Stock Annex: Sprat (*Sprattus sprattus*) in subdivisions 22–32 (Baltic Sea)

Stock-specific documentation of standard assessment procedures used by ICES.

Stock	Sprat (*Sprattus sprattus*) in subdivisions 22–32 (Baltic Sea)
Working Group	Baltic Fisheries Assessment Working Group (WGBFAS)
Last Benchmark	Benchmark Workshop on Baltic Multispecies Assessments and IBPBASH
Date last benchmark	4–8 February 2013, and March 2020 (IBPBASH)
Last update	May 2021
Last updated by	Jan Horbowy
Main modifications	The Inter-Benchmark Process (IBP) on BAltic Sprat (*Sprattus sprattus*) and Herring (*Clupea harengus*) (IBPBASH, ICES 2020) was held in March 2020 to include new estimates of natural mortality (M) from the WGSAM 2019 Baltic Sea SMS keyrun (ICES, 2019). New reference points were calculated based on the new stock assessment results.

A General

A.1 Stock definition

Sprat is distributed mainly in the open sea areas of the entire Baltic Sea though high concentrations of YOY appear in coastal areas (especially in mixed fresh water from rivers and sea waters), primarily in autumn and in the 1st quarter of the year. These areas are also preferred by juvenile herring in the same season. During the year, mixed sprat and herring shoals often occur in both open sea and coastal areas.

Based on the ICES WGs and ACFMs advice sprat in the Baltic Sea has been assessed as a single unit within the ICES subdivisions 22–32 since 1992. In the 1980s and in the early 1990s, attempts were made to distinguish different Baltic sprat stocks/populations, but significant evidence about sprat stock heterogeneity was not found.

A.2 Fishery

The main part of the sprat catches is taken by pelagic single and pair trawling (using a mesh size of 16 mm in the codend). In addition there are demersal trawling activities for Baltic sprat in some parts of the Baltic. The sprat fishery is carried out all year but the main fishing season is in the first half of the year in most countries. In the northern part of the Baltic, ice cover is a limiting factor for all fishing operations.

In some countries Baltic sprat is fished by two types of fleets, small cutters (17–24 m length) with engine power up to 300 h.p., and medium size cutters (25–27 m length) with engine power up 570 h.p. In some countries a third type of vessel is engaged in sprat fishery, i.e. large vessels, over 40 m length with engine power of 1050 h.p. The large vessels have trawls with high vertical opening and operate in the areas deeper than 50 m. According to national regulation (e.g. in Russia) they are obliged to use sorting machines to separate herring from sprat. This fleet targets sprat for human consumption during 1st and 2nd quarters. During summer this fleet targets sprat for reduction purposes and bycatches of small herring increases.

Up to now the annual sprat quota was not exhausted in most countries, whereas the herring quota was fully utilized. This created a strong incentive to misreport herring as sprat.

The questionnaire prepared by WGBFAS in 2012 revealed that the main misreporting takes place in industrial fisheries; however, the national landing figures are adjusted according to the sampling results.

A.3 Ecosystem aspects

Stock trends in Baltic sprat have been driven mainly by released predation by cod and high (although varying) recruitment success since the 1990s (Köster *et al.*, 2003; Casini *et al.*, 2008). The latter may be related to the unusual high state of the North Atlantic Oscillation (NAO), resulting in unusually high temperature conditions. Variations in temperature may be large enough to affect sprat biology (Kalejs and Ojaveer, 1989). Sprat in the Baltic Sea is located near the northern limit of the species' geographic distribution (Muus and Nielsen, 1999), which ranges from the Black Sea to southern central Norway. Low temperatures can therefore be expected to be detrimental for production and survival in the Baltic Sea. Laboratory experiments have shown that cold water prevents hatching of sprat eggs from the North and Baltic Seas (Thompson *et al.*, 1981; Nissling, 2004). Field studies show that the temperatures which suppress sprat egg development in the laboratory also occur in the Baltic Sea at times, places and depths where sprat eggs occur (MacKenzie and Köster, 2004). Comparison of interannual variability in sea temperatures at the main sprat spawning time (May) with sprat recruitment shows a statistically significant positive relationship (MacKenzie and Köster, 2004). The same temperatures that affect sprat recruitment are themselves influenced by winter severity indices, including ice coverage in the Baltic Sea and a winter index (January–February) of the North Atlantic Oscillation (MacKenzie and Köster, 2004).

Another mechanism through which the increase in temperature may have affected sprat recruitment is a change in the food available. Sprat larvae have a strong preference for the copepod *Acartia* spp. (Voss *et al*., 2003), which has drastically increased since the 1990s in parallel to the increase in temperature (Möllmann *et al.*, 2000). This may have led to higher larval survival in general.

Besides an increase in temperature, the unusual climatic situation during the 1990s has resulted in a change in the circulation pattern and thus in the drift pattern of sprat larvae (Hinrichsen *et al.*, 2003). Recent investigation using 3d-hydrodynamic modelling have shown that retention vs. dispersion in the Baltic deep basins have a strong influence on recruitment success of sprat (Baumann *et al*,. 2004).

Besides recruitment, a further important ecosystem-related aspect of sprat in the Baltic is the decrease in growth during the 1990s (Grygiel and Wyszynski, 2003; Götze and Gröhsler, 2004). This has been related to the decrease in abundance of the copepod *Pseudocalanus* sp., one of the most important food items of sprat during spawning in spring (Szypuła *et al.*, 1997; Möllmann *et al.*, 2004), and density-dependent processes mediated by the strong intra-specific competition due to the large stock size after the early 1990s (Casini *et al.*, 2006).

After the mid-1990s, the distribution of sprat has shifted considerably towards the northeastern areas of the Baltic Sea and and the autumn hydro-acoustic surveys revealed low abundances of sprat in the southern Baltic (WGBFAS, 2012). This seems to have triggered a spatial density-dependent process, with a decrease in condition and mean weights mainly in the northeastern areas. As the increased cod stock is distributed mainly in the southern Baltic, the overlap of cod and sprat stocks is much lower than previously (Casini *et al.*, 2011). It is not clear yet whether the shift in sprat distribution to northeastern areas during the past 15 years is an effect of release from cod predation, which has been basically nil in this area after the early 1990s (Casini *et al.*, 2011).

B Data

B.1 Commercial catch

In 1997, sprat catches were at a record high of 529 400 t for the whole Baltic, and have since decreased to the level of 350 000–400 000 t in 2000–2010. In 2011, sprat catches decreased to about 260 000 t.

Sprat catches are utilized for industrial purposes and human consumption. In most of the countries discards of sprat are assumed not to exist because small and lower quality fish can be used for production of fishmeal and feeding in animal farms. In fisheries directed at human consumption, however, young fish are discarded with higher rates in the years with strong year classes recruiting to the fishery. The amount of this discard is unknown.

The species composition of the mixed catches is defined from logbooks and, partly, by observers on board larger commercial vessels in compliance with the special agreement between institute and vessel owners. In some countries e.g. in Denmark and Sweden, data about catch composition and other biological data are delivered by fisheries inspection in harbours and by managers of fish stock exchange.

B.2 Biological

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

The natural mortality coefficients used for assessment varied between years and ages depending on size of cod stock and ranging mostly within 0.3–0.8. These estimates were taken from SMS (Stochastic Multispecies Simulations, Lewy and Vinther, 2004; ICES, 2019), as opposed to estimates used previously, which were derived from SMS run in 2012 and from regression of average M against cod SSB in years for which SMS had not been updated.

The SMS estimates of M are not updated every year. Thus, if the M from SMS is not available for a given year, then mean M for the missing year is estimated from regression of mean M against the spawning biomass of cod. Such regression explains 90% of the M variance (ICES, 2020). Next, age effects are used to obtain M by ages in the missing year.

Both proportion of natural mortality (M_{prop}) and proportion of fishing mortality (F_{prop}) before spawning are set to 0.4.

In the years 1974–2003 knife-edge maturity-at-age 3 was used for this stock. At the assessment in 2002, a new maturity ogive was introduced for the whole time-series. This ogive is based on the distribution of age at first spawning estimated for the last 20 years. The preliminary analysis of the maturity data at the benchmark workshop did not provide reasons to change the maturity parameters. However, it is advised to look at maturity data in more detail and using statistical models.

B.3 Surveys

Three acoustic time-series were selected for the final assessment of Baltic sprat: BASS tuning fleet index for Baltic sprat in the SDs 24–26 and 28 for the years 2001–2011, BIAS tuning fleet index for Baltic sprat in the SDs 22–29 for the years 1991–2011, and BIAS tuning fleet index for Baltic sprat recruitment (age 0) in the SD 22–29 for the years 1991–2011.

The estimates for the years 1993, 1995, and 1997 were excluded from both BIAS time-series due to incomplete coverage of the standard survey area in the SDs 22–29.

B.4 Commercial cpue

Preliminary and very limited data on fishing effort and cpue were provided to WGBFAS some years ago. Taking into account that survey estimates of sprat stock are relatively good, while available commercial CPUE data were very limited and may be considered not relevant for tuning of pelagic stocks, no attempts to include CPUE data in the assessment were undertaken.

B.5 Other relevant data

For some years the NAO index was used to predict recruitment in prediction year in short-term forecast. The statistical relationship between sprat recruitment and NAO explained ca. 25% of recruitment variance. In 2007, that approach was ceased due to lack of expertise in the WG.

C Historical stock development

Model used: XSA (also exploratory assessment with SAM model)

Software used: IFAP / Lowestoft VPA suite

Benchmark assessment in 2013 (WKBALT 2013):

The survey data presented in Section B.3 are used for tuning the assessment model. The age-0 survey indices are forward shifted to represent age 1 at the beginning of next year, because the first age group in the assessment is age 1. The survey data are corrected for area coverage.

Model Options:

1) Three tuning fleets: from International Acoustic Surveys in 1983–2011 in subdivisions 24–29S, Sprat Acoustic Survey in May in 2001–2011 and Acoustic Surveys covering age 0 sprat in SD 22–32 in 1992–2011 (shifted to represent age 1);

2) Tapered time weighting applied, power = 3 over 20 years;

3) Calibration regression;

4) Catchability dependent on stock size for age 1 (only for this age group the slope of regression was significantly different from 1);

5) Catchability independent of age for ages ≥5;

6) Survivor estimates shrunk towards the mean F of the final five years or the three oldest ages;

7) S.E. of the mean to which the estimate are shrunk = 0.75;

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

9) Prior weighting not applied.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1974–last data year		Yes
Canum	Catch-at-age in numbers	1974–last data year	1–8+	Yes
Weca	Weight-at-age in the commercial catch	1974–last data year	1–8+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1974–last data year	1–8+	Yes-assumed to be the same as weight-at-age in the catch
Mprop	Proportion of natural mortality before spawning	1974–last data year	1–8+	No-set to 0.4 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1974–last data year	1–8+	No-set to 0.4 for all ages in all years
Matprop	Proportion mature at age	1974–last data year	1–8+	No-the same ogive for all years, averaged over noisy long time-series (1981–2002)
Natmor	Natural mortality	1974–last data year	1–8+	Yes-estimated from most recent SMS or (if SMS is not updated) from regression of M against biomass of cod ≥20 cm

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	International acoustic (BIAS) in SD 24–29	1983–last data year	1–8+
Tuning fleet 2	International acoustic (BASS) in SD 24–26 & 28	2001–last data year	1–8+
Tuning fleet 3	International acoustic (BIAS) on Age 0 sprat in SD. 26 + 28	1992–last data year	0

D Short-term projection

Model used: Age structured

Software used*:* MFDP ver 1.a

Initial stock size: Taken from the XSA-survivors for assessment year at age 2 and older. The recruitment at age 1 for year in which assessment is conducted is estimated using RCT3. The recruitment in next two years is taken as the long-term geometric mean since 1991.

Natural mortality: Average of the three last years in assessment or last year value if trend in mortality is observed.

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

F and M before spawning: The same values as in assessment

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 in assessment or last year value if trend in weight-at-age is observed.

Exploitation pattern: Average of the three last years in assessment. Unscaled if no clear trend in F_{bar} (3–5) is observed, otherwise scaled to F_{bar} level of the last assessment year.

Intermediate year assumptions: Usually both F *status quo* and TAC constraint options are presented and the option preferred by the WG is indicated.

Stock–recruitment model used: None.

Procedures used for splitting projected catches: Not relevant.

E Medium-term projections

Not considered appropriate for this stock.

F Long-term projections

Not considered appropriate for this stock.

G Biological reference points

The following MSY and PA reference points were re-estimated based on the new stock assessment results using the new M values (WGSAM 2029) in 2020 (IBPBASH 2020):

Reference Point	Value	Rationale
B_{lim}	410 000 t	The average SSB producing 50% of maximal recruitment from the Beverton and Holt S–R function (470 000 t) and from the Ricker S–R function (345 000 t).
B_{pa}	570 000 t	B_{lim} *(exp(1.645*0.2))
MSY $B_{trigger}$	570 000 t	B_{pa}
F_{MSY}	0.31	Estimated by EqSim
$F_{MSYUpper}$	0.41	$F_{p0.5}$
$F_{MSYLower}$	0.22	Estimated by EqSim as the F at 95% of the landings of F_{MSY}
F_{lim}	0.63	Estimated by EqSim as the F with 50% probability of SSB being less than B_{lim}
F_{pa}	0.41	Following decision of ACOM in 2021 it was changed from former 0.45 into the $F_{p0.5}$ value

H Other issues

None.

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