Contents

3 Cod in Division 6.a

3.1 Introduction

The last benchmark for this stock was carried out in February 2020 (ICES, 2020). This resulted in a change of assessment method (TSA to SAM), inclusion of revised catch data from 2003 onwards and updated biological parameters.

The assessment presented here contains a number of deviations associated with the catch estimation process and input data to the approaches agreed at the benchmark and documented in the Stock Annex:

Processed UK VMS data have not been submitted in accordance with the ICES VMS data call deadline and hence were not available ahead of WGCSE. Furthermore, data access issues between UK administrations mean that raw UK VMS data are not directly available for the estimation of Scottish area misreported landings. This applies to data from 2021. Therefore, instead of using these data to estimate area misreported landings (as agreed at WKDEM, ICES, 2020a), the WG has again had to make use of estimates provided by Marine Scotland Compliance (MS-C, which were used by the WG prior to the 2020 benchmark). VMS data for 2019 and 2020 became available just prior to the WG meeting and hence could not be used to revise the previously used MS-C estimates. The MS-C estimates are used for 2019–2021.

In 2021, Scottish observer sampling from the *Nephrops* trawl fleet (OTB_CRU) was extremely limited due to COVID-19 disruption. This has resulted in an underestimate of total discards and unreliable estimates of catch numbers and mean weights-at-ages 1 and 2 which as a consequence have been excluded from the assessment. Sensitivity analysis suggests this has had minimal impact on the assessment (See Section 3.3 & 5.4 for further details and sensitivity analysis).

Due to vessel breakdown in 2022, the Scottish Q1 West Coast survey could not be carried out and hence there was no intermediate year survey included in this year's assessment. Sensitivity analysis suggests this has had minimal impact on the assessment (See Section 3.3 & 5.4 for further details and sensitivity analysis).

3.2 General

3.2.1 Advice

This stock has had zero catch advice since 2004. In recent years, this advice has typically been issued on a biennial basis.

3.2.2 Stock definition and the management unit

The general conclusion from recent workshops on cod stock ID in Division 6.a and the neighbouring North Sea (WK6aCodID; ICES, 2022 & WKNSCODID; ICES, 2020b) was that the current assessment units are not consistent with the stock structure.

WK6aCodID concluded that the available evidence supported a hypothesis of multiple overlapping subpopulations in Division 6a related to the Dogger genetic lineage (with linkage between 4a and 6a) with a separate subpopulation in the Clyde, associated with the Celtic genetic lineage and for which evidence for a link to Division 7a was presented.

The non-Clyde part of Division 6a is considered likely to consist of separate inshore and offshore Dogger subpopulations, but given the very limited data from parts of Division 6a, there remains uncertainty regarding the spatial extent of these. Genetic evidence for a link with the North Sea Dogger unit was supported by tagging data showing mixing between the northern part of a and the northwestern part of 4a in the North Sea.

The Clyde population, genetically associated with the Celtic unit, is different to elsewhere in Division 6a in terms of otolith microchemistry and demographics (maturity and SSB trends). This is confirmed by tagging data showing Clyde cod to be largely resident within the Clyde, with no mixing with other 6a subpopulation and limited exchange with the Irish Sea.

WK6aCodID considered it highly unlikely that it would be possible to collate sufficient appropriately disaggregated data to enable a separate Clyde stock assessment to be conducted in the near future. However, given the currently very minor contribution of Clyde cod catches to the overall catches from Division 6a, the impact of retaining the Clyde cod within a meta-population stock assessment (as part of the Inshore Dogger subgroup within 6a) is likely to be minor and was therefore recommended as a practical way forward for the short to medium term.

Within the North Sea, WKNSCODID (ICES, 2020b) concluded that there were separate Viking (northeast North Sea) and Dogger (remaining North Sea) genetic populations (with boundaries agreed), with the northern offshore component of Division 6a considered likely to be part of the latter.

A process for developing a combined spatial assessment for North Sea and West of Scotland cod, accounting for the substock structure is underway, and will conclude in 2023.

The management unit is ICES Divisions 6.a plus EU and international waters of Division 5.b to the east of 12°00'W. Prior to 2009, the TAC was set for ICES subareas 6, 12 and 14 plus Subdivision 5.b.1.

Recent management

The minimum conservation reference size of cod for human consumption in this area is 35 cm.

From 2012 to 2018, the TAC for cod in Division 6.a was set to zero with allowance for a bycatch of cod to be landed provided that it does not comprise more than 1.5% of the live weight of the total catch retained on board per fishing trip. From 2015, this provision was not allowed for catches subject to the landing obligation.

With the full implementation of the landing obligation in 2019 for fisheries catching cod, a bycatch TAC of 1735 t was set to allow mixed fisheries with a bycatch of cod to continue. In 2020, this TAC has been reduced to 1279 t. The agreed TAC has remained at this level in 2021 and 2022, although the quota share has changed (as agreed under the EU-UK Trade and Cooperation Agreement). A breakdown of these TACs by country can be found below.

TAC 2020

Species:	Cod *Gadus morhua*		**Zone:**	6a; Union and international waters of 5b east of 12°00′ W (COD/5BE6A)
Belgium	2	(1)	Analytical TAC	
Germany	19	(1)	Article 8 of this Regulation applies	
France	203	(1)	Article 3 of Regulation (EC) No 847/96 shall not apply	
Ireland	284	(1)	Article 4 of Regulation (EC) No 847/96 shall not apply	
United Kingdom	771	(1)		
Union	1 279	(1)		
TAC	1 279	(1)		

(1) Exclusively for by-catches of cod in fisheries for other species. No directed fisheries for cod are permitted under this quota.

TAC 2021

Species:	Cod *Gadus morhua*		Zone:	6a; United Kingdom and international waters of 5b east of 12°00′ W (COD/5BE6A)
Belgium	2	(1)	Analytical TAC	
Germany	12	(1)		
France	130	(1)	Article 3 of Regulation (EC) No 847/96 shall not apply	
Ireland	243	(1)	Article 4 of Regulation (EC) No 847/96 shall not apply Article 9 of this Regulation applies	
Union	387	(1)		
United Kingdom	892	(1)		
TAC	1 279	(1)		

(1) Exclusively for by-catches of cod in fisheries for other species. No directed fisheries for cod are permitted under this quota.

TAC 2022

Species:	Cod *Gadus morhua*		Zone	6a; United Kingdom and international waters of 5b east of 12° 00′ W (COD/5BE6A)
Belgium	2	(1)	Analytical TAC	
Germany	11	(1)	Article 9 of this Regulation applies	
France	117	(1)	Article 3 of Regulation (EC) No 847/96 shall not apply	
Ireland	219	(1)		
Union	349	(1)	Article 4 of Regulation (EC) No 847/96 shall not apply	
United Kingdom	930	(1)		
TAC	1 279	(1)		

(1) Exclusively for by-catches of cod in fisheries for other species. No directed fisheries for cod are permitted under this quota.

Technical measures applicable to the West of Scotland, including those associated with the cod recovery plan in force up to 2008 (Council Regulation No. 423/2004), the cod long-term management plan in force from 2009 (Council Regulation No. 1342/2008) were amended by Council Regulation No. 1243/2012. The management plan was further amended in 2016 by Council

Regulation (EU) 2016/2094 to cover the transitional period in which preparations are ongoing towards multiannual plans for multispecies fisheries. In 2018, the cod management plan was discontinued. Cod in Division 6.a is not included as a named target species in the EU multiannual plan for Western Waters (Council Regulation (EU) 2019/472).

3.2.3 The fishery in 2021

The table of official landings statistics is given in Table 3.1 and Figure 3.1. Official landings increased in 2021 (1209 t) compared to 2020 (983 t). Note that updates to official landings data for 2019 associated with national GDPR clauses means that data for this year are now incomplete. In 2021, over 75% of the official landings were reported by UK vessels, approximately 15 % by France with smaller amounts declared by Ireland and Spain. The majority of reported cod landings in Division 6.a are now taken in the far north of the area. In 2021, officially reported BMS (below minimum size) landings of cod in Division 6.a were less than half a tonne.

Due to restrictive TACs, seasonal/spatial closures of the fishery, and effort restrictions based on bycatch composition, the likelihood of misreporting and underreporting of cod in the past is considered to have been high. Underreporting is considered to have been reduced to low levels following the introduction of legislation in Ireland and the UK in 2006. However, area misreporting of cod landings from Division 6.a into Division 4.a (i.e. caught in Division 6.a., but declared in Division 4.a) and to a lesser extent Division 5.b, by the Scottish fleet is believed to occur. The UK legislation introduced in 2006 is also believed to be responsible for a significant increase in discards starting in 2006. Following the full implementation of the landing obligation (2019 onwards) for fisheries catching cod and the availability of a bycatch TAC rather than a 1.5% bycatch allowance, discard rates have been much reduced since 2019 although area misreporting continues to occur (albeit at an apparently lower level in recent years).

3.3 Data

Catch data

Area-misreported landings by the Scottish fleet have been considered to represent a considerable proportion of the total landings. One of the main focuses of the 2020 benchmark was deriving an objective approach for estimating area misreported landings based on an analysis of VMS data linked to daily logbook landings (WD 4.4, ICES, 2020a) rather than using estimates provided by Marine Scotland Compliance (MS-C) based on fishery observations and expert judgement (as used by the WG prior to the 2020 benchmark). However, UK VMS data for 2019 onwards have not been submitted in accordance with the VMS data call deadline and hence have not been available prior to WGCSE. Therefore, as in 2020 and 2021, the WG again had to revert to making use of area misreported landings estimates provided by MS-C. Figure 3.2 and Table 3.2 shows the time-series of estimates of area misreported landings (which come from the UKS large mesh demersal trawl fleet) alongside reported landings for Division 6.a. Total estimated area misreported Division 6.a cod landings in 2021 are 49 t. This represents a decline both in total weight of area-misreported landings and also a reduction in the proportion relative to total landings remains similar (<5 %). These landings are largely reported into Division 4.a, but assumed to actually be taken in Division 6.a. It is not clear why this sharp reduction has taken place. The approaches to identify area-misreporting used by MS-C have not changed since 2020. One explanation could be that an increase in quota share for 6a (for the UK) coupled with a highly restrictive N Sea cod quota have meant that there is less need/opportunity to area misreport across the 4 degrees west line.

The landings uploaded into InterCatch are shown in Figure 3.3 by métier and country, and discard proportions by weight shown in Figure 3.4. The French OTB_DEF≥120 métier is the largest metier with unsampled landings and represents 9% of the total landings in 2021.

In 2021, fishery sampling continued to be disrupted by the COVID-19 pandemic. Sampling of both landings and discards from the main fleet (Scottish OTB_DEF) remained at around half the number of trips in pre-pandemic years. While the number of samples was lower for this fleet, samples were available from both sources (landings and discards) with reasonable seasonal coverage. The most significant impact of the reduced sampling was on the number of samples and seasonal coverage of discard samples from the *Nephrops* trawl fleet (Scottish OTB_CRU). The number of samples from this fleet was around 25% of typical levels (four trips). This fleet usually has a discard rate of almost 100%, but none of the sampled trips caught (and discarded) any cod. Given that there have been no changes in selectivity devices used in the fishery that would result in a reduction in discards, it was considered that these trips were unlikely to be representative of the fishery as a whole and the estimates of zero discards were not uploaded into InterCatch.

Following an analysis of Scottish catch sampling data conducted at WKDEM (ICES, 2020a), it was agreed that for the purposes of allocated age compositions and discard rates, the area-misreported landings should be considered as 'sampled' landings and treated as part of the Scottish demersal trawl fleet. This is in contrast to previous assessment WGs where the area-misreported component was considered un-sampled and were assumed to have zero discards and landings age compositions consistent with the total sampled landings (i.e. all countries).

Due to the lack of discard sampling from the OTB_CRU fleet in 2021, discard proportions and landings and discard age distributions for all unsampled fleets were assigned from the only sampled fleets (Scottish & Irish OTB_DEF fleets) within InterCatch (representing a deviation from the Stock Annex). Allocated discard rates using this approach are shown in Figure 3.5 and estimated total catch by metier in Figure 3.6. The final mix of numbers-at-age from sampled and unsampled landings and sampled and raised (un-sampled) discards is given in Figure 3.7. An extremely small amount (<0.5 t) of below minimum size (BMS) landings was also reported, but is not shown. There is a noticeable lack of age 1 fish in the catch in 2021. Figure 3.8 shows the breakdown of catch numbers-at-age by fleet (OTB_DEF/OTB_CRU) and catch category (landings/discard) in 2021 compared to 2018–2020 (note that 2018 is pre-LO). The OTB_CRU fleet typically catches younger individuals than the OTB_DEF fleet and a significant proportion of the catch numbers-at-age 1 (and to a lesser degree age 2) in 2018–2020 are taken by the OTB_CRU fleet (grey colour in Figure 3.8). These are absent from the data in 2021. As a result, the WG concluded that total discards and catch numbers-at-age 1 and 2 for 2021 were likely to be underestimated due to the lack of samples from the OTB_CRU fleet.

Sampling levels (number of trips) by country are given below and compared to 2019. A limited number of Northern Irish samples are also available in 2020 and 2021. Sampling of the Scottish OTB_DEF landings has been quite poor in the recent past. The small sample sizes (which include a few very large fish with high raising factors) can result in a very high sum of products (SOP, landings-at-age x weight-at-age) for this fleet in some years.

		Scotland			Ireland
	Year	Demersal trawl (OTB_DEF)	*Nephrops* trawl (OTB_CRU)	Total	Total
2019	Landings	19	1	20	21
	Observer	22	18	40	28
2020	Landings	9	1	10	24
	Observer	10	4	14	5
2021	Landings	11	0	11	28
	Observer	9	0^	9	10

^ Four trips sampled with zero discards. Not used due to low confidence in estimates due to low sample size.

The WG estimates of total landings and discards are given in Table 3.2 and shown in Figure 3.9. The total discard proportion by weight is shown in Figure 3.10, and while this has increased somewhat in 2021 (~35%) compared to 2019 (9%), it remains well below the previous 3-year average. (2016–2018) when the discard proportion was estimated to be in excess of 70% of the total catch.

In contrast to the period 2006 to 2018 when there was substantial highgrading and discarding occurring (to some degree) over all age classes, during the years 2019 to 2021, discarding is mostly limited to ages 1 and 2 (and to a lesser degree age 3) (Figures 3.11 and 3.12). In 2021, there is a reduction in discard proportion at age 1 compared the previous ten years. However, given the lack of *Nephrops* discard sampling data (and the underestimate of discards at age 1), it seems unlikely that this apparent reduction is a true indication of changes in the fishery.

Age-compositions and weights-at-age

Raised landings numbers-at-age and discard numbers-at-age are given in Tables 3.3 and 3.5 respectively and total catch numbers-at-age in Table 3.7.

Annual mean weights-at-age in landings, discards and catch are given in Tables 3.4, 3.6 and 3.8. Figure 3.13 shows the mean weights-at-age in the landings and discards. The mean weight of age two and three fish in the landings increased since the mid-2000s in line with the increase in highgrading which occurred at these ages. Other age classes show fluctuations with a long-term downward trend particularly for ages 5 and above. Values at older age are noisy, particularly in recent years (most likely due to low sampling levels). Mean weight-at-age in the discards shows no real trend between 2006 and 2018. In 2020, there is a decline in mean weight-at-age in both the landings and discards at age 1. While the 2020 estimates remain well within historical values (and are not extreme), the lower discard mean weight could potentially be due to the lack of discard samples from quarter 2 onwards (i.e. after individuals have grown) from the *Nephrops* fleet which is typically the most important fleet for age 1 discards. (See above for COVID-19 samples disruption). The reason for the decline in mean weight-at-age 1 in the landings is harder to explain and potentially is noise related to low sample sizes or increased retention of smaller fish (due to the LO). In 2021, there is a substantial increase in mean discard weight (and subsequently catch weight) at age 1 and 2. Closer inspection of mean discard weights-at-age by fleet (Scottish data), Figure 3.14, suggests that this may be due to a lack of samples from the OTB_CRU fleet as this fleet generally catches smaller individuals (at age) than the OTB_DEF fleet. In addition, a number of very large age 1 fish were recorded in 2021 OTB_DEF samples which contribute to the high value. The WG agreed that these discard (and catch) mean weights-at-age in 2021 are therefore likely to be biased estimates.

Biological data

Given the trends in observed mean weights, WKDEM proposed the use of a temporally varying natural mortality would be more appropriate. The catch weights show high interannual variability (Figure 3.13) and therefore it was agreed to use smoothed catch weights as stock weights and then use these with the Lorenzen (1996) function with the 'natural' parameters to obtain natural mortality (WD 4.3, ICES, 2020a).

To derive the stock weights, a GAM is fitted to mean catch weights-at-age (Figure 3.14). Refitting the GAM each year results in typically minor revisions to stock weights used to estimate SSB between assessment years (and also natural mortality, WD 4.3, ICES, 2020a). Including the biased estimates of mean catch weight-at-age 1 and 2 in 2021 in the GAM has a significant impact on the estimated stock weights-at-age. The WG therefore agreed that these values should be excluded from the smoothing process for estimating stock weights, and stock weights-at-age 1 and 2 for 2021 should be set equal to the estimated values for 2020.

The catch mean weight-at-age 2 in 2019 remains a substantial outlier. At WGCSE 2020, the sampling data for 2019 were scrutinized in detail and the estimate could not be attributed to a particularly anomalous or influential sample and therefore the datapoint was considered valid (See ICES, 2020 for further details).

At all ages there is a general downward trend in catch weights (and hence stock weights) over time although with an apparent recent increase at ages 3 and 4. This results in increases in natural mortality, although at most ages the scale of this increase is very small (Figure 3.15). Stock weights and natural mortality are given in Tables 3.9 and 3.10.

The maturity ogive was also updated at WKDEM. An analysis of Scottish survey data (following the approach advocated by ICES, 2008) indicated a proportion of individuals at age 1 to be mature, but no temporal trend in maturity. A new ogive was therefore used for the full time-series (WD 4.2, ICES, 2020a).

Age	1	2	3	4	5	6	7+
WGCSE 2019	0	0.52	0.86	1.0	1.0	1.0	1.0
WKDEM/WGCSE 2020 onwards	0.27	0.53	0.48	0.91	0.97	0.99	1.0

Survey data

All available survey data are given in Table 3.11, with the data used in the assessment highlighted in bold. Survey descriptions are given in the stock annex. Since the inter-benchmark in 2019 (IBPCod6.a), the assessment makes use of three quarter four surveys (one of which is no longer current) and two quarter one surveys (one of which is discontinued). Survey indices for the two current Scottish surveys (UK-SCOWCGFS- Q1 and UK-SCOWCGFS- Q4) are provided with an estimate of variance.

The CPUE by survey haul for recent years for the two Scottish surveys (UK-SCOWCGFS- Q1 and UK-SCOWCGFS- Q4) are shown in Figure 3.16. Both surveys show mostly zero returns over latitudes between 56 degrees N and 58.5 degrees N. This pattern has been consistent in surveys since 2007. The Scottish surveys have highest catch rates to the north of 59 degrees N, in and around the closed area although these seem to have reduced in recent years (coincidental with a reduction in the size of the area closed to fishing, Figure 3.16). South of 56 degrees N, the Q1 surveys catch mostly young cod in the Clyde region. Occasional very large hauls associated with apparent aggregations of older cod (typically age 3 and above) have a significant impact on the survey indices and their variance estimates. In 2017, the indices for age four, five and six cod in the quarter one survey show particularly high uncertainty due to a single very large haul (Figure 3.16) of large cod with most other stations having very low or zero values. In 2018 (in the same survey), there were no large hauls and therefore the estimated variance is low. In 2019, the quarter one survey shows very low catch rates of ages >1 across the survey area, but relatively high catch rates (compared to recent years) of age 1 fish.

The quarter four survey estimates also have substantial uncertainty. This is particularly apparent in the 2016 survey with a CV of over 70% at age 4, and to a lesser degree in the 2018 survey with two hauls catching large numbers of individuals aged 4 to 6 and very low catches elsewhere, resulting in CVs of around 60% for these ages in this year.

Due to vessel breakdown the Scottish Q1 survey was not carried out in 2022.

A series of inshore and offshore Scottish industry–science surveys, known as the West Coast Demersal Fish (WCDF) project were conducted between December 2013 and November 2014. The initiative, funded by the Scottish Government and the European Fisheries Fund, was a joint venture between Marine Scotland Science and the Scottish Fishermen's Federation with the aim of improving the understanding of the current state of demersal stocks to the West of Scotland. The surveys show a broadly similar distribution to the UK-SCOWCGFS- Q1 and UK-SCOWCGFS-Q4 with bigger fish and increased abundance inside the Windsock compared to outside. Biomass estimates from these surveys and from the SIAMISS (anglerfish survey) were presented to WKDEM, but were considered too uncertain to provide useful information for the stock assessment.

3.4 Stock assessment

This assessment uses a SAM run as outlined in the stock annex. Exploratory analysis of the input catch and survey data are also carried out.

Data screening

Log catch (landings + discards) numbers-at-age over time (Figure 3.17) show good tracking of strong and weak cohorts historically. These signals become less apparent and more noisy after 2010, potentially due to low sampling levels and/or ageing errors. There is however, a clear indication of increasing numbers of older fish appearing in the catch since this time, which would be consistent with a reduction in fishing mortality. Catch curves from commercial catch-at-age data are also shown in Figure 3.17. Although the data are noisy, there is some evidence of a flattening off of the catch curves in recent years compared to those of the cohorts spawned in the late 1990s. Figure 3.17 shows that the log catch numbers-at-age 1 are by far the lowest of the time-series which supports the view that these are potentially biased (due to lack of OTB_CRU discard sampling).

A plot of log catch curve gradients derived from commercial catch data over different age ranges is shown in Figure 3.18. Here too there is some evidence of a decreasing mortality in recent years. (Note that these exploratory catch data plots are based on reported landings and discards and will be influenced in part by underreporting of landings in the 1990s and early 2000s).

Figure 3.19 shows the mean standardised catch-at-age by proportion (number). It shows good tracking of the strong cohorts as recently as the 2005 year class which shows well up to age 4.

More recently the data become rather noisy and since 2018, the proportion of the catch-at-age at age four and above are very high. These observations are not supported consistently by above average values at younger ages of the same cohort. Potentially this could be associated with a slight change in the distribution of the fishery and access to a previously closed area (illustrated in Figure 3.16) where a significant proportion of the older fish are located (Figure 3.16), however recent VMS data are unavailable and hence this hypothesis cannot be substantiated.

Figure 3.20 shows the log mean standardised indices from the ScoGFS-WIBTS-Q1 survey by year and by cohort. The early part of the time-series appears to track the cohorts relatively well with no obvious year effects. However, in later years the indices become noisier and there is some evidence of year effects in the survey. The survey ended in 2010. Figure 3.21 shows log catch curves for the ScoGFS-WIBTS-Q1 survey. It shows a strong "hook" at the younger ages (lower catchability), with abundance-at-age two often higher than at-age one. In later years survey abundance also shows increases from age 2 to age 3 in the same year class and the survey's ability to track recent cohorts seems poor relative to the 1990s and early 2000s. The survey scatterplots (Figure 3.22) show some consistency in the estimates of year-class strength across age classes (particularly the younger, adjacent ages), although less so at older ages. There is no trend in the log catch curve gradients derived from this survey that would be consistent with a change in mortality (Figure 3.23) for any of the age ranges considered.

Figure 3.24 shows the log mean standardised indices by cohort and year from the ScoGFS-WIBTS-Q4 survey. The survey shows reasonable tracking of cohorts at ages one to three and no particular evidence of year effects. This is also evident in the survey scatterplots which show reasonable correlation at younger ages (Figure 3.25). This survey catches very few fish at ages five and above.

Figure 3.26 shows the log mean standardised indices by cohort and year from the IRGFS-WIBTS-Q4. The log mean standardised indices plot shows consistent signals at ages 1 and 2 early in the time-series with no obvious year effects. The scatterplots (Figure 3.28) also show reasonable consistency between ages one and two, but the tracking at older ages is less strong. The data cover too few age classes sufficiently well to give an indication of trend in mortality through catch curve gradients (Figure 3.27).

Figure 3.29 shows log mean standardised indices by cohort and year from the UK-SCOWCGFS-Q1. Cohorts tracking within this survey is inconsistent and there is some evidence of survey year effects (2015, 2017 and 2019, particularly for older ages). There appeared to be a general increase in the catch rates of older ages over time to 2017 (four and above), but no equivalent increase in the catch rates of younger ages (from the same cohort). These declined significantly in 2018 and 2019.

The log catch curves from the UK-SCOWCGFS- Q1 are also very noisy (Figure 3.30) and typically do not show a decline as the cohort ages. The survey scatterplots show that even the catch rates of successive age classes (within the same cohort) show weak positive correlation (Figure 3.31).

Figure 3.32 shows log mean standardised indices by cohort and year from the UK-SCOWCGFS-Q4. There is some evidence of cohort tracking, but this is not consistent over time or ages and this is also apparent in the survey scatterplots shown in Figure 3.34. Figure 3.33 shows the log catch curves from the UK-SCOWCGFS-Q4 which are noisy and difficult to interpret given the short time-series and missing year of survey data.

Overall, information on mortality trends from all survey-series (including the ScoGFS-WIBTS-Q1) appears to be fairly poor due to the generally high variability and large CVs (ranging from 30% to 75% depending on age-class) for the two current Scottish surveys.

Figure 3.35 shows a comparison (between surveys) of log mean standardised survey indices at age over time (mean standardised over the common year range of all three surveys). The two

Scottish surveys show reasonable consistency over ages two to four, despite being noisy. The Irish survey also shows reasonable agreement at age two. At older ages (in the Scottish surveys), the general trends are similar, but show different interannual variations.

The inter-benchmark in 2019 agreed that all five surveys should be included in the final assessment (and this was followed at WKDEM in 2020), the basis being that the additional surveys show reasonable internal consistency and in addition, some between survey consistency. It was considered that the Irish survey could provide an additional indicator of year-class strength and could be useful as it covers the period during which there is a break in the Scottish survey indices. The lack of spatial coverage of this survey (only the southern part of Division 6.a) was deemed less important given the index is only being used to provide information on the younger ages.

Final assessment

The SAM configuration file for the final assessment model run is given in Table 3.12. To summarise the main features:

- Fishing mortality at ages 4 and above are assumed equal (See # Coupling of the fishing mortality states, Table 3.12).
- Survey catchabilities are mostly freely estimated for each age with the exception of the two oldest ages (i.e. no survey catchability plateau assumed). The exception to this is the WIBTS.Q1 for which all catchabilities are independently estimated.
- Catch observation variance parameters are allowed to differ for age 1 and age 7+ while other age groups are coupled (# Coupling of the variance parameters for the observations). To allow for greater uncertainty in the catch data for 2006 onwards (when the fishery changes from being a landings fishery to largely discards), the estimated catch observation error standard deviation is doubled for 2006 onwards (based on inspection of the one step ahead residuals).
- Survey observation variance parameters differ between surveys but are coupled for all age groups within a survey.
- Recruitment is modelled as a random walk.
- A catch scaling factor is estimated for 1995–2006 when underreporting of landings was considered significant.
- Fishing mortality across ages is modelled with AR(1) and process variance parameters coupled across all ages with the exception of age 1. Process variance in stock numbers-at-age were assumed coupled with the exception of age 1 (the age at recruitment).

Input data are derived as agreed at the 2020 benchmark with a number of exceptions:

- the use of MS-C estimates of area-misreported landings for 2019–2021 rather than estimates from VMS data (as per assessment WGs in 2020 and 2021). A comparison of VMS estimates and MS-C estimates carried out at WKDEM suggested VMS estimates were generally lower with some correlation between the two sets of estimates.
- The lack of an intermediate year survey (Q1 2022 data missing) due to vessel breakdown.
- The exclusion of age 1 and age 2 catch numbers-at-age due to concerns over bias (likely underestimated) due to lack of discard sampling from the OTB_CRU fleet.

Sensitivity analyses have been conducted to explore the potential impacts of the missing survey data and the exclusion of the catch data. (No further sensitivity analysis was carried out regarding the use of MS-C data since this approach has now been utilised at the past three assessment WGs).

Figure 3.36 shows a retrospective sensitivity analysis to the exclusion of the intermediate year data i.e. comparing previous years' assessments with and without these data included. While the intermediate year estimate of recruitment is sensitive to the inclusion (or not) of the intermediate year survey, the exclusion of the data does not result in major historical revisions to either recruitment, SSB or F. In addition, the analysis also suggests that the use of the intermediate year survey to estimate recruitment does not always provide a good estimate of recruitment (2020 value revised downwards) and that a resampled value (or GM) may in fact provide a better estimate.

The retrospective sensitivity analysis to the exclusion of the age 1 and age 2 catch in the final year also suggests that the assessment is relatively insensitive to the removal of these data in previous years (Figure 3.37) when compared to the assessment runs including all catch data (Intermediate year survey excluded from these assessment runs).

The fits of the model to observations (catch and survey indices on a log scale) are shown in Figures 3.38 to 3.43. The fits to the survey data appear better at younger ages while the model appears to follow the catch data better at ages 2 and above (age 1 observations are likely to be noisier due to uncertain discard estimates).

The standardised one step ahead residuals are shown in Figure 3.44. There are no major outliers in the residuals, with most lying within ±2. There are a few patterns apparent in the (discontinued) survey residuals which are rather similar to those observed in previous TSA assessments (ICES, 2019a & b) and at WKDEM (ICES, 2020): most notably some evidence of a tendency to more positive residuals in the latter half of the WCIBTS.Q1 (at age 1) and WCIBTS.Q4 (at age 2) and some year effects in most of the surveys (years with mostly positive or mostly negative residuals).

The model runs which leave out each survey index in turn are shown in Figure 3.45. With the exception of the period when total catches are excluded from the assessment (catch-scaling factor estimated for 1995–2006), the estimates of SSB and recruitment are relatively robust to the exclusion of the different survey series. Excluding the early Scottish Q4 survey (WCIBTS.Q4) results in higher estimates of SSB, recruitment and catch than the baseline run during this period (when catches area excluded) and excluding the early Scottish Q1 survey much lower estimates. When the WCIBTS.Q4 is excluded, estimates of mean F are lower than the baseline during the first part of this period (to 2000) and higher than the baseline after 2000 while excluding the WCIBTS.Q1 shows the opposite effect. The relative magnitude of the changes when each of these surveys are excluded suggests the WCIBTS.Q1 to be much more influential in the overall assessment of stock trends.

When the SCO.Q4 survey series is excluded there is a downward revision in the estimate of fishing mortality in the final year (although still within the confidence bounds of the estimate) while excluding either the SCO.Q1 or the Irish survey index appears to have little impact on the assessment results.

The retrospective analysis is shown in Figure 3.46. Although the Mohn's rho value for F is within the bounds advised by WKFORBIAS (ICES, 2020c), two of the peels lie outside the confidence intervals of the final assessment run. There appears to be some tendency to over-estimate F. The estimates of mean F appear to be substantially more noisy than SSB. The Mohn's rho values (as %) are as follows:

SSB	Mean F	Recruitment
-13.4	15.4	7.5

In contrast to previous assessments, the recruitment and SSB Mohn's rho do not include the intermediate year in each assessment peel (as this year's assessment does not include an intermediate year survey and hence SSB and R estimates are not available for this year from the assessment). The Mohn's rho in recruitment is therefore much lower than in previous years as the intermediate year estimate typically shows substantial revisions with the inclusion of additional years' data.

Final parameter estimates from the SAM run are given in Table 3.13. Table 3.14 gives the SAM population numbers-at-age and Table 3.15 the estimated F at-age. A full summary output is given in Table 3.16 (including model estimates of catch and catch scaling parameters).

Stock status

The summary plot including reference points is shown in Figure 3.47 and the stock–recruitment estimates are shown in Figure 3.48. The estimated SSB shows a steady downward trend until 2006, an increase to 2016 and then a further decline since then. Recruitment has been very low since 2001 and is extremely poor in 2016–2018 and also in 2021. Although fishing mortality declined between 2009 and 2016 to below F_{lim}, it has shown a slight increase since then and is estimated to be just above F_{lim} in 2020. It is not known whether, and to what extent, this increase is associated with the discontinuation of the days-at-sea regulation in 2017, which was part of the cod recovery plan.

Estimated SSB in the final year is well below B_{lim} (= 14 376 tonnes). Mean F is well above F_{MSY} and has been fluctuating around F_{lim} since 2013. Although the latest assessment shows a flattening off of F since 2013, there has been a clear decrease in mean F since 2009. The decline in mean F is proportionately similar (~50%) to the decline in STECF effort (large and small mesh demersal/crustacean trawl from both regulated and unregulated fleets), although the mean F does not start to decline until several years after the effort.

3.5 Short-term stock projections

Forecasting in SAM takes the form of short-term stochastic projections. A total of 10 000 samples are generated from the estimated distribution of survivors. These replicates are then simulated forward according to model and forecast assumptions (see below), using the usual exponential decay equations, but also incorporating the stochastic survival process (using the estimated survival standard deviation) and subject to different catch-options scenarios.

Some modification to the forecast assumptions has been necessary due to the data issues outlined above (lack of intermediate year survey in 2022 and unreliable catch data at age 1 and 2). Recruitment in the forecast has been resampled from the assessment estimates for 2016 to 2021. This choice was made due to an apparent further reduction in the level of recruitment in this period (usually a ten year window is chosen). The lack of an intermediate year (2022) recruitment estimate from the assessment (lack of intermediate year survey data) has meant a necessary change to the recruitment assumptions with the resampled recruitment also used for the intermediate year in this year's forecast.

Fishing mortality in the intermediate year (2022) was taken as a three-year average over 2019 to 2021 as an estimate of F status quo (given that there is no particular trend in mean F).

Cod in Division 6a has been fully under the landings obligation since 2019 when a bycatch TAC of 1735 t was set to allow mixed fisheries with a cod bycatch to continue (in contrast to a 0 t TAC with 1.5% bycatch regulation in previous years). For 2020 and 2021, the bycatch TAC was reduced to 1279 t. These increases in TAC (and the introduction of the LO) appear to have resulted in a significant change in discarding practices since 2019. The partition of catch into landing/discards components in the forecast is therefore based on a recent three-year average (2019–2021) with the exception of ages 1 and 2 for which the 2021 data are excluded due to the concerns regarding biases in the data for these ages due to lack of OTB_CRU discard samples. A similar approach is also taken for the derivation of forecast mean weights-at-age due to the likely biases in catch mean weights-at-age 1 and 2 in 2021 (See Section 3.3). A summary of the forecast assumptions is given in Table 3.17.

Under the forecast assumption of status quo F, landings in 2022 are predicted to be 1333 t and discards to be 540 t. The SSB in 2023 is forecast to be 2923 t which is well below B_{lim}. This value (2923 t) is similar to that forecast for 2023 from the assessment carried out in 2021 (3038 t) under fishing at F_{lim} (=0.73), similar to this year's 2022 intermediate year assumption.

The forecast under different catch scenarios for 2023 is shown in Table 3.18. Note that the values that appear in the catch scenarios are medians from the distributions that result from the stochastic forecast.

The forecast stock trajectory under the proposed advice for 2023 (shows an increase in SSB in 2024 (Figure 3.49). Figure 3.50 shows the contribution by recruitment year to SSB in 2024 and catch in 2023 (when fished at F_{MSY}). The assumption regarding recruitment in 2022 to 2024 contribute approximately 50% of SSB in 2024 and 15% of the 2023 catch. (Figure 3.50). These values are substantially higher than those reported last year due to the intermediate year recruitment being assumed (rather than an assessment estimate) in this year's forecast.

3.5.1 Reference points

Both MSY and precautionary reference points were reconsidered at WKDEM in February 2020 in accordance with ICES guidelines and are shown below (weights in tonnes). The estimate of F_{MSY} is derived from simulation based on segmented regression stock–recruitment only as both the Ricker and Beverton–Holt stock–recruitment relationships suggest peaks well outside the range of observed values. As in the estimates derived at IBPCOD.6A, yield is defined as catch above MCRS (estimated by assuming a historical discard rate prior to highgrading).

	WKMSYREF4	IBPCod.6a	WKDEM 2020	Rationale (WKDEM; ICES 2020a)
B_{lim}	14 000	14 000	14 376	Tonnes; SSB consistent with high probability of above average recruitment (SSB in 1992 as estimated by WKDEM)
B_{pa}	20 000	20 000	20 126	Tonnes; 1.4 x B_{lim}
F_{lim}	0.82	0.77	0.73	F with 50% probability of SSB<B_{lim}
F_{pa}	0.59	0.55	0.57^	Fp.05; the F that leads to SSB ≥ B_{lim} with 95% probability with ICES AR^
F_{MSY}	0.167	0.29	0.30	Based on simulation using a segmented regression stock–recruitment relationship (EqSim)
MSY $B_{trigger}$	20 000	20 000	20 126	B_{pa}
F_{MSY} upper	0.254	0.41	0.49	F at 95% MSY (above F_{MSY})
F_{MSY} lower	0.108	0.20	0.18	F at 95 % MSY (below F_{MSY})

^ Updated at WGCSE 2021 following guidance issued by ACOM. Fp.05 value derived at WKDEM 2020.

3.5.2 Management plans

Technical measures applicable to the West of Scotland, including those associated with the cod recovery plan in force up to 2008 (Council Regulation No. 423/2004), the cod long-term management plan in force from 2009 (Council Regulation No. 1342/2008) were amended by Council Regulation No. 1243/2012. The management plan was further amended in 2016 by Council Regulation (EU) 2016/2094 to cover the transitional period in which preparations are ongoing towards multiannual plans for multispecies fisheries. In 2018 the cod management plan was discontinued. Cod in Division 6.a is not included as a named target species in the multiannual plan for Western Waters i.e. only considered as a bycatch species (Council Regulation (EU) 2019/472).

3.6 Quality of the assessment

Figure 3.51 shows a comparison between this year's and previous year's assessments. The revised estimates of recruitment and SSB compared to pre-2020 assessments are largely the result of the inclusion of the updated historical catch data at WKDEM (ICES, 2020a). The benchmark changes to the assessment had only minor impact on the perception of the stock.

Landings

Since the early 1990s the most significant problem with the assessment of this stock is with commercial data. Incorrect reporting of landings, species, quantity and management area, is known to have occurred. Scottish landings (from 2006) are adjusted to include estimates of misreporting (in an attempt to reduce bias in the assessment) and in the five years, 2014–2018, area misreported landings accounted for over 50% of the total landings although that has reduced to around 20% in more recent years (and <5% in 2021). The misreporting estimates for 2019–2021have been provided by Marine Scotland Compliance based on intelligence and consideration of VMS data (i.e. vessel activity) due to a lack of access to UK VMS data for these years (See Sections 3.1 and 3.3). Estimates for earlier years are derived from VMS data analysis conducted at WKDEM (ICES, 2020a) and these are somewhat lower than MS-C estimates for those years.

Discards

Although discards have reduced significantly in recent years due to the availability of a bycatch TAC and the implementation of the LO, over the last three years discarding accounts for around 20% of the total catch. Despite an increase in sampling levels, discard estimates are still very uncertain (approximate CV = 50% for Scottish large mesh demersal fleet in 2017) contributing to uncertainty in the estimates of mean F.

In 2020 and 2021, discard sampling, and to a lesser extent landings sampling, has been disrupted due to the COVID-19 pandemic, with the most significant impact on the number of samples and seasonal coverage of discard samples from the *Nephrops* trawl fleet. Due to the lack of *Nephrops* fishery discard samples in 2021, total discards and catch numbers-at-age 1 and 2 are considered to be underestimated and not included in the assessment. This is likely to result in increased uncertainty in the estimates of recruitment in 2021.

Biological factors

Cod consumption by seals (derived from diet composition studies and seal abundance estimates) is estimated to be 7632 tonnes (95% CI: 3542–13 937) in 2010 (Hammond and Wilson, 2016) compared to a TSB estimate of just under 6000 tonnes from the SAM assessment and it has been suggested that seals may be impairing the recovery of this stock. However, there is uncertainty as to whether the seals are actually exploiting the same population as the fishery. Seal foraging mostly occurs on the continental shelf (Russell *et al*., 2017) including rocky areas which are unsuitable for trawl fishing and are not surveyed on RV trips, while most of the cod landings are taken along the continental shelf edge in the north of Division 6a (STECF, 2016) and thus the seals and fishery are largely operating in different areas. Given the complex stock structure and the presence of coastal cod populations, it is clear there is potential for the seals and fishery to be exploiting different substocks.

The final SAM assessment assumes natural mortality to be a function of stock weight-at-age (Lorenzen, 1996) which are in turn derived from smoothed catch weights-at-age. Natural mortality clearly remains a major source of uncertainty in this assessment and incorrect assumptions regarding its trend and magnitude can have a significant impact on estimates of stock status.

Stock structure

Stock structure is complex and a number of different subpopulations are known to occur within this area (WK6aCodID; ICES, 2022). The stock assessment therefore represents an assessment of multiple substocks with the northern component accounting for most of the landings since the mid-2000s. The survey distribution plots show that there is an almost complete absence of cod on the shelf in Division 6.a with the majority of the landings and stock concentrated in an area in the north of the region (around the closed area) bordering Division 4.a. A process is underway within ICES to develop a spatial assessment for Northern Shelf cod (North Sea plus Division 6a) which accounts more appropriately for this substock structure.

Assessment method

The benchmark agreed on the final SAM model configuration by comparing model residuals, AIC and retrospective patterns. There remain some patterns in the residuals particularly in the later surveys which are very noisy and the various sensitivity analyses conducted at WKDEM had little impact on these. Other assessment models also show similar problems. The retrospective analysis in the SAM shows overestimation of fishing mortality during the initial years of decline in mean F (although not persistent across all years of the retrospective analysis), which may suggest the model reacts slowly to changes in fishing mortality.

The input data for this cod assessment are particularly uncertain (both survey indices and commercial data) and as a result, the data can be interpreted in different ways by different assessment methods. The assessment presented by Cook (2019) and a number of exploratory assessments presented at WKDEM show a stock which by 2016 had recovered to levels consistent with those of the 1990s (although with a subsequent decline since then) while the SAM assessment shows little sign of SSB recovery. In this respect, the SAM assessment is very similar to the previous TSA and exploratory a4a assessments considered at the benchmark (ICES, 2020a). The key differences between the Cook (2019) model and the ICES assessment appears to be in the estimates of fishery selectivity and survey catchability and these result in substantial differences in stock trends. An extensive discussion on the plausibility of the estimates can be found in Section 4.3 of ICES (2020a).

Given these model uncertainties, estimates of uncertainty from the final SAM assessment are therefore unlikely to adequately reflect the true uncertainty in the estimates of stock biomass and fishing mortality for this stock.

3.6.1 Recommendation for next Benchmark

problem	solution	expertise necessary[1]	suggested time
Stock identity – multiple substocks within 6a and linkage with northern North Sea	Evaluate a possible merge between northern North Sea and 6.a cod stocks. Or as an alternative, split area 6.a in two areas North and South. Requires development of spatial SAM (or alternative) plus derivation of appropriate substock data sets as necessary (catch, survey & biological)	Scientists from MSS, Cefas & DTUAqua	Next benchmark although would need collaboration with WGNSSK.
Noisy survey data	Explore modelled indices using e.g. delta-logN approach and also modelled ALKs.	Scientists from MSS	Ahead of next benchmark.
Fishery selectivity pattern	Flat-topped & dome-shaped selectivity pattern both plausible – modelling the main fleets separately may help. Implement multifleet SAM assessment.	Scientists from MSS	Fleet-disaggregated data now available in InterCatch for 2003 onwards. Exploratory assessment to be put together ahead of next benchmark.
Assessment model uncertainty – different models with the same assumptions result in quite different stock status	Application of a multiple model approach.	Scientists from MSS	Could be explored as part of WKENSEMBLE. In preparation for next benchmark.

[1] MSS = Marine Scotland Science.

3.6.2 Management considerations

The fisheries for cod have been fully under the landing obligation from 2019 onwards. In the past they have been managed by a combination of landings limits, area closures and technical measures. The measures taken thus far have not recovered the stock. Although fishing mortality declined between 2009 and 2016, it has shown an increase since then. It is not known whether, and to what extent, this increase is associated with the discontinuation of the days-at-sea regulation in 2017, which was part of the cod recovery plan.

Cod are known to form aggregations, so it is still possible to find areas of high cod density at low stock abundance (as apparent in the Scottish Q1 survey in particular). This can lead to high caches in localized areas, generating high fishing mortality even with low fishing effort. The impact of this could potentially be reduced by the use of temporary spatial closures.

The fishing opportunities regulation explicitly made the stock a bycatch species from 2012 to 2018. Allowing landings up to 1.5% of the live weight of the total catch can cause a perverse incentive for vessels to increase catches of other species and does not inhibit the catch of cod.

Although the UK 'Buyers and Sellers' and Irish 'Sales Notes' legislation is considered to have reduced underreporting from 2006, discard data showed increased discards at-ages one and two and a change in discard practices such that fish are discarded at older ages from 2006–2018 (i.e. such that the discards were largely highgrading). With the full implementation of the landing obligation in 2019 for fisheries catching cod, a bycatch TAC of 1735 t was set to allow mixed fisheries with a bycatch of cod to continue. The fishery has responded to this by reducing discards, particularly at older ages. The forecast assumes that this discarding behaviour will continue in future. The bycatch TAC has been reduced to 1279 t for 2020 and 2021.

Estimates of area misreporting (landings believed to be taken in Division 6.a and reported elsewhere) imply ICES landings estimates that are in excess of TAC. Area misreported landings accounted for around 20% of the total landings in 2019–2021 which is a reduction on previous years.

Cod is taken in mixed demersal fisheries, and in Division 6.a is a bycatch species. To greatly reduce cod catch would likely result in having to greatly reduce harvesting of other stocks such as haddock, whiting and anglerfish. It is also important the bycatch from the *Nephrops* fleet is closely monitored (including discard observations). Typically, large trawl gear vessels targeting finfish are responsible for around 90% of cod catches in Division 6.a, the *Nephrops* fleet take approximately 4% and the remainder are taken by other gears, including longliners and gillnets. (Note that data for 2021 are unreliable due to lack of OTB_CRU discard sampling).

A report by the Sea Mammal Research unit (Hammond and Harris, 2006) gives estimates of cod consumed by grey seals to the west of Scotland. Although highly uncertain, the estimates suggest predation mortality on cod is significant and this may impair the ability of the cod stock to recover, but data are limited (Cook *et al.*, 2015).

Cod to the west of Scotland (6a.) are believed to comprise of at least two subpopulations and potentially linked to cod in the North Sea (4a). The current assessments and management do not capture this dynamic as they are treated independently.

3.7 References

Cook, R. M. 2019. Stock collapse or stock recovery? Contrasting perceptions of a depleted cod stock. ICES Journal of Marine Science. doi:10.1093/icesjms/fsy190.

Cook, R. M., Holmes, S. J. and Fryer, R. J. 2015. Grey seal predation impairs recovery of an over-exploited fish stock. J. Applied Ecol., 52(4), 969–979.

EU. 2008. COUNCIL REGULATION (EC) No. 1342/2008 of 18 December 2008 establishing a long-term plan for cod stocks and the fisheries exploiting those stocks and repealing Regulation (EC) No. 423/2004. Official Journal of the European Union, L 348/21. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:348:0020:0033:EN:PDF.

EU. 2016. COUNCIL REGULATION (EU) 2016/2094 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 November 2016 amending Council Regulation (EC) No 1342/2008 establishing a long-term plan for cod stocks and the fisheries exploiting those stocks.

Hammond, P. S., and Harris, R. N. 2006. Grey seal diet composition and prey consumption off western Scotland and Shetland. Final report to Scottish Executive Environment and Rural Affairs Department and Scottish Natural Heritage.

ICES. 2012. Report of the Benchmark Workshop on Western Waters Roundfish (WKROUND), 22–29 February 2012, Aberdeen, UK. ICES CM 2012/ACOM:49. 283 pp.

ICES. 2015. Report of the Inter-Benchmark Protocol of West of Scotland Roundfish (IBPWSRound), February–April 2015. ICES CM 2015/ACOM:37.

ICES. 2019. Inter-benchmark Workshop on West of Scotland Cod (6.a) (IBPCod6.a). ICES Scientific Reports. 1:13. 171 pp. http://doi.org/10.17895/ices.pub.4976.

ICES. 2020a. Benchmark Workshop for Demersal Species (WKDEM). ICES Scientific Reports. 2:31. 136 pp. http://doi.org/10.17895/ices.pub.5548.

ICES. 2020b. Workshop on Stock Identification of North Sea Cod (WKNSCodID). ICES Scientific Reports. 2:89. 82 pp. http://doi.org/10.17895/ices.pub.7499.

ICES. 2020c. 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.

ICES. 2021. Benchmark Workshop on North Sea Stocks (WKNSEA). ICES Scientific Reports. 3:25. 756 pp. https://doi.org/10.17895/ices.pub.7922.

ICES. 2022. Workshop on Stock Identification of West of Scotland Sea Cod (WK6aCodID; outputs from 2021 meeting). ICES Scientific Reports. 4:5. 24 pp. http://doi.org/10.17895/ices.pub.10031.

Lorenzen K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49, 627–647.

STECF. 2011. Scientific, Technical and Economic Committee for Fisheries. Evaluation of Fishing Effort Regimes Regarding Annexes IIA, IIB and IIC of TAC & Quota Regulations, Celtic Sea and Bay of Biscay (STECF-11-13).

STECF. 2011. Scientific, Technical and Economic Committee for Fisheries. Evaluation of Fishing Effort Regimes (STECF-13-13).

Scientific, Technical and Economic Committee for Fisheries (STECF) – Evaluation of Fishing Effort Regimes in European Waters - Part 2 (STECF-14-20). 2014. Publications Office of the European Union, Luxembourg, EUR 27027 EN, JRC 93183, 844 pp.

Table 3.1. Cod.27.6a. ICES official catch statistics.

Country	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Ireland	Netherlands	Norway	Spain	UK (E, W, N.I.)	UK (Scotland)	UK	Official BMS	Total
1985	48	-	-	7411	66	-	2564	-	204	28	260	8032	-		18613
1986	88	-	-	5096	53	-	1704	-	174	-	160	4251	-		11526
1987	33	4	-	5044	12	-	2442	-	77	-	444	11143	-		19199
1988	44	1	11	7669	25	-	2551	-	186	-	230	8465	-		19182
1989	28	3	26	3640	281	-	1642	-	207	85	278	9236	-		15426
1990	-	2	-	2220	586	-	1200	-	150	-	230	7389	-		11777
1991	6	2	-	2503	60	-	761	-	40	-	511	6751	-		10634
1992	-	3	-	1957	5	-	761	-	171	-	577	5543	-		9017
1993	22	2	-	3047	94	-	645	-	72	-	524	6069	-		10475
1994	1	+	-	2488	100	-	825	-	51	-	419	5247	-		9131
1995	2	4	-	2533	18	-	1054	-	61	16	450	5522	-		9660
1996	+	2	-	2253	63	-	1286	-	137	+	457	5382	-		9580
1997	11	-	-	956	5	-	708	2	36	6	779	4489	-		6992
1998	1	-	-	714	6	-	478	1	36	42	474	3919	-		5671
1999	+	+	-	842	8	-	223	-	79	45	381	2711	-		4289
2000	+	-	-	236	6	-	357	-	114	14	280	2057	-		3064
2001	2	-	-	391	4	-	319	-	39	3	138	1544	-		2440
2002	+	-	-	208	+	-	210	-	88	11	195	1519	-		2231
2003	-	-	-	172	+	-	120	-	45	3	79	879	-		1298
2004	-	-	2	91	-	-	34	-	10	-	46	413	-		596
2005	-	-	-	107	-	-	28	-	17	-	25	243	-		420
2006	-	-	1	108	2	-	18	-	30	-	14	318	-		491
2007	-	-	12	92	2	-	70	-	30	-	21	260	-		487
2008	-	-	1	82	1	-	58	-	65	-	6	232	-		445
2009	-	-		74	-	-	24	-	18	-	14	104	-		234
2010	-	-	-	60	-	-	49	-	21	-	4	115	-		249

Country	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Ireland	Netherlands	Norway	Spain	UK (E, W, N.I.)	UK (Scotland)	UK	Official BMS	Total
2011	-	-	-	49	-	-	41	-	8	-	3	107	-		208
2012	-	-	-	4	-	-	18	-	2	-	2	135	-		161
2013	-	-	-	3	-	-	14	-	24	-	1	130	-		172
2014	-	-	-	5	-	-	12	-	13	-	9	121	-		160
2015	-	-	-	11	-	-	17	-	59	-	-	-	168		256
2016	-	11	-	86	-	1	28	-	39	-	-	-	183		348
2017	-	1	-	119	-	-	19	-	14	-	-	-	200		352
2018	-	+	+	101	-	-	12	-	37	-	-	-	217		367
2019	-	-	-	142	-	-	^	-	47	31	-	-	1224	+	1443^
2020*	-	-	-	139	-	3	65	-	4	32	-	-	738	2	983
2021*	-	-	-	162	-	-	98	-	-	27	-	-	923	+	1209

*** Preliminary.**

+ < 0.5 tonnes.

^Incomplete/missing due to part of the data being unavailable under national GDPR clauses.

Table 3.2. Cod.27.6a. Landings (reported into 6a and area misreported), discards, BMS and catch (tonnes) estimates, as used by the WG (caton from InterCatch).

Year	Landings		Discards	BMS	Catch
	reported	misreported			
1981	23865		303		24168
1982	21511		571		22082
1983	21305		197		21503
1984	21272		329		21601
1985	18607		963		19570
1986	11820		263		12083
1987	18971		2388		21358
1988	20413		368		20781
1989	17169		2076		19246
1990	12175		571		12746
1991	10927		622		11549
1992	9086		1779		10865
1993	10314		139		10453
1994	8928		661		9588
1995	9439		141		9580
1996	9427		63		9489
1997	7034		499		7533
1998	5714		538		6252
1999	4201		69		4270
2000	2977		821		3798
2001	2347		92		2439
2002	2243		480		2722
2003	1292		60		1353
2004	573		78		651
2005	516		54		570
2006	470	34	461		965

Year	Landings		Discards	BMS	Catch
	reported	misreported			
2007	485	30	1651		2166
2008	460	102	1037		1598
2009	231	54	1287		1572
2010	239	119	1575		1933
2011	211	130	3867		4208
2012	162	65	1914		2141
2013	172	93	1870		2136
2014	161	234	3369		3764
2015	258	270	2498		3026
2016	336	272	1499		2108
2017	355	320	3519		4195
2018	378	613	2429		3419
2019	1489	571	204		2264
2020	941	332	307	2.5	1583
2021	1215	49	642	+	1907

+ < 0.5 tonnes.

Table 3.3. Cod.27.6a. Landings-at-age (thousands). Values for 2006 onwards include an adjustment for area misreporting.

	1	2	3	4	5	6	7+
1981	461	7016	3220	904	182	29	20
1982	1827	1673	3206	1189	367	111	33
1983	2335	4515	1118	1400	468	148	60
1984	2143	2360	2564	448	555	185	59
1985	1355	5069	1269	1091	140	167	79
1986	792	1486	2055	411	191	40	30
1987	7873	4837	988	905	137	56	26
1988	1008	8336	2193	278	210	39	20
1989	2017	1082	3858	709	113	69	33
1990	513	4024	432	924	170	23	11
1991	1518	1728	1805	188	266	70	23
1992	1407	1868	575	720	69	58	24
1993	328	3596	1050	131	183	24	36
1994	942	1207	1545	280	56	51	20
1995	753	2750	700	630	70	15	11
1996	341	2331	1210	247	204	31	13
1997	1414	1067	989	281	66	62	7
1998	310	3318	293	174	57	16	9
1999	132	884	1047	64	48	24	9
2000	765	532	211	231	15	12	13
2001	96	1241	155	63	52	3	4
2002	337	340	522	41	13	14	4
2003	53	487	93	120	7	2	2
2004	45	99	90	12	27	3	1
2005	37	124	46	40	7	6	0
2006	18	97	78	23	14	2	1
2007	7	170	53	28	2	3	2
2008	0	20	106	21	13	1	2
2009	1	9	10	40	6	1	0
2010	6	80	26	20	11	1	1
2011	0	29	51	18	4	6	1
2012	1	1	18	24	3	2	2
2013	0	8	7	39	9	2	1
2014	0	5	73	34	25	2	0
2015	0	44	40	29	21	19	1
2016	1	17	82	52	17	9	11

	1	2	3	4	5	6	7+
2017	0	13	52	47	46	13	3
2018	2	10	28	78	51	32	11
2019	9	21	129	89	142	57	13
2020	7	75	9	55	44	53	30
2021	1	29	228	49	47	8	12

Table 3.4. Cod.27.6a. Mean weight-at-age in landings (kg).

	1	2	3	4	5	6	7+
1981	0.55	1.166	2.839	4.923	7.518	9.314	10.328
1982	0.692	1.468	2.737	4.749	6.113	7.227	9.856
1983	0.583	1.265	2.995	4.398	6.305	8.084	9.744
1984	0.735	1.402	3.168	5.375	6.601	8.606	10.35
1985	0.628	1.183	2.597	4.892	6.872	8.344	9.766
1986	0.71	1.211	2.785	4.655	6.336	8.283	9.441
1987	0.531	1.312	2.783	4.574	6.161	7.989	10.062
1988	0.806	1.182	2.886	5.145	6.993	8.204	9.803
1989	0.704	1.298	2.425	4.737	7.027	7.52	9.594
1990	0.613	1.275	2.815	4.314	7.021	9.027	11.671
1991	0.64	1.095	2.618	4.346	6.475	8.134	10.076
1992	0.686	1.293	2.607	4.268	6.19	7.844	10.598
1993	0.775	1.316	2.94	4.646	6.244	7.802	8.409
1994	0.644	1.292	2.899	4.71	6.389	8.423	8.409
1995	0.606	1.148	2.857	4.956	6.771	8.539	9.505
1996	0.667	1.221	2.738	5.056	6.892	8.088	10.759
1997	0.595	1.21	2.571	4.805	6.952	7.821	9.63
1998	0.605	1.061	2.264	4.506	6.104	8.017	9.612
1999	0.691	1.039	2.194	4.688	6.486	8.252	9.439
2000	0.689	1.261	2.457	4.126	6.666	7.917	8.392
2001	0.654	0.988	2.679	4.568	5.86	7.741	9.386
2002	0.668	1.14	2.33	4.841	6.175	7.192	9.548
2003	0.659	1.046	2.272	3.82	5.932	8.022	8.681
2004	0.605	1.026	2.191	4.398	6.033	8.242	9.84
2005	0.75	1.109	2.425	3.969	4.775	6.616	10.214
2006	0.659	1.176	2.239	3.813	6.16	7.759	11.041
2007	0.728	1.127	2.592	4.322	6.503	7.738	8.83
2008	0.556	1.157	3.067	4.843	6.283	7.964	8.487
2009	0.974	2.038	2.861	4.781	6.004	8.327	9.137
2010	0.936	1.468	2.918	4.064	5.785	9.158	10.275
2011	0	1.804	2.811	4.51	5.842	6.528	9.837
2012	0.661	1.797	3.118	5.331	6.428	7.617	8.695
2013	0.957	1.368	2.933	4.075	6.135	7.144	9.842
2014	1.028	1.6	2.097	3.051	4.693	5.503	7.207
2015	0.914	2.406	2.958	3.844	5.455	5.558	9.158
2016	0.713	1.429	2.367	3.917	5.137	6.596	7.622
2017	0.902	1.229	2.063	4.533	5.616	5.081	9.243

	1	2	3	4	5	6	7+
2018	0.871	1.686	2.761	4.163	5.427	6.427	8.575
2019	0.857	1.159	2.962	4.242	5.461	7.045	8.841
2020	0.618	1.310	2.308	4.763	5.957	6.362	6.448
2021	0.908	1.207	2.760	3.518	5.443	7.316	7.377

Table 3.5. Cod.27.6a. Discard numbers-at-age (thousands).

	1	2	3	4	5	6	7+
1981	54	907	0	0	0	0	0
1982	1808	8	0	0	0	0	0
1983	843	25	0	0	0	0	0
1984	1088	11	0	0	0	0	0
1985	5188	114	0	0	0	0	0
1986	970	14	0	0	0	0	0
1987	14358	12	0	0	0	0	0
1988	231	1059	2	0	0	0	0
1989	6243	6	0	0	0	0	0
1990	4181	41	0	0	0	0	0
1991	2518	14	2	0	0	0	0
1992	7385	143	3	0	0	0	0
1993	279	84	1	0	0	0	0
1994	2743	6	0	0	0	0	0
1995	625	56	0	0	0	0	0
1996	191	50	0	0	0	0	0
1997	1521	34	0	0	0	0	0
1998	790	972	0	0	0	0	0
1999	230	5	0	0	0	0	0
2000	2882	33	0	0	0	0	0
2001	176	115	0	0	0	0	0
2002	1051	199	0	0	0	0	0
2003	124	27	7	0	0	0	0
2004	238	23	0	0	0	0	0
2005	127	22	0	0	0	0	0
2006	1058	45	25	2	3	1	0
2007	283	1321	46	35	2	3	0
2008	64	151	416	3	1	0	0
2009	590	157	116	146	8	7	0
2010	410	810	150	17	7	0	0
2011	303	579	1255	102	1	4	0
2012	1029	180	605	78	0	0	0
2013	2175	346	220	167	24	0	3
2014	913	948	644	116	45	2	0
2015	264	571	620	72	18	2	0
2016	1253	377	189	94	13	0	0
2017	240	429	912	223	43	5	0

	1	2	3	4	5	6	7+
2018	87	447	206	300	54	18	6
2019	248	112	49	6	1	0	0
2020	304	173	16	10	0	0	0
2021	6	174	131	1	6	0	0

Table 3.6. Cod.27.6a. Mean weight-at-age in discards (kg).

	1	2	3	4	5	6	7+
1981	0.135	0.326					
1982	0.314	0.392					
1983	0.223	0.374					
1984	0.298	0.435					
1985	0.178	0.346					
1986	0.267	0.305					
1987	0.166	0.37					
1988	0.296	0.283					
1989	0.332	0.59					
1990	0.132	0.454					
1991	0.245	0.351					
1992	0.22	1.03	2.382				
1993	0.239	0.812	3.723				
1994	0.24	0.365					
1995	0.203	0.256					
1996	0.226	0.389					
1997	0.321	0.328					
1998	0.23	0.367	0.59				
1999	0.294	0.299					
2000	0.28	0.421					
2001	0.248	0.417					
2002	0.263	1.021					
2003	0.311	0.6	0.388				
2004	0.261	0.576					
2005	0.242	0.483	0.803				
2006	0.276	1.346	2.786	3.501	6.242	5.581	11.151
2007	0.196	0.948	3.014	4.457	4.985	10.635	
2008	0.224	0.999	2.049	3.853	5.216		
2009	0.264	1.333	2.296	3.834	6.051	6.985	9.119
2010	0.273	1.274	2.268	3.218	3.245		
2011	0.266	1.072	2.213	2.993	4.891	4.168	
2012	0.142	1.118	2.179	3.222			
2013	0.125	1.155	2.11	3.05	5.029		6.269
2014	0.15	1.21	2.39	3.066	3.998	4.349	
2015	0.404	1.063	2.33	3.428	4.414	6.103	
2016	0.205	1.096	2.212	3.759	4.435		
2017	0.262	1.048	2.183	3.473	4.397	7.714	

	1	2	3	4	5	6	7+
2018	0.217	1.046	2.219	3.649	5.3	4.98	2.117
2019	0.226	0.548	1.397	2.318	3.516		
2020	0.167	0.922	3.199	4.763			
2021	0.708	1.348	2.821	4.309	5.175		

Table 3.7. Cod.27.6a. Total catch-at-age (thousands).

	1	2	3	4	5	6	7+
1981	515	7923	3220	904	182	29	20
1982	3635	1681	3206	1189	367	111	33
1983	3178	4540	1118	1400	468	148	60
1984	3231	2371	2564	448	555	185	59
1985	6543	5183	1269	1091	140	167	79
1986	1762	1500	2055	411	191	40	30
1987	22231	4849	988	905	137	56	26
1988	1239	9395	2195	278	210	39	20
1989	8260	1088	3858	709	113	69	33
1990	4694	4065	432	924	170	23	11
1991	4036	1742	1807	188	266	70	23
1992	8792	2011	578	720	69	58	24
1993	607	3680	1051	131	183	24	36
1994	3685	1213	1545	280	56	51	20
1995	1378	2806	700	630	70	15	11
1996	532	2381	1210	247	204	31	13
1997	2935	1101	989	281	66	62	7
1998	1100	4290	293	174	57	16	9
1999	362	889	1047	64	48	24	9
2000	3647	565	211	231	15	12	13
2001	272	1356	155	63	52	3	4
2002	1388	539	522	41	13	14	4
2003	176	514	100	120	7	2	2
2004	282	122	90	12	27	3	1
2005	163	146	46	40	7	6	0
2006	1076	143	104	25	17	3	1
2007	290	1492	100	64	5	6	2
2008	64	171	522	24	15	1	2
2009	591	166	126	186	14	8	1
2010	416	889	175	37	17	1	1
2011	303	608	1307	120	5	10	1
2012	1030	181	623	101	3	2	2
2013	2175	355	228	206	33	2	4
2014	913	953	717	149	70	4	0
2015	264	615	660	102	39	21	1
2016	1254	394	271	146	30	9	11
2017	240	442	963	270	89	18	3

	1	2	3	4	5	6	7+
2018	88	457	235	378	105	49	16
2019	256	132	178	95	142	57	13
2020	311	248	26	65	44	53	30
2021	6	203	359	50	53	8	12

Table 3.8. Cod.27.6a. Mean weight-at-age (kg) in total catch.

	1	2	3	4	5	6	7+
1981	0.506	1.07	2.839	4.923	7.518	9.314	10.328
1982	0.504	1.463	2.737	4.749	6.113	7.227	9.856
1983	0.488	1.26	2.995	4.398	6.305	8.084	9.744
1984	0.588	1.398	3.168	5.375	6.601	8.606	10.35
1985	0.271	1.165	2.597	4.892	6.872	8.344	9.766
1986	0.466	1.203	2.785	4.655	6.336	8.283	9.441
1987	0.295	1.31	2.783	4.574	6.161	7.989	10.062
1988	0.711	1.081	2.883	5.145	6.993	8.204	9.803
1989	0.423	1.294	2.425	4.737	7.027	7.52	9.594
1990	0.185	1.267	2.815	4.314	7.021	9.027	11.671
1991	0.394	1.089	2.615	4.346	6.475	8.134	10.076
1992	0.295	1.274	2.606	4.268	6.19	7.844	10.598
1993	0.529	1.304	2.941	4.646	6.244	7.802	8.409
1994	0.343	1.287	2.899	4.71	6.389	8.423	8.409
1995	0.423	1.13	2.857	4.956	6.771	8.539	9.505
1996	0.509	1.204	2.738	5.056	6.892	8.088	10.759
1997	0.453	1.183	2.571	4.805	6.952	7.821	9.63
1998	0.336	0.904	2.264	4.506	6.104	8.017	9.612
1999	0.439	1.035	2.194	4.688	6.486	8.252	9.439
2000	0.366	1.212	2.457	4.126	6.666	7.917	8.392
2001	0.391	0.94	2.679	4.568	5.86	7.741	9.386
2002	0.361	1.096	2.33	4.841	6.175	7.192	9.548
2003	0.415	1.023	2.14	3.82	5.932	8.022	8.681
2004	0.316	0.943	2.191	4.398	6.033	8.242	9.84
2005	0.356	1.014	2.425	3.969	4.775	6.616	10.214
2006	0.282	1.23	2.373	3.789	6.175	7.002	11.046
2007	0.209	0.969	2.788	4.397	5.726	9.174	8.83
2008	0.224	1.018	2.256	4.715	6.189	7.964	8.487
2009	0.266	1.372	2.342	4.039	6.03	7.222	9.111
2010	0.282	1.291	2.363	3.683	4.784	9.158	10.275
2011	0.266	1.107	2.237	3.221	5.722	5.507	9.837
2012	0.142	1.12	2.205	3.713	6.428	7.617	8.695
2013	0.125	1.16	2.137	3.243	5.336	7.144	7.145
2014	0.15	1.212	2.36	3.063	4.245	4.984	7.207
2015	0.405	1.159	2.368	3.548	4.964	5.612	9.158
2016	0.206	1.11	2.259	3.815	4.834	6.596	7.622
2017	0.263	1.053	2.177	3.656	5.032	5.746	9.243

	1	2	3	4	5	6	7+
2018	0.229	1.06	2.285	3.755	5.362	5.909	6.304
2019	0.248	0.644	2.532	4.112	5.450	7.045	8.841
2020	0.178	1.039	2.873	4.763	5.957	6.362	6.448
2021	0.730	1.327	2.782	3.534	5.413	7.316	7.377

Table 3.9. Cod.27.6a. Mean weight-at-age (kg) in stock.

	1	2	3	4	5	6	7
1981	0.496	1.262	2.888	4.854	6.932	8.447	10.100
1982	0.488	1.256	2.874	4.838	6.891	8.421	10.077
1983	0.480	1.250	2.859	4.821	6.849	8.394	10.054
1984	0.473	1.244	2.844	4.803	6.807	8.367	10.030
1985	0.465	1.238	2.827	4.783	6.766	8.340	10.008
1986	0.457	1.232	2.810	4.761	6.724	8.314	9.985
1987	0.450	1.225	2.793	4.738	6.682	8.287	9.961
1988	0.442	1.219	2.776	4.716	6.641	8.260	9.937
1989	0.434	1.213	2.760	4.696	6.599	8.232	9.912
1990	0.427	1.207	2.745	4.681	6.557	8.203	9.885
1991	0.419	1.201	2.729	4.671	6.514	8.173	9.857
1992	0.411	1.195	2.712	4.666	6.472	8.142	9.827
1993	0.404	1.188	2.691	4.665	6.429	8.109	9.796
1994	0.396	1.182	2.666	4.664	6.386	8.075	9.764
1995	0.388	1.176	2.636	4.660	6.342	8.038	9.731
1996	0.380	1.170	2.602	4.649	6.298	7.999	9.698
1997	0.373	1.164	2.564	4.628	6.254	7.957	9.664
1998	0.365	1.158	2.526	4.596	6.210	7.913	9.628
1999	0.357	1.152	2.489	4.553	6.165	7.866	9.591
2000	0.350	1.145	2.455	4.500	6.120	7.816	9.551
2001	0.342	1.139	2.426	4.440	6.075	7.764	9.509
2002	0.334	1.133	2.401	4.377	6.029	7.708	9.463
2003	0.327	1.127	2.381	4.310	5.983	7.650	9.412
2004	0.319	1.121	2.364	4.242	5.937	7.588	9.356
2005	0.311	1.115	2.350	4.172	5.891	7.524	9.294
2006	0.304	1.108	2.338	4.099	5.845	7.457	9.225
2007	0.296	1.102	2.326	4.023	5.799	7.387	9.147

	1	2	3	4	5	6	7
2008	0.288	1.096	2.315	3.944	5.752	7.313	9.061
2009	0.281	1.090	2.305	3.865	5.706	7.237	8.967
2010	0.273	1.084	2.298	3.790	5.660	7.159	8.865
2011	0.265	1.078	2.294	3.726	5.613	7.079	8.755
2012	0.258	1.072	2.295	3.678	5.567	6.997	8.640
2013	0.250	1.065	2.302	3.649	5.521	6.915	8.519
2014	0.242	1.059	2.317	3.643	5.475	6.834	8.395
2015	0.235	1.053	2.340	3.657	5.429	6.753	8.267
2016	0.227	1.047	2.373	3.690	5.383	6.673	8.137
2017	0.219	1.041	2.414	3.736	5.338	6.595	8.004
2018	0.212	1.035	2.462	3.791	5.292	6.518	7.870
2019	0.204	1.028	2.516	3.850	5.247	6.442	7.735
2020	0.196	1.022	2.574	3.912	5.202	6.367	7.599
2021	0.196	1.022	2.633	3.974	5.156	6.292	7.463

Table 3.10. Cod.27.6a. Natural mortality.

	1	2	3	4	5	6	7
1981	0.496	0.378	0.298	0.256	0.231	0.218	0.207
1982	0.498	0.379	0.298	0.256	0.231	0.218	0.207
1983	0.501	0.379	0.298	0.256	0.232	0.218	0.207
1984	0.503	0.380	0.299	0.257	0.232	0.219	0.207
1985	0.505	0.380	0.299	0.257	0.232	0.219	0.208
1986	0.508	0.381	0.300	0.257	0.233	0.219	0.208
1987	0.510	0.382	0.300	0.258	0.233	0.219	0.208
1988	0.513	0.382	0.301	0.258	0.234	0.219	0.208
1989	0.515	0.383	0.301	0.258	0.234	0.220	0.208
1990	0.518	0.383	0.302	0.259	0.235	0.220	0.208
1991	0.521	0.384	0.302	0.259	0.235	0.220	0.208
1992	0.524	0.384	0.303	0.259	0.235	0.220	0.209
1993	0.527	0.385	0.304	0.259	0.236	0.221	0.209
1994	0.529	0.386	0.305	0.259	0.236	0.221	0.209
1995	0.532	0.386	0.306	0.259	0.237	0.221	0.209
1996	0.536	0.387	0.307	0.259	0.237	0.221	0.209
1997	0.539	0.387	0.308	0.260	0.238	0.222	0.210
1998	0.542	0.388	0.309	0.260	0.238	0.222	0.210
1999	0.545	0.388	0.311	0.261	0.239	0.223	0.210
2000	0.549	0.389	0.312	0.262	0.239	0.223	0.210
2001	0.552	0.390	0.313	0.263	0.240	0.223	0.211
2002	0.556	0.390	0.314	0.264	0.240	0.224	0.211
2003	0.560	0.391	0.315	0.265	0.241	0.224	0.211
2004	0.564	0.392	0.315	0.266	0.241	0.225	0.212
2005	0.568	0.392	0.316	0.267	0.242	0.225	0.212
2006	0.572	0.393	0.316	0.269	0.243	0.226	0.212
2007	0.576	0.393	0.317	0.270	0.243	0.227	0.213

	1	2	3	4	5	6	7
2008	0.580	0.394	0.317	0.272	0.244	0.227	0.214
2009	0.585	0.395	0.318	0.273	0.244	0.228	0.214
2010	0.590	0.395	0.318	0.275	0.245	0.229	0.215
2011	0.595	0.396	0.318	0.276	0.245	0.229	0.216
2012	0.600	0.397	0.318	0.277	0.246	0.230	0.217
2013	0.605	0.397	0.318	0.278	0.247	0.231	0.217
2014	0.610	0.398	0.317	0.278	0.247	0.232	0.218
2015	0.616	0.399	0.316	0.278	0.248	0.233	0.219
2016	0.622	0.399	0.315	0.277	0.248	0.233	0.220
2017	0.628	0.400	0.313	0.276	0.249	0.234	0.221
2018	0.635	0.401	0.312	0.275	0.250	0.235	0.222
2019	0.642	0.401	0.310	0.274	0.250	0.236	0.224
2020	0.649	0.402	0.308	0.272	0.251	0.237	0.225
2021	0.649	0.402	0.306	0.271	0.252	0.237	0.226

Table 3.11. Cod.27.6a. Survey data made available to the WG. Data used in update assessment are highlighted in bold. For the Scottish surveys, numbers are standardised to catch rate per ten hours. For the Irish surveys, effort is given as minutes towed and numbers are in units.

ScoGFS- WIBTS- Q1: **Scottish west coast groundfish survey (ages 1–6 used)**

Effort (Hrs)	1	2	3	4	5	6	7	
10	1.5	23.7	8.6	13.6	3.9	2.5	1.2	1985
10	1.5	6.9	26.8	5.6	7.3	2.5	1.9	1986
10	57.4	16.2	15.3	22.8	3.0	2.8	0.0	1987
10	0.0	64.9	14.2	3.4	2.1	0.7	0.2	1988
10	4.5	7.2	45.1	8.6	1.9	0.5	0.8	1989
10	2.0	24.6	4.1	14.7	4.2	1.6	0.8	1990
10	4.8	5.4	17.4	5.2	13.4	2.8	0.5	1991
10	7.3	11.5	5.4	7.6	3.4	2.3	0.5	1992
10	1.7	38.2	12.7	1.7	1.4	1.1	0.0	1993
10	13.6	14.7	25.1	5.8	1.0	0.0	0.0	1994
10	6.4	23.8	14.0	16.5	1.2	1.9	0.7	1995
10	2.8	20.9	24.1	4.1	2.8	1.3	0.0	1996
10	11.1	7.7	11.6	7.9	4.2	4.7	1.0	1997
10	2.8	30.9	5.3	8.7	3.7	0.6	2.0	1998
10	1.5	8.2	8.2	1.4	3.2	0.5	0.5	1999
10	13.3	**5.4**	**6.9**	**1.3**	0.0	0.4	0.0	2000
10	2.7	18.4	5.7	13.2	19.5	1.1	1.6	2001
10	5.3	4.3	10.6	2.6	0.5	3.0	0.0	2002
10	2.7	16.7	2.0	4.7	1.8	0.7	0.4	2003
10	5.7	3.0	5.6	2.3	1.7	0.0	0.0	2004
10	1.3	1.5	1.2	0	0	0.4	0	2005
10	2.2	1.9	1.1	0.3	0	0	0.3	2006
10	2.1	18.8	3.4	1.2	0	0.6	0	2007
10	0.8	2.1	44.2	6.3	0.8	0	0	2008
10	1.8	2.6	2.3	0.4	0	0	0	2009
10	4.6	16.2	3.7	1.0	0.7	0	0	2010

Table 3.11. Continued. Cod.27.6a. Survey data made available to the WG. For the Scottish surveys, numbers are standardised to catch rate per ten hours. For the Irish surveys, effort is given as minutes towed and numbers are in units.

UK-SCOWCGFS-Q1 (index) (ages 1–6 used)

Effort (Hrs)	1	2	3	4	5	6	7	8
10	0.52	32.95	21.07	0.93	0.98	0.74	0.00	2011
10	13.99	27.30	22.72	4.58	3.50	2.20	4.20	2012
10	20.03	40.26	26.38	36.95	7.76	0.30	0.00	2013
10	11.40	41.73	13.44	5.12	4.31	0.75	0.00	2014
10	8.16	36.40	70.70	37.74	23.25	13.00	2.47	2015
10	4.73	56.07	65.41	44.56	5.67	2.36	2.29	2016
10	2.92	33.49	50.58	49.58	156.64	10.71	24.89	2017
10	1.728	20.375	7.199	19.765	9.98	2.261	1.092	2018
10	9.924	4.173	6.888	2.031	3.181	0.318	0.318	2019
10	14.433	28.978	11.516	9.782	1.176	0.646	0.0	2020
10	1.175	12.137	22.988	2.946	2.519	1.236	0.0	2021

UK-SCOWCGFS-Q1 (variance)

Effort (Hrs)	1	2	3	4	5	6	7	8
10	0.09	78.37	24.06	0.22	0.49	0.30	0.00	2011
10	44.18	120.08	33.73	2.31	8.34	4.83	13.02	2012
10	118.35	151.04	136.89	240.05	6.47	0.09	0.00	2013
10	20.17	383.27	12.23	3.04	5.47	0.28	0.00	2014
10	14.35	112.82	1264.73	602.27	289.82	98.91	5.48	2015
10	1.81	214.42	607.48	319.21	5.02	1.60	1.85	2016
10	1.43	155.67	498.57	1061.90	20475.95	84.79	287.62	2017
10	1	24.03	2.21	20.09	7.46	0.5	0.25	2018
10	6.79	2.03	6.12	0.6	1.98	0.1	0	2019
10	121.47	65.29	14.48	24.01	0.46	0.22	0	2020
10	1.03	10.19	31.36	1.35	0.92	0.37	0.13	2021

Table 3.11. Continued. Cod.27.6a. Survey data made available to the WG. For the Scottish surveys, numbers are standardised to catch rate per ten hours. For the Irish surveys, effort is given as minutes towed and numbers are in units.

IreGFS **Irish groundfish survey**

1993	**2002**				
Effort (Hrs)	0	1	2	3	
1849	0.0	312.0	49.0	13.0	1993
1610	20.0	999.0	56.0	13.0	1994
1826	78.0	169.0	142.0	69.0	1995
1765	0.0	214.0	89.0	18.0	1996
1581	6.0	565.0	31.0	10.0	1997
1639	0.0	83.0	53.0	6.0	1998
1564	0.0	24.0	14.0	3.0	1999
1556	0.0	124.0	4.0	1.0	2000
755	3.0	82.0	28.0	2.0	2001
798	0.0	50.6	2.2	1.2	2002

ScoGFS-WIBTS-Q4: **Quarter 4 Scottish ground fish survey (ages 1x4 used)**

1996	**2010**									
Effort (Hrs)	0	1	2	3	4	5	6	7	8	
10	0	0.7	14.4	5	3	1.1	0.5	0	0	1996
10	1	10.9	2.4	1.4	1.4	1.4	0.2	0	0	1997
10	+	14.8	9.7	1.1	0	0	0	0	0	1998
10	2	4	6	9.2	0.5	0	0	0	0	1999
10	0	15.8	2.6	0.4	0.4	0	0	0	0	2000
10	1	1.7	7.3	1.7	0.3	0	0	0	0	2001
10	1	10.4	2.8	6.8	0.6	0	0	0	0	2002
10	1	1.5	11.3	2.9	0.6	0	0	0	0	2003
10	0	5.1	3.8	1.4	0	0.7	0	0	0	2004
10	+	2.1	3	0	0.6	0.3	0	0	0	2005
10	0	16.9	5.9	1.4	0.7	0	0	0	0	2006
10	0	12	20	1.3	0.5	0	0.3	0	0	2007
10	2	7.7	5	7	1	0	0	0	0	2008
10	2	14.2	3.8	1.2	1.2	0.3	0	0	0	2009
10	na	na	na	na	na	na	na	na	na	2010

Table 3.11. Cont. Cod.27.6a. Survey data made available to the WG. For the Scottish surveys, numbers are standardised to catch rate per ten hours. For the Irish surveys, effort is given as minutes towed and numbers are in units.

UK-SCOWCGFS-Q4 (index) (ages 1–6 used)

Effort (Hrs)	0	1	2	3	4	5	6	7	8	
10	0.60	9.71	31.54	10.88	0.93	1.70	2.38	0.00	0.00	2011
10	0.75	19.78	7.12	15.43	13.60	1.02	0.68	0.34	0.00	2012
Survey not completed due to mechanical issues										2013
10	1.67	23.65	28.06	15.63	5.57	6.63	1.37	0.00	0.00	2014
10	3.64	28.17	52.53	34.22	10.58	4.24	5.27	1.18	0.59	2015
10	0.374	6.162	34.941	45.443	118.92	14.893	5.773	3.176	0	2016
10	2.127	10.024	6.221	24.427	10.881	8.538	0.767	0.511	0	2017
10	0	4.569	15.945	4.809	39.902	29.022	10.887	0.829	0	2018
10	0.351	17.65	1.402	3.246	3.457	1.814	0.627	0.363	0	2019
10	0.601	15.988	24.873	3.472	4.936	1.35	0.783	0.392	0	2020
10	0.863	9.348	89.12	14.769	0.392	1.822	1.158	0.256	0	2021

UK-SCOWCGFS-Q4 (variance)

Effort (Hrs)	0	1	2	3	4	5	6	7	8	
10	0.21	31.08	38.07	5.78	0.19	1.56	4.79	0.00	0.00	2011
10	0.14	41.72	2.79	11.37	48.79	1.05	0.46	0.12	0.00	2012
Survey not completed due to mechanical issues										2013
10	0.68	132.97	56.62	44.17	3.87	4.79	0.39	0.00	0.00	2014
10	5.55	98.78	316.23	51.22	8.60	4.43	4.61	0.34	0.12	2015
10	0.14	7.394	419.36	716.38	7654.82	118.64	24.30	6.08	0	2016
10	3.215	11.252	3.816	76.154	14.262	8.928	0.207	0.063	0	2017
10	0	3.71	28.22	8.46	532.1	271.49	44.45	0.39	0	2018
10	0.03	88.63	0.43	1.86	2.6	0.67	0.39	0.13	0	2019
10	0.36	14.8	16.12	1.84	6.76	0.71	0.61	0.15	0	2020
10	0.25	9.38	4509.27	50.26	0.15	0.28	0.26	0.07	0	2021

Table 3.11. Continued. Cod.27.6a. Survey data made available to the WG. For the Scottish surveys, numbers are standardised to catch rate per ten hours. For the Irish surveys, effort is given as minutes towed and numbers are in units.

IRGFS-WIBTS-Q4 Irish West Coast groundfish. (ages 1–3 used)

Effort (Hrs)	0	1	2	3	4	
1127	0	10	11	0	0	2003
1200	0	24	10	1	0	2004
960	63	13	7	0	2	2005
1510	0	95	12	0	0	2006
1173	0	161	12	0	1	2007
1135	0	23	24	4	0	2008
1378	1	75	4	5	0	2009
1291	0	70	31	4	3	2010
1287	1	26	26	4	0	2011
1230	0	74	7	3	0	2012
1295	0	92	11	0	0	2013
1200	0	113	20	2	0	2014
1213	0	15	11	3	0	2015
962	0	27	23	2	0	2016
1196	0	2	17	7	2	2017
966	1	21	3	0	1	2018
1291	0	36	1	0	0	2019
805	6	4	6	2	0	2020
1015	0	15	14	18	4	2021

Table 3.12. Cod.27.6a. SAM configuration file.

```
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 1

$maxAge
# The maximum age class in the assessment
 7

$maxAgePlusGroup
# Is last age group considered a plus group for each fleet (1 yes, or 0 no).
 1 0 0 0 0 0

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
  0  1  2  3  3  3  3
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, 2 AR(1), 3 separable AR(1).
 2

$keyLogFpar
# Coupling of the survey catchability parameters (normally first row is not used, as that is covered by fishing mortality).
 -1 -1 -1 -1 -1 -1 -1
  0  1  2  3  4  5 -1
  6  7  7 -1 -1 -1 -1
  8  9 10 10 -1 -1 -1
 11 12 13 14 15 15 -1
 16 17 18 19 20 20 -1

$keyQpow
# Density dependent catchability power parameters (if any).
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (normally only first row is used)
  0  1  1  1  1  1  1
```

```
 -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
  0  1  1  1  1  1  2
  3  3  3  3  3  3 -1
  4  4  4 -1 -1 -1 -1
  5  5  5  5 -1 -1 -1
  6  6  6  6  6  6 -1
  7  7  7  7  7  7 -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible values are: "ID" "AR" "US"
 "ID" "ID" "ID" "ID" "ID" "ID"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#1-2 2-3 3-4 4-5 5-6 6-7
 NA  NA  NA  NA  NA  NA
 NA  NA  NA  NA  NA  -1
 NA  NA  -1  -1  -1  -1
 NA  NA  NA  -1  -1  -1
 NA  NA  NA  NA  NA  -1
 NA  NA  NA  NA  NA  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton–Holt, and 3 piece-wise constant).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 12

$keyScaledYears
# A vector of the years where catch scaling is applied.
 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006

$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).
 0   0   0   0   0   0   0
 1   1   1   1   1   1   1
```

2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7
8	8	8	8	8	8	8
9	9	9	9	9	9	9
10	10	10	10	10	10	10
11	11	11	11	11	11	11

$fbarRange
lowest and higest age included in Fbar
2 5

$keyBiomassTreat
To be defined only if a biomass survey is used (0 SSB index, 1 catch index, 2 FSB index, 3 total catch, 4 total landings and 5 TSB index).
-1 -1 -1 -1 -1 -1

$obsLikelihoodFlag
Option for observational likelihood | Possible values are: "LN" "ALN"
"LN" "LN" "LN" "LN" "LN" "LN"

$fixVarToWeight
If weight attribute is supplied for observations this option sets the treatment (0 relative weight, 1 fix variance to weight).
0

$fracMixF
The fraction of t(3) distribution used in logF increment distribution
0

$fracMixN
The fraction of t(3) distribution used in logN increment distribution
0

$fracMixObs
A vector with same length as number of fleets, where each element is the fraction of t(3) distribution used in the distribution of that fleet
0 0 0 0 0 0

$constRecBreaks
Vector of break years between which recruitment is at constant level. The break year is included in the left interval. (This option is only used in combination with stock–recruitment code 3)

Table 3.13. Cod.27.6a. SAM estimated model parameters.

	par	sd(par)	exp(par)	Low	High
logFpar_0	-9.82627	0.15868	0.00005	0.00004	0.00007
logFpar_1	-7.97290	0.15238	0.00034	0.00025	0.00047
logFpar_2	-7.09241	0.15248	0.00083	0.00061	0.00113
logFpar_3	-6.64846	0.15466	0.00130	0.00095	0.00177
logFpar_4	-6.17816	0.16649	0.00207	0.00149	0.00289
logFpar_5	-5.77349	0.17573	0.00311	0.00219	0.00442
logFpar_6	-11.07638	0.20538	0.00002	0.00001	0.00002
logFpar_7	-11.32750	0.16446	0.00001	0.00001	0.00002
logFpar_8	-8.21779	0.23178	0.00027	0.00017	0.00043
logFpar_9	-7.16734	0.23223	0.00077	0.00048	0.00123
logFpar_10	-6.87243	0.18456	0.00104	0.00072	0.00150
logFpar_11	-8.50034	0.22149	0.00020	0.00013	0.00032
logFpar_12	-6.33104	0.16249	0.00178	0.00129	0.00246
logFpar_13	-5.87522	0.16068	0.00281	0.00204	0.00387
logFpar_14	-5.46087	0.20059	0.00425	0.00285	0.00635
logFpar_15	-4.93287	0.20523	0.00721	0.00478	0.01086
logFpar_16	-6.96448	0.18865	0.00094	0.00065	0.00138
logFpar_17	-6.13471	0.14544	0.00217	0.00162	0.00290
logFpar_18	-5.52082	0.15834	0.00400	0.00292	0.00549
logFpar_19	-4.73993	0.20667	0.00874	0.00578	0.01321
logFpar_20	-4.14112	0.22248	0.01590	0.01019	0.02482
logSdLogFsta_0	-2.22062	0.73436	0.10854	0.02499	0.47148
logSdLogFsta_1	-2.37973	0.20440	0.09258	0.06151	0.13933
logSdLogN_0	-0.13522	0.12237	0.87353	0.68389	1.11575
logSdLogN_1	-2.53454	0.53318	0.07930	0.02730	0.23034
logSdLogObs_0	-0.54157	0.13520	0.58183	0.44398	0.76248
logSdLogObs_1	-1.51650	0.07853	0.21948	0.18758	0.25681

	par	sd(par)	exp(par)	Low	High
logSdLogObs_2	-0.82221	0.12909	0.43946	0.33947	0.56891
logSdLogObs_3	-0.35243	0.06670	0.70298	0.61519	0.80329
logSdLogObs_4	-0.16578	0.10534	0.84723	0.68629	1.04592
logSdLogObs_5	-0.24846	0.11147	0.78000	0.62412	0.97481
logSdLogObs_6	0.45734	0.09121	1.57987	1.31642	1.89604
logSdLogObs_7	0.28239	0.10186	1.32629	1.08183	1.62598
itrans_rho_0	0.90870	0.40524	2.48110	1.10320	5.57998
logScale_0	0.02550	0.15205	1.02582	0.75685	1.39039
logScale_1	-0.16192	0.17277	0.85051	0.60203	1.20155
logScale_2	-0.10723	0.18484	0.89832	0.62070	1.30011
logScale_3	0.13244	0.19076	1.14161	0.77951	1.67190
logScale_4	0.18771	0.19398	1.20648	0.81853	1.77831
logScale_5	0.36493	0.19735	1.44041	0.97066	2.13750
logScale_6	0.70711	0.20145	2.02812	1.35556	3.03437
logScale_7	0.60486	0.20010	1.83100	1.22711	2.73206
logScale_8	1.12059	0.19596	3.06666	2.07231	4.53812
logScale_9	1.36555	0.18682	3.91786	2.69638	5.69268
logScale_10	1.20026	0.17694	3.32099	2.33120	4.73103
logScale_11	0.68888	0.23380	1.99148	1.24767	3.17872

Table 3.14. Cod.27.6a. SAM estimates of population numbers-at-age (thousands).

	1	2	3	4	5	6	7
1981	10776	19502	7001	1981	475	63	51
1982	24158	5364	7788	2593	728	184	44
1983	14133	11850	2224	2780	896	258	82
1984	24070	6612	4627	775	877	293	112
1985	10610	11370	2454	1467	227	254	121
1986	21633	4729	4108	749	379	63	102
1987	42929	10267	1766	1300	214	108	49
1988	7360	18877	3724	538	351	61	45
1989	21585	3157	6256	1139	155	100	31
1990	7974	9495	1079	1729	320	44	37
1991	11762	3384	3321	352	492	100	26
1992	21848	5012	1089	1004	108	140	38
1993	7886	9524	1693	310	289	33	55
1994	13771	3512	3297	490	91	85	27
1995	10200	6004	1244	1006	139	27	33
1996	4222	4471	1926	365	294	41	18
1997	17062	1829	1408	513	105	86	17
1998	5413	7413	548	369	144	30	30
1999	4314	2212	2164	141	105	43	18
2000	14621	1808	642	563	39	30	18
2001	4137	6079	558	173	160	11	14
2002	6975	1700	1860	150	45	43	7
2003	2303	2806	494	499	41	12	13
2004	3243	908	791	120	130	11	7
2005	2204	1274	262	196	30	31	4
2006	7212	887	409	62	45	7	9
2007	2419	3051	293	106	13	11	4

	1	2	3	4	5	6	7
2008	1751	980	1066	75	25	3	3
2009	5474	734	345	264	16	6	2
2010	6453	2365	270	84	54	3	2
2011	2450	2828	904	69	18	12	1
2012	4188	1082	1162	241	15	4	3
2013	7473	1843	487	383	63	4	2
2014	6372	3357	811	174	115	18	2
2015	5925	2875	1548	292	57	39	7
2016	2226	2763	1338	593	97	20	16
2017	2012	994	1338	534	201	34	13
2018	924	922	442	514	176	67	16
2019	4183	396	411	163	153	55	26
2020	2876	1863	181	155	48	46	25
2021	1974	1264	878	70	46	14	22

Table 3.15. Cod.27.6a. SAM estimates for fishing mortality-at-age.

	1	2	3	4	5	6	7
1981	0.217	0.517	0.689	0.750	0.750	0.750	0.750
1982	0.226	0.531	0.722	0.811	0.811	0.811	0.811
1983	0.245	0.568	0.778	0.894	0.894	0.894	0.894
1984	0.264	0.607	0.844	0.988	0.988	0.988	0.988
1985	0.285	0.643	0.894	1.061	1.061	1.061	1.061
1986	0.279	0.624	0.859	1.010	1.010	1.010	1.010
1987	0.302	0.664	0.896	1.031	1.031	1.031	1.031
1988	0.315	0.690	0.909	1.015	1.015	1.015	1.015
1989	0.323	0.704	0.933	1.032	1.032	1.032	1.032
1990	0.317	0.684	0.873	0.956	0.956	0.956	0.956
1991	0.324	0.715	0.911	0.976	0.976	0.976	0.976
1992	0.313	0.706	0.921	0.974	0.974	0.974	0.974
1993	0.298	0.691	0.918	0.978	0.978	0.978	0.978
1994	0.293	0.690	0.912	0.979	0.979	0.979	0.979
1995	0.301	0.728	0.943	0.978	0.978	0.978	0.978
1996	0.312	0.771	0.994	0.998	0.998	0.998	0.998
1997	0.326	0.814	1.032	1.007	1.007	1.007	1.007
1998	0.336	0.836	1.037	0.995	0.995	0.995	0.995
1999	0.334	0.827	1.030	1.012	1.012	1.012	1.012
2000	0.334	0.809	1.011	1.025	1.025	1.025	1.025
2001	0.340	0.813	1.021	1.059	1.059	1.059	1.059
2002	0.352	0.830	1.035	1.068	1.068	1.068	1.068
2003	0.360	0.841	1.077	1.102	1.102	1.102	1.102
2004	0.352	0.814	1.095	1.160	1.160	1.160	1.160
2005	0.329	0.759	1.098	1.205	1.205	1.205	1.205
2006	0.303	0.699	1.064	1.216	1.216	1.216	1.216
2007	0.284	0.653	1.044	1.204	1.204	1.204	1.204

	1	2	3	4	5	6	7
2008	0.269	0.618	1.050	1.230	1.230	1.230	1.230
2009	0.260	0.599	1.076	1.301	1.301	1.301	1.301
2010	0.243	0.554	1.020	1.234	1.234	1.234	1.234
2011	0.229	0.513	0.968	1.198	1.198	1.198	1.198
2012	0.206	0.450	0.830	1.047	1.047	1.047	1.047
2013	0.193	0.415	0.749	0.951	0.951	0.951	0.951
2014	0.183	0.390	0.691	0.865	0.865	0.865	0.865
2015	0.173	0.367	0.641	0.816	0.816	0.816	0.816
2016	0.171	0.359	0.618	0.801	0.801	0.801	0.801
2017	0.179	0.380	0.653	0.861	0.861	0.861	0.861
2018	0.182	0.390	0.676	0.921	0.921	0.921	0.921
2019	0.179	0.384	0.675	0.965	0.965	0.965	0.965
2020	0.171	0.362	0.642	0.957	0.957	0.957	0.957

Table 3.16. Cod.27.6a. SAM summary table. ('Catch' refers to model estimate).

Year	Recruitment Age 1			SSB			TSB			Catch			Esti-mated catch scaling factor	Fishing mortality Ages 2–5		
	Value	Low	High	Value	Low	High	Value	Low	High	Value	Low	High		Value	Low	High
1981	10776	7807	14874	43252	37639	49703	64140	55761	73777	23538	19296	28712		0.676	0.583	0.785
1982	24158	18021	32385	42471	37367	48273	60463	53440	68408	23619	20156	27678		0.719	0.636	0.812
1983	14133	10568	18900	35762	31720	40320	50490	44906	56769	20932	18149	24142		0.784	0.701	0.876
1984	24070	18038	32119	30414	27051	34196	46017	40823	51872	21318	18390	24712		0.857	0.769	0.955
1985	10610	7966	14131	25388	22611	28505	37829	33525	42684	16365	14129	18955		0.915	0.818	1.023
1986	21633	15806	29608	22021	19475	24899	34921	30561	39904	14256	12210	16643		0.876	0.786	0.976
1987	42929	30989	59470	24089	21365	27161	45783	39160	53525	15739	13382	18511		0.906	0.814	1.007
1988	7360	5432	9974	26656	23062	30811	42426	36220	49695	18976	15915	22627		0.907	0.817	1.008
1989	21585	15987	29143	25011	21701	28826	37972	33126	43527	16265	13707	19300		0.925	0.831	1.03
1990	7974	5803	10959	19427	17139	22020	28743	25318	32630	12787	10918	14975		0.867	0.777	0.968
1991	11762	8745	15821	16219	14331	18356	23972	21194	27115	10464	8975	12200		0.894	0.804	0.995
1992	21848	16244	29386	14351	12777	16120	24827	21626	28502	9253	7979	10730		0.894	0.8	0.999
1993	7886	5717	10879	14335	12438	16522	23169	19832	27068	10983	9255	13034		0.891	0.788	1.008
1994	13771	9656	19640	14118	11784	16916	22213	18387	26836	10065	8410	12045		0.89	0.776	1.021
1995	10200	7016	14828	13032	10213	16629	20413	15894	26217	9419	7337	12092	1.026	0.907	0.792	1.038

Year	Recruitment Age 1			SSB			TSB			Catch			Esti-mated catch scaling factor	Fishing mortality Ages 2–5		
	Value	Low	High	Value	Low	High	Value	Low	High	Value	Low	High		Value	Low	High
1996	4222	2845	6265	10962	8264	14540	15907	11972	21137	8359	6200	11270	0.850	0.94	0.819	1.079
1997	17062	11434	25460	9311	6899	12567	15990	11744	21771	7087	5119	9812	0.898	0.965	0.838	1.112
1998	5413	3586	8172	9098	6591	12560	15061	10845	20916	6095	4302	8635	1.142	0.966	0.842	1.109
1999	4314	2846	6539	7685	5527	10687	11274	8140	15614	5285	3727	7495	1.206	0.97	0.847	1.112
2000	14621	9627	22205	6650	4792	9228	11941	8533	16710	4822	3371	6897	1.440	0.967	0.845	1.107
2001	4137	2711	6313	6966	4971	9763	11651	8278	16400	5057	3497	7314	2.028	0.988	0.863	1.132
2002	6975	4583	10613	6387	4591	8885	10048	7249	13927	4756	3289	6878	1.831	1	0.872	1.147
2003	2303	1531	3466	5208	3811	7115	7704	5643	10517	3649	2566	5190	3.067	1.031	0.896	1.186
2004	3243	2202	4777	3632	2726	4839	5347	4038	7079	2570	1853	3564	3.918	1.058	0.917	1.22
2005	2204	1480	3284	2609	2012	3382	3994	3093	5158	1870	1387	2522	3.321	1.066	0.924	1.23
2006	7212	4920	10572	2476	1981	3095	4779	3748	6093	1856	1401	2458	1.991	1.049	0.909	1.21
2007	2419	1617	3617	3083	2431	3909	5378	4184	6912	2185	1650	2893		1.026	0.893	1.179
2008	1751	1192	2573	3091	2422	3946	4539	3598	5727	2193	1652	2913		1.032	0.897	1.187
2009	5474	3843	7799	2534	2084	3080	4302	3536	5233	1908	1502	2424		1.07	0.922	1.24
2010	6453	4594	9064	2940	2435	3549	5605	4582	6856	2144	1647	2791		1.011	0.874	1.169
2011	2450	1708	3515	3838	3159	4664	6229	5121	7577	2514	1964	3217		0.969	0.831	1.13

Year	Recruitment Age 1			SSB			TSB			Catch			Esti-mated catch scaling factor	Fishing mortality Ages 2–5		
	Value	Low	High	Value	Low	High	Value	Low	High	Value	Low	High		Value	Low	High
2012	4188	2986	5873	3931	3248	4759	5933	4948	7114	2330	1842	2946		0.843	0.723	0.984
2013	7473	5312	10512	4074	3441	4824	6744	5662	8032	2102	1702	2595		0.767	0.653	0.901
2014	6372	4546	8932	5094	4281	6061	8383	6995	10046	2635	2082	3336		0.702	0.595	0.829
2015	5925	4201	8356	6395	5343	7652	9738	8152	11632	3454	2732	4367		0.66	0.554	0.786
2016	2226	1590	3117	6902	5770	8255	9543	8001	11381	3508	2813	4374		0.645	0.538	0.772
2017	2012	1437	2817	6366	5284	7671	8099	6764	9698	3256	2627	4034		0.689	0.585	0.812
2018	924	638	1338	4634	3825	5613	5672	4732	6798	2540	2054	3142		0.727	0.617	0.857
2019	4183	2964	5902	3158	2611	3820	4284	3598	5102	1827	1489	2240		0.747	0.627	0.889
2020	2876	1758	4705	2795	2313	3378	4269	3509	5195	1583	1289	1944		0.73	0.598	0.89
2021	1974	928	4198	3326	2600	4255	4758	3683	6148	2050	1551	2710		0.747	0.584	0.954

Table 3.17. Cod.27.6a. Intermediate year assumptions based on the SAM assessment. Units are tonnes (SSB, landings, discards and catch) or thousands (recruitment).

Variable	Value	Notes
$F_{ages\ 2–5}$ (2022)	0.74	$F_{average\ (2019–2021)}$
SSB (2023)	2923	Short-term forecast; in tonnes.
$R_{age\ 1}$ (2022, 2023 and 2024)	2226	Median recruitment resampled from the years 2016–2021; in thousands.
Total catch (2022)	1873	Short-term forecast; in tonnes.
Projected landings (2022)	1333	Short-term forecast assuming average landing pattern (2019–2021)^; in tonnes.
Projected discards (2022)	540	Short-term forecast assuming average discard pattern (2019–2021)^; in tonnes.

^ Due to inadequate discard sampling coverage of the fishery in 2021, average landings and discards proportions from 2019–2020 are used for ages 1 and 2.

Table 3.18. Cod.27.6a. Catch scenarios based on the SAM assessment and assuming F status quo in the intermediate year. Units are tonnes (SSB, landings, discards and catch) or thousands (recruitment).

Basis	Cat	Lan	Dis	Ftot	Flan	Fdis	SSB	SSB	TAC
MSY approach: F_MSY	809	594	215	0.3	0.23	0.069	3757	29%	-37%
Precautionary approach: Fpa	1359	985	374	0.57	0.44	0.13	3099	6.00%	6.30%
FMSY upper	1210	881	329	0.49	0.38	0.112	3278	12.10%	-5.40%
FMSY lower	514	380	134	0.18	0.139	0.041	4113	41%	-60%
F = 0	0	0	0	0	0	0	4728	62%	-100%
Fpa	1359	985	374	0.57	0.44	0.13	3099	6.00%	6.30%
F = Flim	1625	1169	456	0.73	0.56	0.167	2781	-4.90%	27%
Fsq	1642	1181	461	0.74	0.57	0.17	2760	-5.60%	28%
zero TAC advice - haddock Fmult	2562	1779	783	1.6	1.23	0.37	1650	-44%	100%
zero TAC advice - saith Fmult	1642	1181	461	0.74	0.57	0.17	2760	-5.60%	28%
0.05*Fsq	114	85	29	0.037	0.029	0.008	4590	57%	-91%
0.25*Fsq	527	390	137	0.185	0.143	0.042	4095	40%	-59%
0.5*Fsq	966	708	258	0.37	0.29	0.085	3568	22%	-24%
0.75*Fsq	1333	967	366	0.56	0.43	0.127	3130	7.10%	4.20%
2022F=Fsq then Fmsy HCR	133	99	34	0.043	0.033	0.01	4569	56%	-90%
2022F=Fsq then Fmsy HCR lower	80	60	20	0.026	0.02	0.006	4632	58%	-94%
2022F=Fsq then Fmsy HCR upper	214	159	55	0.071	0.055	0.016	4472	53%	-83%
2022F=Fsq then 0% SSB increase	1507	1088	419	0.66	0.51	0.15	2923	0.00%	17.80%
2022F=Fsq then 10% SSB increase	1263	918	345	0.52	0.4	0.119	3215	10.00%	-1.25%
2022F=Fsq then 20% SSB increase	1019	745	274	0.4	0.3	0.09	3508	20%	-20%
2022F=Fsq then 30% SSB increase	773	569	204	0.28	0.22	0.065	3800	30%	-40%
2022F=Fsq then 40% SSB increase	530	392	138	0.186	0.144	0.042	4092	40%	-59%
2022F=Fsq then 50% SSB increase	286	212	74	0.096	0.074	0.022	4385	50%	-78%
2022F=Fsq then prev.TAC*0.25	320	237	83	0.108	0.083	0.025	4347	49%	-75%
2022F=Fsq then prev.TAC*0.5	640	472	168	0.23	0.177	0.052	3961	36%	-50%
2022F=Fsq then prev.TAC*0.75	959	703	256	0.37	0.28	0.084	3577	22%	-25%
2022F=Fsq then prev.TAC*1	1279	929	350	0.53	0.41	0.12	3196	9.30%	0.00%

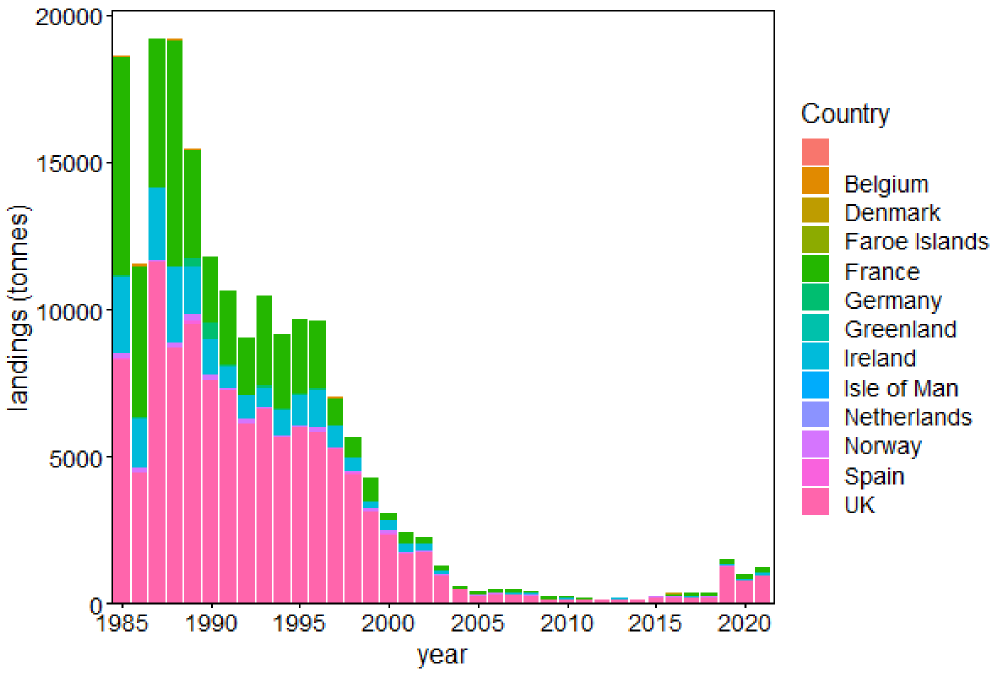


Figure 3.1. Cod.27.6a. ICES official landings by country.

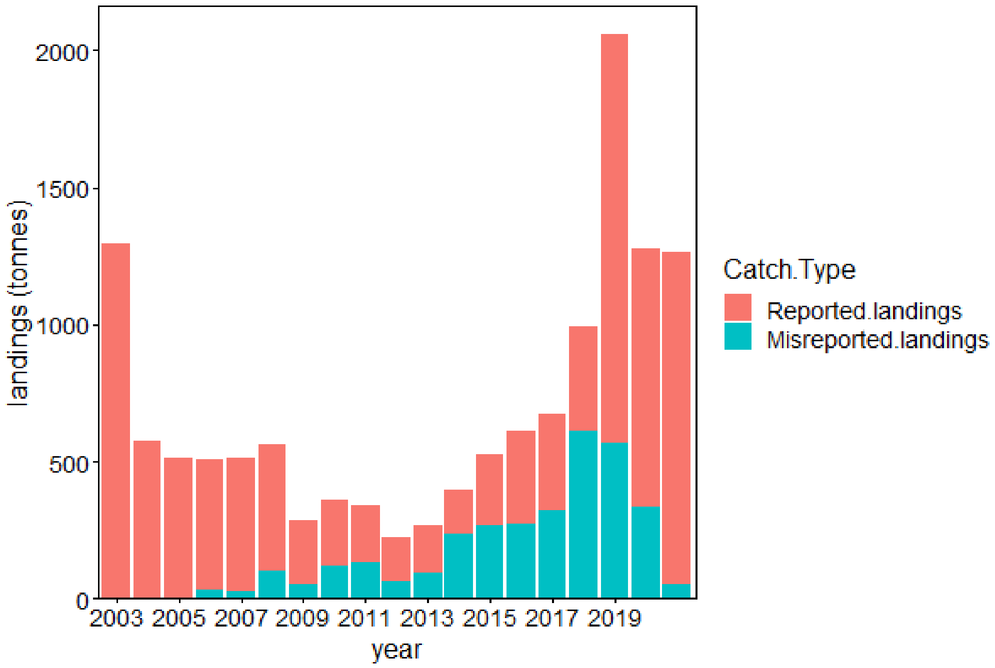


Figure 3.2. Cod.27.6a. ICES estimates of reported (red) and area misreported landings (blue) of cod caught in ICES Division 6.a.

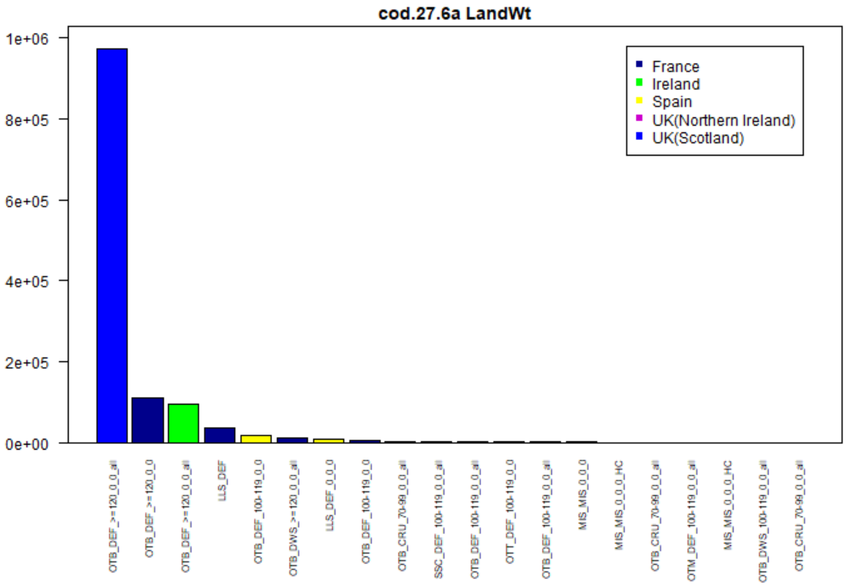


Figure 3.3. Cod.27.6a. Amounts landed by métier (kg) in 2021 as submitted to InterCatch.

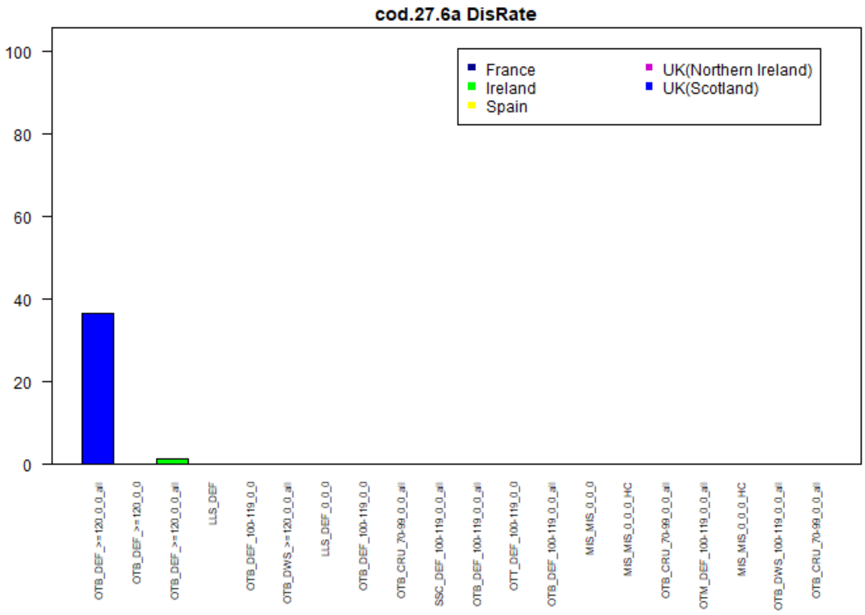


Figure 3.4. Cod.27.6a. Discard rates by weight by métier in 2021 as submitted to InterCatch.

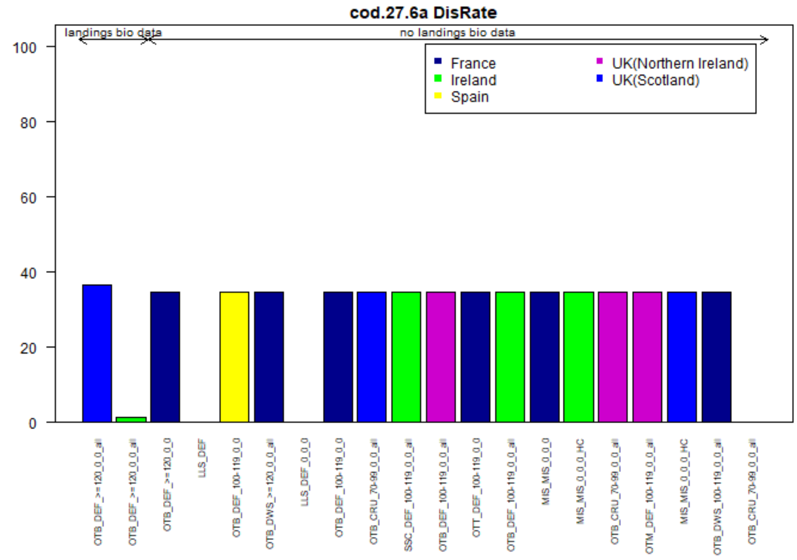


Figure 3.5. Cod.27.6a. Discard rates after allocations within InterCatch.

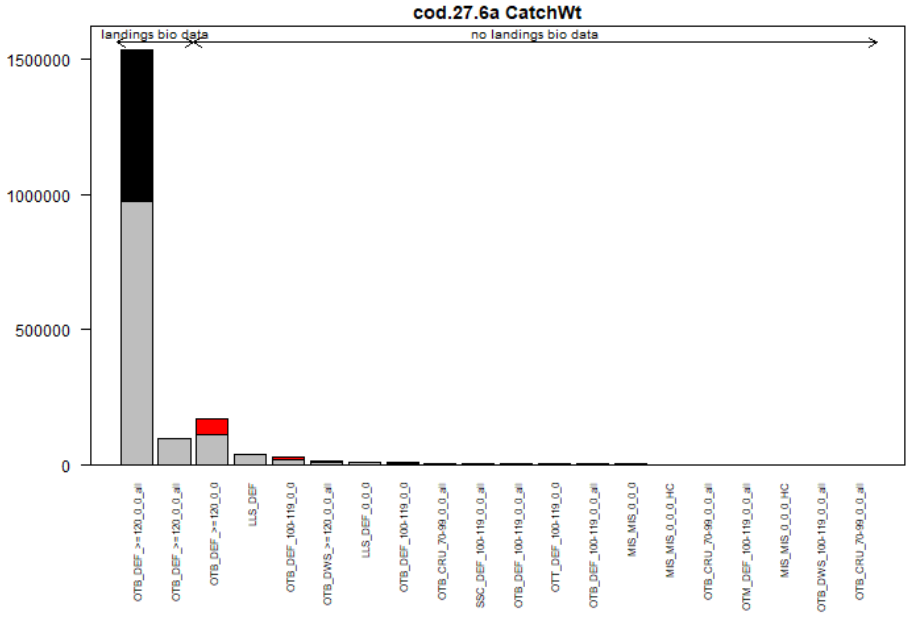


Figure 3.6. Cod.27.6a. Landings (grey), imported (black) and raised (red, but so small so not visible) discards of all fleets after allocations within InterCatch.

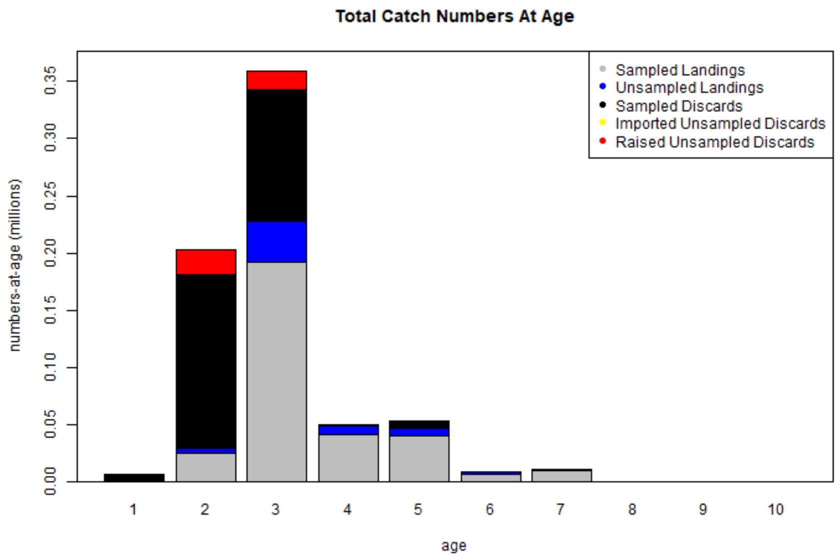


Figure 3.7. Cod.27.6a. Catch numbers-at-age by sampled and unsampled landings and sampled and raised (unsampled) discards, after allocations within InterCatch.

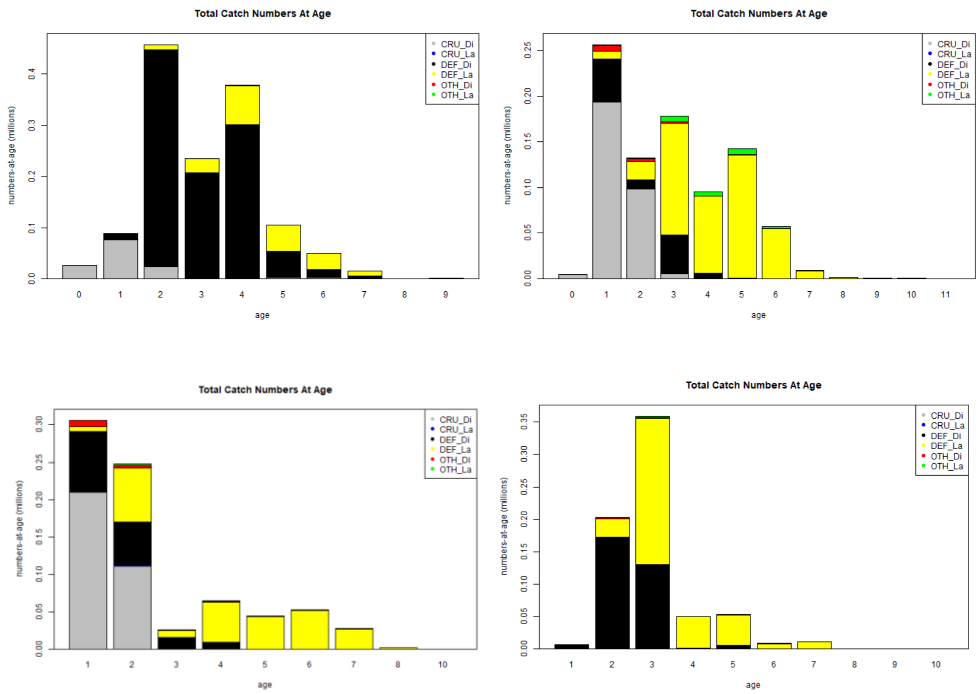


Figure 3.8. Cod.27.6a. Catch numbers-at-age by fleet/catch category after allocations within InterCatch, 2018 (top left) to 2021 (bottom right).

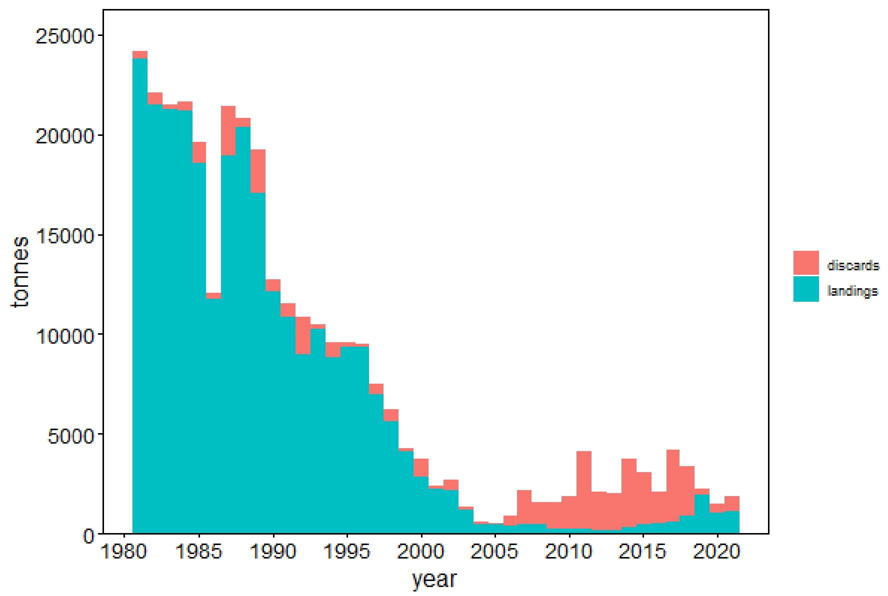


Figure 3.9. Cod.27.6a. Landings and discards estimates by weight, as used by the WG.

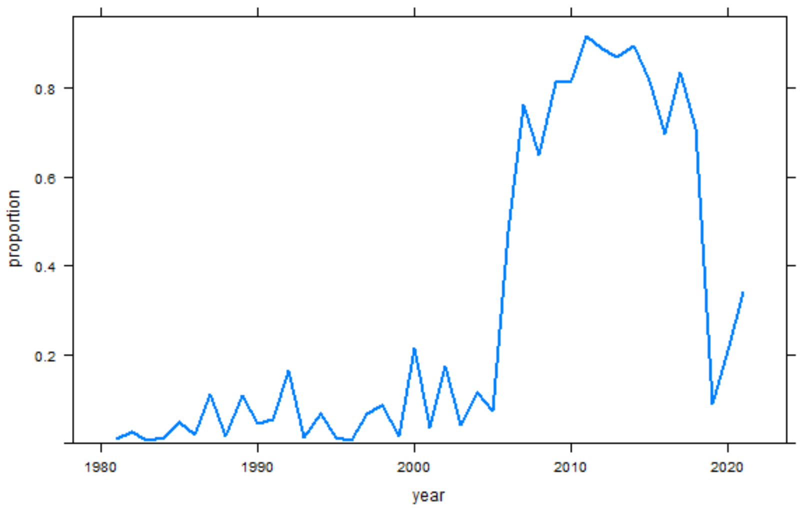


Figure 3.10. Cod.27.6a. Discard proportion (of total catch) by weight.

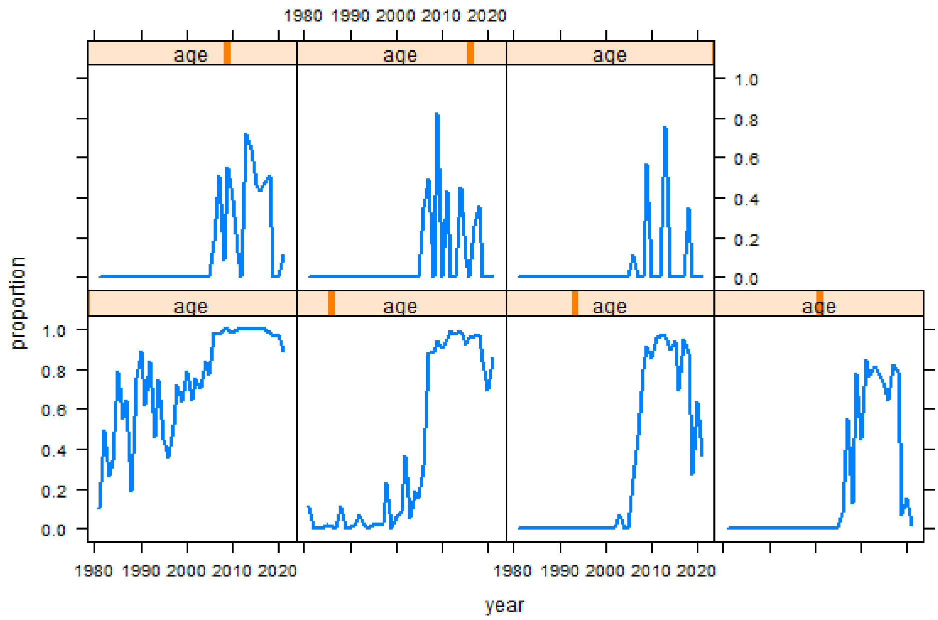


Figure 3.11. Cod.27.6a. Discard proportion by number by age.

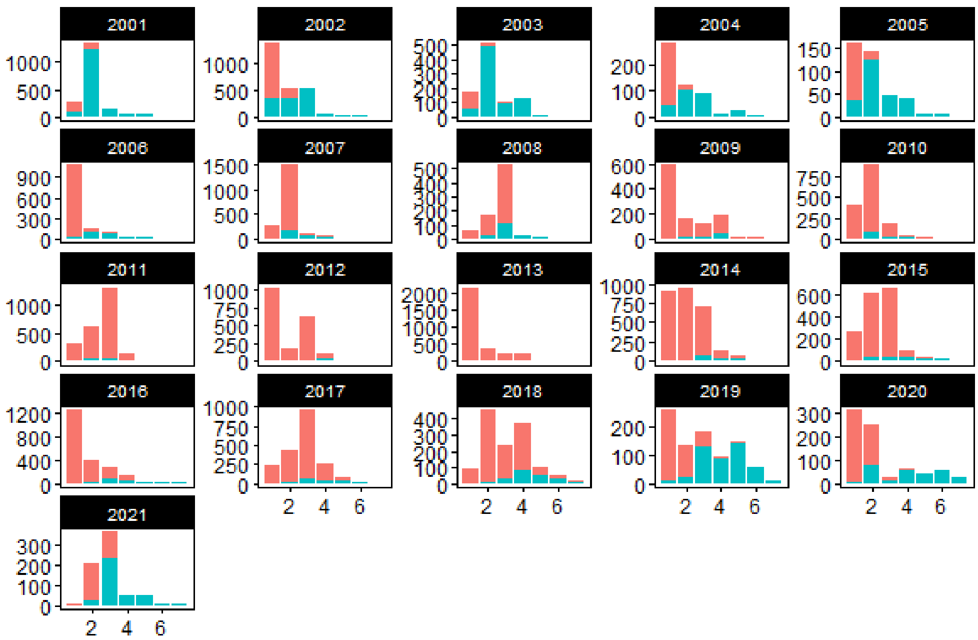


Figure 3.12. Cod.27.6a. Catch-at-age in numbers by year. Red: discards, blue: landings.

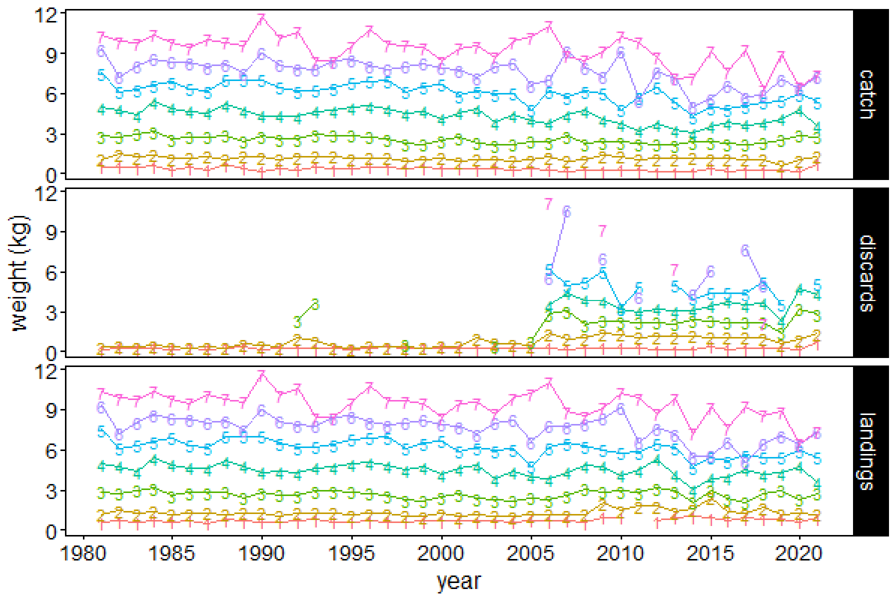


Figure 3.13. Cod.27.6a. Mean weights-at-age in landings and discards.

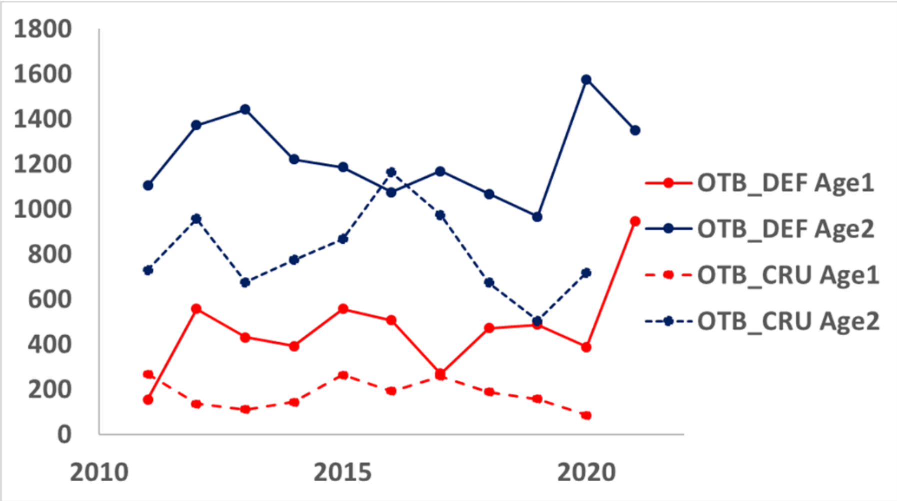


Figure 3.14. Cod.27.6a. Mean discard weights-at-age from Scottish sampling.

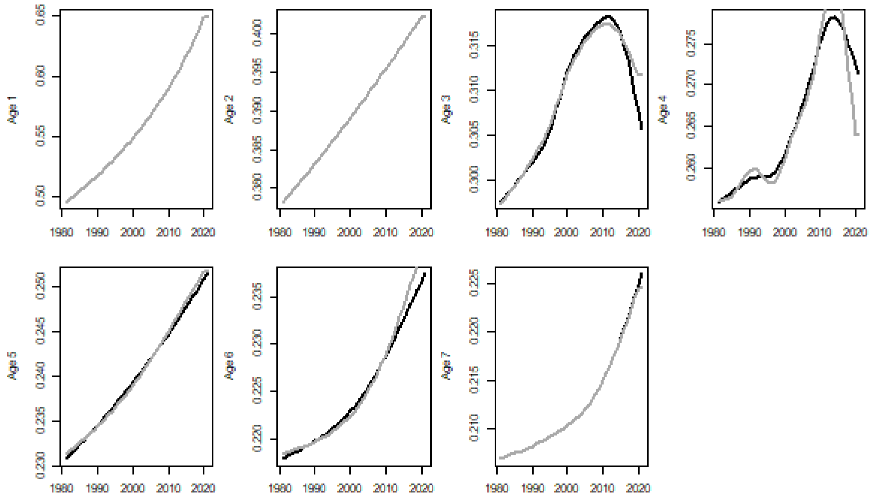


Figure 3.15. Cod.27.6a. Natural mortality-at-age based on stock weight-at-age and mortality–weight relationship (Lorenzen, 1996). (Age 1 bottom left, Age 7+ top right). Black: 2021, Grey: 2020.

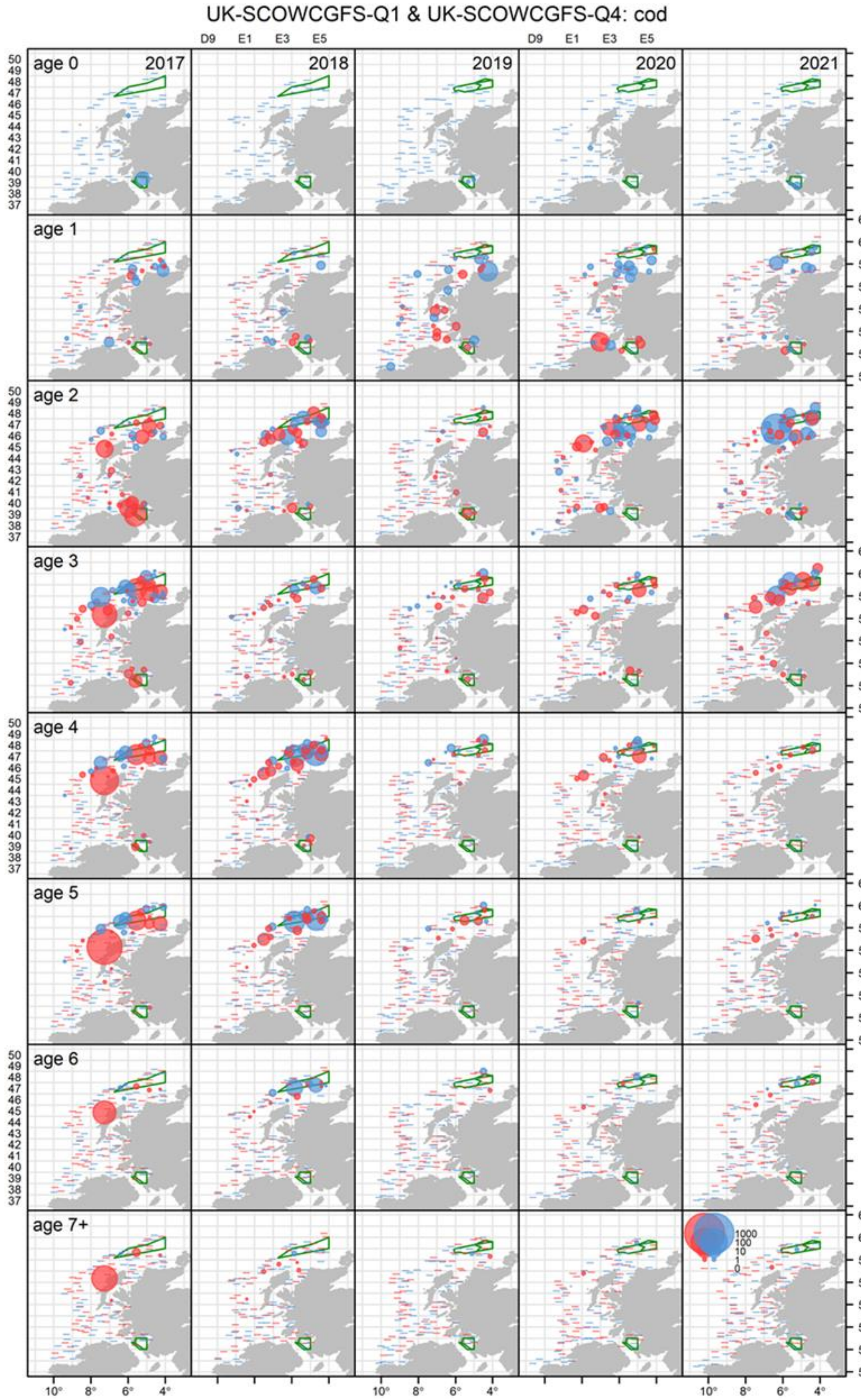
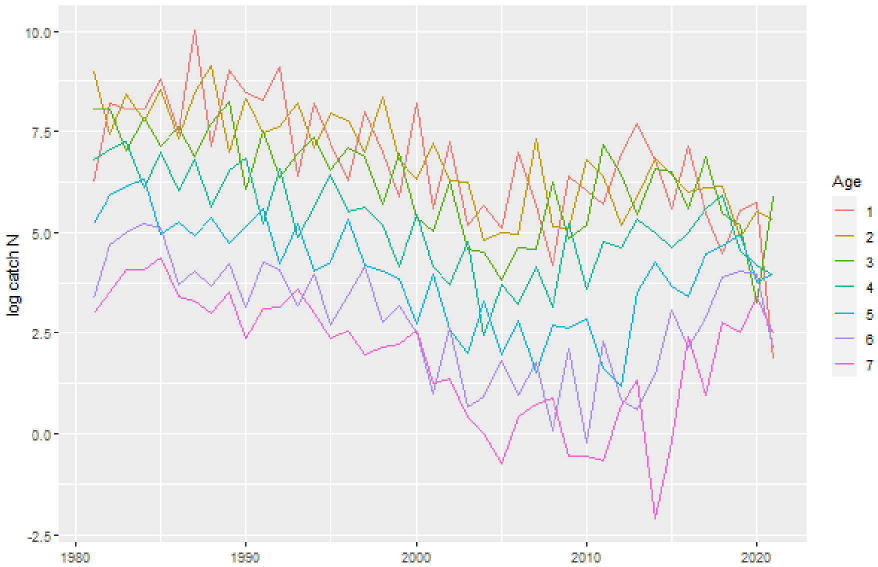


Figure 3.16. Cod.27.6a. CPUE numbers for fish aged at 1+ per tow resulting from Scottish quarter one survey (UK-SCOWCGFS-Q1) in red and (UK-SCOWCGFS-Q4) in blue. Numbers are standardised to 30 minutes towing. Green polygons are areas closed to fishing.



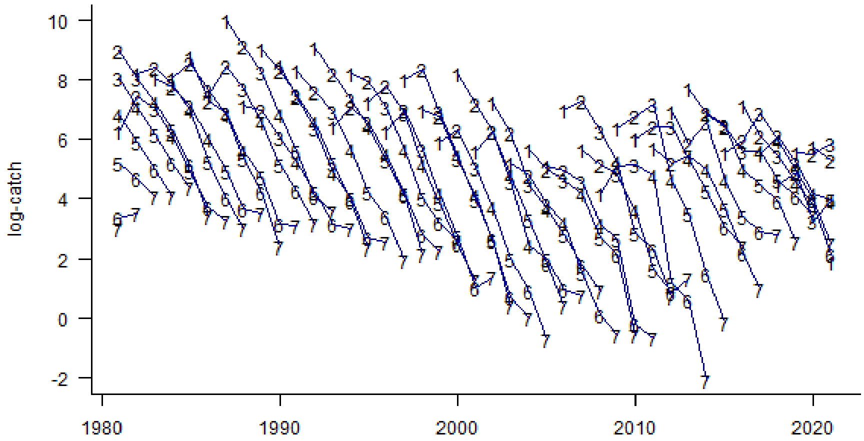


Figure 3.17. Cod.27.6a. Log catch numbers-at-age (upper) and catch curves (lower) from commercial catch-at-age data.

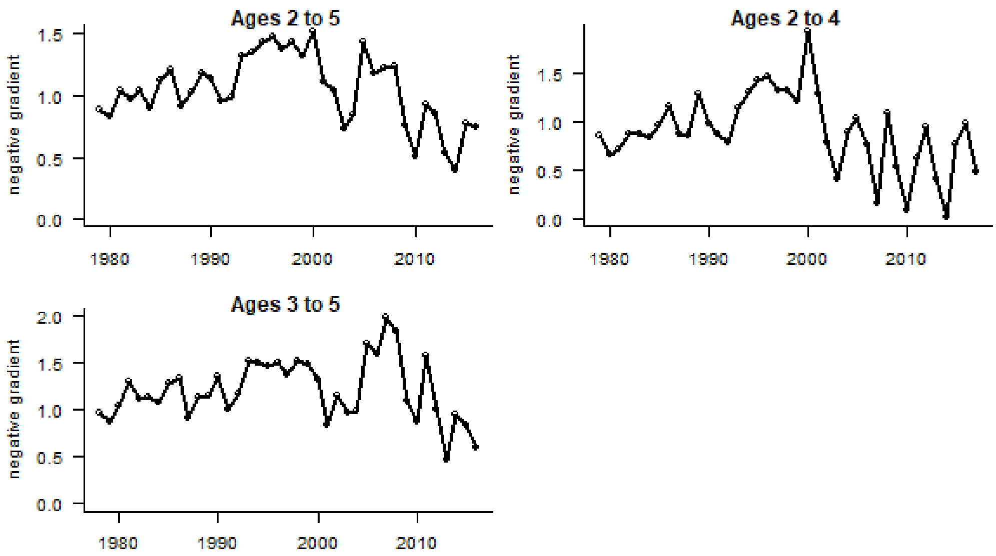


Figure 3.18. Cod.27.6a. Log catch (landings + discards) curve gradient plot using WG commercial catch-at-age data over different age ranges.

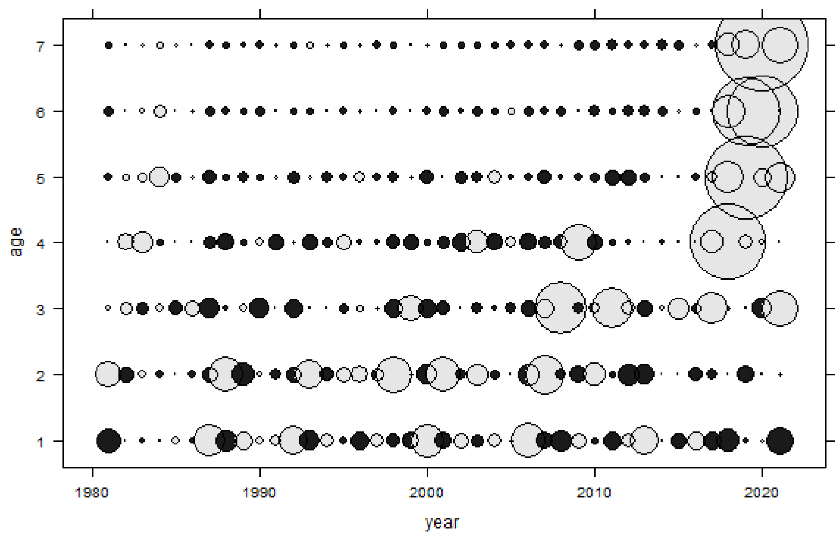


Figure 3.19. Cod.27.6a. Mean standardised catch-at-age proportions by number.

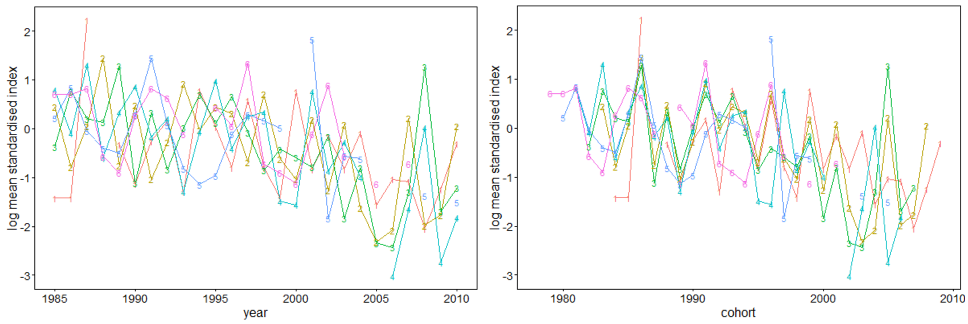


Figure 3.20. Cod.27.6a. Log mean standardised index values -by year- (left) and cohort (right) from Scottish quarter one ground fish survey (ScoGFS-WIBTS-Q1); ages 1–6. Survey finished in 2010.

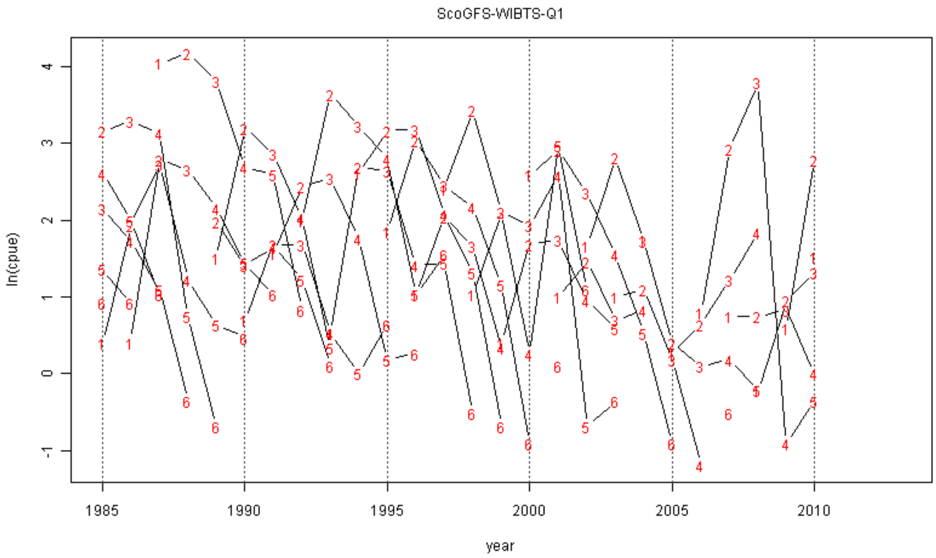


Figure 3.21. Cod.27.6a. Log catch curves from Scottish quarter one ground fish survey (ScoGFS-WIBTS-Q1); ages 1–6. Survey finished in 2010.

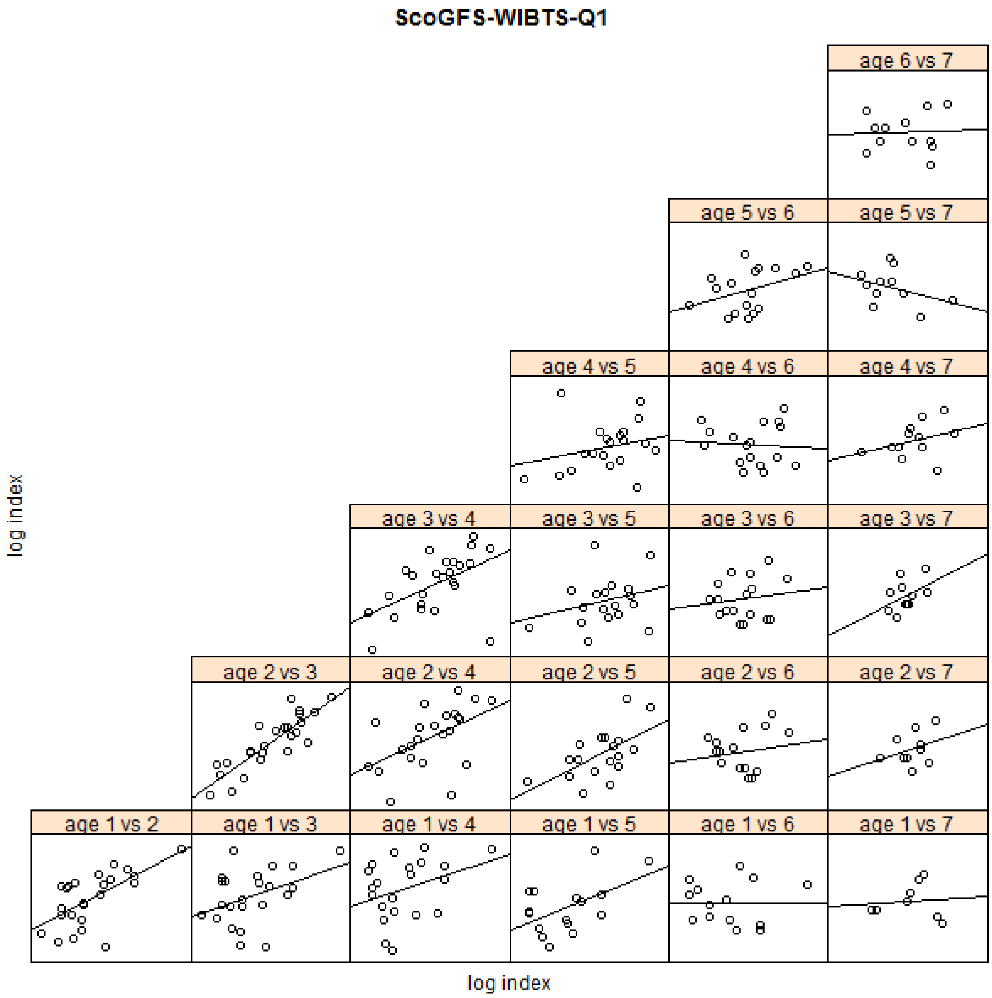


Figure 3.22. Cod.27.6a. Within-survey correlations for the Scottish quarter one ground fish survey (ScoGFS-WIBTS-Q1), comparing index values at different ages for the same cohorts. The straight line in a linear regression. Survey finished in 2010.

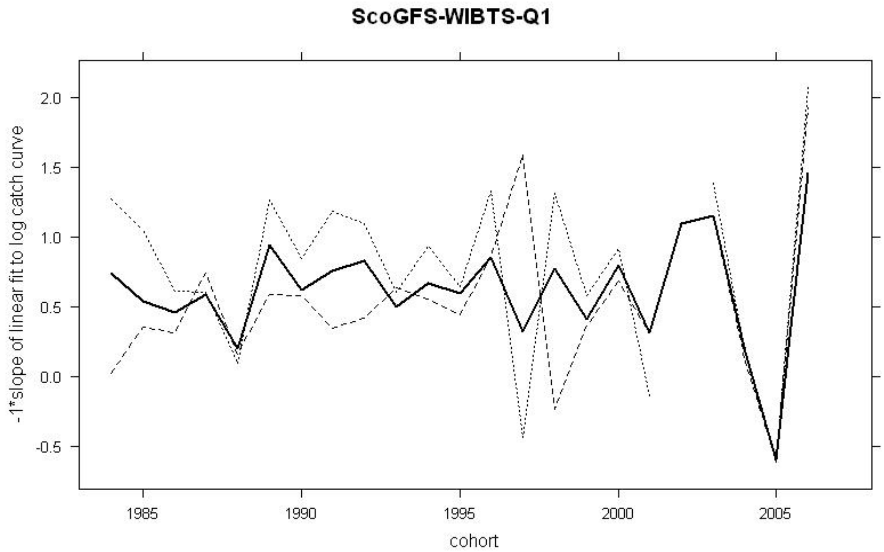


Figure 3.23. Cod.27.6a. Log catch curve gradient plot using ScoGFS-WIBTS-Q1 index data. Solid line shows time-series of gradient of linear fit to curve over the age range 2–5, dashed line over the ages 2–4 and dotted line over the ages 3–5. Last cohort shown was at-age 5 in 2010, the last year of the ScoGFS-WIBTS-Q1 survey.

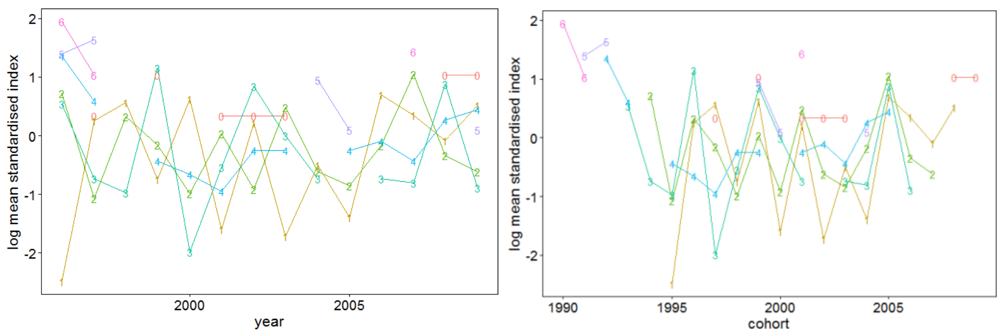


Figure 3.24. Cod in Division6a. Log mean standardised index values by year (left) and cohort (right) from ScoGFS-WIBTS-Q4.

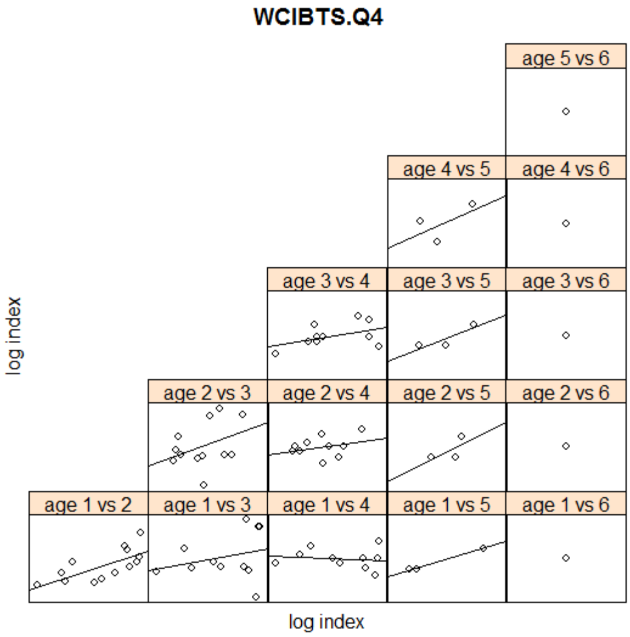


Figure 3.25. Cod.27.6a. Within survey correlations for ScoGFS-WIBTS-Q4 survey, comparing index values at different ages for the same cohorts. The solid line is a linear regression. Insufficient age 6 fish are caught to enable scatterplots to be constructed.

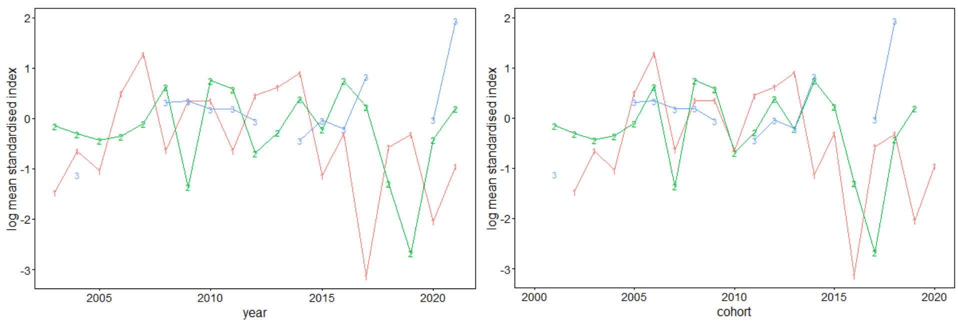


Figure 3.26. Cod.27.6a. Log mean standardised index values -by year (left) and cohort (right) from Irish quarter four ground fish survey (IRGFS-WIBTS-Q4); ages 1–3. Survey started in 2003.

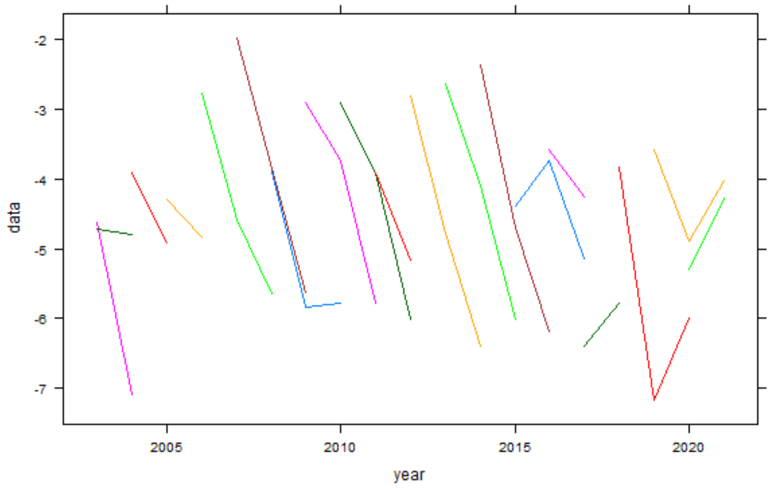


Figure 3.27. Cod.27.6a. Log catch curves from Irish quarter four ground fish survey (IRGFS-WIBTS-Q4); ages 1–3. Survey started in 2003.

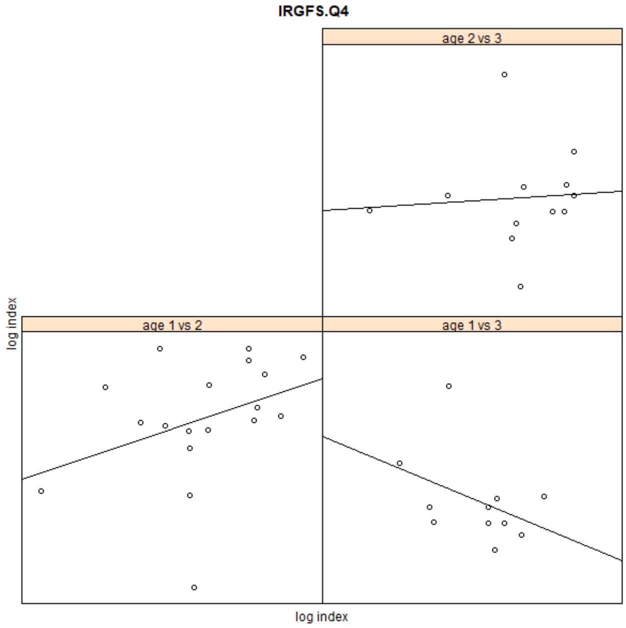


Figure 3.28. Cod.27.6a. Within-survey correlations for the Irish quarter four ground fish survey (IRGFS-WIBTS-Q4), comparing index values at different ages for the same cohorts. The straight line is a linear regression.

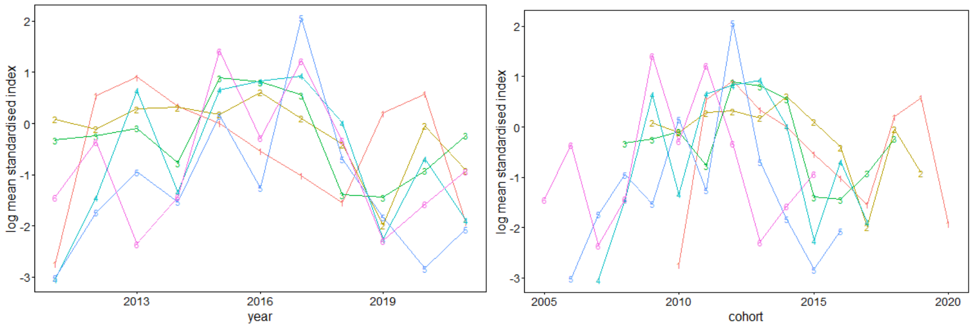


Figure 3.29. Cod.27.6a. Log mean standardised index values -by year (left) and cohort (right) - from Scottish quarter one ground fish survey UK-SCOWCGFS-Q1; ages 1–6.

Figure 3.30. Cod.27.6a. Log catch curves from new Scottish quarter one ground fish survey (UK-SCOWCGFS-Q1); ages 1–7. Survey started in 2011.

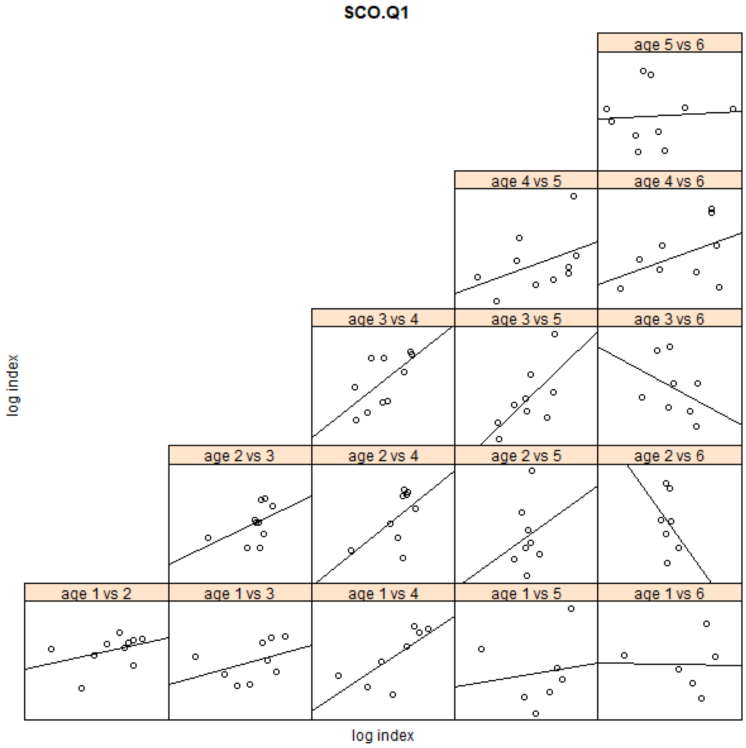


Figure 3.31. Cod.27.6a. Within survey scatterplots from new Scottish quarter one ground fish survey (UK-SCOWCGFS-Q1), comparing index values at different ages for the same cohorts. The straight line in a linear regression.

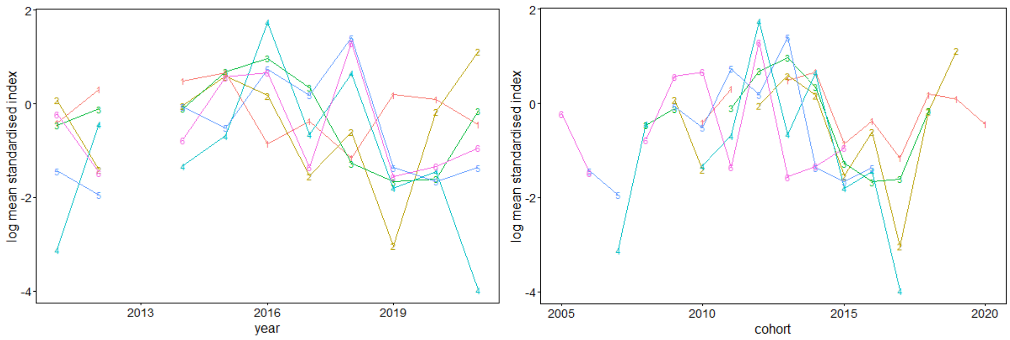


Figure 3.32. Cod.27.6a. Log mean standardised index values by year (left) and cohort (right) from Scottish quarter four ground fish survey UK-SCOWCGFS-Q4); ages 1–6.

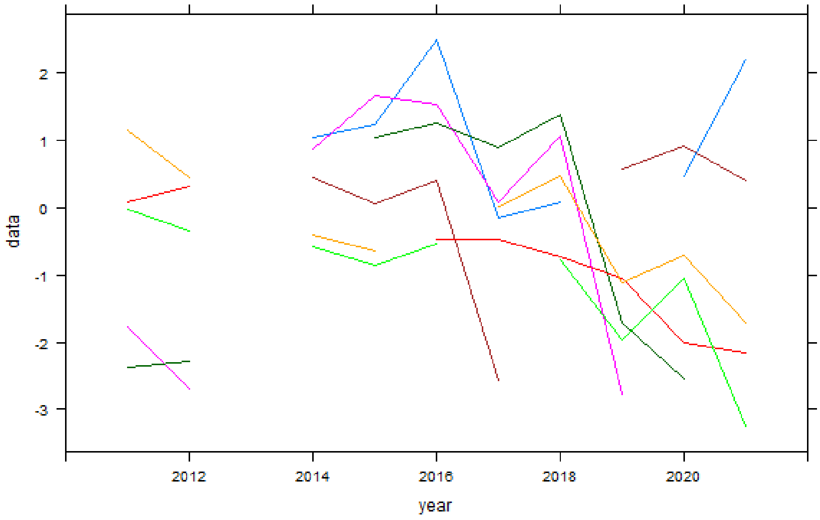


Figure 3.33. Cod.27.6a. Log catch curves from new Scottish quarter four ground fish survey (UK-SCOWCGFS-Q4).

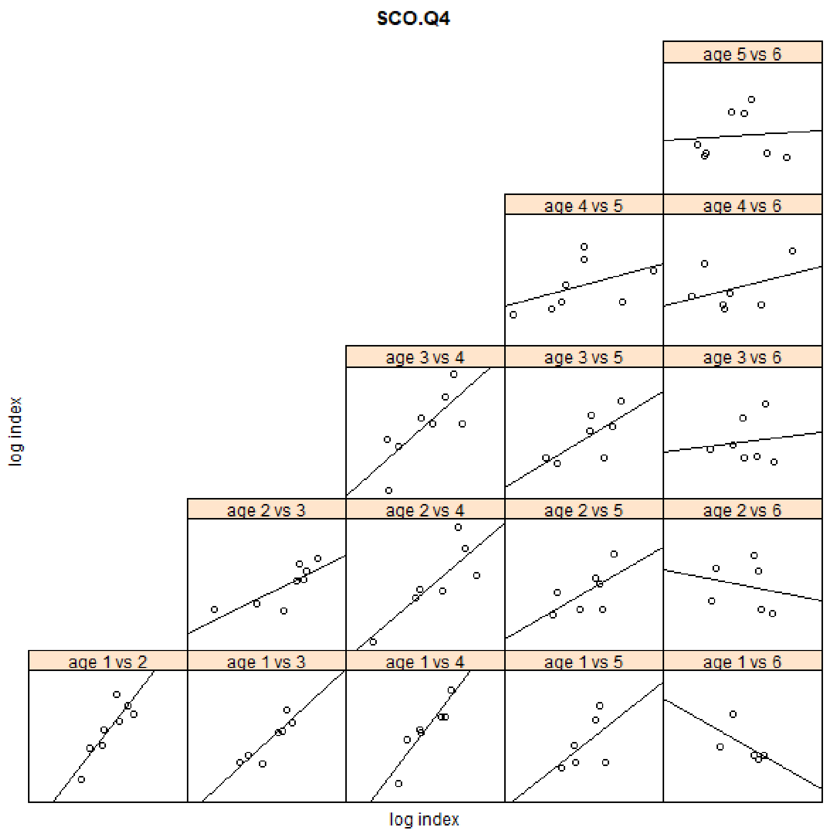


Figure 3.34. Cod.27.6a. Within survey scatterplots from new Scottish quarter four ground fish survey (UK-SCOWCGFS-Q4), comparing index values at different ages for the same cohorts. The straight line in a linear regression.

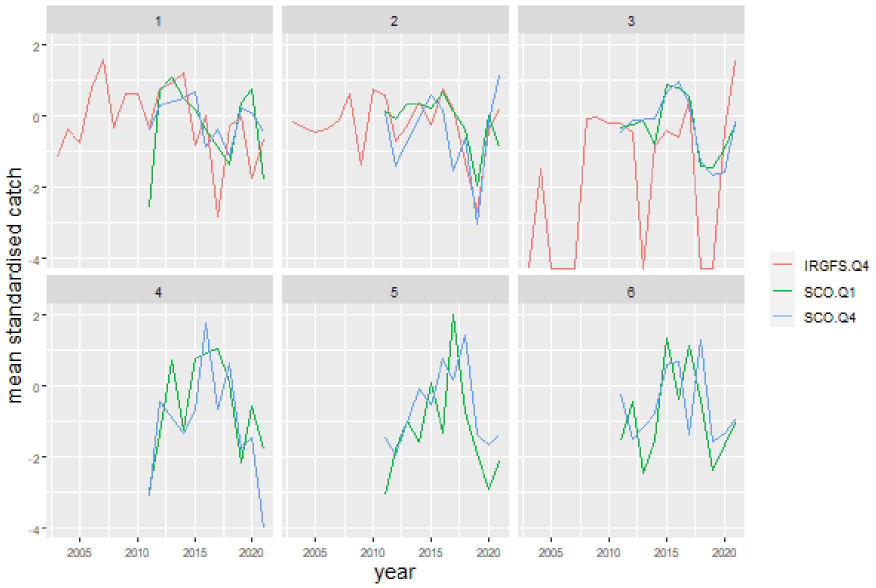


Figure 3.35. Cod.27.6a. Comparison of survey indices by age. Irish Q4 survey (IRGFS.Q4) is compared to the current Scottish surveys (SCO.Q1=UK-SCOWCGFS-Q1 & SCO.Q4=UK-SCOWCGFS-Q4). Values are mean standardised over the time period in common (2011–2021).

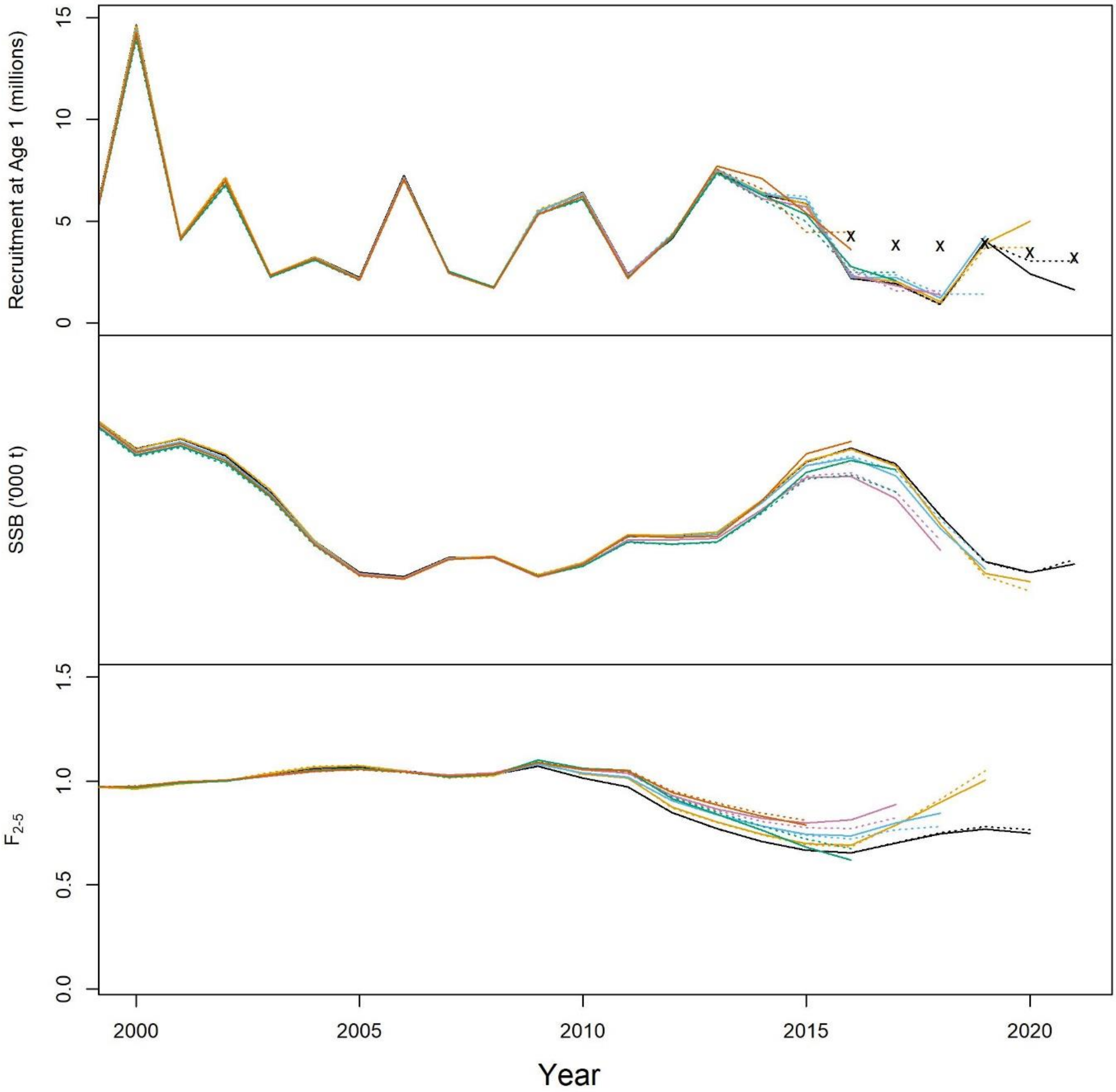


Figure 3.36. Cod.27.6a. Retrospective sensitivity analysis of SAM assessment results to lack of intermediate year survey data. Solid black line: WGCSE 2021 final assessment. Solid lines include intermediate year survey data. Dotted line exclude data.

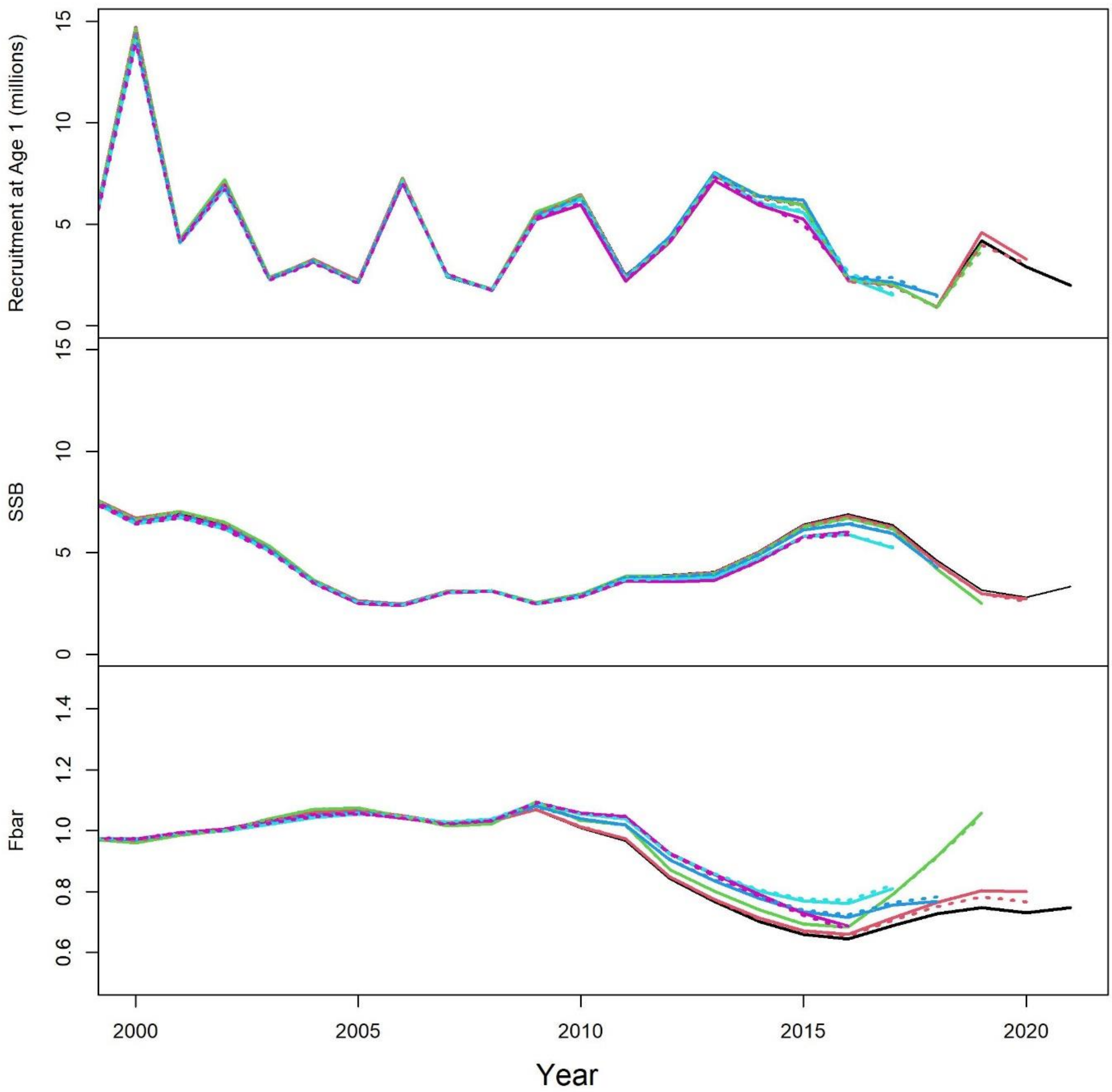


Figure 3.37. Cod.27.6a. Retrospective sensitivity analysis of SAM assessment results to exclusion of age 1 and age 2 catch data. Black line: WGCSE 2022 final assessment. Solid lines include all catch data. Dotted line exclude age 1 and 2.

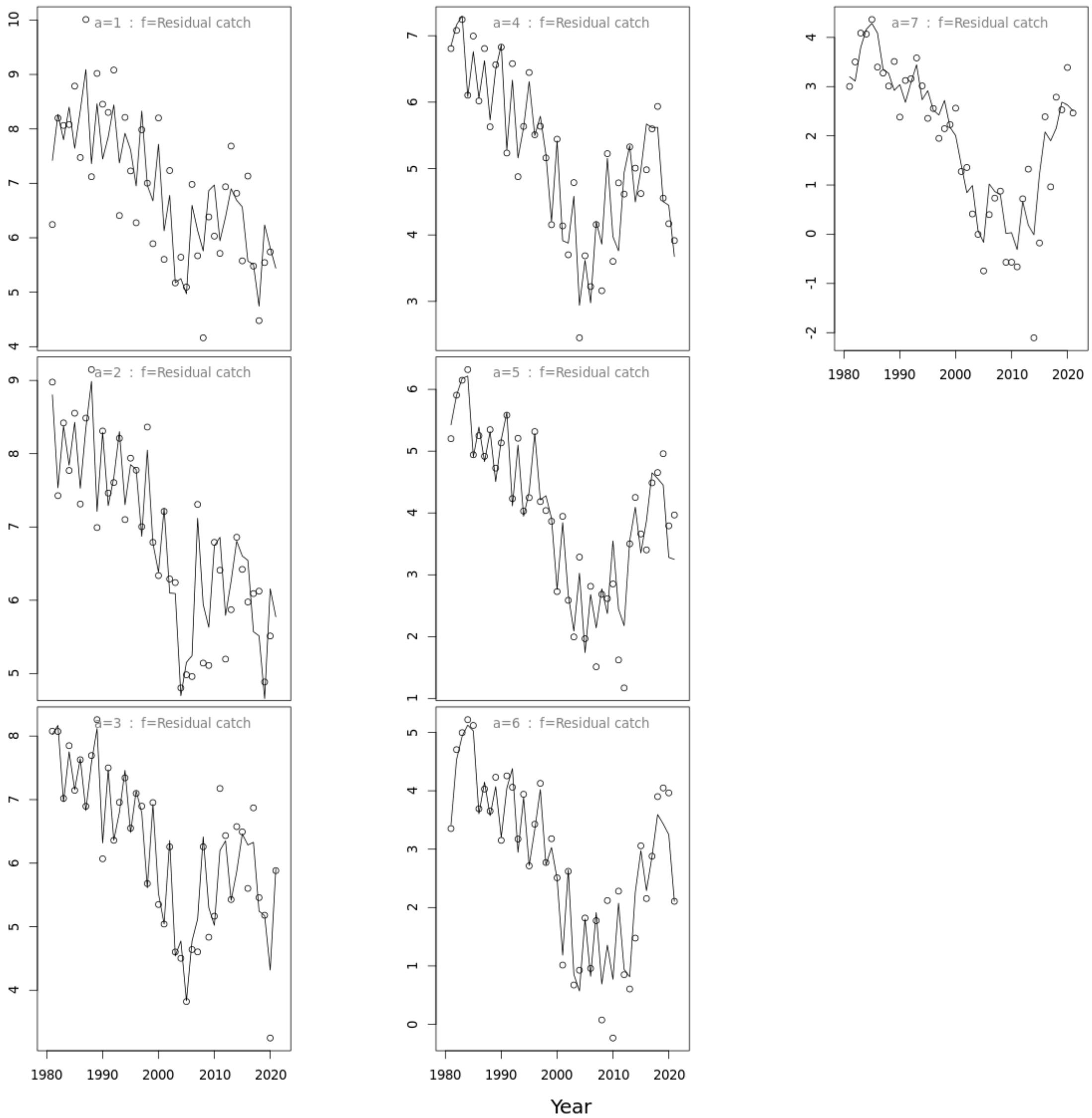


Figure 3.38. Cod.27.6a. SAM final run. Comparison of model estimated and observed log catch numbers-at-age.

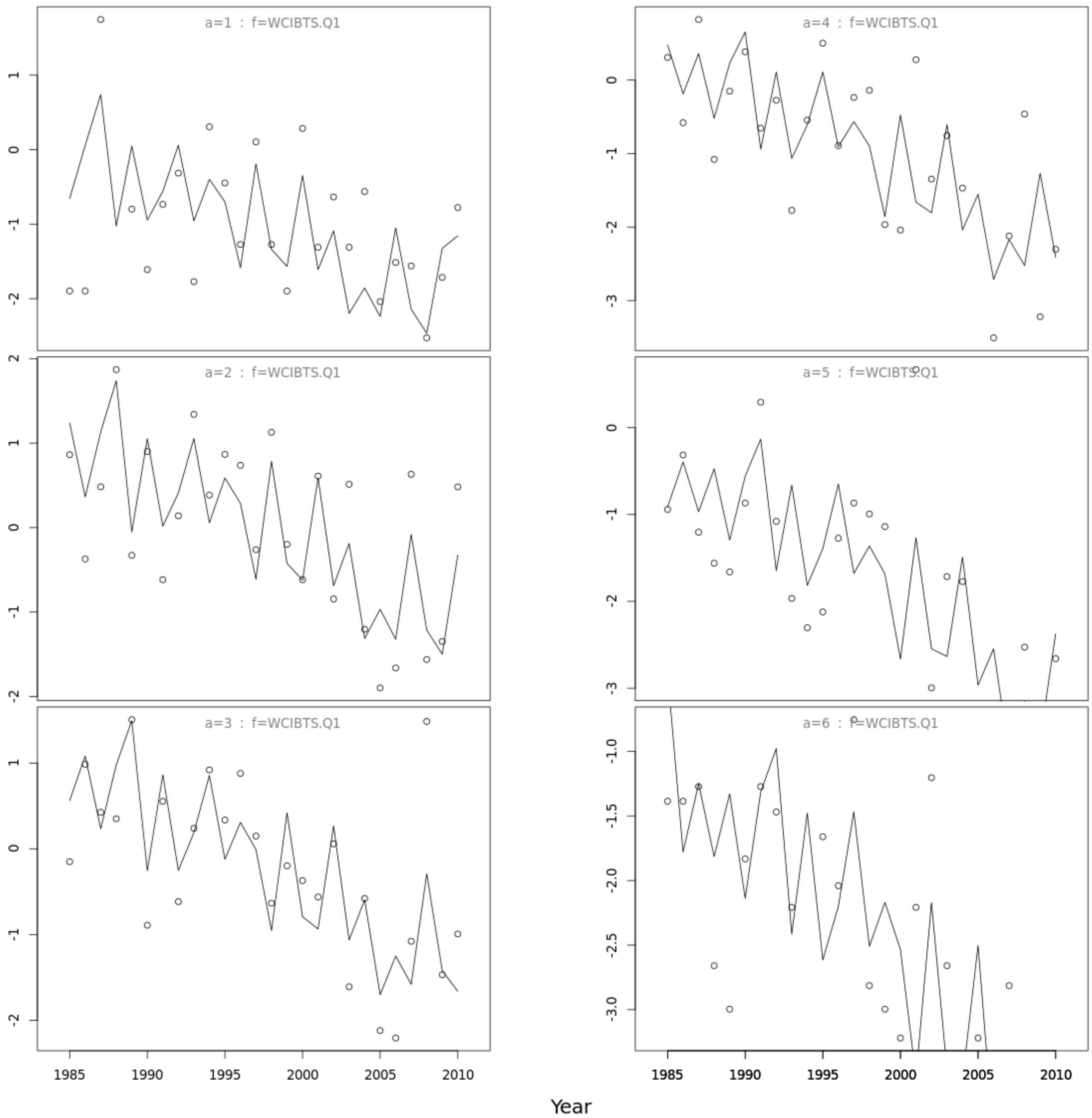


Figure 3.39. Cod.27.6a. SAM final run. Comparison of model estimated and observed log index at age (ScoGFS-WIBTS-Q1).

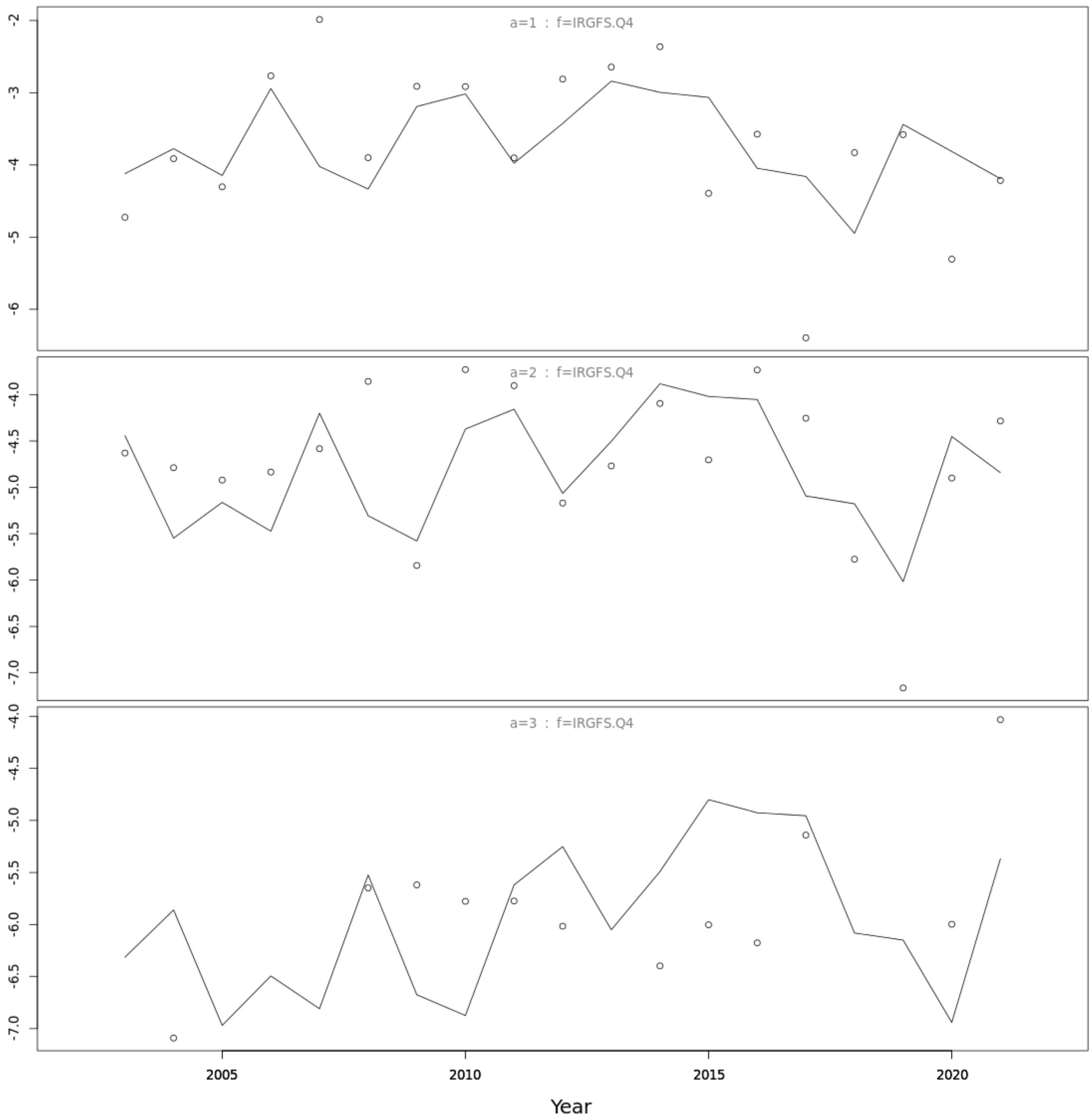


Figure 3.40. Cod.27.6a. SAM final run. Comparison of model estimated and observed log index at-age (IRGFS-WIBTS-Q4).

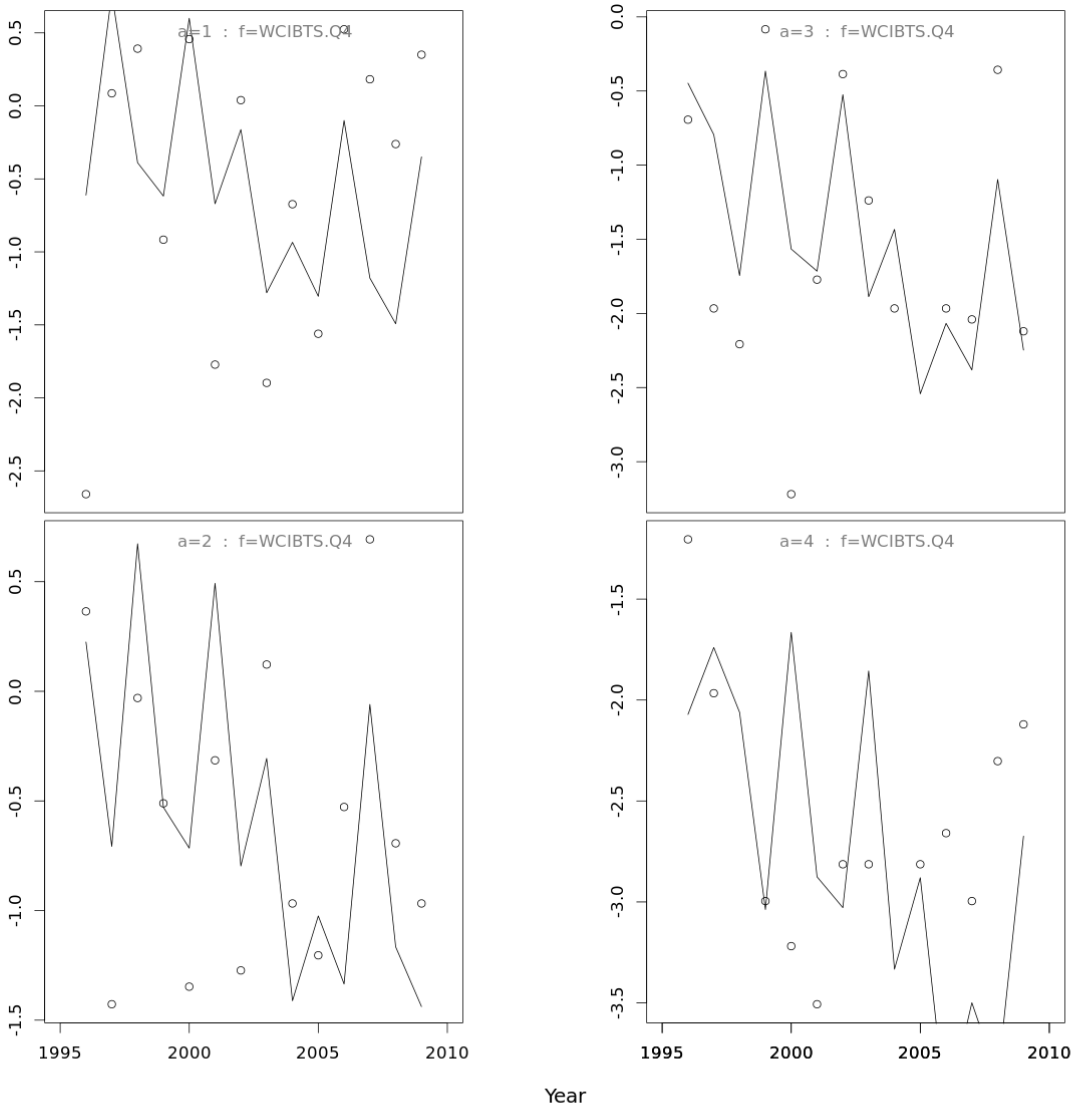


Figure 3.41. Cod.27.6a. SAM final run. Comparison of model estimated and observed log index at-age (ScoGFS-WIBTS-Q4).

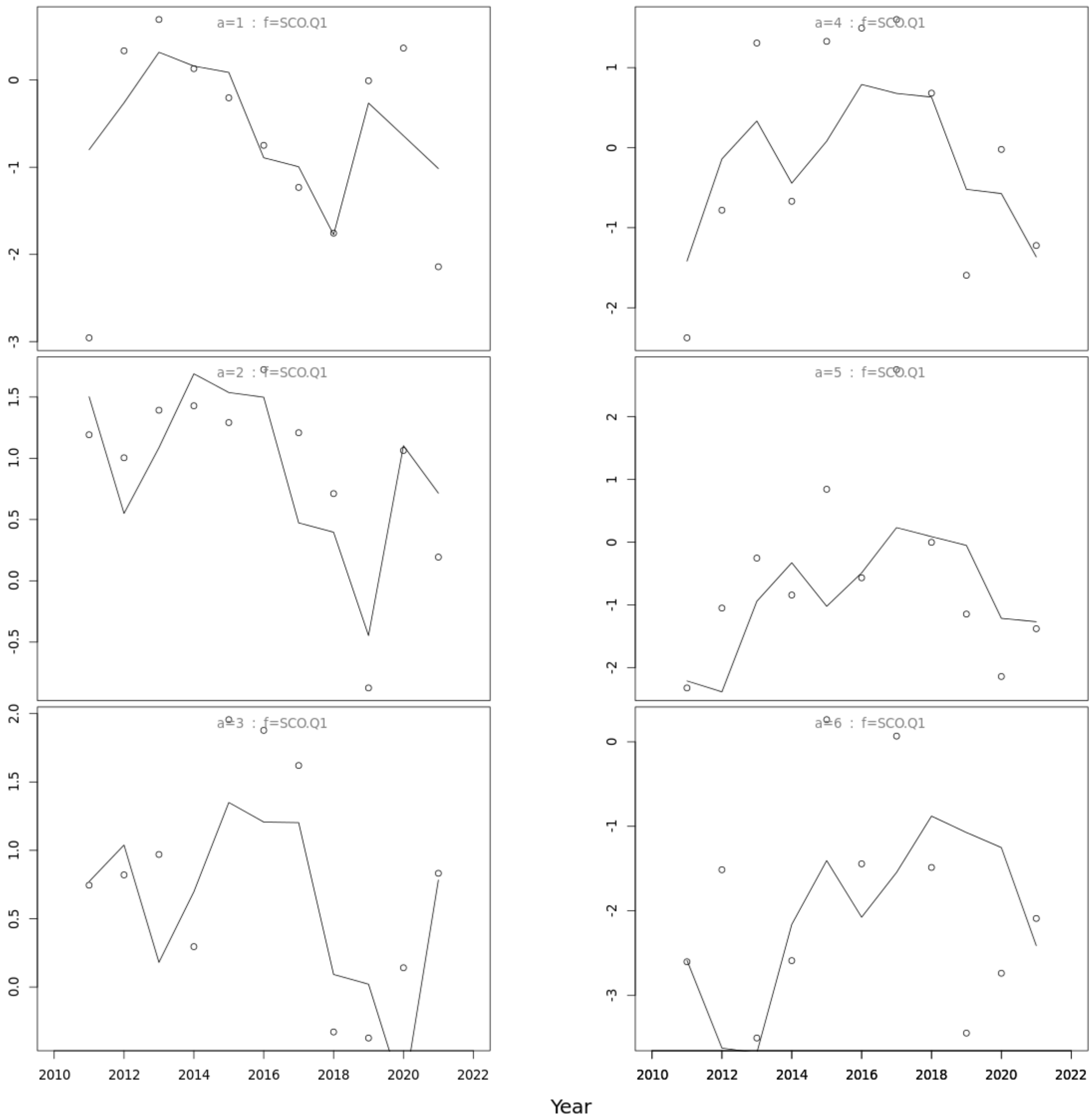


Figure 3.42. Cod.27.6a. SAM final run. Comparison of model estimated and observed log index at-age (UK-SCOWCGFS-Q1).

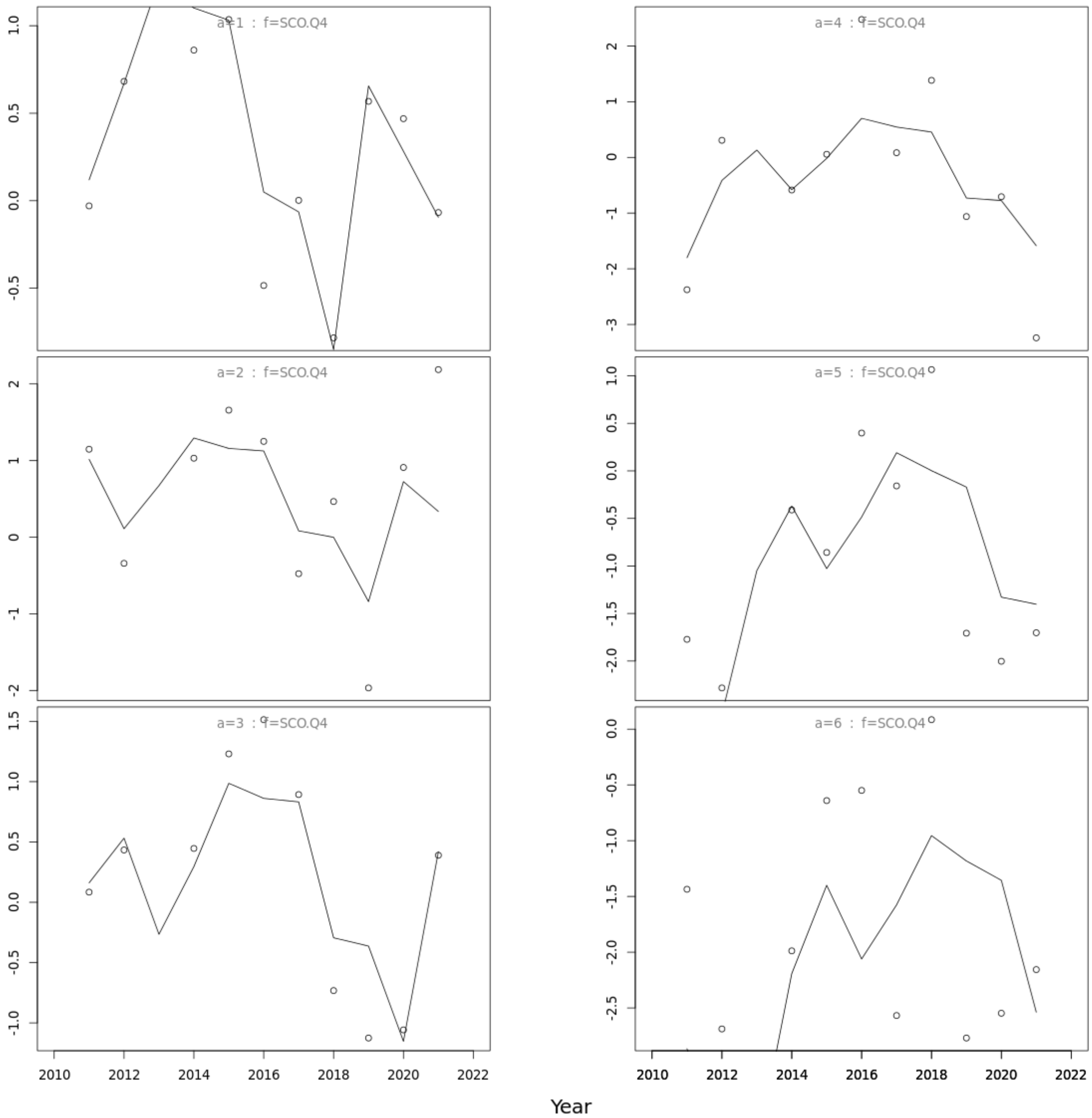
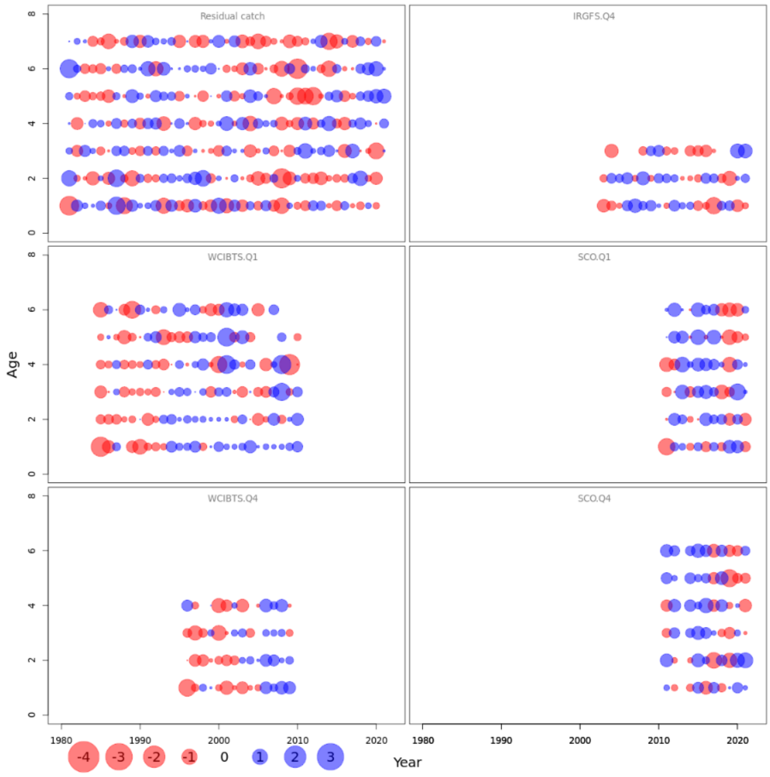


Figure 3.43. Cod.27.6a. SAM final run. Comparison of model estimated and observed log index at-age (UK-SCOWCGFS-Q4).



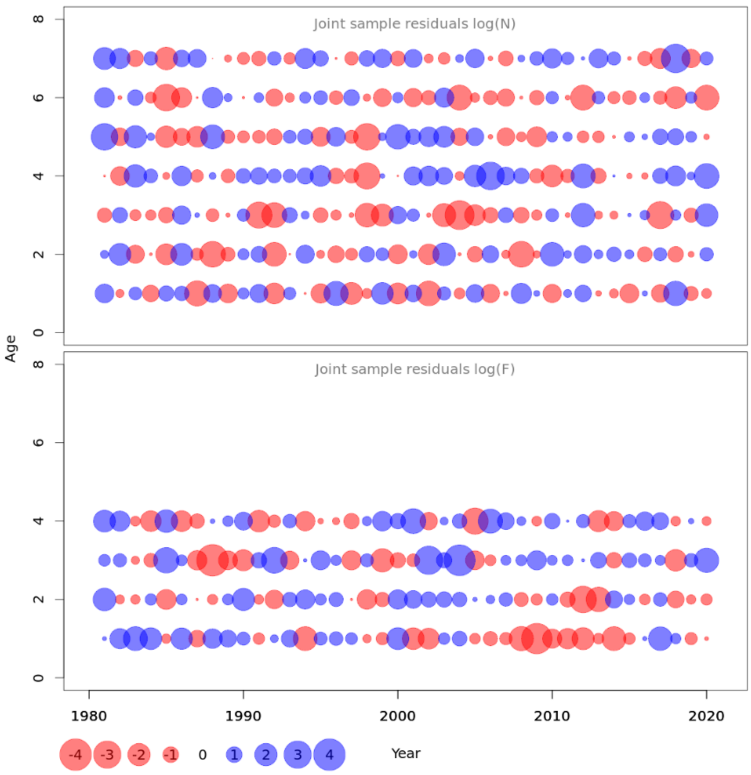


Figure 3.44. Cod.27.6a. SAM final run. One step ahead residuals for catch-at-age data and survey indices (upper panel) and process residuals (lower panel).

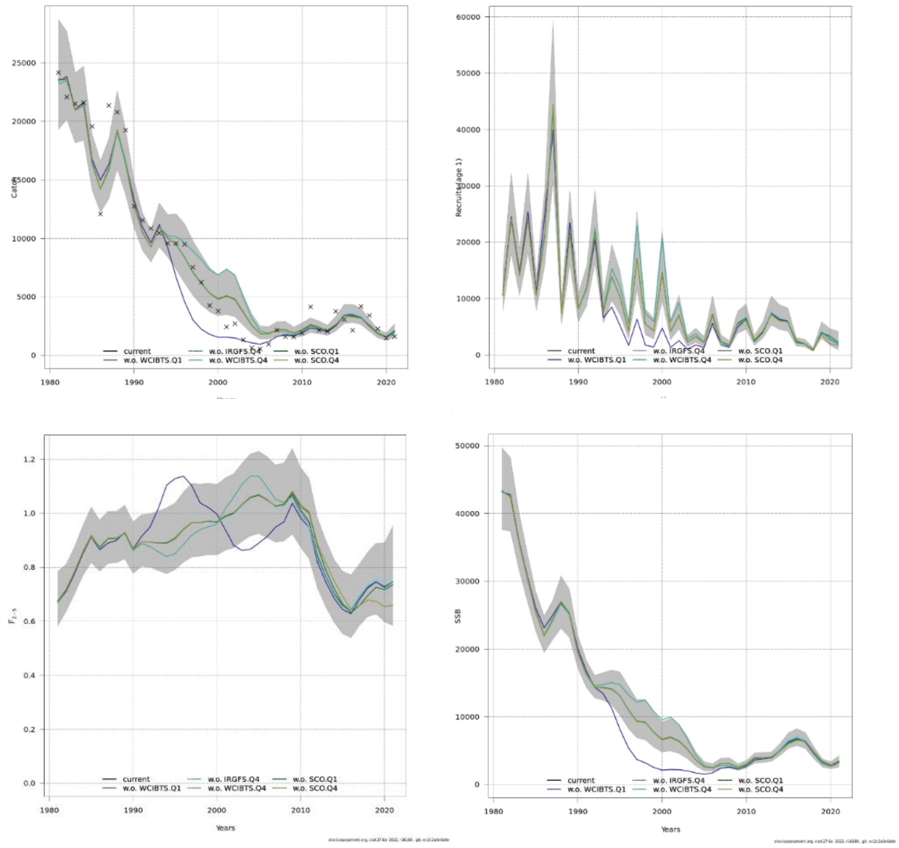


Figure 3.45. Cod.27.6a. SAM final run. Leave one out sensitivity analysis.

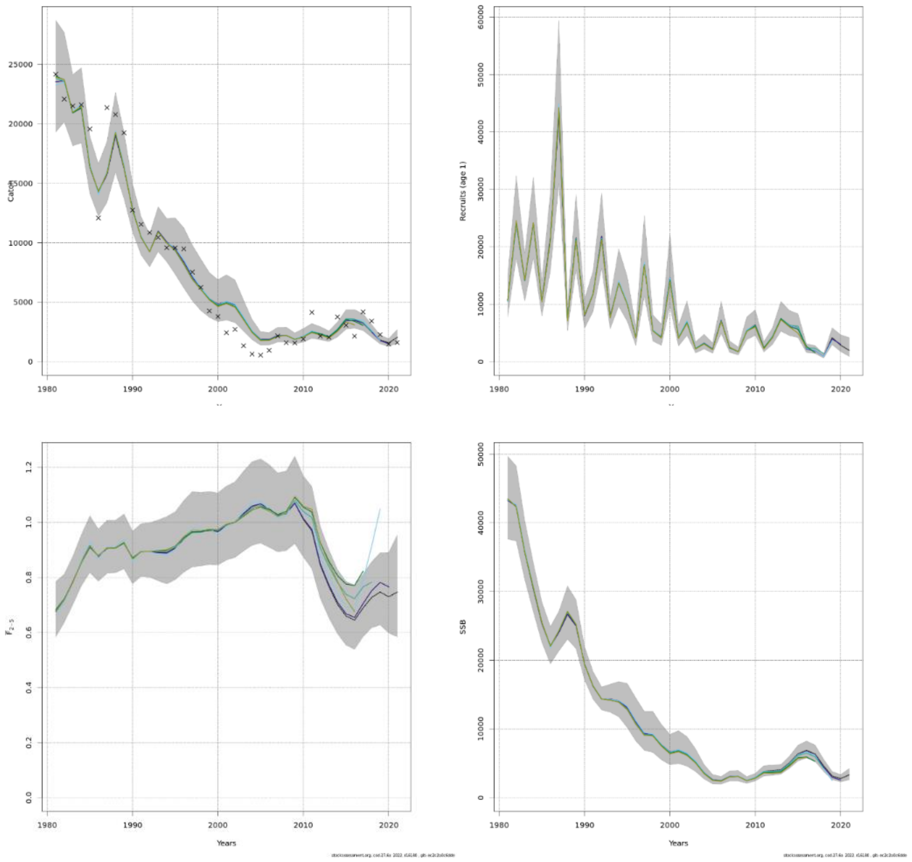


Figure 3.46. Cod.27.6a. Retrospective plots of final SAM run.

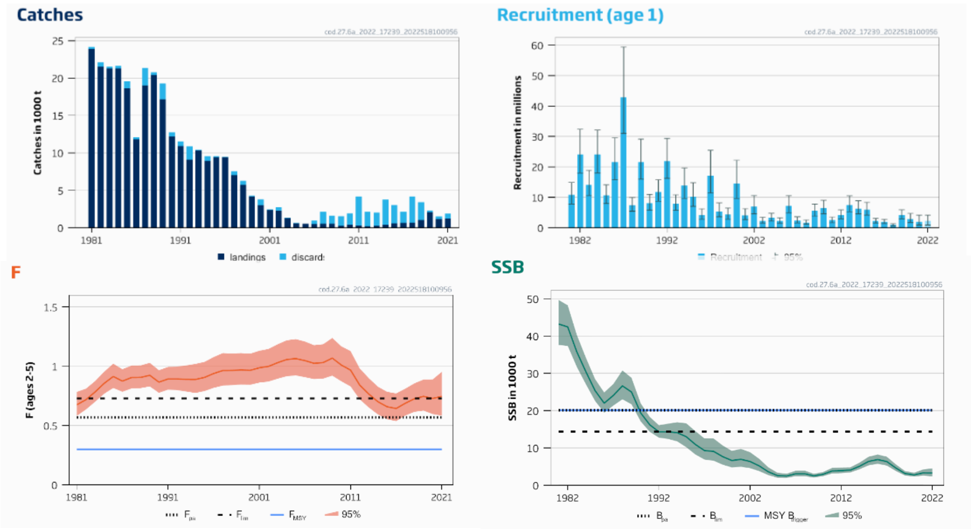


Figure 3.47. Cod.27.6a. Summary of the stock assessment. ICES estimated landings and discards shown in the upper left panel (catches from 1995–2006 (unshaded) are excluded from the assessment). Shaded areas (F and SSB) and error bars (recruitment) correspond to 95% confidence intervals.

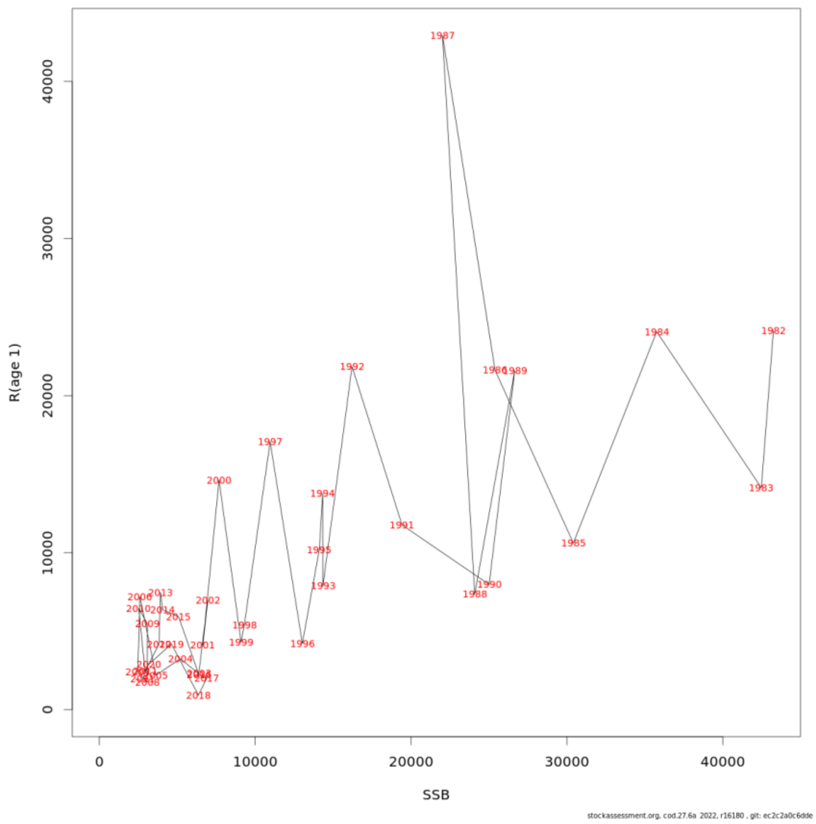


Figure 3.48. Cod.27.6a. SAM final run. Stock–recruit relationship. Numbers indicate recruitment year.

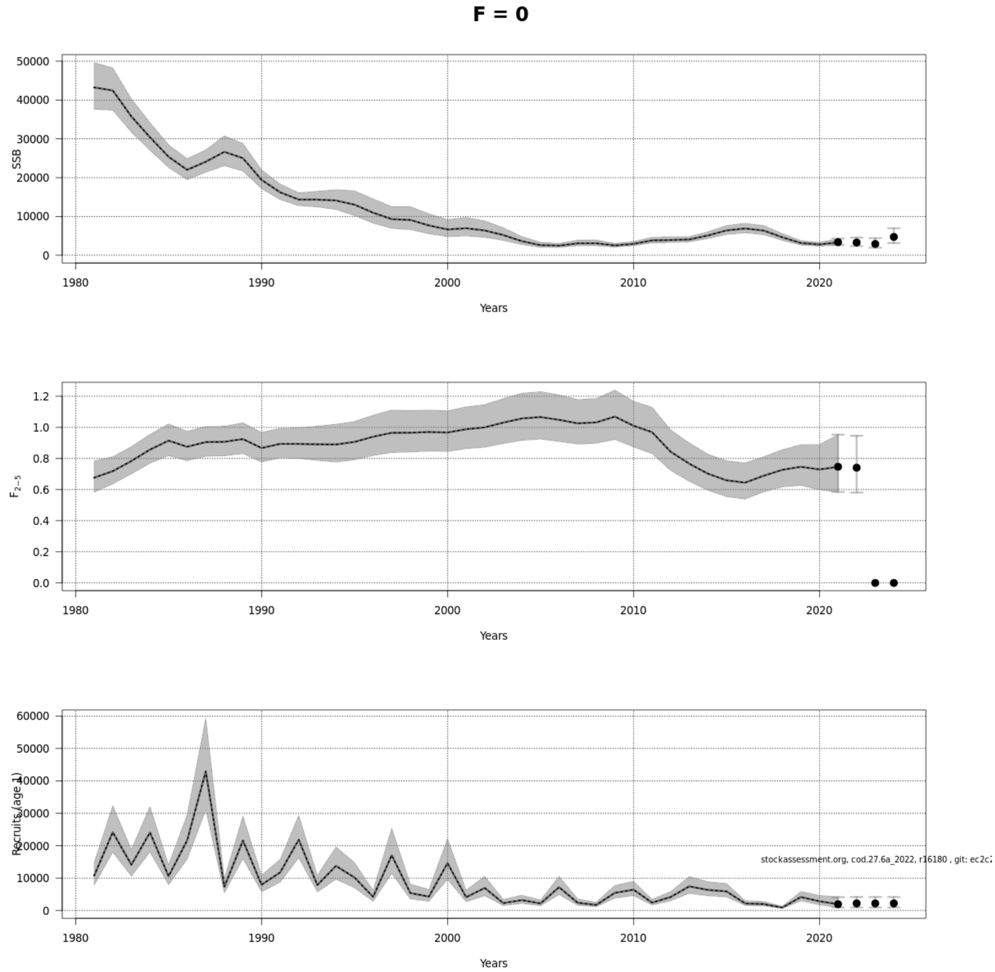


Figure 3.49. Cod.27.6a. SAM forecast assuming Fsq in the intermediate year followed by zero catch (the proposed advice) in subsequent years.

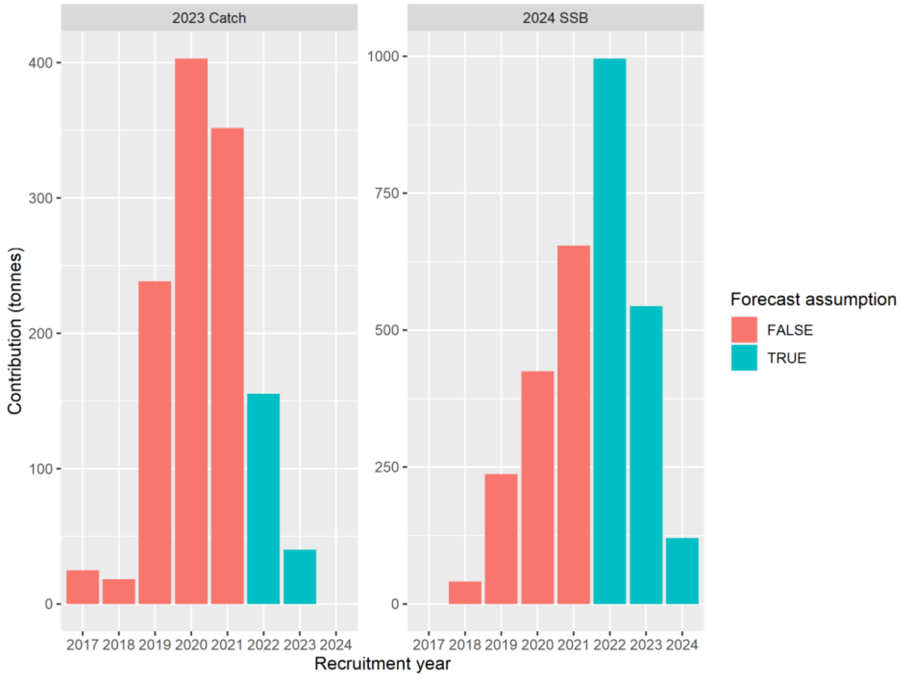


Figure 3.50. Cod.27.6a. Percentage contribution to landings yield in 2021 and SSB in 2022 by recruitment year (not year class). Blue ('TRUE') indicates forecast assumption rather than an assessment model estimate.

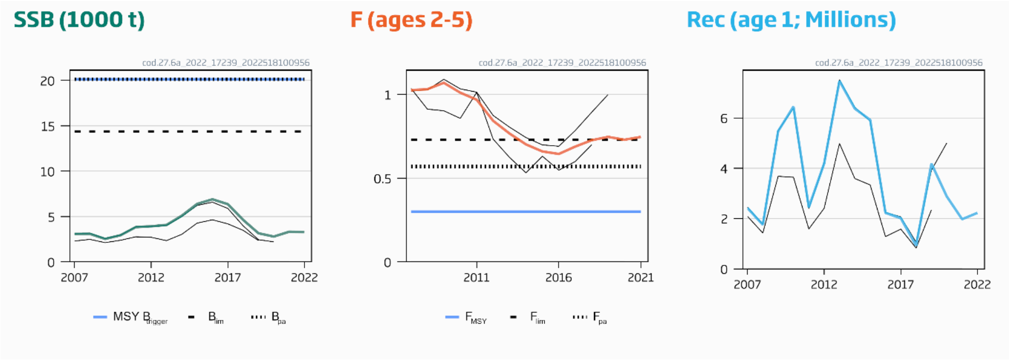


Figure 3.51. Cod.27.6a. Historical assessment comparison plots. Final year recruitment in 2022 assessment is assumed (resampled from 2016–2021) rather than an assessment model estimate due to lack of intermediate year survey.