Stock Annex: Sprat (*Sprattus sprattus*) in Subarea 4 (North Sea)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Sprat
Working Group:	Herring Assessment Working Group for the Area South of 62ºN (HAWG)
Created:	
Authors:	WKSPRAT 2013
Last updated:	13 February 2013
Last updated by:	

A. General

A.1. Stock definition

Sprat (*Sprattus sprattus*, Linnaeus 1758) in ICES area 4 (North Sea) is treated as a single management unit. However, questions have recently been raised about the geographic distribution of this stock and its interaction with neighbouring stocks: in particular, large abundances have been observed close to the southern boundaries of the stock (ICES HAWG 2009). The apparent overlap between North Sea sprat and English Channel sprat is very strong, whereas the overlap between North Sea sprat and Kattegat sprat is not as strong and varies between years.

A detailed genetic study has been performed to analyze the population structure of sprat over large ranges, from scales of seas to regions (Limborg *et al.*, 2009, 2012). The study was performed with individuals from the Baltic Sea, Danish waters, Kattegat, North Sea, Celtic Sea and Adriatic Sea (Figure 2). The analysis partitioned the samples into groups based upon their genetic similarity (Figure 3). The Adriatic Sea population exhibited a large divergence from all other samples. The samples from the North Sea, Celtic Sea and Kattegat were separated from the Baltic Sea samples, with the Belt Sea (Kattegat) sample in between. The authors concluded that there exists a barrier to gene flow from the North Sea to the Baltic Sea, with the Belt Sea being a transition zone. This analysis supports the separation of sprat into three stocks as currently employed by ICES (i.e. subdivision 7.d (English Channel), subdivision 3.a (Skagerrak/Kattegat) and division 4 (North Sea). Glover *et al* (2011) found a significant difference between sprat in the Norwegian fjords and the North Sea, but further research on is required on the populations in the fjords on the Norwegian and Swedish Skagerrak coast and the populations in the 3.a.

Differences in length at age and recruitment indices support separation of stocks in IIIa and 4. There is uncertainty about whether peripheral populations, such as those in the Moray Firth NE Scotland and Firth of Forth E Scotland may be disconnected from the main stock in the southern North Sea. Surveys in the Wadden Sea show a declining population trend there that is opposite to the recent increases in the North Sea stock. However, this could be caused by a shift in distribution of the North Sea sprat stock rather than separate stocks.

There is a necessity to determine whether the sprat in the North Sea (area 4) constitute a stock or whether they encompass one or both the adjoining populations of sprat (i.e. IIIa or VII (English Channel)). This is vital for establishing the correct assessment/stock units in the area.

There is a geographically isolated sprat population in the Moray Firth in northeast Scotland which appears to have little connectivity with the main stock in the southern North Sea. There is another geographically isolated sprat population in the Firth of Forth in east Scotland which also appears to have little connectivity with the main stock in the southern North Sea. Both of these populations have supported sprat fisheries in the past. There are sprats in the Wadden Sea and in the outer Thames estuary, areas that are more closely connected to the main sprat population in the southern North Sea but which may represent populations with distinct dynamics. Also the Norwegian fjords have sprat populations and a coastal sprat fishery. These sprats are, however, not managed as North Sea sprat.

The Moray Firth sprat stock supports internationally important populations of birds and marine mammals. Part of the area has been designated as a Special Protection Area for aggregations of sea ducks (especially red-breasted mergansers). Sprat abundance in the Moray Firth is believed to have fallen to low levels in the 1990s, and most of these birds have left the area.

The Firth of Forth supported a local sprat fishery that caught sprats in the inner parts of the Firth (east of the Forth Bridges). Landings peaked at ca. 20,000 tonnes in the late 1960s. The stock supported large numbers of breeding common terns in the Firth of Forth. When the stock collapsed in the early 1980s, the fishery closed and has remained closed up to the present, and common tern numbers in the region fell considerably. There is evidence from fishermen and from natural predators that sprat biomass has increased in the Firth of Forth. Breeding common tern numbers have now recovered, their breeding success is high, and they feed predominantly on sprats, catching fish in the same area in the inner Firth of Forth that had previously supported the sprat fishery (Jennings *et al*. 2012).

The outer Thames estuary has been designated a Special Protection Area for red-throated divers as it holds the largest winter aggregation of these birds in Europe. It is thought that sprats are important in their diet.

Under the auspices of the National Park Schleswig-Holstein Wadden Sea, a survey of sprat abundance in the German part of the Wadden Sea has been carried out each year since 1991 (Vorberg 2009). The abundance index shows a progressive decline in sprat abundance in the German Wadden Sea, a trend that is the opposite to the trend in abundance in the North Sea as a whole. Common terns in the Wadden Sea feed predominantly on sprats and show declines in breeding success and reductions in breeding numbers that correlate with the Wadden Sea sprat abundance index (Dänhardt and Becker 2011). This suggests either that there is a separate stock of sprats in the Wadden Sea with dynamics that are independent from the main North Sea sprat stock, or that sprats have altered in distribution such that their abundance in the Wadden Sea has declined despite increases in the North Sea as a whole.

Given that dependent predator populations are most likely to aggregate in coastal areas such as those listed above, there is a need to consider the extent to which these local coastal populations of sprats are, or are not, linked to the main North Sea stock which is the subject of the assessment and target of the fishery.

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 has been problematically 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.

Despite the establishment of this sprat box, the juvenile herring bycatches increased in the early 1990's, partly because of larger incoming year classes having a wider distribution (Hoffman *et al* 2004). It was concluded that there was no clear connection between the sprat box and the decrease in herring bycatches in the period 1984-1996. The sprat box is still in operation (Fiskeridirektoratet 2007). An experimental fishery was conducted in the box in 2012 to determine whether there is basis for changing the box (changing spatial coverage or removing it).

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, blue whiting). The directed sprat fishery is regulated by a % minimum limit for sprat in the haul of 60%. Discarding in the sprat fishery in the North Sea is considered low; however, if the bycatch% of herring is exceeded in a haul, the haul is not taken and this may be regarded as slippage/discarding. 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 landings are only considered reliable from 1996 onwards. The reduction in bycatches of juvenile herring in 1996 coincides with the introduction of a bycatch limit on herring in the industrial fisheries, and improvements in catch-sampling.

The bycatches in the Danish industrial small-meshed trawl fishery for sprat (1998-2009) have been estimated from samples of the commercial catches. The major bycatches are herring (4.2-11.1% in weight), horse mackerel (0.0-1.6%), whiting (0.2-1.5%), haddock (0.0-0.1%), mackerel (0.0-2.2%), cod (<0.0%), sandeel (0.0-10.0%) and other (0.3-2.4%). Although these catches are relatively small by weight, they are often juveniles, and therefore can represent a significant number of individuals.

There exists no information about the bycatches of the other fleets.

A.3. Ecosystem aspects

Sprat is an important part of the diet of numerous species, including demersal fish, zooplankton seabirds and other predators (marine mammals and elasmobranchs). The major natural sources of sprat removals include whiting, mackerel, horse mackerel and seabirds (Fig. A.3.1). Thus a fishery on sprat may impact on these other components via second order interactions. There is a paucity of knowledge of effects of a shortage of sprat on the majority of these species, with the exception of seabirds in the breeding season. Other species impact on sprat through inducing natural mortality. This effect is estimated in the multispecies SMS model of the North Sea (WKSPRAT 2013).Sprat can be very important for breeding seabirds in southern areas of the North Sea (Durinck *et al* 1991, Wilson *et al*. 2004). Estimates from 1985 have shown that the total seabird consumption in the North Sea could be on the same level as the fisheries (Hunt and Furness (ed.) 1996). 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.

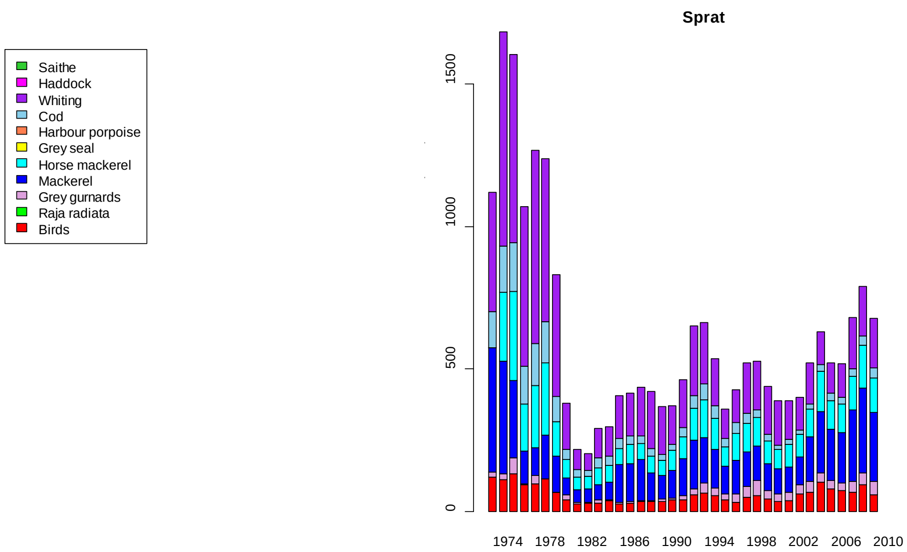


Figure. A.3.1 Biomass (1000t) of sprat eaten by predator. Data from SMS updated run (WKSPRAT 2013).

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 is, since 2000, carried out by purse seiners and pelagic trawlers. The landings are mainly used for reduction purposes. In the last decade, also 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, UK and the Netherlands have sampled their sprat catches. The sampling intensity for biological samples, i.e., age and weight-at-age is mainly 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 div. 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.

Level	Space	Time
1	4 statistical rectangles	Quarter
2	16 statistical rectangles	Quarter
3	North Sea	Quarter
4	North Sea	Half year
5	North Sea	Year

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 sprat per age and kg and tons of sprat caught was estimated and the level noted. If the total North Sea 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 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.

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 total official landings. The decision to match official landings, rather than ICES landings, was taken because some landings from the Danish log-book system cannot be allocated to rectangle or area.

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).

Disagreements in the age reading in North Sea sprat have been reported (*e.g*. Torstensen *et al*. 2004). Problems with correct age determination may arise from three main sources; a) individuals may over winter as larvae and a winter-ring may not be discernible; b) more than one translucent zone may be formed in a specific year and thereby adding false winter zones to the total count as suggested for other species like sand eel; c) the reader's qualification. Validation of annual ring formation from primary increment formation in otoliths has to either rely on a daily periodicity of the primary increments all year round or an annual cycle in the pattern of the otolith microstructure (Panella 1971).

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).

		Validated age		
	Year	1	2	3
	1	90	2	0
	2	5	36	0
Read age	3	0	2	5

Read age vs. validated age for an experienced age reader

A frequent source of error when age reading sprat is the identification of the first wintering probably due to the prolonged spawning period where a subset of a cohort may over winter as larvae and a winter-ring may not be discernible. The encouraging results above are based on one agereader and thus the results of an ongoing exchange under the PGCCDBS on sprat from the North Sea and Celtic Sea should be taken into account when these are available (ICES 2013). However applying the new image analysis techniques (annotating rings, validation by microstructure) will potentially increase both accuracy and precision of the age estimations of sprat.

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.

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 (2013).

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).

Suitability

Internal and external (between IBTS Q1 and IBTS Q3 and between IBTS and HERAS) consistency analyses provide r^2 values > 0.2 for most pairwise comparisons (WKSPRAT 2013). Further, IBTS data are fitted reasonably by the assessment model with CVs around 0.6, although not as well as the acoustic HERAS index.

Internal Consistency

Internal consistency in IBTS Q1 is in general higher than in IBTS Q3 (Figures 4 and 5). In IBTS Q3 internal consistency is only present from age-0 to age-1. It should be noted that a good internal consistency is only expected when total mortality is constant over time, which is not the case for sprat.

Catches of North Sea sprat in hauls in the IBTS survey can occasionally be extremely large; this phenomenon has previously been suggested as being important to the dynamics and uncertainty of IBTS survey indices (ICES HAWG 2007, 2009). In order to examine this phenomenon more closely, the importance of each haul to the index was assessed by calculating the individual contribution of each haul to the total. These hauls were then ranked according to size and aggregated to produce an estimate of the cumulative contribution ranked by sized: in this manner, it is therefore possible to assess, for example, the proportional contribution of the largest 20 hauls in a given year. For all years in the both the IBTS Q1 and Q3, the 10 largest hauls contribute at least 35% of the survey index, and in some cases up to 85% of the index. The IBTS Q3 index appears to have more severe problems with large hauls than the Q1 index: in every year, the five largest hauls make up more than 50% of the index. Three methods to estimate the average catch in the IBTS were examined by WKSPRAT (2013): stratified mean, delta-gamma and delta-normal distributed data. The two latter methods assumed a constant spatial distribution of the sprat stock (multiplicative effect of 4-square area on catch rates). The methods were evaluated based on their consistency with the HERAS acoustic survey. The delta-gamma distribution and the stratified mean each showed the highest correlation in half the cases. Hence, both would appear to be reasonable methods for estimating survey indices. The group chose to proceed with the stratified mean, as no consistent improvement could be reached by using the other two methods and as the assumption of constant distribution may not be valid in periods of environmental change or changes in stock abundance.

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 and onwards.

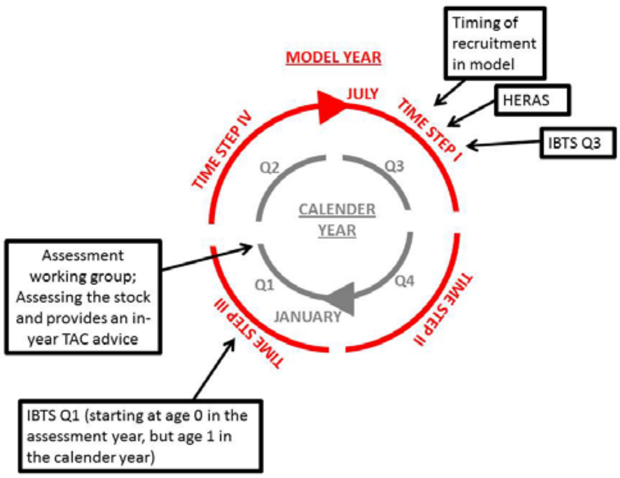
The acoustic survey indices were investigated in WKSPRAT (2013) to determine the start year which corresponded to the highest internal consistency (Figure 6). This was found to be 2001, corresponding to a correlation of 1 to 2 year olds of 0.58 and of 2 to 3 year olds of 0.67 (P<0.05 in both cases, n=12).

B.4. Commercial cpue

None available.

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. The age distribution of quarterly catches of less than 5000 tons is very poorly estimated: with two exceptions, these are based on less than 5 samples (from a total of 148 quarters sampled). As these catches are too small to have any major effect on the stock, they were removed from the likelihood estimation to avoid problems caused by the low sampling level.



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. 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 following 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. Annual maturity ogives are used after 1994 (from IBTS Q1). Before 1994 fixed maturity ogives is used.

The details of the default model settings are summarized in the following table.

Option	North Sea (Div. 4)
Data first year	1974
Time step	Quarterly (model year running from 1 July to 30 June)
First age	Age 0
Last age	Age 3+
Recruitment time	Start of 1st season (in the model year)
Age range for use of catch data in likelihood	Age 0 – age 3+
Last age with age dependent fishing selection	Age 2
Objective function weighting (catch, survey, S/R)	1.0, 1.0, 0.1
Minimum CV of catch observations	0.1
Minimum CV of survey observations	0.3
Minimum CV of S/R relation	0.2
Catch observations: variance group	Age 0 Age 1 Age 2 + Age 3
Treatment of zero catch observations	Not used in likelihood
Year ranges for constant exploitation pattern	1974–1995 & 1996–
Ages for seasonal exploitation pattern	Age 0 Age 1 Age 2 Age 3
Ages for calculation of mean F	Age 1 & age 2
Exclusion of catch data (no or very small catches are available)	< 5000 t (see the main text above)
Catch Variance	Calculated within SMS
Survey variance	Free parameter
S/R variance	Calculated within SMS
Inflexion point (Blim)	90 000
Survey	IBTS Q1: Age 0 – Age 3 (1975-) IBTS Q3: Age 1– Age 3 (1991-) HERAS: Age 1 – Age 3 (2003-)

D. Short-Term Projection

Short term projecttions are made using SMS, the reference points described in the section below and 3 year averages of weight-at-age, proportion mature, and the natural mortality for the incoming year. By the time of the assessment (HAWG is held in March) information is lacking on catches in quarter 1 and 2 (Jan – June). These are estimated by using a value that corresponds to x % of the TAC, where x is the catch in quarter 1 and 2 relative to the combined catch of quarter 3 + 4 averaged over the three previous years (but *x* * TAC should not exceed what is remaining of the TAC). The 25% lower fractile boundary of the long term recruitment mean (1992-2012) is used as the recruitment input in the projection.

Model used: SMS

Software used*:* R

Initial stock size: unknown

Maturity: average of the last 10 years

F and M before spawning: average of the last 3 years

Weight at age in the stock: average of the last 3 years

Weight at age in the catch: average of the last 3 years

Exploitation pattern: average of the last 3 years

Catches in quarter 1 and 2 (Jan – June) are estimated using a value that corresponds to *x* % of the TAC, where *x* is the catch in quarter 1 and 2 relative to the combined catch of quarter 3 + 4 averaged over the three previous years (but *x* * TAC should not exceed what is remaining of the TAC).

Stock recruitment model used:

Geometric recruitment mean for the entire time-series is used as the recruitment input in the projection

E. Medium-Term Projections

F. Long-Term Projections

G. Biological Reference Points

The stock and recruitment relationship generated from the mordel output data indicates an increasing relationship between the SSB and recruitment, and no breakpoint for a hockey stick relationship could be estimated by the model. Blim was not sensitive to choice of approach (ICES 2003), and ended up between 80 000 and 100 000 t. The following approaches were attempted: Increasing relationships, a "cloud" for data from 1991 onwards(B_{lim} = B_{loss} =82 000 t), and a hockey stick with a predefined breakpoint (where years of very high recruitment preferentially should be above B_{lim} and years of very low recruitment below B_{lim}). The lowest B_{lim} came out of the B_{loss} approach. It was decided that ensuring thatyears of very good recruitment occurred when the stock was above B_{lim} and years of very low recruitment occurred when the stock was below Blim were important criteria given the appearance of the relationship. Hence, a B_{lim} of 90 000 t and B_{pa} of 142 000 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 0.28.

H. Other Issues

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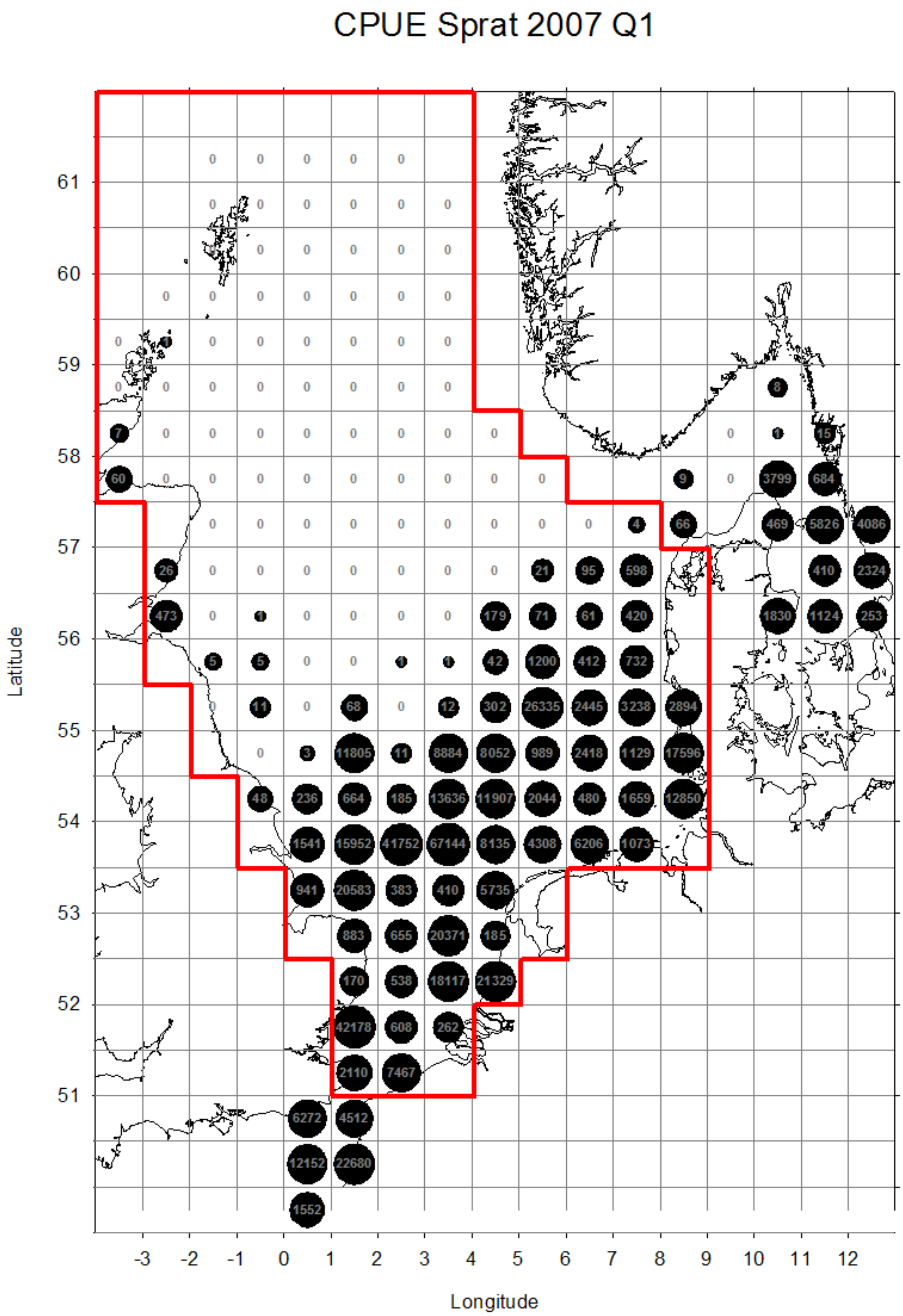

Figure 1. North Sea sprat. IBTS log cpue from subareas; 4, 3.a, 7. The red area encircles the management area used for North Sea sprat. After ICES HAWG 2009.

Figure 2. North Sea sprat. Sampling stations (Limborg *et al*. 2009).

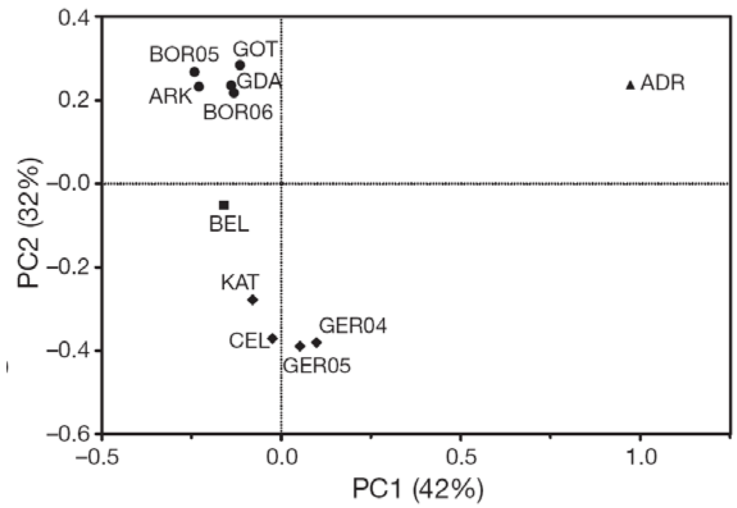

Figure 3. North Sea sprat. Plot of the generic variance in the samples. ADR = Adriatic Sea, ARK = Arkona Basin, BEL = Danish Belt, BOR = Bornholm Basin, CEL = Celtic Sea, GDA = Gdansk Deep, GER = German Bight (North Sea), GOT = Gotland Basin (Limborg *et al*. 2009).

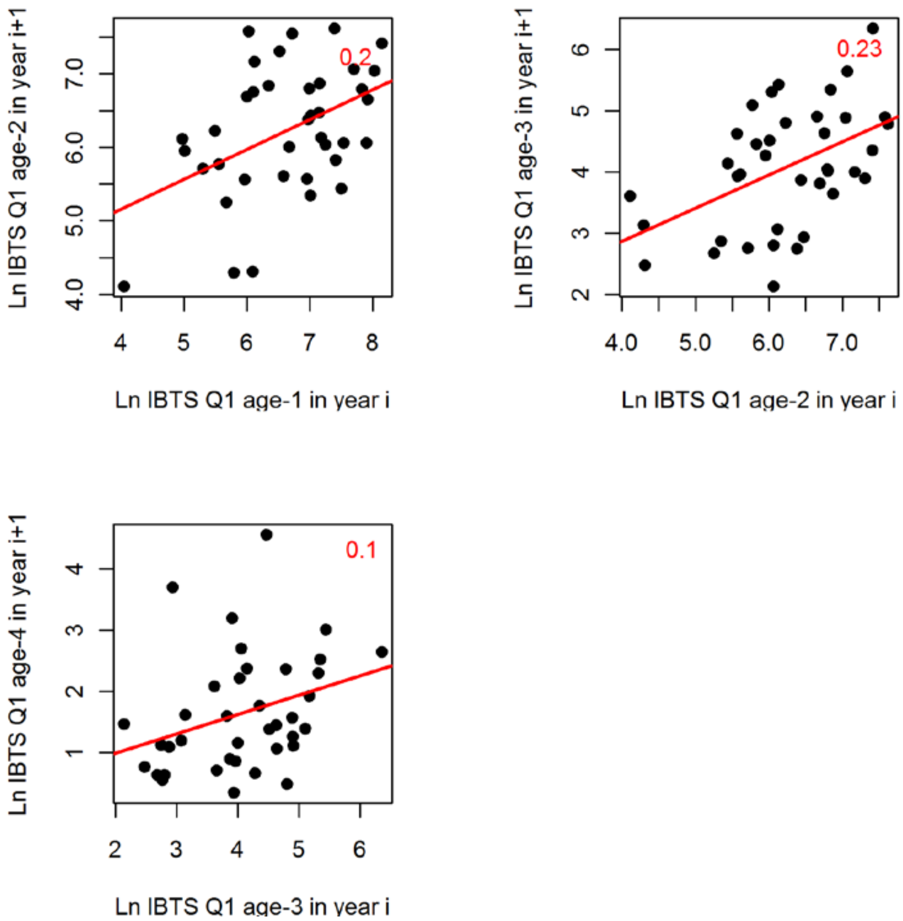

Figure 4. North Sea sprat. Internal consistency analysis from the IBTS Q1 survey. The coefficient of determination (r^2) is provided and is based upon log-transformed values.

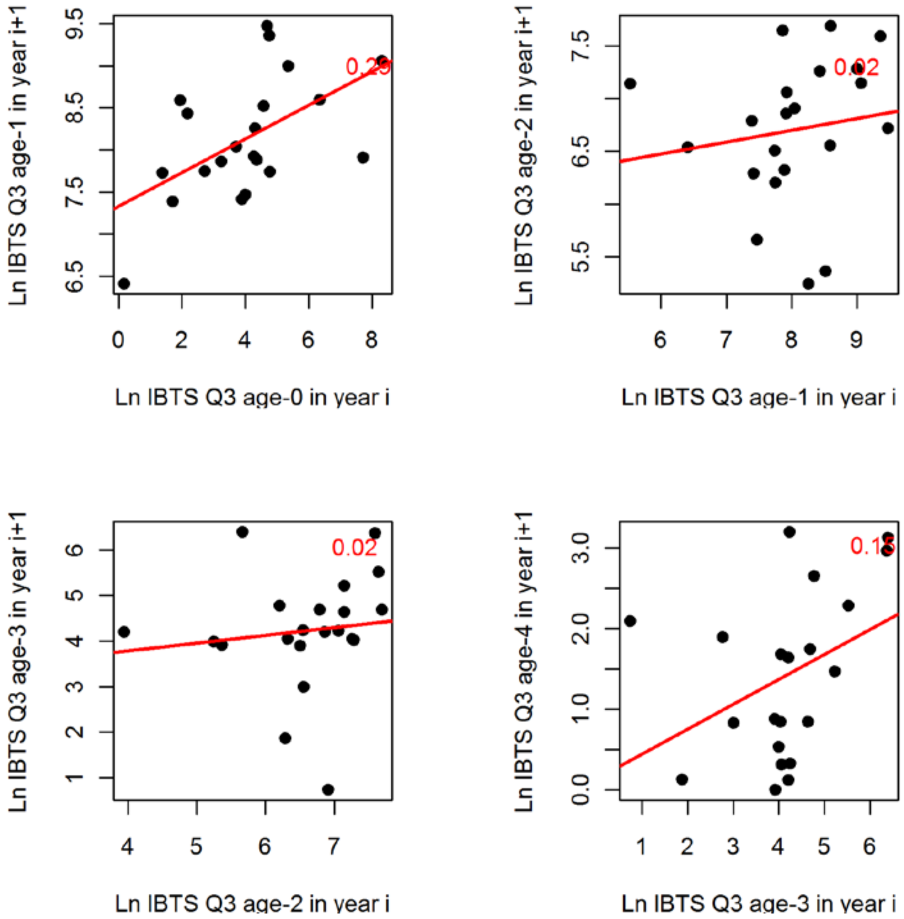

Figure 5. North Sea sprat. Internal consistency analysis from the IBTS Q3 survey. The coefficient of determination (r^2) is given and is based upon log-transformed values.

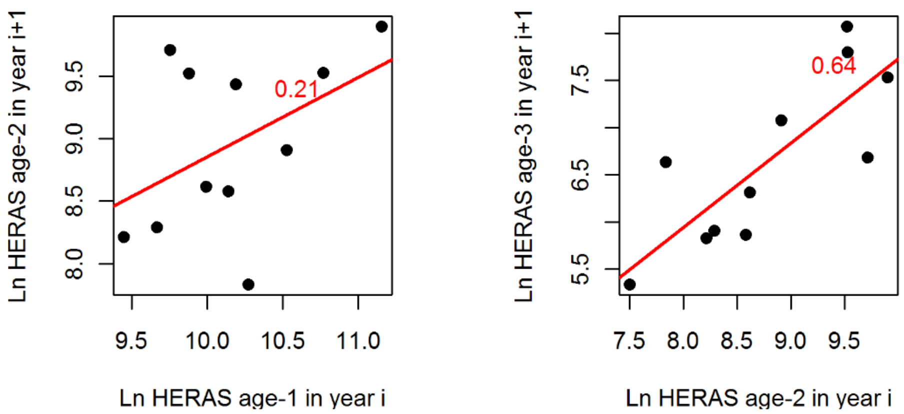

Figure 6. North Sea sprat. Internal consistency analysis from the herring acoustic survey, HERAS. The coefficient of determination (r_2) is given and is based upon log-transformed values.