Stock Annex: Herring (*Clupea harengus*) in subdivisions 20–24, spring spawners (Skagerrak, Kattegat, and western Baltic)

Stock:	Herring
Working Group:	Herring Assessment Working Group for the Area South of 62ºN (HAWG)
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A. General

Terminology

The WG noted that 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 wherever possible 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.

A.1. Stock definition and biology

Stocks

Spring spawning herring distributed in Subdivisions 22-25, and divisions 3a and 4a east. Most herring populations are migratory and often congregate on common feeding and wintering grounds where aggregations may consist of mixtures of individuals from several populations. Thus herring spawning components uphold significant levels of reproductive isolation, possibly affected by selective differences among spawning and/or larval habitats (Limborg *et al.*, 2012). Genetic stratification is likely maintained by mechanisms of natal homing, larval retention and natural selection (Gaggiotti *et al.*, 2009). In the Western Baltic tagging and genetic studies suggest that three to four more or less well-described stock components, that either spawn and use the area as nursery or migrate through it: Rügen herring (RH), local (autumn) spawning Fehmarn herring, herring from the Kattegat and Inner Danish waters, and potentially other Western Baltic herring stocks, each of which have different contributions to the fishery and ecosystem. The RH are assumed to make up the majority of the western Baltic Sea herring in the area (ICES, 2010) and the stock spawn around the Geifswalder Bodden, mainly in March-May, but with some autumn spawning also (e.g. Nielsen *et al.*, 2001; Bekkevold *et al.*, 2007).The other herring populations occurring in the area are found in many of the bays in the area, where at least Kiel, Møn, Schlei, Flensburg, Fåborg, and Fehmarn have been reported as spawning sites for these apparently less abundant herring stocks. Thus the Western Baltic Spring Spawners (WBSS) stock has a complex mixture of different herring populations predominantly spawning during spring, but also local spring-, autumn- and winter spawning stock components. The exact proportions of these stocks are hitherto unknown; however, they are observed in the area to some degree and could potentially be important parts of the total amount of herring available for the fishery.

Given a complex stage-dependent migration pattern, the different components mix during part of the year (Figure 1) and most likely experience different fishing pressures but are assessed and managed as one unit.

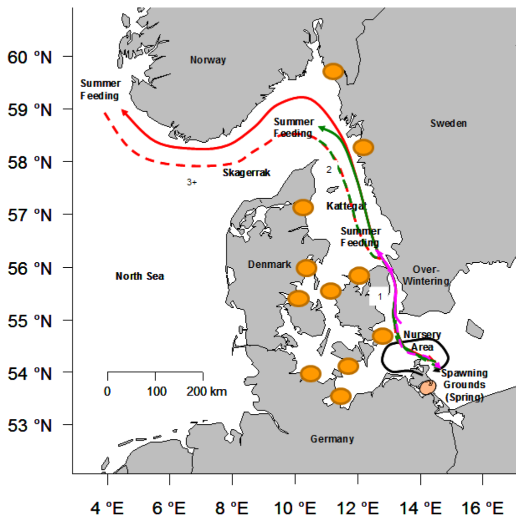


Figure 1 General migration patterns of the WBSS; the numbers indicates the age-dependent migration pattern; the yellow circles indicate local spawning populations (redrawn from M. Payne).

The majority of 2+ ringers migrate out of the area during the 2nd quarter of the year, through the Sound and Belt Sea and propagate into the western part of the Skagerrak and the eastern North Sea to feed (Payne *et al.*, 2009). The extent of the migration is age dependent, where the younger individuals migrates up into Kattegat and Skagerrak and the older fish migrate all the way out into the eastern North Sea. Towards the end of summer the herring aggregate in the eastern Skagerrak and Kattegat before they migrate to the main wintering areas in the southern part of the Kattegat, the Sound and the Western Baltic (ICES, 1991; Nielsen *et al.*, 2001). The extent of the migration is season dependent and variable over time (Clausen *et al.*, 2006).

These distribution patterns had yet to be fully quantified, however, they have been examined in a recent study of the temporal and spatial coverage of all available data in terms of current biological understanding of stock components, their distribution in the Western Baltic and 3.a using combined information from fisheries catches and International surveys in the Western Baltic Sea (including the Sound) and Kattegat, Skagerrak over the past decade. The major migration routes indicated by the temporal-spatial distribution of the herring stock components over time shows for the largest herring stock (the Rügen herring) an outmigration from the spawning sites during April–June through all Belts. This migration is not performed in large dense schools;

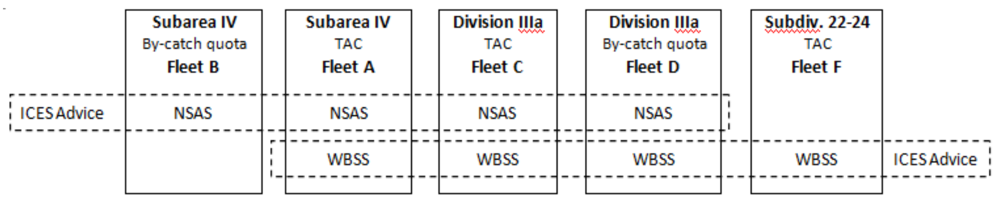
these form during the summer feeding in Skagerrak and Kattegat. The school formation is retained during the overwintering, which mainly occurs in the Southern Kattegat and the Sound.

The fishery on WBSS takes place in the eastern North Sea, Division 3.a and the Western Baltic. In the eastern North Sea and Division 3.a the stock complex mixes with another large herring stock complex; the North Sea Autumn Spawners (NSAS). All spring-spawning herring in the eastern part of the North Sea (4.a & 4.b east), Skagerrak (Subdivision 20), Kattegat (Subdivision 21) and the Western Baltic (Subdivisions 22, 23 and 24) are treated as one stock despite the local stock diversity. Given the mixing with the NSAS, the ICES Herring assessment Working Group (HAWG) make use of biological samples routinely collected to estimate the stock composition of the annual catches. The analysis of stock composition in commercial samples for stock assessment and management purposes of the herring populations in the North Sea and adjacent areas has been routine since the beginning of the 1990s. Recent development of the stock identification methodology has opened for a monitoring of the local stock components beyond the general spawning components of spring-autumn-and winter spawners; however this is not part of the routine treatment of herring catches yet.

The current definition of the Western Baltic herring stock of spring, autumn and winter spawners as a single management unit appears to have been operational in the past, despite potential changes in the relative strengths of the different spawning components and in their relative importance during collapse and recovery.

Methods for stock separation

Mixing of WBSS herring and North Sea herring ICES advises on catch options by fleet for the entire distribution of WBSS and NSAS herring stocks separately. However, the fisheries are managed by areas covering the geographical distribution of the stocks (see the following text diagram).



The method for separation of the herring stock components in the catches has developed over the past decade. Prior to 1996, the splitting key between NSAS and WBSS herring used by ICES was calculated from a sample-based mean vertebral count. This uses a cut off algorithm for calculating the proportion of western Baltic spring-spawning herring (WBSS) in a sample as:

MIN(1,MAX(0,(VSsample-55.8)/(56.5–55.8)))

where VSsample is the sample mean vertebrae count and assuming a population mean VS of 55.8 for WBSS and 56.5 for NSAS. This method is still being used to split samples of Norwegian catches from the transfer area in 4.a East as well as the Norwegian part of the HERAS survey.

In the period from 1996 to 2001 splitting keys were constructed using information from a combination of vertebrae count and otolith microstructure (OM) methods (ICES, 2001). From 2001 and onwards, the splitting keys for division 3a and Danish catches in division 4a east have been constructed solely using the otolith microstructure method which uses visual inspection of season-specific daily increment patterns from the larval origin of the otolith supported by measurements of daily increment widths at predefined distances from the core (Mosegaard and Madsen, 1996; ICES, 2004; Clausen *et al.*, 2007).

Otolith shape analysis has been used to discriminate between populations for a variety of species and for herring this approach has had increasing success with development of imaging techniques and statistical methods. Both temporal and geographical separation of populations gives rise to variation in the shape of otoliths (Messieh, 1972; Lombarte and Lleonart, 1993; Arellano *et al.*, 1995). These variations may suggest differences in the environmental conditions of the dominant habitats of populations within a species. However both genetic and environmental influences have been reported as important in determining otolith shape (Cardinale *et al.*, 2004). Using Fourier Series Shape Analysis on otoliths from Alaskan and Northwest Atlantic herring, Bird *et al.* (1986) showed that otolith shape reflects population differences as well as differences between year classes of the same population. Sagittal otoliths have certain morphological features that are laid down early in the ontogeny of the fish (Gago, 1993), and measurements of internal otolith shape in adult herring has proven a powerful tool for stock discrimination (Burke *et al.*, 2008).

Image analysis software (MATLAB) has been developed to automatically extract otolith contour curves and calculate 60x4 Elliptic Fourier Coefficients from one or two herring sagittal otoliths per image in batches with more than 10000 images.

From 2009 and on otolith shape analysis has been used as a supplementary method to increase sample size for estimating stock proportions of NSAS and WBSS in the mixing areas of Division 3.a. For each assessment year individual population identity has been established by OM visual inspection and used as a baseline for assignment of shape characteristics to the involved stock components. A baseline of about 800–1200 otoliths with known hatch type has then been used as calibration in an age-structured (0, 1, 2, 3+ ringers) discriminant analysis where additionally 3000–4000 otolith shapes have been assigned to one of the two hatch types using a combination of shape Elliptic Fourier Coefficients, otolith metrics, fish metrics, length, weight and maturity as well as longitude–latitude and seasonal parameters (for more details on the shape analysis see the benchmark report and working documents therein, ICES 2018a).

The simultaneous application of the two different split methods (OM and otolith shape analysis) has the advantage that changes to the precision of the OM baseline may be detected as changes in the self assignment efficiency and the characteristics of the confusion matrix. Recent investigations in the Danish lab has reveiled that there are now many otoliths displaying micro increment patterns which do not fall into the typical spawning/hatch types observed in the past (Clausen et al. 2007) which is making it difficult to separate the winter spawners from the spring spawners and to a lesser extent the autumn spawners. The attention to the problem has to some degree remedied the decreasing precision of self-assignemnet of the shape based method, indicating that the ungoing redefinition of the criteria for the OM baseline has improved the split, but further changes are expected following improved population genetic analyses of the same idividuals.

Mixing of WBSS herring and Central Baltic herring

The Central Baltic herring (CBH) is also mainly a Spring spawner, possibly made by different components. Its distribution is centered in the central Baltic (SD25-29, excl.

Gulf of Riga). This herring is mostly resident within the Baltic throughout its life time and it is not known to perform systematic extensive seasonal migrations outside the Baltic. However, the stock structure of the Central Baltic herring stock is rather unclear. Spring spawners individuals spawning along the southern Baltic coasts have been reported and seem to have similar growth characteristic as WBSS herring and differentiate from more off-shore central Baltic herring, that grow slower. The SD24-25 are the main areas of overlap between the WBSS and CBH stocks and evidences exist that their overlap can extend beyond this area, i.e. samples suggest that herrings of possible central Baltic origin can be encountered into the Kattegat, and WBSS herring occur regularly in the SD26.

Typical WBSS and open sea spring spawners of CBH present well distinct growth patterns with the WBSS growing considerably faster and to larger size than this component of CBH. Such difference has stimulated the development of a separation function (SF) to assign individual fish to one of the two stocks based on age and length information (Gröhsler et al. 2013):

$$SF = 25.3962 \cdot \left\{1 - e^{\left[-0.385 \cdot \left(\frac{Am}{12}\right) - 0.262\right]}\right\}$$

where Am is the age expressed in months. The SF is currently used to separate WBSS from CBH in SD22-24 in the GerAS acoustic survey (see section B.3) but not in the commercial catches before the method will be validated using other techniques (ie, genetics, microchemistry).

A.2. Fishery

The fishery

The Western Baltic spring spawners fishery is a multinational fishery that seasonally targets herring in the eastern parts of the North Sea (Eastern 4.a, 4.b), the Skagerrak and Kattegat (Division 3.a) and Western Baltic (SD 22–24). The main fleets come from Denmark, Sweden, Norway and Germany, while Poland has a minor fishing activity in the area. After 1996 the fishery is roughly concentrated in the first and the third quarter of the year, whereas earlier the fishery was more spread over the year since it constituted a substantial part of the 16 mm industrial fishery.

The fishery is regulated according to an area TAC (one for herring catches in the 3.a and one for SD 22–24), but the assessment and fisheries advice is stock based (Western Baltic spring spawning herring (WBSS) to which estimates of potential WBSS catches from the neighbouring area of the eastern North Sea are added.

The fishery for human consumption has mostly single-species catches, although in recent years some mackerel by-catch can have occurred in the trawl fishery for herring. Discarding in the herring fishery in the eastern North Sea is low, with 2–4% discarded by weight (van Helmond and Overzee, 2011). In Division 3.a and SD 22–24 discarding is considered negligible because all sizes are equally valuable and hence there are no incentives for high-grading.

The by-catch of sea mammals and birds is low enough to be below detection levels based on observer programmes (ICES, 2011a). At present there is a very limited industrial fishery in Division 3.a and hence a limited by-catch of juvenile herring. Further, herring by-catch quota is allocated in both the North Sea and Area 3.a. The sprat fishery in SD 22–24 operates with a certain degree of herring by-catch which is closely monitored and counted against the sprat quota (up to 8% herring allowed).

Fleet definitions

One of the unresolved issues from the benchmark in 2018 was the definition of the fleets, which differs between years and countries (ICES 2018b)

The definition of the fleets in the EU TAC and quota regulation, since 1998 (e.g. EU 2017/127 and 2016/1903)

Fleet A: Catches of herring in the North Sea (only Eastern 4.a, 4.b) taken in fisheries using nets with mesh sizes equal to or larger than 32 mm.

Fleet C: Catches of herring in Kattegat and Skagerrak taken in fisheries using nets with mesh sizes equal to or larger than 32 mm.

Fleet D: Exclusively for catches of herring in Kattegat and Skagerrak taken as by-catch in fisheries using nets with mesh sizes smaller than 32 mm.

Fleet F: Not defined directly in the regulation, but landings from Subdivisions 22—24. Most of the catches are taken in a directed fishery for herring and some as by-catch in a directed sprat fishery

The definition used in the WBSS assessment, since 2010

Fleet A: Directed fishery for herring in the North Sea (only Eastern 4.a, 4.b) in which trawlers (with 32 mm minimum mesh size) and purse seiners participate. Excluding Danish industrial fisheries with mesh size equal or greater than 32 mm with a by-catch of herring e.g. norway pout and blue whiting fisheries

Fleet C: Directed fishery for herring in Kattegat and Skagerrak in which trawlers (with 32 mm minimum mesh size) and purse seiners participate. Since 2010 this fleet also includes the Swedish fishery with mesh sizes less than 32 mm, since an earlier change in the Swedish industrial fishery implies that there is no difference in age structure of the landings between vessels using different mesh sizes since both are basically targeting herring for human consumption.

Fleet D: By-catch of herring in Kattegat and Skagerrak in the industrial fleet and only including Danish landings. Covering all fisheries with mesh sizes less than 32 mm e.g. the sprat fishery, but also including other fisheries where herring is landed as by-catch e.g. norway pout and blue whiting fisheries.

Fleet F: Landings from Subdivisions 22—24. Most of the catches are taken in a directed fishery for herring and some as by-catch in a directed sprat fishery.

The selections patterns per fleet are in general stable over time, but for fleet D there is a marked shift in 2010 - before the fleet caught the whole range of ages and after no age 7 and 8+ are caught. This is due to a combination of changes in the Swedish fishery in the D fleet and submission of data over time. The Danish fishery has during the whole time period been a by-catch fishery in the industrial fishery predominantly for sprat and catching young herrings. The Swedish fishery has on the other hand changed during the time series. Until the late 1990's it was an industrial fishery similar to the Danish. After that the fishery started targeting fish similar to fleet C. In 2010 Sweden started to combine the C and D fleet when submitting data to HAWG based on the fact that no significant differences were found in the catch composition in the two fleets. However, it has to be noted that as a consequence the CANUM of the D fleet after 2009 does not reflect all the catches under the bycatch quota.

A.3. Ecosystem aspects

Herring is presumably the key pelagic species in the 3.a and Western Baltic and is thus considered to have major impact as prey and predator to most other fish stocks in that area.

Although knowledge on crucial variables affecting larval herring survival increased since the latest stock collapse in the 1970s, the understanding of particular mechanisms of early herring life-history mortalities is still a major task of fishery science in the North Atlantic Ocean. 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. The suite of variables driving early ontogenetic development and major survival bottlenecks is subject of ongoing research.

Results on time-series analysis of larval herring growth and survival dynamics indicate that distinct hatching cohorts contribute differently to the number of 1+winter ring (wr) recruits in the overall western Baltic Sea. The abundances of the earliest larval stage (5–9 mm TL) explains 62% of the variability of later stage larval abundance and 61% of the variability of surviving (1+ group) juveniles. This indicates important pre-hatching survival bottlenecks associated with spawning and egg development. Furthermore, findings demonstrate that hatching cohorts occurring later during the spawning season contribute most to the surviving year class whereas earlier hatching cohorts do not result in significant growth and survival. This could be explained by limited food supply at hatching prior to spring plankton blooms, indicating an additional bottleneck at the critical period when larvae start feeding.

Availability of suitable prey at the critical period after yolk consumption is generally considered the predominant survival bottleneck in larval fish ecology. However, analyses of zooplankton prey abundance in strong vs. weak year classes did not reveal significant food limitation in the eutrophic waters of Greifswald Bay. However, besides prey abundance larval growth and survival might also be affected by the nutritional quality of prey. Comparative results on essential fatty acid contents of larvae and prey from two different spawning grounds showed no significant differences of larval growth conditions in Kiel Canal and Greifswald Bay. The food quality, however, was found to be generally important for larval growth. Accordingly, even when prey availability is plentiful in mixed, natural feeding conditions, larval growth is affected by nutritional value of prey.

Along the inshore–offshore gradients of Western Baltic watersheds, transitional waters, such as bays, lagoons and estuaries seem to represent significant areas for herring reproduction as i) important spawning grounds and ii) retention of early development stages. It still remains a major challenge to quantify the role of small scale drivers and stressors for overall recruitment strength. The rationale in hypothesizing cascading scale effects is supported by current WBSSH recruitment time-series and the relationship of indices derived on differing spatial scales. The regular correspondence of the regional larval index (4.6.2) with recruitment patterns of WBSSH stock implies a relation between larger scale recruitment success and regional survival bottlenecks. On the other hand the N20 time-series provides a sound background to test the magnitudes of regional effects on the overall WBSSH stock.

The pelagic fisheries on herring claim to be some of the "cleanest" fisheries in terms of bycatch, disturbance of the seabed and discarding (ICES, 2010). 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. As such the discard ban is not believed to make any changes in the fishery or fishing pattern.

Another potential impact of the Western Baltic herring fishery is the removal of fish that could provide other "ecosystem services." The 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. There is, however, no recent research on the multispecies interactions in the foodweb in which the WBSS interact.

B. Data

B.1. Commercial catch

WBSS herring is caught by a number of fleets mostly from Denmark, Sweden, Germany and Norwegian. Misreporting of commercial catches induces bias on the estimated fishing mortality and stock size. The potential of such a bias should be taken into account when decisions on reference points and long-term management plans are taken. Misreporting is not only a question of landing species under a different name but can also be a result of reporting catch in a different area than the catches took place. Area misreporting has probably taken place in 3.a and the adjacent North Sea, where catches from the North Sea have been reported in 3.a. The reason for this misreporting has been due to the size differences of herring in the two areas, where the optimal sized herring were caught in the North Sea but reported as taken from 3.a.

Misreporting is understood to have taken place for the Danish catches during the period from 1997 to 2008. The Danish reported landings have been corrected for this misreporting each year in the period 2002–2009 based on information from the industry, week-by-week evaluation of the fishing trips, and since 2004 by using VMS data.

All Norwegian herring catches in 3.a between 1995–2001 are understood to have been taken in the North Sea and this was corrected for. However, since 2008 management has allowed optional transfers (flexibility in terms of where to take the 3.a TAC), where part of the TAC in 3.a legally could be caught in the North Sea.

It is unclear to what extent Swedish catches reported in 3.a in period 1991–2008 have been reported to the correct area. Similar to Denmark it is suspected that some North Sea catches have been reported as 3.a catches. For the period post-2008 misreporting in Danish and Swedish fishery has been judged unlikely primarily due to new regulations prohibiting the vessels to fish in two management areas in one trip; the flexibility in where to take the 3.a TAC (North Sea or 3.a) is also thought to decrease the incitement for area misreporting.

Conclusively, the past area misreporting has been corrected for year-by-year and thus the catch matrix applied in the assessment can be considered as accurate as possible.

There is at present no information about the relevance of local herring populations in relation to the fisheries and their possible influence on the stock assessment. Recent studies on the genetic differentiation among spawning aggregations in the Skagerrak suggests a potential high representation of these local spawning stocks (Bekkevold *et al.*, 2005). Other results suggest that at least the mature proportion of the different stock components shares migration patterns and feeding areas (Ruzzante *et al.*, 2006; van Deurs and Ramkaer, 2007).

B.2. Biological parameters for assessment

Mean weights-at-age in the catch in the 1st quarter were used as stock weights.

In order to check if this is a valid assumption and represents the actual weights in the stock, the index was compared to the average weights in the catch by age during the whole year. The relationship followed the expected pattern where the weight of the younger age classes in the catch are somewhat higher than in the stock as these are taken as an average over the whole year allowing for growth. From age class 4 the relation between weight in catch and weight in stock followed a 1:1 line as expected. Thus the use of weight in the catch in quarter 1 is a sound indicator for the weight in the stock and does not give a biased representation of the stock.

The proportion of F and M before spawning was assumed constant. F-prop was set to be 0.1 and M-prop 0.25 for all age groups.

Natural mortality was assumed constant at 0.2 for all years and 2+ ringers. A predation mortality of 0.1 and 0.2 was added to the 0 and 1 ringers, which resulted in an increase in their natural mortality to 0.3 and 0.5, respectively. The estimates of predation mortality were derived as a mean for the years 1977–1995 from the Baltic MSVPA (ICES 1997/J:2). No multispecies model is currently available for this extended area of transition between the Baltic and the North Sea where independent models exist (SMS, EwE, Gadget). The lack of multispecies or ecosystem models for the Skagerrak, Kattegat, and western Baltic is well known and it has been acknowledged before (WGSAM).

The maturity ogive was assumed constant between years:

W-RINGS	0	1	2	3	4	5	6	7	8+
Maturity	0.00	0.00	0.20	0.75	0.90	1.00	1.00	1.00	1.00

Catch sampling for size-at-age and stock identity.

In terms of method reliability, the issue of sampling for biological data for the splitting between NSAS and WBSS is an important factor; without a robust and appropriate sampling strategy, the basis for the splitting is somewhat impaired. When sampling commercial catches for the biological composition concerning the proportions of the two herring stocks, it is crucial that the sampling scheme and coverage mirrors the actual distribution of the fishery. The sampling coverage compared to the reported catches by ICES rectangle over the period 2002–2011 is shown in Figure 4.7.1.1

It is apparent that catches concentrate in the northwestern part of Area 3.a, while sampling intensity is highest in the northeastern area.

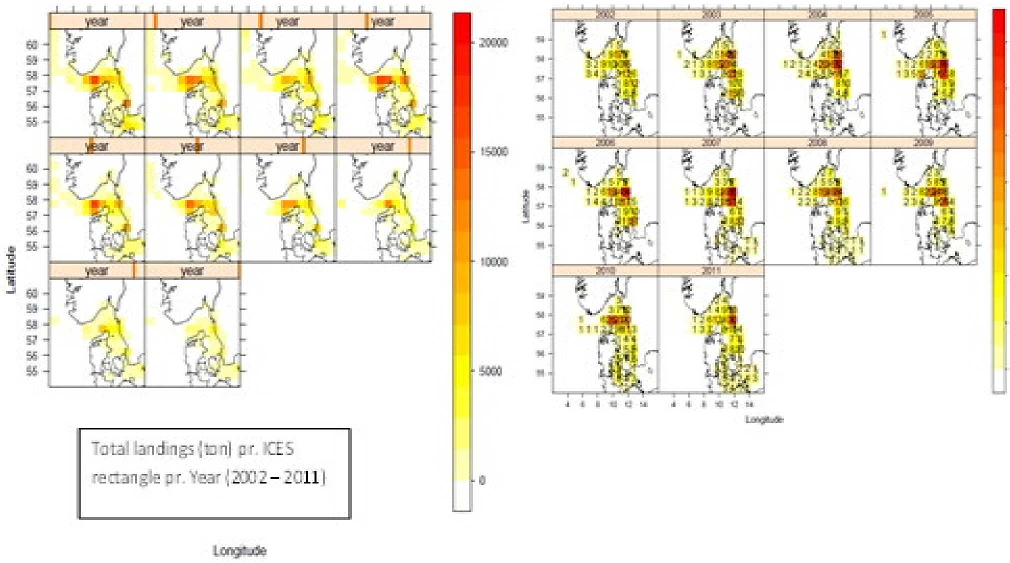


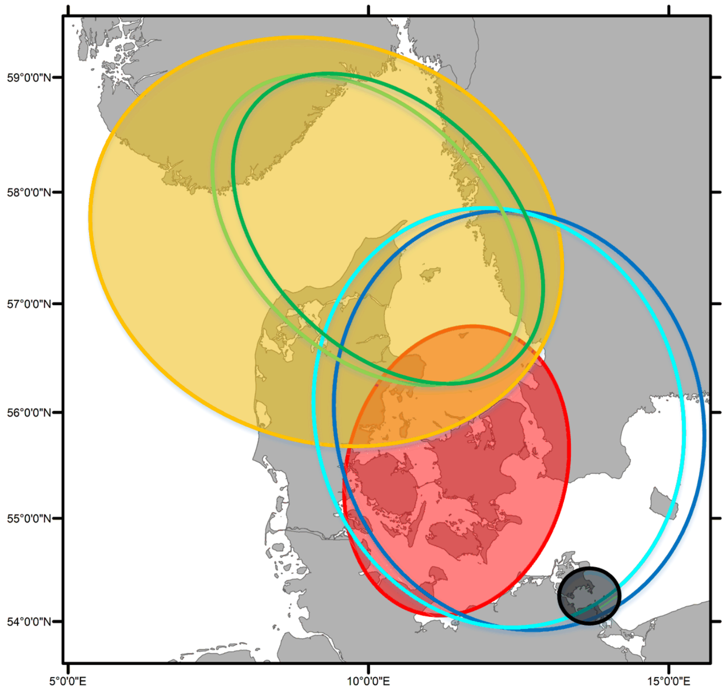
Figure 4.7.1.1. Number of samples by rectangle (right panel) and average landings in tonnes per year by ICES rectangle (left panel) over the period 2002–2011.

In order to get a solid base for estimation of the removals by the fishery, it is of utmost importance that all parts of the distribution area and the fishery herein are covered by the biological sampling. Though the sampling coverage has improved in recent years and at present covers the entire distribution area and follows the spatial and temporal distribution of the catches, there is still room for improvement; the sampling in recent periods very poorly covers the Area 4.aE (Figure 4.7.1.1). Thus it is highly recommended that the sampling intensity in Subdivision 4.aE and eastern parts of 4.b is substantially increased.

B.3. Surveys

The WBSS are sampled by on a number of scientific surveys which can inform about relative changes in the stock abundance (figure 3.B.1). Selection of which surveys and age groups should be included in the assessment model are based initially on evaluation of their internal and external consistency in following cohorts, correlation in the time series of abundance at age among the surveys, and a priori considerations on the expected spatial and temporal overlap between the survey and each age group in the stock. Once a subset of the candidate age classes from each survey is selected based on these criteria, final evaluation is made within the assessment model based on the model fitting to the index and the general model behavior and temporal consistency (ICES 2018a, ICES 2018b).

In the following the available surveys are described shortly as well as their status as tuning indices.



Survey Name	Method	Season	Start time series	Ages (w ringers)
GerAs	Acoustic	October	1991	0 to 8
HERAS	Acoustic	June/July	1991	0 to 8+
N20	Larvae sampling	March/June	1992	0
IBTS-Q1	Bottom trawl	February/March	2002	1-4
IBTS-Q3	Bottom trawl	August/September	2002	1-4
BITS-Q1	Bottom trawl	February/March	2002	1-4
BITS-Q3.4	Bottom trawl	October/Novem-ber	2002	1-4

Figure 3.B.1 Spatial and temporal survey coverage of the WBSS herring stock complex. 'Start time series' is equal to the start of the time series used in the WBSS assesment model, not the survey.

GERAS

The GERman Acoustic Survey (GERAS) has since 1993 included the Subdivisions 21 (Southern Kattegat, 41G0–42G2) to 24 as a part of BIAS (Baltic International Acoustic Survey). The survey is being carried out on the German R/V 'Solea' in October (GERAS). Further details of GERAS can be found in ICES reports from the Working Group of International Pelagic Surveys (WGIPS) and Baltic International Fish Survey Working Group (WGBIFS). The survey design and the specific settings of the hydroacoustic equipment follow the guidelines of the 'Manual for the Baltic International Acoustic Surveys (BIAS)', which is part of the WGBIFS report (ICES, 2017).

Recent results of GERAS indicated that in SD 24, which is part of the WBSSH management area, a considerable fraction of CBH is present and correspondingly erroneously allocated to WBSSH stock indices. Accordingly, a Stock Separation Function (SF) based on growth parameters was established to identify the fraction of Central Baltic herring (CBH) in the WBSSH area (Gröhsler et al., 2013) and applied to survey data from the German Acoustic Survey GERAS from 2005–2011 (WKPELA (ICES 2013)). Results showed a distinct fraction of CBH in SD 24 and indicated that applying the SF greatly improved both abundance and biomass indices for WBSSH (ICES 2013/ACOM:46/WKPELA WD 01: Gröhsler, Oeberst and Schaber). SF was continued to be applied year by year to GERAS from 2012-2016. Full technical details of the survey can be found in the latest WGIPS report (ICES, 2017).

The GERAS exhibits significant internal consistency among age-groups 1-5 ringers (Figure B.3.2). In addition, external consistency was found with age 3-ringers in the HERAS as well as in the IBTS+BITS-Q1 and IBTS+BITS-Q3.4, see figures B.3.4.

GERAS age-groups 1-4 ringers are used as one of the tuning indices in the assessment.

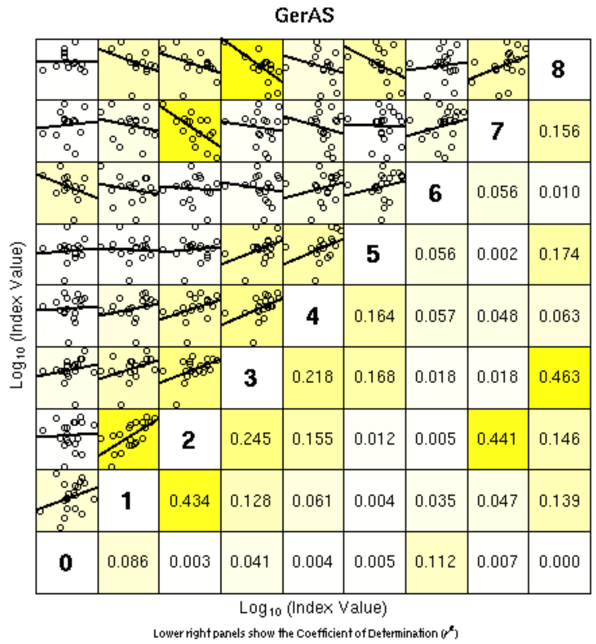


Figure B.3.2 Correlation coefficient diagram for the GERAS survey by cohort.

HERAS

The ICES Coordinated acoustic surveys for herring in the North Sea, Skagerrak and Kattegat gives an index of numbers-at-age for 1–9+-ringers, mean weights-at-age in the stock and proportions mature-at-age. This index has been used in assessments of NSAS since 1994 with the time-series data extending back to 1989. Over the years the survey has been extended to cover Division 3.a to include the overlapping western Baltic spring-spawning stock, the whole of 6.a (North) and since 2008 the whole Malin Shelf. By carrying out the coordinated survey at the same time from the Kattegat to Donegal, all herring in these areas are covered simultaneously, reducing uncertainty due to area boundaries as well as providing input indices to three distinct stocks. The surveys are coordinated under the ICES Working Group for International Pelagic Surveys (WGIPS) and full technical details of the survey can be found in the latest WGIPS report (ICES, 2018).

HERAS samples are in division 27.3.a and 27.4.a.east split into WBSS and NSAS by age-group and transformed to 1-8+-ringers for the WBSS assessment, however the survey area is not considered to fully cover the youngest WBSS age groups (1-2 ringers).

HERAS exhibited significant internal consistency among age-groups 3-6 ringers, see figure B.3.4. Further external consistency was found with age 3-ringers in the GerAS, see figures B.3.4.

HERAS age-groups 3-6 ringers are used as one of the tuning indices in the assessment.

IBTS+BITS-Q1 and IBTS+BITS-Q3.4

The International Bottom Trawl Survey (IBTS) in Division 3.a is part of the IBTS surveys in the North Sea. The survey started out as the International Young Herring Survey (IYHS) in 1966 with the objective of obtaining annual recruitment indices for the combined North Sea herring populations (Heessen *et al.*, 1997). It has been carried out every year since. The survey is considered fully standardized from 1983 onwards, when it became known as the International Bottom Trawl Survey (IBTS). Examination of the catch data from the 1st quarter IBTS showed that these surveys also gave indications of the abundances of the adult stages of herring, and subsequently the catches have been used for estimating 2–5+ ringer abundances. The surveys are carried out in 1st quarter (February) and in 3rd quarter (August–September).

During HAWG 2002 the IBTS survey data (both quarter) were revised from 1991 to 2002 and was deemed unfit as indices for the WBSS, however, as part WKPELA of the benchmark (ICES 2013) benchmark the suitability of the IBTS indices were re-evaluated and included. However The IBTS quarter 1 and quarter 3 in SD 20-21 (the Skagerrak and the Kattegat) have a poor coverage of the expected population distribution to the south and have been found to have low internal consistency. At the benchmark in 2018 (ICES 2018b) two new indices were constructed, one combining IBTS-Q1 and BITS-Q1 into one index, IBTS+BITS-Q1 and another combining IBTS-Q3 and BITS-Q4 into another index IBTS+BITS-Q3.4 using a GAM modelling approach (delta-lognormal) (WD05 in ICES 2018b). The new modelled indices have a better coverage of the WBSS younger age-classes within the distribution area. The ICES standard IBTS indices for herring in SD20-21 were therefore excluded a priori.

The Bottom trawl survey samples are split into WBSS and NSAS by age-group (ringers) for the WBSS assessment (ICES 2018b).

IBTS+BITS-Q1 exhibited significant internal consistency among age-groups 1-3 ringers. Further significant external consistency was found with age 3-ringers in the GerAS, see figures B.3.2. IBTS+BITS-Q3.4 exhibited significant internal consistency among age-groups 2-3 ringers, see figures B.3.3. It was also noted that high and significant external consistency between the two bottom trawl surveys existed between age 0 in quarters 3-4 and age 1 in quarter 1, as well as between age 1 in quarters 3-4 and age 2 in quarter 1 and further between age 2 in quarter 1 and age 2 in quarter 3-4, see figures B.3.3.

IBTS+BITS-Q1 age-groups 1-3 ringers and IBTS+BITS-Q3.4 age-groups 2-3 ringers are used as tuning indices in the assessment.

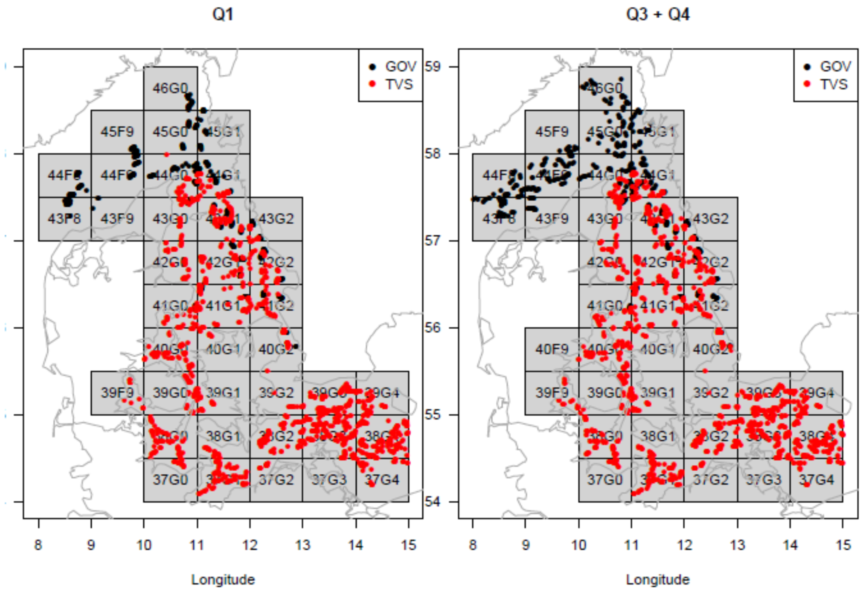


Figure B.3.3 Haul positions from the two trawl surveys indication coverage and overlap. Black dots IBTS (GOV), red dots BITS (TVS)

N20

The inshore waters of Strelasund/Greifswalder Bodden (ICES SD 24) are considered the main spawning area of Ruegen herring which represents a significant component of the WBSS stock. The German Institute of Baltic Sea Fisheries (TI-OF), Rostock, monitors the density of herring larvae as a vector of recruitment success since 1977 within the frame work of the Ruegen Herring Larvae Survey (RHLS). N20 delivers a unique high-resolution dataset on larval herring growth and survival dynamics in the Western Baltic Sea (see WD 04 in ICES 2018b; Oeberst *et al.*, 2009 for detailed description). N20 is therefore used as an 0-group recruitment index for the WBSS stock

In 2006 the rationale and methodology of the survey has been reviewed twice by external scientists (Dickey-Collas and Nash, 2006; Dickey-Collas and Nash, 2011) and the conclusions of this process was that the survey design of the RHLS was greatly improved and efforts were made to test many of the underlying assumptions (ICES 2013, WD 09). The data collected provide an important baseline for detailed investigation of spawning- and recruitment ecology of WBSS herring stocks. As a fishery-independent indicator of stock development, the recruitment index is incorporated into the ICES Herring Assessment Working Group (HAWG) advice since 2007 as the only 0-group recruitment index for the assessment of WBSS herring.

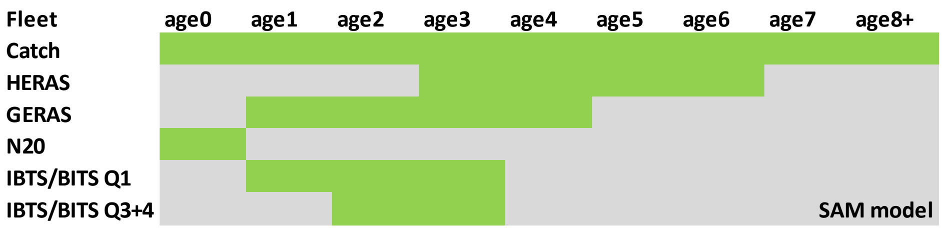
N20 had a high and significant external consistency with the GerAS 1-ringers and was also found to be significant for the GerAS 2-ringers, see figure B.3.3.

N20 age-groups 0 ringers are used as one of the tuning indices in the assessment.

<=d.age		GerAS_age0	GerAS_age1	GerAS_age2	GerAS_age3	GerAS_age4	GerAS_age5	GerAS_age6	GerAS_age7	GerAS_age8	HERAS_age1	HERAS_age2	HERAS_age3	HERAS_age4	HERAS_age5	HERAS_age6	HERAS_age7	HERAS_age8	N20_age0	IBTS+BITS-Q1_age1	IBTS+BITS-Q1_age2	IBTS+BITS-Q1_age3	IBTS+BITS-Q1_age4	IBTS+BITS-Q1_age5	IBTS+BITS-Q3.4_age0	IBTS+BITS-Q3.4_age1	IBTS+BITS-Q3.4_age2	IBTS+BITS-Q3.4_age3	IBTS+BITS-Q3.4_age4	IBTS+BITS-Q3.4_age5
8	Age	0	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	0	1	2	3	4	5	0	1	2	3	4	5
GerAS_age0	0		0.1	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.2	-0.1	0.1	0.0	0.2	0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	**0.3**
GerAS_age1	1	0.1		**0.4**	0.1	0.1	0.0	0.0	0.0	-0.1	0.0	0.1	**0.4**	**0.5**	**0.4**	0.2	0.0	-0.1	**0.6**	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.1	0.0	0.2
GerAS_age2	2	0.0	**0.4**		**0.2**	0.2	0.0	0.0	-0.4	-0.1	-0.1	0.0	**0.2**	0.2	0.0	**0.4**	0.0	-0.2	**0.2**	0.0	0.1	0.0	-0.4	-0.1	0.0	0.0	0.0	0.1	0.0	0.2
GerAS_age3	3	0.0	0.1	**0.2**		**0.2**	**0.2**	0.0	0.0	-0.5	-0.1	0.0	**0.2**	**0.2**	**0.2**	0.1	0.0	-0.2	0.1	0.2	**0.3**	**0.5**	0.0	-0.2	0.3	0.2	0.2	**0.2**	0.0	0.1
GerAS_age4	4	0.0	0.1	0.2	**0.2**		**0.2**	0.1	0.0	-0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	-0.1	0.2	0.1	0.2	0.2	0.1	-0.4	0.2	0.1	0.1	0.0	0.0	0.0
GerAS_age5	5	0.0	0.0	0.0	**0.2**	**0.2**		0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.1	0.2	-0.1	0.0	0.3	0.0	0.2	-0.2	0.0
GerAS_age6	6	-0.1	0.0	0.0	0.0	0.1	0.1		0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.1	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	-0.5	-0.2	-0.1	0.0	-0.2
GerAS_age7	7	0.0	0.0	-0.4	0.0	0.0	0.0	0.1		0.2	0.2	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	-0.1	-0.1	0.0	0.1	0.0	-0.3	-0.1	0.0	0.0	0.0	0.0
GerAS_age8	8	0.0	-0.1	-0.1	-0.5	-0.1	-0.2	0.0	0.2		0.1	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	0.0	-0.6	-0.5	-0.4	0.0	0.0	-0.1	-0.3	-0.8	-0.3	0.3	0.0
HERAS_age1	1	0.2	0.0	-0.1	-0.1	0.0	-0.1	0.0	0.2	0.1		0.0	0.0	0.0	0.0	0.0	0.1	**0.2**	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	-0.1	0.0	0.2
HERAS_age2	2	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	**0.4**	**0.1**	0.0	0.0	0.0	**0.3**	0.0	0.0	0.0	-0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0
HERAS_age3	3	0.1	**0.4**	**0.2**	**0.2**	0.0	0.0	0.0	0.1	-0.1	0.0	0.1		**0.4**	**0.6**	**0.2**	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1
HERAS_age4	4	0.0	**0.5**	0.2	**0.2**	0.1	0.0	0.0	0.1	0.0	0.0	**0.4**	**0.4**		**0.6**	**0.3**	0.1	0.0	**0.4**	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.2
HERAS_age5	5	0.2	**0.4**	0.0	**0.2**	0.1	0.0	-0.1	0.1	0.0	0.0	**0.1**	**0.6**	**0.6**		**0.3**	0.1	0.0	**0.2**	0.0	0.1	0.1	0.0	0.0	0.0	**0.4**	0.1	0.2	0.0	0.1
HERAS_age6	6	0.2	0.2	**0.4**	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	**0.2**	**0.3**	**0.3**		0.1	0.0	**0.2**	0.1	0.2	0.0	-0.2	-0.1	0.3	0.2	0.0	0.0	0.0	**0.2**
HERAS_age7	7	-0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	-0.1	0.1	0.0	0.0	0.1	0.1	0.1		0.0	0.0	**0.5**	0.3	**0.4**	-0.1	-0.1	0.4	0.1	**0.4**	0.0	-0.4	0.0
HERAS_age8	8	0.0	-0.1	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	**0.2**	0.0	0.0	0.0	0.0	0.0	0.0		-0.1	0.0	0.0	0.0	0.1	**0.4**	0.0	0.0	0.0	0.0	0.0	0.0
N20_age0	0	0.0	**0.6**	**0.2**	0.1	0.2	0.0	0.0	0.0	0.0	0.0	**0.3**	0.1	**0.4**	**0.2**	**0.2**	0.0	-0.1		0.0	0.0	0.1	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.1
IBTS+BITS-Q1_age1	1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	-0.1	-0.6	0.0	0.0	0.0	0.0	0.0	0.1	**0.5**	0.0	0.0		**0.4**	0.2	0.0	0.0	**0.5**	0.2	0.0	-0.1	-0.3	0.0
IBTS+BITS-Q1_age2	2	0.0	0.0	0.1	**0.3**	0.2	0.2	-0.2	-0.1	-0.5	0.1	0.0	0.0	0.1	0.1	0.2	0.3	0.0	0.0	**0.4**		**0.5**	0.0	0.0	0.1	**0.6**	**0.5**	0.0	-0.1	0.2
IBTS+BITS-Q1_age3	3	0.0	0.0	0.0	**0.5**	0.2	0.1	0.0	0.0	-0.4	0.1	0.0	0.1	0.1	0.1	0.0	**0.4**	0.0	0.1	0.2	**0.5**		0.0	-0.2	0.1	0.2	**0.4**	0.1	-0.2	0.1
IBTS+BITS-Q1_age4	4	0.0	0.0	-0.4	0.0	0.1	0.2	0.0	0.1	0.0	0.0	-0.1	0.0	0.0	0.0	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0		0.0	-0.1	0.0	0.0	0.0	-0.1	-0.2
IBTS+BITS-Q1_age5	5	0.0	-0.1	-0.1	-0.2	-0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	**0.4**	-0.2	0.0	0.0	-0.2	0.0		-0.1	0.0	0.0	0.0	0.1	0.0
IBTS+BITS-Q3.4_age0	0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	-0.3	-0.1	0.0	-0.1	0.0	0.1	0.0	0.3	0.4	0.0	0.0	**0.5**	0.1	0.1	-0.1	-0.1		0.0	0.0	-0.2	0.0	0.0
IBTS+BITS-Q3.4_age1	1	0.1	0.0	0.0	0.2	0.1	0.3	-0.5	-0.1	-0.3	0.0	-0.1	0.1	0.1	**0.4**	0.2	0.1	0.0	0.0	0.2	**0.6**	0.2	0.0	0.0	0.0		0.2	0.1	-0.1	0.1
IBTS+BITS-Q3.4_age2	2	0.2	0.0	0.0	0.2	0.1	0.0	-0.2	0.0	-0.8	0.1	0.0	0.0	0.1	0.1	0.0	**0.4**	0.0	0.0	0.0	**0.5**	**0.4**	0.0	0.0	0.0	0.2		**0.3**	0.0	0.1
IBTS+BITS-Q3.4_age3	3	0.1	0.1	0.1	**0.2**	0.0	0.2	-0.1	0.0	-0.3	-0.1	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	-0.1	0.0	0.1	0.0	0.0	-0.2	0.1	**0.3**		0.0	0.1
IBTS+BITS-Q3.4_age4	4	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	-0.3	-0.1	-0.2	-0.1	0.1	0.0	-0.1	0.0	0.0		0.2
IBTS+BITS-Q3.4_age5	5	**0.3**	0.2	0.2	0.1	0.0	0.0	-0.2	0.0	0.0	0.2	0.0	0.1	0.2	0.1	**0.2**	0.0	0.0	0.1	0.0	0.2	0.1	-0.2	0.0	0.0	0.1	0.1	0.1	0.2	

Figure B.3.4 tabulated correlations between age-classes within cohorts, within and among surveys. Values are given as R2 with the sign of the correlation. Values in red are positive significant with a p(t,n-2)<0.05, $t=(R^2*(n-2)/(1-R^2))^{0.5}$.

Conclusively, the survey indices used in the assessment are the following (in green):



B.4. Commercial cpue

B.5. Other relevant data

C. Assessment: data and method

In the model used for both assessment and forecast the fishing mortality is given per fleet – multi fleet, see the fleet definitions in section A.2. In parallel a model with the combined fishing mortality is runned for consistency check – single fleet.

General

Model used: State–space model SAM

Software used: SAM (via web-interface https://www.stockassessment.org)

Multi fleet configurations

```
# Configuration saved: Tue Feb 13 12:34:28 2018
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
(The order of fleets: fleet A, fleet C, fleet D, fleet F, HERAS, GerAS, N20,
IBTS+BITS-Q1, IBTS+BITS-Q3.4)
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 0

$maxAge
# The maximum age class in the assessment
 8

$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
 1

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
  -1    0    1    2    3    4    5    6    6
   7    8    9   10   11   12   13   14   14
  15   16   17   18   19   20   21   22   22
  23   24   25   26   27   28   29   30   30
  -1   -1   -1   -1   -1   -1   -1   -1   -1
  -1   -1   -1   -1   -1   -1   -1   -1   -1
  -1   -1   -1   -1   -1   -1   -1   -1   -1
  -1   -1   -1   -1   -1   -1   -1   -1   -1
  -1   -1   -1   -1   -1   -1   -1   -1   -1
  -1   -1   -1   -1   -1   -1   -1   -1   -1

$corFlag
```

```
# Correlation of fishing mortality across ages (0 independent, 1 compound sym-
metry, or 2 AR(1)
 0 2 2 2

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is not
used, as that is covered by fishing mortality).
-1      -1      -1      -1      -1      -1      -1      -1      -1
-1      -1      -1      -1      -1      -1      -1      -1      -1
-1      -1      -1      -1      -1      -1      -1      -1      -1
-1      -1      -1      -1      -1      -1      -1      -1      -1
-1      -1      -1      0       1       2       3       -1      -1
-1      4       5       6       7       -1      -1      -1      -1
 8      -1      -1      -1      -1      -1      -1      -1      -1
-1      9       10      11      -1      -1      -1      -1      -1
-1      -1      12      13      -1      -1      -1      -1      -1
-1      -1      -1      -1      -1      -1      -1      -1      -1


$keyQpow
# Density dependent catchability power parameters (if any).
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only
first row is used)
  -1   0   0   0   0   0   0   0   0
   1   1   1   1   1   1   1   1   1
   2   2   2   2   2   2   2   2   2
   3   3   3   3   3   3   3   3   3
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
        -1      0       1       1       1       1       1       1       1
         2      3       4       4       4       4       4       4       4
         5      6       6       6       6       6       6       6       6
         7      8       8       8       8       8       8       8       8
        -1      -1      -1      9       9       9       9       -1      -1
        -1      10      10      10      10      -1      -1      -1      -1
         11     -1      -1      -1      -1      -1      -1      -1      -1
        -1      12      12      12      -1      -1      -1      -1      -1
        -1      -1      13      13      -1      -1      -1      -1      -1
        -1      -1      -1      -1      -1      -1      -1      -1      -1
```

```
$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US"
for unstructured). | Possible values are: "ID" "AR" "US"
 "ID" "AR" "ID" "AR" "AR" "AR" "ID" "AR" "US" "NA"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) struc-
ture is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they
cannot).
#0-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8
  NA  NA  NA  NA  NA  NA  NA  NA
  3   3   3   3   4   4   4   4
  NA  NA  NA  NA  NA  NA  NA  NA
  3   3    3   3  4   4   4   4
  -1  -1  -1  0  0  1  -1  -1
  -1  2  1  0  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1
  -1  2  1  -1  -1  -1  -1  -1
  -1  -1  NA  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for
Beverton-Holt).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled
years, ncols = no ages).

$fbarRange
# lowest and higest age included in Fbar
 3 6

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index,
and 2 FSB index).
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN" "LN" "LN" "LN" "LN" "LN" "LN"

$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treat-
ment (0 relative weight, 1 fix variance to weight).
 0
```

Single fleet configurations

```
# Configuration saved: Tue Feb 13 12:58:49 2018
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
(The order of fleets: Catch, HERAS, GerAS, N20, IBTS+BITS-Q1, IBTS+BITS-Q3.4)
# Same number indicates same parameter used
```

```
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 0

$maxAge
# The maximum age class in the assessment
 8

$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
 1

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
   0   1   2   3   4   5   6   7   7
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound sym-
metry, or 2 AR(1)
 2

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is not
used, as that is covered by fishing mortality).
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1   0   1   2   2  -1  -1
  -1   3   4   5   5  -1  -1  -1  -1
   6  -1  -1  -1  -1  -1  -1  -1  -1
  -1   7   8   9  -1  -1  -1  -1  -1
  -1  -1  10  11  -1  -1  -1  -1  -1

$keyQpow
# Density dependent catchability power parameters (if any).
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only
first row is used)
   0   0   0   0   0   0   0   0   0
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
   6   0   0   0   0   0   0   0   0
```

```
  -1  -1  -1   1   1   1   1  -1  -1
  -1   2   2   2   2  -1  -1  -1  -1
   3  -1  -1  -1  -1  -1  -1  -1  -1
  -1   4   4   4  -1  -1  -1  -1  -1
  -1  -1   5   5  -1  -1  -1  -1  -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US"
for unstructured). | Possible values are: "ID" "AR" "US"
 "AR" "AR" "AR" "ID" "AR" "US"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) struc-
ture is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they
cannot).
#0-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8
   3  3  3    3   4   4   4   4
  -1  -1  -1  0  0  1  -1  -1
  -1  2  1  0  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1
  -1  2  1  -1  -1  -1  -1  -1
  -1  -1  NA  -1  -1  -1  -1  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for
Beverton-Holt).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.

$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled
years, ncols = no ages).

$fbarRange
# lowest and higest age included in Fbar
 3 6

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index,
and 2 FSB index).
 -1 -1 -1 -1 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN" "LN" "LN"

$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treat-
ment (0 relative weight, 1 fix variance to weight).
 0
```

Input data types and characteristics:

Version	Type	Name	Year range	Age range	Variable from year to year Yes/No
Multi fleet	Canum – fleet A	Catch-at-age in numbers (1000)	1991–last data year	0–8+	Yes
	Canum – fleet C	Catch-at-age in numbers (1000)	1991–last data year	0–8+	Yes
	Canum – fleet D	Catch-at-age in numbers (1000)	1991–last data year	0–8+	Yes
	Canum – fleet F	Catch-at-age in numbers (1000)	1991–last data year	0–8+	Yes
	Weca – fleet A	Weight-at-age in the commercial catch (kg)	1991–last data year	0–8+	Yes
	Weca – fleet C	Weight-at-age in the commercial catch (kg)	1991–last data year	0–8+	Yes
	Weca- fleet D	Weight-at-age in the commercial catch (kg)	1991–last data year	0–8+	Yes
	Weca – fleet F	Weight-at-age in the commercial catch (kg)	1991–last data year	0–8+	Yes
Sinfgle fleet	Canum	Catch-at-age in numbers (1000)	1991–last data year	0–8+	Yes
	Weca	Weight-at-age in the commercial catch (kg)	1991–last data year	0–8+	Yes
Multi and single fleet	West	Weight-at-age of the spawning stock at spawning time (kg)	1991–last data year	0–8+	Yes, assumed as the mean weight in the catch first quarter
	Mprop	Proportion of natural mortality before spawning	1991–last data year	0–8+	No, set to 0.25 for all ages in all years
	Fprop	Proportion of fishing mortality before spawning	1991–last data year	0–8+	No, set to 0.1 for all ages in all years
	Matprop	Proportion mature-at-age	1991–last data year	0–8+	No, constant for all years
	Natmor	Natural mortality	1991–last data year	0–8+	No, constant for all years

Presently used Tuning data:

Version	Type	Name	Year range	Age range
Multi and single fleet	Tuning fleet 1	HERAS	1991–last year data Except 1999	3-6
	Tuning fleet 2	GerAS	1994–last year data Except 2001	1-4
	Tuning fleet 3	N20	1992–last year data	0
	Tuning fleet 4	IBTS+BITS-Q1	2002–last year data	1–3
	Tuning fleet 5	IBTS+BITS-Q3.4	2002–last year data	2-3

D. Short-term projection

Model used: Age structured multifleet SAM: WBSS_HAWG_2018

Software used*:* Rscript (integrated in the SAM web-interface https://www.stockassessment.org)

Initial age structure of the stock for the intermediate year: SAM estimates of survivors (except age0)

Recruitment (age0): Randomly sampled over the five years previous to the assessment year. The forecasts being deterministic, recruitment corresponds to the arithmetic mean recruitment over the five year period

Natural mortality: The same constant vector used for all years in the assessment

Maturity: The same constant vector used for all years in the assessment

F and M before spawning: The same values used for all the years in the assessment

Weight-at-age in the stock: Average weight of the last five years

Weight-at-age in the catch: Average weight of the last five years

The deterministic feature in the SAM multi-fleet model is used to estimate and project the exploitation pattern (selectivity).

Intermediate year assumptions: Catch constraint with the following assumptions:

In case an optional transfer of quota between 3.a and the North Sea is agreed by managers, the Pelagic RAC will provide HAWG with an estimate of the proportion of the TAC for 3.a that will be fished in the North Sea in the assessment year. This estimate will be provided at least two weeks before the working group meeting. If this information is not available, then the proportion of the TAC not taken in 3.a will be assumed to be the average of the most recent three years for which data are available (including only those years where an optional transfer was applied).

The proportion of the Norwegian quota in Division 3.a that is assumed to be caught as NSAS in Subarea 4 is assumed to be the same as last year, and subtracted from the TAC for the C-fleet in Division 3.a.

The TAC utilisation in the F-fleet is assumed 100% and in the D-fleet equal to the average of the recent three years, unless information from the industry provides a reliable different number. The catches in the A-fleet of WBSS in area 4a East is assumed equal to the average catch of the recent three years.

The proportions of WBSS in the catches in the C-, D- and F-fleets are assumed equal to the means of the recent three years.

Stock–recruitment model used: None

Procedures used for splitting projected catches: Projected catches are for WBSS herring only, therefore no splitting is needed. However, when fleet-wise catch options are advised, the same proportions of WBSS as in the intermediate year are used for raising to total catches in the prediction year.

To most closely resemble current WBSS management, a constraint is added to the forecasts so that, after the intermediate year, all scenarios assume the F fleet gets 50% of the total catch for WBSS herring.

E. Medium-term projections

F. Long-term projections

G. Biological reference points

At the last WKPELA benchmark in 2018, the reference points of the WBSS herring have been redefined based on the new assessment and a new interpretation of the S-R relationship for this stock (ICES 2018b). There are two novel implications coming out from the revised interpretation of the S-R relationship:

- Contrary to what concluded from previous analyses, recruitment of the WBSS herring is interpreted as impaired for SSB below approx. 120 kt which is adopted as Blim.
- The years with lowest recruitment all lay in the most recent period (2004-2016) when SSB is also small. However, at present there are no elements sufficient to support or exclude the hypothesis of a shift in the regime productivity for the stock. Hence, the entire time series was used to parameterise the S-R relationship for calculation of the reference points.

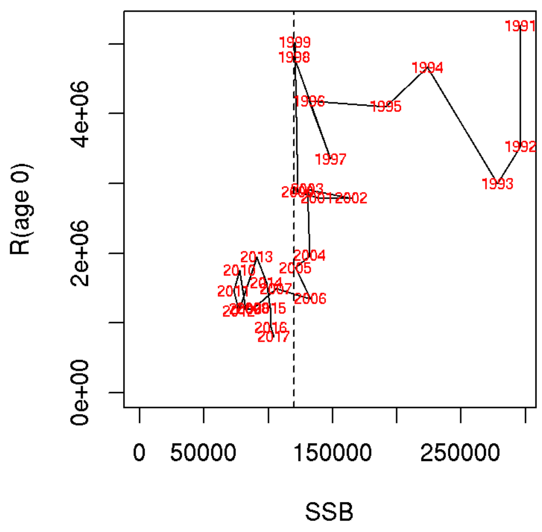


Figure G.1.1. Scatterplot of SSB-Recruitment for the period 1991-2017, with dotted vertical line at 120 kt.

The updated reference points and their technical bases are as follows.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	150000 t	B_{pa} equal to the upper 95% confidence limit of B_{lim}.	ICES (2018)
	F_{MSY}	0.31	Stochastic simulations (Eqsim) with Beverton-Holt, Ricker, and segmented regression stock–recruitment curve from the full time-series (1991–2016).	ICES (2018)
Precautionary approach	B_{lim}	120000 t	Chosen as the mean of the two lowest SSB (1998, 1999) producing still high recruitment levels	ICES (2018)
	B_{pa}	150000 t	Upper 95% confidence limit of B_{lim} with $\sigma \approx 0.136$, using the *CV* from the final-year (2016) SSB estimate in the assessment.	ICES (2018)
	F_{lim}	0.45	$F_{P50\%}$ from stochastic simulations with Beverton-Holt, Ricker, and segmented stock–recruitment curve from the full time-series (1991–2016).	ICES (2018)
	F_{pa}	0.41	The F that leads to SSB ≥ Blim with 95% probability. **	ICES (2018)
Management plan*	MAP MSY $B_{trigger}$	110 000 t	MSY $B_{trigger}$	EU (2016 – Annex II column A)
	MAP B_{lim}	90 000 t	B_{lim}	EU (2016) Annex II column B
	MAP F_{MSY}	0.32	F_{MSY}	EU (2016 – Annex I columns A and B)
	MAP target range F_{lower}	0.23–0.32	Consistent with the ranges provided by ICES (2015a), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2015) and EU (2016 – Annex I column A)
	MAP target range F_{upper}	0.32–0.41	Consistent with the ranges provided by ICES (2015a), resulting in no more than a 5% reduction in long-term yield compared with MSY.	ICES (2015) and EU (2016 – Annex I column B)

* Only applies to herring in SD22-24

** Redefined in 2021 (ICES 2021)

H. Other issues

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