Stock Annex: Herring (*Clupea harengus*) in Subdivision 30 (Bothnian Sea)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Herring (*Clupea harengus*) in Subdivision 30 (Bothnian Sea)
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A. General

A.1. Stock definition

Management units of Atlantic herring, *Clupea harengus*, have traditionally been based on geographic separation in meristic or morphological characteristics or as a result of stocks with different migration and spawning behaviour (ICES, 2002). The amount of genetic differentiation in Atlantic herring is generally small (Larsson, 2008), and spatial structure and morphological characters have not consistently coincided with genetic differences (Ryman *et al*. 1984; Jørgensen *et al*., 2008). Although previous studies did not find genetic differences between Atlantic herring (Ryman *et al*., 1984 and Koskiniemi and Parmanne, 1991), recent genetic research however, supports the need of spatially separate management units due to transoceanic genetic divergence between the Baltic and North Sea herring populations (Bekkevold *et al*., 2005; Jørgensen *et al*., 2005) as well as within the Baltic Sea between spatially distinct populations (Bekkevold *et al* 2005, Jørgensen *et al*., 2005, 2008). Moreover, Jørgensen *et al*. (2005, 2008) found significant associations between genetic differentiation (using microsattelite loci), sea surface temperature and salinity. The variable results that are found depending on the method used to assess spatial and temporal variation of biological characteristics within the current management units (e.g. Rahikainen and Stephenson, 2004) highlight the complexity in the stock structure of herring and calls for future multivariate approaches to stock identification of herring in the Baltic Sea (Waldman, 1999).

In the Gulf of Bothnia the stock boundary is set between Subdivisions 30 (Bothnian Sea) and Subdivision 31(Bothnian Bay) at 63° 30′ N in the north and at 60° 30′ N in the south. For this stock these borders are useful for management purposes and have a reasonable biological basis (ICES, 2001), although the spatial and temporal structure of herring within this subdivision, as well as the potential consequences of managing the components as a single unit require further investigation. The Bothnian Sea herring (SD 30) have been assessed as a unit since the year 1990 (ICES, 2001).

According to tagging studies, there are two spring-spawning coastal herring populations in the Bothnian Sea (Sub-division 30) (Hannerz, 1955, 1956; Otterlind, 1957, 1962, 1976; Sjöblom, 1961; Parmanne and Sjöblom, 1982, 1986), one is distributed along the west coast and the second along the east coast. The autumn spawning stock is very sparse (Sjöblom, 1978). The separation into the coastal and open sea components is not applicable to these populations, although different spawning groups have been proposed (Ehnholm, 1951). The feeding migration from the coastal area off to the open sea and back follow the same pattern on both sides of the Bothnian Sea.

The spring-spawning coastal herring on the Swedish coast spawns in May-July in coastal areas starting in the shallowest areas and shifting to deeper waters following rising water temperatures (Neuman, 1982). Spawning occurs along the entire coastline (Aro, 1989), but is concentrated within the south-western, south-eastern and north-eastern part of the Bothnian Sea (Bergström 2012). The migration of the adult population from the open sea to the spawning grounds on the coast takes place in late autumn and early winter (Aro, 1989), which is also indicated by the concentration of large herring in the main spawning areas in autumn (Bergström 2012). The new spawners, as well as immature fish, overwinter inside the Archipelago Sea and near the coast, and new spawners join the spawning stock during the spawning time. The feeding migration starts soon after spawning. The main feeding areas are the slopes of the Bothnian Sea Basin and the outer Archipelago Sea. The herring in the western side of the Bothnian Sea seem to be more bound to the coast than the southern Baltic stocks (Otterlind, 1976). The feeding migration occurs mainly along the coast and there seems to be some migration to the Åland Sea and the Quark (Otterlind, 1957, 1962), which are transition areas for the southern and northern stocks. The proportion of the eastward migration to the Finnish coast is very low.

The spring-spawning coastal herring on the Finnish coast also spawns in May-July along the whole coastline, from the northern side of the Archipelago Sea up to the Quark. Some of the younger mature age groups also overwinter and feed near the coastline and in the Archipelago Sea (Sjöblom, 1961). The migration of the adult population to the spawning grounds from the feeding and overwintering areas in the open sea, the Archipelago Sea and in the Quark Archipelago, occurs during the winter, when the first spawning shoals are near to the coast. After spawning, the feeding migration the open sea near the slopes of the Bothnian Sea Basin and in the outer Archipelago Sea occurs quite rapidly. Herring is located in the feeding grounds usually during July-December. The feeding migration extends to southern parts of the Bothnian Sea and inside the Archipelago Sea, in the Quark and sometimes inside the Bothnian Bay. There is also some exchange between the Finnish and Swedish coasts (Parmanne and Sjöblom, 1982, 1986). The spring-spawning coastal herring in the east coast of the Bothnian Sea has a clear philipatric behavior as shown by the tagging experiments where about 95 % of the recaptures were obtained within 150 km from the tagging place (Parmanne and Sjöblom, 1986).

According to the tagging experiments migrations from Gulf of Bothnia to Baltic Sea proper are uncommon (Parmanne, 1990). Mixing of the Bothnian Sea stocks and Bothnian Bay (Subdivision 31) stocks occur, but the magnitude of this migration is unknown. The growth of herring in the Bothnian Sea resembles that in the Bothnian Bay and differs from the growth in Subdivisions 29 and 32 (Parmanne, 1988).

A.2. Fishery

Since the mid-1970s the fishery has been dominated by pelagic and demersal trawl and trap-net fisheries. In 2014, the Finnish fishery accounted for 88% of the total catch, of which the trawl fisheries accounted for 94 % of the Finnish catches. The remaining Finnish catches were taken by trap-nets, which targets the spawning component of the stock in May-June, and 0,2% were taken with coastal gill-nets. The Swedish part of the fishery has been much smaller (e.g. 4% of the total catches in 2011) and of a different gear composition. However, since 2011 the Swedish gear composition has changed and the share of Swedish catches has increased, having been 10% in 2013 and 12% in 2014. In 2014, 81 % of the Swedish catch came from pelagic trawls, 15 % from demersal trawls 4 % from gill-nets and < 1 % from other passive gears.Catches increased in the late 1990s because of an increased efficiency in the fishery and again since 2012 to record high levels due to stock growth and TAC increase. The fishery has been regulated by TACs and the Bothnian Sea belongs to Management Unit 3 of the International Baltic Sea Fishery Commission (IBSFC).

In the herring fishery, pelagic and demersal trawl fleets overlap. Many of the vessels carry out pelagic and a demersal trawling, and generally use the e same gear for both. The pelagic trawl fleet exploits the younger part of the stock and the demersal trawling is more directed towards the adult part of the stock. In autumn and early winter before the Bothnian Sea is covered with ice, pelagic pair trawling is used for industrial purposes. Many pelagic trawling vessels operate between the Bothnian Sea (SD 30) and the Åland Sea and northern Baltic proper (SD 29), depending on fishing possibilities and ice cover during winter. Bottom trawls are used exclusively for Baltic herring whereas pelagic trawls also catch sprat. As the pelagic trawlers, the bottom trawlers operate in different fishing grounds depending on the fishing possibilities and ice cover.

In the trap-net fishery for Baltic herring a variety of trap-net types are used. This fishery is conducted near the coast and inside the archipelago and is mainly targeting the spawning component of Baltic herring stock in spring and early summer (May-June).

The herring discarding rates in Swedish fisheries was estimated in 6–12% of herring catches in 2008–2010. Further analyses on discarding in the Swedish herring fisheries in SD 30 are needed to estimate the herring discarding rates in earlier years.

Discarding rates in the Finnish fisheries are negligible (estimated to a few tonnes annually) and have therefore not been taken into account in assessments. Sweden is catching herring primarily for human consumption, and the preferred fish size is ≥16 cm while smaller sized fish are (presumably) discarded. Another reason for discarding is connected with market fluctuations. In gillnet fisheries all the fish with damages caused by grey (*Halichoerus grypus*) or ringed (*Phoca hispida*) seals' predation is typically discarded. In autumn, herring is also sometimes bycaught in the vendace (*Coregonus vandesius*) and whitefish fisheries. As the reporting of discards is voluntary in the Swedish herring fishery, only a few records of discards are available in the official statistics each year, although the amount reported has increased in recent years. Most of the discards are reported in the herring gillnet fishery and about 17–18 tonnes are discarded annually in SD 30. Fishers themselves regard the discard level of herring in gillnet fisheries as marginal in the Bothnian Sea, but the official estimates show that already reported herring discard is around 13% of the total herring landings of gill-nets. In SD 30, 1–2 tonnes of discarded herring are additionally reported from the trawl fisheries every year, which accounts to less than 1% of the total landings of that fishery. However, interviews of fishermen indicated that they estimated the discard rate to be about 10% for the entire year.

Disagreement between our estimates and official statistics can be explained by the low reporting level of discards in trawl fisheries. Based on the Swedish official statistics (in 2008-2010) and an interview to fishermen (carried out in 2012 by Swedish University of Agricultural Sciences), it can be assumed that 6–12% of Swedish herring catches, taken from SD 30 have been discarded in recent years. It will form up to 1% of the total herring catches in SD 30.

A.3. Ecosystem aspects

The increasing trend in stock size of the Bothnian Sea herring observed since the 1990s has been driven by good recruitment. The biomass dynamics of recruits (age 1) have been linked to increased abundance of *Bosmina* sp. (Lindegren *et al*., 2011), which is an important food source for both young of the year herring <5 cm in the northern Baltic Proper (Arrhenius, 1996), and for herring in the Bothnian Sea (Flinkman *et al*., 1992). Recruit abundance models also show that the number of recruits (age 1) is best explained by *Bosmina* sp. abundance and sea temperature during the main growing season (July-Sept) for the young-of-the-year, while the best model did not identify an effect in recruitment of the spawning stock size (Gårdmark, Working Document 1 for WKPELA; ICES, 2012).

Bothnian Sea herring is the prey of several predators, including cod (*Gadus morhua*), salmon (*Salmo salar*), coastal piscivores, grey seals,ringed seals, and birds such as cormorants (*Phalacrocorax carbo*). Grey seals can be regarded as the main predator for several reasons: cod and salmon rare less abundant and herring makes up to about 70% of the biomass in the diet of an average grey seal (Lundström *et al*., 2010; Gårdmark *et al*., 2012). The proportion of herring in the food of cormorants is below 35% (J.Salmi, pers.comm.) and there are only a low number of ringed seals in the Bothnian Sea (Anonymous 2007).)

Grey seals predate selectively on larger individuals of herring, and mean length of prey was about 18 cm (Gårdmark *et al*., 2012). While grey seals have not been found to be a major driver of herring population dynamics (Lindegren *et al*., 2011), this size-selective removal of herring by grey seals may have led to a decrease in average weight at age of herring cohorts over the last decades (Östman *et al*., 2014.). The decrease in average herring body size is also associated with zooplankton resources (*Eurytemora* sp.), intraspecific density, and age- and cohort-specific fishing mortality (Östman *et al*., 2014).

As no long time-series of fishery-independent herring data or of grey seal diet composition are available from the Bothnian Sea, independent estimates of the trajectory of mortality due to grey seal predation are not possible. Instead, Gårdmark *et al*. (2012) estimated grey seal consumption of herring based on data from gut content analyses of grey seals (Lundström *et al*., 2010), the grey seal population size estimated from aerial surveys combined with a photo-identification (Hiby *et al*., 2007), and a simple bioenergetic model to derive daily intake by grey seals. These estimates of annual age-specific abundances of herring consumed by grey seals were then used in a stock assessment model XSA, combined with a state-space assessment model, to test whether ignoring grey seal predation caused significant bias in herring stock estimates (Gårdmark *et al*., 2012). The authors showed that the abundance of the oldest age classes (8+) was greatly underestimated if the consumption by grey seals was not accounted for. In contrast, the effect of sseal predation in SSB was smaller (at most 19%) which was well within the confidence interval of the standard estimates obtained when ignoring predation (Gårdmark *et al*., 2012). In other words, the uncertainty of standard estimates (due to measurement errors in fisheries catch-at-age data) was much greater than the bias caused by ignoring grey seal consumption. The smaller bias in SSB occurred because the oldest age class only accounted for a small part of the spawning or total stock biomass. Because of this small effect (in relation to the uncertainty due to catch-at-age data) of grey seal consumption on SSB, and the lack of updated grey seal diet composition data, grey seal predation is not included in the current stock assessment. However, the grey seal predation analysis (Gårdmark *et al*., 2012) is limited by the available grey seal diet data, which only covered 2001–2005, and Gårdmark *et al.* point out that the impact of grey seals on the Bothnian Sea herring will need to be reassessed if stock age composition, grey seal feeding preferences or total stock development change. Notable changes to the stock age composition have occurred, with an increasing number of 9+ year old individuals because of the large year class of 2002. The possible effects of grey seal predation through time should therefore be followed and if the number of 9+ year old individuals continue to increase or other changes to the stock composition are registered, new analyses on the potential impact of grey seals on herring should be conducted.

Sprat occurs in the area in late autumn, winter and early spring but the sprat bycatches in herring fisheries are usually low. Sticklebacks are also caught in small, but growing numbers. Sprat and stickleback in the herring trawl fisheries are used for fodder along with the herring.

B. Data

B.1. Commercial catch

Finnish commercial herring catch statistics is based on catch notifications submitted by fishermen at set intervals. The application of the Act (1139/94) on implementing the Common Fisheries Policy of the European Union obliges all professional fishermen to submit catch notifications.

The fishing data of vessels ≥10 metres long are entered in the EU fishing logbook. The data entered are the dates of fishing by fishing trip, the size of the catch by species, the fishing (statistical) rectangle, the gear and number of gears used in fishing, and the trawling time in hours. A fisherman is obliged to keep an up to date logbook onboard his vessel. The logbook must be returned to the regional authorities within 48 hours of the catch being landed.

With the exception of salmon catches, the Finnish fishing data of vessels ≤10 metres long are entered monthly in a coastal fishery form. The data entered are the size of the catch by species by the statistical rectangle, the type and number of gears used in fishing, and the number of fishing days. The forms must be returned to the regional authorities by the fifth day of the following month. All logbooks and most of the other catch notification forms are checked by national authorities.

The proportion of the Baltic herring catch landed in Finland for the food and processing industry in relation to the total catch of that species is estimated with the aid of the fish purchasing register maintained by the Ministry of Agriculture and Forestry.

Because all the main fisheries (pelagic trawls, demersal trawls and trap-nets) have different exploitation patterns, their catches are also sampled separately. The sampling in Bothnian Sea herring fishery is performed according to EU DCF requirements covering 12 strata (3 fleets and 4 year-quarters).

Since the study projects funded by DG XIV (International Baltic Sea Sampling Programs I & II) in 1998–2001, a length stratified sub-sampling scheme has been applied to estimate age compositions of Finnish catches of Baltic herring. This sampling scheme is designed to be compatible with international databases and uses standardized methodologies in data processing. Baltic herring samples are collected mainly in fishing harbours and, if necessary, also onboard commercial fishing vessels. In the sampling scheme the annual life cycle of Baltic herring and the presence of the ice coverage during the winter in the Bothnian Sea have been taken into account. Because of icing conditions, the three fishing gears are not in use year-round (e.g. trap net fishery is usually conducted only in spawning time during quarters 2 and 3). The sampling effort is roughly based on the proportions of catches in different fisheries. Moreover, the sampling intensity in general is locally adjusted during the year according to temporal and regional changes in fisheries. The seasonal herring fishing intensity is predominantly dependent on the TAC, which may cause fishing restrictions in certain fisheries and/or seasons and may therefore change the sampling intensity from the original plan. A minimum coverage requirement is one sample by fishery per month (or three samples by fishery per year-quarter). The sampling strategy is to have age-length samples from all major gears in each quarter.

The Finnish and Swedish input files are uploaded to ICES InterCatch database. The data can also be found in the national laboratories and with the stock co-ordinator. The national data have been aggregated to international data in InterCatch.

Table 1. Description of the types of data available per country.

	Kind of data				
Country	Caton (catch in weight)	Canum (catch at age in numbers)	Weca (weight at age in the catch)	Matprop (proportion mature by age)	Length composition in catch
Finland	x	x	x	x	x
Sweden	x	x	x		x

B.2. Biological

The age and weight data is obtained from both Finnish and Swedish landings as well as from the catch samples in acoustic surveys. The maturity ogives are based on the proportions of mature individuals of each age class in Finnish sampling data, and are updated every year.

From 2002 to 2006, Finnish samples were age determined with two different methods in parallel, using traditionally whole otoliths and as a new method, neutral red stained slices of cut otoliths. The effects of the age determination method were presented at the WGBFAS meeting in 2006 (Raitaniemi and Pönni, 2006). The method affects the age distribution as well as the proportion mature fish at age. Especially in old age groups (from age 5 or 6 on), determination from cut otoliths generally results in an older assessed age compared to whole otoliths. In the comparison, the numbers at age in the total catch differed about 2% on average, but ranged from 0.4% to 52% depending on year and age. On average the proportion of four- to eight-year-olds in the catch was 11% lower, and the proportion of ages 9+ was 32% higher, when using neutral red stained slices compared to whole otoliths. According to Peltonen *et al*. (2002), the agreement between the determinations of different age readers was better with the cut otoliths technique than with whole otoliths. The later resulted in a considerable negative bias in old fish. A combination of age data from Finnish cut otoliths (representing 98% of the catch) and Swedish whole otoliths (representing 2% of the catch) was used between 2002-2006. The slicing method was calibrated between Finland and Sweden in 2007, and it has been applied also to Swedish catches as well as Bothnian Sea surveys since 2007. Since age determination using cut otoliths is considered to be more accurate (Raitaniemi & Pönni 2006), this method is used as the standard method for ageing all the samples, and the time series including ages from whole otoliths from 1973 - 2001 and cut otoliths from 2002 onwards is used in the assessments of this stock.

B.3. Surveys

Annual hydroacoustic surveys were conducted in October from 2007 until 2010 with Swedish R/V Argos. In 2011 and in 2012 the survey was performed with the Danish R/V Dana and since 2013 with Finnish R/V Aranda. This survey is co-ordinated by ICES within the Baltic International Acoustic Surveys (BIAS).

The acoustic survey has been considered as a reliable tuning fleet and has been included in the assessment in 2013 after an independent review process (ICES, 2015a).

B.4. Commercial cpue

The three main fleets operating in Baltic herring fisheries in the Bothnian Sea are:

- Pelagic trawling (single- and pair-trawling)
- Demersal trawling
- Trapnet fisheries (during the spawning period only)

In the Finnish trawl fishery the same gear is often used for pelagic and demersal trawling. There has been an increase in trawl gear size and changes in gear characteristics since the early 1980s. In the past reported fishing effort data (trawling hours) may not been accurate. Thus a correction coefficient for trawl fishing effort data in the time series was applied. This method estimates the increase in average trawl size to quantify the relative change in fishing power of the herring trawling fleet. The annual correction coefficient is derived using a model which estimates the average size of the opening of the trawl (Rahikainen and Kuikka, 2002). The model uses data of trawls sold annually, their size and an estimated annual abolition rate. The total reported fishing effort in trawling hours by year was multiplied by the estimated coefficient. As the same gear is often used both in demersal trawling and pelagic trawling, the same coefficient was used for both fleets. The correction factors of cpue data were used in assessments since 1997. In recent years the data from the manufacturers has not been available and therefore the correction coefficient can't be applied. This creates uncertainty to the trawl fishing effort and therefore the trawl fleets cannot be used for calculating cpue and as a tuning index.

The trap-net tuning fleet has been revised in 2012. Before 2012, the total number of trap-nets set in SD 30 was used as effort for the herring catch caught. Throughout the 1980s the total number of trap-nets decreased but since 1990s it remained more or less stable. Due to reduction in effort in earlier years, the revised dataset starts at 1990.

The revised dataset is checked so that it is considered geographically representative and only includes trap-nets that are used for catching herring in spawning time (April-June). The 1990 - 2006 dataset used in the assessment made in 2015 includes only those areas (statistical rectangles) that have unbroken time series for the catches and the corresponding effort (number of herring trap-nets). The cpue taking into account the difference in catchability between sites is used as an index for stock size (numbers at age) in the assessment. The index of numbers-at-age by year, Ny,a, is estimated by a general linear model (GLM) and fitted to data from the three sites with unbroken series:

$$\log C_{y,a,s} = \log N_{y,a} + \log Q_s + \log E_{y,s}$$

where catch, C, by age (a), year (y) and site (s) depends on the site-specific catchability (Q_s), numbers-at-age by year $N_{y,a}$, and effort (number of traps) per site and year, $E_{y,s}$.

In 2015, the trapnet index was, however, not considered sufficiently reliable by the working group, as it is introducing increasing uncertainties to the assessment.

After a review process (ICES, 2015a) it was decided that the trapnet tuning series should be truncated and the last eight years of data (2007-2014; overlap period between the acoustic and the trapnet tuning series) have not been included in the latest assessment (ICES, 2015a).

A benchmark is suggested for this in the near future, to further investigate the quality of the tuning indices.

C. Assessment: data and method

Model used: stochastic state-space model SAM (ICES, 2009).

The model was run using web interface that can be viewed at https://www.stockassessment.org.

Details concerning input data and model configuration can also be found on this webpage (username: guest, password: guest).

The model configurations are as follows:

- The input data are based on age determination from whole otoliths for 1973-2001 and from cut otoliths from 2002 and onwards.
- For the total catches it is assumed that the logarithm of the fishing mortalities for each group follow a random walk that are correlated for ages 3,4,….8 but not correlated for ages 1,2 and 9+. The variances of these random walks are assumed to be the same. A correlation parameter between the individual random walks is estimated within the model. All age groups have different fishing mortalities.
- The model assumes no stock recruitment relationship, instead the one year old stock size is assumed to follow a random walk on a logarithmic scale.
- Each of the two tunings series have separate catchability parameters for ages below 5 years, and shared catchability parameters for ages 5 and above, all catchability parameters are assumed constant over time
- The variance of the random walk for the logarithm of the numbers at age is assumed common for ages two and above, but age one has an independent variance parameter.
- For the acoustic series the logarithm of the indices for all ages are assumed to have the same observation variance. For the trap-net series all ages 4 and above, are assumed to have the same variance on logarithmic scale, but age 3 has an independent variance parameter.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1973 – last data year		Yes
Canum	Catch at age in numbers	1973 – last data year	1 – 9+	Yes
Weca	Weight at age in the commercial catch	1973 – last data year	1 – 9+	Yes
West	Weight at age of the spawning stock at spawning time.	1973 – last data year	1 – 9+	Yes - assumed to be the same as weight at age in the catch
Mprop	Proportion of natural mortality before spawning	1973 – last data year	1 – 9+	No – set to 0.33 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1973 – last data year	1 – 9+	No – set to 0.15 for all ages in all years
Matprop	Proportion mature at age	1973 – last data year	1 – 9+	Yes
Natmor	Natural mortality	1973 – last data year	1 – 9+	No – set to 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Finnish trap net fleet	1990 – 2006	3-9+
Tuning fleet 2	Acoustic	2007– last data year	2-8+

D. Short-Term Projection

The short term forecast was run by SAM age structured prediction module (ICES, 2015).

The model has been run using web interface that can be viewed at https://www.stock-assessment.org. (username: guest, password: guest)

The short term forecast is based on the SAM short term forecast module. The short term prediction carried out by the SAM model is simulation based, and accounts for uncertainty in the final year estimates. From the assessment model it takes the final estimates of fishing mortality and stock numbers, and their estimation variances and covariances. These quantities are then simulated forward in time for a number of specified scenarios (e.g. scaling of fishing mortality levels). The uncertainties are propagated forward in time, and the process variation (as estimated from the historic period) is added. The simulation is carried out at logarithmic scale, and medians are used as main summary statistic on the untransformed scale. It is important to note that taking uncertainty into account does not merely supply confidence intervals on the final future catch estimates, but can also affect the estimates themselves as the errors accumulate in the non-linear projections.

The settings for the short term projection are as follows:

Initial stock size: Final year estimates from SAM.

Maturity: Assumed to be equal to the average of maturity ogives across the last three years

F and M before spawning: The proportion of total annual natural mortality before spawning is assumed to be 33% and proportion of F before spawning 15% of the annual fishing mortality. Natural mortality is set at 0.2.

Weight at age in the stock and the catch: These are assumed to be equal to the average of mean weights at age across the last three years

Exploitation pattern: The average selectivity pattern, scaled to F in the last year

Stock recruitment model used: Recruitment are based on resampling from the sampled distribution in all years

G. Biological Reference Points

New Fmsy reference points with upper and lower ranges were calculated by the WKREF3 working group (ICES, 2015b) Following the assessment method updates carried out in 2015 and where one of the tuning fleets was truncated (ICES, 2015a, see above) the reference points were recalculated as shown in the table below.

	Type	Value	Technical basis
MSY Approach	FMSY	0.15	equilibrium scenarios constrained by prob(SSB<Blim)<5%
	FMSY upper	0.15	
	FMSY lower	0.11	

MSY $B_{trigger}$ has been estimated in 316000 tonnes (ICES, 2013)

The effect of the recruitment function on F_{MSY} was examined in 2012 using the output from the XSA assessment (WD2, Herring in SD30, ICES 2012). With this assessment there was a negative density-dependence in the recruits-SSB function. There was an indication that temperature affected recruitment for this stock. The choice of recruitment function could both increase and decrease the current estimate of F_{MSY}. Environmental factors and their impact on recruitment should be addressed in future studies.

H. Other Issues

A benchmark is suggested for this stock in 2017, to further investigate the quality of the tuning indices and potential mixing and stock identity of her-30 and her-31 stocks.

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