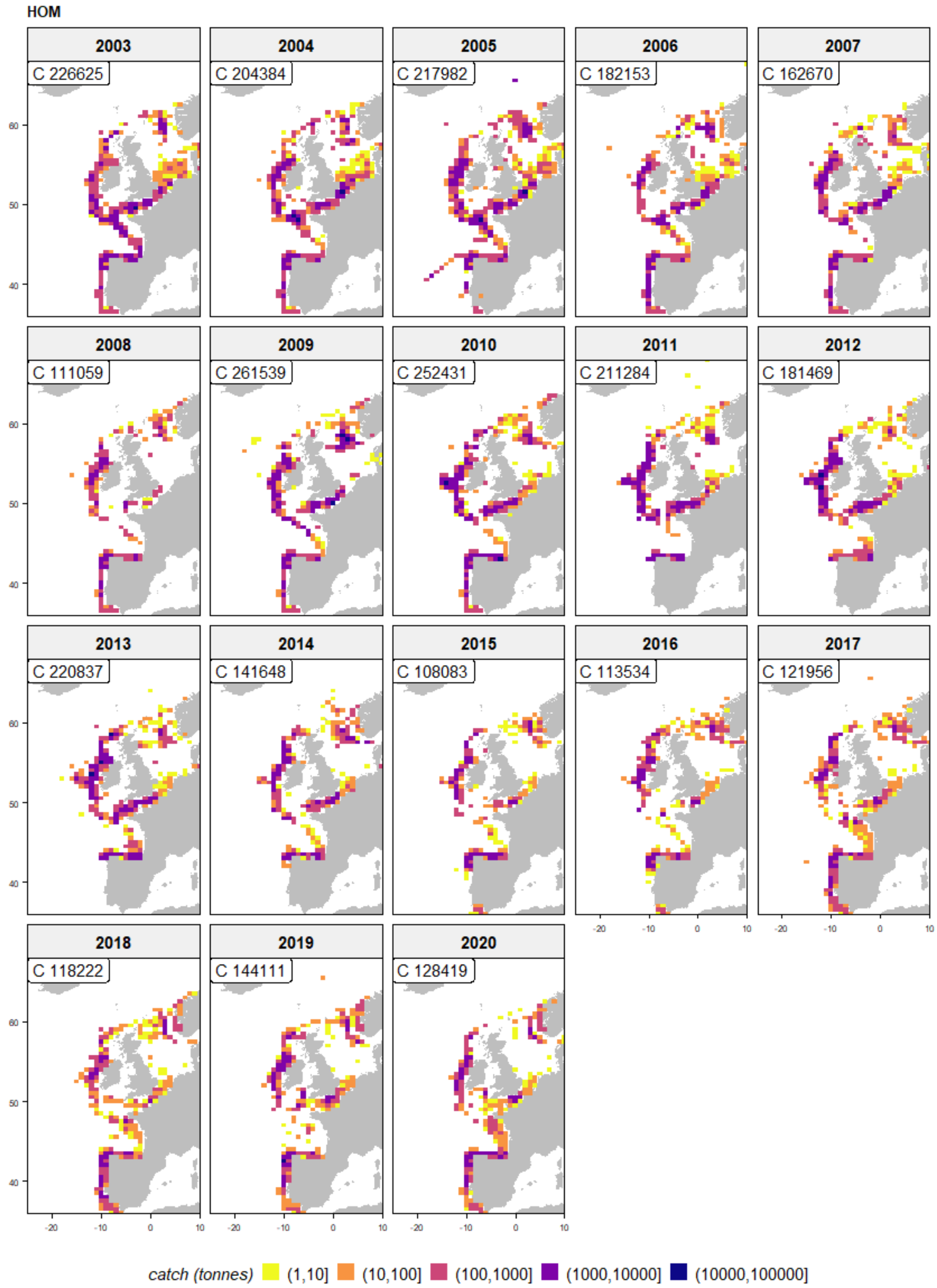

Figure 1.10.6: Catch of horse mackerel (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

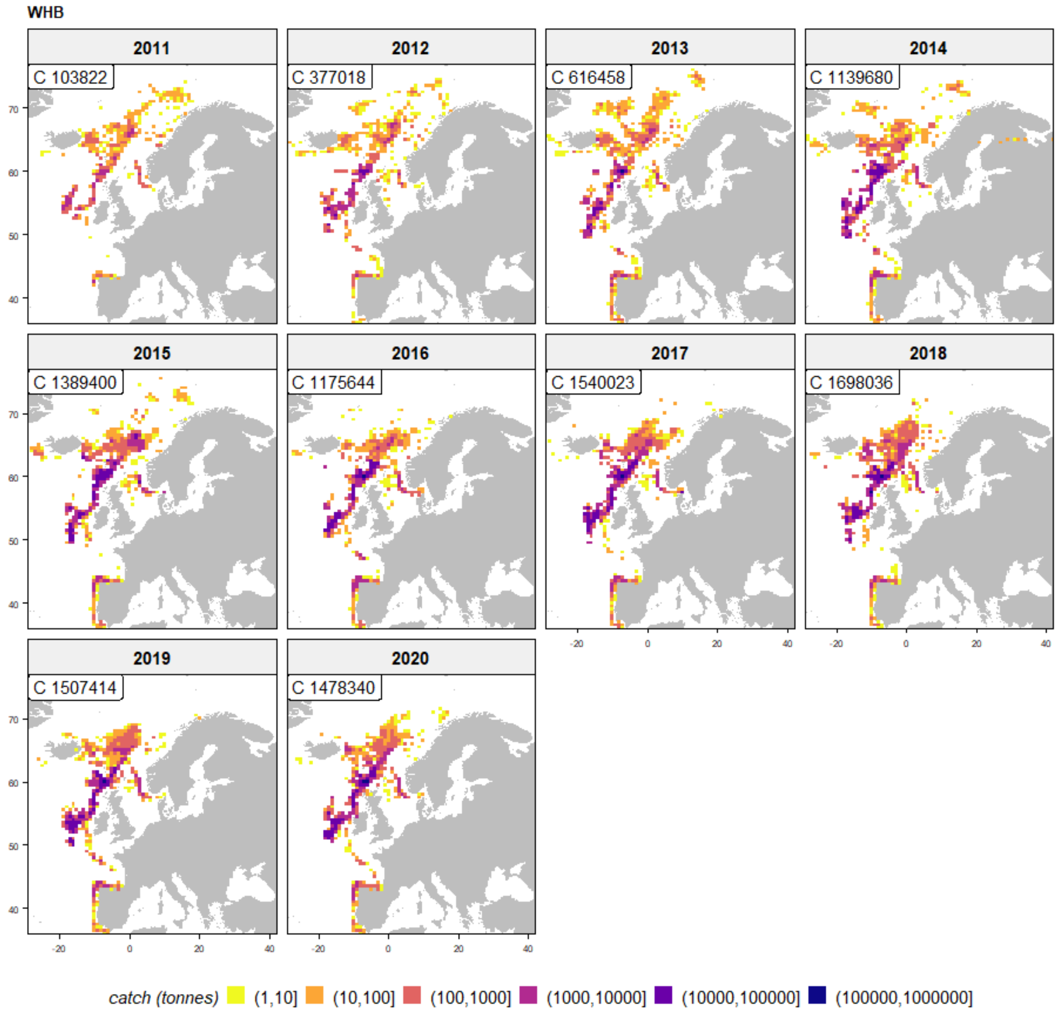

Figure 1.10.7: Catch of blue whiting (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

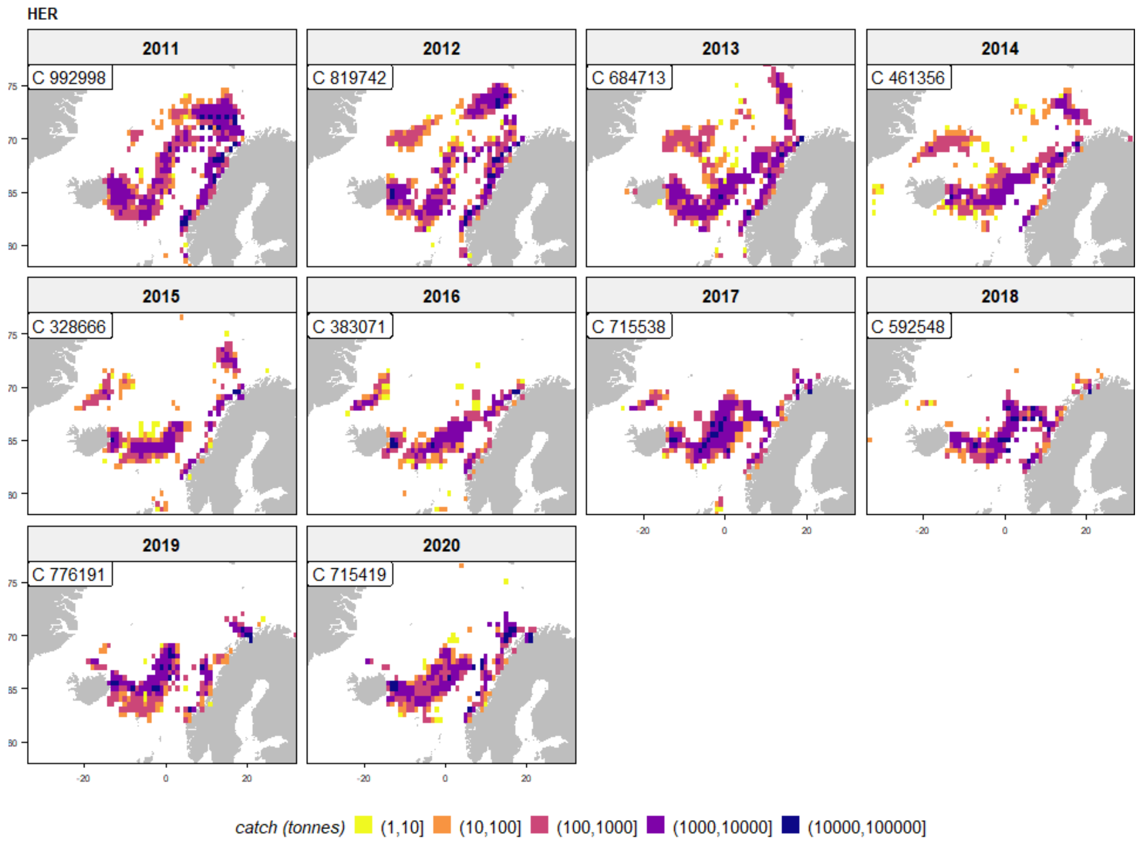

Figure 1.10.8: Catch of Norwegian spring-spawning (Atlanto-scandian) herring (tonnes) by year and rectangle. Catch by rectangle data do not represent the official catches and cannot be used for management purposes. In general, the total annual catches by rectangle are within 10 % from the official catches.

1.9 Ecosystem considerations for widely distributed and migratory pelagic fish species

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

1.9.1 Climate variability and climate change

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

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

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

1.9.2 Circulation pattern

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

1.9.3 Recent trends in oceanography and zooplankton in Norwegian Sea

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

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

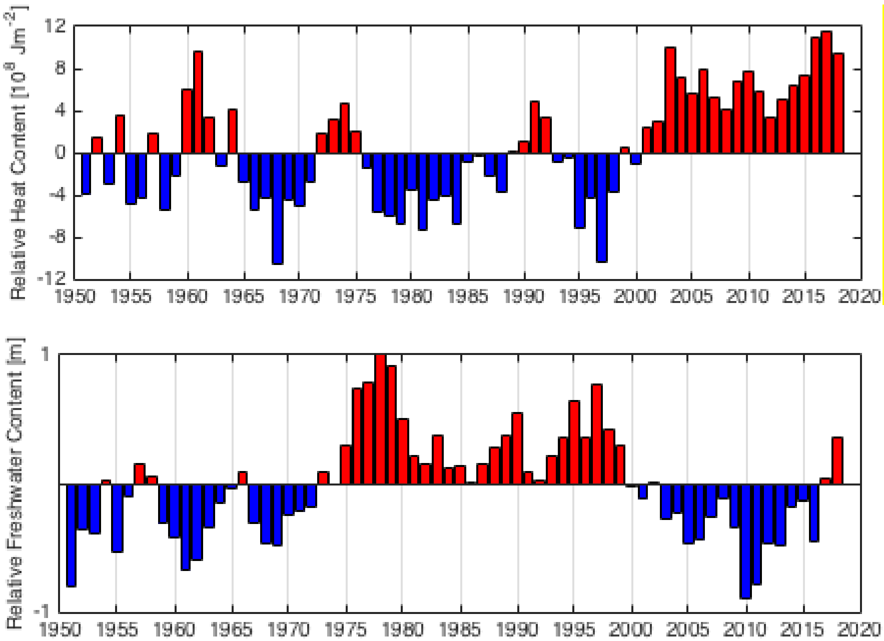

Figure 1.11.1. Time-series of anomalies of heat content (upper panel) and salinity (lower panel) of and the Atlantic waters in Norwegian Sea for the years 1951-2018(ICES 2019a).

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

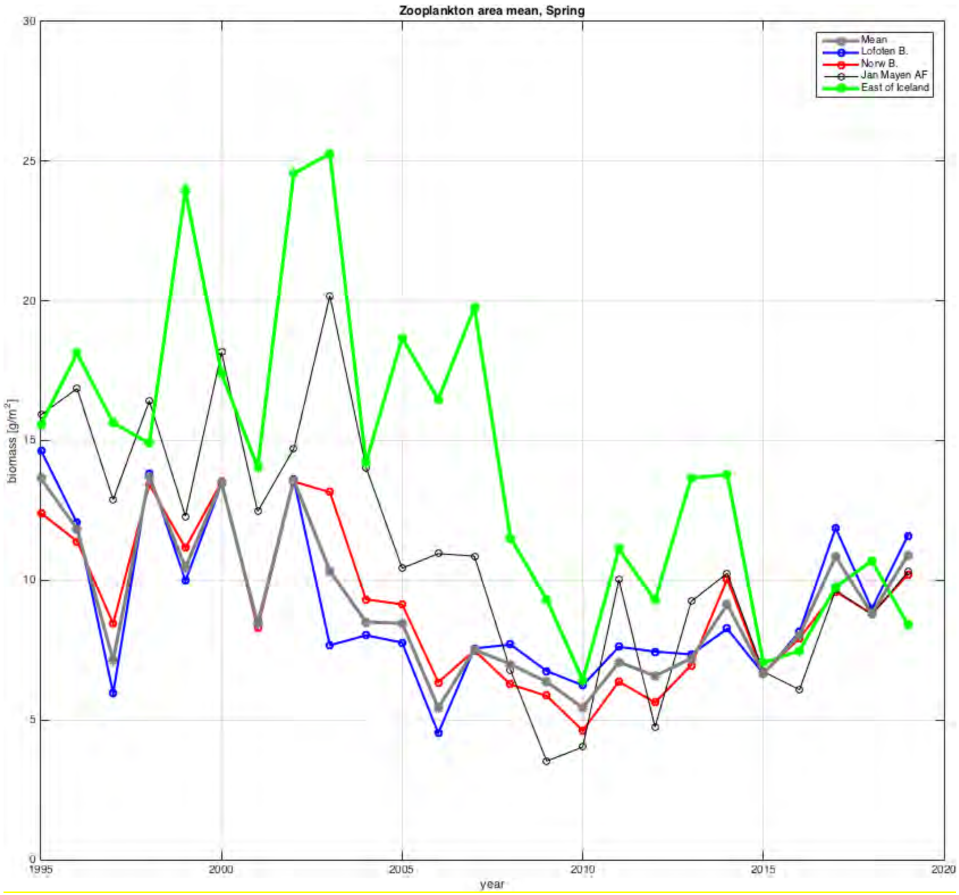

Figure 1.11.2. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in different areas in and near Norwegian Sea from 1995 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (ICES 2019b; see details on methods and areas in ICES 2016a).

1.9.4 Species interactions

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

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

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

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

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

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

1.10.1 NEA Mackerel

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

In 2020, WGWIDE discussed and proposed the establishment of a workshop to review information on the stock structure of NEA Mackerel and subsequent implications for the current (component based) regional management measures (minimum landing size, area and seasonal closures). The current basis, whereby the stock is considered to consist of 3 separate components (North Sea, Western and Southern) derives from research conducted several decades ago. Since this time, there have been advances in several stock identification methods (*e.g.* genetics, simulation approaches). The workshop (WKEVALMAC) will review available information from appropriate methods to infer the stock structure of NEA Mackerel. WGWIDE 2021 agreed to proceed with identification of chairs and scheduling of the workshop at the earliest convenient opportunity..

1.10.2 Blue Whiting

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

1.10.3 NSS Herring

The Norwegian spawning ground survey was reintroduced in 2015 as part of the tuning series (fleet 1). However, changes were made to the survey compared to the older part of the series. At the 2016 assessment benchmark, the inclusion of the surveys from 2015 was accepted as an extension to the tuning series. It is now considered appropriate to investigate the splitting of this survey series, particularly since 2020 has provided the sixth estimate from the survey since it was reintroduced. and the time series is now long enough to do this exercise. An inter-benchmark exercise to explore this was proposed during WGWIDE 2020, but it was later decided to postpone such exploration for the next benchmark. Some exploratory work was presented in WGWIDE 2021.

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

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

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

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

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

1.10.4 Western Horse Mackerel

Considering the potential of mixing between Western and North Sea horse mackerel occurring in Division 7.d and 7.e, improved insight into the origin of catches from that area will be a major benefit for improvement of the quality of future scientific advice and thus management of the North Sea and Western horse mackerel stocks. A project addressing stock structure and boundaries of horse mackerel was initiated by the Northern Pelagic Working Group in collaboration with University College Dublin and Wageningen Marine Research. In 2018, the results of the genetic analysis have been published (Farrell *et al* 2018) which concluded that the spawners of North Sea and Western horse mackerel can be genetically identified as two distinct stocks. However, at that stage it was not yet possible to separate the two stocks when they occur in mixed samples. Subsequently, a full genome sequencing on horse mackerel has been carried out (Fuentes-Pardo et al 2020), which confirmed the earlier results on separating western, North Sea and southern horse mackerel (see also text below on North Sea horse mackerel). In addition, this study concluded that it would also be possible to distinguish horse mackerel from different spawning populations in mixed samples. Such samples have been collected during the winter of 2020 and will hopefully be analysed in the fall of 2021. Results may be expected for WGWIDE 2022.

The 2020 study also concluded that further analysis on the mixing between the Western stock and the Southern stock in area 8c should be carried out: the fishery in the area targets mainly juveniles, would be therefore be very important to understand the impact of this fishery on each of the two stocks.

1.10.5 North Sea horse mackerel

Firstly, studies on stock identity and the degree of connection and migrations between the North Sea and the Western Stock are considered particularly relevant. On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated. Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015- 2017. The full genome of horse mackerel was sequenced and results indicated that the western horse mackerel stock is clearly genetically different from the North Sea stock (Farrell and Carlsson, 2019; Fuentes-Pardo *et al*., 2020). Markers were identified that are be able to reveal the stock identity of individual horse mackerel caught in potential mixing areas. Horse mackerel samples from Division 7.d and 7.e have been be collected by the PFA on board of commercial vessels in the Autumn of 2020, while horse mackerel from Division 4.a have been collected during the NS-IBTS in Q3. With the genetic markers developed, the stock identity of the individual horse mackerel caught can be identified, which will shed light on mixing in the sampled areas during Q3. Additionally, the Institute of Marine Research in Norway sampled horse mackerel in coastal waters within 4.a during all quarters in 2019. Preliminary results presented at WGWIDE 2021 showed that the genetic profile of individuals caught in all quarters matched well with the genetic profile of the Western HOM stock, with just one or two individuals matching better with North Sea HOM profile (Florian Berg, pers. comm.). More samples and research is needed to confirm these results.

Efforts are required to upload historic age and length data to the InterCatch database. The current stock assessment method is based on length data and, with only data from 2016 onwards currently available in InterCatch, it is impossible to compare the F/F_{MSY} proxy and the length-based indicators that the proxy is based on with information from earlier years. Furthermore, length data are only submitted by accessions to stock coordinators directly, and not through InterCatch. This makes the process of combining the data from different countries prone to error and lack transparency. Since 2020, national data submitters were requested to submit data both via the accessions as well as through InterCatch. A comparative analysis has to be carried out to evaluate the feasibility of using length data from InterCatch only in the future. Moreover, it was discovered that several hundred Dutch age readings coming from foreign vessels (mainly UK) have not been uploaded to InterCatch in the past. Efforts will be made to ensure this historic information will be uploaded in order to increase (the currently low) confidence in the estimates of catch-at-age. In 2021, it was the first time that Dutch age samples from 2020 were used in the raising procedure of UK and uploaded to InterCatch.

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

1.10.6 Boarfish

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

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

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