Stock Annex: Sprat (*Sprattus sprattus*) in Division 3.a and Subarea 4 (Skagerrak, Kattegat and North Sea)

Stock specific documentation of standard assessment procedures used by ICES.

**Stock:** Sprat (*Sprattus sprattus*) in Division 3.a and Subarea 4 (Skagerrak, Kattegat and North Sea)

**Working Group:** Herring Assessment Working Group for the Area South of 62°N (HAWG)

**Authors:** WKSPRAT 2018

**Last updated:** 15 March 2019

**Last updated by:** Mikael van Deurs and Anna Rindorf

---

**A. General**

**A.1. Stock definition**

Sprat (*Sprattus sprattus*, Linnaeus 1758) in ICES area 3.a (Kattegat and Skagerrak), 4 inshore along the Norwegian coast and 4 off-shore (North Sea) have historically been treated as separate management units. However, questions have recently been raised about the geographic distribution of this stock and its interaction with neighbouring stocks (ICES WKSPRAT, 2018). A detailed genetic study confirmed that individuals from the Baltic Sea, Norwegian fjords and the North Sea are genetically different (ICES WKSPRAT, 2018) whereas the sprat in Kattegat and Skagerrak appear to be a mixture of genetically North Sea sprat and genetical hybrids near the Swedish coast. ICES WKSPRAT, 2018 further showed that the consistency between the assessment and the survey was substantially improved by joining the survey from 3.a and 4. As a consequence of this, the stock area is identified as 3.a and 4 excluding sprat in Norwegian fjords.

There is uncertainty about whether peripheral populations, such as those in the Moray Firth NE Scotland, Firth of Forth E Scotland and the English Channel are connected to the main stock. The geographically isolated sprat population in the Moray Firth and the Firth of Forth in east Scotland may have little connectivity with the main stock in the southern North Sea. Both of these populations have supported sprat fisheries in the past.

**A.2. Fishery**

The majority of the sprat landings are taken in the Danish industrial small-meshed trawl fishery. The Norwegian sprat fishery has mainly been carried out by purse seiners. From about 2000, pelagic trawlers were licensed to take part in the sprat fishery in the North Sea. In the first years the catches taken by trawlers were low but in the last years their share of the total Norwegian catches has increased. The Danish and Norwegian landings are mainly used for reduction purposes.

The Norwegian vessels have a maximum vessel quota when fishing in the EU zone. They are not allowed to fish in the Norwegian zone before the quota has been taken in the EU-zone.
In the last decade, also the UK, Sweden, Germany and the Netherlands occasionally landed small amounts of sprat.

In 2007 a new quota regulation (IOK) for the Danish vessels was implemented and realized from 2008 and onwards. The regulation gives quotas to the vessel, but these can be traded or sold. A large number of small vessels have been taken out of the fishery and their quotas sold to larger vessels. Today the Danish fleet consists of 18–20 large vessels.

Historically, the bycatch of juvenile herring in the industrial sprat fisheries was high (Hoffman et al 2004). To reduce this bycatch, an area closed to the sprat fishery (the “sprat box”) was established off the western coast of Denmark (from Vadehavet to Hanstholm) in October 1984. It was estimated that about 90% of the bycatches of juvenile herring in the industrial fisheries was taken within this box, and the intention of the sprat box was thus to reduce this juvenile herring bycatch. However, the juvenile herring bycatches increased in the early 1990’s. It was concluded that there was no clear connection between the sprat box and herring bycatches and the sprat box was removed in 2017.

After 1996, the bycatch mortality of juvenile herring was reduced (ICES, HAWG 2009). This coincided with the introduction of a bycatch limit on herring in the industrial fisheries and improvements in the catch sampling.

The sprat fishery is regulated by a bycatch-quota on herring in the Danish industrial fishery. Once this is exceeded, all industrial fisheries are ceased (including for Norway pout). The directed sprat fishery is controlled by a voluntary system where the acceptable % minimum limit for sprat in the catch is 60% in the North Sea and 55 % in Kattegat/skaggerak. Discarding in the sprat fishery in the North Sea is considered and this may be regarded as slippage/discardung. In the Norwegian North Sea sprat fishery, there is a maximum bycatch-limit of 10% herring. Herring bycatches are taken from the vessel’s quota of North Sea herring. The degree of mixing with juvenile herring varies both within and between years, related to the size and distribution of the juvenile herring population.

**Evaluation of the quality of the catch data**

Due to large but unknown bycatches of juvenile North Sea herring in the industrial sprat fisheries prior to 1996 (Hoffman et al 2004), sprat total landings were corrected by HAWG according to best available knowledge. There is no information on slipping, but this is assumed to be a minor issue in later years.

**A.3. Ecosystem aspects**

Sprat is an important part of the diet of numerous species, including demersal fish, seabirds and marine mammals. The major natural sources of sprat removals include whiting, mackerel, cod and seabirds (Figure A.3.1). There are few peer reviewed documents describing effects of a shortage of sprat on the majority of these species, with the exception of seabirds in the breeding season. Other species impact sprat through inducing natural mortality or competing with sprat for zooplankton. Sprat can be very important for breeding seabirds in southern areas of the North Sea (Durinck et al 1991, Wilson et al. 2004). In winter, when sandeel are not available to most seabirds (because they are buried in the sand) many of the seabirds that overwinter in the North Sea take sprat as part of their diet. However, it is uncertain whether sprat abundance in the North Sea will affect seabird breeding success or overwinter survival.
The effect of predation on sprat is estimated in the multispecies SMS model of the North Sea (WGSAM 2017, WKSPRAT 2018).

Figure. A.3.1 Predation mortality of sprat induced by different predators. Data from SMS updated run (WGSAM 2017).

B. Data

B.1. Commercial catch

The majority of the sprat landings are taken in the Danish industrial small-meshed trawl fishery. The Norwegian sprat fishery has since 2000 been carried out by purse seiners and pelagic trawlers. The landings in both countries are mainly used for reduction purposes. In the last decade, the UK, Sweden, Germany and the Netherlands occasionally landed small amounts of sprat.

The commercial catches are sampled for biological parameters. In the most recent years Denmark, Norway and Sweden have sampled their sprat catches. The sampling intensity for biological samples, i.e., age and weight-at-age is generally performed following the EU regulation 1639/2001, requiring 1 sample per 2000 tonnes.

By far the majority of the biological samples are collected by Denmark (90%). Seasonal sampling intensity reflect fishing patterns, hence, most samples are collected in quarter 3 and 4 and in SE North Sea. All samples collected within Division 3.a and 4 are combined irrespective of nationality. The method suggested by Rindorf and Lewy (2001) was used to assure that the estimation is optimized when sampling is sparse. This method is used to estimate an age-length-key for each combination of year, time and area. The estimated proportion at a given age was considered to be reliable when the number of fish sampled of the given age or older exceeded 50 or the confidence limits of the estimate were less than +/- 25%. When the number of fish aged is too low to allow a reliable estimation on a given spatial level, higher aggregation levels were used.
The probability of being of a given age is set to zero at lengths outside the interval of lengths observed for this age +/- 1 cm unless the given age was not observed at all and more than 50 fish were sampled, in which case the probability was set to zero for all lengths. Overdispersion (Rindorf and Lewy 2001) was not estimated.

The number of sprat of each age (0 to 4+) per kg and the mean weight per individual of each age in each length distribution sample was estimated by combining the age length key, length distribution specific to that statistical rectangle and period and weight at length estimates.

In Danish samples, the weight at length was determined for all samples length measures whereas in the Norwegian samples, weight was determined for fish age determined. To achieve an estimate of weight at length in the Norwegian samples, a monthly weight-length relationship was estimated for each sandeel sampling area and used to estimate weight for each length group. If no Norwegian samples were taken in the given month and sandeel sampling area, the monthly weight length relationship estimated from the combined Danish and Norwegian data were used.

The average number per age per kg and their mean weight at a given spatial and temporal scale was estimated as the average of that recorded in individual samples when at least 5 samples were available. Mean weight was only estimated when the total number of fish in the samples of a given age in the area exceeded 10. When less than 5 samples were taken at the finest aggregation level, the next aggregation level was used and so forth. Hence, for each area, quarter and year, the average number of sprat per age and kg and tons of sprat caught was estimated and the level noted. If the total North Sea and 3 a sampling resulted in less than 10 sprat of a particular age, the mean weight over all years was used.

The Danish landings per statistical rectangle and month from 1991 an onwards are known from samples for species composition taken by the Fishery Inspectors for control of the bycatch regulation. At least one sample (10–15 kg) per 1000 tons landings is taken and these samples are used to estimate average species composition by area (ICES rectangles) and month. This species/area/period key, logbook data (spatial distribution) and landings slip data (quantity) are used to derive the Danish WG estimates of landings of sprat. These data were assumed to represent the spatio-temporal distribution of both the Danish and international catches in the years 1991 to 2002.

From 2002, the catch by statistical rectangle of Norway, Sweden, UK, Germany, Scotland and Netherlands was provided as input and included together with the Danish data.

The total international catch in tonnes taken by Denmark and other countries as reported to ICES was distributed on statistical rectangles and quarter in the particular year according to the distributions described above.
Catches of Norwegian coastal sprat were not included; neither in the North Sea nor Division 3.a. In Division 3.a, these catches were excluded by excluding catches from rectangles 45F7, 45F8, 46F8, 46F9, 47F9, 46G0, 47G0, 48G0, and 47G1.

The catch in numbers per age (1000s), month and statistical rectangle was estimated as the product of catches and the number of sprat per age per kg in the particular area. The mean weight is estimated as the weighted average mean weight (weighted by catch in numbers of the age group in the statistical rectangle). Mean weight is given in kg. In the end, catches are raised to match the ICES landings.

Catches in quarter 2 of the year were generally small, taken in June and rarely sampled sufficiently to allow the estimation of the age composition. As these catches were not well known but impacted forecast and model fit, it was decided to merge these with the quarter 3 catches (ICES WKSPRAT, 2018).

### B.2. Biology

Sprat in the North Sea has a prolonged spawning season ranging from early spring to late autumn. Early in the year the start of the spawning is triggered by the water temperature (Alheit et al. 1987; Alshuth 1988a; Wahl and Alheit 1988). Sprat is a batch spawner, producing up to 10 batches in one spawning season and 100-400 eggs per gram of body weight (Alheit 1987; George 1987). The majority of the sprat in age groups 1+ in the summer acoustic surveys in June-July are spawners (ICES WGIPS, 2010).

Studies of microstructures in sprat otoliths (sagittae) have demonstrated structural differences between what are defined as true and false translucent (winter) rings (Mosegaard and Baron, 1999). When the translucent ring is deposited the width of the daily increments gradually reduces in width. This pattern can be found in true winter rings in the sagittae of sprat aged 0 – 2 years old. A false winter ring has no gradual reduction in the width of the daily rings in front of it, neither immediately after the translucent zone. Thus, in otoliths where the age reader is in doubt whether a translucent zone is true or false, the validity of the ring can be examined by reading the otolith microstructure. The accuracy of the age readings was analysed applying the daily ring widths of the annotated winter-rings by an experienced age reader. The text table below shows the results for the experienced Danish age reader; the accuracy for the 1 group is very high (94% correct) and a bit lower for age group 2 (89% correct).

<table>
<thead>
<tr>
<th>Read age</th>
<th>Validated age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

**Read age vs. validated age for an experienced age reader**

Mean weights-at-age in the spawning stock is taken as the mean weight-at-age in the catch at spawning time, which is defined as Quarter 3.

Natural mortality (M) is estimated by the SMS multi species model (also see ecosystem section above), meaning that inter-annual variability in M is used as input to the model. However, since the multi-species SMS is not updated on an annual basis (WGSAM),
the model uses the average M for the last three years (where variable M is variable) for years in between the multi-species SMS updates. It is assumed that the natural mortality for the North Sea also applies to 3.a (no multispecies SMS runs is available for 3.a).

B.3. Surveys
Three surveys cover this stock. Two International Bottom Trawl Surveys (IBTS) cover the stock in the first and third quarters of the year, respectively. Additionally, the herring acoustic survey (HERAS) covers the same area during June–July.

The appropriateness and suitability of these surveys for use in the assessment of the North Sea sprat stock, was examined by the WKSPRAT (ICES, 2018).

B.3.1. International Bottom Trawl Surveys (IBTS)

Background
The North-Sea International Bottom Trawl Surveys started as a coordinated international survey in the mid-1960s as a survey directed towards juvenile herring. The gear used was standardised in 1977 to use the GOV trawl, but took time to be phased in. By 1983 all participating nations were using this gear, and the index can be considered consistent from this point onwards. A third-quarter North Sea IBTS survey using the same methodology was started in 1991 and can be considered consistent from its initiation. IBTS Surveys were also performed in the North Sea in the second and fourth quarters in the period 1991–1996, but are not considered further here (ICES, 2006). More details on the surveys are available from the manual (ICES, 2012).

Estimation of age based indices
The precision of survey indices calculated with a Delta-Lognormal model is likely to drop if large areas with nearly zero densities are included. The northern part (above 57° latitude for longitudes larger than -1.5° or above 59° for longitudes less than -1.5°, and all hauls taken at longitudes larger than 7°) of the North Sea has therefore been excluded from the index calculations. This was done for both Q1 and Q3 data (see figures 1 and 2). Only hauls taken with the GOV gear are included (less than 10% of the hauls are taken with other gear types).

Spatially varying age-length keys are estimated using the methodology described in (Berg and Kristensen, 2012). Numbers-at-age by haul are then calculated using the observed numbers-at-length and the estimated ALKs. This methodology was found to give internal consistency in survey indices for haddock when compared to current standard approach of estimating ALKs that are constant within Roundish (RF) areas (Berg and Kristensen, 2012). It avoids ad-hoc borrowing of samples from neighbour RF areas, when certain age groups are missing, and it provides an objective procedure for missing length groups. The methodology has been implemented in the DATRAS package with full source code available (Kristensen and Berg, 2012).

Survey indices by age were calculated considering a broader class of equations describing the observed abundance in each haul. While Berg and Kristensen (2012) considered a time-invariant spatial effect and a data set consisting almost exclusively of 30 min hauls, the model classes used for sprat contains a space-time smoother, which allows for smooth changes in the spatial distribution of each age group over time, as well as haul duration effect. The standard stratified mean method (for each year and age group: average CPUE per ICES rectangle, averaged over all rectangles) is also applied for comparison.
The following equation describes the maximal model considered for both the presence-absence and the positive parts of the model:

\[ g(\mu_i) = \text{Year}(i) + f_1(\text{Year}_i, \text{lon}_i, \text{lat}_i) \]
\[ + f_2(\text{depth}_i) + f_3(\text{timeOfDay}_i) + \log(\text{HaulDur}_i) \]  

An offset is used for the effect of haul duration (HaulDur), i.e. the coefficient is not estimated but taken to be 1. \( f_1 \) is a 3-dimensional tensor product spline (a 2D thin-plate spline for space is a 1D cubic spline for time), \( f_2 \) is a 1-dimensional thin plate spline for the effect of bottom depth, and \( f_3 \) is a cyclic cubic spline for the effect of time of day. The function \( g \) is the link function, which is taken to be the logit function for the binomial model. The positive part of the delta-distribution is assumed be lognormal distributed. Each combination of quarter age group are estimated separately.

The fitted models are then used to sum the expected catches over a fine grid by year and age to obtain the survey index. Nuisance variables such as time-of-day and haul duration are corrected for in this process. For simplicity no vessel effects were considered here.

The whole procedure consists of the following steps:

1. Apply spatial ALK
2. Fit model for catch-at-age by age and quarter
3. Select grid of haul positions
4. Predict abundance on grid by year (using reference vessel, time-of-day etc).
5. Sum of grid points = index

The model contains a space-time interaction (a 3D smoother) providing the opportunity for spatial distribution to change over time.

The indices are evaluated in terms of internal consistencies (Fig.3). The internal consistency (IC) is defined as the correlation between \( \log I_{y,a} \) and \( \log I_{y+1,a+1} \). Positive consistencies implies that cohorts catch rates are consistent within (see e.g. WKSPRAT (ICES,2018) for details). ICs are averaged over quarters and age-groups in order to obtain a single number for comparison. The average IC are 60.2% when age group 0 is included and 61.1% excluding age group 0.

**B.3.2. Herring Acoustic Survey (HERAS)**

**Background**

The Herring Acoustic Survey is a summer acoustic survey that has been performed by an international consortium since the 1980s. Sprat has been reported as a separate species in this survey from 1996 onwards. However, as the survey is targeted towards herring, which are generally in the northern half of the North Sea during summer, coverage in the southern-half has received less attention. The area covered was expanded progressively over time, and by 2004 covered the majority of the stock, reaching 52°N (the eastern entrance to the English Channel) and all of the way into the German Bight (ICES PGHERS, 2005). The coverage of this survey has remained relatively unchanged.
since 2004 (e.g., ICES PGIPS, 2009) and we consider the survey from this point onwards.

The acoustic survey indices for the combined stock area 3.a and 4 were estimated as the sum of the biomass estimates for area 3.a and area 4. Since the biomasses are much smaller in 3.a compared to 4, the difference between the area 4 index and the area 4+3.a index were minor. Internal consistency is presented in Figure 4.

**B.4. Commercial cpue**

Commercial CPUEs were investigated in WKSPRAT (ICES, 2018). The CPUEs showed a good consistency with number at age from the assessment but are not used in the assessment as the CPUE of highly aggregated species may show hyperstability.

**C. Assessment methodology**

The sprat assessment is made using SMS (Lewy and Vinther 2004) with quarterly time steps. Three surveys are included, IBTS Q1 ages 1–4+ (1974 and onward), IBTS Q3 ages 1–3 (1991 and onward) and HERAS (Q3) ages 1–3 (2001 and onward). 0-group sprat are unlikely to be fully recruited to the GOV in Q3 and this age group was excluded from runs. Catches in quarter 2 (season 4) are very small and poorly sampled making model estimations highly uncertain. Hence, the small number of catches are reallocated to quarter 3 (season 1 in the following model year).

In order to be able to give timely advice and to follow the natural life cycle of sprat, the input data were shifted to model a year going from July to June. Hence, 2000 season 1 refers to 2000 quarter 3, 2000 season 2 refers to 2000 quarter 4, 2000 season 3 refers to 2001 quarter 1 and 2000 season 4 refers to 2001 quarter 2. SSB and recruitment was estimated at July 1st, consequently the “birthday” of this fish in the model is also July 1st and not January 1st. In figures and tables with assessment output and input, the years refer to the shifted model year (1 July to 30 June) and in each figure and table it is noted whether it is model year or the calendar year apply (when the model year is given the year refers to the year at the beginning of the model year; for example: 2000 refers to the model year 2000/2001). The schematic illustrates the shifted model year relative to the calendar year and provides an overview of the timing of surveys etc.

Natural mortality by age, quarter and year as estimated in the multispecies model is used in the assessment. However, since the multi-species SMS is not updated on an
annual basis (WGSAM), the model uses the average M for the last three years (where variable M is variable) for the years in between the multi-species SMS updates. Constant maturity is used (long-term average from IBTS Q1).
The details of the default model settings are summarized in the following table.

<table>
<thead>
<tr>
<th>OPTION</th>
<th>NORTH SEA (DIVISION 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data first year</td>
<td>1974</td>
</tr>
<tr>
<td>Time step</td>
<td>Quarterly (model year running from 1 July to 30 June)</td>
</tr>
<tr>
<td>First age</td>
<td>Age 0</td>
</tr>
<tr>
<td>Last age</td>
<td>Age 3+</td>
</tr>
<tr>
<td>Recruitment time</td>
<td>Start of 1st season (in the model year)</td>
</tr>
<tr>
<td>Age range for use of catch data in likelihood</td>
<td>Age 0--age 3+</td>
</tr>
<tr>
<td>Last age with age dependent fishing selection</td>
<td>Age 2</td>
</tr>
<tr>
<td>Objective function weighting</td>
<td>1.0, 1.0, 0.1 (the assumed S/R is a hockey stick with Blim as break point, but since it is down weighted to 0.1, the influence on the model output is tiny)</td>
</tr>
<tr>
<td>Minimum CV of catch observations</td>
<td>0.1</td>
</tr>
<tr>
<td>Minimum CV of survey observations</td>
<td>0.3</td>
</tr>
<tr>
<td>Minimum CV of S/R relation</td>
<td>0.2</td>
</tr>
<tr>
<td>Catch observations: variance group</td>
<td>Age 0</td>
</tr>
<tr>
<td></td>
<td>Age 1</td>
</tr>
<tr>
<td></td>
<td>Age 2 + Age 3</td>
</tr>
<tr>
<td>Treatment of zero catch observations</td>
<td>Not used in likelihood</td>
</tr>
<tr>
<td>Year ranges for constant exploitation pattern</td>
<td>1974–</td>
</tr>
<tr>
<td>Ages for seasonal exploitation pattern</td>
<td>Age 0</td>
</tr>
<tr>
<td></td>
<td>Age 1</td>
</tr>
<tr>
<td></td>
<td>Age 2</td>
</tr>
<tr>
<td></td>
<td>Age 3</td>
</tr>
<tr>
<td>Ages for calculation of mean F</td>
<td>Age 1 &amp; age 2</td>
</tr>
<tr>
<td>Exclusion of catch data (when no or very small catches are available)</td>
<td>&lt; 5000 t (see the main text above)</td>
</tr>
<tr>
<td>Catch Variance</td>
<td>Calculated within SMS</td>
</tr>
<tr>
<td>Survey variance</td>
<td>Calculated within SMS</td>
</tr>
<tr>
<td>S/R variance</td>
<td>Calculated within SMS</td>
</tr>
<tr>
<td>Inflexion point (Blim)</td>
<td>94 000</td>
</tr>
<tr>
<td>Survey</td>
<td>IBTS Q1: Age 0 – Age 3 (calendar year: 1983; model year: 1982) (2 catch variance groups: 0 &amp; 1-3)</td>
</tr>
<tr>
<td></td>
<td>IBTS Q3: Age 1 – Age 3 (calendar year: 1992) (2 catch variance groups: 1 &amp; 2-3)</td>
</tr>
<tr>
<td></td>
<td>HERAS: Age 1 – Age 3 (calendar year: 2006) (2 catch variance groups: 1 &amp; 2-3)</td>
</tr>
<tr>
<td>Power model applied to survey indices</td>
<td>Power model is applied to the IBTS Q1 age-0 index to dampen the effect of very high index-values and thereby reducing the retrospective bias</td>
</tr>
</tbody>
</table>
The model has been further developed for the sprat stock: in particular, a power function for the age 0 catchability in the IBTS Q1 survey was included. This feature was introduced to account for the higher catchability of younger ages in correspondence of high recruitment events, therefore preventing the strong retrospective pattern that has been observed in the past.

The equation would then be:

\[ E(\log(CPU_{\text{survey},a,y})) = \log(Q_{\text{survey},a} \cdot (\bar{N}_{\text{SURVEY},a,y})^{P_{a1}}) \]

Where P is an exponent applied to the younger age group in the survey.

D. Short-Term Projection

The short term projection use stock numbers at age after the final year of the assessment, 3 year averages of weight-at-age, 3 year averages of natural mortality, 3 year averages of proportion mature (which is not so important since the SMS model use constant proportion mature). Exploitation pattern is the latest estimated by the SMS. The geometric mean of recruitment in the period from 11 years before the assessment year to 2 years before the assessment year is used as the recruitment input in the projection.

The assessment working group takes place in March, hence, catch information used as input to the final year of the assessment is incomplete. This is, however, assumed to be of minor importance, since the few season 4 catches is moved to season 1 in the following year (see text on assessment methodology) and on average very few catches is taken in March. Therefore, rather than estimating the remaining catches of season 3, the available catch information by the time of the working group is what goes in to the assessment model to produce stock numbers at age after the final assessment year.

The MSY advice is based on a B_{escapement} strategy with an F_{cap}, meaning that if the F associated with the TAC derived from the raw B_{escapement} strategy (i.e. deterministically targeting B_{pa}) is above F_{cap}, then the TAC should be re-calculated based on an F equal to the F_{cap}. The F_{cap} was re-estimated in connection to WKspratMSE (2018, process finalized in February 2019) using both a full MSE and a short-cut version. Both methods resulted in an F_{cap} = 0.69.

Model used: SMS
Software used: R
Initial stock size: Estimates from most recent assessment
Maturity: constant
F and M before spawning: 0
Weight at age in the stock: average of the last 3 assessment years
Weight at age in the catch: average of the last 3 assessment years
Exploitation pattern: Constant
Stock recruitment model used: None
Recruitment in the coming year: Geometric mean of recruitment in the period from 11 years before the assessment year to 2 years before the assessment year.
E. Medium-Term Projections

F. Long-Term Projections

G. Biological Reference Points

The stock and recruitment relationship generated from the model output data indicates an decrease recruitment at low SSB but no clear plateau when all years are included. As the earliest years seemed to represent a different recruitment regime, the years from 1981 onwards were selected for estimating reference points. Using the method appropriate for type 1 stocks resulted in a $B_{lim}$ value in the range of 87,000 to 102,000 t corresponding to the lowest SSB providing recruitment above the median and the SSB providing a recruitment above the 75 percentile of recruitment. Assuming a type 2 relationship, the breakpoint of a hockey stick relationship was estimated to be 94,000 t. $B_{lim}$ was hence not very sensitive to choice of approach (ICES, 2003), and a value of 94,000 t was agreed. $B_{pa}$ is defined as the upper 90% confidence interval of $B_{lim}$ and calculated based on a terminal SSB CV of 0.173 and is estimated at 125,000 t.

H. Other Issues

I. References


Mosegaard H. and Baron P.R. 1999. Validation of annual rings by primary increment characteristics in herring and sprat sagitta otoliths. Lecture at EFAN meeting, notes can be found on the internet site www.efan.no


Figure 1. North Sea sprat. IBTS Q1 log cpue from subareas 4 and 3.a. Crosses represent zero catches and bubbles are proportional to biomass caught. The blue area encircles the survey index calculation area used for North Sea sprat.
Figure 2. North Sea sprat. IBTS Q3 log cpue from subareas 4 and 3.a. Crosses represent zero catches and bubbles are proportional to biomass caught. The blue area encircles the survey index calculation area used for North Sea sprat.
Figure 3. Internal consistency using DG2 in Q1 (top left), SMM in Q1 (top right), DG2 in Q3 (bottom left), and SMM in Q3 (bottom right).

Figure 4. North Sea sprat. Internal consistency analysis from the herring acoustic survey, HERAS. The coefficient of determination ($r^2$) is given and is based upon log-transformed values.