1 Introduction

1.1 Terms of Reference

2018/2/ACOM07 The Herring Assessment Working Group for the Area South of 62ºN (HAWG), chaired by Susan Lusseau*, UK, and Valerio Bartolino*, Sweden, will meet at ICES Head-quarters for two meetings: 29–31 January 2019 to:

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

and 13–21 March 2019 to:

b) compile the catch data of North Sea and Western Baltic herring on 13–14 March;

c) address generic ToRs for Regional and Species Working Groups 15-21 March for all other stocks assessed by HAWG.

The assessments will be carried out based on the Stock Annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group on the dates specified in the 2019 ICES data call. HAWG will report by 11 February and 5 April 2019 for the attention of ACOM.

Fish Stock	Stock Name	Stock Coord.	Assesss. Coord. 1	Assess. Coord. 2	Advice	Review (SA)
san-sa	Sandeel in Division 3.a and Subarea 4	Denmark	Denmark	Norway	Update	Sweden/Germany/Norway/Denmark
her-27.20-24	Herring in Subdivisions 20–24 (Western Baltic Spring spawners)	Denmark	Denmark	Denmark	Update	UK/Denmark
her-27.3a47d	Herring in Subarea 4 and Division 3.a and 7.d (North Sea Autumn spawners)	Germany	NL	UK (Scotland)	Update	Norway/UK (Scotland)/Denmark
her-27.irls	Herring in Division 7.a South of 52° 30’ N and 7.g-h and 7.j-k (Celtic Sea and South of Ireland)	Ireland	Ireland		Update	Netherlands
her-27.6a7bc	Herring in Divisions 6.a and 7.b and 7.c	UK (Scotland) / Ireland	Ireland	UK (Scotland)	Update	UK (Northern Ireland)
her-27.nirs	Herring in Division 7.a North of 52° 30’ N (Irish Sea)	UK (Northern Ireland)	UK (Northern Ireland)	-	Update	Netherlands

Fish Stock	Stock Name	Stock Coord.	Assesss. Coord. 1	Assess. Coord. 2	Advice	Review (SA)
spr-27.3a4	Sprat in Division 3.a (Skagerrak - Kattegat) and Subarea 4 (North Sea)	Norway	Denmark	-	Update	France/(Denmark/Norway
spr-27.7de	Sprat in the Western Channel	UK	UK	-	Update	Norway / Ireland
spr-27.67a-cf-k	Sprat in the Celtic Seas	UK	UK	-	Update	

1.2 Generic ToRs for Regional and Species Working Groups

2018/2/ACOM05 The following ToRs apply to: AFWG, HAWG, NWWG, NIPAG, WGWIDE, WGBAST, WGBFAS, WGNSSK, WGCSE, WGDEEP, WGBIE, WGEEL, WGEF, WGHANSA and WGNAS

The working group should focus on:

- Consider and comment on Ecosystem and Fisheries overviews where available;
- b) For the aim of providing input for the Fisheries Overviews, consider and comment for the fisheries relevant to the working group on:
- i) descriptions of ecosystem impacts of fisheries
- ii) descriptions of developments and recent changes to the fisheries
- iii) mixed fisheries considerations, and
- iv) emerging issues of relevance for the management of the fisheries;
- c) Conduct an assessment on the stock(s) to be addressed in 2019 using the method (analytical, forecast or trends indicators) as described in the stock annex and produce a brief report of the work carried out regarding the stock, summarising where the item is relevant:
- i) Input data and examination of data quality;
- ii) Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;
- iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area) estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2018.
- iv) Estimate MSY proxy reference points for the category 3 and 4 stocks
- v) The developments in spawning stock biomass, total stock biomass, fishing mortality, catches (wanted and unwanted landings and discards) using the method described in the stock annex;
- vi) The state of the stocks against relevant reference points;
- vii) Catch scenarios for next year(s) for the stocks for which ICES has been requested to provide advice on fishing opportunities;
- viii)Historical and analytical performance of the assessment and catch options with a succint description of quality issues with these. For the analytical performance of category 1 and 2 age-structured assessment, report the mean Mohn's rho (assessment retrospective (bias) analysis) values for R, SSB and F. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working

Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

- d) Review progress on benchmark processes of relevance to the Expert Group;
- e) Prepare the data calls for the next year update assessment and for planned data evaluation workshops;
- f) Identify research needs of relevance for the work of the Expert Group.

Information of the stocks to be considered by each Expert Group is available here.

The ToRs are addressed in the sections shown in the text table below.

Stock	Addressed in Section
Herring in Subarea 4 and Division 3.a and 7.d (North Sea Autumn spawners)	Section 02
Herring in Division 3.a and subdivisions 20–24 (Western Baltic Spring spawners)	Section 03
Herring in divisions 6.a and 7.b-c	Section 04
Herring in divisions 6.a (South), 7.b–c, and 6.a (North), separately	Section 05
Herring in Division 7.a South of 52° 30′ N and 7.g-h and 7.j-k (Celtic Sea and South of Ireland)	Section 06
Herring in Division 7.a North of 52° 30′ N (Irish Sea)	Section 07
Stocks with limited data	Section 08
Sandeel in Division 3.a and Subarea 4	Section 09
Sprat in Division 3.a (Skagerrak - Kattegat)	Section 10
Sprat in Subarea 4 (North Sea) and Division 3.a (Kattegat-Skagerrak)	Section 11
Sprat in Division 7.d and 7.e	Section 12
Sprat in the Celtic Seas	Section 13

1.3 Reviews of groups or projects important for the WG

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

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

As usual WGCHAIRS met at the beginning of the year in preparation of the new year of advice and science working groups' activities.

Under the new ICES strategy, a new steering group, Fisheries Resources Steering Group (FRSG), will be created. Activities of advisory working groups such as HAWG will be conducted under the umbrella of FRSG. This re-organisation is mainly motivated by the intention to enhance the transfer of new science into advice and facilitate interaction between the individual working groups and both ACOM and SCICOM, FRSG will become operative throughout 2019. Advisory expert groups will maintain their prerogative of "closed groups" in the sense that members will be still nominated at a national level.

Overall, the format of the advice had no major changes. 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 assigning at least two members as auditors for each stock.

This year ICES has increased its attention towards evaluation of potential Conflict of Interest (CoI) in relation to any of its advisory activity. Expert groups are now considering CoI even more carefully than before with specific reference to a code of conduct which has been discussed and explicitly agreed by all members of HAWG at the beginning of the meeting.

WGCHAIRS remarked that while considerable progresses have been made in the documentation and quality assurance of scientific data (incl. both surveys and commercial data collected for scientific purposes), quality of the landing data is generally poorly documented by member countries. It remains the responsibility of the individual countries to implement quality assurance frameworks for the landings data.

From 2019, ICES will publish the reports from expert working groups (incl. assessment groups) as part of the new ICES scientific report series. This means that all the reports will have an ISSN and a DOI number, and most importantly authorship of the report will now lay on the members of the working group with the chairs named as editors and all the members presented as authors.

1.3.2 Working Group for International Pelagic Surveys (WGIPS)

The Working Group of International Pelagic Surveys (WGIPS) met in Santa Cruz, Spain on 14–18 January 2019. 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 2019 surveys.

Results of the surveys covered by WGIPS and coordination plans for the 2019 pelagic acoustic surveys are available from the WGIPS report (WGIPS, ICES 2019). The following text refers only to the surveys of relevance to HAWG.

Review of larvae surveys in 2018:

These surveys are no longer dealt with in WGIPS. From 2019 the planning, analysis and reporting on larvae surveys will fall under WGSINS. In the interim period results from for the 2017/18 larvae surveys can be found in the HAWG report, Section 3.3.2 and for 2018/19 they will be coordinated and reported on in WGEGGS2.

North Sea, West of Scotland and Malin Shelf summer herring acoustic surveys in 2018: 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 higher than previous year at 2.3 million tonnes (2017: 1.9) due to an increase in the number of fish (2017: 11.621 mill. fish, 2018: 12.315) and an increase in weight-at-age for mature herring. The spawning stock is dominated by young fish of age 4 and 5 wr, which is in accordance with the strongest year classes in the 2017 survey.

The 2018 estimate of **Western Baltic spring-spawning herring** 3+ group is 107 000 tonnes and 745 million. This is a decrease of 52 and 45%, respectively, compared to the 2017 estimates of 221 000 tonnes and 1353 million fish.

The **West of Scotland** estimate (6.a.N) of SSB is 152 000 tonnes and 875 million individuals, a small increase compared to the 139 000 tonnes and 765 million herring estimate in 2017.

The 2018 SSB estimate for the **Malin Shelf area (6.a and 7.b,c)** is 159 000 tonnes and 925 million individuals. This is a about the same level as the 2017 estimates (145 000 tonnes and 798 million herring). There was some herring distribution south of 56°N in 2017–2018; this resulted in a slightly higher estimate for the Malin Shelf compared to the West of Scotland.

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 2018 was estimated at 120 141 million individuals and the biomass at 834 000 tonnes (Table 5.10). This is nearly 3 times as many sprat as last year, the second highest in the time series and high above the long-term average of the time series, in terms of both abundance (137% above) and biomass (88%). The stock is dominated by 1-year-old sprat (89% in numbers). The estimate also included 0-gr sprat (3% in numbers, and 0.1% in biomass), which only occasionally is observed in the HERAS survey.

In for **sprat in Division 3.a**, the abundance in 2018 is estimated at 3438 million individuals and the biomass at 33 400 tonnes; the second highest estimate of the time series as for the North Sea. This is well above the long-term average both in terms of abundance (86%) and biomass (38%). The stock is dominated by 1- and 2-year-old sprat.

Irish Sea Acoustic Survey:

The herring abundance for the Irish Sea and North Channel (7.a.N) in Aug/Sept 2017 and Aug/Sept 2018 was reported by Northern Ireland The estimate of herring SSB of 91 332 tonnes for 2016 was near the series high 2010 estimate. In 2018 the estimate was 39 997 tonnes, similar to that observed in 2017. The biomass estimate of 54 661 tonnes for 1+ ringers is a 25% increase on last year's biomass estimate. Unlike in previous years when a large proportion of the 1+biomass estimate is seen in north of the Isle of Man and in North Channel, in the current year the majority of biomass was observed in the south east of the Isle of Man area. The western and northern Irish Sea are areas of mixed size fish. In 2018 the sampling intensity was relatively high during the 2018 survey with 32 successful trawls completed. The herring were fairly widely distributed within mixed schools at low abundance, with a few distinct high abundance areas. The bulk of 1+ herring targets in 2018 were observed off the east coast of the Isle of Man, and on the eastern coast of Northern Ireland, with a fairly scattered lower abundance observed throughout the Irish Sea. Sprat and 0-group herring were distributed around the periphery of the Irish Sea, with the most abundance of 0-group herring in the eastern side. 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 presented to WGIPS in 2017 prior to inclusion into the benchmark. The results of the survey is reported in the WGIPS 2018 report (ICES, 2018). The survey is included in the assessment as a SSB index. The SSB in 2017 was estimated as 2017 1 41, 683 declining to 38 974 in 2018. The herring were distributed within a few distinct high abundance areas to the southwest and southeast of the Isle of Man. The estimate of herring SSB from the 2018 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 2018 was reported by the Marine Institute, Ireland. The Celtic Sea herring stock was considered to have been contained within the survey area in 2018. The spawning stock biomass (SSB) estimate in 2018 was 7760 tonnes and is comparable to the 2017 survey estimate. Both years represent the lowest SSB points in the survey time series. The CV on the survey estimate was high (~0.50) in 2018. 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 WESPAS summer survey in June 2018 confirm the currently low standing stock abundance of herring in the Celtic Sea. The potential of a positive signal in recruitment was evident from survey catches with 0-group herring observed across the CSHAS survey area and further east into UK waters. The biomass and abundance of sprat in 2018 was higher than in 2017 and more in line with the 2016 estimate.

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 2018. Geographical coverage extended southwards in 2017 to include French waters in the western Channel and in 2018 was further extended in to Division 7.d Both the number of completed acoustic transects and trawls exceeded those achieved in 2017. Preliminary results indicated some differences in ichthyofauna observations when compared to 2017. In the Bristol Channel, other than the usual hotspot inside the estuary, the majority of fish biomass was found more inshore, as demonstrated also by the location of the trawl effort. In the French waters of the western Channel more fish activity was found along the western-most transects. Further east in the western Channel, very few schools were encountered, which matched last year's results. The transects east of Lyme Bay, sampled for the first time during PELTIC, yielded little fish biomass. Sprat was in general the dominant small pelagic species in the trawl samples, with highest densities in the eastern parts of the western Channel and the Bristol Channel. As in previous years, large schools in the Bristol Channel appeared to consist mainly of juvenile sprat, whereas those in the English Channel also included larger size classes. The age distribution of sprat in the survey area shows a marked distinction between the young fish (0 and 1) found in the Bristol Channel and the older age classes that occupy the Western English Channel. Whether the two clusters belong to the same stock has yet to be proved: the circulation pattern of the area would allow sprat eggs/larvae to travel northward, from division 7.e to 7.g; however, the formation of a front in late spring/early summer seems to suggest the hypothesis of two different stocks.

Sprat biomass had increased in Lyme Bay in 2017 (English Channel: 34 109 tonnes) compared to the low biomass estimate from 2016. A decline in biomass was observed in 2018 again to 17 091 tonnes.

1.3.3 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 prioritisation 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 2018) reviewed the following activities falling within its remit and of interest for HAWG:

- Herring (*Clupea harengus*) Otolith Microstructure (OM) exchange. In 2018, 4 readers from Sweden and Denmark took part in an exchange of ground and polished otoliths (n=96) from ICES areas 3.aN, 3.aS and 4.b, the overall agreement across readers was 45%. 23 of the samples had a genetically validated stock ID, there were just 5 of these where all 4 readers were in agreement with the genetic results. Readers agreed that overtime OM patterns have changed and it has become more and more difficult to clearly distinguish between the spawning types, mostly between the Western Baltic spring spawners (WBSS) and the Downs winter spawners. In early 2019 another exchange took place with the same 4 readers participating and all samples (n=93) had a genetically validated stock ID assigned. The overall agreement was 85% with the Downs winter spawners being the most difficult to identify correctly. The presence of samples from sub-stocks where the OM varies from those described in the past can cause confusion for the readers and work continues on updating reading guidelines using genetically identified stock IDs.
- The Workshop on sexual maturity staging of herring and sprat (WKMSHS2) concluded; agreement with the validated material (herring 52%) was much lower compared to the agreement with the modal stage (herring 74%); there was no improvement achieved over the calibration rounds for herring and a small improvement for sprat; males are generally more difficult to stage compared to females and a mismatch exists between the herring stage description and the WKMATCH scale.
- The Workshop for advancing sexual maturity staging in fish (WKASMSF) proposed the 'WKMATCH 2012 maturity scale revised', prepared conversion tables to be used when uploading national maturity data to the ICES survey and commercial fisheries databases and prepared an implementation plan for reporting maturity data in the 'WKMATCH 2012 maturity scale revised' to these databases from 1 January 2020.

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 data sets can be weighted in an assessment model according to their relative quality.

WGCATCH 2018 finalized best practice guidelines for sampling and estimation of foreign landings in national ports. These guidelines were based on case studies highlighting the present problems and successes with sampling of foreign landing (a lot of the case studies focused on small pelagic fish). WGCATCH 2018 started to work on best practice guidelines in data request and provision for frequency data (e.g. DLS stocks), by summarising current national practise and developing tools to support national data submitters and stock coordinators to summarise the quality of the data provided. Further the group continued the work on guidelines for best-practice in sampling of small-scale fisheries, data recording, estimation of commercial catches under the landing obligation and sampling of commercial catches, including by-catch of protected, endangered and threatened species (PETS).

1.3.4 WGSAM

The Working Group on Multispecies Assessment Methods WGSAM provides estimates of natural mortality (M) for a number of fish stocks based on estimates from multispecies models. WGSAM provides M estimates for the following HAWG stocks: North Sea herring (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 2019 HAWG assessments.

1.3.5 WKNSMSE

The Workshop on North Sea stocks Management Strategy Evaluation (WKNSMSE) evaluated long-term management strategies for a number of jointly-managed stocks in the North Sea between the European Union and Norway, following a request from EU-Norway. The North Sea Autumn spawning herring was among those stocks. The full-feedback simulations performed by WKNSMSE aimed to find "optimal" combinations of harvest control rule parameters (F_{target} and $B_{trigger}$) for management strategies with (scenarios C,D,E) or without (scenarios A,B) stability mechanisms (TAC constraints and banking and borrowing scenarios; see Table 1.2.5.1). "Optimal" combinations were defined as those combinations of F_{target} and $B_{trigger}$ that simultaneously maximised long-term yield while being precautionary (long-term risk 3 ≤ 5%).

The Management Strategy Evaluation (MSE) considers four components: the biological stock unit of herring in the North Sea [1], four fisheries targeting the stock unit [2], the fisheries-independent surveys [3], the stock assessment procedure which is used to obtain a perceived status of the stock unit and to set management targets [4]. The framework includes feedback loops, where over time, the result of setting management targets affects the stock unit the year after, and thereby also affects the fisheries and management. In order to reflect the uncertainties related to stock dynamics, fisheries dynamics and management implementation, the simulations are run with 1000 replicates, each representing a different but likely version of the true dynamics of the stock unit and fisheries.

Contrary to the expectations, the risk criteria does not stabilize in the medium to long term. Therefore the results referred to as "long-term" are achieved at equilibrium and are actually conditional to some of the assumptions (i.e., 20-year projection period, 1000 replicates and risk 3 ≤ 5% over the last 10 years). This means that the outcomes of the MSE should be considered precautionary only within the 20 years evaluated and the strategies should be re-evaluated within that time frame.

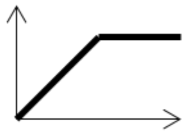
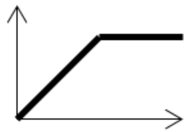
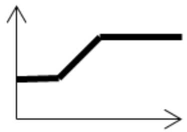
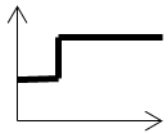
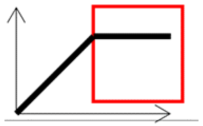
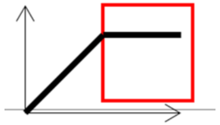
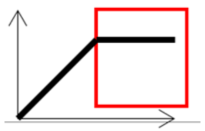
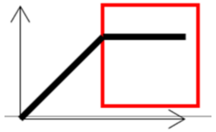
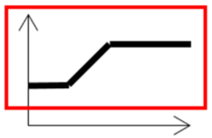
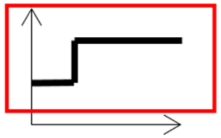
All the scenarios tested are precautionary with the exception of the strategy E for which no optimal target was found. In general, for all the other scenarios (A–D) there is less than 0.2% difference in the long-term yield (Table 1.2.5.2).

The optimal F_{target} values for all the scenarios (0.22–0.23) are somewhat smaller than the F_{MSY} value (0.26) estimated using EqSim at the last benchmark in 2018. Thus, the current F_{MSY} in combination with an MSY $B_{trigger}$ of 1.4 mt has an associated risk > 5%. There are fundamental differences in the way EqSim and the MSE evaluate risk and make use of implementation error which may explain the difference (i.e., the up to 50% flexibility for the human consumption fishery in 3a is accounted in the identification of the F_{target} but it is not part of the EqSim calculation).

Among the sensitivity tests performed, the MSE evaluated the consequences of reducing the bycatch of the B and D fleets which showed a reduction in risk and some consequent increase in fishing opportunities for the human consumption fishery (A-fleet). These results are in line with previous results as obtained in ICES 2015 (WKHerTAC).

Despite the use of high-performance clusters, computational time represented a challenge (running time for a 1000 replicate scenario was around 500 h with approx. 50 evaluations per core) which limited part of the evaluation.

Table 1.2.5.1 Management strategies for the North Sea herring stock tested at WKNSMSE.

HCR	A-fleet	B-fleet	Condition	Stability	Bank & Borrowing
A					
B					
C			if SSB > B_{trig}	TAC_y A-fleet in AdY 0.8 TAC_{y-1} < TAC_y < 1.25 TAC_{y-1}	+/-10%
D			if SSB > B_{trig}	TAC_y A+B-fleet in AdY 0.8 TAC_{y-1} < TAC_y < 1.25 TAC_{y-1}	+/-10%
E				TAC_y A+B-fleet in AdY 0.8 TAC_{y-1} < TAC_y < 1.25 TAC_{y-1}	+/-10% except when: SSB < B_{pa} & F > F_{pa} in AdY B < B_{pa} in AdY and CtY

SSB and F are calculated at spawning time; ImY, AdY, CtY are the intermediate, advice and continuation years. The red square shows when stability and flexibility measures apply.

Table 1.2.5.2 Short-, medium- and long-term yield (total catch) and SSB for the "optimised" strategies and for FMSY given the "optimal" $B_{trigger}$. Cases where risk3 > 5% are in red text. E is not included since no "optimum" was found for it. The time period are: short = 2019:2021, med = 2022:2026, long = 2027:2036. Management strategies with an asterisk indicate F_{target} = F_{MSY} and $B_{trigger}$ = MSY $B_{trigger}$.

Management Strategy	F case	F_{target}	$B_{trigger}$	Yield			SSB			risk3			IAV			Realised mean $F_{(2–6)}$		
				short	med	long	short	med	long	short	med	Long	short	med	long	short	med	long
F=0	**F=0**	**0**	**0**	**0**	**0**	**0**	**2310249**	**2643789**	**2687033**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A	**F_{target}**	**0.22**	**1400000**	**269747**	**339827**	**345646**	**1293350**	**1461235**	**1471026**	**0.037**	**0.025**	**0.046**	**0.186**	**0.147**	**0.151**	**0.179**	**0.219**	**0.219**
A*	F_{MSY}	0.26	1400000	296446	361936	358346	1253241	1370185	1363961	0.065	0.053	0.072	0.190	0.164	0.168	0.205	0.253	0.248
B	**F_{target}**	**0.22**	**1400000**	**271574**	**338313**	**344582**	**1291883**	**1456469**	**1467080**	**0.037**	**0.029**	**0.05**	**0.183**	**0.147**	**0.149**	**0.179**	**0.219**	**0.219**
B*	F_{MSY}	0.26	1400000	298388	359776	356365	1250953	1360849	1354684	0.061	0.054	0.081	0.188	0.165	0.168	0.205	0.251	0.247
C	**F_{target}**	**0.22**	**1400000**	**269690**	**335932**	**345095**	**1293654**	**1469648**	**1473686**	**0.037**	**0.025**	**0.048**	**0.186**	**0.158**	**0.157**	**0.179**	**0.219**	**0.219**
C*	F_{MSY}	0.26	1400000	296510	359024	358001	1253728	1377431	1365667	0.062	0.051	0.076	0.190	0.172	0.171	0.205	0.253	0.249
D	**F_{target}**	**0.23**	**1400000**	**276805**	**342173**	**349286**	**1283906**	**1446680**	**1446241**	**0.048**	**0.03**	**0.049**	**0.186**	**0.162**	**0.159**	**0.186**	**0.228**	**0.228**
D*	F_{MSY}	0.26	1400000	296510	359438	358937	1253750	1378526	1368652	0.061	0.047	0.076	0.189	0.171	0.171	0.205	0.254	0.249

1.3.6 WKSPRAT & WKSPRATMSE

The 2018 benchmark workshop on sprat (WKSPRAT) focused on the following three stocks: North Sea (area 4) sprat, Kattegat-Skagerrak (area 3.a) sprat and the Channel sprat. During the benchmark process, several evidences including genetics, otolith shape, recruitment and cohort dynamics were presented on the connection between sprat in the North Sea and in the Kattegat-Skagerrak. It was therefore agreed to merge the two stocks and assess them as one stock assessment unit. For the purposes of the new joined assessment for the two areas, both the catch data and the indices of abundance from 3.a were included in the data from area 4. Three surveys are carried out throughout the assessment area including the IBTS in Q1 and Q3 and the acoustic HERAS survey. All the surveys were used as tuning indices in the model. The indices were standardized using a delta-GAM approach: the inclusion of 3.a data increased the internal consistency between all age classes for all indices. The SMS model, previously used to assess the North Sea component, was used to assess the new combined stock. The final model formulation includes a power function for the age 0 catchability of IBTS Q1, a constant maturity ogive and the inclusion of the very few catches reported for Q4 in the Q1 of the following year. The new stock assessment shows a considerable improvement in the retrospective pattern, as well a better fitting to some ages of the IBTS surveys. The stock reference points were revised following ICES standard guidelines using a segmented stock recruitment relationship limited to years from 1982 and onwards. B_{lim} was estimated at 94 000 t as the breakpoint of the segmented regression and B_{pa} was derived from B_{lim} at a value of 124 946 t. However, an escapement strategy, where the stock is fished down to B_{pa}, has been proved not to be precautionary for such stock, unless an F limit control rule (F_{cap}) is applied. For this reason, a full closed loop management strategy evaluation was carried out after the benchmark by WKSPRATMSE to test for different F_{cap} values, where the F_{cap} chosen corresponds to the F providing a probability of SSB falling below B_{lim} lower than 5%. The results suggested that an F_{cap} of 0.69 is precautionary under the assumption that only errors in the stock numbers and exploitation patterns are included.

WKSPRAT benchmarked also sprat from the area 7.d,e. Not enough evidences were available to change the boundaries of this stock. An acoustic survey (revised for the benchmark) is carried out in the English part of area 7.e since 2013, and extended to the French part of 7.e in 2017 and to the Eastern Channel in 2018. In addition, an IBTS index in Q1 is available for the Eastern Channel from 2007 onwards. Overall, the short time series in the acoustic index and the lack of sufficient contrast in the data do not allow any analytical model to converge. Thus, the stock is in a category 3 (data poor stock). The benchmark proposed a seasonal advice based on an empirical method where trends are informed by both the indices, but only the acoustic survey is used for provision of the advice. In line with preliminary results from WKLIFE, the benchmark agreed that the "2-over-3" rule is not appropriate for short, highly productive stocks as sprat in area 7.d,e. Therefore, WKSPRATMSE compared through simulations the performances of the alternative "1-over-2" rule and of different fixed harvest rates. The results suggested that a 1-over-2 rule might cause the stock to fall below safe levels and eventually to collapse because the rule is not reactive enough to limit the catches when there is a recruitment failure. The risk decreases but remains still above safe limits also when removing the uncertainty cap. Simulations suggest that a 20% fixed harvest rate may be considered appropriate to maintain the stock at safe biomass levels and to produce relatively high yield. Further work is required in the light of the relevant upcoming Workshop for Data-limited Short-lived Stocks (WKDLSSLS).

1.3.7 IBPher6a7bc

The Inter-Benchmark Protocol for Herring in 6.a, 7.b-c 2019 (IBPher6a7bc, ICES 2019) was held to seek a solution to the consistent and increasing retrospective bias in the assessment of this herring stock.

At the meeting several improvements to the survey series used in the assessment were presented and reviewed. This included re-calculated and extended Scottish West Coast International Bottom Trawl Survey Quarter 1 and Quarter 4 (SWS BTS Q1 and Q4) and the two acoustic survey indices used in the assessment were re-examined and combined in to one to give a better acoustic index. Survey data analysis improvements were carried out first and agreed, and model optimisation was performed with the improved indices in the attempt to minimise the retrospective bias.

Extensive work was carried out to find a model configuration that would improve the retrospective, but it became clear that minimising the retrospective bias caused problems elsewhere in the models. Eventually, the interbenchmark agreed on a final model configuration. Although it was agreed the final model is a better assessment, there is still a retrospective bias. The new assessment also provides a radically different perception of the stock than previously and the assessment output raises a number of questions as to the dynamics of these combined stocks, over the time series that could not be investigated in depth during the inter-benchmark.

With an agreed final assessment the MSY and PA reference points were investigated according to ICES guidelines. The new stock assessment data, when implemented in the routines for estimating the reference points, using the same procedures as previously, lead to a number of questions as to how one could ‘objectively’ apply the ICES guidelines for estimating reference points. Extensive explorations, including limiting the length of the time series, indicated that the reference points were very sensitive to the choice of input data.

Surplus Production in Continuous Time (SPiCT) analysis was also undertaken but did not provide an alternative way of estimating sensible/believable reference points. The final conclusion was that since there was no objective way to choose a definitive data set for use in calculating a set of plausible reference points, no new reference points, based on the new assessment, were presented.

In regard to advice, it was decided that the assessment should be considered as a representation of trends rather than absolute estimates of stock size. Therefore, it is appropriate to consider the stock assessment as category 3 so that relative changes in fishing and stock size are used as basis for ICES advice (i.e the 2/3 rule, where advice based on previous advice, modified according to index information; typically the trend in the last 5-years of the index).

1.3.8 IHLS and MIK surveys

The International herring larvae survey (IHLS) index provides information on the contribution and distribution of the different spawning components to the North Sea herring stock. This is the only index currently used in the assessment to provide information on the relative sizes of the four North Sea herring stock components, as in the other surveys or catch data the fish cannot be split into the different spawning components. The IHLS thus provides important information for the management of this stock.

In recent years the coverage of the IHLS survey has been compromised due to technical issues with the vessels available to conduct the surveys. This has led to the decision in 2018 to reject the information of 3 of the 4 surveys in the IHLS. Due to this break in the time-series it is necessary to review the current setup of the IHLS. Because information on the relative sizes of stock components of North Sea herring is required, HAWG is recommending that the Working Group on Surveys on Ichthyoplankton in the North Sea and adjacent Seas (WGSINS) review the current design of the IHLS, in the light of the available survey effort, to deliver information on the relative stock components abundances, and if necessary to implement a new survey protocol that can deliver these data.

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, 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. Due to time constraints it was not possible to cover the whole larvae distribution area. Compared to the MIK, numbers of herring larvae found in the DRS samples were much higher per sample. Length distributions of the herring larvae in the DRS were very similar to that for the MIK in 2018.

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 one year 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. In 2019 IMR, Norway will participate in the DRS and for 2020 Danish Industry and IFREMER, France are investigating possibly participation. HAWG recommends that WGSINS investigate calculation of a Downs and combined North Sea herring recruitment index based on the combination of the IBTS-MIK and DRS data.

1.3.9 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. Presently only the mixing between North Sea herring and Western Baltic Spring spawning herring in catches in the transfer area and in the HERAS survey in the Danish and Norwegian strata is 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 also arranged to facilitate exchange of ideas and foster collaboration of researchers working of different aspects and methods and to update HAWG on progress on projects currently underway of relevance to HAWG stocks.

1.3.9.1 Stock separation mini symposium

The mini symposium was held on 19th March with 6 talks on projects of relevance to HAWG stocks. Detailed summaries of these talks are in Annex 6.

Edward Farrell from UCD updated the HAWG on progress made to assess the genetic population structure of herring stocks in ICES 6.a/7.bc and to develop genetic baselines of the 6.aN and 6.aS/7.bc stocks to be used to discriminate mixed aggregations of non-spawning herring in area 6a.

Dorte Bekkevold from DTU Aqua presented how Single Nucleotide Polymorphism (SNP) marker classification tools can already be used with high statistical accuracy to distinguish among major herring stocks and sub-stocks mixing in the North Sea, 3.a and Division 22–25.

Florian Berg from IMR is working on splitting Norwegian Spring-spawning herring, North Sea and Western Baltic Spring spawning herring in the HERAS survey and in catches using otolith shape analysis.

Julie Coad Davies from DTU Aqua presented the latest in using otolith microstructure to separate mixed catches of Western Baltic Spring spawners and North Sea herring and presented results from calibration exercises between readers using otoliths from fish genetically assigned to stock.

Jan Arge Jacobsen from Faroe Marine Research Institute presented the otolith classification method used to separate Norwegian spring-spawning herring (NSSH) and other herring stocks (e.g. Icelandic summer-spawning ISSH, Faroese autumn-spawning (FASH) and North Sea type autumn-spawning herring (NASH)) in the International ecosystem surveys in the Nordic Seas (IESNS and IESSNS).

Finally, Michaël Gras from the Marine Institute in Ireland gave an update on the project to use body and otolith morphometry to discriminate herring in 6.a, 7.bc.

Seeing these projects presented together made it clear how much progress is being made towards understanding the population structures of the herring stocks assessed in HAWG and towards developing operational tools to allow routine discrimination of different stocks in the surveys and catches used in the assessments. Many of the researchers already collaborate and exchange material and compare results and will continue to do so, and already were discussing how to further increase these collaborations. One of the outcomes from the symposium is a drive to collect tissue samples for genetic analysis from the entire HERAS survey area in 2019 as well as otoliths from the same fish for shape analysis from the northern most area. This will create a unique dataset to compare results from several methods and help to identify the best method (or combination of methods) to reliably separate different stocks in this survey (6.aN, 6.aS, North Sea Autumn spawners, Western Baltic Spring spawners and potentially also Norwegian spring spawners).

It would be valuable to continue to invite presentations to HAWG on this topic to continue to work towards solutions until enough progress is made to warrant a second round of workshops along the lines of WKSIDAC and WKMIXHER.

1.3.9.2 WKMIXHER 2018

The workshop on mixing of western and central Baltic herring stocks (WKMixHer) took place on 11–13 September 2018 in Gdynia. The aims of workshop were to review recent research and available methods to discriminate western Baltic spring spawning herring and central Baltic herring in mixed catches, evaluate potential implication of mixing for the assessment, develop a coordinated plan to collect and analyse relevant data to quantify the mixing. The central Baltic herring is dominated by a northern component and a southern component and analyses presented at the workshop suggested how the latter actually shares numerous characters with the adjacent western Baltic herring stock (i.e., growth pattern, otolith shape, parasite infestation, etc.). Preliminary analyses performed in conclusion of the workshop suggested a progressive genetic differentiation along the entire southern Baltic coasts from SD24 to SD26 rather than a clear cut division between different assessment units. The workshop results suggest that the issue of separating of the Central Baltic herring stock from the western Baltic spring spawning herring stock is related to understand if the southern component should be considered together with the western Baltic herring, maintained with the central Baltic herring, or if it should be considered separately. Depending on the task, the methodologies reviewed for stock identification could be promising or insufficient. A coordinated plan for sampling herring at spawning time was delineated at the workshop with the objective to validate herring assessment units in the area and look for operational methods to separate them in mixed catches.

Table 1.2.9.2.1 Methodologies for separating the different herring components found in the western and central Baltic (SD22–26) and discussed at the workshop. WBC: WBSSH from SD22–24; CBSC: Southern component of Spring spawning CBH; CBNC: Northern component of the Spring spawning CBH; AC: Autumn spawning component. The score-card below is limited to the results presented at the workshop, the suitability of the different techniques for stock discrimination span from high (green), limited or *to be confirmed* TBC (yellow) and none (red). Copied from WKMixHer report (ICES, 2018).

Stock discrimination methods	WBC-CBSC	WBC-CBNC	CBSC-CBNC	WBC-AC	CBSC-AC	CBNC-AC
Growth	NO	YES	YES	limited	limited	limited
Natural tags *Anisakis simplex*	NO	YES	YES	NA	NA	NA
Otolith shape	limited	YES	YES	YES	YES	YES
Body morphometry	TBC	YES	YES	NA	NA	NA
Vertebrae	NA	NA	NA	NA	NA	NA
Other meristics	NA	NA	NA	NA	NA	NA
Otolith chemistry	TBC	TBC	NA	NA	NA	NA
Genetics 9 microsatellite	limited	limited	limited	NA	NA	NA
Genetics 96 SNPs	TBC	YES	YES	YES	YES	YES

1.3.9.3 WKSIDAC 2017

In 2017 the "Workshop on stock identification and allocation of catches of herring to stocks" (WKSIDAC) was held in Galway, Ireland.

This workshop had several objectives; improve the accuracy and precision of the methods currently applied across laboratories by area; compare alternative available methods; outline a common generic approach in terms of methods; and draft guidelines for conducting stock-splits for assessment purposes. Key issues relating to stock mixes in each of the management areas (2, 3, 5, 6 and 7) were outlined along with why the stock identification was important for the assessments of each of these stocks (see Table 1.2.5.1).

Table 1.2.5.1: Co-occurrence of herring stocks in management areas.

Stocks/stock complexes	stockcode	Spawning components	2a	3a	3 sd22-24	3 sd25	4a	4bc	5a	5b	6aN	6aS	clyde	7aN	7bc	7d	7e	7g-k
Norwegian Spring Spawning	her.27.1-24a514a	NSSH	x	?			?		?	?	?							
North Sea Autumn Spawning	her.3a47d	Downs	x2							x	x	x	x					
		Banks	x2							x	x	x	x					
		Buchan	x2							x	x	x	x					
		Orkney-Shetland	x2							x	x	x	x					
Western Baltic Spring Spawning	her.27.20-24	Rugen	?	x	x	x	x											
		local Spring		x	x													
		local Aut-Winter		x	?													
Central Baltic	her.27.25-2932	CBH		?	x	x												
North West of the British Isles	her.27.6a7bc	6aN	?				?			?	x	x			x			
		6aS-7bc					?				x	x		?	x			
		Clyde									x	x	x		x			
Irish Sea	her.27.7c	Douglas Bank									x	x	x	x	x			
		Mourne									x	x	x	x	x			
Celtic Sea, South West Ireland	her.27.irls	Celtic Sea					-							x			?	x

The workshop concluded from the review on information on stock identification and validation work done so far that there was no consistency between areas and in most either there was no validation or the validation needed to be updated. Only a few areas currently utilize herring stock identification methodology for the assessments, namely areas 3.a and 4 for separation of WBSS from NSAS although the methodology was not ideal, Icelandic waters for separation of ISS from NSS and in Faroese waters for separating autumn from spring spawners. The workshop was focused on potential methods and highlighted the necessity of validation and Standard protocols or operating procedures. The workshop also concluded that the optimal allocation method for stock assessment purposes (as perceived by the Workshop members) varied by area (see Table 1.2.5.2). Otolith shape analyses appeared the most widely recommended, however, other techniques such as genetics and otolith microstructure and micro-chemistry would be necessary for validating the shape analyses results. In the Baltic, separation based on the growth, through length-at-age was favoured and in Area 6.a, a combined approach using genetics and morphology is preferred. Baselines would also need to be updated on a regular basis.

The Workshop was not able to provide an outline of a manual by method for stock identification of herring for implementation in individual laboratories nor provide guidance on retrospective corrections of herring survey time-series but recommended that these topics need to be taken up in some future Workshop/Meeting when further progress has been made.

Table 1.2.5.2. Methodologies for separating herring stocks in each of the management areas.

Table 2: methods in areas	2a	3a	3 sd22-24	3 sd25	4a	4bc	5a	5b	6aN	6aS	Clyde	7bc	7aN	7d	7e	7g-k
Genetic analyses		a,c	a,c	a,c	a,c,e	a,c,e	a	a	c	c		c	c	b	b	c
Otoliths shape analyses		a,b,d	c	c	b	b	b	b	c	c		c	c	a		a
Otolith microstructure		a,b,d			e	e							c			c
Otolith microchemistry		a			e	e			a	a		a	a	a		a
Otolith isotopes		a														
Morphometrics			a						c	c		c	a			a
Parasites		a?,b	a,b	a,b	a	a			a	a		a	a			a
Fatty acids									-	-		-	-			-
Vertebrae counts		d?			a,b,d	a			a	a		a	a			a
Pyloric caecae					a	a			a	a		a	a			a
Tagging			a		a	a			a	a		a	a			a
Growth			a,b,d													

a paper/historic
b data collection
c planned application
d in use in the assessment
e screening/validation

1.3.10 Other activities relevant for HAWG

Industry-Science survey of herring in 6.a, 7b–c. in 2018.

(see Section 06 for additional details).

In 2018, 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 (EU2018/120), 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 and 2017 surveys.

Biological samples taken during the survey and subsequent commercial catches were used to construct a catch-at-age used in the 2019 stock assessment. Acoustic surveys on the biomass of the spawning components (ICES, 2019) provide a third set of data points in a spawning stock time series. Morphometric and 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. This information would be considered in a future benchmark assessment.

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 1.2.6.1). 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 and 2019 IBTSQ1 surveys, the occurrences of *Ichthyophonus* in the Norwegian part were again fairly low: 4.4% and less than 1%, respectively. In the Kattegat-Skagerrak, the data suggests levels of incidence generally < 3% but with areas of > 20% infestation (Figure 1.2.6.2) and with a peak around 50% in 45G0 in 2018, although the sample was rather small. Infestation in Q3 2018 appears more localised in the north-eastern part of the Skagerrak compared to 2017. In 2017 the infestation affected mainly age 0-4 and rapidly declined for older fish, while in 2018 also fish of age 5–7 present some level of infestation. 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.

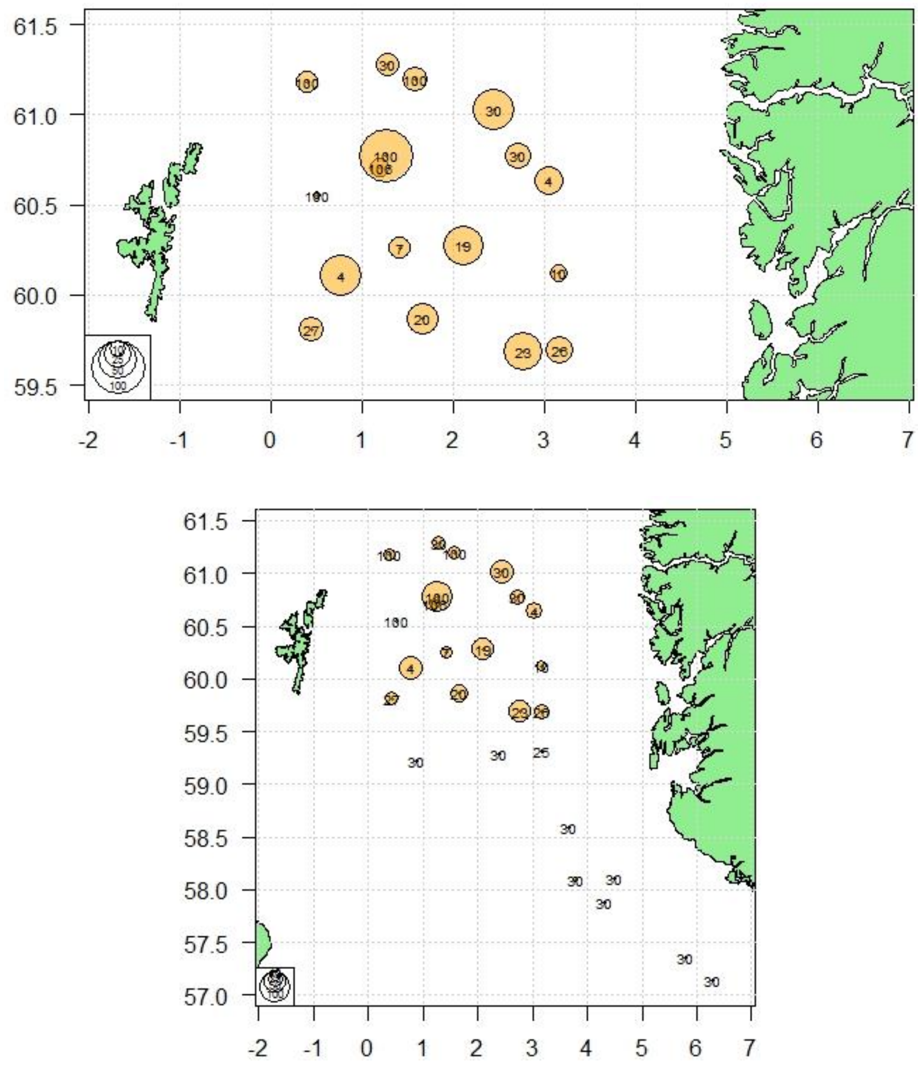


Figure 1.2.6.1 Occurrence of *Ichthyophonus hoferi* in the Norwegian part of the IBTSQ1 2017. Bubble size show the percentage of diseased herring, whereas the numbers show the number of herring.

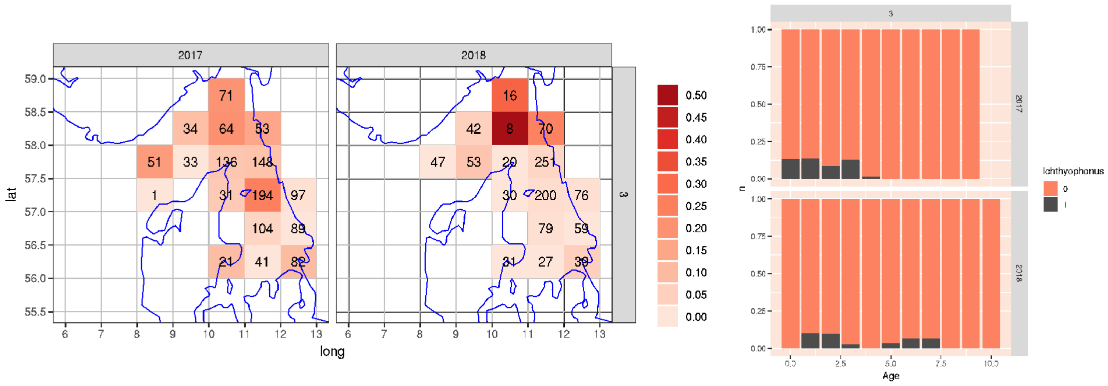


Figure 1.2.6.2 Occurrence of *Ichthyophonus hoferi* in the Kattegat-Skagerrak from Swedish samples collected during the IBTSQ3 2017–2018. Left map with distribution of the proportion of infested herring and number of samples in each rectangle; right distribution of infestation among ages.

HAWG's feedbacks to RDBES

During this year meeting, HAWG had a discussed on the process leading to a joint regional estimation of assessment input data. In particular, HAWG finds that it would be preferable if the estimator role is led by a single individual with input from national experts. This is preferred over an intermediate step within the RDBES wherein the estimation is carried out by multiple individuals with intermediate creation of data subsets. A single estimation would be carried out using a scripted method prepared with input from all national experts currently carrying out estimation procedures. This represents a collaborative approach to define a combined method as a foundation of a single estimation process, it is foreseen that the responsibility to apply the combined method would be taken by a single individual e.g. the stock coordinator.

<table>
<tr><td>Countries\Role</td><td>National Expert</td><td>Estimator Role</td><td>Stock coordinator Role</td></tr>
<tr><td>Tasks-></td><td>View data and view estimation</td><td>Perform the estimation</td><td>View/check all data and combine all national estimates into the stock estimate and export it</td></tr>
<tr><td>Country 1</td><td>Person 1</td><td>Person 1 working with Person 3</td><td rowspan="4">Person 3</td></tr>
<tr><td>Country 2</td><td>Person 2</td><td>Person 3</td></tr>
<tr><td>Country 3</td><td>Person 3</td><td>Person 3</td></tr>
<tr><td>Country 4</td><td>Person 4</td><td>Person 4 working with Person 3</td></tr>
</table>

HAWG also discussed the importance of implementing a framework for co-production and feedback which could allow participation of the different actors to the actual estimation. Need for data check and quality control procedures has been stressed by the group. The general process discussed and proposed by HAWG can be summarised in the main following steps:

- Data are submitted by individual countries which have responsibility on the quality of what they submit (procedures for checking data quality at the level of submission are necessary and should be expected).

- Once data are in the RDB the stock coordinator runs a first diagnostic script which check the data quality once again and eventually report back to the data submitter possible "anomalies". Ideally, this should trigger an iterative process where errors are corrected with amendments on the initial submission.
- The stock coordinator runs an exploratory data analysis script which produces both visual and tabulated representation of the data. These are circulated among the stock coordinator, assessor and all the experts working on the stock for comments and feedback.
- Once agreed on the quality and interpretation of the data, the stock coordinator runs the estimation script which implements an estimation procedure agreed among the stock coordinator, assessor and other experts contributing to the assessment of the stock. Visual and tabulated output (i.e., WECA, CANUM, …) are circulated among these same experts for comments and feedback.
- Once agreed on the representativeness and quality of the estimation outputs, these can be passed to the assessment model.

1.4 Commercial catch data collation, sampling, and terminology

1.4.1 Commercial catch and sampling: data collation and handling

Input spreadsheet and initial data processing

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

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 1 March 2019 All EU member states and Norway delivered their data in due time.

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

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

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

1.4.2 Sampling

Quality of sampling for the whole area

The level of catch sampling by area is given in the table below for all herring stocks covered by HAWG (in terms of fraction of catch sampled and number of age readings per 1000 tonnes catch). There is considerable variation between areas. Further details of the sampling quality and the required 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)	74581	71183	1247	17
4.a(W)	374490	335958	5612	15
4.b	107796	80034	1455	13
4.c	2188	671	109	50
7.d	43277	14284	445	10
7.a(N)	6804	3567	1119	164
6.a(N)	4 063	3 867	717	176
3.a	23258	20745	3567	153
SD22-24	18992	18860	4675	246
Celtic, 7.j	3982	3671	599	150
6.a(S), 7.b and 7.c	1495	1495	1852	1239

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

1.4.3 Terminology

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

1.5 Methods Used

1.5.1 SAM

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

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

1.5.2 ASAP

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

1.5.3 SMS

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

1.5.4 Short term predictions

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

The Western Baltic Spring Spawning herring uses an R-based multi-fleet forecast routine available at www.stockassessment.org.

1.5.5 Reference Points

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

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

The 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 on-going discussion on reference points.

1.5.6 Repository setup for HAWG

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

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

1.6 Ecosystem overview and considerations

General ecosystem overviews for the areas relevant for 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, 2016a, 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 in the biology and ecology of species and populations (including biological and environmental drivers), and disease.

It should be pointed out that whilst 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. 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 currently 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 recent ACOM request (March 2019), HAWG has collected information 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 parenthesis) 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 was 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	0	0	0	0	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

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

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

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

The North Sea herring fishery is a multinational fishery that seasonally targets herring in the North Sea and English Channel. An industrial fishery, which catches juvenile herring as a by-catch 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 by-catch 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 by-catch juvenile herring. The pelagic fisheries on herring and mackerel 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 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 larvae 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. The influence of the environment of herring productivity means that the biomass will always fluctuate. North Sea herring has a complex sub-stock structure with different spawning components, producing offspring with different morphometric and physiological characteristics, different growth patterns and differing migration routes. Productivity of the spawning components varies. The three northern components show similar recruitment trends and differ from the Downs component, 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 may occur in the trawl fishery for herring. In addition, North Sea herring are also caught within Division 3.a. The by-catch of sea mammals and birds is low enough to be below detection levels based on observer programmes. At present there is a very limited 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 by-catch 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 by-catch 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 sea birds. 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 the 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 by-catch 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. Whilst 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 from 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 second order 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 by-catch is acknowledged for this fishery with by-catch regulations in force. The by-catch 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 by-catch 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 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 by-catch. If a fishery was to be prosecuted in the Clyde and Irish Seas then by-catch of young herring may become an issue due to the overlap in distribution between young herring and sprat. 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. 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 sub-populations. Whereas the fishing grounds are assumed to remain relatively constant over time, the actual distribution of the fishery varies greatly from year to year in response to both changes in the availability of sandeel and changes in management between areas.

Sandeel is targeted by a highly seasonal industrial fishery which has experienced a progressive change towards fewer larger vessels owing most of the quota since the introduction of ITQ in

2004. Time restrictions and bycatch limits represent the main management measures. Although the fishery has little bycatch of protected species, competition with other predators is a central aspect of the sandeel management within an ecosystem approach.

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

1.8 Stock overview

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

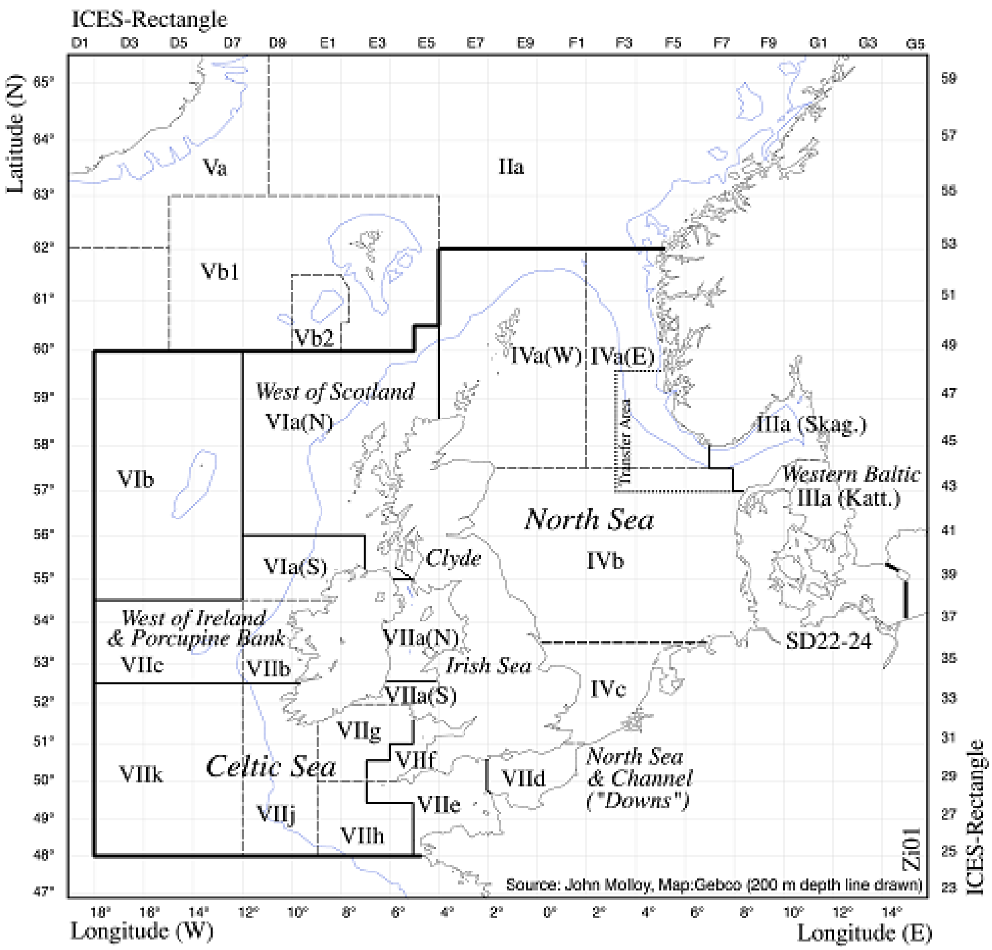


Figure 1.7.1 ICES areas as used for the assessment of herring stocks south of 62°N. Area names in italics indicate the area separation applied to the commercial catch and sampling data kept in long term storage. "Transfer area" refers to the transfer of Western Baltic Spring Spawners caught in the North 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. In 2019, no management plan was in place and the advice is based on the F_{MSY} advice rule. The spawning stock at spawning time in 2018 is estimated at 1.9 million tonnes. Recruitment in 2018 has increased compared to 2017 but remains within the low recruitment regime observed since 2015. The strongest recruitment remains the one observed back in 2014. Mean $F_{2\text{–}6}$ in 2018 is estimated at approximately 0.21, which is below F_{MSY}. The SSB for the stock from the 2019 assessment has been revised upward for a number of years.

In 2019 SSB is expected to decrease to ~1.5 million tonnes. Under all scenarios, SSB is predicted to decrease in 2020 (to approx. 1.3 million tonnes) and further in 2021 to around 1.1 million tonnes. SSB is expected to be above B_{pa} in 2020 and 2021.

Western Baltic Spring Spawners (her.27.20-24) is the only spring spawning stock assessed within this WG. It is distributed in the eastern part of the North Sea, the Skagerrak, the Kattegat and the subdivisions 22, 23 and 24. Within the northern area, the stock mixes with North Sea autumn spawners, and recently mixing with Central Baltic herring stock has been reported in the western Baltic area. The stock has decreased consistently during the second half of the 2000s. SSB was at a minimum of about 70 000 t in 2011 and recruitment is record low in 2018. Under a historical perspective the estimate of SSB of 74 132 tonnes in 2018 is considered low, below both B_{pa} and B_{lim}. Fishing mortality ($F_{3\text{–}6}$) was reduced from 0.50 in 2009 to 0.37 in 2011. It had then remained stable slightly above F_{MSY} (0.31) until 2015 (~0.36) but showed an increase in recent years with an estimated $F_{3\text{-}6}$ in 2018 well above F_{MSY} (0.416). The 2020 advised catch of WBSS is 0 t, which if applied by managers, will result in an increase in SSB from 76 273 t in 2020 to 101 269 t in 2021. The zero catch will not allow the stock to rebuild above B_{lim} (120 000 t) by 2021.

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 23 000 t in 2018, which is below B_{pa} (at 54 000 t) and B_{lim} (34 000 t). Recruitment has been below average since 2013. Fishing mortality ($F_{2\text{–}5}$) declined between 2003 and 2009 but started to rise again in 2010 due to increased catches. F decreased in 2018 in line with reduced catches. This year assessment estimates a fishing mortality, $F_{2\text{–}5}$ of 0.33 in 2018 which a decrease from 2017 (0.64) but above the F_{MSY} (0.26) and below F_{lim} (0.45). Short term projections predict SSB to remain around 23 000 t in 2019.

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 estimated combined. 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 in 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 2018, SSB and recruitment have been estimated at 22 020 t and 333 701 thousand respectively, estimates of SSB in recent years appear to be relatively stable. $F_{4–6}$ is estimated at 0.16 in 2018. Under the MSY approach the stock is expected to show minor decline to 22 005 t in 2020.

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. Sprat in Division 3.a and Subarea 4 were combined into a single assessment unit during the recent WKSPRAT benchmark (ICES, 2018). Various changes were made to the assessment model, which improved the quality in terms of both fitting and retrospective bias. The advice is based on the MSY escapement strategy with an additional precautionary F_{cap} which has been re-evaluated by a dedicated workshop (WKSPRATMSE; ICES 2019). 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. The long-term dynamics and perception of the status of the combined stock is consistent with previous perception for sprat in Subarea 4. 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 2019 show an SSB of 249 000 t which is nearly double of B_{pa} (125 000 t). The ICES advise for the period 1 July 2019–30 June 2020 indicates that catches of sprat should not exceed 138 726 t.

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 2018 remained at low level in relation to the estimates for 2013–2015. The advised catch for 2020 is 20% lower compared to last year (applying the uncertainty cap).

Sprat in the Celtic Sea (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 inter-annual 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 eco-region 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 sub-populations. 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) since 2016, but a marked decrease is estimated in the last year which brings the SSB at the beginning of 2019 down to 97 000 t which is below B_{lim} (110 000 t). Recruitment in 2018 was slightly above the geometric mean of the time-series, following the 2017 lowest record. Fishing mortality (F) has fluctuated, showing a declining trend since the mid-2000s followed by an increase in 2017 and 2018 to approximately the long-term average. The pronounced decrease in SSB contributes to a reduction in the advised catch.

A2: SSB has been below B_{lim} since 2004 (except in 2011), it increased in 2018 to above B_{pa} as the result of the exceptionally high 2016 year class but decreased again in 2019 to just below B_{lim}. With the exception of 2016, recruitment has been low since 2000 and continued to be very low in the last two years. A zero-catch advice is confirmed for this year.

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 270 000 t in 2018 followed by a decrease to around 182 600 t at the beginning of 2019 consistently with the low 2017 recruitment. The recruitments in 2016 and 2018 were among the five highest on record which explain the 23% increase in the advised catch.

A4: Fishing mortality (F) has been low since 2006 but increased in 2018. SSB has increased from the time-series low in 2009 to levels well above precautionary reference points (B_{pa} = MSY $B_{escapement}$) and has remained at this level since 2016. The 2016 and 2017 year classes are estimated to be above the long-term average, but the 2018 year class is estimated to be the second lowest on record. This results in SSB falling to just below MSY $B_{escapement}$ in 2020, even in the absence of fishing, which triggered a zero-catch advice.

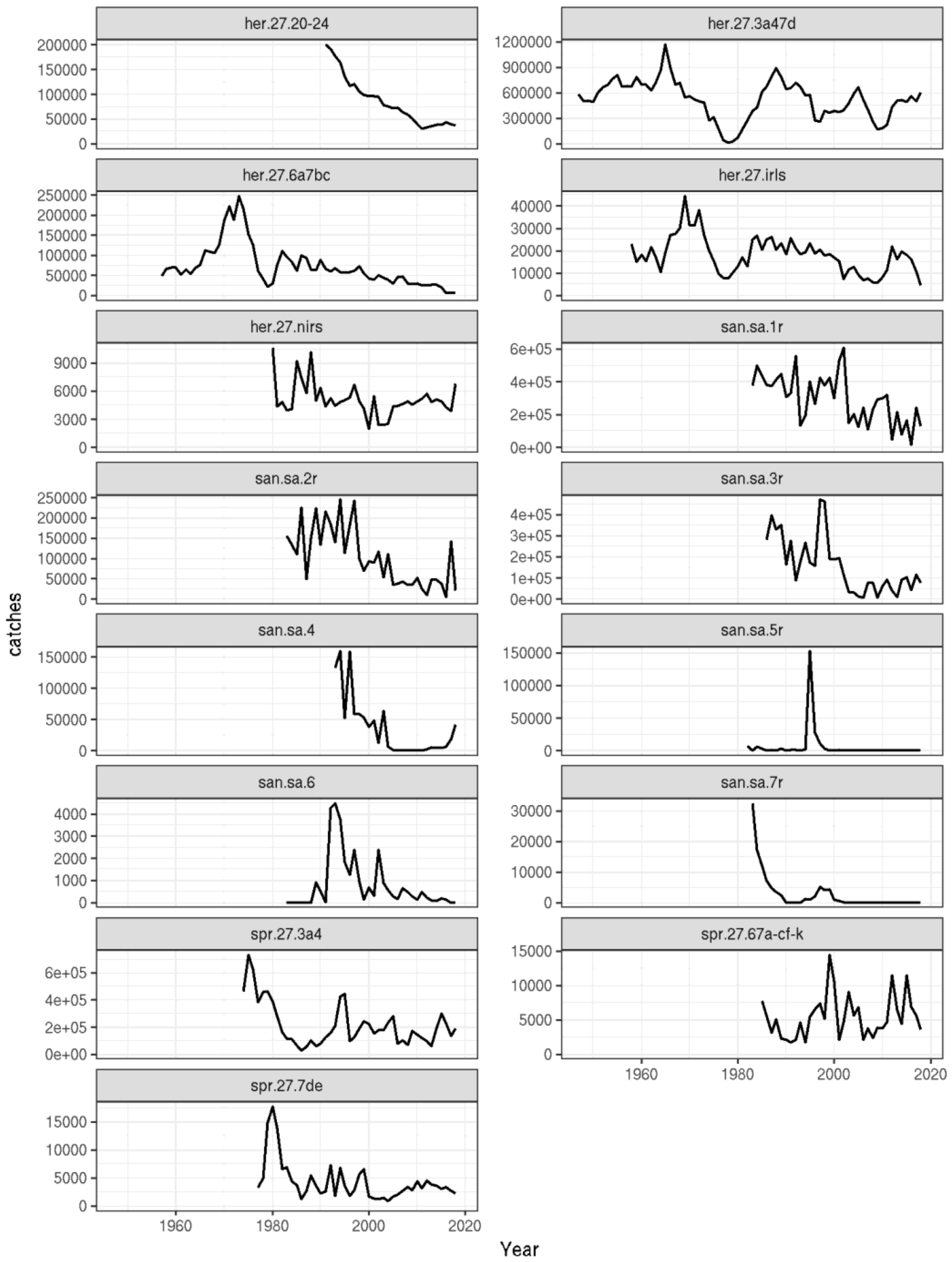


Figure 1.7.2 WG estimates of catch/landings (yield) of the herring, sprat and sandeel stocks presented in HAWG 2019.

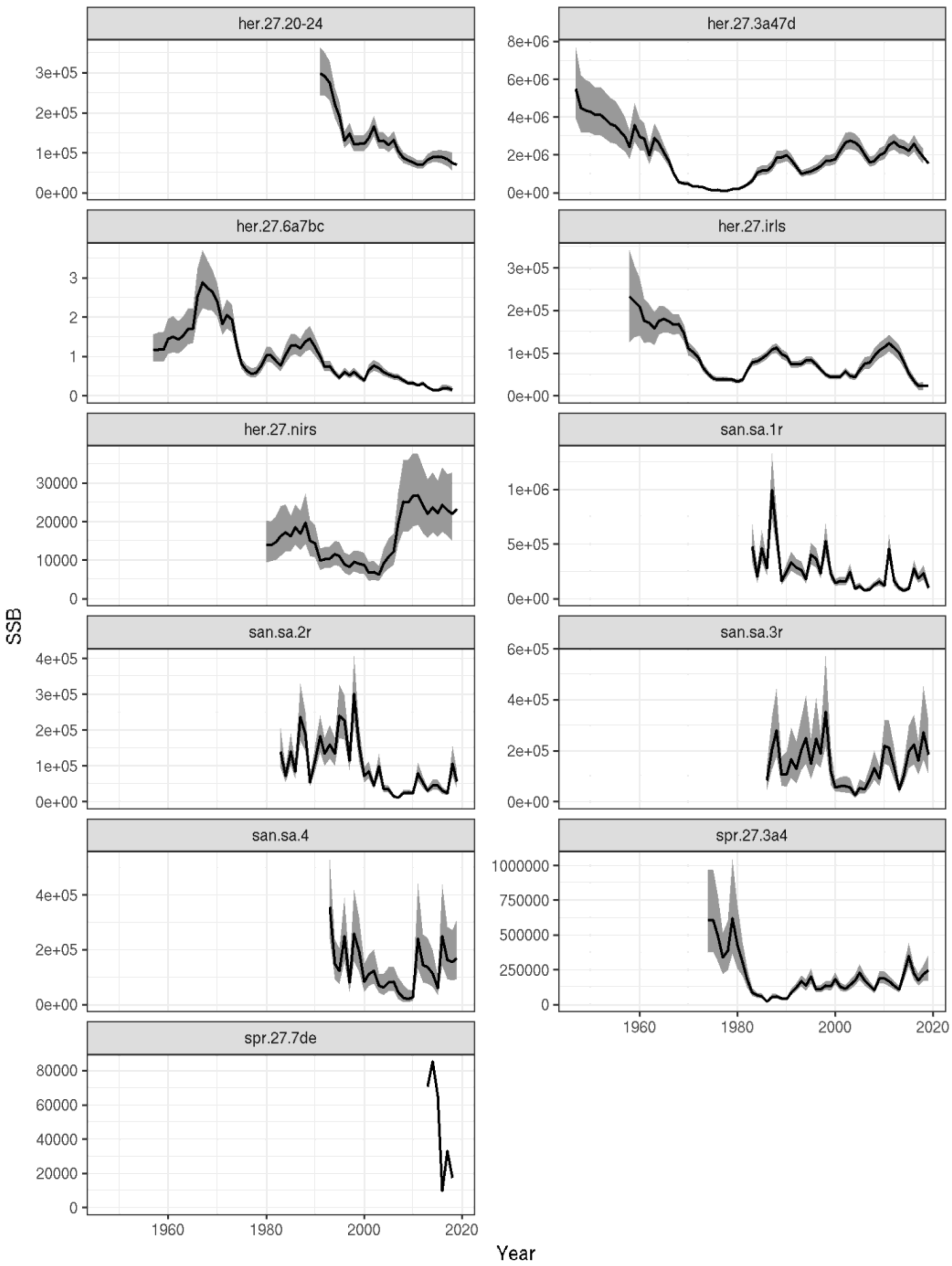


Figure 1.7.3 Spawning stock biomass estimates for the sprat, herring and sandeel stocks presented in HAWG 2019.

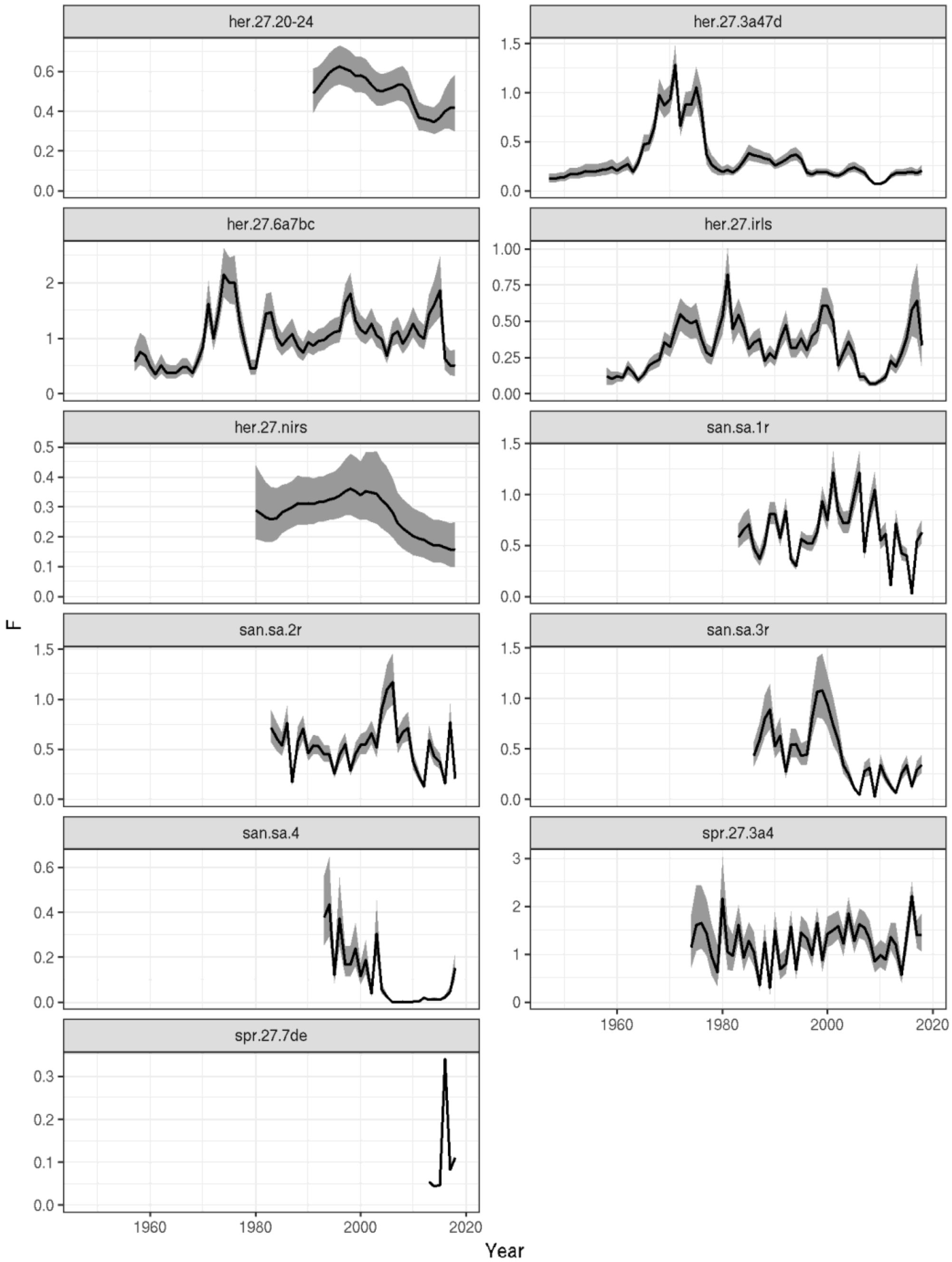


Figure 1.7.4 Estimates of mean F for the sprat, herring and sandeel stocks presented in HAWG 2019.

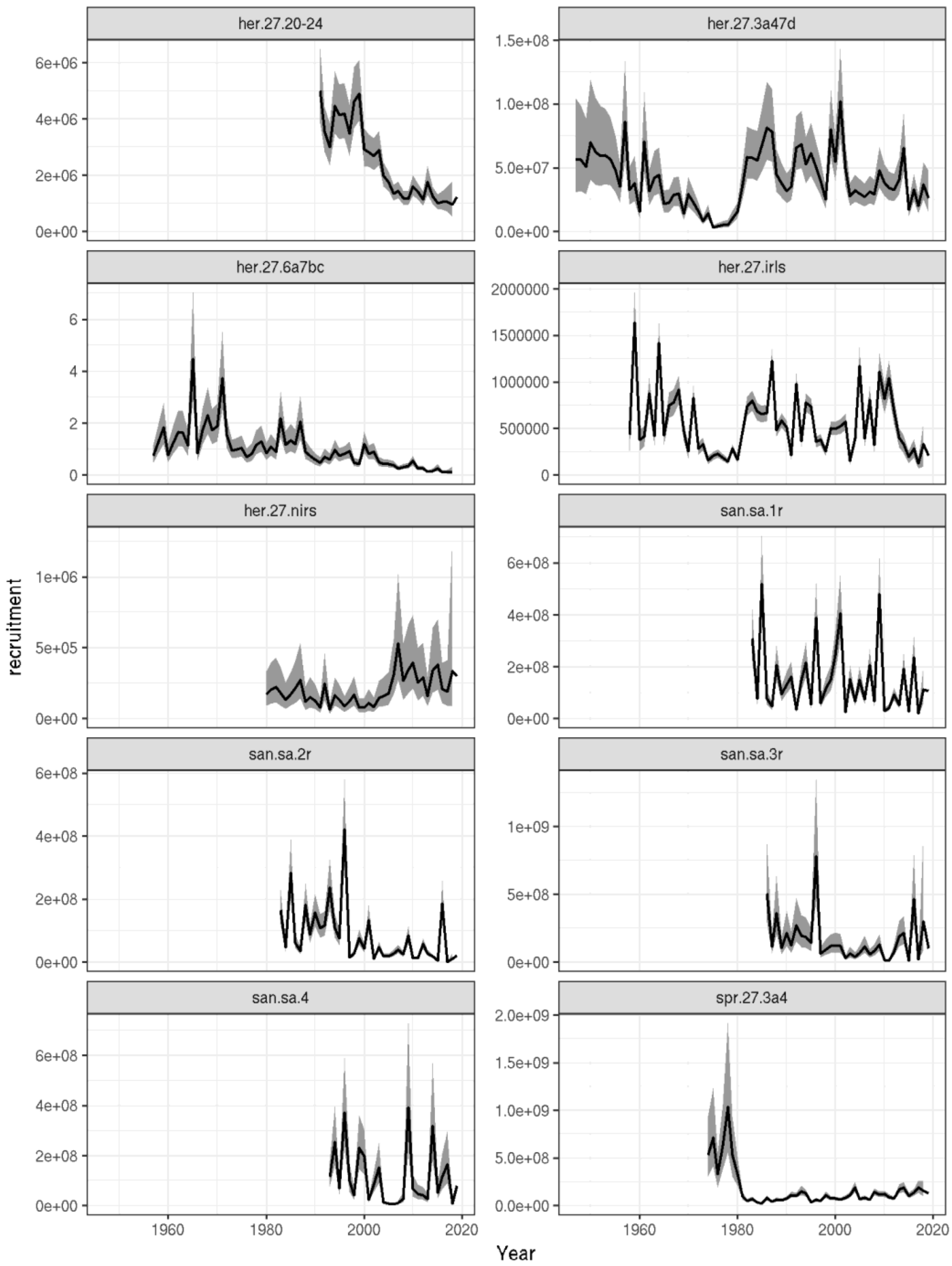


Figure 1.7.5 Estimates of recruitment for the sprat, herring and sandeel stocks presented in HAWG 2019.

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) for the stocks in the North Sea (NSH, her.27.3a47d), the Malin Shelf (MSH, her.27.6a7bc) and the Irish Sea (ISH, her.27.nirs).

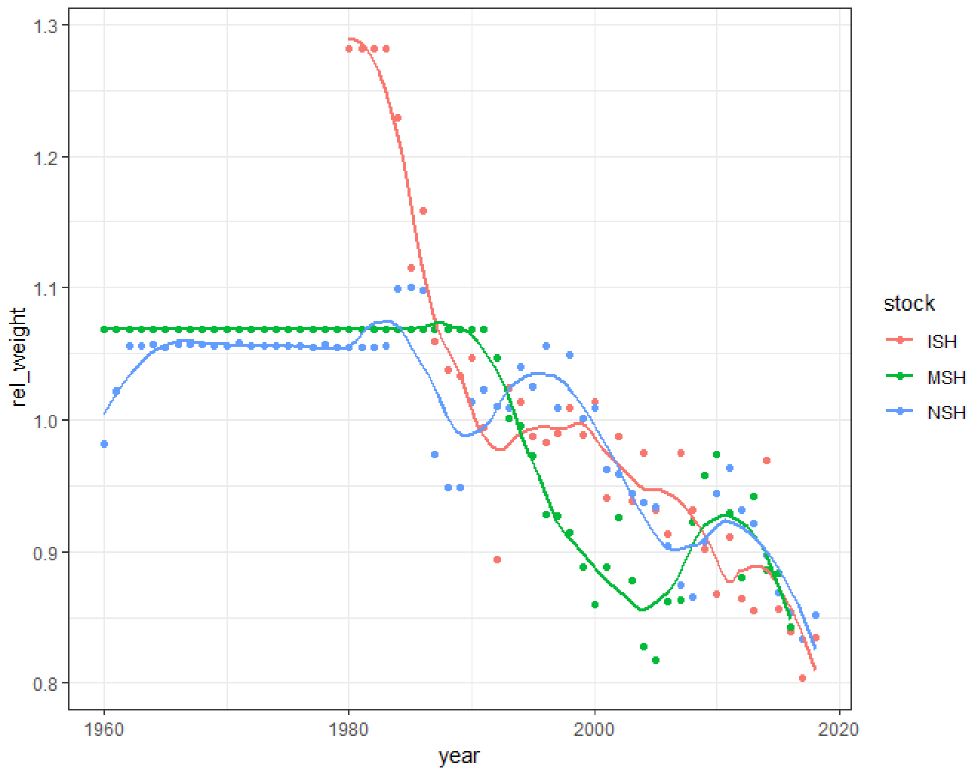


Figure 1.7.6 Relative mean individual weight is calculated by average of stock weight-at-age by year and then it is divided by the mean weight of the time series for each stock.

1.9 Mohn's rho and Bias in the assessments

ICES is planning a workshop in Autumn 2019 (WKFORBIAS) to document the extent of the retrospective bias in SSB, F_{bar} and recruitment for category 1 and 2 assessments based on the 2018–2019 assessments. Additional objectives are to identify and compile possible causes for retrospective bias and to develop approaches for retrospective bias correction and guidelines for acceptability of a stock assessment with retrospective bias. To support the workshop and in response to the ToR c-viii, HAWG reports on retrospective bias in category 1 and 2 age-based fish stock assessments made in 2019. Mohn's rho values have been uploaded at https://community.ices.dk/ExpertGroups/Lists/Retrobias2019/Allitems.aspx and they are included in this report in Table 1.8.1.

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

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

* 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

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 is truncated to have terminal year 2016 (T-i).

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.nirs	2018	5	0.0520	No	0.0.700	No	-13.8000
her.27.3a47d	2018	5	-12.0000	No	11.1000	No	8.0000
her.27.6a7bc	2018	5	25.0000	No	-23.2700	No	-7.8700
san.sa.1r	2018	3	-0.1200	Yes	0.2800	Yes	-0.1200
san.sa.2r	2018	3	-0.0900	Yes	0.7300	Yes	0.7600
san.sa.3r	2018	5	0.0200	Yes	0.1000	Yes	1.1000
san.sa.4	2018	5	-0.0300	Yes	0.1300	Yes	0.2200
her.27.irls	2018	5	-0.0580	No	0.1720	No	1.1000
her.27.20-24	2018	5	-0.0700	No	0.1300	No	-0.0700
spr.27.3a4	2019	5	0.0890	No	0.2700	No	0.2200

1.10 Transparent Assessment Framework (TAF)

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

The following HAWG 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.

1.11 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 2019) there are no plans to benchmark stocks assessed by HAWG.

Stock	Ass status	Latest benchmark	Benchmark next 12 months	Planning Year +2	Further planning	Comments
NSAS	Update	2018	No	No		Issue list in prep
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 in prep, likely need for an interbenchmark to revisit reference points
6.a, 7.bc	Update	2015, interbenchmark in 2019	No	2021*	Splitting of surveys and assessment, recruitment signal	Issue list in prep
Celtic Sea	Update	2015, Interbenchmark in 2018	No	No	Mixing with Irish Sea herring, recruitment signal	Issue list in prep
7.aN	Update	2017	No	No	Explore stock mixing and review acoustic survey design and methods, recruitment signal	Issue list in prep
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	No	No	Consider stock components	Issue list in prep
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 in prep

*** Provisional, timeline to be decided**

1.11.1 Ecosystem and long-term benchmark planning

HAWG is developing a longer-term perspective towards its benchmark process, by identifying issues that should be addressed in the next round of benchmarks, even though they are several years in the future. The following list of issues is intended to focus development work during this inter-benchmark period.

General

- Develop assessment tools that can take account of uncertainty estimates in surveys.

North Sea Autumn Spawning (NSAS) herring

- Splitting of catches, where possible, into autumn and winter-spawning components.
- Refinement of the IBTS0 index calculation to provide component-resolved information.
- Modification of the assessment model to account for reduced precision in catch statistics prior to the 1960s.
- In-depth understanding of the reasons at the origin of the retrospective pattern related to inclusion of the 2018 data
- Investigate the use of a wider range of ages for the F_{bar} (currently age2–6) and application of a weighted mean of F

Western Baltic Spring Spawning (WBSS) herring

- Account for mixing of central Baltic herring (CBH) in the commercial catches in SD22–24. Check for mixing of WBSS-CBH in SD25 catch
- Account for mixing of WBSS-NSAS outside of the transfer area (4.a.E, 4.b.E).
- Improve estimation of catch matrix in synergy with the RDBES
- Identify main drivers of stock productivity
- Reference points may need to be revisited.

6.a herring

- Extraction of West of Scotland herring larval abundance estimates from the North Sea IBTS0 survey.
- Develop genetic methods to split surveys and commercial catches by components

Irish Sea herring

- Develop techniques to maximize the information content in the Irish Sea larval survey. Explore levels of stock mixing, spawning behaviour and timing.

Celtic Sea herring

- Use genetic techniques to assess the mixture of Celtic Sea herring in the Irish Sea.
- Assess the interannual variation in this mixing as well as the distribution patterns.

1.12 Recommendations

All recommendations have been uploaded to the ICES Recommendation database.