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i Expert group information

Expert group name	Herring Assessment Working Group for the Area South of 62° N (HAWG))
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Year cycle started	2022
Reporting year in cycle	1/1
Chairs	Afra Egan, Ireland
	Cecilie Kvamme, Norway
Meeting venues and dates	25-27 January 2022, virtual meeting (13 participants)
	March-May 2022, by correspondence (13 participants)
	9-12 May and 18 May 2022, virtual meeting, (xx participants - tbd)

9 Sandeel in Division 3.a and Subarea 4 and Division 6.a

Larval drift models and studies on recruitment and growth differences have indicated that the assumption of a single stock unit in the area is invalid. As a result, the total stock is divided in several sub-populations (ICES, 2016, Figure 9.1.1), each of which is assessed by area specific assessments. Currently fishing takes place in five out of these seven areas (sandeel area (SA) 1r, 2r, 3r, 4, and 6). Analytical stock assessments are currently carried out in SA 1r–3r and 4, whereas SA 6 is managed under the ICES approach for data limited stocks (Category 5).

In 2010, the SMS-effort model was used for the first time to estimate fishing mortalities and stock numbers-at-age by half year, using data from 1983 to 2010. This model assumes that fishing mortality is proportional to fishing effort and is still used to assess sandeel in SAs 1r, 2r, 3r and 4.

Further information on the stock areas and assessment model can be found in the Stock Annex and in the benchmark report (ICES, 2016).

9.1 General

9.1.1 Ecosystem aspects

Sandeel in the North Sea can be divided into a number of more or less reproductively isolated sub-populations (see the Stock Annex). A decline in the sandeel population in several areas in recent years concurrent with a marked change in distribution has increased the concern about local depletion, of which there has been some evidence (ICES, 2007; ICES, 2008, ICES 2016). Since 2010 this has been accounted for by dividing the North Sea and 3.a into seven management areas.

Local depletion of sandeel aggregations at a distance less than 100 km from seabird colonies may affect some species of birds, especially black-legged kittiwake and sandwich tern, whereas the more mobile marine mammals and fish are likely to be less vulnerable to local sandeel depletion.

The Stock Annex contains a comprehensive description of ecosystem aspects.

9.1.2 Fisheries

General information about the sandeel fishery can be found in the Stock Annex.

The size distribution of the Danish fleet has changed through time, with a clear tendency towards fewer and larger vessels (ICES, 2007). During the last fifteen years, the number of Danish vessels participating in the North Sea sandeel fishery has been stable with around 100 active vessels.

The same tendency has been seen for the Norwegian vessels towards fewer and larger vessels. In 2008, 42 vessels participated in the sandeel fishery, but in 2020, 27 vessels participated in the fishery. From 2011 to 2020, the average GRT per vessel in the Norwegian fleet increased from 1100 to 1540 tonnes.

The rapid changes of the structure of the fleet that have occurred in the past may introduce more uncertainty in the assessment, as the fishing pattern and efficiency of the current fleet may differ from the previous fleet and the participation of fewer vessels has limited the spatial coverage of the fishery. This is to some degree accounted for in the stock assessments through the introduction of separate catchability periods.

The sandeel fishery in 2020 was opened 1 April and continued until the end of July. In NEEZ the fishery opened 15 April and ended 23 June.

9.1.3 ICES Advice

ICES advised that the fishery in 2020 should be allowed only if the analytical stock assessment indicated that the stock would be above B_{pa} by 2021 (Escapement strategy). This approach resulted in an advised TAC for 2020 in SA 1r, SA 2r, SA 3r, and 4 of 113 987t, 62 658 t, 155 072t and 39 611 t, respectively. Advised catches for SA 5, SA 6, and SA 7 for 2019 and 2020 were based on data limited approaches and set at 0 t, 175 t and 0 t, respectively.

9.1.4 Norwegian advice

Based on a recommendation from the Norwegian Institute for Marine Research, an opening TAC of 70 000 tonnes for 2020 was given. As the acoustic survey abundance estimate of age 1 and the total biomass estimate (659 000 tonnes, RSE=0.18%) was the highest observed in the time series the final TAC increased to 250 000 tonnes. Fishery was allowed in the subareas 1a, 1c, 2b, 2c,3b,3c, 4a (see Stock Annex for area definitions).

9.1.5 Management

Norwegian sandeel management plan

An Area Based Sandeel Management Plan for the Norwegian EEZ was fully implemented in 2011 but was also partly used in 2010. The areas with known sandeel fishing grounds are divided into 5 areas (each divided into subareas). An area is closed for fishery unless the biomass (Age1+) is at least 20 000 tonnes. If an Area is open for fishery, one of the sub-areas is closed. A preliminary TAC for all Areas combined is given in February based on a precautionary prediction of total biomass and a harvesting rate of 0.4. An updated in-season TAC is given 15 May as the 40% percentile of the survey biomass estimate and harvesting rate of 0.4. Areas can be opened based on the updated information (Johnsen 2020).

Closed periods

From 2005 to 2007, the fishery in the Norwegian EEZ opened 1 April and closed again 23 June. In 2008, the ordinary fishery was stopped 2 June, and only a restricted fishery with five vessels continued. No fishery was allowed in 2009. From 2010 to 2014 the fishing season was 23 April–23 June, and from 2015 and onwards from 15 April to 23 June in the Norwegian EEZ.

Since 2005, Danish vessels have not been allowed to fish sandeel before 31 March and after 1 August.

Closed areas

The Norwegian EEZ was only open for an exploratory fishery in 2006 based on the results of a three-week RTM fishery. In 2007, no regular fishery was allowed north of 57°30′N and in the ICES rectangles 42F4 and 42F5 after the RTM fishery ended. In 2008, the ordinary fishery was closed except in ICES rectangles 42F4 and 44F4, and for five vessels only, the ICES rectangles 44F3, 45F3, 44F2 and 45F2 were open. The Norwegian EEZ was closed to fishery in 2009. In accordance with the Norwegian sandeel management plan, many of the Norwegian management subareas have been closed each year (see Stock Annex for details).

In the light of studies linking low sandeel availability to poor breeding success of kittiwake, there has been a moratorium on sandeel fisheries on Firth of Forth area along the U.K. coast since 2000. Note that a limited fishery for stock monitoring purposes occurs in May–June in this area.

9.1.6 Catch

Adjustment of official catches

Previously, there has been substantial misreporting of catches between areas (ICES, 2015, 2016b (HAWG)). Since 2015, the Danish regulation has not allowed fishing in several stock areas on a single fishing trip. This eliminated the misreporting issue for Danish catches. However, German and Swedish catches were still high in the four rectangles, and an analysis of Swedish VMS for the years 2012 to 2015 indicated that misreporting had also occurred of Swedish catches in 2014 and 2015 (see HAWG 2017). Because of this, the working in accordance with previous year's reallocated reported catches (14781 t) from rectangles 41F2, 41F3 and 41F4 to SA 1 in 2015. From 2016 onwards, no correction was made.

Catch and trends in catches

Catch statistics for Division 4 are given by country in Table 9.1.1. Catch statistics and effort by assessment area are given in Tables 9.1.2–9.1.7. Figure 9.1.1 shows the areas for which catches are tabulated.

The sandeel fishery developed during the 1970s, and catches peaked in 1997 and 1998 with more than 1 million t. Since 1983 the total catches have fluctuated between 1.2 million t (1997) and 73420 t (2016) (Figure 9.1.3).

Spatial distribution of catches

Yearly catches for the period 2000–2020 distributed by ICES rectangle are shown in Figure 9.1.2 (with no spatial adjustment of official catches distribution in 2014 and 2015). The spatial distribution is variable from one year to the next, however with common characteristics. The Dogger Bank area includes the most important fishing banks for SA 1r sandeel. The fishery in SA 3r has varied over time, primarily as a result of changes in regulations and very low abundance of sandeel on the northern fishing grounds.

Table 9.1.2 shows catch weight by area. There are large differences in the regional patterns of the catches. SAs 1r and 3r have consistently been the most important with regard to sandeel catches. On average, these areas together have contributed ~76% of the total sandeel catches in the period since 1983.

The third most important area for the sandeel fishery is SA 2r. In the period since 2003 catches from this area contributed ~16% of the total catches on average.

SA 4 has contributed about 6% of the total catches since 1994, but there have been a few outstanding years with particular high catches (1994, 1996 and 2003 contributing 19, 17 and 20% of the total catches, respectively). In 2017 and 2018, the first non-monitoring fishery was advised in the area since 2011 with a total TAC of 54043 t and 59345 t, respectively. In 2019, only a monitoring TAC was advised but in 2020, a TAC of 39 611t was advised

Several banks in the northern areas of Norwegian EEZ have not provided catches between 2001 and 2008. In this period, almost all catches from the Norwegian EEZ came from the Vestbank area (Norwegian management area 3 in Figure 9.1.5). From 2010, catches have been taken mainly from the Norwegian management areas 1, 2 and 3, and from area 4 from 2016.

Effect of vessel size on CPUE

In order to avoid bias in effort introduced by changes in the average size of fishing vessels over time, the CPUEs are used to estimate a vessel standardization coefficient, *b*. The parameter *b* was estimated using a mixed model for separate periods. Because the model estimates the parameter from several years of data, the time-series for the most recent period is updated for all years as the parameter *b* is updated with the most recent data. More information can be found in the Stock Annex.

9.1.7 Sampling the catch

Sampling activity for commercial catches is shown in Table 9.1.8.

9.1.8 Survey indices

Abundance of sandeel is monitored by a Danish/Norwegian dredge survey (covering SA 1r–3r) and a Scottish dredge survey (SA 4) in November/December. See the Stock Annex for more details. An acoustic survey was carried out in Norwegian EEZ in April/May following the standard procedures described in the benchmark report (ICES, 2010a).

The dredge survey in 2020 was carried out as planned in areas 1r, 2r and 3r and nearly all planned positions were covered in accordance with the survey protocol. However, because of bad weather and a temporary technical obstacle, the survey was extended by 1 week and a few of the low-priority stations were not visited (all high-priority stations were visited).. The survey in area 1r and 2r was expanded to the south in 2017, where new positions were visited south of 54°N. Since 2017 two vessels were used to complete the survey. This was arranged to ensure that all positions can be visited within the 3-week period of the survey (note that new positions have been included gradually over time). All available data were included in the estimated dredge index by area. In area 4, the coverage of the dredge survey was low in 2020, and only 11 stations were sampled and only two out of four main banks (compared to around 50 stations in 2019).

9.2 Sandeel in SA 1r

9.2.1 Catch data

Total catch weight by year for SA 1 is given in tables 9.1.2–9.1.4. Catch numbers-at-age by half-year is given in Table 9.2.1.

In 2021, 1-group and 2-group were equally represented in the catches. The catches contained very few 3-group and older (Figure 9.2.1).

9.2.2 Weight-at-age

The methods applied to compile age-length-weight keys and mean weights-at-age in the catches and in the stock are described in the Stock Annex.

The mean weights-at-age observed in the catch are given in Table 9.2.2 and Figure 9.2.2 by half year. Mean weight-at-age in the first half year decreased in 2021 and is below the long term mean.

9.2.3 Maturity

Maturity estimates are obtained from the average observed in the Danish dredge survey in December as described in the Stock Annex. The values used are given in Table 9.2.3.

9.2.4 Natural mortality

In 2020, WGSAM provided updated estimates of natural mortality-at-age from multispecies modelling of southern sandeel (SMS, WGSAM 2020). Natural mortality was therefore updated. The full time-series was replaced and 3-year moving averages was used (same procedure as last time the time-series was updated). The new time-series did not affect the stock-recruitment plot to an extent that required a revision of reference points. The new time-series contains values of M that are equal to or slightly higher than the values in the old time-series, except for 2018 and onward where the new values are slightly lower in the 1st half of the year. The values used in the 2018 and 2019 assessments were simply replicates of the 3-year average value from 2015. Natural mortalities are listed in Table 9.2.8.

9.2.5 Effort and research vessel data

Trends in overall effort and CPUE

Tables 9.1.5–9.1.7 and Figure 9.2.3 show the trends in the international effort over years measured as number of fishing days standardized to a 200 GRT vessel. The standardization includes just the effect of vessel size and does not take changes in efficiency into account. Total international standardized effort peaked in 2001, after which substantial effort reduction has taken place. Effort has fluctuated without a trend since 2006.

The average CPUE in the period 1994 to 2002 was around 60 t^{-day}. In 2003, CPUE declined to the all-time lowest at 21 t^{-day}. Since 2004, the CPUE has increased and reached the all-time highest (101 t^{-day}) in 2010 followed by progressively lower CPUEs ending with CPUEs in 2013–2014 below long-term average. CPUE peaked again in 2016-2017, but have decreased to levels below average in 2018, 2019, 2020, and 2021.

Tuning series used in the assessments

A commercial tuning series (RTM) describing the average catch in numbers-at-age per fishing day of a standard vessel in April/early May is used in the assessment.

CPUE data from the dredge survey (Table 9.2.4 and Figure 9.2.5) in 2021 show indices of age 0 and 1 well below the average.

The internal consistency, i.e. the ability of the RTM to follow cohorts, (shows a good consistency correlation between the 1-group and 2-group as well as between 2 and 3-group (i.e. r^2 =0.47 and 0.54, respectively on log scales).

9.2.6 Data analysis

Following the two latest Benchmark assessments (ICES, 2010, 2016) the SMS-effort model was used to estimate fishing mortalities and stock numbers-at-age by half year, using data from 1983 to 2021. In the SMS model, it is assumed that fishing mortality is proportional to fishing effort. For details about the SMS model and model settings, see the Stock Annex.

The diagnostics output from SMS are shown in Table 9.2.5. The seasonal effect on the relation between effort and F ("F, Season effect" in the table) is rather constant over the 5-year ranges used. The “age selection” (“F, age effect” in the table) shows a change in the fishery pattern where the fishery was mainly targeting the age 2+ sandeel in the beginning of the assessment period, to a fishery targeting age 1+ in a similar way, and then in the most recent period back to mainly targeting 2+ sandeel.

The CV of the dredge survey (“sqrt (Survey variance) ~CV” in the table) is low (0.49) for age 0 and high (0.78) for age 1. The survey residual plot (Figure 9.2.6) shows no clear patterns.

The CV of the RTM time-series is low to moderate for ages 1, 2, and 3 (0.53, 0.43, and 0.49). The survey residual plot (Figure 9.2.6b) shows no clear patterns.

The model CV of catch-at-age (“sqrt(catch variance) ~CV”, in Table 9.2.5 is low (0.35) for age 1 and age 2 in the first half of the year and moderate to high (> 0.5) for the remaining ages and season combinations. The catch-at-age residuals (Figure 9.2.7) show a tendency for the cohorts to die out more rapidly than expected in 2019, 2020 and 2021 (negative catch residuals for all ages).

The CV of the fitted Stock recruitment relationship (Table 9.2.5) is high (0.86), which is also indicated by the stock recruitment plot (Figure 9.2.8). The high CV of recruitment is probably due to biological characteristic of the stock (i.e. weak stock-recruitment relationship) and not so much due to the quality of the assessment. The *a priori* weight on likelihood contributions from SSR-R observations is therefore set low (0.05 in “objective function weight” in Table 9.2.5) such that SSB-R estimates do not contribute much to the overall likelihood and model fit.

The retrospective analysis (Figure 9.2.9) shows consistent assessment results from one year to the next for F. For recruitment and SSB, there seems to have been an overestimation in the previous assessments. It is likely that this is connected to the short period used for the latest exploitation pattern, a decision made under the benchmark to accommodate an intermediate period around 2009 with a significantly different exploitation pattern. Further, the negative catch and dredge residuals observed in 2019–2021 will tend to decrease the recruitment estimate as fish of the different cohorts are observed less frequently than expected after the initial dredge index of recruitment. The stability of F estimates is partly due to the assumed robust relationship between effort and F, which is rather insensitive to removal of a few years. Recruitment and SSB estimates show a retrospective bias (5-year Mohn´s Rho for R and SSB is 0.43 and 0.87, respectively).

Uncertainties of the estimated SSB, F and recruitment (Figure 9.2.10) are in general small. The overall pattern with a lower F:effort ratio for older data indicates that the model assumption of no efficiency creeping is violated across periods but not within catchability periods.

9.2.7 Final assessment

The output from the assessment is presented in Tables 9.2.6 (fishing mortality-at-age by year), 9.2.7 (fishing mortality-at-age by half year), 9.2.9 (stock numbers-at-age) and 9.2.10 (stock summary).

9.2.8 Historic Stock Trends

The stock summary (Figure 9.2.13 and Table 9.2.10) shows that SSB have been at or below B_{lim} from 2004 to 2007 and again in 2013-2015. $F_{(1–2)}$ is estimated to have been just below the long-time average since 2010. Recruitment in 2017 was estimated to be the lowest observed in the time-series. 2018 recruitment was also low whereas 2019 shows average recruitment. In 2020 and 2021 the recruitment was below average again.

9.2.9 Short-term forecasts

Input

Input to the short-term forecast is given in Table 9.2.11. Stock numbers in the TAC year are taken from the assessment for age 1 and older. Recruitment in 2022 is the geometric mean of the recruitment 1983–2020 (111 billion-at-age 0). The exploitation pattern and F_{sq} is taken from the assessment values in 2021. However, as the SMS-model assumes a fixed exploitation pattern since 2010, the choice of years is not critical. Mean weight-at-age in the catch and in the sea is the average value for the years 2017–2021. Natural mortality is the same as applied in the assessment in the final year. The Stock Annex gives more details about the forecast methodology.

Output

The short-term forecast (Table 9.2.12) shows that even a fishing mortality of zero will bring SSB below B_{pa}. However, a monitoring TAC of 5000 t is recommended to ensure the quality of the assessment, consistent with previous year's advice (ICES, 2019).

9.2.10 Biological reference points

B_{lim} is set at 110 000 t and B_{pa} at 145 000 t. MSY $B_{trigger}$ is set at B_{pa}.

Further information about biological reference points for sandeel in 1 can be found in the Stock Annex.

9.2.11 Quality of the assessment

The quality of the present assessment has improved compared to the combined assessment for the whole of the North Sea previously presented by ICES before 2010. This is mainly due to the fact that the present division of stock assessment areas better reflects the spatial stock structure and dynamics of sandeel. Addition of fishery independent data from the dredge survey has also improved the quality of the assessment. Together with the application of the statistical assessment model SMS-effort, this has removed the retrospective bias in F and SSB for the most recent years. The model provides rather narrow confidence limits for the model estimates of F, SSB and recruitment, but a poorer fit for the oldest data.

The model uses effort as basis for the calculation of F. The total international effort is derived from Danish CPUE and total international catches. Danish catches are by far the largest in the area, but effort data from the other countries could improve the quality of the assessment.

Abundance of the 1-group, which in most years dominates the catches, is estimated on the basis of the 0-group index from the dredge survey in December of the preceding year. The model estimates a low variance on the survey index for age 0. There are indications of a retrospective pattern in recent years as older fish do not seem to appear in the catches at the expected level. This pattern can be caused by uncertainty in the selection pattern when using a relatively short period to estimate this or unallocated mortality caused by e.g. overwintering mortality increasing when fish condition is low.

9.2.11.1 Status of the stock

The SSB was below B_{lim} in 2019 and 2020. In 2021, it was estimated to be above B_{lim}, but below B_{pa}. SSB in 2022 is similar to 2021. As noted in last year's report (ICES, 2019), the introduction of a very low recruitment in 2018 combined with a continued decrease in mean weight-at-age led to a stock below MSY B_{lim} and $B_{trigger}$ at the beginning of 2020. The SSB in 2022 is slightly lower than expected from the forecast in 2021. There can be several reasons for that, such as reduced weight-at-age and catches exceeding the TAC advice (due to borrowing and banking).

9.2.12 Management Considerations

A management plan needs to be developed. The ICES approach for MSY based management of a short-lived species such as sandeel is the so-called escapement strategy, i.e. to maintain SSB above MSY $B_{trigger}$ after the fishery has taken place. Management strategy evaluations presented at the ICES WKMSYREF2 and WKMSYREF5 meetings (ICES, 2014a, 2017) indicated that the escapement-strategy is not sustainable for short-lived species, unless the strategy is combined with a ceiling (F_{cap}) on the fishing mortality. This means that if the TAC that comes out of the escapement strategy corresponds to an F_{bar} that exceeds F_{cap}, then the escapement strategy should be disqualified and the TAC is instead determined based on a fishing mortality corresponding to F_{cap}. F_{cap} for SA 1r is 0.49 (ICES, 2017).

Based on the misreporting of catches as observed in 2014 and 2015, management measures to avoid area misreporting (only one fishing area per trip) have been mandatory for the Danish fishery since 2015. There are indications of area misreporting for other nations (e.g. Sweden) in 2015 but likely not in the most recent years. Similar management measures as used for the Danish fishery would reduce further the risk of misreporting for other nations as well.

Self-sampling on board the commercial vessels for biological data should be mandatory for all nations utilising a monitoring TAC. Today samples are only obtained from the Danish fishery.

9.3 Sandeel in SA 2r

9.3.1 Catch data

Total catch weight by year for SA 2r is given in tables 9.1.2-9.1.4. Catch numbers-at-age by half-year are given in Table 9.3.1.

The proportion of the 1-group in the catch was high in both 2020 and 2021, although not as high as in 2017 (98%), following the high recruitment in 2016. The 2016 year class was even seen in the 2019 catch as a high proportion of 3-group fish (52%) (Figure 9.3.1).

9.3.2 Weight-at-age

The methods applied to compile age-length-weight keys and mean weights-at-age in the catches and in the stock are described in the Stock Annex.

The mean weights-at-age observed in the catch are given in Table 9.3.2 by half year. It is assumed that the mean weights in the sea are the same as in the catch. The time-series of mean weight in the catch and in the stock is shown in Figure 9.3.2. Mean weight-at-age for all age groups in 2019 was above the historic average, reaching 108% of the long-term average on average. In 2020, a slight decrease in weights was observed for the 1-group compared to 2019, whereas weight at age of older age-groups increased. In 2021, weights had declined across all age-groups compared to 2020.

9.3.3 Maturity

Maturity estimates are obtained from the average observed in the Danish dredge survey in December as described in the Stock Annex. The values used are given in Table 9.3.3.

9.3.4 Natural mortality

Long-term averages of natural mortality-at-age from multispecies modelling of southern and northern sandeel (SMS, WGSAM 2015, ICES 2016) were used. More details are given in the Stock Annex. Natural mortalities are listed in Table 9.3.8. Mortalities were not updated in response to the new WGSAM key run (WGSAM 2020) as the update is not likely to affect long-term averages greatly.

9.3.5 Effort and research vessel data

Trends in overall effort and CPUE

Tables 9.1.5–9.1.7 and Figure 9.3.3 show the trends in the international effort over years measured as number of fishing days standardised to a 200 GRT vessel. The standardisation includes just the effect of vessel size and does not take changes in efficiency into account.

Total international standardized effort in 2021 was the second lowest in the time-series, but also the CPUE was the second lowest, coming down from a relatively high CPUE in 2020.

Tuning series used in the assessments

No commercial tuning series are used in the present assessment.

The dredge survey in SA 2r (Table 9.3.4 and Figure 9.3.5) increased coverage in 2010 and this is therefore used as the start year of the dredge time-series for the assessment. The coverage has however varied somewhat in this period and the time-series is still short. Details about the dredge survey are given in the Stock Annex and the benchmark report (ICES, 2016). Dredge CPUEs were high in 2021, and in particularly high in the Northern parts, resulting in the second highest age-0 index in the time-series. This year a few explorative hauls were taken close to some of the existing stations. However, catch rates in these hauls were not much different from the adjacent fixed station hauls. The explorative hauls were uploaded to the database as valid hauls, and were therefore included in the survey index.

Adjustment to standard settings to accommodate retrospective pattern in recruitment

In previous years, there has been a large overestimation of recruitment in the terminal year in cases where the dredge survey showed large abundance of age 0. In 2020, the working group examined the relationship between dredge survey catches-at-age 0 and the number of recruits as estimated in the SPALY run and considered that the retrospective pattern could be caused by ignoring density dependence in catchability (increased catchability at high abundance). The relationship seemed to be well fitted using a power relationship between dredge index and abundance, with no indication of this given errors in estimated abundance in high or low abundance years. The use of a power model for survey catchability of the youngest age groups is routinely used for North Sea sprat (ICES 2018). It is an adjustment of the model where one additional parameter is estimated. HAWG evaluated the retrospective bias in recruitment in 2020 without density dependent catchability (Mohn's ro = 0.63) and with density dependent catchability (Mohn's ro = 0.52). The AIC of the model including density dependent was unchanged. Based on these considerations, HAWG 2020 decided to include density dependent catchability in the final run. HAWG 2021 re-examined the density dependent parameter and found it still to be significant.

9.3.6 Data analysis

The diagnostics output from SMS-effort are shown in Table 9.3.5.

The CV of the dredge survey (Table 9.3.5) is low (0.30 for the 0-group) after the introduction of the density dependent catchability for age 0, indicating a high consistency between the results from the dredge survey and the overall model results. The residual plot (Figure 9.3.6) shows no bias for this time-series.

The model CV of catch-at-age 1 and 2 is low (0.40) in the first half of the year and medium or high (> 0.70) for the remaining ages and season combinations. The residual plots for catch-at-age (Figure 9.3.7) confirm that the fit is generally poor except for age 1 and 2 in the first half year. The residual plot (Figure 9.3.7) shows no long-term bias for this time-series for ages 1 and 2 in the first half year.

The CV of the fitted stock recruitment relationship (Table 9.3.5) is high (1.02 which is also indicated by the stock recruitment plot (Figure 9.3.8). The high CV of recruitment is probably due to highly variable recruitment success and less due to the quality of the assessment.

Uncertainties of the estimated SSB, F and recruitment (Figure 9.3.10) are in general low, which gives narrow confidence limits on estimated values (Figure 9.3.11).

The plot of standardized fishing effort and estimated F (Figure 9.3.12) shows a good relationship between effort and F as specified by the model. As the model assumes a different efficiency and catchability for the five periods 1983–1988, 1989–1998, 1999–2004, 2005–2009, and 2010–2020, the relation between effort and F varies between these periods. An effort unit in the early part of the time-series gives a smaller F than an effort unit in the most recent years. This indicates technical creep, i.e. a standard 200 GT vessel has become more efficient over time (see Stock Annex for further discussion, ICES 2016).

The retrospective analysis (Figure 9.3.9) shows consistent assessment estimates of F from one year to the next. There has been a systematic overestimation of SSB in most years since 2011 (with few exceptions), some times, but not always, as a result of an overestimation of recruitment (and therefore lower than expected abundance of these cohorts in the subsequent catches). This pattern was improved by the introduction of density dependent catchability in the model. The 5-year Mohn´s Rho values are, however, still fairly high (0.55 and 0.37 for SSB and recruitment, respectively). Reasons for the previous pattern can be connected to either overestimation of recruitment in the dredge survey lower than expected survival of the two cohorts, or lower than expected catchability of these cohorts in the fishery. Both the selectivity pattern and the dredge survey are based on a relatively short time-series, and hence variation between years is to be expected.

9.3.7 Final assessment

The output from the assessment is presented in tables 9.3.6 (fishing mortality-at-age by year), 9.3.7 (fishing mortality-at-age by half year), 9.3.9 (stock numbers-at-age) and 9.3.10 (stock summary).

9.3.8 Historic Stock Trends

The stock summary (Figure 9.3.13 and Table 9.3.10) show that recruitment has been highly variable and with a weak decreasing trend over the full time-series until the 2016 year class, which is estimated to be the 4th strongest on record, followed by a 2017 year class which is estimated to be the lowest observed and a 2018 year class which was the fifth lowest on record. In 2019, the recruitment was average and in 2020 below average. SSB has been at or below B_{lim} in 1989, 2002, from 2004 to 2010 and again from 2012 to 2017 and 2019 to 2022. Since 2004, SSB has been below B_{pa} in all years. F_{1-2} is estimated to have been below the long-time average since 2010 with the exception of 2013, 2017 and 2020.

9.3.9 Short-term forecasts

Input

Input to the short-term forecast is given in Table 9.3.11. Stock numbers for age 1 and older in the TAC year are taken from the assessment. Recruitment in 2022 is the geometric mean of the recruitment in 2011–2020. The exploitation pattern and F_{sq} is taken from the assessment values in 2021. As the SMS-model assumes a fixed exploitation pattern since 2010, the choice of year is not critical. Mean weight-at-age in the catch and in the sea is the average (i.e. 5-year mean) value for the years 2017–2021. Natural mortality and proportion mature are the fixed values applied in the terminal year in the assessment.

Output

The short-term forecast (Table 9.3.12) shows that a fishing mortality of 0.57 will bring SSB down to B_{pa} in 2023. However, since F_{cap} for this area is 0.44, the TAC should instead be based on a fishing mortality of 0.44, which results in a TAC of 71 859 tonnes in 2022.

B_{lim} is set at 56 000 t and B_{pa} at 84 000 t. MSY $B_{trigger}$ is set at B_{pa}. F_{cap} is set at 0.44 (ICES, 2016). Further information about biological reference points can be found in the Stock Annex and Benchmark report from 2016 (WKSAND, 2016).

9.3.10 Quality of the assessment

This stock was benchmarked between the 2016 and 2017 assessments where the ICES statistical rectangles included in sandeel area 2 changed. The assessment now includes fisheries independent information from a dredge survey representative for the area. The assessment is considered to be of good quality but with some indications of a retrospective pattern in recent years as older fish do not seem to appear in the catches at the expected level. This pattern can be caused by uncertainty in the selection pattern when using a relatively short period to estimate this or unallocated mortality caused by e.g. overwintering mortality increasing when fish condition is low (van Deurs *et al.,* 2011.). HAWG also highlighted that the pattern might also have a link to the possible multispecies fishery within this area (i.e. suspected to catch *Ammodytes tobianus*). The dredge survey time-series in SA 2 is still short (2010–2021) and the quality of the assessment will likely improve once a longer time-series becomes available. Next benchmark will take place in 2022.

9.3.11 Status of the Stock

A moderate F in most of the years from 2010 in combination with a low recruitment have given a slow increase in SSB since the historical low values in 2004 to 2010. SSB in 2020 are estimated below B_{lim} for the second year in a row. In 2021 the stock is expected to be just above B_{lim}. The stock has been below B_{lim} in 17 out of the last 20 years and only at or above B_{pa} in 1 out of 20 years (20 years ago)., Recruitment in 2016 is estimated to be the fourth highest on record. The 2019–recruitment was estimated to be the fifth highest since 1997. Recruitment in 2017 and 2018 were extremely low. Recruitment in 2019 was average and recruitment in 2020 was low is medium. The recruitment in 2021 appears to be high. However, based on the retrospective patterns of this stock, we anticipate some down-scaling in the coming years.

9.3.12 Management considerations

A management plan needs to be developed. The ICES approach for MSY based management of a short-lived species such as sandeel is the escapement strategy, i.e. to maintain SSB above MSY $B_{trigger}$ after the fishery has taken place. Management strategy evaluations (ICES, 2016) established that the escapement-strategy is not sustainable for short-lived species, unless the strategy is combined with a ceiling (F_{cap}) on the fishing mortality and estimated this F_{cap} for SA 2r sandeel at 0.44. This means that if the TAC that results from the escapement strategy corresponds to an F_{bar} that exceeds F_{cap}, then the TAC is determined based on a fishing mortality corresponding to F_{cap}.

9.4 Sandeel in SA 3r

9.4.1 Catch data

Total catch weight by year for SA 3 is given in tables 9.1.2–9.1.4. Catch numbers-at-age by half-year is given in Table 9.4.1.

In 2021, the 1-group and 2-group fish dominated the catches, but also a large proportion (second largest in the time-series) of 4-groups was observed. 3-groups were the least frequent.

9.4.2 Weight-at-age

The mean weights-at-age observed in the catch are given in Table 9.4.2 by half year. It is assumed that the mean weights in the sea are the same as in the catch. The time-series of mean weight in the catch and in the stock is shown in Figure 9.4.2. Mean weight-at-age in the first half-year has increased for four consecutive years in all age-groups, and is now the highest ever observed for age-1 and age-2.

9.4.3 Maturity

Maturity estimates are obtained from the average observed in the dredge survey in December as described in the Stock Annex. The values used are given in Table 9.4.3.

9.4.4 Natural mortality

In 2020, WGSAM provided updated estimates of natural mortality-at-age from multispecies modelling of northern sandeel (SMS, WGSAM 2020).

The effect of using 3-year averages of these new values on historical development and stock recruitment relationship of the stock was evaluated by the working group and it was decided that the new natural mortality values resulted in a substantial change in the historic perception of the stock, including possible changes to reference points. For this reason, it was decided not to use the new natural mortalities but to refer to HAWG for consideration of whether new reference points should be estimated.

3-year averages of natural mortality-at-age from the 2015 multispecies modelling of southern and northern sandeel (SMS, WGSAM 2015, ICES 2016) were used. The last value provided was used for all years following the latest data point. More details are given in the stock annex. Natural mortalities are listed in Table 9.4.8.

9.4.5 Effort and research vessel data

Trends in overall effort and CPUE

Tables 9.1.5–9.1.7 and Figure 9.4.3 show the trends in the international effort over years measured as number of fishing days standardised to a 200 GRT vessel. The standardisation includes just the effect of vessel size and does not take changes in efficiency into account. Total international standardized effort peaked in 1998 and declined thereafter and has been less than 2000 days per year since 2003. The last two years, effort has increased, reaching 3492 days in 2020. In 2021, effort is down to the same level as in 2021. CPUE has been increasing for four consecutive years, and in 2021 it was the fourth highest of the time-series.

Tuning series used in the assessments

CPUE data from the dredge survey (Table 9.4.4 and Figure 9.4.5) in 2021 show average indices for both age 0 and age 1 (Table 9.4.4). The internal consistency plot (Figure 9.4.4) shows medium consistency for age 0 vs. age 1 (i.e. $r^2 = 0.38$ on log scales). In 2014, 13 new positions were included in the survey in SA 3r. Only two of the new positions were taken in squares not included before (42F5 and 42F6). All the new positions have been included in the survey index since 2014 (Table 9.4.4) for assessment purposes, to obtain a better spatial coverage. Details about the dredge survey are given in the Stock Annex and the benchmark report (ICES, 2016).

The Norwegian acoustic survey (2009–2021) carried out in Norwegian EEZ is used as tuning series in the assessment in SA 3r (Table 9.4.13 and figures 9.4.14–9.4.16). The survey covers the main sandeel grounds in SA 3r. This year a few explorative hauls were taken close to one of the existing stations. However, catch rates in these hauls were not much different from the adjacent fixed station hauls. The explorative hauls were uploaded to the database as valid hauls, and were therefore included in the survey index. The acoustic estimate in number of individuals by age and survey is presented in Table 9.4.13.

Adjustment to standard settings to accommodate retrospective pattern in recruitment

In previous years, there has been a large overestimation of recruitment in the terminal year in cases where the dredge survey showed large abundance of age 0. The working group examined the relationship between dredge survey catches-at-age 0 and the number of recruits as estimated in the SPALY run (see Figure below, where I is the survey index of age-0 and N0 the number of recruits) and considered that the retrospective pattern could be caused by ignoring density dependence in catchability (increased catchability at high abundance). The relationship seemed to be well fitted using a power relationship between dredge index and abundance, with no indication of this given errors in estimated abundance in high or low abundance years. The use of a power model for survey catchability of the youngest age groups is routinely used for North Sea sprat (ICES 2018). It is an adjustment of the model where one additional parameter is estimated. HAWG evaluated the retrospective bias in recruitment without density dependent catchability (Mohn's rho = 0.57) and with density dependent catchability (Mohn's rho = 0.13). The AIC of the model including density dependent was unchanged. Based on these considerations, HAWG 2020 decided to include density dependent catchability in the final run. This approach was continued in 2021 and 2022.

9.4.6 Data Analysis

The diagnostics output from SMS-effort model is shown in Table 9.4.5.

The CV of the dredge survey (Table 9.4.5) is medium for age 0 (0.69) and high for age 1 (0.79), showing an overall poor consistency between the results from the dredge survey of age 1 and the overall model results. The internal consistency of the survey seems to indicate the large and small year classes can be followed in the dredge, but the exact size of small or large cohorts cannot.

The CV of the acoustic survey (Table 9.4.5) is medium for both age 1 and age 2 (0.60) and high for age 3 (1.08), showing an overall medium consistency between the results from the acoustic survey and the overall model results. The residual plot shows high positive residuals in 2020, indicating that the very high acoustic indices were not confirmed by the model.

The model CV of catch-at-age is medium (0.69) for age 1 and age 2 in the first half of the year (Table 9.4.5). For the older ages and for all ages in the second half year, the CVs are high (> 1.00). The catch residual plots for catch-at-age (Figure 9.4.7) confirm that the fits are generally very poor except for age 1 and 2 in the first half year. There is a tendency for clusters of negative or positive residuals for ages 1 and 2 but no trend in recent years.

The CV of the fitted stock recruitment relationship (Table 9.4.5) is high (1.07), which is also indicated by the stock recruitment plot (Figure 9.4.8). The high CV of recruitment is probably due to the biological characteristics of the stock and less due to the quality of the assessment. The *a priori* weight on likelihood contributions from SSR-R observations is therefore set low (0.01 in "objective function weight" in Table 9.4.5) such that SSB-R estimates do not contribute much to the overall model likelihood and fit.

There used to be a large retrospective pattern in the recruitment that consistently overestimated large recruiting year-classes. However, after implementing density dependence on the relationship between recruitment and the dredge survey in 2020 (i.e. increasing catchability with increasing densities), the retrospective bias was reduced from a Mohn´s Rho > 0.5 to -0.10 in the present year´s assessment.

Uncertainties of the estimated SSB, F and recruitment (Figure 9.4.10) are in general medium, which gives wide confidence limits (Figure 9.4.11) on output variables.

The plot of standardized fishing effort and estimated F (Figure 9.4.12) shows a moderate relation between effort and F as assumed by the model specification. As the model assumes a different catchability-at-age for the three periods 1986–1998, 1999–present, the relation between effort and F varies between these periods. There is a shift in the ratio between effort and F over the full time-series. In the year range 1986–1998, F is in generally lower than effort on the plot, while the opposite is the case for the remaining periods, corresponding to a technical creep over time (ICES, 2016).

9.4.7 Final assessment

The output from the final assessment is presented in Tables 9.4.6 (fishing mortality-at-age), 9.4.7 (fishing mortality-at-age by half year), 9.4.9 (stock numbers-at-age) and 9.4.10 (Stock summary).

9.4.8 Historic Stock Trends

SSB has been at or below B_{lim} from 1999 to 2006 after which SSB increased to above B_{pa} in 2008. This was followed by SSB below B_{lim} in 2013 (Figure 9.4.16 and Table 9.4.17). Above average recruitments in 2016, 2018, 2019 and 2020 together with a fishing mortality below average in most years and increased weights have resulted in SSB being above B_{pa} in 2015 onwards.

9.4.9 Short-term forecasts

Input

Input to the short-term forecast is given in Table 9.4.11. Stock numbers in the TAC year are taken from the assessment for age 1 and older. Recruitment in 2022 is the geometric mean of the recruitment 1986–2020 (112 billion-at-age 0). The exploitation pattern and F_{sq} is taken from the assessment values in 2020. As the SMS-model assumes a fixed exploitation pattern since 1999, the choice of year is not critical. Mean weight-at-age in the catch and in the sea is the average value (i.e. 5-year mean) for the years 2017–2021. Proportion mature and natural mortality are equal to the terminal assessment year.

The Stock Annex gives more details about the forecast methodology.

Output

The short-term forecast (Table 9.4.12) shows that a TAC of 85 559 t in 2021 will result in a fishing mortality of 0.29, identical to F_{cap}, and leave SSB at 151 563 t, well above MSY $B_{trigger}$ of 129 000 t, in 2021. The TAC according to the escapement strategy is therefore 151 563 t in 2021.

9.4.10 Biological reference points

B_{lim} is set at 80 000 t and B_{pa} is estimated to 129 000 t. MSY $B_{trigger}$ is set at B_{pa}. Further information about biological reference points can be found in the Stock Annex and in the benchmark report from 2016 (WKSAND, 2016).

9.4.11 Quality of the assessment

This stock was benchmarked between the 2016 and 2017 assessment. The new sandeel area 3r is slightly different from the previous sandeel area 3, and mainly consists of fishing grounds in Norwegian EEZ. There is a large retrospective pattern in the recruitment that overestimates high recruitments. This pattern may be caused by a variety of issues in the assessment, most likely of which are the shift in 2011 from using Danish to using Norwegian effort data and the change in the spatial coverage of the dredge survey. Even though the new assessment for SA 3r sandeel is considered uncertain, it is considered adequate as the basis for TAC advice.

9.4.12 Status of the Stock

The SSB has increased from below B_{lim} in 2013 to above B_{pa} since 2015, due to above average recruitment in 2013, 2014, 2016, 2018 to 2020 combined with a low fishing mortality. However, fishing mortality has increased since 2016, peaking in 2020. SSB decreased considerably between 2021 and 2022, due to high fishing mortality and decreasing recruitment (but SSB is still well above B_{pa}). Recruitment estimates for 2018–2020 were all above average, but declining since 2019. Recruitment in 2021 was estimated to be below average.

9.4.13 Management Considerations

Since 2011 the Norwegian sandeel fishery in the current SA3r has been managed according to an area-based management plan for the Norwegian EEZ and an advice provided by the IMR in Bergen.

9.5 Sandeel in SA 4

9.5.1 Catch data

Catch numbers-at-age by half-year from area SA 4 is given in Table 9.5.1. Total catch weight by year for SA 4 is given in tables 9.5.2–9.5.4. In 2021, catch numbers were dominated by ages of 1- and 2-groups, whereas older age-groups were not common. This was also the case in 2016 (Figure 9.5.1).

9.5.2 Weight-at-age

The methods applied to compile age-length-weight keys and mean weights-at-age in the catches and in the stock are described in the Stock Annex. The mean weights-at-age observed in the catch are given in Table 9.5.2 and Figure 9.5.2 by half year. Mean weight-at-age in the first half year seems to have recovered to above average and currently stable for all ages after the very low levels in 2001 to 2005. The second half year the mean weights are affected by the very limited sampling at this time of year.

9.5.3 Maturity

Maturity estimates are obtained from the averages observed in the dredge survey (1983–2016) in December as described in the Stock Annex. Maturities are listed in Table 9.5.3.

9.5.4 Natural mortality

Long-term averages of natural mortality-at-age from multispecies modelling of northern sandeel (SMS, WGSAM 2015, ICES 2016) were used. More details are given in the stock annex. Natural mortalities are listed in Table 9.5.8. Mortalities were not updated in response to the new WGSAM key run (WGSAM, 2020) as the update is not likely to affect long-term averages greatly.

9.5.5 Effort and research vessel data

Trends in overall effort and CPUE

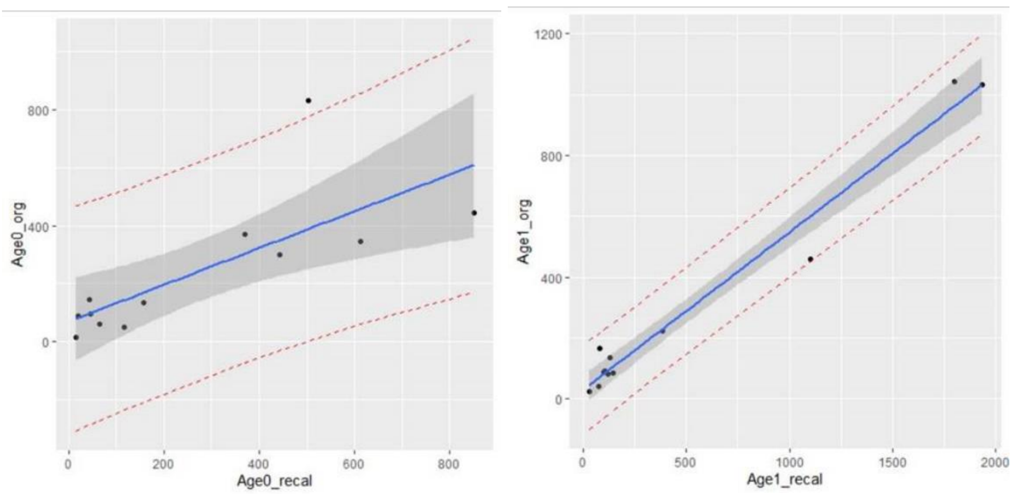
Table 9.5.5–9.5.7 and Figure 9.5.3 show the trends in the international effort over years measured as number of fishing days standardized to a 200 GRT vessel. The standardization includes just the effect of vessel size and does not take changes in efficiency into account. Total international standardized effort peaked in 1994, after which substantial effort reduction has taken place. The effort in 2021 were the third highest in the time-series reflecting the high TAC given. This is in contrast to the most recent decades since 2004 with the effort reflects either a closed or very limited fishery, where only 2018 showed any evident effort that lower than average.

Tuning series used in the assessments

No commercial tuning series are used in the present assessment. CPUE data from the dredge survey (Table 9.5.4 and Figure 9.5.5) show that 2021 around average, whereas for consecutive two years prior (2019 and 2020) strong year-classes have entered.

The ability of the area 4 dredge survey to provide accurate estimates of abundance by age was discussed in detail. All of the values are estimated as stratified mean values (mean within position followed by mean within square followed by mean across squares), an approach which is known to be sensitive to skewed data at low sampling levels. Up to 2018, indices of cohorts at age 1 averaged at 1.22 times the catch of the index of the cohort at age 0 (range 0.6-2.35). The corresponding number from age 1 to 2 was 0.46 (range 0.09-1.58). In 2019, the index of 1-year olds (2018 cohort) was 5.75 times the index of the cohort at age 0. This pattern persisted in 2020 where the index of 1-year olds (2019 cohort) was 5.10 times the index of the cohort at age 0. The 2020 index of the 2018 cohort was 1.87 times the 2019 index of the cohort. In all cases, these values represent all time high appearance relative to earlier estimates of the cohort. In the 2021 survey index, the 2019 and the 2020 cohorts were registered as 0.24 and 0.03 times the values observed in 2020. Both of these values are the lowest relative changes observed in the time series. This led to the question of whether the 2020 should be considered a year where the survey for unknown reasons had much higher than usual catchability or the 2020 survey was accurate but a large mortality even had eliminated the sandeel. As the decline was observed in both the fished and closed area, it was considered most likely that the large mortality was caused by factors other than fishing. A possible reason mentioned was harmful algal blooms. A first look at the sandeel dredge data at the station level indicated that internal consistency (abundance of age 0 at t and abundance of age 1 at t+1) was normal between 2019 (age 0) and 2020 (age 1) and followed the general relationship observed at station level between 2008 and 2021. However, between 2020 (age 0) and 2021 (age 1) the relationship showed a clear lack of age 1 fish in 2021. This suggests that catchability was not the issue as values consistent with the time-series were observed for the 2019 cohort and that the issue with the recent indices are likely related to the stratified mean approach in years with reduced sampling at the most productive stations. In addition, the lack of age 1 fish of the 2020 cohort in 2021, also apparent from the station level analysis, is consistent with a large mortality event. In the 2021 assessment, the 2020 index was downscaled to account for changes in sampling distribution as the 2020 index was considered to be likely to be too high due to differences in sampling distribution in this year. The group decided to keep the revised values from 2020 but to run an exploratory assessment excluding this survey year to investigate the impact that the 2020 survey index had on the 2022 assessment.

The internal consistency, i.e. the ability of the survey to follow cohorts, (Figure 9.5.4) shows a high correlation between the 0-group and 1-group explaining 54% of the variation.



Relationship between index estimated for all stations (vertical axis) and index estimated for the 11 stations sampled in 2020 (horizontal axis).

9.5.6 Data analysis

Following the Benchmark assessment (ICES, 2016) the SMS-effort model was used to estimate fishing mortalities and stock numbers-at-age by half year, using data from 1993 to 2021. In the SMS model, it is assumed that fishing mortality is proportional to fishing effort. For details about the SMS model and model settings, see the Stock Annex.

The diagnostics output from SMS are shown in Table 9.5.5. The CV of the dredge survey ("sqrt (Survey variance) ~CV" in the table) is low to moderate (<0.60) for all ages. However, the CV have increased for age 0 from 0.3 to 0.55 from the 2021 to the 2022 assessment. The survey residuals in 2020 are large and positive for both ages, indicating that the large observed indices in 2020 are not supported by other information about the abundance of these cohorts.

The model CV of catch-at-age ("sqrt(catch variance) ~CV", in Table 9.5.5 is moderate (0.74) for age 1 and 2. The catch-at-age residuals (Figure 9.5.6) show no alarming patterns, except for a tendency to positive residuals (observed catch is higher than model catch) for age 1 in the beginning of the time-series.

The CV of the fitted Stock recruitment relationship (Table 9.5.5) is high (1.50), which is also indicated by the stock recruitment plot (Figure 9.5.7). The high CV of recruitment is probably due to biological characteristic of the stock and not so much due to the quality of the assessment. The *a priori* weight on likelihood contributions from SSR-R observations is therefore set low (0.05 in "objective function weight" in Table 9.5.5) such that SSB-R estimates do not contribute much to the overall likelihood and model fit.

The retrospective analysis (Figure 9.5.9) shows very consistent assessment results from one year to the next with the exception of the 2020 peel. The high recruitment in the 2019 and 2020 cohort expected from the 2020 survey was downscaled after adding the 2021 survey, leading to a very high retrospective bias in both recruitment and SSB in 2019 and 2020.

As a result of the indications that the 2020 survey may have had an abnormally high catchability, an explorative assessment was conducted removing the 2020 survey index. The results showed an assessment where the 0-group CV of the dredge survey returned to previous levels:

Assessment	CV 0-group in the survey	CV 1-group in the survey	Recruitment 2020 (10^9)	Recruitment 2021 (10^9)	SSB 2022 (10^3 t)
2020	0.30	0.40			
2021	0.30	0.37	303		
2022 all data	0.55	0.30	62.4	46.5	72.8
2022 without 2020 survey	0.30	0.42	36.3	63.5	53.5

The impact on the latest two recruitments and terminal year SSB were substantial (-40 to +37%). Having considered these changes, the group decided that the survey index should be investigated in detail at the upcoming benchmark but that excluding individual years in the survey time series in an update assessment should be avoided. Therefore, the final assessment presented below includes all survey data.

Uncertainties of the estimated SSB, F and recruitment (Figure 9.5.9) are moderate to high.

9.5.7 Final assessment

The output from the assessment is presented in tables 9.5.6 (fishing mortality-at-age by year), 9.5.7 (fishing mortality-at-age by half year), 9.5.9 (stock numbers-at-age) and 9.5.10 (stock summary).

9.5.8 Historic Stock Trends

The stock summary (Figure 9.5.13 and Table 9.5.10) shows that SSB have been at or below B_{lim} from 2007 to 2010. Since 2010, SSB has been above B_{lim} in 2011, 2016 and 2021, but below B_{pa} in 2015 only. SSB is estimated at 72 766 in 2022. $F_{(1–2)}$ is estimated to have been very low since 2005 increasing in 2018 to the highest since 2004 with a decrease in 2019 and 2020, to a record-high (second) F in 2021. Recruitment has been high in 2014, 2016, 2017 and 2019. The high F in 2021 was the result of the lack of confirmation in the 2021 survey of the high survey indices in 2020. The biomass did however not decline below B_{lim}.

9.5.9 Short-term forecasts

Input

Input to the short-term forecast is given in Table 9.5.11. Stock numbers in the TAC year are taken from the assessment for age 1 and older. Recruitment in 2022 is the geometric mean of the recruitment 2011–2020 (55 billion-at-age 0). The exploitation pattern and F_{sq} is taken from the assessment values in 2021. However, as the SMS-model assumes a fixed exploitation pattern, the choice of years is not critical. Mean weight-at-age in the catch and in the sea is the average value (i.e. 5-year mean) for the years 2017–2021. Natural mortality and maturity are as applied in the assessment in final year. The Stock Annex gives more details about the forecast methodology.

Output

The short-term forecast (Table 9.3.12) shows that a SSB will be below the MSY $B_{trigger}$ of 102 000 t and above B_{lim} of 48.000 t in 2022. Although, even a fishing mortality of zero will bring SSB below Bpa. The TAC is therefore 0 t in 2022. However, a monitoring TAC of 5000 t is recommended to ensure the quality of the assessment, consistent with previous year's advice (ICES, 2019).

9.5.10 Biological reference points

B_{lim} is set at 48 000 t and B_{pa} at 102 000 t. MSY $B_{trigger}$ is set at B_{pa}.

Further information about biological reference points for sandeel in SA 4 can be found in the Stock Annex.

9.5.10.1 Quality of the assessment

The analytical assessment of SA 4 was initiated in 2017 following the 2016 benchmark of the stock.

Abundance of the 1-group, which in most years dominates the catches in most years, is estimated on the basis of the 0-group index from the dredge survey in December of the preceding year. The model estimates a low variance on the survey index for age 0 but the CV on SSB in 2022 is high (0.40).

9.5.10.2 Status of the Stock

Recruitment in 2014, 2016, 2017, 2019, 2020 and 2021 are all above the long-term average, while 2018 is lower. A very restrictive F since 2005 together with the return of recruitment to historic levels has resulted in SSB above B_{pa} in 2016 to 2019 and in 2021. It is between B_{lim} and B_{pa} in 2020 and 2022.

9.5.10.3 Management considerations

A management plan needs to be developed. The ICES approach for MSY based management of a short-lived species such as sandeel is the escapement strategy, i.e. to maintain SSB above MSY $B_{trigger}$ after the fishery has taken place. Management strategy evaluations presented at the ICES WKMSYREF2 and WKMSYREF5 meeting (ICES, 2014a, 2017) indicated that the escapement-strategy is not sustainable for short-lived species, unless the strategy is combined with a ceiling (F_{cap}) on the fishing mortality. This means that if the TAC that comes out of the Escapement-strategy corresponds to an F_{bar} that exceeds F_{cap}, then the Escapement-strategy should be disqualified and the TAC is instead determined based on a fishing mortality corresponding to F_{cap}. F_{cap} for SA 4 (in accordance with the concepts of a conventional management strategy evaluation and a selection criterion of 0.05 probability of SSB < B_{lim}) is set at 0.15 (ICES, 2016).

However, it is important to acknowledge that the assessment model does not consider that a significant part of SA 4 (East coast of Scotland, sand banks covered by the dredge survey) is closed to fishing. Accordingly, the estimated TAC would in practice be achieved in a much smaller region than the whole SA 4 which raises concerns of local depletion. Therefore, such a high TAC may not be sustainable and future work should consider how to incorporate the spatial management in place in future advice.

9.6 Sandeel in SA 5r

9.6.1 Catch data

Total catch weight by year for SA 5 is given in tables 9.1.2–9.1.4. No catches from this area have been taken since 2004. Acoustic surveys have been carried out since 2005 on Vikingbanken, which is the main sandeel ground in SA 5. The survey estimates show that the biomass of sandeel on Vikingbanken still is very low (Table 9.6.1)

9.7 Sandeel in SA 6

9.7.1 Catch data

Total catch weight by year for SA 6 is given in tables 9.1.2–9.1.4.

9.8 Sandeel in SA 7

9.8.1 Catch data

Total catch weight by year for SA 7 is given in tables 9.1.2–9.1.4 No catches from this area have been taken since 2003.

9.9 Sandeel in ICES Division 6.a

9.9.1 Catch data

Total catch weight by year for sandeel in ICES Division 6.a is given in Table 9.9.1 Catches from this area have been zero or very low since 2005.

9.10 References

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van Deurs, M., Hartvig, M., & Steffensen, J. F. (2011). Critical threshold size for overwintering sandeels (*Ammodytes marinus*). Marine biology, 158(12), 2755-2764.

Table 9.1.1 Sandeel. Official catches ('000 t), 1952–2021 for area 27.4 and 27.3.a. Note that catches from 27.3.a are only available from 1973–2021.

Year	Area	Denmark	Germany	Faroes	Ireland	Netherlands	Norway	Sweden	UK	Lithuania	France	Total
1952	27.4	1.6	-	-	-	-	-	-	-	-	-	1.6
1953	27.4	4.5	-	-	-	-	-	-	-	-	-	4.5
1954	27.4	10.8	-	-	-	-	-	-	-	-	-	10.8
1955	27.4	37.6	-	-	-	-	-	-	-	-	-	37.6
1956	27.4	81.9	5.3	-	-	-	1.5	-	-	-	-	88.7
1957	27.4	73.3	25.5	-	-	3.7	3.2	-	-	-	-	105.7
1958	27.4	74.4	20.2	-	-	1.5	4.8	-	-	-	-	100.9
1959	27.4	77.1	17.4	-	-	5.1	8	-	-	-	-	107.6
1960	27.4	100.8	7.7	-	-	-	12.1	-	-	-	-	120.6
1961	27.4	73.6	4.5	-	-	-	5.1	-	-	-	-	83.2
1962	27.4	97.4	1.4	-	-	-	10.5	-	-	-	-	109.3
1963	27.4	134.4	16.4	-	-	-	11.5	-	-	-	-	162.3
1964	27.4	104.7	12.9	-	-	-	10.4	-	-	-	-	128.0
1965	27.4	123.6	2.1	-	-	-	4.9	-	-	-	-	130.6
1966	27.4	138.5	4.4	-	-	-	0.2	-	-	-	-	143.1
1967	27.4	187.4	0.3	-	-	-	1	-	-	-	-	188.7
1968	27.4	193.6	-	-	-	-	0.1	-	-	-	-	193.7
1969	27.4	112.8	-	-	-	-	-	-	0.5	-	-	113.3
1970	27.4	187.8	-	-	-	-	-	-	3.6	-	-	191.4
1971	27.4	371.6	0.1	-	-	-	2.1	-	8.3	-	-	382.1
1972	27.4	329.0	-	-	-	-	18.6	8.8	2.1	-	-	358.5
1973	27.3.a + 27.4	282.9	-	1.4	-	-	17.2	1.1	4.2	-	-	306.8
1974	27.3.a + 27.4	432.0	-	6.4	-	-	78.6	0.2	15.5	-	-	532.7

Year	Area	Denmark	Germany	Faroes	Ireland	Netherlands	Norway	Sweden	UK	Lithuania	France	Total
1975	27.3.a + 27.4	372.0	-	4.9	-	-	54	0.179	13.6	-	-	444.7
1976	27.3.a + 27.4	446.1	-	-	-	-	44.2	0.067	18.7	-	-	509.1
1977	27.3.a + 27.4	680.4	-	11.4	-	-	78.7	6.132	25.5	-	-	802.1
1978	27.3.a + 27.4	669.2	-	12.102	-	-	93.5	2.321	32.5	-	-	809.7
1979	27.3.a + 27.4	483.1	-	13.2	-	-	101.4	0.003	13.4	-	-	611.1
1980	27.3.a + 27.4	581.6	-	7.2	-	-	144.8	0.009	34.3	-	-	767.9
1981	27.3.a + 27.4	523.8	-	4.9	-	-	52.6	0.044	46.7	-	-	628.1
1982	27.3.a + 27.4	528.4	-	4.9	-	-	46.5	0.405	52.2	-	-	632.4
1983	27.3.a + 27.4	515.2	-	2	-	-	12.378	0.23	37	-	-	566.8
1984	27.3.a + 27.4	618.9	-	11.3	-	-	28.3	-	32.6	-	-	691.1
1985	27.3.a + 27.4	601.7	-	3.9	-	-	13.1	-	17.2	-	-	635.9
1986	27.3.a + 27.4	832.7	-	1.2	-	-	82.1	0.002	12	-	-	928.0
1987	27.3.a + 27.4	609.2	-	18.6	-	-	193.4	-	7.2	-	-	828.4
1988	27.3.a + 27.4	708.8	-	15.5	-	-	185.265	-	5.8	-	-	915.3
1989	27.3.a + 27.4	841.6	-	16.6	-	-	186.84	-	11.5	-	-	1056.3
1990	27.3.a + 27.4	512.1	-	2.2	-	0.3	88.999	-	3.9	-	-	607.5
1991	27.3.a + 27.4	726.5	-	11.2	-	-	128.8	-	1.2	-	-	867.7
1992	27.3.a + 27.4	803.7	-	9.1	-	-	89.349	0.588	4.9	-	-	907.6
1993	27.3.a + 27.4	533.4	-	0.344	-	-	95.5	-	1.5	-	-	630.8
1994	27.3.a + 27.4	688.6	-	10.3	-	-	165.8	0.02	5.9	-	-	870.7
1995	27.3.a + 27.4	672.6	-	-	-	-	263.4	0.04	6.7	-	-	942.8
1996	27.3.a + 27.4	649.5	-	5	-	-	160.7	-	9.7	-	-	824.8
1997	27.3.a + 27.4	831.8	-	11.2	-	-	350.209	0.001	24.6	-	-	1217.8
1998	27.3.a + 27.4	628.2	-	11	-	-	343.3	8.565	23.8	-	-	1014.8
1999	27.3.a + 27.4	511.3	-	13.2	0.4	-	187.6	23.21	11.5	-	-	747.1

Year	Area	Denmark	Germany	Faroes	Ireland	Netherlands	Norway	Sweden	UK	Lithuania	France	Total
2000	27.3.a + 27.4	557.3	-	-	-	-	119	28.643	10.8	-	-	715.7
2001	27.3.a + 27.4	650.0	-	-	-	-	183	49.979	1.3	-	-	884.3
2002	27.3.a + 27.4	659.5	-	0.025	-	-	176	19.211	4.9	-	-	859.6
2003	27.3.a + 27.4	282.8	-	-	-	-	29.6	21.822	0.5	-	-	334.7
2004	27.3.a + 27.4	288.8	2.7	-	-	-	48.5	33.331	-	-	-	373.3
2005	27.3.a + 27.4	158.9	-	-	-	-	17.3	0.472	-	-	-	176.6
2006	27.3.a + 27.4	255.4	3.2	-	-	-	5.6	27.858	-	-	-	292.8
2007	27.3.a + 27.4	166.9	1	2	-	-	51.1	7.875	1	-	-	229.9
2008	27.3.a + 27.4	246.9	4.4	2.4	-	-	81.6	12.51	-	-	-	347.8
2009	27.3.a + 27.4	293.0	12.2	2.5	-	1.8	27.4	12.4	3.6	-	-	352.9
2010	27.3.a + 27.4	285.9	13	-	-	-	78	32.72	4	0.6	-	414.2
2011	27.3.a + 27.4	278.5	9.8	-	-	-	109	32.717	6.1	1.65	-	437.8
2012	27.3.a + 27.4	51.8	1.70844	-	-	0.317	42.4804	5.652	-	-	0.00328	101.9
2013	27.3.a + 27.4	208.7	7.89833	-	-	0.387	30.44615	26.811	2.436	1.32035	0.00387	278.0
2014	27.3.a + 27.4	156.5	5.05196	-	-	-	82.49885	18.815	0.03	0.82463	0.00262	263.8
2015	27.3.a + 27.4	166.5	9.09745	-	-	-	100.85862	33.43879	2.00003	-	4e-05	311.9
2016	27.3.a + 27.4	28.4	-	-	-	-	40.86736	4.2595	-	-	-	73.5
2017	27.3.a + 27.4	353.9	5.7985	-	-	-	120.20534	42.33624	3.32389	-	-	525.5
2018	27.3.a + 27.4	175.6	5.937	-	-	-	69.53076	16.655512	1.848779	-	-	269.6
2019	27.3.a + 27.4	93.7	3.95	-	-	1.2e-05	124.7855	11.54334	1.05792	-	-	235.1
2020	27.3.a + 27.4	169.2	3.81522	-	-	-	244.37908	25.5189974	3.89595	-	2e-05	446.8
2021	27.3.a + 27.4	69.9	1.8223	-	-	-	146.442119	14.977623	-	-	-	233.2

Table 9.1.2 Sandeel. Total catch (tonnes) by area as estimated by ICES.

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
1983	382629	156208	24828	2782	0	364	0	566810
1984	498671	133398	49111	2563	5821	791	744	691098
1985	460057	111889	20859	38122	3004	1927	0	635858
1986	382844	225581	282334	12718	628	13219	10650	927973
1987	373021	49067	395298	8154	1713	1163	0	828417
1988	422805	151543	336919	1338	0	2726	0	915330
1989	446129	227292	374252	4384	2903	909	450	1056318
1990	306302	133796	163224	3314	374	499	0	607508
1991	332204	215565	274839	41372	1168	17	2529	867694
1992	558602	184241	87022	68905	1099	4277	3455	907600
1993	144389	147964	200123	133136	586	4490	80	630768
1994	193241	244944	267281	158690	2757	3748	4	870666
1995	400759	122155	213168	52591	152274	1830	0	942776
1996	291709	186460	159304	158490	27570	1263	1	824796
1997	426414	242680	474093	58446	10772	2372	3061	1217839
1998	372604	99305	474843	58911	3010	941	5228	1014841
1999	425478	70085	193621	53338	145	0	4415	747083
2000	374724	101952	196525	37792	303	0	4371	715667
2001	540248	97210	196209	47918	1678	26	971	884260
2002	610161	120520	115207	12762	8	493	453	859604
2003	178642	56248	35365	64049	44	111	260	334718
2004	215352	116837	33658	6882	0	573	0	373302
2005	126261	34569	13994	1557	0	259	0	176640
2006	247510	37952	7094	86	0	161	0	292802
2007	110395	44069	75376	11	4	0	0	229855
2008	236069	35655	74943	1168	0	0	0	347836
2009	309712	37049	6161	0	0	0	0	352922
2010	300896	52470	60542	275	0	0	0	414183
2011	320241	24310	92450	270	0	489	0	437761
2012	45954	12672	40141	2618	0	214	0	101599
2013	214787	48172	9838	5119	0	72	0	277989
2014	99059	64707	95426	4505	0	65	0	263762
2015	162861	39492	104607	4736	0	198	0	311894
2016	15407	9569	44074	6232	0	123	0	75405
2017	242069	141314	115642	18474	0	0	0	517499
2018	131898	20240	75143	42298	0	0	0	269579

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
2019	86723	5151	136901	6666	0	96	0	235537
2020	108944	70198	247411	20116	0	97	0	446765
2021	16944	4980	157752	53370	0	133	0	233178
arith. mean	284941	99423	151938	30619	5535	1119	940	574516

Table 9.1.3 Sandeel. Total catch (tonnes) by area, first half year as estimated by ICES.

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
1983	314744	92566	21008	2782	0	364	0	431465
1984	419640	86141	43578	2563	5821	735	744	559223
1985	377702	76422	17131	37900	3004	973	0	513132
1986	346053	181733	138020	12539	108	12020	7832	698305
1987	307194	36400	394339	7833	1713	1091	0	748570
1988	395186	107289	288174	1257	0	2114	0	794020
1989	435721	173510	371557	4382	1587	897	450	988104
1990	285321	101899	105554	2926	0	485	0	496185
1991	257591	153869	215770	17140	1168	17	2529	648083
1992	521575	135823	83068	67068	1099	4270	3455	816357
1993	129403	86179	155984	123143	250	4393	3	499354
1994	177685	184792	242027	147019	2754	3222	4	757503
1995	365681	70518	203151	52497	152269	1829	0	845945
1996	257507	63193	110862	48496	14551	1168	0	495777
1997	345199	178735	394181	47668	8615	2194	2448	979040
1998	352275	70075	354639	57373	2907	939	4565	842773
1999	395813	27461	94655	51183	145	0	2152	571409
2000	333044	82405	192474	37792	288	0	3808	649812
2001	368782	49319	59951	47492	1678	26	735	527983
2002	604584	105397	114646	12762	8	493	101	837991
2003	155006	25111	22803	62580	44	111	187	265841
2004	199483	91405	21632	6860	0	571	0	319951
2005	121795	24841	13982	1557	0	259	0	162434
2006	241345	23497	6959	55	0	160	0	272015
2007	110389	44069	75376	11	4	0	0	229849
2008	232249	32602	74943	1168	0	0	0	340963
2009	293529	25399	6024	0	0	0	0	324952
2010	293359	44910	60251	275	0	0	0	398796
2011	316351	24045	92450	270	0	489	0	433605
2012	45946	11520	40141	2618	0	213	0	100438
2013	207886	43818	9838	5119	0	72	0	266733
2014	94278	62110	95426	4505	0	65	0	256383
2015	162860	38723	104607	4736	0	197	0	311123

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
2016	15407	9519	44074	6232	0	123	0	75354
2017	239742	130640	115642	18474	0	0	0	504498
2018	125303	19957	74567	42298	0	0	0	262126
2019	71590	5148	136896	6666	0	96	0	220396
2020	107762	69894	247411	19896	0	97	0	445060
2021	16481	4978	157627	51075	0	133	0	230293
arith. mean	257473	71690	128242	26057	5077	1021	744	490304

Table 9.1.4 Sandeel. Total catch (tonnes) by area, second half year as estimated by ICES.

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
1983	67885	63641	3820	0	0	0	0	135345
1984	79031	47257	5532	0	0	55	0	131875
1985	82355	35468	3728	222	0	953	0	122726
1986	36791	43848	144314	179	519	1199	2818	229668
1987	65828	12667	959	321	0	72	0	79847
1988	27619	44254	48744	81	0	612	0	121310
1989	10407	53782	2694	2	1316	12	0	68214
1990	20981	31896	57670	388	374	14	0	111323
1991	74613	61697	59069	24232	0	0	0	219611
1992	37027	48418	3954	1837	0	6	0	91243
1993	14986	61785	44138	9993	336	97	78	131414
1994	15557	60152	25254	11671	3	526	0	113163
1995	35078	51637	10017	94	5	1	0	96831
1996	34202	123267	48441	109994	13020	95	1	329019
1997	81215	63945	79912	10779	2157	179	613	238799
1998	20329	29230	120203	1538	103	1	663	172068
1999	29666	42624	98967	2155	0	0	2263	175674
2000	41680	19547	4051	0	15	0	562	65855
2001	171466	47891	136258	426	0	0	236	356277
2002	5577	15123	561	0	0	0	352	21613
2003	23636	31137	12562	1469	0	0	73	68877
2004	15869	25432	12026	22	0	2	0	53351
2005	4466	9728	11	0	0	0	0	14206
2006	6165	14455	136	30	0	0	0	20787
2007	6	0	0	0	0	0	0	6
2008	3821	3053	0	0	0	0	0	6873
2009	16183	11650	137	0	0	0	0	27970
2010	7537	7560	291	0	0	0	0	15387
2011	3891	265	0	0	0	0	0	4156
2012	8	1153	0	0	0	0	0	1161

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
2013	6902	4354	0	0	0	0	0	11256
2014	4781	2598	0	0	0	0	0	7379
2015	1	769	0	0	0	0	0	771
2016	0	50	0	0	0	0	0	51
2017	2327	10673	0	0	0	0	0	13000
2018	6595	283	576	0	0	0	0	7453
2019	15133	3	5	0	0	0	0	15141
2020	1182	304	0	220	0	0	0	1705
2021	463	3	125	2295	0	0	0	2885
arith. mean	27468	27733	23696	4563	458	98	196	84213

Table 9.1.5 Sandeel. Effort (days fishing for a standard 200 GT vessel) by area, as estimated by ICES.

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
1983	8992	4719	864	63	0	9	0	14649
1984	10166	4009	1378	48	212	50	37	15901
1985	10876	3570	619	655	139	65	0	15923
1986	7372	5038	4641	284	12	469	145	17962
1987	5680	1153	5094	177	64	45	0	12213
1988	7980	3876	7472	42	0	90	0	19460
1989	8553	6552	7677	57	31	44	0	22914
1990	8529	4209	5143	55	0	24	0	17960
1991	5991	5117	5864	338	19	1	0	17330
1992	8805	4944	2383	571	0	197	0	16900
1993	3893	4396	5124	1387	29	265	0	15093
1994	3149	4230	4854	1588	0	114	0	13934
1995	5899	2497	3791	437	1915	50	0	14589
1996	5497	4608	4352	1464	605	48	0	16573
1997	5366	5308	7749	622	0	60	6	19111
1998	6580	2743	11062	611	96	26	0	21118
1999	8900	1975	6179	850	0	0	0	17904
2000	7141	2597	4117	421	5	0	149	14429
2001	11021	2505	4726	669	0	1	0	18921
2002	8162	3162	2491	140	1	13	0	13968
2003	6805	2351	1634	1098	19	6	0	11913
2004	7057	4208	1264	203	0	27	0	12758
2005	3412	1131	468	88	0	10	0	5109
2006	4160	1235	205	1	0	5	0	5606
2007	1560	874	1214	1	0	0	0	3650
2008	2878	906	1344	7	0	0	0	5136
2009	3551	802	111	0	0	0	0	4464

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
2010	2859	1136	1446	4	0	0	0	5444
2011	3195	677	924	7	0	18	0	4821
2012	585	472	561	68	0	13	0	1699
2013	3876	1799	273	37	0	8	0	5992
2014	2270	1416	1072	51	0	4	0	4812
2015	2073	1233	1412	43	0	5	0	4767
2016	146	429	561	79	0	6	0	1220
2017	2711	2082	1198	166	0	0	0	6157
2018	3126	563	1437	524	0	0	0	5651
2019	2823	136	1957	203	0	3	0	5121
2020	2696	1384	3392	165	0	5	0	7642
2021	418	336	2049	1378	0	4	0	4185
arith. mean	5250	2574	3028	374	81	43	9	11359

Table 9.1.6 Sandeel. Effort (days fishing for a standard 200 GT vessel) by area, first half year as estimated by ICES.

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
1983	6926	3032	739	63	0	9	0	10770
1984	7910	2471	1172	48	212	46	37	11896
1985	8449	2564	508	652	139	29	0	12341
1986	6568	3884	2508	281	4	437	81	13763
1987	4287	779	5063	161	64	42	0	10395
1988	7172	2660	6030	40	0	69	0	15970
1989	8240	4852	7586	56	31	42	0	20808
1990	8008	3380	3738	49	0	24	0	15201
1991	4588	3538	4750	111	19	1	0	13008
1992	7926	3793	2290	309	0	197	0	14514
1993	3496	2597	3950	1200	29	256	0	11527
1994	2852	3097	4411	1410	0	98	0	11867
1995	5298	1527	3589	436	1915	50	0	12815
1996	4805	1627	3147	519	441	48	0	10587
1997	3997	3440	5895	490	0	52	0	13874
1998	6011	1707	7059	576	93	26	0	15473
1999	7875	772	3204	850	0	0	0	12702
2000	6181	1991	4040	421	5	0	149	12786
2001	8041	1362	1681	656	0	1	0	11741
2002	7942	2489	2491	140	1	13	0	13076
2003	5907	1034	1246	1027	19	6	0	9239
2004	6601	3179	862	201	0	27	0	10870
2005	3288	816	468	88	0	10	0	4670
2006	3982	858	200	1	0	5	0	5046

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
2007	1560	874	1214	1	0	0	0	3650
2008	2793	797	1344	7	0	0	0	4942
2009	3377	608	110	0	0	0	0	4094
2010	2725	948	1436	4	0	0	0	5113
2011	3070	665	924	7	0	18	0	4684
2012	585	447	561	68	0	13	0	1674
2013	3704	1618	273	37	0	8	0	5639
2014	2174	1344	1072	51	0	4	0	4645
2015	2073	1214	1412	43	0	5	0	4748
2016	146	413	561	79	0	6	0	1205
2017	2661	1827	1198	166	0	0	0	5852
2018	2817	558	1425	524	0	0	0	5324
2019	2489	136	1957	203	0	3	0	4788
2020	2656	1304	3392	165	0	5	0	7522
2021	389	259	2041	1266	0	4	0	3959
arith. mean	4604	1807	2450	318	76	40	7	9302

Table 9.1.7 Sandeel. Effort (days fishing for a standard 200 GT vessel) by area, second half year as estimated by ICES.

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
1983	2066	1687	126	0	0	0	0	3879
1984	2256	1538	207	0	0	4	0	4005
1985	2427	1005	110	3	0	35	0	3582
1986	804	1154	2133	3	8	32	64	4199
1987	1393	374	31	16	0	3	0	1817
1988	809	1215	1442	2	0	22	0	3490
1989	313	1700	92	0	0	1	0	2106
1990	520	828	1405	5	0	0	0	2759
1991	1403	1579	1113	227	0	0	0	4322
1992	879	1151	93	262	0	0	0	2385
1993	398	1799	1174	187	0	10	0	3567
1994	297	1133	443	178	0	16	0	2067
1995	601	970	201	1	0	0	0	1774
1996	691	2981	1205	945	163	0	0	5986
1997	1369	1868	1854	132	0	7	6	5237
1998	568	1036	4003	35	3	0	0	5645
1999	1024	1203	2975	0	0	0	0	5202
2000	960	606	78	0	0	0	0	1643
2001	2979	1143	3044	13	0	0	0	7180
2002	220	672	0	0	0	0	0	892
2003	898	1316	388	71	0	0	0	2673

	Area 1r	Area 2r	Area 3r	Area 4	Area 5r	Area 6	Area 7r	All
2004	456	1028	402	2	0	0	0	1888
2005	124	316	0	0	0	0	0	439
2006	178	377	5	0	0	0	0	560
2007	0	0	0	0	0	0	0	0
2008	85	109	0	0	0	0	0	194
2009	174	194	2	0	0	0	0	370
2010	134	187	10	0	0	0	0	331
2011	126	11	0	0	0	0	0	137
2012	0	25	0	0	0	0	0	25
2013	172	181	0	0	0	0	0	353
2014	96	71	0	0	0	0	0	167
2015	0	19	0	0	0	0	0	19
2016	0	15	0	0	0	0	0	15
2017	50	255	0	0	0	0	0	305
2018	309	6	12	0	0	0	0	327
2019	334	0	0	0	0	0	0	334
2020	40	80	0	0	0	0	0	120
2021	29	76	8	112	0	0	0	225
arith. mean	646	767	578	56	4	3	2	2057

Table 9.1.8 Sandeel. Number of samples from commercial catches by year and area.

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	All
1983	79	49	0	0	0	0	0	128
1984	116	46	13	0	2	3	0	180
1985	101	32	1	19	2	3	0	158
1986	26	17	27	1	0	1	0	72
1987	62	12	60	1	0	1	0	136
1988	42	15	67	0	0	1	0	125
1989	40	9	43	0	0	1	0	93
1990	1	4	37	0	0	2	0	44
1991	25	32	30	1	0	0	0	88
1992	56	42	24	4	0	7	0	133
1993	23	63	64	15	0	7	0	172
1994	20	38	50	15	0	4	0	127
1995	41	32	58	7	7	2	0	147
1996	43	62	113	27	19	1	0	265
1997	41	84	116	25	8	3	0	277
1998	53	30	145	7	0	2	0	237
1999	263	42	40	44	0	0	0	389
2000	102	34	47	59	0	0	0	242

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	All
2001	213	39	32	90	1	0	0	375
2002	288	97	50	62	0	0	0	497
2003	281	75	30	160	0	1	0	547
2004	451	217	26	47	0	1	0	742
2005	320	42	34	30	0	1	0	427
2006	550	56	72	2	0	2	0	682
2007	295	79	95	0	0	0	0	469
2008	290	100	45	1	0	0	0	436
2009	302	102	3	0	0	0	0	407
2010	169	194	30	1	0	0	0	394
2011	167	54	17	4	0	4	0	246
2012	220	112	31	21	0	12	0	396
2013	292	220	41	5	0	3	0	561
2014	143	133	29	18	0	5	0	328
2015	308	117	48	38	0	4	0	515
2016	154	159	42	35	0	0	0	390
2017	279	204	50	40	0	0	0	573
2018	350	136	162	71	0	0	0	719
2019	282	81	140	32	0	0	0	535
2020	241	182	184	36	0	1	0	644
Sum	6729	3042	2096	918	39	72	0	12896

Table 9.2.1 Sandeel Area-1r. Catch at age numbers (million) by half year.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	10223	1846	264	28971	3085	772	564	320	2
1984	0	47117	9241	1701	90	10002	566	333	43
1985	8524	6217	1354	31364	2305	1987	1595	211	213
1986	87	44940	4163	7553	228	1652	188	31	14
1987	187	4504	1938	23572	4173	1199	123	171	32
1988	0	1997	0	8564	162	15229	1439	2354	47
1989	0	62503	757	6364	77	1346	16	4736	58
1990	522	16846	1257	13917	417	2060	62	622	18
1991	7344	14939	6917	6870	209	983	67	338	0
1992	104	50883	3041	8451	298	845	122	524	26
1993	1624	2181	362	5882	271	1638	156	491	43
1994	0	22172	1533	2669	126	1195	55	882	78
1995	76	36677	3440	6236	940	737	109	289	28
1996	6470	10402	1064	12301	1027	4527	211	860	65
1997	19	38667	8899	2332	177	3522	164	713	56

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1998	211	9387	438	28364	1384	2164	136	1505	90
1999	440	44621	2498	5433	205	10158	717	699	149
2000	7887	32625	2760	3355	170	630	84	1076	122
2001	47080	56780	3127	8549	474	1098	49	972	98
2002	16	84878	605	10772	108	1212	15	225	6
2003	2474	3843	386	13302	4390	1117	141	302	31
2004	566	30654	2479	786	110	2364	230	480	47
2005	44	11106	383	4435	211	263	14	435	27
2006	37	33600	800	2590	94	817	43	163	19
2007	0	10581	0	4674	0	315	0	172	0
2008	6	26735	281	4009	75	1205	33	214	6
2009	979	18898	2254	14265	278	1556	12	392	3
2010	10	39951	1184	2130	35	942	16	108	2
2011	5	1894	39	32692	325	1305	14	266	1
2012	0	383	0	419	0	3354	0	129	0
2013	3	18090	598	7916	131	2182	100	4301	49
2014	925	8930	131	3354	98	401	23	360	25
2015	0	25326	0	1918	0	579	0	172	0
2016	0	208	0	1193	0	97	0	17	0
2017	3	33038	253	3015	40	4604	38	103	7
2018	91	1699	158	14468	792	971	44	331	10
2019	5947	4703	96	830	18	1885	19	101	0
2020	54	11911	80	1098	12	270	2	457	5
2021	4	1069	41	940	25	50	1	31	1
arith. mean	2614	22380	1611	8648	578	2237	184	664	36

Table 9.2.2 Sandeel Area-1r. Individual mean weight (gram) at age in the catch and in the sea.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	3.3	4.9	4.0	9.7	8.3	17.2	13.2	20.5	11.6
1984	3.7	5.5	7.3	10.1	12.8	14.1	16.8	13.4	15.8
1985	3.0	5.1	5.8	9.2	10.7	16.4	12.9	17.9	16.6
1986	3.0	5.3	7.5	11.7	12.7	11.7	12.8	13.6	14.7
1987	4.0	7.2	7.8	10.6	11.2	18.5	20.2	14.7	16.1
1988	3.9	6.1	6.8	10.4	12.0	16.0	17.0	17.8	24.4
1989	6.2	5.0	9.6	8.6	15.5	9.1	17.2	12.0	28.3
1990	5.0	6.6	9.0	9.6	13.1	14.2	19.3	17.0	23.1
1991	3.8	7.8	6.1	14.2	11.8	37.8	32.0	19.6	17.2
1992	4.9	7.8	9.5	11.9	15.3	17.7	19.7	19.0	21.2

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1993	4.0	7.3	7.5	11.5	10.5	14.4	13.6	20.2	18.2
1994	4.4	5.5	7.6	8.7	12.3	12.7	16.3	19.8	18.8
1995	3.8	7.6	6.8	11.3	9.9	14.1	14.1	19.0	19.0
1996	2.9	5.6	4.6	8.4	7.6	12.2	9.5	17.7	14.2
1997	3.7	7.3	8.5	8.3	14.2	9.9	15.5	14.4	16.1
1998	3.2	6.3	6.7	8.9	10.0	11.5	11.9	13.5	14.5
1999	3.4	5.3	5.9	7.5	9.6	10.3	12.8	13.1	14.7
2000	3.1	6.3	4.8	8.7	7.9	11.9	10.6	14.5	12.2
2001	3.1	4.5	5.0	8.7	12.1	11.5	16.5	16.6	23.6
2002	3.8	6.0	6.7	7.4	10.8	9.8	14.4	13.8	16.5
2003	2.2	3.6	2.7	7.2	3.6	9.5	8.4	12.8	9.1
2004	3.5	5.1	4.5	8.3	6.6	9.0	6.7	10.4	8.8
2005	3.0	6.5	5.3	8.7	8.5	10.3	11.3	12.1	13.0
2006	3.2	5.9	5.5	9.7	8.9	11.6	11.9	13.0	13.7
2007	4.1	5.6	7.0	9.4	11.3	13.5	15.1	14.7	17.3
2008	4.5	6.3	7.8	10.9	12.6	13.3	16.8	15.8	19.3
2009	2.8	6.2	4.9	9.4	7.9	12.1	10.5	13.2	12.1
2010	3.4	6.3	5.9	12.4	9.5	13.9	12.6	17.2	14.5
2011	2.8	5.3	4.9	8.7	7.8	12.7	10.4	14.8	12.0
2012	3.8	6.4	6.6	9.5	10.6	11.3	14.1	14.5	16.2
2013	3.8	4.7	6.5	6.5	10.5	10.1	14.0	11.3	16.1
2014	3.0	4.7	5.2	7.1	8.5	9.5	11.3	11.7	13.0
2015	4.0	5.5	6.9	8.3	11.1	10.6	14.8	14.0	17.0
2016	3.2	5.2	5.4	10.1	8.7	12.5	11.6	14.7	13.3
2017	2.9	5.3	6.0	7.1	8.2	9.2	10.5	10.7	12.4
2018	3.3	4.7	8.2	7.0	10.6	9.5	13.9	11.5	15.5
2019	3.3	4.7	8.2	7.7	10.6	8.4	13.9	10.7	15.5
2020	3.3	7.1	8.2	9.6	10.6	12.3	13.9	13.8	15.5
2021	3.3	5.9	8.2	9.7	10.6	11.4	13.9	12.8	15.5
arith. mean	3.6	5.8	6.6	9.3	10.4	12.9	14.2	14.8	16.1

Table 9.2.3 Sandeel Area-1r. Proportion mature.

	Age 1	Age 2	Age 3	Age 4
1983–2016	0.02	0.8	0.99	1

Table 9.2.4. Sandeel Area-1r. Dredge survey indices.

Year	Age 0	Age 1
2004	140061.87	7077.655
2005	277241.20	3288.987
2006	117233.03	12244.596
2007	402355.16	5326.731
2008	35633.70	13619.791
2009	474590.87	9040.642
2010	49722.00	125308.581
2011	77113.07	27178.527
2012	136586.42	3922.222
2013	80356.85	13156.382
2014	235943.73	3413.488
2015	23030.02	13597.662
2016	304655.46	7277.881
2017	32663.00	38561.000
2018	165064.00	11168.000
2019	199148.10	18720.400
2020	71890.40	7497.200
2021	65614.29	8315.977

Table 9.2.5 Sandeel Area-1r. SMS settings and statistics.

```
Date: 01/26/22  Start time:09:46:31 run time:1 seconds

objective function (negative log likelihood):  17.8446
Number of parameters: 80
Maximum gradient: 0.000100632
Akaike information criterion (AIC):   195.689
Number of observations used in the likelihood:
                            Catch    CPUE     S/R Stomach     Sum
                             351      75      39       0     465

objective function weight:
                          Catch  CPUE   S/R
                          1.00  1.00  0.05

unweighted objective function contributions (total):
                Catch    CPUE    S/R   Stom.  Stom N.  Penalty     Sum
               25.4    -8.2    13.5     0.0     0.0      0.00      31


unweighted objective function contributions (per observation):
                Catch   CPUE     S/R   Stomachs
               0.07   -0.11    0.35    0.00


contribution by fleet:
----------------------
Dredge survey 2004-2021     total:   0.941   mean:   0.026
RTM 2007-2021               total:  -9.122   mean:  -0.234
```

```
F, season effect:
-----------------
age: 0
    1983-1988:   0.000 1.000
    1989-1998:   0.000 1.000
    1999-2004:   0.000 1.000
    2005-2009:   0.000 1.000
    2010-2021:   0.000 1.000
age: 1 - 4
    1983-1988:   0.457 0.500
    1989-1998:   0.466 0.500
    1999-2004:   0.374 0.500
    2005-2009:   0.254 0.500
    2010-2021:   0.573 0.500

F, age effect:
--------------
                0      1      2      3      4
1983-1988:  0.025  0.259  0.959  1.423  1.423
1989-1998:  0.011  0.539  0.722  0.732  0.732
1999-2004:  0.067  1.027  1.142  1.135  1.135
2005-2009:  0.007  1.436  2.177  2.240  2.240
2010-2021:  0.016  0.252  0.596  1.004  1.004


Exploitation pattern (scaled to mean F=1)
-----------------------------------------
                        0      1      2      3      4
1983-1988 season 1:      0  0.320  1.188  1.762  1.762
          season 2:  0.020  0.105  0.388  0.575  0.575

1989-1998 season 1:      0  0.821  1.100  1.116  1.116
          season 2:  0.001  0.033  0.045  0.045  0.045

1999-2004 season 1:      0  0.807  0.897  0.892  0.892
          season 2:  0.018  0.140  0.156  0.155  0.155

2005-2009 season 1:      0  0.740  1.122  1.154  1.154
          season 2:  0.001  0.055  0.083  0.086  0.086

2010-2021 season 1:      0  0.570  1.347  2.269  2.269
          season 2:  0.003  0.025  0.058  0.097  0.097


sqrt(catch variance) ~ CV:
--------------------------

              season
----------------------
age        1       2

 0             1.655
 1       0.343   0.581
 2       0.343   0.581
 3       0.657   1.024
 4       0.657   1.024


Survey catchability:
--------------------
                             age 0    age 1    age 2    age 3
 Dredge survey 2004-2021       2.646    1.089
```

```
 RTM 2007-2021                         0.861    1.820    2.810

sqrt(Survey variance) ~ CV:
---------------------------
                           age 0    age 1    age 2    age 3
 Dredge survey 2004-2021        0.49     0.78
 RTM 2007-2021                           0.53     0.43     0.49

Recruit-SSB            alfa      beta       recruit s2     recruit s
Area-1r            1017.564   1.100e+005   0.734          0.856
```

Table 9.2.6 Sandeel Area-1r. Annual fishing mortality (F) at age.

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
1983	0.012	0.286	1.029	1.511	1.519	0.657
1984	0.013	0.324	1.163	1.706	1.715	0.743
1985	0.014	0.347	1.244	1.833	1.828	0.796
1986	0.005	0.245	0.875	1.277	1.272	0.560
1987	0.008	0.182	0.661	0.970	0.969	0.421
1988	0.005	0.266	0.950	1.376	1.370	0.608
1989	0.001	0.818	1.064	1.068	1.061	0.941
1990	0.002	0.815	1.059	1.062	1.058	0.937
1991	0.005	0.548	0.721	0.730	0.730	0.634
1992	0.003	0.823	1.079	1.084	1.084	0.951
1993	0.001	0.363	0.474	0.481	0.480	0.418
1994	0.001	0.300	0.389	0.392	0.390	0.345
1995	0.002	0.562	0.727	0.732	0.729	0.645
1996	0.003	0.527	0.680	0.683	0.682	0.603
1997	0.005	0.497	0.644	0.649	0.652	0.571
1998	0.002	0.652	0.826	0.828	0.828	0.739
1999	0.017	1.024	1.083	1.064	1.066	1.053
2000	0.016	0.819	0.861	0.852	0.850	0.840
2001	0.049	1.239	1.323	1.315	1.318	1.281
2002	0.004	0.949	1.013	0.975	0.968	0.981
2003	0.015	0.789	0.846	0.819	0.822	0.818
2004	0.007	0.833	0.880	0.848	0.849	0.857
2005	0.000	0.895	1.281	1.308	1.305	1.088
2006	0.001	1.094	1.566	1.590	1.586	1.330
2007	0.000	0.413	0.594	0.604	0.600	0.504
2008	0.000	0.771	1.104	1.114	1.111	0.938
2009	0.001	0.952	1.369	1.391	1.383	1.161
2010	0.002	0.418	0.932	1.496	1.487	0.675
2011	0.001	0.476	1.037	1.674	1.658	0.756
2012	0.000	0.090	0.199	0.324	0.321	0.145
2013	0.000	0.544	1.165	1.913	1.904	0.855

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
2014	0.001	0.316	0.683	1.133	1.131	0.500
2015	0.000	0.304	0.652	1.086	1.077	0.478
2016	0.000	0.022	0.047	0.078	0.077	0.034
2017	0.001	0.405	0.896	1.461	1.446	0.650
2018	0.004	0.400	0.906	1.468	1.463	0.653
2019	0.004	0.391	0.885	1.437	1.433	0.638
2020	0.001	0.382	0.860	1.385	1.380	0.621
2021	0.000	0.058	0.133	0.216	0.216	0.096
arith. mean	0.005	0.542	0.869	1.075	1.072	0.706

Table 9.2.7 Sandeel Area-1r. Fishing mortality (F) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	0.012	0.193	0.063	0.714	0.233	1.059	0.345	1.059	0.345
1984	0.013	0.220	0.069	0.815	0.254	1.209	0.377	1.209	0.377
1985	0.014	0.235	0.074	0.870	0.273	1.290	0.405	1.290	0.405
1986	0.005	0.183	0.024	0.677	0.091	1.004	0.135	1.004	0.135
1987	0.008	0.119	0.042	0.442	0.157	0.655	0.233	0.655	0.233
1988	0.005	0.199	0.025	0.739	0.091	1.096	0.135	1.096	0.135
1989	0.001	0.664	0.027	0.889	0.036	0.902	0.037	0.902	0.037
1990	0.002	0.645	0.045	0.864	0.060	0.876	0.061	0.876	0.061
1991	0.005	0.370	0.121	0.495	0.162	0.502	0.165	0.502	0.165
1992	0.003	0.639	0.076	0.855	0.102	0.868	0.103	0.868	0.103
1993	0.001	0.282	0.034	0.377	0.046	0.383	0.047	0.383	0.047
1994	0.001	0.230	0.026	0.308	0.034	0.312	0.035	0.312	0.035
1995	0.002	0.427	0.052	0.572	0.070	0.580	0.071	0.580	0.071
1996	0.003	0.387	0.060	0.519	0.080	0.526	0.081	0.526	0.081
1997	0.005	0.322	0.118	0.431	0.158	0.437	0.161	0.437	0.161
1998	0.002	0.491	0.049	0.658	0.066	0.667	0.067	0.667	0.067
1999	0.017	0.740	0.129	0.823	0.143	0.818	0.142	0.818	0.142
2000	0.016	0.581	0.121	0.646	0.134	0.642	0.133	0.642	0.133
2001	0.049	0.756	0.374	0.840	0.416	0.836	0.414	0.836	0.414
2002	0.004	0.747	0.028	0.830	0.031	0.826	0.031	0.826	0.031
2003	0.015	0.555	0.113	0.617	0.125	0.614	0.125	0.614	0.125
2004	0.007	0.620	0.057	0.689	0.064	0.686	0.063	0.686	0.063
2005	0.000	0.693	0.052	1.051	0.078	1.081	0.080	1.081	0.080
2006	0.001	0.838	0.074	1.271	0.112	1.308	0.115	1.308	0.115
2007	0.000	0.329	0.000	0.498	0.000	0.513	0.000	0.513	0.000
2008	0.000	0.588	0.035	0.892	0.054	0.918	0.055	0.918	0.055
2009	0.001	0.711	0.072	1.078	0.110	1.109	0.113	1.109	0.113

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
2010	0.002	0.310	0.013	0.733	0.031	1.234	0.053	1.234	0.053
2011	0.001	0.350	0.009	0.827	0.022	1.392	0.037	1.392	0.037
2012	0.000	0.067	0.000	0.158	0.000	0.266	0.000	0.266	0.000
2013	0.000	0.421	0.000	0.995	0.000	1.675	0.000	1.675	0.000
2014	0.001	0.242	0.008	0.571	0.019	0.961	0.033	0.961	0.033
2015	0.000	0.236	0.000	0.557	0.000	0.938	0.000	0.938	0.000
2016	0.000	0.017	0.000	0.039	0.000	0.066	0.000	0.066	0.000
2017	0.001	0.314	0.005	0.743	0.012	1.251	0.020	1.251	0.020
2018	0.004	0.301	0.029	0.712	0.068	1.198	0.115	1.198	0.115
2019	0.004	0.290	0.034	0.686	0.079	1.156	0.134	1.156	0.134
2020	0.001	0.302	0.004	0.715	0.009	1.203	0.016	1.203	0.016
2021	0.000	0.044	0.003	0.105	0.007	0.176	0.012	0.176	0.012
arith. mean	0.005	0.401	0.053	0.674	0.088	0.852	0.106	0.852	0.106

Table 9.2.8 Sandeel Area-1r. Natural mortality (M) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	0.499	0.400	0.462	0.357	0.378	0.261	0.326	0.243	0.337
1984	0.499	0.400	0.462	0.357	0.378	0.261	0.326	0.243	0.337
1985	0.519	0.385	0.468	0.345	0.382	0.281	0.358	0.253	0.337
1986	0.534	0.376	0.475	0.342	0.409	0.270	0.368	0.249	0.353
1987	0.550	0.387	0.490	0.344	0.422	0.269	0.371	0.252	0.358
1988	0.553	0.396	0.484	0.357	0.418	0.282	0.358	0.270	0.344
1989	0.532	0.415	0.460	0.377	0.392	0.303	0.356	0.271	0.333
1990	0.544	0.403	0.471	0.341	0.395	0.282	0.355	0.267	0.343
1991	0.560	0.394	0.457	0.326	0.384	0.230	0.344	0.227	0.344
1992	0.549	0.397	0.434	0.311	0.371	0.218	0.328	0.221	0.331
1993	0.530	0.407	0.404	0.343	0.331	0.240	0.318	0.221	0.309
1994	0.530	0.386	0.447	0.327	0.362	0.243	0.329	0.217	0.315
1995	0.521	0.380	0.470	0.337	0.376	0.247	0.339	0.217	0.324
1996	0.552	0.340	0.492	0.304	0.391	0.244	0.351	0.211	0.341
1997	0.567	0.372	0.508	0.323	0.389	0.271	0.349	0.224	0.341
1998	0.615	0.416	0.546	0.350	0.392	0.305	0.352	0.237	0.343
1999	0.620	0.456	0.566	0.379	0.401	0.315	0.350	0.249	0.340
2000	0.608	0.469	0.551	0.391	0.369	0.322	0.334	0.243	0.309
2001	0.614	0.410	0.528	0.366	0.366	0.297	0.326	0.227	0.297
2002	0.671	0.454	0.566	0.424	0.456	0.354	0.357	0.272	0.329
2003	0.690	0.475	0.585	0.442	0.472	0.388	0.377	0.320	0.368
2004	0.709	0.544	0.629	0.473	0.476	0.417	0.375	0.356	0.368

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
2005	0.695	0.542	0.554	0.426	0.396	0.395	0.371	0.318	0.354
2006	0.729	0.571	0.580	0.441	0.417	0.346	0.365	0.288	0.348
2007	0.769	0.549	0.566	0.405	0.433	0.312	0.396	0.270	0.376
2008	0.725	0.541	0.610	0.414	0.456	0.300	0.385	0.268	0.375
2009	0.704	0.460	0.597	0.346	0.452	0.282	0.406	0.250	0.383
2010	0.715	0.475	0.667	0.366	0.540	0.299	0.443	0.256	0.419
2011	0.787	0.528	0.731	0.367	0.544	0.321	0.472	0.273	0.437
2012	0.787	0.593	0.710	0.454	0.541	0.368	0.455	0.321	0.433
2013	0.732	0.591	0.655	0.495	0.435	0.369	0.407	0.324	0.388
2014	0.723	0.522	0.605	0.481	0.390	0.324	0.364	0.302	0.357
2015	0.718	0.578	0.622	0.442	0.391	0.299	0.380	0.276	0.356
2016	0.725	0.526	0.617	0.394	0.396	0.288	0.384	0.268	0.354
2017	0.673	0.534	0.600	0.425	0.454	0.307	0.394	0.286	0.363
2018	0.619	0.440	0.538	0.427	0.454	0.328	0.360	0.293	0.345
2019	0.619	0.440	0.538	0.427	0.454	0.328	0.360	0.293	0.345
2020	0.619	0.440	0.538	0.427	0.454	0.328	0.360	0.293	0.345
2021	0.619	0.440	0.538	0.427	0.454	0.328	0.360	0.293	0.345
arith. mean	0.629	0.457	0.544	0.387	0.420	0.303	0.367	0.266	0.352

Table 9.2.9 Sandeel Area-1r. Stock numbers (millions). Age 0 at start of 2nd half-year, age 1+ at start of the year.

	Age 0	Age 1	Age 2	Age 3	Age 4
1983	299015	13260	52130	2841	242
1984	75976	179350	4339	9694	422
1985	512274	45519	56771	714	1152
1986	77581	300596	14239	8751	186
1987	47398	45284	104383	3122	1514
1988	206586	27125	16027	26651	1015
1989	92629	118264	8995	3220	4263
1990	131123	54377	24694	1653	1563
1991	163993	75981	11376	4692	675
1992	37010	93162	19867	2898	1553
1993	155890	21312	19849	3854	975
1994	223917	91585	6904	6624	1810
1995	56134	131647	30831	2461	3394
1996	403422	33277	34864	7956	1746
1997	63130	231744	9261	9566	2939
1998	121133	35632	61895	2518	3749
1999	159266	65331	7933	14295	1636

	Age 0	Age 1	Age 2	Age 3	Age 4
2000	252679	84243	9865	1385	3158
2001	418211	135479	15068	2117	1168
2002	26725	215558	17118	2064	524
2003	160692	13616	35820	3000	552
2004	67979	79446	2418	6836	800
2005	163089	33196	12486	441	1647
2006	79307	81351	5268	1774	327
2007	194907	38213	10326	560	252
2008	77150	90322	9021	2714	244
2009	560359	37363	15321	1469	566
2010	34547	277020	5933	2103	306
2011	42280	16878	63962	1116	320
2012	103313	19221	3346	11004	158
2013	60111	47021	4888	1056	3760
2014	214166	28923	8874	713	437
2015	36587	103861	7304	2057	216
2016	272957	17842	24718	1819	453
2017	19491	132257	5594	10792	1098
2018	31171	9935	30909	1092	1661
2019	95467	16729	2686	5876	384
2020	52902	51206	4550	518	870
2021	39617	28483	14177	915	213
2022		21333	10218	5259	475

Table 9.2.10 Sandeel Area-1r. Estimated recruitment, total stock biomass (TBS), spawning stock biomass (SSB), catch weight (modelled yield) and average fishing mortality.

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean $F_{1\text{-}2}$
1983	299013715	625840	460929	378795	0.601
1984	75981466	1165290	196025	498626	0.679
1985	512084393	783157	453160	437114	0.725
1986	77593949	1862800	270493	382844	0.487
1987	47393706	1512290	973838	373021	0.380
1988	206539038	775842	574928	413646	0.527
1989	92618550	747470	154662	446028	0.808
1990	131169377	647380	247707	306240	0.807
1991	163938186	944290	330050	332204	0.574
1992	37021153	1042320	284361	558599	0.836
1993	155942826	459344	260407	132024	0.370
1994	223964922	683504	177726	193241	0.299
1995	56119842	1449690	399113	400588	0.560

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean $F_{1\text{-}2}$
1996	403222872	605958	364762	265869	0.523
1997	63148522	1894180	232815	426089	0.515
1998	121084596	854977	524919	377073	0.632
1999	159252253	577355	222348	422718	0.917
2000	252772391	677968	142059	299167	0.741
2001	418003348	787195	161297	531265	1.193
2002	26722060	1439260	156217	606466	0.818
2003	160691992	343463	243045	148039	0.705
2004	67998758	491587	93246	203646	0.715
2005	163120541	349493	116425	123422	0.937
2006	79319932	554785	75508	240646	1.148
2007	194900553	320875	93620	109624	0.413
2008	77129779	704471	129832	234447	0.784
2009	560309574	399923	145365	290995	0.985
2010	34552829	1852980	129573	300508	0.544
2011	42287412	666689	467895	318840	0.604
2012	103284720	281048	152970	46117	0.112
2013	60128831	305106	83200	214359	0.708
2014	214109902	211344	64861	78830	0.420
2015	36579554	655139	85221	163381	0.396
2016	273004818	372064	231422	14613	0.028
2017	19481970	849954	156530	241916	0.537
2018	31171039	293905	204843	133659	0.555
2019	95439204	153229	71254	66444	0.545
2020	52904555	426837	60901	106100	0.515
2021	39626157	318828	126880	17064	0.079
2022			128284		
arith. mean	149491895	745842	236222	277802	0.608
geo. mean	106856781				

arith. mean for the period 1983–2021

geo. mean for the period 1983–2020

Table 9.2.11 Sandeel Area-1r. Input to forecast.

	Age 0	Age 1	Age 2	Age 3	Age 4
Stock numbers(2022)	106885.513	21333	10218.5	5258.51	474.614
Exploitation pattern 1st half		0.044	0.105	0.176	0.176
Exploitation pattern 2nd half	0.000	0.003	0.007	0.012	0.012
Weight in the stock 1st half		5.544	8.217	10.190	11.888
Weight in the catch 1st half		5.544	8.217	10.190	11.888
weight in the catch 2nd half	3.221	7.739	10.099	13.239	14.905
Proportion mature(2022)	0.000	0.021	0.801	0.988	1.000
Proportion mature(2023)	0.000	0.021	0.801	0.988	1.000
Natural mortality 1st half		0.440	0.427	0.328	0.293
Natural mortality 2nd half	0.619	0.538	0.454	0.360	0.345

Table 9.2.12 Sandeel Area-1r. Short term forecast (000 tonnes).

Basis: Fsq=F(2021)=0.0794; Yield(2021)=17.064; Recruitment(2021)=39.626157; Recruitment(2022)=geometric mean (GM 1983-2020)=106.885513 billion; SSB(2022)=128.284

F multiplier	Basis	F(2022)	Catch(2022)	SSB(2023)	%SSB change*	%TAC change**
0	F=0	0.000	0.001	136.622	7 %	-100 %
0.99	Fsq*0.99	0.079	20.173	123.863	-3 %	18 %
1	Fsq*1	0.079	20.290	123.790	-4 %	19 %
2	Fsq*2	0.159	38.323	112.532	-12 %	125 %
1	Fsq*1	0.079	20.290	123.790	-4 %	19 %
0.08	Fsq*0.08	0.006	1.734	135.520	6 %	-90 %
1.8	Fsq*1.8	0.143	34.856	114.684	-11 %	104 %
2.2	Fsq*2.2	0.175	41.642	110.477	-14 %	144 %
0.11	Fsq*0.11	0.009	2.359	135.123	5 %	-86 %
No conversion for calculation of MSY catch		NA	NA	NA		

***SSB in 2023 relative to SSB in 2022**

****TAC in 2022 relative to catches in 2021**

Table 9.3.1 Sandeel Area-2r. Catch at age numbers (million) by half year.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	12882	4162	476	6190	877	203	104	67	0
1984	0	10284	3846	912	186	1154	193	38	10
1985	1827	1411	392	5501	768	473	387	109	50
1986	1443	24479	3495	3144	208	436	95	6	7
1987	45	831	512	2621	591	131	17	20	4
1988	5602	1030	545	3379	226	3163	775	478	31

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1989	2819	23364	3809	1666	273	938	10	909	34
1990	5046	7332	854	3967	196	587	29	177	9
1991	10053	14203	3628	2099	110	451	35	156	1
1992	6830	12016	886	4066	85	475	34	298	7
1993	14083	4814	873	1294	660	642	226	475	56
1994	0	25596	4477	3619	919	341	275	199	118
1995	1798	4897	1316	1598	1777	209	211	88	159
1996	26463	2472	7161	1573	475	905	278	260	186
1997	284	29071	8330	1640	193	628	83	207	47
1998	1070	645	106	4749	1424	437	136	348	144
1999	4130	841	1113	177	102	855	501	186	149
2000	519	8160	1066	566	164	217	98	518	134
2001	5767	2625	2414	1010	563	129	73	367	228
2002	4	15855	1379	891	185	393	35	85	28
2003	3711	267	79	1723	453	136	43	67	17
2004	755	10761	2034	711	212	537	297	174	55
2005	15	2171	490	513	336	48	32	116	91
2006	8	2441	1030	276	125	100	64	27	39
2007	0	6431	0	240	0	32	0	5	0
2008	1	4621	187	434	64	90	36	15	5
2009	103	2817	1867	671	145	42	25	4	1
2010	2	6490	1308	193	35	374	27	60	4
2011	0	404	19	1474	91	236	17	59	3
2012	0	168	6	194	51	293	6	60	10
2013	0	4824	431	1158	47	296	16	99	5
2014	301	2987	141	2371	28	340	3	119	5
2015	0	2275	42	772	9	561	2	197	2
2016	4	272	1	136	3	108	0	66	0
2017	0	23040	1325	243	5	51	25	20	2
2018	0	50	0	1949	22	63	2	11	0
2019	0	226	0	52	0	172	0	4	0
2020	4	8068	16	433	1	173	1	356	3
2021	0	746	0	128	0	2	0	3	0
arith. mean	2707	7004	1427	1650	298	421	107	165	42

Table 9.3.2 Sandeel Area-2r. Individual mean weight (gram) at age in the catch and in the sea.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	3.3	5.2	9.9	10.8	16.5	12.8	22.9	15.0	27.3
1984	5.9	5.6	10.2	11.1	14.1	15.6	25.8	18.8	30.1
1985	4.5	6.7	10.7	9.9	16.8	17.5	23.3	24.1	27.5
1986	3.2	5.9	9.8	10.3	15.8	12.7	15.0	15.0	17.0
1987	2.8	5.8	8.7	11.1	12.9	16.4	21.1	14.6	19.4
1988	3.5	5.5	7.2	11.1	15.3	16.1	21.0	23.1	30.6
1989	4.8	5.7	9.4	9.1	13.4	10.1	14.4	12.1	18.0
1990	4.4	7.1	8.1	9.7	11.8	14.4	17.4	17.3	20.8
1991	3.8	7.7	5.7	12.1	11.0	35.8	32.6	21.2	20.1
1992	4.7	6.9	15.0	9.9	20.6	13.5	29.3	17.9	29.2
1993	2.8	7.7	9.3	15.1	14.8	16.9	17.5	22.3	22.0
1994	3.6	5.4	7.6	10.5	18.8	15.3	23.0	19.5	20.7
1995	5.2	7.6	8.9	12.4	13.2	16.0	17.6	19.2	21.1
1996	2.7	7.0	4.9	12.4	13.2	17.0	15.8	27.9	24.5
1997	3.2	5.3	7.1	8.0	11.2	13.1	13.8	15.9	14.9
1998	3.4	6.2	6.7	11.4	14.0	14.7	16.5	17.4	18.3
1999	5.3	8.1	9.1	11.8	12.8	15.4	15.3	19.1	19.6
2000	3.1	6.8	10.2	10.0	13.0	15.2	17.9	18.1	19.5
2001	4.0	6.0	5.0	12.9	16.1	16.6	21.7	20.4	26.2
2002	3.2	5.7	8.3	8.4	13.2	9.6	15.3	17.3	17.7
2003	5.4	6.0	8.1	11.3	16.0	15.1	21.4	18.2	27.2
2004	4.8	6.5	7.4	9.4	10.9	12.4	12.2	13.1	13.7
2005	3.4	7.5	7.4	11.8	11.9	14.4	15.4	14.8	17.5
2006	4.6	7.6	9.9	11.5	15.9	13.9	20.6	14.8	23.4
2007	5.8	6.2	6.2	12.4	12.4	15.4	15.4	17.8	17.8
2008	3.4	5.5	7.5	12.5	12.0	16.1	15.6	18.0	17.7
2009	6.0	6.1	5.0	8.7	10.9	16.5	18.6	12.2	11.0
2010	2.5	5.7	5.3	10.3	8.4	11.5	11.0	13.2	12.5
2011	3.6	6.9	7.6	11.1	12.2	13.8	15.8	14.6	18.0
2012	4.4	8.2	9.4	12.4	15.1	14.8	19.6	21.8	22.3
2013	3.9	5.9	8.8	7.9	11.5	14.2	14.4	14.1	16.5
2014	3.3	5.3	7.0	9.9	11.2	12.0	14.6	18.6	16.6
2015	5.3	6.8	11.4	12.4	18.4	15.3	23.9	17.3	27.1
2016	2.6	3.3	5.5	12.2	8.9	14.6	11.5	16.0	13.1
2017	2.9	5.5	7.8	7.8	10.7	13.1	10.8	14.8	15.5
2018	3.8	4.6	8.2	9.6	13.9	12.4	18.6	14.0	20.7

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
2019	3.8	7.7	8.2	12.4	13.9	15.4	18.6	18.7	20.7
2020	3.8	6.6	8.2	12.8	13.9	16.2	18.6	20.4	20.7
2021	3.8	5.0	8.2	9.3	13.9	13.0	18.6	16.3	20.7
arith. mean	4.0	6.3	8.2	10.9	13.6	15.0	18.3	17.6	20.4

Table 9.3.3 Sandeel Area-2r. Proportion mature.

	Age 1	Age 2	Age 3	Age 4
1983–2016	0.02	0.83	1	1

Table 9.3.4. Sandeel Area-2r. Dredge survey indices.

Year	Age 0	Age 1
2010	938.752	1482.382
2011	2290.448	259.021
2012	11342.580	94.156
2013	7546.966	2103.482
2014	5760.235	810.806
2015	706.350	106.920
2016	53839.804	113.297
2017	899.000	2976.000
2018	2326.000	372.000
2019	26129.000	522.000
2020	7662.000	665.000
2021	45488.020	499.877

Table 9.3.5 Sandeel Area-2r. SMS settings and statistics.

```
Date: 01/26/22  Start time:09:45:41 run time:0 seconds

objective function (negative log likelihood):  86.0187
Number of parameters: 75
Maximum gradient: 9.66494e-005
Akaike information criterion (AIC):   322.037
Number of observations used in the likelihood:
                            Catch    CPUE     S/R Stomach     Sum
                             351      24      39       0     414

objective function weight:
                          Catch  CPUE   S/R
                          1.00  1.00  0.10

unweighted objective function contributions (total):
               Catch    CPUE     S/R   Stom.  Stom N.  Penalty     Sum
              90.2    -6.2    20.2     0.0     0.0      0.00     104
```

```
unweighted objective function contributions (per observation):
                Catch   CPUE     S/R   Stomachs
               0.26   -0.26    0.52    0.00


contribution by fleet:
----------------------
Dredge survey 2010-2021     total:  -6.243   mean:  -0.260

F, season effect:
-----------------
age: 0
    1983-1988:   0.000 1.000
    1989-1998:   0.000 1.000
    1999-2004:   0.000 1.000
    2005-2009:   0.000 1.000
    2010-2021:   0.000 1.000
age: 1 - 4
    1983-1988:   0.475 0.500
    1989-1998:   0.685 0.500
    1999-2004:   0.421 0.500
    2005-2009:   0.191 0.500
    2010-2021:   0.571 0.500

F, age effect:
--------------
                0      1      2      3      4
1983-1988:  0.041  0.280  0.901  1.490  1.490
1989-1998:  0.099  0.337  0.403  0.476  0.476
1999-2004:  0.041  0.598  0.717  0.721  0.721
2005-2009:  0.001  1.960  1.647  1.731  1.731
2010-2021:  0.001  0.270  0.440  0.555  0.555


Exploitation pattern (scaled to mean F=1)
-----------------------------------------
                        0      1      2      3      4
1983-1988 season 1:      0  0.299  0.962  1.592  1.592
          season 2:  0.051  0.175  0.564  0.932  0.932

1989-1998 season 1:      0  0.725  0.868  1.025  1.025
          season 2:  0.109  0.185  0.222  0.262  0.262

1999-2004 season 1:      0  0.310  0.371  0.373  0.373
          season 2:  0.082  0.600  0.719  0.723  0.723

2005-2009 season 1:      0  0.540  0.454  0.477  0.477
          season 2:  0.001  0.546  0.459  0.482  0.482

2010-2021 season 1:      0  0.638  1.038  1.310  1.310
          season 2:  0.001  0.123  0.201  0.254  0.254


sqrt(catch variance) ~ CV:
--------------------------

              season
----------------------
age        1       2

 0               1.641
 1       0.404   0.825
 2       0.404   0.825
```

```
 3       0.880   1.082
 4       0.880   1.082


Survey catchability:
--------------------
                           age 0    age 1
 Dredge survey 2010-2021       0.356   23.650

Stock size dependent catchability (power model)
-----------------------------------------------    age 0    age 1
Dredge survey 2010-2021        1.32     1.00

sqrt(Survey variance) ~ CV:
---------------------------
                           age 0    age 1
 Dredge survey 2010-2021        0.30     0.76

Recruit-SSB            alfa      beta       recruit s2     recruit s
Area-2r           1093.169   5.600e+004   1.038          1.019
```

Table 9.3.6 Sandeel Area-2r. Annual fishing mortality (F) at age.

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
1983	0.037	0.369	1.175	1.936	1.935	0.772
1984	0.034	0.310	0.990	1.638	1.637	0.650
1985	0.022	0.290	0.916	1.500	1.497	0.603
1986	0.025	0.416	1.302	2.115	2.111	0.859
1987	0.008	0.092	0.292	0.482	0.481	0.192
1988	0.027	0.309	0.980	1.610	1.608	0.645
1989	0.076	0.728	0.854	0.996	0.994	0.791
1990	0.037	0.489	0.572	0.664	0.662	0.531
1991	0.070	0.552	0.650	0.760	0.759	0.601
1992	0.051	0.561	0.657	0.765	0.763	0.609
1993	0.080	0.442	0.524	0.618	0.617	0.483
1994	0.050	0.470	0.551	0.643	0.642	0.510
1995	0.043	0.255	0.302	0.356	0.355	0.279
1996	0.132	0.379	0.460	0.554	0.555	0.420
1997	0.083	0.555	0.656	0.770	0.768	0.606
1998	0.046	0.286	0.339	0.398	0.397	0.312
1999	0.036	0.370	0.456	0.471	0.472	0.413
2000	0.017	0.550	0.649	0.648	0.647	0.599
2001	0.036	0.479	0.581	0.594	0.595	0.530
2002	0.020	0.665	0.784	0.782	0.780	0.724
2003	0.037	0.441	0.538	0.552	0.552	0.489
2004	0.030	0.897	1.060	1.060	1.059	0.978
2005	0.001	1.177	0.996	1.060	1.060	1.086
2006	0.001	1.229	1.046	1.119	1.119	1.138

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
2007	0.000	0.752	0.615	0.631	0.628	0.684
2008	0.000	0.808	0.671	0.700	0.699	0.740
2009	0.000	0.773	0.653	0.695	0.695	0.713
2010	0.000	0.393	0.622	0.773	0.771	0.508
2011	0.000	0.254	0.400	0.495	0.493	0.327
2012	0.000	0.145	0.228	0.282	0.281	0.187
2013	0.000	0.628	0.988	1.221	1.217	0.808
2014	0.000	0.476	0.747	0.920	0.917	0.612
2015	0.000	0.419	0.656	0.806	0.804	0.538
2016	0.000	0.181	0.284	0.350	0.349	0.233
2017	0.001	0.815	1.280	1.581	1.577	1.047
2018	0.000	0.245	0.383	0.471	0.469	0.314
2019	0.000	0.057	0.089	0.110	0.110	0.073
2020	0.000	0.560	0.877	1.080	1.077	0.718
2021	0.000	0.110	0.172	0.211	0.211	0.141
arith. mean	0.026	0.485	0.667	0.831	0.830	0.576

Table 9.3.7 Sandeel Area-2r. Fishing mortality (F) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	0.037	0.216	0.127	0.696	0.408	1.151	0.674	1.151	0.674
1984	0.034	0.176	0.115	0.567	0.371	0.938	0.614	0.938	0.614
1985	0.022	0.183	0.076	0.590	0.244	0.976	0.404	0.976	0.404
1986	0.025	0.277	0.087	0.891	0.279	1.474	0.461	1.474	0.461
1987	0.008	0.056	0.028	0.179	0.090	0.296	0.150	0.296	0.150
1988	0.027	0.190	0.091	0.610	0.294	1.010	0.486	1.010	0.486
1989	0.076	0.501	0.128	0.600	0.153	0.709	0.181	0.709	0.181
1990	0.037	0.349	0.062	0.418	0.075	0.494	0.088	0.494	0.088
1991	0.070	0.365	0.119	0.438	0.143	0.517	0.168	0.517	0.168
1992	0.051	0.392	0.087	0.469	0.104	0.554	0.123	0.554	0.123
1993	0.080	0.268	0.136	0.321	0.162	0.379	0.192	0.379	0.192
1994	0.050	0.320	0.085	0.383	0.102	0.452	0.121	0.452	0.121
1995	0.043	0.158	0.073	0.189	0.088	0.223	0.103	0.223	0.103
1996	0.132	0.168	0.225	0.201	0.269	0.238	0.318	0.238	0.318
1997	0.083	0.355	0.141	0.425	0.169	0.502	0.199	0.502	0.199
1998	0.046	0.179	0.078	0.214	0.093	0.253	0.110	0.253	0.110
1999	0.036	0.138	0.267	0.165	0.320	0.166	0.322	0.166	0.322
2000	0.017	0.359	0.127	0.430	0.152	0.433	0.153	0.433	0.153
2001	0.036	0.222	0.267	0.266	0.321	0.268	0.322	0.268	0.322
2002	0.020	0.441	0.144	0.529	0.172	0.532	0.173	0.532	0.173

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
2003	0.037	0.192	0.269	0.230	0.322	0.231	0.324	0.231	0.324
2004	0.030	0.580	0.222	0.695	0.267	0.699	0.268	0.699	0.268
2005	0.001	0.583	0.590	0.490	0.495	0.515	0.521	0.515	0.521
2006	0.001	0.558	0.704	0.469	0.592	0.493	0.622	0.493	0.622
2007	0.000	0.600	0.000	0.505	0.000	0.530	0.000	0.530	0.000
2008	0.000	0.529	0.189	0.444	0.159	0.467	0.167	0.467	0.167
2009	0.000	0.390	0.375	0.328	0.315	0.344	0.331	0.344	0.331
2010	0.000	0.278	0.054	0.452	0.087	0.570	0.110	0.570	0.110
2011	0.000	0.187	0.020	0.305	0.032	0.385	0.040	0.385	0.040
2012	0.000	0.109	0.007	0.178	0.012	0.224	0.015	0.224	0.015
2013	0.000	0.465	0.056	0.756	0.090	0.955	0.114	0.955	0.114
2014	0.000	0.364	0.021	0.592	0.034	0.748	0.043	0.748	0.043
2015	0.000	0.327	0.006	0.533	0.009	0.673	0.011	0.673	0.011
2016	0.000	0.139	0.004	0.226	0.007	0.285	0.009	0.285	0.009
2017	0.001	0.605	0.073	0.985	0.120	1.244	0.151	1.244	0.151
2018	0.000	0.191	0.002	0.310	0.003	0.392	0.003	0.392	0.003
2019	0.000	0.044	0.000	0.072	0.000	0.091	0.000	0.091	0.000
2020	0.000	0.430	0.023	0.699	0.038	0.883	0.048	0.883	0.048
2021	0.000	0.085	0.000	0.139	0.000	0.176	0.000	0.176	0.000
arith. mean	0.026	0.307	0.130	0.436	0.169	0.550	0.209	0.550	0.209

Table 9.3.8 Sandeel Area-2r. Natural mortality (M) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1983	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1984	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1985	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1986	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1987	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1988	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1989	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1990	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1991	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1992	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1993	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1994	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1995	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1996	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1997	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1998	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
1999	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2000	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2001	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2002	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2003	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2004	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2005	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2006	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2007	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2008	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2009	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2010	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2011	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2012	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2013	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2014	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2015	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2016	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2017	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2018	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2019	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2020	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
2021	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41
arith. mean	0.92	0.57	0.59	0.44	0.49	0.32	0.42	0.31	0.41

Table 9.3.9 Sandeel Area-2r. Stock numbers (millions). Age 0 at start of 2nd half-year, age 1+ at start of the year.

	Age 0	Age 1	Age 2	Age 3	Age 4
1983	158917	16431	14521	729	27
1984	47208	61033	3656	1901	58
1985	280397	18190	14296	564	198
1986	60449	109293	4400	2449	92
1987	35468	23489	23822	539	175
1988	174767	14019	6773	7181	219
1989	87304	67817	3319	1082	792
1990	158712	32262	11328	616	370
1991	113021	60965	6701	2730	265
1992	117418	41991	11773	1480	722

	Age 0	Age 1	Age 2	Age 3	Age 4
1993	231610	44462	8156	2619	538
1994	108224	85213	9306	1984	854
1995	77846	41013	17812	2260	768
1996	418473	29716	10206	5331	1048
1997	16077	146094	6290	2516	1752
1998	26957	5897	27887	1370	1018
1999	75193	10260	1429	8087	799
2000	43989	28897	2146	347	2607
2001	133274	17230	5572	473	798
2002	10281	51217	3312	1223	340
2003	47588	4018	8950	648	370
2004	19118	18285	795	2033	281
2005	19287	7392	2570	120	421
2006	27034	7681	717	378	93
2007	40603	10764	681	98	74
2008	25407	16181	1851	162	49
2009	78639	10123	2475	400	54
2010	8418	31324	1476	513	110
2011	11325	3353	7051	340	151
2012	45359	4513	855	1986	154
2013	25698	18075	1259	279	805
2014	17956	10236	3368	213	180
2015	4966	7154	2185	711	86
2016	122957	1979	1608	501	192
2017	3783	48999	538	502	248
2018	9563	1507	7791	70	89
2019	45903	3811	390	2248	52
2020	26409	18293	1143	143	1002
2021	100926	10522	3647	216	219
2022		40221	3028	1252	176

Table 9.3.10 Sandeel Area-2r. Estimated recruitment, total stock biomass (TBS), spawning stock biomass (SSB), catch weight (modelled yield) and average fishing mortality.

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean F_{1-2}
1983	158934067	251523	141775	155664	0.723
1984	47204510	410875	71396	133343	0.615
1985	280476360	277668	134592	110546	0.547
1986	60430228	718573	83200	225470	0.767
1987	35462984	413235	233748	49070	0.176
1988	174773254	273465	184795	149466	0.593

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean $F_{1\text{-}2}$
1989	87312134	439951	53316	223507	0.692
1990	158775212	353697	111190	133874	0.452
1991	113011484	652157	180052	215508	0.532
1992	117388558	441433	135944	184033	0.526
1993	231710661	521263	165215	139826	0.444
1994	108254988	603092	137173	244939	0.445
1995	77827080	584986	240386	113899	0.254
1996	418421560	454272	228891	182562	0.431
1997	16078604	882459	117948	242094	0.545
1998	26963644	392074	302247	99814	0.282
1999	75225438	240168	155749	69427	0.445
2000	43969202	270755	74013	92908	0.534
2001	133284967	198800	85905	90200	0.538
2002	10282973	335242	46444	117388	0.643
2003	47583661	141597	100912	53710	0.506
2004	19115307	154485	37459	110546	0.882
2005	19288122	93467	34269	34396	1.079
2006	27044656	72874	14644	37860	1.162
2007	40588689	77448	11142	43090	0.552
2008	25418810	116369	24441	35604	0.660
2009	78609255	90010	26265	35687	0.704
2010	8418986	201457	23576	51670	0.435
2011	11330401	108620	72475	24896	0.272
2012	45353595	80403	42319	10594	0.153
2013	25699960	131764	25745	47814	0.683
2014	17948193	93429	34787	48033	0.505
2015	4965378	88355	35846	37902	0.437
2016	122914555	36435	26796	5230	0.188
2017	3782894	286154	19141	141314	0.892
2018	9559060	84166	64602	20307	0.253
2019	45901117	69640	40175	5091	0.058
2020	26403312	157776	37235	68932	0.595
2021	100936282	92452	35490	4979	0.112
2022			51277		
arith. mean	78372459	279297	91067	97210	0.521
geo. mean	44633712				

arith. mean for the period 1983–2021

geo. mean for the period 1983–2020

Table 9.3.11 Sandeel Area-2r. Input to forecast.

	Age 0	Age 1	Age 2	Age 3	Age 4
Stock numbers(2022)	19066.388	40221.1	3028.4	1251.88	175.923
Exploitation pattern 1st half		0.085	0.139	0.176	0.176
Exploitation pattern 2nd half	0.000	0.000	0.000	0.000	0.000
Weight in the stock 1st half		5.873	10.367	13.999	16.826
Weight in the catch 1st half		5.873	10.367	13.999	16.826
weight in the catch 2nd half	3.621	8.133	13.271	17.076	19.689
Proportion mature(2022)	0.000	0.020	0.830	1.000	1.000
Proportion mature(2023)	0.000	0.020	0.830	1.000	1.000
Natural mortality 1st half		0.570	0.440	0.320	0.310
Natural mortality 2nd half	0.920	0.590	0.490	0.420	0.410

Table 9.3.12 Sandeel Area-2r. Short term forecast (000 tonnes).

Basis: Fsq=F(2021)=0.1123; Yield(2021)=4.979; Recruitment(2021)=100.936282; Recruitment(2022)=geometric mean (GM 2011-2020)=19.066388 billion; SSB(2022)=51.277

F multiplier	Basis	F(2022)	Catch(2022)	SSB(2023)	%SSB change*	%TAC change**
0.000	F=0	0.000	0.001	137.618	168 %	-100 %
3.920	Fsq*3.92	0.440	71.859	93.977	83 %	1343 %
1.000	Fsq*1	0.112	20.970	124.704	143 %	321 %
3.040	Fsq*3.04	0.341	57.941	102.283	99 %	1064 %
0.080	Fsq*0.08	0.009	1.700	136.567	166 %	-66 %
7.000	Fsq*7	0.786	112.558	70.216	37 %	2161 %
9.000	Fsq*9	1.011	133.602	58.313	14 %	2583 %
11.000	Fsq*11	1.235	151.324	48.551	-5 %	2939 %
13.000	Fsq*13	1.460	166.321	40.520	-21 %	3241 %
5.097	MSY	0.572	88.771	84.000	64 %	1683 %

***SSB in 2023 relative to SSB in 2022**

****TAC in 2022 relative to catches in 2021**

Table 9.4.1 Sandeel Area-3r. Catch at age numbers (million) by half year.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1986	7965	18939	7987	2063	533	161	2	0	0
1987	5	33760	65	14020	4	453	0	200	0
1988	8769	6584	853	17321	233	893	144	19	13
1989	159	47004	190	1844	13	2806	0	4	0
1990	9793	9302	1377	2791	286	413	43	125	13
1991	14442	24009	942	1391	30	526	9	184	3
1992	525	7100	87	2862	8	342	3	215	1
1993	9663	15164	851	558	155	211	71	1336	12

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1994	0	23742	615	4818	684	938	78	386	10
1995	1020	25037	484	1894	78	238	13	156	17
1996	6263	4319	3111	3394	97	465	33	399	248
1997	2975	66856	10388	2912	134	607	13	194	9
1998	30136	3954	992	28137	740	2553	192	290	32
1999	6444	5182	1835	1554	118	1979	401	421	169
2000	0	18793	344	3286	4	541	1	533	9
2001	18263	5327	3968	992	9	163	2	160	6
2002	0	9075	21	2680	3	387	1	135	0
2003	2755	939	61	808	53	130	2	78	1
2004	1091	1976	737	256	16	74	6	92	1
2005	0	1404	1	146	0	21	0	12	0
2006	0	769	3	47	1	27	0	4	0
2007	0	8600	0	571	0	86	0	19	0
2008	0	4077	0	2012	0	460	0	73	0
2009	1	827	12	69	2	8	0	0	0
2010	0	3042	51	740	1	1006	1	173	0
2011	0	1304	0	5224	0	825	0	24	0
2012	0	32	0	186	0	1157	0	356	0
2013	0	648	0	211	0	55	0	42	0
2014	0	5384	0	2373	0	643	0	319	0
2015	0	6451	0	2340	0	956	0	99	0
2016	0	156	0	2006	0	415	0	284	0
2017	0	11734	0	671	0	434	0	409	0
2018	0	413	6	6631	48	40	1	305	1
2019	0	7105	0	716	0	4241	0	131	0
2020	0	21133	0	1981	0	391	0	1249	0
2021	11	3211	6	2768	1	530	0	1378	0
arith. mean	3341	11204	972	3396	90	699	28	272	15

Table 9.4.2 Sandeel Area-3r. Individual mean weight (gram) at age in the catch and in the sea.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1986	4.0	6.1	12.7	9.7	21.0	12.4	18.9	15.9	20.4
1987	6.9	6.4	12.8	11.7	20.4	20.5	31.6	22.5	29.6
1988	4.1	5.1	6.4	13.1	16.1	23.0	22.5	36.2	31.5
1989	4.8	6.1	9.3	10.5	12.7	14.3	14.0	18.8	17.5
1990	4.4	7.5	7.7	9.8	11.2	15.2	16.5	20.2	19.8
1991	3.7	7.3	5.7	11.4	13.8	36.4	27.5	26.3	16.3

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1992	4.6	6.1	13.4	10.3	26.7	14.7	28.7	23.0	30.9
1993	3.5	5.8	7.3	16.4	16.7	17.9	20.8	23.3	22.4
1994	3.6	6.1	13.0	14.6	20.8	20.6	35.2	21.1	27.1
1995	4.7	5.6	8.2	9.7	10.2	13.8	13.7	16.5	16.1
1996	2.5	8.8	8.0	13.3	14.0	26.1	15.7	38.5	24.0
1997	2.9	5.2	6.7	10.1	10.2	13.7	14.2	18.3	14.4
1998	3.2	5.0	7.0	10.1	15.2	13.7	17.3	20.3	20.7
1999	8.7	7.4	14.5	10.1	19.4	14.1	21.1	26.3	30.7
2000	5.2	6.9	10.8	10.5	17.4	15.3	23.7	20.5	25.6
2001	5.6	6.8	8.9	13.7	16.0	17.8	15.9	23.2	25.5
2002	9.4	8.1	19.7	12.7	31.6	14.6	43.2	19.2	46.7
2003	4.3	5.3	5.4	14.6	15.3	20.3	24.1	26.9	26.7
2004	5.8	7.3	7.3	9.5	14.1	14.5	18.4	15.1	12.7
2005	3.4	7.8	7.0	16.5	11.2	19.9	15.3	22.6	16.6
2006	11.0	7.5	23.1	13.5	36.9	17.1	50.5	26.9	54.5
2007	4.1	7.5	8.6	15.1	13.9	21.7	18.9	14.6	20.5
2008	4.1	8.0	8.6	15.0	13.9	22.0	18.9	25.8	20.5
2009	4.2	6.3	8.8	10.4	14.1	19.9	19.2	12.1	20.8
2010	2.5	7.5	5.2	17.7	8.3	20.7	11.4	24.3	12.3
2011	4.1	7.7	8.6	12.6	13.9	19.4	18.9	36.2	20.5
2012	4.1	9.9	8.6	15.2	13.9	22.7	18.9	30.0	20.5
2013	4.1	9.1	8.6	11.6	13.9	14.3	18.9	16.2	20.5
2014	4.1	8.6	8.6	12.7	13.9	13.9	18.9	18.3	20.5
2015	3.8	8.3	8.4	12.7	15.4	19.3	20.2	30.1	21.9
2016	3.8	4.0	8.4	12.4	15.4	19.8	20.2	32.1	21.9
2017	3.8	7.7	8.4	11.9	15.4	17.7	20.2	24.2	21.9
2018	3.8	5.8	8.4	9.9	15.4	13.5	20.2	20.6	21.9
2019	3.8	8.5	8.4	11.6	15.4	15.2	20.2	20.2	21.9
2020	3.8	8.8	8.4	14.6	15.4	17.2	20.2	19.3	21.9
2021	3.8	12.8	8.4	19.8	15.4	27.8	20.2	34.0	21.9
arith. mean	4.6	7.2	9.4	12.6	16.2	18.4	21.5	23.3	23.3

Table 9.4.3 Sandeel Area-3r. Proportion mature.

	Age 1	Age 2	Age 3	Age 4
1983-2016	0.04	0.77	1	1

Table 9.4.4. Sandeel Area-3r. Dredge survey indices.

Year	Age 0	Age 1
2005	68667.988	
2006	55709.239	1225.934
2007	10611.085	3717.149
2008	16658.095	1521.160
2009	37088.951	16328.039
2010	1844.740	5076.749
2011	973.111	1961.856
2012	47713.266	767.514
2013	174467.733	790.887
2014	92703.238	5349.152
2015	2667.397	11100.794
2016	194644.941	322.967
2017	6359.000	15640.000
2018	82359.000	5980.000
2019	112538.400	10448.300
2020	69976.000	20816.000
2021	23486.023	6259.908

Table 9.4.5 Sandeel Area-3r. SMS settings and statistics.

```
Date: 01/26/22  Start time:09:44:46 run time:1 seconds

objective function (negative log likelihood):  124.547
Number of parameters: 61
Maximum gradient: 4.83144e-005
Akaike information criterion (AIC):   371.094
Number of observations used in the likelihood:
                            Catch    CPUE     S/R Stomach     Sum
                             324      85      36       0     445

objective function weight:
                          Catch  CPUE   S/R
                          1.00  1.00  0.01

unweighted objective function contributions (total):
                Catch    CPUE    S/R   Stom.  Stom N.  Penalty     Sum
              102.4    22.0    17.9     0.0     0.0      0.00     142


unweighted objective function contributions (per observation):
                Catch   CPUE     S/R   Stomachs
               0.32    0.26    0.50    0.00


contribution by fleet:
----------------------
Dredge survey 2004-2021     total:   4.217   mean:   0.128
Acoustic survey             total:  17.760   mean:   0.342

F, season effect:
```

```
-----------------
age: 0
    1986-1998:   0.000 1.000
    1999-2021:   0.000 1.000
age: 1 - 4
    1986-1998:   0.883 0.500
    1999-2021:   1.021 0.500

F, age effect:
--------------
               0      1      2      3      4
1986-1998:  0.103  0.372  0.413  0.333  0.333
1999-2021:  0.056  0.169  0.254  0.243  0.243


Exploitation pattern (scaled to mean F=1)
-----------------------------------------
                       0      1      2      3      4
1986-1998 season 1:      0  0.640  0.710  0.574  0.574
          season 2:  0.170  0.308  0.342  0.276  0.276

1999-2021 season 1:      0  0.551  0.827  0.790  0.790
          season 2:  0.164  0.249  0.373  0.357  0.357


sqrt(catch variance) ~ CV:
--------------------------

              season
----------------------
age        1       2

 0               1.132
 1       0.673   1.038
 2       0.673   1.038
 3       1.021   1.232
 4       1.021   1.232


Survey catchability:
--------------------
                           age 0    age 1    age 2    age 3    age 4
 Dredge survey 2004-2021       0.509    0.509
 Acoustic survey                        3.011    4.839    4.611    4.611

Stock size dependent catchability (power model)
-----------------------------------------------    age 0    age 1    age 2    age 3
age 4
Dredge survey 2004-2021        1.03     1.00
Acoustic survey                           1.00     1.00     1.00     1.00

sqrt(Survey variance) ~ CV:
---------------------------
                           age 0    age 1    age 2    age 3    age 4
 Dredge survey 2004-2021        0.61     0.79
 Acoustic survey                         0.69     0.69     1.06     1.06

Recruit-SSB            alfa      beta       recruit s2     recruit s
Area-3r            1481.927   8.000e+004   0.994          0.997
```

Table 9.4.6 Sandeel Area-3r. Annual fishing mortality (F) at age.

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
1986	0.076	0.453	0.495	0.399	0.401	0.474
1987	0.001	0.713	0.758	0.598	0.596	0.736
1988	0.051	0.915	0.975	0.778	0.778	0.945
1989	0.003	1.033	1.097	0.885	0.882	1.065
1990	0.050	0.580	0.623	0.502	0.502	0.602
1991	0.040	0.701	0.753	0.603	0.602	0.727
1992	0.003	0.326	0.346	0.270	0.270	0.336
1993	0.042	0.604	0.651	0.519	0.518	0.628
1994	0.016	0.646	0.692	0.540	0.537	0.669
1995	0.007	0.514	0.553	0.434	0.433	0.534
1996	0.043	0.504	0.547	0.432	0.431	0.525
1997	0.066	0.906	0.982	0.790	0.786	0.944
1998	0.140	1.149	1.255	1.014	1.007	1.202
1999	0.140	0.733	1.091	1.028	1.023	0.912
2000	0.004	0.754	1.089	0.993	0.987	0.922
2001	0.145	0.473	0.714	0.682	0.685	0.594
2002	0.000	0.496	0.709	0.673	0.670	0.602
2003	0.019	0.265	0.383	0.368	0.367	0.324
2004	0.019	0.184	0.268	0.259	0.258	0.226
2005	0.000	0.089	0.128	0.120	0.119	0.108
2006	0.000	0.038	0.054	0.051	0.051	0.046
2007	0.000	0.224	0.323	0.302	0.301	0.274
2008	0.000	0.242	0.349	0.332	0.331	0.295
2009	0.000	0.020	0.030	0.028	0.028	0.025
2010	0.000	0.262	0.382	0.359	0.356	0.322
2011	0.000	0.170	0.246	0.233	0.230	0.208
2012	0.000	0.103	0.149	0.143	0.142	0.126
2013	0.000	0.050	0.073	0.070	0.069	0.061
2014	0.000	0.200	0.290	0.277	0.275	0.245
2015	0.000	0.262	0.381	0.364	0.362	0.322
2016	0.000	0.103	0.149	0.143	0.142	0.126
2017	0.000	0.227	0.330	0.316	0.313	0.279
2018	0.000	0.243	0.352	0.337	0.335	0.297
2019	0.000	0.364	0.528	0.506	0.502	0.446
2020	0.000	0.610	0.883	0.846	0.840	0.747
2021	0.000	0.370	0.537	0.514	0.510	0.453
arith. mean	0.024	0.431	0.532	0.464	0.462	0.482

Table 9.4.7 Sandeel Area-3r. Fishing mortality (F) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1986	0.076	0.285	0.137	0.317	0.152	0.256	0.123	0.256	0.123
1987	0.001	0.576	0.002	0.639	0.002	0.516	0.002	0.516	0.002
1988	0.051	0.686	0.093	0.761	0.103	0.615	0.083	0.615	0.083
1989	0.003	0.863	0.006	0.957	0.007	0.774	0.005	0.774	0.005
1990	0.050	0.425	0.090	0.472	0.100	0.381	0.081	0.381	0.081
1991	0.040	0.540	0.072	0.600	0.080	0.484	0.064	0.484	0.064
1992	0.003	0.261	0.006	0.289	0.007	0.234	0.005	0.234	0.005
1993	0.042	0.449	0.076	0.498	0.084	0.403	0.068	0.403	0.068
1994	0.016	0.502	0.029	0.557	0.032	0.450	0.026	0.450	0.026
1995	0.007	0.408	0.013	0.453	0.014	0.366	0.012	0.366	0.012
1996	0.043	0.358	0.078	0.397	0.086	0.321	0.070	0.321	0.070
1997	0.066	0.670	0.119	0.744	0.133	0.601	0.107	0.601	0.107
1998	0.140	0.794	0.254	0.881	0.282	0.712	0.228	0.712	0.228
1999	0.140	0.470	0.212	0.705	0.318	0.674	0.304	0.674	0.304
2000	0.004	0.592	0.006	0.889	0.008	0.850	0.008	0.850	0.008
2001	0.145	0.247	0.220	0.371	0.330	0.354	0.315	0.354	0.315
2002	0.000	0.368	0.000	0.553	0.000	0.528	0.000	0.528	0.000
2003	0.019	0.183	0.029	0.274	0.044	0.262	0.042	0.262	0.042
2004	0.019	0.126	0.029	0.190	0.043	0.181	0.041	0.181	0.041
2005	0.000	0.069	0.000	0.103	0.000	0.098	0.000	0.098	0.000
2006	0.000	0.029	0.000	0.044	0.001	0.042	0.001	0.042	0.001
2007	0.000	0.178	0.000	0.267	0.000	0.255	0.000	0.255	0.000
2008	0.000	0.197	0.000	0.295	0.000	0.282	0.000	0.282	0.000
2009	0.000	0.017	0.000	0.025	0.000	0.024	0.000	0.024	0.000
2010	0.000	0.213	0.001	0.319	0.001	0.305	0.001	0.305	0.001
2011	0.000	0.135	0.000	0.203	0.000	0.194	0.000	0.194	0.000
2012	0.000	0.082	0.000	0.123	0.000	0.118	0.000	0.118	0.000
2013	0.000	0.040	0.000	0.060	0.000	0.057	0.000	0.057	0.000
2014	0.000	0.160	0.000	0.240	0.000	0.230	0.000	0.230	0.000
2015	0.000	0.211	0.000	0.316	0.000	0.303	0.000	0.303	0.000
2016	0.000	0.082	0.000	0.123	0.000	0.118	0.000	0.118	0.000
2017	0.000	0.183	0.000	0.274	0.000	0.262	0.000	0.262	0.000
2018	0.000	0.195	0.000	0.292	0.000	0.280	0.000	0.280	0.000
2019	0.000	0.294	0.000	0.441	0.000	0.422	0.000	0.422	0.000
2020	0.000	0.497	0.000	0.745	0.000	0.712	0.000	0.712	0.000
2021	0.000	0.299	0.000	0.448	0.000	0.428	0.000	0.428	0.000
arith. mean	0.024	0.325	0.041	0.413	0.051	0.364	0.044	0.364	0.044

Table 9.4.8 Sandeel Area-3r. Natural mortality (M) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1986	1.340	0.760	0.60	0.600	0.470	0.420	0.370	0.360	0.350
1987	1.430	0.750	0.57	0.600	0.440	0.420	0.350	0.360	0.340
1988	1.540	0.710	0.58	0.570	0.430	0.390	0.350	0.350	0.340
1989	1.330	0.680	0.49	0.550	0.360	0.390	0.330	0.360	0.320
1990	1.280	0.630	0.48	0.490	0.350	0.340	0.300	0.310	0.290
1991	1.220	0.630	0.47	0.490	0.350	0.330	0.290	0.300	0.280
1992	1.190	0.650	0.52	0.490	0.390	0.330	0.290	0.300	0.290
1993	1.140	0.670	0.52	0.510	0.400	0.350	0.320	0.330	0.310
1994	1.110	0.690	0.58	0.530	0.460	0.360	0.340	0.340	0.320
1995	1.010	0.710	0.55	0.560	0.450	0.410	0.350	0.380	0.340
1996	0.990	0.660	0.57	0.530	0.470	0.390	0.360	0.360	0.350
1997	0.900	0.640	0.53	0.520	0.430	0.400	0.380	0.380	0.360
1998	0.970	0.630	0.51	0.490	0.410	0.380	0.360	0.350	0.330
1999	1.040	0.730	0.58	0.540	0.470	0.360	0.330	0.330	0.300
2000	1.120	0.800	0.65	0.610	0.550	0.420	0.390	0.390	0.370
2001	1.190	0.820	0.78	0.660	0.670	0.490	0.510	0.450	0.490
2002	1.220	0.840	0.80	0.720	0.670	0.580	0.630	0.540	0.610
2003	1.220	0.830	0.77	0.720	0.640	0.580	0.620	0.540	0.600
2004	1.210	0.850	0.70	0.710	0.570	0.560	0.550	0.510	0.530
2005	1.150	0.840	0.65	0.690	0.530	0.500	0.470	0.470	0.450
2006	1.120	0.820	0.61	0.660	0.490	0.480	0.420	0.440	0.410
2007	1.050	0.770	0.58	0.610	0.470	0.450	0.400	0.420	0.390
2008	0.990	0.680	0.50	0.550	0.400	0.430	0.380	0.400	0.370
2009	0.990	0.590	0.47	0.480	0.390	0.370	0.340	0.340	0.330
2010	1.110	0.590	0.50	0.450	0.420	0.360	0.370	0.330	0.350
2011	1.210	0.660	0.55	0.510	0.460	0.390	0.420	0.350	0.390
2012	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2013	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2014	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2015	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2016	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2017	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2018	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2019	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2020	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
2021	1.190	0.700	0.54	0.550	0.450	0.420	0.440	0.390	0.420
arith. mean	1.166	0.712	0.57	0.565	0.462	0.419	0.406	0.386	0.389

Table 9.4.9 Sandeel Area-3r. Stock numbers (millions). Age 0 at start of 2nd half-year, age 1+ at start of the year.

	Age 0	Age 1	Age 2	Age 3	Age 4
1986	510341	81391	5618	276	690
1987	116127	123867	13687	1206	318
1988	360728	27760	18563	2547	426
1989	107678	73467	3507	2877	711
1990	198082	28385	9565	538	808
1991	124100	52392	5586	2330	458
1992	257964	35216	9456	1223	872
1993	190940	78219	8373	2918	899
1994	180436	58569	14079	1883	1229
1995	153307	58535	9679	2905	976
1996	742461	55439	10896	2209	1257
1997	63923	264307	10483	2472	1124
1998	93207	24330	37233	1688	822
1999	121485	30713	2729	4733	478
2000	133994	37321	4190	357	988
2001	127087	43558	4814	536	264
2002	31976	33433	5513	632	154
2003	72768	9440	4487	790	140
2004	47107	21074	1542	838	209
2005	80268	13782	3830	340	280
2006	114995	25416	2900	1020	218
2007	58672	37512	5905	878	487
2008	89724	20532	8141	1536	459
2009	137164	33339	5181	2343	675
2010	15674	50962	11359	2117	1462
2011	11102	5163	13841	3455	1297
2012	84278	3310	1345	4283	1775
2013	207141	25639	882	437	2313
2014	223070	63017	7129	306	1146
2015	8121	67853	15536	2062	508
2016	705102	2471	15900	4165	812
2017	32491	214507	659	5171	1888
2018	223823	9884	51718	184	2331
2019	303286	68092	2354	14201	843
2020	160646	92266	14685	557	4188
2021	77181	48872	16249	2565	1030
2022		23480	10490	3818	1005

Table 9.4.10 Sandeel Area-3r. Estimated recruitment, total stock biomass (TBS), spawning stock biomass (SSB), catch weight (modelled yield) and average fishing mortality.

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean F_{1-2}
1986	510550442	567338	74236	282315	0.446
1987	116104360	987817	182773	395296	0.610
1988	360859773	458951	265136	330358	0.822
1989	107715064	541626	98913	350409	0.916
1990	198044042	330066	104089	163224	0.544
1991	124149867	544535	159692	274839	0.646
1992	257878732	350577	120451	86788	0.281
1993	190850317	662154	194464	175786	0.554
1994	180456444	625916	234685	267281	0.559
1995	153314205	476147	140225	173607	0.444
1996	742104035	738395	234451	159024	0.459
1997	63910869	1541930	185350	470670	0.833
1998	93175931	535338	331373	462081	1.105
1999	121448395	332708	108662	191253	0.852
2000	133953060	326032	68665	186837	0.748
2001	127038405	378300	76726	193684	0.584
2002	31960138	352699	75660	116298	0.461
2003	72783512	135401	71754	34673	0.265
2004	47110195	183270	32048	31285	0.194
2005	80277505	183214	65382	13991	0.086
2006	114949102	252982	60114	7094	0.037
2007	58644245	395299	104402	74972	0.222
2008	89701675	332573	145365	74933	0.246
2009	137206823	319880	103570	6261	0.021
2010	15665948	662839	247459	61241	0.267
2011	11106044	327267	248451	92452	0.169
2012	84309069	203662	167376	40116	0.103
2013	207159586	287986	59934	9844	0.050
2014	223070852	654582	113777	90876	0.200
2015	8121294	815063	226160	104631	0.264
2016	705205636	315656	260146	42845	0.103
2017	32475613	1791780	202400	115642	0.228
2018	223741069	617770	442856	75388	0.244
2019	303229348	838505	275130	135899	0.368
2020	160691992	1118810	284077	246139	0.621

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean F_{1-2}
2021	77206947	1051620	375120	157472	0.373
2022			210029		
arith. mean	171290233	562186	171661	158208	0.415
geo. mean	112898529				

arith. mean for the period 1986–2021

geo. mean for the period 1986–2020

Table 9.4.11 Sandeel Area-3r. Input to forecast.

	Age 0	Age 1	Age 2	Age 3	Age 4
Stock numbers(2022)	112945.768	23480.1	10489.9	3818.36	1005.44
Exploitation pattern 1st half		0.299	0.448	0.428	0.428
Exploitation pattern 2nd half	0.000	0.000	0.000	0.000	0.000
Weight in the stock 1st half		8.716	13.566	18.282	23.645
Weight in the catch 1st half		8.716	13.566	18.282	23.645
weight in the catch 2nd half	3.782	8.413	15.411	20.172	21.859
Proportion mature(2022)	0.000	0.036	0.766	1.000	1.000
Proportion mature(2023)	0.000	0.036	0.766	1.000	1.000
Natural mortality 1st half		0.700	0.550	0.420	0.390
Natural mortality 2nd half	1.190	0.540	0.450	0.440	0.420

Table 9.4.12 Sandeel Area-3r. Short term forecast (000 tonnes).

Basis: Fsq=F(2021)=0.3735; Yield(2021)=157.472; Recruitment(2021)=77.206947; Recruitment(2022)=geometric mean (GM 1986-2020)=112.945768 billion; SSB(2022)=210.029

F multiplier	Basis	F(2022)	Catch(2022)	SSB(2023)	%SSB change*	%TAC change**
0.000	F=0	0.000	0.001	200.747	-4 %	-100 %
0.780	Fsq*0.78	0.290	85.559	151.563	-28 %	-46 %
1.000	Fsq*1	0.373	106.151	140.019	-33 %	-33 %
0.400	Fsq*0.4	0.149	46.963	173.527	-17 %	-70 %
0.600	Fsq*0.6	0.224	68.080	161.460	-23 %	-57 %
0.800	Fsq*0.8	0.299	87.775	150.315	-28 %	-44 %
0.100	Fsq*0.1	0.037	12.371	193.529	-8 %	-92 %
0.120	Fsq*0.12	0.045	14.793	192.120	-9 %	-91 %
0.140	Fsq*0.14	0.052	17.198	190.722	-9 %	-89 %
1.233	MSY	0.461	126.038	129.000	-39 %	-20 %

***SSB in 2023 relative to SSB in 2022**

****TAC in 2022 relative to catches in 2021**

Table 9.4.13. Sandeel Area-3r. Acoustic survey indices (millions of individuals).

Year	Age 1	Age 2	Age 3	Age 4
2009	7709.06 (CV=0.29)	4923.33 (CV=0.34)	945.29 (CV=0.3)	64.03 (CV=0.47)
2010	16852.06 (CV=0.19)	6133.6 (CV=0.18)	1123.19 (CV=0.38)	608.57 (CV=0.4)
2011	816.16 (CV=0.73)	8622.2 (CV=0.19)	855.81 (CV=0.33)	192.37 (CV=0.49)
2012	846.68 (CV=0.81)	211.31 (CV=0.67)	3226.29 (CV=0.25)	368.16 (CV=0.24)
2013	2154.47 (CV=0.2)	258.25 (CV=0.36)	72.62 (CV=0.41)	554.48 (CV=0.43)
2014	21889.62 (CV=0.23)	1711.1 (CV=0.36)	170.41 (CV=0.64)	80.34 (CV=0.85)
2015	9466.6 (CV=0.12)	2254.92 (CV=0.27)	686.55 (CV=0.29)	7.03 (CV=1.18)
2016	79.55 (CV=1)	6317.38 (CV=0.29)	679.13 (CV=0.25)	259.1 (CV=0.37)
2017	35267.58 (CV=0.16)	131.65 (CV=0.77)	3465.88 (CV=0.27)	631.09 (CV=0.27)
2018	1544.39 (CV=0.31)	16989.62 (CV=0.1)	79.82 (CV=0.34)	440.33 (CV=0.31)
2019	9564.52 (CV=0.16)	464.24 (CV=0.25)	15573.73 (CV=0.12)	214.53 (CV=0.33)
2020	42141.65 (CV=0.27)	10064.47 (CV=0.27)	535.24 (CV=0.42)	9944.09 (CV=0.2)
2021	14564.25 (CV=0.19)	12971.11 (CV=0.17)	2770.14 (CV=0.2)	285.07 (CV=0.33)

Table 9.5.1 Sandeel Area-4. Catch at age numbers (million) by half year.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1993	674	1235	149	6337	381	1861	122	534	39
1994	0	1070	256	1522	62	5144	257	2092	159
1995	4	2690	4	1229	1	529	0	30	0
1996	2666	754	2584	2536	3461	476	227	130	1110
1997	0	2879	1369	291	35	1683	43	413	10
1998	0	2159	61	3766	97	235	6	130	3
1999	0	1472	86	1137	46	1543	47	252	11
2000	0	6537	0	376	0	323	0	297	0
2001	0	2048	64	4961	20	601	1	377	0
2002	0	337	0	807	0	511	0	101	0
2003	145	4322	148	1002	10	2721	5	1253	1
2004	0	920	4	220	1	45	0	82	0
2005	0	49	0	145	0	32	0	17	0
2006	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0
2012	0	83	0	40	0	196	0	3	0
2013	0	182	0	100	0	71	0	133	0
2014	0	346	0	54	0	15	0	47	0

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
2015	0	866	0	29	0	9	0	14	0
2016	0	181	0	406	0	20	0	36	0
2017	0	719	0	468	0	578	0	30	0
2018	0	874	0	1259	0	355	0	1133	0
2019	0	314	0	159	0	143	0	60	0
2020	33	2363	17	256	0	72	0	82	0
2021	2	3323	16	2196	83	354	11	383	42
arith. mean	122	1232	164	1010	145	604	25	263	47

Table 9.5.2 Sandeel Area-4. Individual mean weight (gram) at age in the catch and in the sea.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1993	3.0	7.4	6.7	11.9	12.0	14.9	14.0	20.1	18.9
1994	3.8	10.9	8.6	11.1	15.5	14.7	18.0	20.5	24.4
1995	4.4	8.4	10.1	15.7	18.0	19.1	21.0	15.5	28.5
1996	6.3	5.3	7.3	12.9	13.1	18.6	18.0	23.0	22.3
1997	3.1	6.7	7.0	7.5	12.4	11.2	14.5	18.1	19.6
1998	2.6	6.1	6.0	10.4	10.7	13.6	12.5	14.6	16.9
1999	3.2	6.1	7.2	10.8	12.9	16.1	15.1	20.2	20.4
2000	4.0	3.9	9.0	8.0	16.2	13.2	18.8	17.3	25.5
2001	1.8	3.4	4.2	6.0	7.5	9.0	8.7	14.2	11.8
2002	4.0	3.8	9.0	5.9	16.2	9.5	18.8	17.9	25.5
2003	3.6	4.6	5.6	6.6	6.2	8.1	7.8	10.9	10.1
2004	1.4	4.0	3.3	7.4	5.8	9.3	6.8	13.8	9.2
2005	4.0	4.2	9.0	6.1	16.2	8.6	18.8	11.0	25.5
2006	4.0	5.5	9.0	10.0	16.2	14.3	18.8	18.1	25.5
2007	4.0	4.8	9.0	8.8	16.2	12.6	18.8	16.0	25.5
2008	4.0	4.8	9.0	8.7	16.2	12.4	18.8	15.7	25.5
2009	4.0	5.8	9.0	10.7	16.2	15.2	18.8	19.3	25.5
2010	4.0	5.1	9.0	9.4	16.2	13.4	18.8	17.0	25.5
2011	4.0	4.9	9.0	8.9	16.2	12.7	18.8	16.1	25.5
2012	4.0	4.0	9.0	8.2	16.2	9.6	18.8	12.2	25.5
2013	4.0	5.3	9.0	9.3	16.2	14.7	18.8	17.1	25.5
2014	4.0	7.1	9.0	12.4	16.2	17.2	18.8	20.0	25.5
2015	4.4	4.4	7.7	9.5	10.7	11.4	14.6	16.2	17.6
2016	4.4	5.0	7.7	9.9	10.7	18.1	14.6	24.7	17.6
2017	4.4	7.5	7.7	10.2	10.7	13.4	14.6	18.5	17.6
2018	4.4	5.7	7.7	9.4	10.7	13.1	14.6	18.3	17.6
2019	4.4	5.9	7.7	10.2	10.7	13.7	14.6	20.2	17.6

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
2020	4.4	6.7	7.7	8.6	10.7	11.9	14.6	12.4	17.6
2021	4.4	5.6	7.7	9.2	10.7	11.9	14.6	17.8	17.6
arith. mean	3.9	5.6	7.9	9.4	13.2	13.2	16.0	17.1	21.1

Table 9.5.3 Sandeel Area-4. Proportion mature.

	Age 1	Age 2	Age 3	Age 4
1983-2016	0	0.79	0.98	1

Table 9.5.4. Sandeel Area-4. Dredge survey indices.

Year	Age 0	Age 1
1999	615	494
2000	586	3170
2001	48	2656
2002	243	404
2003	580	
2004		
2005		
2006		
2007		
2008	52	24
2009	832	87
2010	147	1032
2011	89	165
2012	95	135
2013	62	85
2014	445	43
2015	136	1044
2016	300	81
2017	346	223
2018	16	461
2019	371	92
2020	585	1010
2021	160	194

Table 9.5.5 Sandeel Area-4. SMS settings and statistics.

```
Date: 01/26/22  Start time:09:43:34 run time:1 seconds

objective function (negative log likelihood):  14.7669
Number of parameters: 48
Maximum gradient: 2.44224e-005
Akaike information criterion (AIC):   125.534
Number of observations used in the likelihood:
                            Catch    CPUE     S/R Stomach     Sum
                             261      37      29       0     327

objective function weight:
                          Catch  CPUE   S/R
                          1.00  1.00  0.05

unweighted objective function contributions (total):
                Catch    CPUE    S/R   Stom.  Stom N.  Penalty     Sum
               36.9   -23.1    20.4     0.0     0.0      0.00      34


unweighted objective function contributions (per observation):
                Catch   CPUE     S/R   Stomachs
               0.14   -0.63    0.70    0.00


contribution by fleet:
----------------------
New Dredge survey 2008-2021     total: -13.592   mean:  -0.485
Old Dredge survey 1999-2003     total:  -9.555   mean:  -1.062

F, season effect:
-----------------
age: 0
    1993-2021:   0.000 1.000
age: 1 - 4
    1993-2021:   0.724 0.500

F, age effect:
--------------
                0      1      2      3      4
1993-2021:  0.002  0.097  0.194  0.274  0.274


Exploitation pattern (scaled to mean F=1)
-----------------------------------------
                        0      1      2      3      4
1993-2021 season 1:      0  0.601  1.205  1.704  1.704
          season 2:  0.003  0.065  0.129  0.183  0.183


sqrt(catch variance) ~ CV:
--------------------------

              season
----------------------
age        1       2

 0               2.102
 1       0.736   0.587
 2       0.736   0.587
 3       0.679   1.240
 4       0.679   1.240
```

```
Survey catchability:
--------------------
                           age 0    age 1
 New Dredge survey 2008-2021       0.790    4.221
 Old Dredge survey 1999-2003       0.784   18.050

sqrt(Survey variance) ~ CV:
---------------------------
                           age 0    age 1
 New Dredge survey 2008-2021        0.55     0.30
 Old Dredge survey 1999-2003        0.30     0.30

Recruit-SSB            alfa      beta       recruit s2     recruit s
Area-4            1250.432   4.800e+004   1.500          1.225
```

Table 9.5.6 Sandeel Area-4. Annual fishing mortality (F) at age.

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
1993	0.001	0.346	0.671	0.923	0.921	0.509
1994	0.001	0.402	0.778	1.067	1.064	0.590
1995	0.000	0.120	0.232	0.316	0.315	0.176
1996	0.006	0.234	0.479	0.696	0.700	0.357
1997	0.001	0.148	0.289	0.400	0.399	0.218
1998	0.000	0.161	0.312	0.427	0.426	0.237
1999	0.000	0.234	0.450	0.613	0.610	0.342
2000	0.000	0.116	0.224	0.306	0.304	0.170
2001	0.000	0.182	0.351	0.479	0.477	0.266
2002	0.000	0.039	0.075	0.102	0.102	0.057
2003	0.000	0.289	0.558	0.763	0.760	0.423
2004	0.000	0.056	0.108	0.147	0.147	0.082
2005	0.000	0.024	0.047	0.065	0.064	0.036
2006	0.000	0.000	0.001	0.001	0.001	0.001
2007	0.000	0.000	0.001	0.001	0.001	0.000
2008	0.000	0.002	0.004	0.005	0.005	0.003
2009	0.000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.001	0.002	0.003	0.003	0.002
2011	0.000	0.002	0.004	0.005	0.005	0.003
2012	0.000	0.019	0.036	0.049	0.049	0.027
2013	0.000	0.010	0.020	0.027	0.027	0.015
2014	0.000	0.014	0.027	0.036	0.036	0.020
2015	0.000	0.011	0.021	0.029	0.029	0.016
2016	0.000	0.022	0.042	0.057	0.057	0.032
2017	0.000	0.047	0.092	0.125	0.125	0.070
2018	0.000	0.135	0.261	0.356	0.354	0.198
2019	0.000	0.058	0.111	0.152	0.151	0.084

	Age 0	Age 1	Age 2	Age 3	Age 4	Avg. 1-2
2020	0.000	0.046	0.088	0.120	0.120	0.067
2021	0.001	0.357	0.689	0.943	0.940	0.523
arith. mean	0.000	0.106	0.206	0.283	0.282	0.156

Table 9.5.7 Sandeel Area-4. Fishing mortality (F) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1993	0.001	0.260	0.028	0.521	0.056	0.736	0.079	0.736	0.079
1994	0.001	0.305	0.027	0.612	0.053	0.865	0.075	0.865	0.075
1995	0.000	0.094	0.000	0.189	0.000	0.267	0.001	0.267	0.001
1996	0.006	0.112	0.141	0.225	0.283	0.318	0.401	0.318	0.401
1997	0.001	0.106	0.020	0.212	0.039	0.300	0.056	0.300	0.056
1998	0.000	0.124	0.005	0.249	0.010	0.352	0.015	0.352	0.015
1999	0.000	0.185	0.000	0.370	0.000	0.523	0.000	0.523	0.000
2000	0.000	0.091	0.000	0.183	0.000	0.259	0.000	0.259	0.000
2001	0.000	0.142	0.002	0.285	0.004	0.403	0.006	0.403	0.006
2002	0.000	0.030	0.000	0.061	0.000	0.086	0.000	0.086	0.000
2003	0.000	0.223	0.011	0.447	0.021	0.632	0.030	0.632	0.030
2004	0.000	0.044	0.000	0.087	0.001	0.124	0.001	0.124	0.001
2005	0.000	0.019	0.000	0.038	0.000	0.054	0.000	0.054	0.000
2006	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.000
2007	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000
2008	0.000	0.002	0.000	0.003	0.000	0.004	0.000	0.004	0.000
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.001	0.000	0.002	0.000	0.002	0.000	0.002	0.000
2011	0.000	0.001	0.000	0.003	0.000	0.004	0.000	0.004	0.000
2012	0.000	0.015	0.000	0.029	0.000	0.041	0.000	0.041	0.000
2013	0.000	0.008	0.000	0.016	0.000	0.023	0.000	0.023	0.000
2014	0.000	0.011	0.000	0.022	0.000	0.030	0.000	0.030	0.000
2015	0.000	0.009	0.000	0.017	0.000	0.025	0.000	0.025	0.000
2016	0.000	0.017	0.000	0.034	0.000	0.048	0.000	0.048	0.000
2017	0.000	0.037	0.000	0.075	0.000	0.105	0.000	0.105	0.000
2018	0.000	0.106	0.000	0.213	0.000	0.302	0.000	0.302	0.000
2019	0.000	0.045	0.000	0.090	0.000	0.128	0.000	0.128	0.000
2020	0.000	0.036	0.000	0.072	0.000	0.101	0.000	0.101	0.000
2021	0.001	0.274	0.017	0.549	0.034	0.777	0.047	0.777	0.047
arith. mean	0.000	0.079	0.009	0.159	0.017	0.225	0.024	0.225	0.024

Table 9.5.8 Sandeel Area-4. Natural mortality (M) at age.

	Age 0, 2nd half	Age 1, 1st half	Age 1, 2nd half	Age 2, 1st half	Age 2, 2nd half	Age 3, 1st half	Age 3, 2nd half	Age 4+, 1st half	Age 4+, 2nd half
1993	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
1994	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
1995	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
1996	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
1997	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
1998	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
1999	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2000	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2001	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2002	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2003	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2004	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2005	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2006	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2007	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2008	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2009	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2010	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2011	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2012	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2013	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2014	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2015	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2016	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2017	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2018	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2019	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2020	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
2021	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378
arith. mean	1.14	0.767	0.592	0.602	0.488	0.431	0.392	0.398	0.378

Table 9.5.9 Sandeel Area-4. Stock numbers (millions). Age 0 at start of 2nd half-year, age 1+ at start of the year.

	Age 0	Age 1	Age 2	Age 3	Age 4
1993	118989	25765	23897	7791	1483
1994	233754	38010	4965	4515	1816
1995	62359	74674	7008	858	1100
1996	329020	19943	17455	1950	676

	Age 0	Age 1	Age 2	Age 3	Age 4
1997	93616	104596	3976	3531	569
1998	42109	29915	23698	1039	1269
1999	225520	13464	6752	6146	721
2000	182791	72126	2876	1568	1796
2001	23268	58460	16913	805	1170
2002	79947	7441	13001	4259	593
2003	154617	25568	1854	4113	1966
2004	11572	49427	5200	390	1398
2005	6949	3701	12154	1601	720
2006	4248	2222	933	3932	980
2007	6307	1359	571	313	2176
2008	19031	2017	349	192	1138
2009	276709	6086	517	117	605
2010	47595	88497	1564	174	330
2011	35026	15222	22718	525	228
2012	27988	11202	3905	7616	334
2013	18201	8951	2836	1275	3357
2014	254612	5821	2281	938	2057
2015	34055	81430	1479	751	1318
2016	73102	10892	20740	489	913
2017	90992	23379	2751	6741	605
2018	23107	29101	5787	859	2915
2019	200668	7390	6722	1572	1271
2020	62418	64177	1815	2064	1122
2021	46546	19962	15909	568	1286
2022		14876	3834	2987	369

Table 9.5.10 Sandeel Area-4. Estimated recruitment, total stock biomass (TBS), spawning stock biomass (SSB), catch weight (modelled yield) and average fishing mortality.

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean F_{1-2}
1993	119043556	618393	366957	132599	0.432
1994	233805469	571687	145801	158690	0.498
1995	62332904	772094	120090	52591	0.142
1996	329142057	382202	228662	158490	0.381
1997	93642978	779492	72330	58446	0.189
1998	42118600	459550	226387	58746	0.195
1999	225538177	268367	169397	53334	0.277
2000	182817693	354099	69564	37714	0.137
2001	23277552	323825	103881	47902	0.217
2002	79957036	156276	111302	12736	0.046

	Recruits (thousands)	TSB (tonnes)	SSB (tonnes)	Yield (tonnes)	Mean F_{1-2}
2003	154545638	184694	63831	63731	0.351
2004	11570855	259656	53210	6882	0.066
2005	6948247	111495	79937	1557	0.029
2006	4248175	95431	80178	0	0.000
2007	6305924	50393	42702	0	0.000
2008	19038999	32923	22652	0	0.002
2009	276577049	54412	17771	0	0.000
2010	47583661	475943	19456	0	0.001
2011	35039971	286284	169736	0	0.002
2012	27979985	154307	101114	2585	0.022
2013	18201235	149987	96761	5225	0.012
2014	254548005	126895	79301	4314	0.016
2015	34038405	399110	40905	4392	0.013
2016	73075229	291562	193881	6188	0.025
2017	90966330	305129	121905	18474	0.056
2018	23115178	285935	107474	42296	0.160
2019	200635422	159464	100811	6651	0.068
2020	62395268	481854	50312	20101	0.054
2021	46548252	288685	145656	51882	0.437
2022			72766		
arith. mean	96038438	306212	109151	34673	0.132
geo. mean	54570282				

arith. mean for the period 1993–2021

geo. mean for the period 1993–2020

Table 9.5.11 Sandeel Area-4. Input to forecast.

	Age 0	Age 1	Age 2	Age 3	Age 4
Stock numbers(2022)	55898.143	14875.6	3834.27	2986.51	368.905
Exploitation pattern 1st half		0.274	0.549	0.777	0.777
Exploitation pattern 2nd half	0.001	0.017	0.034	0.047	0.047
Weight in the stock 1st half		6.292	9.522	12.802	17.445
Weight in the catch 1st half		6.292	9.522	12.802	17.445
weight in the catch 2nd half	4.408	7.693	10.738	14.556	17.601
Proportion mature(2022)	0.000	0.000	0.790	0.980	1.000
Proportion mature(2023)	0.000	0.000	0.790	0.980	1.000
Natural mortality 1st half		0.767	0.602	0.431	0.398
Natural mortality 2nd half	1.140	0.592	0.488	0.392	0.378

Table 9.5.12 Sandeel Area-4. Short term forecast (000 tonnes).

Basis: Fsq=F(2021)=0.4368; Yield(2021)=51.883; Recruitment(2021)=46.548252; Recruitment(2022)=geometric mean (GM 2011-2020)=55.898143 billion; SSB(2022)=72.766

F multiplier	Basis	F(2022)	Catch(2022)	SSB(2023)	%SSB change*	%TAC change**
0	F=0	0.000	0.001	70.783	-3 %	-100 %
3.25	Fsq*3.25	1.418	103.545	15.406	-79 %	100 %
1	Fsq*1	0.437	49.577	41.872	-42 %	-4 %
2	Fsq*2	0.874	79.937	26.093	-64 %	54 %
3	Fsq*3	1.310	99.723	17.017	-77 %	92 %
4	Fsq*4	1.747	113.364	11.516	-84 %	119 %
5	Fsq*5	2.184	123.223	8.016	-89 %	138 %
6	Fsq*6	2.621	130.628	5.697	-92 %	152 %
7	Fsq*7	3.058	136.362	4.110	-94 %	163 %
No conversion for calculation of MSY catch		NA	NA	NA		

***SSB in 2023 relative to SSB in 2022**

****TAC in 2022 relative to catches in 2021**

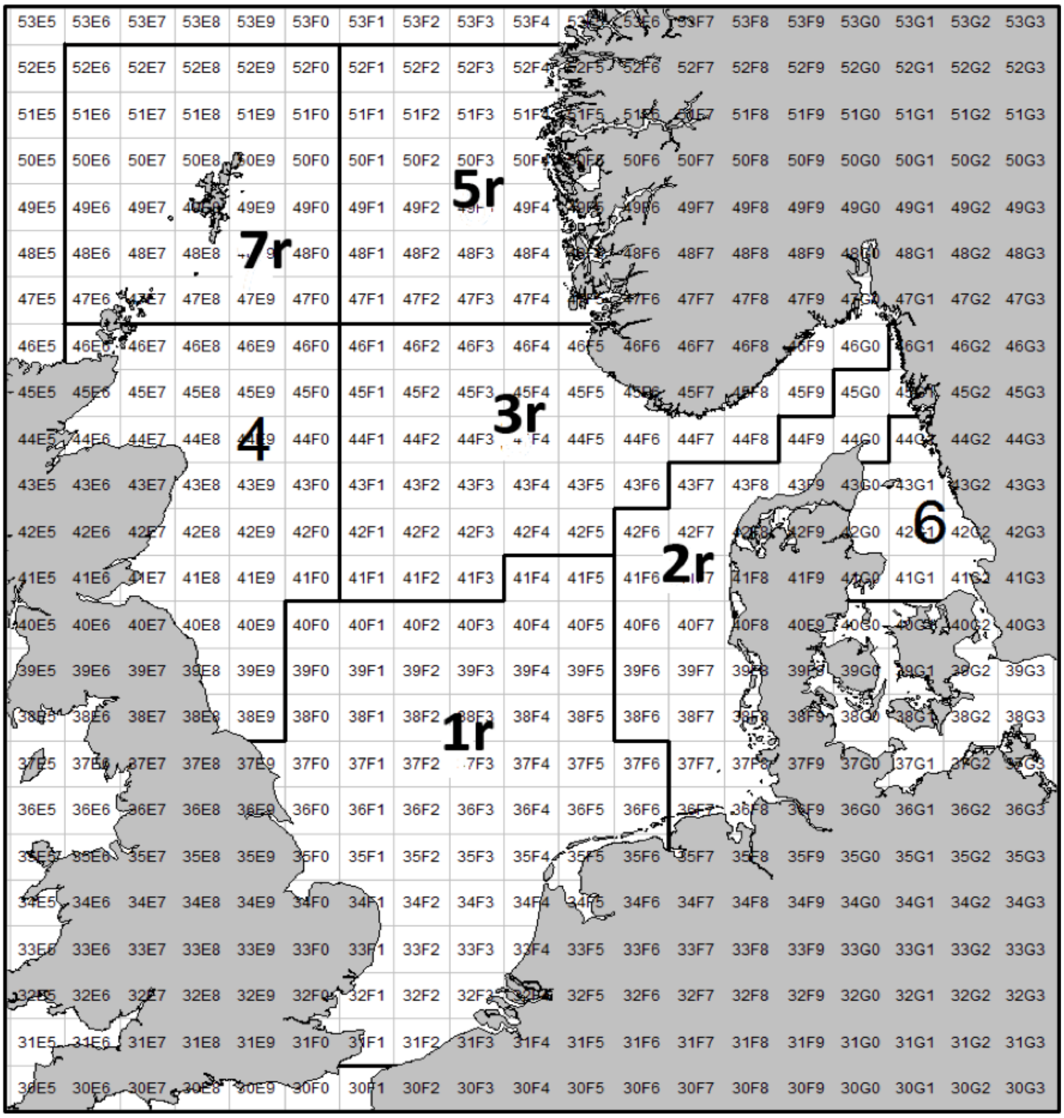


Figure 9.1.1 Sandeel in ICES Subarea 4 and Div. 3.a. Sandeel management areas.


2021
2020
2019
2018
2017
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006

Figure 9.1.2 Sandeel in ICES Subarea 4 and Div. 3.a. Catch by ICES rectangles 2006–2021 (upper, red circles). Number of samples per ICES square in commercial catches (lower, blue circles). Area of the circles is proportional to catch by rectangle.

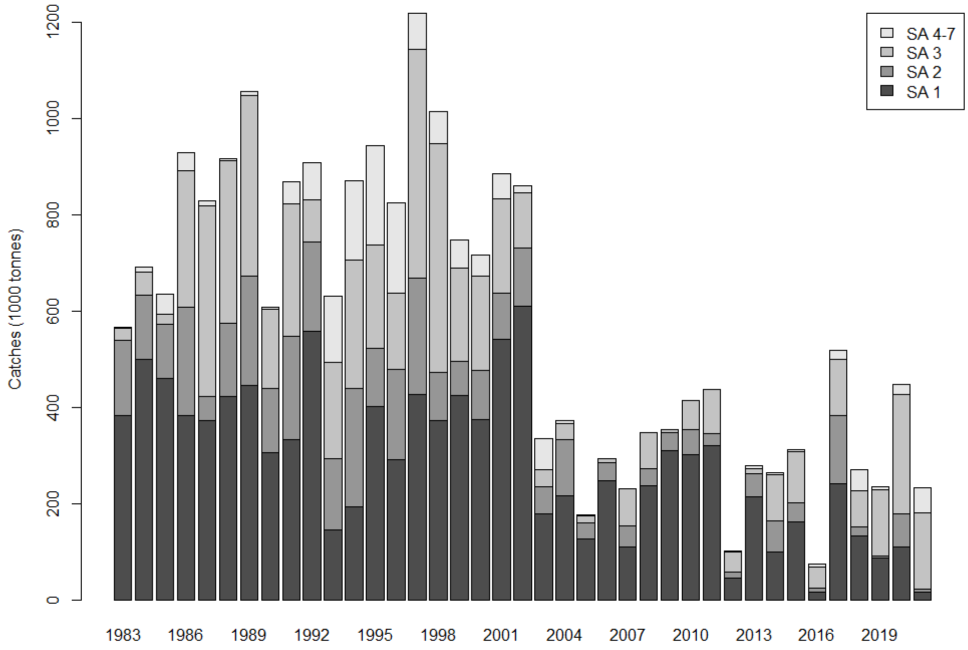


Figure 9.1.3 Sandeel in ICES Subarea 4 and Div. 3.a. Total catches by year and area.

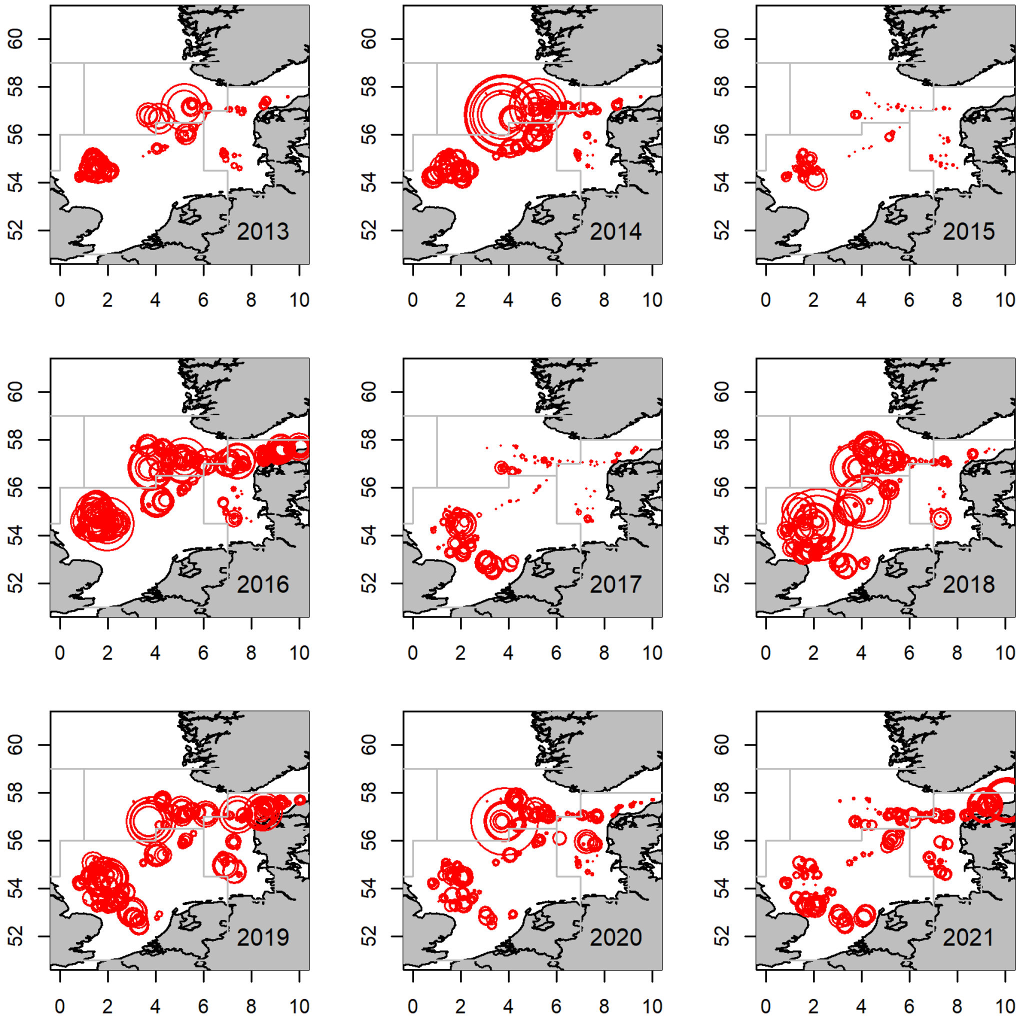


Figure 9.1.4 Sandeel in ICES Subarea 4 and Div. 3.a. Danish survey catches by haul for 0-group. Area of the circles is proportional to catch number.

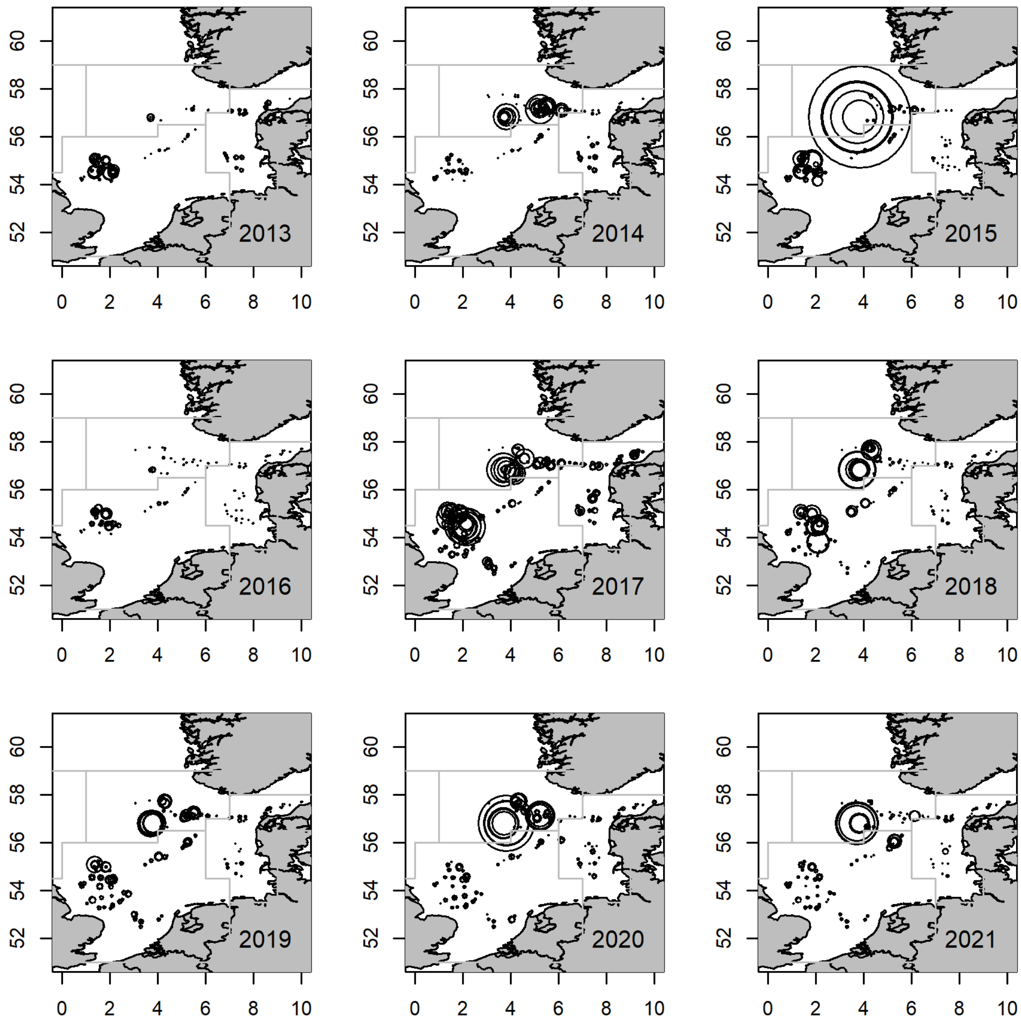


Figure 9.1.5 Sandeel in ICES Subarea 4 and Div. 3.a. Danish survey catches by haul for 1-group. Area of the circles is proportional to catch number.

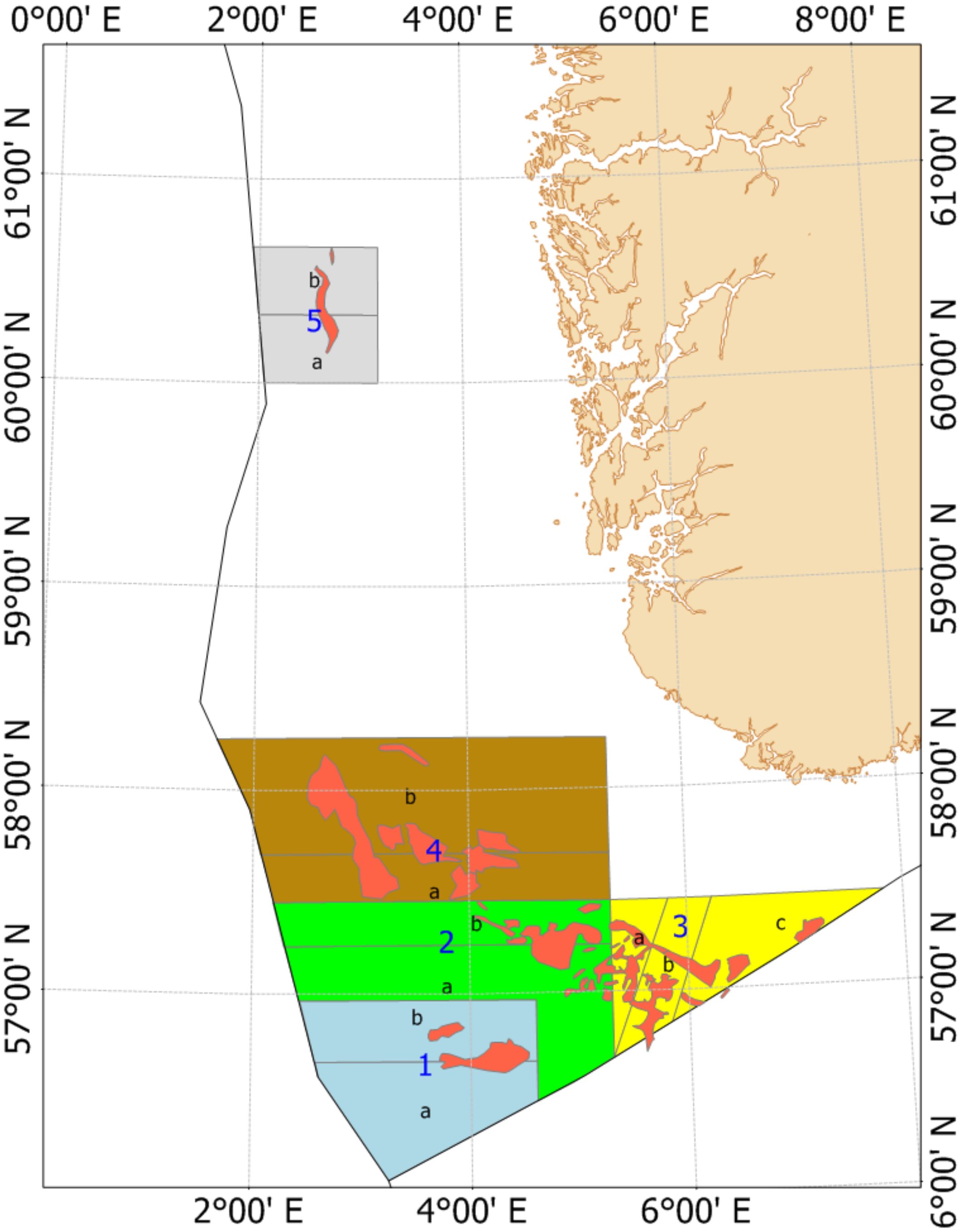


Figure 9.1.6 Sandeel in ICES Subarea 4 and Div. 3.a. Norwegian sandeel management areas. There are 6 main areas consisting of subareas a and b. Sub Area3 consist of three subareas a, b, and c.

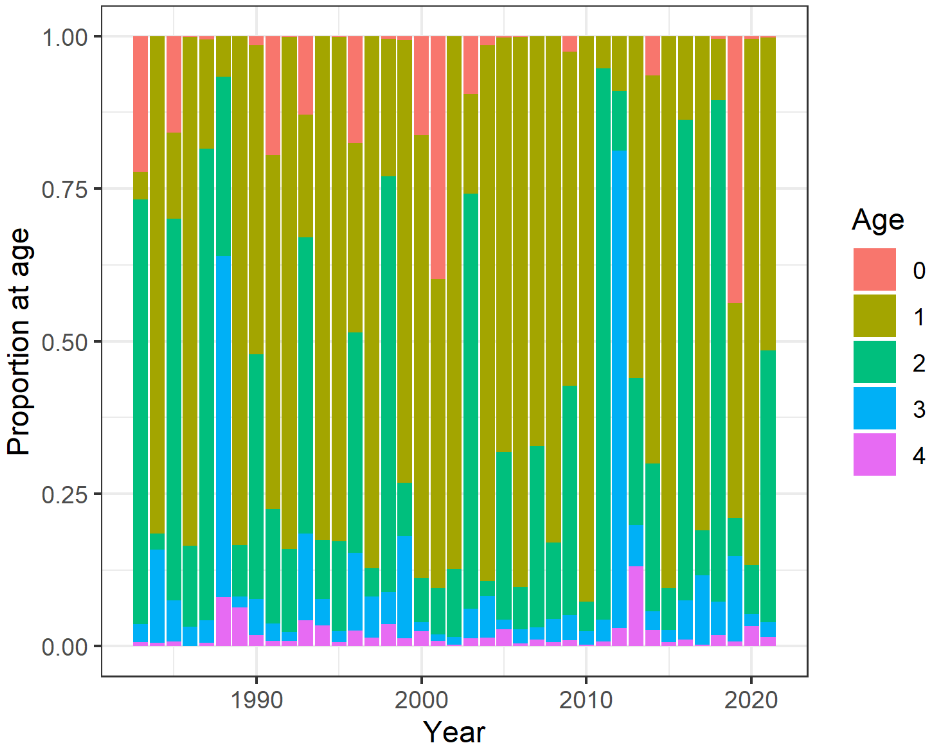


Figure 9.2.1 Sandeel Area-1r. Catch numbers, proportion at age.

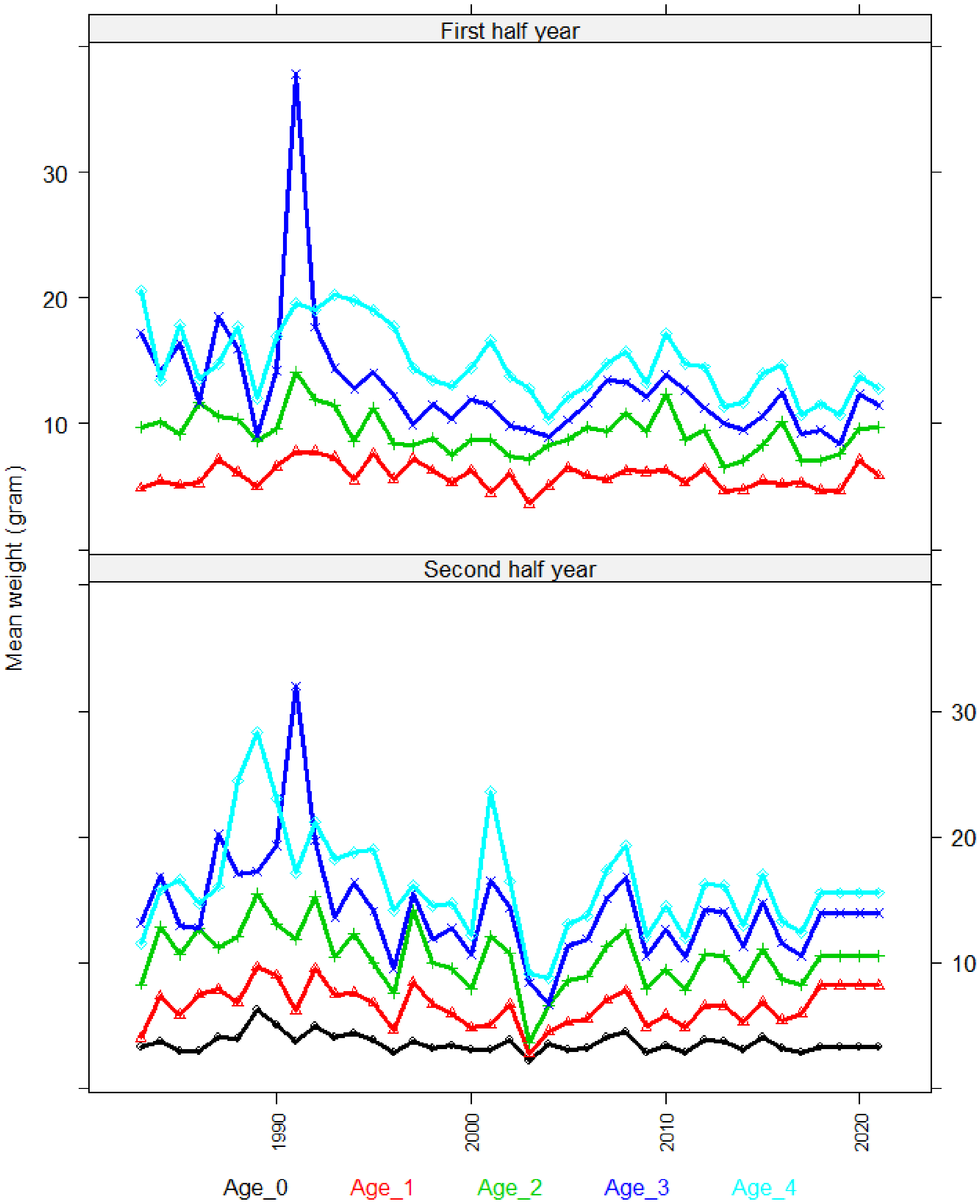


Figure 9.2.2 Sandeel Area-1r. Mean weight at age in the first half year (age 1–4+) and second half year (age 0–4+).

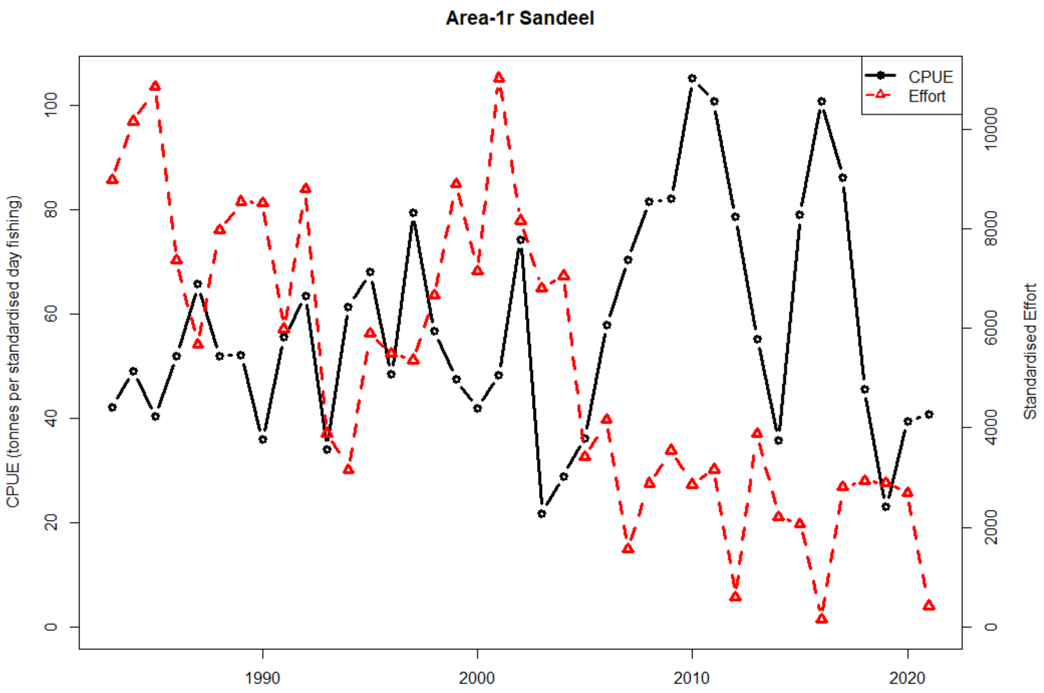


Figure 9.2.3 Sandeel Area-1r. CPUE and effort.

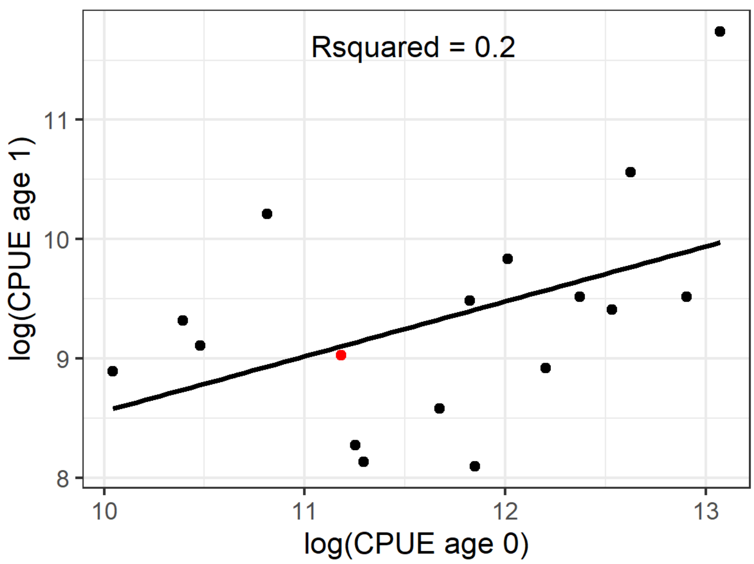


Figure 9.2.4 Sandeel Area-1r. Internal consistency by age of the dredge survey. Red dot indicates the most recent data point.

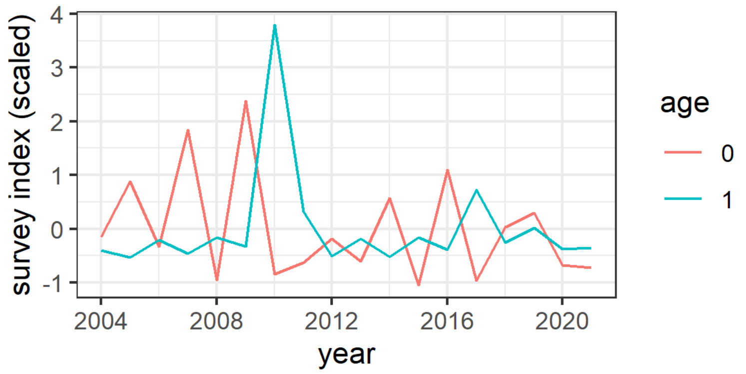


Figure 9.2.5 Sandeel Area-1r. Dredge survey index timeline.

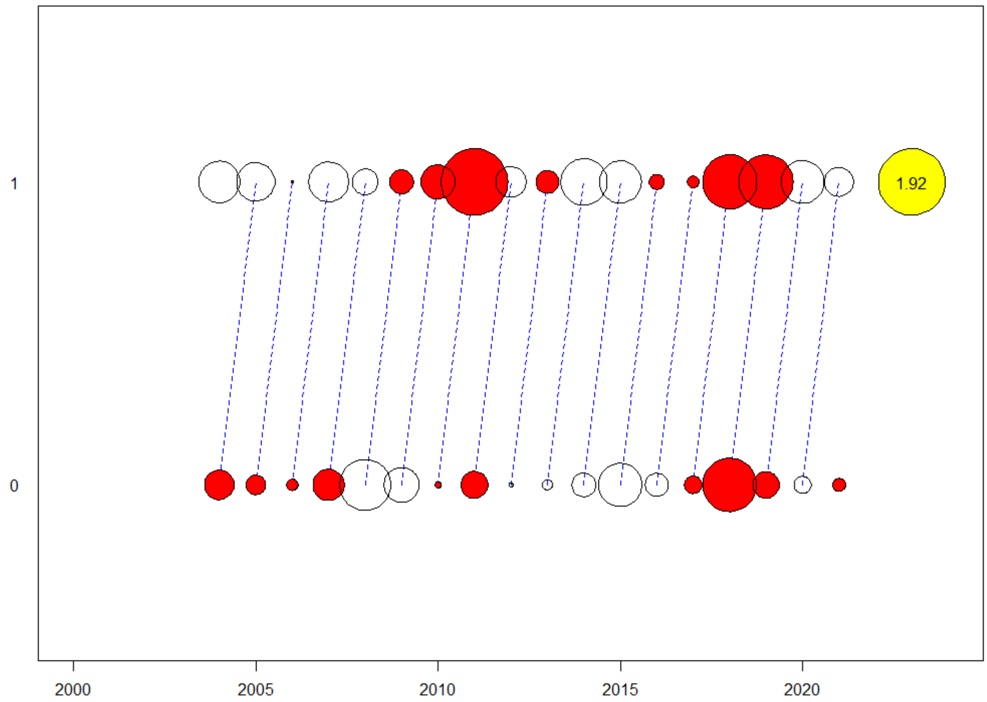


Figure 9.2.6 Sandeel Area-1r. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE). "Red" dots show a positive residual.

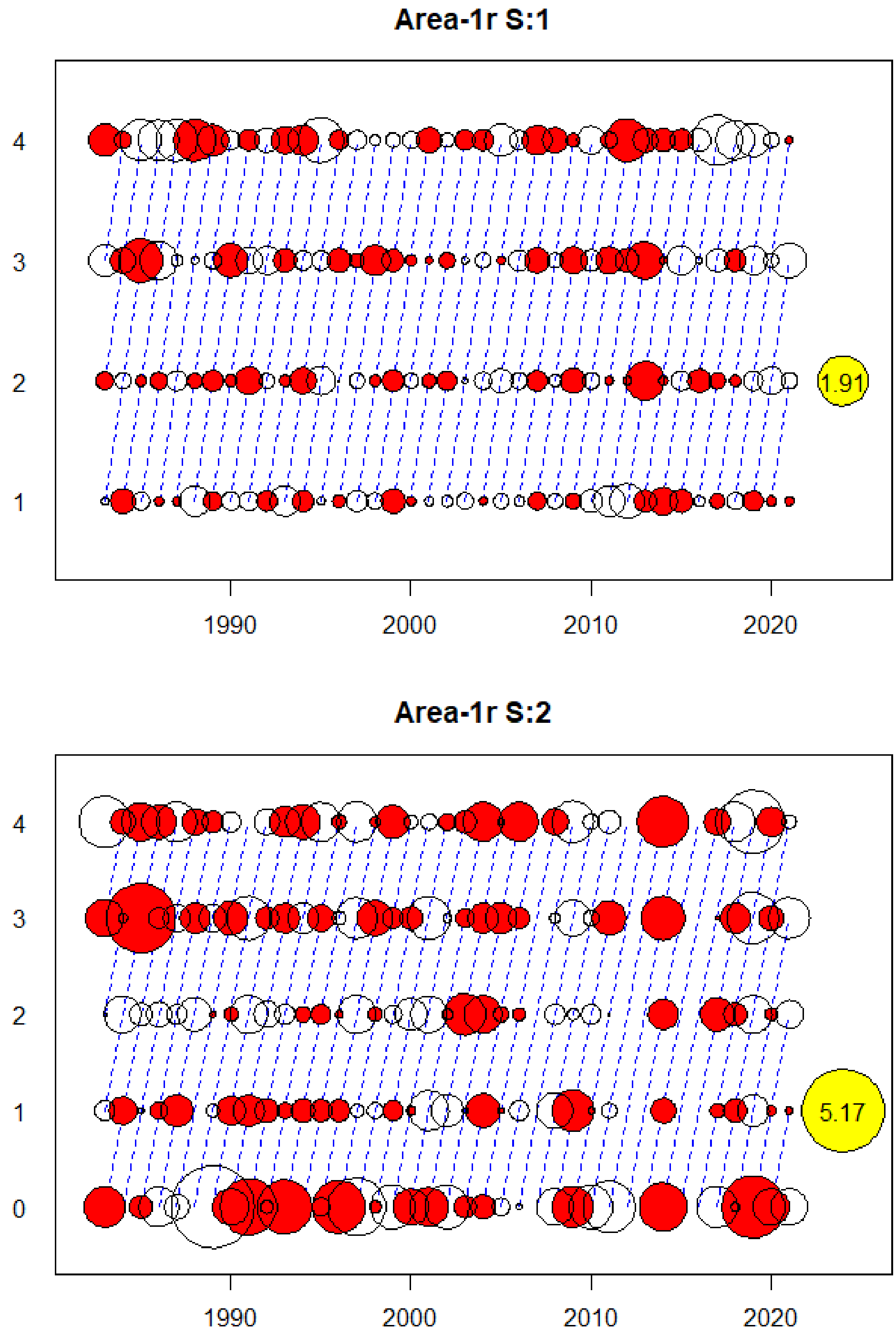


Figure 9.2.7 Sandeel Area-1r. Catch at age residuals (log(observed CPUE)- log(expected CPUE). "Red" dots show a positive residual.

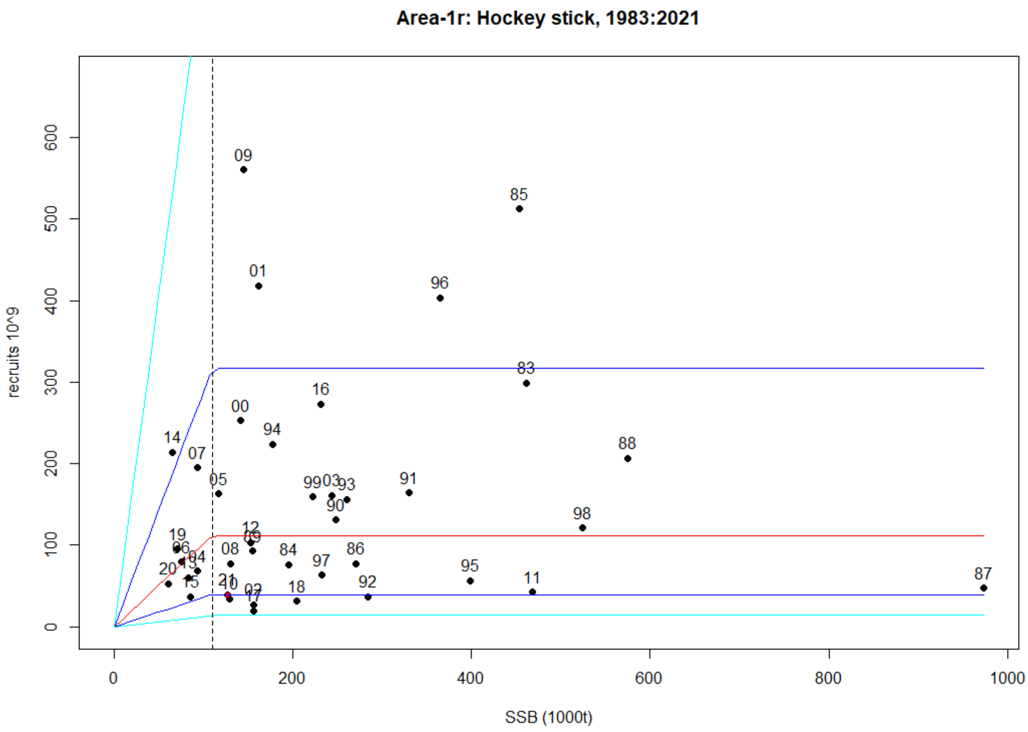


Figure 9.2.8 Sandeel Area-1r. Estimated stock recruitment relation. Red line = median of the expected recruitment, Dark blue lines = one standard deviation, Light blue lines = 2 standard deviations. The area within the light blue lines can be seen as the 95% confidence interval of recruitment. Years shown in red are not used in the fit.

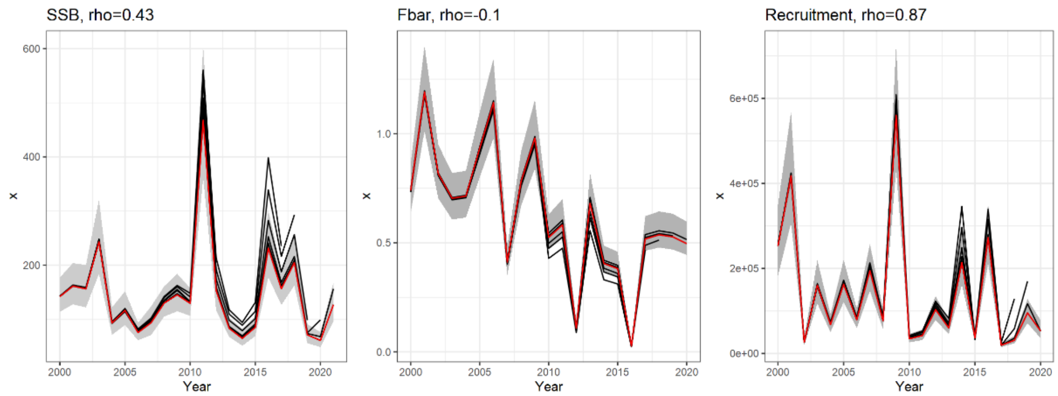


Figure 9.2.9 Sandeel Area-1r. Retrospective analysis.

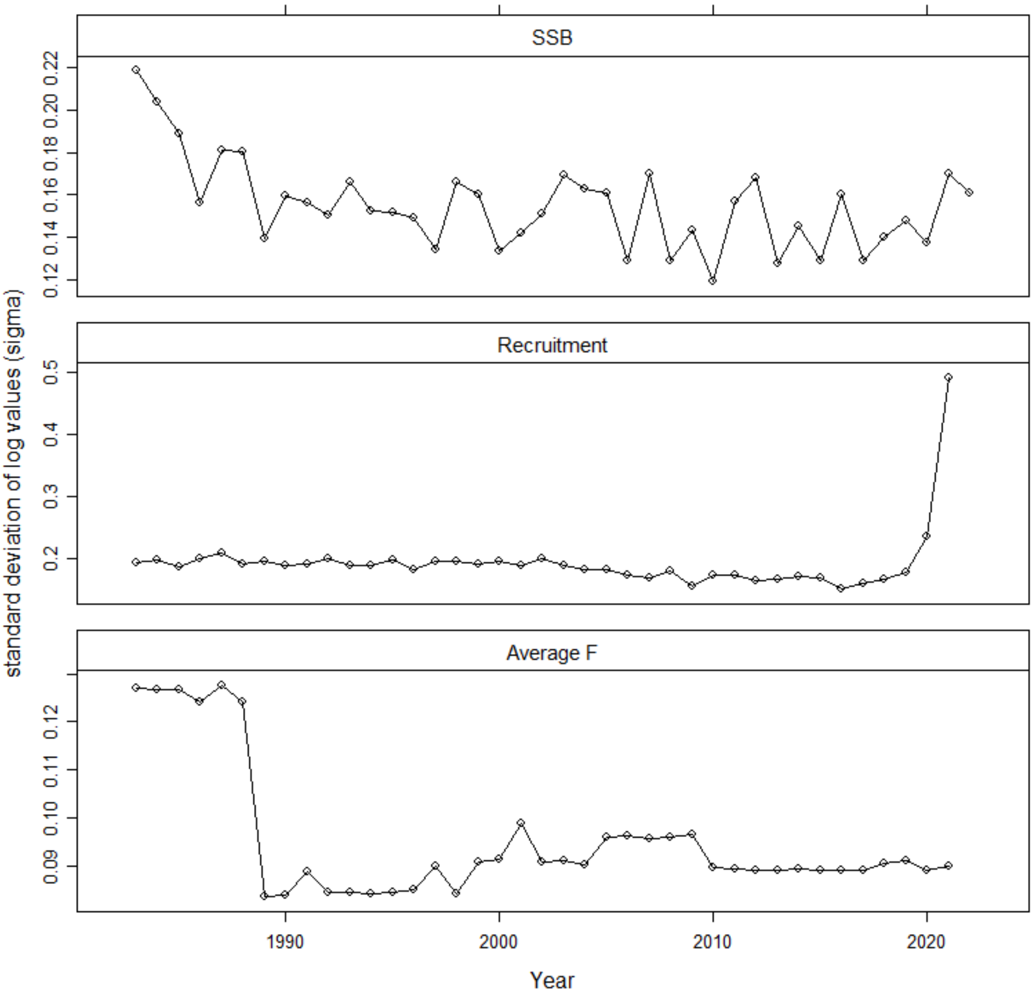


Figure 9.2.10 Sandeel Area-1r. Uncertainties of model output estimated from parameter uncertainties derived from the Hessian matrix and the delta method.

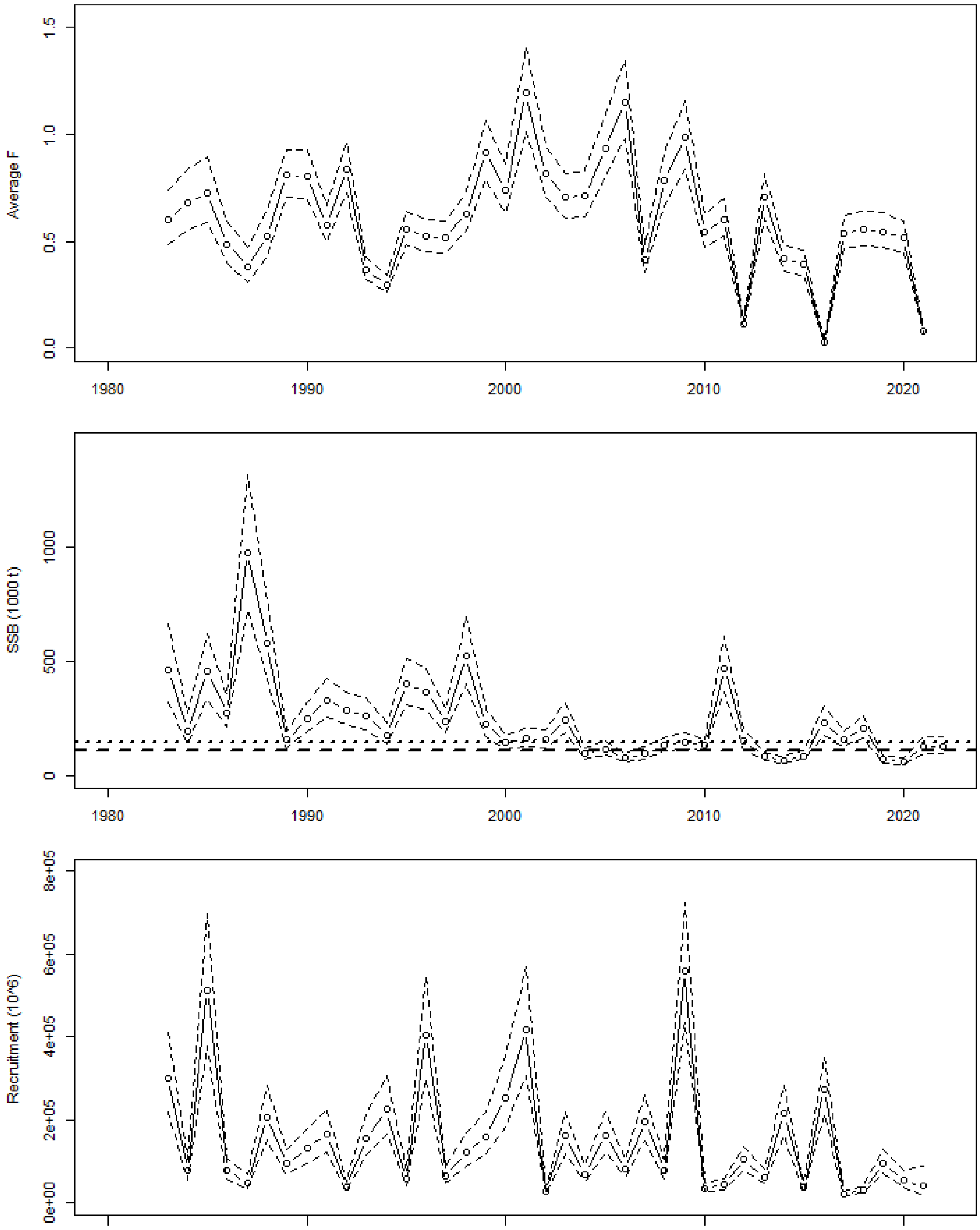


Figure 9.2.11 Sandeel Area-1r. Model output (mean F, SSB and Recruitment) with mean values and plus/minus 2 * standard deviation.

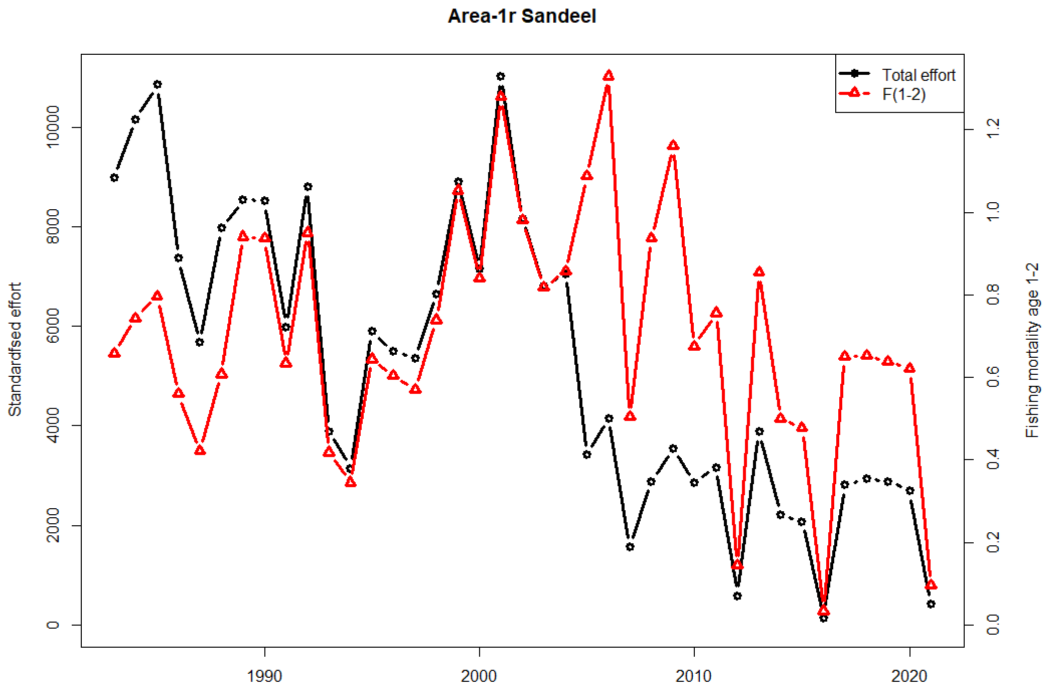


Figure 9.2.12 Sandeel Area-1r. Total effort (days fishing for a standard 200 GT vessel) and estimated average Fishing mortality.

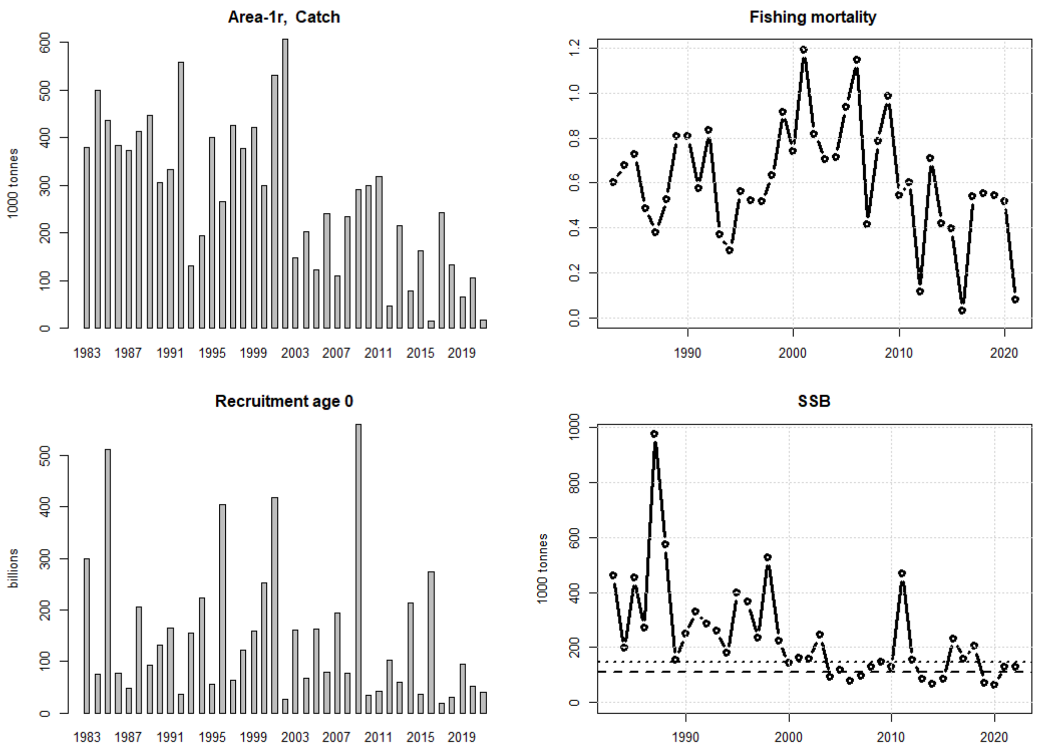


Figure 9.2.13 Sandeel Area-1r. Stock summary.

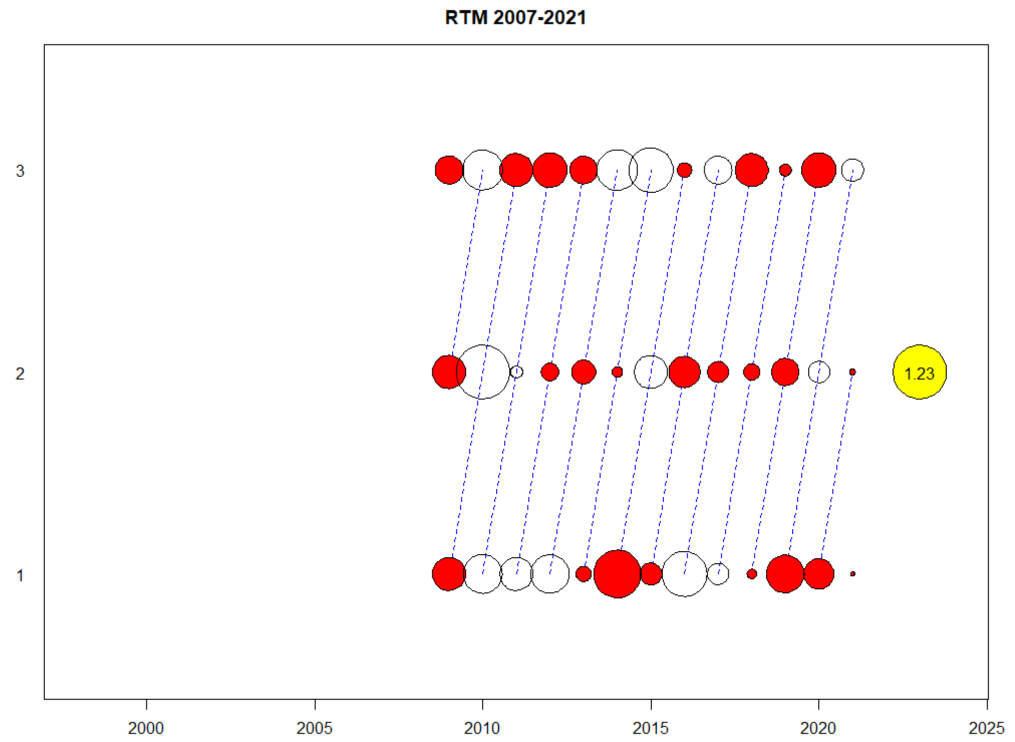


Figure 9.2.14 Sandeel Area-1r. RTM survey. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.

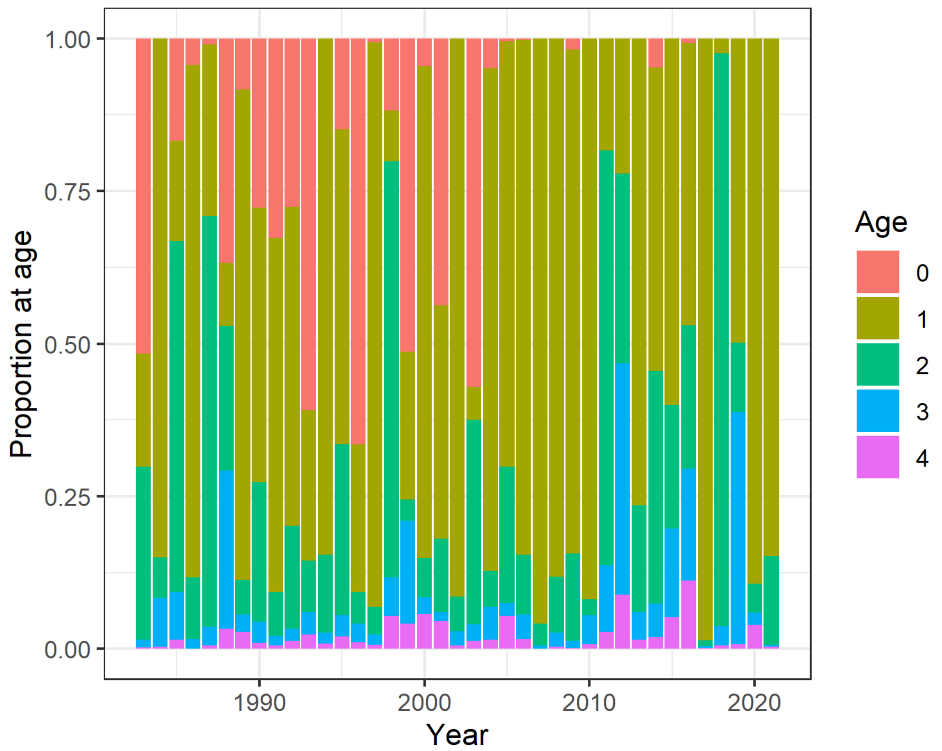


Figure 9.3.1 Sandeel Area-2r. Catch numbers, proportion at age.

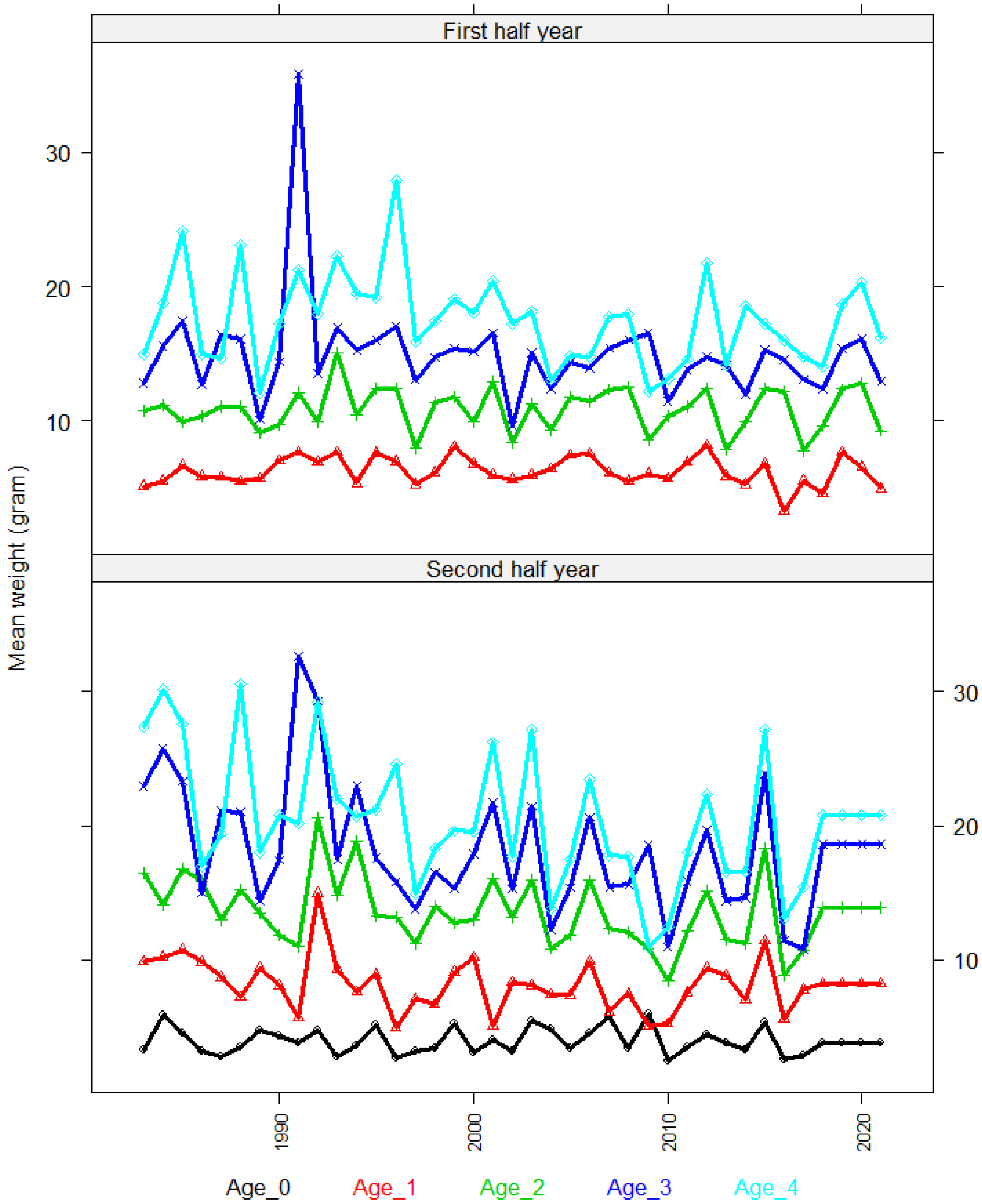


Figure 9.3.2 Sandeel Area-2r. Mean weight at age in the first half year (age 1–4+) and second half year (age 0–4+).

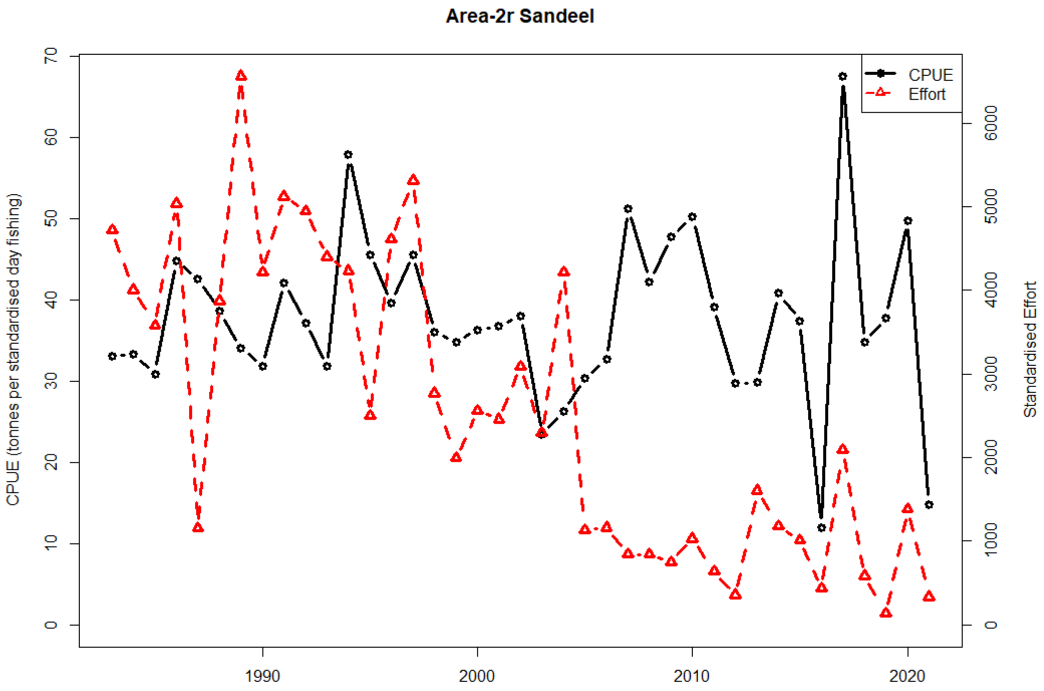


Figure 9.3.3 Sandeel Area-2r. CPUE and effort.

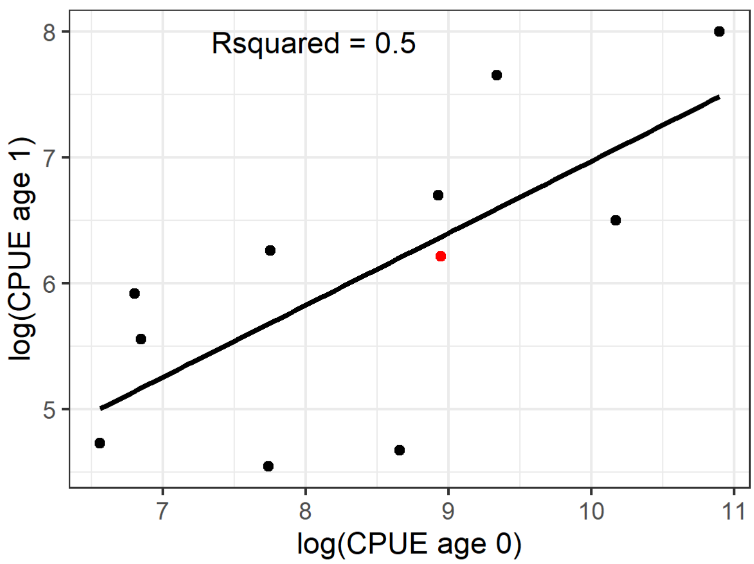


Figure 9.3.4 Sandeel Area-2r. Internal consistency by age of the dredge survey. Red dot indicates the most recent data point.

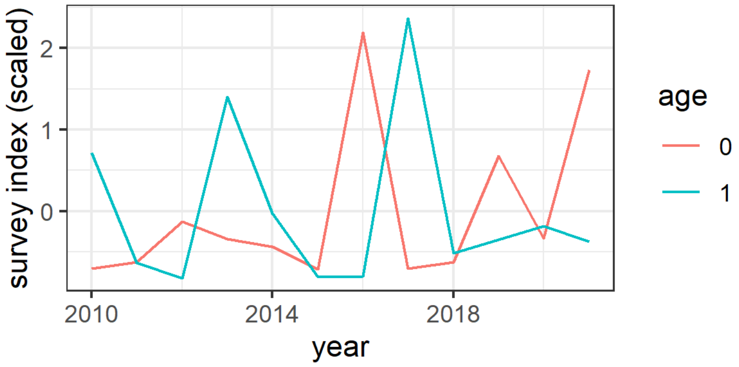


Figure 9.3.5 Sandeel Area-2r. Dredge survey index timeline.

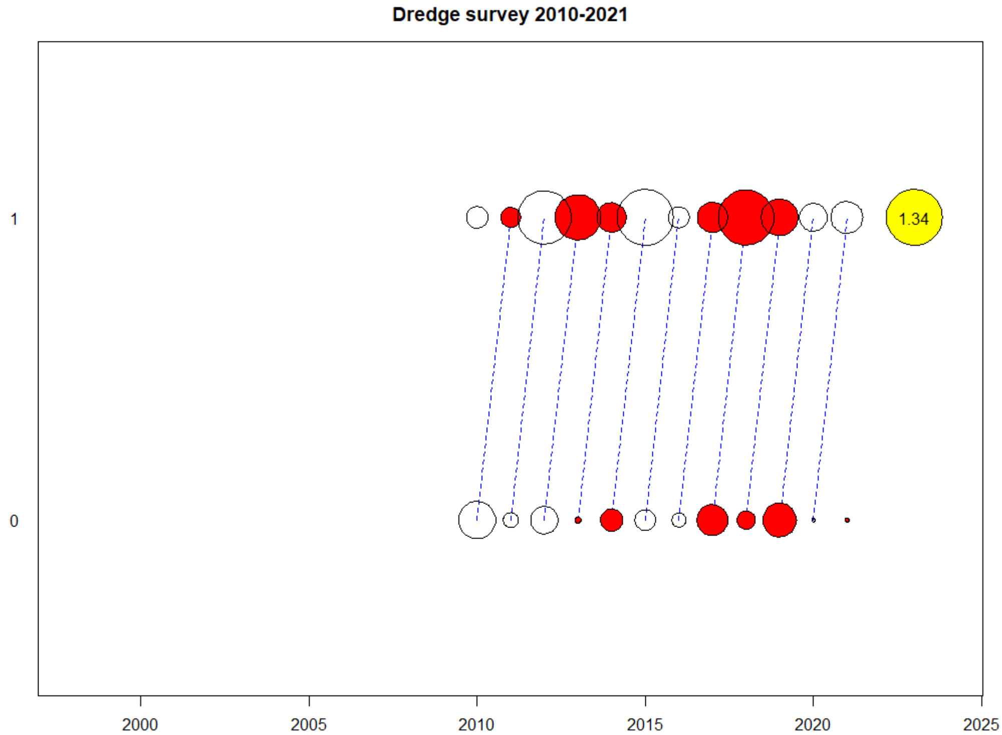
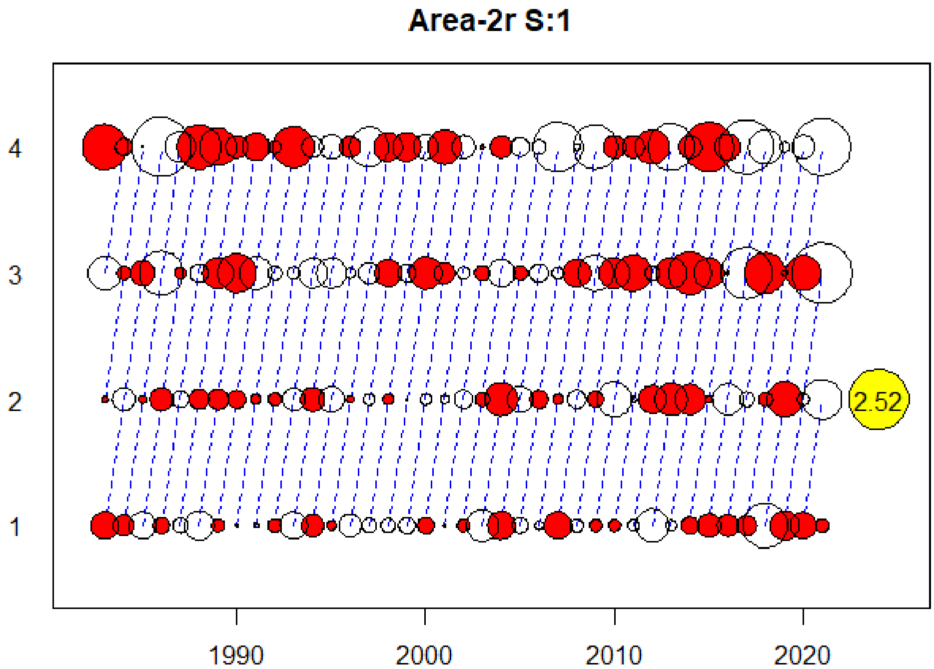


Figure 9.3.6 Sandeel Area-2r. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.



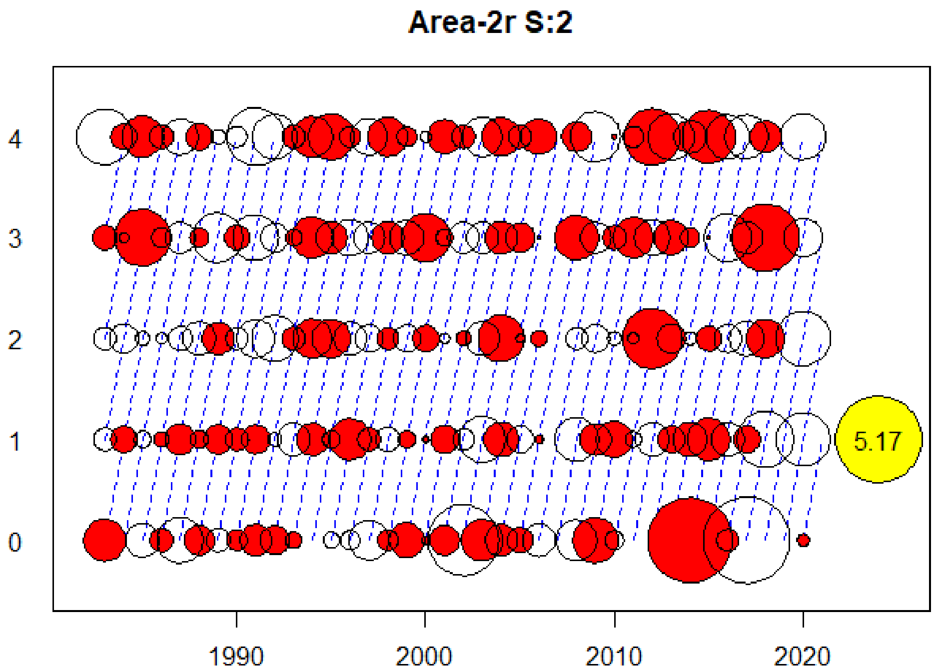


Figure 9.3.7 Sandeel Area-2r. Catch at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.

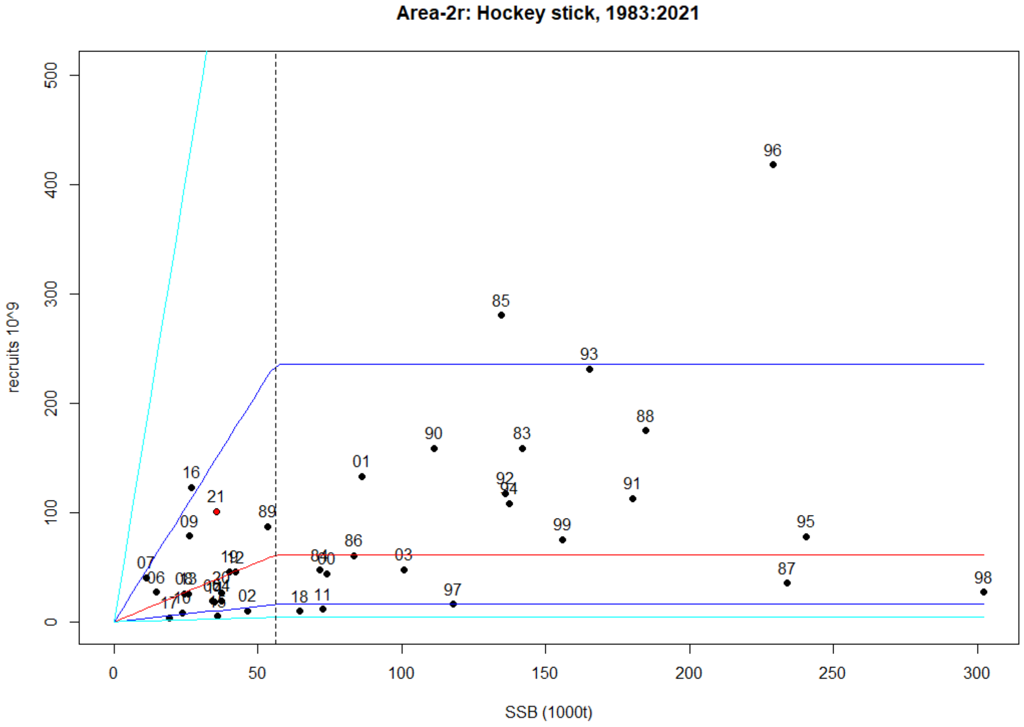


Figure 9.3.8 Sandeel Area-2r. Estimated stock recruitment relation. Red line = median of the expected recruitment, Dark blue lines = one standard deviation, Light blue lines = 2 standard deviations. The area within the light blue lines can be seen as the 95% confidence interval of recruitment. Years shown in red are not used in the fit.

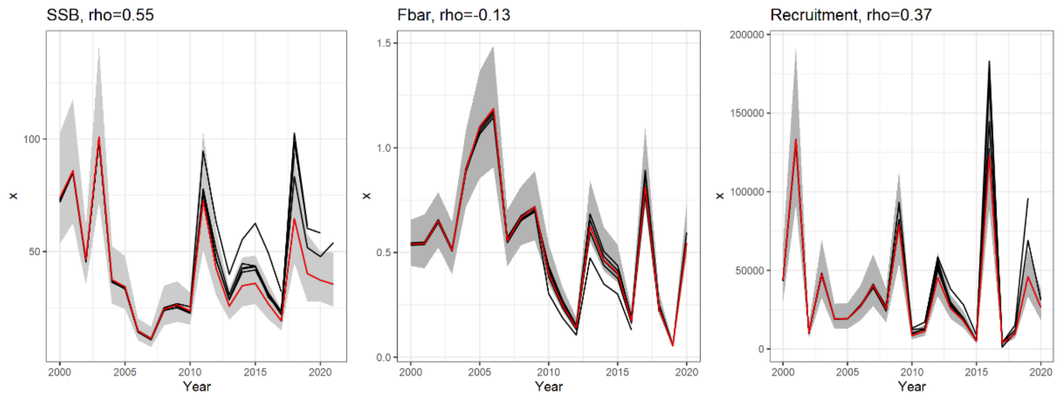


Figure 9.3.9 Sandeel Area-2r. Retrospective analysis.

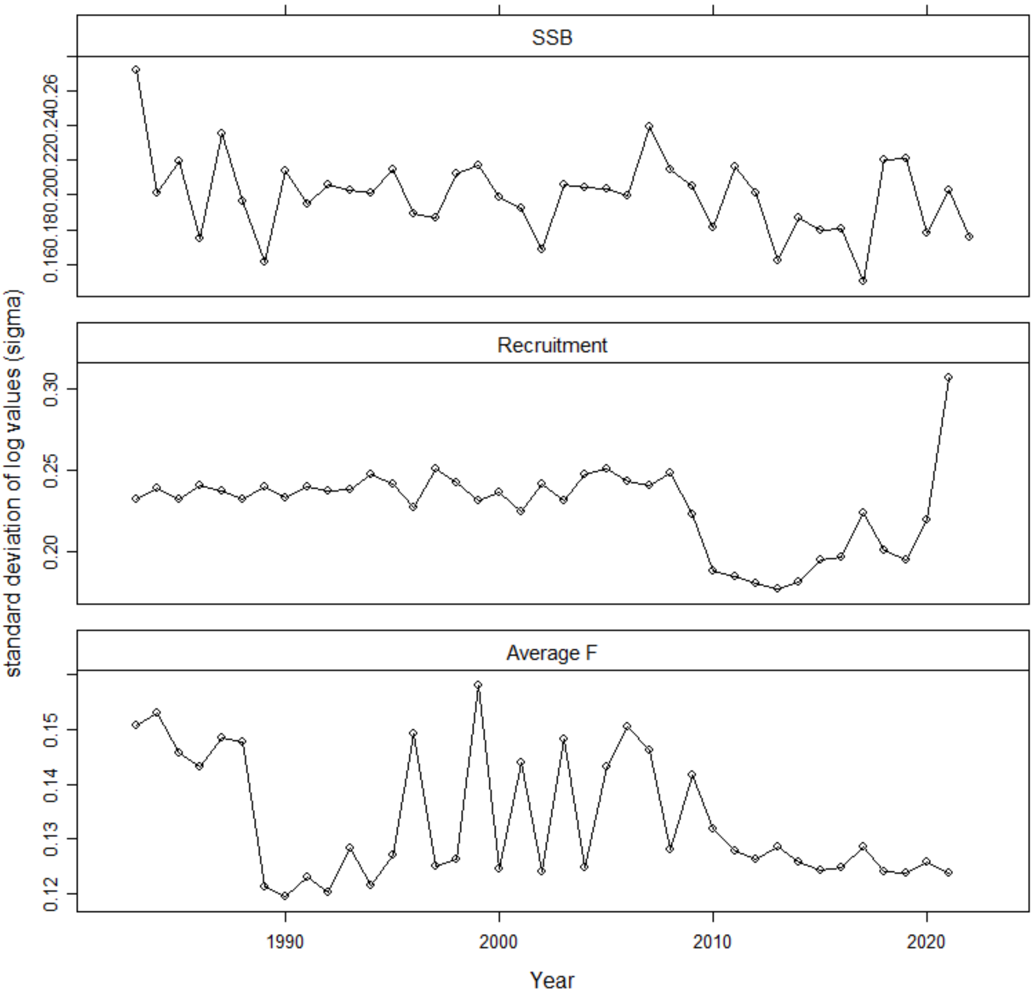


Figure 9.3.10 Sandeel Area-2r. Uncertainties of model output estimated from parameter uncertainties derived from the Hessian matrix and the delta method.

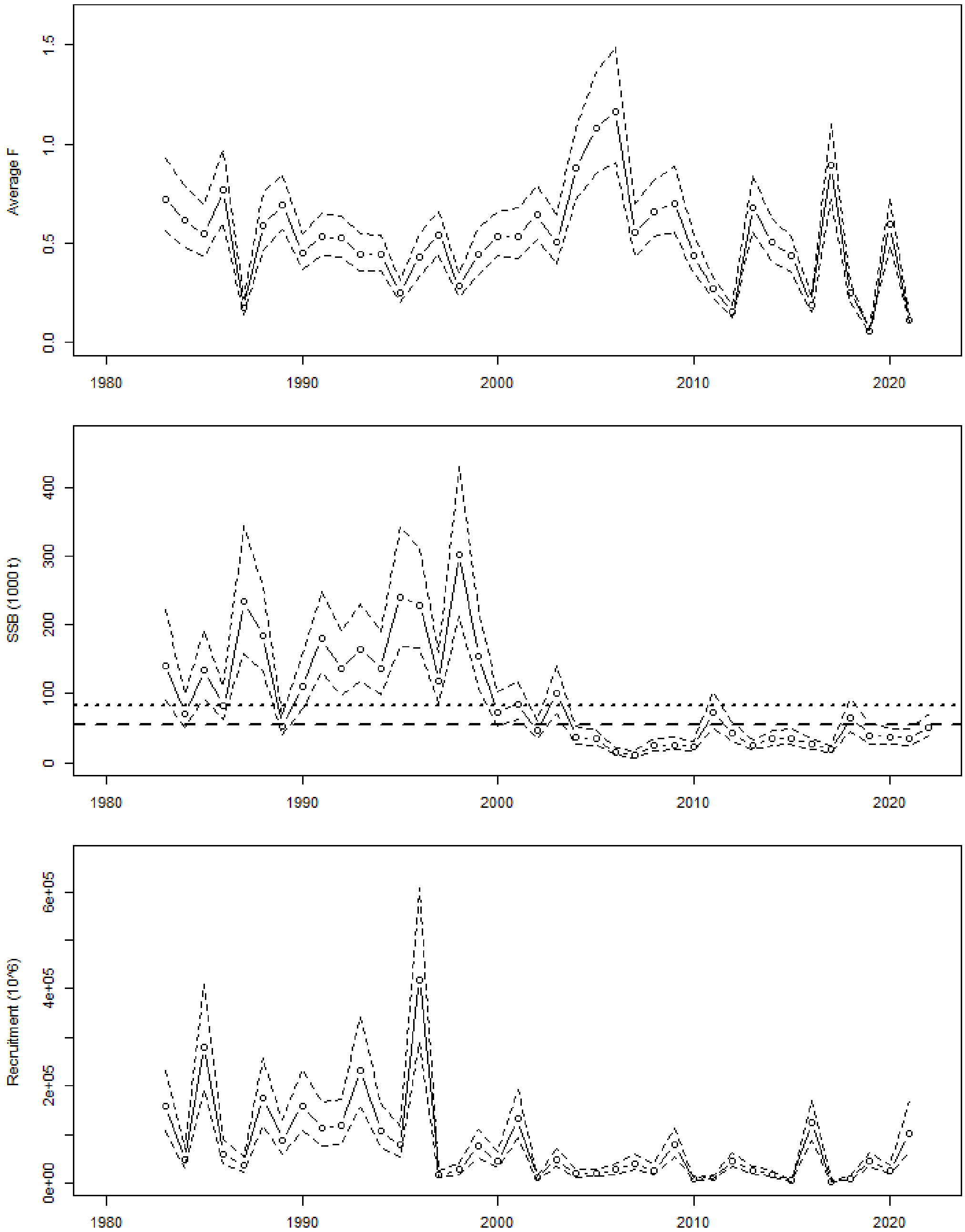


Figure 9.3.11 Sandeel Area-2r. Model output (mean F, SSB and Recruitment) with mean values and plus/minus 2 * standard deviation.

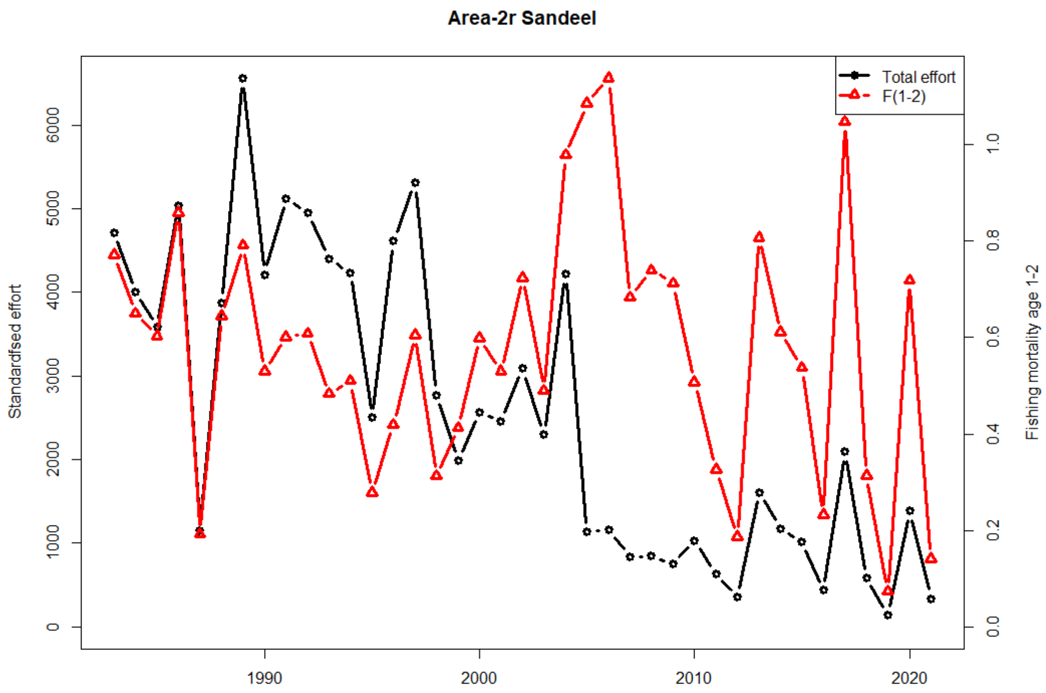


Figure 9.3.12 Sandeel Area-2r. Total effort (days fishing for a standard 200 GT vessel) and estimated average Fishing mortality.

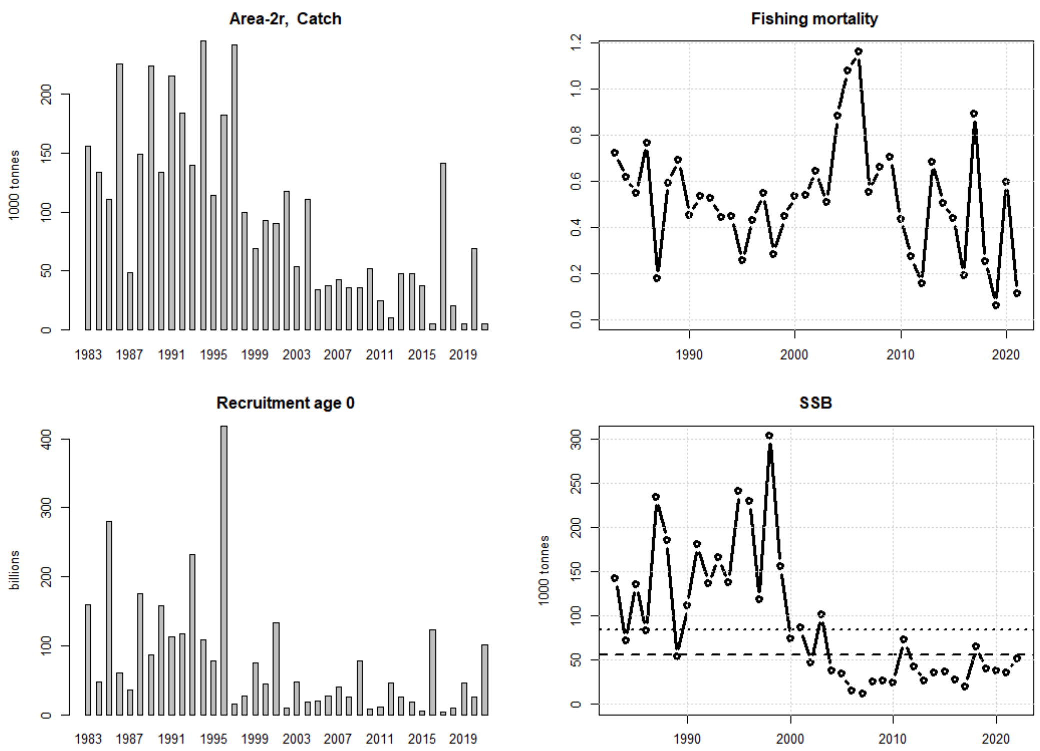


Figure 9.3.13 Sandeel Area-2r. Stock summary.

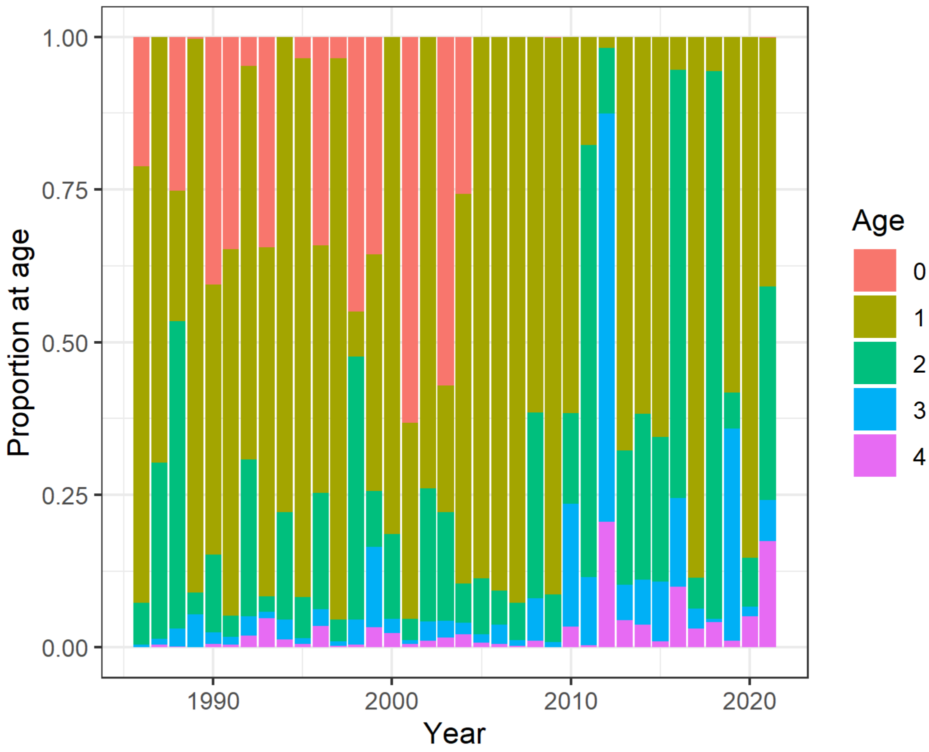


Figure 9.4.1 Sandeel Area-3r. Catch numbers, proportion at age.

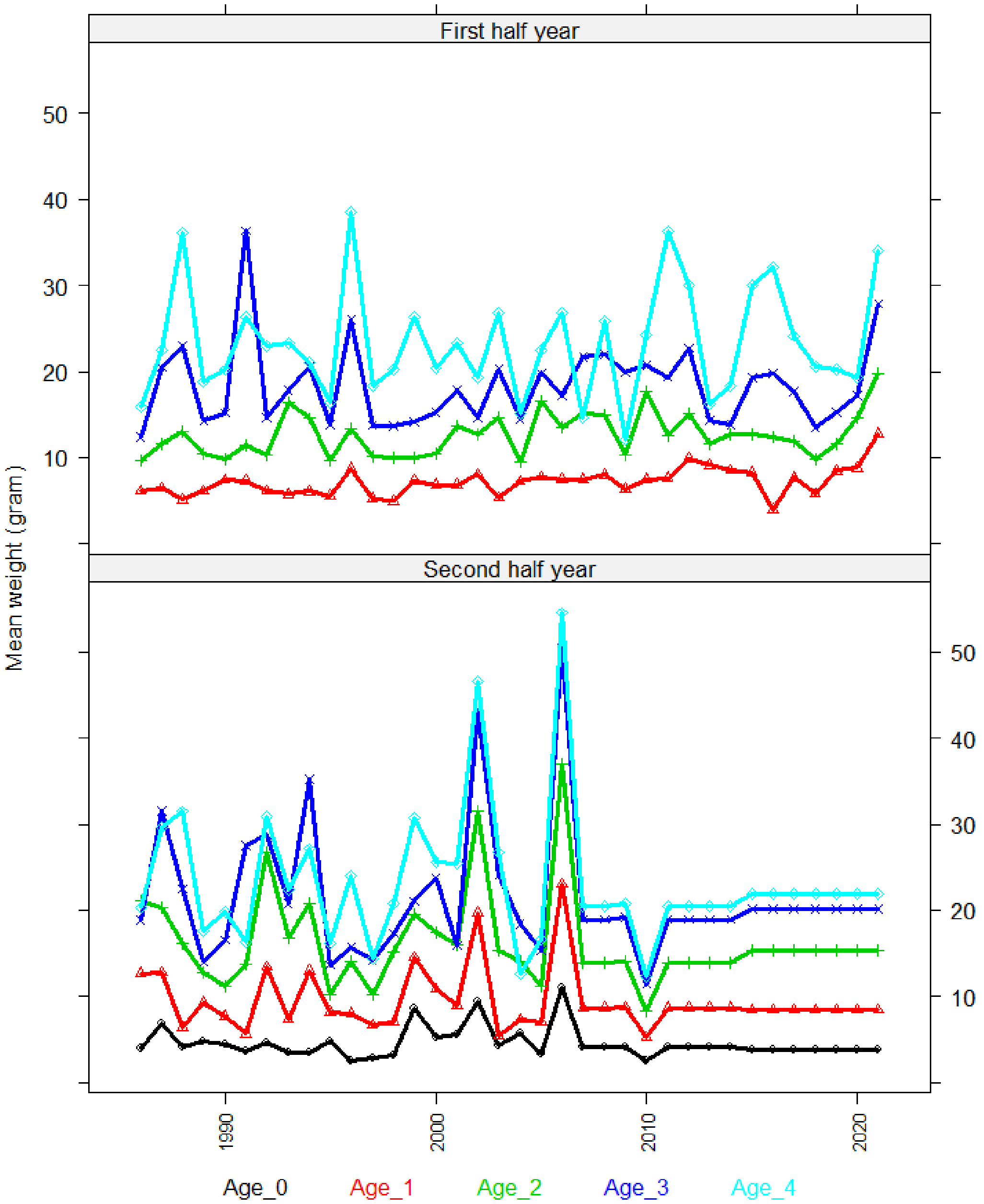


Figure 9.4.2 Sandeel Area-3r. Mean weight at age in the first half year (age 1–4+) and second half year (age 0–4+).

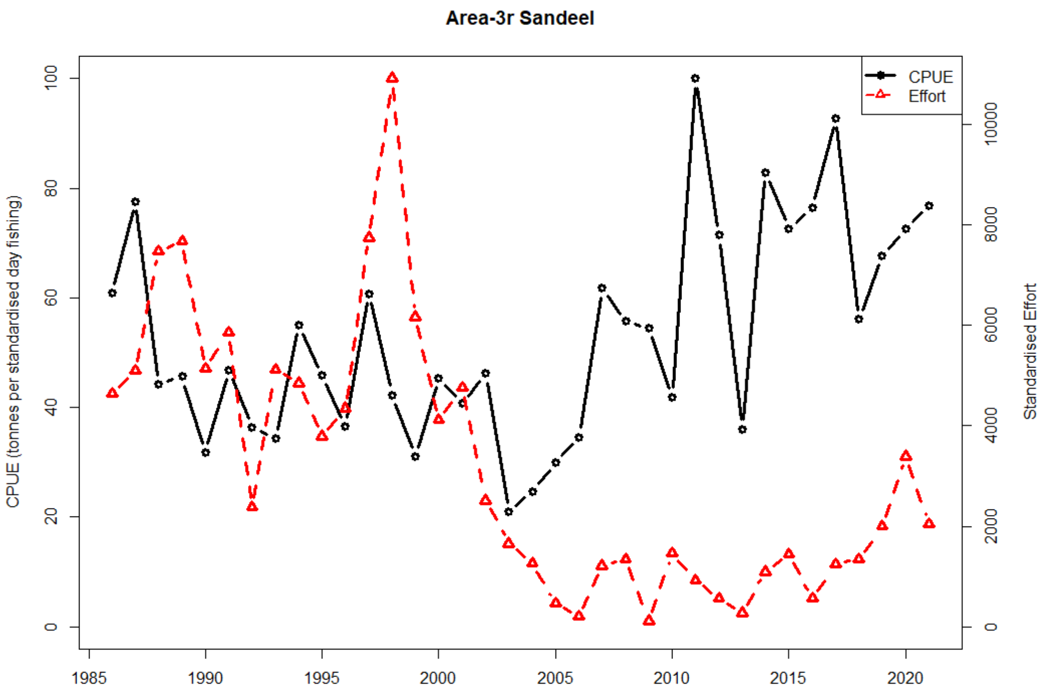


Figure 9.4.3 Sandeel Area-3r. CPUE and effort.

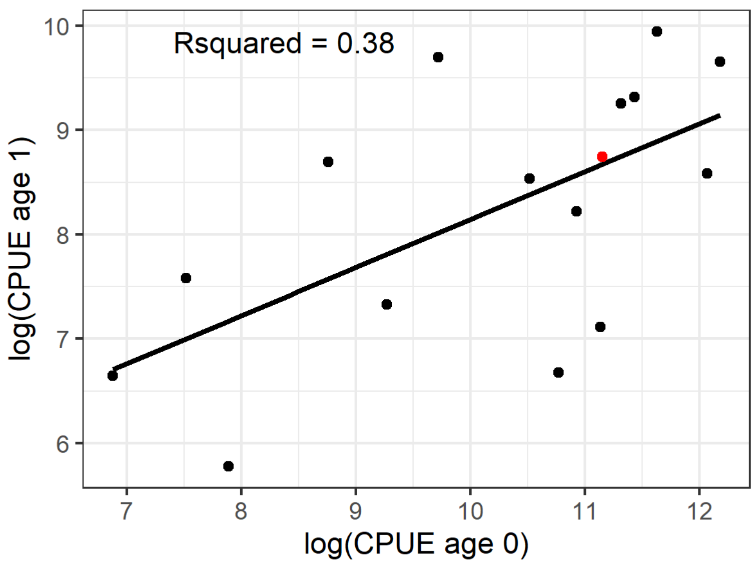


Figure 9.4.4 Sandeel Area-3r. Internal consistency by age of the dredge survey. Red dot indicates the most recent data point.

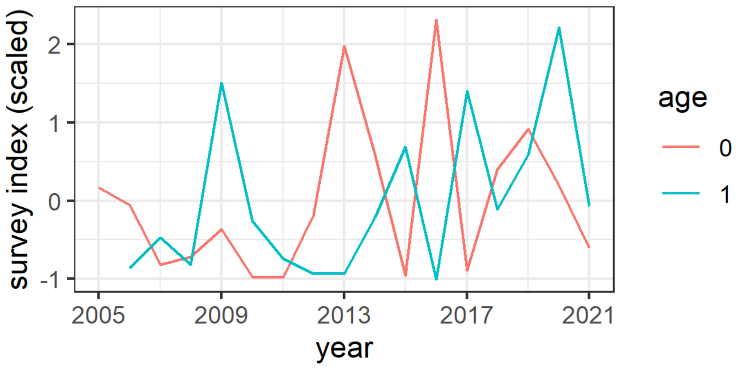


Figure 9.4.5 Sandeel Area-3r. Dredge survey index timeline.

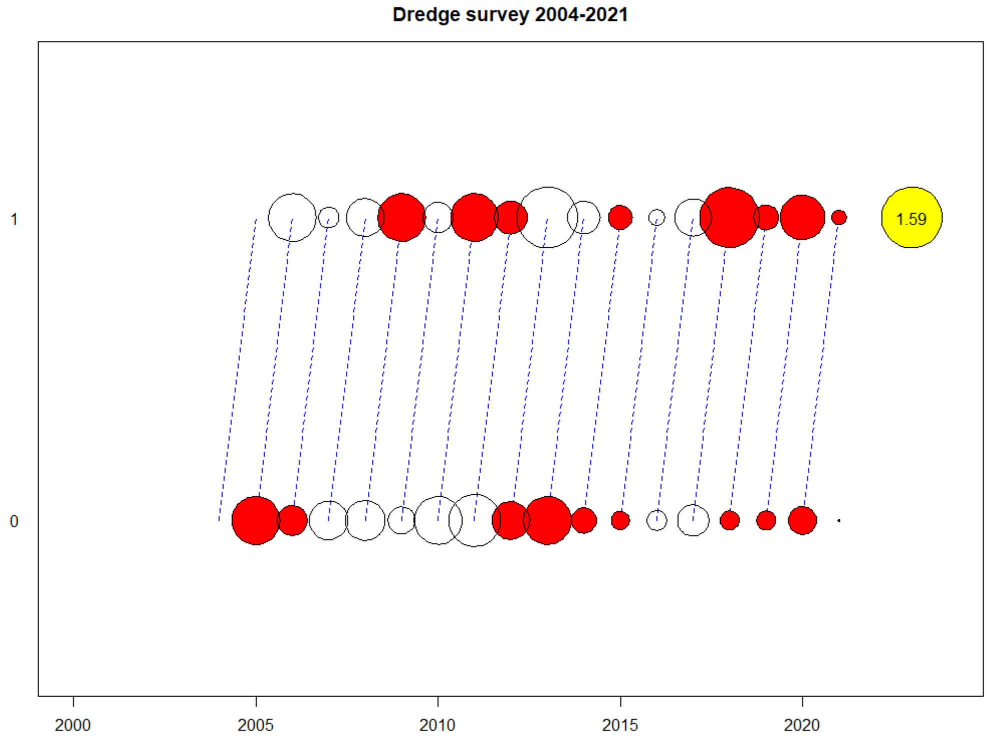


Figure 9.4.6 Sandeel Area-3r. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.

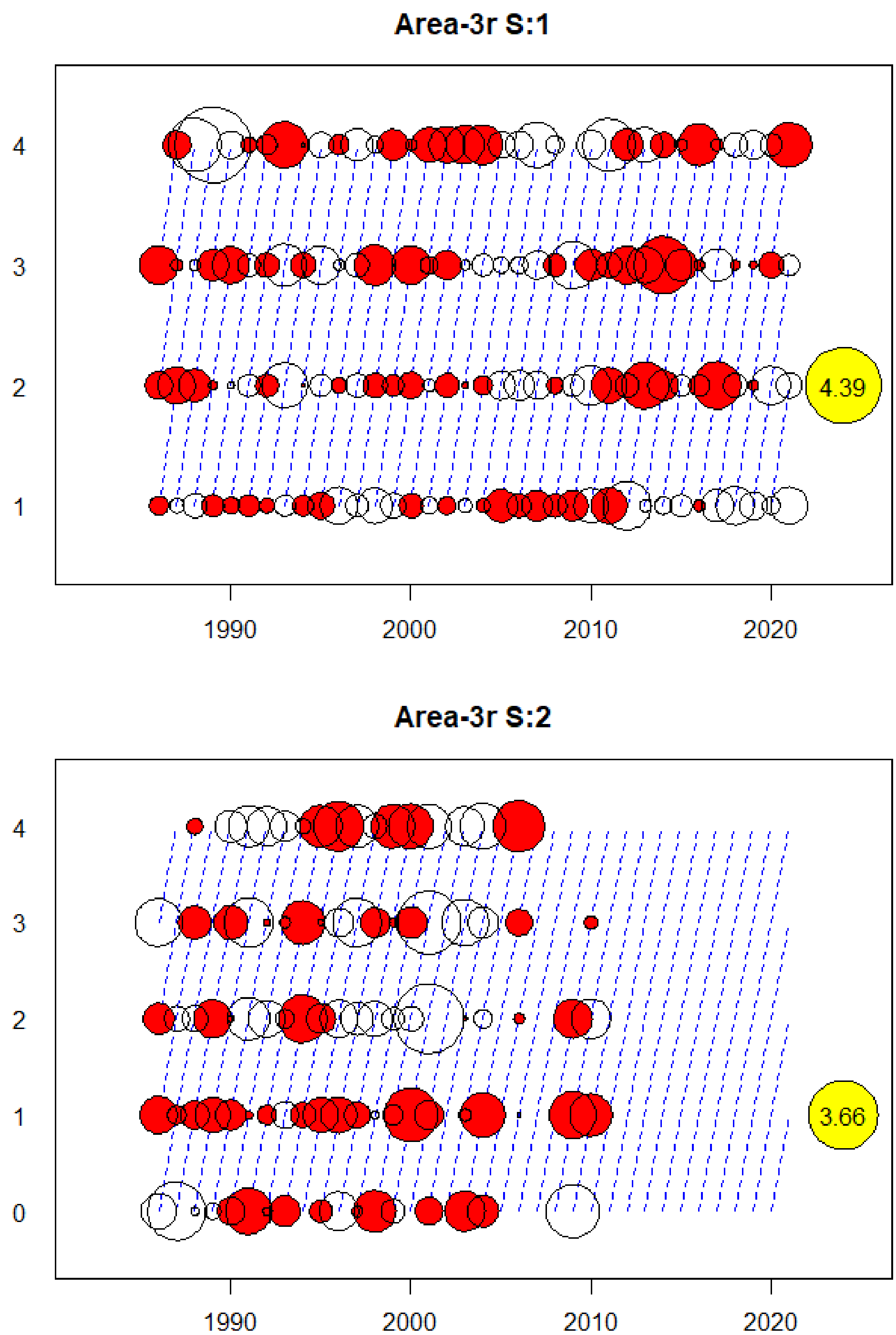


Figure 9.4.7 Sandeel Area-3r. Catch at age residuals (log(observed CPUE)- log(expected CPUE)). “Red” dots show a positive residual.

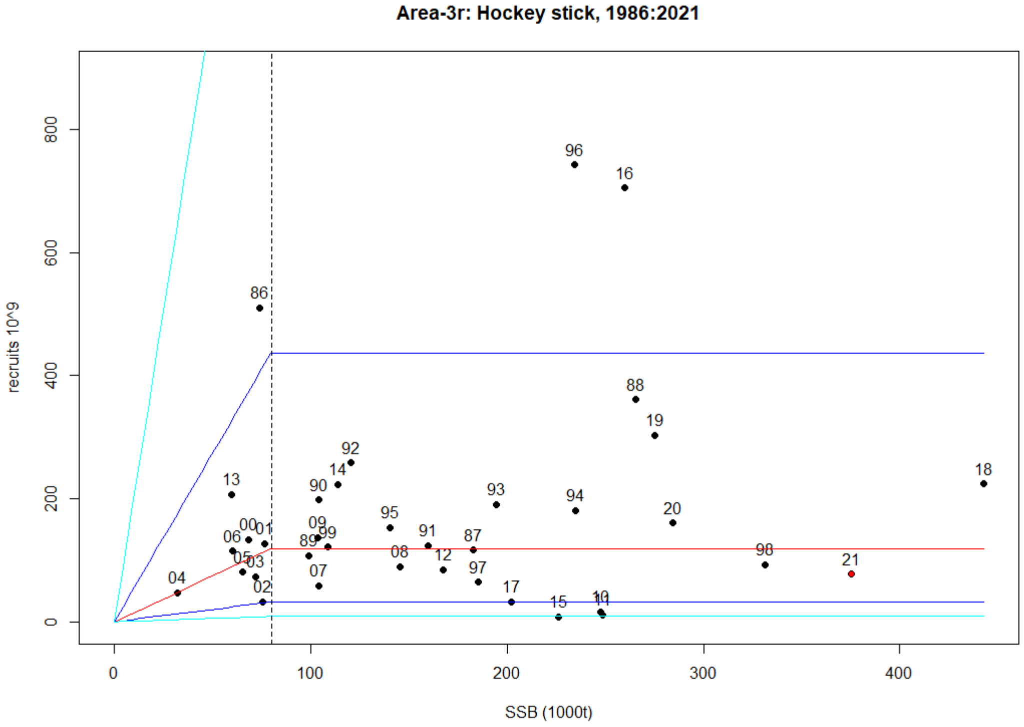


Figure 9.4.8 Sandeel Area-3r. Estimated stock recruitment relation. Red line = median of the expected recruitment, Dark blue lines = one standard deviation, Light blue lines = 2 standard deviations. The area within the light blue lines can be seen as the 95% confidence interval of recruitment. Years shown in red are not used in the fit.

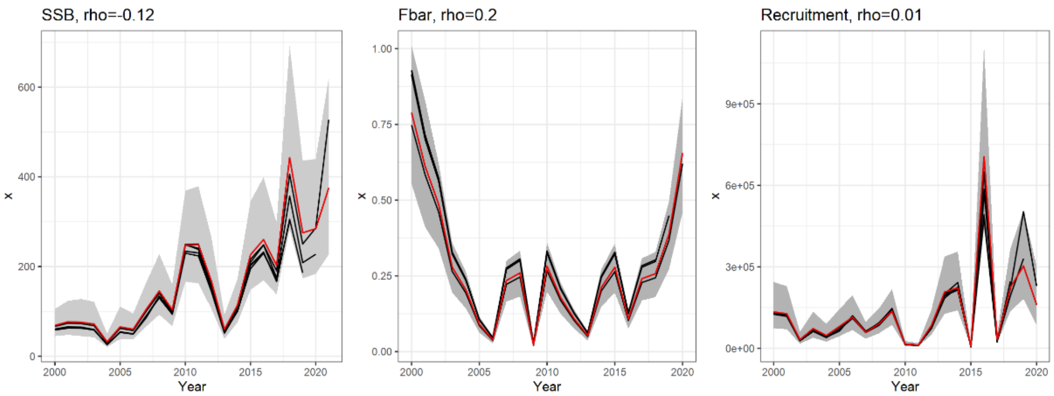


Figure 9.4.9 Sandeel Area-3r. Retrospective analysis.

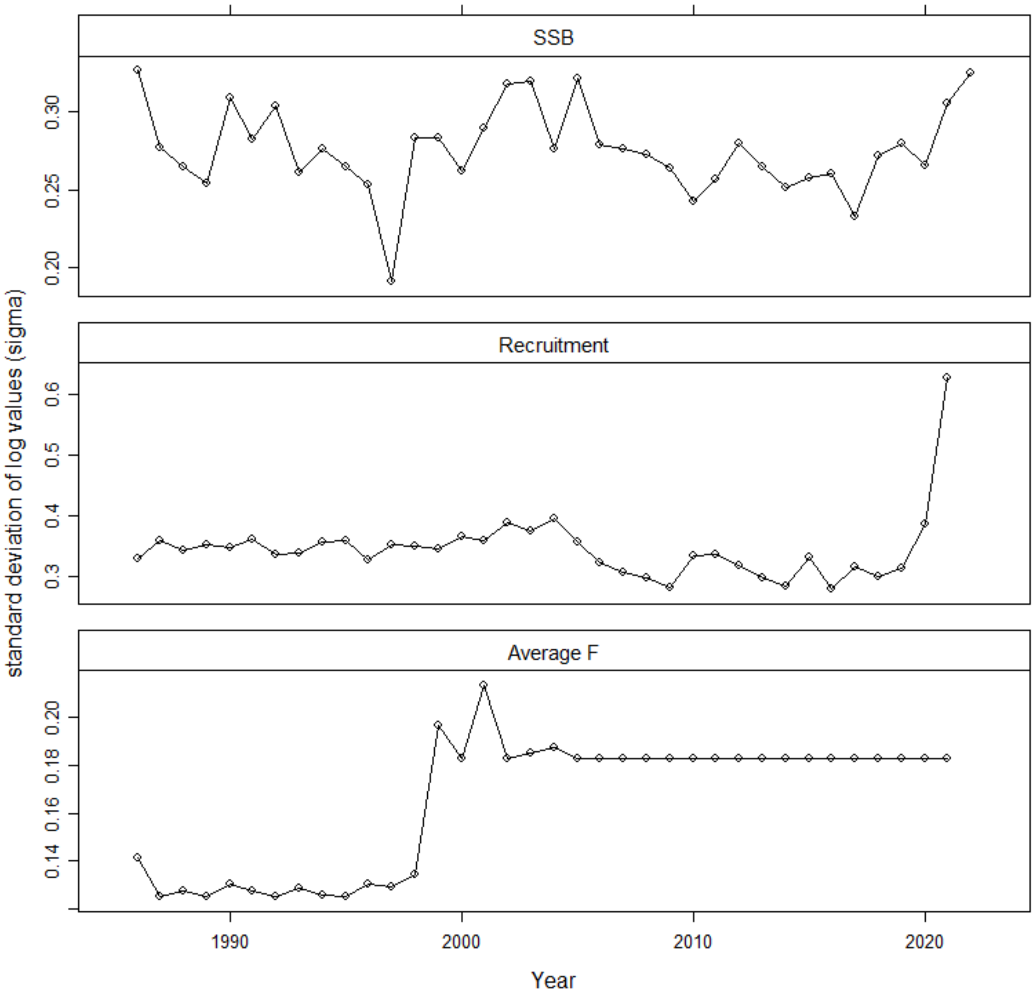


Figure 9.4.10 Sandeel Area-3r. Uncertainties of model output estimated from parameter uncertainties derived from the Hessian matrix and the delta method.

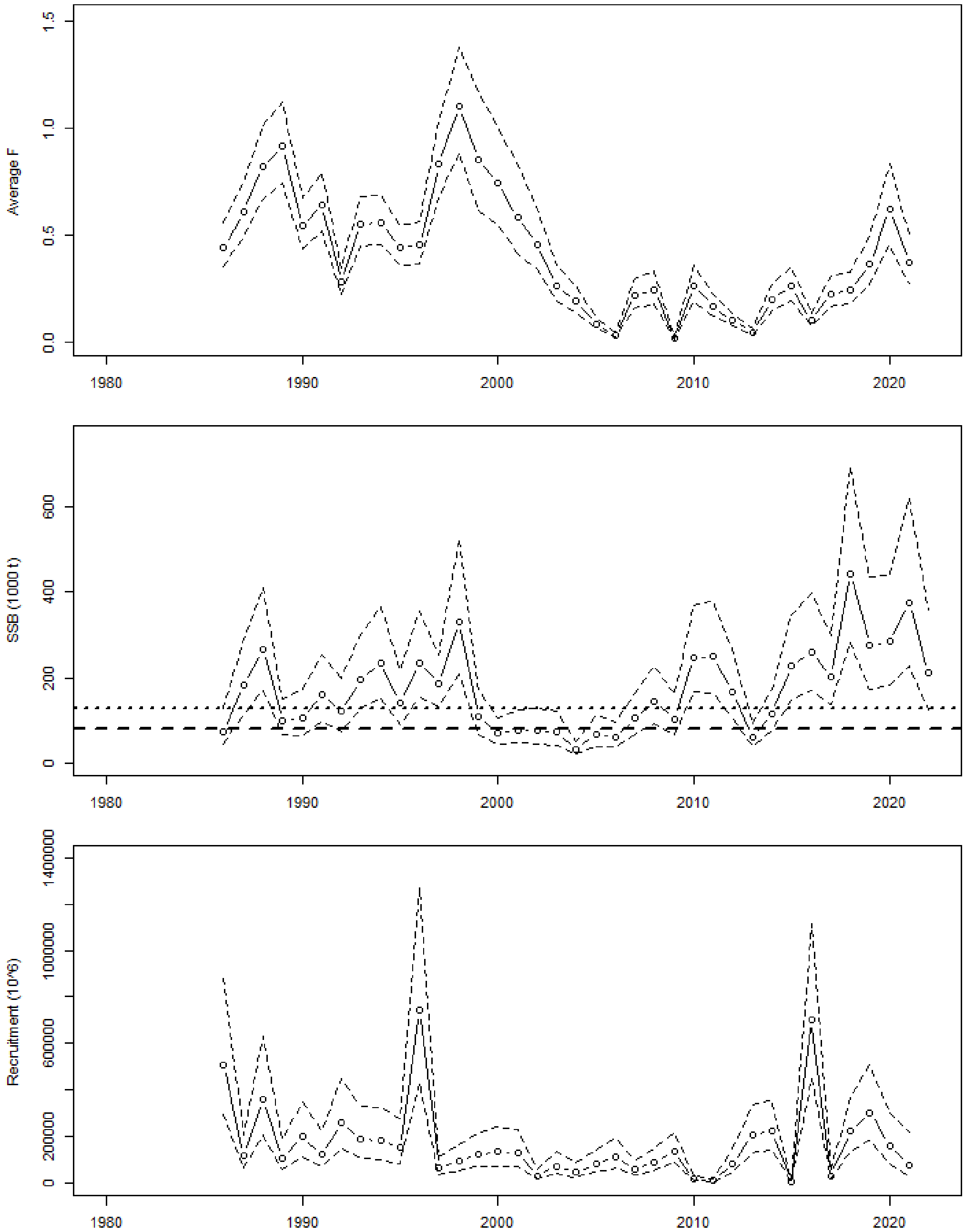


Figure 9.4.11 Sandeel Area-3r. Model output (mean F, SSB and Recruitment) with mean values and plus/minus 2 * standard deviation.

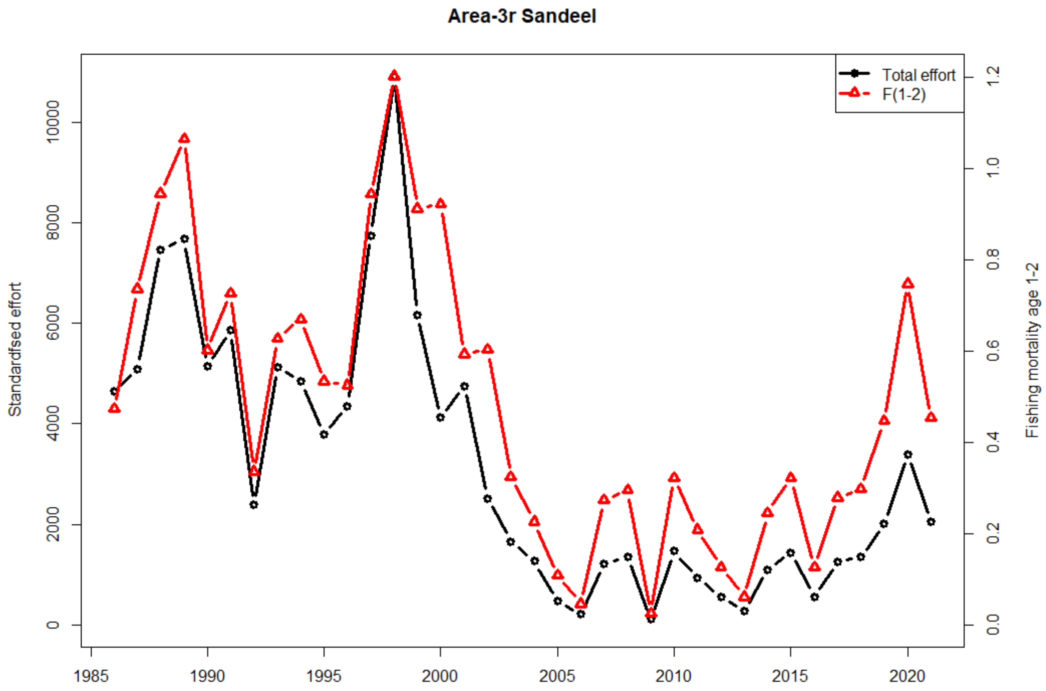


Figure 9.4.12 Sandeel Area-3r. Total effort (days fishing for a standard 200 GT vessel) and estimated average Fishing mortality.

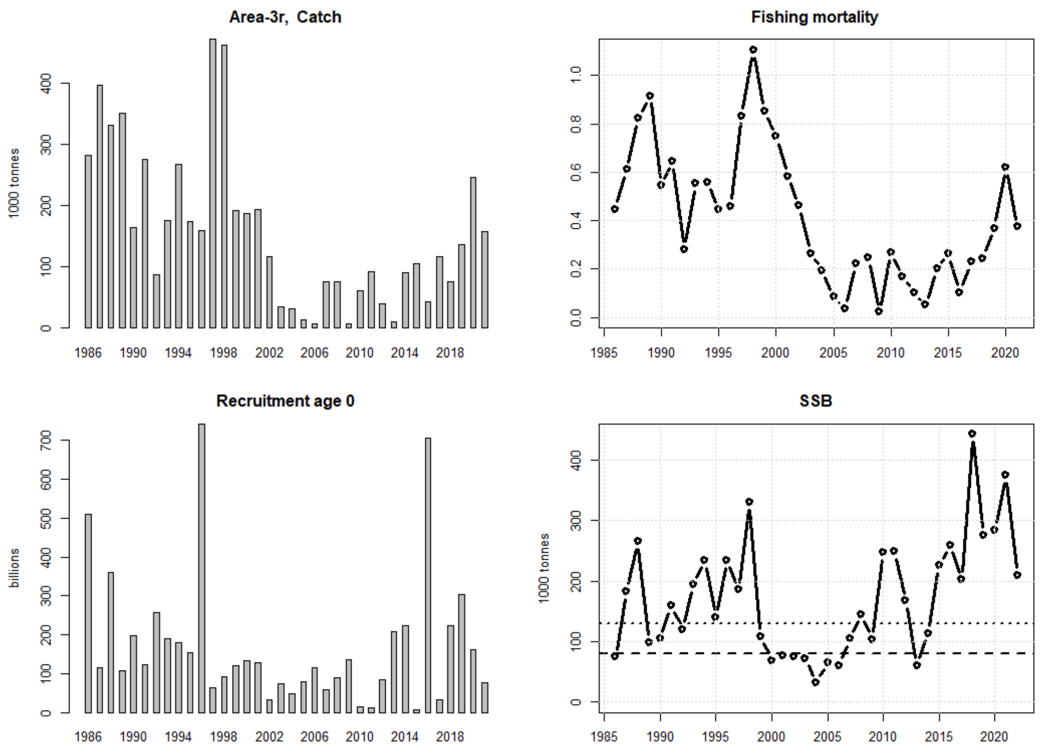


Figure 9.4.13 Sandeel Area-3r. Stock summary.

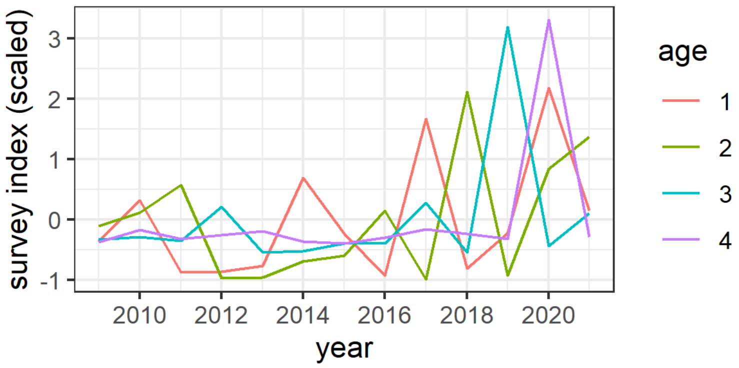


Figure 9.4.14 Sandeel Area-3r. Acoustic survey index timeline.

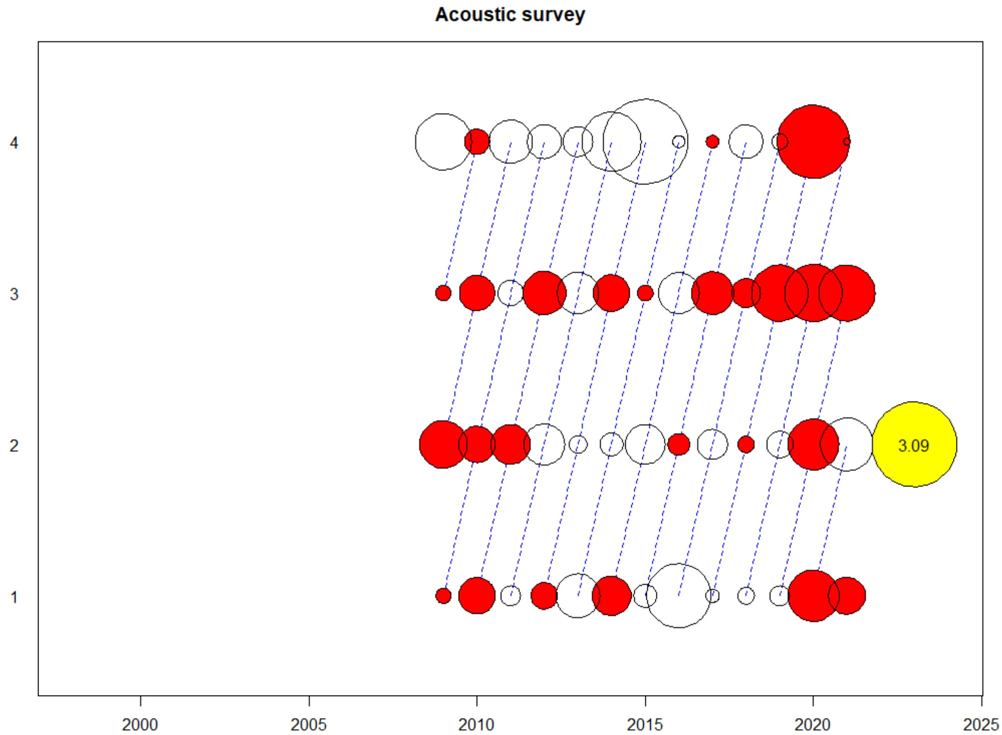


Figure 9.4.15 Sandeel Area-3r. Norwegian acoustic survey. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.

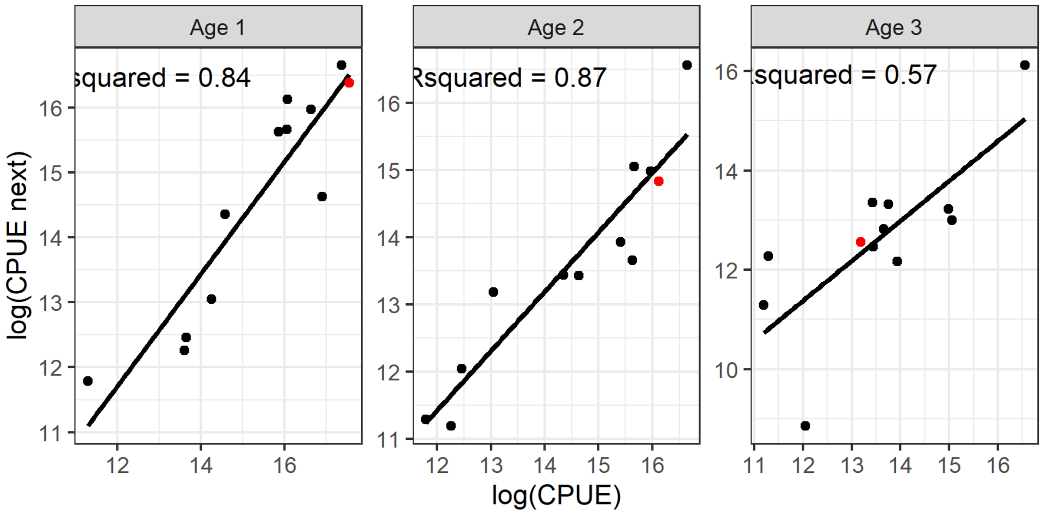


Figure 9.4.16 Sandeel Area-3r. Internal consistency by age of the acoustic survey. Red dot indicates the most recent data point.

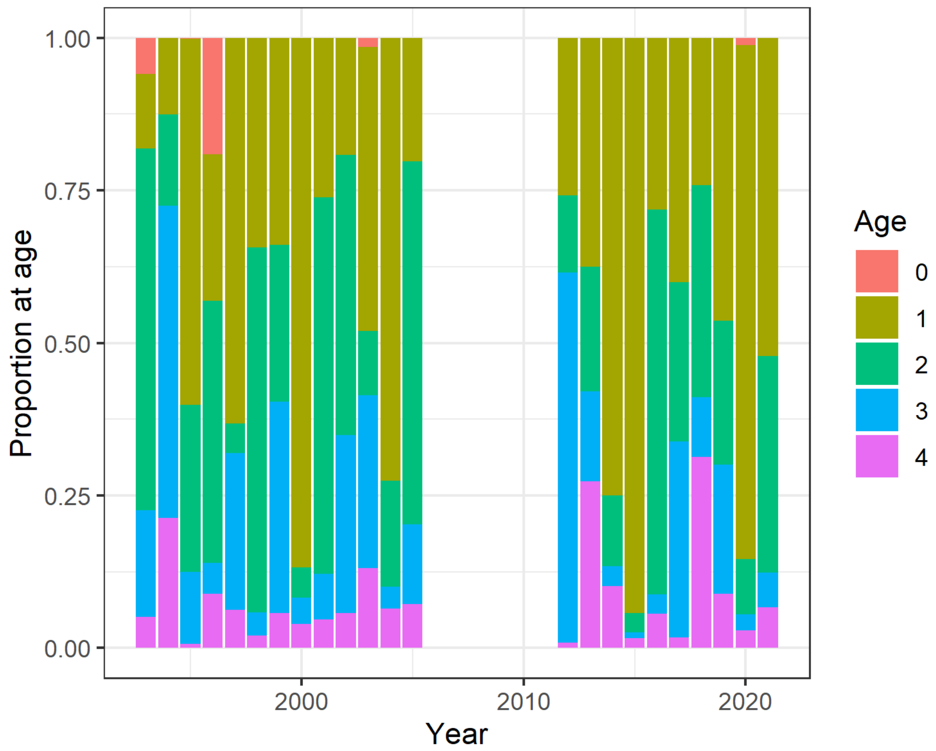


Figure 9.5.1 Sandeel Area-4. Catch numbers, proportion at age.

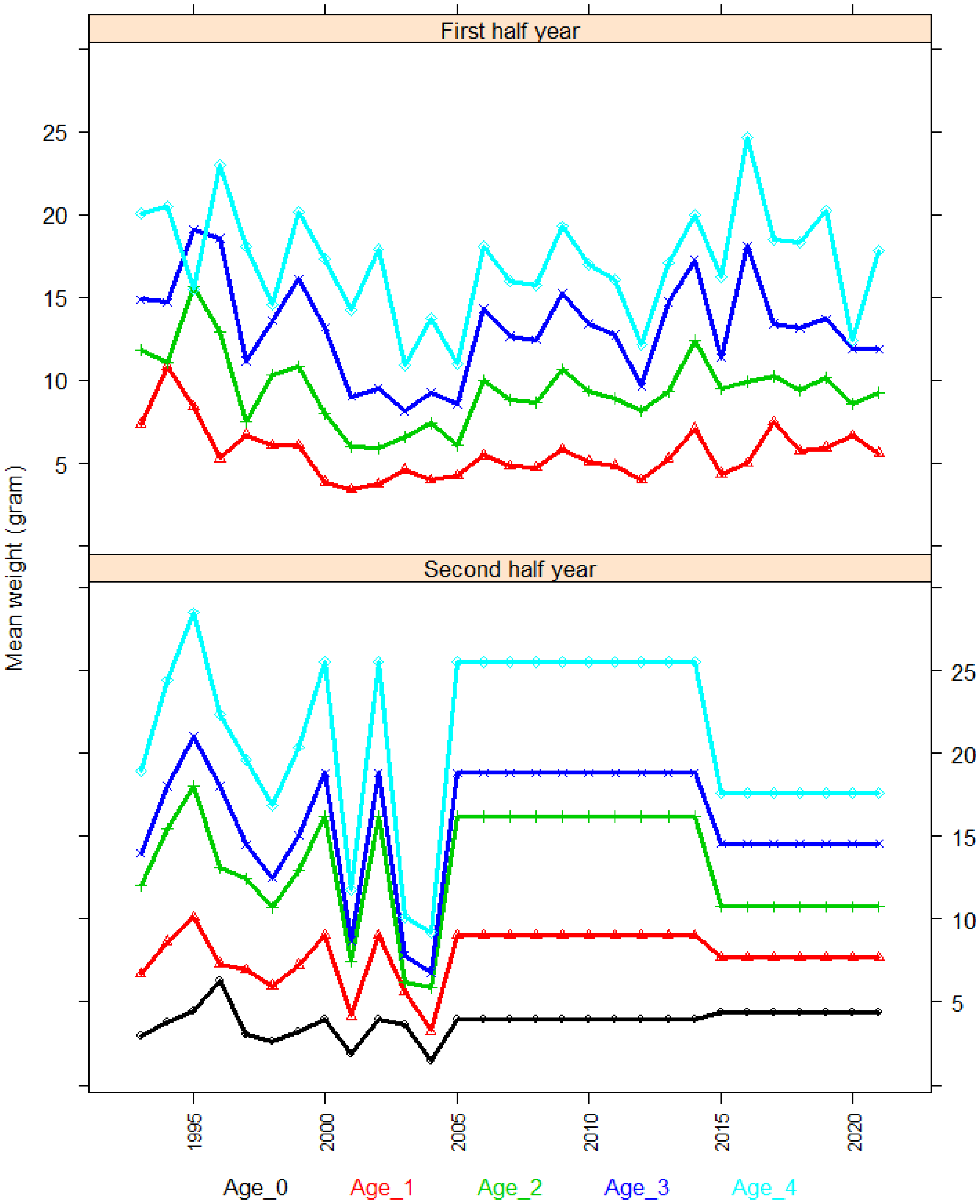


Figure 9.5.2 Sandeel Area-4. Mean weight at age in the first half year (age 1–4+) and second half year (age 0–4+).

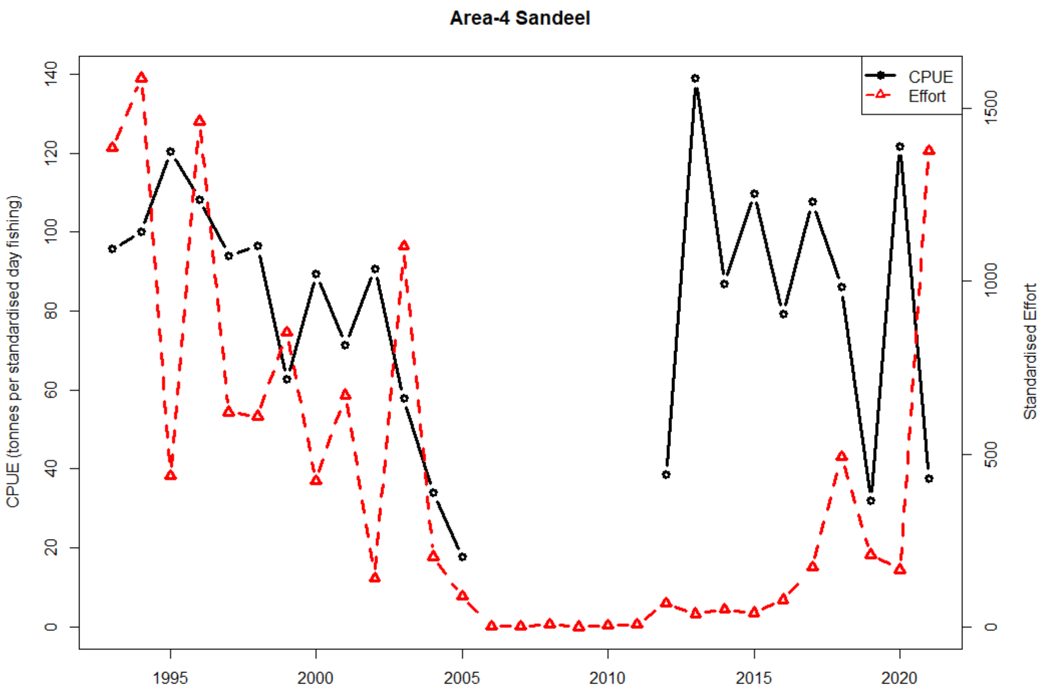


Figure 9.5.3 Sandeel Area-4. CPUE and effort.

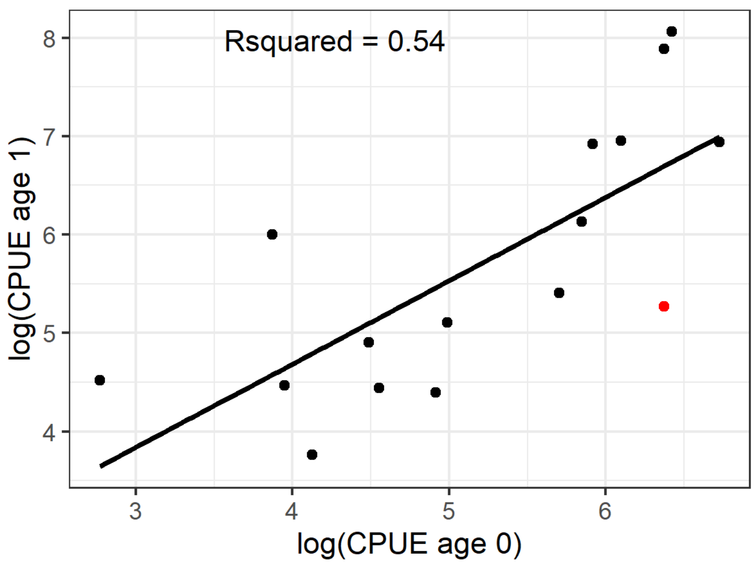


Figure 9.5.4 Sandeel Area-4. Internal consistency by age of the dredge survey. Red dot indicates the most recent data point.

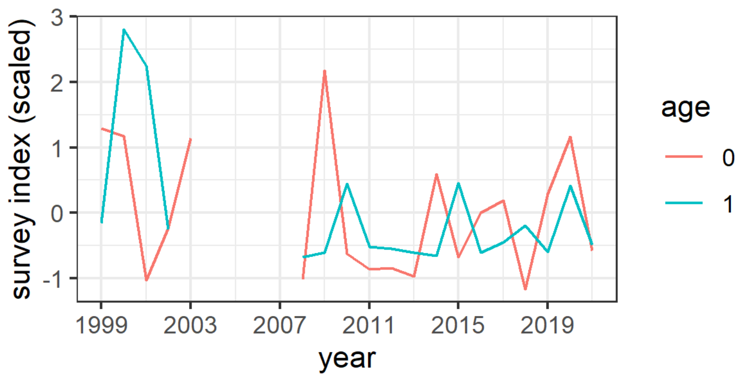


Figure 9.5.5 Sandeel Area-4. Dredge survey index timeline.

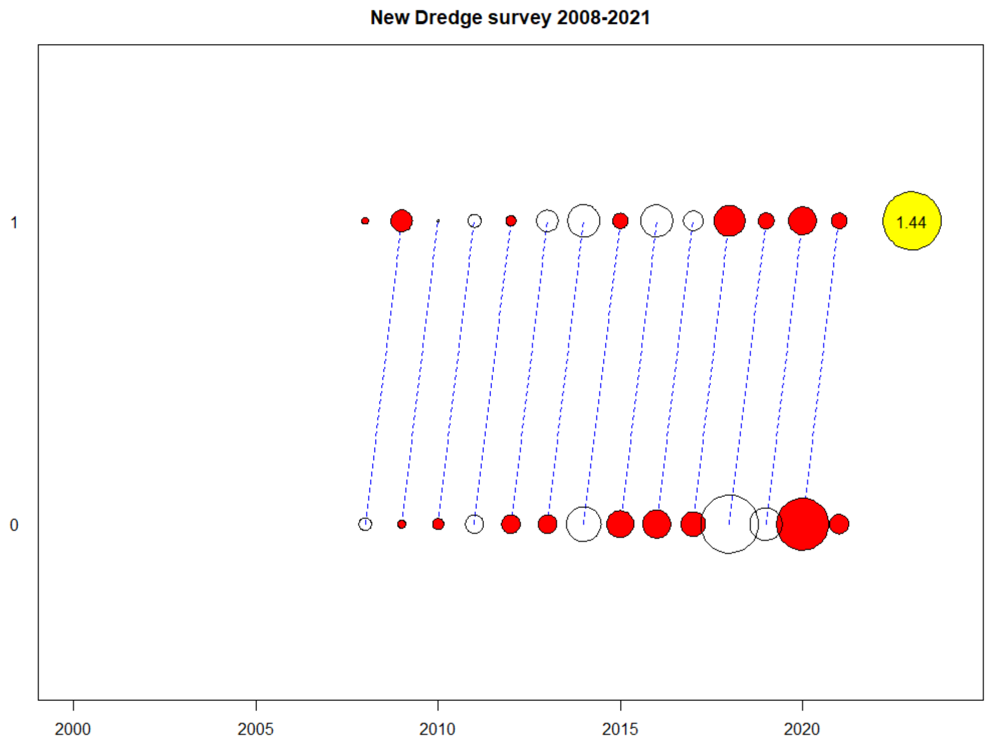


Figure 9.5.6 Sandeel Area-4. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE)). “Red” dots show a positive residual.

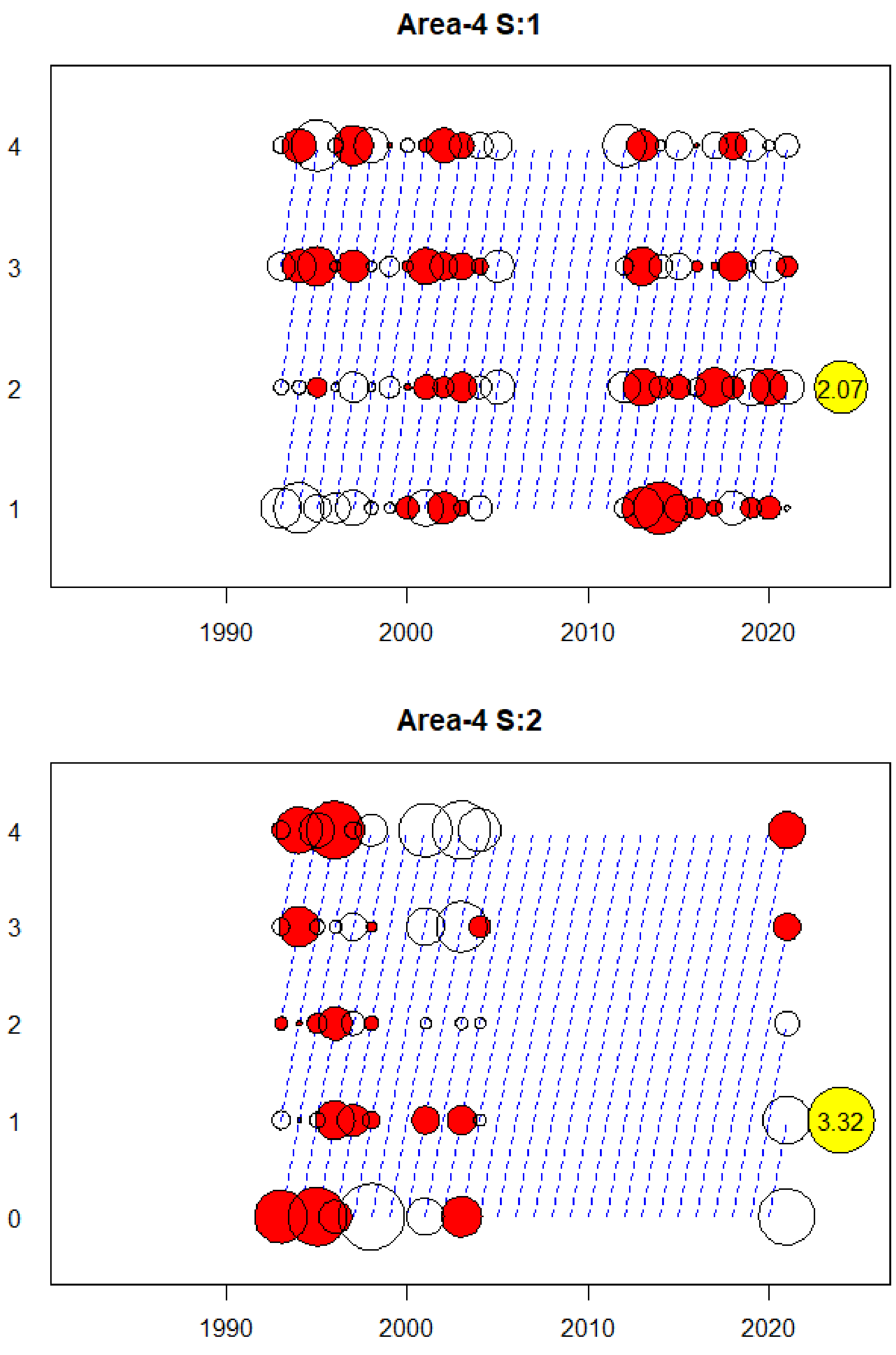


Figure 9.5.7 Sandeel Area-4. Catch at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.

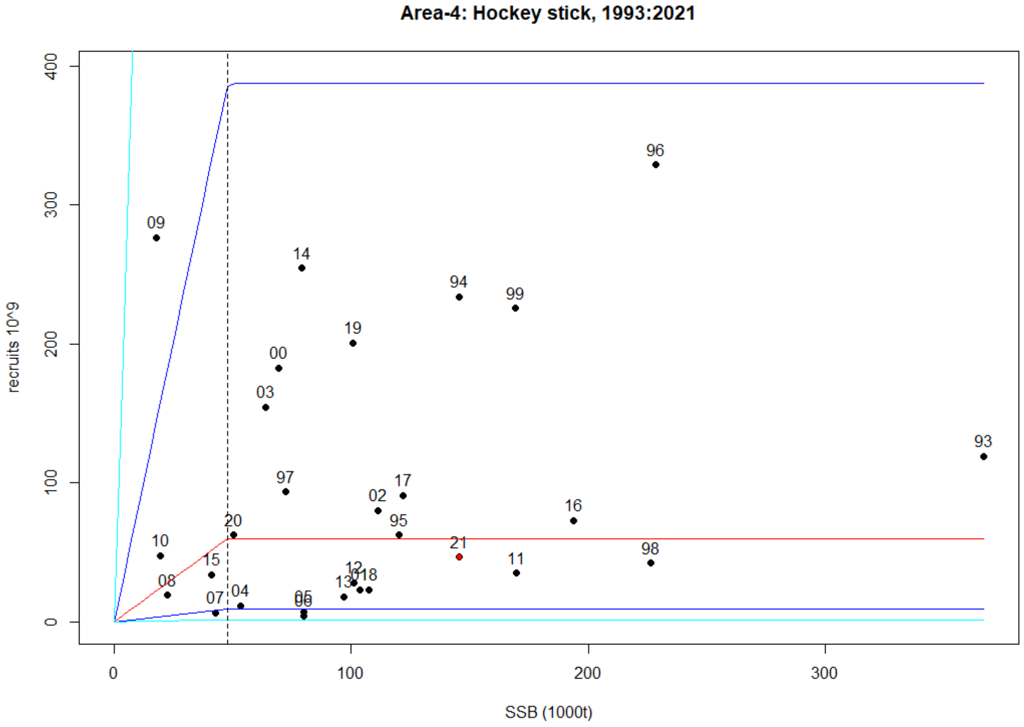


Figure 9.5.8 Sandeel Area-4. Estimated stock recruitment relation. Red line = median of the expected recruitment, Dark blue lines = one standard deviation, Light blue lines = 2 standard deviations. The area within the light blue lines can be seen as the 95% confidence interval of recruitment. Years shown in red are not used in the fit.

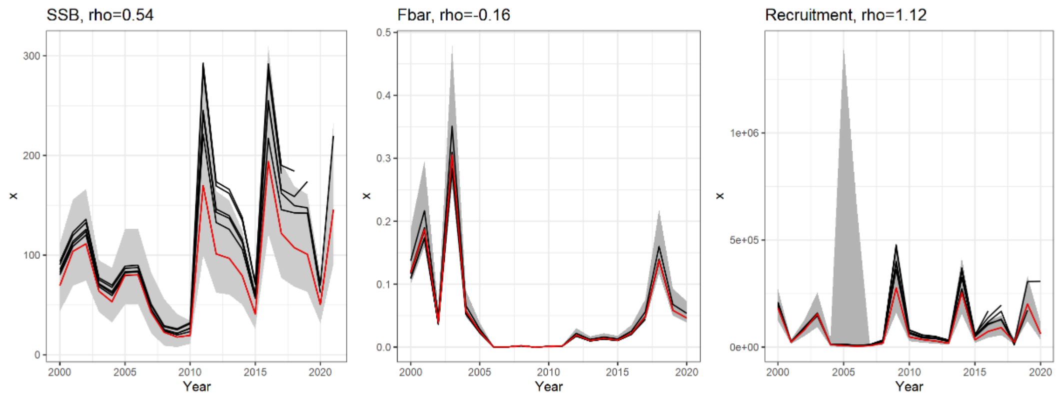


Figure 9.5.9 Sandeel Area-4. Retrospective analysis.

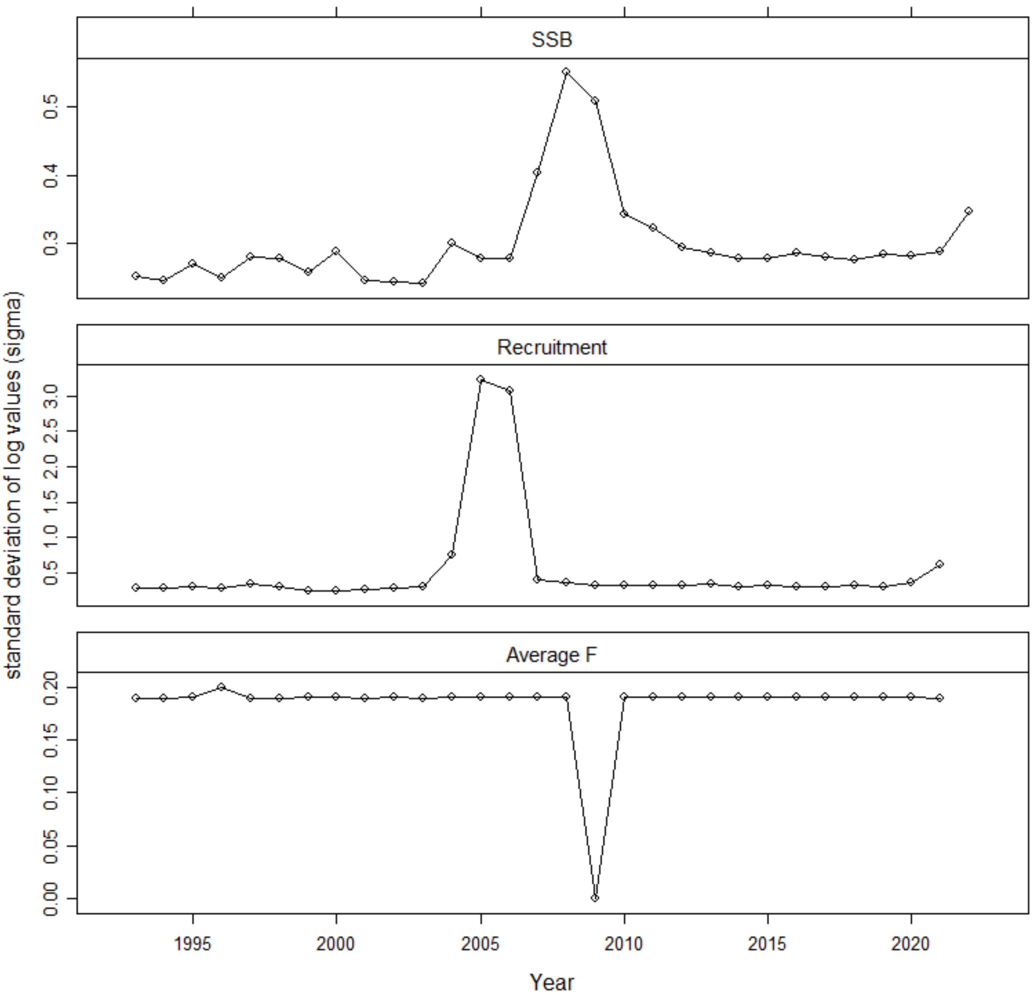


Figure 9.5.10 Sandeel Area-4. Uncertainties of model output estimated from parameter uncertainties derived from the Hessian matrix and the delta method.

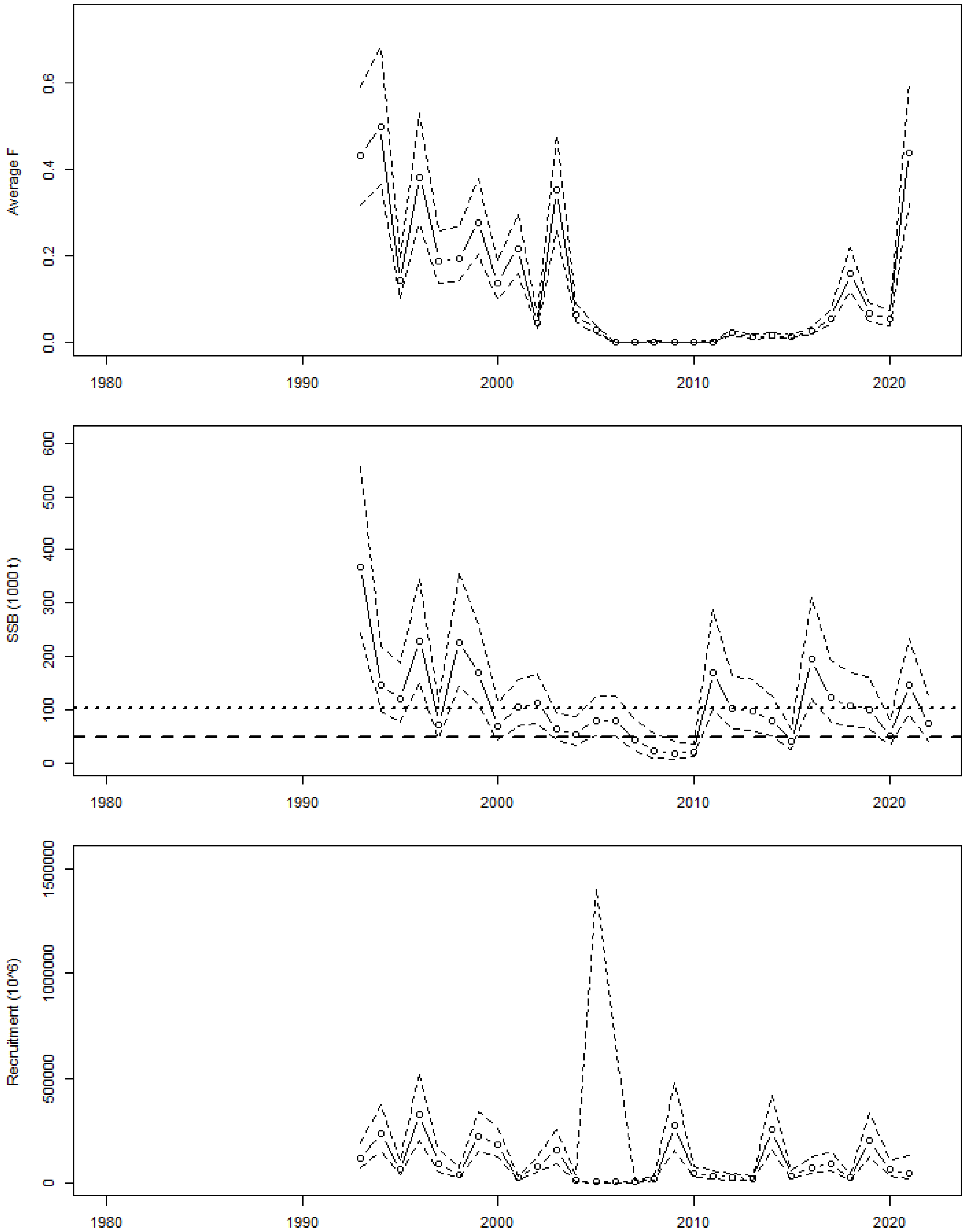


Figure 9.5.11 Sandeel Area-4. Model output (mean F, SSB and Recruitment) with mean values and plus/minus 2 * standard deviation.

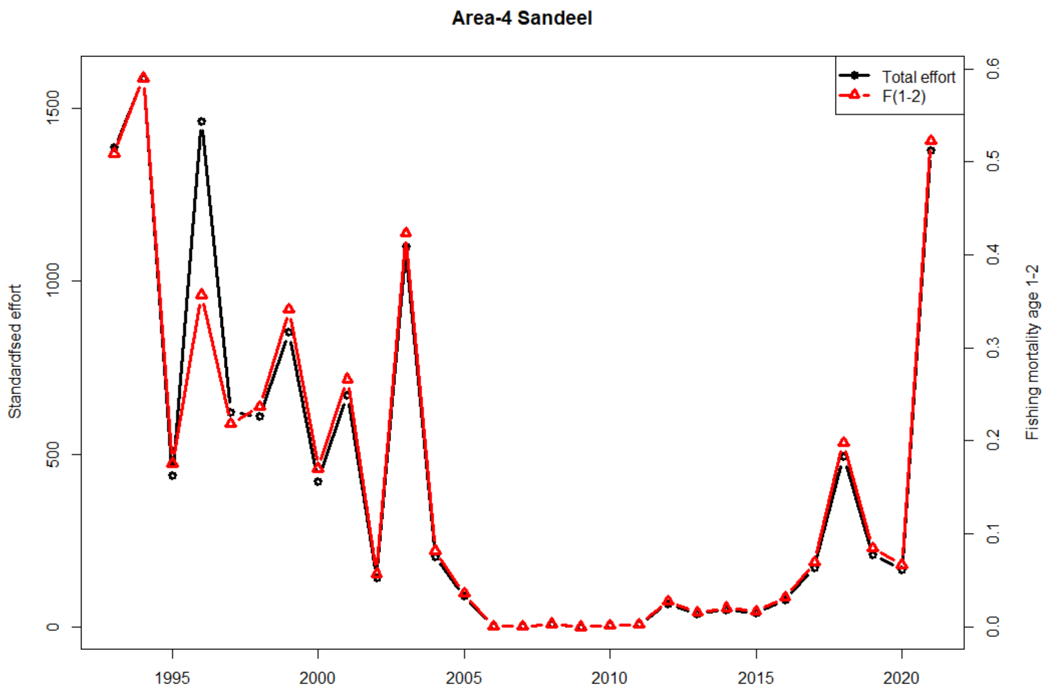


Figure 9.5.12 Sandeel Area-4. Total effort (days fishing for a standard 200 GT vessel) and estimated average Fishing mortality.

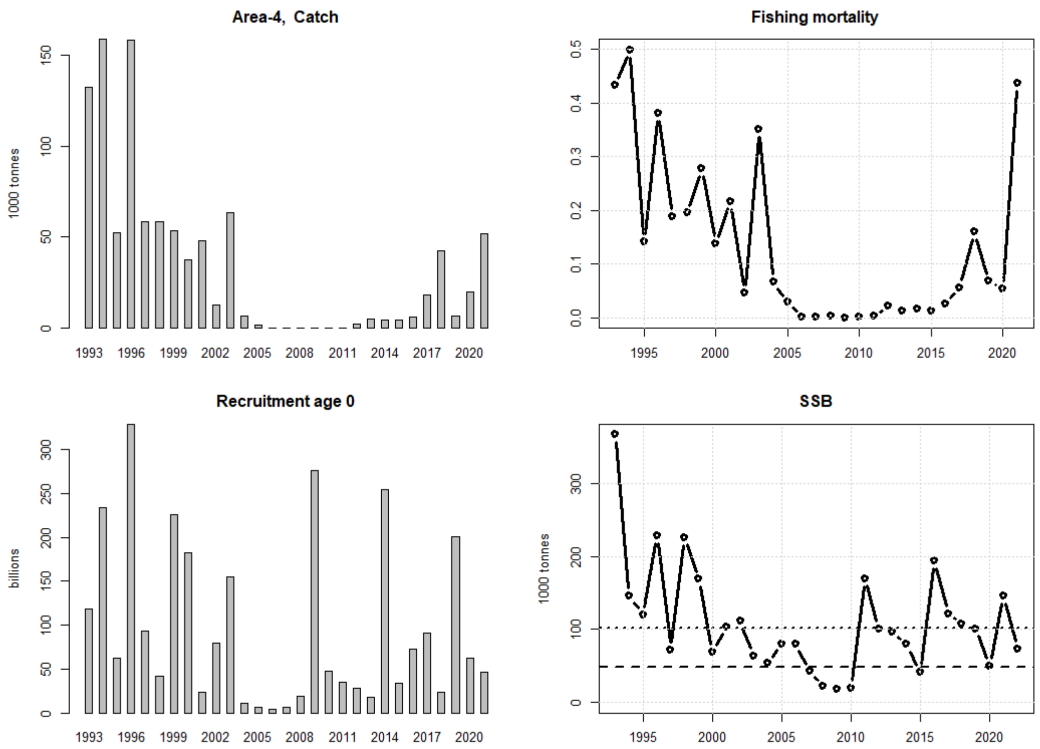


Figure 9.5.13 Sandeel Area-4. Stock summary.

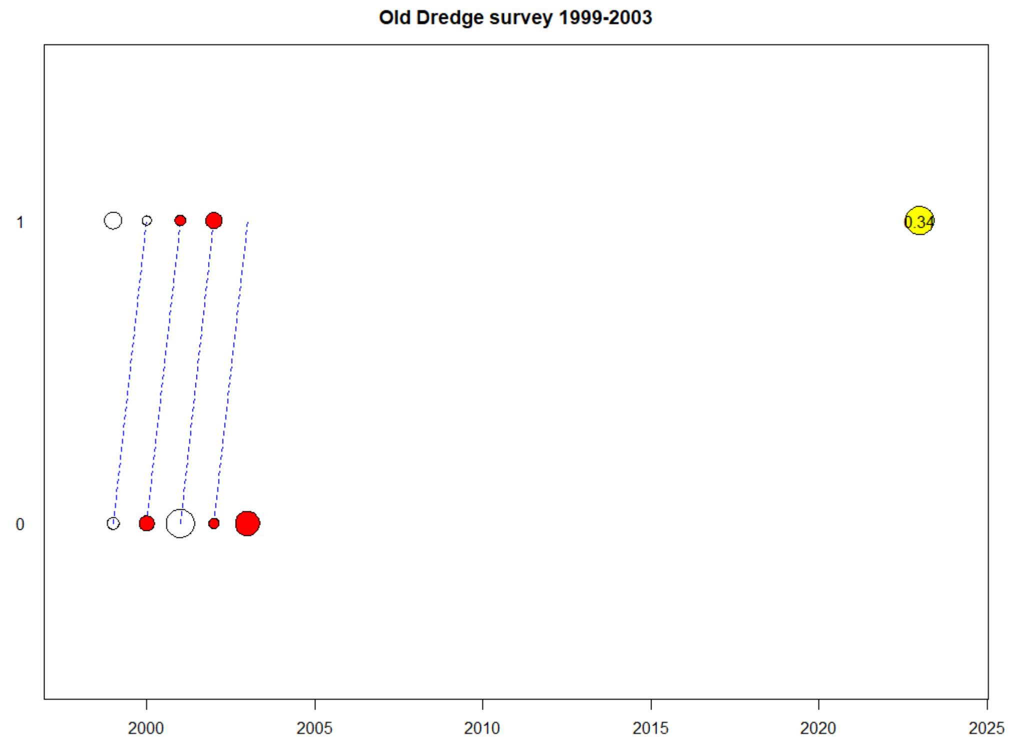


Figure 9.5.1 Sandeel Area-4. Old dredge survey. Survey CPUE at age residuals (log(observed CPUE)- log(expected CPUE)). "Red" dots show a positive residual.

10 Sprat in Division 3.a and Subarea 4 (Skagerrak, Kattegat and North Sea)

10.1 The Fishery

10.1.1 ACOM advice applicable to 2020 and 2021

There have never been any explicit management objectives for this stock. Last year, the advised TAC (July 2021 to June 2022) was set to 106 715 t for sprat in Subarea 4 and Division 3.a. The 2021 herring bycatch quotas were 7 750 t for the North Sea and 6 659 t for Division 3.a. During the WKSPRAT benchmark meeting in 2018, sprat in Subarea 4 and Division 3.a were merged into one stock assessment model. Also, several other modifications were made to the configurations of the assessment model (see (WKSPRAT: ICES, 2018) for further details).

10.1.2 Catches in 2021

Catch statistics for 1997–2021 for sprat in the North Sea by area and country are presented in Table 10.1.1. Catch data prior to 1996 are considered less reliable due to uncertainty of potential bycatches of North Sea herring (see Stock Annex). The small catches of sprat from the fjords of Norway are not included in the catch tables (Table 10.1.1–10.1.2). The WG estimate of total catches for the North Sea and Division 3.a in 2021 were 80 761t (total official catches amounted to 81 807 t). This is a 56% decrease compared to 2020. The Danish catches represent 86% of the total catches.

The spatial distribution of landings was similar to 2020, although smaller catches were seen (Figure 10.1.1). A very low percentage (~1% in 2021) of the catches were landed in the first and second quarter of 2021 (Table 10.1.2).

10.1.3 Regulations and their effects

Most sprat catches are taken in an industrial fishery where catches are limited by herring bycatch quantities. Bycatches of herring are practically unavoidable except in years with high sprat abundance or low herring recruitment. Bycatch is especially considered to be a problem in area 4.c. This led to the introduction of a closed area (sprat box) to ensure that sprat catches were not taken close to the Danish west coast where large bycatches were expected.

ICES evaluated the effectiveness of the sprat box in 2017 (ICES, 2017). The evaluation showed that fishing inside the sprat box would be expected to reduce unwanted catches of herring by weight but not in number and concluded that other management measures are sufficient to control herring bycatch. The sprat box was removed in 2017.

The Norwegian vessels have a maximum vessel quota of 550 t when fishing in the North Sea. A herring bycatch of up to 10% in biomass is allowed in Norwegian sprat catches.

10.1.4 Changes in fishing technology and fishing patterns

No major changes in fishing technology and fishing patterns for the sprat fisheries in the North Sea have been reported. From about 2000, Norwegian pelagic trawlers were licensed to take part in the sprat fishery in the North Sea. In the first years, the Norwegian catches were mainly taken by purse-seine, and the catches taken by trawl were low. In recent years, the share of the total Norwegian catches taken by trawl has increased (2020: 92% taken by trawl).

10.2 Biological composition of the catch

Only data on bycatch from the Danish fishery were available to the Working Group (Table 10.2.1). The Danish sprat fishery was conducted with a 7.2% and 10.7% bycatch of herring in 2021 in the North Sea and Division 3.a, respectively. The total amount of herring caught as bycatch in the sprat fishery has mostly been less than 10%. From 1st of April 2020 the Danish methodology behind the by-catch estimation in the fisheries for reduction changed. Before, the Danish fishery control regularly sampled the landings for reduction, and afterwards a species composition was estimated per month, square and fishery. Now, each and every landing for reduction into Denmark is subsampled by the buyer and the estimated species composition is reported directly in the sale slips. Many of the buyers use independent companies, 3rd party, for sampling.

The estimated quarterly landings at age in numbers for the period 1974–2021 are presented in Table 10.2.2. In the model year 2021 (1 July 2021–30 June 2022), one-year old sprat contributed 68% of the total landings, which is close to the 1990–2020 average (66%). 2-year-olds contributed 20% in 2021 (model year), which is above the 1990–2020 average (15%). 0-year-olds contributed 8% of the total landings, which is lower than the 1990–2020 average (16%).

Denmark and Sweden provided age data of commercial landings in 2021 (Table 10.2.4). Quarter 1, 3 and 4 were covered. Quarter 1 in 2021 had very low catches and low number of samples. The sample data were used to raise the landings data from the North Sea, Skagerrak, and Kattegat. The landings by Germany (3 572 t), the Netherlands (139 t), UK-Scotland (105 t), UK-England and Wales (33 t) and Belgium (<1 t) were unsampled and Norway didn't catch the stock in 2021. The sampling level has been greatly improved since 2014 because of the implementation of a sampling programme for collecting haul-based samples from the Danish sprat fishery. However, the sampling level in 2020 (model year) was substantially reduced with only 0.6 samples taken per 2000 t. The low level of sampling in 2020 was caused by a not fully implemented change in the Danish sampling program. Since the introduction of the new by-catch estimation method in 2020, mentioned above, the Danish institute has been able to get samples from most of the buyers / 3rd party companies. Therefore, the Danish institute introduced a new sampling strategy in 2020, where vessels above 24 meters are sampled with a higher frequency than smaller vessels. Vessels above 24 meters are still being encouraged to deliver self-samples, but if not, a 3rd party sample is used as a substitute. All samples from vessels below 24 meters comes from the 3rd party companies. The new sampling strategy has secured a high level of sampling in 2021.

The number of samples used for the assessment, both length and age-length samples, is shown in Table 10.2.4–5 and Figure 10.2.1.

10.3 Fishery Independent Information

10.3.1 IBTS Q1 and Q3

Table 10.3.1 and Figure 10.3.1 and 10.3.2 give the time-series of IBTS indices by age (calculated using a delta-GAM model formulation; see WKSPRAT report (2018) for further details). The data source is the IBTS Q1 data from 1983–2022. The index for IBTS Q1 1-year old in 2021 (age-0 in the model and the table, serving as a recruitment index) was 35% below average and 45% lower than last year's index. There has been a tendency for an increase in the IBTS age 0 in the time-series since 1990. Furthermore, older age-groups (i.e. age-1 and age-2) decreased by >45% compared to the year before. Note that due to both rough weather and outbreaks of Covid-19, IBTS Q1 survey was limited, which affected the sampling coverage. Thus, the coverage was reduced drastically for some parts of the North Sea. Although, it is not expected to have any significant effect for the sprat assessment, a 15% increase in CV for the index is reported compared to last year. Spatial pattern in residuals was checked and did not raise any concerns. Furthermore, the model is designed to handle such issues to some extent. IBTS Q3 survey indices were also used in the assessment for older age-groups, and the 2021 values for all age-groups (i.e. age-1, age-2 and age-3+) were more than 50% lower compared to 2020.

10.3.2 Acoustic Survey (HERAS)

Abundance indices were provided by WGIPS (ICES, 2022) (see Section 1.4.2). The abundance indices for Subarea 4 and Division 3.a were summed (Table 10.3.2 and Figure 10.3.2b). The 2021 values were 22% higher, 61% lower, and 27% lower (age-1, age-2, and age-3, respectively) compared to the 2020-values.

10.4 Mean weights-at-age and maturity-at-age

Mean weights-at-age in catches are given in Table 10.2.3 and Figure 10.4.1. Mean weights in model season 1 and 2 (S1 and S2; quarter 3 and 4), where most of the catches are taken, show a declining trend over the past decade. In 2019, the mean weights of age-1 and age-3 fish in S1 were the lowest observed for nearly two decades but since 2020 this decline was arrested. Weights were almost identical for all age-groups S1 compared to 2020. In contrast weights for all age-groups declined in S2 (Figure 10.4.1).

Proportion of mature fish was derived from IBTSQ1, following the benchmark procedure. Long-term average maturity ogives were used in the assessment model (0.0, 0.41, 0.87, and 0.95 for age-0 to age-3+). More details about the maturity staging are given in Section 4.5.3.2 in the WKSPRAT 2013 report (ICES, 2013).

10.5 Recruitment

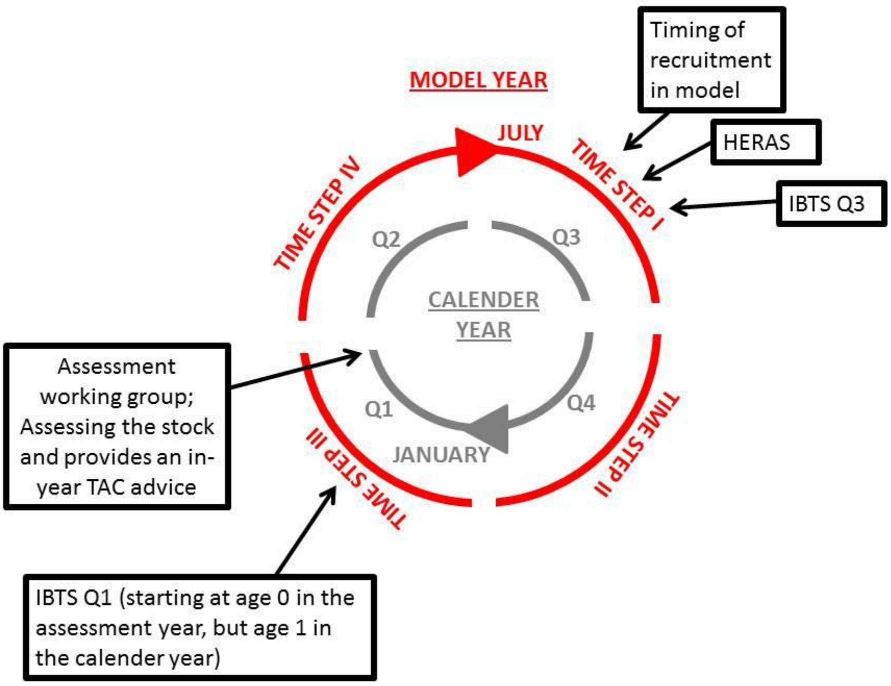
The IBTS Q1 age-1 index (age-0 in the model) (Table 10.3.1) is used as a recruitment index for this stock. The 2022 value, indicative of the 2021 recruitment, was 35% below average, corresponding to a 45% decrease of the recruitment index in the previous year. The recruitment estimated by the model for 2021 is 19% lower than the recruitment in 2020 and 43% below the 2011-2020 geometric mean (Table 10.6.4). At the most recent benchmark, it was decided to implement a power model (directly within the assessment model) to the age-0 IBTS Q1 index to dampen the effect of very high index values. This was done to reduce the retrospective bias on recruitment (see WKSPRAT 2018 for further details).

10.6 Stock Assessment

The stock assessment was benchmarked in November 2018 (WKSPRAT: ICES, 2018). During the WKSPRAT benchmark meeting in 2018, sprat in Subarea 4 and Division 3.a were merged into one stock assessment model. Also, several other modifications were made to the configuration of the assessment model (see WKSPRAT report (ICES, 2018) for further details).

In-year advice is the only possible type of advice for this short-lived species with catches dominated by 1- and 2-year-old fish. This, however, requires information about incoming 1-year old fish. To meet this requirement and to come up with a model that logically matches the natural life cycle of sprat, the annual time-step in the model was shifted, relative to the calendar year, to a time-step going from July to June (see text table below). SSB and recruitment was estimated at 1 July. In figures and tables with assessment output and input, the years refer to the shifted model year (July to June) and in each figure and table it is noted whether model year or 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 1 July 2000 to 30 June 2001). The following schematic illustrates the shifted model year relative to the calendar year and provides an overview of the timing of surveys etc.

Model year		Calendar year	
2000	Season 1	2000	Quarter 3
2000	Season 2	2000	Quarter 4
2000	Season 3	2001	Quarter 1
2000	Season 4	2001	Quarter 2



10.6.1 Input data

10.6.1.1 Catch data

Information on catch data are provided in Tables 10.1.1–2 and in Figures 10.1.1 and 10.6.1. Sampling effort is presented in Table 10.2.5 and Figure 10.2.1.

Since catches in quarter 2 (season 4 in the model) are often less than 5000 tonnes, these are poorly estimated by the model and the number of samples from these catches are low (sometimes no samples). Furthermore, at the time of the assessment working group, S4 catches are unknown. Therefore, during the latest benchmark it was decided to move S4 catches into S1 in the following model year. In 2022, only 478 t were taken in quarter 1 and no age samples taken. To avoid the resulting high uncertainty in the age distribution of these catches, they were transferred to 2021 quarter 4, leading to a total catch of 15 617 t in this quarter.

10.6.1.2 Weight-at-age

The mean weights at age observed in the catch are given in Table 10.2.3 and Figure 10.4.1 by season. It is assumed that the mean weights in the stock are the same as in the catch. The mean weight at age of S1 that is used to calculated SSB.

10.6.1.3 Surveys

Three surveys were included (Tables 10.3.1–3), IBTS Q1 (1975–present), IBTS Q3 (1991–present) and HERAS (Q3) (2003–present). 0-group (young-of-the-year) sprat is unlikely to be fully recruited by the time of IBTS Q3 and HERAS, and for this reason these age indices were excluded from the model.

10.6.1.4 Natural mortality

New natural mortalities were available from the 2020 North Sea key run from WGSAM (ICES, 2017). The major changes were changes to mean weight of whiting leading to lower mortalities particularly in the early part of the time series. HAWG reviewed stock assessments based on the old and new M's. The new mortalities reduced AIC of the model from 865 to 859, indicating a substantially improved fit. CVs for the catches decreased by up to 3% while survey CVs changed by -4 to +5% (average +0.2%). The CV on the terminal SSB increased by 9%. For comparison, the change from the 2019 to the 2020 assessment, both using old mortalities, was an increase in CVs for the catches of up to 4% while survey CVs changed by -5 to +20% (average +6%). The CV on the terminal SSB decreased by 20%). In summary, the AIC of the assessment using new mortalities was substantially improved and changes to estimated parameters were within the range observed in annual updates. The change in average recruitment, SSB and F over the past 20 years were 2%, -4% and +1% (new compared to old). The change to selection pattern was between -2 and 5% for age groups 1 and 2 (the F-bar ages). The group inspected the stock-recruitment plot and found no substantial changes. According to benchmark guidelines, no substantial changes in stock parameters or stock-recruitment plot would lead to the adoption of new mortalities in the assessment. However, the recent guidance from ACOM LS requires that reference points are re-estimated and an inter-benchmark process conducted when new M's are introduced. Given the strict time schedule for advice on this stock and the fact that the reference points according to the benchmark are estimated in a full (time consuming) MSE model, the group did not consider it feasible to conduct an inter-benchmark in time for the 2021 advice. Further, the group felt that they could not guarantee that using new mortalities would not lead to changes in reference points if these were re-estimated. Therefore, the old mortalities were used in the assessments from 2021 and onwards. Variable mortality is applied as three-year averages up till 2015, and after this the average mortality for 2013–2015 is used. Natural mortalities used in the model are given in Table 10.6.1.

10.6.1.5 Proportion mature

Proportion of mature fish was derived from IBTSQ1, following the benchmark procedure. Long-term average maturity ogives were used in the assessment model (0.0, 0.41, 0.87, and 0.95 for age-0 to age-3+). More details about the maturity staging are given in Section 4.5.3.2 in the WKSPRAT 2013 report (ICES, 2013).

10.6.2 Stock assessment model

The assessment was made using SMS (Lewy and Vinther, 2004) with quarterly time-steps (referred to as season S1–S4). Three surveys were included, IBTS Q1 ages 1–4+, IBTS Q3 ages 1–3 and HERAS (Q3) ages 1–3. 0-group sprat is unlikely to be fully recruited to the IBTSQ3 or HERAS in Q3 and these age indices were excluded from runs. External consistency between IBTS Q1, IBTS Q3 and HERAS can be found in the benchmark report (WKSPRAT2018: ICES, 2018).

The model converged and fitted the catches of the main ages caught in the main seasons reasonably (ages 1–2, seasons 1 and 2, Table 10.6.2). All surveys had low CVs (Table 10.6.2). There were no patterns in the residuals raising concern. Although, there appears to be a periodic cycling (on a decadal time-scale) between positive and negative residuals in the IBTS Q3 survey and the catches (Figures 10.6.2–3). Common CVs were estimated for the groups: 1 to 3-year olds in IBTS Q1 and 2 and 3-year olds in IBTS Q3 and HERAS.

The retrospective analyses showed a tendency to overestimate recruitment (5 years Mohn´s rho = 0.27) (Figure 10.6.5). As 41% (see 10.6.1.5) of the recruiting year class mature in their first year and thus contributes to the SSB at the end of the year, there is a similar large retrospective pattern in SSB (5-year Mohn´s rho = 0.25). The assessment model was improved with this respect during the last benchmark and Mohn´s rho was reduced by roughly a factor of 3 due to the improvement.

The final outputs detailing trends in mean F, SSB and recruitment are given in Figures 10.6.4–7 and Tables 10.6.3–4.

10.7 Reference points

A B_{lim} of 94 000 t (Figure 10.7.1) and B_{pa} of 125 000 t were agreed at the most recent benchmark. B_{pa} is defined as the upper 90% confidence interval of B_{lim} and calculated based on a terminal SSB CV of 0.173.

10.8 State of the stock

The sprat stock has a decreasing trend during the last couple of years judging by all the surveys and by the assessment output. The stock has been well above B_{pa} since 2013 and above B_{lim} since 1991 but is now estimated to be below B_{pa} for the first time in nine years. The current SSB is 20% below B_{pa}. Fishing mortality has fluctuated without a trend, but the F of 2.169 in 2021 was the third highest in the time-series. The advised TAC was based on the predicted catch at F equal to F_{cap} (0.69). A large overshoot of F_{cap} is seen in simulations applying the escapement strategy on very large incoming year classes, and this is the rationale for implementing an F_{cap} as otherwise, the escapement strategy is not precautionary at large stock sizes.

A stock summary from the assessment output can be found in Table 10.6.4 and Figure 10.6.7.

10.9 Short-term projections

Management strategy evaluations for this stock were made in December 2018 (WKSPRATMSE: ICES, 2018). These evaluations clearly show that the current management strategy ($B_{escapement}$) is not precautionary unless an additional constraint is imposed on the fishing mortality (referred to as F_{cap}). During the WKSPRATMSE (ICES, 2018) 0.69 was found to be the optimal F_{cap} value (from both a full MSE and a shortcut MSE, see the WKSPRATMSE report (WKSPRATMSE: ICES, 2018) for further details), which is a revision of the previous value of 0.7. This means, that the fishing mortality (F_{bar}(1–2)) derived from the $B_{escapement}$ strategy, should not exceed 0.69.

SSB in 2023 is expected to be higher than in 2022 and above the long-term average, and well above B_{pa} (+45%). Using the input and assumptions detailed above, the projection for an F = 0 is an SSB in July 2023 of 222 210 t (Table 10.9.2). The F_{MSY} approach prescribes the use of an F value of 0.69 (F_{cap}, see explanation above) and results in a TAC advice of 69 690 t (July 2022–June 2023), which is expected to result in an SSB of 181 215 t in July 2023, well above B_{pa}.

10.10 Quality of the assessment

The data used within the assessment, the assessment methods and settings were carefully scrutinized during the 2018 benchmark (ICES, 2018). A complete overview of the choices made during the benchmark can be found in the WKSPRAT report (ICES, 2018) and these are also described in the Stock Annex for sprat in Division 3.a and Subarea 4.

The assessment shows medium to high CVs for the catches but low CVs for surveys. The CVs of F, SSB and recruitment are generally low (see Table 10.6.2 and Figure 10.6.4). The model converged and fitted the catches of the main ages caught in the main seasons (the periods with most samples) reasonably well (ages 1–2, season 2, Table 10.6.2). The retrospective pattern in SSB and recruitment (5-years Mohn´s rho of 0.25 and 0.27, respectively) is below the advised limit of 0.3 discussed in WKFORBIAS (2019).

There appears to be a systematic pattern in the catch residuals of model season 1 (quarter 3), which remains unexplained.

10.11 Management Considerations

A management plan needs to be developed for this stock. Sprat is an important forage fish; thus, also multispecies considerations should be made.

The sprat stock in the North Sea is dominated by young fish. The stock size is mostly driven by the recruiting year class. Thus, the fishery in a given year will be dependent on that year's incoming year class.

Industrial fisheries are allocated a bycatch of 8174 t and 6659 t of juvenile herring in 2022 in the North Sea and Division 3.a, respectively. It is important to continue monitoring bycatch of juvenile herring to ensure compliance with this allocation.

10.11.1 Stock units

After the latest benchmark, sprat in the Subarea 4 and Division 3.a is considered to be one cohesive stock. This is documented in the WKSPRAT report (ICES, 2018). In addition, there are several peripheral areas of the North Sea and Division 3.a where there may be populations of sprat that behave as separate stocks from the main stock. Local depletion of sprat in such areas can be an issue of ecological concern.

10.12 Ecosystem Considerations

Sprat is an important prey species in the North Sea ecosystem. The influence of the sprat fishery on other fish species and seabirds are at present not documented to be substantial.

In the North Sea, the key predators consuming sprats are included in the stock assessment, using SMS estimates of sprat consumption for each predatory fish stock, and estimates for seabirds though this information is as described under natural mortality not up to date. Impacts of changes in zooplankton communities and consequent changes in food densities for sprats are not included in the assessment, but it may be useful to explore the possibility of including this, or a similar proxy bottom-up driver, in future assessments. However, the effect of changes in productivity is included in the observed quarterly weight-at-age and in the estimated recruitment, as a decline in e.g. available food can lead to lower observed weights and lower estimated recruitment even in the absence of a causal link in the model.

10.13 Changes in the environment

Temperatures in this area have been increasing over the last few decades. This may have implications for sprat, although the correlation between temperature and recruitment from the model has been found to be low (see WKSPRAT2018: ICES, 2018).

Table 10.1.1. North Sea & 3.a sprat. Landings (' 000 t) 1998–2021. See ICES CM 2006/ACFM:20 for earlier data. Catch in coastal areas of Norway excluded. Data provided by Working Group members. These figures do not in all cases correspond to the official statistics and cannot be used for management purposes.

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Division 27.4.a																								
Denmark		0.7		0.1	1.1		*		*	0.8	*	*					*	*	0.1	0.1		*	0.5	*
Norway												*		*								0.1	*	
Sweden				0.1																				
UK (Scotland)														0.5						*	*			
Germany																		*	*					
Netherlands																		*						
Total		0.7		0.2	1.1		*		*	0.8	*	*		0.5			*	*	0.1	0.1	*	0.1	0.5	*
Division 27.4.b																								
Denmark	119.3	160.3	162.9	143.9	126.1	152.9	175.9	204.0	79.5	55.5	51.4	115.6	80.8	90.9	65.7	44.7	121.3	234.4	177.6	100.6	156.5	110.3	138.4	66.0
Norway	15.3	13.1	0.9	5.9	*		0.1		0.8	3.7	1.3	4.0	8.0	0.1	6.2	*	8.9	0.3	19.6	9.7	9.3	10.0	9.3	
Sweden	1.7	2.1		1.4				*				0.3	0.6	1.1	1.8	0.1	3.9	5.5	11.7	8.1	7.6	7.5	3.5	5.9
UK (Scotland)		1.4								0.1		2.5	1.1	1.9	0.7						*	1.3	1.7	*
UK (Engl. & Wales)												*								*	*		0.1	
Germany														3.3	0.5	0.6	1.5	3.1	5.4	6.0	3.7	3.4	10	3.6
Netherlands														1.1	2.7	0.4	2.4	1.2	1.0	1.6	1.6		0.5	
Faroe Islands																			4.7	1.0	1.0		1	
Total	136.3	176.9	163.8	151.2	126.1	152.9	176.0	204.1	80.3	59.3	52.7	122.4	90.4	98.4	77.5	45.8	138.0	244.6	220.0	127.0	179.7	132.6	164.7	75.5
Division 27.4.c																								
Denmark	11.8	3.3	28.2	13.1	14.8	22.3	16.8	2.0	23.8	20.6	8.1	8.2	48.5	20.0	3.2	15.4	2.2	34.0	18.7	1.5	6.2	8.9	2.4	2.7
Norway	16.0	5.7	1.8	3.6					9.0	2.9		1.8	3.2	9.9	3.0	1.7	0.1	8.8	0.6		0.5	0.6	0.7	

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sweden												0.6	0.6	0.2	0.4	1.3		1.2	0.4					1.1
UK (Scotland)											0.2			0.4					*				0.7	0.1
UK (Engl. & Wales)	0.2	1.6	2.0	2.0	1.6	1.3	1.5	1.6	0.5	0.3	*	*	0.8	0.6	0.5	*	*	*	*	*	0.1	0.2	0.1	*
Germany														*	*	1.0		0.6	0.2				0.1	
Netherlands		0.2												4.2	1.0	0.7	*	1.2	0.8	*	0.7		1.6	0.1
Belgium														*		*	*	*	*	*		*	*	*
France																		*		*				
Total	28.0	10.8	32.0	18.7	16.4	23.6	18.3	3.6	33.4	23.8	8.4	10.6	53.0	35.2	8.0	20.1	2.3	45.8	20.6	1.6	7.5	9.6	5.6	4.0
Division 27.3.a																								
Denmark	11.2	17.2	12.8	20.2	13.4	10.2	14.4	31.9	7.8	9.9	5.8	6.9	8.4	8.0	8.4	1.9	16.7	11.7	6.7	1.0	2.9	3.9	9.5	0.6
Sweden	6.2	9.3	6.4	7.6	4.3	5.5	6.5	7.7	4.4	4.2	2.4	1.6	1.4	2.0	1.5	1.1	1.5	1.3	1.1	0.2	1.1	1.7	2.4	0.7
Germany																	*				*			
Faroe Islands																			*					
Total	17.4	26.5	19.2	27.7	17.7	15.7	20.9	39.6	12.2	14.1	8.2	8.5	9.8	10.0	9.9	3.0	18.3	13.0	7.9	1.2	4.0	5.6	11.9	1.3
Total North Sea and Skagerrak-Kattegat																								
Denmark	142.3	181.5	203.9	177.3	155.4	185.4	207.1	237.9	111.2	86.7	65.4	130.7	137.7	119.0	77.4	62.1	140.2	280.1	203.1	103.3	165.6	123.1	150.9	69.3
Norway	31.3	18.8	2.7	9.5	*		0.1		9.8	6.7	1.3	5.8	11.1	10.0	9.1	1.7	9.0	9.1	20.2	9.7	9.8	10.6	10	
Sweden	7.9	11.4	6.4	9.1	4.3	5.5	6.5	7.8	4.4	4.2	2.4	2.5	2.6	3.3	3.7	2.5	5.4	8.1	13.2	8.3	8.7	9.2	5.9	7.6
UK (Scotland)		1.4								0.1	0.2	2.5	1.1	2.8	0.7				*	*	*	1.3	2.5	0.1
UK (Engl. & Wales)	0.2	1.6	2.0	2.0	1.6	1.3	1.5	1.6	0.5	0.3	*	*	0.8	0.6	0.5	*	*	*	*	*	*	0.2	0.2	*
Germany														3.3	0.5	1.6	1.6	3.7	5.6	6.0	3.7	3.4	10.1	3.6
Netherlands		0.2												5.3	3.7	1.1	2.4	2.4	1.8	1.6	2.3		2.1	0.1

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Faroe Islands																			4.7	1.0	1.0		1	
Belgium														*		*	*	*	*	*		*	*	*
France																		*		*				
Total	181.7	214.9	215.1	197.9	161.3	192.2	215.2	247.3	125.9	97.9	69.3	141.6	153.3	144.1	95.5	68.9	158.7	303.3	248.5	129.9	191.2	147.8	182.7	80.8

* < 50 t

Table 10.1.2. North Sea & 3.a sprat. Catches (tonnes) by quarter. Catches in coastal areas of Norway excluded. Data for 1996–1999 in ICES CM 2007/ACFM:11.

Year	Quarter	Division 27.4.a	27.4.b	27.4.c	27.3.a	Total
2000	1		18 126	28 063		46 189
	2		1722	45		1767
	3		131 306	1216		132 522
	4		12 680	2718		15 398
	Total		163 834	32 042		195 876
2001	1	115	40 903	9716		50 734
	2		1071			1071
	3		44 174	481		44 655
	4	79	65 102	8538		73 719
	Total	194	151 249	18 735		170 177
2002	1	1 136	2182	2790		6108
	2		435	93		528
	3		70 504	647		71 151
	4		52 942	12 911		65 853
	Total	1 136	126 063	16 441		143 640
2003	1		11 458	7727	5217	24 402
	2		625	26	1397	2049
2012	1		81	1649	4668	6399
	2		2924	0	909	3832
	3		26 779	307	1631	28 717
	4		47 765	6060	2728	56 553
	Total		77 549	8016	9936	95 501
2013	1		1281	3158	1296	5734
	2		32	0	443	474
	3		25 577	720	211	26 509
	4		18 892	16 276	943	36 110
	Total		45 781	20 154	2893	68 827
2014	1		59	125	384	568
	2		11 631	3	1415	13 050
	3	1	88 457	1428	9622	99 507
	4	7	37 851	822	6905	45 586
	Total	8	137 999	2378	18 327	158 711
2015	1	*	14 816	16 972	1442	33 230
	2		16 843	107	619	17 568

Year	Quarter	Division 27.4.a	27.4.b	27.4.c	27.3.a	Total
	3		56 207	165	1720	58 092
	4		84 629	15 651	7349	107 629
	Total		152 919	23 570	15 683	192 172
2004	1		827	1831	4456	7113
	2	7	260	16	1510	1793
	3		54 161	496	4138	58 794
	4		120 685	15 937	10 775	147 397
	Total	7	175 932	18 280	20 879	215 097
2005	1		11 538	2457	8148	22 143
	2		2515	123	4722	7360
	3		107 530		19 418	126 948
	4		82 474	1033	7296	90 803
	Total		204 057	3613	39 584	247 254
2006	1	47	13 713	33 534	8105	55 399
	2		190	8	324	522
	3		40 051	8	1440	41 499
	4	2	26 579	77	2335	28 993
	Total	49	80 533	33 627	12 204	126 413
2007	1		582	247	2646	3475
	2		241	3	1291	1535
	3		16 603		5357	21 960
	4	769	41 850	23 531	4761	70 911
	Total	769	59 276	23 781	14 055	97 881
2008	1		2872	43	2890	5805
	2		52	*	1017	1069
	3		21 787		636	22 423

Year	Quarter	Division 27.4.a	27.4.b	27.4.c	27.3.a	Total
	3		124 512	335	6528	131 375
	4	25	88 395	28 375	4389	121 184
	Total	25	244 566	45 789	12 978	303 358
2016	1	68	18 487	5969	746	25 250
	2		8927	51	669	9 647
	3	*	158 522	111	4664	163 297
	4	2	34 070	14 466	1764	50 301
	Total	70	220 007	20 596	7843	248 516
2017	1	1	3432	1220	92	4 745
	2		1327	0	33	1 360
	3	*	92 885	217	227	93 329
	4	94	29 310	174	849	30 426
	Total	95	126 954	1611	1200	129 860
2018	1	*	8994	1628	168	10 790
	2		11 898	0	224	12 122
	3		112 361	1	1328	113 690
	4		46 411	5922	2249	54 582
	Total	*	179 664	7551	3969	191 184
2019	1		389	9 592	627	10 609
	2	2	3 606	11	379	3 999
	3	2	95 829	7	2 249	98 087
	4	49	32 750	3	2 296	35 098
	Total	53	132 574	9 614	5 551	147 793
2020	1	3	298	1 076	378	1 746
	2		19 430	*	173	19 603
	3	2	120 890	*	4 268	125 160

Year	Quarter	Division 27.4.a	27.4.b	27.4.c	27.3.a	Total
	4		27 994	8334	3672	40 001
	Total		52 706	8377	8215	69 298
2009	1		36	1268	2600	3904
	2		2526	1	300	2827
	3	22	41 513		3300	44 835
	4		78 373	9336	2400	90 109
	Total	22	122 448	10 604	8600	141 675
2010	1		10 976	17 072	1462	29 510
	2		3235	3	648	3886
	3		14 220		3405	17 625
	4		62 006	35 973	4278	102 257
	Total		90 437	53 048	9793	153 278
2011	1		3747	21 039	3216	28 002
	2		2067	3	617	2687
	3		22 309	451	2311	25 072
	4	8	70 256	13 759	3887	87 910
	Total	8	98 380	35 252	10 031	143 671

Year	Quarter	Division 27.4.a	27.4.b	27.4.c	27.3.a	Total
	4	520	24 049	4 489	7 087	36 145
	Total	526	164 667	5 566	11 896	182 654
2021	1	0	137	236	445	818
	2	*	326	1	11	338
	3	1	63 401	902	57	64 361
	4	1	11 601	2 850	791	15 244
	Total	2	75 464	3 989	1 305	80 761
2022	1**		81		330	412

* < 0.5 t

** Until the 1st of March

Table 10.2.1. North Sea & 3.a sprat. Species composition in Danish sprat fishery in tonnes and percentage of the total catch. Left: North Sea, right: Division 3.a.

	Year	Sprat	Herring	Horse mack	Whiting	Haddock	Mackerel	Cod	Sandeel	Other	Total		Year	Sprat	Herring	Horse mack	Whiting	Haddock	Mackerel	Cod	Sandeel	Other	Total
t	1998	129 315	11 817	573	673	6	220	11	2 174	1 187	145 978	t	1998	9 143	3 385	230	467	54	0	49	7	2 866	16 202
t	1999	157 003	7 256	413	1 088	62	321	7	4 972	635	171 757	t	1999	16 603	8 470	138	1 026	210	5	75	3 337	2 896	32 760
t	2000	188 463	11 662	3 239	2 107	66	766	4	423	1 911	208 641	t	2000	12 578	8 034	5	1 062	308	8	52	13	3 556	25 617
t	2001	136 443	13 953	67	1 700	223	312	4	17 020	1 141	170 862	t	2001	18 236	8 196	75	1 266	50	13	35	4 281	1 271	33 423
t	2002	140 568	16 644	2 078	2 537	27	715	0	4 102	801	167 471	t	2002	11 451	12 982	21	1 164	3	6	30	606	2 280	28 541
t	2003	172 456	10 244	718	1 106	15	799	11	5 357	3 504	194 210	t	2003	8 182	4 928	340	252	4	4	4	1	567 14	14 282
t	2004	179 944	10 144	474	334	0	4 351	3	3 836	1 821	200 906	t	2004	13 374	4 620	97	976	18	24	27	116	2 155	21 408
t	2005	201 331	21 035	2 477	545	4	1 009	16	6 859	974	234 251	t	2005	30 157	6 171	244	871	63	18	20	746	1 758	40 047
t	2006	103 236	8 983	577	343	25	905	4	5 384	576	120 033	t	2006	6 814	2 852	215	276	13	3	45	1	232 10	10 451
t	2007	74 734	6 596	168	900	6	126	18	6	253	82 807	t	2007	7 116	2 043	34	190	31	8	4	1	469 9	9 896
t	2008	61 093	7 928	26	380	10	367	0	23	1 735	71 563	t	2008	4 805	1 948	14	285	0	0	11	462	39 7	7 563
t	2009	112 721	7 222	44	307	3	116	1	1 526	407	122 345	t	2009	4 839	3 016	37	169	15	0	1	53	47 8	8 177
t	2010	112 395	4 410	11	119	2	18	0	1 236	577	118 769	t	2010	2 851	2 134	25	142	6	1	2	135	171 5	5 466
t	2011	109 376	8 073	35	191	0	127	0	1 881	345	120 026	t	2011	4 754	2 461	0	43	0	7	1	141	40 7	7 447
t	2012	67 263	8 573	2	354	0	246	0	93	411	76 943	t	2012	5 707	5 495	9	149	7	10	5	0	228 11	11 610
t	2013	55 792	5 176	47	445	0	277	2	1	369	62 109	t	2013	1 143	1 751	2	46	0	0	1	1	27 2	2 971
t	2014	123 180	11 402	0	897	0	70	16	16	1 700	137 280	t	2014	16 751	3 777	5	343	1	20	5	12	888 21	21 801
t	2015	265 356	4 568	5	1 809	0	527	0	147	3 311	275 723	t	2015	11 448	5 831	0	565	0	29	8	1	154 18	18 036
t	2016	192 718	11 107	18	4 223	0	439	0	46	2 093	210 643	t	2016	7 001	2 140	0	335	1	19	3	0	78 9	9 579
t	2017	100 833	5 130	1	1 344	0	197	0	503	12 386	120 394	t	2017	963	328	0	172	0	19	1	0	32 1	1 515
t	2018	161 536	7 528	174	716	0	366	0	24	344	170 687	t	2018	2 872	257	2	150	1	11	0	0	12 3	3 304
t	2019	118 302	2 757	1	897	1	176	0	3	503	122 639	t	2019	3 429	351	0	59	0	2	0	0	8 3	3 850
t	2020	140 954	6 227	19	898	93	1 188	0	11	724	150 114	t	2020	9 494	551	4	249	5	41	1	0	27 10	10 372
t	2021	68 492	5 518	39	1 064	345	747	0	3	602	76 809	t	2021	638	82	0	13	1	1	0	0	32	767
%	1998	88.6	8.1	0.4	0.5	0	0.2	0	1.5	0.8	100	%	1998	56.4	20.9	1.4	2.9	0.3	0	0.3	0	17.7	100
%	1999	91.4	4.2	0.2	0.6	0	0.2	0	2.9	0.4	100	%	1999	50.7	25.9	0.4	3.1	0.6	0	0.2	10.2	8.8	100
%	2000	90.3	5.6	1.6	1	0	0.4	0	0.2	0.9	100	%	2000	49.1	31.4	0	4.1	1.2	0	0.2	0.1	13.9	100
%	2001	79.9	8.2	0	1	0.1	0.2	0	10	0.7	100	%	2001	54.6	24.5	0.2	3.8	0.2	0	0.1	12.8	3.8	100

	Year	Sprat	Herring	Horse mack	Whiting	Haddock	Mackerel	Cod	Sandeel	Other	Total		Year	Sprat	Herring	Horse mack	Whiting	Haddock	Mackerel	Cod	Sandeel	Other	Total
%	2002	83.9	9.9	1.2	1.5	0	0.4	0	2.4	0.5	100	%	2002	40.1	45.5	0.1	4.1	0	0	0.1	2.1	8	100
%	2003	88.8	5.3	0.4	0.6	0	0.4	0	2.8	1.8	100	%	2003	57.3	34.5	2.4	1.8	0	0	0	0	4	100
%	2004	89.6	5	0.2	0.2	0	2.2	0	1.9	0.9	100	%	2004	62.5	21.6	0.5	4.6	0.1	0.1	0.1	0.5	10.1	100
%	2005	85.9	9	1.1	0.2	0	0.4	0	2.9	0.4	100	%	2005	75.3	15.4	0.6	2.2	0.2	0	0	1.9	4.4	100
%	2006	86	7.5	0.5	0.3	0	0.8	0	4.5	0.5	100	%	2006	65.2	27.3	2.1	2.6	0.1	0	0.4	0	2.2	100
%	2007	90.3	8	0.2	1.1	0	0.2	0	0	0.3	100	%	2007	71.9	20.6	0.3	1.9	0.3	0.1	0	0	4.7	100
%	2008	85.4	11.1	0	0.5	0	0.5	0	0	2.4	100	%	2008	63.5	25.8	0.2	3.8	0	0	0.1	6.1	0.5	100
%	2009	92.1	5.9	0	0.3	0	0.1	0	1.2	0.3	100	%	2009	59.2	36.9	0.5	2.1	0.2	0	0	0.6	0.6	100
%	2010	94.6	3.7	0	0.1	0	0	0	1	0.5	100	%	2010	52.2	39	0.5	2.6	0.1	0	0	2.5	3.1	100
%	2011	91.1	6.7	0	0.2	0	0.1	0	1.6	0.3	100	%	2011	63.8	33	0	0.6	0	0.1	0	1.9	0.5	100
%	2012	87.4	11.1	0	0.5	0	0.3	0	0.1	0.5	100	%	2012	49.2	47.3	0.1	1.3	0.1	0.1	0	0	2	100
%	2013	89.8	8.3	0.1	0.7	0	0.4	0	0	0.6	100	%	2013	38.5	58.9	0.1	1.6	0	0	0	0	0.9	100
%	2014	89.7	8.3	0	0.7	0	0.1	0	0	1.2	100	%	2014	76.8	17.3	0	1.6	0	0.1	0	0.1	4.1	100
%	2015	96.2	1.7	0	0.7	0	0.2	0	0.1	1.2	100	%	2015	63.5	32.3	0	3.1	0	0.2	0	0	0.9	100
%	2016	91.5	5.3	0	2	0	0.2	0	0	1	100	%	2016	73.1	22.3	0	3.5	0	0.2	0	0	0.8	100
%	2017	83.8	4.3	0	1.1	0	0.2	0	0.4	10.3	100	%	2017	63.6	21.6	0	11.4	0	1.2	0.1	0	2.1	100
%	2018	94.6	4.4	0.1	0.4	0	0.2	0	0	0.2	100	%	2018	86.9	7.8	0.1	4.5	0	0.3	0	0	0.4	100
%	2019	96.5	2.2	0	0.7	0	0.1	0	0	0.4	100	%	2019	89.1	9.1	0	1.5	0	0.1	0	0	0.2	100
%	2020	93.9	4.1	0	0.6	0.1	0.8	0	0	0.5	100	%	2020	91.5	5.3	0	2.4	0	0.4	0	0	0.3	100
%	2021	89.2	7.2	0.1	1.4	0.4	1.0	0.0	0.0	0.8	100.0	%	2021	83.1	10.7	0.0	1.6	0.2	0.1	0.0	0.0	4.2	100.0

Table 10.2.2. North Sea & 3.a sprat. Catch in numbers by age (1000's) by season and year. (Model year, e.g., 2021 = July 2021–June 2022)

Catch-at-age used as input for the assessment model (years refer to the model years)					
Note that all catches in S4 have been moved to S1 in the following year					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
1974	1	0	16101061	2155723	475613
1974	2	1884146	11544114	866399	48228
1974	3	2842702	11091303	1336036	34534
1974	4	1302331	2511315	359117	14822
1975	1	250931	27723510	10052550	260182
1975	2	1179567	14541887	4378415	166807
1975	3	5240024	4755878	2206781	66186
1975	4	0	0	0	0
1976	1	2143211	42209830	2888653	180913
1976	2	7439656	18762732	1613139	88604
1976	3	7703416	6925346	267638	8289
1976	4	0	0	0	0
1977	1	2690194	12786056	5181867	109712
1977	2	2520082	4904593	3679153	67688
1977	3	15857197	1843468	2200876	37836
1977	4	0	0	0	0
1978	1	454090	32184524	427473	96435
1978	2	5517665	10344970	1209584	116695
1978	3	6154606	4973568	1119045	29941
1978	4	0	0	0	0
1979	1	3579389	36866800	644042	117139
1979	2	1052920	11355949	2152261	63386
1979	3	3882781	6399259	332781	25964
1979	4	0	0	0	0
1980	1	0	14237558	17421360	1481066
1980	2	0	9415158	11520576	979415
1980	3	2536060	3866612	389674	8724
1980	4	0	0	0	0
1981	1	428776	12322431	1483241	130805
1981	2	40632	3540737	3025289	202048
1981	3	374254	3854059	319763	9835
1981	4	0	0	0	0
1982	1	545769	6350511	601581	64879
1982	2	818525	5021082	1070960	55333
1982	3	2530673	401839	46913	3525
1982	4	0	0	0	0

Catch-at-age used as input for the assessment model (years refer to the model years)					
Note that all catches in S4 have been moved to S1 in the following year					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
1983	1	5613728	2819244	969599	155653
1983	2	2375763	1334333	588678	91112
1983	3	1697718	596857	7271	0
1983	4	0	0	0	0
1984	1	954757	6475021	417235	2532
1984	2	521866	2535354	247654	4803
1984	3	405095	612407	10648	1053
1984	4	0	0	0	0
1985	1	0	1304457	1972027	37680
1985	2	0	576004	870780	16638
1985	3	84760	215856	150819	14916
1985	4	0	0	0	0
1986	1	0	177780	452745	347620
1986	2	0	156913	399604	306818
1986	3	580936	58710	740	0
1986	4	0	0	0	0
1987	1	2236	2250587	128512	2525
1987	2	49451	1790264	267597	978
1987	3	209788	826994	34626	32980
1987	4	0	0	0	0
1988	1	4082942	2096911	2830054	42364
1988	2	1163964	314106	527986	11526
1988	3	1817700	637489	129384	5491
1988	4	0	0	0	0
1989	1	12451	1706824	3613841	5716
1989	2	783	76415	88925	342
1989	3	469458	416920	34789	12751
1989	4	0	0	0	0
1990	1	1568	2633068	2234213	342514
1990	2	1225	2058041	1746290	267714
1990	3	291837	62050	1941	429
1990	4	0	0	0	0
1991	1	40504	1684266	2416750	8159
1991	2	1552315	2936717	614233	9587
1991	3	208352	64565	1036	99
1991	4	0	0	0	0
1992	1	18948	9695465	1315325	177584
1992	2	222991	1185132	132166	16491

Catch-at-age used as input for the assessment model (years refer to the model years)					
Note that all catches in S4 have been moved to S1 in the following year					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
1992	3	1279875	1583952	259251	5821
1992	4	0	0	0	0
1993	1	264173	3026867	5339043	247839
1993	2	1441317	4911453	1324444	31435
1993	3	1867838	1819506	338969	43965
1993	4	0	0	0	0
1994	1	445326	40720484	516854	100737
1994	2	1856101	7146622	1455656	142774
1994	3	818875	2936362	559871	22813
1994	4	0	0	0	0
1995	1	170693	24466578	3192395	371759
1995	2	612010	8620522	2863267	505875
1995	3	1797666	4488224	533786	128194
1995	4	0	0	0	0
1996	1	299367	233497	816511	286503
1996	2	1083655	776795	2208631	911256
1996	3	1670742	289815	113580	49534
1996	4	0	0	0	0
1997	1	6447	2286585	130593	202822
1997	2	148657	4395265	1078225	277615
1997	3	596223	728240	181187	46667
1997	4	0	0	0	0
1998	1	86124	3567341	1498339	258993
1998	2	5465889	2665032	1451844	326463
1998	3	1615982	1096547	489541	241493
1998	4	0	0	0	0
1999	1	830	15939248	477815	69219
1999	2	90557	2456063	254931	44836
1999	3	1967130	3351942	641059	183015
1999	4	0	0	0	0
2000	1	6101	9822669	1767256	70160
2000	2	81906	801375	384854	49827
2000	3	1093613	2807143	1310052	176418
2000	4	0	0	0	0
2001	1	13056	5767627	315550	7694
2001	2	550512	3967343	1528712	498496
2001	3	143017	531588	59709	13418
2001	4	0	0	0	0

Catch-at-age used as input for the assessment model (years refer to the model years)					
Note that all catches in S4 have been moved to S1 in the following year					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
2002	1	63416	6586442	594557	108679
2002	2	927294	4326530	661656	59022
2002	3	1182692	1199165	296900	65718
2002	4	0	0	0	0
2003	1	197639	4003316	594498	68144
2003	2	2785630	6826281	1115905	218400
2003	3	713229	39824	29774	26427
2003	4	0	0	0	0
2004	1	229309	4217281	731500	78913
2004	2	24806798	4735686	264373	53425
2004	3	5233945	309955	44145	15707
2004	4	0	0	0	0
2005	1	97602	13409729	479222	88858
2005	2	839944	7903545	228337	22051
2005	3	1089274	5408581	230703	38557
2005	4	0	0	0	0
2006	1	0	1987696	1401797	295158
2006	2	319709	493221	1003837	235542
2006	3	176742	129541	176585	10933
2006	4	0	0	0	0
2007	1	0	1693273	189551	67672
2007	2	609939	4186796	1681648	254768
2007	3	404452	329724	19675	20964
2007	4	0	0	0	0
2008	1	11590	422430	1447939	329770
2008	2	2087187	1901763	1006626	260966
2008	3	893785	131774	41692	21858
2008	4	0	0	0	0
2009	1	0	4776947	219922	39037
2009	2	231412	8163927	554425	137328
2009	3	168362	3385107	519516	88967
2009	4	0	0	0	0
2010	1	12414	1732171	689166	90040
2010	2	349703	3105417	3011291	2157387
2010	3	298472	2412405	683264	90603
2010	4	0	0	0	0
2011	1	2469	1847215	1105017	281708
2011	2	420004	4234059	2917969	999295

Catch-at-age used as input for the assessment model (years refer to the model years)					
Note that all catches in S4 have been moved to S1 in the following year					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
2011	3	57320	250247	95834	42266
2011	4	0	0	0	0
2012	1	147896	2527701	729427	121665
2012	2	187098	3756225	1690250	281071
2012	3	78240	463743	86910	30157
2012	4	0	0	0	0
2013	1	10002	1973364	411558	72705
2013	2	462029	2176971	745578	144434
2013	3	193678	1554	2447	4794
2013	4	0	0	0	0
2014	1	2640874	9499013	627237	105519
2014	2	1215080	4046244	323320	92685
2014	3	1755944	2496884	177328	21685
2014	4	0	0	0	0
2015	1	1682642	12947813	2926867	161595
2015	2	615375	10862082	1632428	226924
2015	3	374504	1926029	733105	90223
2015	4	0	0	0	0
2016	1	4450616	12775033	4537366	439570
2016	2	3593237	1451842	1251213	301252
2016	3	533954	47715	7358	2718
2016	4	0	0	0	0
2017	1	1767809	9076648	738627	88295
2017	2	1302514	2796713	182538	82806
2017	3	658881	807010	184005	68052
2017	4	0	0	0	0
2018	1	4548741	11562002	2878462	310552
2018	2	2090509	2888456	1516387	534059
2018	3	157673	1090798	254223	15776
2018	4	0	0	0	0
2019	1	2420231	9775216	3342785	163696
2019	2	799272	2399200	1041391	139590
2019	3	211007	34475	3918	413
2019	4	0	0	0	0
2020	1	207574	10153348	3429492	429318
2020	2	69142	2695178	385767	137741
2020	3	28346	78759	8459	1779
2020	4	0	0	0	0

Catch-at-age used as input for the assessment model (years refer to the model years)					
Note that all catches in S4 have been moved to S1 in the following year					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
2021	1	539434	5840604	1505982	255540
2021	2	254055	814057	395606	139605
2021	3	0	0	0	0
2021	4	0	0	0	0

Table 10.2.3. North Sea & 3.a sprat. Mean weight at age (kg) in catches by season and year. (Model year, e.g., 2021 = July 2021–June 2022)

Weight-at-age used as input for the assessment model (years refer to the model years)					
Note that weights in S4 are not used since there are no catches in S4					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
1974	1	0.0063	0.0083	0.0135	0.0184
1974	2	0.0058	0.0089	0.0150	0.0197
1974	3	0.0050	0.0077	0.0150	0.0197
1974	4	0.0066	0.0107	0.0183	0.0163
1975	1	0.0048	0.0086	0.0129	0.0172
1975	2	0.0075	0.0111	0.0168	0.0216
1975	3	0.0048	0.0106	0.0154	0.0192
1975	4	0.0062	0.0116	0.0170	0.0171
1976	1	0.0049	0.0070	0.0113	0.0134
1976	2	0.0043	0.0090	0.0153	0.0190
1976	3	0.0022	0.0059	0.0104	0.0126
1976	4	0.0034	0.0057	0.0085	0.0106
1977	1	0.0054	0.0082	0.0126	0.0180
1977	2	0.0059	0.0110	0.0146	0.0196
1977	3	0.0023	0.0080	0.0106	0.0138
1977	4	0.0025	0.0063	0.0083	0.0122
1978	1	0.0038	0.0069	0.0122	0.0146
1978	2	0.0044	0.0103	0.0155	0.0196
1978	3	0.0031	0.0089	0.0123	0.0166
1978	4	0.0020	0.0052	0.0087	0.0094
1979	1	0.0050	0.0058	0.0087	0.0113
1979	2	0.0057	0.0105	0.0150	0.0173
1979	3	0.0032	0.0077	0.0129	0.0165
1979	4	0.0029	0.0106	0.0121	0.0153
1980	1	0.0063	0.0052	0.0068	0.0083
1980	2	0.0051	0.0052	0.0069	0.0083
1980	3	0.0032	0.0086	0.0131	0.0168
1980	4	0.0046	0.0073	0.0105	0.0101
1981	1	0.0038	0.0099	0.0129	0.0156

Weight-at-age used as input for the assessment model (years refer to the model years)

Note that weights in S4 are not used since there are no catches in S4

Year	Season	age 0	age 1	age 2	age 3
1981	2	0.0082	0.0126	0.0153	0.0194
1981	3	0.0049	0.0089	0.0157	0.0194
1981	4	0.0060	0.0139	0.0191	0.0192
1982	1	0.0085	0.0089	0.0171	0.0155
1982	2	0.0071	0.0110	0.0160	0.0219
1982	3	0.0029	0.0075	0.0115	0.0174
1982	4	0.0044	0.0078	0.0114	0.0160
1983	1	0.0044	0.0092	0.0128	0.0152
1983	2	0.0042	0.0124	0.0169	0.0211
1983	3	0.0034	0.0094	0.0174	0.0163
1983	4	0.0038	0.0093	0.0127	0.0156
1984	1	0.0060	0.0081	0.0121	0.0166
1984	2	0.0053	0.0122	0.0168	0.0164
1984	3	0.0093	0.0135	0.0197	0.0197
1984	4	0.0093	0.0135	0.0197	0.0197
1985	1	0.0063	0.0093	0.0135	0.0197
1985	2	0.0051	0.0093	0.0135	0.0197
1985	3	0.0073	0.0099	0.0166	0.0166
1985	4	0.0073	0.0099	0.0166	0.0166
1986	1	0.0063	0.0073	0.0099	0.0166
1986	2	0.0051	0.0073	0.0099	0.0166
1986	3	0.0083	0.0164	0.0228	0.0163
1986	4	0.0084	0.0156	0.0208	0.0156
1987	1	0.0066	0.0086	0.0117	0.0153
1987	2	0.0060	0.0093	0.0112	0.0165
1987	3	0.0064	0.0125	0.0175	0.0206
1987	4	0.0068	0.0125	0.0167	0.0189
1988	1	0.0042	0.0088	0.0115	0.0138
1988	2	0.0046	0.0085	0.0113	0.0137
1988	3	0.0052	0.0132	0.0208	0.0158
1988	4	0.0063	0.0117	0.0155	0.0175
1989	1	0.0054	0.0086	0.0099	0.0170
1989	2	0.0044	0.0082	0.0109	0.0130
1989	3	0.0048	0.0077	0.0125	0.0155
1989	4	0.0046	0.0086	0.0115	0.0129
1990	1	0.0046	0.0070	0.0092	0.0115
1990	2	0.0038	0.0069	0.0092	0.0113
1990	3	0.0044	0.0099	0.0133	0.0156

Weight-at-age used as input for the assessment model (years refer to the model years)

Note that weights in S4 are not used since there are no catches in S4

Year	Season	age 0	age 1	age 2	age 3
1990	4	0.0048	0.0089	0.0119	0.0135
1991	1	0.0128	0.0143	0.0154	0.0168
1991	2	0.0048	0.0146	0.0189	0.0168
1991	3	0.0052	0.0101	0.0147	0.0172
1991	4	0.0062	0.0118	0.0152	0.0186
1992	1	0.0081	0.0099	0.0124	0.0148
1992	2	0.0058	0.0121	0.0153	0.0178
1992	3	0.0035	0.0096	0.0141	0.0179
1992	4	0.0042	0.0078	0.0104	0.0118
1993	1	0.0065	0.0109	0.0123	0.0138
1993	2	0.0075	0.0107	0.0135	0.0164
1993	3	0.0022	0.0080	0.0116	0.0152
1993	4	0.0023	0.0128	0.0154	0.0134
1994	1	0.0068	0.0067	0.0095	0.0129
1994	2	0.0087	0.0104	0.0125	0.0151
1994	3	0.0030	0.0082	0.0097	0.0140
1994	4	0.0038	0.0068	0.0090	0.0131
1995	1	0.0032	0.0082	0.0117	0.0121
1995	2	0.0051	0.0101	0.0133	0.0155
1995	3	0.0084	0.0096	0.0129	0.0158
1995	4	0.0058	0.0107	0.0142	0.0161
1996	1	0.0071	0.0108	0.0142	0.0175
1996	2	0.0079	0.0115	0.0150	0.0169
1996	3	0.0029	0.0062	0.0087	0.0103
1996	4	0.0031	0.0057	0.0077	0.0086
1997	1	0.0071	0.0128	0.0148	0.0163
1997	2	0.0058	0.0120	0.0161	0.0199
1997	3	0.0071	0.0097	0.0122	0.0147
1997	4	0.0052	0.0095	0.0127	0.0144
1998	1	0.0056	0.0139	0.0166	0.0186
1998	2	0.0050	0.0124	0.0153	0.0177
1998	3	0.0043	0.0061	0.0095	0.0094
1998	4	0.0039	0.0073	0.0097	0.0110
1999	1	0.0053	0.0097	0.0115	0.0121
1999	2	0.0046	0.0116	0.0135	0.0164
1999	3	0.0036	0.0094	0.0118	0.0138
1999	4	0.0052	0.0097	0.0129	0.0146
2000	1	0.0067	0.0122	0.0148	0.0185

Weight-at-age used as input for the assessment model (years refer to the model years)					
Note that weights in S4 are not used since there are no catches in S4					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
2000	2	0.0062	0.0149	0.0174	0.0183
2000	3	0.0051	0.0105	0.0131	0.0150
2000	4	0.0036	0.0046	0.0080	0.0135
2001	1	0.0078	0.0109	0.0118	0.0159
2001	2	0.0048	0.0116	0.0136	0.0166
2001	3	0.0062	0.0127	0.0150	0.0162
2001	4	0.0065	0.0120	0.0161	0.0181
2002	1	0.0073	0.0109	0.0141	0.0154
2002	2	0.0077	0.0122	0.0142	0.0158
2002	3	0.0047	0.0101	0.0133	0.0145
2002	4	0.0060	0.0116	0.0129	0.0155
2003	1	0.0042	0.0125	0.0146	0.0228
2003	2	0.0058	0.0108	0.0145	0.0167
2003	3	0.0049	0.0115	0.0135	0.0141
2003	4	0.0050	0.0092	0.0123	0.0139
2004	1	0.0088	0.0116	0.0139	0.0154
2004	2	0.0041	0.0094	0.0126	0.0153
2004	3	0.0030	0.0097	0.0112	0.0130
2004	4	0.0044	0.0093	0.0115	0.0129
2005	1	0.0076	0.0097	0.0130	0.0154
2005	2	0.0066	0.0103	0.0115	0.0141
2005	3	0.0055	0.0080	0.0114	0.0138
2005	4	0.0047	0.0087	0.0115	0.0130
2006	1	0.0063	0.0108	0.0133	0.0152
2006	2	0.0055	0.0143	0.0158	0.0180
2006	3	0.0041	0.0095	0.0129	0.0134
2006	4	0.0050	0.0093	0.0124	0.0139
2007	1	0.0063	0.0119	0.0131	0.0149
2007	2	0.0065	0.0101	0.0127	0.0151
2007	3	0.0045	0.0075	0.0106	0.0126
2007	4	0.0048	0.0089	0.0118	0.0133
2008	1	0.0088	0.0103	0.0114	0.0131
2008	2	0.0044	0.0076	0.0126	0.0142
2008	3	0.0034	0.0076	0.0082	0.0085
2008	4	0.0044	0.0068	0.0090	0.0081
2009	1	0.0063	0.0096	0.0123	0.0142
2009	2	0.0046	0.0095	0.0130	0.0160
2009	3	0.0043	0.0077	0.0103	0.0135

Weight-at-age used as input for the assessment model (years refer to the model years)					
Note that weights in S4 are not used since there are no catches in S4					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
2009	4	0.0087	0.0096	0.0105	0.0141
2010	1	0.0066	0.0080	0.0097	0.0137
2010	2	0.0047	0.0094	0.0114	0.0148
2010	3	0.0050	0.0072	0.0094	0.0130
2010	4	0.0038	0.0071	0.0095	0.0107
2011	1	0.0052	0.0085	0.0101	0.0134
2011	2	0.0044	0.0089	0.0114	0.0145
2011	3	0.0042	0.0102	0.0128	0.0171
2011	4	0.0050	0.0092	0.0123	0.0139
2012	1	0.0085	0.0087	0.0106	0.0150
2012	2	0.0072	0.0087	0.0119	0.0152
2012	3	0.0040	0.0069	0.0113	0.0146
2012	4	0.0047	0.0087	0.0117	0.0132
2013	1	0.0061	0.0096	0.0120	0.0150
2013	2	0.0043	0.0097	0.0124	0.0156
2013	3	0.0026	0.0051	0.0071	0.0084
2013	4	0.0022	0.0094	0.0128	0.0153
2014	1	0.0086	0.0086	0.0104	0.0168
2014	2	0.0070	0.0079	0.0116	0.0139
2014	3	0.0053	0.0083	0.0116	0.0119
2014	4	0.0065	0.0099	0.0101	0.0115
2015	1	0.0076	0.0082	0.0104	0.0150
2015	2	0.0072	0.0088	0.0109	0.0155
2015	3	0.0038	0.0078	0.0107	0.0153
2015	4	0.0044	0.0082	0.0109	0.0123
2016	1	0.0041	0.0077	0.0112	0.0145
2016	2	0.0051	0.0074	0.0118	0.0145
2016	3	0.0073	0.0143	0.0199	0.0235
2016	4	0.0076	0.0141	0.0188	0.0212
2017	1	0.0064	0.0083	0.0103	0.0139
2017	2	0.0038	0.0078	0.0099	0.0162
2017	3	0.0042	0.0064	0.0098	0.0130
2017	4	0.0076	0.0141	0.0188	0.0212
2018	1	0.0046	0.00664	0.0086	0.0126
2018	2	0.0053	0.0074	0.0097	0.0134
2018	3	0.0041	0.0067	0.0095	0.0136
2018	4	0.0057	0.0065	0.00762	0.0129
2019	1	0.0034	0.0063	0.0088	0.0116

Weight-at-age used as input for the assessment model (years refer to the model years)					
Note that weights in S4 are not used since there are no catches in S4					
Year	**Season**	**age 0**	**age 1**	**age 2**	**age 3**
2019	2	0.0041	0.0076	0.0098	0.0141
2019	3	0.0058	0.0010	0.0130	0.0165
2019	4	0.0064	0.0078	0.0105	0.0157
2020	1	0.0049	0.0093	0.0122	0.0162
2020	2	0.0071	0.0108	0.0144	0.0172
2020	3	0.0057	0.0100	0.0143	0.0165
2020	4	0.0065	0.0103	0.0134	0.0161
2021	1	0.0061	0.0071	0.0110	0.0131
2021	2	0.0061	0.0087	0.0117	0.0158
2021	3	0.0101	0.0132	0.0170	0.0197
2021	4	0.0064	0.0102	0.0133	0.0160

Table 10.2.4. North Sea and Division 3.a sprat. Sampling for biological parameters in 2021. This table only shows age-length samples, and therefore the number of samples may differ from Table 10.2.5.

Country	Quarter	Landings ('000 tonnes)	No. samples	No. measured	No. aged
Denmark	1	0.4	2	202	99
	2	0.2	0	0	0
	3	59.1	84	9086	3979
	4	9.6	14	1350	594
	Total	69.3	100	10638	4672
Norway	1	0.0	0	0	0
	2	0.0	0	0	0
	3	0.0	0	0	0
	4	0.0	0	0	0
	Total	0.0	0	0	0
Sweden	1	0.4	9	237	236
	2	0.0	0	0	0
	3	3.6	0	0	0
	4	3.6	8	489	489
	Total	7.6	17	726	725
All countries	1	0.8	11	439	335
	2	0.2	0	0	0
	3	62.7	84	9086	3979
	4	13.2	22	1839	1083
Total		76.9	117	11364	5397

Table 10.2.5. North Sea and Division 3.a sprat. Number of biological samples taken from 1974 and onward. The number of samples may differ from Table 10.2.4, since this table shows both length and age-length samples. These are the samples used to generate the catch-at-age matrix for the assessment model (Model year, e.g., 2021 = July 2021–June 2022).

Year	S1	S2	S3	S4
1974	15	31	102	25
1975	67	46	40	11
1976	54	70	53	16
1977	37	51	32	18
1978	52	78	47	22
1979	86	55	90	9
1980	0	0	49	28
1981	61	32	29	14
1982	27	48	13	16
1983	11	44	27	8
1984	9	23	29	7
1985	4	4	0	4
1986	4	1	0	1
1987	16	15	4	3
1988	8	4	9	1
1989	13	0	7	2
1990	4	0	13	1
1991	6	56	15	8
1992	42	35	24	4
1993	21	30	24	7
1994	42	50	32	5
1995	40	47	41	4
1996	2	12	8	3
1997	9	34	12	1
1998	25	38	16	3
1999	41	25	25	1
2000	29	23	22	14
2001	23	9	17	4
2002	26	37	28	7
2003	12	60	17	2
2004	26	43	24	15
2005	77	56	56	2
2006	23	7	13	0
2007	34	40	13	4
2008	10	9	14	5
2009	33	36	18	5
2010	35	28	15	3
2011	28	57	20	3

Year	S1	S2	S3	S4
2012	37	88	15	3
2013	31	23	2	10
2014	116	19	19	13
2015	165	47	21	2
2016	90	30	3	0
2017	69	21	11	6
2018	65	60	20	5
2019	65	45	2	12
2020	27	30	6	0
2021	85	22	0	NA

Table 10.3.1. North Sea sprat. Abundance indices by age from IBTS Q1

IBTS Q1 survey index (area 4 and 3a combined; years apply to the calendar year and ages the model year)				
Index is calculated using a delta GAM model formulation (see Stock Annex)				
Year	**Age 0**	**Age 1**	**Age 2**	**Age 3**
1983	252619	551262	574173	47111
1984	619180	553686	100186	25687
1985	374594	292408	75083	19254
1986	116338	137304	39250	9993
1987	503284	86061	25143	9769
1988	248663	789924	77117	15148
1989	744970	154929	114877	11326
1990	360108	185946	47580	21180
1991	1412224	176334	33438	7582
1992	1882139	281520	36961	9645
1993	1863182	1224852	103248	10709
1994	1195289	887347	132008	8288
1995	2258852	2257140	263386	10391
1996	604673	967027	199658	28253
1997	599335	270098	168138	27513
1998	1072937	1104108	180777	16056
1999	5183400	583736	73757	5308
2000	2017439	1164352	150449	25036
2001	1997862	1309083	239142	13995
2002	1191954	968965	87712	10393
2003	2493114	589410	66441	5540
2004	4084377	685280	106637	9076
2005	8918279	675529	29062	2718
2006	1230441	1416990	58676	7654
2007	1917763	1035569	162880	12506

IBTS Q1 survey index (area 4 and 3a combined; years apply to the calendar year and ages the model year)				
Index is calculated using a delta GAM model formulation (see Stock Annex)				
Year	**Age 0**	**Age 1**	**Age 2**	**Age 3**
2008	1526985	803061	47400	8526
2009	4133598	312030	34043	3833
2010	3288300	2489705	118665	17586
2011	1078333	926246	206207	47562
2012	3356603	3143308	245116	36666
2013	1137772	1116849	203191	29306
2014	3886605	443621	50655	9871
2015	7727188	3460669	317090	26651
2016	2112309	3409890	675849	37763
2017	10317128	1707447	128002	15146
2018	10440866	1547476	94598	11384
2019	6097175	2511994	226057	9585
2020	7316245	2219294	421523	40023
2021	3308192	1977916	196830	16693
2022	1810546	769303	57700	6537

Table 10.3.1. North Sea sprat. Abundance indices by age from IBTS Q3

IBTS Q3 survey index (area 4 and 3a combined; years and ages apply to both the model year and calendar year)			
Index is calculated using a delta GAM model formulation (see Stock Annex)			
Year	**Age 1**	**Age 2**	**Age 3**
1992	14555861	2633020	104865
1993	5767651	3015219	217792
1994	16468664	1326478	95089
1995	30622687	7433288	454582
1996	2317117	2219591	215543
1997	13080865	1171944	200385
1998	2676263	1107920	117795
1999	13792780	1719505	82599
2000	8212868	3228536	133847
2001	8998081	2277278	187452
2002	10011480	1319291	102476
2003	11610320	1272970	66231
2004	14371331	1945227	122791
2005	52835449	2266372	102272
2006	9340785	5459057	155440
2007	10549586	1552282	184767
2008	7894186	2085499	130785
2009	35252950	3032568	337850
2010	35355908	9422666	428224
2011	16742275	8341042	1191533
2012	11469646	5231406	575643
2013	9052264	3060010	414534
2014	63182232	3573736	215965
2015	59775893	18619852	653613
2016	27891385	4266699	482295
2017	27754797	2886164	173266
2018	18709889	3123833	200733
2019	40210818	8468920	521293
2020	53930015	16906066	1479519
2021	21858420	5602150	519985

Table 10.3.2. North Sea and Division 3.a sprat. HERAS survey index.

HERAS abundance index (area 4 and 3.a summed), data are from WGIPS (2019)			
Years and ages apply to both the model year and calendar year			
Year	**Age 1**	**Age 2**	**Age 3**
2006	21923	21368	1413
2007	42862	5837	2252
2008	17188	7868	840
2009	47690	16920	2815
2010	20328	14087	1174
2011	26581	14207	3412
2012	22036	12831	4693
2013	9347	6342	2049
2014	59020	20274	3982
2015	27082	22676	10142
2016	58604	33989	8160
2017	38135	3664	1465
2018	109180	10113	779
2019	93775	28020	5275
2020	38415	17993	2055
2021	46918	7051	1509

Table 10.6.1. North Sea and Division 3.a sprat. Natural mortality input (Model year, e.g. 2021 = July 2021–June 2022). From multispecies SMS (WKSAM: ICES, 2017) 2017 key run.

Year	Season	age 0	age 1	age 2	age 3
1974	1	0.483	0.456	0.402	0.280
1974	2	0.327	0.235	0.217	0.188
1974	3	0.297	0.275	0.175	0.175
1974	4	0.445	0.409	0.318	0.318
1975	1	0.518	0.492	0.422	0.237
1975	2	0.289	0.220	0.200	0.169
1975	3	0.329	0.299	0.218	0.218
1975	4	0.474	0.442	0.423	0.423
1976	1	0.490	0.466	0.415	0.290
1976	2	0.318	0.242	0.225	0.195
1976	3	0.364	0.332	0.240	0.240
1976	4	0.485	0.443	0.421	0.421
1977	1	0.441	0.411	0.368	0.312
1977	2	0.373	0.245	0.227	0.199
1977	3	0.380	0.351	0.248	0.248
1977	4	0.490	0.440	0.432	0.432
1978	1	0.411	0.398	0.385	0.330
1978	2	0.347	0.230	0.218	0.192
1978	3	0.382	0.356	0.208	0.208
1978	4	0.445	0.396	0.374	0.374
1979	1	0.436	0.424	0.419	0.405
1979	2	0.416	0.252	0.245	0.227
1979	3	0.393	0.366	0.232	0.232
1979	4	0.444	0.389	0.377	0.377
1980	1	0.470	0.464	0.444	0.415
1980	2	0.447	0.261	0.257	0.230
1980	3	0.388	0.355	0.232	0.232
1980	4	0.419	0.372	0.336	0.336
1981	1	0.501	0.486	0.448	0.360
1981	2	0.409	0.271	0.267	0.232
1981	3	0.361	0.314	0.222	0.222
1981	4	0.376	0.330	0.267	0.267
1982	1	0.511	0.431	0.377	0.245
1982	2	0.331	0.231	0.217	0.177
1982	3	0.305	0.231	0.182	0.182
1982	4	0.318	0.277	0.205	0.205
1983	1	0.532	0.429	0.349	0.224
1983	2	0.336	0.235	0.217	0.194
1983	3	0.296	0.207	0.173	0.173

Year	Season	age 0	age 1	age 2	age 3
1983	4	0.312	0.259	0.168	0.168
1984	1	0.539	0.425	0.287	0.182
1984	2	0.397	0.236	0.209	0.189
1984	3	0.309	0.239	0.177	0.177
1984	4	0.321	0.274	0.197	0.197
1985	1	0.549	0.502	0.373	0.198
1985	2	0.482	0.277	0.251	0.210
1985	3	0.323	0.249	0.178	0.178
1985	4	0.318	0.269	0.165	0.165
1986	1	0.590	0.534	0.422	0.254
1986	2	0.452	0.313	0.288	0.227
1986	3	0.346	0.258	0.188	0.188
1986	4	0.335	0.284	0.169	0.169
1987	1	0.596	0.484	0.443	0.256
1987	2	0.470	0.315	0.299	0.232
1987	3	0.356	0.217	0.190	0.190
1987	4	0.338	0.281	0.185	0.185
1988	1	0.622	0.502	0.455	0.258
1988	2	0.493	0.342	0.316	0.270
1988	3	0.371	0.238	0.220	0.220
1988	4	0.361	0.301	0.233	0.233
1989	1	0.603	0.509	0.433	0.214
1989	2	0.525	0.332	0.294	0.261
1989	3	0.356	0.228	0.221	0.221
1989	4	0.374	0.312	0.281	0.281
1990	1	0.518	0.489	0.402	0.244
1990	2	0.496	0.331	0.283	0.261
1990	3	0.337	0.260	0.249	0.249
1990	4	0.387	0.319	0.287	0.287
1991	1	0.462	0.423	0.320	0.263
1991	2	0.396	0.269	0.232	0.211
1991	3	0.310	0.264	0.223	0.223
1991	4	0.389	0.320	0.287	0.287
1992	1	0.410	0.360	0.281	0.255
1992	2	0.312	0.227	0.204	0.180
1992	3	0.294	0.275	0.212	0.212
1992	4	0.371	0.299	0.270	0.270
1993	1	0.456	0.414	0.340	0.303
1993	2	0.238	0.209	0.190	0.173
1993	3	0.272	0.253	0.192	0.192

Year	Season	age 0	age 1	age 2	age 3
1993	4	0.347	0.274	0.244	0.244
1994	1	0.502	0.446	0.348	0.337
1994	2	0.292	0.223	0.197	0.182
1994	3	0.258	0.219	0.190	0.190
1994	4	0.318	0.248	0.223	0.223
1995	1	0.512	0.460	0.338	0.308
1995	2	0.290	0.223	0.195	0.182
1995	3	0.222	0.191	0.178	0.178
1995	4	0.265	0.211	0.190	0.190
1996	1	0.504	0.395	0.263	0.214
1996	2	0.363	0.227	0.202	0.177
1996	3	0.215	0.171	0.151	0.151
1996	4	0.238	0.195	0.156	0.156
1997	1	0.451	0.293	0.210	0.155
1997	2	0.298	0.204	0.187	0.154
1997	3	0.227	0.193	0.171	0.171
1997	4	0.269	0.214	0.171	0.171
1998	1	0.430	0.283	0.226	0.190
1998	2	0.362	0.197	0.176	0.145
1998	3	0.252	0.209	0.173	0.173
1998	4	0.318	0.245	0.197	0.197
1999	1	0.421	0.287	0.232	0.214
1999	2	0.291	0.191	0.169	0.152
1999	3	0.275	0.241	0.191	0.191
1999	4	0.335	0.267	0.242	0.242
2000	1	0.406	0.342	0.253	0.219
2000	2	0.355	0.199	0.180	0.170
2000	3	0.254	0.213	0.157	0.157
2000	4	0.279	0.236	0.192	0.192
2001	1	0.409	0.328	0.233	0.190
2001	2	0.299	0.213	0.202	0.195
2001	3	0.266	0.225	0.191	0.191
2001	4	0.306	0.258	0.213	0.213
2002	1	0.434	0.321	0.240	0.171
2002	2	0.315	0.223	0.214	0.206
2002	3	0.252	0.206	0.194	0.194
2002	4	0.323	0.262	0.218	0.218
2003	1	0.419	0.269	0.215	0.168
2003	2	0.295	0.229	0.208	0.204
2003	3	0.259	0.229	0.226	0.226

Year	Season	age 0	age 1	age 2	age 3
2003	4	0.383	0.308	0.286	0.286
2004	1	0.436	0.276	0.231	0.192
2004	2	0.278	0.216	0.193	0.185
2004	3	0.231	0.212	0.208	0.208
2004	4	0.376	0.302	0.278	0.278
2005	1	0.442	0.321	0.227	0.216
2005	2	0.309	0.219	0.181	0.174
2005	3	0.220	0.201	0.179	0.179
2005	4	0.367	0.291	0.225	0.225
2006	1	0.504	0.315	0.226	0.215
2006	2	0.265	0.212	0.172	0.166
2006	3	0.217	0.197	0.172	0.172
2006	4	0.364	0.277	0.202	0.202
2007	1	0.480	0.312	0.204	0.184
2007	2	0.287	0.222	0.170	0.166
2007	3	0.210	0.175	0.152	0.152
2007	4	0.312	0.237	0.175	0.175
2008	1	0.478	0.307	0.187	0.166
2008	2	0.269	0.203	0.157	0.151
2008	3	0.200	0.173	0.167	0.167
2008	4	0.304	0.225	0.197	0.197
2009	1	0.444	0.362	0.233	0.162
2009	2	0.327	0.200	0.158	0.150
2009	3	0.190	0.170	0.163	0.163
2009	4	0.293	0.215	0.190	0.190
2010	1	0.527	0.412	0.312	0.170
2010	2	0.395	0.217	0.179	0.164
2010	3	0.207	0.182	0.159	0.159
2010	4	0.309	0.226	0.197	0.197
2011	1	0.511	0.437	0.386	0.182
2011	2	0.381	0.239	0.193	0.179
2011	3	0.229	0.202	0.179	0.179
2011	4	0.338	0.254	0.224	0.224
2012	1	0.509	0.432	0.344	0.176
2012	2	0.368	0.238	0.191	0.178
2012	3	0.219	0.176	0.145	0.145
2012	4	0.292	0.225	0.180	0.180
2013	1	0.399	0.367	0.285	0.150
2013	2	0.271	0.209	0.164	0.158
2013	3	0.206	0.175	0.148	0.148

Year	Season	age 0	age 1	age 2	age 3
2013	4	0.270	0.221	0.178	0.178
2014	1	0.367	0.335	0.245	0.140
2014	2	0.257	0.198	0.167	0.154
2014	3	0.211	0.181	0.153	0.153
2014	4	0.272	0.227	0.184	0.184
2015	1	0.365	0.339	0.249	0.139
2015	2	0.237	0.194	0.164	0.149
2015	3	0.212	0.177	0.149	0.149
2015	4	0.278	0.224	0.181	0.181
2016	1	0.377	0.347	0.260	0.143
2016	2	0.255	0.200	0.165	0.153
2016	3	0.212	0.177	0.149	0.149
2016	4	0.278	0.224	0.181	0.181
2017	1	0.377	0.347	0.260	0.143
2017	2	0.255	0.200	0.165	0.153
2017	3	0.212	0.177	0.149	0.149
2017	4	0.278	0.224	0.181	0.181
2018	1	0.377	0.347	0.260	0.143
2018	2	0.255	0.200	0.165	0.153
2018	3	0.212	0.177	0.149	0.149
2018	4	0.278	0.224	0.181	0.181
2019	1	0.377	0.347	0.260	0.143
2019	2	0.255	0.200	0.165	0.153
2019	3	0.212	0.177	0.149	0.149
2019	4	0.278	0.224	0.181	0.181
2020	1	0.377	0.347	0.260	0.143
2020	2	0.255	0.200	0.165	0.153
2020	3	0.212	0.177	0.149	0.149
2020	4	0.278	0.224	0.181	0.181
2021	1	0.377	0.347	0.260	0.143
2021	2	0.255	0.200	0.165	0.153
2021	3	0.212	0.177	0.149	0.149
2021	4	0.278	0.224	0.181	0.181

Table 10.6.2. North Sea sprat. Assessment diagnostics.

ate: 03/23/22 Start time:17:06:28 run time:1 seconds

objective function (negative log likelihood): 299.074
Number of parameters: 143
Maximum gradient: 0.239804
Akaike information criterion (AIC): 884.147
Number of observations used in the likelihood:

Catch	CPUE	S/R	Stomach	Sum
768	298	48	0	1114

objective function weight:

Catch	CPUE	S/R
1.00	1.00	0.10

unweighted objective function contributions (total):

Catch	CPUE	S/R	Stom.	Stom N.	Penalty	Sum
412.8	-114.9	11.8	0.0	0.0	0.00	310

unweighted objective function contributions (per observation):

Catch	CPUE	S/R	Stomachs
0.54	-0.39	0.25	0.00

contribution by fleet:

IBTS Q1	total: -74.980	mean: -0.469
IBTS Q3	total: -31.619	mean: -0.351
Acoustic	total: -8.283	mean: -0.173

F, Year effect:

1974: 1.000
1975: 1.802
1976: 1.884
1977: 1.624
1978: 1.073
1979: 0.684
1980: 2.495
1981: 1.247
1982: 1.080
1983: 1.772
1984: 1.057
1985: 1.458
1986: 1.248
1987: 0.397
1988: 1.388
1989: 0.448
1990: 1.602
1991: 0.876
1992: 0.941
1993: 1.726
1994: 0.871
1995: 1.495

1996: 1.539
1997: 1.112
1998: 1.885
1999: 0.964
2000: 1.605
2001: 1.740
2002: 1.776
2003: 1.387
2004: 2.176
2005: 1.423
2006: 1.766
2007: 1.853
2008: 1.678
2009: 0.948
2010: 1.178
2011: 1.067
2012: 1.500
2013: 1.569
2014: 0.680
2015: 1.428
2016: 2.494
2017: 1.595
2018: 1.583
2019: 1.325
2020: 2.010
2021: 2.730

F, season effect:
----
age: 0
 1974-2021: 0.037 0.201 0.362 0.250
age: 1
 1974-2021: 0.541 0.527 0.196 0.250
age: 2
 1974-2021: 0.240 0.474 0.114 0.250
age: 3
 1974-2021: 0.219 0.549 0.351 0.250

F, age effect:

	0	1	2	3
1974-2021:	0.037	0.399	1.520	1.520

Exploitation pattern (scaled to mean F=1)

		0	1	2	3
1974-2021	season 1:	0.001	0.192	0.326	0.297
	season 2:	0.007	0.188	0.642	0.744
	season 3:	0.012	0.070	0.154	0.476
	season 4:	0.008	0.089	0.339	0.339

sqrt(catch variance) ~ CV:
----

season

----

age	1	2	3	4
0	1.414	1.414	1.271	0.100
1	0.853	0.763	1.414	0.100
2	1.012	1.084	1.414	0.100
3	1.012	1.084	1.414	0.100

Survey catchability:

----

	age 0	age 1	age 2	age 3
IBTS Q1	0.000	1.590	3.153	6.540
IBTS Q3		0.870	1.126	1.140
Acoustic		1.172	2.362	6.561

Stock size dependent catchability (power model)

----

	age 0	age 1	age 2	age 3
IBTS Q1	1.65	1.00	1.00	1.00
IBTS Q3		1.00	1.00	1.00
Acoustic		1.00	1.00	1.00

sqrt(Survey variance) ~ CV:

----

	age 0	age 1	age 2	age 3
IBTS Q1	0.43	0.37	0.37	0.37
IBTS Q3		0.48	0.40	0.40
Acoustic		0.44	0.55	0.55

Average F:

----

	sp. 1
1974:	1.109
1975:	1.705
1976:	1.802
1977:	1.602
1978:	1.049
1979:	0.676
1980:	2.299
1981:	1.152
1982:	0.986
1983:	1.589
1984:	0.987
1985:	1.308
1986:	1.117
1987:	0.361
1988:	1.259
1989:	0.423
1990:	1.494
1991:	0.848
1992:	0.916
1993:	1.587
1994:	0.804
1995:	1.342
1996:	1.395
1997:	1.049
1998:	1.765

1999: 0.936
2000: 1.485
2001: 1.644
2002: 1.676
2003: 1.372
2004: 2.085
2005: 1.356
2006: 1.659
2007: 1.722
2008: 1.578
2009: 0.886
2010: 1.072
2011: 0.969
2012: 1.336
2013: 1.422
2014: 0.638
2015: 1.314
2016: 2.253
2017: 1.459
2018: 1.448
2019: 1.217
2020: 1.827
2021: 2.169

Recruit-SSB		alfa	beta	recruit s2	recruit s
Sprat	Hockey stick -break.:	1316.549	9.000e+04	0.601	0.776

Table 10.6.3. North Sea and Division 3.a Sprat. Assessment output: Stock numbers (thousands) (years, seasons (S1-S4), and age (A0-A3+) refer to the model year, e.g., 2021 = July 2021–June 2022)

Year/Age Quarter	A0_S1	A0_S2	A0_S3	A0_S4	A1_S1	A1_S2	A1_S3	A1_S4	A2_S1	A2_S2	A2_S3	A2_S4	A3+_S1	A3+_S2	A3+_S3	A3+_S4
1974	543036000	334604000	239556000	175705000	139916000	71456700	45757200	32147400	10206300	4740150	1856610	1311090	564485	306102	110129	54212
1975	709595000	421523000	311385000	218722000	111574000	46246900	25400300	16362000	19327000	6562280	1467900	864143	679416	294583	55264	16978
1976	327714000	200305000	143739000	97395300	136215000	56933800	30088300	18618100	10520700	3492490	718691	408031	577268	230920	39462	11353
1977	630579000	405010000	275610000	184507000	59943200	28014100	15589700	9660700	11954300	4571630	1131060	666272	275344	117455	24819	8136
1978	1071680000	709383000	497293000	334648000	113084000	60277900	38202800	24590400	6223900	2862460	1062380	717015	437888	220394	74254	34022
1979	539449000	348437000	228676000	152913000	214500000	121129000	81524400	53582800	16543100	8477520	4053540	2856720	516645	274597	123664	68080
1980	334838000	208560000	130888000	85906800	98051400	36021800	16412600	9464200	36302200	9368020	1201790	618695	2006250	577864	57232	11974
1981	87282900	52813800	34749200	23829500	56502300	26570100	15585600	10329200	6522900	2644320	824742	532257	450514	207577	58145	23924
1982	45555800	27300800	19447700	14127300	16355000	8419360	5327480	3884760	7423910	3432010	1269890	878234	425886	232756	79136	37065
1983	58821600	34454900	24295000	17645200	10279300	4569930	2488660	1761840	2945250	1088410	244596	151429	745375	330588	62084	20282
1984	31588200	18407300	12284500	8893450	12912600	6719240	4250850	3082660	1359230	693448	262874	183354	145108	85103	29152	13886
1985	23019800	13264800	8102330	5754980	6448840	2852700	1591720	1107200	2343350	947696	258165	168002	161927	81829	19657	7560
1986	70963900	39277900	24758600	17228700	4186070	1876160	1055200	739060	845766	351832	107452	71770	148853	76240	21440	9129
1987	38488000	21196500	13203800	9196920	12322200	6971920	4678720	3652010	556102	308891	172070	132845	68300	46320	26377	17645
1988	55817100	29924200	18094000	12251500	6559980	2945170	1562910	1104490	2757330	1053900	283000	178650	125118	60921	14603	5587
1989	48771900	26657400	15711900	10939400	8536000	4657730	3040950	2336520	817077	449786	242811	180096	146005	101554	53824	33961
1990	67307700	40016200	24089900	16834900	7524810	3267040	1675650	1139490	1710590	637302	151469	89498	161558	74287	15031	4981
1991	103265000	64967900	43460400	31493600	11432900	6200460	3939730	2825750	828606	436979	184461	126784	70924	40750	15885	7960
1992	98542600	65307900	47469400	34938400	21346600	12158200	7950910	5609240	2051690	1098170	454928	312678	101110	57313	21822	10679
1993	129113000	81680600	63540700	47296400	24116200	10990800	6205100	4208490	4159450	1576050	376218	230322	246785	102653	20436	6710
1994	113155000	68384200	50722500	38749000	33413800	17722600	11803700	8852710	3198710	1643500	721318	513028	185724	99320	40055	20808
1995	35487900	21223000	15701900	12328100	28200700	12905300	7538890	5541070	6909940	2854090	800120	517089	427172	191081	45770	17247
1996	59588600	35915800	24695800	19517200	9461590	4574380	2637400	1969810	4487250	1966670	530904	349843	442030	213995	49667	18785
1997	46909200	29830500	21972400	17247600	15384400	9032030	5829660	4405610	1621100	875433	326079	226809	315342	186651	63298	29481

Year/Age Quarter	A0_S1	A0_S2	A0_S3	A0_S4	A1_S1	A1_S2	A1_S3	A1_S4	A2_S1	A2_S2	A2_S3	A2_S4	A3+_S1	A3+_S2	A3+_S3	A3+_S4
1998	105848000	68705600	47185300	35779000	13178700	6617570	3655170	2559150	3555840	1424570	307293	186608	216003	95415	17109	5262
1999	75667400	49581800	36815200	27619900	26037400	15871400	10710000	7806430	2002530	1116250	470693	329117	157605	92331	35463	17511
2000	72250500	48034400	33277400	25274800	19765200	9939310	5813380	4142640	5976400	2582580	679193	439846	272028	128241	28364	10294
2001	58320100	38658700	28297200	21180500	19128800	9471370	5307730	3696480	3272880	1373460	320622	195989	371477	172239	33179	10824
2002	77193400	49869200	35902200	27255600	15592300	7710180	4248190	3007840	2854650	1173930	263910	159833	167104	78070	14439	4607
2003	98936600	64923600	47852100	36257500	19739000	11186500	6648750	4742960	2315440	1125270	336658	211375	132257	70488	18072	6880
2004	166990000	107622000	80201400	61834900	24730700	11740100	5984970	4083420	3485160	1250330	215256	120043	163976	65654	8877	2257
2005	63546300	40780100	29619800	23312100	42466000	22680000	13511500	9887520	3017980	1430700	428579	280082	92584	46486	11917	4660
2006	80677800	48624200	36830800	28953900	16154400	8061150	4500040	3218460	7388710	3094690	730428	452924	227374	102001	19789	6488
2007	56916600	35127100	25990800	20548200	20114100	9873790	5357310	3890690	2439230	1011160	224692	140075	375259	168619	30422	9719
2008	124143000	76807100	57979500	46400900	15035700	7707420	4419340	3259170	3068290	1378780	352157	223023	125743	60963	12924	4468
2009	104609000	67004900	47975700	39157400	34238000	19432600	13031200	10210100	2601340	1457570	629108	453453	186832	115897	45212	23146
2010	109958000	64799600	43261800	34634500	29225800	15010200	9430000	7166920	8232240	3919490	1402810	975767	394248	224740	71364	32451
2011	89088900	53381500	36186600	28382500	25428900	13053500	8216910	6175170	5714940	2632520	1006520	699597	828122	484339	166193	78607
2012	67893400	40718700	27860800	21938900	20241300	9515820	5469660	4079530	4791890	1964890	551427	367917	621832	316709	75810	29442
2013	151849000	101659000	76624500	61038400	16386900	8094030	4723490	3506530	3257200	1380800	378710	248903	332029	169702	39123	14596
2014	171345000	118599000	91223000	73167400	46597100	28788900	20463600	16192200	2811660	1716910	890556	679152	220470	152916	74360	44370
2015	95014500	65823400	51382800	40770100	55746600	29190300	17814700	13342900	12902800	5972630	1814030	1220960	602108	325834	85265	34283
2016	136982000	93631400	71213800	55706300	30878400	12747800	6175880	4254930	10661400	3307910	465689	260642	1047910	396437	42419	9652
2017	168157000	115082000	88114100	69758900	42190700	21142500	12375000	9147960	3399830	1464670	393931	257575	225649	115102	26081	9591
2018	163028000	111574000	85435800	67649600	52833800	26546400	15578300	11527100	7309530	3163210	858347	562436	223037	114237	26153	9680
2019	139860000	95751900	73460700	58368200	51236300	27215200	16861000	12730800	9210530	4379360	1430820	980317	477617	266526	75670	32143
2020	85515000	58490800	44646600	35150700	44206700	20256400	10864900	7774630	10172300	3765950	751141	457106	845227	375561	60179	17729
2021	69413200	47430600	36011600	29123700	26622400	10446200	4816020	4033920	6212200	1768500	210101	181019	396405	138661	12187	10500
2022	0				22057600				3223240				159885			

Table 10.6.4. North Sea & 3.a Sprat. Assessment output: Estimated recruitment, spawning-stock biomass (SSB), average fishing mortality (F), and landings weight (Yield). All estimates refer to the model year, e.g., 2021 = July 2021–June 2022.

Year	Recruitment (thousands)	High	Low	SSB (tonnes)	High	Low	Catches (tonnes)	F ages 1-2 (per year)	High	Low
1974	543036000	974148742	302713625	607031	989431	372423	463344	1.109	1.745	0.705
1975	709595000	1246579022	403925507	622040	1003062	385752	732312	1.705	2.538	1.145
1976	327714000	568380217	188951801	501939	813172	309827	628598	1.802	2.602	1.247
1977	630579000	1072938408	370598976	338439	521324	219712	385257	1.602	2.337	1.098
1978	1071680000	2020964214	568292112	389956	614573	247433	458804	1.049	1.768	0.623
1979	539449000	951361745	305882831	641332	1100917	373604	463638	0.676	1.302	0.351
1980	334838000	523306464	214246324	440425	747259	259581	387434	2.299	3.174	1.666
1981	87282900	128749607	59171479	307740	455678	207831	280582	1.152	1.754	0.757
1982	45555800	66143585	31376148	176147	263737	117646	162357	0.986	1.419	0.685
1983	58821600	79197337	43688093	82240	111675	60563	115440	1.589	1.941	1.300
1984	31588200	46065568	21660742	59357	76799	45877	113444	0.987	1.369	0.712
1985	23019800	31533307	16804808	55195	72629	41947	62514	1.308	1.657	1.033
1986	70963900	98483537	51134182	22058	29283	16616	27520	1.117	1.486	0.839
1987	38488000	52243884	28354059	50112	67314	37307	53942	0.361	0.549	0.238
1988	55817100	81761291	38105424	52957	67389	41616	103652	1.259	1.572	1.008
1989	48771900	67851635	35057346	39506	53836	28990	58420	0.423	0.804	0.222
1990	67307700	92743440	48847946	36902	50947	26728	78180	1.494	1.890	1.181
1991	103265000	134841771	79082766	79217	105401	59537	125815	0.848	1.175	0.613
1992	98542600	132518416	73277694	110149	138739	87450	156471	0.916	1.229	0.682
1993	129113000	203275378	82007801	155391	200600	120370	208848	1.587	1.894	1.330
1994	113155000	150994478	84798161	120194	177863	81223	424206	0.804	1.085	0.596
1995	35487900	47272692	26640984	169861	229949	125474	446555	1.342	1.679	1.072
1996	59588600	78950898	44974805	104983	130860	84223	95496	1.395	1.705	1.141
1997	46909200	62490879	35212707	106236	134353	84003	125174	1.049	1.354	0.813
1998	105848000	142504252	78620805	130525	162642	104750	188907	1.765	2.072	1.504
1999	75667400	98896332	57894517	125568	164272	95983	243158	0.936	1.248	0.702
2000	72250500	94446022	55271092	180665	227382	143546	222027	1.485	1.826	1.208
2001	58320100	75670180	44948143	124318	156010	99064	153321	1.644	1.981	1.364
2002	77193400	102094534	58365720	106899	133428	85644	174713	1.676	1.992	1.411
2003	98936600	131377949	74506041	132982	168882	104713	174988	1.372	1.700	1.108
2004	166990000	218038501	127893285	161765	206207	126901	231352	2.085	2.414	1.801
2005	63546300	81669576	49444756	203907	260209	159787	280275	1.356	1.666	1.104
2006	80677800	103508005	62883131	160733	200768	128681	78028	1.659	1.987	1.384
2007	56916600	74132739	43698633	130934	162701	105369	99902	1.722	2.046	1.449
2008	124143000	158849105	97019649	95608	119311	76613	69892	1.578	1.913	1.301
2009	104609000	134930708	81101204	164733	205575	132005	170934	0.886	1.182	0.664
2010	109958000	153382153	78827696	170207	211284	137116	145415	1.072	1.377	0.835

Year	Recruitment	High	Low	SSB	High	Low	Catches	F ages 1-2	High	Low
	(thousands)			(tonnes)			(tonnes)	(per year)		
2011	89088900	115680121	68610164	149422	192407	116040	122472	0.969	1.296	0.724
2012	67893400	86480522	53301179	124904	153810	101430	96030	1.336	1.634	1.093
2013	151849000	206375367	111729027	103116	127342	83499	60207	1.422	1.808	1.119
2014	171345000	232252288	126410419	192302	251584	146989	190268	0.638	0.883	0.461
2015	95014500	126602235	71308024	311969	410654	236999	298227	1.314	1.629	1.059
2016	136982000	176588472	106258739	216052	278800	167426	227169	2.253	2.561	1.982
2017	168157000	216616887	130538192	176752	221935	140768	135824	1.459	1.774	1.199
2018	163028000	217041203	122456605	200339	249556	160828	190779	1.448	1.749	1.199
2019	139860000	183850729	106395116	209892	267130	164919	137489	1.217	1.558	0.951
2020	85515000	115933635	63077598	288838	368367	226479	181990	1.827	2.159	1.546
2021	69413200	106348965	45305493	141574	178714	112152	80032	2.169	2.567	1.832
2022	120979028			100495	138634	72848				

* Geometric mean recruitment (2011–2020)

Table 10.9.1. North Sea and Division 3.a Sprat. Input to forecast (years and age refer to the model year, e.g., 2021 = July 2021–June 2022).

Age	Age 0	Age 1	Age 2	Age 3
Stock numbers(2022) (millions)	120979	22058	3223	160
Exploitation pattern S1	0.003	0.433	0.734	0.668
Exploitation pattern S2	0.015	0.423	1.447	1.678
Exploitation pattern S3	0.027	0.157	0.348	1.073
Exploitation pattern S4	0.000	0.000	0.000	0.000
Weight in the stock S1 (gram)	4.800	7.593	10.633	13.621
Weight in the catch S1 (gram)	4.80	7.59	10.63	13.62
Weight in the catch S2 (gram)	5.78	9.00	11.84	15.58
Weight in the catch S3 (gram)	5.81	9.34	12.21	15.19
Weight in the catch S4 (gram)	6.44	9.42	12.36	15.93
Proportion mature(2020)	0.00	0.41	0.87	0.95
Proportion mature(2021)	0.00	0.41	0.87	0.95
Natural mortality S1	0.38	0.35	0.26	0.14
Natural mortality S2	0.26	0.20	0.16	0.15
Natural mortality S3	0.21	0.18	0.15	0.15
Natural mortality S4	0.28	0.22	0.18	0.18

Table 10.9.2. Sprat North Sea Division 3.a. Short-term predictions options table. Years refer to the model year, e.g., 2021 = July 2021–June 2022.

Catch options. Catches and SSB are in thousands of tonnes.

3-year average weight-at-age was used to calculate SSB. Recruitment(2021) = geometric average 2011–2020.

Basis	Catches(2022)	F(2022)	SSB(2023)	%SSB change*	%TAC change**
F_{cap}	68.690	0.69	181215	80%	-36%
F=0	0	0	222210	121%	-100%
F=0.1	12.231	0.1	214704	114%	-89%
F=0.2	23.557	0.2	207825	107%	-78%
F=0.3	34.071	0.3	201505	101%	-68%
F=0.4	43.852	0.4	195688	95%	-59%
F=0.5	52.971	0.5	190322	89%	-50%
F=0.6	61.490	0.6	185363	84%	-42%
F=0.7	69.465	0.7	180772	80%	-35%
F=0.8	76.944	0.8	176512	76%	-28%
F=0.9	83.971	0.9	172554	72%	-21%
F=1.0	90.586	1	168869	68%	-15%
$B_{escapement}$ without F_{cap}	178.672	3.28	125000	24%	-67%

* SSB in July 2023 relative to SSB in July 2022

** catch (July 2022-June 2023) relative to the sum of the TACs (106715 tonnes) for July 2021–June 2022 in Subarea 4 and Division 3.a.

Figure 10.1.1. North Sea and Division 3.a sprat. Sprat catches in the North Sea and Division 3.a (in tonnes) for each calendar year by statistical rectangle.

Figure 10.2.1. North Sea and Division 3.a sprat. Number of samples taken in the North Sea and Division 3.a for each calendar year by statistical rectangle.

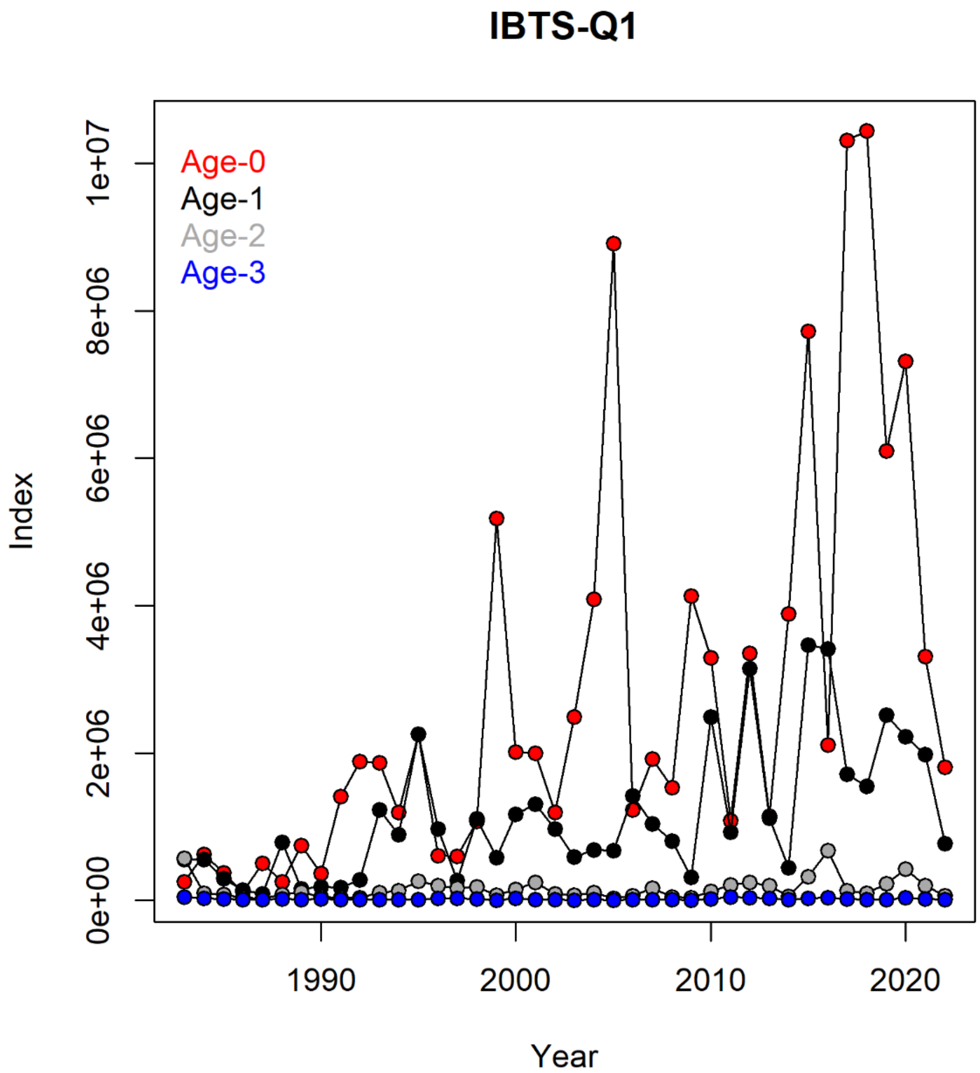


Figure 10.3.1. North Sea and Division 3.a sprat. IBTS Q1 survey index for Subarea 4 and Division 3.a combined. The index is calculated using a delta-GAM model formulation (see WKSPRAT report (ICES, 2018) for details). Years refer to the calendar year.

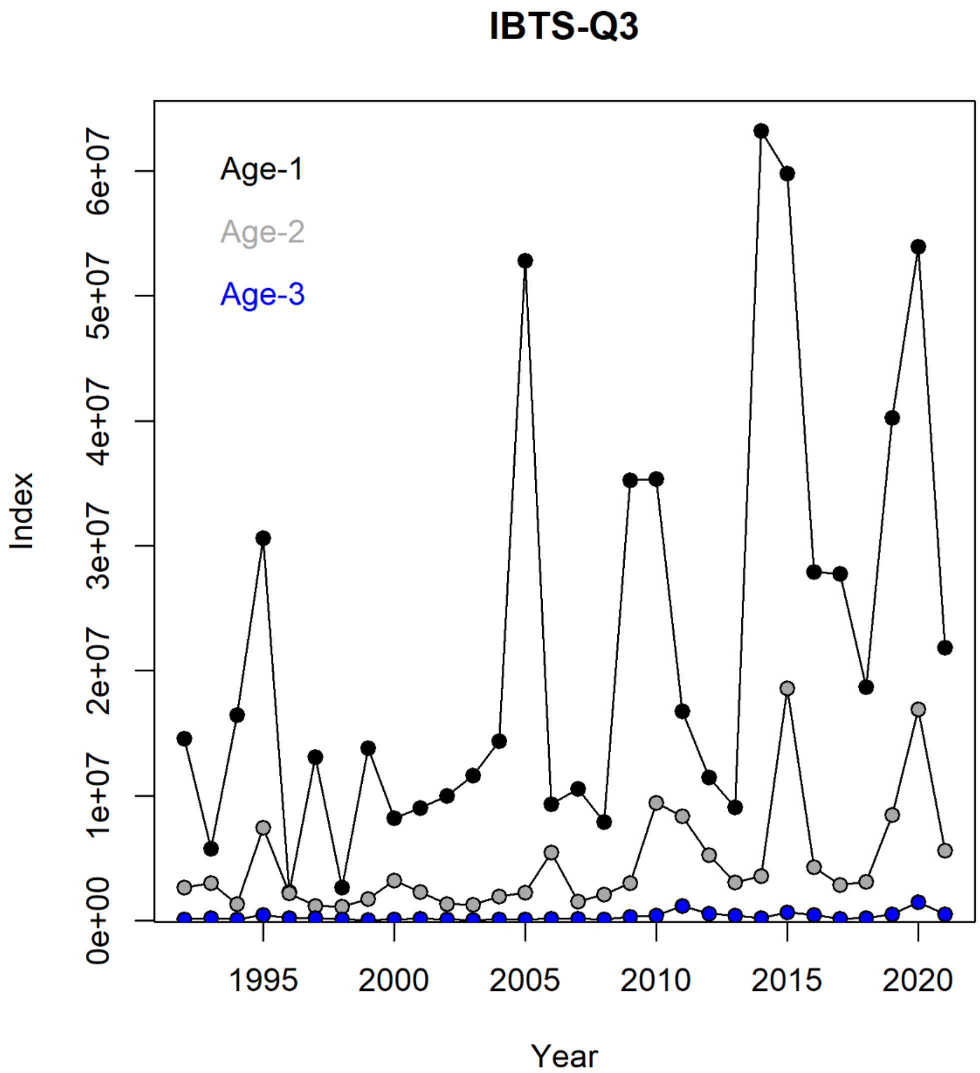


Figure 10.3.2a. North Sea and Division 3.a sprat. IBTS Q3 survey index for Subarea 4 and Division 3.a combined. The index is calculated using a delta-GAM model formulation (see WKSPRAT report (ICES, 2018) for details). Years refer to the calendar year.

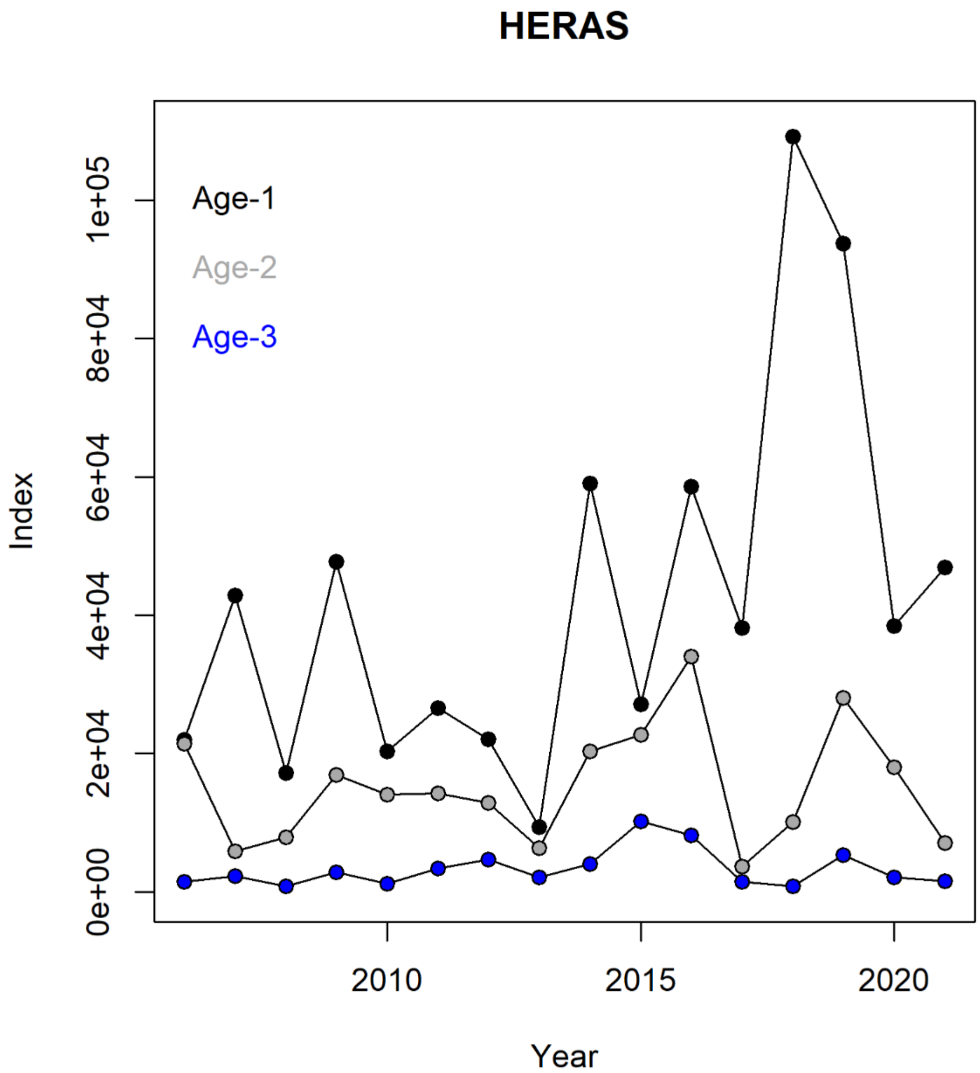
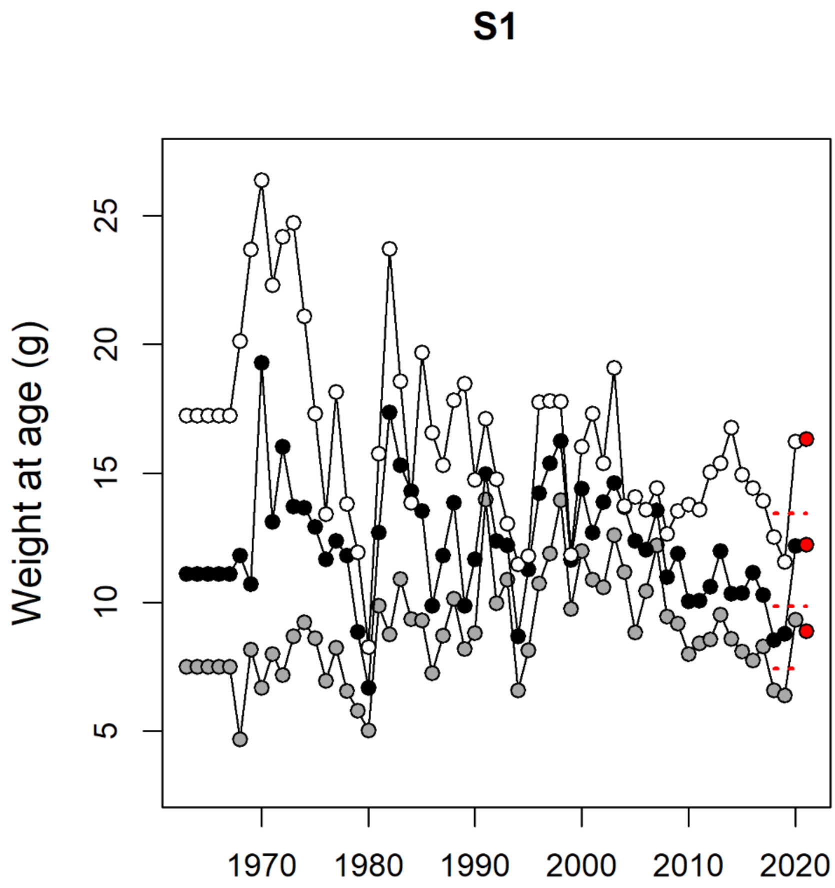
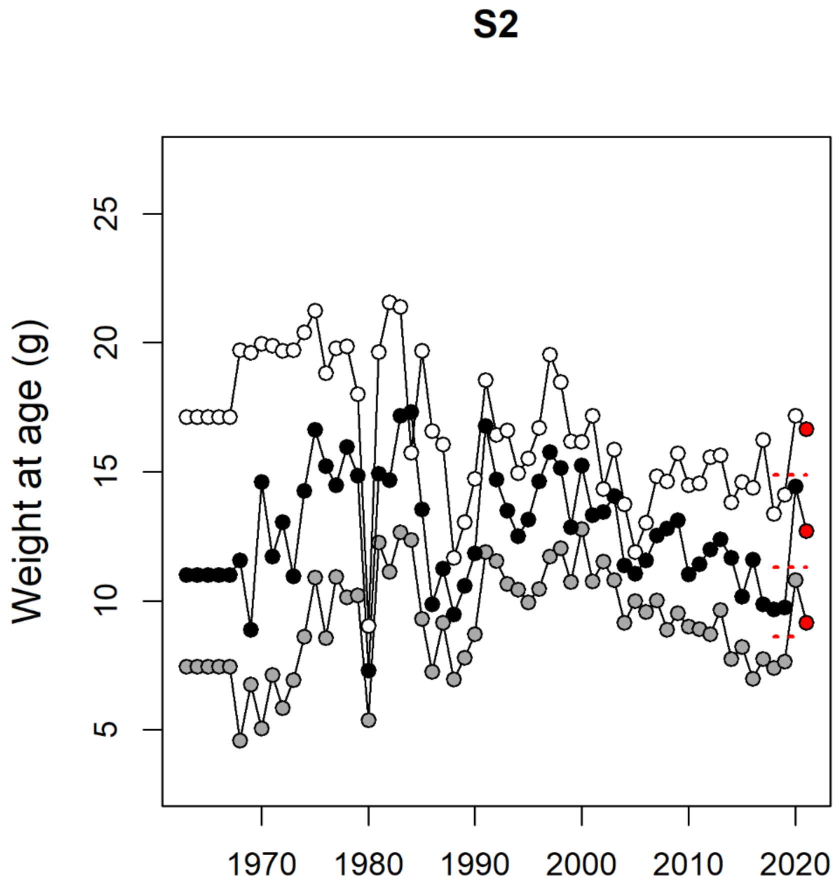
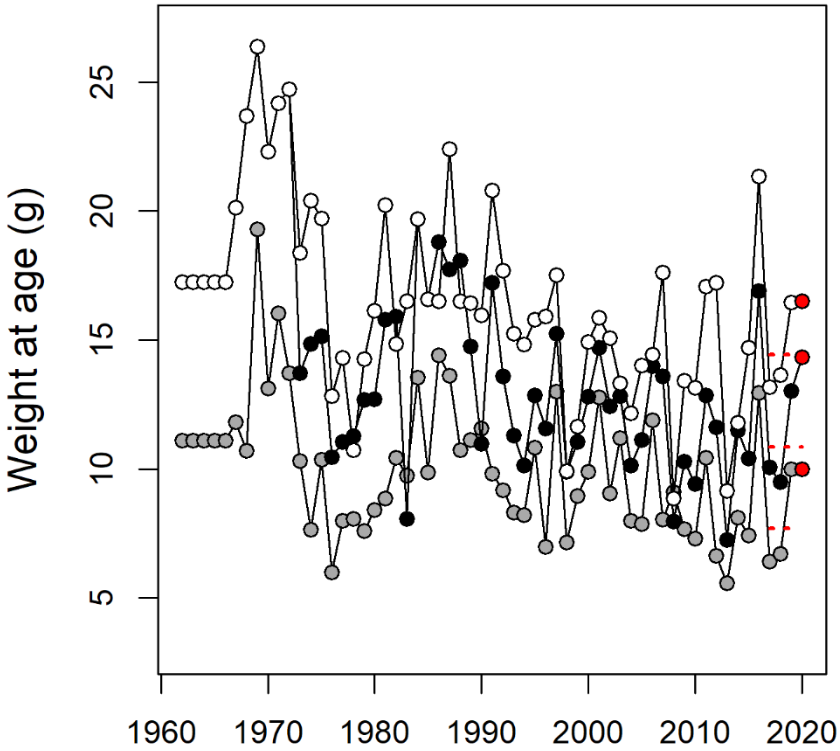


Figure 10.3.2b. North Sea and Division 3.a sprat. HERAS survey index for Subarea 4 and Division 3.a combined (sum of abundance indices published by WGIPS). Years refer to the calendar year.


S1
Weight at age (g)
5
10
15
20
25
1970
1980
1990
2000
2010
2020


S2
Weight at age (g)
5
10
15
20
25
1970
1980
1990
2000
2010
2020

S3



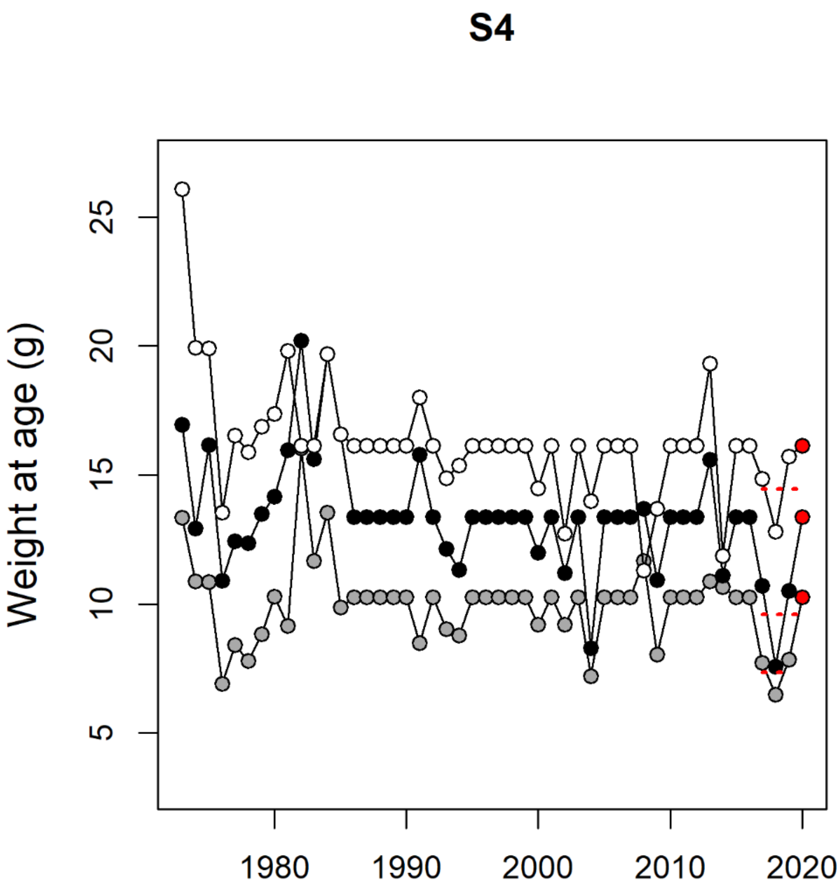


Figure 10.4.1. North Sea & 3.a sprat. Mean weight at age in season 1–4 (S1–S4) (years refer to the model year, e.g., 2021 = July 2021–June 2022). Age 1 (grey), age 2 (black), age 3 (white). Red dot is the status quo weight and the red dashed line refer to the 3-year average used in the forecast last year.

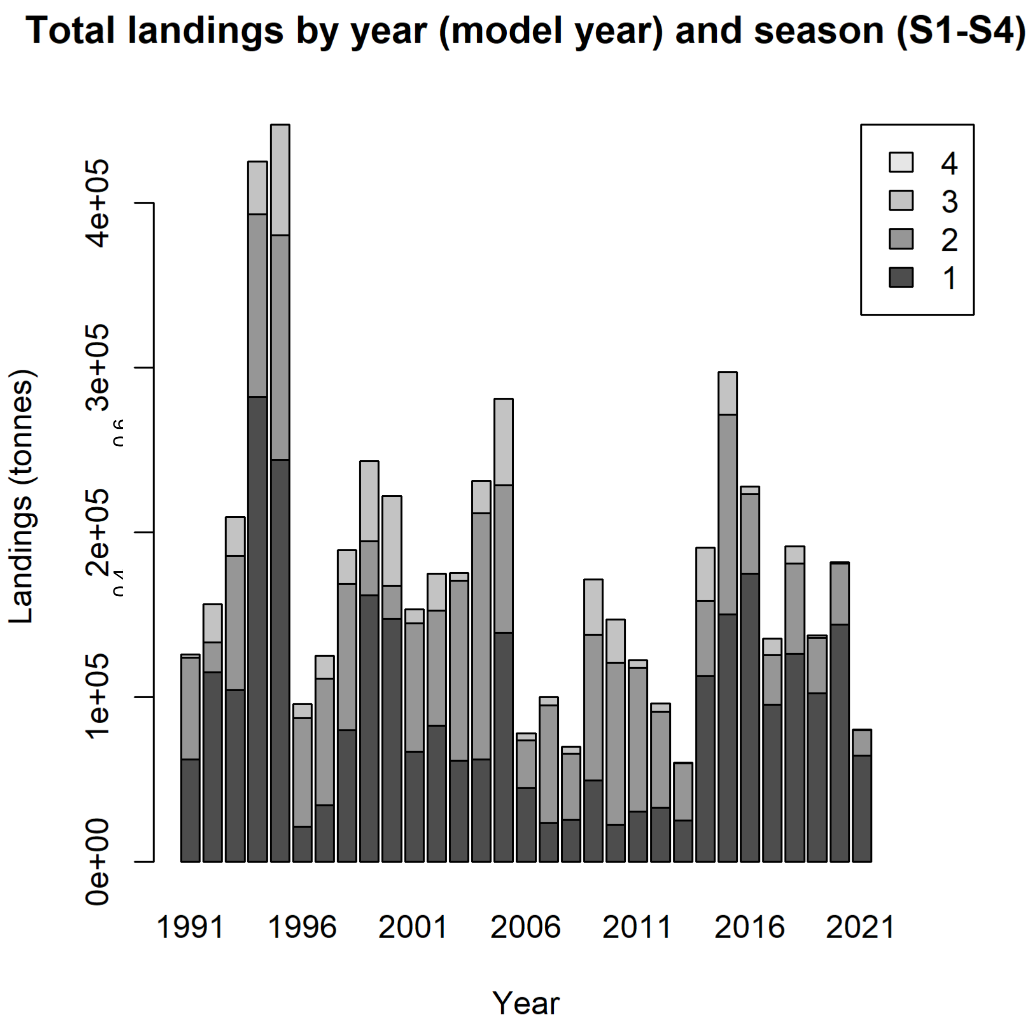


Figure 10.6.1a. North Sea & 3.a sprat. Seasonal distribution of catches. Year and season 1-4 refer to the time-steps of the model (e.g., 2021 = July 2021–June 2022). Note that since the model year of 2021 is not yet finished, the 2021 column will be updated next year. Also note that there are no catches shown for S4, since these are moved to S1 in the following year (see WKSPRAT 2018 report (ICES, 2018) for details).

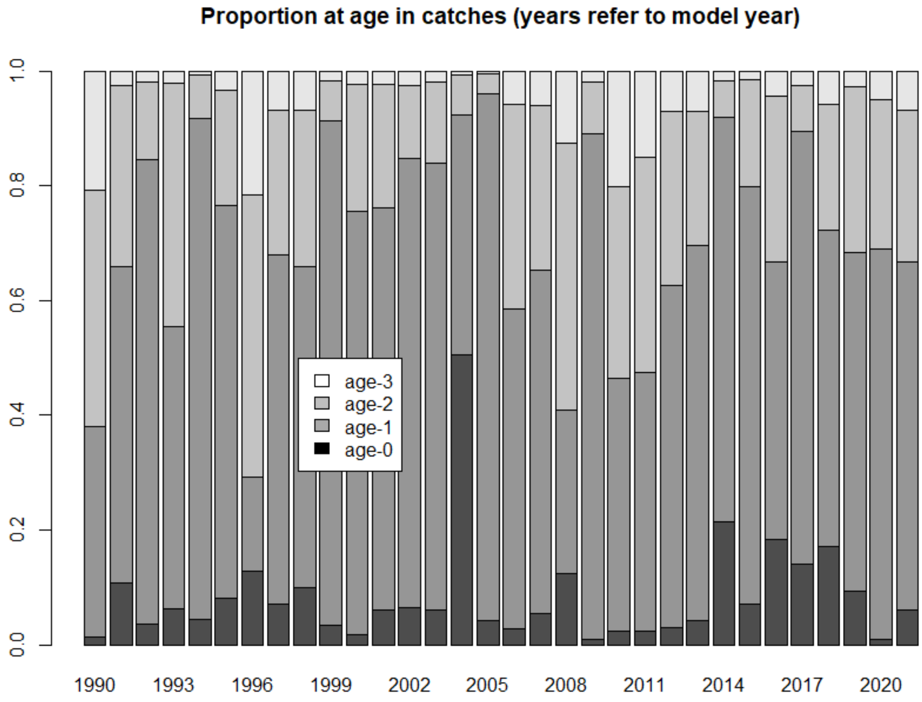


Figure 10.6.1b. North Sea & 3.a sprat. Proportion of each age group in the catches. Year and age refer to the model year (e.g., 2021 = July 2021–June 2022).

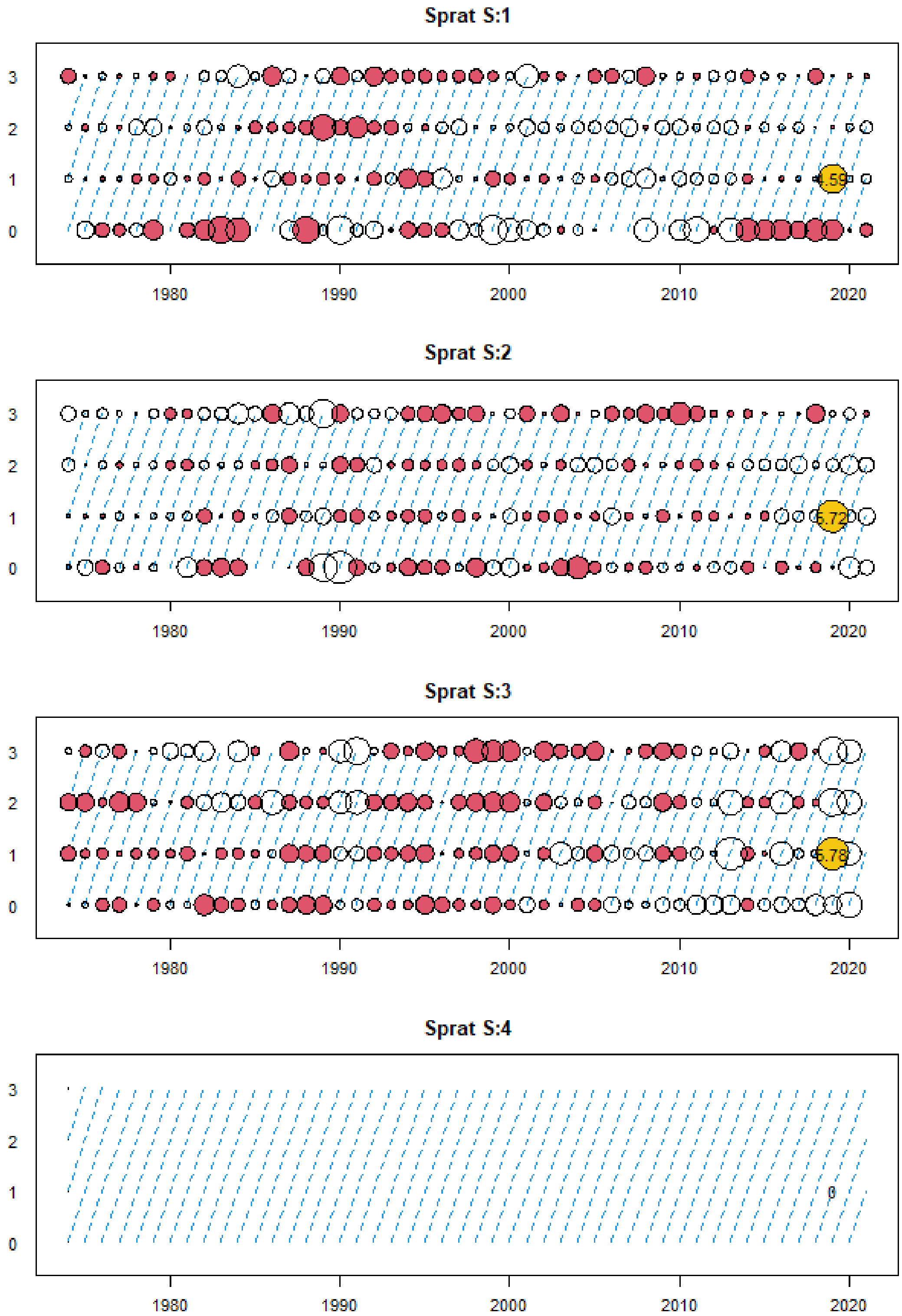


Figure 10.6.2. North Sea & 3.a sprat. Catch residuals by age. (Model year, e.g., 2021 = July 2021–June 2022)

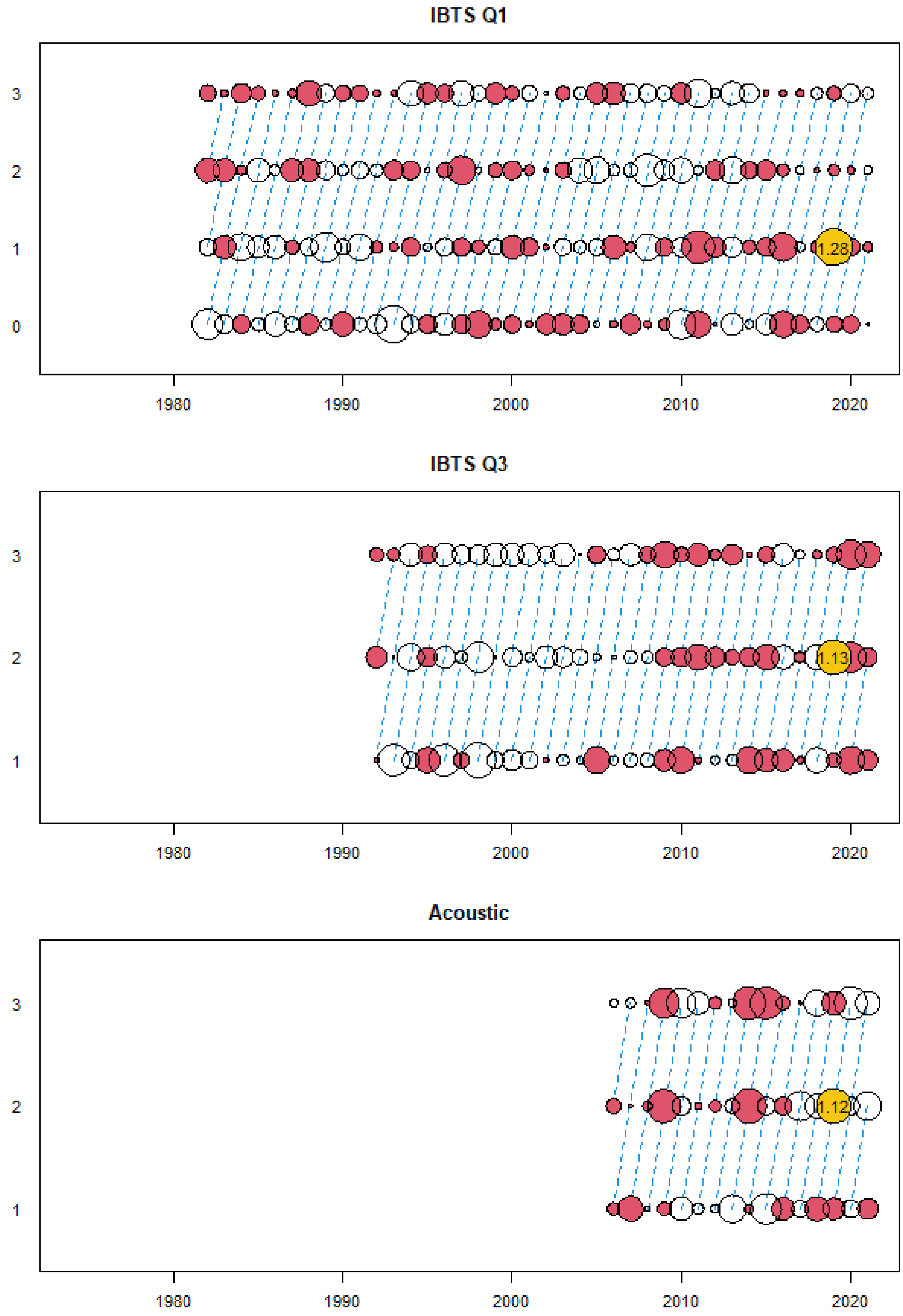


Figure 10.6.3. North Sea & 3.a sprat. Survey residuals by age. (Model year, e.g., 2021 = July 2021–June 2022)

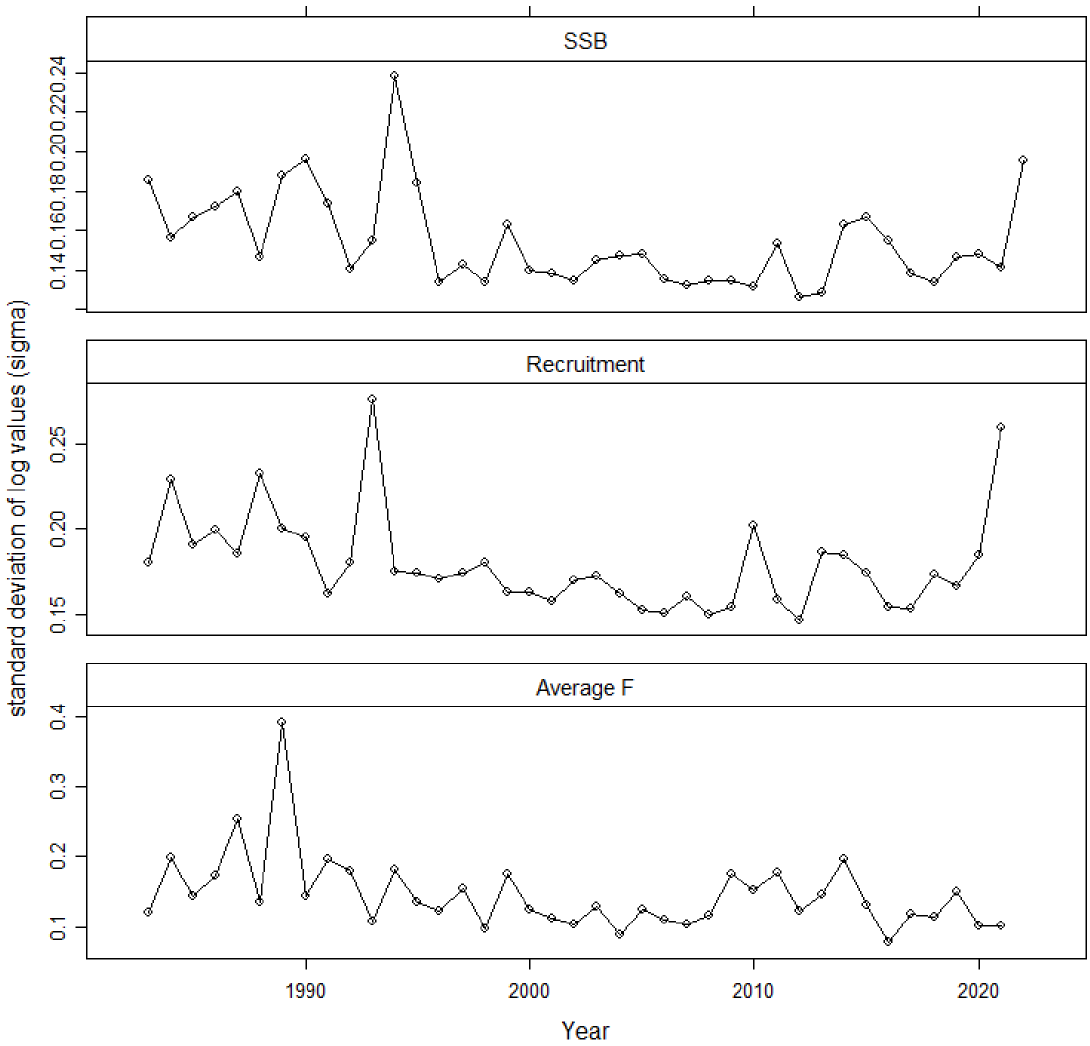


Figure 10.6.4. North Sea & 3.a sprat. Coefficients of variance (Model year, e.g., 2021 = July 2021–June 2022).

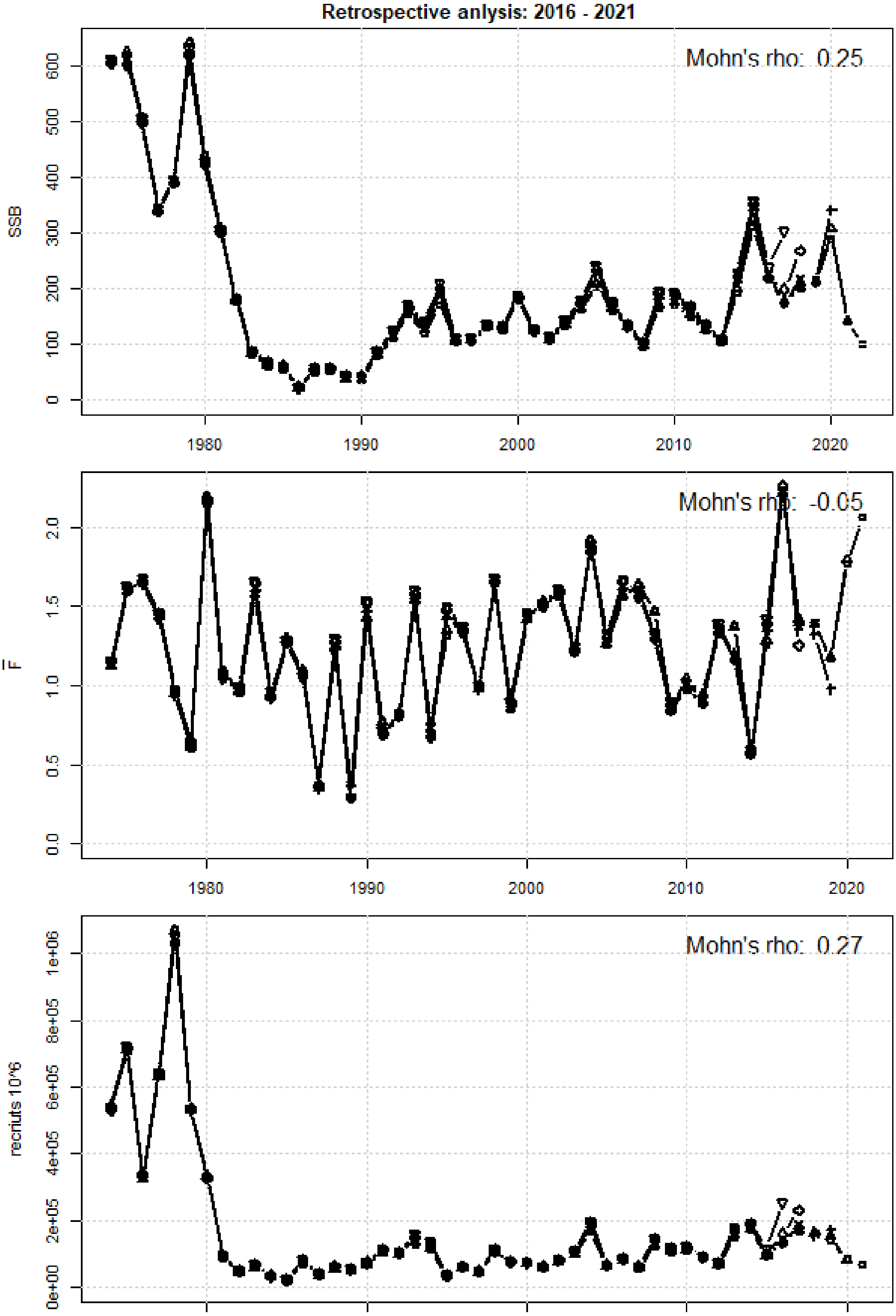


Figure 10.6.5. North Sea & 3.a sprat. Retrospective analysis (Model year, e.g., 2021 = July 2021–June 2022)

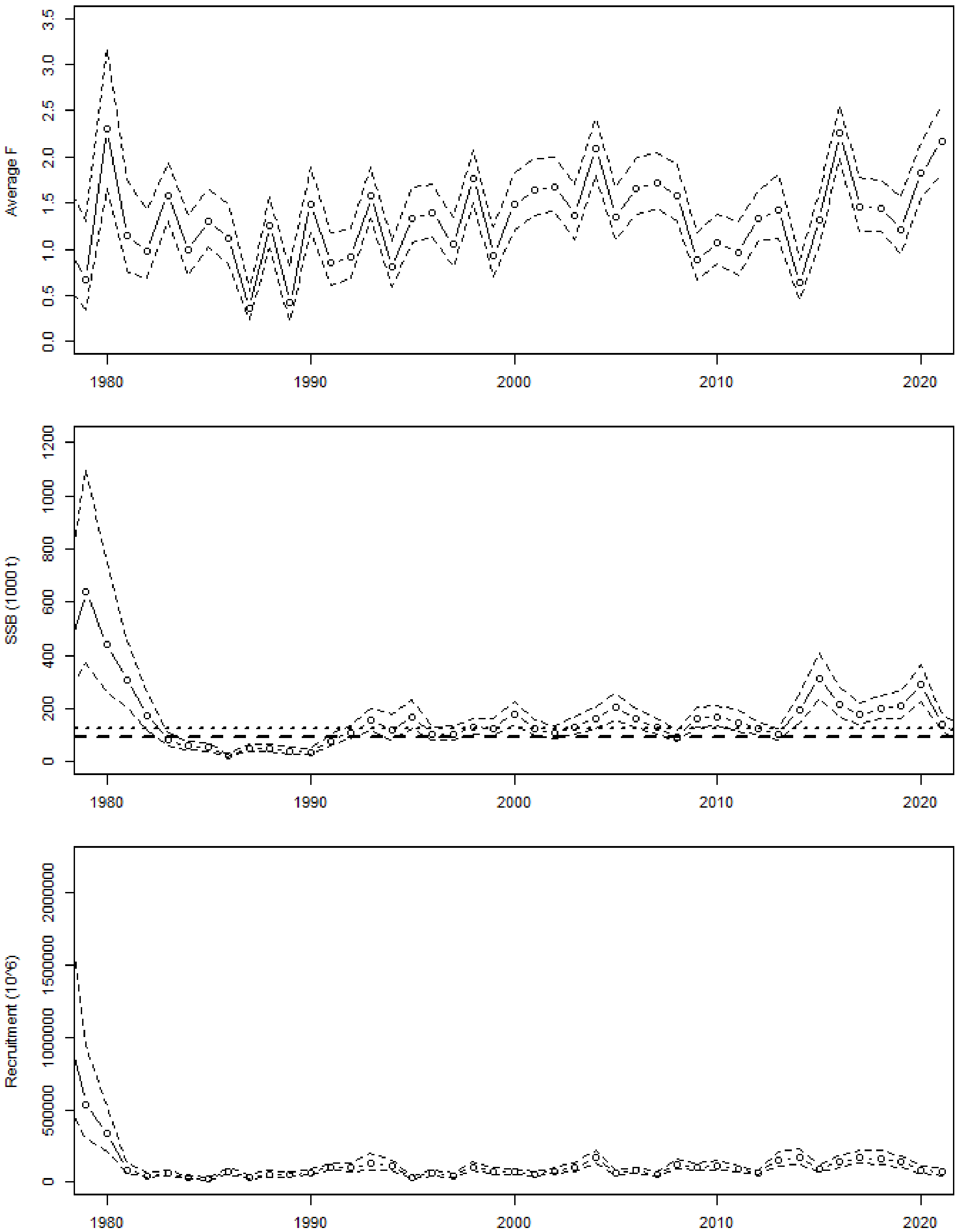


Figure 10.6.6. North Sea & 3.a sprat. Temporal development in Mean F, SSB and recruitment. Hatched lines are 95% confidence intervals (Model year, e.g., 2021 = July 2021–June 2022).

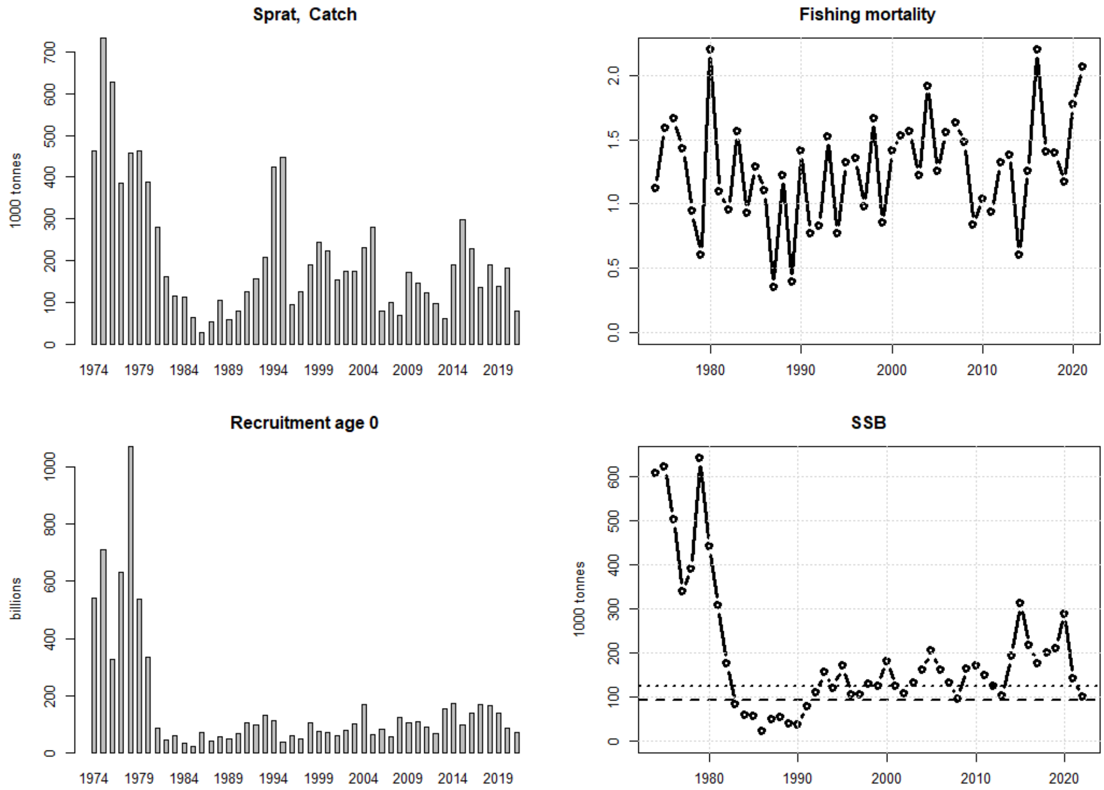


Figure 10.6.7. North Sea & 3.a sprat. Assessment summary (Model year, e.g., 2021 = July 2021–June 2022).

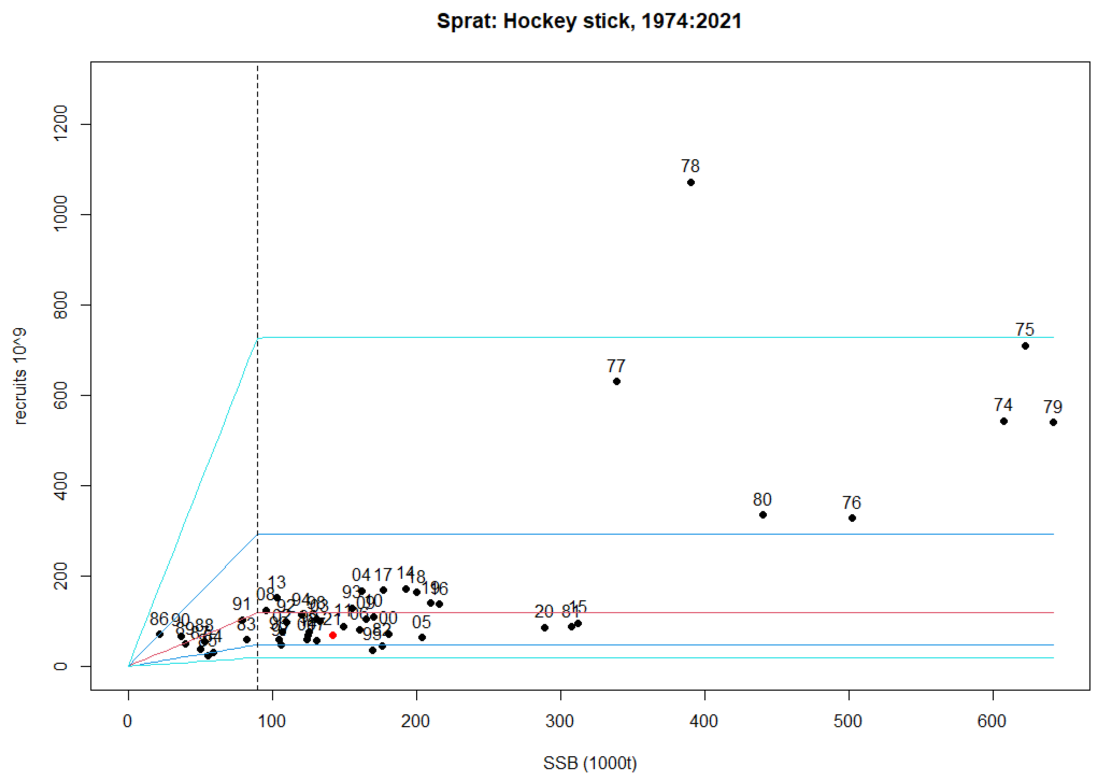


Figure 10.7.1. North Sea & 3.a sprat. Stock-recruitment relationship (Model year, e.g., 2021 = July 2021–June 2022).

10.14 References

WKSPRAT 2013. Report of the Benchmark Workshop on Sprat Stocks. ICES CM 2013/ACOM:48

WGSAM 2017. Interim Report of the Working Group on Multispecies Assessment Methods (WGSAM). ICES CM 2017/SSGEPI:20

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ICES. 2022. ICES Working Group of International Pelagic Surveys (WGIPS). ICES Scientific Reports. *In prep*.

ICES. 2020. Workshop on Catch Forecast from Biased Assessments (WKFORBIAS; outputs from 2019 meeting). ICES Scientific Reports. 2:28. 38 pp. http://doi.org/10.17895/ices.pub.5997

11 Sprat in the North Sea

The information formerly kept in this section is now found in Section 10: "Sprat in the North Sea and 3.a"

12 Sprat in the English Channel (divisions 7. de)

The stock structure of sprat populations in this region is not clear, despite evidence from acoustic surveys suggesting the stock is mainly confined to the UK side of 7.e. Further investigations and work are required to resolve this uncertainty.

12.1 The Fishery

12.1.1 ICES advice applicable for 2022

The advised catch for the English Channel (7.d and e) was set equal to 9200 tonnes.

12.1.2 Landings

The total sprat landings by country from 1986-2021 are provided in Table 12.1.1. Total landings from the international sprat fishery are available since 1950 (Figure 12.1.1.). Sprat landings prior to 1985 in 7.de were extracted from official catch statistics dataset (STATLANT27, Historical Nominal Catches 1950–2010, Official Nominal Catches 2006–2013), from 1985 onwards they come from WG estimates. Since 1985 sprat catch has been taken mainly by the UK (England, Wales and Northern Ireland). According to official catch statistics large catches were taken by Danish trawlers in the English Channel between the late 1970s and 1980s. The identity of these catches was not confirmed by the Danish data managers, raising the question of whether those reported catches were the result of species misreporting (i.e. herring misreported as sprat). Therefore, ICES cannot verify the quality of catch data prior to 1988.

The fishery starts in August and runs into February and sometimes March the following year. Most of the catch is taken in 7.e, in the Lyme Bay area. In the last decade catch from the UK covered about 93% of landed sprat, however in 2015 and 2016 this percentage diminished, with Netherlands, Denmark appearing, and taking a portion of the catch. Denmark and the Netherlands represent the two principle “transient fishing fleets” that appear occasionally in the time series and have been allocated a portion of the TAC under the common fisheries policy in previous years. In 2021 99.5% of the catches were taken by UK vessels. Landings were very low in 2021, 49 tonnes in total (Figure 12.1.1), which has been attributed to a large number of small sprat in the catch, leading to a short season for the UK fleet and a switch to beaming and scalloping.

Sprat is found by sonar search and sometimes the shoals are found too far offshore for sensible economic exploitation. This offshore/near shore shift may be related to environmental variability such as spatial and temporal changes in temperature and/or salinity.

12.1.3 Fleets

In the English Channel the primary gear used for the capture of sprat is midwater trawl. Within that gear type three vessels under 15 m have actively targeted sprat and have been responsible for the majority of landings (since 2003 they took on average 96% of the total landings). Sprat is also caught by driftnet, fixed nets, lines and pots and most of the landings are sold for human consumption.

12.1.4 Regulations and their effects

There is a TAC for sprat in ICES divisions 7.de, English Channel. Figure 12.1.2. shows the agreed TAC and the ICES catch from 2000-2022 and shows the catch is always below the agreed TAC.

12.1.5 Changes in fishing technology and fishing patterns

There is insufficient information available.

12.2 Biological Composition of the Catch

12.2.1 Catches in number and weight-at-age

In 2017/2018 fishing season a pilot self-sampling program started in the Southwest of UK, involving sprat fishers from Lyme bay. This program has continued in 2021 however due to low uptake in the fishery only 1 vessel submitted data. The graphs have therefore not been updated this year as the previous year's data better represents the stock, when taken by the fishery. The 2019-2020 data shown are raw numbers-at-length in the samples, and not raised to the total catches (Figure 12.2.1 and Figure 12.2.2).

The skippers have collected length measurements from the catches and recorded information on fishing trips since 2018. In 2019, the sprat lengths in the fishers' samples ranged from 7.5 to 15 cm (Figure 12.2.1). The main processors for the fishery were engaged in 2019 and have provided length and weight data from landings subsamples. The length distributions recorded by the processors was reasonably consistent in 2020 (Figure 12.2.2). Due to low uptake in the fishery during 2021, the fishery operated for only two months of the season (August and September) and the FSP program provided very little data.

Biomass estimates for 2021 showed a huge increase in Sprat biomass, The PELTIC survey reports that there was a very strong recruitment (0-group) (Figure 12.3.3). These small fish were very widespread throughout the survey area. Anecdotal evidence from the Fisheries (self) sampling program (FSP) program and fishers also support the survey findings, with the Pelagic fisheries noting difficulties in being able to fish because of too much "whitebait" everywhere, below marketable size. The demand in the fishery tied more to size and marketability than stock biomass, with the processors reluctant to take catches with small fish. Figure 12.3.3 supports this and shows the large increase in 0 age fish in 2022 compared to 2021.

12.3 Fishery-independent information

PELTIC Acoustic Survey (A6259)

Cefas carried out the annual PELTIC survey (Pelagic Ecosystem Survey of the Celtic Sea and Western Channel) in autumn in the English Channel and the Celtic Sea to acoustically assess the biomass of the small pelagic fish community within this area (divisions 7.e–f), and sprat is one of the target species. This survey, conducted from the RV *Cefas Endeavour*, started in 2013, when it first focused only on UK waters but, from 2017, it expanded to also cover the southern area of division 7.e (French waters). In 2018 a one-off extension of the survey was conducted into division 7.d to investigate the presence of the stocks in the eastern channel, the survey found almost no sprat present.

As detailed in the ICES survey manual (Doray *et al*., 2021), calibrated acoustic data were collected during daylight hours only at three frequencies (38, 120, 200 kHz) from transducers mounted on a lowered drop keel at 8.2 m below the surface. All non-fish acoustic targets were removed by creating a multi-frequency filter and only backscatter from swimbladder fish was retained for further analyses. The resulting echotraces were further partitioned by species based on the trawl catches and were converted into abundance and biomass estimates (plus Coefficient of Variation) in StoX software.

To convert acoustic biomass to abundance, a Target Strength (TS) equation is used. As no dedicated sprat specific TS equation is available for the area, the generic clupeid value of b20 = -71.2 dB is used. This was found to be an acceptable conversion and it was noted that more negatively values (leading to a higher biomass) have been used for sprat stocks in adjacent waters.

As part of the 2021 sprat inter benchmark process (IBP), the ability of the survey to capture the sprat stock (catchability) was evaluated, as this feeds heavily into assumptions of the, management strategy evaluation (MSE). It was noted that the assessment is based on a biomass estimate from only a small area of the total management unit and is therefore likely to be a conservative estimate.

The survey also provides age and length structure for sprat aged 0–6 (Figure 12.3.2 and Figure 12.3.3). While there is high variability in the age distributions, this does not affect the overall estimate of biomass. However, it does preclude cohort tracking in the survey. The IBP found that the survey provided a robust estimate of biomass for application of a constant harvest rate (CHR) and is evaluated at two ICES working groups, WGIPS and WGACEGG each year."

Biological data

Biological information from trawl catches carried out during the 2021 PELTIC acoustic survey, identified 5 age classes from 0 to 4 contributing on average to 91.61%, 2.1%, 5.9%,0.32%, and 0.02% respectively in the samples collected. The age structure observed in 2021 is shown in Figure 12.3.2 and 12.3.3. This supports anecdotal information from the fishery and is linked to the reduced catch in 2021, citing a high volume of small fish.

12.4 Mean weight-at-age and maturity-at-age

No data on mean weight-at-age or maturity-at-age in the catch are available.

12.5 Recruitment

The acoustic surveys may provide an index of sprat recruitment in divisions 7.d–e.

12.6 Stock Assessment

This stock is considered a category 3 stock with the assessment and advice based on survey trends (ICES Advice 2018).

The stock went through an interbenchmark in February 2021 to update the assessment method based on the new guidance issued by WKLIFEX and developed by WKDLSSSLS2. The IBP tested the available data against the updated guidelines and assessed the suitability of three data limited methods for the stock.

1. 1 over 2 ratio-based advice with a 20% and an 80% uncertainty cap
2. Constant Harvest Rate
3. Surplus Production model (SPiCT)

Three exploratory SPiCT assessments were performed:

- an annual model using calendar year (January–December)
- an annual model using fishing year (July–June);
- a model using quarterly data.

The IBP concluded that SPICT analysis of the stock was not viable at this point in time due to the limited time series available for the PELTIC survey (2014–2020). There is also a strong transient component to the fishery from Denmark and the Netherlands which has not been present in recent years. The IBP determined that SPICT should be re-examined in the future.

A constant harvest rate (CHR) was determined by management strategy evaluation (MSE). The CHR was tested alongside the 1o2 with 80% and 20% uncertainty caps. The MSE tested three survey catchability options, with an assumption of 0%, 50% and 100% over estimation of the underlying biomass from the PELTIC survey. Assuming that some overestimation may take place on the survey, the IBP determined that the 50% overestimation should be adopted. Three scenarios of fishing pressure, prior to implementation of the catch advice options, were simulated for 25 years to establish starting points for the stock.

This MSE was carried out on a seasonal time step due to limitations in the framework. The IBP notes that the current advice is given annually, however it is recommended to move to an annual- seasonal calendar. This will reduce the time lag between survey and advice, while keeping the stock within the HAWG. WKDLSSLS determined that the reduced lag between survey and advice was the key component of providing precautionary advice for short lived species. A CHR determined on a seasonal timestep will still be applicable to the stock and is more precautionary than the 1o2 rule.

The CHR was found to be more precautionary for the stock than the current 1o2 rule (with both UC values), supporting the findings of WKDLSSL1 & 2. The CHR of 12% was the maximum value estimated under the 50% survey catchability overestimation level that kept the risk <5% in the long term under all fishing histories while giving the highest yield. A correction factor to the CHR was applied to account for a mismatch between survey weight at age in the PELTIC biomass and the weight at age in survey biomass simulated in the MSE. This was done to account for in year growth and results in a correction factor of 0.714 equal to the ratio of the MSEindex/"PelticIndex", where PelticIndex equates to the weight-at-age structure present at the time of the survey. This time-step accounts for a seven-month growth period, comprising the months between spawning in March and the survey in October. The IBP concluded that an adjusted CHR to 8.57% was the most appropriate assessment method for the stock (ICES, 2021b).

Further investigation of the CHR, specifically using sprat in 7.de, was conducted at WKDLSSLS3 in 2021. The group examined the effect of applying an 80% uncertainty cap (UC) to the CHRs. The conclusion from this was an UC resulted in minimal risk reduction for CHR's below the 5% risk threshold. It did reduce risk for CHR's that are too high but could not bring them below the ICES risk threshold. The only significant difference between CHR and CHR+UC was a decrease in interannual variability in the stock. This contrasts with work by other members of the WKDLSSLS group, who note that UC's may introduce unnecessary risks to the stock when requiring rapid reduction of catches. Alternatively following a drop of catch advice, may prevent recovery of yield (Fischer *et al*. 2020, 2021 and Sánchez-Maroño *et al*. 2021). The group found that unconstrained CHRs appear robust to past fishing history, initial stock status and advice schedule but are sensitive to survey catchability. No recommendations from the WKDLSSLS were made in regard to applying a UC to CHR's. Application of uncertainty cap is a current research topic and future guidelines may clarify how they are applied as part of a CHR.

12.6.1 Data exploration

Biomass Index

A 9-year time-series of biomass estimates from the PELTIC survey is shown in Table 12.6.1. The extension of the survey into ICES division 7.d and the southern part of 7.e suggests that the stock is mainly located in the more northerly part of division 7.e during October. The survey conducted in 2021 showed a very large concentration of age 0 sprat in Lyme bay, Figure 12.6.1 and 12.3.2. The survey also covered the area around the Channel Islands (Figure 12.6.1) and found a large quantity of sprat present off the coast of France. This biomass does not feed into the assessment, which looks only at the "core area" of Lyme Bay.

Sprat was in general the dominant small pelagic species in the trawl samples, with highest densities in the eastern parts of the western Channel and the Bristol Channel, with the bulk of the biomass centred in Lyme bay. As in previous years, large schools in the Bristol Channel appeared to consist mainly of juvenile sprat, whereas those in the English Channel also included larger size classes. In 2018, the PELTIC survey was extended into the eastern channel and found no discernible Sprat biomass, indicating a separation between 27.7.de and Sprat in the Eastern channel.

For more details on the survey design see Figure 12.3.1 and ICES 2021b.

A 2015 analysis of the age distribution of sprat in the survey area shows a marked distinction between the young fish (0 and 1) found in the Bristol Channel and the older age classes that occupy the Western English Channel (ICES 2015). Whether the two clusters belong to the same stock has yet to be proved: the circulation pattern of the area would allow sprat eggs/larvae to travel northward, from division 7.e to 7.g; however, the formation of a front in late spring/early summer seems to suggest these may be two different stocks.

The stock was examined using RAD-seq-derived SNPs (Restriction-site-associated DNA *sequencing* and single nucleotide polymorphisms) in 2020 (McKeown *et al.*, 2020). This was part of a larger study of North Sea and Baltic sprat. The study found that amongst the North Sea population there was a lack of genetic differentiation between sampled stocks, indicating a high gene flow in the North Sea population. This would indicate that all sprat in the North Sea form one genetic unit, however the study suggests further work is needed. Specifically, for fisheries management, it should be noted that genetically connected stocks may still be isolated on the time scale of fisheries management.

12.7 State of the Stock

The acoustic estimates for 2017 (32 751t) show a three fold increase compared to the all-time low value in 2016 (9826 t), although the biomass is still half of the high levels recorded in the period 2013–2015 (70680 t, 85184 t and 65219 t respectively), Table 12.6.1. The PELTIC biomass has increased substantially from 36 798 tonnes in 2020 to 107355 tonnes in 2021. The harvest rate has dropped from 3% to 0.05%. This is due low catches in 2021 which has been attributed to a large number small sprat mixed in with the catch. The fleet is thought to have switched to beam trawling and scalloping because of this but should be expected to return when these small sprats mature.

12.8 Catch Advice

Applying the constant harvest rate of 8.57% to the current estimate of PELTIC biomass gives an advised catch of 9200 tonnes.

12.9 Short-term projections

No projections are presented for this stock.

12.10 Reference Points

The IBP suggested the use of the Istat value developed as part of WKDSLLS2 (ICES, 2021) could be used as a proxy B_{lim} for the stock. The Istat is defined as

Geomean(*Ihist*)*exp(-1.645*sd(log(*Ihist*))

Where *Ihist* refers to the biomass index, this gives a value of 11527.9 tonnes biomass for the stock. Note this should not be referred to as SSB or total biomass as SSB cannot be derived for the stock and the PELTIC does not capture the total biomass of the stock. Length based F (MSY) proxies were suggested by the ADG as being possibly applicable to the stock and providing useful information. They have not been explored to date but could be looked at in the future. The inclusion of the FSP sampling data (which includes length frequencies) could also be incorporated into these methods and provide interesting comparison between survey and fisheries derived data.

12.11 Quality of the Assessment

The coverage of the PELTIC acoustic survey was extended in 2017 towards the southern part of Division 7.e: this extension confirmed that the bulk of the sprat distribution in 7.e is located in Lyme Bay and surrounding areas, and very little extend outside. In fact, the transects carried out off the French coast found very little sprat, mostly of ages 0 and 1. This pattern may have changed somewhat in recent years as sprat have been recorded off the coast of France and around the channel island in 2018 and 2019. 2021 also saw sprat present off the coast of France, in line with a general increase in biomass across the area and consisted primarily of small age 0 fish. They do not feed into the advice, as they lie outside of the core Lyme bay area.

The extent to which the population migrates into Division 7.d was investigated during the 2018 survey. The survey showed that very little sprat was found on the eastern border of division 7.e suggesting no movements of sprat between the two areas and very little found in 7.d.

Concerns have been raised about the connection between the Western English Channel stock and the Bristol Channel, where large numbers of juveniles are found, it is currently believed the Bristol channel may represent a separate stock. See the data exploration section for details.

12.12 Management Considerations

Sprat is a short-lived species with large interannual fluctuations in stock biomass. The natural interannual variability of stock abundance, mainly driven by recruitment variability, is high and does not appear to be strongly influenced by the observed levels of fishing effort.

Sprat annual landings from 7.d–e over the past 20 years have been 2532 tonnes on average. The average harvest rate for the 9-year time-series is 8%, however if the 2016 value of 34% is removed, this drops to 5%. The average harvest rate is 2 % over the last 3 years. In general, however, it seems that Lyme Bay, where most of the fishery occurs, consistently hosts quite a substantial part of the sprat stock: this is confirmed by the fact that even in 2016, when the estimated biomass was overall very low, Lyme Bay still contributed 50% of the total sprat population in the Western English Channel.

The strong biomass fluctuations observed in the acoustic index and the relatively strong increase in biomass observed in 2017, suggests that the low level of catch is not impairing the stock. 2021 has seen another large increase in biomass. Due to the low fishing pressure and reports of average oceanographic condition from the survey, it is likely the increase is driven by environmental conditions or interactions with other stocks.

The timing of the advice relative to the PELTIC survey has been considered, previously the advice has been issued on an annual basis. This led to a lag between survey, advice and uptake, which was identified as problematic in a short-lived species. An agreement has been reached between the ICES members to move the advice to a seasonal calendar in line with the fishery for 2022/2023. The advice will now run across the fishing season (1 July–30 June) instead of on an annual basis.

The PELTIC survey takes place in October of the advice year minus 1, with the advice issued in March of the advice year for the fishing season. The fishing season runs from 1 July advice year, to 30 June advice year plus 1. Therefore, there is an 8-month delay between survey and advice. This is a weakness in the advice as Sprat can undergo rapid changes in biomass. The TAC issued separately to the ICES advice has been issue on a seasonal basis for 2022. A small delay is still present but has been greatly reduced. A further improvement to better respond to changing stock conditions would be a review mechanism at the time of the PELTIC in October to update the advice, if needed. However, this would present problems for issuing of the advice and there is currently little appetite to reopen advice mid-year for stocks in ICES or member states.

12.13 Ecosystem Considerations

Multispecies investigations have demonstrated that sprat is one of the important prey species in the North Sea ecosystem, for both fish and seabirds. At present, there are no analysis available on the total amount of sprat, and in general of other pelagic species, taken by seabirds, marine mammals, and large predators in the Celtic Seas Ecoregion. However, a wide spectrum of data that covers the whole trophic chain have been collected during the PELTIC acoustic survey: these data will in the future provide a substantial contribution to the knowledge base for the area.

Table 12.1.1 Sprat in 7.d-e. Landings of sprat, 1986–2021.

Country	Denmark	France	Netherlands	UK Eng+Wales+N.Irl.	UK Scotland	Other	Total
1986	15	0	0	1163	0	0	1178
1987	250	23	0	2441	0	0	2714
1988	2529	2	1	2944	0	0	5476
1989	2092	10	0	1520	0	0	3622
1990	608	79	0	1562	0	0	2249
1991	0	0	0	2567	0	0	2567
1992	5389	35	0	1791	0	0	7215
1993	0	3	0	1798	0	0	1801
1994	3572	1	0	3176	40	0	6789
1995	2084	0	0	1516	0	0	3600
1996	0	2	0	1789	0	0	1791
1997	1245	1	0	1621	0	0	2867
1998	3741	0	0	1973	0	0	5714
1999	3064	0	1	3558	0	0	6623
2000	0	1	1	1693	0	0	1695
2001	0	0	0	1349	0	0	1349
2002	0	0	0	1196	0	0	1196
2003	0	2	72	1368	0	0	1442
2004	0	6	0	836	0	0	842
2005	0	0	0	1635	0	0	1635
2006	0	7	0	1969	0	0	1976
2007	0	0	0	2706	0	0	2706
2008	0	0	0	3367	0	0	3367
2009	0	2	0	2773	0	0	2775
2010	0	2	0	4408	0	0	4410
2011	0	1	37	3138	0	0	3176
2012	6	2	8	4458	0	0	4474

Country	Denmark	France	Netherlands	UK Eng+Wales+N.Irl.	UK Scotland	Other	Total
2013	0	0	0	3793	0	0	3793
2014	45	0	275	3338	0	0	3658
2015	0	1	352	2659	0	0	3012
2016	185	7	231	2867	0	49	3339
2017	0	0	235	2498	0	0	2733
2018	474	1	0	1776	0	0	2252
2019	0	0.67	0	1544	0	28	1573
2020	0	0	0	873	0	0	873
2021	0	0.25	0	48.75	0	0	49

Table 12.6.1. Sprat in 7.d–e. Annual sprat biomass in ICES Subdivision 7.e (Source: Cefas annual pelagic acoustic survey)

Survey	Area	Season	2013	2014	2015	2016	2017	2018	2019	2020	2021
PELTIC	W Eng Ch	Oct	70 680	85 184	65 219	9826	32 751	21 772	36 789	33 798	107 355

*** ICES rectangles 29E6, 30E6**

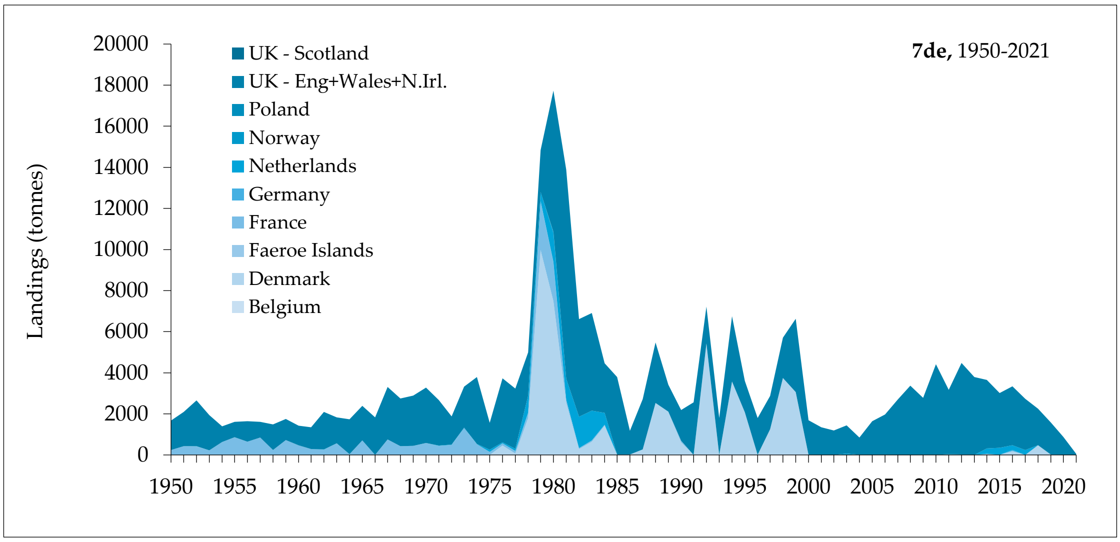

Figure 12.1.1. Sprat in 7.d-e. Landings of sprat 1950–2021.

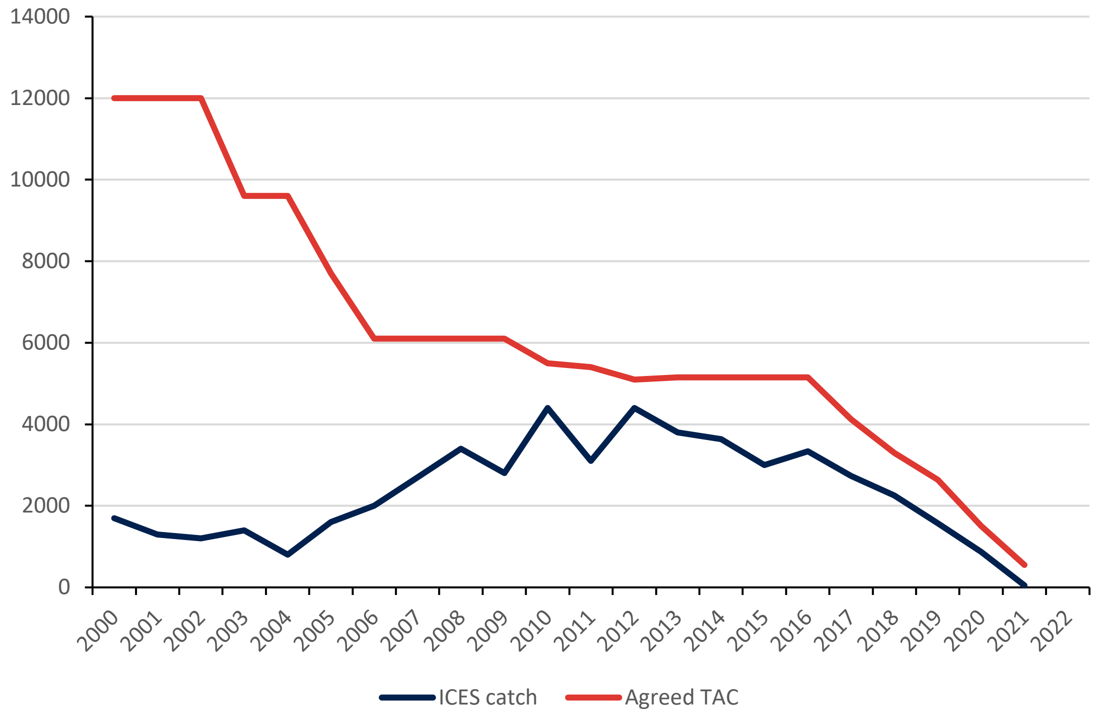

Figure 12.1.2. Sprat in 7.d-e. ICES catch (blue line) and agreed TAC (red line) from 2000 to 2022.

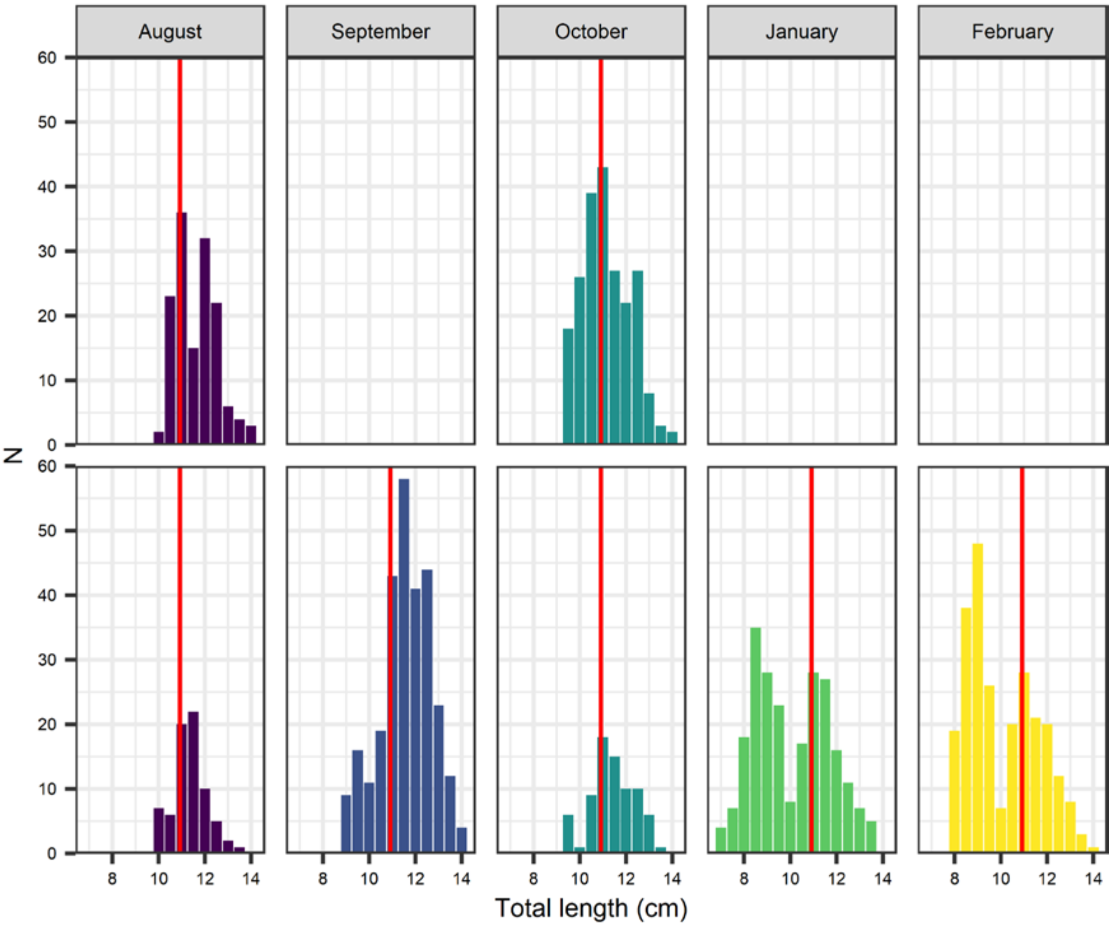

Figure 12.2.1. Length distribution collected by the fishers by month. Red line indicates weighted mean length at each month 2019, For the two boats supplying the FSP program.

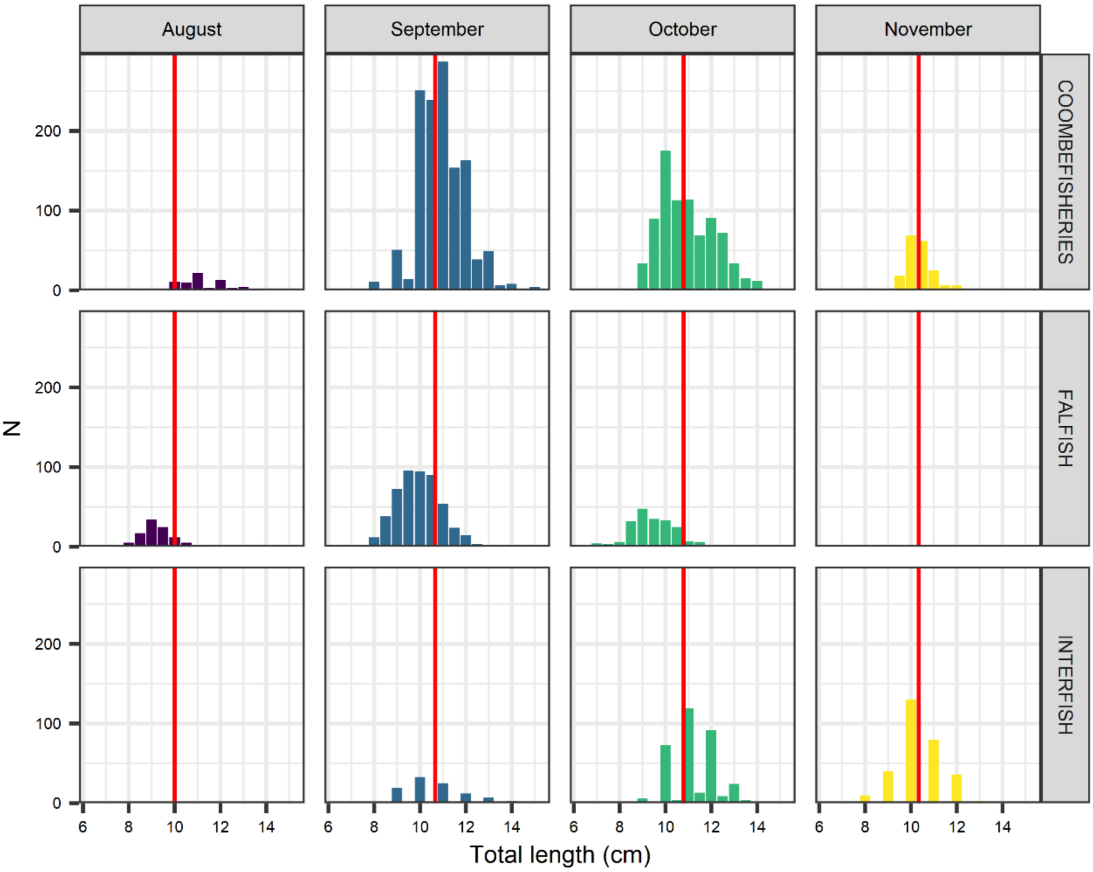

Figure 12.2.2. Monthly sprat total length distribution collected by the three processors in the 2020 season. Red line indicates weighted mean length at each month.

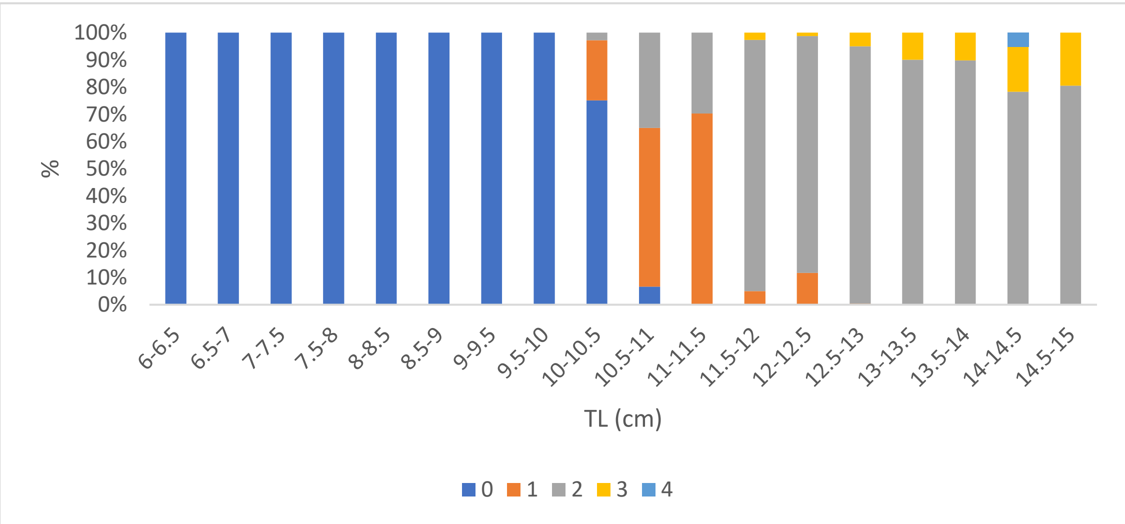

Figure 12.3.2. Sprat in 7.d-e. Proportion of numbers-at-age in the biological sample collected during the 2021 PELTIC acoustic survey.

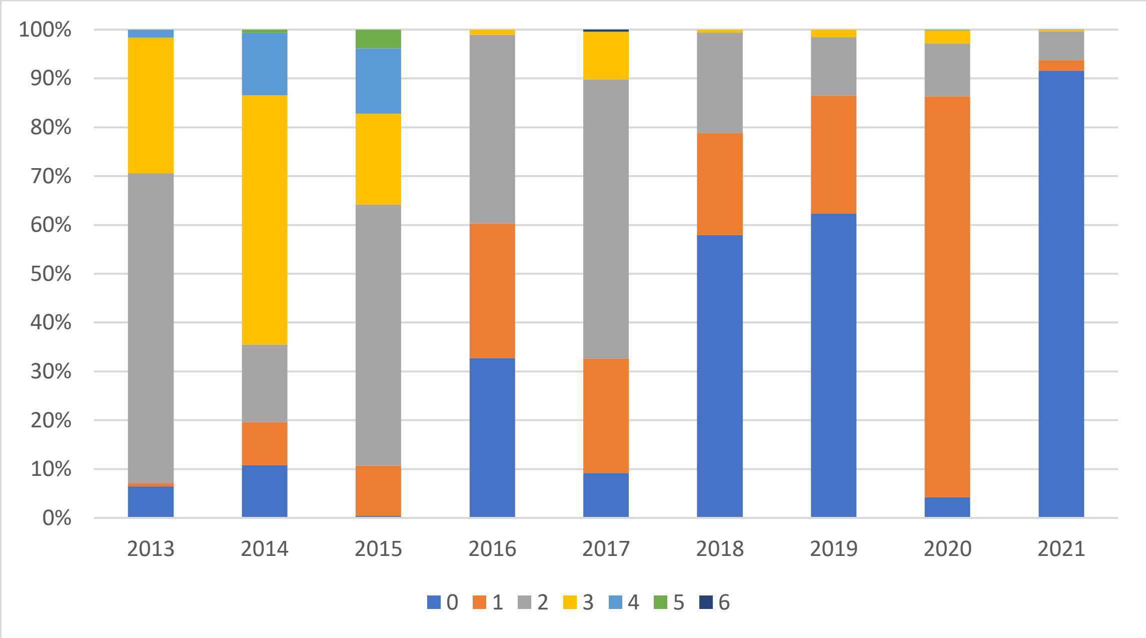

Figure 12.3.3. Sprat in 7.d-e. Proportion of numbers-at-age in the biological samples collected during the 2013–2021 PELTIC acoustic surveys.

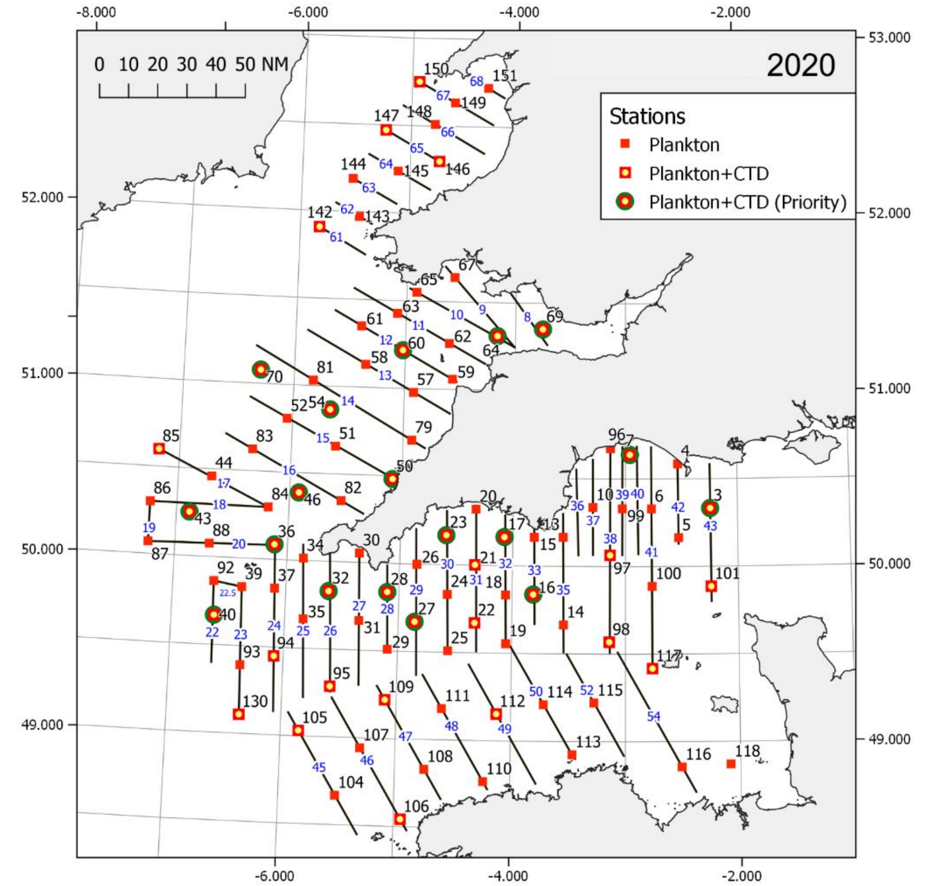

Figure 12.3.1. Sprat in 7.d–e. Survey design (2021) with acoustic transects (blue lines), zooplankton stations (red squares) and oceanographic stations (yellow circles).

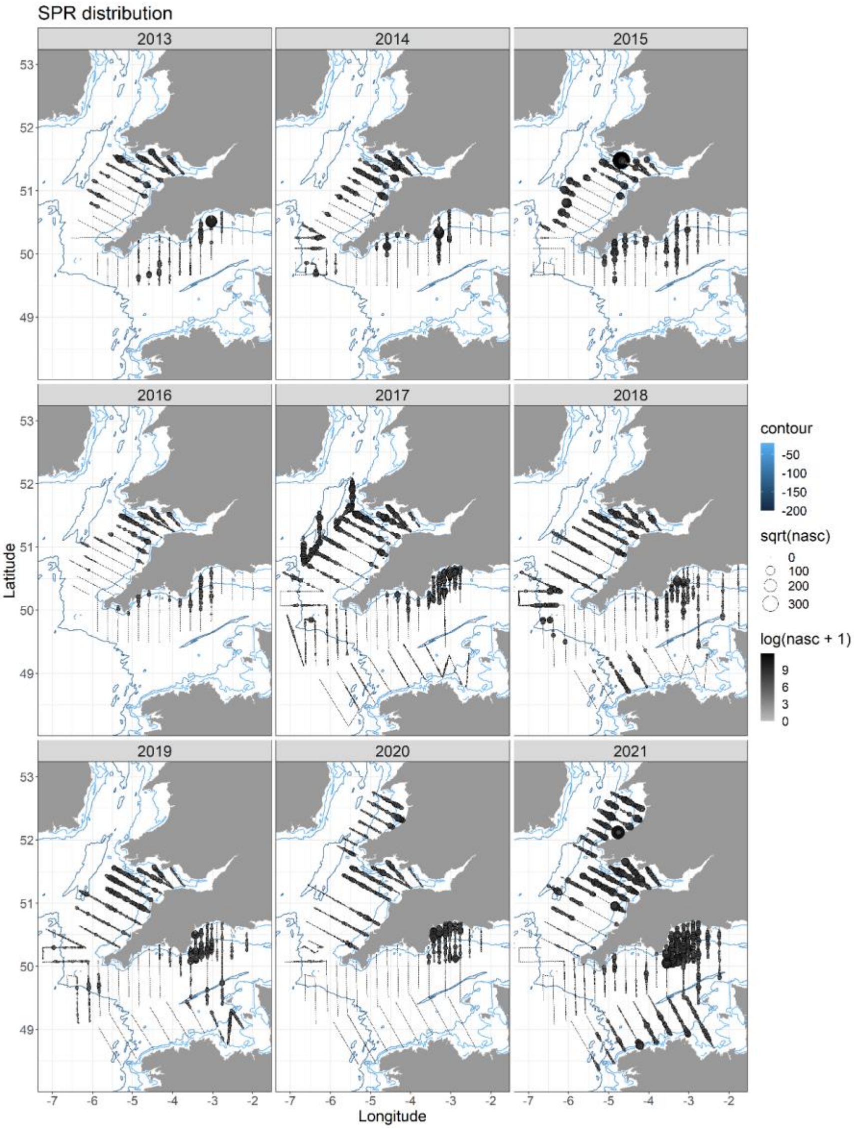

Figure 12.6.1. Sprat in 7.d–e. Acoustic backscatter attributed to sprat per 1 nmi equidistant sampling unit (EDSU) during October from the 2013–2021 PELTIC surveys.

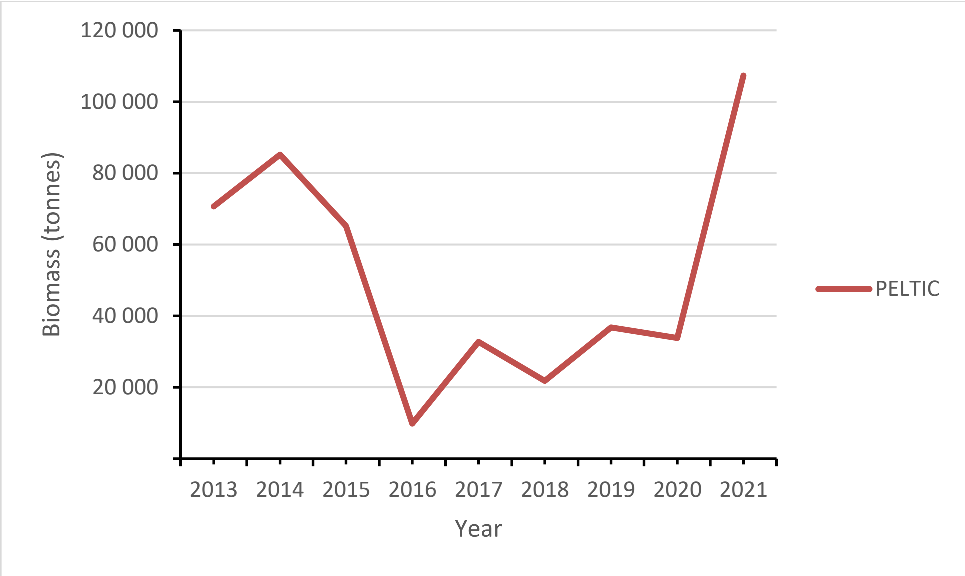

Figure 12.6.2. Sprat in 7.d-e. Biomass of sprat estimated from the PELTIC acoustic survey from 2013 to 2021 for Division 7.e (red line) and the Lyme Bay area (blue line). The Partial survey has not been run since 2019.

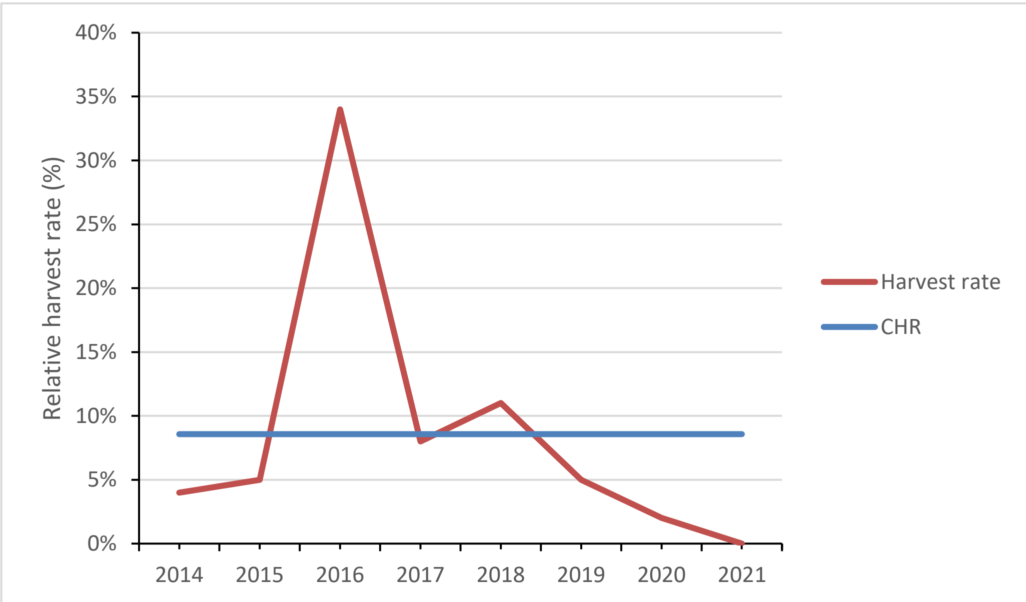

Figure 12.7.1. Sprat in 7.d-e. Constant Harvest rate index (ratio between landings and PELTIC acoustic survey biomass estimate).

12.14 References

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Please note: This report will be published in parts. Estimated publication dates for the various sections and the full report are outlined below.

31 May 2022

- Section 3 Herring in Division 3a and subdivisions 22–24

25 February 2022

- Section 9 Sandeel in Division 3.a and Subarea 4 and Division 6.a

9 May 2022

- Section 10 Sprat in the North Sea and 3
- Section 12 Sprat in the English Channel (division 7.de)

30 June 2022

- Full report

Annex 1: List of participants

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25–27 January 2022 - online meeting

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HAWG Sprat

March – May 2022 – by correspondence

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Annex 2: Resolutions

HAWG – Herring Assessment Working Group for the Area South of 62ºN

2021/2/FRSG03 The **Herring Assessment Working Group for the Area South of 62ºN** (HAWG), chaired by Afra Egan, Ireland, and Cecilie Kvamme, Norway will meet:

Online/hybrid meeting 25–27 January 2022 to:

a) Compile the catch data of sandeel in assessment areas 1r, 2r, 3r, 4, 5r, 6, and 7r and address generic ToRs for Regional and Species Working Groups that are specific to sandeel stocks in the North Sea ecoregion;

and in Copenhagen, Denmark 15–23 March 2022 to:

b) compile the catch data of North Sea and Western Baltic herring on 15–16 March;

c) address generic ToRs for Regional and Species Working Groups 17–23 March for all other stocks assessed by HAWG.

The assessments will be carried out based on the Stock Annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group on the dates specified in the 2022 ICES data call.

HAWG will report by 11 February (sandeel), 28 March (sprat) and 6 April (herring) 2022 for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group