17 North Sea sole

An error was found in the forecast calculation used to provide advice in June 2024. This was corrected in November 2024. Please see Annex 8.

sol.27.4 – *Solea solea* in Subarea 27.4

17.1 General

The assessment of sole in Subarea 27.4 is performed using the Stock Synthesis 3 platform (Methot and Weltzel, 2013), as agreed at the recent benchmark in February 2024 (WKBFLATFISH; ICES 2024). Catch data, indices of abundance (using three surveys: BTS Q3, SNS and DYFS), stock weights and natural mortality estimates were also updated or revised during the benchmark. Finally, age 0 is now included and age reading error adjustments are applied to all ages.

17.1.1 Stock structure and definition

North Sea sole is assumed to consist of a single stock unit. Stock identity of sole stocks was investigated in the second quarter of 2022 using genetic markers (SNPs) (Maes *et al*., in prep). Sole was collected onboard commercial fishing vessels from 3 different rectangles in Division 27.4.c (31F1 close to the Thames estuary; 31F2 and 31F3 close to the Belgian coast). Results showed significant genetic differentiation with samples collected in neighbouring areas (7.d, 7.e). Within the southern North Sea (4.c), subtle significant population sub-structuring was detected between sole collected near the Thames estuary (31F1) and Belgian coast (31F2). No genetic differentiation was detected for sole from 4.c and statistical rectangle 29F0 (7.d), samples from 31F1 and 30E9 (7.d), and 31F3 and 28E9 (7.d). The combined result of limited larval connectivity and restricted adult dispersal, particularly during late spring/early summer (i.e., collection time of sole in this study), might explain some of the sub-structuring detected in the southern North Sea and English Channel.

17.1.2 Ecosystem aspects

North Sea sole is commonly distributed in the southern North Sea. Spawning takes place in spring in shallow waters along the coasts (Van der Land, 1991) following a latitudinal gradient (Rijnsdorp and Vingerhoed, 1994). Episodic large recruitment events take place at irregular intervals.

17.1.3 Fisheries

The Dutch fleet catches most of North Sea sole landings, mainly using beam trawls with mesh sizes between 70 and 99 mm. From 2011 onwards, many vessels in the beam trawl fleet, targeting sole in the North Sea, transitioned to using electrical pulse gears. In 2011, 42 licenses for pulse trawls were taken into operation, under 2 separate EU derogations. In 2014, another 42 licenses were added, resulting in a total of 84 vessels with licenses for pulse trawling.

The catch composition of pulse trawls was found to be different from the traditional beam trawls (ICES, 2018). The use of pulse trawls in the main fishery operating in the North Sea increased from 2011 and from 2014 and less vessels were operating with traditional beam trawls. The pulse gear allows fishing at softer grounds and as a result the spatial distribution of the main fisheries changed to the southern part of Division 4.c (ICES, 2018).

In 2019, the European Parliament decided to ban pulse fisheries in European waters. This ban on pulse fishing implied that ultimately only 5% of the fleet of each member state could continue its fishing activities with the pulse trawl until 1 July 2021, after which a total ban has been applied. The precise response of the fleet to the ban appears to be more varied than simply a return to gear configurations in use before the advent of pulse. The choice of gear has also been affected by the increase in fuel prices. The number of vessels with sole catches has been reduced from more than 200 vessels in 2002 to approximately 90 in 2022. A large number of beam trawl/pulse vessels are decommissioned since 2021 and this trend still continues in 2023.

BMS landings of sole reported to ICES are currently much lower than the estimates of catch below the minimum conservation reference size (MCRS): 394 kg BMS reported and 360 000 kg discards estimated from observer programmes (8.2% of catches).

17.1.4 Management regulations

Management of sole in Subarea 4 is implemented by a TAC and technical measures.

The minimum landing size for sole is 24 cm. Sole in the North Sea has been under the landing obligation since 2016 (EU, 2013/1380). Survivability and *de minimis* exemptions apply to this stock (EU, 2023/2459). The survivability exemption applies to common sole below MCRS caught with otter trawls (OTB) with a cod-end mesh size of 80–99 mm in ICES Division 4.c, within 6 nautical miles of the coast but outside identified nursery areas, by vessels with a maximum length of 10 metres and a maximum engine power of 221 kW, fishing in waters with a depth of 30 metres or less and with tow durations of no more than 90 minutes. The *de minimis* exemption is of use to common sole caught with 1) gillnets and trammel nets in Union waters of ICES Division 3.a, and ICES Subarea 4 and should not exceed 3% of total annual catches of that species and 2) beam trawls of mesh size 80–119 mm equipped with a Flemish panel in Subarea 4.

The EU has progressively banned the use of electric pulse fisheries in European waters (EU, 2019/1241). The total ban took effect in July 2021. Pulse fishing had been adopted by a total of 84 Dutch vessels, which have since returned to beam trawling, switched to other gears or have been decommissioned.

ICES is aware of the multiannual management plan (MAP) which has been adopted by the EU for this stock (EU, 2018) and which ICES considers to be precautionary. There is no agreed shared management plan with UK for this stock, and ICES provides advice according to ICES MSY approach. Catch scenarios consistent with the MAP F_{MSY} ranges are provided. Since 2021, advice is no longer provided using the MAP, but is provided according to the ICES MSY approach.

17.2 Fisheries data

17.2.1 Official landings

The official landings by country are presented in Figure 17.1. The landings have been fluctuating around 10 000 tonnes from 2006–2018, but decreased rapidly since 2019. In 2023, landings are the lowest of the time series. A time-series of the official landings by country and overall total, the officially reported BMS landings and the agreed TAC are presented in Table 17.1. Official BMS landings were 21 tonnes in 2023. The TAC has not been overshot since 2016 and is largely undershot in most recent years. In 2023, official landings amounted to 41.9% of the TAC. When comparing ICES catch estimates to the catch TAC, there is a 84% uptake in 2019, 60% in 2020, 42% in 2021, 38% in 2022 and 48% in 2023. This is atypical for a target species such as sole.

17.2.2 ICES catch estimates

The entire catch time series 2002–2022 was re-estimated during the WKBFLATFISH benchmark to avoid potential inconsistencies in the substitution and raising of samples over the years (ICES 2024). Raising and age allocation procedures were developed in R scripts instead of the usual InterCatch interface. The same procedures were applied to the 2023 data.

Discard raising was performed on a gear level regardless of season or country. Raising within a gear group was performed when the proportion of landings for which discard weights are available was equal or larger than 50% compared to the total landings of that group. For landings and discards (including BMS landings) age allocations, a similar method was used. When the threshold of 50% was reached for the proportion of landings or discards covered by age and >= 100 length measurements were registered, allocation of age occurred with all available information within that gear group. When the threshold was not reached, unsampled strata were pooled in the REST group and ages were allocated using all sampled data.

The Dutch fleet plays an important role for this stock, both in terms of landings and sampled strata. Considering the large impact of Dutch sampling, the Dutch discards self-sampling programme was evaluated (ICES 2024). Every year, observer trips are carried out on boats taking part on the discards self-sampling program, and their results then compared. For sole, the results indicate that self-sampling might be leading to underestimated amount of discards. A majority of the compared hauls showed larger discard estimates from observer data than from self-sampling, but haul and yearly averages showed a wide range, indicating the existence of error in the estimates rather than a constant bias. It was pointed out that the current self-sampling protocol is better tailored to other stocks, such as plaice, and could be improved for sole and other less common species.

Information on potential unreported catches and discard survival are currently not used.

For 2023, 87% of the landings had associated discard information (similar to 2022: 88%) and respectively 98% and 89% of the discards and landings were sampled for age.

Figure 17.2 presents the time series of total ICES catches, landings and discards over the 1957–2023 period. Discards were included in the SS3 assessment model as a bycatch fleet and were not reconstructed prior to 2002. This should be explored in the future. Total catches reported to ICES in 2023 were 4376 tonnes, which is 25% lower than catches in 2022.

Landings, in numbers-at-age (1–10+), as used as input for the assessment, are presented in Table 17.2 and Figure 17.3. Discards, in numbers-at-age (1–10+), as used as input for the assessment, are presented in Table 17.3 and Figure 17.4. The proportions of discarded sole by age over the 2002–2023 period, over which data on discards is available, is presented in Figure 17.5.

17.3 Weights-at-age

Weights-at-age in the landings of sole in Subarea 27.4 can be found in Table 17.4 and Figure 17.6. These are measured weights from the various national catch and market sampling programs. Discard weights-at-age (Table 17.5 and Figure 17.7) are derived from the various national catch and discard programs (both observer and self-sampling).

Stock weights-at-age have been extracted for both quarter 1 and quarter 2, as the Stock Synthesis model uses weights at age at the start and middle of the year (Table 17.6). The mean stock weights-at-age have shown a continuous downward trend, returning to and lower than values similar to those observed at the start of the time series (Figure 17.8). Mean weights-at-age for younger ages have also shown a decrease, but appear to be increasing in the most recent years (Figure 17.9).

17.4 Maturity and natural mortality

A knife-edged maturity-ogive with full maturation at age 3 is assumed for sole in Subarea 27.4 (Table 17.7). The recent benchmark explored different data sources to update this ogive (ICES, 2024). Van Keeken *et al.* (2004) investigated maturity over the period 1965–2005 and showed that the proportion of mature females in quarter 1 at age 2 and 3 increased from 1995 onwards: for age 2 from 0% to 25–50% mature and for age 3 from 50% to almost 100% mature. However, more recent Belgian and Dutch maturity data from commercial catches could not provide updated estimates due to the low proportion of immature individuals in the catches. Additionally, assuming that age 2 fish are still immature which could result in a potential underestimation of the SSB, is considered more precautionary in light of the absence of better data. The benchmark recommended to collect more maturity data at age in the first quarter from a broad length range, for example from discards or surveys (with smaller mesh sizes) to modify the currently used ogive in the future. This maturity assumption results in large year-classes causing large jumps in SSB as they reach age 3.

Natural mortality estimates were changed during the most recent benchmark (ICES, 2024) to follow a pattern at age related to body size. The empirical relationship proposed by Lorenzen (2022) takes the form $M_a = W_a^{-0.288} \cdot 3$ with W_a being the mean weight-at-age in the stock for age a. These were obtained from a von Bertalanffy growth model and a length-weight relationship, with parameters taken from a mean of multiple North sea studies (Linf=40.4, K=0.33 t0=0 and a=0.0068, b=3.09).

The relative pattern thus constructed is scaled by an average over the whole age range based on the maximum age in the stock (T_{max}), as presented by Then *et al.* (2014): $M = 4.899 \cdot T_{max}^{-0.916}$. A value of 26 years, reported in various databases, was used for the parameter, although a single fish in the BTS samples in 1996 has been determined as being 28 years old. No time-varying pattern in natural mortality was considered.

17.5 Survey data

Three survey series are used in the assessment of North Sea sole:

- Quarter 3 Beam Trawl Survey (BTS), covering the 1990–2023 period and containing samples for ages 0 to 10+.
- Quarter 3 Sole Net Survey (SNS), extending from 1990 to 2023, with the exception of 2003, and with samples including ages 0 to 6.
- Demersal Young Fish Survey (DYFS), extending from 1990 to 2023 and with samples including ages 0 and 1.

Data for all three has been extracted from the ICES DATRAS database.

Two indices of abundance are constructed from those surveys. The first one (BTS) uses the BTS Q3 samples collected by The Netherlands, Belgium, the United Kingdom and Germany (Figure 17.10). A standardized age-based index is calculated using a delta-lognormal GAM model, using the methodology presented in Berg *et al.* (2014). The second index (COAST) uses SNS (sampled by The Netherlands) and DYFS (sampled by The Netherlands, Belgium and Germany), and is calculated using a delta-lognormal GAM model, standardized for ages 0–5. Please refer to the WKBFLATFISH report (ICES, 2024) for further details on the analysis[1].

A standardized comparison of the two indices over the available time-series is presented on Figure 17.11, while Figures 17.12 and 17.14 present each individual index in their actual scales at age. The internal consistency plots of the cohorts of the two indices are presented in Figures 17.13 and 17.15. Changes over the last three decades on the internal consistency of the coastal survey index are shown in Figure 17.16. The actual values of the two survey indices used in the assessment are presented in Tables 17.8 and 17.9.

In addition to the age based abundance, the estimated total biomass of the two delta-lognormal GAM indices are also used in the assessment, functioning as a scaling parameters over the total magnitude. Estimated and retrospective analysis of biomass indices for BTS and COAST are illustrated in Figure 17.17 and 17.18 respectively.

17.6 Age reading error

Since the most recent benchmark, bias in age reading was incorporated in the assessment model. A time-invariant age reading error matrix, obtained from the exchange exercise in 2016 (ICES, 2016), was applied to age data for the entire time series. The age reading error matrix is presented below.

Modal age	0	1	2	3	4	5	6	7	8	9	10
0	0.972	0.028	0	0	0	0	0	0	0	0	0
1	0.006	0.988	0.006	0	0	0	0	0	0	0	0
2	0	0.007	0.986	0.007	0	0	0	0	0	0	0
3	0	0	0.021	0.941	0.038	0	0	0	0	0	0
4	0	0	0	0.201	0.774	0.025	0	0	0	0	0
5	0	0	0	0.011	0.137	0.784	0.063	0.005	0	0	0
6	0	0	0	0	0.011	0.114	0.795	0.080	0	0	0
7	0	0	0	0	0	0.003	0.188	0.760	0.035	0.014	0
8	0	0	0	0	0	0	0.020	0.149	0.741	0.090	0
9	0	0	0	0	0	0	0	0.013	0.161	0.719	0.098
10	0	0	0	0	0	0.007	0.010	0.013	0.066	0.185	0.629

17.7 Assessment

During the recent benchmark, the assessment model was changed from the Aarts and Poos statistical catch-at-age model (AAP; Aarts and Poos, 2009) to Stock Synthesis (SS3, Methot and Wetzel, 2013). The SS3 reference model is age-based, with combined sex, a single area, two fleets to model separately landings and discards, and two indices of abundance. Selectivity is modelled via a random walk, time-varying for the landings fleet, while time-invariant for the discards fleet and both surveys. They are in all cases assumed to be constant from age 5. Spawning stock biomass is computed at the beginning of the year and fecundity is assumed proportional to individual weight. Recruitment is assumed to take place at the beginning of the year, with 0 as recruitment age, and following a Beverton-Holt stock recruitment relationship. The steepness of the relationship has been fixed at a value of h = 0.6646, obtained from the correlations from stocks of *S. Solea* in the FishLife dataset (Thorson, 2019). Ages 2 to 6 are considered fully selected and used in the computation of the mean fishing mortality metric $\acute{F}$.

[1] Input data, source code and output of the index standardization is available at the https://github.com/ices-taf/2024_sol.27.4_survey/TAF repository.

Sole in Subarea 4. Settings of the SS3 stock assessment model.

Setting	Description
Plus group	Age 10
First tuning year	1990
Selectivity for landings and discards constant for age >=	5
Selectivity for landings	Time-varying random walk
Selectivity for discards and survey	Time-invariant
Catchability surveys constant for ages >=	5

A summary of the assessment results (recruitment, F and SSB, including confidence bounds) is presented in Figure 17.19. Fishing pressure in 2023 is estimated as the lowest value of the time series, similar to the catches, while SSB is estimated at similar levels as in 1999. Recruitment fluctuated around a long term mean, but is estimated lower than before 2019. The estimates of spawning stock biomass and corresponding recruitment at age 0 are shown in Figure 17.20. The proportion of spawning stock biomass estimated by age and year is presented in Figure 17.21. The strong 2018 year class is estimated to represent 50% of the SSB over the last 3 years and does not seem to have decreased. Log-standardized residuals of the model fit to the four data sources employed (landings and discards numbers-at-age and the two indices of abundance) are presented in Figure 17.22. Some residual patterns are present in the model output, especially for the recent years in the BTS fleet, which could be linked to the estimates of fleet selectivity. Moreover, there is a cohort pattern in the residuals of the landings (Fleet) and age 4 is always overestimated, which has a significant contribution to the catches (Table 17.2). One step ahead (OSA) residuals of the model fit to the four data sources employed (landings and discards numbers-at-age and the two indices of abundance) are presented in Figure 17.23. The one-step ahead residuals also show residual patterns for the BTS fleet, in most recent years and for ages 0–5. Additionally, the landings (Fleet) shows patterns for a number of ages and over several periods of time, similar to in Figure 17.22. The runs test for the mean age in landings, discards and both indices (Carvalho *et al*., 2021) are presented in Figure 17.24. For both the BTS index and the fleet (landings), there is evidence that the hypothesis of randomly distributed time series of residuals should be rejected, confirming the patterns that were identified in Figures 17.22 and 17.23. Fits to the BTS and COAST index are presented in Figures 17.25 and 17.26. The fit to the biomass trends in both indices of abundance is reasonable for the BTS index with the exception of the last three years, where the model does not fit the data points. For the COAST index, the fit is reasonable with the exception of years where large recruitments appear in the beginning of the time series (around 2000) and in 2018–2020. The deviation in 2018–2020 represents the stronger 2018 year class being picked up by the COAST index (ages 0–2), but not followed by the model. From age 3 onwards, sole resides more offshore, and thus the index no longer picks up on the stronger year class. That's when this year class should be picked up by the BTS index (ages 3–5 in 2021–2023). However, these fish are not caught by the BTS survey and estimates are low. Nevertheless, the model is unable to correct for the absence of this stronger year class and therefore deviates from the BTS index in 2021–2023, resulting in a larger SSB estimate. In conclusion, the assessment model is unable to fully follow the trends in the biomass survey indices in the most recent years, which could lead to the overestimation of current stock status.

The selectivity of the fleet as estimated by the SS3 model is presented in Figure 17.27. It shows that the model struggles to fit the strong 2018 year class, especially from 2022 onwards. Stock numbers at age 4 are high in 2022 (Table 17.10) and have only been estimated as high 4 times over the entire time series. If a similar selectivity pattern (without drop at age 4) as estimated in the previous years would be applied, this would result in a much too high prediction of the numbers at age 4. Therefore, the model reduced the selectivity at age 4 (unexpected drop; ~40% reduction) to obtain a better fit. Despite this reduction, a high positive residual can still be observed for age 4 (Figure 17.22). Similarly, selectivity is estimated lower for age 5 (and older ages, as it is set constant; drop of ~35%) in 2023 compared to the previous years, where selectivity was always highest for these older ages.

The retrospective patterns for recruitment, spawning biomass and fishing mortality are summarized in Figure 17.28. The retrospective analysis for the model shows a robust configuration that does not suffer from a problematic Mohn's rho value, being between 0.20 and −0.15 for both SSB and F. The Mohn's rho on recruitment is however outside the defined limits (0.53). Figures 17.29 and 17.30 present the results of an analysis of prediction skills by means of hindcasting cross-validation (carried out following Carvalho *et al*., 2021). The evaluation of the prediction skill of the reference assessment model for both indices of abundance (Figures 17.29 and 17.30) show the effect of the lack of fit to biomass trends in the last three years of the series, as mentioned above. This diagnostic uses a retrospective forecast and allows comparison of forecasted values, based on a known quantity (catch) with actual observations that were not included in the model run. A MASE value of less than 1 indicates that the model is able to predict subsequent indices of abundance with sufficient skill, given the observed catches. The results (MASE > 1 for both indices) bring into view the discrepancies in the evolution of stock abundance that the population model contains: the drop in biomass evidenced by the 2021 values from both indices and the catch and age composition. The question remains on whether these values reflect an unexplained drop in biomass linked to biological or environmental factors not included in the model, issues in the ability of the survey to provide robust information on abundance for the stock in that particular period, or issues with the assessment model. Further investigation will be required to resolve this issue.

Yearly estimates of abundances and fishing mortality-at-age obtained by the model run are presented in Tables 17.10 and 17.11, respectively.

17.8 Recruitment assumption

The short term forecast for the stock requires an assumption about recruitment in the intermediate year, 2024. This has been set to the geometric mean of the 1957–2020 time series of recruitment estimates, 1477423 thousands individuals. The decision to exclude the most recent years is due both to the lack of fit to the last three years of the survey indices, as well as a high Mohn's rho on the recruitment (0.53). The inclusion of the most recent recruitment estimates would change the recruitment assumption estimate by less than 2% and only impacts the catches at age 1 in the advice year which are considered very small.

17.9 Short-term forecast and advice for 2025

Short-term forecasts were carried out with the following settings:

- Natural mortality, maturity and weights-at-age in landings, discards and stock for 2024–2025 set as the average of the last three years (2021–2023).
- Selectivity-at-age for 2024–2025 set as the average of the last five years (2019–2023).
- Ratio of discards to landings-at-age as the average over the last three years (2021–2023).

Population numbers in the intermediate year for ages 1 and older are taken from the SS3 survivors estimates.

An overview of the interim year assumptions are given in the table below.

Sole in Subarea 4. Values in the forecast and for the interim year.

Variable	Value	Notes
$F_{ages\ 2–6}$ (2024)	0.053	Based on catch constraint for 2024. Average exploitation pattern (2019–2023).
SSB (2024)	55 955	Short-term forecast (STF); tonnes
SSB (2025)	61 320	STF; tonnes
$R_{age\ 0}$ (2024, 2025)	1 477 423	Geometric mean of recruitment (GM; 1957–2020); thousands
Total catch (2024)	3675	TAC for 2024; tonnes
Projected landings (2024)	3410	STF, assuming average estimated landing ratio by age, 2021–2023; tonnes
Projected discards (2024)	265	STF, assuming average estimated discard ratio by age, 2021–2023; tonnes

Forecasts were carried out using the FLR toolset[2] (Kell *et al.*, 2007), and in particular the FLasher package[3] (Scott and Mosqueira, 2016). Source code for this analysis is available at the corresponding TAF repository[4].

The catch advice for 2025 is presented in Table 17.12 and amounts to 10196 tonnes. The change in advice (+177%) is mainly due the upward revision of stock status after the recent benchmark (ICES, 2024). Because of an improvement in the quality of the assessment, the basis for advice has changed and no longer corrects the numbers-at-age for the bias in SSB (ICES, 2023).

17.10 Reference points

The reference points for sole in Subarea 4 have been updated at the last benchmark (ICES, 2024), following the procedures of ICES WKMSYREF3 (2014). All values are derived from the reference run of the SS3 model. The reference points in use for the stock are as follows:

[2] https://flr-project.org

[3] https://flr-project.org/FLasher

[4] https://github.com/ices-taf/2023_sol.27.4_forecast/

Sole in Subarea 4. Proposed set of reference points computed during the 2024 benchmark based on a segmented regression stock-recruitment relationship.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	52 532	B_{pa}; in tonnes.	ICES (2024)
	F_{MSY}	0.157	EqSim analysis, assuming a hockey stick stock–recruit relationship, based on the recruitment period 1958–2021. Capped at F_{pa}.	ICES (2024)
Precautionary approach	B_{lim}	37 804	Lowest SSB level that in the past has resulted in good recruitment; in tonnes.	ICES (2024)
	B_{pa}	52 532	$B_{lim} \times \exp(1.645 \times \sigma)$, σ = 0.20; in tonnes.	ICES (2024)
	F_{lim}	0.265	The F that on average leads to B_{lim}.	ICES (2024)
	F_{pa}	0.157	The F that provides a 95% probability for SSB to be above B_{lim} ($F_{P.05}$ with advice rule).	ICES (2024)
EU management plan (MAP)*	MAP MSY $B_{trigger}$	52 532	MSY $B_{trigger}$; in tonnes.	ICES (2024)
	MAP B_{lim}	37 804	B_{lim}; in tonnes.	ICES (2024)
	MAP F_{MSY}	0.157	F_{MSY}	ICES (2024)
	MAP range F_{lower}	0.144–0.157	Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2024)
	MAP range F_{upper}	0.157–0.157	Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2024)

***EU multiannual plan (MAP) for the North Sea (EU, 2018).**

17.11 Quality of the assessment

The stock was benchmarked in 2024, which resulted in a new assessment model, as well as updated indices of abundance, catch statistics, and natural mortality assumption (ICES, 2024). Both the estimated stock development over time and current status have changed from those provided by the previous assessment.

The assessment model is unable to fully follow the trends in the biomass survey indices in the most recent years, which could lead to the overestimation of current stock status. The reason for this pattern is currently unknown and will require further investigation.

17.12 Status of the stock

The new model estimates stock size to have declined in 2023, despite the substantial reduction in catches. With the exception of 2022, recruitment (age 0) since 2019 has been estimated to be notably lower than the geometric mean (1957–2020) used in the short-term forecast (1 477 423), on average 47% lower than this value (Table 17.13). The current assessment estimates spawning stock biomass to be above the B_{lim} and $MSY B_{trigger}$ values, and fishing pressure is below F_{MSY}.

17.13 Management considerations

Sole is mostly taken by beam trawlers in a mixed fishery with plaice in the southern and part of the North Sea. The fishery has changed notably over the last decade with the adoption and subsequent ban of pulse fishing, which was especially successful catching sole.

Discards of sole are allowed for multiple gears under the survivability and *de minimis* exemptions. These include the beam trawlers (TBB-DEF-70-99) targeting the stock, and responsible for most of the catch.

17.14 Issues for future benchmark

- Investigate the combination of both survey indices (BTS and COAST) to account for migration of sole from the coastal areas to more offshore areas related to their life cycle, or explore an area-based assessment to handle patterns in the surveys.
- Assess the suitability of the COAST index, including SNS and DYFS surveys, considering that these surveys only cover the continental coast of the North Sea, whereas important spawning grounds along the UK coasts are not covered in this index.
- Reconstruct discards back in time for the period prior to 2002, where estimates are lacking.
- The benchmark recommended to collect more maturity data at age in the first quarter from a broad length range, for example from discards or surveys (with smaller mesh sizes) to modify the currently used ogive in the future, which could avoid large jumps in SSB when a year class becomes mature.
- Prior to the benchmark, the natural mortality in 1963 was set to 0.9 as a result of a very harsh winter. New natural mortality estimates as a result of the benchmark do not consider the effects of this harsh winter. This should be investigated and the possibility and effect on adding time varying M should be considered.
- Fine-tune configuration of the assessment model linked to the mismatch between model estimates and survey estimates.
- Update the age error matrix after the publication of the report of the 2024 exchange workshop.

17.15 References

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17.16 Figures and tables

Table 17.1. Sole in Subarea 4. Time-series of the official landings by country and overall total, the official BMS landings, the landings and discards reported to ICES and the total TAC (figures rounded to the nearest tonne).

Year	Belgium	Denmark	France	Germany	Netherlands	UK	Other	Official landings	Official BMS landings	ICES landings	ICES discards	TAC
1982	1900	524	686	266	17686	403	2	21467		21578		21000
1983	1740	730	332	619	16101	435	0	19957		24927		20000
1984	1771	818	400	1034	14330	586	1	18940		26839		20000
1985	2390	692	875	303	14897	774	3	19934		24248		22000
1986	1833	443	296	155	9558	647	2	12934		18201		20000
1987	1644	342	318	210	10635	676	4	13829		17368		14000
1988	1199	616	487	452	9841	740	28	13363		21590		14000
1989	1596	1020	312	864	9620	1033	50	14495		21804		14000
1990	2389	1427	352	2296	18202	1614	263	26543		35121		25000
1991	2977	1307	465	2107	18758	1723	271	27608		33514		27000
1992	2058	1359	548	1880	18601	1281	277	26004		29341		25000
1993	2783	1661	490	1379	22015	1149	298	29775		31491		32000
1994	2935	1804	499	1744	22874	1137	298	31291		33002		32000
1995	2624	1673	640	1564	20927	1040	312	28780		30468		28000
1996	2555	1018	535	670	15344	848	229	21199		22650		23000
1997	1519	689	99	510	10241	479	204	13741		14902		18000
1998	1844	520	510	782	15198	549	339	19742		20867		19100
1999	1919	828	n/a	1458	16283	645	501	21634*		23475		22000
2000	1806	1069	362	1280	15273	600	539	20929		22641		22000
2001	1874	772	411	958	13345	597	394	18351		19944		19000
2002	1437	644	266	759	12120	451	292	15969		15944	3457	16000
2003	1605	703	728	749	12469	521	363	17138		15654	1902	15900
2004	1477	808	655	949	12860	535	544	17828		17932	3281	17000
2005	1374	831	676	756	10917	667	357	15579		15777	1885	18600
2006	987	582	714	475	8299	912	36	12005		12216	1986	17700

Year	Belgium	Denmark	France	Germany	Netherlands	UK	Other	Official landings	Official BMS landings	ICES landings	ICES discards	TAC
2007	973	413	591	458	10364	1208	5	14012		14439	1406	15000
2008	1379	501	574	514	9456	851	16	13291		14206	897	12800
2009	1368	476	910	555	9606	952	1	13868		14282	1210	14000
2010	1268	406	630	537	8770	943	2	12556		12794	2896	14100
2011	864	347	566	327	8137	820	2	11063		11497	1863	14100
2012	607	418	634	440	9085	610	3	11797		12210	2854	16200
2013	706	497	687	561	9967	870	1	13289		13145	2336	14000
2014	966	314	675	642	9018	843	<0.5	12458		13091	1949	11900
2015	935	271	542	765	9273	813	<0.5	12599		12920	1755	11900
2016	768	355	362	861	9600	706	<0.5	12652		14133	1237	13262
2017	557	433	393	761	9482	514	<0.5	12140	30	12373	1325	16123
2018	404	368	432	721	8581	432	3	10941	57	11193	1184	15694
2019	254	109	109	620	6997	334	1	8424	47	8647	1963	12555
2020	240	123	37	919	6760	547	<0.5	8626	43	8864	1472	17545
2021	271	172	167	648	6231	476	<0.5	7965	36	8242	950	21361
2022 **	160	78	26	144	4302	348	<0.5	5058	22	5277	541	15330
2023 **	157	43	4	182	3180	267	<0.5	3833	21	4015	361	9152

*** Total does not include official landings of all countries.**

**** Preliminary.**

n/a = not available.

Table 17.2. Sole in Subarea 4. Time-series of landings at age (in thousands) which serves as input to SS3.

Year	1	2	3	4	5	6	7	8	9	10+
1957	0	1472	10556	13150	3913	3041	6780	1803	529	6541
1958	0	1863	8482	14240	9547	3501	3023	4461	2264	6590
1959	0	3694	12139	10499	9060	5823	1217	2044	2598	5668
1960	0	11965	14043	16691	9248	8313	4815	1583	1049	7851
1961	0	972	50470	19403	12574	4760	3998	4338	847	7355

Year	1	2	3	4	5	6	7	8	9	10+
1962	0	1584	6173	58836	15254	10478	4797	4087	2074	7450
1963	0	670	8271	8485	45823	8420	6603	2403	3365	8316
1964	53	150	2041	5518	3680	16749	3020	1749	790	2913
1965	0	45180	1045	1534	4798	2381	11990	1494	1463	3077
1966	0	12145	132170	979	1168	3649	736	6255	694	2424
1967	0	3769	26260	87039	1998	548	1962	777	5160	2978
1968	1034	17093	13852	24894	48417	461	244	1639	323	6502
1969	404	24404	21884	5433	12638	25646	338	249	1214	5379
1970	1299	6141	25996	8236	1784	3231	11961	246	140	5234
1971	425	33765	14596	12909	4538	1459	2355	7300	194	4649
1972	354	7511	36356	6997	4911	1548	517	1218	4654	2772
1973	716	12459	13025	16493	4101	2368	1013	779	1241	5899
1974	100	15171	21248	5412	6965	1896	1563	649	396	4750
1975	267	23193	28833	11839	2110	3870	798	916	513	3481
1976	1064	3619	28571	14316	4923	987	1950	562	434	2721
1977	1780	22747	12299	15593	7580	1812	325	1133	261	2155
1978	27	24921	29163	6102	6610	4231	1730	608	643	1595
1979	9	8280	41681	16259	3033	3262	1769	826	244	1546
1980	650	1233	12762	18138	7444	1479	2241	1437	374	1227
1981	434	29983	3344	7046	8439	3757	973	909	786	932
1982	2697	26799	46375	1868	3584	4855	1701	623	613	1295
1983	391	34545	41551	21273	626	1383	1958	982	388	1181
1984	192	30839	44081	22631	8821	744	857	1047	526	897
1985	163	16449	42773	20079	9307	3520	207	375	631	965
1986	372	9304	18381	17591	7698	5480	2256	109	281	1671
1987	93	28896	21927	8851	6477	3102	1559	898	81	690
1988	10	13206	47135	15217	4377	3878	1549	890	523	317
1989	115	45652	17973	22295	4551	1627	1414	637	451	459
1990	854	11816	103380	9667	9099	3315	1032	1186	548	837

Year	1	2	3	4	5	6	7	8	9	10+
1991	118	12938	24985	76580	6609	3612	1706	707	718	1072
1992	965	6730	43713	15961	37745	2440	2995	730	393	1163
1993	53	49870	16575	31047	13709	23758	1472	1170	456	833
1994	709	7710	86349	13387	18513	5642	11174	458	905	897
1995	4766	12674	16700	68073	6262	7254	1981	5971	293	665
1996	170	18609	16005	16770	26946	3814	4725	932	3267	976
1997	1574	5987	23418	7253	5058	12667	1189	2303	330	1672
1998	242	56162	15011	14806	3466	1924	4727	787	1022	838
1999	284	15601	71730	8103	6049	1200	657	1964	328	804
2000	2329	14929	32425	42394	3257	2453	796	431	922	708
2001	857	25045	20925	19260	16211	1383	808	266	163	701
2002	1098	10963	31237	10090	7017	6064	599	470	86	291
2003	849	29423	13902	13746	4654	3335	2442	322	90	450
2004	255	14911	45860	8245	7007	2100	872	860	339	538
2005	1182	7014	22271	28499	3831	3781	1325	566	683	336
2006	4675	9741	11480	10343	11944	1429	1592	773	380	496
2007	298	39680	9713	6275	5578	4819	715	645	432	446
2008	2344	6827	37763	6076	2889	2262	2328	343	363	410
2009	1655	11588	11403	25748	3249	1695	1539	1475	256	832
2010	424	11809	13979	8158	13588	1884	1092	803	1140	993
2011	6	12121	19959	8758	5028	6364	1020	459	317	893
2012	0	6665	27450	10878	4501	1930	3956	589	261	1067
2013	0	2480	25770	19556	5896	2316	1630	1748	335	1114
2014	452	8025	6713	21576	11343	3118	1830	806	880	990
2015	212	10703	15618	4789	14299	6187	1629	652	513	904
2016	120	6256	24006	11386	4704	8894	4523	904	322	1143
2017	273	4917	16263	15816	5827	2044	3812	1949	488	565
2018	375	11836	9255	11696	9935	3751	991	1835	773	386
2019	457	6366	15708	6220	5030	4659	1544	695	1630	423

Year	1	2	3	4	5	6	7	8	9	10+
2020	131	17752	9891	10600	2684	2231	1442	596	158	1301
2021	339	2334	24335	7669	4382	1166	790	717	242	150
2022	291	2931	2542	12855	2712	1766	758	350	262	101
2023	1339	3970	3486	1435	4894	1059	695	163	120	147

Table 17.3. Sole in Subarea 4. Time-series of discards at age (in thousands) which serves as input to SS3.

Year	1	2	3	4	5	6	7	8	9	10+
2002	10963	21132	8807	1750	463	0	0	0	0	0
2003	535	15951	2063	418	47	39	9	0	0	0
2004	4314	19030	11369	2522	758	17	0	0	0	0
2005	3584	8486	6950	1796	540	77	27	0	0	0
2006	5091	10907	5018	1192	362	44	30	12	0	0
2007	4774	8366	4810	998	341	80	6	1	1	0
2008	1939	4516	2703	576	170	15	10	0	0	0
2009	3238	5606	861	1499	289	48	21	0	0	0
2010	5631	11875	8945	1954	2442	111	1623	21	76	0
2011	3581	13750	3658	1550	105	96	2	0	0	0
2012	1198	22305	10458	915	239	49	15	0	8	0
2013	4587	6387	14095	3975	326	64	14	1	0	0
2014	20638	6959	2746	4023	1556	256	229	7	0	0
2015	5013	8777	3890	1976	1545	372	15	49	8	1
2016	4309	5327	5286	1466	297	567	248	3	0	0
2017	5734	4462	3968	2949	494	88	368	143	0	0
2018	2850	8791	1858	1588	1267	116	16	141	39	0
2019	12178	8530	5641	1469	819	820	249	20	84	1
2020	2531	13753	2270	1251	337	74	66	13	6	0
2021	2366	1511	5783	913	395	39	9	20	3	0
2022	871	2758	954	2091	176	94	27	28	26	0
2023	1036	1723	623	188	586	84	4	0	0	0

Table 17.4. Sole in Subarea 4. Time-series of the mean weights-at-age in the landings of sole in Subarea 27.4. Age 0 is 0.01 constant for all years. Input to SS3.

Year	1	2	3	4	5	6	7	8	9	10+
1957	0.155	0.154	0.177	0.204	0.248	0.279	0.29	0.335	0.436	0.408
1958	0.155	0.145	0.178	0.22	0.254	0.273	0.314	0.323	0.388	0.413
1959	0.155	0.162	0.188	0.228	0.261	0.301	0.328	0.321	0.373	0.426
1960	0.155	0.153	0.185	0.235	0.254	0.277	0.301	0.309	0.381	0.418
1961	0.155	0.146	0.174	0.211	0.255	0.288	0.319	0.304	0.346	0.419
1962	0.155	0.155	0.165	0.208	0.241	0.295	0.32	0.321	0.334	0.412
1963	0.155	0.163	0.171	0.219	0.258	0.309	0.323	0.387	0.376	0.485
1964	0.153	0.175	0.213	0.252	0.274	0.309	0.327	0.346	0.388	0.481
1965	0.155	0.169	0.209	0.246	0.286	0.282	0.345	0.378	0.404	0.48
1966	0.155	0.177	0.19	0.18	0.301	0.332	0.429	0.399	0.449	0.501
1967	0.155	0.192	0.201	0.252	0.277	0.389	0.419	0.339	0.424	0.491
1968	0.157	0.189	0.207	0.267	0.327	0.342	0.354	0.455	0.465	0.508
1969	0.152	0.191	0.196	0.255	0.311	0.373	0.553	0.398	0.468	0.523
1970	0.154	0.212	0.218	0.285	0.35	0.404	0.441	0.463	0.443	0.533
1971	0.145	0.193	0.237	0.322	0.358	0.425	0.42	0.49	0.534	0.547
1972	0.169	0.204	0.252	0.334	0.434	0.425	0.532	0.485	0.558	0.629
1973	0.146	0.208	0.238	0.346	0.404	0.448	0.552	0.567	0.509	0.586
1974	0.164	0.192	0.233	0.338	0.418	0.448	0.52	0.559	0.609	0.653
1975	0.129	0.182	0.225	0.32	0.406	0.456	0.529	0.595	0.629	0.669
1976	0.143	0.19	0.222	0.306	0.389	0.441	0.512	0.562	0.667	0.665
1977	0.147	0.188	0.236	0.307	0.369	0.424	0.43	0.52	0.562	0.619
1978	0.152	0.196	0.231	0.314	0.37	0.426	0.466	0.417	0.572	0.666
1979	0.137	0.208	0.246	0.323	0.391	0.448	0.534	0.544	0.609	0.763
1980	0.141	0.199	0.244	0.331	0.371	0.418	0.499	0.55	0.598	0.684
1981	0.143	0.187	0.226	0.324	0.378	0.424	0.442	0.516	0.542	0.63
1982	0.141	0.188	0.216	0.307	0.371	0.409	0.437	0.491	0.58	0.656
1983	0.134	0.182	0.217	0.301	0.389	0.416	0.467	0.489	0.505	0.642
1984	0.153	0.171	0.221	0.286	0.361	0.386	0.465	0.555	0.575	0.634

Year	1	2	3	4	5	6	7	8	9	10+
1985	0.122	0.187	0.216	0.288	0.357	0.427	0.447	0.544	0.612	0.645
1986	0.135	0.179	0.213	0.299	0.357	0.407	0.485	0.543	0.568	0.61
1987	0.139	0.185	0.205	0.277	0.356	0.378	0.428	0.481	0.393	0.657
1988	0.127	0.175	0.217	0.27	0.354	0.428	0.484	0.521	0.559	0.712
1989	0.118	0.173	0.216	0.288	0.336	0.375	0.456	0.492	0.47	0.611
1990	0.124	0.183	0.227	0.292	0.371	0.413	0.415	0.514	0.476	0.62
1991	0.127	0.186	0.21	0.263	0.315	0.436	0.443	0.467	0.507	0.558
1992	0.146	0.178	0.213	0.258	0.298	0.38	0.409	0.46	0.487	0.556
1993	0.097	0.167	0.196	0.239	0.264	0.3	0.338	0.441	0.496	0.603
1994	0.143	0.18	0.202	0.228	0.257	0.3	0.317	0.432	0.409	0.51
1995	0.151	0.186	0.196	0.247	0.265	0.319	0.344	0.356	0.444	0.592
1996	0.163	0.177	0.202	0.234	0.274	0.285	0.318	0.37	0.39	0.594
1997	0.151	0.18	0.206	0.236	0.267	0.296	0.323	0.306	0.384	0.44
1998	0.128	0.182	0.189	0.252	0.262	0.289	0.336	0.292	0.335	0.504
1999	0.163	0.179	0.212	0.229	0.287	0.324	0.354	0.372	0.372	0.453
2000	0.145	0.17	0.2	0.248	0.29	0.299	0.323	0.368	0.402	0.428
2001	0.143	0.185	0.202	0.27	0.275	0.333	0.391	0.414	0.433	0.493
2002	0.142	0.182	0.218	0.254	0.278	0.309	0.356	0.332	0.583	0.604
2003	0.14	0.188	0.22	0.258	0.258	0.305	0.346	0.33	0.555	0.398
2004	0.138	0.183	0.209	0.252	0.269	0.285	0.388	0.376	0.332	0.462
2005	0.168	0.186	0.204	0.24	0.254	0.272	0.27	0.331	0.32	0.373
2006	0.152	0.177	0.21	0.248	0.277	0.313	0.281	0.34	0.39	0.385
2007	0.152	0.184	0.21	0.241	0.26	0.287	0.321	0.304	0.299	0.343
2008	0.151	0.181	0.223	0.243	0.278	0.333	0.32	0.333	0.352	0.427
2009	0.152	0.19	0.211	0.258	0.275	0.279	0.329	0.336	0.331	0.393
2010	0.16	0.179	0.216	0.237	0.272	0.302	0.294	0.316	0.379	0.39
2011	0.144	0.16	0.191	0.228	0.239	0.271	0.266	0.288	0.326	0.353
2012	0.144	0.169	0.189	0.234	0.255	0.252	0.278	0.295	0.34	0.332
2013	0.145	0.169	0.185	0.222	0.248	0.263	0.294	0.316	0.319	0.365

Year	1	2	3	4	5	6	7	8	9	10+
2014	0.138	0.19	0.213	0.23	0.261	0.268	0.257	0.274	0.321	0.345
2015	0.146	0.17	0.209	0.243	0.264	0.273	0.299	0.298	0.328	0.363
2016	0.15	0.173	0.199	0.234	0.256	0.272	0.271	0.288	0.341	0.325
2017	0.152	0.177	0.205	0.24	0.282	0.275	0.312	0.31	0.279	0.347
2018	0.123	0.166	0.2	0.235	0.258	0.265	0.241	0.26	0.268	0.265
2019	0.156	0.163	0.186	0.224	0.234	0.228	0.243	0.219	0.197	0.319
2020	0.147	0.158	0.184	0.214	0.236	0.236	0.214	0.233	0.21	0.203
2021	0.133	0.165	0.181	0.206	0.236	0.253	0.264	0.236	0.209	0.342
2022	0.127	0.16	0.186	0.224	0.237	0.24	0.227	0.268	0.199	0.335
2023	0.16	0.19	0.216	0.234	0.276	0.265	0.303	0.271	0.294	0.245

Table 17.5. Sole in Subarea 4. Time-series of the mean weights-at-age in the discards of sole in Subarea 27.4. Input to SS3.

Year	0	1	2	3	4	5	6	7	8	9	10+
1957	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1958	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1959	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1960	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1961	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1962	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1963	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1964	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1965	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1966	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1967	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1968	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1969	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1970	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1971	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1972	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1973	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137

Year	0	1	2	3	4	5	6	7	8	9	10+
1974	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1975	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1976	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1977	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1978	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1979	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1980	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1981	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1982	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1983	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1984	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1985	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1986	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1987	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1988	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1989	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1990	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1991	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1992	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1993	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1994	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1995	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1996	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1997	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1998	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
1999	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
2000	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
2001	0.01	0.059	0.082	0.096	0.104	0.112	0.106	0.12	0.131	0.137	0.137
2002	0.01	0.07	0.08	0.089	0.096	0.101	0.086	0.085	0.088	0.137	0.137

Year	0	1	2	3	4	5	6	7	8	9	10+
2003	0.01	0.036	0.099	0.116	0.115	0.157	0.161	0.186	0.166	0.325	0.321
2004	0.01	0.067	0.08	0.097	0.108	0.118	0.096	0.101	0.098	0.101	0.321
2005	0.01	0.051	0.086	0.098	0.107	0.115	0.103	0.107	0.098	0.101	0.321
2006	0.01	0.074	0.086	0.098	0.105	0.109	0.115	0.113	0.121	0.113	0.117
2007	0.01	0.026	0.081	0.091	0.098	0.105	0.104	0.116	0.102	0.102	0.111
2008	0.01	0.074	0.085	0.098	0.111	0.132	0.121	0.11	0.091	0.1	0.09
2009	0.01	0.068	0.101	0.106	0.107	0.109	0.145	0.127	0.092	0.1	0.086
2010	0.01	0.052	0.088	0.095	0.115	0.117	0.138	0.097	0.19	0.142	0.118
2011	0.01	0.051	0.083	0.094	0.09	0.134	0.128	0.177	0.153	0.199	0.182
2012	0.01	0.062	0.075	0.09	0.101	0.111	0.113	0.123	0.095	0.121	0.095
2013	0.01	0.043	0.075	0.086	0.1	0.121	0.11	0.108	0.136	0.14	0.1
2014	0.01	0.026	0.079	0.089	0.097	0.106	0.101	0.117	0.099	0.155	0.106
2015	0.01	0.057	0.077	0.095	0.087	0.105	0.124	0.131	0.124	0.159	0.2
2016	0.01	0.029	0.073	0.086	0.094	0.113	0.105	0.119	0.203	0.207	0.18
2017	0.01	0.051	0.073	0.086	0.085	0.093	0.109	0.106	0.101	0.123	0.161
2018	0.01	0.041	0.066	0.086	0.091	0.097	0.102	0.1	0.105	0.126	0.087
2019	0.01	0.045	0.071	0.083	0.094	0.095	0.105	0.105	0.098	0.117	0.129
2020	0.01	0.053	0.071	0.085	0.092	0.093	0.1	0.11	0.13	0.106	0.129
2021	0.01	0.07	0.081	0.089	0.101	0.11	0.117	0.12	0.099	0.109	0.129
2022	0.01	0.063	0.064	0.086	0.093	0.091	0.096	0.105	0.089	0.108	0.129
2023	0.01	0.071	0.085	0.086	0.105	0.096	0.121	0.114	0.094	0.307	0.129

Table 17.6. Sole in Subarea 4. Time-series of stock weights-at-age in the middle of the year. Input to SS3.

Year	0	1	2	3	4	5	6	7	8	9	10+
1957	0.01	0.025	0.07	0.147	0.187	0.208	0.253	0.262	0.355	0.39	0.365
1958	0.01	0.025	0.07	0.164	0.205	0.226	0.228	0.297	0.318	0.393	0.422
1959	0.01	0.025	0.07	0.159	0.198	0.239	0.271	0.292	0.276	0.303	0.426
1960	0.01	0.025	0.07	0.163	0.207	0.234	0.24	0.268	0.242	0.36	0.431
1961	0.01	0.025	0.07	0.148	0.206	0.235	0.232	0.259	0.274	0.281	0.396
1962	0.01	0.025	0.07	0.148	0.192	0.24	0.301	0.293	0.282	0.273	0.441

Year	0	1	2	3	4	5	6	7	8	9	10+
1963	0.01	0.025	0.07	0.148	0.193	0.243	0.275	0.311	0.363	0.329	0.465
1964	0.01	0.025	0.07	0.159	0.214	0.24	0.291	0.305	0.306	0.365	0.474
1965	0.01	0.025	0.14	0.198	0.223	0.251	0.297	0.337	0.358	0.526	0.46
1966	0.01	0.025	0.07	0.16	0.149	0.389	0.31	0.406	0.377	0.385	0.505
1967	0.01	0.025	0.177	0.164	0.235	0.242	0.399	0.362	0.283	0.381	0.459
1968	0.01	0.025	0.122	0.171	0.248	0.312	0.28	0.629	0.416	0.41	0.486
1969	0.01	0.025	0.137	0.174	0.252	0.324	0.364	0.579	0.415	0.469	0.521
1970	0.01	0.025	0.137	0.201	0.275	0.341	0.367	0.423	0.458	0.39	0.554
1971	0.01	0.034	0.148	0.213	0.313	0.361	0.41	0.432	0.474	0.483	0.533
1972	0.01	0.038	0.155	0.218	0.313	0.419	0.443	0.443	0.443	0.508	0.602
1973	0.01	0.039	0.149	0.226	0.322	0.371	0.433	0.452	0.472	0.446	0.536
1974	0.01	0.035	0.146	0.218	0.329	0.408	0.429	0.499	0.565	0.542	0.618
1975	0.01	0.035	0.148	0.206	0.311	0.403	0.446	0.508	0.582	0.58	0.65
1976	0.01	0.035	0.142	0.201	0.301	0.379	0.458	0.508	0.517	0.644	0.665
1977	0.01	0.035	0.147	0.202	0.291	0.365	0.409	0.478	0.487	0.531	0.644
1978	0.01	0.035	0.139	0.211	0.29	0.365	0.429	0.427	0.385	0.542	0.644
1979	0.01	0.045	0.148	0.211	0.3	0.352	0.429	0.521	0.562	0.567	0.743
1980	0.01	0.039	0.157	0.2	0.304	0.345	0.394	0.489	0.537	0.579	0.645
1981	0.01	0.05	0.137	0.2	0.305	0.364	0.402	0.454	0.522	0.561	0.622
1982	0.01	0.05	0.13	0.193	0.27	0.359	0.411	0.429	0.476	0.583	0.642
1983	0.01	0.05	0.14	0.2	0.285	0.329	0.435	0.464	0.483	0.51	0.636
1984	0.01	0.05	0.133	0.203	0.268	0.348	0.386	0.488	0.591	0.567	0.663
1985	0.01	0.05	0.127	0.185	0.267	0.324	0.381	0.38	0.626	0.554	0.642
1986	0.01	0.05	0.133	0.191	0.278	0.345	0.423	0.495	0.487	0.587	0.686
1987	0.01	0.05	0.154	0.191	0.262	0.357	0.381	0.406	0.454	0.332	0.62
1988	0.01	0.05	0.133	0.193	0.26	0.335	0.409	0.417	0.474	0.486	0.654
1989	0.01	0.05	0.133	0.195	0.29	0.35	0.34	0.411	0.475	0.419	0.594
1990	0.01	0.05	0.148	0.203	0.294	0.357	0.447	0.399	0.494	0.481	0.653
1991	0.01	0.05	0.139	0.184	0.254	0.301	0.413	0.447	0.522	0.548	0.573

Year	0	1	2	3	4	5	6	7	8	9	10+
1992	0.01	0.05	0.156	0.194	0.257	0.307	0.398	0.406	0.472	0.5	0.54
1993	0.01	0.05	0.128	0.184	0.229	0.265	0.293	0.344	0.482	0.437	0.583
1994	0.01	0.05	0.143	0.174	0.209	0.257	0.326	0.349	0.402	0.494	0.459
1995	0.01	0.05	0.151	0.179	0.24	0.253	0.321	0.365	0.357	0.545	0.545
1996	0.01	0.05	0.147	0.178	0.208	0.274	0.268	0.321	0.375	0.402	0.546
1997	0.01	0.05	0.15	0.19	0.225	0.252	0.303	0.319	0.325	0.36	0.424
1998	0.01	0.05	0.14	0.173	0.234	0.267	0.281	0.328	0.273	0.336	0.455
1999	0.01	0.05	0.131	0.187	0.216	0.259	0.296	0.34	0.322	0.369	0.464
2000	0.01	0.05	0.139	0.185	0.226	0.264	0.275	0.287	0.337	0.391	0.376
2001	0.01	0.05	0.144	0.185	0.223	0.263	0.319	0.327	0.421	0.41	0.53
2002	0.01	0.05	0.145	0.197	0.245	0.267	0.267	0.299	0.308	0.435	0.435
2003	0.01	0.05	0.146	0.194	0.24	0.256	0.288	0.33	0.312	0.509	0.47
2004	0.01	0.05	0.137	0.195	0.24	0.245	0.305	0.316	0.448	0.356	0.601
2005	0.01	0.05	0.15	0.189	0.234	0.237	0.258	0.276	0.396	0.369	0.429
2006	0.01	0.05	0.148	0.197	0.25	0.27	0.319	0.286	0.341	0.409	0.455
2007	0.01	0.05	0.152	0.179	0.216	0.242	0.245	0.275	0.252	0.257	0.364
2008	0.01	0.05	0.154	0.198	0.212	0.239	0.302	0.282	0.231	0.274	0.4
2009	0.01	0.05	0.142	0.185	0.232	0.255	0.279	0.283	0.333	0.302	0.39
2010	0.01	0.05	0.149	0.2	0.23	0.272	0.307	0.336	0.336	0.361	0.41
2011	0.01	0.05	0.141	0.179	0.223	0.261	0.276	0.32	0.36	0.444	0.391
2012	0.01	0.025	0.058	0.144	0.205	0.23	0.209	0.251	0.235	0.334	0.223
2013	0.01	0.034	0.068	0.117	0.186	0.254	0.258	0.309	0.241	0.325	0.562
2014	0.01	0.022	0.079	0.136	0.188	0.212	0.227	0.228	0.29	0.343	0.603
2015	0.01	0.07	0.075	0.142	0.148	0.227	0.244	0.263	0.288	0.37	0.389
2016	0.01	0.01	0.067	0.151	0.186	0.232	0.248	0.236	0.261	0.221	0.281
2017	0.01	0.021	0.074	0.131	0.174	0.231	0.242	0.249	0.217	0.233	0.367
2018	0.01	0.026	0.084	0.146	0.18	0.205	0.237	0.228	0.219	0.26	0.425
2019	0.01	0.027	0.072	0.133	0.153	0.191	0.168	0.177	0.224	0.194	0.248
2020	0.01	0.039	0.077	0.144	0.174	0.218	0.214	0.197	0.249	0.173	0.244

Year	0	1	2	3	4	5	6	7	8	9	10+
2021	0.01	0.051	0.088	0.137	0.182	0.2	0.231	0.276	0.178	0.199	0.374
2022	0.01	0.126	0.128	0.156	0.195	0.204	0.216	0.201	0.202	0.202	0.235
2023	0.002	0.087	0.151	0.215	0.235	0.292	0.330	0.312	0.286	0.361	0.174

Table 17.7. Sole in Subarea 4. Maturity and natural mortality-at-age in the stock.

Age	Maturity	M
0	0	1.302
1	0.0	0.754
2	0.0	0.465
3	1.0	0.368
4	1.0	0.321
5	1.0	0.295
6	1.0	0.278
7	1.0	0.267
8	1.0	0.260
9	1.0	0.254
10+	1.0	0.248

Table 17.8. Sole in Subarea 4. Index of abundance, based on the BTS Q3 survey samples from The Netherlands, Germany, Belgium and the United Kingdom, used in the assessment of sole in Subarea 27.4.

Year	0	1	2	3	4	5	6	7	8	9	10+
1990	338.4	3516.1	3263.1	4817.1	375.5	179.8	79.0	13.1	12.5	12.2	12.1
1991	1010.8	2491.9	3913.5	1137.9	1846.3	105.1	66.3	23.5	18.0	19.4	30.2
1992	272.9	14893.9	1471.5	2468.5	781.4	1593.2	41.8	64.6	9.9	5.8	11.7
1993	192.6	3391.2	7490.5	531.9	660.4	310.1	558.3	15.5	37.7	14.3	41.7
1994	527.9	3785.4	1185.1	3205.5	74.6	287.2	72.6	257.5	13.8	6.0	16.2
1995	476.1	4014.3	1874.9	1197.2	1602.8	275.6	278.8	67.0	200.3	17.7	22.2
1996	72.1	1418.0	2556.6	740.9	693.7	875.4	458.3	351.7	85.6	155.7	90.7
1997	304.0	9228.7	1612.5	776.8	264.3	201.0	221.0	106.4	50.4	30.2	33.5
1998	141.2	2063.8	4368.4	497.8	321.6	117.1	102.1	156.7	84.7	14.8	52.4
1999	446.5	3287.5	1910.2	2294.4	348.2	309.2	70.8	28.7	178.0	66.2	126.8

Year	0	1	2	3	4	5	6	7	8	9	10+
2000	143.4	2645.1	1563.2	750.8	596.3	143.3	49.4	16.8	14.7	65.5	42.9
2001	245.5	1477.4	2578.3	1060.7	412.9	358.9	84.3	44.2	18.5	5.4	61.0
2002	283.5	2753.8	957.5	795.4	487.3	119.3	218.1	49.0	18.2	14.1	82.0
2003	209.6	1993.9	2386.7	430.7	372.8	171.7	47.9	124.7	20.2	22.9	23.2
2004	148.5	1080.3	1323.8	1028.3	176.0	178.7	31.0	36.5	8.2	8.4	18.1
2005	408.3	1253.2	1085.5	525.6	620.4	102.8	166.4	80.6	14.4	17.4	56.0
2006	139.3	3422.9	1182.5	325.5	339.9	304.1	62.7	79.3	51.0	6.6	49.8
2007	273.1	1277.4	3025.2	502.0	157.5	184.3	243.7	42.6	54.2	23.7	27.4
2008	285.6	1952.8	1427.4	1590.9	321.1	76.2	93.4	151.2	24.0	31.0	32.5
2009	230.6	2347.4	1471.5	784.9	874.5	165.3	51.1	104.2	98.8	41.1	76.5
2010	263.7	2619.9	1333.4	526.5	328.8	273.8	118.1	31.7	36.7	24.7	53.2
2011	289.1	2770.4	2943.0	750.2	259.6	227.1	217.4	41.6	24.5	23.7	50.4
2012	114.1	1175.1	3853.7	1686.2	393.9	173.3	136.4	87.3	44.1	18.6	54.8
2013	89.5	1329.2	1090.5	2431.5	786.0	203.5	56.8	79.2	87.2	12.7	46.9
2014	1089.2	3127.2	2475.6	630.8	1040.0	438.1	110.9	43.3	50.4	24.7	18.1
2015	138.2	2905.1	2424.5	1555.7	466.1	843.8	324.0	137.3	32.5	43.5	56.0
2016	351.5	1245.1	2423.1	1234.7	720.7	222.6	390.9	127.0	30.9	4.8	48.8
2017	374.0	5081.0	1295.0	1532.6	580.8	317.5	124.0	167.2	84.5	2.1	34.5
2018	516.3	2559.5	3260.6	680.2	732.4	193.6	166.7	70.9	81.7	21.2	10.5
2019	517.0	9114.2	1782.9	1669.1	311.2	301.6	89.5	97.6	37.0	35.3	31.0
2020	456.3	1808.8	6241.5	1347.6	885.7	163.3	219.5	84.9	64.5	41.1	66.1
2021	399.2	1834.0	1092.9	2315.1	496.1	328.9	81.8	68.6	12.7	9.0	46.5
2022	521.1	3042.2	1853.4	535.8	970.7	239.8	160.0	31.0	33.0	8.5	26.8
2023	475.8	3998.3	1676.0	780.2	269.0	495.9	134.3	119.4	25.3	18.9	13.4

Table 17.9. Sole in Subarea 4. Index of abundance (COAST), based on the combined SNS and DYFS survey samples from The Netherlands, Germany, Belgium, used in the assessment of sole in Subarea 27.4.

Year	0	1	2	3	4	5
1990	2431.10	2564.88	1375.19	838.68	62.39	20.38
1991	15434.41	918.60	2639.99	502.68	582.46	15.09
1992	2403.24	10312.08	510.60	622.89	166.53	250.67

Year	0	1	2	3	4	5
1993	2846.77	2138.39	4346.28	110.27	274.25	94.53
1994	2964.20	923.17	742.02	1122.42	6.53	66.84
1995	1989.70	1024.80	446.84	236.76	321.89	7.82
1996	7680.00	638.64	622.56	107.58	70.05	82.31
1997	5912.91	8102.75	644.57	257.10	70.44	58.95
1998	3163.21	2334.56	2173.42	103.31	64.31	3.64
1999	5280.75	1273.37	1692.68	871.27	15.56	17.92
2000	3303.23	1736.82	604.50	245.99	112.01	6.71
2001	8078.21	1008.31	1166.39	145.90	72.65	37.48
2002	4842.83	3591.75	665.66	361.87	62.18	19.76
2003	2444.85	2761.89	1712.34	226.88	148.21	13.41
2004	1805.99	882.37	602.40	401.18	59.87	47.98
2005	5716.09	582.22	347.27	124.01	49.00	0.44
2006	1419.55	3045.64	260.00	26.24	51.46	29.79
2007	3411.34	767.30	1467.82	38.11	19.88	4.48
2008	3369.35	746.51	525.85	453.88	15.15	0.57
2009	4579.07	1120.31	463.83	159.86	211.63	3.60
2010	5753.80	2090.96	639.99	114.47	42.81	41.48
2011	2217.96	2084.51	1073.46	230.06	42.10	20.76
2012	2287.76	422.40	1003.73	283.85	45.83	12.87
2013	3306.78	1202.86	554.35	612.18	226.50	31.27
2014	2427.07	1500.16	689.52	70.56	158.71	53.12
2015	2160.23	1164.86	1148.41	287.03	34.45	74.45
2016	2212.31	871.20	1029.62	482.49	140.80	11.33
2017	3530.24	917.01	538.96	338.28	202.27	33.80
2018	6018.31	880.88	545.96	200.11	131.86	54.09
2019	1819.43	4415.17	720.00	251.96	62.22	33.97
2020	2303.68	599.21	3216.26	388.39	133.87	20.78
2021	2078.96	499.71	248.27	649.33	157.77	51.32

Year	0	1	2	3	4	5
2022	3043.88	1049.03	407.51	105.76	295.91	68.62
2023	1160.63	1578.32	576.73	108.53	25.47	72.07

Table 17.10. Sole in Subarea 4. Time series of abundances at age (stock numbers in thousands) estimated by the SS3 stock assessment.

Year	0	1	2	3	4	5	6	7	8	9	10+
1957	1901350	686496	218210	193188	137145	30973	28942	70258	23147	11990	25528
1958	8753860	517144	322982	135835	125271	86451	20038	19045	46745	15509	25393
1959	626098	2380940	243306	201442	88384	76477	54168	12771	12272	30333	26800
1960	1179510	170291	1120180	150059	130020	54771	48641	35043	8353	8083	37965
1961	508423	320813	80118	694205	93798	76894	33245	30030	21874	5251	29265
1962	430792	138285	150935	49962	438758	53627	45121	19842	18122	13293	21209
1963	10376800	117170	65059	93629	33794	250285	31397	26870	11947	10988	21123
1964	1582780	2822350	55125	40315	58295	18195	138302	17647	15269	6837	18559
1965	636897	430495	1327840	34472	26937	36009	11535	89184	11505	10025	16848
1966	1180120	173228	202521	798543	22987	16517	22662	7384	57720	7499	17687
1967	1541570	320977	81487	119441	443230	14516	10705	14939	4922	38742	17078
1968	779713	419286	150977	48448	70706	249067	8372	6280	8861	2940	33603
1969	2108090	212072	196644	81863	22634	38837	140411	4801	3641	5173	21582
1970	598317	573375	99477	105139	38535	12461	21944	80696	2789	2130	15826
1971	1139210	162734	268918	57898	51310	22294	7399	13254	49278	1715	11168
1972	1659720	309852	76273	143456	28423	28055	12511	4223	7649	28638	7572
1973	1741620	451424	145527	42387	69383	16082	16292	7390	2522	4600	21936
1974	586381	473698	211941	82009	19701	36666	8723	8988	4122	1417	15069
1975	1640130	159488	222759	121666	39199	10500	20057	4853	5056	2335	9447
1976	2265720	446095	74856	122700	61204	19854	5459	10605	2595	2722	6412
1977	727995	616247	209202	44437	62676	31605	10523	2943	5780	1424	5065
1978	335150	198005	288775	114113	21555	32388	16762	5676	1605	3175	3602
1979	2080060	91157	93099	162489	55006	10959	16900	8896	3046	867	3696
1980	2196760	565750	42852	52565	79356	27076	5536	8684	4622	1594	2414
1981	2117530	597490	265780	25925	27728	39853	13956	2903	4603	2467	2160

Year	0	1	2	3	4	5	6	7	8	9	10+
1982	2171810	575942	280767	143997	15309	14343	21158	7536	1585	2531	2566
1983	1198700	590704	269276	156285	61889	7984	7677	11519	4148	878	2851
1984	1631850	326031	277610	144016	76474	29155	3860	3775	5727	2077	1887
1985	3357480	443842	153264	151525	65927	35921	14055	1893	1872	2859	1997
1986	705200	913191	208686	84167	71477	31786	17775	7074	963	959	2510
1987	8565650	191805	429411	123960	44649	35054	15999	9100	3662	502	1827
1988	1142980	2329750	90204	247646	68112	24823	20002	9286	5340	2164	1391
1989	2955430	310876	1095990	47005	133724	37572	14053	11518	5406	3131	2102
1990	961604	803839	146217	653906	18975	79362	22885	8707	7215	3410	3329
1991	5234730	261544	377665	84222	367542	10992	47184	13840	5324	4442	4187
1992	968523	1423780	122970	227789	47767	201009	6170	26939	7989	3095	5061
1993	966665	263426	669179	71831	121828	26735	115468	3605	15914	4753	4899
1994	1353560	262921	123823	381403	37657	64078	14432	63401	2001	8897	5445
1995	1007970	368151	123213	72274	196834	19052	33273	7622	33856	1076	7776
1996	3592810	274155	170198	67173	41954	93316	9270	16467	3814	17060	4511
1997	1531690	977200	128795	93689	34803	19697	44965	4543	8160	1903	10843
1998	1132910	416601	458846	76885	47440	17788	10333	23992	2451	4433	7002
1999	1674370	308136	195813	250282	40664	23713	9126	5392	12658	1302	6134
2000	1049380	455406	144806	113652	118260	21296	12745	4989	2980	7046	4185
2001	2303480	285418	213176	82250	58262	53052	9805	5969	2362	1421	5399
2002	1246750	626518	133809	118604	44026	26576	24837	4669	2874	1145	3343
2003	752201	339099	290757	72979	55912	21868	13757	13245	2517	1560	2462
2004	863663	204589	157224	154942	37589	27743	11308	7329	7134	1365	2203
2005	2633670	234905	94952	83761	70488	18486	14219	5971	3912	3835	1937
2006	1003610	716325	108455	51324	38925	30528	8344	6611	2807	1852	2755
2007	1286660	272970	329698	57086	24776	18306	14963	4213	3375	1443	2391
2008	1407180	349954	126628	164970	29513	12614	9713	8179	2328	1878	2155
2009	2338500	382734	160736	69671	79954	15439	6877	5455	4644	1331	2328
2010	3115130	636042	176550	84578	36943	38118	7671	3520	2823	2420	1926

Year	0	1	2	3	4	5	6	7	8	9	10+
2011	939349	847275	295472	94658	43142	17890	19237	3988	1850	1494	2321
2012	1645090	255491	394000	167164	45763	21617	9342	10349	2169	1013	2110
2013	2394360	447444	118814	230182	89618	22322	10989	4892	5479	1157	1682
2014	1824530	651237	208068	68939	133328	44184	11469	5817	2618	2953	1545
2015	1118510	496249	302558	117622	41700	70482	24342	6509	3338	1513	2620
2016	2113200	304221	230629	172250	65621	22604	39818	14167	3830	1978	2473
2017	1675080	574764	141403	133367	96296	33944	12186	22113	7955	2166	2540
2018	**4180900**	455601	267131	81031	77285	52921	19441	7190	13191	4779	2853
2019	649123	**1137150**	211660	151894	47840	42748	30505	11545	4317	7976	4653
2020	854251	176553	**528573**	122181	89712	27735	25828	18988	7265	2736	8069
2021	966512	232346	82025	**303495**	73966	54237	17475	16764	12461	4801	7216
2022	1621190	262879	107871	47582	**182286**	46723	35704	11851	11495	8604	8378
2023	648105	440944	122071	62408	30621	**118036**	31530	24822	8330	8137	12129

Table 17.11. Sole in Subarea 4. Time series of fishing mortality at age estimated by the SS3 stock assessment.

Year	1	2	3	4	5	6	7	8	9	10+
1957	0.000	0.009	0.065	0.140	0.140	0.140	0.140	0.140	0.140	0.140
1958	0.000	0.007	0.062	0.172	0.172	0.172	0.172	0.172	0.172	0.172
1959	0.000	0.018	0.070	0.158	0.158	0.158	0.158	0.158	0.158	0.158
1960	0.000	0.013	0.102	0.204	0.204	0.204	0.204	0.204	0.204	0.204
1961	0.000	0.007	0.091	0.238	0.238	0.238	0.238	0.238	0.238	0.238
1962	0.000	0.013	0.023	0.240	0.240	0.240	0.240	0.240	0.240	0.240
1963	0.000	0.014	0.106	0.298	0.298	0.298	0.298	0.298	0.298	0.298
1964	0.000	0.004	0.035	0.161	0.161	0.161	0.161	0.161	0.161	0.161
1965	0.000	0.044	0.037	0.168	0.168	0.168	0.168	0.168	0.168	0.168
1966	0.000	0.063	0.221	0.139	0.139	0.139	0.139	0.139	0.139	0.139
1967	0.000	0.055	0.156	0.255	0.255	0.255	0.255	0.255	0.255	0.255
1968	0.003	0.147	0.393	0.278	0.278	0.278	0.278	0.278	0.278	0.278
1969	0.003	0.161	0.385	0.276	0.276	0.276	0.276	0.276	0.276	0.276
1970	0.003	0.076	0.349	0.226	0.226	0.226	0.226	0.226	0.226	0.226

Year	1	2	3	4	5	6	7	8	9	10+
1971	0.004	0.163	0.343	0.283	0.283	0.283	0.283	0.283	0.283	0.283
1972	0.002	0.122	0.358	0.248	0.248	0.248	0.248	0.248	0.248	0.248
1973	0.002	0.109	0.398	0.317	0.317	0.317	0.317	0.317	0.317	0.317
1974	0.000	0.090	0.370	0.308	0.308	0.308	0.308	0.308	0.308	0.308
1975	0.002	0.131	0.319	0.359	0.359	0.359	0.359	0.359	0.359	0.359
1976	0.003	0.057	0.304	0.340	0.340	0.340	0.340	0.340	0.340	0.340
1977	0.004	0.141	0.355	0.339	0.339	0.339	0.339	0.339	0.339	0.339
1978	0.001	0.110	0.362	0.355	0.355	0.355	0.355	0.355	0.355	0.355
1979	0.001	0.107	0.349	0.388	0.388	0.388	0.388	0.388	0.388	0.388
1980	0.001	0.038	0.272	0.368	0.368	0.368	0.368	0.368	0.368	0.368
1981	0.001	0.148	0.159	0.338	0.338	0.338	0.338	0.338	0.338	0.338
1982	0.006	0.121	0.476	0.330	0.330	0.330	0.330	0.330	0.330	0.330
1983	0.001	0.161	0.347	0.432	0.432	0.432	0.432	0.432	0.432	0.432
1984	0.001	0.140	0.413	0.435	0.435	0.435	0.435	0.435	0.435	0.435
1985	0.001	0.134	0.383	0.409	0.409	0.409	0.409	0.409	0.409	0.409
1986	0.001	0.056	0.266	0.391	0.391	0.391	0.391	0.391	0.391	0.391
1987	0.000	0.085	0.231	0.266	0.266	0.266	0.266	0.266	0.266	0.266
1988	0.000	0.187	0.248	0.274	0.274	0.274	0.274	0.274	0.274	0.274
1989	0.000	0.051	0.539	0.201	0.201	0.201	0.201	0.201	0.201	0.201
1990	0.001	0.087	0.208	0.225	0.225	0.225	0.225	0.225	0.225	0.225
1991	0.001	0.041	0.199	0.282	0.282	0.282	0.282	0.282	0.282	0.282
1992	0.001	0.073	0.258	0.259	0.259	0.259	0.259	0.259	0.259	0.259
1993	0.001	0.097	0.278	0.322	0.322	0.322	0.322	0.322	0.322	0.322
1994	0.004	0.073	0.293	0.360	0.360	0.360	0.360	0.360	0.360	0.360
1995	0.018	0.142	0.176	0.425	0.425	0.425	0.425	0.425	0.425	0.425
1996	0.001	0.132	0.290	0.435	0.435	0.435	0.435	0.435	0.435	0.435
1997	0.002	0.051	0.313	0.350	0.350	0.350	0.350	0.350	0.350	0.350
1998	0.001	0.141	0.269	0.372	0.372	0.372	0.372	0.372	0.372	0.372
1999	0.001	0.079	0.382	0.326	0.326	0.326	0.326	0.326	0.326	0.326

Year	1	2	3	4	5	6	7	8	9	10+
2000	0.005	0.101	0.300	0.481	0.481	0.481	0.481	0.481	0.481	0.481
2001	0.004	0.121	0.257	0.464	0.464	0.464	0.464	0.464	0.464	0.464
2002	0.014	0.141	0.384	0.379	0.363	0.351	0.351	0.351	0.351	0.351
2003	0.015	0.164	0.295	0.380	0.365	0.352	0.352	0.352	0.352	0.352
2004	0.014	0.165	0.420	0.389	0.373	0.361	0.361	0.361	0.361	0.361
2005	0.019	0.150	0.398	0.516	0.500	0.488	0.488	0.488	0.488	0.488
2006	0.022	0.177	0.360	0.433	0.418	0.405	0.405	0.405	0.405	0.405
2007	0.014	0.227	0.292	0.354	0.339	0.326	0.326	0.326	0.326	0.326
2008	0.024	0.132	0.356	0.327	0.312	0.299	0.299	0.299	0.299	0.299
2009	0.020	0.177	0.266	0.420	0.404	0.392	0.392	0.392	0.392	0.392
2010	0.013	0.158	0.305	0.404	0.389	0.376	0.376	0.376	0.376	0.376
2011	0.012	0.105	0.359	0.370	0.355	0.342	0.342	0.342	0.342	0.342
2012	0.012	0.072	0.255	0.397	0.382	0.369	0.369	0.369	0.369	0.369
2013	0.012	0.079	0.178	0.386	0.371	0.358	0.358	0.358	0.358	0.358
2014	0.013	0.105	0.135	0.316	0.301	0.288	0.288	0.288	0.288	0.288
2015	0.012	0.098	0.216	0.291	0.276	0.263	0.263	0.263	0.263	0.263
2016	0.012	0.083	0.214	0.338	0.323	0.310	0.310	0.310	0.310	0.310
2017	0.012	0.092	0.178	0.278	0.262	0.250	0.250	0.250	0.250	0.250
2018	0.013	0.100	0.159	0.271	0.256	0.243	0.243	0.243	0.243	0.243
2019	0.012	0.084	0.159	0.224	0.209	0.196	0.196	0.196	0.196	0.196
2020	0.013	0.090	0.134	0.182	0.167	0.154	0.154	0.154	0.154	0.154
2021	0.013	0.080	0.142	0.138	0.123	0.110	0.110	0.110	0.110	0.110
2022	0.013	0.082	0.073	0.114	0.098	0.086	0.086	0.086	0.086	0.086
2023	0.016	0.091	0.113	0.078	0.063	0.050	0.050	0.050	0.050	0.050

Table 17.12. Sole in Subarea 4. Catch scenarios.

Basis	Total catch* (2025)	Projected landings (2025)	Projected discards** (2025)	F_{total}# (ages 2–6) (2025)	$F_{projected\ landings}$ (ages 2–6) (2025)	$F_{projected\ discards}$ (ages 1–3) (2025)	SSB (2026)	% SSB change ^	% TAC change ^^	% advice change ^^
ICES advice basis										
MSY approach: F_{MSY}	10196	9333	862	0.157	0.106	0.022	48710	−20	177	177
Other scenarios										
$F_{MSY\ upper}$	10196	9333	862	0.157	0.106	0.022	48710	−20	177	177
$F_{MSY\ lower}$	9408	8613	795	0.144	0.098	0.021	49338	−19.5	156	156
F = 0	0	0	0	0	0	0	56884	−7.2	−100	−100
F_{pa}	10196	9333	862	0.157	0.106	0.022	48710	−20	177	177
F_{lim}	16400	14995	1405	0.265	0.179	0.038	43799	−29	346	346
SSB (2026) = B_{pa} = MSY $B_{trigger}$	5411	4957	454	0.080	0.055	0.0115	52532	−14.3	47	47
SSB (2026) = B_{lim}	24073	21975	2098	0.41	0.28	0.059	37804	−38	555	555
F = F_{2024}	3587	3287	300	0.053	0.036	0.0075	53995	−11.9	−2.4	−2.4
Rollover advice	3675	3368	307	0.054	0.037	0.0077	53925	−12.0	0	0

*** Differences between the total catch and the sum of projected landings and discards result from rounding.**

**** Including BMS landings. Assuming average estimated discard rate by age 2021–2023.**

^ SSB 2026 relative to SSB 2025.

^^ Total advised catch in 2025 relative to the advice value 2024 and TAC (both 3675 tonnes).

 # Fprojected landings and Fprojected discards do not add up to Ftotal as they are calculated using different ages.

Table 17.13. Sole in Subarea 4. Assessment summary: spawning stock biomass, fishing mortality and recruitment, with lower and upper confidence intervals, estimated by the SS3 model. Recruitment is in thousands, SSB is in tonnes.

Year	SSB	SSB lower	SSB upper	F	F lower	F upper	Recruits	Recruits lower	Recruits upper
1957	108428	93065	123791	0.099	0.084	0.114	1901350	1083728	2718972
1958	109396	93510	125282	0.117	0.099	0.136	8753860	7386143	10121577
1959	110210	94311	126109	0.112	0.095	0.130	626098	229659	1022537
1960	106550	90746	122354	0.146	0.122	0.169	1179510	736495	1622525
1961	174684	155175	194193	0.162	0.130	0.195	508423	205958	810888
1962	141994	124200	159788	0.151	0.127	0.176	430792	154175	707409

Year	SSB	SSB lower	SSB up-per	F	F lower	F upper	Recruits	Recruits lower	Recruits upper
1963	115963	98451	133475	0.203	0.167	0.239	10376800	9144824	11608776
1964	84845	68975	100715	0.104	0.082	0.127	1582780	885551	2280009
1965	72494	57670	87317	0.117	0.087	0.147	636897	318417	955377
1966	181219	163404	199034	0.140	0.098	0.182	1180120	801227	1559013
1967	160932	145550	176314	0.195	0.170	0.221	1541570	1130605	1952535
1968	131045	116058	146032	0.275	0.212	0.338	779713	457663	1101763
1969	101602	88046	115158	0.275	0.233	0.317	2108090	1685628	2530552
1970	89043	76536	101550	0.221	0.188	0.253	598317	335577	861057
1971	75338	63590	87086	0.271	0.223	0.319	1139210	798184	1480236
1972	81833	70205	93461	0.245	0.206	0.285	1659720	1222801	2096639
1973	63282	52956	73607	0.291	0.232	0.351	1741620	1312582	2170658
1974	59956	49497	70415	0.277	0.224	0.330	586381	313032	859730
1975	63334	52816	73853	0.306	0.242	0.369	1640130	1227624	2052636
1976	65856	55847	75865	0.276	0.222	0.330	2265720	1781810	2749630
1977	51294	42239	60348	0.303	0.243	0.363	727995	432784	1023206
1978	56424	46723	66124	0.308	0.239	0.376	335150	135567	534733
1979	71479	60252	82706	0.324	0.251	0.396	2080060	1589102	2571018
1980	55368	44866	65870	0.282	0.220	0.345	2196760	1611782	2781738
1981	40207	30491	49922	0.264	0.194	0.335	2117530	1557907	2677153
1982	52880	42319	63442	0.317	0.225	0.410	2171810	1614413	2729207
1983	64471	53233	75708	0.361	0.265	0.456	1198700	711148	1686252
1984	69023	57329	80716	0.372	0.289	0.454	1631850	1005599	2258101
1985	67385	54961	79809	0.349	0.268	0.430	3357480	2497465	4217495
1986	60687	46849	74524	0.299	0.219	0.380	705200	366459	1043941
1987	60641	45522	75759	0.223	0.158	0.288	8565650	7555031	9576269
1988	90366	73134	107598	0.251	0.185	0.317	1142980	745282	1540678
1989	75736	59540	91933	0.239	0.150	0.327	2955430	2480451	3430409
1990	187735	170890	204580	0.194	0.137	0.251	961604	717813	1205395
1991	145447	131868	159026	0.217	0.188	0.247	5234730	4793215	5676245

Year	SSB	SSB lower	SSB upper	F	F lower	F upper	Recruits	Recruits lower	Recruits upper
1992	139621	128568	150674	0.222	0.200	0.243	968523	759571	1177475
1993	95876	87094	104658	0.268	0.229	0.306	966665	781006	1152324
1994	125233	117682	132784	0.290	0.245	0.334	1353560	1158024	1549096
1995	95371	88723	102019	0.319	0.289	0.348	1007970	815197	1200743
1996	64774	59204	70344	0.345	0.311	0.380	3592810	3312806	3872814
1997	53604	48597	58611	0.283	0.249	0.317	1531690	1326464	1736916
1998	45269	40590	49947	0.305	0.251	0.360	1132910	970854	1294966
1999	73664	68493	78836	0.288	0.225	0.351	1674370	1501886	1846854
2000	63644	59017	68271	0.369	0.330	0.407	1049380	914892	1183868
2001	51680	47150	56210	0.354	0.311	0.397	2303480	2124905	2482055
2002	52112	47795	56430	0.324	0.283	0.364	1246750	1118652	1374848
2003	44245	40186	48303	0.311	0.270	0.352	752201	658759	845643
2004	56803	52555	61050	0.341	0.290	0.393	863663	759586	967740
2005	45818	42286	49350	0.411	0.368	0.453	2633670	2452052	2815288
2006	35605	32285	38925	0.359	0.318	0.400	1003610	881753	1125467
2007	26916	24253	29579	0.308	0.252	0.363	1286660	1153811	1419509
2008	49090	45650	52529	0.285	0.231	0.340	1407180	1259883	1554477
2009	41694	38509	44879	0.332	0.298	0.366	2338500	2131561	2545439
2010	41930	38595	45264	0.327	0.287	0.366	3115130	2853231	3377029
2011	40056	36801	43312	0.306	0.266	0.346	939349	798807	1079891
2012	44294	41108	47480	0.295	0.248	0.342	1645090	1461757	1828423
2013	56258	52599	59917	0.275	0.239	0.310	2394360	2166338	2622382
2014	50441	46783	54100	0.229	0.211	0.248	1824530	1632997	2016063
2015	49065	45364	52767	0.229	0.206	0.252	1118510	967606	1269414
2016	58809	54549	63070	0.253	0.225	0.282	2113200	1872187	2354213
2017	53686	49640	57731	0.212	0.193	0.231	1675080	1467822	1882338
2018	48181	44132	52231	0.206	0.187	0.225	4180900	3816828	4544972
2019	46522	42555	50490	0.174	0.155	0.194	649123	537521	760725
2020	52769	48194	57345	0.145	0.128	0.162	854251	733545	974957

Year	SSB	SSB lower	SSB upper	F	F lower	F upper	Recruits	Recruits lower	Recruits upper
2021	80424	74187	86660	0.119	0.104	0.133	966512	833179	1099845
2022	68623	63045	74201	0.090	0.083	0.098	1621190	1371809	1870571
2023	62604	57478	67729	0.079	0.073	0.085	648105	430735	865475

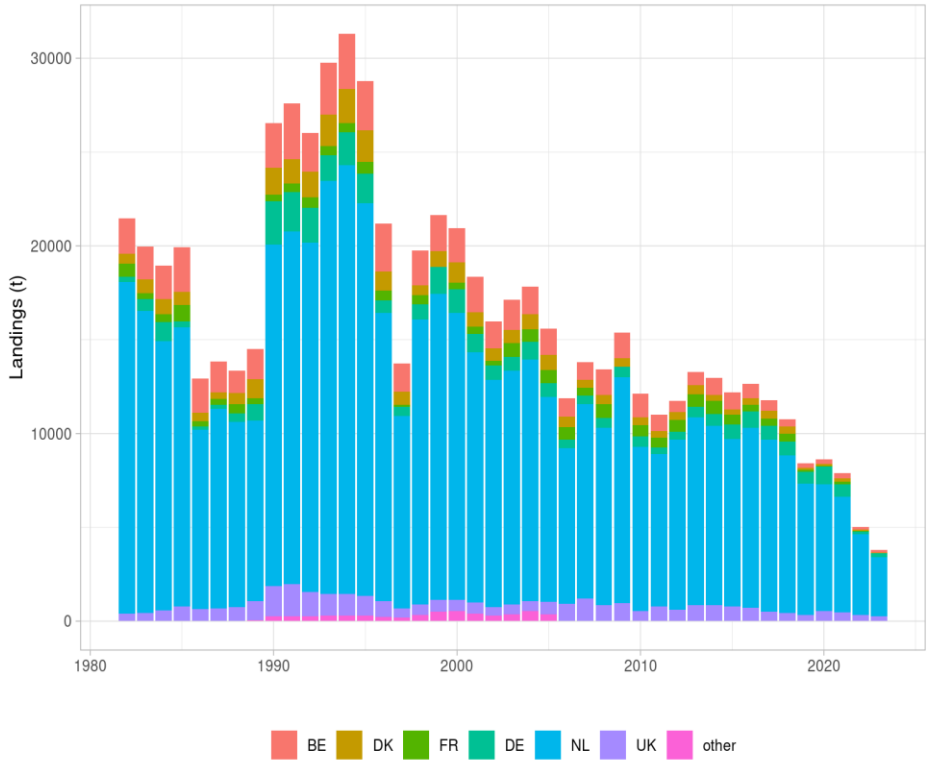

Figure 17.1. Sole in Subarea 4. Official landings reported to ICES by country.

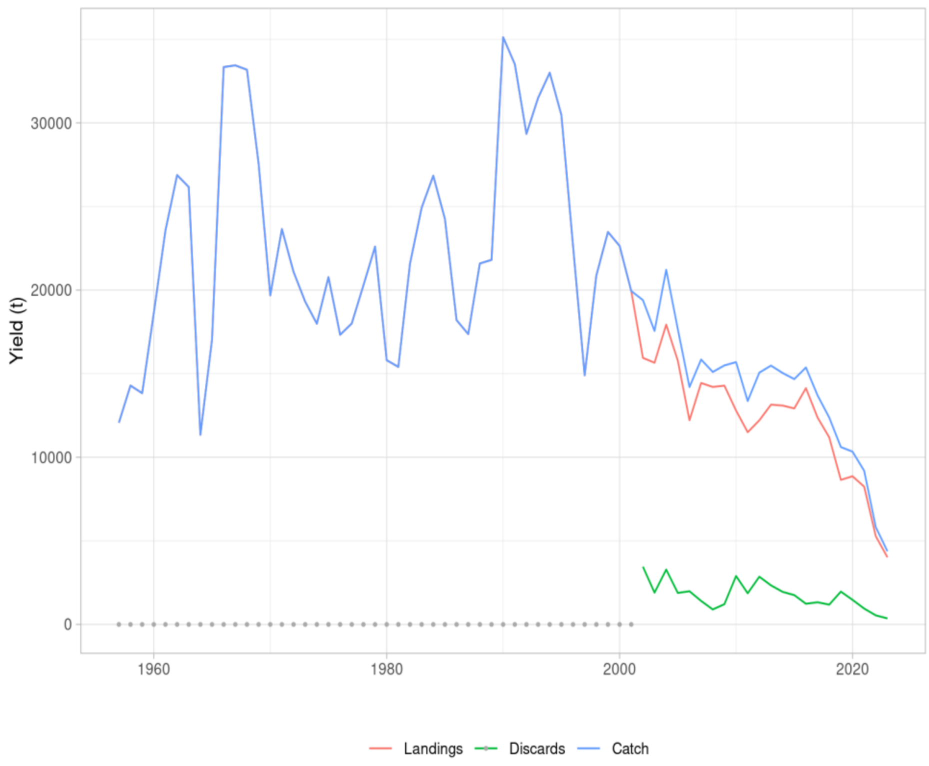

Figure 17.2. Sole in Subarea 4. Time-series of ICES catches, landings and discards (in tonnes).

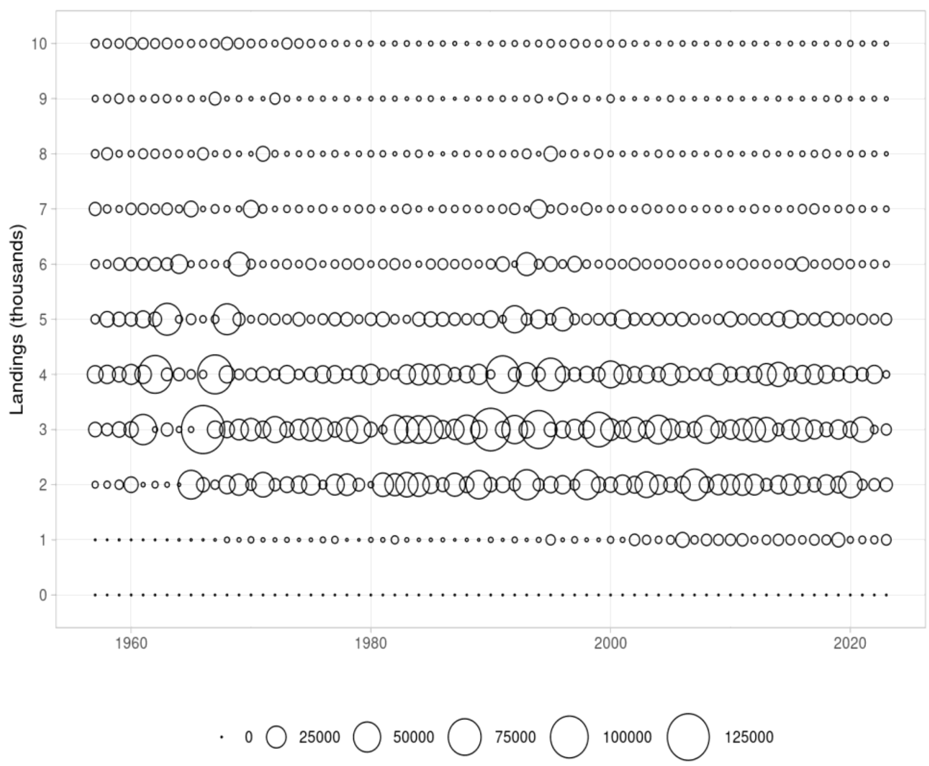

Figure 17.3. Sole in Subarea 4. Time series of landings at age (in thousands).

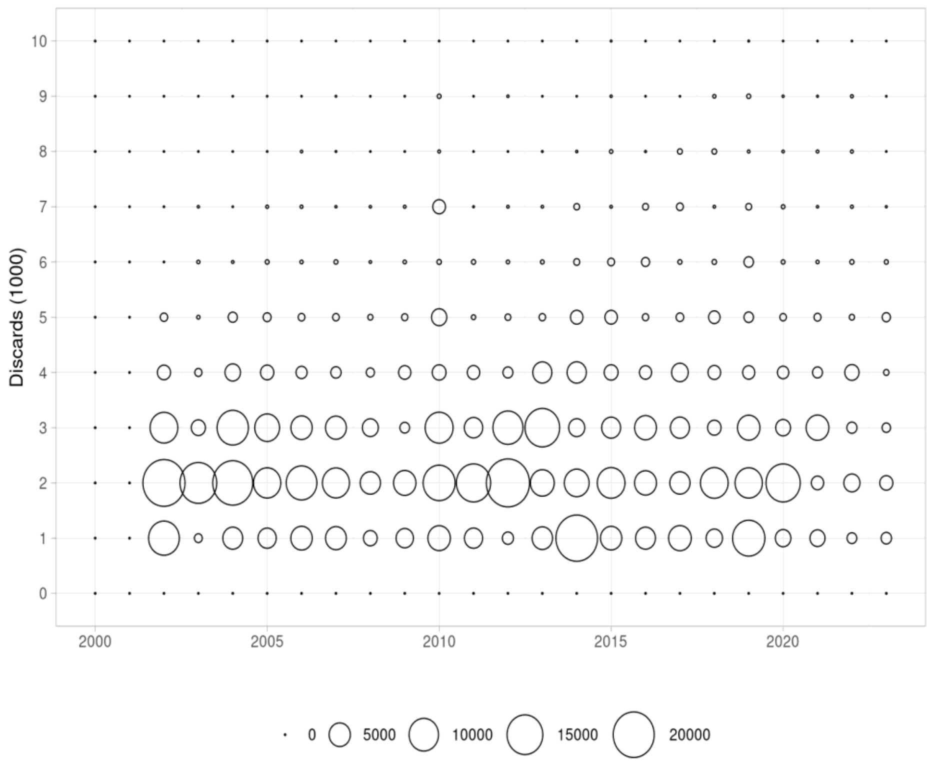

Figure 17.4. Sole in Subarea 4. Time-series of discards at age (in thousands).

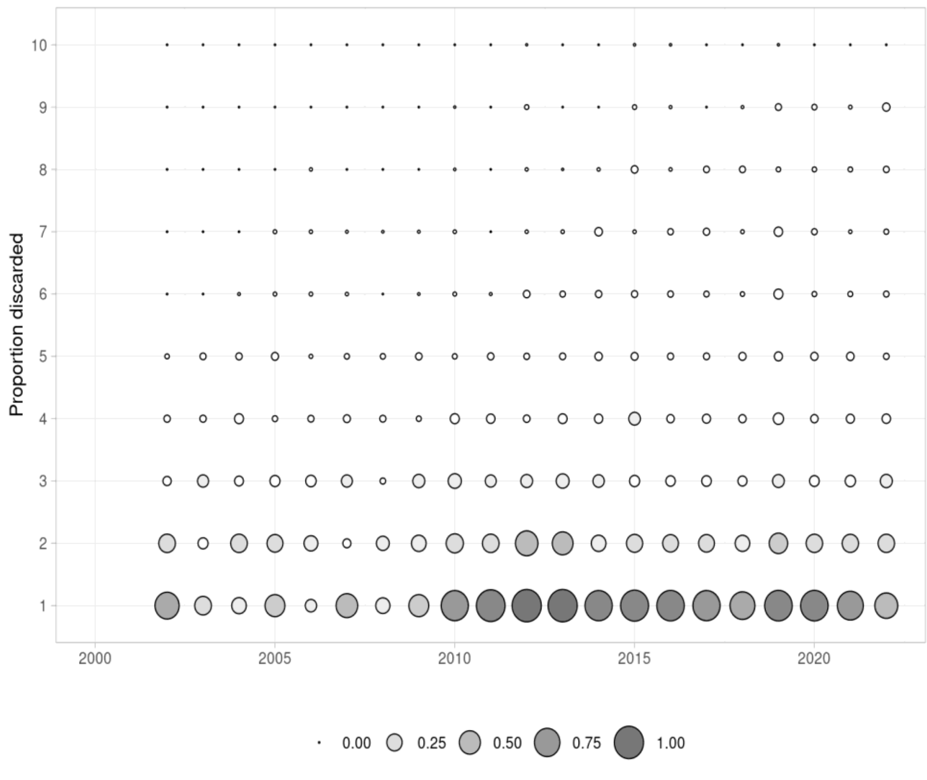

Figure 17.5. Sole in Subarea 4. Proportions of discarded sole by age over the period for which discards are available.

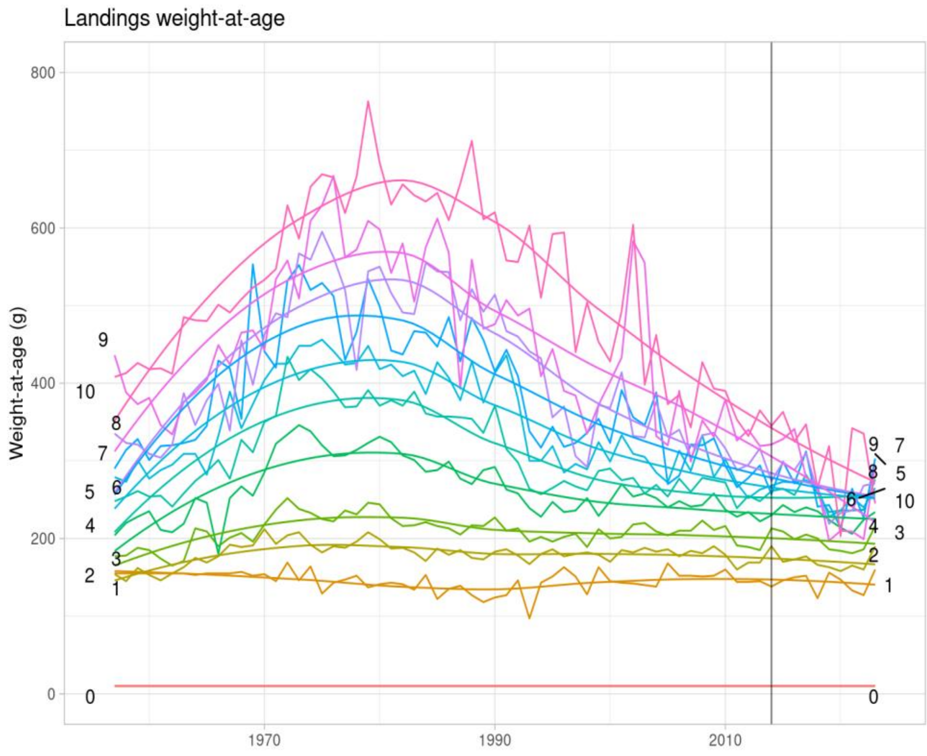

Figure 17.6. Sole in Subarea 4. Time-series of mean weight-at-age in the landings (in grammes).

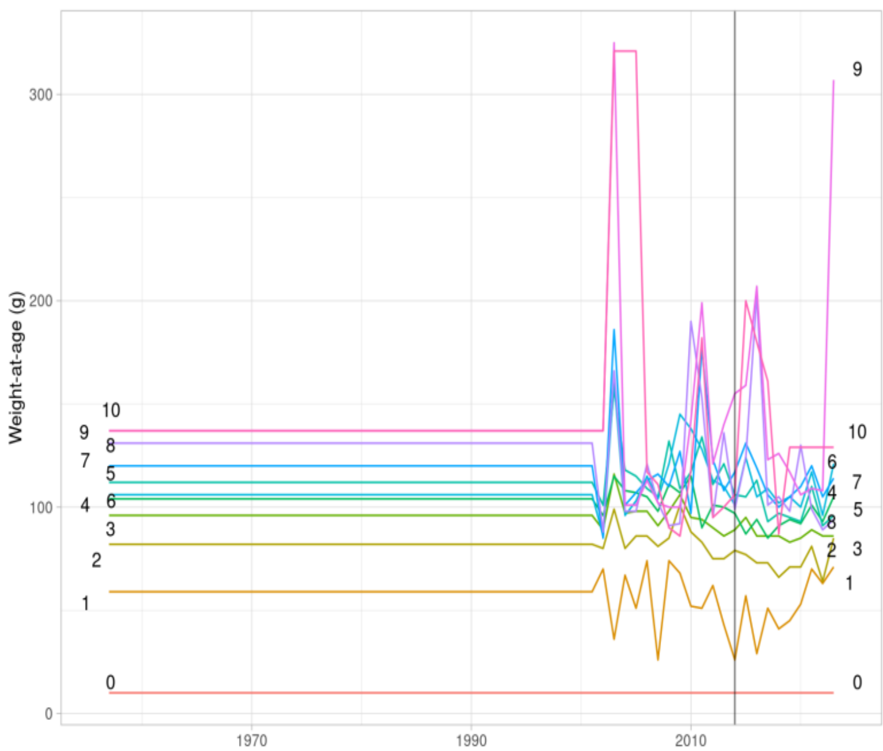

Figure 17.7. Sole in Subarea 4. Time-series of mean weight-at-age in the discards (in grammes).

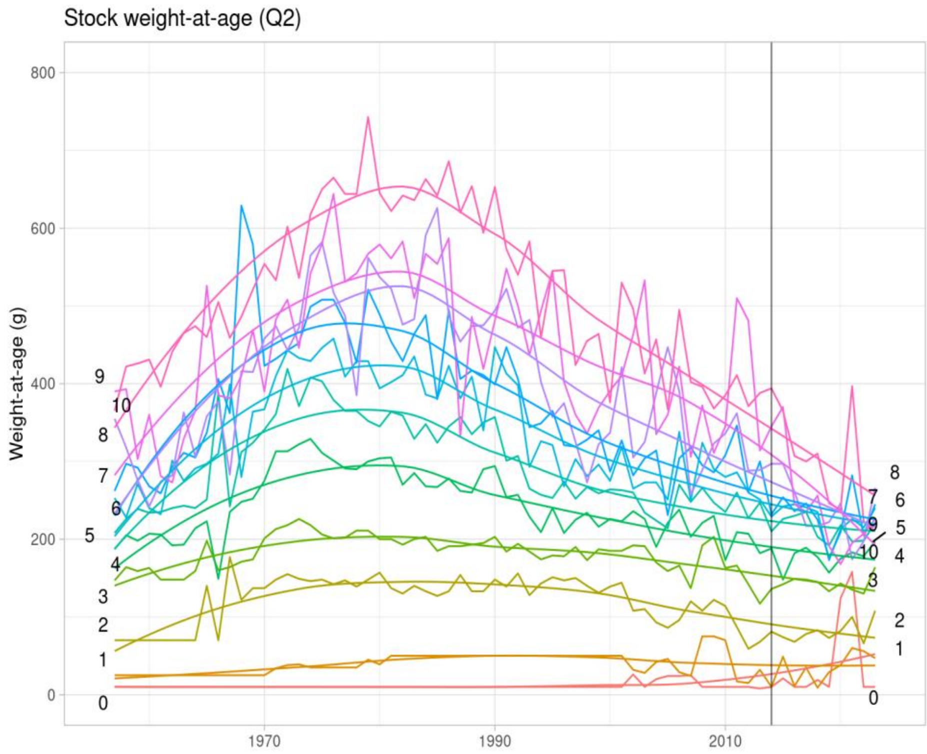

Figure 17.8. Sole in Subarea 4. Time-series of mean weight-at-age in the stock (in grammes).

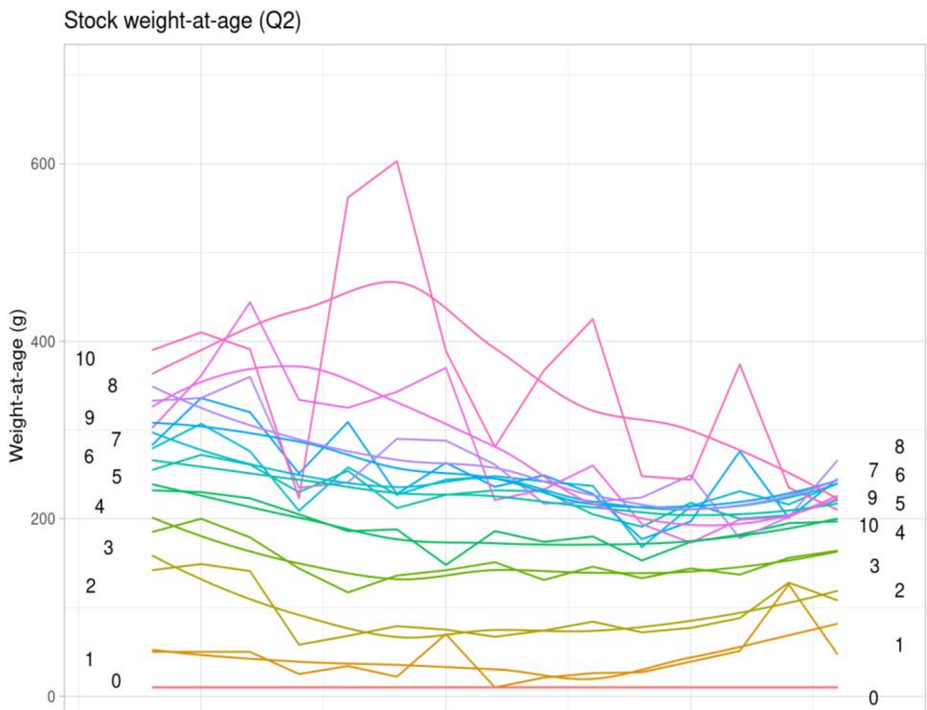

Figure 17.9. Sole in Subarea 4. Recent values of the time-series (2009–2023) of mean weight-at-age in the stock (in grammes).

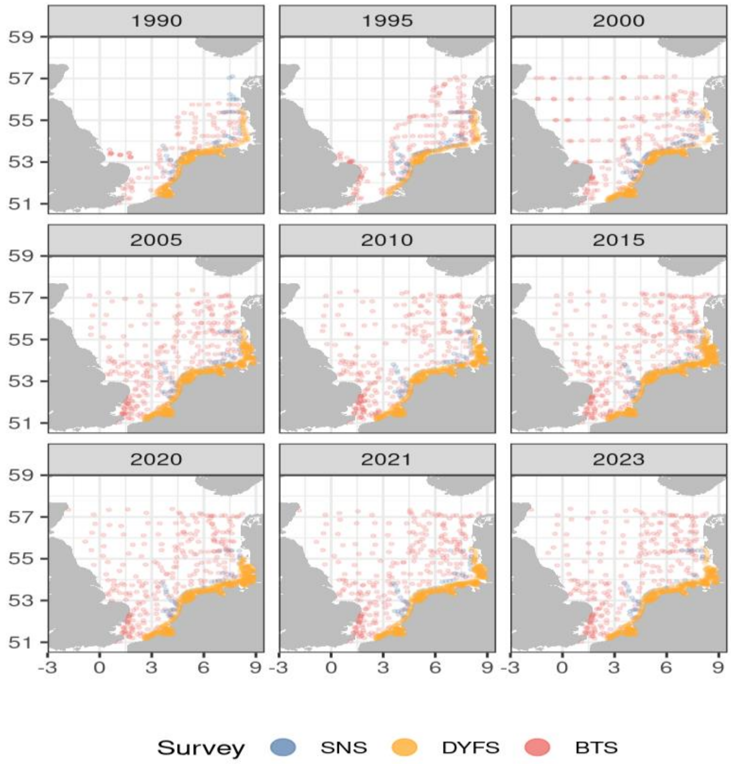

Figure 17.10. Sole in Subarea 4. Location of stations sampled during the BTS Q3 survey included in the BTS index of abundance and the SNS Q3 survey and DYFS Q3 survey, both included in the COAST index of abundance. Data shown for a selection of years.

Figure 17.11. Sole in Subarea 4. Comparison of the time series of the two indices of relative stock biomass: BTS Q3 delta-lognormal GAM standardized (1990–2023) and COAST (SNS + DYFS, 1990–2023).

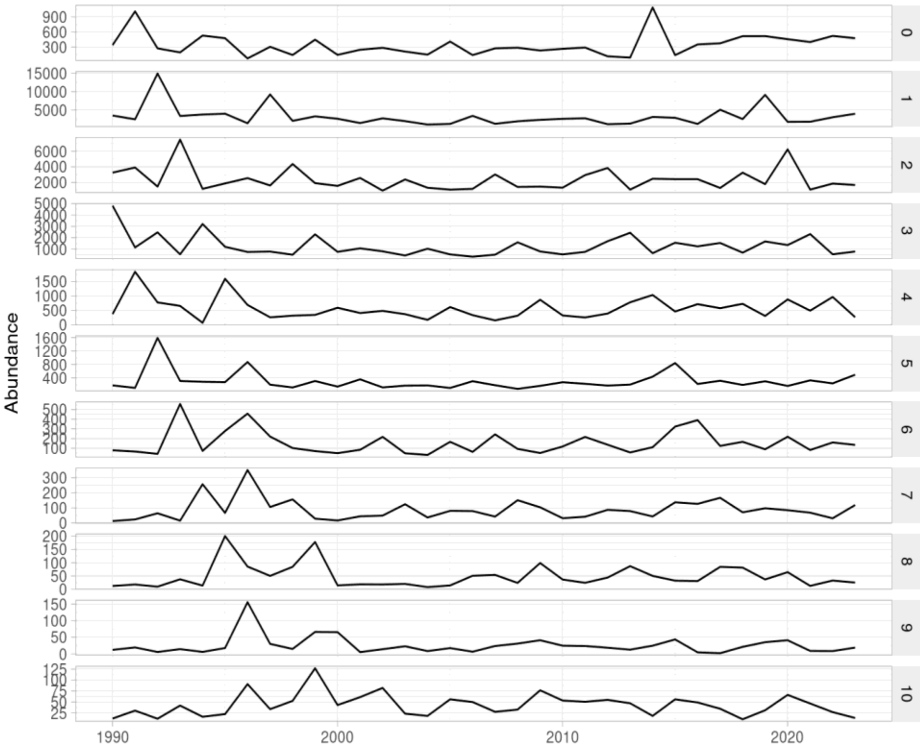

Figure 17.12. Sole in Subarea 4. Time series of relative abundance at age from the BTS Q3 delta-lognormal GAM standardized index of abundance (1990–2023).

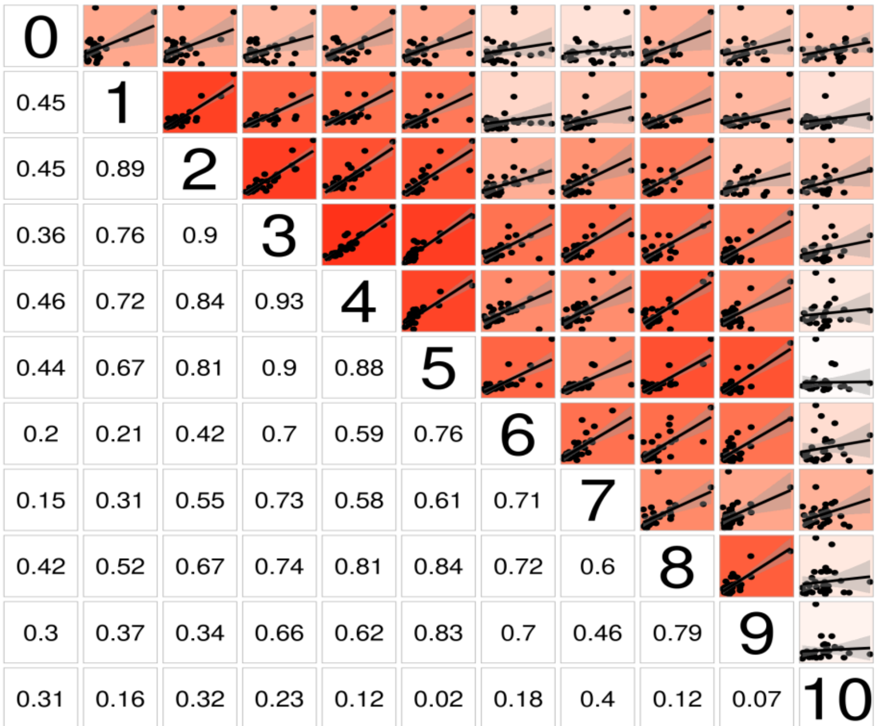

Figure 17.13. Sole in Subarea 4. Bivariate cross-correlation plots showing the internal consistency in signals by cohort for the BTS Q3 delta-lognormal GAM standardized index of abundance (1990–2023).

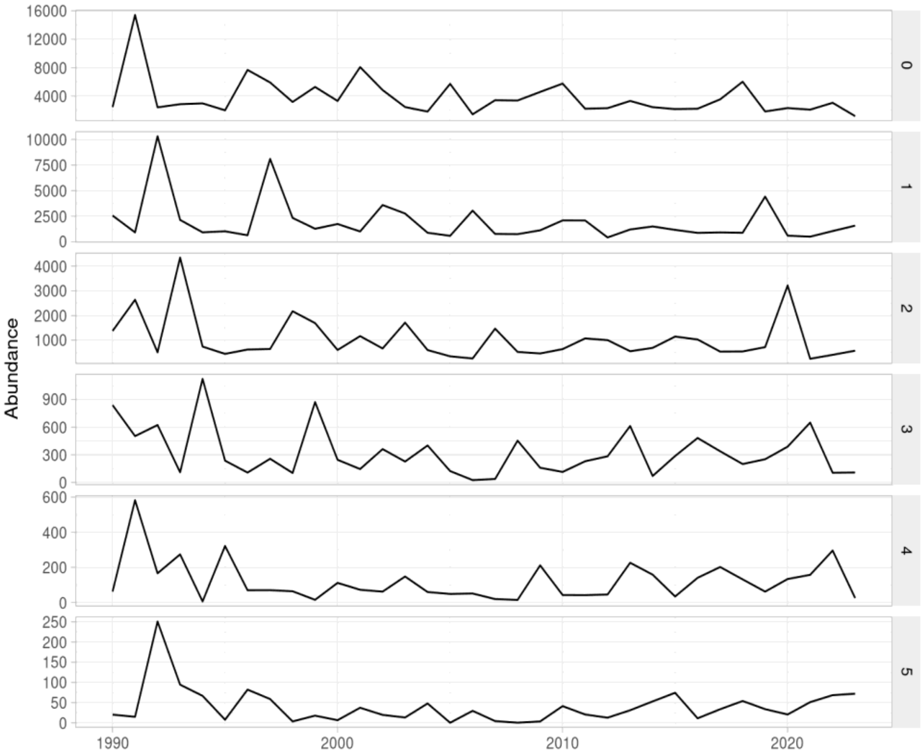

Figure 17.14. Sole in Subarea 4. Time series of relative abundance at age from the COAST (SNS + DYFS) index of abundance (1990–2023).

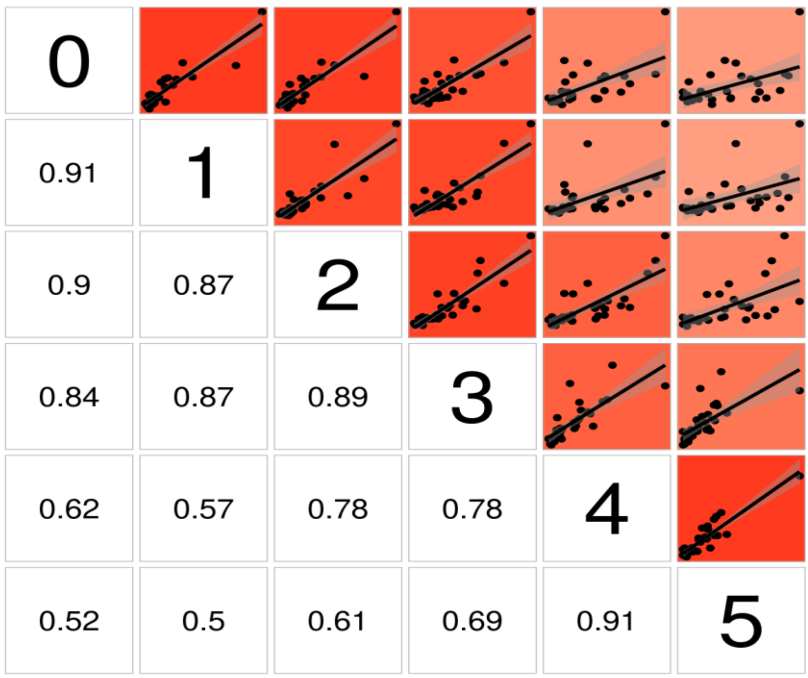

Figure 17.15. Sole in Subarea 4. Bivariate cross-correlation plots showing the internal consistency in signals by cohort for the COAST (SNS + DYFS) index of abundance (1990–2023).

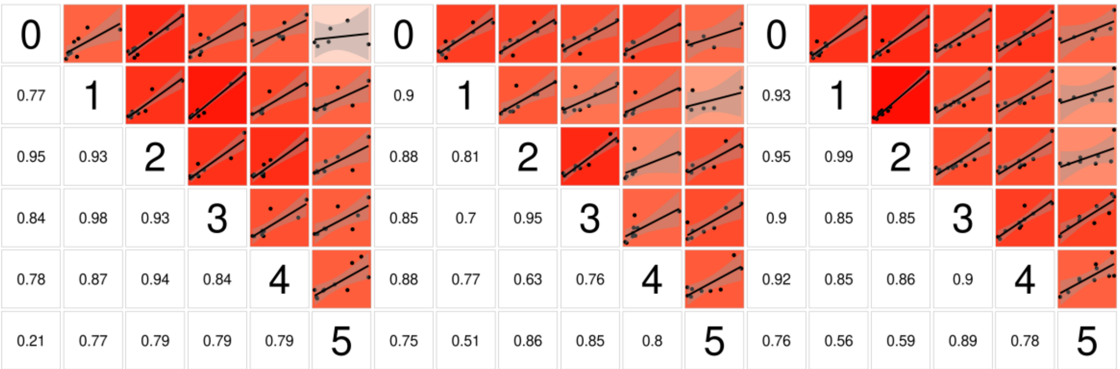

Figure 17.16. Sole in Subarea 4. Bivariate cross-correlation plots showing the internal consistency in signals by cohort for the COAST (SNS + DYFS) index of abundance, over the last three decades (left to right 1994–2003, 2004–2013 and 2014–2023).

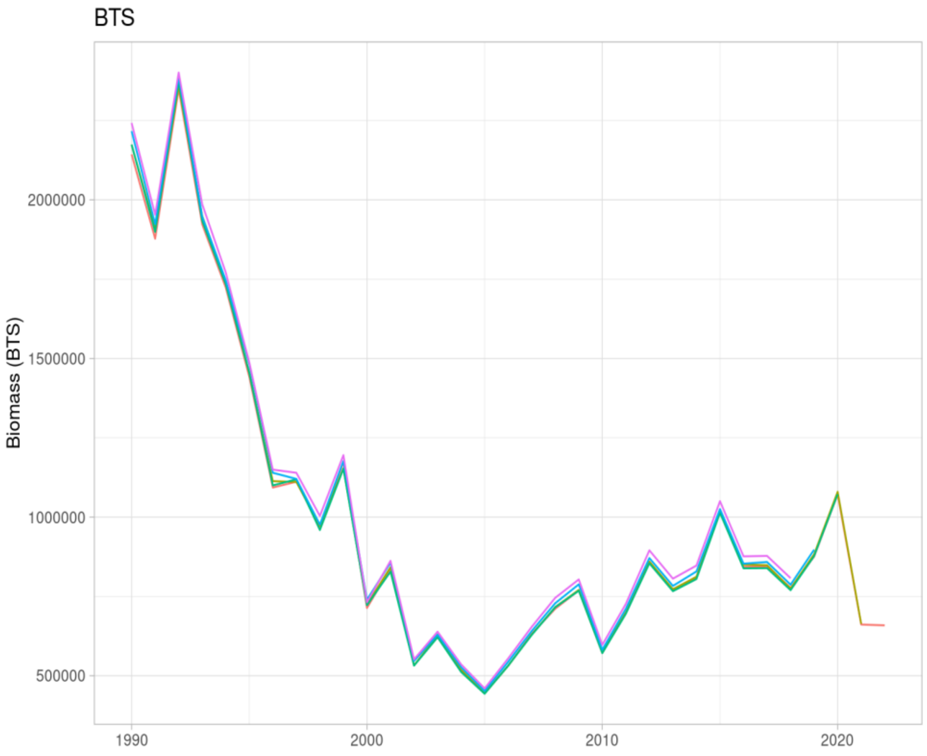

Figure 17.17. Sole in Subarea 4. Retrospective pattern in the lognormal GAM-standardized BTS Q3 index of abundance in biomass.

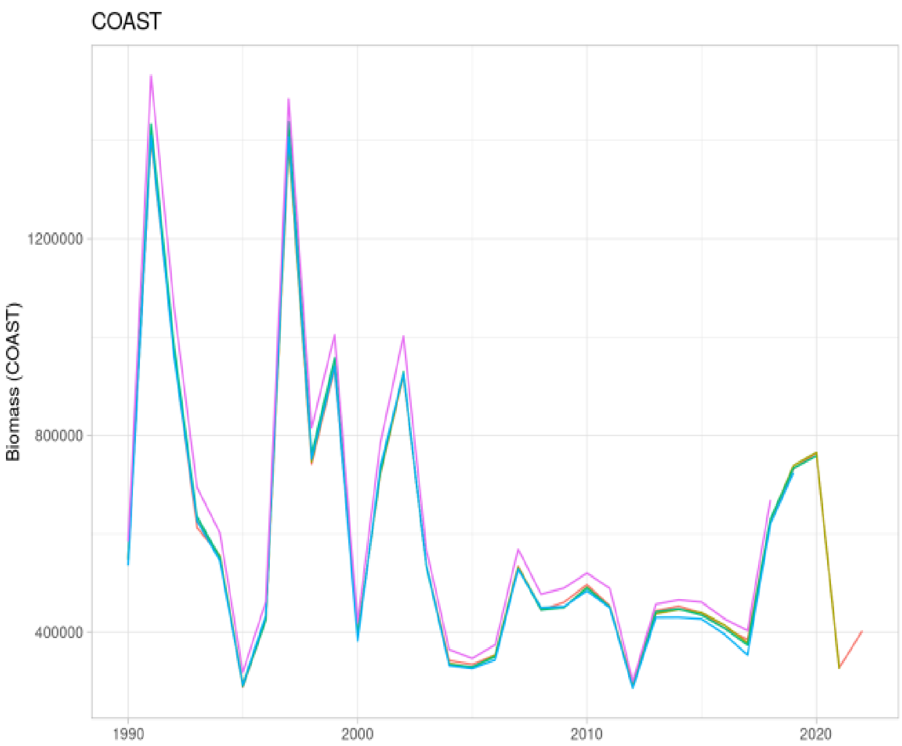

Figure 17.18. Sole in Subarea 4. Retrospective pattern in the lognormal GAM-standardized BTS Q3 index of abundance in biomass.

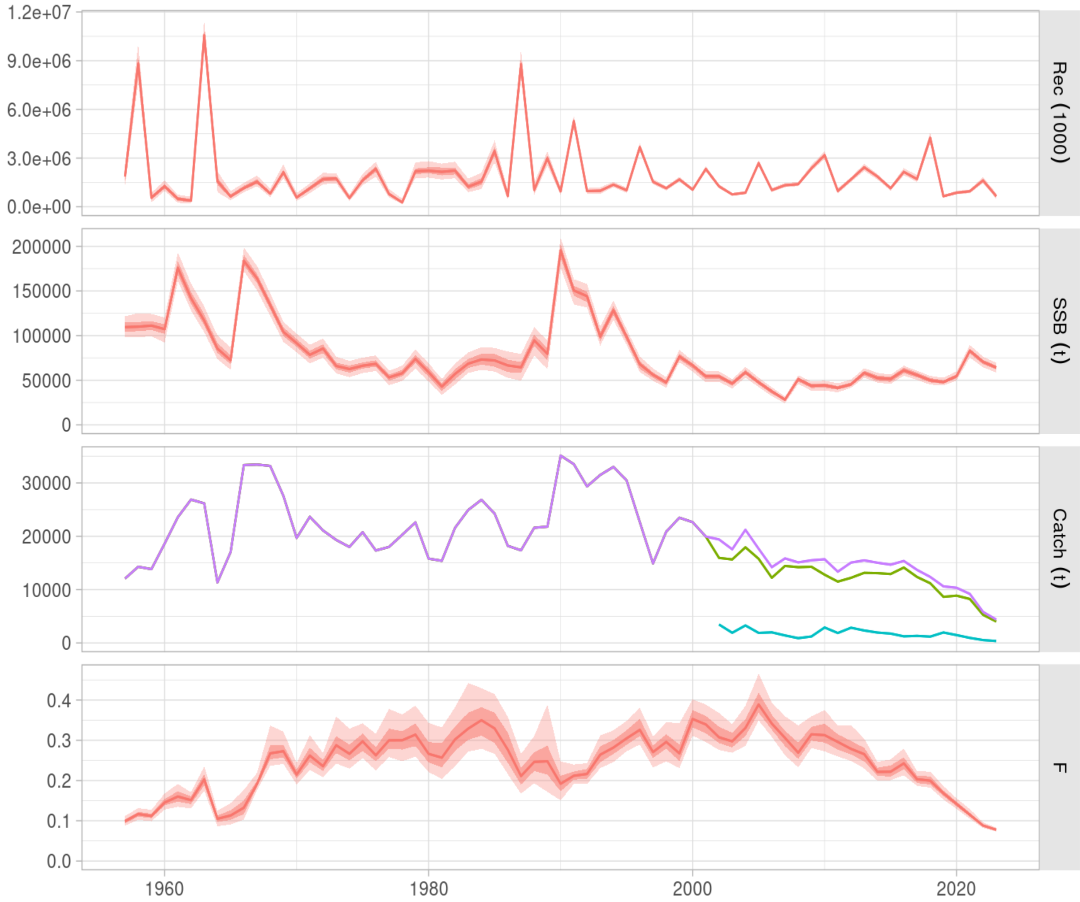

Figure 17.19. Sole in Subarea 4. Time series of recruitment at age 0 (in thousands), spawning stock biomass (in tonnes) and fishing mortality (as average of ages 2 to 6), together with total catch, landings and discards (in tonnes). Shaded bands show the 80% and 95% uncertainty computed from the MVLN approximation.

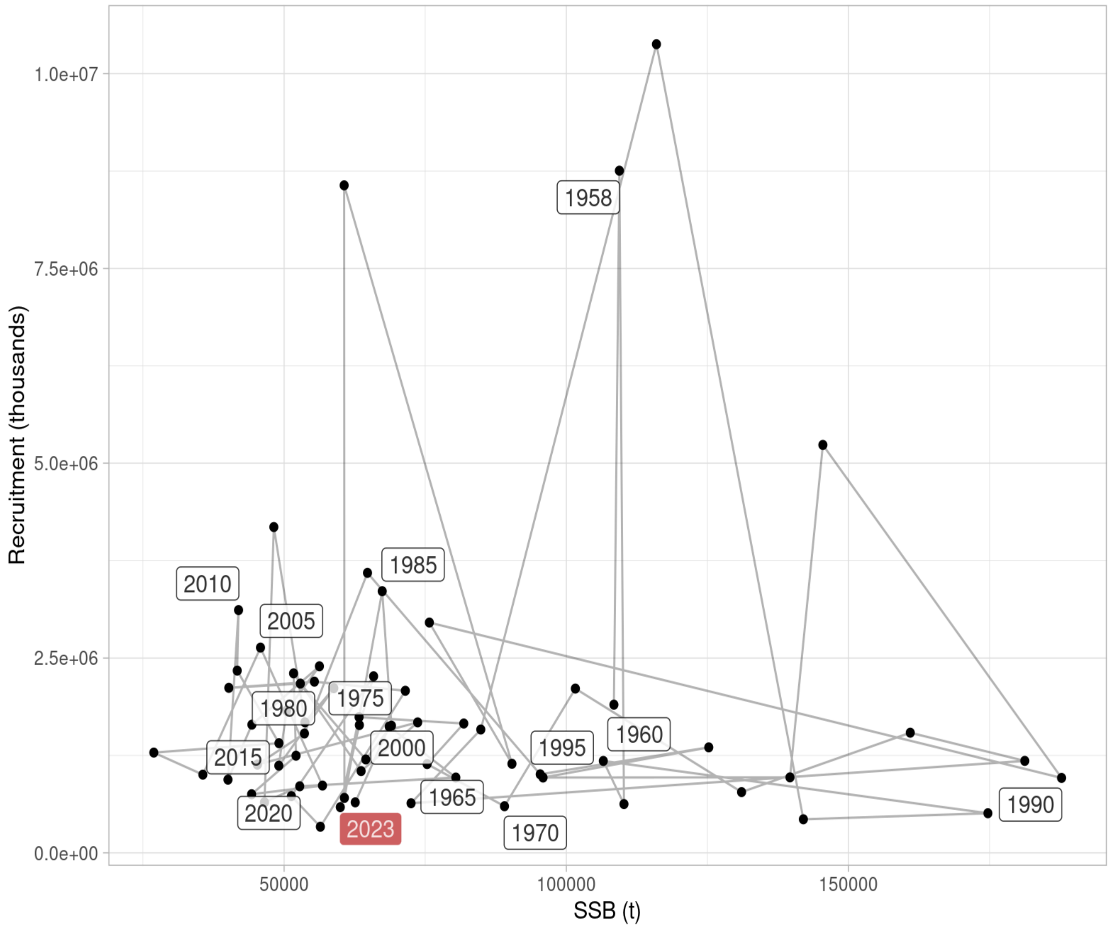

Figure 17.20. Sole in Subarea 4. Estimates of recruitment at age 0 (in thousands) and spawning biomass (in tonnes), connected in time. Labels refer to the year in which recruitment was observed.

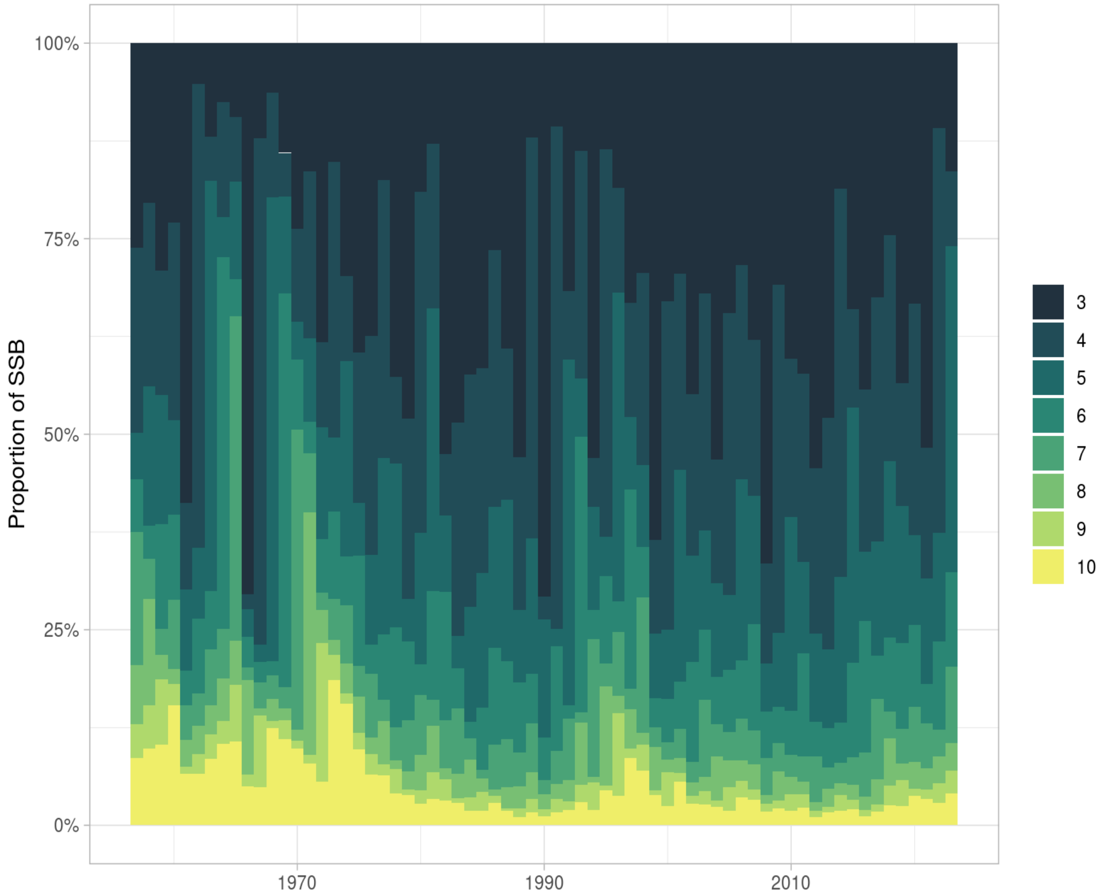

Figure 17.21. Sole in Subarea 4. Estimated proportions of spawning stock biomass by age and year.

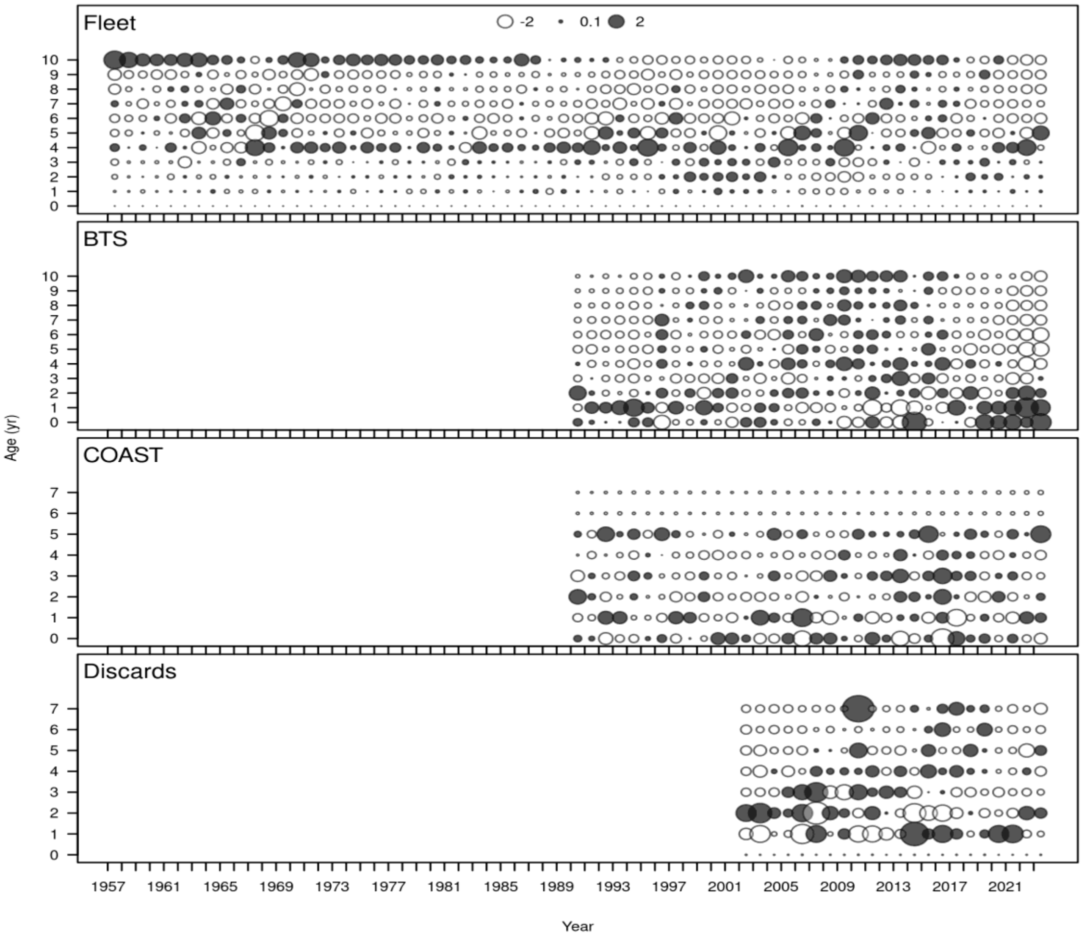

Figure 17.22. Sole in Subarea 4. Residuals of model fit to the four sources of data: BTS and COAST indices of abundance, landings-at-age (Fleet) and discards-at-age (Discards).

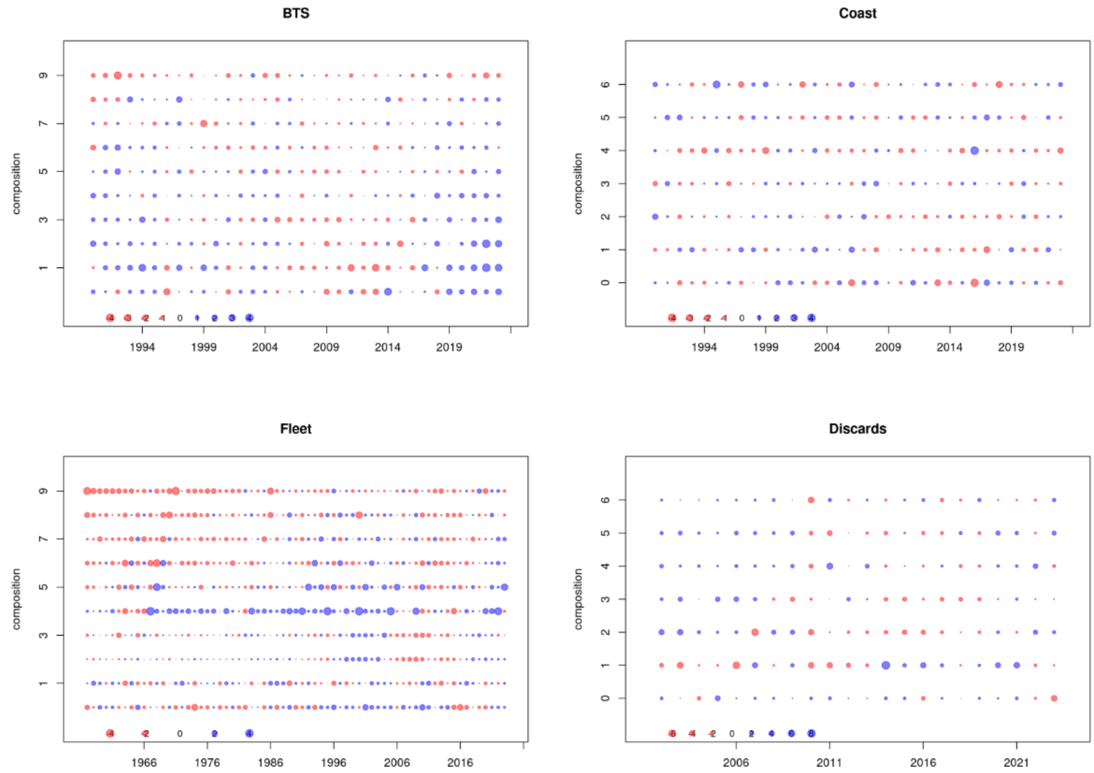

Figure 17.23. Sole in Subarea 4. One step ahead (OSA) residuals of model fit to the four sources of data: BTS and COAST indices of abundance, landings-at-age (Fleet) and discards-at-age (Discards).

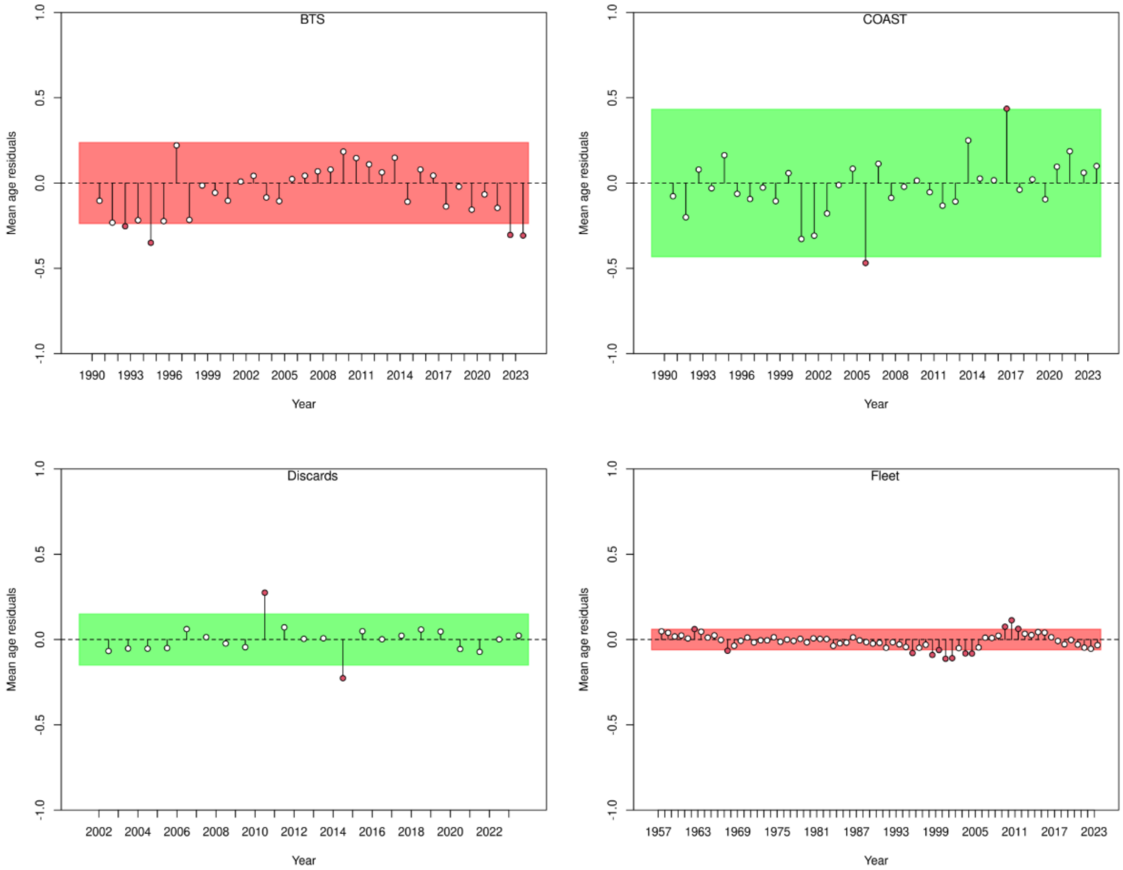

Figure 17.24. Sole in Subarea 4. Runs test of model fit to the mean age of the landings, discard and for the two indices of abundance: BTS and COAST. Green shading indicates no evidence and red shading evidence to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded area spans three residual standard deviations to either site from zero, and the red points outside of the shading violate the 'three-sigma limits' for that series.

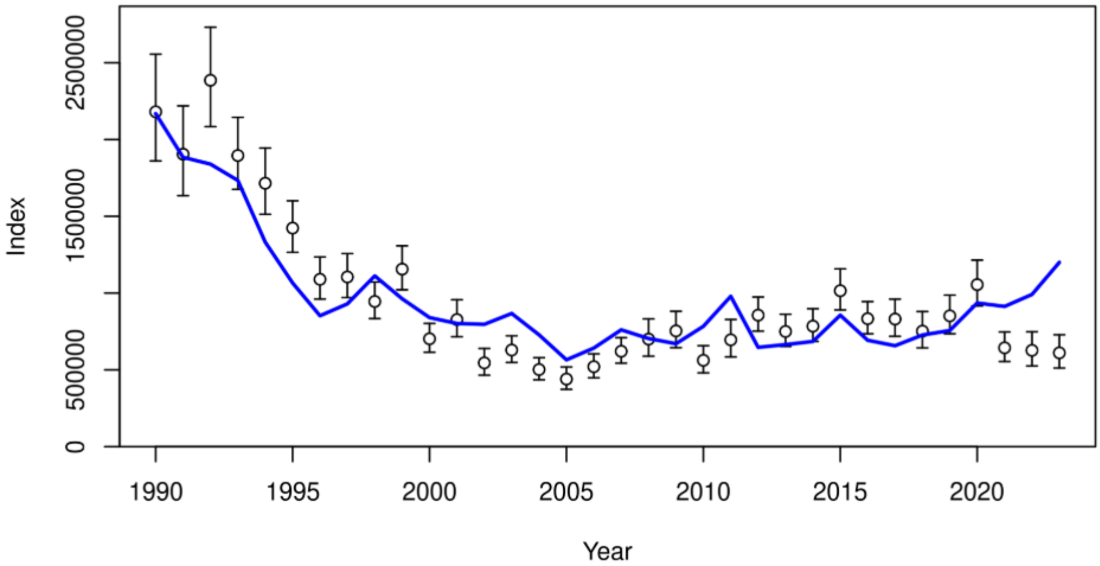

Figure 17.25. Sole in Subarea 4. Fit to the BTS index of abundance in biomass.

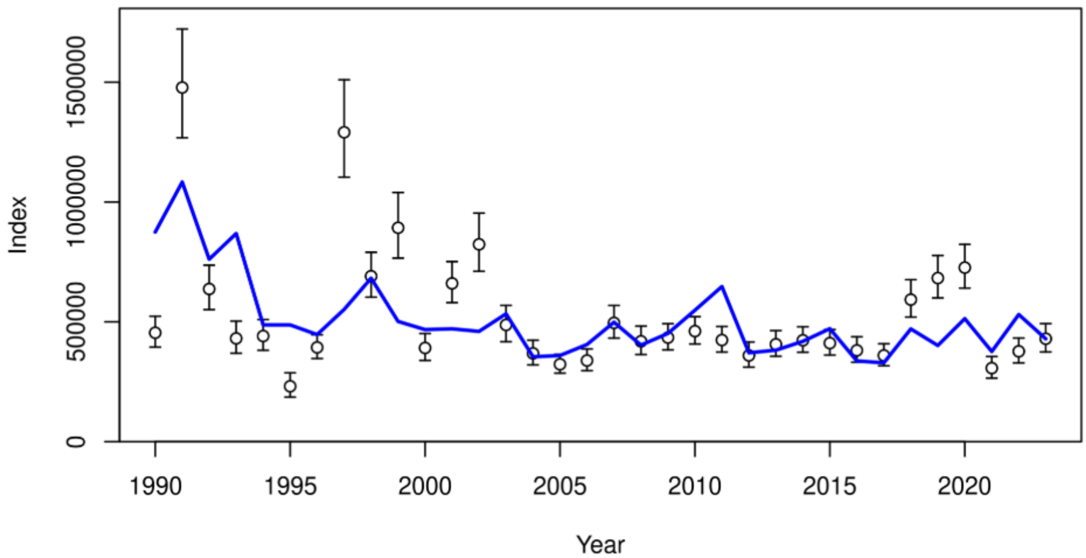

Figure 17.26. Sole in Subarea 4. Fit to the COAST (SNS + DYFS) index of abundance in biomass.

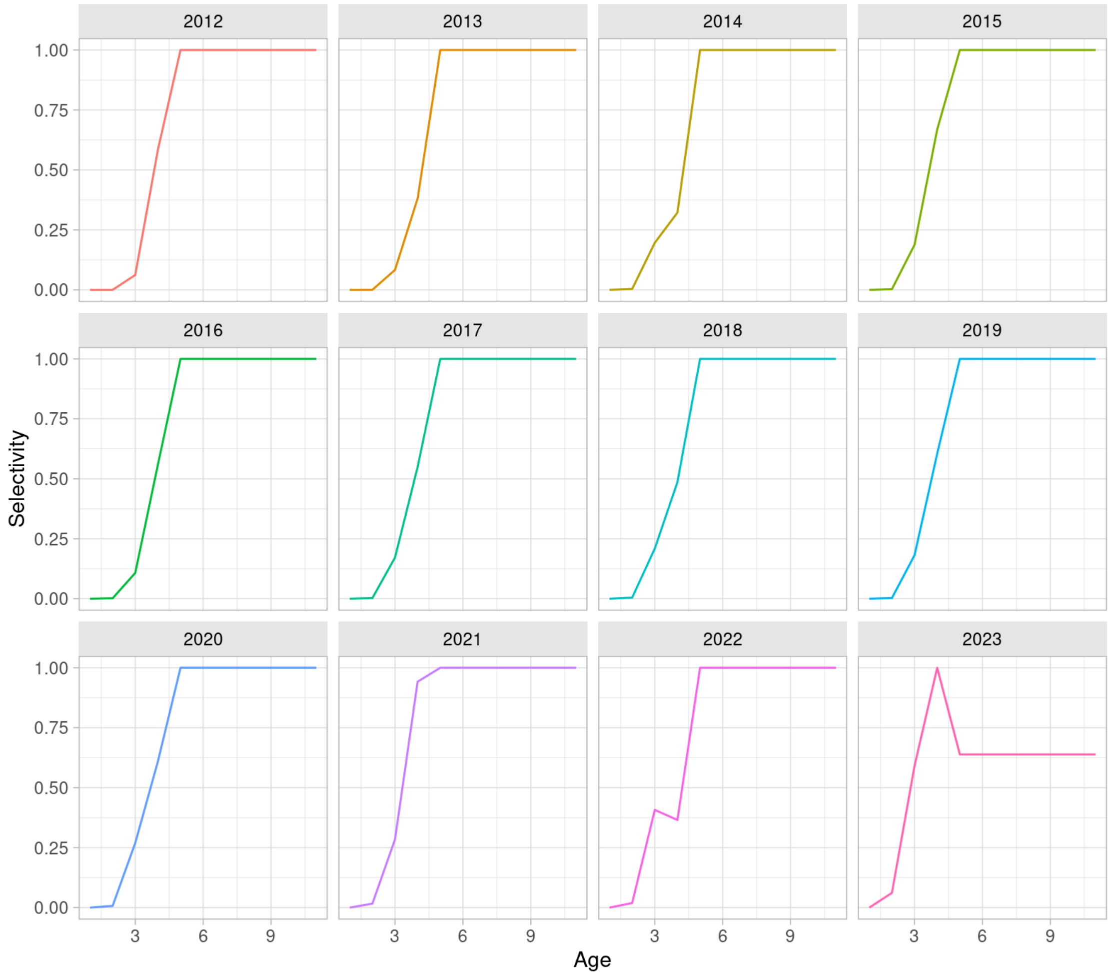

Figure 17.27. Sole in Subarea 4. Selectivity of the fleet at age for the period 2012–2023 as estimated by the SS3 model, with selectivity fixed to be constant from age 5 onwards.

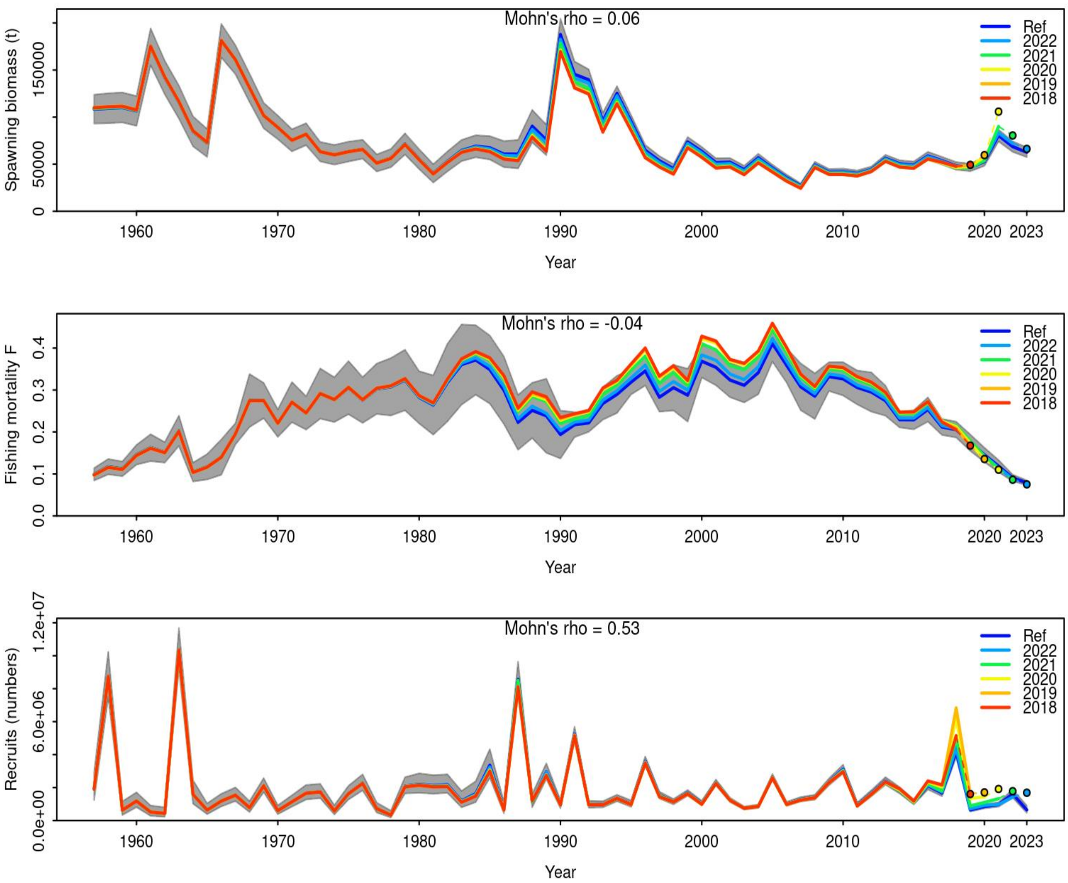

Figure 17.28. Sole in Subarea 4. Retrospective patterns in estimated age 0 recruitment, spawning stock biomass and mean fishing pressure, computed over five one-year steps.

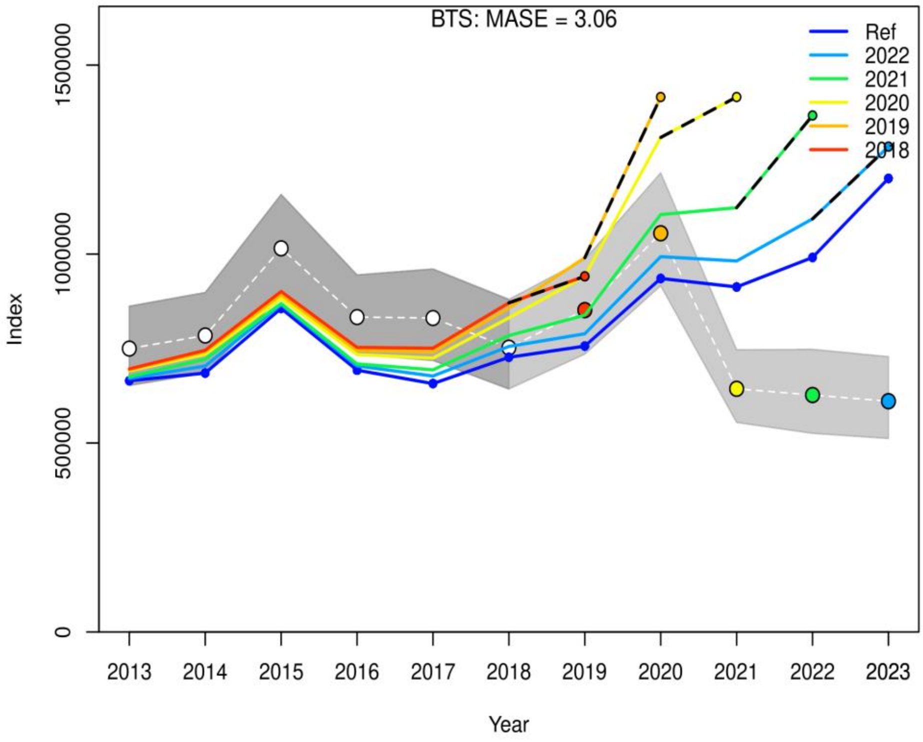

Figure 17.29. Sole in Subarea 4. Hindcasting cross-validation of the BTS index of abundance to estimate assessment model prediction skill.

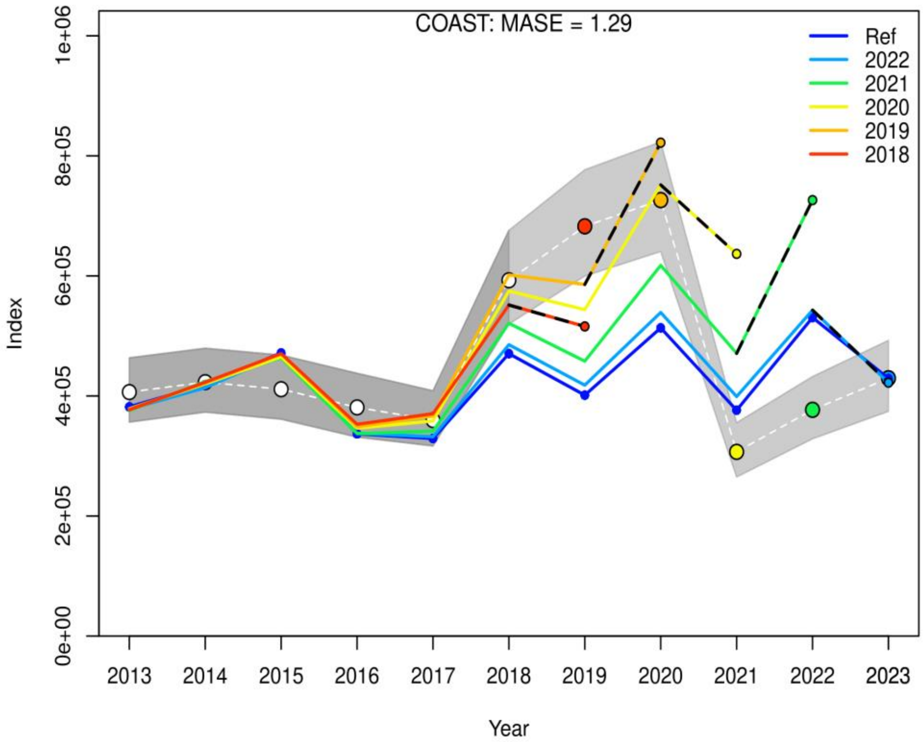

Figure 17.30. Sole in Subarea 4. Hindcasting cross-validation of the COAST index of abundance to estimate assessment model prediction skill.

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