1 Introduction

1.1 HAWG 2021 Terms of Reference

2020/2/FRSG03 The Herring Assessment Working Group for the Area South of 62ºN (HAWG), chaired by Afra Egan, Ireland, and Cecilie Kvamme, Norway will meet: online 20th –22nd January 2021 to:

a) Compile the catch data of sandeel in assessment areas 1r, 2r, 3r, 4, 5r, 6, and 7r and address generic ToRs for Regional and Species Working Groups that are specific to sandeel stocks in the North Sea ecoregion;

and online 16th –24th March 2021 to:

b) compile the catch data of North Sea and Western Baltic herring on 16th–17th March;
c) address generic ToRs for Regional and Species Working Groups 18th –24th March for all other stocks assessed by HAWG.

The assessments will be carried out based on 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 on the dates specified in the 2021 ICES data call. HAWG will report by 12th February (sandeel), 29th March (sprat) and 7th April (herring) 2021 for the attention of ACOM.

A summary of the HAWG stocks, assessment method and advice frequency is given in the table below.

Stock Name	Stock Coord.	Assesss. Coord.	Assessment Method
Sandeel in Divisions 4b-c, SA1r (central and southern North Sea, Dogger Bank)	Denmark	Denmark	SMS-effort
Sandeel in Divisions 4b-c and SD20, SA2r (central and southern North Sea)	Denmark	Denmark	SMS-effort
Sandeel in Divisions 4b-c and SD20, SA3r (northern and central North Sea, Skagerrak)	Denmark / Norway	Denmark	SMS-effort
Sandeel in Divisions 4a-b, SA4 (northern and central North Sea)	Denmark	Denmark	SMS-effort
Sandeel in Division 4a, SA5r (northern North Sea, Viking and Bergen banks)	Denmark / Norway		No assessment
Sandeel in SD20-22, SA6 (Skagerrak, Kattegat and Belt Sea)	Denmark		No assessment
Sandeel in Division 4a, SA7r (northern North Sea, Shetland)	Denmark / UK (Scotland)		No assessment
Sandeel in Division 6a (West of Scotland)	ICES		No assessment
Herring in Subdivisions 20–24 (Western Baltic Spring spawners)	Denmark	Denmark	SAM
Herring in Subarea 4 and Division 3.a and 7.d (North Sea Autumn spawners)	Germany	The Netherlands	SAM
Herring in Division 7.a South of 52° 30’ N and 7.g-h and 7.j-k (Celtic Sea and South of Ireland)	Ireland	Ireland	ASAP

Stock Name	Stock Coord.	Assesss. Coord.	Assessment Method
Herring in Divisions 6.a and 7.b and 7.c	UK (Scotland) / Ireland	UK (Scotland)	SAM
Herring in Division 7.a North of 52° 30′ N (Irish Sea)	UK (Northern Ireland)	UK (Northern Ireland)	SAM
Sprat in Division 3.a (Skagerrak - Kattegat) and Subarea 4 (North Sea)	Denmark	Denmark	SMS
Sprat in the Western Channel	UK (E&W)	UK(E&W)	Survey biomass
Sprat in the Celtic Seas	UK(E&W)		No assessment

1.2 Generic ToRs for Regional and Species Working Groups

2020/2/FRSG01 The following ToRs apply to: AFWG, HAWG, NWWG, NIPAG, WGWIDE, WGBAST, WGBFAS, WGNSSK, WGCSE, WGDEEP, WGBIE, WGEEL, WGEF, WGHANSA and WGNAS.

The working group should focus on:

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/WKF ORBIAS_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) 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) 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) 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 of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

d) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines. i. In the section 'Basis for the assessment' under input data match the survey names with the relevant "SurveyCode" listed ICES survey naming convention (restricted access) and add the "SurveyCode" to the advice sheet.

e) eReview 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)

f) f) Prepare the data calls for the next year's update assessment and for planned data evaluation workshops; g) Identify research needs of relevance to the work of the Expert Group.

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

h) i) 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.

1.3 Reviews of groups or projects important for the WG

HAWG was briefed throughout the meeting about other groups and projects that were of relevance to their work. Some of these briefings and/or groups are described below.

1.3.1 Meeting of the Chairs of Assessment Related Expert Groups (WGCHAIRS)

WGCHAIRS met online in January 2021 in preparation for the new year of advice and science working group activities. This was the first year WGCHAIRS was held remotely. The meeting was held over 4 days. The agenda on day 1 was tailored for new chairs. On day 2 the focus was for assessment groups chaired by ACOM leadership. A joint ACOM/SCICOM session was held on the third day and on the final day the focus was for SCICOM groups.

Under the ICES strategy, activities of advisory working groups such as HAWG are conducted under the umbrella of the Fisheries Resources Steering Group (FRSG) which became operational in 2019. Advisory expert groups maintain their prerogative of "closed groups" in the sense that members will be still nominated at a national level. A separate FRSG meeting was held on the 11th February to discuss the changes to the advice sheets for 2021, the RDBES and any data issues assessment groups may encounter related to the COVID disruption.

A number of presentations were given which were relevant to HAWG. The revamped benchmark system and the role of the benchmark oversight group was explained. A benchmark is a peer review of data and methods that requires prior development, analysis and documentation before it can proceed. Benchmark needs should be identified early and a prioritization process followed. The benchmark oversight group (BOG) has been formed to provide support and have an overall coordination role. A benchmark planning checklist has been developed to help groups to prioritize issues and agree a timeline for each issue to be completed. If high priority issues are not completed, then the benchmark may be delayed to allow sufficient time to work on these tasks.

The principles of reference points and how they are applied in the advice rules were presented. Also the decision by ACOM that the basis for F_{pa} should be $F_{p0.5}$ was communicated across the assessment groups. Work is ongoing on reference points in relation to MSE work. WKGMSE3 developed guidelines for when and how reference points should be extracted when an MSE is conducted. WKRPCHANGE highlighted that there is increasing awareness that reference points will vary with demographic parameters, species interactions and other environmental changes. Density dependence is important and should be included in EQSIM.

The new guide to ICES advice was presented and the ten principles for ICES advice highlighted. The guide explains how these ten principles are applied to recurrent advice, special requests, overviews and viewpoints. The basis and rationale for advice for fishing opportunities and for ecosystem services and impacts are provided in subsections of the guide. The different roles of expert groups in producing the ecosystem overviews was also discussed.

WGCHAIRS discussed gender equality, diversity and inclusion in the ICES community. The gender diversity across several aspects of ICES work was presented, including the ASC participation, chairs of working groups, national representatives at ACOM and SCICOM, council delegates and executive committee members. It was highlighted that we should follow the ICES meeting etiquette and we are all accountable. We treat each other with respect, embrace diversity, include equally, communicate thoughtfully, avoid harassment and promote wellbeing.

1.3.2 Working Group for International Pelagic Surveys (WGIPS)

The Working Group of International Pelagic Surveys (WGIPS) met online on Teams 18th–22nd January 2021. Among the core objectives of the Expert Group are combining and reviewing results of annual pelagic ecosystem surveys to provide indices for the stocks of herring, sprat, mackerel, boarfish, and blue whiting in the Northeast Atlantic, Norwegian Sea, North Sea, and Western Baltic; and to coordinate timing, coverage, and methodologies for the upcoming 2021 surveys.

Results of the surveys covered by WGIPS and coordination plans for the 2021 pelagic acoustic surveys are available from the WGIPS report (ICES 2021, WGIPS). The following text refers only to the surveys of relevance to HAWG.

North Sea, West of Scotland and Malin Shelf summer herring acoustic surveys (HERAS) in 2020: Six surveys were carried out during late June and July covering most of the continental shelf in the North Sea, West of Scotland, Malin Shelf, West of Ireland and Celtic Sea.

The estimate of **North Sea Autumn Spawning herring** spawning stock biomass is lower than previous year at 1.7 million tonnes (2019: 1.9 million tonnes) due to a decrease in the number of fish (2019: 10 295 million fish, 2020: 8 915 million fish).

The 2020 estimate of **Western Baltic Spring Spawning herring** 3+ group is 103 000 tonnes and 667 million. This is an increase of 39% and 16%, respectively, compared to the 2019 estimates of 74 000 tonnes and 574 million fish.

The **West of Scotland herring** estimate (6.a.N) of SSB is 158 000 tonnes and 943 million individuals, a large increase compared to the 76 000 tonnes and 406 million herring estimate in 2019.

The 2020 SSB estimate for **the Malin Shelf area (6.a and 7.b, c combined)** is 226 000 tonnes and 1 435 million individuals. This is higher than the 2019 estimates (128 000 tonnes and 740 million herring). There were again low numbers of herring found in the northern strata (to the north of Scotland and east to the 4˚W line) in 2020, which is similar to 2019. There were significant numbers of herring distributed south of 56°N again in 2020, dominated by immature herring.

For consistency, the survey results continue to be presented separately for sprat in the North Sea and Skagerrak-Kattegat although these two stocks were combined in a benchmark in 2018 (ICES 2018 WKSPRAT).

The total abundance of **North Sea sprat** (Subarea 4) in 2020 was estimated at 67 055 million individuals and the biomass at 531 000 tonnes. This is a decrease from last year, but slightly above the long-term average of the time series, in terms of both abundance and biomass. The stock is dominated by 1- and 2-year-old sprat (92% in biomass). The estimate includes 0-group sprat (19% in numbers, and 2% in biomass), which only occasionally is observed in the HERAS survey.

For **Div. 3.a,** the sprat abundance in 2020 is estimated at 4 282 million individuals and the biomass at 39 900 tonnes. This is the second highest estimate of the time series in terms of biomass, and well above the long-term average both in terms of abundance (107%) and biomass (52%). The stock is dominated by 1-year-old sprat.

Irish Sea Acoustic Survey: The herring abundance for the Irish Sea and North Channel (7.a.N) during 25th August–11th September 2020 was reported by Northern Ireland. The herring stock estimate in the Irish Sea/North Channel area was estimated to be 101,253t. The major contribution of ages to the total estimates is from age 1 and age 2 fish by number and weight. The herring were fairly widely distributed within mixed schools at low abundance, with a few distinct high abundance areas. The bulk of 1+ herring in 2020 were observed west of the Isle of Man and off the Mull of Galloway on the Scottish coast with scattered lower abundance observed throughout the Irish Sea. The estimate of herring SSB of 40,076t is within the observed range for the time series and the biomass estimate of 59,645t for 1+ ringers for 2020 also remains within the observed range since 2011. Sprat and 0-group herring were distributed around the periphery of the Irish Sea, with the most abundance of 0-group herring in the eastern side and in areas along the northern Irish coast to the west.

Irish Sea spawning acoustic survey: A series of additional acoustic surveys has been conducted since 2007 by Northern Ireland, following the annual pelagic acoustic survey (conducted during the beginning of September). The survey uses a stratified design similar to the AC(7.aN). Survey methodology, data processing and subsequent analysis is the same as for AC(7.aN) and follows standard protocols for surveys coordinated by WGIPS. The survey is included in the assessment as a SSB index. The major contribution of ages to the total estimates is from ages 1 fish by number and weight. The herring were distributed within a few distinct high abundance areas to the west and east of the Isle of Man. The estimate of herring SSB of 47,933t for the 2020 acoustic survey is an increase from 44,184 t in 2019. The survey estimates are influenced by the timing of the spawning migration.

Celtic Sea herring acoustic survey (CSHAS): Herring and sprat abundance for the Celtic Sea in October 2020 was reported by the Marine Institute, Ireland. Geographical coverage was lower than in 2019 and can be accounted for by the lack of herring in offshore waters. The core distribution areas were however comprehensively covered and the stock was considered contained within the Celtic Sea survey area. Herring were observed exclusively within coastal waters (10 nmi) and were composed of mixed age classes.

The 2020 total standing stock estimate is 4,717 t and 67,368,000 individuals (CV 0.51) is an increase on the 2019 estimate (2,245 t and a total abundance of 106,900,000 individuals). The standing stock biomass however still remains in a low state. The stock is dominated by 2-wr fish representing over 57% of the total biomass and 48% of total abundance. This cohort is now considered recruited to the spawning stock.

The low abundance of sprat observed is the lowest in the recent time series but is considered a year effect of the survey rather than a change in stock state. The nearshore distribution of sprat likely led to the stock not being fully contained within the survey area.

Pelagic ecosystem survey in Western Channel and eastern Celtic Sea (PELTIC): This survey was conducted by Cefas, UK, in the Western Channel and eastern Celtic Sea in October 2020. For the fourth year, the survey was extended beyond the area covered between 2012 and 2016. The 2020 survey coverage included the French waters of western English Channel and for the first time Cardigan Bay in the southern Irish Sea. The pelagic fish objectives of the survey were successfully completed. In total 2019 nautical miles of acoustic sampling units were collected and supplemented with 36 valid trawls. Sprat were very localised in Lyme Bay and sizes were smaller than in previous years. The biomass in Lyme Bay, which is the core area sampled since 2013 and is relevant to the stock assessment of sprat in 7de, was 33,798 t which was slightly lower than the 2019 estimate of 36,789t.

Baltic International Acoustic Survey (BIAS): This survey is conducted throughout the Baltic Sea during the months of September-October with participation of the different Baltic countries. BIAS is coordinated by the Working Group on Baltic International Fish Survey (WGBIFS). Germany is responsible for the survey covering the western Baltic and the Kattegat (SDs 21-24). The results of the **German Autumn Acoustic Survey (GERAS)** are presented to WGIPS and WGBIFS, whereas mainly the herring data are of interest for WGIPS and the sprat data for WGBIFS, respectively. The GERAS-index, which refers only to Western Baltic Spring-spawning herring (WBSSH), is used within the assessment of the Herring stock in Division 3a and subdivisions 22–24 (see Chapter 3). Mixing with the adjacent central Baltic herring stock generally occurs in SD 24 and in 2020 also in SD 21. The GERAS-index is routinely adjusted to account for the mixing of the two stocks. The adjustment is based on growth parameters.

The 2020 GERAS-index was estimated to be 1.4 x 10^9 fish or about 37.0 x 10^3 tonnes in subdivisions 21–24. The biomass index in 2020 represents the lowest in the time series.

1.3.3 WGQUALITY, WGBIOP and WGCATCH

Operationalising the outputs from the former PGDATA (final report), now falls within the remit of the ICES working group on the Governance of Quality Management of Data and Advice (WGQuality), which held its first meeting in January 2021. Supporting the objectives of the ICES Advisory Plan, WGQuality work focusses on developing and promoting quality assurance within ICES advisory processes - from data management, data integration, data analysis, and data use, to the process of translating that data into ICES advice. It is affiliated to the Data Science and Technology Steering Group (DSTSG), which is also the parent group for WGBIOP and WGCATCH. These three groups work together to ensure the quality of data going into stock assessments and development of methods for identifying improvements in data quality, or collections of new data, that have the greatest impacts on the quality of advice.

WGBIOP focusses on the quality of biological parameters collected and used in assessments and advice. This includes age and maturity, but also other biological parameters. WGBIOP coordinates the practical implementation of quality assured and statistically sound development of methods, standards and guidelines for the provision of accurate biological parameters for stock assessment purposes. The overall aim for WGBIOP is to review the status of current issues, achievements and developments of biological parameters and identify future needs in line with ICES requirements and the wider European environmental monitoring and management.

As biological parameters are among the main input data for most stock assessment and mixed fishery modelling, these activities are considered to have a very high priority. The main link between assessment working groups and WGBIOP is through the benchmark process. WGBIOP works in close association with the BSG (ICES benchmark steering group), reviewing all available issue lists, providing information on listed issues, identifying missing issues in relation to specific stocks and guiding the process to get issues related to biological parameters resolved. WGBIOP tries to align its scheduling of age and maturity calibration exchanges and workshops with the newly proposed ICES benchmark prioritization system. WGBIOP has a close working relationship with WGSMART (The Working Group on SmartDots Governance) and in cooperation will further develop the SmartDots tool as a platform for supporting the provision of quality assured data to the end-users.

The last WGBIOP (October-November 2020) reviewed the following activities falling within its remit and of interest for HAWG:

- One workshop was planned during the previous year for herring (*Clupea harengus*) and sprat (*Sprattus sprattus)* stocks assessed by HAWG. There was no workshop or exchange planned for Sandeel (*Ammodytes*).
- A workshop on the identification of clupeid larvae (WKIDCLUP2) was scheduled on 31 August – 4 September 2020 to be held in Bremerhaven, Germany. Due to COVID-19 measures this workshop could not take place. Instead an online short workshop was held as a starter to identify problem areas in clupeid identification. SmartDots was expanded with a fish larvae module specific for this workshop. The module allowed sharing of images of various clupeid larvae of different spawning areas (from the Portuguese coast to the Baltic) and other species co-occurring with the clupeid larvae. Within SmartDots each participant could measure, count myotomes and identify the larvae to species. This first test of the module was promising and will be further developed and used for fish larvae calibration exercises in the future. The results of this short workshop were

promising as the agreement in larvae identification was higher compared to the 2014 workshop. The full workshop is postponed to 30th August – 3rd September 2021.

Other clupeid stocks

- An otolith exchange was held for sprat in the Baltic Sea. Results were not available for the WGBIOP 2020 meeting.

Planning of future workshops and exchanges

- WGBIOP is planning to organise a workshop in 2023 on the comparison between age reading methods of NSSH using scales and otoliths. WGIPS is requested to collect samples in 2022. The focus is on NSSH but could have implications for NSH as well.

WGCATCH continues to document national fishery sampling schemes, establish best practice and guidelines on sampling and estimation procedures, and provide advice on other uses of fishery data. The group evaluates how new data collection regulations, or management measures (such as the landings obligation) will alter how data need to be collected and provide guidelines about biases and disruptions this may induce in time-series of commercial data. WGCATCH also develop and promote the use of a range of indicators of fishery data quality for different types of end-users. These include indicators to allow stock assessment and other ICES scientists to decide if data are of sufficient quality to be used, or how different datasets can be weighted in an assessment model according to their relative quality.

WGCATCH 2020 was focused on how to communicate relevant information about sampling design and estimation to ICES assessment working groups, how to get a better process around delivering quality catch data for benchmarks and started up the process of creating practical, updated and accessible guidelines for sampling. In respect to the small-scale fisheries, WGCATCH 2020 updated and refined the risk assessment for transversal data quality methodology and started to document the sampling effort on biology for this part of the fleet. Further, the group continued the close relation to WGBYC and the RDBES.

1.3.4 WGSAM

The Working Group on Multispecies Assessment Methods WGSAM provides estimates of natural mortality (M) for a number of fish stocks based on estimates from multispecies models. WGSAM provides M estimates for the following HAWG stocks: North Sea herring, North Sea sprat, sandeel SA1 and sandeel SA3. This year, a new key run of the North Sea SMS model is available (ICES 2021, WGSAM) with updated estimates of predation mortalities (available by age and quarter for the period 1974-2019 as direct output of SMS) for the stocks mentioned above. The 2020 key run is primarily an update of the 2017 key run by extension of the input data and their update when the single species stock assessment input data were revised through benchmarks or inter-benchmarks.

In the SMS model, predators include both assessed species (i.e., cod, haddock, saithe, whiting, mackerel) and species with given input population size (North Sea horse mackerel, western horse mackerel, grey gurnard, starry ray, hake, fulmar, gannet, great black backed gull, guillemot, herring gull, kittiwake, puffin, razorbill, grey seal, and harbour porpoise). The assessed predators are parametrised using a combination of commercial and survey data (i.e., same input as for the single species assessments) except saithe and mackerel which are closely tuned to the ICES stock assessment by using number-at-age from the single species assessment models as input of SMS.

Main changes to input data since the 2017 key run include:

- Update of “single-species data” (catch-at-age numbers, mean weights, proportion mature, survey indices, etc.) with use of the most recent ICES assessment input data. The most important changes are:
  - Whiting benchmark with mean weight at age in the sea derived from survey data, whereas mean weights from the catches were used previously. This gives lower mean weight at ages for the youngest ages and higher mean weights for the oldest ages compared to the 2017 key run
  - Sprat benchmark with inclusion of subdivision 3a in the stock area and re-estimation of historical catch data
  - Mackerel benchmark with new stock size estimate
- Re-estimation of the hake stock within the North Sea
- Re-estimation of horse mackerel and their proportion of the stock within the North Sea

Comparison with previous values of predation mortalities suggest:

- **Herring** - the pattern in M is in general consistent between the two key runs but some differences are estimated in the first and last part of the time series. Differences in most recent years are due to lower stock size of the predators cod and saithe, and by increased predation by whiting and hake.
- **Sprat** - the pattern in M is in general consistent between the two key runs, but the new estimates downscale the absolute values of predations mortality for all ages except age0.
- **Sandeel** – estimates of predation mortality are highly consistent for both the northern and the southern sandeel modelled stocks (i.e., current SMS considers sandeel as two units within the model, approx. corresponding to SA1 and SA3) between the new and previous key runs. Some marginal differences are visible for the southern sandeel with an upscale of M in the last part of the time series for all ages and a downward revision in the first part of the time series for age3+.

Overall, the model structure and main assumptions are consistent with the previous key run. Based on an internal review process, WGSAM considered the new key run appropriate in relation to the purpose of providing predation mortality estimates.

1.3.5 MIK surveys

Down’s herring recruitment information

In 2016, WKHERLARS evaluated the North Sea herring larvae surveys (ICES, 2016), and concluded that the current IBTS-MIK recruitment index does not contain information on the Downs spawning component. It was recommended to investigate the possibility to collect data to include information on Down’s recruitment. In 2017, the effect of omitting one of the three IHLS surveys, carried out on the Downs component, from the herring assessment was investigated. The omission resulted in a negligible effect and it was, thus, decided to drop the Dutch IHLS participation in the second half of January. The vessel time and budget of this survey was instead used to conduct a Downs Recruitment Survey (DRS) in April.

The DRS was carried out in April 2018 and 2019. Due to COVID-19 measures it was not possible to carry out a DRS in April 2020. As herring larvae need to be caught at the same development stage as the IBTS-MIK, it was not possible to move the survey to a later date in 2020. The survey is planned to continue in April 2021.

The DRS is carried out following the IBTS-MIK protocol, but sampling both day and night, instead of only at night. Comparative fishing trials to check for difference in catchability between day and night are planned for 2021 and 2022.

HAWG has a positive view on the continuation of the Downs Recruitment Survey (DRS) but cannot include the survey in the advice based on only two years of a survey. HAWG foresees potential future use of the combined IBTS0-DRS-index for a complete NSAS recruitment index for the advice if the surveys are continued. Thus, HAWG supports the continuation of the exploratory surveys in April and have had a positive response from several laboratories. HAWG recommends that WGSINS investigate calculation of a Downs and combined North Sea herring recruitment index based on the combination of the IBTS-MIK and DRS data.

1.3.6 Stock separation of herring in surveys and catches

The mixing of herring stocks in surveys and catches is an issue in many of the stock assessments carried out in HAWG. Currently only the mixing between North Sea herring and Western Baltic Spring-spawning herring (in the catches, in the HERAS and IBTS surveys) and between Western Baltic Spring-spawning herring and Central Baltic herring (limited to the GerAS survey) are routinely quantified and accounted for in the assessments. The development of operational methods to enable estimation of proportion contribution from different stock in catches and survey indices throughout the management areas for herring assessed by HAWG is a topic that HAWG continues to have high on the list of issues to solve to improve upon assessments. Several ICES workshops have been held to progress this topic, most recently WKMIXHER in 2018 and WKSIDAC in 2017. During HAWG 2019 a mini symposium was arranged to facilitate exchange of ideas and foster collaboration of researchers working on different aspects and methods. An update on progress of those projects dealing with stock identification and mixing of relevance to HAWG is provided below.

Update on Stock Identification of 6a/7b,c Herring

Atlantic herring west of Scotland and northwest of Ireland comprise at least two reproductively isolated biological populations. The 6aN herring spawn off Cape Wrath in northwest Scotland in Autumn (September/October) and the 6aS/7bc herring spawn off Donegal in northwest Ireland in winter (November to January). The stocks are believed to form mixed feeding aggregations west of the Hebrides in summer, where they are targeted by the Malin Shelf Herring Acoustic Survey (MSHAS), conducted annually by the Marine Institute and Marine Scotland. The MSHAS survey index is a primary input into the stock assessments of the two stocks. Up to now it has not been possible to separate the data from the MSHAS into population/stock of origin, therefore only a combined index is available and hence a combined assessment (ICES, 2015). Based on the combined assessment, ICES provides combined advice for the two areas and stocks, and has recommended a zero TAC for the last six years. Scientific samples are obtained during the scientific monitoring fisheries in 6aS/7bc and industry surveys in 6aN.

The EASME herring project

In December 2020 University College Dublin (UCD), the Marine Institute (MI) and Marine Scotland Science (MSS) completed the European Commission's Executive Agency for Small and Medium-sized Enterprises (EASME) funded, 36-month, project entitled 'Herring in Divisions 6.a, 7.b and 7.c: Scientific Assessment of the Identity of the Southern and Northern Stocks through Genetic and Morphometric Analysis'. This project built on industry and Institute funded studies on the same subject which were initiated in UCD in 2015 and ran until commencement of the EASME project in December 2017.

The primary objective of this study was to assess the identity of herring stocks in ICES Divisions 6a, 7b and 7c, through genetic analysis, in order to develop genetic profiles of the northern (ICES Division 6a North) and southern (ICES Divisions 6a South, 7b and 7c) stocks, which could be used to discriminate the two stocks during times of mixing, such as, in the summer acoustic surveys. In addition, body and otolith morphometric methods were developed to test if the variation in body and otolith shape could also be used to discriminate the stocks in these areas. The study comprised an extensive review of the history of the existing stock delineations, comprehensive sampling for both the genetic and morphometric components of the project, genetic marker development, genetic screening of samples, the establishment of a genetic protocol for large scale sample screening, morphometric analyses and comparative analyses of both methods.

Genetic analyses

Genetic baseline spawning samples were collected over five spawning seasons (2014-2019) and archive samples from the WESTHER project (2003-2004) were also reanalysed. In total c.4,900 individuals from Divisions 6.a, 7.b and 7.c, 1,860 individuals from outgroup populations, 650 individuals from the WESTHER samples and 3,665 individuals from the MSHAS (2014-2019) samples were analysed as part of the genetic analysis tasks.

The genetic analyses indicated that herring in ICES Division 6a comprise at least three distinct populations; 6aS herring, 6aN autumn spawning herring and 6aN spring spawning herring. The 6aS herring are a primarily a winter spawning population though there is a later spawning component present in the area also. These components are currently inseparable and for the purposes of stock assessment should be combined as 6aS herring. No baseline spawning samples could be collected in Divisions 7b or 7c therefore the relationship between the herring that spawn in this area and those that spawn in 6aS is unknown. Non-spawning herring caught in Division 7b assigned genetically to the 6aS population. Samples of herring from Lough Foyle were shown to be genetically and biologically 6aS herring, though they are currently defined as 6aN autumn spawning herring according to the ICES stock delineation.

Across the six years of MSHAS samples that were genetically assigned (2014-2019), there was a consistent pattern of a higher proportion of 6aS herring in the samples than 6aN autumn spawning herring. The 6aS assigned fish were distributed across the survey area both south and north of the current stock delineation line of 56°N latitude, confirming that this geographic delineator for the collation of survey data is not appropriate. The highest proportions of 6aS fish were observed in the hauls closest to the Irish coast. The highest proportions of 6aN autumn spawning fish were observed in the most northerly hauls adjacent to the 4°W stock delineator. Generally, the proportion of 6aN autumn spawning herring in the hauls was less than 20%. Potential 6aN spring spawning herring comprised a significant proportion of the MSHAS hauls west of the Hebrides in the 2014-2019 MSHAS samples.

There is no historical or contemporary evidence to support the differentiation of 6aN autumn spawning herring and North Sea autumn spawning herring. The term 'west of Scotland herring' originally referred to populations of spring spawning herring that spawned in the Minch area. It now refers to autumn spawning herring that occur west of the 4°W boundary during the period of the MSHAS. The Celtic Sea herring and Irish Sea herring are distinct from each other and from the populations in ICES Divisions 6a however the current genetic marker panel is not optimised for their inclusion in the baseline assignment dataset. This is not considered to be a significant issue as there is no robust evidence that Irish Sea herring are found in large abundance west of the Hebrides during summer. Historical evidence does suggest that they may be found in the Clyde area at this time before returning to spawn in the Irish Sea in autumn.

Morphometric analyses

Morphometric (body and otolith shape) data from spawning samples of 6aN autumn spawning herring and 6aS winter spawning herring were collected to develop a morphometric baseline profile of the spawning stocks. This baseline was then used to determine the stock composition of mixed samples collected during the MSHAS. The baseline data consisted of morphometric measurements taken from 1429 spawning herring, collected between 2014 and 2019. In 2020, the model chosen to differentiate between the 6aN and 6aS stocks was finalised and trained using the baseline data. The model demonstrated a significant difference between the two stocks and resulted in classification rates of >75%. The 6aS stock showed a higher misclassification rate than 6aN, which may be attributed to the possible presence of a later spawning cohort that was detected by the genetic analysis. Three samples of known origin were input blindly to the model to see how well they could be assigned back to their stock of origin. Two of the samples that were tested resulted in the majority of individuals assigning back to the correct stock of origin (<70%). This does create uncertainty around the assignments, with ~30% of the individuals being misassigned. Most of the individuals from the third sample were assigned back to the wrong stock and demonstrated a possible inter-annual variability issue. Although the self-assignments looked promising initially, a significant amount of uncertainty in the assignments was observed when the model was tested with 'known-unknown' samples.

During the MSHAS, morphometric data was collected from herring of unknown stock of origin between 2010 and 2019. Over 10,000 mixed herring were sampled during this 10-year period and processed for input to the model. The classification model was initially tested using the 2015 MSHAS samples. They were collected over a wide distribution throughout ICES Division 6a, including samples south of the 56° line of latitude. The assumption would be that the more northern hauls will contain a larger proportion of 6aN herring and the southern hauls, closer to Ireland, would contain more 6aS herring. These samples of unknown origin were input to the model which provides a predicted stock of origin for each individual herring. The results of the MSHAS sample assignments were inconclusive because the majority of herring were classified as unknown. The herring that were assigned to a stock, did not conform with what would be expected biologically. The results were then compared with the results from the genetic assignments and there was very little agreement between the two stock discriminations methods at an individual herring level.

One of the main conclusions of the EASME project was that morphometrics is not suitable to discriminate between mixed herring along the Malin Shelf. Although the use of body and otolith shape showed potential in discriminating between 6aN and 6aS stocks initially, the method was not powerful enough to discriminate mixed herring samples due to the complex temporal-spatial mixing of these two stocks along the Malin Shelf. The genetic markers and assignment methods presented in the final EASME report (Farrell et al, 2020) constitute a tool that can be used for the assignment of herring caught in mixed survey and commercial catches in Division 6a into their population of origin with a high level of accuracy (>90%). This approach should be used for regular monitoring of MSHAS and commercial catches of herring in this area.

2021 6.a herring genetic analyses

Prior to the commencement of the benchmark process, it is possible to undertake additional analyses in order to fill any potential data gaps identified during the EASME project. It was agreed to undertake the following additional analyses in preparation for the benchmark.

Resolve the maturity staging issue.

A potential maturity staging issue concerning some of the 6aN autumn spawning baseline samples was discussed in detail in Section 4.9 of the EASME report (Farrell et al., 2020). In brief, the samples concerned were collected in 2018 and 2019 by PFA vessels, were processed by WUR and were considered to be stage 3 spawning fish (6-point scale). Genetic analyses indicated that a significant proportion of the samples assigned to the 6aS/6aN_Sp baseline. Additional samples collected by SPFA vessels in the same area at the same time and processed by MSS with the 9-point maturity scale indicated a wide range of maturity stages present in the same area at the same time as the genetically analysed samples. This indicates a potentially large degree of mixing of autumn and later spawning populations close to the 6aN spawning area during the autumn spawning period. Genetic analysis of the MSS samples will help to determine if there was a maturity staging issue with the IMARES samples and if this is the case then it will provide justification for removing them from the baseline dataset and will thus increase the resolution of the assignment model. This is considered to be an important issue to resolve prior to the benchmark.

Additional samples to analyse

1. MSHAS 2020 samples
2. The 2020 industry survey and fishery samples
3. 6aS Q1 monitoring fishery and additional 6aN_Sp samples
4. MSHAS 2021

Further information on the results presented here are available in the final EASME project report (Farrell et al., 2020) or from Edward Farrell (edward.d.farrell@gmail.com) and Emma White (emma.white@marine.ie).

Updates on tools to split herring populations

Discrimination and splitting of mixed stocks are essential to stock assessment and advice. Herring stocks assessed by HAWG are mainly separated based on a priori assumptions that fish stocks rigidly follow artificial geographical boundaries. Currently, splitting methods are only applied for the separation of North Sea autumn spawning herring (NSASH, her.27.3a47d) and western Baltic spring spawning herring (WBSSH, her.27.20-24). Splitting is limited to Danish, Swedish and Norwegian samples from commercial catches and scientific surveys in Skagerrak-Kattegat and the north-eastern North Sea. Further, applied splitting methods are not consistent between labs and countries.

Otolith shape analysis is one of the splitting methods used to separate NSASH and WBSSH. In recent years, the use of otolith shape analysis to discriminate fish stocks has increased rapidly. Open-access packages like shapeR (Libungan and Pálsson, 2015) allow scientists to easily extract otolith outlines for further analysis. Otolith shape analysis of Atlantic herring reveals clear differences between populations in the north-eastern Atlantic (Libungan *et al*., 2015). Further, there is a clear genetic effect on herring otolith shape (Berg *et al*., 2018). Smoliński et al. (2020) have compared the assignment performance of different statistical classifiers, including traditional and machine learning classifiers. Their study provides a solid reference guideline for otolith shape analysis.

In previous years, results of preliminary otolith shape analysis and other splitting methods have been reported in HAWG reports (ICES, 2019, 2020). The results of Berg et al. (2019) are shortly summarized again, since they have been reused for updated studies using genetics. A baseline of spawning individuals from three herring stocks (NSASH, WBSSH, and Norwegian spring spawning herring = NSSH) was established. The otolith shape of herring was transformed into 64 wavelet coefficients for further testing. Cross-validation was performed following the guidelines of Smoliński et al. (2020). In general, the overall assignment accuracy was relatively high (>80%), indicating that our baseline is suitable for assignment of individuals from unknown catches. The aim was to assign unknown herring from mixed catches to their original stock. Herring samples of unknown origin were collected during several scientific surveys in the North Sea and adjacent areas (Figure 1.2.7.1), and otoliths as well as genetics were sampled for further analysis. Several classifiers were applied to assign unknown otoliths and the results were compared. Otoliths were not assigned if the difference in assignment probability between the two most likely stocks was <20%. The results demonstrated that otolith shape analysis can, combined with machine learning techniques, be used to assign individuals of unknown origin to one of these three stocks (~82.5% assigned, ~17.5% not assigned).

A recent study (Berg et al. 2020) combined different discrimination methods to assign autumn and spring spawning herring. The results suggest gene flow between autumn and spring spawning herring and are thus highly relevant to the HAWG assessments. In addition to the traditional splitting method using otolith microstructure, newly developed genetic markers as well as their maturity development were used to discriminate autumn and spring spawning herring. Herring were only sampled during the spawning seasons in spring and autumn. Most herring (~77%) had an otolith microstructure and genetic assignment coinciding with the phenotypically assigned spawning season (based on maturity stages). Non-spawning herring (<5%) classified as belonging to the current spawning season using genotyping and otolith-typing were assigned as skipped spawners. For ~8% of spawning herring, the genetic and otolith assignment contradicted the phenotypically assigned spawning season, characteristic of straying individuals. Otolith-typing contradicted the genetic and phenotypical assignment in ~7% of the cases, potentially representing individuals reuniting back to the spawning season favored by their genotype. The disagreement of ~23% could have potential influence on splitting of herring solely based on otolith microstructure, as applied in the assessment of NSAS and WBSS.

In the most recent study, Berg et al. (2021) applied both genetic and otolith shape analysis on the same individuals. The objective was to apply a new diagnostic panel of SNPs to assign individual herring from trawl samples in the HERAS survey to their stock(s) of origin. The SNP panel was established based on Han et al. (2020). 950 individuals from the Norwegian part of the HERAS survey were genotyped. In total, 809 (85%) individuals were successfully assigned to their stock of origin. It was demonstrated that the stock's spatial distribution and phenotypic characteristics agreed with expectations. However, some individuals were assigned as NSSH in the survey area. This will have a bias on the survey estimates because NSSH are usually bigger than other herring. The benefit of using genetic methods to identify stock components in the study region, in comparison with traditionally implemented phenotyping methods, was demonstrated. A disadvantage for all methods, is that fish from stocks not included in the baseline, that appear in mixed catches, cannot be properly assigned.

All in all, discrimination methods used for assignment of unknown individuals need to be further developed and adjusted. Preliminary analyses comparing genetic and otolith shape assignments showed relatively low overall agreement (71%, excluding not assigned individuals). The results further indicate that the geographical boundaries, not only for stocks, but also for the so-called "transfer area" (Figure 1.7.1), should be discussed. Boundary adjustments and including more stocks for the assignment and splitting might improve the assessment and advice of herring stocks in the greater North Sea ecoregion. Further information on this work is available from florian.berg@hi.no.

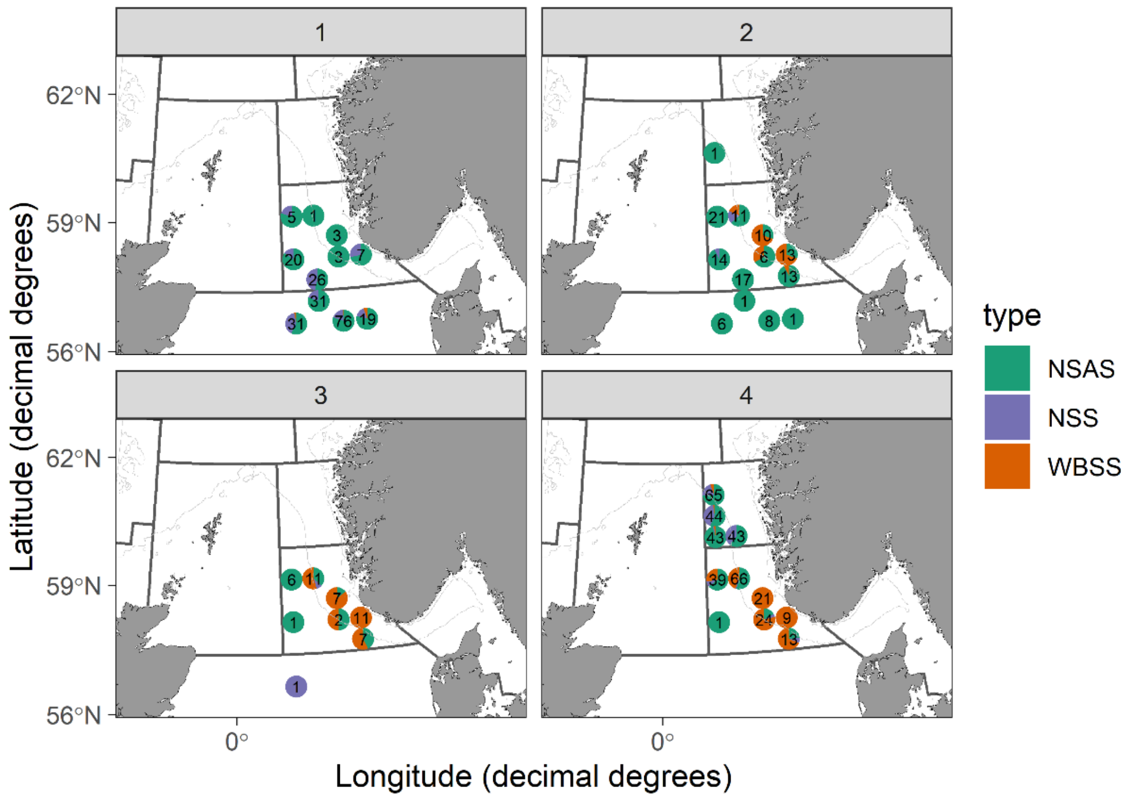

Figure 1.2.7.1: Genetic assignment of individual herring to their original stock. Norwegian part of HERAS 2020 separated by age 1-3 and 4+ winter ringer. Numbers indicate the numbers of analyzed herring.

Updates on the analyses of the WKMixHer sample

The 2018 workshop on mixing of western and central Baltic herring stocks (WKMixHer) recommended coordinated sampling of spring spawning herring with the objective to further evaluate mixing of herring stocks in the western-central Baltic and to implement operational methods for separation.

Samples were collected by Sweden, Germany, Poland and Lithuania during the 2019 and 2020 spawning peak on 7 coastal spawning grounds in the Hanö Bay, Bay of Lübeck, Greifswald Bay, Pomeranian Bay, Kolozbreg, Vistula Lagoon and Klaipéda (Figure 1.2.7.2).

Herring were collected at spawning time from spawning aggregations, resulting in samples from late March till early May as the spawning peak showed a seasonal progression through the region from west to east. Sampling was restricted to ripe and running individuals corresponding to maturity stages 5 to 7. 592 individuals were sampled, covering ages 2-13 winter rings, and stock separation by growth function was applied. Otolith shapes were extracted, and preliminary analyses conducted on 449 of these herring (ages 4-7).

A Canonical Analysis of Principal Coordinates performed on the standardized wavelet coefficients from the otolith shapes showed that herring from the sampled locations group into two well distinct clusters, with a clear geographical longitudinal separation (Figure 1.2.7.3). Samples from part of the Polish coast in SD25 (station "SWI-31" and "ROW") group with the western Baltic cluster.

Among the classifiers tested (both traditional techniques and machine learning algorithms), Random Forest (with k-fold cross validation) provided the best overall accuracy in the discrimination between the two clusters based on otolith shape analysis with overall assignment accuracy of

~70%. When using the growth analysis on the WKMixHer samples (growth is currently used for separating western and central Baltic herring in SD22-24 in the GerAS survey) assignment accuracy to one of the two clusters yield ~97%.

Further work in progress:

- Combine otolith shape and growth analysis when conducting assignments;
- Adding genetic analysis to evaluate the number of components present and validate results from the otolith shape;
- Collect samples of spawning herring from the central part of the Polish coast to evaluate the gradient of differentiation along the southern Baltic coast.

Further information on this is work is available from Valerio Bartolino (valerio.bartolino@slu.se).

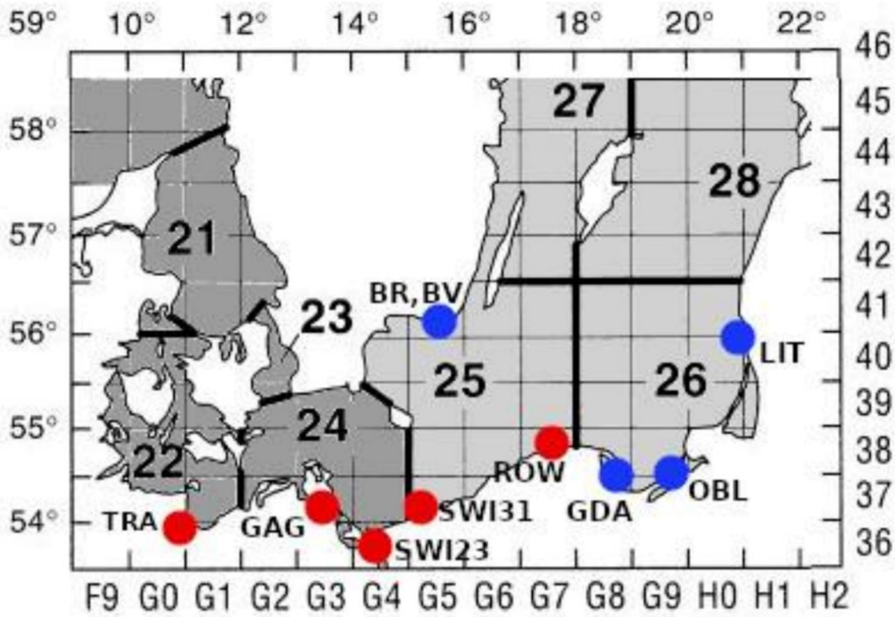

Figure 1.2.7.2. Map with sampling locations of spawning herring during spring 2019-2020. Colors correspond to the two clusters identifies in the Canonical Analysis of Principal Coordinates (See Figure 1.2.7.3).

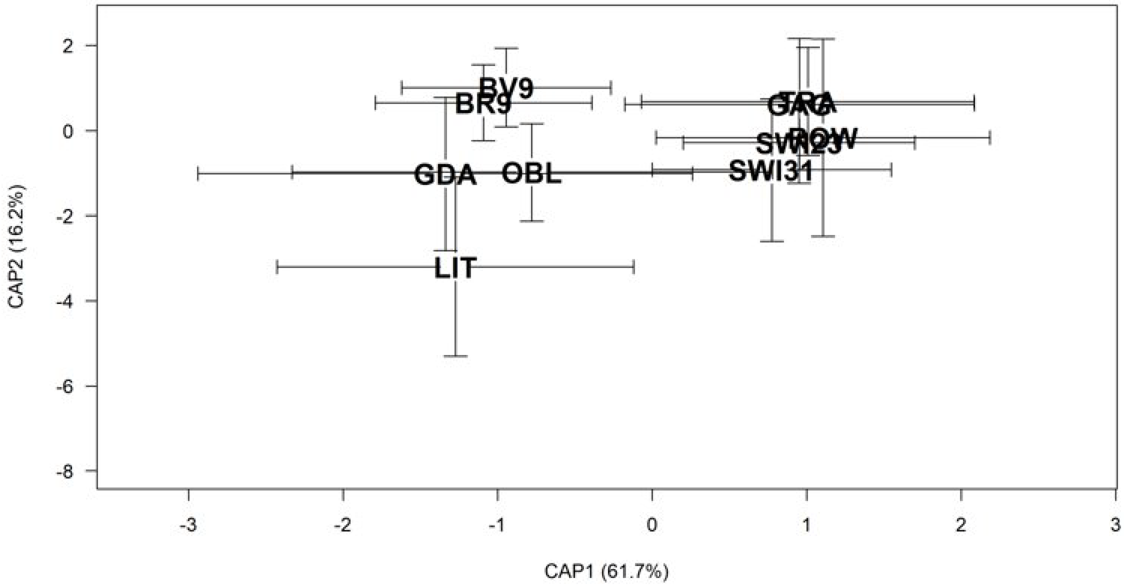

Figure 1.2.7.3. Plot of the first and second Principal Components from the analysis of standardized Wavelet coefficients. The black labels show the centroid for each spawning location. TRA: Bay of Lübeck (GER), GAG: Bay of Greifswald (GER), SWI23: Pomeranian Bay (POL), SWI31: Kolobrzeg (POL), ROW: Rowy (POL), GDA: Gulf of Gdansk (POL), OBL Vistula lagoon (POL), LIT: Klaipėda (LTU), BR9 - BV9: Hanö Bay (SWE).

1.3.7 WKFORBIAS

The workshop on catch forecasts from biased assessments, WKFORBIAS, met on 11-15 November 2019 to address and develop general guidelines for dealing with the issue of retrospective patterns in stock assessments. WKFORBIAS reaffirmed previous recommendations that retrospective analysis should always be conducted as a diagnostic to examine the internal consistency of analytical stock assessments. Across the wide range of ICES stocks examined, no obvious explanatory variables, such as model type, location, fishery type, or biological trait, separate stocks with and without strong retrospective patterns. A decision tree was developed to help expert groups to determine the severity of retrospective patterns and a course of action.

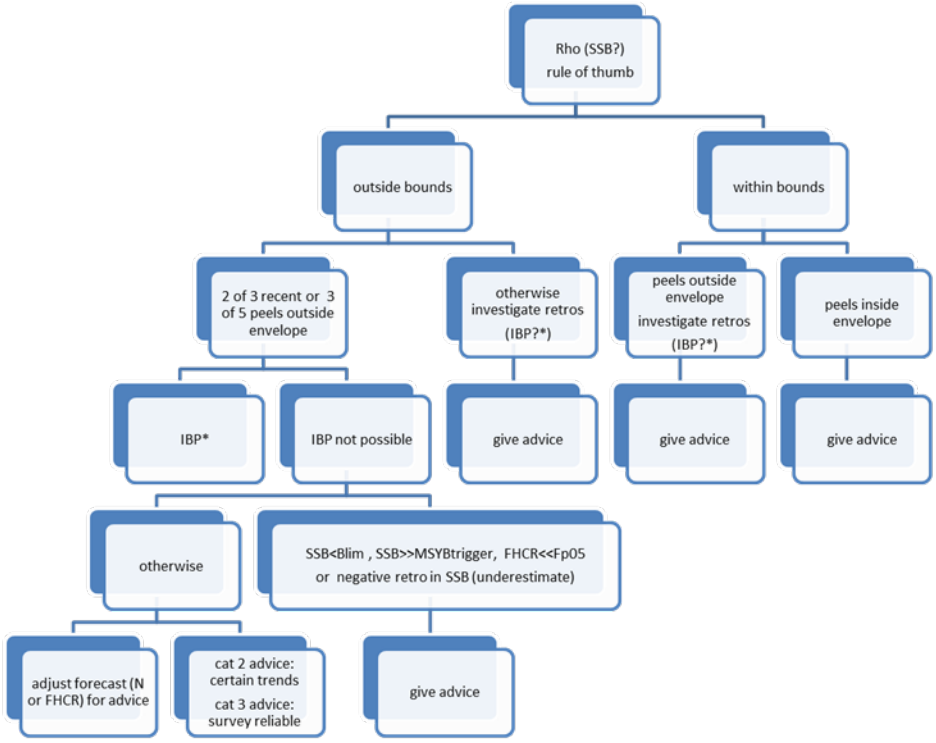

Figure 1.2.8.1: Decision tree for handling assessments with retrospective patterns produced by WKFORBIAS.

General recommendations from WKFORBIAS include:

- when evaluating a retrospective pattern, the consistency of the pattern is of primary importance;
- a large Mohn's rho statistic driven by one outlier should not be treated in the same manner as a consistent directional retrospective pattern;
- retrospective patterns should be viewed as one of many diagnostics to be used in determining whether to use an assessment for management advice or not;
- Management Strategy Evaluation can potentially be a useful tool for examining the robustness of harvest control rules to different magnitudes of retrospective pattern

Two presentations directly linked to HAWG were presented at WKFORBIAS and contributed to the workshop:

- Retrospective Bias in Some Short-lived North Sea Stocks (Van Deurs M.)
- Successes and Failures in the Daily Fight to Stock Assessment biases: Experience from an ICES assessment Working Group (Bartolino V.)

1.3.8 WKDLSSLS

The Workshop on Data Limited Stocks of Short-Lived Species 2 (WKDLSSLS2) built on the work of the previous workshop in 2019 (WKDLSSLS) to further develop methods for stock assessment and catch advice for category 3–4 short-lived species. Work was also carried out to evaluate the management procedures currently in use and their appropriateness for short- lived species by means of Long-Term Management Strategy Evaluations (LT-MSE). A number of stocks were examined including Sprat in 7d, e. WKDLSSLS 2020 tested seasonal Surplus Production in Continuous Time (SPiCT) models and variations and refined the application of harvest rates and tend based assessments, including the 1o2 rule with 80% uncertainty cap (UC). SPiCT was found to have comparable estimates compared to data rich models (specifically tested against Gadget model output) and emerged as the preferential choices for data limited stocks. The working group also noted that seasonal fishing mortality was a key factor when modelling such species and assessments should aim for bellow MSY as a precaution. MSE testing of HCR and trend-based rules, conditioned on 7d, e sprat, confirmed a constant harvest rate is more precautionary than a trend-based rule. The 1o2 with a 20% UC was determined to be not precautionary and may result in stock collapse while accepting it is an improvement on the 2o3 rule, the 1o2 rule with 80% UC in combination with a biomass safeguard is preferred. Although the working group notes this is a provisional rule and may lead to decreasing catches and may not be precautionary for depleted stocks. The work of WKDLSSLS is not considered finished and will look into optimizing the application of harvest control rules including the CHR and 1o2 rule. Refinement to the current guidelines may be expected in 2021.

1.3.9 IBSPRAT

An Interbenchmark for 7.de Sprat was carried out in February 2021 to revise the advice framework based on the most recent changes to data limited short lived species assessments. The advice was previously based on a 2 over 3 rule following the ICES framework for data limited category 3 stocks. This was deemed to be unsuitable for short lived species by WKDLSSLS1 and 2 (ICES 2019b, ICES 2020). A 1 over 2 rule was implemented at HAWG 2020, along with a request for an interbenchmark (IBP) in 2021.

The inter-benchmark was tasked with clarifying the application of the latest advice for category 3 short-lived species following the conclusion of WKDLSSLS 2020 (working group for data-limited stocks of short-lived species) to the Sprat 27.7de stock.

a) a) Review the conclusions of WKDLSSLS for implementation in ICES advice for short-lived category 3 stocks.

b) b) Review and calculate the options for providing advice, using the conclusions from WKDLSSLS 2020 for sprat 27.7de.

Three advice approaches for short lived data limited species were explored, namely Surplus Production in Continuous Time (SPiCT), Management Strategy Evaluation (MSE) determined constant harvest rate (CHR) and a 1o2 rule with an 80% uncertainty cap (UC). The IBP determined that SPiCT was not currently viable for the stock and that a CHR as determined by management strategy evaluation was the most appropriate assessment and advice framework. The 1o2 rule with an 80%UC was also examined, but it has been determined by both WKDLSSLS 1&2 that a properly determined CHR is more precautionary. The 1o2 rule with an 80% UC is a default option when no other approach can be applied. The final harvest rate was determined to be 12 %, which was then adjusted down to 8.57% to account for a timing differential between the MSE and the actual survey. The CHR is directly applied to the last year of survey biomass from the PELITC. The IBP considered the proposed CHR to be heavily precautionary. Full details and justification for the MSE parameters can be found in the IBP report (ICES 2021, IBPSprat) along with a detailed explanation of the correction factor.

1.3.10 Other activities relevant to HAWG

Industry-Science survey of herring in 6.a, 7b–c. in 2020

(see Section 05 for additional details).

In 2020, industry and scientific institutions from Scotland, Netherlands and Ireland successfully carried out scientific surveys with the aim to improve the knowledge base for the herring spawning components in 6.aN and 6.aS, 7.b–c, and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan.

Following agreement on a monitoring fishery TAC of 4 840 t (3480 t in 6aN and 1360 t in 6aS/7bc) the scientific survey was designed using ICES advice on sampling required to collect assessment-relevant data, a review of spawning areas and timing and discussions with fishing skippers following the experiences from the 2016-2019 surveys.

The survey provides a fifth data point in a new survey series, the details of and utility of which will be explored during the benchmark in 2022. Genetic data from spawning fish will continue to contribute to the new baseline data required to assess separately the stocks in 6.aN and 6.aS, 7.b–c, during the 2022 benchmark.

Ichthyophonus

Ichthyophonus hoferi is a parasite found in fish. It has a low host-specificity, has been observed in more than 80 fish species, mostly marine, and is common in herring, haddock and plaice. *Ichthyophonus* belong to the Class Mesomycetozoea, a group of micro-organisms residing between the fungi and animals (McVivar and Jones, 2013). Epidemics associated with high mortality have been reported several times for Atlantic herring: in 1991–1994 for herring in the North Sea, Skagerrak, Kattegat and the Baltic Sea (Mellergaard and Spanggaard, 1997), and in 2008–2010 for Icelandic summer-spawning herring (Óskarsson and Pálsson, 2011). A time-series of the Norwegian data on *Ichthyophonus* was presented at HAWG 2017. The occurrence is usually below 1%, except for the beginning of the 1990s, but high occurrences (22%) were again observed again in the Norwegian IBTSQ1 2017 which is carried on in the North Sea (Figure 1.2.14.2). Because of the high lethal level of this parasite and episodic outburst, HAWG 2017 decided to continue monitoring the level of *Ichthyophonus* infestation in the following years and Sweden extended the coverage of the sampling to the Skagerrak and Kattegat since IBTSQ3. In the 2018-2021 IBTSQ1 surveys, the occurrences of *Ichthyophonus* in the Norwegian part were again low: 4.4%, <1%, 1.2% and 0.6%, respectively. In the Kattegat-Skagerrak, the IBTS data suggests levels of incidence generally < 3% but occasionally ICES rectangles with > 20% infestation have been observed in some recent years 2017-2018. The level of infection is generally lower in IBTS Q3 compared to Q1 and this confirmed also in 2019 and 2020. The level of infection is lower in 2020 than in 2019 and shifted more towards younger ages. After an unusual complete lack of infection in the Swedish commercial samples from 2019, the 2020 commercial samples confirm very low infection levels (<1%) in both the Kattegat and Skagerrak and throughout all the quarters sampled based on visual inspection. It is relevant that all countries continue to screen herring for *Ichthyophonus* during the IBTS surveys (both Q1 and Q3) and HERAS, as well as for the commercial sampling.

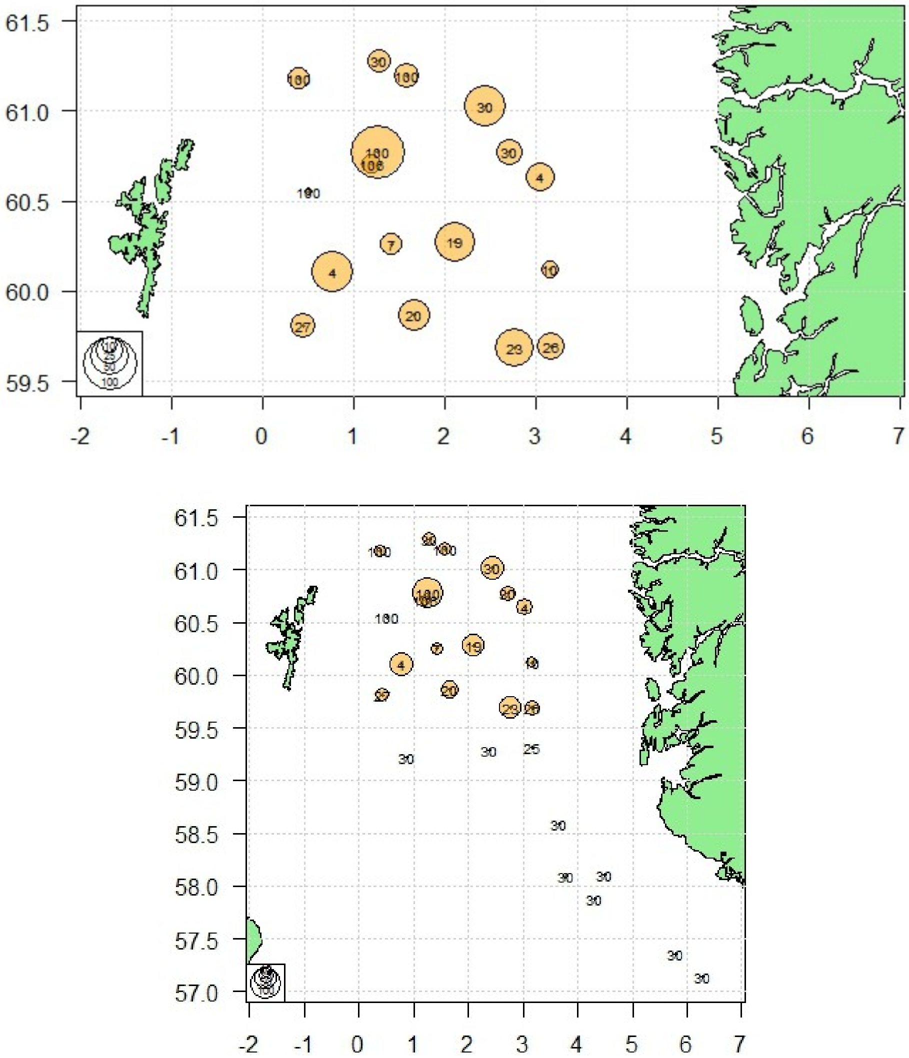

Figure 1.2.14.2 Occurrence of *Ichthyophonus hoferi* in the Norwegian part of the IBTSQ1 2017, the last year with high prevalence. Bubble sizes show the percentage of diseased herring, whereas the numbers show the number of herring examined. The upper figure shows the details of the area with infection.

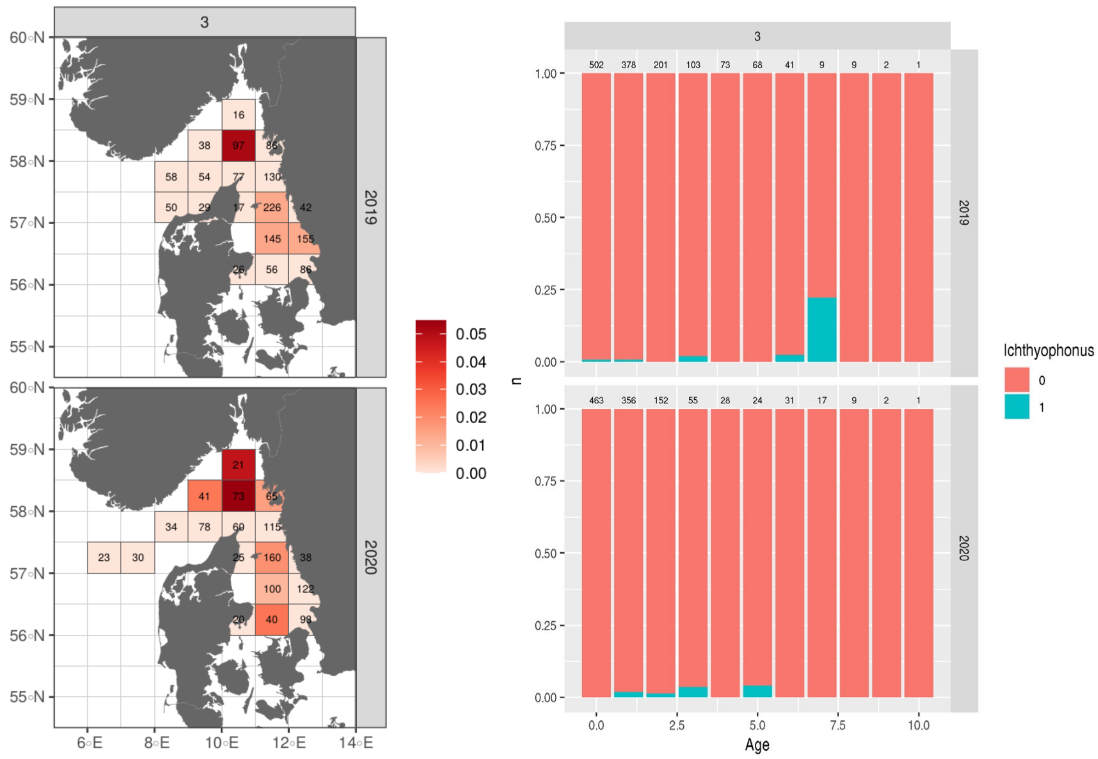

Figure 1.2.14.3 Occurrence of *Ichthyophonus hoferi* in the Kattegat-Skagerrak from Swedish samples collected during the IBTSQ3 2019-2020. Left map with distribution of the proportion of infested herring and number of samples in each rectangle; right distribution of infestation among ages.

Regional Database and Estimation System (RDBES)

The RDBES is still under development, and in 2020 had its first major upload of data, from sampling schemes covering a small group of stocks, spr.27.22-32, cod.27.21, whb.27.1-91214, YFT (Yellowfin tuna (tropical)), sol.27.7fg, mur.27.67a-ce-k89a, mon.27.78abd, mon.27.8c9a, ank.27.78abd, ank.27.8c9a, mac.27.nea. The stocks were chosen to ensure that most countries were involved in this first major test of the system. This data call did not include any stocks covered by HAWG, but all counties were encouraged to submit more stocks.

The 2021 data call will be similar to the data call in 2020. However, landing and effort data will be requested for all species, while last year landing and effort data were requested for only 11 selected stocks. Detailed sample data should be uploaded to the RDBES for the 11 stocks requested in 2020 and potentially a few extra stocks which may include stocks from HAWG.

In 2021, three further workshops will be held in relation to the RDBES, WKRDB-POP Workshop on Populating the RDBES data model (June 14th-18th), WKRDB-EST –Workshop on Estimation with the RDBES data model (September 20th-24th) and WKRDB-RAISE&TAF - support migrating of present estimation routines to TAF. In 2021, a data call requesting upload of all stock will be launched.

Further information about the RDBES status and roadmap can be found in ICES (2020).

1.4 Commercial catch data collation, sampling, and terminology

1.4.1 Commercial catch and sampling: data collation and handling

Input spreadsheet and initial data processing

Since 1999 (catch data 1998), the Working Group members have used a spreadsheet to provide all necessary landing and sampling data. These data were then further processed with the SALLOC-application (Patterson, 1998). This program gives the required standard outputs on sampling status and biological parameters. It documents any decisions made by the species co-ordinators for filling in missing data and raising the catch information of one nation/quarter/area with information from another dataset.

Since 2015, ICES requested relevant countries within a data call to submit the national catches into InterCatch or to accessions@ices (via the standard exchange files). National catch data submission was due by 1st March 2021. Not all countries delivered their data in due time.

"InterCatch is a web-based system for handling fish stock assessment data. National fish stock catches are imported to InterCatch. Stock coordinators then allocate sampled catches to unsampled catches, aggregate to stock level and download the output. The InterCatch stock output can then be used as input for the assessment models". Stock coordinators used InterCatch for the first time at the 2007 Herring Assessment Working Group. However, InterCatch does not provide the output as needed for the assessment of NSAS and WBSS. Both data collation methods are, therefore, still used in parallel.

Excel was used to allocate samples to catches for 6.a following the same procedure outlined in WD01 to HAWG 2017.

More information on data handling transparency, data archiving and the current methods for compiling fisheries assessment data are given in the Stock Annex for each stock. Figure 1.5.1 shows the separation of areas as applied to the data in the archive.

1.4.2 Sampling

Quality of sampling for the whole area

The level of catch sampling by area is given in the table below for all herring stocks covered by HAWG (in terms of fraction of catch sampled and number of age readings per 1000 tonnes catch). There is considerable variation between areas. Further details of the sampling quality and the level of samples can be found by stock in the respective sections in the report and the stock annexes.

Area	Official Catch	Sampled Catch	Age Readings	Age Readings per 1000t
4.a(E)	58597	58326	704	12
4.a(W)	235613	195184	5152	22
4.b	95422	71901	1926	20
4.c	4922	1464	50	10
7.d	32768	22915	394	12
7.a(N)	7927	7927	1226	155
6.a(N)	177	64	50	282
3.a	17779	15085	3100	174
SD22-24	3966	3306	4041	1019
Celtic, 7.j	132	40	150	1136
6.a(S), 7.b and 7.c	1220	1212	2610	2129

Given the diversity of the fleets harvesting most stocks assessed by HAWG, an appropriate spread of sampling effort over the different métiers is more important to the quality of catch-at-age data than a sufficient overall sampling level. The WG therefore recommends that all métiers with substantial catch should be sampled (including bycatches in the industrial fisheries), that catches landed abroad should be sampled, and information on these samples should be made available to the national laboratories and incorporated into the national InterCatch upload.

1.4.3 Terminology

The WG noted that for herring the use of “age”, “winter rings”, “rings” and “ringers” still causes confusion outside the group (and sometimes even among WG members). The WG tries to avoid this by consequently using “rings”, “ringers”, “winter ringers” or “wr” instead of “age” throughout the report. However, if the word “age” is used it is qualified in brackets with one of the ring designations. It should be observed that, for autumn and winter spawning stocks, there is a difference of one year between “age” and “rings”. Further elaboration on the rationale behind this, specific to each stock, can be found in the individual Stock Annexes. It is the responsibility of any user of age-based data for any of these herring stocks to consult the relevant annex and if in doubt consult a relevant member of the Working Group.

1.5 Methods Used

1.5.1 SAM

The Spate-space stock Assessment Model SAM described in described in Nielsen and Berg (2014) is currently used to assess several of the HAWG stocks. This model has the standard exponential decay equations to carry forth the Ns (with appropriate treatment of the plus-group), and the Baranov catch equation to calculate catch-at-age based on the Fs. The additional components of SAM are the introduction of process error down the cohort (additional error term in the exponential decay equations), and the random walk on Fs. The steps (or deviations) in the random walk process are treated as random effects that are "integrated out", so are not viewed as estimable parameters. The sigma parameter controls how large the random walk deviations are, and this parameter is estimated. SAM provides the option of correlated errors across ages for the random walks on F, where the correlation is an additional parameter estimated to be estimated. The current implementation of SAM is an R-package based on Template Model Builder (TMB) (Kristensen *et al.*, 2016) and is maintained and available at https://github.com/fishfollower/SAM. At WKPELA 2018 a multi-fleet version of SAM was presented (ICES, 2018) and it is currently used for the assessment and forecasts of Western Baltic Spring-spawning herring, and to provide fleet specific selection patterns for short and medium-term forecasts for the North Sea herring.

SAM is currently run by HAWG via both the web browser at www.stockassessment.org and within the FLR (Fisheries Library in R) system (www.flr-project.org) which is an attempt to implement a framework for modelling integrated fisheries systems including population dynamics, fleet behaviour, stock assessment and management objectives. The stock assessment tools in FLR can also be used on their own in the WG context. The combination of the statistical and graphical tools in R with the stock assessment aids the exploration of input data and results.

1.5.2 ASAP

The ASAP 3 (http://nft.nefsc.noaa.gov) model has been used for Celtic Sea herring. ASAP (A Stock Assessment Program) is an age-structured stock assessment modelling program (Legault and Restrepo, 1998). ASAP is a variant of a statistical catch-at-age model that can integrate annual catches and associated age compositions (by fleet), abundance indices and associated age compositions, annual maturity, fecundity, weight, and natural mortality-at-age. It is a forward projecting model that assumes separability of fishing mortality into year and age components, but allows specification of various selectivity time blocks. It is also possible to include a Beverton-Holt stock-recruit relationship and flexible enough to handle data poor stocks without age data (dynamic pool models) or with only new and post-recruit age or size groups.

1.5.3 SMS

SMS is a stochastic multispecies assessment model, including seasonality, used for sandeel in Division 3.a and Subarea 4, for sprat in the North Sea and 3.a. The model is run in single species mode for these stock assessments. Major difference with the other stock assessment models used by HAWG is the ability to assess in seasonal time-steps, necessary to distinguish the fishing season and off-season for both the sandeel and sprat stocks. Furthermore, it integrates catches, effort time-series, maturity, weight and natural mortality-at-age. The model allows to set separate selectivity year blocks to account for changes in the fishing fleet.

1.5.4 Short-term predictions

Short-term predictions for the North Sea used a code developed in R. The method was developed in 2009 and intensively compared to the MFDP approach. Celtic Sea herring and Irish Sea herring forecast used the standard projection routines developed under FLR package FLCore (version 2.6.0.20170228). For sprat in the North Sea, a forecast using the FLR framework is in use. North Sea herring is assessed using a fleet-wise projection method using native R and FLR routines (some maintenance of the code has been done this year mainly to improve readability and documentation).

The Western Baltic Spring-spawning herring uses an R-based multifleet forecast routine available at www.stockassessment.org.

1.5.5 Reference Points

The eqsim software (https://github.com/ices-tools-prod/msy) was used in recent benchmarks to estimate MSY reference points for herring stocks of HAWG.

For sprat in the North Sea (Division 4) and sandeel in management area 1–4, the ICES guide for setting management reference points for category 1 stocks is used to find B_{lim}. MSY $B_{escapement}$ is equal to B_{pa} and is calculated as $B_{lim} \times e^{\sigma \times 1.645}$. An upper level on the fishing mortality is implemented (F_{cap}) if the difference between B_{lim} and MSY $B_{escapement}$ is not compatible with the ICES F_{MSY} criteria (i.e. that the average probability in the long-term of getting below B_{lim} should be no more than 5% per year). F_{cap} is calculated/optimized using a management strategy evaluation framework (MSE).

The most recent benchmark (WKPELA 2018) of the North Sea herring, Western Baltic herring and Celtic Sea herring presented considerable challenges in the estimation of reference points and their calculation remains at time still controversial. An overview and critical discussion of those main challenges are provided in last year's report (ICES 2018, Section 1.2.6) and maintain their validity in the ongoing discussion on reference points.

F_{pa} is defined as the exploitation rate reference point below which exploitation is considered to be sustainable, having accounted for assessment uncertainty. In 2020 a decision was made by ACOM to standardize the basis for F_{pa} whereby it is equal to the fishing mortality including the advice rule that, if applied as a target in the ICES MSY advice rule (AR) would lead to SSB ≥ B_{lim} with a 95% probability (also known as Fp05). The derivation of F_{pa} should include the expected stochastic variability in biology and fishery, as well as advice error.

1.5.6 Repository setup for HAWG

To increase the efficiency and verifiability of the data and code used to perform the assessments as well as the short-term forecasts within HAWG a repository system was set up in 2009. Within this repository, all stocks own a subfolder where they store their data and code used to run the assessments presented in this report and used as base for the advice. At the same time, there is one common folder, used by all assessments, that ensures that the FLR libraries used are identical for all stocks, as well as the output generated to evaluate the performance of the assessment.

The repository was moved from google code to github in 2016 and is now available as a branch of the ICES github site. https://github.com/ICES-dk/wg_HAWG. Contributing to the repository is not possible for outsiders as a password is required. Downloading data and code is possible to the public. The repository is maintained by members of the WG and the ICES Secretariat.

1.6 Ecosystem overview and considerations

General ecosystem overviews for the areas relevant to herring, sprat and sandeel stocks covered by the Herring Assessment Working Group for herring stocks south of 62°N (HAWG) are given for the Greater North Sea and Celtic Seas Ecoregions (ICES, 2020e, f).

A more detailed account specific to herring is documented in ICES HAWG (2015). A number of topics are covered in this section including the use of single species assessment and management, the use of ecosystem drivers, factors affecting early life-history stages, the effects of gravel extraction, variability of the biology and ecology of species and populations (including biological and environmental drivers), and disease.

It should be pointed out that while numerous studies have greatly improved our understanding on the effects of environmental forcing on the herring stock productivity and dynamics, further work is still required to move beyond simple correlative understanding and elucidate the underlying mechanisms. One specific case is the persistent decrease in mean weight-at-age for many of the herring stocks in the region (Figure 1.7.6). Furthermore, mechanisms to incorporate this understanding into the provision of management advice are limited. ICES could therefore benefit greatly from developments that unify these two aspects of its community.

ICES is reviewing the level of inclusion of ecosystem information into the single-species assessments that provide the base for the current advices to evaluate progresses toward ecosystem-based fisheries management. The intent is to quantify whether and how the ICES assessments incorporated broader system-level considerations, from the inclusion of technical interactions among fisheries (i.e. catch and bycatch of target and non-target species) to interactions with the physical environment (i.e. environmentally-driven recruitment, climate), and biological components (i.e. density-dependency, predation).

Following the ACOM request (March 2019), HAWG collected information and has updated this on where and how change in ecosystem productivity (either annually or over time-periods) is incorporated in its fish stock assessments, MSE operating models and management advice products for the following six categories (relevant variables in parentheses) below:

1. Stock assessments (weight-at-age [in stock or catch], length distribution, maturity, sex ratio)
2. Forecasts (recruitment over recent years – reflecting productivity changes, recent weight-at-age, maturity, natural mortality)
3. Natural mortality (predation, diseases, parasites) assessed and included as variable by year (including smoothed)
4. Stock distribution (changes caused by year class strength, predators, prey, habitat suitability/quality)
5. Mixed fisheries (catch and bycatch of target/non-target species)
6. Climate change (is this considered and how?)

Because the inclusion of system-level information may span from the use of qualitative background considerations to inclusion of quantitative information into analytical assessments, the following scoring system recently proposed by Marshall *et al*. (2019) has been applied:

- Score 0 – information unavailable / not used.
- Score 1 (Background) – productivity is mentioned in the report and/or considered in the output as background information.
- Score 2 (Qualitative) – applicable in two cases: i) when quantitative data/information on productivity change were included in the report, but not used in any analyses/models, or ii) explicit link between the productivity change and assessment parameters or output was established. *For example, including numerical data from diet studies on the target species would receive a score of 2, as would discussing a link between sea surface temperature and recruitment predictions.*
- Score 3 (Quantitative) – productivity-related data were explicitly included in the assessment model through data inputs or estimated parameters.

Stock code	Stock assessment					Short-term forecast				
	variable w@a	length distribution	variable mat@a	estimated variable nat mort	estimated variable sex ratio	environ. driven recruitment	truncating recruitment time-series	recent or trend weight@a	recent or trend mat@a	recent or trend nat mort
her.27.20-24	3	2	3	3	0	1	3	3	3	3
her.27.3a47d	3	2	0	3	0	1	3	3	0	3
her.27.6a7bc	3	2	3	2	0	1	2	2	2	2
her.27.irls	3	2	1	2	0	0	3	3	0	0
her.27.nirs	3	2	3	2	0	0	3	3	3	2
san.sa.1r	3	0	1	3	0	0	1	3	1	3
san.sa.2r	3	0	1	1	0	0	3	3	1	1
san.sa.3r	3	0	1	3	0	0	1	3	1	3
san.sa.4	3	0	1	1	0	0	3	3	1	1
san.sa.5r	0	0	0	0	0	0	0	0	0	0
san.sa.6	0	0	0	0	0	0	0	0	0	0
san.sa.7r	0	0	0	0	0	0	0	0	0	0
San.27.6a	0	0	0	0	0	0	0	0	0	0
spr.27.3a4	3	0	1	3	0	0	3	3	1	3
spr.27.67a-cf-k	3	0	0	0	0	0	0	0	0	0
spr.27.7de	3	0	0	0	0	0	0	0	0	0

Stock code	MSE (management/rebuilding plans). Uncertainty or differing operating models					Advice	Distribution & habitats			Mixed fisheries			Climate
	environ. driven recruitment	truncating recruitment time-series	variable weight@a (env or density)	recent or trend mat@a (envir or density)	dynamic nat mort	escapement or other productivity rule	influence of population state	habitat suitability/ quality	within species stock mixing	Catch and bycatch of target species	bycatch of non-target species	consideration in mixed fisheries advice	consideration of changes from climate
her.27.20-24						0	2	2	3	3	3	0	1
her.27.3a47d	0	3	2	2	2	0	2	1	3	3	1	0	1
her.27.6a7bc						0	2	2	1	3	3	0	0
her.27.irls	0	3	0	0	0	0	1	1	1	0	1	0	0
her.27.nirs						0	1	1	1	0	0	0	0
san.sa.1r	0	3	0	0	0	3	0	1	0	0	0	0	1
san.sa.2r	0	3	0	0	0	3	0	1	0	0	0	0	0
san.sa.3r	0	3	0	0	0	3	0	1	0	0	0	0	0
san.sa.4	0	3	0	0	0	3	0	1	0	0	0	0	0
san.sa.5r						0	0	0	0	0	0	0	0
san.sa.6						0	0	0	0	0	0	0	0
san.sa.7r						0	0	0	0	0	0	0	0
san.27.6a													
spr.27.3a4	0	3	0	0	0	3	0	0	0	0	1	0	0
spr.27.67a-cf-k						0	0	0	0	0	0	0	0
spr.27.7de	0	2	2	0	2	0	0	1	0	0	0	0	1

1.7 Summary of relevant Mixed fisheries overview and considerations, species interaction effects and ecosystem drivers, Ecosystem effects of fisheries, and Effects of regulatory changes on the assessment or projections for all stocks.

Brief summaries are given here; more detailed information can be found in the relevant stock summaries.

North Sea Autumn spawning herring (her.27.3a47d):

The North Sea herring fishery is a multinational fishery that seasonally targets herring in the North Sea and English Channel. An industrial fishery, which catches juvenile herring as a bycatch operates in the Skagerrak, Kattegat and in the central North Sea. Most fleets that execute the fishery on adult herring target other fish at other times of the year, both within and beyond the North Sea (e.g. mackerel *Scomber scombrus*, horse mackerel *Trachurus trachurus* and blue whiting *Micromestistius poutasou*). In addition, Western Baltic Spring spawners are also caught in this fishery at a certain time of the year in the northern North Sea to the west of the Norwegian coast. The fishery for human consumption has mostly single-species catches, although some mixed herring and mackerel catches occur in the northern North Sea. The bycatch of sea mammals and birds is also very low, i.e. undetectable using observer programmes. There is less information readily available to assess the impact of the industrial fisheries that bycatch juvenile herring. The pelagic fisheries on herring and mackerel claim to be some of the "cleanest" fisheries in terms of bycatch, disturbance of the seabed and discarding. Herring like other pelagic forage fish has a central ecological role in the North Sea ecosystem, directly interacting with zooplankton, demersal fish and other predators (sea mammals, elasmobranchs and seabirds). Thus, a fishery on pelagic fish may impact on these other components via second order interactions. There is a paucity of knowledge of these interactions, and the inherent complexity in the system makes quantifying the impact of fisheries very difficult.

Another potential impact of the North Sea herring fishery is the removal of fish that could provide other "ecosystem services". The North Sea ecosystem needs a biomass of herring to graze the plankton and act as prey for other organisms. If herring biomass is very low other species, such as sandeel, may replace its role or the system may shift in a more dramatic way. Likewise, large numbers of herring can have a predatory impact on species with pelagic egg and larval stages.

The populations of herring constitute some of the highest biomass of forage fish in the North Sea and are thus an integral and important part of the ecosystem, particularly the pelagic components. North Sea herring has a complex sub-stock structure with different spawning components, producing offspring with different morphometric and physiological characteristics, different growth patterns and differing migration routes. Productivity of the spawning components varies. The three northern components (Autumn spawners) show similar recruitment trends and differ from the Downs component (Winter spawners), which appears to be influenced by different environmental drivers. Having their spawning and nursery areas near the coasts, means herring are particularly sensitive and vulnerable to anthropogenic impacts. The most serious of these is the ever-increasing pressure for marine sand and gravel extraction and the development of wind farms. Climate models predict a future increase in air and water temperature and a change in wind, cloud cover and precipitation. Analysis of early life stages' habitats and trends over time suggests that the projected changes in temperature may not widely affect the potential habitats but may influence the productivity of the stock. Relatively major changes in wind patterns may affect the distribution of larvae and early stage of herring.

Western Baltic Spring-spawning herring (her.27.20-24):

The Western Baltic herring fishery is a multinational fishery that seasonally targets herring in the eastern parts of the North Sea (Eastern 4.a and 4.b), the Skagerrak and Kattegat (Division 3.a) and Western Baltic (SD 22–24). The fishery for human consumption has mostly single-species catches, although in recent years some mackerel by-catch occurred in the trawl fishery for herring. In addition, North Sea herring are also caught within Division 3.a. The bycatch of sea mammals and birds is low enough to be below detection levels based on observer programmes. At present, there is a very limited and progressively decreasing industrial fishery in Division 3.a and hence a limited by-catch of juvenile herring. The pelagic fisheries on herring claim to be some of the "cleanest" fisheries in terms of by catch, disturbance of the seabed and discarding. Pelagic fish interact with other components of the ecosystem, including demersal fish, zooplankton and predators (sea mammals, elasmobranchs and seabirds). Another potential impact of the Western Baltic herring fishery is the removal of fish that could provide other "ecosystem services." There is, however, no recent research on multispecies or ecosystem interactions in which the WBSS interact. Although a fishery on pelagic fish may impact on these other components via second order interactions.

Dominant drivers of larval survival and year-class strength of recruitment are considered to be linked to oceanographic dispersal, sea temperatures and food availability in the critical phase when larvae start feeding actively. However, research on larval herring survival dynamics indicates that driving variables might not only vary at the population level and by region of spawning but also by larval developmental stage. Since WBSS herring relies on inshore, transitional waters for spawning and larval retention, the suit of environmental variables driving reproduction success potentially differs from other North Atlantic stocks recruiting from coastal shelf spawning areas.

Herring in the Celtic Sea and 7.j (her.27.irls):

There are few documented reports of bycatch in the Celtic Sea herring fishery. Small quantities of non-target whitefish species were caught in the nets. Of the non-target species caught whiting was most frequent followed by mackerel and haddock. The only marine mammals recorded were grey seals (*Halichoerus grypus*). The seals were observed on a number of occasions feeding on herring when the net was being hauled and during towing. They appear to be able to avoid becoming entangled in the nets. Occasional entanglement of cetaceans may occur, but overall incidental catches are thought to be minimal.

Temperatures in this area have been increasing over the last number of decades. There are indications that salinity is also increasing. Herring are found to be more abundant when the water is cooler while pilchards favour warmer water and tend to extend further east under these conditions. However, studies have been unable to demonstrate that changes in the environmental regime in the Celtic Sea have had any effect on productivity of this stock. Herring larval drift occurs between the Celtic Sea and the Irish Sea. The larvae remain in the Irish Sea for a period as juveniles before returning to the Celtic Sea. Catches of herring in the Irish Sea may therefore impact on recruitment into the Celtic Sea stock. The residence of Celtic Sea fish in the Irish Sea may have an influence on growth and maturity rates.

The spawning grounds for herring in the Celtic Sea are well known and are located inshore close to the coast. Spawning grounds tend to be vulnerable to anthropogenic influences such as dredging and sand and gravel extraction. Herring are an important component of the Celtic sea ecosystem. There is little information on the specific diet of this stock. Herring form part of the food source for larger gadoids such as hake. Recent research showed that fin whales *Balaenoptera physalus* are an important component of the Celtic Sea ecosystem, with a high re-sighting rate indicating fidelity to the area. There is the suggestion that the peak in fin whale sightings in November may coincide with the inshore spawning migration of herring.

Herring in 6.a North (part of her-6.a):

Herring are an important prey species in the ecosystem and also one of the dominant planktivorous fish. Herring fisheries tend to be clean with little bycatch of other fish. Herring represent an important prey item for many predators including cod and other large gadoids, dogfish and sharks, marine mammals and seabirds. Because of the trophic importance of herring puts its stocks under immense pressure from constant exploitation.

The benthic spawning behaviour of herring makes this species vulnerable to anthropogenic activity such as offshore oil and gas industries, gravel extraction and the construction of wind farms. There are many hypotheses as to the cause of the irregular cycles shown in the productivity of herring stocks (weights-at-age and recruitment), but in most cases it is thought that the environment plays a key role (through prey, predation and transport). The 6.aN herring stock has shown a marked decline in productivity during the late 1970s and has remained at a low level since then.

Herring in 6.a South and 7.b and 7.c (part of her-6.a):

Sea surface temperatures from Malin head on the North coast of Ireland since 1958 indicate that since 1990 sea surface temperatures have displayed a sustained increasing trend, with winter temperatures > 6°C and higher summer temperatures. Environmental conditions can cause significant fluctuations in abundance in a variety of marine species including fish. Oceanographic variation associated with temperature and salinity fluctuations appears to affect herring in the first year of life, probably during winter larval drift.

Productivity in this region is reasonably high on the shelf but drops rapidly west of the shelf break. This area is important for many pelagic fish species. The shelf edge is a spawning area for mackerel *Scomber scombrus* and blue whiting *Micromesistius potassou*. Preliminary examination of productivity shows that overall productivity in this area is currently lower than it was in the 1980s.

The spawning grounds for herring along the northwest coast are located in inshore areas close to the coast and tend to be vulnerable to anthropogenic influences such as dredging and sand and gravel extraction.

Herring in the Irish Sea (her.27.nirs):

The targeted fishery for herring in the Irish Sea is considered to have limited bycatch of other species. Herring are preyed upon by many species but at present the extent of this is not quantified. The main fish predators on herring in the Irish Sea include spurdog (*Squalus acanthias*), whiting (*Merlangius merlangus*) (mainly 0–1 ring) and hake (*Merluccius merluccius*) (all age classes). Small clupeids are an important source of food for piscivorous seabirds and marine mammals which can occur seasonally in areas where herring aggregate. While small juvenile herring occur throughout the coastal waters of the western and eastern Irish Sea, their distribution overlaps extensively with sprats (*Sprattus sprattus*).

Stock discrimination techniques, tagging, and otolith microstructure and shape show that juveniles originating in the Celtic Sea are present in the Irish Sea. The majority of mixing between these populations occurs at winter rings 1–2. Over the period 2006 to 2010 interannual variation in the proportion of mixing was large, with between 15% and 60% observed in the wintering 1+ biomass estimate during the study period. There are irregular cycles in the productivity of herring stocks which are probably caused by changes in the environment (e.g. transport, prey, and predation).

North Sea and 3a sprat (spr.27.3a4):

Sprat is a short-lived forage fish that is predated by a wide range of marine organisms, from predatory gadoids, through birds to marine mammals. Therefore, the dynamics of sprat populations are affected by the dynamics of other species through annually varying natural mortality rates. Because sprat interacts with many other components of the ecosystem (fish, zooplankton and predators) the fishery may impact on these other components via these food web interactions. It is uncertain how many sprat migrate into and out of adjacent management areas, i.e. the English Channel (7.d and 7.e) and the western Baltic and the Sound (SD22–24), or how this may vary annually. Uncertain is also the boundary with local populations occurring along the Scandinavian Skagerrak coasts. While genetic information has supported the exclusion of sprat along the Norwegian coasts from the current assessment unit, similar information was insufficient for the Swedish coasts despite the fact that local populations likely exist. Young herring as a bycatch is acknowledged for this fishery with bycatch regulations in force. The bycatch of marine mammals and birds is considered to be very low (undetectable using observer programs).

Sprat in the English Channel (7.d and 7.e) (spr.27.7de):

The fishery considered here is primarily in Lyme Bay with small trawlers targeting sprat with very little to no bycatch of other species. The relationship of the sprat in this area to the sprat stock or population in the adjacent areas is unknown: Sprat larvae most likely drift away from the main spawning area in Lyme Bay, but to which extent they expand westward into the Celtic Sea or eastern deep into the Eastern English Channel and the North Sea is unknown. The potential for mixed fisheries, if the fisheries are expanded to cover the whole of the English Channel, is unknown at present. It is acknowledged that sprat is prey for many species and these will affect the natural mortality, however, this has not been quantified in this area. In addition, changes in the size of the sprat population through fishing will affect the available prey for a number of commercially exploited species.

Sprat in the Celtic Seas ecoregion (6 and 7 (excluding 7.d and 7.e)) (spr.27.67a-cf-k):

This ecoregion currently has fisheries in the Celtic Sea, northwest of Ireland and a variety of Scottish Sea lochs with the possibility of fisheries being revived in the Clyde. Generally, mixed fisheries are not an issue as sprat are targeted with very little to no other species caught as a bycatch. If a fishery was to be prosecuted in the Clyde and Irish Sea then bycatch of young herring may become an issue due to the overlap in distribution between young herring and sprat. It is acknowledged that sprat are prey for many species and these will affect the natural mortality, however, this has not been quantified in this area. Since sprat preys on e.g. zooplankton and is preyed upon by many species fisheries for sprat can have effects on the ecosystem dynamics.

Sandeel in the North Sea ecoregion (san.sa.1r-7r)

A mosaic of sandeel fishing grounds occur throughout different areas of the North Sea ecoregion. The grounds present different degrees of larval connectivity which has supported the division of sandeel in the North Sea into a number of more or less reproductively isolated subpopulations. Whereas the fishing grounds are assumed to remain relatively constant over time, the actual distribution of the fishery varies greatly from year to year in response to both changes in the availability of sandeel and changes in management between areas.

Sandeel is targeted by a highly seasonal industrial fishery which has experienced a progressive change towards fewer larger vessels owing most of the quota since the introduction of ITQ in 2004. Time restrictions and bycatch limits represent the main management measures. Although the fishery has little bycatch of protected species, competition with other predators is a central aspect of the sandeel management within an ecosystem approach.

Sandeel play in fact an important role in the North Sea food web as they are a high quality, lipid-rich food resource for many predatory fish, seabirds and marine mammals. Concerns of local depletion exist, especially for those sandeel aggregations occurring at less than 100 km from seabird colonies as some bird species (i.e. black-legged kittiwake and sandwich tern) may be particularly affected whereas more mobile marine mammals and fish are likely to be less vulnerable to local sandeel depletion.

1.8 Stock overview

The WG was able to perform analytical assessments for 10 of the 16 stocks investigated. Results of the assessments are presented in the subsequent sections of the report and are summarized below and in figures 1.7.2–1.7.5.

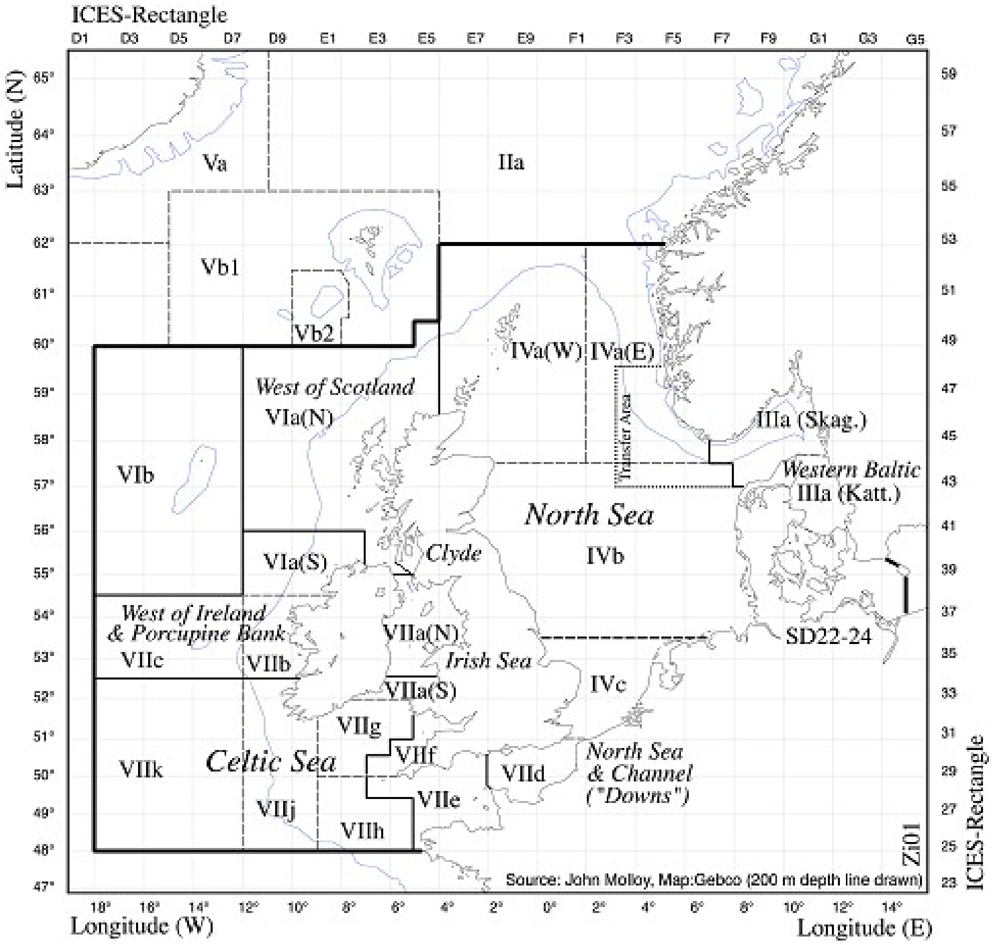

Figure 1.7.1 ICES areas as used for the assessment of herring stocks south of 62°N. Area names in italics indicate the area separation applied to the commercial catch and sampling data kept in long term storage. "Transfer area" refers to the transfer of Western Baltic Spring Spawners caught in the North Sea to the Baltic Assessment.

North Sea autumn spawning herring (her.27.3a47d) is the largest stock assessed by HAWG. The spawning-stock biomass was low in the late 1970s and the fishery was closed for a number of years. This stock began to recover until the mid-1990s when it appeared to decrease again. A management scheme was adopted to halt this decline. Based on the WG assessment the stock was classified as being at full reproductive capacity and harvested sustainably at F_{MSY} and under the management plan target for several years. Since 2019, no management plan is in place for North Sea Herring.

The 2021 assessment has been postponed and an interbenchmark will take place in June 2021 and the advice will follow in September 2021.

Western Baltic Spring Spawners (her.27.20-24) is the only spring-spawning stock assessed within this WG. It is distributed in the eastern part of the North Sea, the Skagerrak, the Kattegat and the subdivisions 22, 23 and 24. Within the northern area, the stock mixes with North Sea autumn spawners, and recently mixing with Central Baltic herring stock has been reported in the western Baltic area. The stock has decreased consistently during the second half of the 2000s. The 2019 SSB (57 841 t) and 2020 recruitment (582 158 thousand) are record low. The estimate of SSB in 2020 (58 434 t) is considered low, below both B_{pa} and B_{lim}. Fishing mortality (F_{3-6}) was reduced from 0.58 in 2008 to 0.32 in 2011. It had then remained above F_{MSY} (0.31) until 2014 (0.35-0.38) but showed an increase in 2015-2018 with an estimated F_{3-6} above 0.43. The 2019 F_{3-6} has decreased

(0.288) below F_{MSY} and the 2020 $F_{3\text{–}6}$ decreased even further to 0.19. The 2022 advised catch of WBSS is 0 t, which if applied by managers, will result in an increase in SSB from 65 046 t in 2021 to 68 903 t in 2022. The zero catch will not allow the stock to rebuild above B_{lim} (120 000 t) by 2023 (83 794 t). A medium-term forecast to 2024 showed that SSB can increased to 102 194 t if F=0 in 2022-2023 but will still remain below B_{lim}.

Herring in the Celtic Sea and 7.j (her.27.irls): The herring fisheries to the south of Ireland in the Celtic Sea and in Division 7.j have been considered to exploit the same stock. For the purpose of stock assessment and management, these areas have been combined since 1982. The stock has fluctuated over time. Low stock size was observed from the mid-70s to the early 80s. The SSB increased again before declining in the late 90s. From 2005 the stock increased when several strong cohorts (2004, 2008, 2009, 2010 and 2013) entered the fishery and as they gained weight, they maintained the stock at a high level. The SSB has decreased since its peak in 2011 and is estimated to be 11 680 t in 2020, which is well below B_{pa} (at 54 000 t) and B_{lim} (34 000 t). Recruitment has been below average since 2013. An increase in recruitment can be seen in 2020 however the assessment is highly uncertain, and recruitment has been consistently overestimated in recent years. Fishing mortality ($F_{2\text{–}5}$) declined between 2003 and 2009 but started to rise again in 2010 due to increased catches. F decreased in 2020 in line with greatly reduced catches. This year assessment estimates a fishing mortality, $F_{2\text{–}5}$, of 0.023 in 2020 which is the lowest in the time series and below all reference points (F_{MSY} is 0.26 and F_{lim} is 0.45). Short-term projections predict SSB to increase to 19 278 t in 2021.

Herring in 6.a: The stock was much larger in the 1960s when the productivity of the stock was higher. The stock experienced a heavy fishery in the mid-1970s following closure of the North Sea fishery. The fishery was closed before the stock collapsed. It was opened again along with the North Sea. In the mid-1990s there was substantial area misreporting of catch into this area and sampling of catch deteriorated. Area misreporting was reduced to a very low level and information on catch has improved; in recent years misreporting has remained relatively low. The assessment is a combination of two herring stocks, one residing in 6.aS, 7.b and 7.c, and one in 6.aN. It is currently not possible to separate the two stocks for assessment purposes and therefore stock size is a combined estimate. SSB and recruitment have been declining since around 2000 and are currently predicted to be at the lowest level in the time-series. Fishing mortality has reduced since 2016 when catches have been limited to a scientific monitoring TAC.

Herring in the Irish Sea (her.27.nirs): comprises two spawning groups (Manx and Mourne). This stock complex experienced a decline during the 1970s. In the mid-1980s the introduction of quotas resulted in a temporary increase, but the stock continued its decline from the late 1980s up to the early 2000s. During this time period the contribution of the Mourne spawning component declined. An increase in activity on the Mourne spawning area has been observed since 2006. In the past decade there have been problems in assessing the stock, partly as a consequence of the variability of spawning migrations and mixing with the Celtic Sea stock. A benchmark in 2017 resulted in a substantial revision of SSB perception leading to an increased SSB in the most recent period compared to pre-benchmark perceptions. In 2020, SSB and recruitment have been estimated at 23 435 t and 470 241 thousand respectively, estimates of SSB in recent years appear to be relatively stable. $F_{4\text{–}6}$ is estimated at 0.20 in 2020. Under the MSY approach the stock is expected to show an increase to 25 394 t in 2022.

North Sea and 3a sprat (spr.27.3a4): The catches are dominated by age 1–2 fish. Due to the short life cycle and early maturation, most of the stock consists of mature fish. To undertake the assessment and fit with the natural life cycle of sprat the assessment model is shifted by six months so that an assessment year and advice runs from 1 July to 30 June each year, and thus provide in-year advice. Since the last benchmark (ICES 2018), sprat in Division 3.a and Subarea 4 are combined into a single assessment unit. The advice is based on the MSY escapement strategy with an additional precautionary F_{cap}. The F_{cap} of 0.69 is used to ensure that after the fishery has been conducted, escapement biomass is preserved above B_{lim} with high probability. Even though fishing mortality in the last years has fluctuated at high levels between 0.6–2.2, recruitments slightly above the average during recent years have contributed to an increase in SSB well above MSY $B_{escapement}$. The estimates for 2021 show an SSB of 162 000 t which is above B_{pa} (125 000 t). The ICES advise for the period 1 July 2021–30 June 2022 indicates that catches of sprat should not exceed 106 715 t which represents a 49% decrease on the last year advice.

Sprat in the English Channel (7.d and 7.e) (spr.27.7de): Consists of a small midwater trawl fleet targeting sprat primarily in the vicinity of Lyme Bay, western English Channel. The stock identity of sprat in the English Channel relative to sprat in the North Sea and Celtic Sea is unknown. This year, ICES has provided catch advice for sprat in divisions 7.d and 7.e (primarily in the vicinity of Lyme Bay) based on criteria for data limited stocks. Data available are catches, a time-series of LPUE (1988–2016) and one acoustic survey that has been carried out since 2013 in the area where the fishery occurs and further offshore, also including the waters north off the Cornish Peninsula and, from 2017, the French part of the Western English Channel. The 2020 survey also extended into Cardigan Bay. The advice provided is based on the application of a constant harvest rate of 8.57% to the 2020 acoustic survey biomass estimate. The advised catch of 2897 t for 2022 is 100% higher compared to last year (applying the 1 over 2 rule with the uncertainty cap and the precautionary buffer).

Sprat in the Celtic Seas (spr.27.67a-cf-k): The stock structure of sprat populations in this ecoregion (subareas 6 and 7 (excluding 7.d and 7.e)) is not clear, and further work for the identification of management units for sprat is required. Most sprat in the Celtic Seas ecoregion are caught by small pelagic vessels that also target herring, mainly Irish and Scottish vessels. The quality of information available for sprat is heterogeneous across this composite area. There is evidence from different survey sources of significant interannual variation in sprat abundance. Landed biomass, but not biological information on the catch, is available from 1970s in some areas (i.e. 6.a and 7.a), while Irish acoustic surveys started in 1991, with some gaps in the time-series provide sprat estimates but their validity to provide a reliable sprat index is questionable because they do not always cover the core of sprat distribution in the area. Acoustic estimates in the Irish Sea are more reliable. The state of the stock of sprat in the Celtic Seas ecoregion is uncertain. ICES advice a catch of no more than 2240 tonnes for 2022 and 2023 in this ecoregion based on the precautionary approach.

Sandeel in 4 (san-nsea): A decline in the sandeel population in recent years concurrent with a marked change in distribution has increased the concern about local depletion, of which there has been some evidence. Since 2010 this has been accounted for by dividing the North Sea into 7 management areas. Denmark and Norway are responsible for most of the fishery of sandeel in the North Sea. The catches are largely represented by age 1 fish. Analytical assessments are performed in four of the management areas (A1r–4) where most of the fishery takes place and data are available. Note that a benchmark in 2016 revised most of the area definitions.

A1: SSB has been above B_{pa} (145 000 t) in 2016-2018 and dropped to 74 000 t in 2019 and 69 000 t in 2020. The forecasting indicates that SSB will increase to a level above B_{lim} (110 000 t), but below B_{pa}, in 2021. Recruitment in 2020 was below the geometric mean of the time-series, and lower than in 2019. Fishing mortality (F) has fluctuated, showing a declining trend since the mid-2000s followed by an increase in 2017 to approximately the long-term average where it has remained relatively stable for the last four years (c. 0.5).

A2: SSB has been below B_{lim} (56 000 t) since 2004, with few exceptions. SSB increased in 2018 above B_{pa} as the result of the exceptionally high 2016-year class and decreased again in 2019 and further in 2020 to set at 47 000 t. There is indications that recruitment will be just above B_{lim} in 2021, with the exception of the 2016 year class. The 2019-year class is estimated to be below the long-term average. Fishing mortality was relatively high in 2020 due to monitoring large TAC for 2020.

A3: The stock has increased from the record low SSB in 2004 when it was half of B_{lim} (80 000 t) to above B_{pa} (129 000 t). SSB had a peak of more than 360 000 t in 2018 and is estimated to 318 000 t in 2020. The recruitments in 2016 and 2019 were among the five highest on record. Fishing mortality. Forecast indicate an SSB in 2021 similar to 2020. Fishing mortality (F) declined in the early 2000s and has been low until2018. F has been increasing in the last couple of years and is now above the long-term average

A4: Fishing mortality (F) has been low since 2005 but increased in 2018 before decreasing again in 2019. SSB has fluctuated above precautionary reference points (B_{pa} = MSY $B_{escapement}$) since 2011 with the exception of 2015 and 2020. Recruitment was low in 2018 but the 2019-year class is estimated to be above the long-term average which drives a large increase in the advised catch. Recruitment in 2020 is expected to be similar to 2019.

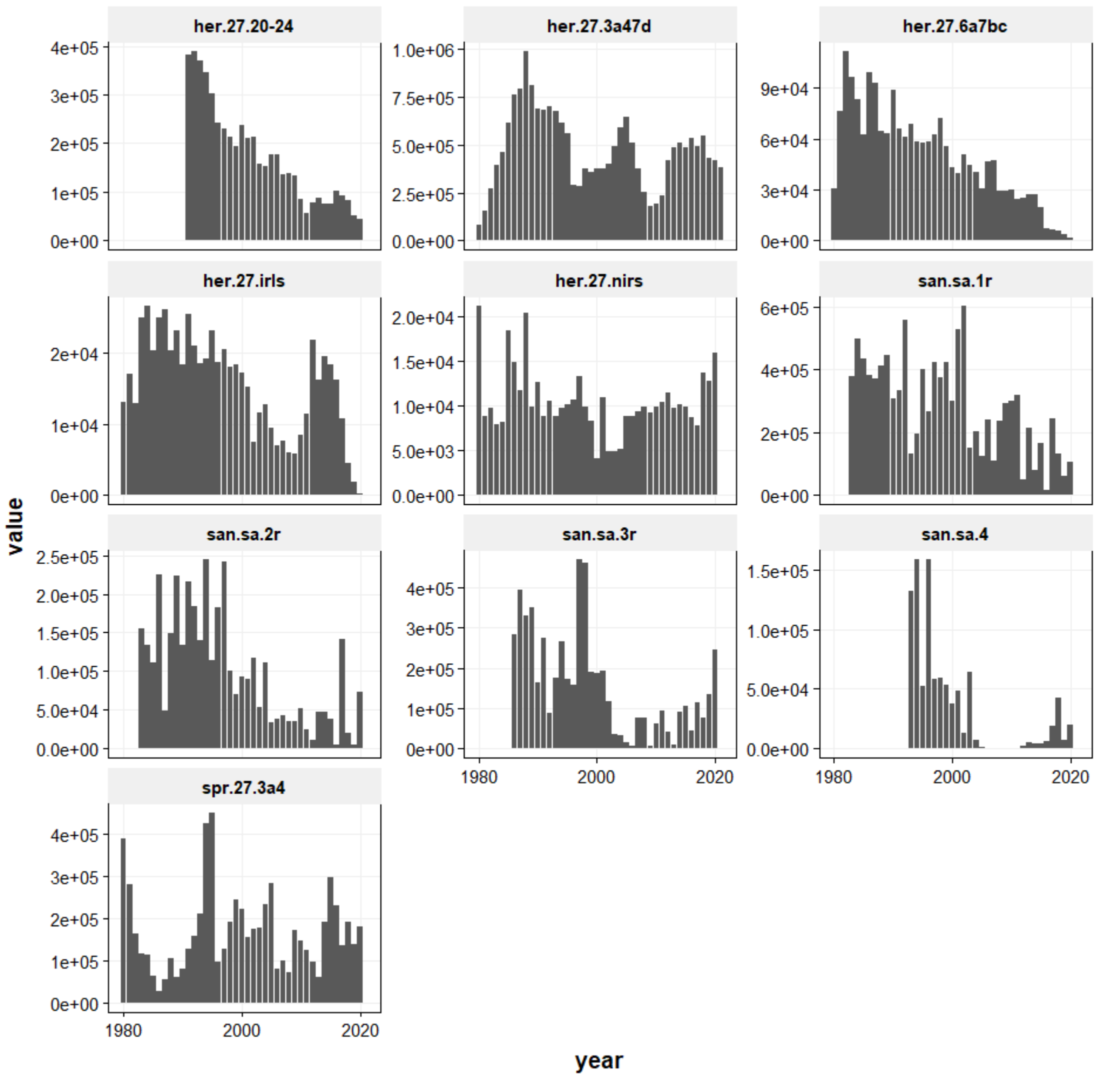

Figure 1.7.2 WG estimates of catch/landings (yield) of the herring, sprat and sandeel stocks presented in HAWG 2021

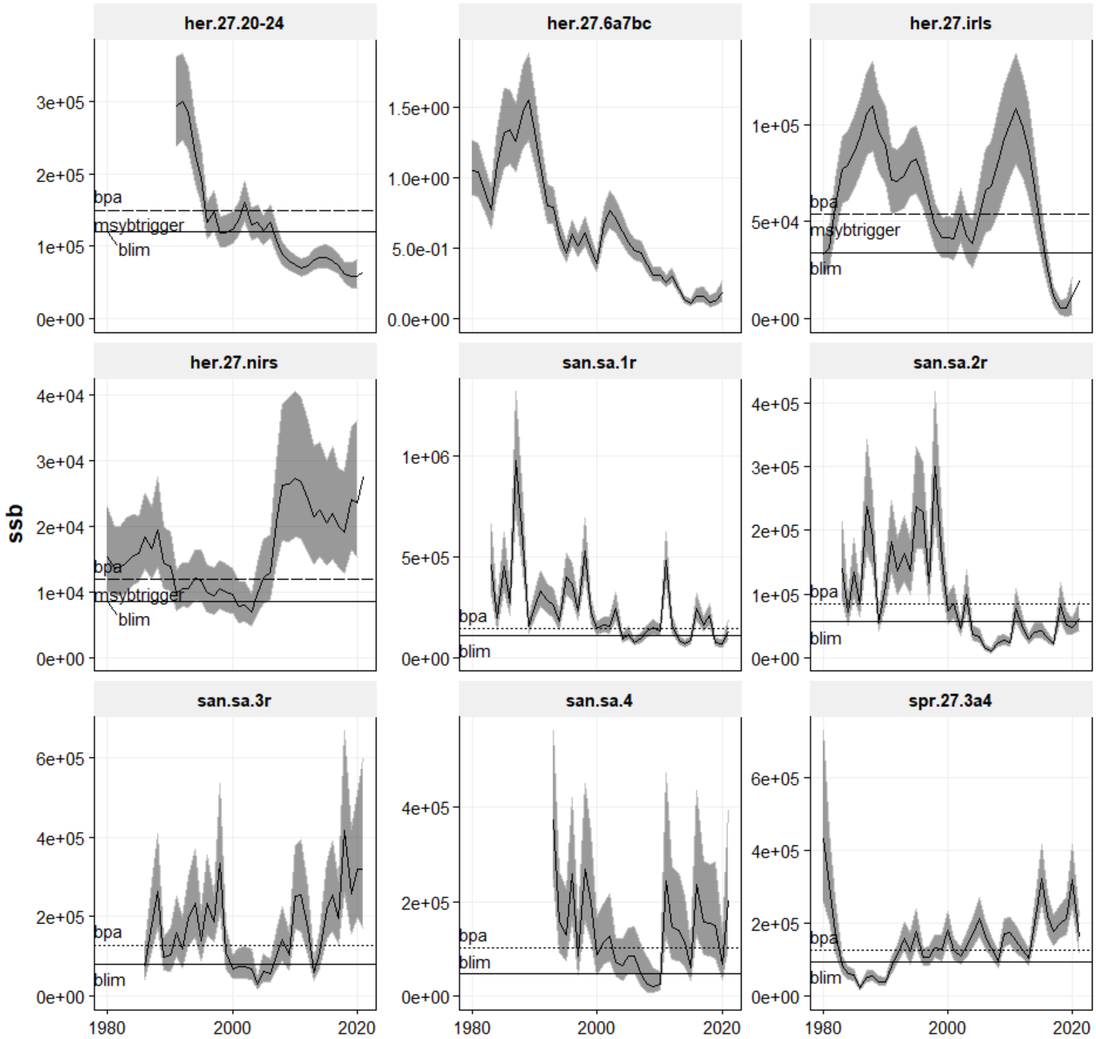

Figure 1.7.3 Spawning-stock biomass estimates for the sprat, herring and sandeel stocks assessed at HAWG 2021.

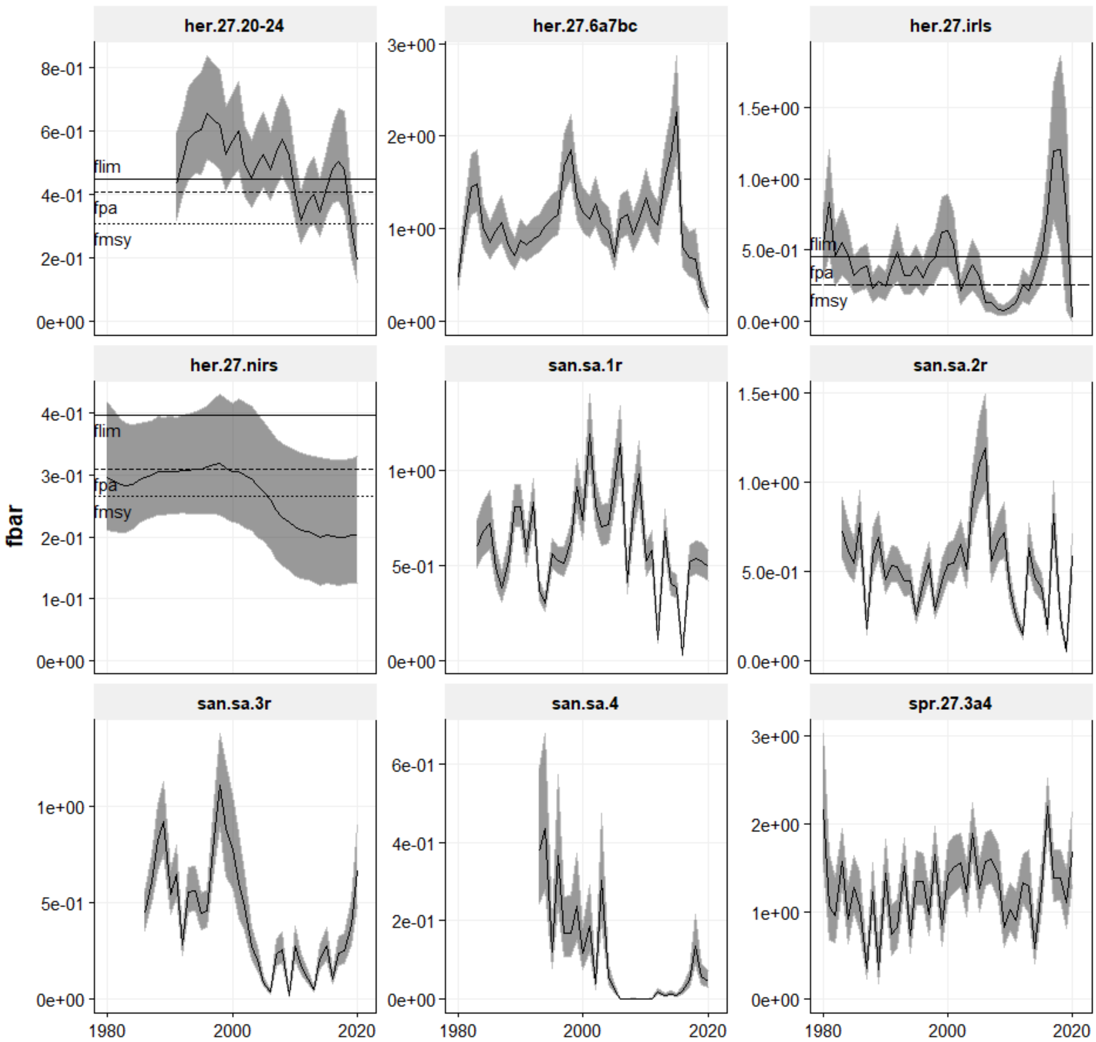

Figure 1.7.4 Estimates of mean F for the sprat, herring and sandeel stocks assessed at HAWG 2021.

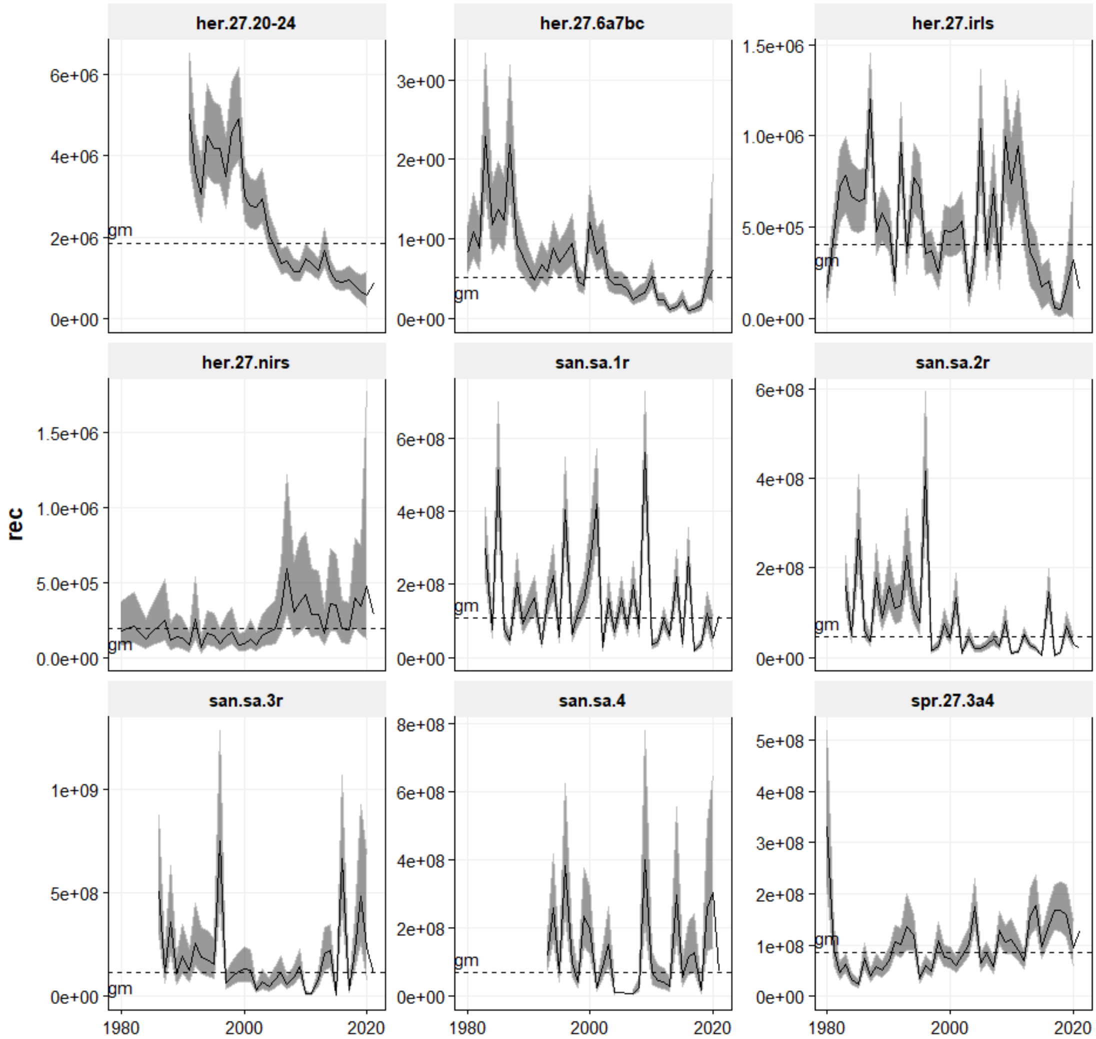

Figure 1.7.5 Estimates of recruitment for the sprat, herring and sandeel stocks assessed at HAWG 2021.

Given the marked decrease in the weight-at-age of several of the herring stocks assessed by HAWG, the time-series of the relative weight change are presented for comparative reasons (Figure 1.7.6).

Figure 1.7.6 Time-series of herring mean individual weight in the catch.

1.9 Mohn's rho and retrospective patterns in the assessments

The analysis of retrospective patterns is one of the core diagnostics of the analytical assessments performed by ICES working groups, including HAWG. Mohn's rho (ϱ) is the metric which is currently used to quantify retrospective patterns.

Mohn's rho (ϱ) is calculated as the relative difference between an estimate from an assessment with a truncated time-series and an estimate of the same quantity from an assessment using the exact same methodology over the full time-series. The average of the relative change over a series of years is calculated as*:

$$\rho_n = \frac{1}{n} \sum_{i=1}^{n} \frac{X_{y=T-i,dd=T-i} - X_{y=T-i,dd=T}}{X_{y=T-i,=T}}$$

where $X_{y,d}$ is the assessment quantity, e.g. SSB or F_{bar}, for year y from the assessment with terminal year d, T is the terminal year of the most recent assessment (the year of the most recent catch-at-age data), and n is the number of retrospective assessments used to calculate rho.

The two-year subscripts for quantity X refer to the year for the quantity and the terminal year of the assessment from which the quantity was derived. For example, for an assessment WG in 2018, using catch-at-age up to 2017, the relevant quantities for the first retrospective ($i = 1$) calculation are: $X_{y=T-i,d=T} = X_{y=2016,dd=2017}$ which corresponds to the assessment quantity for 2016(T-i) derived from the assessment using the full time-series with terminal year 2017 (T); and $X_{y=T-i,=T-i} = X_{y=2016,dd=2016}$ which is the estimate of the assessment quantity for the same year T-i = 2016) estimated from an assessment where the data are truncated to have terminal year 2016 (T-i).

Mohn's rho values have been uploaded at https://community.ices.dk/Expert-Groups/Lists/Retrobias2020/Allitems.aspx and they are included in this report in Table 1.8.1.

* From ICES guidelines

Table 1.8.1 Mohn's rho value calculated by HAWG on category 1 and 2 stocks with age-based fish stock assessments.

Stock code	Terminal year of catch data	Number of retrospective assessments used (n)	F_{bar} rho value	SSB rho: was the inter- mediate year used as the terminal year?	SSB rho value	Recruitment rho: was the intermediate year used as the terminal year?	Recruitment rho value
her.27.20-24	2020	5	-0.134	No	0.196	No	0.073
her.27.3a47d*	2020	5		No		No	
her.27.6a7bc	2020	5	0.177	No	-0.123	No	0.221
her.27.irls	2020	5	-0.435	No	1.397	No	2.956
her.27.nirs	2020	5	-0.162	No	0.076	No	-0.384
san.sa.1r	2020	5	-0.110	No	0.450	No	0.590
san.sa.2r	2020	5	-0.120	No	0.490	No	0.290
san.sa.3r	2020	5	0.190	No	-0.230	No	-0.100
san.sa.4	2020	5	-0.040	No	0.140	No	0.110
spr.27.3a4	2020	5	-0.070	Yes	0.280	No	0.250

1.10 Transparent Assessment Framework (TAF)

TAF (https://taf.ices.dk) is a framework to organize all ICES stock assessments. Using a standard sequence of R scripts, it makes the data, analysis, and results available online, and documents how the data were pre-processed. Among the key benefits of this structured and open approach are improved quality assurance and peer review of ICES stock assessments. Furthermore, a fully scripted TAF assessment is easy to update and rerun later, with a new year of data.

The following HAWG scripts are now available on TAF (https://taf.ices.dk/app/stock#!/):

1. North Sea herring (her.27.3a47d) update single-fleet SAM assessment, multi-fleet model run required for the forecast, and the forecast analysis (Update in progress 2021)
2. Herring west of Scotland and Ireland (her.27.6a7bc) SAM assessment (Last updated 2019, will be updated after the benchmark in 2022)
3. Herring south of 52°30'N Irish Sea, Celtic Sea, and southwest of Ireland (her.27.irls) ASAP assessment (Update in progress 2021)
4. Sprat in 7d, e Category 3, biomass trends (Last updated 2018)
5. Sandeel in area 1r (san.sa.1r) SMS assessment (Last updated 2019)
6. Sandeel in area 5r (san.sa.5r) category 5.4 analysis (Last updated 2019)
7. Sandeel in area 6 (san.sa.6) category 5.2 analysis (Last updated 2019)
8. Sandeel in area 7r (san.sa.7r) category 5.3 analysis (Last updated 2019)

WKREPTAF

The TAF Reporting Workshop (WKREPTAF) met in January 2021 and explored the reporting process for ICES expert groups (with special focus on stock assessment groups) and how this could become simpler, less time consuming, and of better quality. The workshop focussed on how to expand TAF to facilitate the reporting process within working groups. The workshop concluded that 1. Script-based reports (i.e. markdown) would allow stock assessment groups to automate the process of inserting and formatting tables and figures in the report. 2. The data to be held within TAF can be documented within the report sections of the current ICES report in a standardized manner. With more data becoming available in TAF, there is the opportunity to more easily link ecosystem considerations and mixed fisheries considerations within stock specific chapters. 3. The transition from conventional reporting to script-based reports would benefit from agreeing on standardized stock assessment inputs for TAF. 4. The script-based reports open up the opportunity to directly incorporate information from the regional database (RDBES), DATRAS, Stock Information Database and Stock Assessment Graph database (SAG). 5. Training in TAF and markdown reporting are essential for the ICES community (ICES, 2021, WKREPTAF).

1.11 Benchmark process

HAWG has made some strategic decisions regarding the future benchmarking of its stocks listed in the table below. An Interbenchmark will be held in June 2021 for North Sea herring. Herring in 6.a, 7.b,c will be benchmarked in early 2022.

Stock	Assessment category	Latest benchmark	Benchmark or Interbechmark in the next 12 months	Further planning	Comments
NSAS herring	1	2018 Interbenchmark 2021	Yes	Exploration of M scaling methodologies, model configuration, new M values	Issue list available
WBSS herring	1	2018	No	Split mixed catches with central Baltic herring. Compile catch matrix by fleet from data in the Regional Database and move to RDBES when non-EU countries on-board	Issue list available, likely need for an interbenchmark to revisit reference points
6.a, 7.bc herring	3	2015 Interbenchmark 2019 Benchmark 2022	Yes	Splitting of survey and new assessment, explore new indices, reference points, MSE	Issue list available
Celtic Sea herring	1	2015 Interbenchmark 2018	No	Mixing with Irish Sea herring, recruitment signal	Issue list available
7.aN herring	1	2017	No	Explore stock mixing, recruitment signal and F in the assessment	Issue list available
Sprat NS.3a	1	2018	No	Consider stock component, local components in 3a, boundary with the Baltic	Issue list available
Sprat 7.de	3	2018 Interbenchmark 2021	No	Consider stock components, review advice guidance for short lived species	Issue list available
Sprat Celtic	5	2013	No	Research roadmap to review and plan sprat work	Issue list available
Sandeel areas 1r–4	1	2016	No	Update reference points for sandeel area 3 based on the new M estimates.	Issue list available