Stock Annex: Herring (*Clupea harengus*) in Division IIIa and Subdivisions 22–24 (spring spawners) (Skagerrak and Kattegat, Western Baltic)

Stock:	Herring (*Clupea harengus*) in Division IIIa and Subdivisions 22–24 (spring spawners) (Skagerrak and Kattegat, Western Baltic) (her-3a22)
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 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

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 (abbreviated RHS), 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 RHS 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 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.

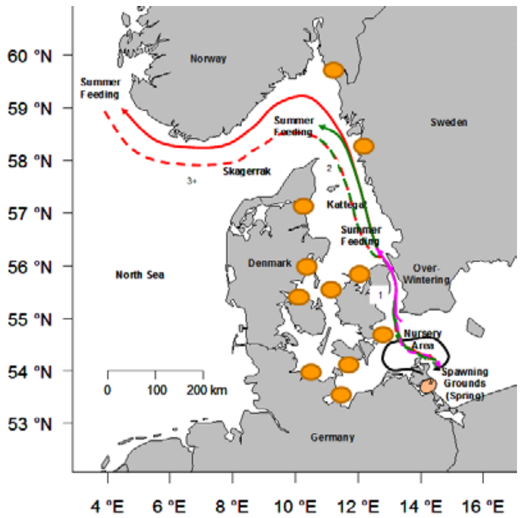


Figure 1. General migration patterns of the WBSS; the numbers indicates the age-dependent migration pattern; the yellow circles indicate local spawning populations (redrawn from M. Payne).

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 IIIa 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.

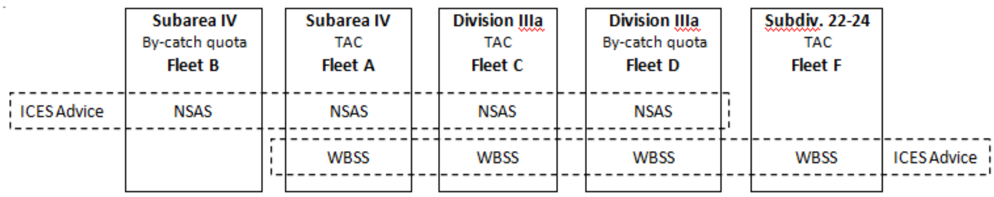
The fishery on WBSS takes place in the eastern North Sea, Division IIIa and the Western Baltic. In these areas the stock complex mixes with another large herring stock complex; the North Sea Autumn Spawners (NSAS). All spring-spawning herring in the eastern part of the North Sea (IVa&b east), Skagerrak (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

Background

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 IVa East.

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 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, with the exception of the splitting key made for the mixture area in Subdivision IVa East, where vertebrae counts currently is the only method used to split the mixed-stock (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 1000 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 IIIa. 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 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.

Validation

The purpose of classifying individual spawning type is to estimate proportions of the two major stock components by age in catches and surveys from the different areas and seasons. Combining OM with otolith shape and fish meristic characters in a discriminant analysis approach will increase precision of the estimated stock propor-tions if errors in estimated proportions are low. Validation of the shape and meristic based methodology may be performed using samples of known spawning type (from OM analysis) and classifying subsets by shape/meristics to test for bias and variation in estimated proportions.

OM and otolith shape data from the 2010 HAWG were used as a typical example of the procedure for estimating proportions of hatch type representing North Sea autumn and winter spawners and western Baltic spring spawners in the samples. The data were disaggregated into age groups 0, 1, 2 and 3+ and individuals of known autumn/winter or spring hatched types were used to assign the corresponding shape parameters and fish metrics from the same individuals by cross-validated nonpara-metric nearest neighbour discriminant analysis.

The accuracy of individual assignment of 1279 otoliths into known hatch type varied somewhat among hatch types and ages (2%–100%) but exhibited an overall error rate of 15.7% (see Table 4.1.1). However, more importantly, the average absolute error of the proportions of WBSS was only 2%, indicating a reasonably robust method for up-scaling the baseline to the larger production sample.

Table 4.1.1. Stock assignment data from 2009 commercial samples of herring in Division IIIa.

		assigned to type		known type	estimated	deviasion		% error in	
Age group	known type	WBSS	NSAS	number	number	Individ. assignm.	prop.	Individ. assignm.	prop.
0	WBSS	34	13	47	44	13	3	27.7%	-6.4%
	NSAS	10	145	155	158	10	3	8.2%	1.9%
1	WBSS	188	72	260	254	72	6	27.7%	-2.3%
	NSAS	66	204	270	276	66	6	26.1%	2.2%
2	WBSS	288	14	302	305	14	3	4.6%	1.0%
	NSAS	17	3	20	17	17	3	82.4%	-15.0%
3+	WBSS	216	4	220	221	4	1	1.8%	0.5%
	NSAS	5	0	5	4	5	1	100.0%	-20.0%
		824	**455**	**1279**	**1279**	**201**	**26**	**15.7%**	**2.0%**

A.2. Fishery

Fleet definitions

The fleet definitions used since 1998 for the fishery in Division IIIa are:

- **Fleet C**: directed fishery for herring in which trawlers (with 32 mm minimum mesh size) and purse seiners participate.
- **Fleet D**: All fisheries in which trawlers (with mesh sizes less than 32 mm) and small purse seiners, fishing for sprat along the Swedish coast and in the Swedish fjords, participate. For most of the landings taken by this fleet, herring is landed as bycatch.

Danish and Swedish bycatches of herring from the sprat, Norway pout and blue-whiting fisheries are included in fleet D.

In Subdivisions 22–24 most of the catches are taken in a directed fishery for herring and some as bycatch in a directed sprat fishery. All landings from Subdivisions 22–24 are treated as one fleet.

The fishery

The Western Baltic herring fishery is a multinational fishery that seasonally targets herring in the eastern parts of the North Sea (Eastern IVa,b), the Skagerrak and Kattegat (Division IIIa) 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 (herring catches in the IIIa and 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 bycatch 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 IIIa and SD 22–24 discarding is considered negligible because all sizes are equally valuable and hence there are no incentives for highgrading since hence.

The bycatch 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 IIIa and hence a limited bycatch of juvenile herring. Further, herring bycatch quota is allocated in both the North Sea and Area IIIa. The sprat fishery in SD 22–24 operates with a certain degree of herring bycatch which is closely monitored and counted against the sprat quota (up to 8% herring allowed).

A.3. Ecosystem aspects

Herring is presumably the key pelagic species in the IIIa 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.

Rügen herring is considered a significant component of WBSSH. 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 IIIa and the adjacent North Sea, where catches from the North Sea have been reported in IIIa. 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 IIIa.

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 IIIa 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 IIIa TAC), where part of the TAC in IIIa legally could be caught in the North Sea.

It is unclear to what extent Swedish catches reported in IIIa 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 IIIa 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 IIIa TAC (North Sea or IIIa) 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).

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 IIIa, while sampling intensity is highest in the northeastern area.

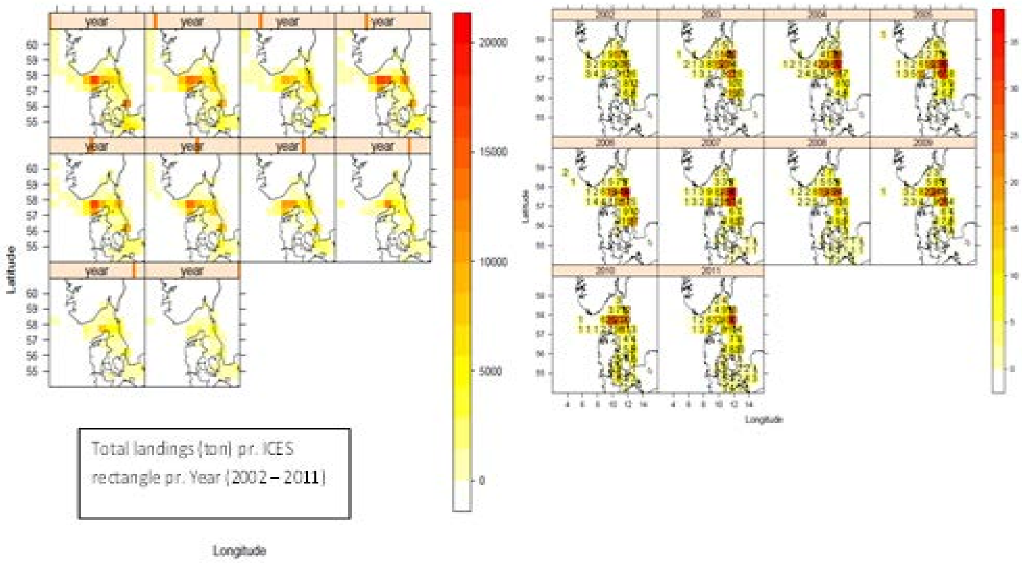
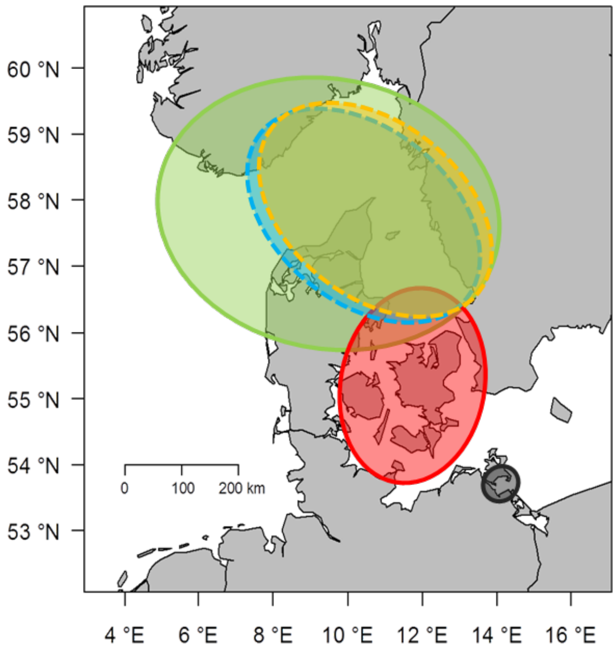


Figure 4.7.1.1. Number of samples by rectangle (right panel) and average landings in tonnes per year by ICES rectangle (left panel) over the period 2002–2011.

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 the past 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 IVaE (Figure 4.7.1.1). Thus it is highly recommended that the sampling intensity in Subdivision IVaE and eastern parts of IVb is substantially increased.

B.3. Surveys

The WBSS stock has several survey indices available as tuning indices for the assessment (Figure 4.7.2.1). During the benchmark process, an objective selection of survey datasets for inclusion in the stock assessment was performed. In essence, any dataset included should increase the net amount of information, adding more signal than noise. The signal-to-noise ratio in a survey depends on both the noise level and the magnitude of the underlying signal itself (i.e. for a given constant noise level, signals that vary slightly will always be harder to detect than those that vary widely). For example, sample size, survey design, spatial coverage (including how well the spatial distribution of the stock is captured), and consistency of performance can all contribute significant amounts of noise to survey data. In the following the available surveys are described shortly as well as their status as tuning indices.



Survey name	Method	Season	Time-series	Ages	Colour code
GERAS	Acoustic	October	1991-2011	0 to 8	
HERAS	Acoustic	June/July	1991-2013	0 to 8+	
IBTS Q1	Bottom trawl	February/March	1991-2014	1 to 4	
IBTS Q3	Bottom trawl	September	1991-2015	1 to 4	
N20	Larvae sampling	September	1992-2011	0	

Figure 4.7.2.1. Spatial and temporal survey coverage of the WBSS herring stock complex.

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, 2012).

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. 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).

WKPELA (ICES 2013/ACOM:46) thoroughly compared the performance of the GERAS with and without the CBH component and as a result, the GERAS without the CBH component is applied in the assessment (ICES 2013/ACOM:06).

In order to analyse the external consistency between GERAS and the non-larvae surveys, the pairwise correlations of index time-series between all combinations surveys and for each age class respectively in order to analyse to what extent surveys indicate the same development in herring abundance over time. GERAS displayed high external consistency with IBTS-Q1 for age-3 and for the larval survey when correlating the larvae-index in year i with age class 1 in year i+1 and age class 2 in year i+2, etc.

Thus conclusively; both versions of the GERAS are suitable as indices for the WBSS, however, if judging solely on the internal consistency, the 'new' version appear better fit than the version including the CBH. **GERAS is used as one of the tuning indices in the assessment.**

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 IIIa to include the overlapping western Baltic spring-spawning stock, the whole of VIa (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 (e.g. ICES, 2012).

The internal consistency of HERAS was analysed following the same procedure as applied for GERAS.

As shown in Figure B.3.1, HERAS displayed high internal consistency for ages 3–6, but no internal consistency for ages 1–2.

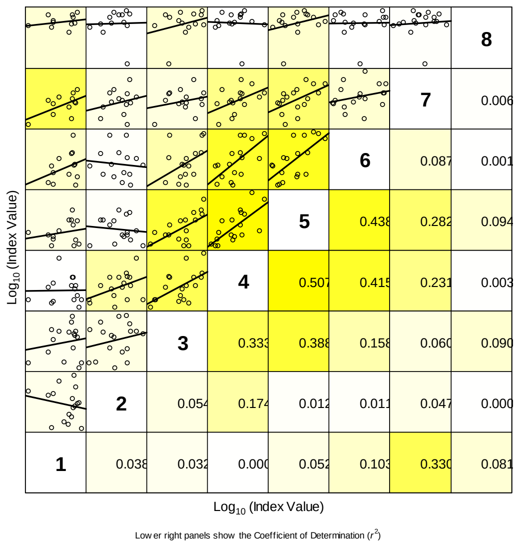


Figure B.3.1. Correlation coefficient diagram for acoustic survey by cohort.

The external consistency between HERAS and the non-larvae surveys was analysed following the same procedure as described for GERAS above. HERAS showed a relatively high consistency with IBTS-Q3 for age-4.

Conclusively; the HERAS index consistently provides age-disaggregated information on WBSS herring. There is a strong internal consistency when tracking cohorts as obtained from the acoustic survey time-series and it correlates with other indices on the older age groups. Thus the time-series derived from the acoustic survey from 1996 to the present is regarded as a relatively good and precise indicator for abundance -at-age. **HERAS is used as one of the tuning indices in the assessment.**

IBTS Q1 and Q3

The International Bottom Trawl Survey (IBTS) in Division IIIa 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 the 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 of the WKPELA benchmark the suitability of these indices were re-evaluated.

The internal consistency of both surveys was analysed following the procedure described for GERAS, and in general the internal consistency in the two IBTS time-series was less than for the acoustic surveys. Overall consistency was highest among older fish and in IBTS-Q1 (Figure B.3.2).

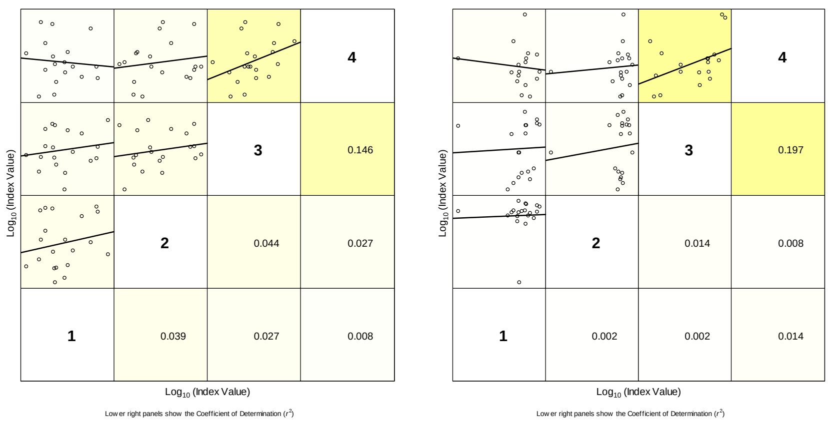


Figure B.3.2. Correlation coefficient diagram for IBTS Q1 (left panel) and IBTS Q3 (right panel) survey by cohort.

The external consistency between the IBTS surveys and the non-larvae surveys was analysed following the same procedure as described for GERAS above. The external consistency between HERAS and IBTS-Q3 for age-4 and between IBTS-Q1 and IBTS-Q3 for age 1 was relatively high. Therefore, **IBTS Q1 and Q3 are used as indices in the assessment.**

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 09; Oeberst *et al.*, 2009 for detailed description).

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.

The consistency/ability of the N20 to match the recruitment of the WBSS stock was analysed by correlating the larvae-index in year i with age class 1 in year i+1 and age class 2 in year i+2, etc. Figure B.3.3 shows the consistency between the N20 and the revised GerAS index which proved to be the survey fitting the N20 best. The index from the Larvae survey is externally highly consistent with GERAS age 1 (best for the new time-series) and to some extent with age 0 in the same survey. Therefore, **the N20 is used as index in the assessment.**

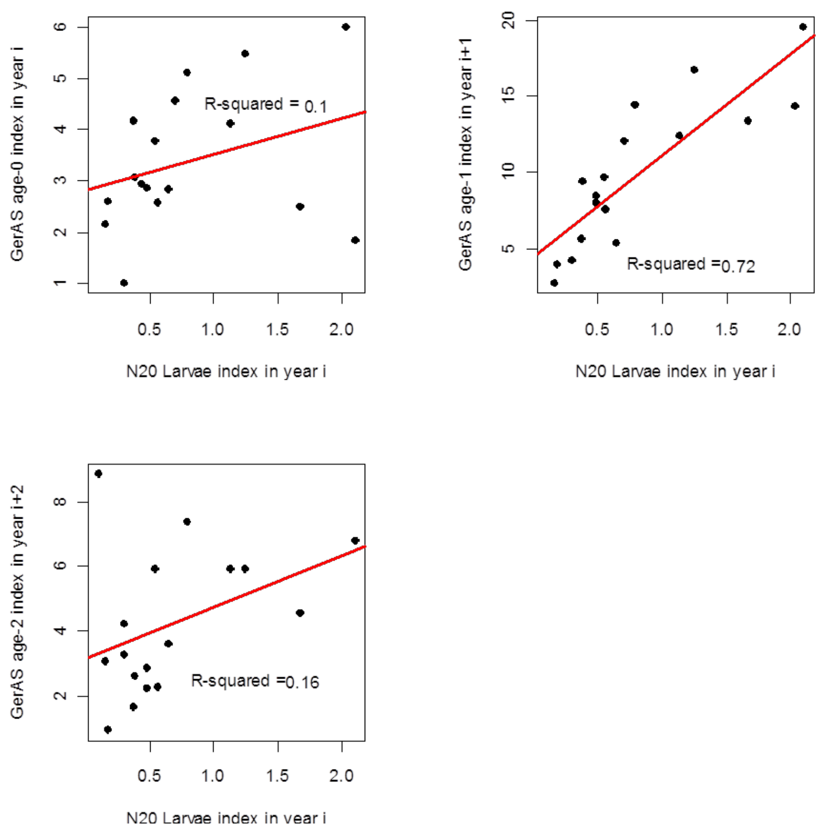


Figure B.3.3. Correlation coefficient diagram for N20 with the revise GerAS index by age group.

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

B.4. Commercial cpue

None.

B.5. Other relevant data

None.

C. Assessment: data and method

Model used: State–space model SAM

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

Model Options chosen:

Minimum age: 0

Maximum age: 8+

Coupled ages of fishing mortality states: 0,1,2,3,4,5+

Correlated random walk on F

Coupled ages of HERAS catchability: 1,2,3,4,5,6,7+

Coupled ages of GerAS catchability: 0,1,2,3,4,5,6,7+

Coupled ages of IBTS q1 catchability: 1,2,3,4

Coupled ages of IBTS q3 catchability: 1,2,3,4

Coupled ages of F variance: 0,1+

Coupled ages of logN variance: 0-8+

Coupled ages of catch observation variance: 0,1-4,5-8+

Coupled ages of HERAS observation variance: 1,2,3–6,7+

Coupled ages of GerAS observation variance: 0–3,4–5,6+

Coupled ages of IBTS q1 observation variance: 1–4

Coupled ages of IBTS q3 observation variance: 1–2,3–4

Coupled ages of N20 observation variance: 0

FBAR age: 3–6

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Canum	Catch-at-age in numbers	1991–last data year	0–8+	Yes
Weca	Weight-at-age in the commercial catch	1991–last data year	0–8+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1991–last data year	0–8+	Yes, assumed as the Mw 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:

Type	Name	Year range	Age range
Tuning fleet 1	Danish part of HERAS in Division IIIa	1991–last year data Except 1999	1–8+
Tuning fleet 2	German part of BIAS in SDs 22–24	1994–last year data Except 2001	0–8+
Tuning fleet 3	N20 larval survey, Greifswalder Botten	1992–last year data	0
Tuning fleet 4	IBTS quarter 1	1991–last year data	1–4
Tuning fleet 5	IBTS quarter 3	1991–last year data	1–4

D. Short-term projection

Model used: Age structured

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 and age1)

Recruitment (age0): Geometric mean of the recruitment over the five years previous to the assessment year

Age1: calculated by simple exponential decay [$N_{1,t+1} = N_{0,t} \cdot e^{-(F_0+M_0)}$] assuming the same geometric mean recruitment in the year of the assessment

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 three years

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

Exploitation pattern (selectivity): Average selection pattern of the last three years

Intermediate year assumptions: Catch constraint with the following assumptions:

In case an optional transfer of quota between IIIa and the North Sea is agreed by managers, the Pelagic RAC will provide HAWG with an estimate of the proportion of the TAC for IIIa 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 IIIa 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 IIIa that is assumed to be caught as NSAS in Subarea IV will be assumed to be the same as last year, and subtracted from the TAC for the C-fleet in Division IIIa.

The fractions of the catch by fleet to the above reduced total TAC in the assessment year is the same as in the previous year.

The proportion of WBSS in the catches in by fleet are assumed equal to the previous year.

Stock–recruitment model used: None

Procedures used for splitting projected catches: Projected catches are for WBSS herring only, therefore no splitting is needed.

E. Medium-term projections

No medium-term projections are carried out for this stock.

F. Long-term projections

No long-term projections are carried out for this stock.

G. Biological reference points

New precautionary biomass reference points were defined at WKPELA 2013. MSY reference points were revised at HAWG 2013.

	Type	Value	Technical basis
MSY	MSY Btrigger	110 000 t	Based on management plan development and the lowest observed SSB in the 2008 assessment.
Approach	FMSY	0.25	Management plan evaluations (ICES, 2008).
	Blim	90 000 t	Blim = Bloss, the 2011 estimate, estimated in 2012.
Precautionary	Bpa	110 000 t	95% confidence interval of the last year's estimate.
Approach	Flim	Not defined	
	Fpa	Not defined	

H. Other issues

None.

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