# 1 Introduction

## 1.1 HAWG 2020 work in relation to the generic ToR

In light of the disruptions caused by COVID 19 in 2020, the 17th-25th March meeting, which was initially planned at the ICES Headquarters, was conducted using virtual meetings and based on re-prioritized generic ToRs (see Annex 2).

## 1.2 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.

### 1.2.1 Meeting of the Chairs of Assessment Related Expert Groups (WGCHAIRS)

As usual, WGCHAIRS met in January in preparation for the new year of advice and science working group activities. Activities of working groups in 2019 were reviewed. Progress made on issues that were highlighted last year were summarized.

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.

The newly published ICES advisory plan was introduced which aims to keep advice resilient to future challenges. It aims to enhance credibility and transparency of advice, following FAIR (Findable, Accessible, Interoperable, Reusable) and TAF (Transparent Assessment Framework) principles. It facilitates the move towards ecosystem advice and will better utilize the science and data available in ICES (ICES 2019). The plan also aims to improve sharing and communicating advice to meet the stakeholders/requestors needs.

Six priority areas for development are identified in the plan:

1. Assuring quality
2. Incorporating innovation
3. Highlighting benefits
4. Sharing Evidence
5. Evolving advice
6. Identifying needs

The different channels for publications were discussed including in house publication such as the Cooperative Research Report CRR for reference publications and the Techniques in Marine Environmental Sciences TIMES for practical guidelines. ID Leaflets can be published on specific topics. Scientific advice is published through the ICES scientific reports and the ICES advice. Peer reviewed scientific work is published in the ICES journal of Marine Science. Other communication channels that can be utilized include social media, ICES news, annual reports and factsheets.

Overall, the format of the advice had no major changes in January. WGCHAIRS remarked the importance of quality assurance of the ICES advice and the role of the audit system in this. Audits should be performed rigorously according to a given template (same as last year). At HAWG this is implemented by assigning at least two members as auditors for each stock. After the WGCHAIRS meeting and in light of the Covid-19 disruption the format of the ICES advice changed and HAWG adopted these changes.

### 1.2.2 Working Group for International Pelagic Surveys (WGIPS)

The Working Group of International Pelagic Surveys (WGIPS) met in Bergen, Norway on 14–18 January 2020. 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 2020 surveys.

Results of the surveys covered by WGIPS and coordination plans for the 2020 pelagic acoustic surveys are available from the WGIPS report (WGIPS, ICES 2020). The following text refers only to the surveys of relevance to HAWG.

**Review of larvae surveys in 2019:** These surveys are no longer dealt with in WGIPS. From 2019 the planning, analysis and reporting on larvae surveys will fall under WGSINS. The results from the larvae surveys can be found in the HAWG report, Section 2.3.2 and for 2018/19 onwards they will be coordinated and reported on in WGEGGS2.

**North Sea, West of Scotland and Malin Shelf summer herring acoustic surveys in 2019:** 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 1.9 million tonnes (2018: 2.3) due to a decrease in the number of fish (2018: 12 315 mill. fish, 2019: 10 295). The mean weight of mature fish is similar to last year at 186.4 g and the decrease in biomass follows directly from a decrease in numbers. The spawning stock is dominated by young fish of age 3 and 5 wr, which is in accordance with the strongest year classes in the 2018 survey.

The 2019 estimate of **Western Baltic spring-spawning herring** 3+ group is 74 000 tonnes and 574 million. This is a decrease of 31 and 23%, respectively, compared to the 2018 estimates of 107 000 tonnes and 574 million fish.

The **West of Scotland** estimate (6.a.N) of SSB is 76 000 tonnes and 406 million individuals, a large decrease compared to the 152 000 tonnes and 875 million herring estimate in 2018.

The 2019 SSB estimate for the **Malin Shelf area (6.a and 7.b,c)** is 128 000 tonnes and 740 million individuals, a decrease compared to the 159 000 tonnes and 925 million herring estimate in 2018 and the second lowest level in the time-series. In 2019 there was a larger proportion of herring distributed south of 56°N compared to previous years. This is due to a combination of decreased abundance in the 6aN part and increased abundance in the 6aS part.

There was a sprat benchmark in November 2018 (ICES, 2018), resulting in the two sprat stocks in the North Sea and Skagerrak-Kattegat being merged into one. For consistency, the survey results are presented separately in this report for these two areas.

The total abundance of **North Sea sprat (Subarea 4)** in 2019 was estimated at 124 999 million individuals and the biomass at 880 000 tonnes. This is at the same level as the historic high in the time-series (2016) in terms of abundance and the second highest in terms of biomass. Compared to the 2016 estimate, abundance and biomass is 0.3% higher and 21% lower, respectively. The stock was dominated by 1- and 2-year-old sprat (92% of biomass). The 2019, as the 2014-2016 and 2018, sprat biomass estimates are all well above the long-term average for the survey time-series, whereas the 2017 estimate is 24% lower.

In for **sprat in Division 3.a**, the abundance in 2019 is estimated at 2645 million individuals and the biomass at 38 400 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 (52%) and biomass (39%). The stock is dominated by 2-year-old sprat.

**Irish Sea Acoustic Survey:** The herring abundance for the Irish Sea and North Channel (7.a.N) during 28th August–13th September was reported by Northern Ireland. In 2019 the estimate was 39 319 tonnes, similar to that observed in 2018. The biomass estimate of 68 078 t for 1+ ringers is a further 25% increase on last year's biomass estimate. A large proportion of the 1+biomass estimate was seen to the west of the Isle of Man and in North Channel close to the Scottish coast. The western and northern Irish Sea are areas of mixed size fish. Sampling intensity was high during the 2019 survey with 30 successful trawls completed. Sprat and 0-group herring were distributed around the periphery of the Irish Sea. Highest abundance of 1+ herring targets in 2019 were observed on both the western sides of the Isle of Man and on the Scottish coast of the North Channel. Local high areas of high abundance of herring were also observed on the known spawning banks toward the county Down coast. The length frequencies generated from these trawls highlight the spatial heterogeneous nature of herring age groups in the Irish Sea. The survey estimates are influenced by the timing of the spawning migration.

**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 exactly the same as for AC(7.aN) and follows standard protocols for surveys coordinated by WGIPS. The survey was examined at WKHASS in 2019 and recommended for inclusion the Acoustic Survey manual. The results of the survey are reported in the WGIPS 2019 report (ICES, 2019). The survey is included in the assessment as a SSB index. The SSB in 2019 was estimated 44 428t. The herring were distributed primarily to the southeast of the Isle of Man on the inshore sections of survey transects, associated with known spawning areas. The estimate of herring SSB from the 2019 commercial acoustic survey remain within range for the time-series.

**Celtic Sea herring acoustic survey (CSHAS):** Herring and sprat abundance for the Celtic Sea in October 2019 was reported by the Marine Institute, Ireland. The Celtic Sea herring stock was considered to have been contained within the survey area in 2019 for the main grounds in the Celtic Sea and saw increased acoustic sampling effort as compared to 2018 (25%). The spawning-stock biomass (SSB) estimate in 2019 was the lowest in the time-series. The CV on the survey estimate was high (0.55) in 2019. The downward trend in the standing stock biomass has continued from a medium term high around 2012 and has been exacerbated by a prolonged period of poor recruitment since then. Observations made during the CSHAS 2018 and the WESPAS summer survey in June 2019 showed potential of a recruiting year class. However, recruiting herring were not observed in the numbers expected during this year's survey.

The biomass and abundance of sprat in 2019 was higher than in 2018. Overall, the standing stock of sprat remains relatively consistent within the survey time-series. One important caveat within the sprat time-series is that the survey is conducted over 24 hrs and not during daylight hours only. The latter survey design being best suited to measuring sprat abundance due day/night behavioural effects and the availability of targets to the acoustic equipment.

**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 2019. This year, for the third year running, the survey was extended beyond the area covered between

2012 and 2016. The extended survey coverage included the French waters of western Channel (ICES 7e). The pelagic fish objectives of the survey were successfully completed. In total just under 1800 nautical miles of acoustic sampling units were collected and supplemented with 38 valid trawls. The results indicated that sprat was found to be more widespread than in recent years, although combined sprat biomass for the whole survey area was comparable to 2018.

The biomass in Lyme Bay, which is relevant to the stock assessment of sprat in 7de, was up from 2018, to 36,789 t.

### 1.2.3 Working Group on Baltic International Fish Survey (WGBIFS)

The Working Group on Baltic International Fish Survey plans, coordinates, and implements both demersal trawl surveys and hydroacoustic surveys for the Baltic Sea. All the acoustic indices used by HAWG are provided by WGIPS with the exception of the GerAs index which is derived from the Baltic International Acoustic Survey (BIAS).

**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. Germany is responsible for the survey covering the western Baltic and the Kattegat (SD21-24), from which the GerAs index is derived for Western Baltic Spring-spawning herring (WBSSH). Mixing with the adjacent central Baltic herring stock generally occurs in SD 24 and in 2019 also in SD21,23. The index is routinely adjusted to account for the mixing of the two stocks based on growth parameters. The 2019 GerAs index for the WBSSH was 2.3 x $10^9$ individuals and 51.6 x $10^3$ tonnes which is the lowest biomass value on record.

### 1.2.4 PGDATA, WGBIOP and WGCATCH

The Planning Group on Data Needs for Assessments and Advice (PGDATA coordinates the activities of both WGBIOP and WGCATCH. One of its main focuses is on 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.

The ICES Working Group on 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 stock-assessment working groups and WGBIOP is through the benchmark process. WGBIOP works in close association with the BSG (ICES benchmark steering group), reviewing all issue lists pointing to either missing issues in relation to specific stocks and guiding the process to get issues related to biological parameters resolved. WGBIOP will 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 2019) reviewed the following activities falling within its remit and of interest for HAWG:

- No exchanges or workshops were held during the previous year for herring (*Clupea harengus*) and sprat (*Sprattus sprattus)* stocks assessed by HAWG.
- A workshop on the identification of clupeid larvae (WKIDCLUP2) is scheduled on 31 August – 4 September 2020 to be held in Bremerhaven, Germany.
- There was a Sandeel (*Ammodytes marinus*) small otolith exchange during 2019 focused on samples from SA1, SA3 and SA5 (available at https://smartdots.ices.dk/ViewEvent?key=219). Results show a weighted average percentage agreement (PA) based on modal ages for all advanced readers of 81 % (71% based on all readers) and the weighted average coefficient of variation (CV) is 24 % (26% based on all readers). At modal age 0, the PA calculated across all readers is 78%. At modal ages 1 and 2 the PA increases to 80% and 89% respectively. From modal ages 3 to 8 the PA is between 75 and 50% and at modal age 9 it is 83%. At modal age 1 the overall CV is high at 41% and no reader achieving a CV below 27%. CV decreases with an increase in age. At modal age 0, 1 and 2 the overall bias, calculated across all age readers, is 0.28, 0.12 and 0.05 respectively, indicating an overestimation compared with modal age (as with modal age 6). At modal ages 3-5 and 7-9 the overall negative bias indicates underestimation compared with modal age. Three stocks were included in this exchange. PA is highest for san.sa.1r (SA1), followed by san.sa.3r (SA3) and san.sa.5r (SA5). The CV is the highest for san.sa.1r followed by san.sa.3r and san.sa.5r. Again, the overall relative bias indicates overestimation at modal ages 0, 1 and 2 and underestimation at modal age 3 and 4. In comparison, the highest bias is seen in san.sa.3r and san.sa.5r respectively.

The ICES Working Group on Commercial Catches (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 2019 finalized best practice guidelines for sampling of the small-scale fleet and best practice guidelines for provision of frequency data for AWG's, when number of samples are limited. The group started documenting current estimations methods used when providing commercial catch data, developing methods for evaluating the completeness of declarative data in respect to the small sale fleet and continued the close relation to WGBYC by reviewing sampling protocols for protected, endangered and threatened species (PETS) and the inclusion of relevant PETS data in the RDBES.

### 1.2.5 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 (updated at WKPELA 2018), North Sea sprat (evaluated and updated at HAWG 2018), sandeel SA1 (evaluated and updated at HAWG 2018), sandeel SA3 (evaluated and NOT updated at HAWG 2018). No update of natural mortalities are available from WGSAM for the 2020 HAWG assessments.

### 1.2.6 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 2018.

The DRS was carried out in April 2018 and 2019, following the IBTS-MIK protocol, but the sampling was carried out both day and night, instead of only at night. Results were presented at HAWG. A survey was also planned for April 2020, but due to COVID-19 measures this survey was cancelled. In April 2021 the survey will continue, provided the COVID-19 measures are released. 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.

### 1.2.7 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 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 these two stocks. It is not currently 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 five years. Scientific samples are obtained during the scientific monitoring fisheries in 6aS/7bc and 6aN.

The 6a/7bc herring stock identification project is developing three stock identification methods; genetics, body morphometrics and otolith shape analysis, to distinguish between herring stocks in ICES areas 6a, 7b and 7c. The aims of the project are to assess the identity of herring stocks in 6a/7bc using genetics, body morphology and/or otolith shape analysis; to provide a breakdown of the stocks captured during the MSHAS as far back as the data collection will allow; contribute to the achievement of MSY assessment of the stocks; provide advice on data collection required to distinguish between the stocks going forward.

Data being analysed during this project were collected between 2010 and 2019 for baseline samples and mixed samples. Some archive samples from the WESTHER project (2003-2005) are also available, inclusion of which will increase the temporal scale of the analyses.

Body morphology and otolith shape analysis data have been collected by the Marine Institute and Marine Scotland during the MSHAS from 2010 to present (ICES SGHERWAY, 2010). This 10 year period of data collection has resulted in over 10,000 fish with biological, body morphology and otolith shape data recorded during the time of year that herring stocks in this area are believed to form mixed aggregations. A focus on collecting baseline spawning data began in 2014, when two samples of spawning fish were collected from both 6aS and 6aN during the commercial fisheries in these areas. Between 2016, 2017 and 2019, 11 more baseline spawning samples were collected from commercial fisheries (5 samples from 6aS and 6 samples from 6aN). No spawning samples were collected in 2015 or 2018 despite a continued effort to do so.

Genetic sample collection began in 2014 for both mixed and baseline spawning samples. From 2014 onwards all fish that were sampled for body morphormetrics and otolith shape during the MSHAS also had a tissue sample collected for genetic analyses. Tissue samples have also been collected from additional baseline spawning samples in 6aN, 6aS/7bc and from surrounding stocks, including the Irish Sea, Celtic Sea and North Sea. In total 177 samples comprising over 12,500 herring have been analysed with a panel of genetic markers that have been shown to discriminate between the target populations.

The data collected from herring in 6a/7bc are being analysed using a combination of R scripts written by project partners and various packages available to perform tasks and analysis specific to stock identification and multivariate data.

R scripts written in-house are being used to calculate body morphometric measurements, including truss measurements across the body. The R package geomorph (Adams & Otárola-Castillo, 2013) is also being explored as another method of describing the shape of the body using geometric morphometrics. The R package ShapeR (Libungan & Pálsson, 2015) is being used to extract the outline of each otolith in order to describe its shape. Both elliptic Fourier analysis and Wavelet transform are calculated by this package so data from both methods of shape description have been recorded. Genotype data for all samples have been generated using a modified genotyping by sequencing approach (see Farrell et al. 2016). The R package adegenet (Jombart, 2008) is being used to explore the data and undertake standard genetic analyses including summary statistics, Hardy-Weinberg Equilibrium (HWE) tests and *F* statistics. Multivariate analyses, including discriminant analysis of principle components (dapc), of both the genetic and morphometric data are also being undertaken using adegenet to identify and visualize the clusters found within the datasets. Preliminary results from the genetic analyses conclude that the 6aN and

6aS/7bc herring stocks represent at least two genetically distinct populations, and this result appears to be stable over time. The 6aN samples are indistinguishable from the North Sea samples analysed and both are relatively temporally stable at the molecular markers analysed. The 6aS, Celtic Sea and Irish Sea samples all showed strong population differentiation between each other and the samples from 6aN and NS.

To ensure that all three stock identification methods are working independently before comparing and combining them, data analyses are being conducted separately to fine tune each dataset. The R package assignPOP (Chen et al., 2018) works with genetic, morphometric and integrated (genetic and morphometric) datasets to perform population assignments using machine learning classification algorithms. The package is currently being used to evaluate the baseline datasets of each stock identification method and will later be used on an integrated baseline dataset. This dataset will then be used to predict source populations of the mixed MSHAS samples, all within assignPOP.

The project is now in its final year and the project partners are currently conducting data analyses and comparison work between the three stock identification methods. All three methods are demonstrating a strong ability to distinguish between 6aS and 6aN herring, with self-classification rates of 70-95%. Further analyses are underway to fine tune the baselines and to ensure that both the genetic and morphometric methods are in agreement. This is essential as all methods will be used to split the 2014-2019 MSHAS samples into population of origin. There is no genetic data available for the MSHAS samples collected from 2010 to 2013 so the morphometric data will be analysed in an effort to provide a retrospective split of the survey data for these 4 years.
Further information on this project is available from Ed 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). However, the splitting is limited to Danish and Swedish samples from commercial landings and scientific surveys in division 3.a, Norwegian samples from scientific surveys, and samples from commercial landings in the "transfer area" in subarea 4. Further, applied splitting methods are not consistent between labs and countries.

One of the used splitting methods to separate NSASH and WBSSH is otolith shape analysis. In recent years, the use of otolith shape analysis to discriminate fish stocks increased rapidly. Open-access packages like shapeR (Libungan and Pálsson, 2015) allow scientist to easily extract otolith outlines for further analysis. Otolith shape analysis of Atlantic herring reveal clear differences between populations in the northeastern Atlantic (Libungan *et al.*, 2015). Further, there is a clear genetic effect on the otolith shape of Atlantic herring (Berg *et al.*, 2018). In the meantime, 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.

Results of preliminary otolith shape analysis and other splitting methods have been reported in Annex 6.3 of the last HAWG report (ICES, 2019). Here, new results of follow-up studies will be presented based on the same and updated material from last year (Berg et al. 2019). Shortly, a baseline was build-up including otoliths from herring collected at spawning grounds as well as herring of all three stocks (NSASH, WBSSH, and NSSH). As suggested, this baseline was updated with annual samples and not rebuilt for the current year. 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. While Smoliński et al. (2020) focused on the validation of the baseline, our aim was to assign unknown herring for mixed catches to their original stock. Unknown catches were collected during several scientific surveys in the greater North Sea ecoregion and adjacent areas (Figure 1.2.7.1). We applied several classifiers, provided by the assignPOP package in R (Chen *et al*., 2018), to assign unknown otoliths and compared their results. During the assignment each otolith receives a probability for each of the three stocks (Figure 1.2.7.2). Otoliths were not assigned if the difference in assignment probability between the two most likely stocks was <20%.

Our results demonstrate that otolith shape analysis can, combined with machine learning techniques, be used to assign individuals of unknown origin to one of these stocks (~82.5% assigned, ~17.5% not assigned). Similar to Smoliński et al. (2020), estimations of the level of mixing are sensitive to the machine learning technique applied (Figure 1.2.7.2). A disadvantage is that stocks not included in the baseline, that appear in mixed catches, cannot be assigned. Further, the fixed threshold (<20%) used to not assign individuals needs to be evaluated, especially regarding to the statistical power needed for sustainable assessment and management. More analyses to estimate the extent of mixing and potential effects on stock biomass/catches are encouraged, also in combination with other discrimination methods like genetics. Since last year, 2019, genetic samples were collected on Norwegian scientific surveys, in addition to the standard sampling including otoliths. The collection of genetic material will be continued and extended this year, and genetic analyses will be started. This allows for a larger comparison of assignments based on different discrimination methods comparable to the results presented in the last HAWG report (ICES 2019).

A recent study by Berg et al. (2020) combined different discrimination methods to assign autumn- and spring-spawning herring. Their results are highly relevant to the assessment provided by HAWG because they suggest gene flow between autumn and spring-spawning herring. In addition to the traditional splitting method using otolith microstructure, Berg et al. (2020) used newly developed genetic markers as well as their maturity development to discriminate autumn- and spring-spawning herring. In their study, most herring (~77%) had an otolith microstructure and genetic assignment coinciding with the phenotypically assigned spawning season. Non-spawning herring (<5%) that were 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 the splitting of herring solely based on otolith microstructure as applied for the assessment of NSAS and WBSS.

All in all, discrimination methods used for the splitting and assignment of unknown individuals need to be further developed and adjusted. Also, our preliminary results indicate that the geographical boundaries, not only for stocks, but also for the "transfer area", should be discussed. Potential readjustments or the implementation of splitting several stocks 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.

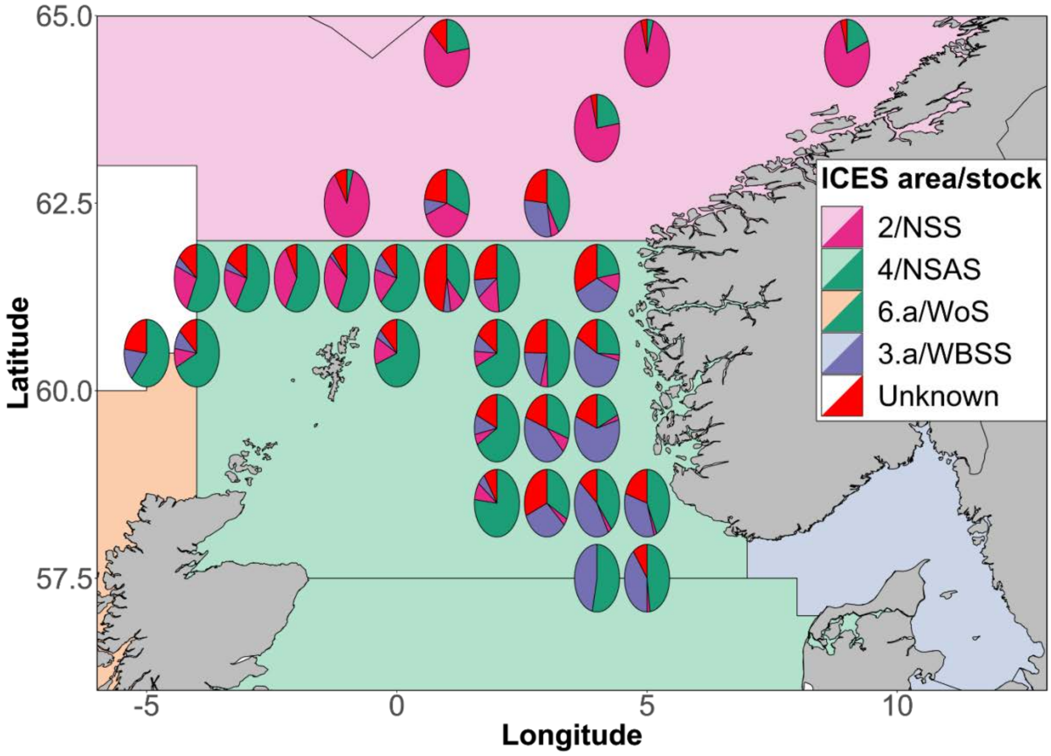


**Figure 1.2.7.1: Map of the greater North Sea ecoregion indicating geographical boundaries of four different herring stocks. Assignment results of individual fish of unknown origin to one of these stocks using otolith shape analysis and machine learning techniques, in this case support vector machine (SVM).**

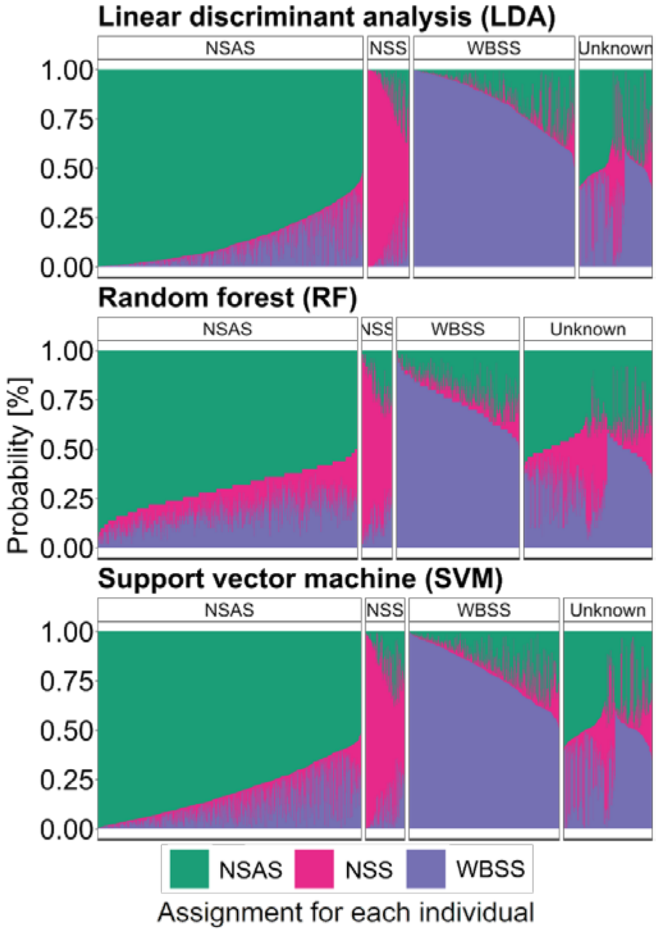


**Figure 1.2.7.2: Assignment results for individuals of unknown origin to their potential stocks based on different machine learning techniques.**

## Updates on the analyses of the WKMixHer sample

The 2018 workshop on mixing of western and central Baltic herring stocks (WKMixHer) was concluded with a recommendation and proposal for coordinated sampling of Spring-spawning herring with the objective to further evaluate mixing of herring stocks in the western-central Baltic and implement operational methods for their separation.

Accordingly, Spring-spawning herring were collected by Sweden, Germany, Poland and Lithuania during the 2019 spawning peak on 7 coastal spawning grounds in the Hanö Bay, Bay of Lübeck, Greifswald Bay, Pomeranian Bay, Kolozbreg, Vistula Lagoon and Klaipéda (Figure 1.2.7.3).

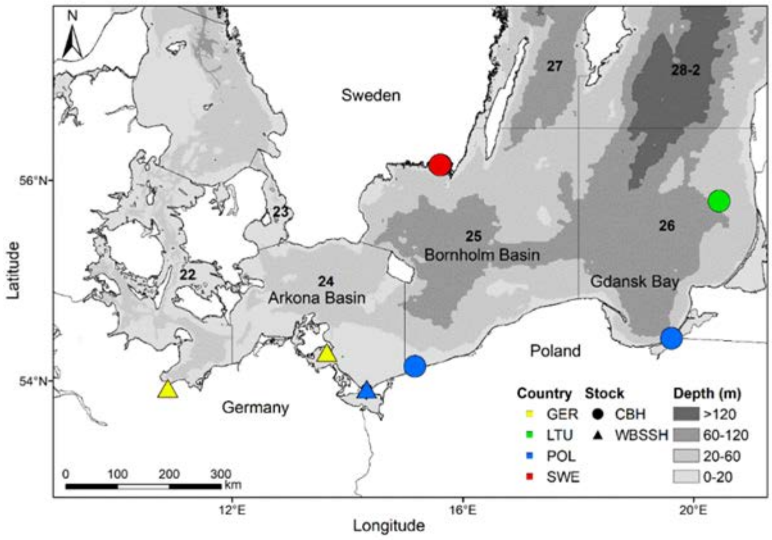


**Figure 1.2.7.3. Map with sampling locations of spawning herring during Spring 2019.**

Herring was collected at spawning time on spawning aggregations, resulting in samples covering the period between late March and early May as the spawning peak showed a seasonal progression throughout the region. Sampling was restricted to ripe and running individuals corresponding to maturity stages between 5 and 7. The sample comprised 399 individuals from which otolith shapes were extracted and preliminary analyses conducted.

A Canonical Analysis of Principal Coordinates performed on the standardized wavelet coefficients showed that herring from the sampled locations group into two well distinct clusters, with a clear geographical longitudinal separation (Figure 1.2.7.4). Based on the 2019 samples the two clusters approximate the Western and the Central Baltic herring stocks, but Polish samples from the western part of SD25 (station "SWI-31") group with the western Baltic cluster. A wide geographical gap in the 2019 sampling did not allow other inference on the level of otolith differentiation along the southern Baltic coast.

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 with overall promising assignment accuracy of approx. 70%.

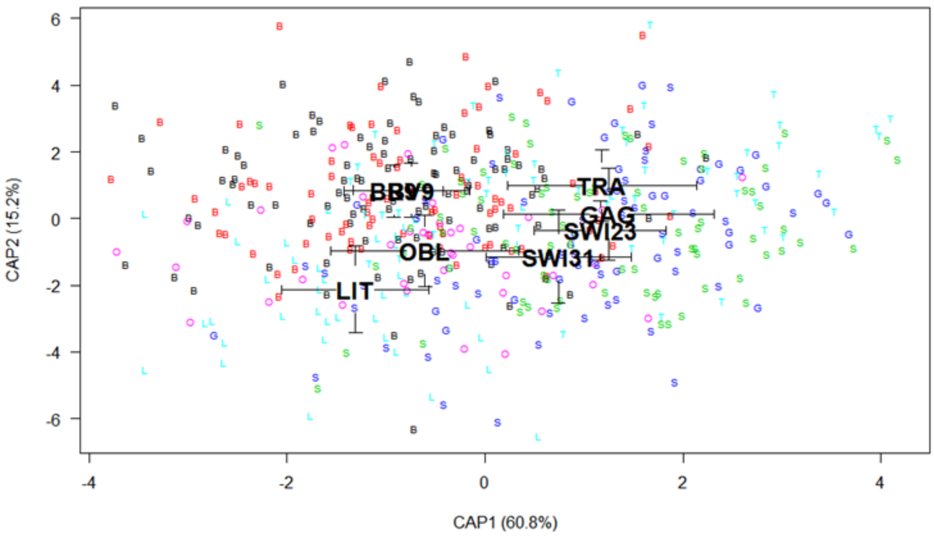


**Figure 1.2.7.4. Plot of the first and second Principal Components from the analysis of standardized Wavelet coefficients. The black labels show the centroid for each spawning location.**

Further work is in progress to:

- improve the level of accuracy in the assignment of mixed samples by combining otolith shape and growth data;
- collect samples of spawning herring from the central part of the Polish coast to evaluate gradient of differentiation along the southern Baltic coast.

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

## 1.2.8 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.

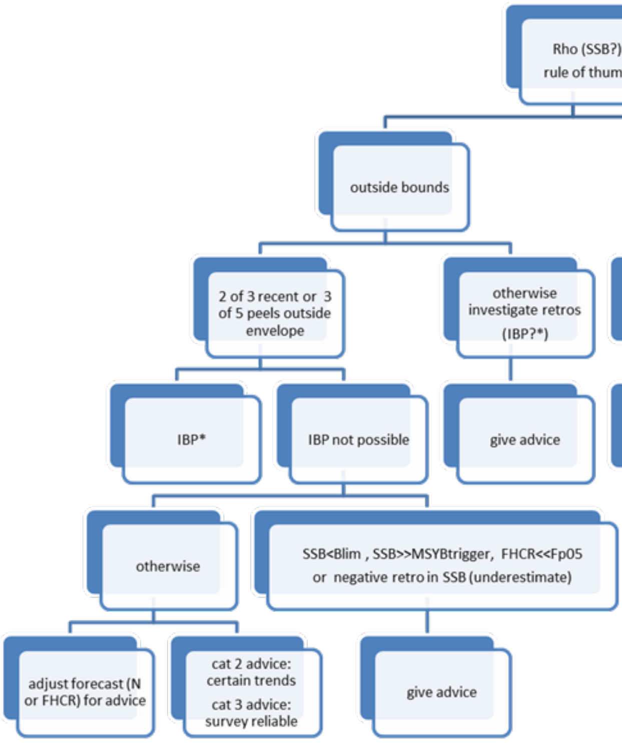


**Figure 1.2.8.1: Decision tree for handling assessments with retrospective patterns produced by WKFORBIAS.**

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.)

## 1.2.9 WKREBUILD

The Workshop on guidelines and methods for the evaluation of rebuilding plans (WKREBUILD) chaired by Vanessa Trijoulet (Denmark) and Martin Pastoors (Netherlands) met from 24 to 28 February 2020. The workshop attracted 27 participants from the US, Canada, Europe and FAO.

When stocks are estimated to be below Blim and there is no perceived possibility of rebuilding above Blim within the time frame of a short term forecast, ICES has regularly recommended zero catch in combination with the development of a rebuilding plans.

A review was carried out on the international experience on the development, evaluation and implementation of rebuilding plans for fisheries management in the Northeast Atlantic and in other fora around the world. In the Northeast Atlantic, rebuilding plans have been implemented in the past (e.g. the cod recovery plans of the early 2000s) but ICES has played a limited role in evaluating the performance of such recovery plans and does not have the tools or criteria to evaluate such plans. Recently, when a rebuilding plan for herring in 6a7bc was submitted to ICES for evaluation, ICES refrained from providing such an evaluation. In the US and Canadian approaches, the legal framework determines the triggering and required elements of rebuilding plans. Such a legal imperative does not exist in the Northeast Atlantic. Nevertheless, the US and Canadian experiences provided useful elements that could be included in the ICES approach to rebuilding plans.

Several case studies were presented on application of potential tools for the evaluation of rebuilding plans. Particular attention was given to the harvest control rule options of such a plan. The tools focused mostly on short to medium term explorations of the probability of achieving a re-building of stocks. Because rebuilding plan evaluations can be expected to be needed on relatively short time frames, it was concluded that relatively standardized tools (i.e. packages or com-piled code) to carry out such evaluations would be preferable over custom-made evaluation tools. In addition, certain modelling considerations were highlighted as important such as the probability of achieving a rebuilding of stocks and realistic assumptions of productivity, uncertainty, bias in assessments and implementation error.

Criteria for the acceptability of rebuilding plans will require agreed reference points for triggering a rebuilding plan (e.g. Blim), definition of rebuilding fishing mortality or biomass targets, time frames and probabilities of achieving the rebuilding targets, taking into account realistic levels of uncertainty and being consistent with international best (scientific) practices. Although it was recognized that Blim would be the most likely candidate for triggering a rebuilding plan, the current basis for Blim in ICES was questioned during the workshop because it requires a more or less subjective classification of the stock-recruitment pairs into different types. In other regions, the Limit Reference Point (LRP) is often set as a certain proportion of Bmsy (e.g. 40% Bmsy). If changes in productivity have been experienced in recent years, the proportion of Bmsy approach would likely lead to greater changes in the estimated value of Blim than the current procedures, which rely on stock-recruitment pairs or Bloss. This could have a large impact on the rebuilding target for stocks that show signs of low productivity regimes. Some concerns were raised regard-ing the relatively small distance between Blim and MSY Btrigger compared with the distance between trigger and limit in other jurisdictions. MSY Btrigger could therefore represent a late trigger to start decreasing fishing mortality when SSB is decreasing. The workshop recommend-ed a future workshop on the revision of the procedure to estimate reference points within the ICES framework.

The minimum time (Tmin) by which rebuilding may be expected, could be calculated by assuming zero catch. This should be used as baseline for comparison with other rebuilding scenarios. The maximum time for rebuilding in the US and Canadian jurisdictions is set to Tmax = 2 * Tmin or to Tmin plus one generation time. While the workshop did not arrive at an overall agreement on a default value for Tmax, it was suggested that Tmax = 2 * Tmin could be explored as a potential bounding on the rebuilding period, although this should be subject to scientific analysis on potential effects.

The workshop generated a guidance table summarizing the best practices for evaluation of rebuilding plans against the potential criteria of acceptability. The guidance table includes elements such as estimation of reference points, time frames for rebuilding, rebuilding targets, handling uncertainties and bias, probability of achieving rebuilding targets and visualizing results. The workshop recommended that a follow-up workshop (WKREBUILD2) be organized for testing the guidelines with actual test cases. This should enable to narrow down and refine the guidelines i.e. learning by doing.

Some of the elements that were discussed in the workshop but that have not (yet) entered the guidelines for evaluation of rebuilding plans are socio-economic trade-offs (e.g. between fast and slow rebuilding), mixed fisheries aspects (e.g. unavoidable bycatch due to mixed fisheries) and elements in rebuilding plans other than the HCR part (e.g. monitoring to improve the knowledge base).

Most of the discussion at WKREBUILD was centred on stocks with analytical assessments (Category 1+2). Identifying when a data limited stock is in need of rebuilding (or has rebuilt) and how to evaluate rebuilding plan options for such stocks would likely require a separate process.

### 1.2.10 WKDLSSLS

The Workshop on Data Limited Stocks of Short-Lived Species (WKDLSSLS) aimed to provide guidelines on the estimation of MSY proxy reference points for category 3–4 short-lived species and 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 stock were examined including Sprat in 7d and e.

WKDLSSLS 2019 investigated the use of SPICT, length based indicators and two-stage biomass models for developing biological and MSY proxy reference point and application of the existing advice rules to category 3 and 4, short lived data limited species using long-term management strategy evaluation. Index based HCR were tested using MSE with a range of operating models. In year advice was found to result in larger catches and reduced risk in all tests due to the reduced lag between observation, advice and management when tested against annual advice. The principle cause of risk in simulations was historical exploitation (trend), HCR and the uncertainty cap. A 1o2 advice rule was found to outperform the current 2o3 rule for short lived stocks, 1o2 was tested with a range of uncertainty caps and biomass safeguard such as Imin (minimum observed abundance index) and Itrigger (1.4*Imin). Investigation of the uncertainty cap and biomass safeguards is currently ongoing and will be resolved at WKDLSSLS 2020. Rule 1-over-2 with symmetrical 80% Uncertainty cap might be preferred as a compromise between moderate risks and catches though it can lead to major reduction of catches in the long term.

### 1.2.11 IBSANDEEL

The sandeel advice is largely influenced by the most recent recruitment, which is informed by the recent age-0 survey index. During the sandeel assessment and advice meeting (held on 22$^{nd}$-24$^{th}$ January 2020 at the ICES HQ as part of HAWG), a retrospective bias was observed by the expert group for both area 2r and 3r in both recruitment (R) and spawning-stock biomass (SSB). This triggered an inter-benchmark IBPSANDEEL with the aim to evaluate the use of a density-dependent survey catchability model to reduce retrospective patterns in the assessment of sandeel in area 2r and 3r. IBPSANDEEL concluded that the method proposed is appropriate and can be applied to provide advice on these two stocks.

The sandeel advice on fishing opportunities is highly influenced by good incoming year classes. High uncertainty is usually associated with estimation of high recruitments, which justified the implementation of an Fcap strategy. However, sandeel assessments in 2r and 3r have also strong retrospective patterns in recruitment (i.e. the model has a tendency to overestimate recruitment in the terminal year) which are not properly accounted by the current Fcap.

Sandeel recruitment in 2019 is estimated to be high throughout the entire North Sea, including areas 2r and 3r. For this reason an adjustment to the assessment model was proposed to provide more reliable estimates of recruitment in the terminal year. A power function was implemented in the assessment of sandeel 2r and 3r to capture density-dependency catchability of age 0 fish in the survey. The adjusted models provided downward correction of the terminal year recruitment which is considered more reliable as suggested by the reduced Mohn's rho statistic, while estimates of stock dynamics (SSB and R) remained highly consistent with the previous assessment.

### 1.2.12 WKHASS

The Workshop on Herring Acoustic Spawning Surveys (WKHASS) reviewed the methodology (survey design, timing, identification of the sources of uncertainties and how to address them, among other issues), and abundance estimates (including CV) from acoustic surveys carried out in 6aN, 6aS/7b and 7a on commercial vessels. The results will be used by WGIPS to establish survey protocols to be included in future in the Manual for International Pelagic Surveys (SISP 9). Analyses carried out during this workshop showed that both the 6aN and 6aS/7bc industry-led surveys are not yet sufficiently developed for them to be included in the SISP 9 survey manual because they are still undergoing regular changes as they learn from testing different designs regarding the issues and the solutions proposed to address them. WKHASS recommends that:

- the acoustic and biological data from the herring acoustic spawning surveys in 6aN, 6aS/7b and 7a are uploaded to and hosted on the ICES Acoustic trawl surveys database. This is recommended to ensure transparency in the calculation of survey indices and allow for comparison with standard methods (e.g. StoX).
- a workshop is held on scrutinising of acoustic data from the herring acoustic spawning surveys in 6aN, 6aS,7bc and 7.a. It is important that all scientists responsible for the scrutinisation of an acoustic survey follow mutually agreed and documented procedures for each survey and that these agreed procedures are developed specifically for the survey. This is particularly important when surveys are carried out on board commercial vessels, resulting in some differences in the acoustic equipment used (e.g. different transducer frequencies and/or hull or towed body mounted).
- the 7a survey in the Irish Sea is included in the SISP 9 manual for pelagic acoustic surveys, because this survey is already used as a biomass index in the Irish Sea herring assessment and thus transparency is required in the calculation of survey indices.

### 1.2.13 WKIRISH

The WKIrish workshop series was a multiyear process focusing on improving single-species stock assessments (principally cod, haddock, whiting, plaice, herring), incorporating a mixed fisheries model, and developing the integration of ecosystem aspects and working towards an integrated assessment and advice. The final Workshop (WKIrish 6) set out to operationalize an Ecosystem Based Approach to Fishery Management for the Irish Sea. WKIrish defined a framework to incorporate ecosystem information into the ICES single-species stock assessment process. The series initiated independent ecosystems models. Of these, an Ecopath with Ecosim (EwE) model, reviewed by the ICES Working Group on Multispecies Assessment Methods (WGSAM), is the most developed. WKIrish propose to use relevant ecosystem indicators to inform the $F_{MSY}$ within established F ranges ($F_{MSYLower}$ to $F_{MSYUpper}$). This $F_{IND}$ uses indicators of current ecosystem suitability for individual stocks to refine the F target values within these precautionary ranges. $F_{IND}$ is based on finding ecosystem indicators which are positively related to the stock development over the model tuning range, and where the likely underlying mechanisms for this link are likely to continue acting in the short to medium term. In essence the value of the indicator is used to explore if the ecosystem is in a favorable state for the stock and consequently F in the upper range may be advised. Conversely, where the indicator suggests the ecosystem may be in an unfavorable state, F should be in the lower range. In this framework in no case does the proposed F target lie outside the ranges defined as being precautionary and thus the system proposed here remains according to the ICES principles.

The EwE model was used to provide ecosystem indicator(s) for individual stocks (cod, whiting, haddock, sole, plaice, herring, and *Nephrops*). Management Strategy Evaluation simulations were applied for Irish Sea herring testing resilience of the stock to fishing at the extremes of the F range. The selection of the indicator aimed to cover a range of possible ecosystem processes on each stock. Through this approach, WKIrish has identified a route by which ecosystem information can be incorporated into the current single species assessment process. However, the approach can be developed further; a potential frame-work for a more complete Ecosystem Based Fishery Management is described. This framework suggests the use of ecosystem descriptors to inform decision-making within assessment benchmarking processes. This may involve, exploring productivity change across the assessment time-series, examining trends in aspects of population dynamics such as natural mortality and recruitment success, and input into the definition of reference points.

## 1.2.14 Other activities relevant to HAWG

### Industry-Science survey of herring in 6.a, 7b–c. in 2019.

(see Section 06 for additional details).

In 2019, industry and scientific institutions from Scotland, Northern Ireland, Netherlands and Ireland again 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 5800 t (EU2019/124), 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 2016-2018 surveys.

Biological samples taken during the survey and subsequent commercial catches were used to construct a catch-at-age used in the 2020 stock assessment. Acoustic surveys on the biomass of the spawning components (ICES, 2020) provide a third set of data points in a spawning stock time-series. 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 benchmark scheduled for 2022.

### Pelagic fish fat as ecosystem indicator

A presentation was made to HAWG on behalf of Susan Kenyon, a PhD student at Aberdeen University, whose research title is ‘Fats as ecosystem indicators: Revealing the ecological value of industry data on Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) fat content’. The PhD accesses historical data on fish fat measurements recorded by Scottish pelagic processing factories and onboard pelagic freezer trawler vessels. The premise of the research is that as a direct indicator of body condition, fat content measurements are relevant to understanding changes in survival, growth, recruitment of pelagic fish. Linking changes in fat content to changes in environmental conditions could help serve as an early warning indicator of changes in stock productivity. Key research questions are:

- Do industry and scientific data on two different condition indices for Atlantic herring show similar interannual variation?

- Is there interannual spatial and temporal variation in Atlantic herring and Atlantic mackerel fat content in the Northeast Atlantic?
- Is interannual variation in Atlantic herring and Atlantic mackerel fat content impacted by variation in food availability and temperature?

While the research is still in its early stages, focused on gathering and standardization of data, initial data exploration show clearly temporal and seasonal changes among different herring stocks (Figure 1.2.14.1)

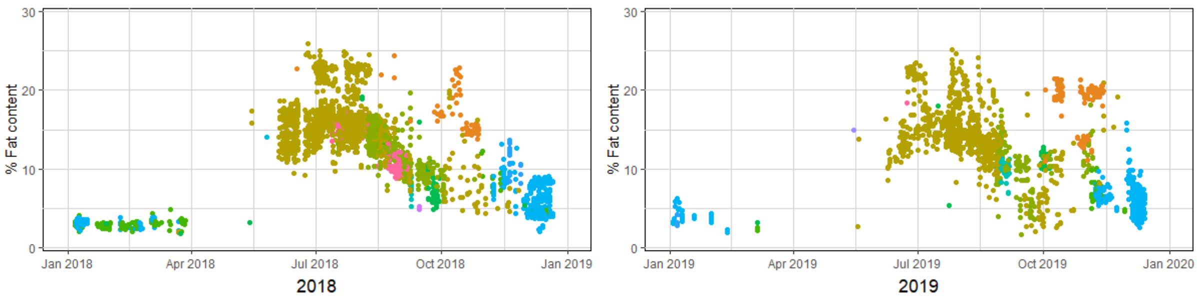


**Figure 1.2.14.1. Example of herring fat content data from freezer trawler vessels. (different colours represent different ICES statistical areas)**

## Data from the herring processing industry (her.27.20-24)

A time-series of herring catch composition data in industrial samples taken during production process in a herring factory in Germany back until 2004 was provided by the industry (processing approx. 1/3 of WBSS SD22-24 TAC landings). The dataset is currently being processed and might contribute to a higher resolution of commercial catch sampling as well as closer cooperation and improved communication between fisheries and science in Germany.

First results reveal high correspondence between scientific and factory sampling of the catches, whereby the industry only records weight data, resulting in some complications regarding comparability and usability of data. However, industrial data of the last 5 years reveal a general shift of the catch composition towards a smaller proportion of light fish and within the individual spawning seasons, no changes in the weight distribution of the prespawning aggregations become apparent.

## 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 2018-2020 IBTSQ1 surveys, the occurrences of *Ichthyophonus* in the Norwegian part were again fairly low: 4.4%, less than 1% and 1.2%, respectively. In the Kattegat-Skagerrak, the IBTS data suggests levels of incidence generally < 3% but with areas of > 20% infestation in some recent years 2017-2018 and with a peak around 50% in 45G0 in 2018, although the sample was rather small. In 2019, the infection was generally lower in IBTS Q3 (Figure 1.2.14.3) and comparable to previous years in Q1. In contrast to the IBTS samples and the commercial samples from previous years, of the >3300 individuals collected in 2019 in 3a in the Swedish commercial samples none was infected 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.

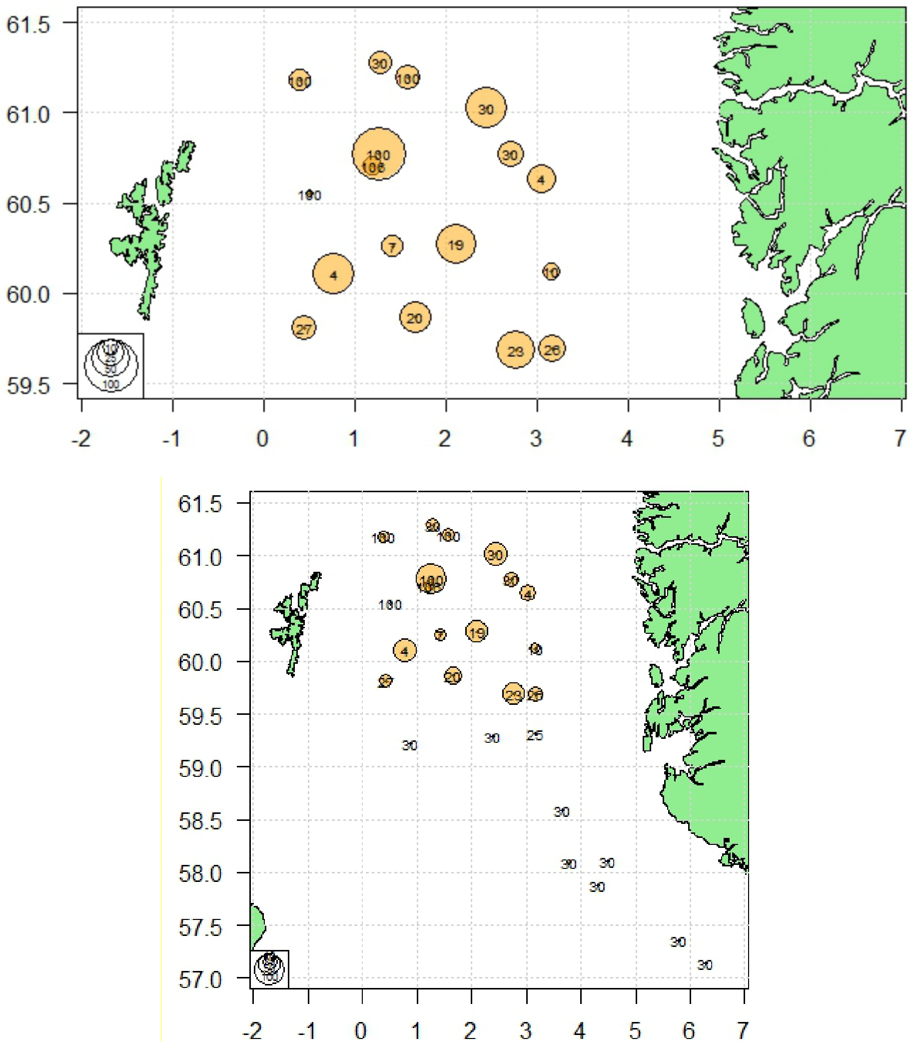


**Figure 1.2.14.2 Occurrence of *Ichthyophonus hoferi* in the Norwegian part of the IBTSQ1 2017. Bubble size show the percentage of diseased herring, whereas the numbers show the number of herring examined. The upper figure shows the details of the area with infection.**

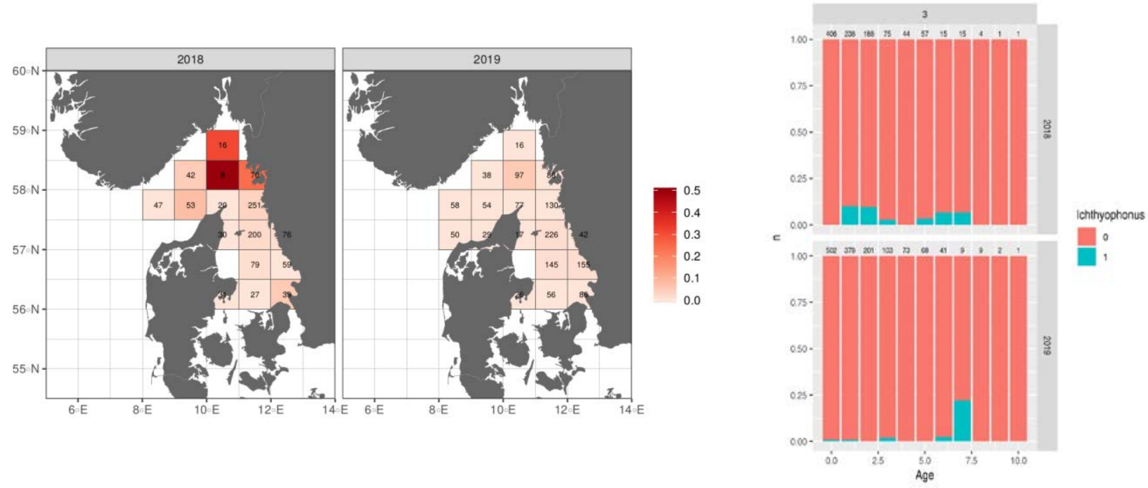


**Figure 1.2.14.3 Occurrence of *Ichthyophonus hoferi* in the Kattegat-Skagerrak from Swedish samples collected during the IBTSQ3 2018-2019. Left map with distribution of the proportion of infested herring and number of samples in each rectangle; right distribution of infestation among ages.**

### HAWG's feedbacks to RDBES

Regional Database and Estimation System (RDBES)

The RDBES is still under development, but is now ready for the first major upload of data, so this year the first data call will be launched late spring / early summer, requesting 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 have been chosen to ensure that most countries will be involved in this first major test of the system. None of the stocks are covered by HAWG, but all counties have been encouraged to submit more stocks.

In 2020, three workshops will be held in relation to the RDBES, WKRDB-POP 2 – Second Workshop on Populating the RDBES data model, WKRDB-EST2 – Second Workshop on Estimation with the RDBES data model 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).

## 1.3 Commercial catch data collation, sampling, and terminology

### 1.3.1 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 3rd March 2020. Not all countries delivered their data in due time. With regards to the North Sea herring assessment, some reported with a delay of more than one week and hindered the overall catch data preparation for the assessment until the very last day.

*"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.

## 1.3.2 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) | 64692 | 64589 | 1062 | 16 |
| 4.a(W) | 25486 | 215739 | 5073 | 24 |
| 4.b | 86325 | 66602 | 1245 | 19 |
| 4.c | 2583 | 0 | 0 | 0 |
| 7.d | 37170 | 24266 | 401 | 17 |
| 7.a(N) | 6377 | 5400 | 1529 | 240 |
| 6.a(N) | 1739 | 1522 | 569 | 101 |
| 3.a | 14918 | 12646 | 4036 | 271 |
| SD22-24 | 9831 | 9003 | 4285 | 436 |
| Celtic, 7.j | 1841 | 1803 | 1280 | 710 |
| 6.a(S), 7.b and 7.c | 1690 | 1625 | 2350 | 1446 |

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.

### 1.3.3 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.

## 1.4 Methods Used

### 1.4.1 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 multifleet 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.

### 1.4.2 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.

### 1.4.3 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.

### 1.4.4 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.

### 1.4.5 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.

### 1.4.6 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.

## 1.5 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, 2019a, b).

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. A subgroup has been tasked to look in to this phenomenon over the next year and report back to the 2021 HAWG. 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 dis-tribution | 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 |
| 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 popula-tion 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 |
| 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 |

## 1.6 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 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, especially in the purse-seine fishery. 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 substock 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, dog-fish 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 temperature**s** 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 winterrings 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 foodweb 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 foodweb 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.

## 1.7 Stock overview

The WG was able to perform analytical assessments for 10 of the 15 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.

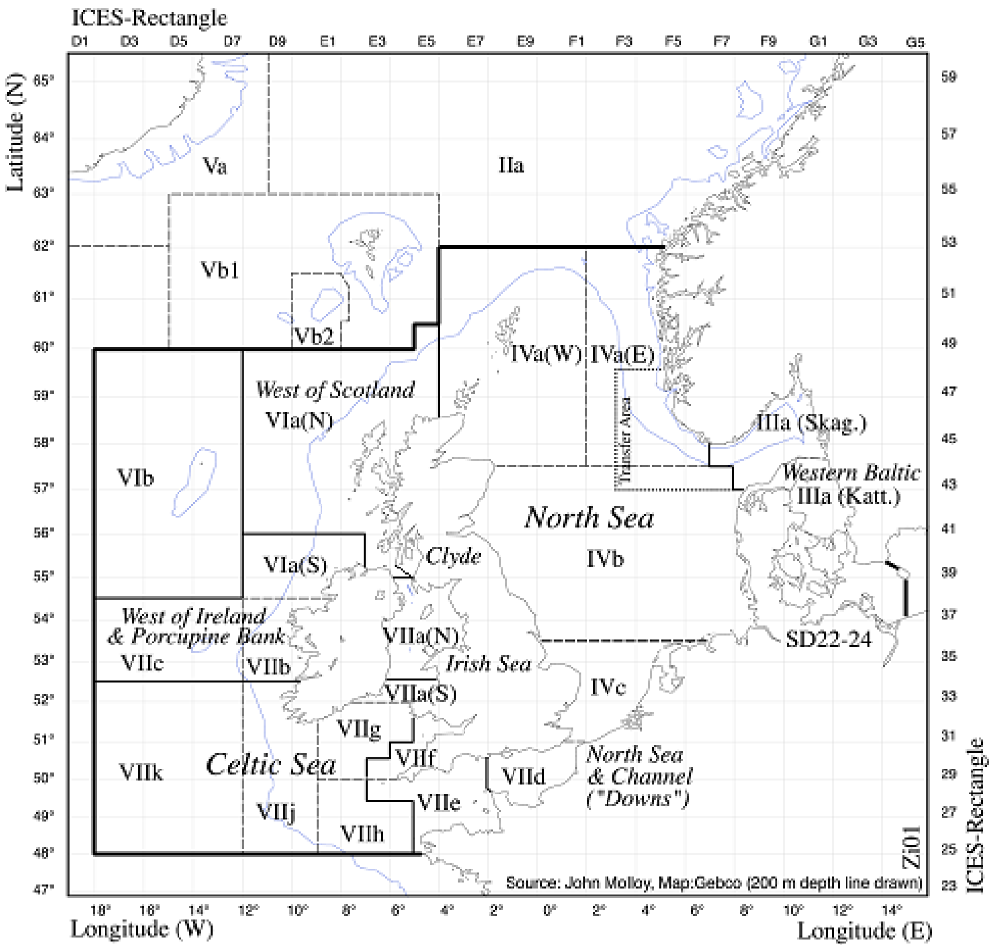


**Figure 1.7.1 ICES areas as used for the assessment of herring stocks south of 62°N. Area names in italics indicate the area separation applied to the commercial catch and sampling data kept in long term storage. "Transfer area" refers to the transfer of Western Baltic Spring Spawners caught in the 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 is classified as being at full reproductive capacity and is being harvested sustainably at $F_{MSY}$ and under management plan target for several years. Since 2019, no management plan is in place and the advice is based on the $F_{MSY}$ advice rule. The spawning stock at spawning time in 2019 is estimated at 1.7 million tonnes. Recruitment in 2019 is comparable to the 2018 value and remains within the low recruitment regime observed since 2015. The strongest recruitment remains the one observed back in 2014. Mean $F_{2–6}$ in 2019 is estimated at approximately 0.18, which is below $F_{MSY}$. The SSB for the stock from the 2020 assessment has been further revised upward for a number of years.

Given the agreed TACs, the 2020 SSB is expected to decrease to ~1.3 million tonnes. Under most scenarios, SSB is predicted to decrease in 2021. Based on the present advice SSB in 2021 is estimated to approx. 1.2 million tonnes which is well above $B_{pa}$ (0.9 million tonnes).

**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 (56 621 t) and recruitment (778 899 thousands) are record low. The estimate of SSB in 2019 is considered low, below both $B_{pa}$ and $B_{lim}$. Fishing mortality ($F_{3–6}$) was reduced from 0.51 in 2009 to 0.37 in 2011. It had then remained stable above $F_{MSY}$ (0.31) until 2014 (~0.38) but showed an increase in 2015-2018 with an estimated $F_{3-6}$ above 0.42. The 2019 $F_{3–6}$ has decreased (0.382) but is still well above $F_{MSY}$. The 2021 advised catch of WBSS is 0 t, which if applied by managers, will result in an increase in SSB from 57 124 t in 2020 to 66 824 t in 2021. The zero catch will not allow the stock to rebuild above $B_{lim}$ (120 000 t) by 2022 (87 890 t). A medium-term forecast to 2023 showed that SSB can increased to 111 745 t if F=0 in 2021-2022 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 around 12 000 t in 2019, which is well below $B_{pa}$ (at 54 000 t) and $B_{lim}$ (34 000 t). Recruitment has been below average from 2013-2018. An increase in recruitment can be seen in 2019. Fishing mortality ($F_{2–5}$) declined between 2003 and 2009 but started to rise again in 2010 due to increased catches. F decreased in 2019 in line with reduced catches. This year assessment estimates a fishing mortality, $F_{2–5}$ of 0.49 in 2019 which is a decrease from the high F in 2018 (1.10) but is still above the $F_{MSY}$ (0.26) and $F_{lim}$ (0.45). Short-term projections predict SSB to increase to around 17 500 t in 2020.

**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 2019, SSB and recruitment have been estimated at 24 785 t and 343 863 thousand respectively, estimates of SSB in recent years appear to be relatively stable. $F_{4-6}$ is estimated at 0.18 in 2019. Under the MSY approach the stock is expected to show minor decline to 21 973 t in 2021.

**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. Despite the fact that 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 2020 show an SSB of 266 000 t which is more than double of $B_{pa}$ (125 000 t). The ICES advise for the period 1 July 2020–30 June 2021 indicates that catches of sprat should not exceed 207 807 t which represents a 50% increase 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 advice provided is based on the biomass estimates from the acoustic survey which in 2019 remained at low level in relation to the estimates for 2013–2015. The advised catch for 2021 is 4% lower 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 2800 tonnes for 2020 and 2021 in this ecoregion based on the precautionary approach.

**Sandeel in 4 (san-nsea)**: Sandeels in the North Sea can be divided into a number of more or less reproductively isolated subpopulations. 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 68 000 t in 2019. SSB increased to 85 000 t in 2020 but it remains still below $B_{lim}$ (110 000 t). Recruitment in 2019 was above the geometric mean of the time-series, and higher than in 2018. 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 for the last two years. The 2019 year class is large enough to contribute both to an increase in SSB and the catch advice.

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 but decreased again in 2019 and further in 2020 to set at 47 000 t. Recruitment has been low since 2000, with the exception of the 2016 year class. The 2019 yearclass is estimated to be just above the long-term average. Fishing mortality was low in 2019 due to the monitoring TAC.

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) where it has been since 2015. SSB had a peak of more than 360 000 t in 2018 and is estimated 221 000 t in 2020. The recruitments in 2016 and 2019 were among the five highest on record which contributes to explain the 16% increase in the advised catch. Fishing mortality (F) declined in the early 2000s and has been low since then. F has increased in the last 3 years but it is still below 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 2019. 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.

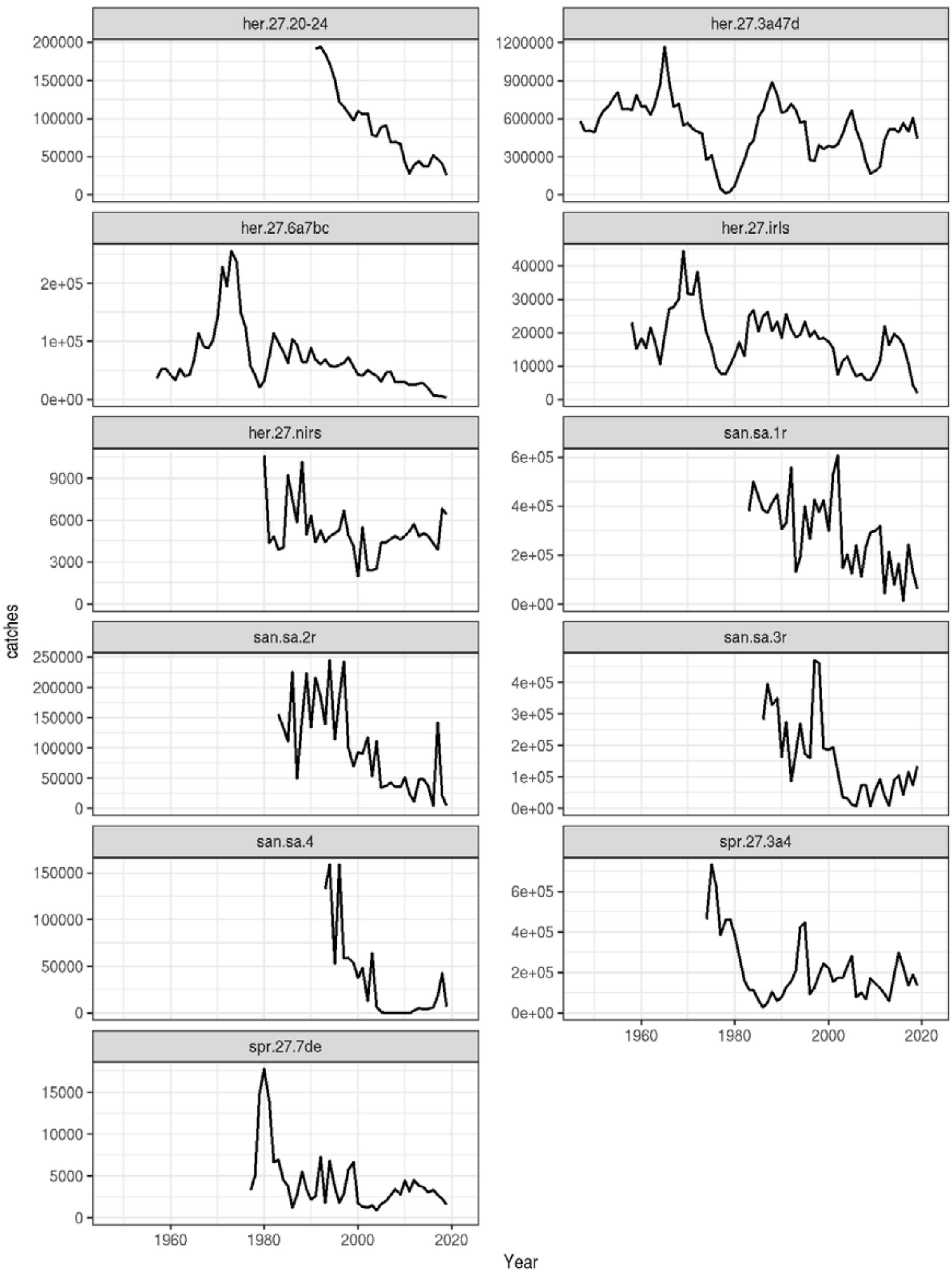


**Figure 1.7.2 WG estimates of catch/landings (yield) of the herring, sprat and sandeel stocks presented in HAWG 2020.**

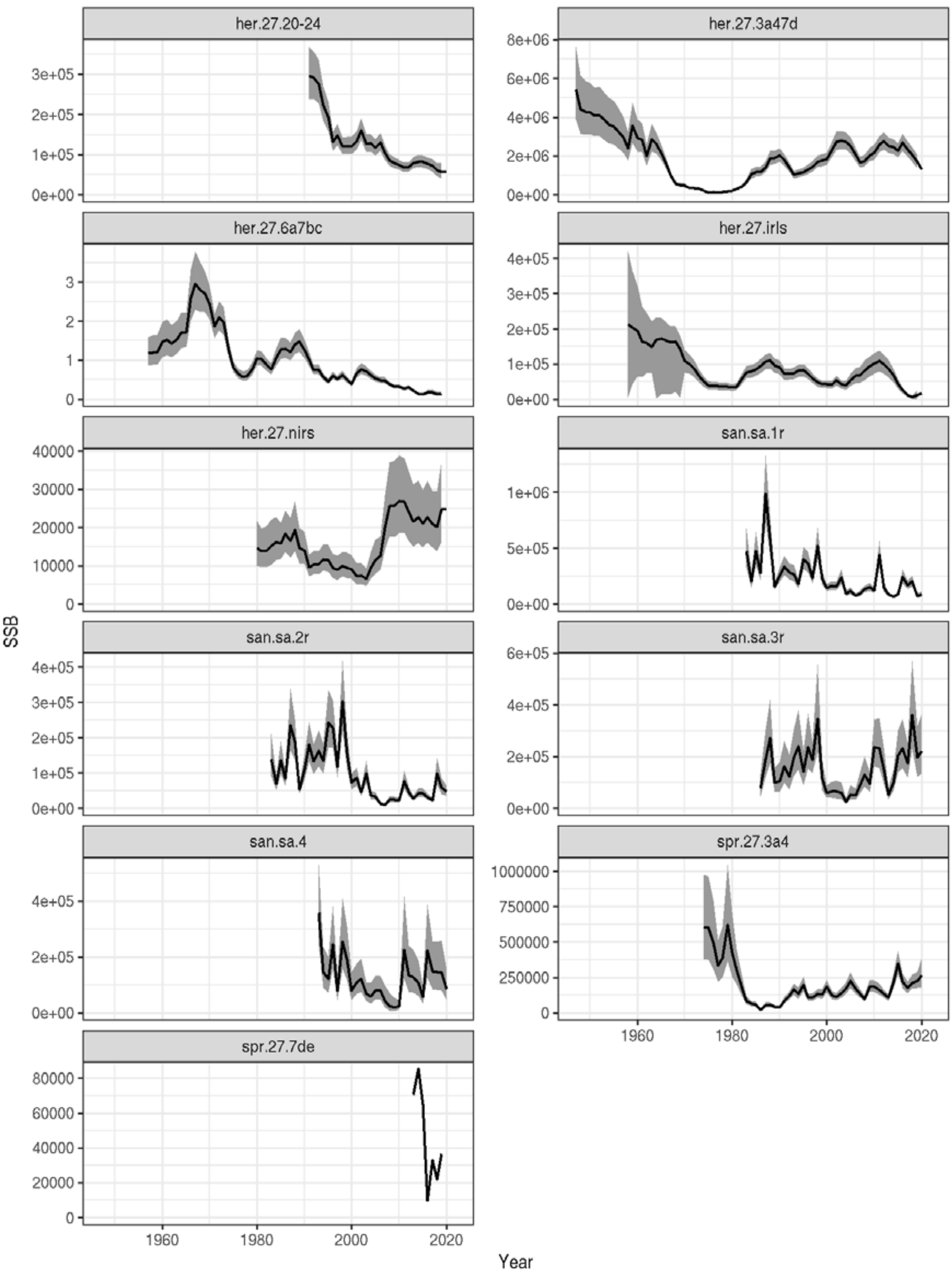


**Figure 1.7.3 Spawning-stock biomass estimates for the sprat, herring and sandeel stocks presented in HAWG 2020.**

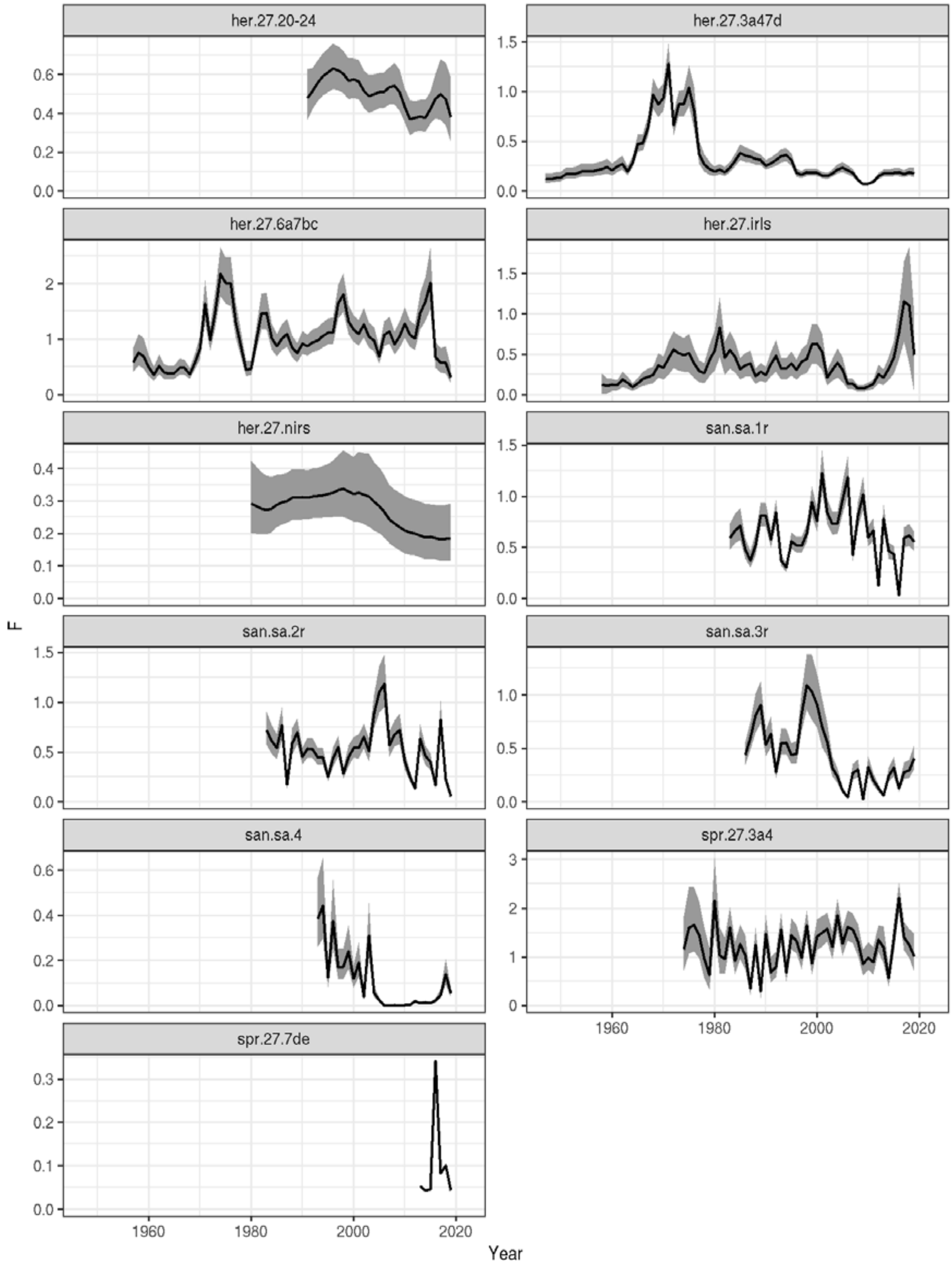


**Figure 1.7.4 Estimates of mean F for the sprat, herring and sandeel stocks presented in HAWG 2020.**

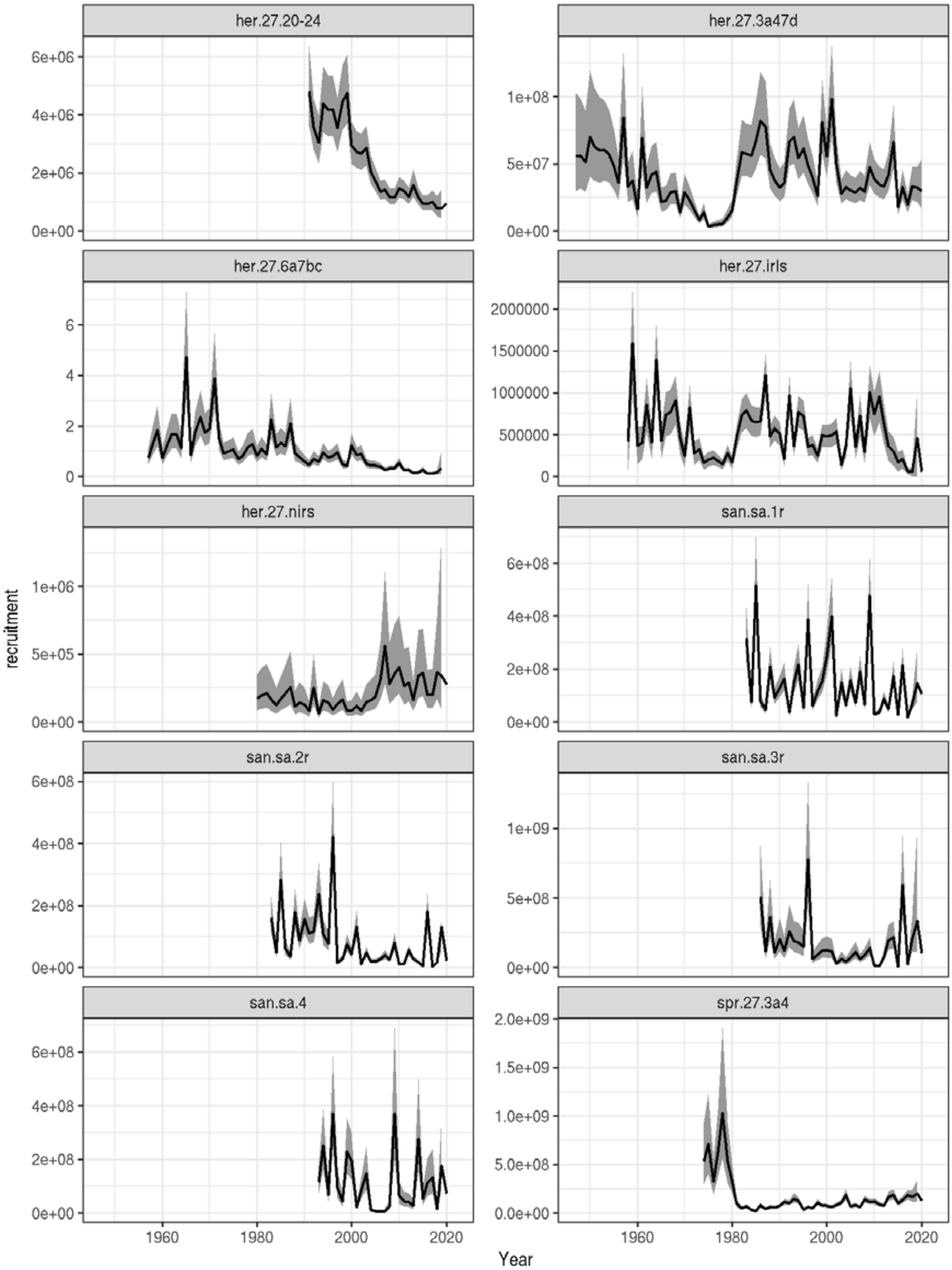


**Figure 1.7.5 Estimates of recruitment for the sprat, herring and sandeel stocks presented in HAWG 2020.**

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).

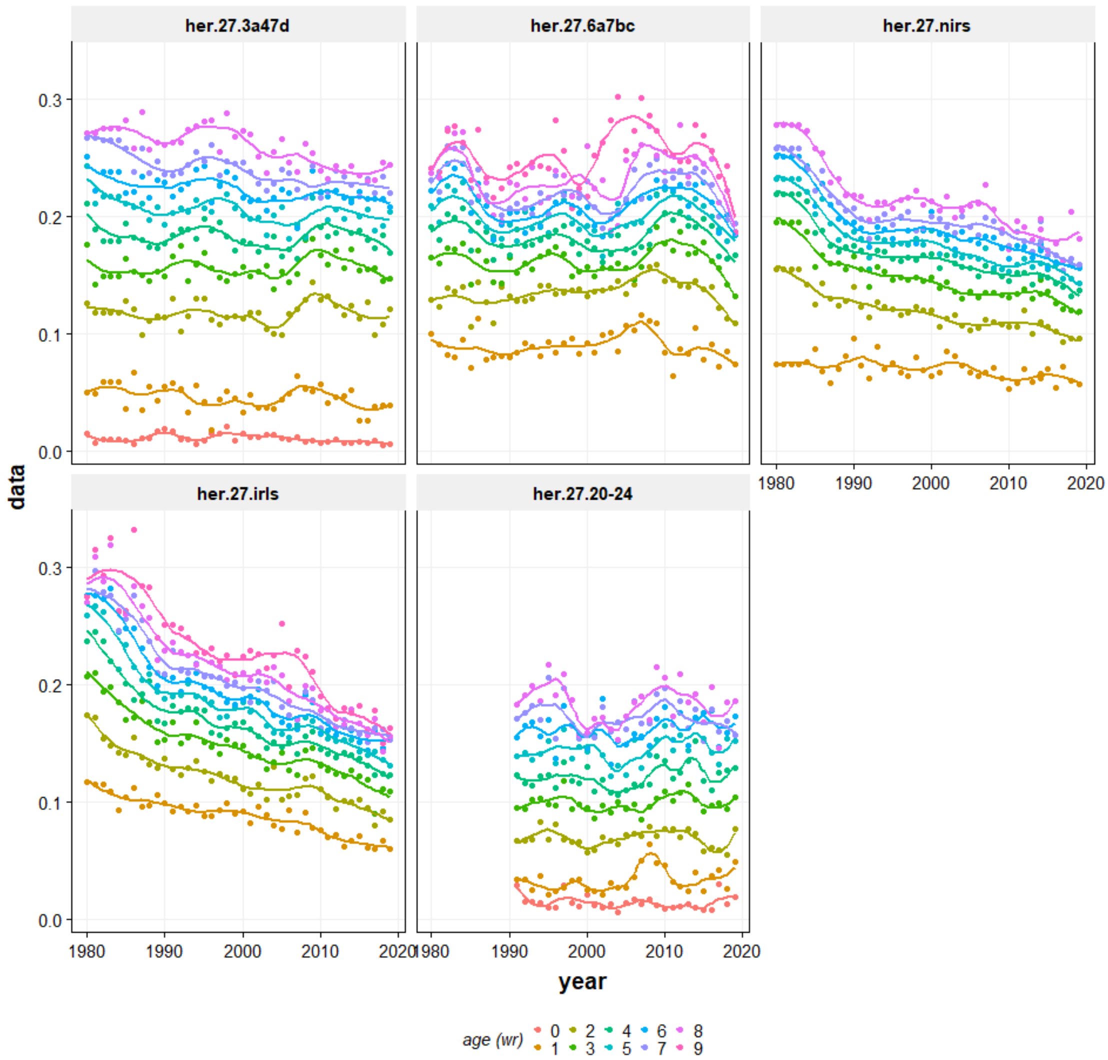


**Figure 1.7.6 Time-series of herring mean individual weight in the catch.**

# 1.8 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*:

* From ICES guidelines https://community.ices.dk/ExpertGroups/HAWG/_layouts/15/WopiFrame.aspx?sourcedoc=%2FExpert-Groups%2FHAWG%2F2018%20Meeting%20docs1%2F03%2E%20Background%20documents%2FGuide%5FMohnsRho%5Fcalculation%5FRetroBias%2Edocx&action=view

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

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: $X_{y=T-i,d=T} = X_{y=2016,d=2017}$ 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 $X_{y=T-i,d=T-i} = X_{y=2016,d=2016}$ 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/ExpertGroups/Lists/Retrobias2020/Allitems.aspx and they are included in this report in Table 1.8.1.

**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 intermediate 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 | 2019 | 5 | -0.178 | No | 0.247 | No | 0.016 |
| her.27.3a47d | 2020 | 5 | -0.123 | No | 0.115 | No | 0.03 |
| her.27.6a7bc | 2019 | 5 | 0.161 | No | -0.203 | No | 0.242 |
| her.27.irls | 2019 | 5 | -0.356 | No | 1.104 | No | 2.797 |
| her.27.nirs | 2019 | 5 | -0.158 | Yes | 0.088 | No | -0.262 |
| san.sa.1r | 2019 | 5 | -0.200 | No | 0.670 | No | 0.200 |
| san.sa.2r | 2019 | 5 | -0.160 | No | 0.570 | No | 0.520 |
| san.sa.3r | 2019 | 5 | 0.030 | No | -0.060 | No | 0.130 |
| san.sa.4 | 2019 | 5 | -0.05000 | No | 0.25000 | No | 0.19000 |
| spr.27.3a4 | 2019 | 5 | 0.02000 | No | 0.35000 | No | 0.31000 |

## 1.9 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 preprocessed. 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 2019 scripts are now on TAF:

1. North Sea herring (her.27.3a47d) update single-fleet SAM assessment, multifleet model run required for the forecast, and the forecast analysis.
2. Herring west of Scotland and Ireland (her.27.6a7bc) SAM assessment.
3. Herring south of 52°30'N Irish Sea, Celtic Sea, and southwest of Ireland (her.27.irls) ASAP assessment.
4. Sandeel in area 1r (san.sa.1r) SMS assessment.
5. Sandeel in area 5r (san.sa.5r) category 5.4 analysis.
6. Sandeel in area 6 (san.sa.6) category 5.2 analysis.
7. Sandeel in area 7r (san.sa.7r) category 5.3 analysis.

## 1.10 Benchmark process

HAWG has made some strategic decisions regarding the future benchmarking of its stocks listed in the table below. In the next 12 months (end of 2020) there are no plans to benchmark stocks assessed by HAWG. An Interbenchmark is recommended for Sprat in 7d,e in Spring 2021.

| Stock | Ass status | Latest benchmark | Benchmark next 12 months | Planning Year +2 | Further planning | Comments |
|---|---|---|---|---|---|---|
| NSAS | Update | 2018 | No | No | | Issue list available |
| WBSS | Update | 2018 | No | No | Split mixed catches with central Baltic herring. Compile catch matrix by fleet from data in the Regional Database | Issue list available, likely need for an interbenchmark to revisit reference points |
| 6.a, 7.bc | Update | 2015, interbenchmark in 2019 | No | 2022* | Splitting of survey and new assessment, explore new indices, reference points, MSE | Issue list available |
| Celtic Sea | Update | 2015, Interbenchmark in 2018 | No | No | Mixing with Irish Sea herring, recruitment signal | Issue list available |
| 7.aN | Update | 2017 | No | No | Explore stock mixing, recruitment signal and F in the assessment | Issue list available |
| Sprat NS.3a | Update | 2018 | No | No | Consider stock component, local components in 3a, boundary with the Baltic | Issue list in prep |
| Sprat 7.d and 7.e | Exploratory | 2018 | IBP recommended for 2021 | No | Consider stock components, review advice guidance for short lived species | Issue list available |
| Sprat Celtic | Exploratory | 2013 | No | No | Consider stock components | Issue list in prep |
| Sandeel areas 1–4 | Update | 2016 | No | 2021* | Update reference points for sandeel area 3 based on the new M estimates. | Issue list available |

*** Provisional, timeline to be decided**