Stock Annex: Herring (*Clupea harengus*) in Subdivision 28.1 (Gulf of Riga)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Herring (*Clupea harengus*) in Subdivision 28.1 (Gulf of Riga)
Working Group:	Baltic Fisheries Working Group (WGBFAS)
Last benchmark:	
Date of last benchmark:	April 2008 (ICES, 2008)
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Last updated by:	Kristiina Hommik, Tiit Raid and Maris Plikshs
Main modifications:	Minor clarification in short-term projection concerning the recruitment, Table of Reference points was updated

General

A.1. Stock definition

Gulf of Riga herring is a separated population of Baltic herring (*Clupea harengus*) that occurs mainly in the Gulf of Riga (ICES Subdivision 28.1). It is a slow-growing herring with one of the smallest length and weight at age in the Baltic and thus differs considerably from the neighbouring herring stocks in the Baltic Proper (Subdivisions 25-29). The differences in otolith structure serve as a basis for discrimination of Baltic herring populations (ICES, 2005). The stock does not perform migrations into the Baltic Proper; only minor part of the older herring leaves the gulf after spawning season in summer –autumn period but afterwards returns to the gulf. There is evidence, that the migrating fish mainly stay close to the Irben Strait region in Subdivision 28.2 and do not perform longer migrations. The extent of this migration depends on the stock size and the feeding conditions in the Gulf of Riga. In 1970s and 1980s when the stock was on low level the amount of migrating fish was considered negligible. At the beginning of 1990s when the stock size increased also the number of migrating fish increased and since then the catches of Gulf of Riga herring outside the Gulf of Riga in Subdivision 28 were taken into account in the assessments.

A.2. Fishery

Gulf of Riga herring fishery is performed only by Latvia and Estonia. There are two main kinds of fishery: trawl and trapnet. Trawl fishery can be performed all year around except a 30-day ban in May-June during the peak spawning of herring. In Estonia, an additional ban for trawl fishery has been introduced from 15 June to 15 September. In most winters the fishery is stopped or reduced due to ice coverage of the gulf. In Latvia the number of trawlers as well as the total engine power has not been allowed to increase since the end of 1990s. In recent years the number of vessels is gradually decreasing due to scrapping. Each fishing company perform fishery according its particular catch quota. In Estonia, only the vessels with maximum 300 HP engines area allowed to operate in the Gulf. The trapnet fishery takes place during the spawning period from mid-April until July and aims at capturing the spawning fish exclusively. In Latvia the number of trapnets is limited and it was rather stable since the mid-1990s, but has been decreasing since 2004. The relative importance of these two fisheries is different in Latvia and Estonia. From the total Latvian catches about 80–85% are taken by trawls and 15–20% by trapnets. In Estonia the trapnet fishery is more important constituting about 70% of the total catches while trawl catches make on average only 30% of the total catches.

A.3. Ecosystem aspects

The Gulf of Riga is a separate semi-enclosed ecosystem of the Baltic Sea characterized by low salinity of about 5 psu and separated from the Baltic Proper by a strong hydrological front in the Irben Strait. That influences the residence of marine species in the Gulf of Riga and herring is the dominant species in the gulf. The trawl fishery in the gulf targets herring. There is some bycatch of sprat only when the sprat stock is on a high abundance level. There is also a lack of predators in the gulf since cod are present in the Gulf of Riga only in these periods when the cod stock is on a very high level (last time in early 1980s).

The investigations of herring spawning grounds in 1980s showed that their overall spawning area has decreased compared with the situation in 1950s. That happened due to disappearance of demersal vegetation from larger depths as a result of increased eutrophication of the gulf that led to increased mortality of eggs. Since then, the status of the spawning grounds has not been investigated. Estonia has performed the mapping of herring spawning grounds in its waters of the Gulf of Riga in 2011. However, it could be stated that the pollution of the gulf has considerably decreased since the end of 1980s when changes in industry and agriculture took place and several sewage treatment plants were built.

The year-class strength of Gulf of Riga herring strongly depends on the severity of winter. It has been stated already in the 1960s that after mild winters rich year classes are registered (Rannak, 1971). After mild winters spawning starts earlier and the spawning activity is more evenly distributed over the spawning season, which results in lower mortality of eggs on the spawning grounds. Additionally, after mild winters the zooplankton is more abundant providing better feeding conditions for herring larvae. The relationships with average water temperature in April, when the spawning starts, and the abundance of *Copepoda* in May, when the hatching of larvae begins, were used to predict recruitment until 2006.

However, in the more recent RCT3 predictions the weight of zooplankton abundance in the prediction of recruitment has considerably decreased due to appearance of two very rich year classes. Zooplankton abundance in May in those years was only slightly above the average and thus these years stand out of line in the relationship between zooplankton abundance and year-class strength.

Therefore, during the ICES Workshop of Recruitment processes of herring in the Baltic Sea (ICES, 2007) other factors explaining the year-class strength were analysed. It was stated that the average water temperature of 0–20 m depth layer in May and the biomass of the copepod *Eurytemora affinis* have significant relationship with year-class strength of Gulf of Riga herring. Therefore for prediction of 2006 year class at age 1 in 2007 we used new data mentioned above. The same procedure was used in since 2008.

In 2011 the analysis of factors determining year-class strength was performed and a paper at ICES Annual science conference in Gdańsk was presented (Putnis *et al.*, 2011). Two additional significant relationships were found for the herring year-class strength. It was shown that since 2000 the year-class strength strongly depend on the feeding conditions during the herring feeding season. The feeding conditions were characterized as the average Fulton's condition factor for ages 2–5. In 2000, 2002, and 2005 when very rich year classes appeared the Fulton's condition factors were among the highest in 2000–2010. Apparently in good feeding years the feeding competition between older herring and the young-of-the-year decreases and the latter have bigger chance to survive. A strong negative relationship between neighbouring year classes was also found. The very rich year classes were usually followed by poor or below average year classes. Since the one year old herring does not spawn and starts feeding much earlier than the mature herring it strongly affects the amount of food for the young-of-the-year, especially in the end of spring- beginning of summer during the new generation is in larval stage. In 2012 the found relationships were tested in RCT3 but were found insignificant due to high variation ratio. Since 2012 the geometric mean over recent climate period with higher stock abundance and recruitment dynamic (1990-present) is used for incoming year-class abundance estimation.

B. Data

B.1. Commercial catch

Estonian and Latvian catch data by quarter and separately for trawls and trapnets are available. No discards are reported or accounted for. There was confidence that some misreporting takes place in Latvian fishery and based on the interviews with fishers the official catch figures have been raised in 1995–1999 by 20% and in 2000–2007 by 15%. Due to scrapping of vessels the level of misreporting has decreased and in 2008-2010 the official landing figures were increased by 10%.The official landing figures were used in the assessment since 2011. Since in Latvia the trawl fishing fleet has decreased almost two times it is considered that the fishing capacity now are more or less balanced with the fishing possibilities and there are no unallocated catches.

The sampling strategy is similar in Estonia and Latvia. Mainly random samples are collected in the fishing harbours of the Gulf of Riga. In Latvia about three samples (each including 200 fish) are collected every month from the trawl fishery from different parts of the gulf. The biological analysis of the sample is performed in the laboratory where length, weight, sex, and maturity stage are recorded and the otoliths are taken for age determination. Ten fish from each 0.5 cm length group are aged. Occasionally the samples are collected onboard fishing vessels participating in the commercial fishery. The catch in numbers and mean weight-at-age is obtained on a monthly basis applying the average age composition and average mean weight-at-age (from samples collected during a certain month) on monthly catches separately for trawl and trapnet fishery. From the trapnet fishery random samples are taken more frequently due to large differences in age composition during the spawning season. In general in Latvia four samples (each including 200 fish) from different parts of the gulf are taken every ten days resulting in about 30 samples for the whole spawning season. Estonia samples trapnet fishery during the spawning season on average once per 10 day.

B.2. Biological information

Weight-at-age in the stock is assumed to be the same as weight-at-age in the catch.

A fixed natural mortality of 0.2 is used both in the assessment and the forecast.

The proportion of natural mortality before spawning (M_{prop}) is set at 0.35 and the proportion of fishing mortality before spawning (F_{prop}) are set at 0.2.

A constant maturity ogive is used for the whole time-series. The gulf of Riga herring starts to spawn at the age of 2, when 93% of the fish is mature and by the age of 5 it is considered that all fish are mature. No special survey to determine the proportion of mature fish is carried out. However, the data from commercial samples before spawning (March-April) indicate that the use of a maturity ogive could be reasonable.

B.3. Surveys

Since 1999 a joint Estonian-Latvian acoustic survey specially designed for the Gulf of Riga herring has been conducted annually in the end of July – beginning of August in the Gulf of Riga. The survey covers all the area of the gulf till the depth of 20 m. Since there are no other abundant pelagic species in the gulf, the survey is targeted exclusively on the Gulf of Riga herring and the aim was to use the acoustic index as a tuning fleet in XSA. That was made for the first time in the stock assessment in 2004. The analysis of log-catchability residuals showed that in years after cold winters the spawning is later and the herring could stay longer near the coast and not counted by the hydroacoustic survey (mainly negative residuals in these years). Therefore, WGBFAS recommends that the survey is started not earlier than in August.

B.4. Commercial CPUE

In the period 1993–2004 the XSA for the Gulf of Riga herring was tuned using data on the effort (number of trapnets) directed at the Gulf of Riga herring in the Estonian and Latvian trapnet fishery and the corresponding abundance (catch in numbers-at-age) of gulf herring in the trapnet catches. The dataseries starts in 1980. Since 2007 assessment the trapnet dataseries was shortened and started from 1996 due to positive trend in log-catchability residuals. The CPUE data for trawl fishery are not available.

B.5. Other relevant data

Data from oceanographic and zooplankton surveys performed by LATFRI were used for the prediction of recruitment. The corresponding dataseries start from 1970.

C. Historical Stock Development

Model used: XSA

Software used: IFAP / Lowestoft VPA suite

Model Options chosen:

Tapered time weighting applied, power = 3 over 20 years

Catchability independent on stock size for all ages

Catchability independent of age for ages ≥5

Survivor estimates shrunk towards the mean F of the final 5 years or the 3 oldest ages

S.E. of the mean to which the estimate are shrunk = 0.500

Minimum standard error for population estimates derived from each fleet = 0.300

Prior weighting not applied

The settings were inspected in the benchmark assessment of 2008 and were left unchanged.

Model Options chosen:

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	yes
Canum	Catch-at-age in numbers	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	yes
Weca	Weight-at-age in the commercial catch	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	yes
West	Weight-at-age of the spawning stock at spawning time.	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	yes
Mprop	Proportion of natural mortality before spawning	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	no
Fprop	Proportion of fishing mortality before spawning	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	no
Matprop	Proportion mature at age	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	no
Natmor	Natural mortality	1970-last data year, 1977 – last data year since 2003	0-10+ (0-8+ in XSA)	yes, in 1979-1983 M=0.25, in all other years M=0.2

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Trapnets	21 years including last data year, 1996 – last data year since 2007	2-8
Tuning fleet 2	Acoustics	1999-last data year	1-8
Tuning fleet 3	none		
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D. Short-Term Projection

Model used: Age structured

Software used*:* IFAP prediction with management option table and yield-per-recruit routines

Initial stock size: Until 2002 the numbers-at-age 2 in the start of the intermediate year were calculated from the number of 1-year-olds at the beginning of the previous year (RCT3 estimate) applying a natural mortality of 0.2 and fishing mortality according to the catches of this age group taken. In the assessments until 2003 taken from the XSA for age 2 and older, in the assessment performed in 2004–2005 taken from the XSA for age 1 and older because a new acoustic tuning fleet containing abundance index for age group 1 was available The recruitment-at-age 1 in the intermediate year until 2011 was estimated using RCT3 where the values of mean water temperature in April and abundance of zooplankton in May were regressed against the 1-group from the XSA. It was found that RCT3 poorly predicts the rich year classes. In 2011 the analysis of factors determining year-class strength was performed and other significant factors influencing herring year-class strength were discovered (Putnis *et al.*, 2011). In 2012 RCT3 analysis was performed by replacing the previously used average water temperature in May by the average herring Fulton's coefficient. Although the obtained recruitment estimates in the recent years gave closer correspondence with the XSA results the estimate of 2011 year class was rejected due to high variation ratio. It was decided for the recruitment in 2012 and following years to use the geometric mean of recruitment of 1989–present year classes-1 (e.g. excluding the latest year-class).

Natural mortality: Set to 0.2 for all ages in all years

Maturity: The same ogive as in the assessment is used for all years

F and M before spawning: Set respectively to 0.2 and 0.35 for all ages in all years

Weight-at-age in the stock: Assumed to be the same as weight at age in the catch

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

Exploitation pattern: Average of the three last years, scaled by the F_{bar} (3-7) to the level of the last year in the case of obvious trend.

Intermediate year assumptions: TAC constraint or status quo F or both

Stock recruitment model used: None, the long-term geometric mean recruitment-at-age 1 is used

Procedures used for splitting projected catches: Not relevant

E. Medium-Term Projections

Not performed since 2004. Environmental factors, particularly winter temperature and zooplankton abundance are believed to have significant effect on the recruitment of the Gulf of Riga herring (e.g. ICES, 1995). A number of abundant year classes have been recruited into the stock following increasing trends observed in temperature and zooplankton during the recent decades. So, during the period since the late 1980, when most of the winters were mild, a series of rich recruitment years can be observed. The severe winters of 2002/2003 and 2005/2006 resulted in poor year classes. Hence, no obvious relationship between SSB and recruitment could be defined for that stock and the WG was not in the position to present any medium-term prediction.

Medium-Term projection performed until 2003:

Model used: Age structured double linear model

Software used: Excel spreadsheet

Initial stock size: Same as in the short-term projections

Natural mortality: M=0.2 in all ages and years

Maturity: Permanent and the same as in the assessment

F and M before spawning: Respectively 0.1 and 0.33 in all ages and years

Weight-at-age in the stock: Assumed to be the same as weight-at-age in the catch

Weight-at-age in the catch: Same as in the short-term projections - average weight of the three last years

Exploitation pattern: *statusquo* F

Intermediate year assumptions: stock size from XSA

Stock recruitment model used: Beverton–Holt stock–recruitment relationship

Uncertainty models used: none

G. Biological Reference Points

In 1996 the WGBFAS proposed a MBAL of 50 000 t, based on the frequent occurrence of poor year classes below this level of SSB. The MBAL value was treated as an estimate of B_{pa} since there were many points left of the MBAL in the stock recruitment plot. Assuming a standard error of log at the 0.2 level (based on XSA estimates of standard errors), the estimate of B_{lim} was 36 500 t. In 2003 it was proposed to shorten the time-series for the assessment because the fishing mortalities in the years 1970–1976 were considered to be too high for pelagic fish stock. It resulted in a loss of few high recruitment estimates in the left side of stock–recruitment. Therefore it was necessary to change the MBAL estimate which was obtained as previously and was defined at the level of 60 000 t, and correspondingly B_{lim} was calculated at the level of 43 800 t. B_{loss} value obtained from PA analysis in 2004 was 38 600 t. This was rejected by ACFM.

In 2008 ACOM stated that biomass reference points are not valid due to a regime shift.

The F_{pa} = 0.4 was obtained from the medium term simulations (ICES, 1998).

The WKMAMPEL (ICES, 2009) recommended a trigger spawning-stock biomass of 60 000 t for this stock. The evaluations performed by WKMAMPEL using Stochastic Multi Species model and forecast model suggested two candidates for F_{MSY}: F_{MSY} = 0.35 and F_{MSY} = $F_{0.1}$ = 0.26 with the TAC constraint for the two F options of 20% and 15%, respectively. ICES decided to use the value based on stochastic simulations (F_{MSY} = 0.35) as in addition to data used in yield-per-recruit analyses, it uses also stock recruitment relationships.

Based on the ICES Special Request advice Greater North Sea, Baltic Sea Ecoregions (ICES, 2015) a new F_{MSY} range for the Gulf of Riga herring was calculated. WKMSYREF3 (ICES, 2015) workshop recalculated F_{MSY} with upper and lower ranges.

The new F_{MSY} value that was used for catch advice in 2016 is F_{MSY} = 0.32. For the analysis of F_{MSY} range the assessment results from the XSA assessment (1977–2013) were used.

WGBFAS 2016 calculated new precautionary reference points for the stock as follows.

The B_{lim} value was obtained estimating the stock–recruitment relationship and the knowledge of fisheries and stock development of the Gulf of Riga herring. It was considered that Gulf of Riga herring belongs to the stocks with no evidence that recruitment has been impaired or that a relation exists between stock and recruitment for which $B_{lim} = B_{loss}$ is applied. The corresponding value is B_{lim} =40 800 t. The B_{pa} value was obtained from the following equation:

$B_{pa} = B_{lim} \times \exp(\sigma \times 1.645) = B_{lim} \text{ x } 1.4 = 57\,100$ t.

F_{lim} was then derived from B_{lim} in the following way. R/SSB was calculated at B_{lim}, and the slope of the replacement line at B_{lim}, and then it was inverted to give SSB/R. This SSB/R was used to derive F_{lim} from the curve of SSB/R against F. The obtained value F_{lim} = 0.88. The F_{pa} value was obtained from the equation $F_{lim} = F_{pa}/1.4$ and was F_{pa} = 0.63.

Framework	Reference point	Value	Technical basis	Source
MSY approach	F_{MSY}	0.32		ICES (2015)
	MSY $B_{trigger}$	60 000 t	From stock–recruitment relationship	ICES (2009)
Precautionary approach	B_{lim}	40 800 t	$B_{lim} = B_{loss}$	ICES (2016)
	B_{pa}	57 100 t	$B_{pa} = B_{lim} \times \exp(\sigma \times 1.645)$	ICES (2016)
	F_{lim}	0.88	F_{lim} derived from the curve of SSB/R against F	ICES (2016)
	F_{pa}	0.63	$F_{pa} = F_{lim}/1.4$	ICES (2016)
	SSB_{MGT}	Not defined		
Management plan	MAP MSY $B_{trigger}$	60 000	MSY $B_{trigger}$	EU(2016-Annex II Column A)
	MAP B_{lim}	Not defined		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}-F_{msy}	0.24 - 0.32	Consistent with the ranges provided by ICES (2015), 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_{msy}- F_{upper}	0.32 - 0.38	Consistent with the ranges provided by ICES (2015), resulting in no more than 5% reduction in long-term yield compared with MSY	ICES (2015)and EU(2016-Annex I Column B)

H. Other Issues

Output from InterCatch was compared with the input data used for the assessment and it was stated that there are no differences. It should be pointed out that sampling of Gulf of Riga herring stock has no gaps and no allocation schemes are used.

I. References

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