

Annex 09 – Stock Annex – Sprat in the North Sea

Quality Handbook	ANNEX: Sprat in the North Sea
Stock specific documentation of standard assessment procedures used by ICES.	
Stock:	Sprat in the North Sea
Working Group	Herring Assessment Working Group (HAWG)
Date:	21 March 2010
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A. General

A.1. Stock definition

Sprat (*Sprattus sprattus* Linnaeus 1758) in ICES area IV (North Sea).

Sprat in the 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). 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 does not support the separation of sprat into three stocks that is currently employed by ICES (i.e. subdivision VIIId (English Channel), subdivision IIIa (Skagerrak/Kattegat) and division IV (North Sea)). However, it is also important to note that this work is based on neutral markers, which are relatively insensitive. Further research on this issue is required.

A.2. Fishery

The majority of the sprat landings are taken in the Danish industrial small-meshed trawl fishery. The Norwegian sprat fishery is mainly carried out by purse seiners. Both landings are used for reduction to fish meal and fish oil. In the last decade, also the UK occasionally lands small amounts of sprat.

The commercial catches are sampled for biological parameters. In the most recent years Denmark, Norway and Scotland 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.

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 is therefore dominated by large vessels.

There exists no information about discards and unallocated catches, but it is not expected to be a problem for this fishery.

Historically, the by-catch of juvenile herring in the industrial sprat fisheries has been problematically high (Figure 4). To reduce this by-catch, 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 (Hoffman *et al* 2004). It was estimated that about 90% of the by-catches 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 by-catch.

Despite the establishment of this sprat box, the juvenile herring by-catches 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 by-catches in the period 1984-1996. The sprat box is still in operation (Fiskeridirektoratet 2007).

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

Evaluation of the quality of the catch data

Due to large but unknown by-catches of juvenile North Sea herring in the industrial sprat fisheries prior to 1996 (Figure 4), sprat landings are only considered reliable from 1996 onwards. The reduction in by-catches of juvenile herring in 1996 coincides with the introduction of a by-catch limit on herring in the industrial fisheries, and improvements in catch-sampling.

The by-catches in the Danish industrial small-meshed trawl fishery for sprat (1998-2009) have been estimated from samples of the commercial catches. The major by-catches 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 (0.2-2.2%), 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 by-catches of the other fleets.

A.3. Ecosystem aspects

Many predators in the North Sea feed extensively on sprat, including predatory fish, marine mammals and seabirds. Its role in the ecosystem has been evaluated in the 1981 and 1991 stomach sampling programs (ICES 1989, ICES 1997). Predation was strongest from whiting and mackerel (ICES SGMSNS 2006, ICES 1997). Predation from cod on sprat have been suggested to increase after the last sampling campaign in 1991 as sandeel and Norway pout stocks have decreased (ICES 1997).

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.

Attempts have previously been made to include sprat in the MSVPA in the North Sea (ICES SGMSNS 2005). Recently, as no single species assessment on North Sea sprat has been performed, sprat was not included explicitly in the MSVPA. Sprat was therefore treated in the recent model as 'other food', and is thus included in the model indirectly as a prey organism. Unfortunately this method does not allow for an estimate on the predation mortality on sprat (ICES WGSAM 2008). Historically, MSVPA runs have included sprat by which it was found that the predation mortality on the species exceeds the fishing mortality (ICES SGMSNS 2005).

B. Data

B.1. Commercial catch

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B.2. Biological

Sprat in the North Sea has a prolonged spawning season ranging from early spring to the late autumn, and is triggered by the water temperature (Alheit *et al.*, 1987; Alshulth 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 shown to be spawners (ICES WGIPS 2010).

Disagreements in the age reading in North Sea sprat have been reported (*e.g.* Torstensen *et al.* 2004). The problems arise due to interpretation of winter rings. False winter rings can be set in periods of bad feeding conditions/starvation and due to rapid changes in temperature (E. Torstensen, personal communication 2009). False winter rings also occur in other species and areas, *e.g.* Baltic sprat (Kornilovs (edi.) 2006), herring (ICES WKARGH 2008) and sandeel (Clausen *et al.* 2006). Furthermore, the interpretation of the first winter ring can be difficult, as sprat can spawn until late autumn and larvae from these late spawning will likely not set down a winter ring

during their first winter (Torstensen *et al* 2004). The absence of such rings can lead to errors in age determination, as these individuals cannot be distinguished from the individuals born the following year. Age readings in North Sea sprat were estimated to have a high coefficient of variance (CV) of 28% (Torstensen *et al.* 2004).

Mean weight-at-age in the North Sea sprat is variable over time (ICES HAWG 2009). This may be ascribed due to both the aging problems previously described, and also the prolonged spawning period, by which the individuals can have very different birthdates and thus also different growth conditions, i.e temperature and nutrition available. The mean weight-at-age in the catches for age 1 is approximately 4 g, at age 2 app. 10 g, at age 3 app. 11 g, and at age 4+ app. 14 g (see Sec 8-North Sea sprat in ICES HAWG 2010).

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 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 WKSHORT (2009).

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 survey are available from the manual (ICES 2004).

Suitability

The appropriateness of the IBTS survey for use as an estimate of the abundance of North Sea sprat was examined in a working document to the WKSHORT (Jansen *et al* 2009). Acoustic data collected during trawls performed as part of the IBTS were analysed, with focus on the vertical distribution. The relationship between the amount of sprat available in the water column (from acoustics) and the amount of sprat captured by the gear was found to be weak and highly variable in nature. The proportion of sprat in the water column that were in the bottom five metres was found to range widely between 0 and 100%, and also found to be a function of the time of day. The work therefore suggests that the IBTS survey, as it exists, may not be appropriate for use with sprat in the North Sea. However, further investigation, including the addition of further data points and comparison with results from other species (*e.g.* herring) are required before firm conclusions can be drawn.

Internal Consistency

Internal consistency analysis (Payne *et al* 2009 and references therein) was used to examine the ability of the IBTS survey to track the abundance of individual cohorts. This method involves plotting the log-abundance estimated by the survey at one age against the log-abundance of the same cohort in the following year: in cases where the total mortality is constant and the relative survey noise is low, this relationship should be linear. However, deviations from linearity may arise due to either high noise levels in the survey or variations in the total mortality experienced by the stock. The test is therefore asymmetric, in that a linear relationship is a strongly positive result, whilst the absence of a relationship does not automatically mean that the survey is of poor quality. Examination of the internal consistency can therefore be used as a measure (albeit biased) of the survey quality.

We find that the relationship between the abundance of successive ages in a cohort from the first quarter (Figure 5) and third quarter (Figure 6) surveys is extremely poor, and is dominated by noise. This noise may arise due to either the nature of the survey (e.g. survey design, variability in catchability) or variations in total mortality. In the absence of information regarding either fishing mortality (e.g. from a stock assessment) or natural mortality (e.g. from a multispecies model), it is not possible to separate these two sources of variability.

Confidence Intervals

Distribution of the IBTS indices are available from the ICES DATRAS database, following a bootstrapping procedure agreed upon in 2006 (ICES 2006). This data was analysed to extract key values characterising the distribution, including the confidence intervals for both IBTS Q1 (Figure 7) and Q3. Generally, the confidence intervals for the indices were found to be extremely broad. The median upper confidence limit is 250% greater than the value of the index estimated (although in some cases this can be as much as 4600% greater) and the median lower confidence limit is 40% less than the estimated index. The uncertainties are therefore much larger than the estimated dynamics of the stock and it is thus not possible to say, statistically, that the index value in one year is statistically different from another.

Composition of the Index

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, ICES HAWG 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 (Figure 8) and Q3 (Figure 9), 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.

Alternative Analysis Methods

The method used by the ICES DATRAS database to calculate the IBTS indices is relatively simplistic, essentially comprising a set of stratified means (i.e. the mean CPUE per statistical rectangle is averaged over the entire North Sea). As an attempt to re-

solve problems caused by the presence of large hauls in the calculation of the index, a Log-Gaussian Cox Process (LGCP) was fitted to the individual haul data (Kristensen *et al* 2006, Kristensen 2009a, Kristensen and Lewy 2009). The LGCP model is a statistical model that can be used to account for the statistical nature of the catch process, including correlations between size classes, spatial correlation and between years. The model was fitted in a simplified form, where only spatial correlations were included. Total CPUE of sprat, CPUE by age and CPUE by length class were all used as classification schemes and each fitted individually using the model.

Unfortunately, the LGCP model failed to fit the IBTS survey data adequately. Goodness of fit tests on the fitted model showed that a number of key assumptions in the model were frequently violated. Furthermore, the confidence intervals on the estimated abundances were extremely broad, in some cases spanning more than six orders of magnitude. It was therefore concluded that the model, as fitted, was inappropriate for the data set.

It is currently unclear as to why the LGCP model fails to fit the IBTS sprat data. A number of candidate explanations have been considered, including the high number of zero hauls and the extreme “boom-bust” nature of the catches. It is currently unclear whether this modelling framework is capable of dealing with the nature of the sprat catches in the IBTS survey: the ultimate appropriateness of this method should be considered carefully before further work is performed.

Conclusions

The IBTS Q1 and Q3 surveys are the best time series of data available for use in characterising the abundance of sprat in the North Sea, covering the years from 1984 and 1991 onwards respectively: for comparison, the time series of catches begins in 1996 and the acoustic survey (see below) in 2004. However, the survey is greatly impacted by the presence of extremely large individual hauls that can make up 85% or more of the index in some years. The problem is compounded by the manner in which the ICES DATRAS database calculates the indices – the use of simple arithmetic means here does not account for the extremely high variability of sprat catches in the IBTS survey and propagates these problems through to the index value. The extremely broad confidence intervals and the lack of internal consistency can also be understood as consequences of this problem. Variability in the catchability of sprat in the IBTS’s GOV gear caused by the time of day and the pelagic nature of sprat may contribute to this problem to a degree but seem unlikely to explain the order-of-magnitude variability observed. Instead, the highly schooling nature of sprat is likely to be the most important underlying cause: if the gear encounters and captures a high-density school of sprat, an extremely large haul could be produced.

Given the potential importance of the IBTS indices for the assessment of this stock, further investigations are warranted. The current analysis method is extremely simplistic and appears to be the main source of the problem. Future investigations should focus on attempting to analyse this large and valuable source of information in a manner that can account for both the large number of zero hauls and also the extremely large individual hauls. Qualitative indicators, such as distribution area, presence/absence metrics, and the frequency of large hauls may also be of use in an advice context.

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 PGMERS 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.

Suitability

In theory, the herring acoustic survey should be better suited for the estimation of sprat abundance than the bottom trawl IBTS survey, given that it integrates over the entire water column and is thus less susceptible to changes in vertical distribution and the presence of large schools.

However, there are a number of difficulties with the acoustic estimation of sprat that must be considered. Each survey report since 2004 has noted that the survey does not appear to reach the southern boundary of the stock, with there being significant concentrations of sprat at or close to this limit. Failing to reach the southern boundary line would lead to an underestimation of the stock size and may increase the inter-annual variability of the estimate. Similar observations have also been obtained from the IBTS survey, suggesting that the population may continue into the English Channel and subdivision VIIId (ICES HAWG 2009; see also section 6.3).

The acoustic signatures of herring and sprat are also very similar and make the separation of these two species challenging. In the 2005 survey, an area containing large amounts of sprat was covered by two of the vessels, allowing a direct comparison of the estimated abundances. Unfortunately, the results varied widely, suggesting that the precision of the total abundance estimate may be poor (ICES PGMERS 2006).

Finally, the time series of acoustic estimates is short, and may not be of sufficient length for use in a stock assessment.

Internal Consistency

The internal consistency analysis employed above was also employed for the HERAS estimates of sprat abundance (Figure 10). The coefficients of determination for the relationship between the abundance at age for each cohort were appreciably better than those seen for the IBTS surveys, and are comparable to those used in other assessments (*e.g.* western Baltic spring-spawning herring (Payne *et al* 2009)). However, the length of the time series is also extremely short (four pairs of observations), and there is therefore insufficient information to draw meaningful conclusions. Further data points in the time series would be beneficial to understanding the suitability of this survey.

Confidence Intervals

There are currently no confidence intervals available for the estimated acoustic abundances. Future versions of the FISHFRAME database used to estimate the abun-

dances from the raw acoustic data are intended to include the estimation of uncertainties (T. Jansen, personal communication 2009).

Conclusions

The herring acoustic survey shows potential as an estimate of the abundance of sprat in the North Sea. However, the current time series is too short for use, and further data points are required before its potential can be fully assessed. Furthermore, problems regarding the acoustic identification of sprat and herring, and the southern boundary of the stock may severely limit the applicability of this survey: resolving these issues should be considered a high priority.

B.4. Commercial CPUE

None available.

B.5. Other relevant data

C. Assessment methodology ---

No assessment is currently available for this stock.

D. Short-Term Projection ---

No projections are performed.

E. Medium-Term Projections ---

No projections are performed.

F. Long-Term Projections ---

No projections are performed.

G. Biological Reference Points ---

No reference points are available.

H. Other Issues ---

None.

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CPUE Sprat 2007 Q1

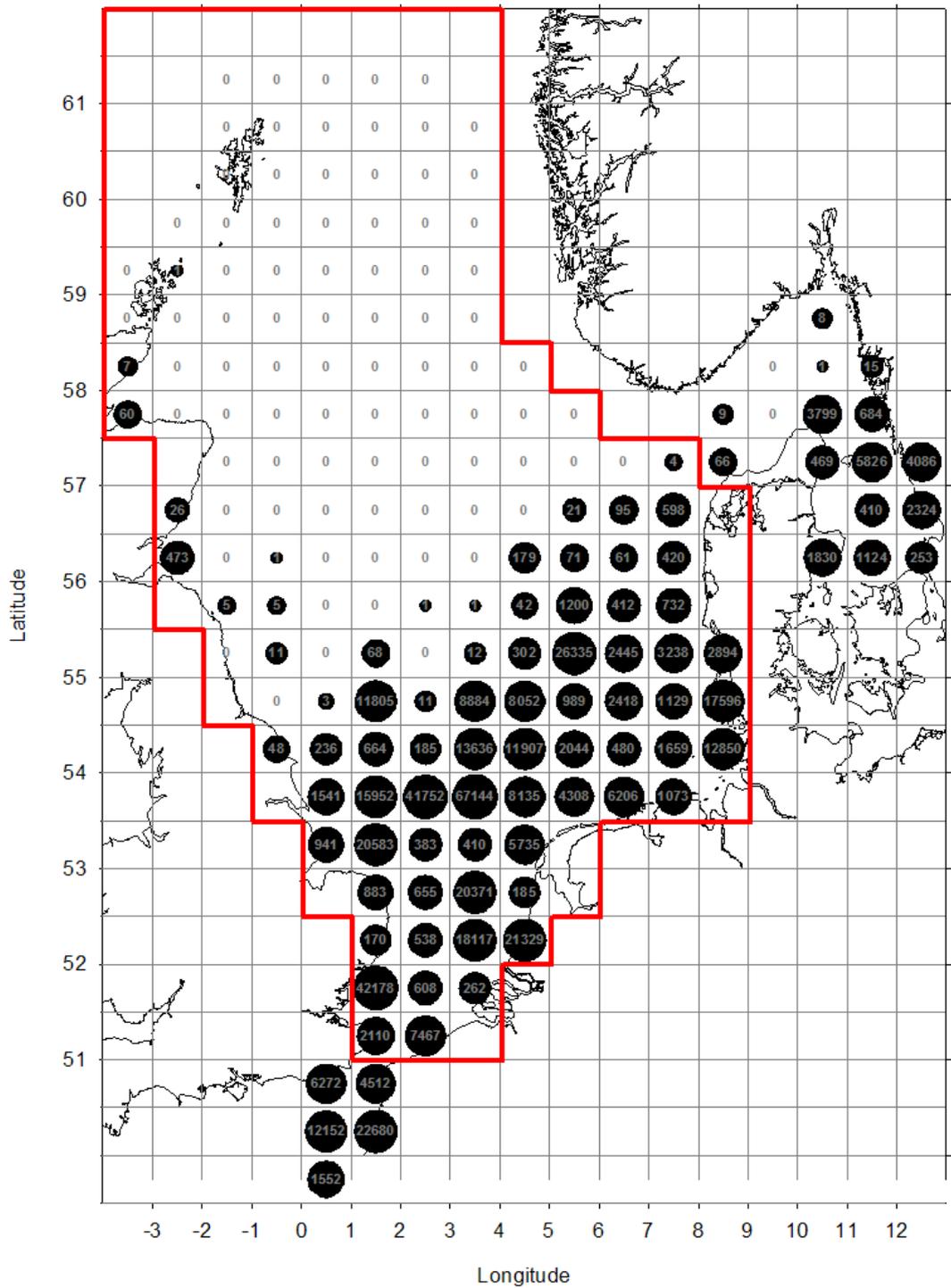


Figure 1. North Sea sprat. IBTS logCPUE from subareas; IV, IIIa, VII. The red area encircles the management area used for North Sea sprat. After ICES HAWG 2009.



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

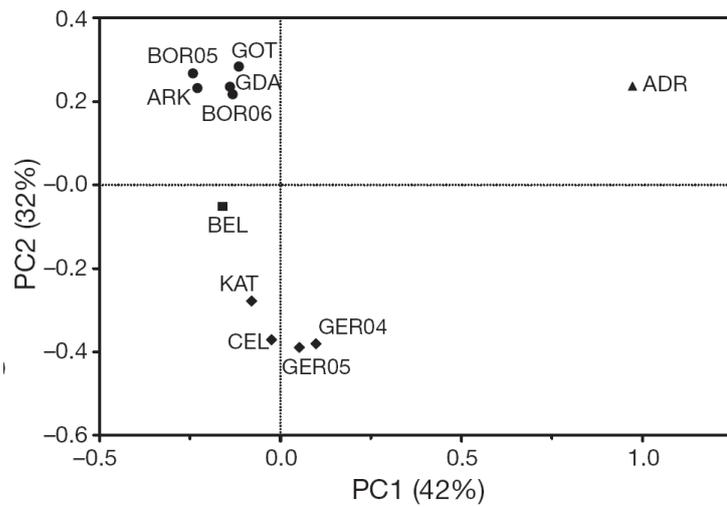


Figure 3. North Sea sprat. Plot of the generic variance in the samples. ADR = Adriatic Sea, ARK = Arkona Basin, BEL = Danish Belt, BOR = Bornholm Basin, CEL = Celtic Sea, GDA = Gdansk Deep, GER = German Bight (North Sea), GOT = Gotland Basin (Limborg *et al.* 2009).

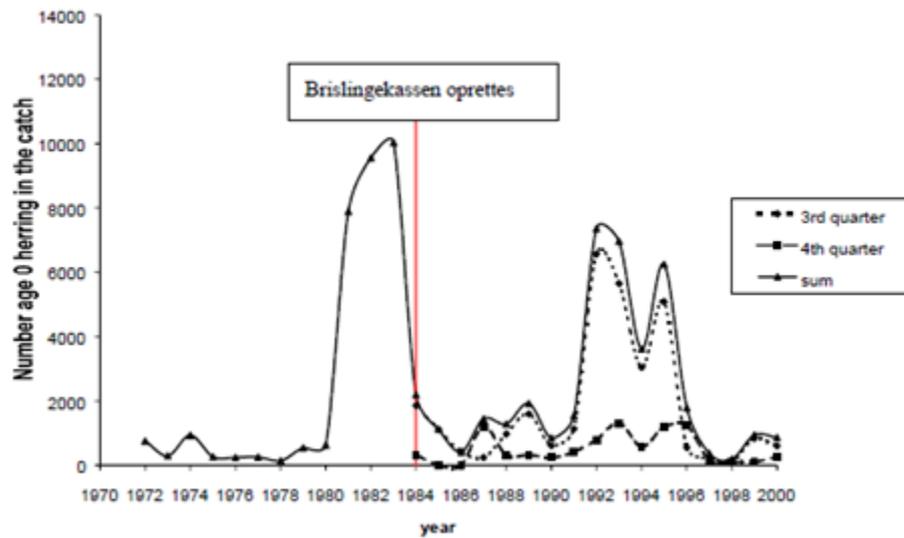


Figure 4: Catches of 0-group herring in the industrial fisheries in the central North Sea (IVb) in the 3rd and 4th quarter 1972-2000. The red line shows the time for establishing the sprat box. From Hoffman *et al* 2004.

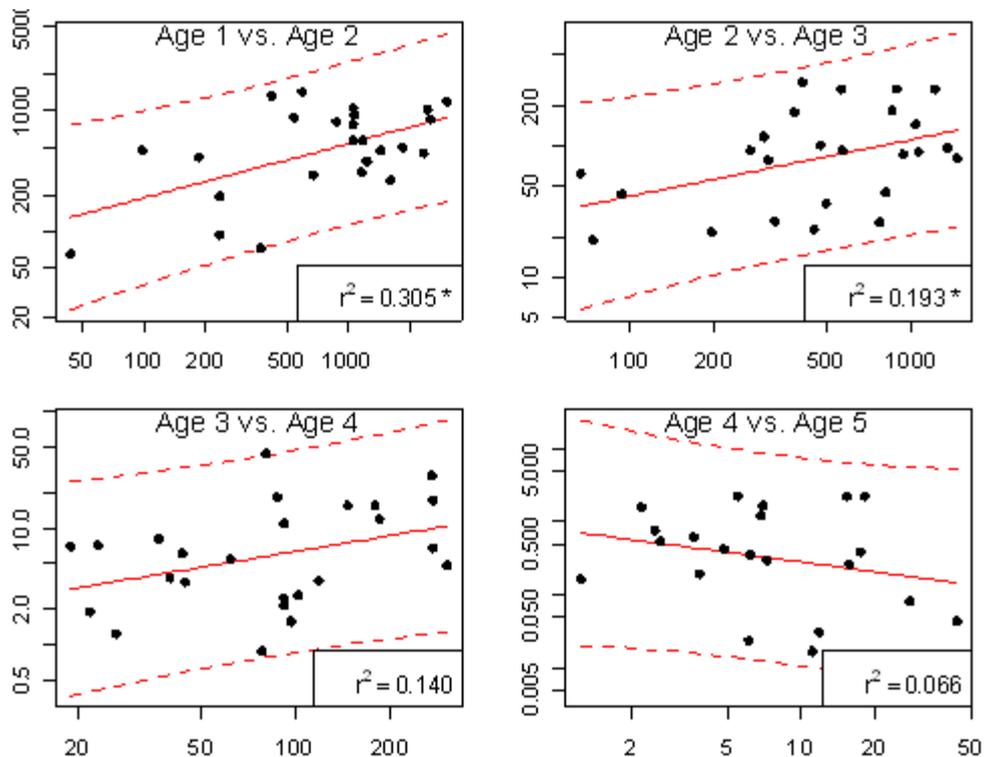


Figure 5 North Sea sprat. Internal consistency analysis from the IBTS Q1 survey. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. The top two relationships are statistically significant at the 95% level, whilst the bottom two are not.

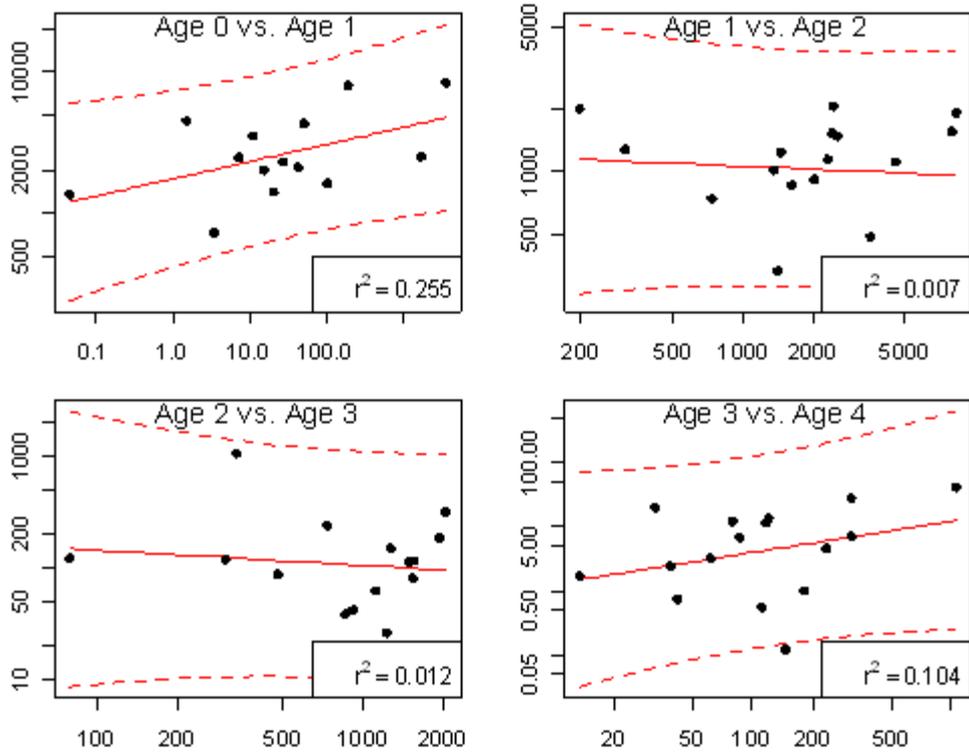


Figure 6. North Sea sprat. Internal consistency analysis from the IBTS Q3 survey. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. No correlations are statistically significant at the 95% level.

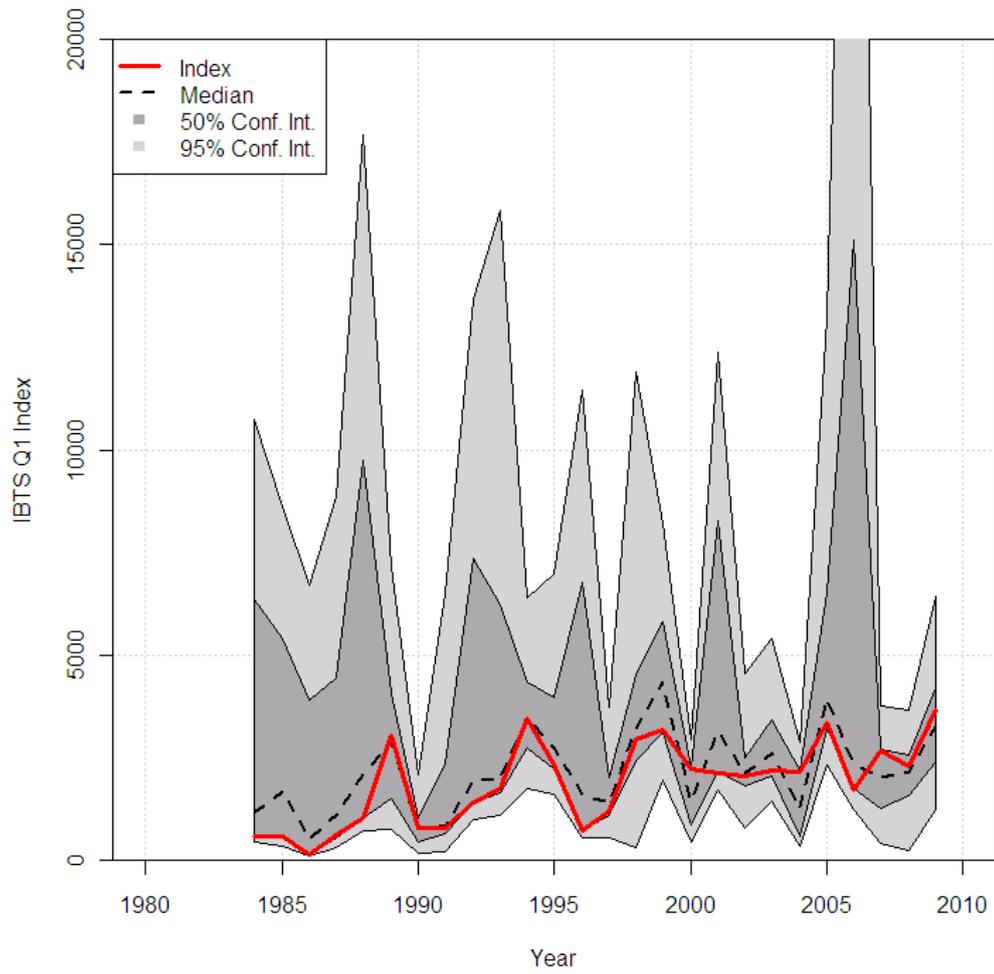


Figure 7. North Sea sprat. Distribution of index values for the IBTS Q1 index, as estimated by the DATRAS database. Values of both the mean index and median value are plotted, in addition to the 50% and 95% confidence bands.

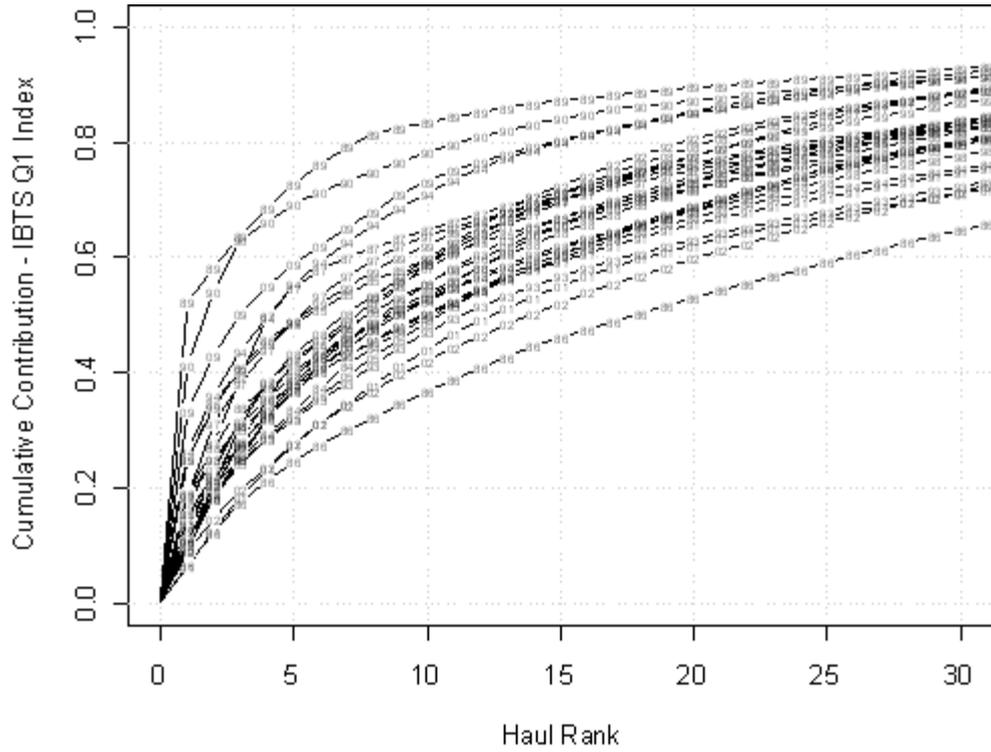


Figure 8. North Sea sprat. Cumulative distribution of the per-haul contribution to the total IBTS Q1 index. The 300-450 individual-haul contributions to the IBTS index in each year are sorted by size and then aggregated to calculate a cumulative-distribution. The plot shows only the contributions for the 30 largest hauls. Numbers on each line indicate the year for the survey.

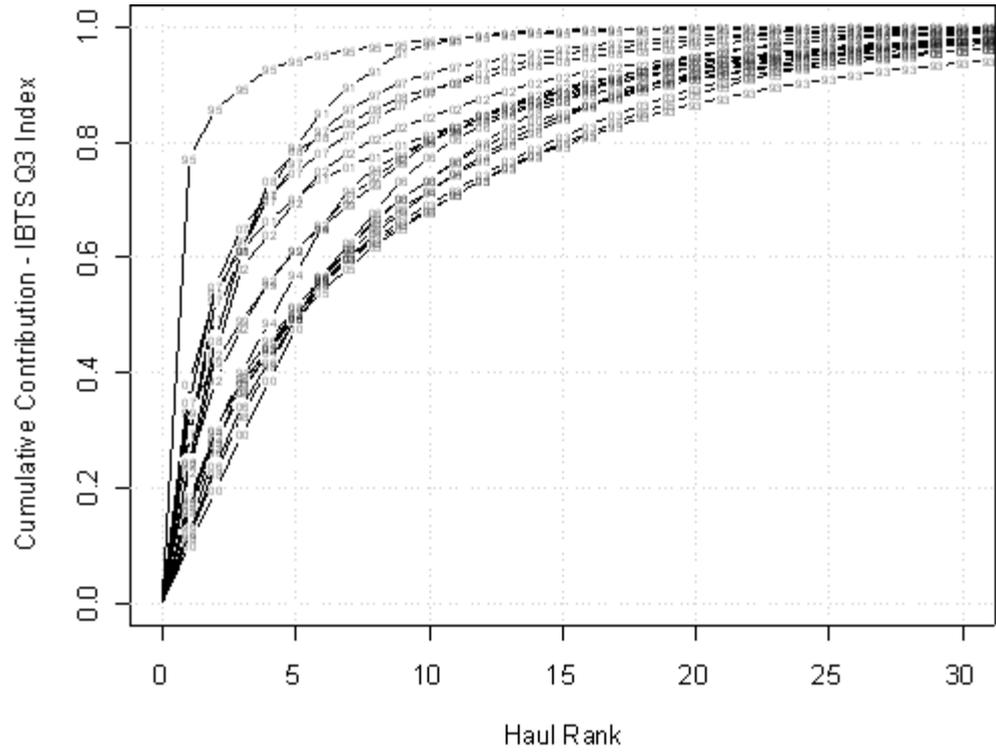


Figure 9. North Sea sprat. Cumulative distribution of the per-haul contribution to the total IBTS Q3 index. The 300-450 individual-haul contributions to the IBTS index in each year are sorted by size and then aggregated to calculate a cumulative-distribution. The plot shows only the contributions for the 30 largest hauls. Numbers on each line indicate the year for the survey.

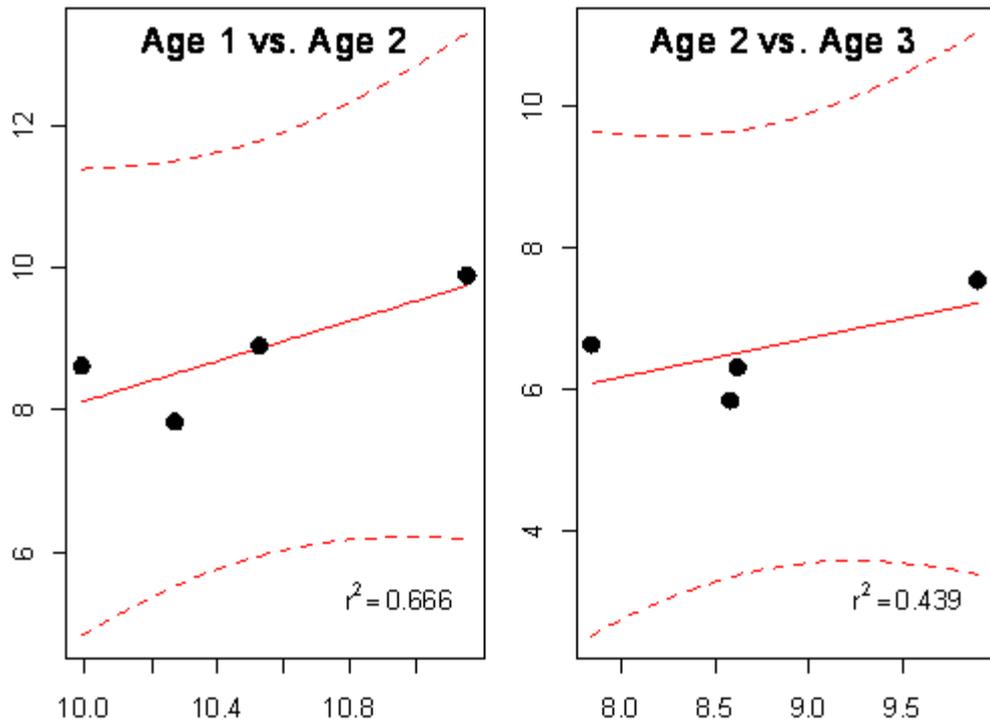


Figure 10. North Sea sprat. Internal consistency analysis from the herring acoustic survey, HERAS. Each panel plots, on a log scale, the abundance of a cohort perceived at a given age (horizontal axis) against the abundance of the same cohort as perceived one year later (vertical axis). The coefficient of determination (r^2) is given in the lower-right corner and is based upon log-transformed values. The title of each panel gives the ages plotted, with the first age plotted on the horizontal axis and the second on the vertical. Neither correlation is statistically significant at the 95% level.