NORTHWESTERN WORKING GROUP (NWWG)

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Teunis Jansen • Helga Bára Mohr Vang

Authors

Karolin Adorf • Tanja Bågø Buch • Helga Bára Mohr Vang • Birkir Bárðarson • Sigurvin Bjarnason
Höskuldur Björnsson • Jesper Boje • Henrik Christiansen • Bjarki Þór Elvarsson • Einar Hjörleifsson
Teunis Jansen • Kristján Kristinsson • Adriana Nogueira-Gassent • Anja Retzel • Frank Farsø Riget
Petur Steingrund • Karl-Michael Werner • Pamela Woods

Contents

i Executive summary[1]

The Northwestern Working Group (NWWG) reports on the status and considerations for management of some of the demersal fish stocks (cod, haddock, saithe, plaice, and Greenland halibut) around Greenland, Iceland and Faroes, as well as two pelagic fish stocks in Icelandic Waters (summer spawning herring and capelin) and five redfish stocks in Greenland, Iceland, and the Irminger Sea.

Capelin in the Iceland-East Greenland-Jan Mayen area

In October 2023, MFRI advised an intermediate TAC of 0 tonnes based on an acoustic survey in September.

In November 2023, ICES advised an initial quota of 0 tonnes for the fishing season 2024/2025.

In February 2024, MFRI advised a final TAC of 0 t for 2023/2024 based on acoustic surveys in January-February 2024. All advice was based on the HCR from the ICES Benchmark Workshop on Icelandic Stocks (WKCAPELIN; ICES, 2023).

The total landings in the fishing season 2023/2024 amounted to 0 tonnes (preliminary data).

West Greenland offshore spawning Cod

The cod stocks in Greenland were benchmarked in 2023, here they were separated into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022.

The West Greenland offshore spawning cod assessment is based on genetic split of commercial and survey data. Mixing occurs between this stock and others in West Greenland both inshore and offshore. This mixing is accounted for in the assessment.

New reference points were calculated in 2024, and F range was changed from ages 4–7 to ages 5 –8.

The stock has been recovering from very low level in early 2000s. Spawning-stock biomass is below MSY $B_{trigger}$, but is forecasted to be above in the start of 2025. Fishing mortality ($F_{5\text{-}8}$) has been above Fmsy for the entire assessment period, from above 1 in the first years of the time-series to 0.57 in 2013. In 2023 $F_{5\text{-}8}$ was 0.68. According to the ICES MSY approach catches in 2024 should be no more than 3 238 tonnes.

Cod from this stock mix with the other stocks outside the spawning season and this should be taken into account when defining management actions (such as area-based TACs) to avoid exceeding the advice for any of the stock units.

Northwest Greenland Inshore spawning cod

The cod stocks in Greenland were benchmarked in 2023, here they were separated into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022.

The Northwest Greenland inshore spawning cod assessment is based on genetic split of commercial and survey data into West Greenland inshore spawning cod. Further the inshore stock

[1] This section was last updated Spring 2024.

is split into a Northern and a southern component based on especially tagging, but also catch history which indicate difference in dynamics.

New reference points were calculated in 2024, and F range was changed from ages 4–7 to ages 5–8.

The stock has been recovering from very low level in early 2000s, peaked in 2016, followed by a reduction to a level above MSY $B_{trigger}$ in the most recent years. $F_{5\text{-}8}$ has been between 0.6 and 1.0, well above F_{MSY} for the entire assessment period. According to ICES MSY approach catch in 2024 should be no more than 2151 tonnes.

Cod from the two offshore spawning stocks migrate into the inshore areas used by this inshore spawning stock component and this should be taken into account when defining management actions (such as area-based TACs) to avoid exceeding the advice for any of the stock units.

Southwest Greenland Inshore Spawning cod

The cod stocks in Greenland were benchmarked in 2023, here they were separated into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022.

The Southwest Greenland inshore spawning cod assessment is based on genetic split of commercial and survey data into West Greenland inshore spawning cod. Further the inshore stock is split into a Northern and a southern component based on especially tagging, but also catch history which indicate difference in dynamics.

New reference points were calculated in 2024, and F range was changed from ages 4–7 to ages 5 –8.

The stock has been recovering from very low level in early 2000s and been on a high level for the last decade, well above MSY $B_{trigger}$. Fishing mortality ($F_{5\text{-}8}$) has been between 0.7 and 1.2, well above F_{MSY} for the entire assessment period. According to ICES MSY approach catches in 2024 should be no more than within the range from 1285 to 2304 tonnes corresponding to the F-range 0.27–0.54 (F_{MSY}).

Cod from the two offshore spawning stocks migrate into the inshore areas used by this inshore spawning stock component and this should be taken into account when defining management actions (such as area-based TACs) to avoid exceeding the advice for any of the stock units.

East Greenland Iceland Offshore Spawning cod

The cod stocks in Greenland were benchmarked in 2023, here they were separated into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022.

The East Greenland Iceland offshore spawning cod assessment is based on genetic split of commercial and survey data. In the assessment model a proportion of the catch, since 2012, is estimated to belong to a stock not covered by the survey (non-surveyed stock component). This stock has the same genetic profile as cod spawning offshore in east Greenland and Iceland. At the ADGANW 15–19 May 2023 the assessment model was rejected, and the stock was changed to a category 5 stock. Advice for 2024 is based on catch of the stock in 2022. Since this was the first year the approach was applied a precautionary buffer of 20% was added. The final advice is that catches in 2024, 2025, and 2026 should be no more than 23 518 tonnes.

In recent years the cod catches on Dohrn Bank in the Denmark strait have increased to a level where they constitute a major component of the cod catches in Greenland. It is assumed, based on the modelling made during the benchmark, that a large proportion of these cod originate in another stock outside the Greenland EEZ. To i) better understand the dynamics occurring in this area, and ii) to improve the assessment and management advice of cod stocks in Greenland and Iceland (including changing the EGIOSC from a category 5 to 1 stock), NWWG requests the relevant national institutes to conduct studies on this topic. Pilot studies have indicated that tagging and otolith chemistry studies are promising techniques for this specific case.

Icelandic saithe

Annual landings in the fishing year 2021/2022 are estimated to be 63 206 tonnes or 81% of the TAC of 77 691. Since the fishing year 2014/2015 around 84% of the annual TAC has been caught on average.

The assessment has since 2010 been based on an assessment model tuned with indices from the Icelandic spring survey (often referred to as ice-smb in this report). The assessment, benchmarked in 2019, is relatively uncertain due to fluctuations in the survey data, poor recruitment estimates, and irregular changes in fleet selectivity. This uncertainty is taken into account when evaluating the management plan.

The current assessment shows a downward revision of the stock size compared to the last five assessments, but the stock size is still estimated to be well above average. Mohn's rho based on last five assessments is 0.30 for B4+ ending in the assessment year (basis for advice). The retrospective pattern for the last 5 years is caused by a very high 2018 survey index and again relatively high index in 2021. Retrospective runs since assessment year 2025 show periods of positive and negative Mohn's rho with an average close to 0.

Investigation of alternative model setup shows the adopted assessment to be in the middle of plausible values and the range of results was not very wide. Saithe is considered a relatively difficult species to catch with demersal gear and the harvest rate in the management plan might be reduced for the saithe fisheries to work in mixed fisheries with more easily caught species. Still, low catches compared to TAC could be an indication that the stock is overestimated.

To the extent possible, the part of the TAC that is not caught is transferred to other species, but a large part is not used at all. There are indications that overestimation will not lead to risk to the saithe stock, the fisheries will not become profitable, and the TAC will not be caught, something that could change with higher saithe prices.

According to the management plan, catches in the fishing year 2023/2024 should be no more than 66 533 tonnes.

Icelandic cod

The results of this year's assessment show that the spawning stock in 2024 is estimated to be 377 477 kt. The values estimated in recent years are higher than have been observed during the last five decades. The reference biomass B_{4+} in 2024 is estimated to be 1 075 600 kt. Year classes since the mid-1980s are estimated to be relatively stable but with the mean around 35% lower than observed in the period 1955 to 1985.

The TAC for the current fishing year (2023/2024) based on last year's assessment was 211 309 kt.

Following the current HCR, the catch for the coming fishing year (2024/2025) should be 213 214 kt based on the following:

The input in the analytical age-based assessment are catch-at-age 1955–2023 (age 3 to 14) and ages 1 to 14 (from the 1985–2024 spring (often referred to as SMB in this report) and ages 3 to 13 from the 1996–2023 autumn groundfish surveys (often referred to as SMH in this report).

The reference biomass (B_{4+}) upon which the TAC in the fishing year is set is derived from population numbers at the beginning of the assessment year and catch weights in that year. The catch weights are not known and hence need to be predicted. An alternative model to the current catch weight prediction model was explored which has shown improvement in predictive capability in the past, but this year showed little difference from the current model. The WG thus proceeded with the current model, noting that in future a working document should be produced to evaluate alternative models.

Icelandic summer spawning herring

The total reported landings in 2023/24 fishing season were 94.4 kt (including summer fishery 2023) although the TAC was set at 92.6 kt. Analyses of biological samples from the past fishing season indicate the continuation of new infection by *Ichthyophonus* in the stock in the coming fishing year 2024/2025.

The assessment method was reevaluated in 2024 and the stock is now assessed using a catch- at-age based assessment model (SAM). *Ichthyophonus* infection mortality was revaluated for the period 2009-2023, resulting in applying lower infection mortality than previously. In this update assessment, where the 2023/24 catch and survey data have been added to the input data, additional natural mortality was applied for 2024 because of the *Ichthyophonus* infection in the stock.

The effect of the SAM assessment model results in a downward revision of the reference biomass (age 4+) and in the spawning-stock biomass compared to the 2023 assessment but includes uncertainty estimates which the NFT-Adapt model was lacking. The results from the assessment model also indicate a downward revision in stock size from last year, due to the large 2017–2019 year classes, who have now entered fully into the fishery, are not perceived as strong as previously suspected. Spawning-stock biomass for 2024 is estimated 412.1 kt and the reference biomass of age 4+ (B_{Ref}) is 428.2 kt at the beginning of the year 2024. As the SSB will be above MGT $B_{trigger}$ = 273 kt, the advised TAC according to the Iceland Management Plan is $HR_{MGT} \times B_{Ref} = 0.19 \times 428\,249 = 81\,637$ tonnes.

Golden redfish (*Sebastes norvegicus*) in Subareas 5, 6, 12 and 14

Annual landings increased gradually since the 2000s, when they were at low level, to 2016. Since then, landings have decreased. Total landings in 2022 were 35 988 t, which is about 3 000 t more than in 2022. About 95% of the catches were taken in Division 5.a.

The stock was benchmarked in February 2023 (WKBNORTH 2023, ICES 2023) which resulted in changes in the assessment method (age-based model - SAM) and updated reference points. The model uses catch in numbers and age-disaggregated indices from surveys conducted on the continental shelves and slopes of East Greenland, Iceland, and Faroe Islands.

Relatively high recruitment during 2000–2013 corresponds to increased spawning-stock biomass (SSB) and catches after 2010. However, recruitment has decreased greatly in 2014 and shows a prolonged period of low recruitment. Fishing mortality has declined since 1990. The assessment model indicates that fishing mortality has been low and below F_{MSY} since 2009. Total biomass and SSB has been decreasing since 2016 but remain high. The spawning-stock biomass observed over the past decade in this model is higher than that observed in the previous Gadget model, largely because of variable growth.

Results from surveys in Iceland and East Greenland indicate that cohorts from 2009 to ca. 2019 are poor. There are, however, indications in the 2021-2023 surveys in both areas of increased number of small golden redfish (< 12 cm). The accuracy of the surveys as an indicator of recruitment is not known but recruitment in the next few years is expected to be poor.

Icelandic slope beaked redfish (Sebastes mentella) in 5.a and 14

Annual landings in the years 2011–2022 were between 8300 and 12 000 t. The total catch in 2023 were 6676 t, a decrease of about 2800 t from previous year.

The stock was benchmarked in 2023 (ICES, 2023) and is now assessed as a category 1 stock using an age and length-based assessment model (Gadget). During the meeting the reference points were defined. An error in the procedure for calculating biomass from the model output was found in 2024, which affected the estimates of total biomass and spawning-stock biomass, and thus the reference points B_{lim} and B_{pa}. Correcting the biomass levels therefore necessitates re-calculation of the stock's reference points. The error did not affect estimated recruitment levels nor exploitation rates.

The assessment results show a steep decline in the spawning stock is seen from the late 1980s to the early 2000s. This was followed by a period of stability in the 2000s and a gradual decline in the 2010s. The SSB is currently at its lowest point in the time-series and below all defined reference points ($B_{trigger}$, B_{pa}, and B_{lim}). Since a recruitment spike in 2003, annual recruitment has also steadily declined, and furthermore, since 2010 recruitment has remained at exceptionally low values resulting in a declining total stock size and a stock composition that is increasingly dominated by older, mature fish. Fishing mortality has declined since the 1990s. In the years 2020–2023 fishing mortality was above defined reference points (F_{lim}, F_{MSY} and F_{pa}).

Since 2007, survey estimates of *S. mentella* have consistently shown very low abundance of pre-fishery juveniles (< 30 cm). This raises concerns about the productivity of the stock. Without substantial recruitment biomass levels will likely continue to decline.

Beaked redfish (*Sebastes mentella)* in Division 14.b, demersal (Southeast Greenland)

Before 2009, *Sebastes mentella* was mainly a bycatch in the fishery for Greenland halibut, but afterwards, a directed mixed fishery towards demersal redfish (*S. mentella* and *S. norvegicus*) has taken place. In 2023, total landings of demersal *S. mentella* were 1255 tonnes in East Greenland. The proportion of *S. mentella* in this mixed fishery is monitored on a yearly basis, and with the exception of 2019, *S. norvegicus* has dominated the catches since 2016.

Sebastes mentella is a slow growing, late maturing species and is therefore considered vulnerable to overexploitation. Biomass and abundance indices from the Greenland Shallow Water Survey (GRL-GFS) for adult *S. mentella* have been low in the past ten years. The biomass index in 2020 was the lowest in the entire time-series. No survey has been conducted in 2021 and in 2022 and 2023 the biomass indices were higher than in 2020 but still very low. Juvenile redfish (*Sebastes* spp.) have been nearly absent from 2013 to 2019. In the 2020 survey an increase in juvenile redfish has been detected in the GRL-GFS survey, which was confirmed in 2022 and 2023. The abundance of juveniles in 2022 was the highest seen since 2009, but it is unknown to which stock these juveniles will recruit. The low stock biomass of adult *S. mentella* is supported by the German Groundfish Survey index (GER(GRL)-GFS-Q4), although no data are available from this survey for 2021 and 2022, and only very few stations were taken in 2023.

The Greenlandic demersal *S. mentella* is a data-limited stock (DLS) and follows the ICES framework for category 3 stocks. The low biomass indices obtained in recent years indicate that the stock is below any candidates for biomass reference points and given the poor recruitment for a decade no catch level could be identified in accordance with the precautionary approach. For a data-limited stock with extremely low biomass, ICES method 3.1.4 was applied and zero catches for 2025 are proposed. The stock has been proposed for benchmark in 2026.

Icelandic Haddock

All the signs from commercial catch data and surveys indicate that haddock in 5.a is at present in a good state. This is confirmed in the assessment. At the ICES Workshop on evaluation of the adopted harvest control rules for Icelandic haddock and saithe (WKICEMSE – ICES, 2019), the harvest rate target applied by the HCR in the period between 2013 and 2018 was estimated to be no longer precautionary while a rate of 0.35 was in-line with both the precautionary and ICES MSY approach. As the 2019- and 2020-year classes are strong the stock size is estimated to have increased.

Due to this good state of the stock, and CPUE being at its highest value, the landings substantially exceeded the TAC advice for the fishing year 2022/2023.

Greenland Halibut in Subareas 5, 6, 12, and 14

The estimated spawning stock size of Greenland halibut in subareas 5, 6, 12 and 14 is now estimated below $B_{trigger}$ but is predicted to increase above $B_{trigger}$ in the coming year due to incoming recruitment. Catches have ranged between 20 and 30 kt in the last two decades and amount to 25 424 t in 2022 which is a 16% increase in total catches compared to 2022. The biomass indices used as input to the assessment (combined survey index from Greenland and Iceland, with Greenland index fixed values since 2016, when the last survey took place) showed an increasing trend while logbook information from Iceland trawler fishery showed a decreasing trend. The increase in survey biomass index was due to increase of fish larger than 40 cm.

An age and length-based assessment model (GADGET) is used to assess the stock status and catch forecast. The model synthesizes information from commercial catch samples and surveys and is based on the combined Greenland and Iceland autumn surveys. The remaining available tuning indices are currently not used in the analytical assessment due to conflicting signals (logbook information from East Greenland and Faroese trawl fishery, and biomass index from a Faroese survey). The Greenland fishery in Division 14.b suggest a high but declining biomass while the Faroese indices suggest a significantly lower but increasing biomass in the eastern areas of the stock distribution. From Icelandic Waters survey estimates of abundance of fish smaller than 40 cm showed reduced productivity since 2014 but has increased in the last two years. This reduction of recruitment is estimated to have had an impact the fishable stock, but the stock is estimated to rebound in the near term. Stock structure and connectivity between the main fishing areas within the stock distribution area remains partly unknown but is currently being investigated.

This year an error was detected in the assessment that affected the estimate of spawning stock size. This resulted in an upwards revision of the entire SSB time-series. Reference points were therefore revised this year.

Icelandic plaice

Icelandic plaice fishery in 5.a has been considered stable in the last two decades and annual total landings have been between 5 and 8 thousand tonnes during this period. In 2023, landings were 6631 tonnes, approximately 646 tonnes decrease from the previous year. Historical landings of plaice have fluctuated during different periods, with highest landings registered in the 1980s, with 14 500 tonnes landed in 1985. Demersal seine is the main fishing gear for plaice (59–71% since 2011) in Iceland followed by demersal trawl (23–37%).

Results from Icelandic surveys indicate that the Icelandic plaice stock is stable, however the surveys are not adequately covering the main recruitment grounds for plaice, as recruitment takes place in shallow water in habitats unsuitable for demersal trawling. Juvenile abundance indices (<20 cm) from those surveys indicate low levels since 1998 with occasional small peaks.

An analytical age-based stock assessment model using catch in numbers and age-disaggregated indices from the spring survey was benchmarked in 2022. A management plan for plaice was evaluated at the same time. The model runs from 1981 onwards and ages 3–12 are tracked by the model, where age 12 is a plus group. Natural mortality is set to 0.15 for all age groups. Considerable uncertainty is present in the model due to limited information on recruitment. The result of the assessment indicates that the stock size is stable and the fishing pressure is in-line with the goals of the management plan, where the target F is set as 0.3.

Faroe Bank cod

This stock was subject to a multiannual 0 catch advice for 2020 to 2022.

In 2022, a category 3 (rb rule) type of advice was formulated. According to this framework, catches in 2023 should be no more than 78 t.

Faroe Plateau cod

Since ICES in November 2022 issued a zero advice for this stock for 2023 and 2024 this assessment is just for information, but also acts as basis for the allocation of fishing days according to the Faroese management plan. While the landings historically fluctuated between 20 and 40 thousand tonnes, the landings since 2005 have only been around 10 000 tonnes. The stock is monitored by a groundfish survey in March and a groundfish survey in August. Both surveys showed record low values in 2022 and 2023. A category 1 age-based assessment using the SAM model was performed showing that the spawning-stock biomass was well below B_{lim} of 17 803 tonnes. Fishing mortality was very high in 2019–2020, and has remained high afterwards. Recruitment and SSB have been markedly revised downwards, probably due to low food availability in 2019 and 2020, but this problem seems to have levelled off. A short-term forecast with a 'no fishing' scenario showed that the spawning stock may become larger than B_{lim} in 2026. Since cod and haddock are caught in a mixed fishery, the poor state of the cod stock may represent a problem when managing both stocks under an effort management system.

Faroe haddock

This stock was benchmarked in 2017 and the assessment has since then been carried out in SAM. An interbenchmark (IBPFAR) in 2022 investigated the inclusion of interim catch-at-age data. Reference points were also recalculated during IBPFAR and finalized at the autumn NWWG meeting in 2022.

The spawning-stock biomass (SSB) decreased significantly from 2003 and is estimated to have been below B_{lim} in the period 2009–2017 and since 2018, SSB has been above MSY $B_{trigger}$ = 23 030 tonnes. Nominal landings in 2021 amounted to 6850 tonnes. Estimated fishing mortality in 2022 is $F_{3\text{-}7}$ = 0.28, which is above F_{MSY} = 0.27 but beneath F_{pa} = 0.54 F_{lim} = 1.43. According to the MSY approach, catches in 2021 should be no more than 11 853 tonnes.

In recent years, the quality of this assessment has been reduced and during IBPFAR multiple approaches were investigated to reduce the retrospective bias. However, no solution did resolve these issues fully, but it was found beneficial to include preliminary catch-at-age data for the interim year, as the SAM-assessment would then rely on more data than before.

A category 3 type of advice was also formulated. According to this framework, catches in 2023 should be no more than 6111 t.

Faroe saithe

This stock was benchmarked in 2017. Since 2017 the advice is based on SAM. An interbenchmark in 2020 investigated the introduction of interim catch-at-age data (ICAA) for the assessment year. The revision improved the overall bias observed in the assessment. Reference points were recalculated using EqSim.

Landings have dropped substantially since 2011 and are estimated to be 17 038 tonnes in 2021.

Fishing mortality has decreased significantly since 2015 and it is in 2021 below F_{MSY} = 0.38.

SSB is stable at low levels since 2018 and it is above MSY $B_{trigger}$ = 36 412 tonnes. Recruitment has fluctuated with no clear trend since 2000 and it is estimated at the lowest level in 2022. According to the MSY approach, catches in 2023 should be no more than 17 843 t. The current assessment is a downward revision of last year's assessment due to lower and higher estimates of SSB and F, respectively.

A category 3 type of advice was also formulated. According to this framework catches in 2023 should be no more than 31 689 t.

ii Expert group information

Expert group name	Northwestern Working Group (NWWG)
Expert group cycle	Annual
Year cycle started	2023
Reporting year in cycle	1/1
Chairs	Helga Bára Mohr Vang, Faroe Islands
	Teunis Jansen, Denmark
Meeting venue and dates	NWWG-1: 22–26 April 2024, Copenhagen, Denmark (19 participants)
	NWWG-2: 4–6 September 2024, online meeting (scheduled)
	NWWG-3: 21–24 October 2024, online meeting (scheduled)

1 Introduction

1.1 Terms of Reference (ToRs)

2023/AT/FRSG05

The **Northwestern Working Group** (NWWG), chaired by Helga Bára Mohr Vang*, Faroe Islands, and Teunis Jansen, Greenland and Denmark, will meet at ICES Headquarters, Copenhagen, 22–26 April 2024 to:

a) Address generic ToRs for Regional and Species Working Groups for all stocks except those listed in ToR b) and ToR c);

online during 4–6 September 2024 to:

b) Address generic ToRs for Regional and Species Working Groups, for Beaked redfish (*Sebastes mentella*) in ICES Subareas 5, 12, and 14 (Iceland and Faroe grounds, North of Azores, East of Greenland) and NAFO subareas 1 and 2 (deep pelagic stock > 500 m), and for Beaked redfish (*Sebastes mentella*) in ICES Subareas 5, 12, and 14 (Iceland and Faroe grounds, North of Azores, East of Greenland) and NAFO subareas 1 and 2 (shallow pelagic stock < 500 m).

and online during 21–24 October 2024 to:

c) Address generic ToRs for Regional and Species Working Groups, for Cod (*Gadus morhua*) in Subdivision 5.b.1 (Faroe Plateau), Cod in Subdivision 5.b.2 (Faroe Bank,) Haddock (*Melanogrammus aeglefinus*) in Division 5.b (Faroes grounds) and Saithe (*Pollachius virens*) in Division 5.b (Faroes grounds).

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant to the meeting must be available to the group on the dates specified in the 2024 ICES data call.

NWWG will report by 15 May, 10 September, and 10 November 2024 for the attention of ACOM.

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

1.2 Work in relation to generic ToRs

Section 1.2 will be updated after the autumn NWWG meetings.

1.3 Work in relation to the WG-specific ToRs

The group will meet three times in 2024 (see ToRs). The report will be updated with the respective stocks after each meeting.

1.4 Assessment methods applied to NWWG stocks

The methods applied to assess the stock status of the NWWG stocks cover a wide range from descriptive to age-based analytical assessments as follows:

Stock	Assessment model	Input*
Faroe Bank cod	DLS category 3	Survey
Faroe Plateau cod	SAM	Survey
Faroe haddock	SAM	Survey
Faroe saithe	SAM	Survey
Iceland saithe	Muppet (statistical catch-at-age)	Survey
Iceland cod	Muppet (statistical catch-at-age)	Survey
Iceland haddock	Muppet (statistical catch-at-age)	Survey
Iceland herring	SAM	Survey
Icelandic plaice	SAM	Survey
Capelin	Acoustic survey	Survey
West Greenland Offshore spawning cod	SAM	Survey
Southwest Greenland Inshore spawning cod	SAM	Survey
Northwest Greenland Inshore spawning cod	SAM	Survey
East Greenland Iceland Offshore spawning cod	Category 5	
Offshore West Greenland cod	Descriptive	Survey
Greenland halibut	Gadget	Survey
Golden redfish	SAM	Survey
Iceland slope *S. mentella*	GADGET	Survey
Deep pelagic *S. mentella*	Gadget	Survey
Shallow pelagic *S. mentella*	DLS category 3	Survey
Greenland Slope *S. mentella*	DLS category 3.2	Survey

*** Catches or catches by age are input to all assessments**

1.5 Audits

The audit reports are attached to this report in Annex 5. The remaining audit reports will be added to this report when it is updated after the subsequent NWWG meeting.

1.6 Recommendations

1.6.1 Recommendations to NWWG

BOG: Based on results from WKCAPELIN benchmark, follow up correspondence work to fully explore the combining of surveys that was done for Icelandic capelin to be carried out.

- NWWG response: For current season we will follow the survey proportions advised by the Benchmark. Currently we don’t have any results from correspondence work to fully explore the combining of surveys.

BOG: Based on WKCAPELIN results, a MSE testing the capelin HCRs is recommended to take place in the near future.

- NWWG response: We see this as a recommendation for future benchmark work. We are at the initial stage of evaluating what data are needed to perform MSE testing for this capelin stock. Such evaluation has not been completed.

WKGREENCOD: Due to the uncertainty regarding the reference point simulations for all assessed stocks as well as a short time-series it is recommended to re-estimate these at the NWWG meeting in 2024.

- NWWG response: This was done during the April-meeting, described in the relevant sections in this report and used for the draft advice.

WKGREENCOD: In recent years the cod catches on Dohrn Bank in the northeastern area close to the Icelandic EEZ have visibly increased, and it is assumed, based on the modelling made during the benchmark, that a large proportion of these cod originate in another stock outside the Greenland EEZ. To better understand the dynamics occurring in this area it is recommended to have tagging and otolith chemistry studies based on samples from Greenland and Icelandic catches.

- NWWG response: The recommended work has been initiated and a subgroup meeting was held during the April-meeting. A project group was created, and the next steps were discussed. Further planning will be done by correspondence in the coming months. Initial results suggests that this may affect the assessments of all cod stocks in East Greenland and Icelandic Waters and should therefore be added to the benchmark issue lists for those stocks.

WKGREENCOD: The NWWG should consider including the above mentioned unallocated catches in the assessment of the Cod5a stock. This would be in line with the current procedure of adding the large migrating year classes at age 6, i.e. 1984 and 2003, in the assessment where interactions with the East Greenland area are accounted for.

- NWWG response: The mentioned catches were included in the EGIOSC when this was changed from a category 1 to a category 5 stock during NWWG 2023. For a longer term solution, see the recommendation above.

WKGREENCOD: Since the assignment of catch and biological data to either of the three cod stocks is based on genetic analysis, it is also recommended that sufficient number of samples from both fisheries dependent and fisheries independent catches area collected.

- NWWG response: The Greenlandic Institute of Natural Resources have initiated genetic monitoring with an annual sampling program that NWWG considers appropriate.

1.6.2 Recommendations from NWWG

At NWWG-1 in 2024, the Icelandic Marine and Freshwater Institute (MFRI) requested that five fish stocks be moved from the Working Group for Deep-Sea Fisheries (WGDEEP) to the North-western Working Group (NWWG). The stocks in questions are:

- Blue ling in East Greenland and Iceland Grounds (bli.27.5a14)
- Greater silver smelt in East Greenland and Iceland grounds (aru.27.5a14)
- Tusk in East Greenland and Iceland grounds (usk.27.5a14)
- Ling in Iceland grounds (lin.27.5a)
- Atlantic wolffish in Iceland grounds(caa.27.5a)

The rationale for this relocation is:

- Better overview of the fisheries as these species are mainly caught in a mixed fishery with the species assessed in NWWG
- Better allocation of resources within the MFRI
- Facilitate better discussion with Greenlandic scientists on the three stocks whose distribution spans 5a and 14.

The NWWG working had no objections to this proposal, and **recommended** ACOM Leadership consider implementing this in 2025. If approved, the NWWG meeting will need to be extended by one day.

The assessment of Golden redfish (*Sebastes norvegicus*) in subareas 5, 6, 12, and 14 (Iceland and Faroes grounds, West of Scotland, North of Azores, East of Greenland) includes subarea 6 in its stock definition, however there is limited evidence of the presence of this species in this area, and data suggests that redfish in this area are mostly *S.mentella* and *S.viviparus*. Within the assessment, the limited catches from this area are reported separately as Sebastes sp. NWWG **recommends** ACOM consider removing this subarea from the stock definition.

Due to the uncertainty and short time-series, it was **recommended** that the reference points of the northern and southern components of Cod (*Gadus morhua*) in NAFO Subarea 1 (West Greenland Inshore Spawning Cod) and Cod (*Gadus morhua*) in NAFO Subarea 1 (West Greenland offshore spawning cod) should be re-evaluated by NWWG during 2026.

1.6.3 Research needs in relevance to the work of NWWG

EGIOSC – Cod5a migration and mixing dynamics

In recent years the cod catches on Dohrn Bank in the Denmark strait have increased to a level where they constitute a major component of the cod catches in Greenland. It is assumed, based on the modelling made during the benchmark, that a large proportion of these cod originate in another stock outside the Greenland EEZ. To i) better understand the dynamics occurring in this area, and ii) to improve the assessment and management advice of cod stocks in Greenland and Iceland (including changing the IGIOSC from a category 5 to 1 stock), NWWG requests the relevant national institutes to conduct studies on this topic. Pilot studies have indicated that tagging and otolith chemistry studies are promising techniques for this specific this case.

1.7 Benchmarks and workshops

WKICEHER[2] met in 2024 to evaluate harvest control rules for Icelandic summer spawning herring (ISSH) and to revise the assessment method (ICES, 2024). Three harvest control rules were evaluated during the benchmark, and all were considered precautionary. The NFT-ADAPT assessment model was replaced by SAM.

A benchmark workshop on Iceland-East Greenland-Jan Mayen capelin took place in November 2022 ((WKCAPELIN)[3] and the results were finalized in 2023.

[2] ICES. 2024. Workshop on the assessment and management plan evaluation for Icelandic herring (WKICEHER). ICES Scientific Reports. 6:37. 91 pp. https://doi.org/10.17895/ices.pub.25605135

[3] ICES. 2023. Benchmark workshop on capelin (WKCAPELIN). ICES Scientific Reports. 5:62. 282 pp. https://doi.org/10.17895/ices.pub.23260388

2 Demersal stocks in the Faroes area[1]

Demersal stocks in Division 5.b and Subdivision 2.a4

This section will be updated Autumn 2024.

[1] NWWG-3 is scheduled 21–24 October 2024. For the last published version of this report section, see: ICES. 2023. North-western Working Group (NWWG). ICES Scientific Reports. 5:64. 1029 pp. https://doi.org/10.17895/ices.pub.23267153

3 Faroe Bank cod[1]

cod.27.5b2 – *Gadus morhua* in Subdivision 5.b.2

This section will be updated Autumn 2024.

[1] NWWG-3 is scheduled 21–24 October 2024. For the last published version of this report section, see: ICES. 2023. North-western Working Group (NWWG). ICES Scientific Reports. 5:64. 1029 pp. https://doi.org/10.17895/ices.pub.23267153

4 Faroe Plateau cod[1,2]

cod.27.5b1 – *Gadus morhua* in Subdivision 5.b.1

This section will be updated Autumn 2024.

[1] NWWG-3 is scheduled 21–24 October 2024. For the last published version of this report section, see: ICES. 2023. Northwestern Working Group (NWWG). ICES Scientific Reports. 5:64. 1029 pp. https://doi.org/10.17895/ices.pub.23267153

[2] Note that a zero advice for 2023 and 2024 was released by ICES in November 2022. Hence, this assessment is not used as basis for the ICES advice for 2024 but is provided for information. Note that this assessment, along with the assessments of haddock and saithe, acts as basis for the allocation of fishing days according to the Faroese management plan.

5 Faroes grounds haddock[1]

had.27.5b – *Melanogrammus aeglefinus* in Division 5.b

This section will be updated Autumn 2024.

[1] NWWG-3 is scheduled 21–24 October 2024. For the last published version of this report section, see: ICES. 2023. North-western Working Group (NWWG). ICES Scientific Reports. 5:64. 1029 pp. https://doi.org/10.17895/ices.pub.23267153

6 Faroes grounds saithe[1]

pok.27.5b – *Pollachius virens* in Division 5.b

This section will be updated Autumn 2024.

[1] NWWG-3 is scheduled 21–24 October 2024. For the last published version of this report section, see: ICES. 2023. North-western Working Group (NWWG). ICES Scientific Reports. 5:64. 1029 pp. https://doi.org/10.17895/ices.pub.23267153

7 Ecosystem and fisheries overviews

Last updated April 2024.

Faroe Islands:

- ICES. 2023. Faroese ecoregion – Ecosystem overview. In Report of the ICES Advisory Committee, 2023. ICES Advice 2023, Section 7.1, https://doi.org/10.17895/ices.advice.24711000
- ICES. 2023. Faroes ecoregion – Fisheries overview. In Report of the ICES Advisory Committee, 2023. ICES Advice 2023, section 8.2. https://doi.org/10.17895/ices.advice.22047293

Greenland:

- ICES. 2020. Greenland Sea ecoregion – Fisheries overview. In Report of the ICES Advisory Committee, 2020. ICES Advice 2020. https://doi.org/10.17895/ices.advice.7599
- ICES. 2023. Greenland Sea ecoregion – Ecosystem overview. In Report of the ICES Advisory Committee, 2023. ICES Advice 2023, section 10.1, https://doi.org/10.17895/ices.advice.22664881

Iceland:

- ICES. 2022. Icelandic Waters ecoregion – Ecosystem overview. *In* Report of the ICES Advisory Committee, 2022. ICES Advice 2022, section 11.1, https://doi.org/10.17895/ices.advice.21731663
- ICES. 2022. Icelandic Waters ecoregion – Fisheries overview. *In* Report of the ICES Advisory Committee, 2022. ICES Advice 2022, section 11.2. https://doi.org/10.17895/ices.advice.21487635

8 Iceland grounds saithe

pok.27.5a – *Pollachius virens* in Division 5.a

8.1 Stock description and management units

Description of the stock and management units is provided in the Stock Annex.

The stock was benchmarked, and the management plan evaluated in March 2019 (ICES, 2019a). The result was no change in assessment setup. A minor change in the management plan was introduced as $MGMTB_{trigger}$ was decreased from 65 to 61 thousand tonnes to be in line with ICES MSY $B_{trigger}$. Other reference points were unchanged except HR_{lim} and HR_{pa} were introduced to replace F_{lim} and F_{pa}.

Following the management plan, the advised TAC for the fishing year 2024/2025 is 66 705 tonnes but was 66 533 tonnes for the fishing year 2023/2024.

8.2 Fisheries-dependent data

Landings of saithe in Icelandic Waters in 2023 are estimated to have been 41 717 t (Table 8.1 and Figure 8.1). This is 33% decrease from last year, and far below the allocated TAC that has been between 65 and 80 thousand tonnes (Figure 8.4)

Of the landings, 35 924 tons were caught by trawl, 1333 t by gillnets, and the rest caught by other fishing gear, mostly handlines. In recent decades most of the catch has been taken by bottom-trawl (83% in 2010–2017, 90% in 2018–2022) and 86% in 2023. In 2023 the share of jiggers was relatively high or 7%. The share taken by the gillnet fleet was larger in the past, 26% in 1987–1996 compared to 9% in 1998–2022 (Figure 8.1). The reduction in the gillnet fisheries was caused by general reduction in gillnet boats that are mostly targeting cod and increased mesh size in gillnet fisheries targeting cod.

The reduction in the gillnet fleet was driven by boats changing from gillnets and other types of gear to longlines, a change driven by cod and haddock fisheries. Price of large gillnet cod sold for bacalau reduced compared to "normal size", so it became more economical to operate long-liners that supply fish evenly throughout the year. Increase in the haddock stock in the early 2000s and progress in automatic baiting were also an important factor. This trend has been changing recently but the effort by longliners decreased by 25% between 2013–2016 and 2020–2023.

For saithe fisheries the important factor is that saithe is rarely caught by longliners, so the fleet became less of saithe fleet than before. The share of longlines in the saithe catch increased gradually from 0.8% before 2000 to 2.5% in 2014–2015 but reduced again to 1.5% in 2020 and 0.8% in 2021 and 2022. In 2023 the share of longliners increase to 1.3% but the catch was similar while longline effort decreased.

The fleet using demersal trawl can be divided in two parts, those that freeze the catch and those that land it fresh. The trend in last decade has been that the proportion of the trawler fleet that land the catch fresh has increased. Freezing trawlers have taken larger proportion of the catch of saithe and redfish compared to cod and haddock (Figure 8.6). The main reason for this is relative price of frozen vs. fresh fish for each species, but mixed fisheries issues like avoiding redfish when landing fresh fish can be a factor (redfish scratches the bycatch). The trend in recent years has been reduction in catch of all species by the freezing trawlers.

Spatial distribution of the saithe fisheries changed much from 2002–2014. (Figures 8.5 and 8.7). Before 2002 most of the saithe was caught south and west of Iceland but between 2012 and 2022 40–50% of the catch have been taken northwest of Iceland. Comparable percentage before 2002 was 3–8%. Similar increase can be seen for golden redfish, but redfish and saithe have for a long time been caught by the same vessels, not necessarily in the same hauls, rather as night and day fish. The area where saithe is caught now (Hali Figure 8.7) has since early in the 20th century been the most important cod fishing ground for trawlers.

8.2.1 Logbook data

The form of the logbooks data changed in 2022 and some work is needed to look if the registration is comparable, it is especially the year 2022 that is problematic.

CPUE from the bottom-trawl fleet is shown in figure 8.15 indicating drop in CPUE in recent years, based on all records where saithe is registered and especially records where saithe is > 50% of the total catch. The 50% criterion is sensitive to CPUE of other species, mostly cod and the change in the logbook data implemented in 2022 might have some effects on both criteria.

8.2.2 Landings, advice and TAC

For all Icelandic stocks that are managed by a TAC system the TAC is given for fishing year where fishing year **y/y+1** is from September 1st in the year **y** to August 31st in year **y+1**. Assessment done in spring year **y**, is used to give advice for the fishing year starting September 1st the same year. For most stocks the survey conducted in March is the most influential data source and the most recent survey from March in the assessment year is used in the advice process.

The management plan and assessment for Icelandic saithe have been identical since 2010 and both advice and TAC based on the 20% harvest control rule. Since 2014/2015 the TAC has not been caught (Figure 8.4) but in the period 1997/1998 to 2013/2014 the TAC was caught in all years except 2007/2008 and 2008/2009. The catch in the fishing year 2022/2023 is estimated to have been 45 836 tonnes, while the set TAC was 70 300 tonnes. Development of the catch in the fishing year 2023/2024 indicates that it will be around 40-45 thousand tonnes while the TAC is 66 638 tons.

The Icelandic Fisheries management system allows some transfer between species based on cod-equivalence factors that are supposed to reflect the price of the species compared to cod (see ICES, 2021). Cod is though not included in the system that is quite limited. In recent years saithe has been converted to other species (Figure 8.2) that are probably more economical to catch than saithe. And considerable part of the saithe quota has not been used, that might be a signal of overestimation of the stock or that catching saithe is not economical. As described before, the fleet has been less of a saithe fleet in recent years and historical assessment shows that fishing mortality of Icelandic saithe was never really high (NWWG report; ICES, 2002).

But those have been the explanations in recent year. The discrepancy between catches and set TAC in the current and last fishing year is much larger than observed before, something that needs to be examined.

8.2.3 Landings by age

Compilation of catch in numbers is based on age and length distributions from the catches where the number aged is usually considerably less than number length measured. Discarding is not considered to be a problem in the Icelandic saithe fisheries, with an estimated discard proportion of 0.1% (annual reports by Palsson *et al.*, 2003 and later). Recently, the fleet does also seem to have difficulty in catching the set TAC making discards more unlikely. Since the amount discarded is likely to be small, not taking discards into account in the total catches and catch in numbers is not considered to have major effect on the stock assessment.

Foreign landings that are 159 tonnes are included in the landings above. They are mostly caught by longlines (71 tonnes), handlines (89 tonnes). Nearly all the foreign landings have in recent years been taken by the Faroese fleet.

Catch in numbers are compiled based on 2 fleets, bottom-trawl and gillnets, 1 region and 1 season. Bottom-trawl accounts for 90% of the landings and other fleets than gillnets are included with the bottom-trawl.

The samples used to derive catch in numbers are both taken by observers at sea and from shore samples. The trawlers that freeze the catch account for large part of sea samples while all shore samples are from fresh fish trawlers. In addition, relatively few fishes from sea samples are sampled for otoliths but the age–length keys are most likely similar.

Length distributions from sea and shore samples show some difference in recent years, the shore samples show more of large fish, specially 105cm+ (Figure 8.8). This difference might be reflecting the difference in composition of the catch of the trawlers that freeze the catch and those that land the catch fresh.

Length distributions from bottom-trawl show tendency to catch small fish from 2000–2017, larger fish in 2018–2020 but smaller again in 2021 and 2022 (Figure 8.10). In 2020 the +105 cm group was unusually abundant.

Numbers sampled in 2020–2023 are shown in figure 8.2. Sampling effort was low in 2020, mostly due to Covid. In recent years sea samples account on the average for about 75% of the length measured fish that is used in the calculation of the catch in number and 67% of the length samples (Figure 8.3). On the other hand, < 20% of the aged otoliths come from sea samples. These numbers were different in 2020 when no aged fish and 50% of length measured fish came from sea samples.

90% of the length samples are taken from trawl that accounts for 85-90% of the catches.

The sampling program has been revised in last decades, the number of age samples reduced and the number of fish per sample has also reduced (Figure 8.3 and stock annex).

Two age–length keys are used to calculate catch-at-age, one key for the gillnet catch and another key for other gears combined. The same length-weight relationship ($W = 0.02498 * L^{\wedge}2.75674$) is applied to length distributions from both fleets.

Catch in numbers by age are listed in Table 8.2 and in Figure 8.9 where they are compared to prediction from last year, fitting reasonably well (red and blue bars).

8.2.4 Mean weight and maturity-at-age

Weights of all age groups have been slightly below average in recent years, the older age groups though closer to average (Table 8.3 and Figures 8.11–8.13). The large 2012 year class had the lowest mean weight of all year classes at age 4 and 5, both in catches and in the survey. This is in line with density-dependent growth that has been observed in this stock and can for example be seen for year classes 1984 and 2000 that are both large. The long-term trend since 1980 has been decline for younger age groups but increase for older age groups (Figure 8.12).

Weight at age in the landings are used to compile the reference biomass (B4+) that is the basis for the catch advice. Catch weights are also used to compile the spawning stock. Catch weights for the assessment year are predicted by applying a linear model using survey weights in the assessment year and the weight of the same year class in catches in the previous year as predictors (Magnusson, 2012 and stock annex).

Maturity-at-ages 4–9 has decreased in recent years and is currently below the average since 1985 (Figure 8.11). A model using maturity-at-age from the Icelandic groundfish spring survey is used to derive smoothed trends in maturity by age and year (see stock annex).

8.3 Scientific surveys

In the benchmarked assessments from 2010 and 2019, only spring survey (ice-smb) data are used to calibrate the assessment. Compared to the autumn survey (ice-smh) the spring survey has larger number of stations (lower CV) and longer time-series. Saithe is among the most difficult demersal fishes to get reliable information on from bottom-trawl surveys. In the spring survey, which has 500–600 stations, a large proportion of the saithe is caught in relatively few hauls and there seems to be considerable interannual variability of the number of these hauls.

The biomass indices from the spring survey (Figure 8.16) fluctuated greatly from 1985–1995 but were consistently low from 1995–2001. Since 1995 the indices have been variable but compared to the period 1985–1995 the variability seems "real" rather than noise. This difference is also seen by the estimated confidence intervals of the indices that are smaller after 1995. In 2018 the indices were the highest in the series and had tripled since 2014. (Table 8.7 and Figure 8.18). Most of the increase was caused by year class 2012 that was strong in the surveys 2015–2020 (Figures 8.20 and 8.21). The biomass index from the March survey reduced much from 2018–2019 but has fluctuated since, with the 2021 value relatively high and 2022 low. Usually, high CV is associated with high average value. The 2024 index is well above average, but the CV is high.

Estimated CV of age disaggregated indices from the survey is often relatively high and many low values appear in the survey matrix, both for the youngest and oldest age groups. The youngest age groups (age 3–4 and younger) are considered to inhabit waters shallower than the survey covers and the older age groups are reducing in numbers or could also be more pelagic.

To take this into account the survey residuals are compiled as $\frac{log(I+\epsilon)}{log(\hat{I}+\epsilon)}$ where ϵ is a number that should avoid giving low values too much weight as they do in log-log fit. Typical value of ϵ is the value that 3–4 otoliths will give, that would be 0.15 for saithe. Higher values are used for saithe 0.3 for the older ages, 0.5 for ages 3–5 and 0.7 for age 2, a value giving index of age 2 lower weight when the index is low compared to lower value of ϵ.

The autumn survey shows similar trend as the spring survey and the index was at high level from 2012–2018 (2004 and 2018 are outliers due to large CV). The values before 2000 might be underestimate due to stations added in 2000 in an area where large schools of saithe are sometimes found. Excluding these stations leads to lower but more stable index.

Catch curves from the spring survey indicate that Z ~ 0.5 assuming similar q with age (Figure 8.22).

Indices from the gillnet survey conducted south and west of Iceland since 1996 have been high since 2011 compared to the years 1996–2010 (Figure 8.17). The highest index is in 2019 when the large 2012 year class was 7 years old. The 2023 index is among the highest in the series. The gillnet survey is mostly targeting large saithe (mean weight in 2022 was 7.5 kg). The data from the 2024 gillnet survey are not available when this text is written.

To summarize, survey indices show increasing stock for last 2 years, after decrease from 2018–2021.

The high index in March 1986 (Figure 8.18) was mostly the result of one large haul that is scaled down to the second largest haul when compiling indices for tuning. The scaling is from 16 tonnes to 1 ton.

Internal consistency in the March survey measured by the correlation of the indices for the same year class in 2 adjacent surveys is relatively poor, with R^2 close to 0.46 where it is highest (Figure 8.19).

8.4 Assessment method

In accordance with the recommendation from the benchmark (ICES, 2019a), a separable forward-projecting statistical catch-age model Muppet (Björnsson, 2019), developed in AD Model Builder, is used to fit commercial catch-at-age (ages 3–14 from 1980 onwards) and survey indices at age (ages 2–10 from 1985 onwards). The selectivity pattern is constant within each of 3 periods (Figure 8.23). Natural mortality is set at 0.2 for all ages. The survey residuals ($\frac{log(I+\epsilon)}{log(\hat{I}+\epsilon)}$) are modelled as multivariate normal distribution with the correlation estimated (one coefficient).

The assessment model is also used for short-term forecast, the Muppet model cannot be run without prediction.

Future weights and maturity are shown in figure 8.11 and 8.14.

Future weights, maturity, and selectivity are assumed to be the same as in the assessment year, as described in the stock annex. Recruitment predictions are based on the segmented stock–recruitment function estimated in the assessment model which is essentially geometric mean when the stock is above estimated breakpoint that is near B_{loss}.

8.5 Reference points and HCR

In April 2013, the Icelandic government adopted a management plan for managing the Icelandic saithe fishery (Ministry of Industries and Innovation, 2013). ICES evaluated this management plan and concluded that it was precautionary and in conformity with ICES MSY framework.

The management plan for the Icelandic saithe fishery, adopted for the first time in 2013 was re-evaluated by ICES in March 2019 and found to be precautionary and in conformity with ICES MSY approach (ICES, 2019a).

The TAC set in year *t* is for the upcoming fishing year, from 1 September in year *t*, to 31 August in year *t*+1. The TAC according to the management plan is calculated as follows.

If $SSB_y \geq MGMTB_{trigger}$

$$Tac_{y/y+1} = \frac{Tac_{y-1/y} + 0.2 \times B_{4+,y}}{2}$$

If $SSB_y \leq MGMTB_{trigger}$

$$Tac_{y/y+1} = \alpha \times Tac_{y-1/y} + (1 - \alpha) \times \frac{SSB_y}{MGMTB_{trigger}} \times 0.2 \times B_{4+,y}$$

$$\alpha = 0.5 \times \frac{SSB_y}{MGMTB_{trigger}}$$

Where $Tac_{y/y+1}$ is the TAC for the fishing year starting 1 September in year y ending 31 August in year $y + 1$. $B_{4+,y}$ the biomass of age 4 and older at the beginning of the assessment year compiled from catch weights. The latter equation shows that the weight of the last years Tac does gradually reduce from 0.5 to 0.0 when estimated SSB changes from $MGMTB_{trigger}$ to 0.

Reference points were also re-evaluated at WKICEMSE 2019 (See table below and ICES, 2019a). B_{lim}, B_{pa}, MSY $B_{trigger}$, HR_{MSY} and HR_{Mgt} were unchanged, MGMT $B_{trigger}$ changed from 65 to 61 thousand tonnes and HR_{lim} and HR_{pa} were defined but earlier F_{lim} and F_{pa} had been defined.

Item	B_{lim}	B_{pa}	MSY $B_{trigger}$	MGT $B_{trigger}$	HR_{MSY}	HR_{Mgt}	HR_{lim}	HR_{pa}
Value	44	61	61/65	61	0.2	0.2	0.36	0.26/0.25
Basis	B_{loss}/1.4	B_{loss}	B_{pa}	B_{pa}	Stochastic simulations.			

The recipe to evaluate MSY $B_{trigger}$ and HR_{pa} has changed since 2019 so those reference points were evaluated based on the same simulations as in 2019, leading to MSY $B_{trigger}$ = 65 thousand tonnes and HR_{pa} = 0.25.

8.6 State of the stock

The results of the principal stock quantities (Table 8.5 and Figure 8.22) show that the reference biomass (B4+) has historically ranged from 136 to 415 kt (in 1999 and 1988), but this range has been narrower since 2003, between 235 and 334 kt. The current estimated stock size of $B4+_{2023}$ = 334 kt is above average (85th percentile). Spawning biomass is estimated as 140 kt, also near 80th percentile since 1980 and well above B_{pa} (61 thousand tonnes).

The harvest rate peaked around 32% in the mid-1990s but has since 2013 been near HR_{Mgt} target of 20% on the average. The harvest rate in 2023 is estimated to be 0.16. The explanations for close to intended harvest rate since 2013 are two factors that cancel each other out.

- The allocated TAC has not been caught.
- The stock has on the average been overestimated.

Fishing mortality has been low since 2000 compared to before that. Part of the difference is caused by change in selection pattern (Figure 8.21) that leads to F before and after 2004 not being comparable measures of fishing pressure.

Recruitment has been relatively stable since year class 2006 and slightly higher than before. Year class 2012 is estimated to be strong and year class 2015 poor but the remaining year classes from 2006–2018 are close to geometric mean. Geometric mean is the first guess in the model for each year class. Deviations from the mean are then driven by the survey and catches but survey indices for ages 3 and 4 have been around average in recent years, except for year class 2015 where all survey indices have been low, and the year class estimated poor since in the 2018 assessment.

The commercial catch-at-age residuals in 2023 (Figure 8.25) are negative for age 10 but positive for age 7. Age 11 is the largest year class for 20 years (2012) and age 8 the smallest (2015). The survey residuals (Figure 8.27) show large positive values in 2017 and 2018 for ages 4–7, the age groups accounting for most of the biomass, therefore the survey biomass in 2017 and 2018 exceeds prediction by large margin (Figure 8.23). The survey residuals in 2023 are small and the survey biomass in 2024 is above prediction (Figure 8.26). But as a warning the CV in the 2024 survey is relatively high.

Assumptions about catch in the assessment year deviate from the stock annex that specifies the catch in the calendar year 2024 as the remaining TAC from the fishing year 2023/2024 on 1 January 2023 plus 1/3 of the catch in the fishing year 2023/2024. 54 thousand tonnes of the catch for the fishing year 2022/2023 were remaining 1 January and the total catch for the calendar year 2024 will be 76 thousand. tonnes following this procedure. Development of landings indicate that the catch for fishing year 2023/2024 will be around 40 thousand tonnes so the parameter "remaining TAC" in the model is set to 28 thousand tonnes. The advice for next fishing year is based on biomass at the beginning of the assessment year so assumptions about catch in the assessment year do not affect the advice.

8.7 Uncertainties in assessment and forecast

The assessment of Icelandic saithe is relatively uncertain due to fluctuations in the survey data, poor recruitment estimates and irregular changes in the fleet selectivity. The internal consistency in the spring bottom-trawl survey is low for saithe (Figure 8.19). This is not surprising, considering the nature of the species that is partly pelagic, schooling, and relatively widely migrating. Mcmc runs of the assessment model assessment model indicate that CV of the biomass 4+ is around 0.2, rather high value for this kind of estimate that is usually underestimation of the real uncertainty.

The 2024 assessment of Icelandic saithe is downward revision of the stock compared to the 2023 assessment, biomass 4+ in 2023 is estimated 4% lower than last year. Catches well below advice do on the other hand lead to increase in stock size between 2023 and 2024.

The retrospective pattern (Figure 8.26) reveals some of the assessment uncertainty. The harvest control rule evaluations incorporated uncertainties in assessment as well as other sources of uncertainty (ICES, 2019).

Using retrospective pattern based on the assessment years 2019–2023 Mohns rho is 0.30 for the reference biomass, -0.2 for the Harvest rate, 0.34 for SSB and 0.1 for recruitment (Table 8.6 called Stdsettings,figure 8.33). The retrospective pattern in last 5 years is caused by the very high 2017-2019 survey indices and then again relatively high 2021 index. Higher Mohns rho for the SSB than for B4+ is not unexpected as old/large saithe are due to pelagic behaviour, difficult to catch by demersal gear. Retrospective pattern of Mohns rho (figure 8.30) shows periods of over and underestimations.

Other model settings have little lower Mohns rho than the adopted settings (table 8.6).

Using peels of 5 years for stock with low fishing mortality is rather questionable, the assessments used in the evaluations have not converged. Retrospective pattern of Mohns rho illustrates this problem well (Figure 8.33). The value of Mohns rho cannot be obtained from the HCR simulations where only current estimate and "correct value" are available, the first value is the basis for advice and the second value basis for development of the stock. Intermediate values do not affect, neither the advice nor the stock.

Alternative settings of the Muppet model and one SAM run were tested (Figure 8.27) . The results show low estimated biomass when the survey data are downweighted, the same result is obtained with the leaveout run in SAM, both showing that catch in numbers indicate smaller stock compared to survey indices. The SAM model indicates smaller stock than the Muppet models. Last year a SAM model gave similar results but two changes in configurations lead to much change in behaviour.

- Observation variances in the survey for ages 3 and 4 is now the same.
- Stock recruitment code 3 instead of 0.

The estimated uncertainty in the run where the survey is downweighted is though very high ($CV_{B4+} \approx 0.4$) Winchorised surveycd indices lead to less noise in the indices and therefore more weight on the survey in the assessment. The Adapt model used is just the Muppet model, using N of the oldest fish from the forward running model. The backwards running model is selected by changing one number in the main input file. An advantage with the Adapt approach is that CV of survey can be estimated independently for each age group, if attempted in a catch-at-age model the survey CV of one age will be set to zero. "The reweighted" model show lower biomass but it does also converge to lower biomass as the selection pattern of the oldest fish is different (figure 8.28).

All the Muppet models except the model with less weight on survey show similar retrospective pattern in recent years, ≈5% reduction in estimate of B4+ between assessment years 2023 and 2024 and ≈30% between assessment years 2018 and 2024. The SAM model has better retrospective pattern.

The table below show $B4+_{2024}$, the number that matters for the advice. The values are in thousand tonnes. The difference between Std settings 2023 and 2024 is mostly explained by less catch than predicted.

Std settings 2024	Winchorised survey	Adapt	LessWeight on survey	Reweighed survey CV	Ages 3–14 in survey.	Survey CV	Std settings 2023	SAM
334	428	328	181	342	378	328	293	248

If all the models would be taken as equally plausible configurations (which they are not) the average B4+2023 is 305 and CV 0.19. Estimated CV in of B4+ based on the standard settings is also 0.19.

The SAM settings are correlated random walk, 3 observation variance blocks for the catches and 3 for the survey and stockRecruitment model 3. Looking at what is happening with the catches the SAM model would be the preferred basis of advice.

A major problem in the assessment is the fact that the TAC has not been fished in some recent years (Figure 8.4). Despite overestimation of the stock, the assessment models do not indicate high fishing mortality nor harvest rate in last 5 years (Figure 8.24), mostly because the TAC has not been fished. The selection pattern observed since 2004 (Figure 8.23) indicates that the fisheries are targeting younger fish than before, something that could be interpreted as lack of large fish. This trend is even greater than observed in the figure as mean weight at age of ages 4–5 have been low in recent decades (Figure 8.12). The gillnet survey that is an indicator of large saithe shows high abundance in 2023 (Figure 8.19) and the autumn survey shows similar trend as the March survey (figure 8.18). Assessment tuned with the autumn survey indicates little lower biomass than assessment based on the March survey and assessment based on both surveys considerably higher.

What seems to be the main problem in the assessment is relative weight on catchvs.surveys that the model is not able to do properly (perhaps impossible). Weighting the surveys manually down in Muppet, leads to lower biomass with lower weight on survey. Tuning with both March and October survey gives more weight to surveys except correlation between surveys were estimated. Looking at estimated CV the SAM model estimates higher uncertainty of the survey (figure 8.31) i.e. less weight on survey. Multivariate random walk on fishing mortality in SAM does also have effect when the reduction in catch is as much as here as between 2022 and 2023. Tuning with winchorised survey indices leads to increased weight on the survey (less noise) and larger estimated stock.

The problem seen in recent years is not new and the fact that fishing mortality of saithe was never high, indicates that it is difficult to catch saithe. One reason is that most of the gear is demersal while saithe is partly pelagic. Change of fleet and fishing practice in recent 20 years might also have effects.

The effect of too high TAC of saithe is increased catch of some other species through the transfer system, something that could change with higher price of saithe. Also, too much effort is used to fish saithe and at the same time avoid catching other species. Cod landed fresh should nto be much older than 2–3 days, so cod is avoided during first days of a fishing trip. To account for problems in mixed fisheries the best solution is to reduce the harvest rate of saithe below what single species MSY considerations would call for.

But none of those speculations explains the sudden reduction in catch of saithe between 2022 and 2023 when plenty of quota is available.

8.8 Ecosystem considerations

Changes in the distribution of large pelagic stocks (blue whiting, mackerel, Norwegian spring-spawning herring, Icelandic summer-spawning herring) may affect the tendency of saithe to migrate off shelf and between management units. Saithe is a migrating species and makes both vertical and long-distance feeding and spawning migrations (Armannsson *et al.*, 2007, Armannsson and Jonsson, 2012, i Homrum *et al.*, 2013). The evidence from tagging experiments (ICES, 2008) shows some migrations along the Faroe-Iceland Ridge, as well as onto the East Greenland shelf.

Saithe is an important predator of capelin and is included in the predation model used to compile advice for Icelandic capelin.

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8.10 Tables and figures

Table 8.1. Saithe in Division 5.a. Nominal catch (t) by countries, as officially reported to ICES.

	Belgium	Faroes	France	Germany	Iceland	Norway	UK[1]	UK[2]	UK	Total
1980	980	4930			52436	1				58347
1981	532	3545			54921	3				59001
1982	201	3582	23		65124	1				68931
1983	224	2138			55904					58266
1984	269	2044			60406					62719
1985	158	1778			55135	1	29			57101
1986	218	2291			63867					66376
1987	217	2139			78175					80531
1988	268	2596			74383					77247
1989	369	2246			79796					82411
1990	190	2905			95032					98127
1991	236	2690			99811					102737
1992	195	1570			77832					79597
1993	104	1562			69982					71648
1994	30	975		1	63333					64339
1995		1161		1	47466	1				48629
1996		803		1	39297					40101
1997		716			36548					37264
1998		997		3	30531					31531
1999		700		2	30583	6	1	1		31293
2000		228		1	32914	1	2			33146
2001		128		14	31854	44	23			32063

[1] England, Wales, and Northern Ireland.

[2] Scotland.

	Belgium	Faroes	France	Germany	Iceland	Norway	UK[1]	UK[2]	UK	Total
2002		366		6	41687	3	7	2		42071
2003		143		56	51857	164			35	52255
2004		214		157	62614	1	105			63091
2005		322		224	67283	2			312	68143
2006		415		33	75197	2			16	75663
2007		392			64008	3			30	64433
2008		196			69992	2				70190
2009		269			61391	3				61663
2010		499			53772	1				54272
2011		735			50386	2				51123
2012		940			50843					51783
2013		925			57077					58002
2014		746			45733	4				46483
2015		499			47973	3				48473
2016		287			48920	5				49212
2017		261			48786	4			4	49057
2018		270			65090					65360
2019		231			64295	6				64532
2020		188			50058	6				50253
2021		156			59618	1				59774
2022		147			61734	1				61881
2023		151			41557	8				41717

Table 8.2. Saithe in Division 5.a. Commercial catch-at-age (thousands).

Year	3	4	5	6	7	8	9	10	11	12+
1980	275	2540	5214	2596	2169	1341	387	262	155	209
1981	203	1325	3503	5404	1457	1415	578	242	61	417
1982	508	1092	2804	4845	4293	1215	975	306	59	129
1983	107	1750	1065	2455	4454	2311	501	251	38	18

Year	3	4	5	6	7	8	9	10	11	12+
1984	53	657	800	1825	2184	3610	844	376	291	546
1985	376	4014	3366	1958	1536	1172	747	479	74	166
1986	3108	1400	4170	2665	1550	1116	628	1549	216	95
1987	956	5135	4428	5409	2915	1348	661	496	498	133
1988	1318	5067	6619	3678	2859	1775	845	226	270	132
1989	315	4313	8471	7309	1794	1928	848	270	191	221
1990	143	1692	5471	10112	6174	1816	1087	380	151	168
1991	198	874	3613	6844	10772	3223	858	838	228	51
1992	242	2928	3844	4355	3884	4046	1290	350	196	125
1993	657	1083	2841	2252	2247	2314	3671	830	223	281
1994	702	2955	1770	2603	1377	1243	1263	2009	454	428
1995	1573	1853	2661	1807	2370	905	574	482	521	154
1996	1102	2608	1868	1649	835	1233	385	267	210	447
1997	603	2960	2766	1651	1178	599	454	125	95	234
1998	183	1289	1767	1545	1114	658	351	265	120	251
1999	989	732	1564	2176	1934	669	324	140	72	75
2000	850	2383	896	1511	1612	1806	335	173	57	57
2001	1223	2619	2184	591	977	943	819	186	94	69
2002	1187	4190	3147	2970	519	820	570	309	101	53
2003	2284	4363	6031	2472	1942	285	438	289	196	72
2004	952	7841	7195	5363	1563	1057	211	224	157	124
2005	2607	3089	7333	6876	3592	978	642	119	149	147
2006	1380	10051	2616	5840	4514	1989	667	485	118	229
2007	1244	6552	8751	2124	2935	1817	964	395	190	99
2008	1432	3602	5874	6706	1155	1894	1248	803	262	307
2009	2820	5166	2084	2734	2883	777	1101	847	555	373
2010	2146	6284	3058	997	1644	1571	514	656	522	409
2011	2004	4850	4006	1502	677	1065	1145	323	433	469
2012	1183	4816	3514	2417	903	432	883	1015	354	549

Year	3	4	5	6	7	8	9	10	11	12+
2013	1163	5538	6366	2963	1610	664	375	537	460	320
2014	668	3499	4867	2805	1276	725	347	241	312	401
2015	781	2712	6461	2917	1509	694	589	249	133	347
2016	1588	6230	2653	2838	1648	1059	526	337	148	131
2017	750	3333	7542	1806	1449	813	648	229	127	237
2018	689	6681	4267	7908	1446	962	455	258	192	175
2019	1292	1585	6325	2752	4543	693	675	339	242	231
2020	1333	2310	1496	3228	1334	1700	710	351	379	666
2021	1832	6777	4160	1305	2380	1082	1303	471	197	190
2022	1861	5748	6217	2662	1129	1066	935	592	310	357
2023	1653	5673	3416	2137	763	265	372	207	284	191

Table 8.3. Saithe in Division 5.a. Mean weight at age (g) in the catches and in the spawning stock, with predictions in grey.

Year	3	4	5	6	7	8	9	10	11	12+
1980	1428	1983	2667	3689	5409	6321	7213	8565	9147	9979
1981	1585	2037	2696	3525	4541	6247	6991	8202	9537	9523
1982	1547	2194	3015	3183	5114	6202	7256	7922	8924	10021
1983	1530	2221	3171	4270	4107	5984	7565	8673	8801	9445
1984	1653	2432	3330	4681	5466	4973	7407	8179	8770	10520
1985	1609	2172	3169	3922	4697	6411	6492	8346	9401	10767
1986	1450	2190	2959	4402	5488	6406	7570	6487	9616	11080
1987	1516	1715	2670	3839	5081	6185	7330	8025	7974	10886
1988	1261	2017	2513	3476	4719	5932	7523	8439	8748	9823
1989	1403	2021	2194	3047	4505	5889	7172	8852	10170	11194
1990	1647	1983	2566	3021	4077	5744	7038	7564	8854	11284
1991	1224	1939	2432	3160	3634	4967	6629	7704	9061	9547
1992	1269	1909	2578	3288	4150	4865	6168	7926	8349	10181
1993	1381	2143	2742	3636	4398	5421	5319	7006	8070	9842
1994	1444	1836	2649	3512	4906	5539	6818	6374	8341	10388

Year	3	4	5	6	7	8	9	10	11	12+
1995	1370	1977	2769	3722	4621	5854	6416	7356	6815	8799
1996	1229	1755	2670	3802	4902	5681	7182	7734	9256	9601
1997	1325	1936	2409	3906	5032	6171	7202	7883	8856	9865
1998	1347	1972	2943	3419	4850	5962	6933	7781	8695	10043
1999	1279	2106	2752	3497	3831	5819	7072	8078	8865	10872
2000	1367	1929	2751	3274	4171	4447	6790	8216	9369	10443
2001	1280	1882	2599	3697	4420	5538	5639	7985	9059	10419
2002	1308	1946	2569	3266	4872	5365	6830	7067	9240	10190
2003	1310	1908	2545	3336	4069	5792	7156	8131	8051	10825
2004	1467	1847	2181	2918	4017	5135	7125	7732	8420	9547
2005	1287	1888	2307	2619	3516	5080	6060	8052	8292	8569
2006	1164	1722	2369	2808	3235	4361	6007	7166	8459	9583
2007	1140	1578	2122	2719	3495	4114	5402	6995	7792	9848
2008	1306	1805	2295	2749	3515	4530	5132	6394	7694	9589
2009	1412	1862	2561	3023	3676	4596	5651	6074	7356	9237
2010	1287	1787	2579	3469	4135	4850	5558	6289	6750	8785
2011	1175	1801	2526	3680	4613	5367	5685	6466	6851	7739
2012	1160	1668	2369	3347	4430	5486	6161	6448	7220	8236
2013	1056	1675	2219	3244	4529	5628	6397	7055	7378	8342
2014	1211	1575	2229	2983	4378	5598	6773	8023	7875	9020
2015	1072	1639	2141	3122	4262	5555	6633	7697	8269	8773
2016	1105	1468	2260	3071	4127	5272	6379	7247	8566	8969
2017	1282	1674	2199	3255	4314	5718	6361	7630	8590	9238
2018	1346	1724	2335	3005	4178	5319	6544	7773	8530	9324
2019	1485	2054	2449	3128	4104	5694	6483	7750	8563	9488
2020	1285	2015	2386	3131	4065	5059	6284	7025	8285	9175
2021	1336	1719	2515	3227	4379	5296	6265	7152	8045	9062
2022	1226	1857	2394	3139	4117	5367	6081	6751	7963	8842
2023	1422	1798	2505	3419	4915	5800	6548	7506	8060	9060

Year	3	4	5	6	7	8	9	10	11	12+
2024	1317	1853	2352	3306	4517	6011	6902	7108	8088	8617
2025	1317	1853	2352	3306	4517	6011	6902	7108	8088	8617

Table 8.4. Saithe in Division 5.a. Survey indices by age.

Year	2	3	4	5	6	7	8	9	10
1985	0.59	0.57	3.1	5.32	1.81	1.1	0.52	1.43	0.16
1986	2.34	2.46	2.15	2.21	1.5	0.65	0.3	0.19	0.32
1987	0.38	11.84	13.22	6.61	4.09	3.19	0.82	0.37	0.27
1988	0.31	0.47	2.74	2.86	1.76	0.98	0.42	0.07	0.08
1989	1.42	4.01	5.08	6.68	2.65	1.74	0.89	0.37	0.01
1990	0.73	1.32	4.96	6.42	12.53	3.38	1.23	0.65	0.12
1991	0.22	1.38	1.7	2.18	1.12	2.49	0.31	0.02	0.04
1992	0.14	0.91	5.91	5.67	2.84	2.69	1.93	0.28	0.06
1993	1.27	11	1.93	6.61	2.33	2.2	1.02	3.92	0.66
1994	0.83	0.72	1.96	1.79	2.07	0.72	1.13	1.2	2.77
1995	0.49	1.98	1.12	0.52	0.29	0.34	0.1	0.15	0.15
1996	0.13	0.49	3.78	1.16	1.03	0.59	0.98	0.06	0.09
1997	0.32	0.91	4.73	3.98	0.95	0.4	0.16	0.1	0.05
1998	0.13	1.66	2.36	2.55	1.27	0.72	0.3	0.09	0.07
1999	0.73	3.74	0.94	1.27	1.7	0.59	0.16	0.02	0.02
2000	0.38	2.01	2.55	0.61	0.86	0.54	0.45	0.08	0.03
2001	0.92	2.06	2.73	1.68	0.22	0.23	0.4	0.14	0.07
2002	1.02	2.23	3.01	3.11	2.19	0.42	0.47	0.32	0.22
2003	0.05	9.79	5.14	2.98	1.37	0.78	0.21	0.05	0.1
2004	0.9	1.39	9.6	6.27	4.52	1.52	0.84	0.17	0.17
2005	0.25	4.29	2.41	7.5	4.73	2.36	0.88	0.45	0.13
2006	0	2.19	6.77	1.98	8.86	3.5	1.21	0.29	0.25
2007	0.06	0.31	1.75	3.27	0.82	1.64	0.71	0.29	0.16
2008	0.08	2.26	1.81	2.88	4.05	0.62	0.79	0.34	0.15

Year	2	3	4	5	6	7	8	9	10
2009	0.21	2.45	1.85	0.69	0.91	0.84	0.12	0.26	0.15
2010	0.07	1.24	5.07	2.55	0.64	0.61	0.47	0.07	0.12
2011	0.15	3.84	4.24	3.1	1.17	0.41	0.39	0.44	0.17
2012	0.02	1.77	12.01	6.75	2.76	0.63	0.17	0.38	0.5
2013	0.11	4.28	7.57	6.85	4.67	2.58	1.12	0.3	0.43
2014	0.03	0.39	3.89	3.74	2.02	0.87	0.42	0.15	0.11
2015	0.04	1.08	1.93	3.22	1.73	0.82	0.72	0.66	0.43
2016	0.05	3.17	16.21	2.75	2.27	1.08	0.53	0.44	0.28
2017	0.02	1.48	6.67	14.64	3.03	1.68	0.87	0.45	0.3
2018	0.03	0.5	17.92	10.51	15.28	1.51	0.84	0.43	0.32
2019	0.08	3.75	1.22	3.46	2.61	4.07	0.82	0.61	0.14
2020	0.09	1.89	2.57	0.7	2.14	1.19	2.36	0.35	0.18
2021	0.36	2.55	4.53	3.42	1.06	2.69	0.67	1.17	0.23
2022	1.2	2.43	4.39	3	1.11	0.24	0.69	0.25	0.53
2023	0.07	1.67	7.07	4.03	2.32	0.65	0.22	0.58	0.26
2024	0.08	1.53	5.01	7.87	2.9	1.26	0.63	0.14	0.36

Table 8.5. Saithe in Division 5.a. Main population estimates.

Year	Recruitment (Age 3) in thousands	Stock size		Harvest rate B_{4+}	Total catch
		Reference biomass ages 4+	SSB		
1980	28178	313109	113243	0.184	57659
1981	20194	305669	120193	0.211	57548
1982	21565	295399	137549	0.204	67865
1983	32130	270756	137664	0.218	56504
1984	41750	287858	140312	0.194	60405
1985	35308	299820	138435	0.205	53728
1986	66971	318735	136506	0.236	65230
1987	90648	335378	127999	0.233	80237
1988	50504	414225	124717	0.195	77244

Year	Recruitment (Age 3) in thousands	Stock size		Harvest rate B_{4+}	Total catch
		Reference biomass ages 4+	SSB		
1989	32064	396841	128387	0.233	82339
1990	20850	376495	136009	0.267	97537
1991	29465	336565	146747	0.259	102201
1992	14914	288440	138666	0.257	79568
1993	19947	231285	114749	0.286	71539
1994	17854	188320	95046	0.283	63559
1995	30158	154515	70841	0.274	48296
1996	26069	151203	61813	0.248	39352
1997	17244	159171	62550	0.205	36671
1998	8984	157667	68978	0.195	30657
1999	31393	136382	74302	0.236	30898
2000	32388	148416	77172	0.215	32751
2001	55662	170133	85351	0.226	31570
2002	65086	230133	105005	0.212	41969
2003	73091	293439	131135	0.206	52306
2004	25938	335449	152177	0.201	64668
2005	72622	301545	162418	0.243	69054
2006	41755	326880	169312	0.208	75462
2007	18465	297445	163592	0.228	64261
2008	25859	265881	161048	0.238	69426
2009	37646	238524	148766	0.235	60266
2010	35671	234822	136766	0.221	53853
2011	42131	234947	126642	0.217	50769
2012	38298	236035	121164	0.235	51252
2013	38454	236938	119439	0.209	57522
2014	27503	228083	115257	0.208	45538
2015	76896	222997	116981	0.22	48476
2016	36376	270215	122207	0.182	49223

Year	Recruitment (Age 3) in thousands	Stock size		Harvest rate B_{4+}	Total catch
		Reference biomass ages 4+	SSB		
2017	46225	289125	133606	0.208	49054
2018	14920	310974	146503	0.206	65583
2019	29875	282170	152328	0.193	63130
2020	43934	256402	142390	0.221	50245
2021	44859	267802	142296	0.228	59762
2022	62862	265565	126770	0.182	61872
2023	48742	303254	127238	0.156	41710
2024	33722	334383	140139		

Table 8.6. Mohns rho for the 5 models compared as candidate assessment model. The value is based on assessment years 2018–2022. Stdsettings is the adopted model today. The lower table applies if year < Assessment year but the upper table if year <= Assessment year.

model	B4+	ssb	N3	hr	f4–9
Stdsettings	0.309	0.366	0.058	-0.206	-0.236
ChangedCVpattern	0.211	0.262	-0.03	-0.153	-0.178
SurveyCV	0.145	0.182	-0.149	-0.111	-0.133
Ages3to14	0.238	0.278	-0.053	-0.172	-0.199

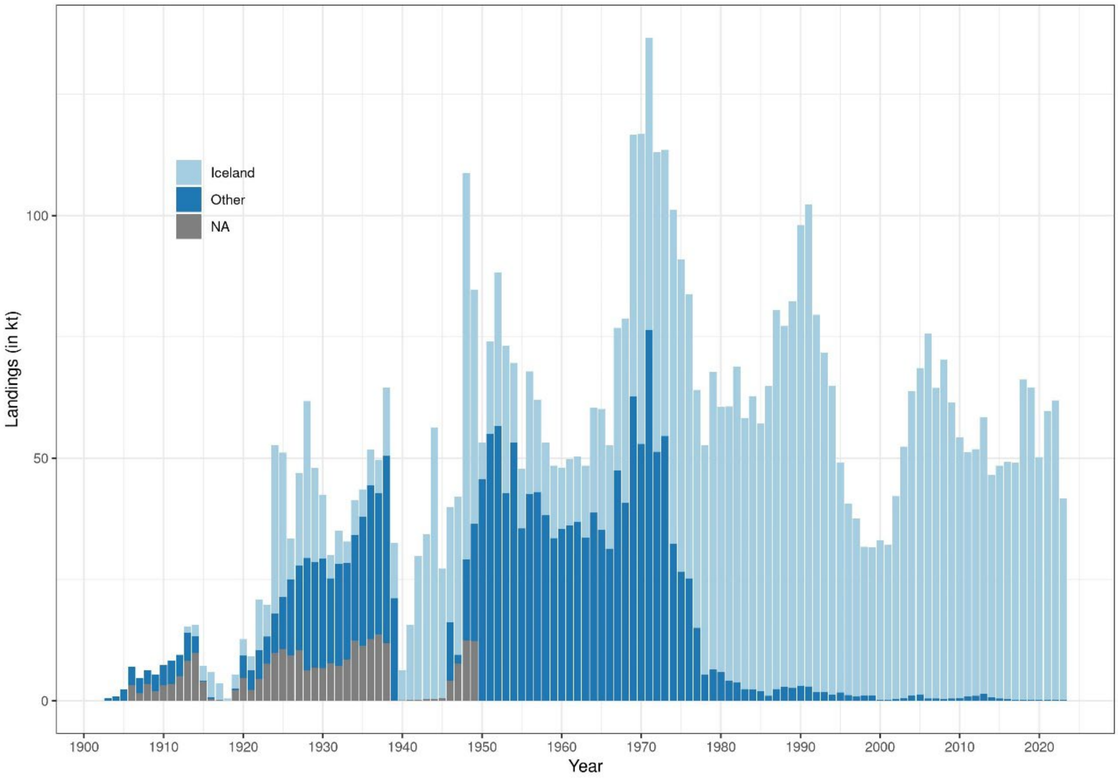
model	B4+	ssb	N3	hr	f4–9
Stdsettings	0.271	0.291	0.155	-0.206	-0.236
ChangedCVpattern	0.186	0.206	0.102	-0.153	-0.178
SurveyCV	0.133	0.145	0.072	-0.111	-0.133
Ages3to14	0.214	0.218	0.106	-0.172	-0.199

Table 8.7. Saithe in Division 5.a. Output from short-term projections.

2024			
B4+	SSB	Fbar	Landings
345	140	0.177	50.2

2025				2026		
B4+	SSB	Fbar	Landings	B4+	SSB	Rationale
342	159	0.232	67.0	329	168	20% HCR

20% HCR = average between 0.2 B4+ (current year) and last year's TAC.



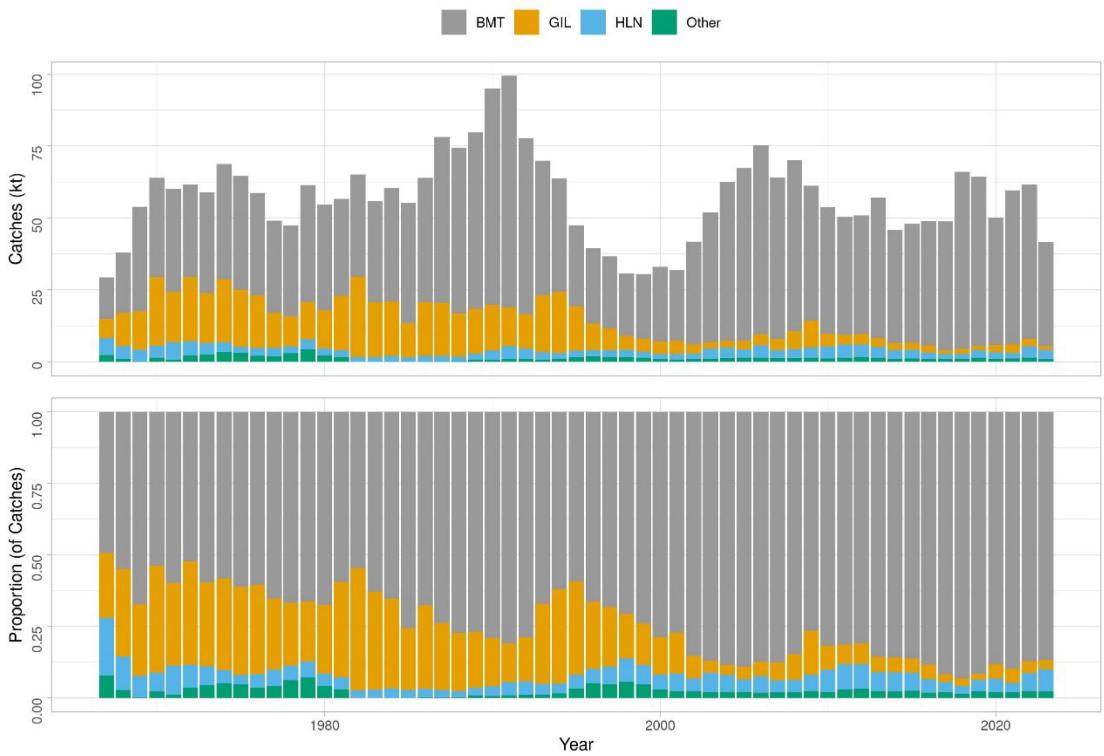


Figure 8.1 Saithe in Division 5.a. Landings by country. Landings and percent by gear.

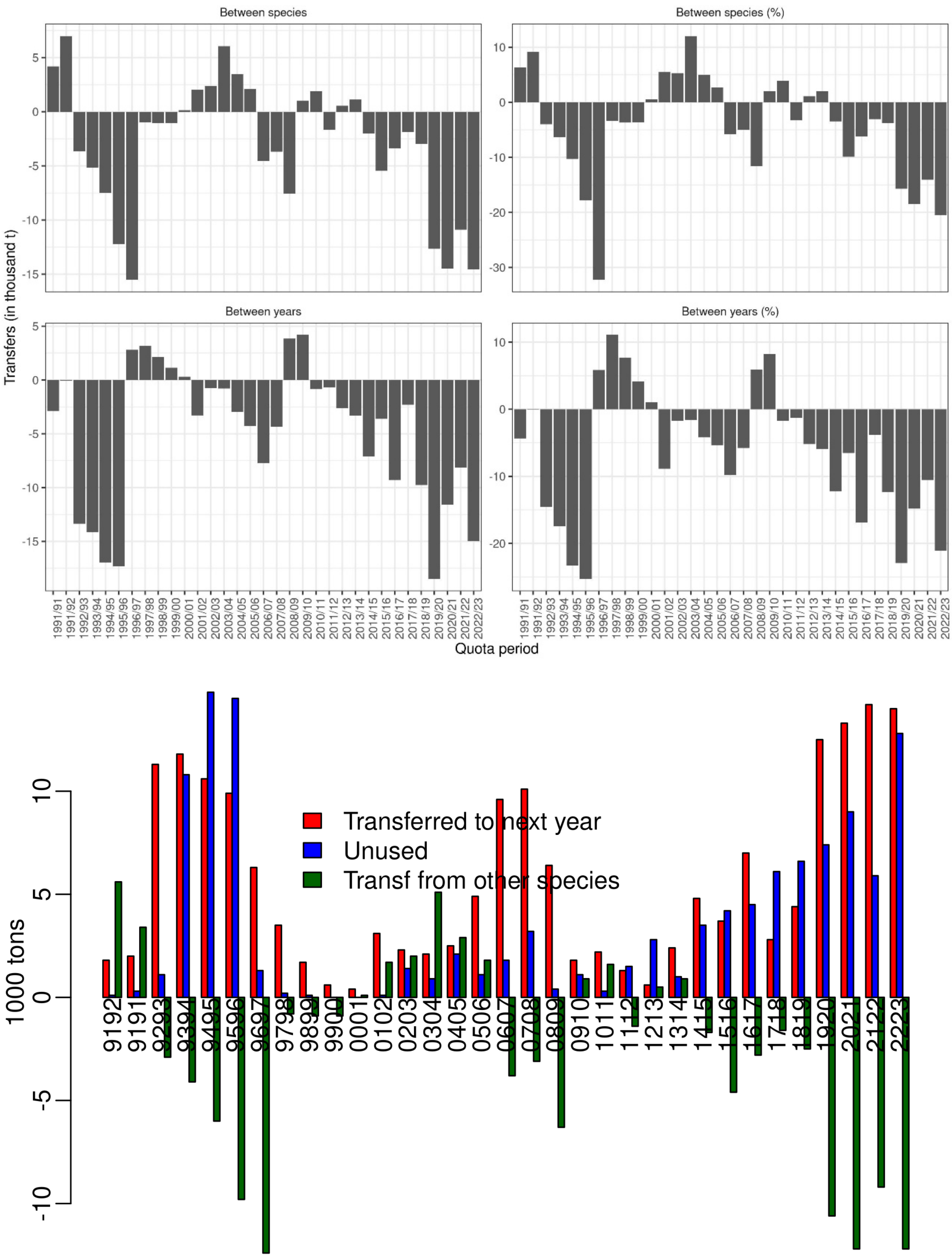
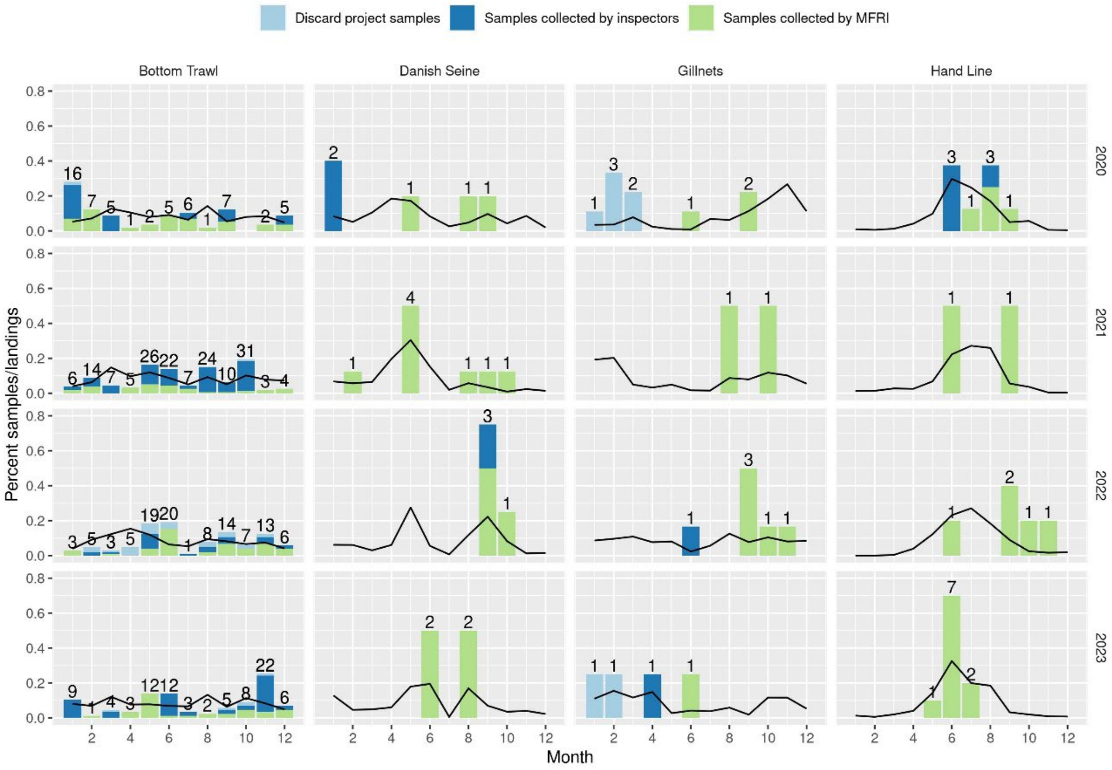


Figure 8.2 Saithe in Division 5.a. Upper figure. Transfer from other species to saithe. Negative values mean transfer from saithe to other species. The lower figure shows similar things but also "unused" Tac.



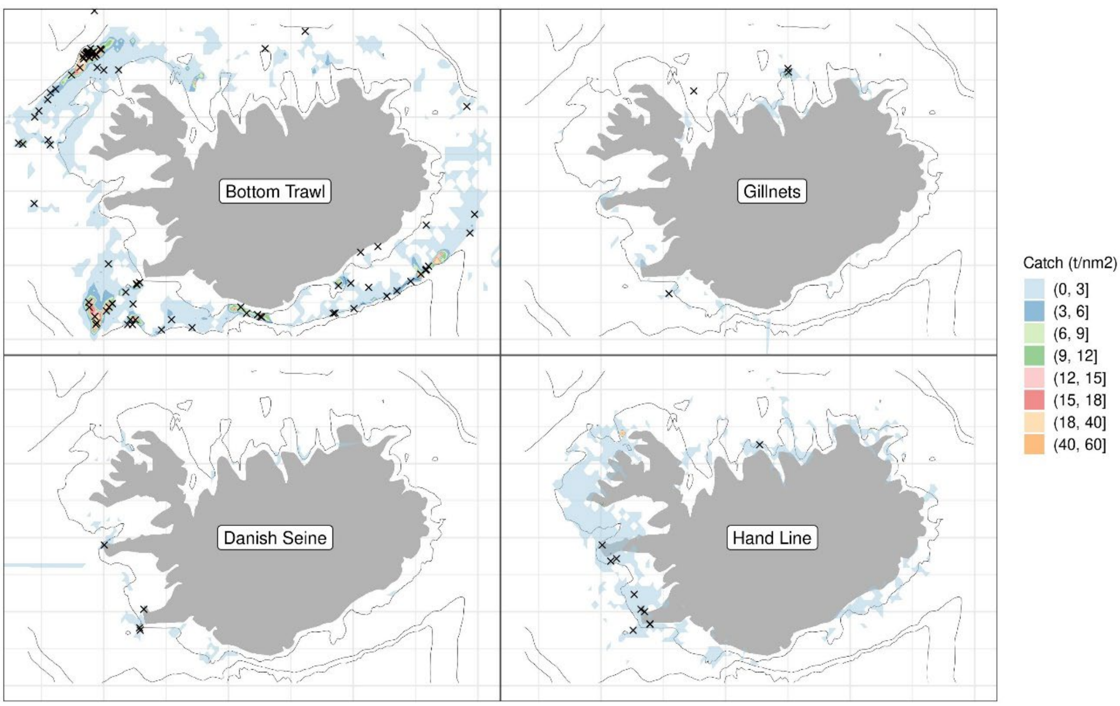


Figure 8.3 Saithe in Division 5.a. Development of sampling intensity from catches. Red is sea samples from the Fisheries Directorate, blue harbour samples from the MFRI and green from a discard project, combination of sea and shore samples.

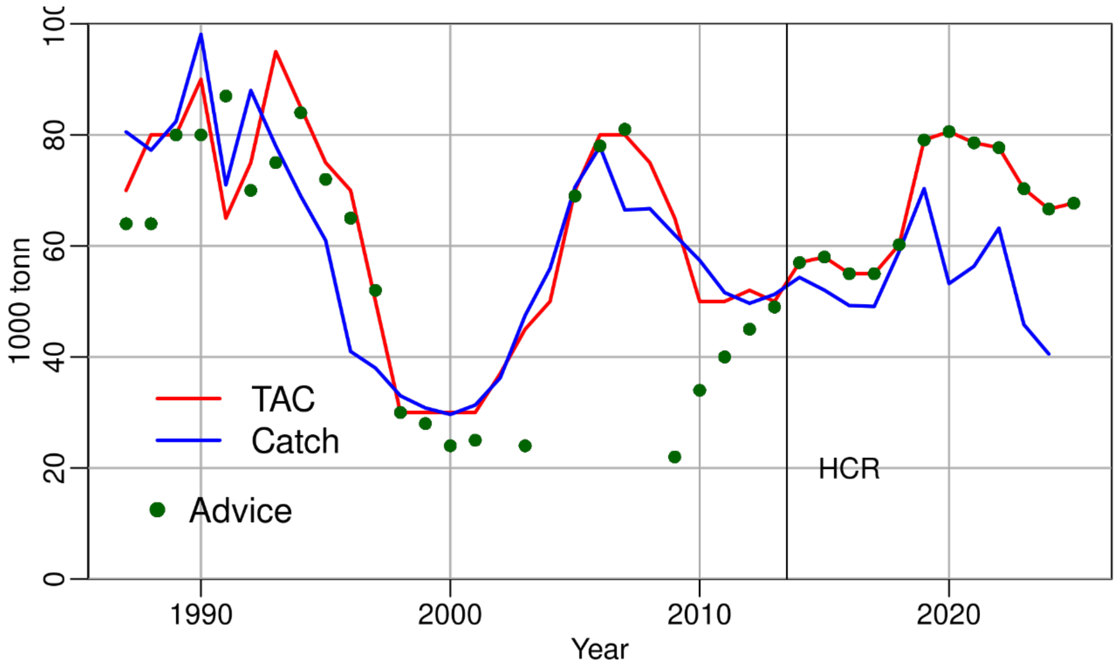


Figure 8.4. Advice, TAC and catch of saithe since 1987.

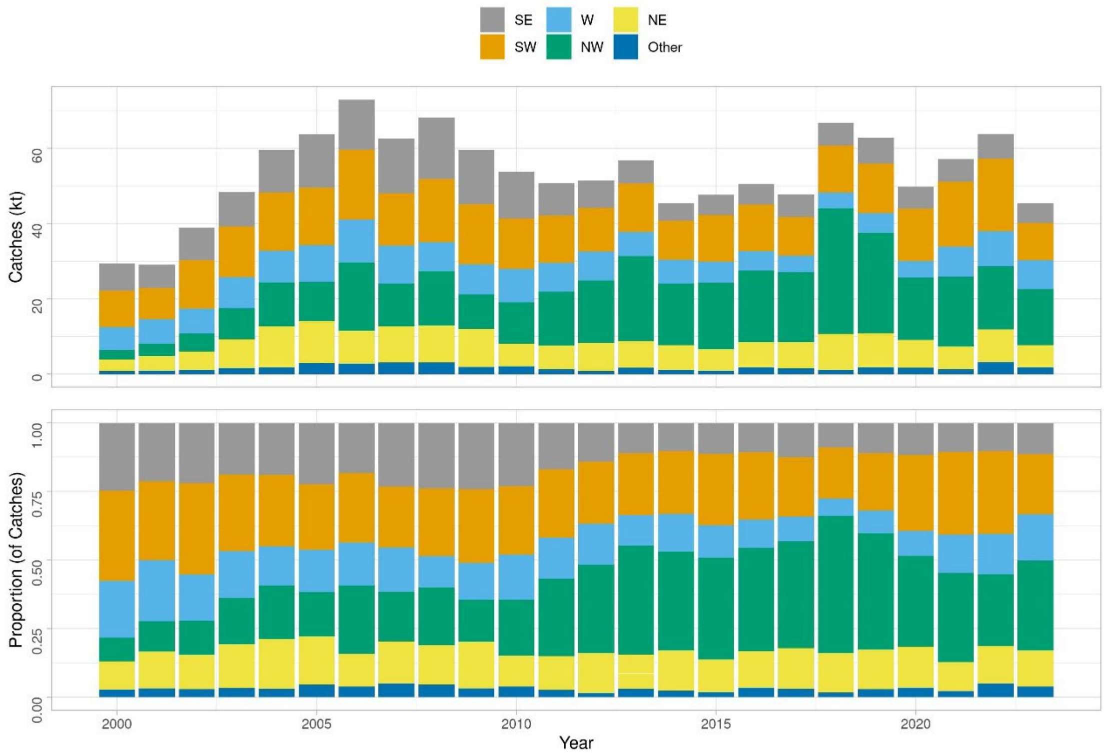


Figure 8.5. Saithe in Division 5.a. Upper figure percent of landings by regions defined in the lower figure to the left. Lower right, stations added in the autumn survey in 2000 (red dots).

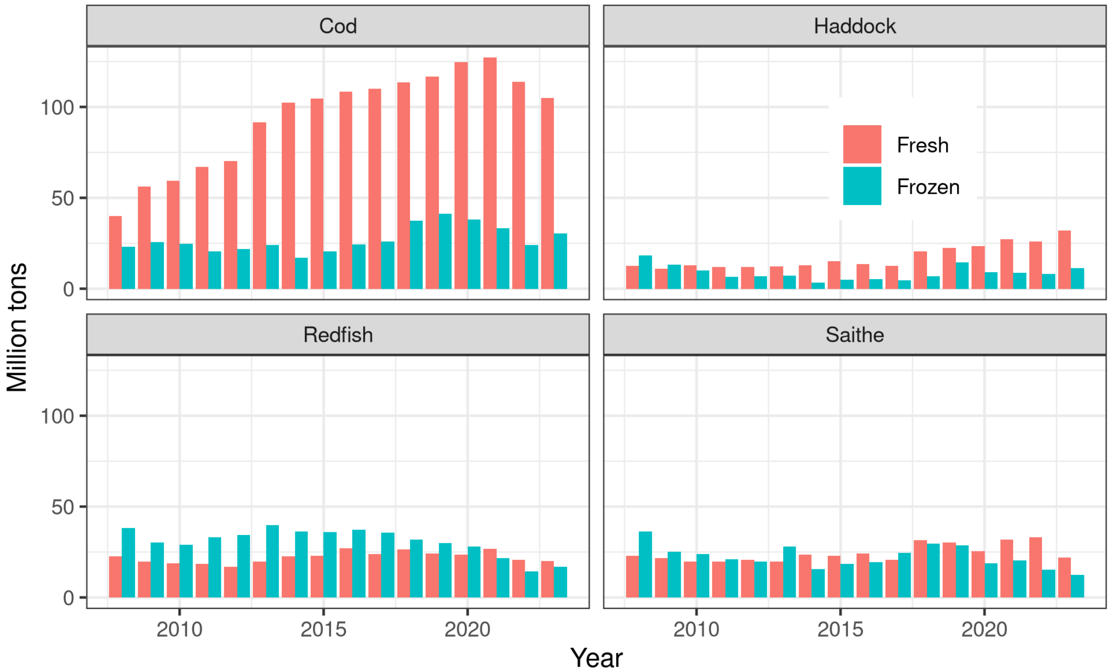


Figure 8.6 Saithe in Division 5.a. Catch by trawlers divided between those that freeze the catch and those that do not.

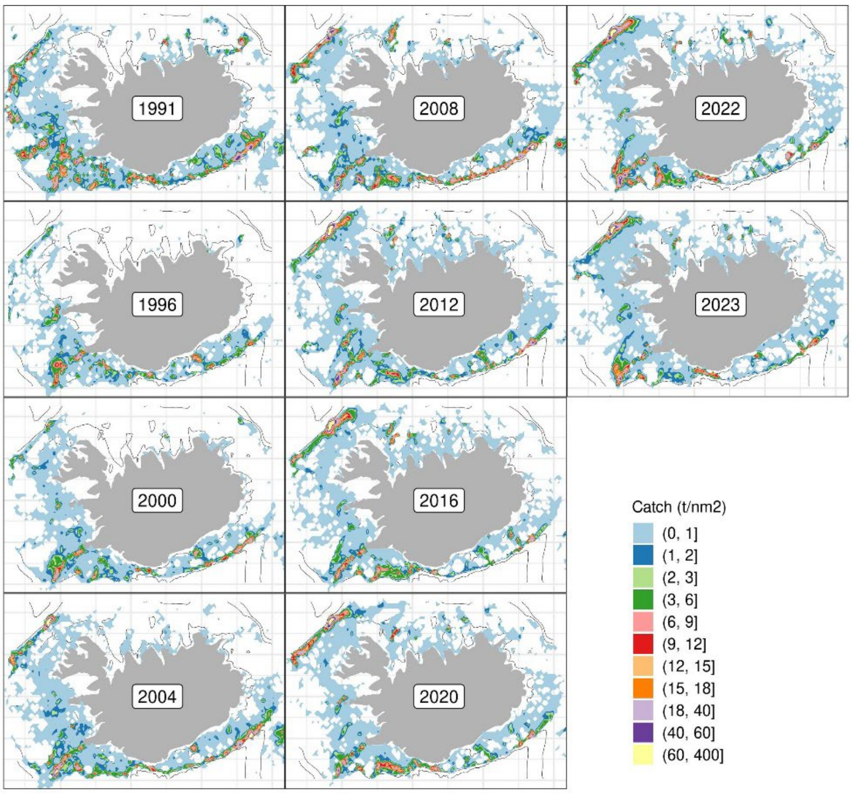


Figure 8.7. Spatial distribution of saithe fisheries as tonnes per square nautical mile per year.

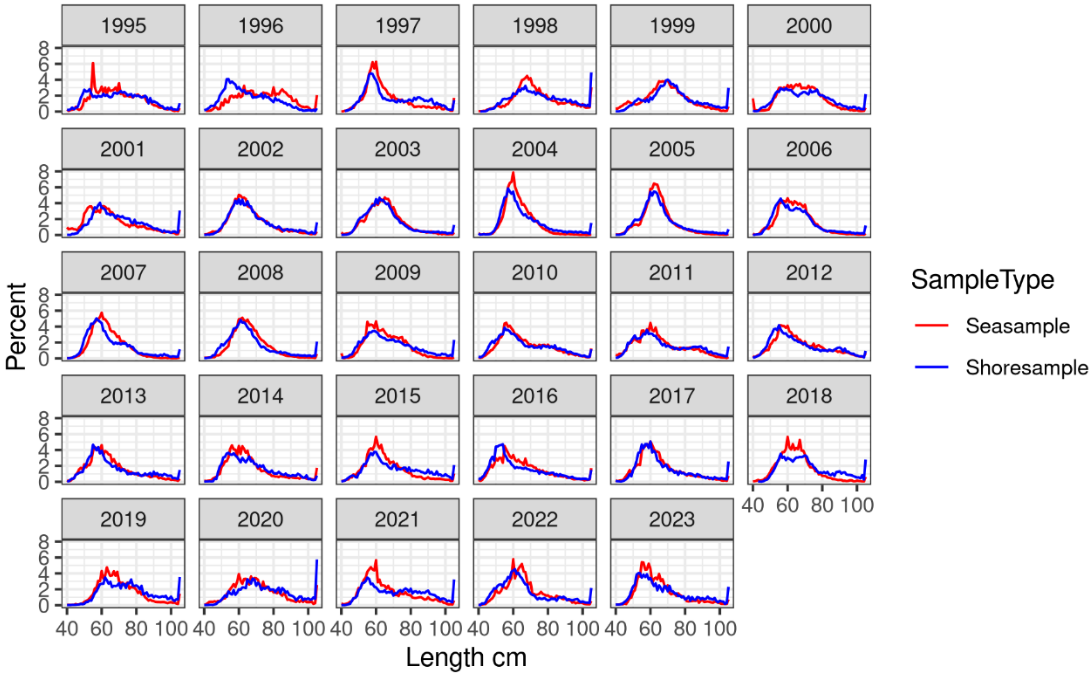


Figure 8.8. Length distributions from sea and shore samples.

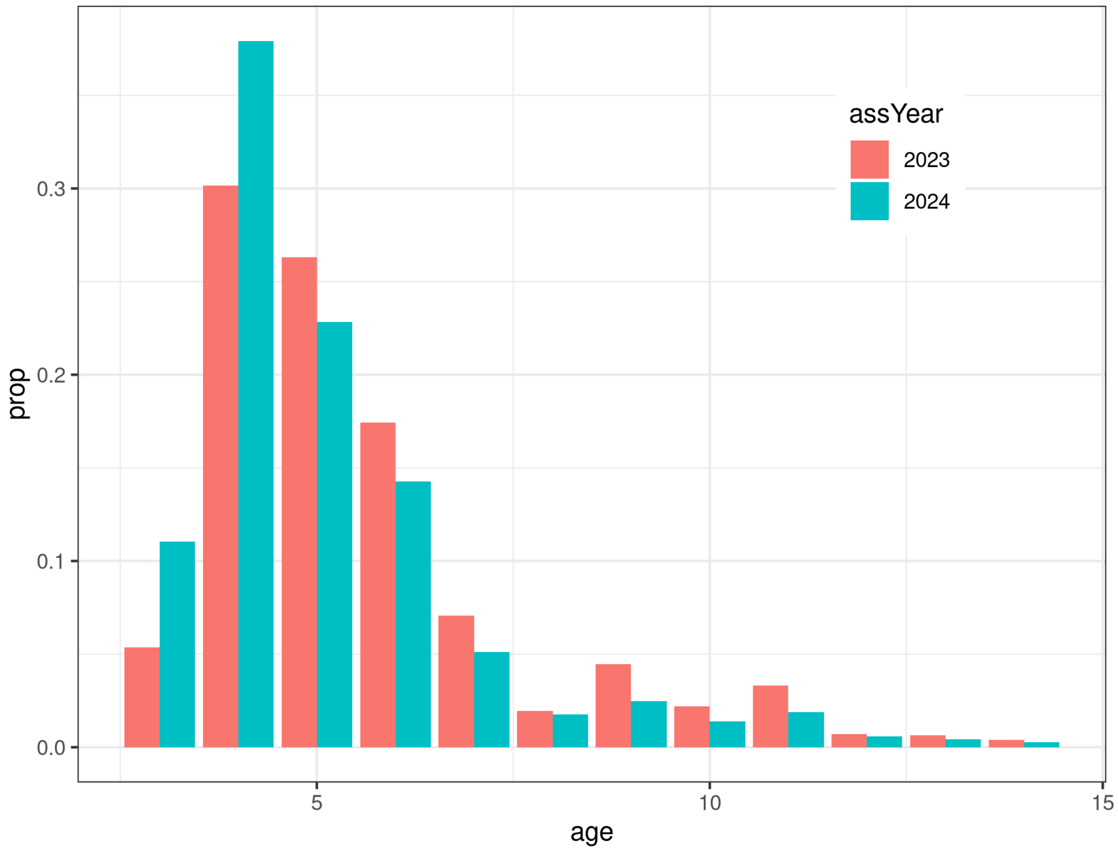


Figure 8.9. Catch in numbers 2023 compared to last year's prediction. The figure shows proportions.

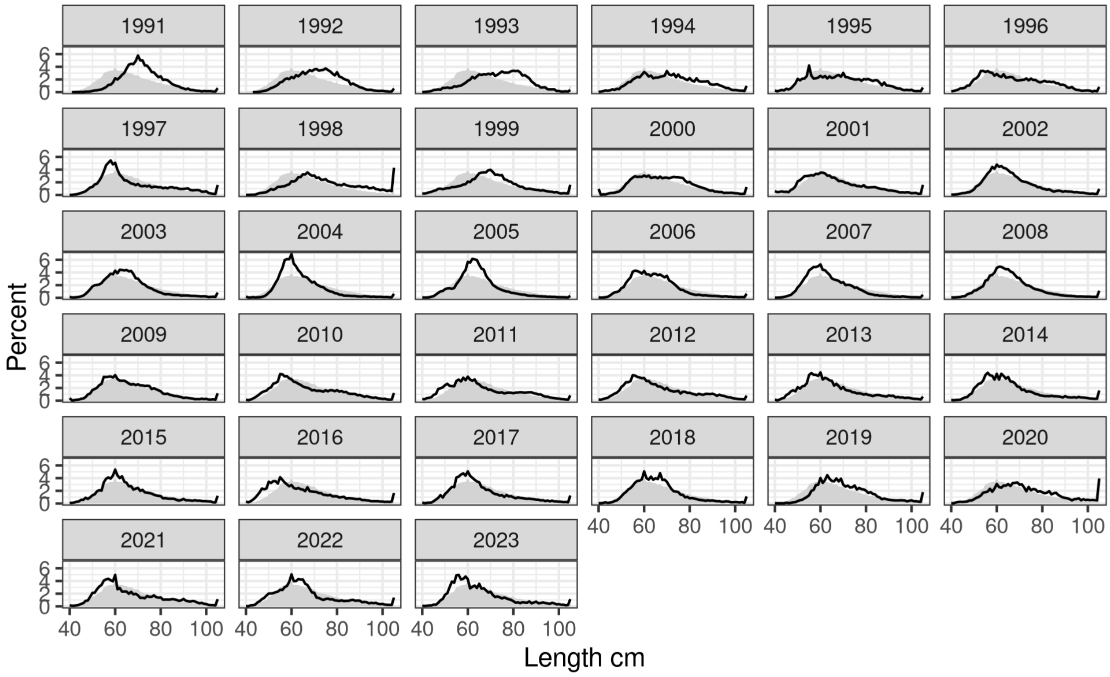


Figure 8.10. Length distributions from bottom-trawl catches (lines) compared to average (grey shading).

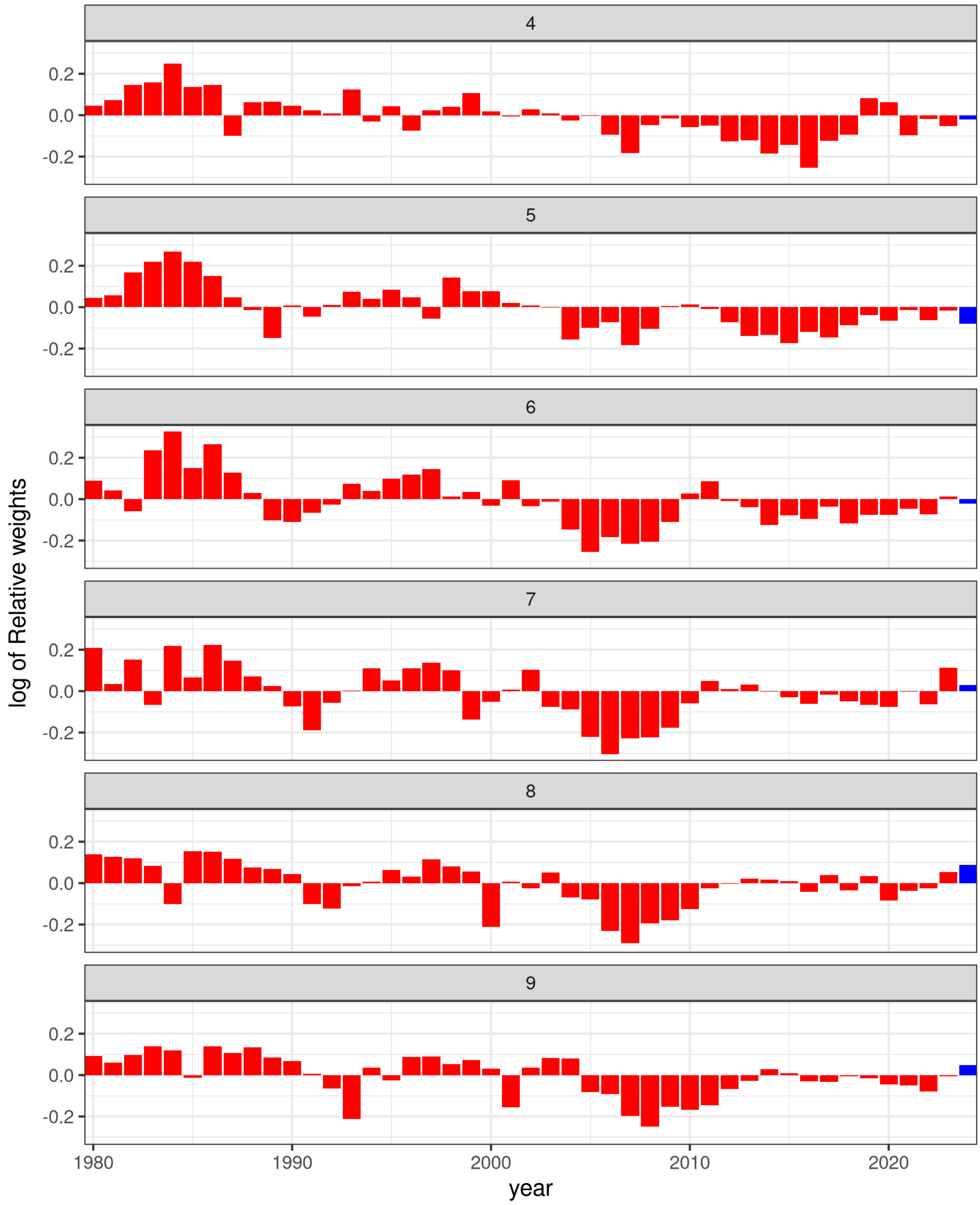


Figure 8.11. Saithe in Division 5.a. Weight at age in the catches, as relative deviations from the mean. Blue bars show prediction.

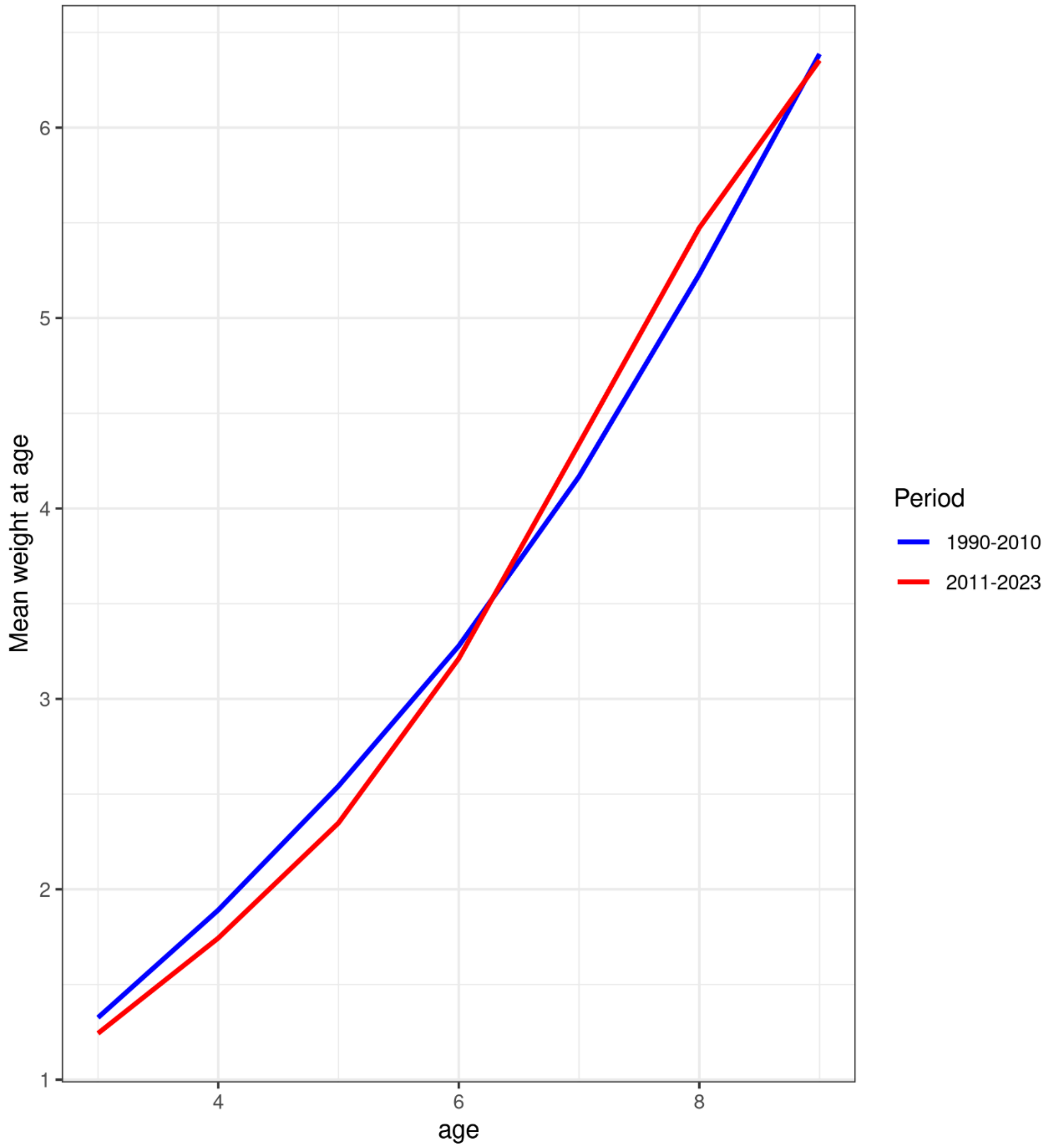


Figure 8.12. Saithe in Division 5.a. Weight at age in the catches shown as average for 2 periods.

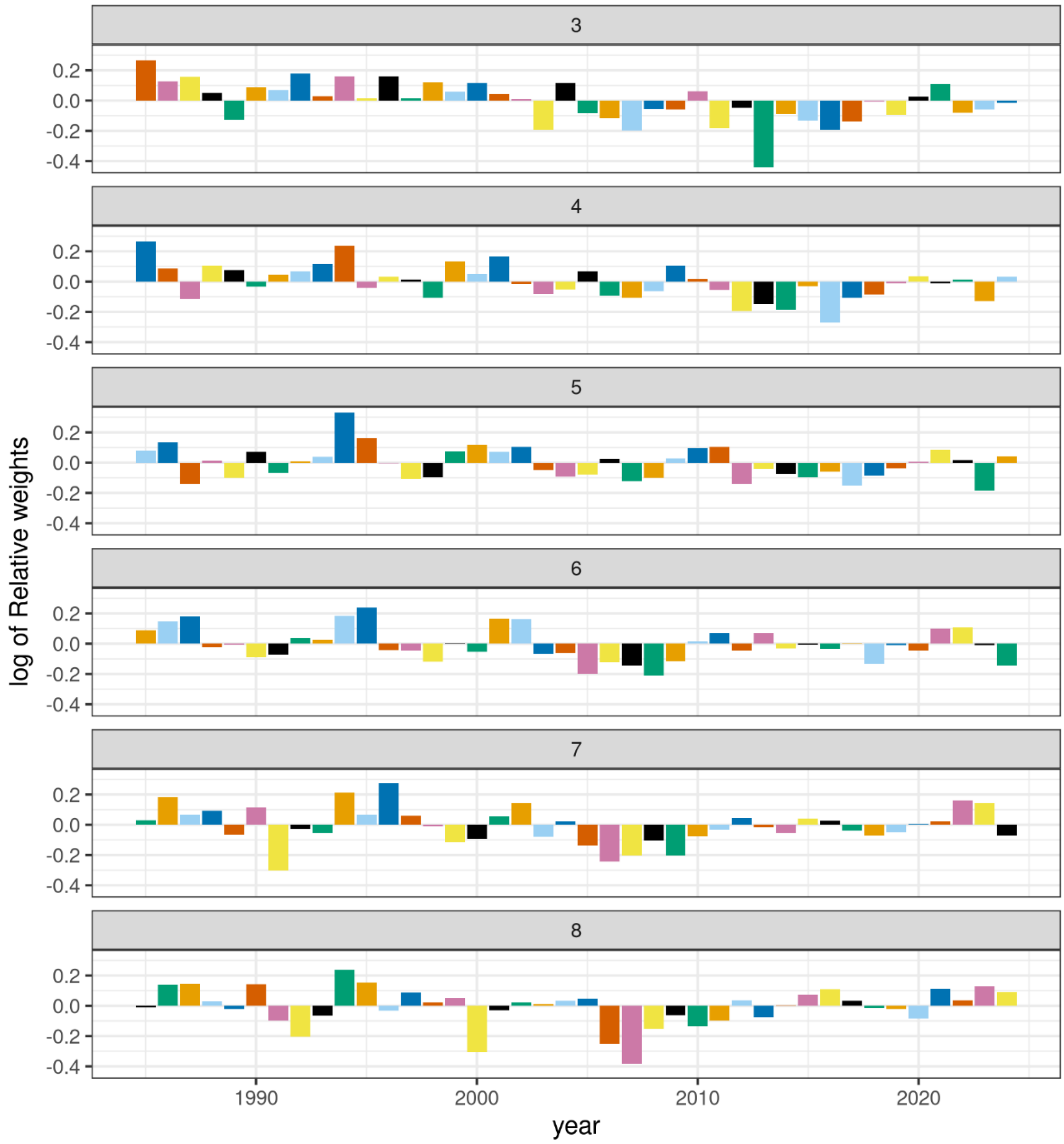


Figure 8.13 Saithe in Division 5.a. Weight at age in the survey, as relative deviations from the mean. Colours can be used to follow year classes.

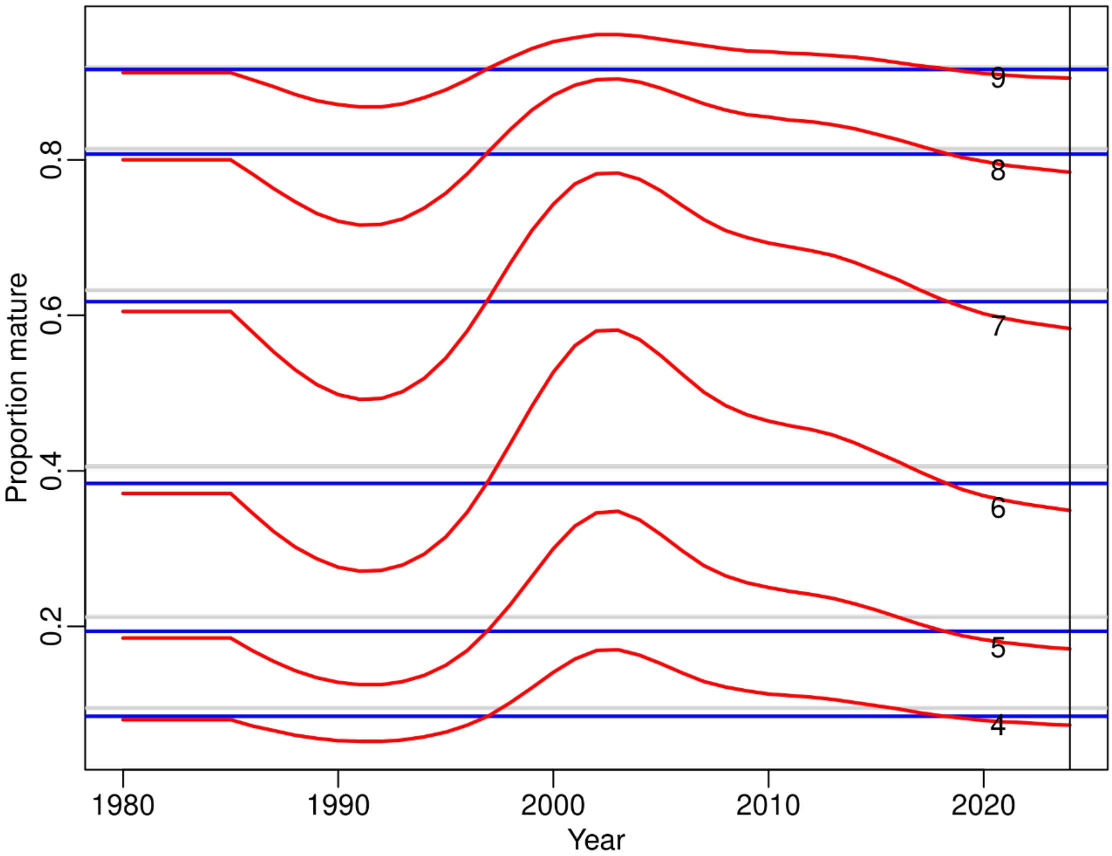


Figure 8.14. Saithe in Division 5.a. Maturity-at-age used for calculating the SSB. The horizonal lines show the average of last 10 years (blue one) and the average since 1985.

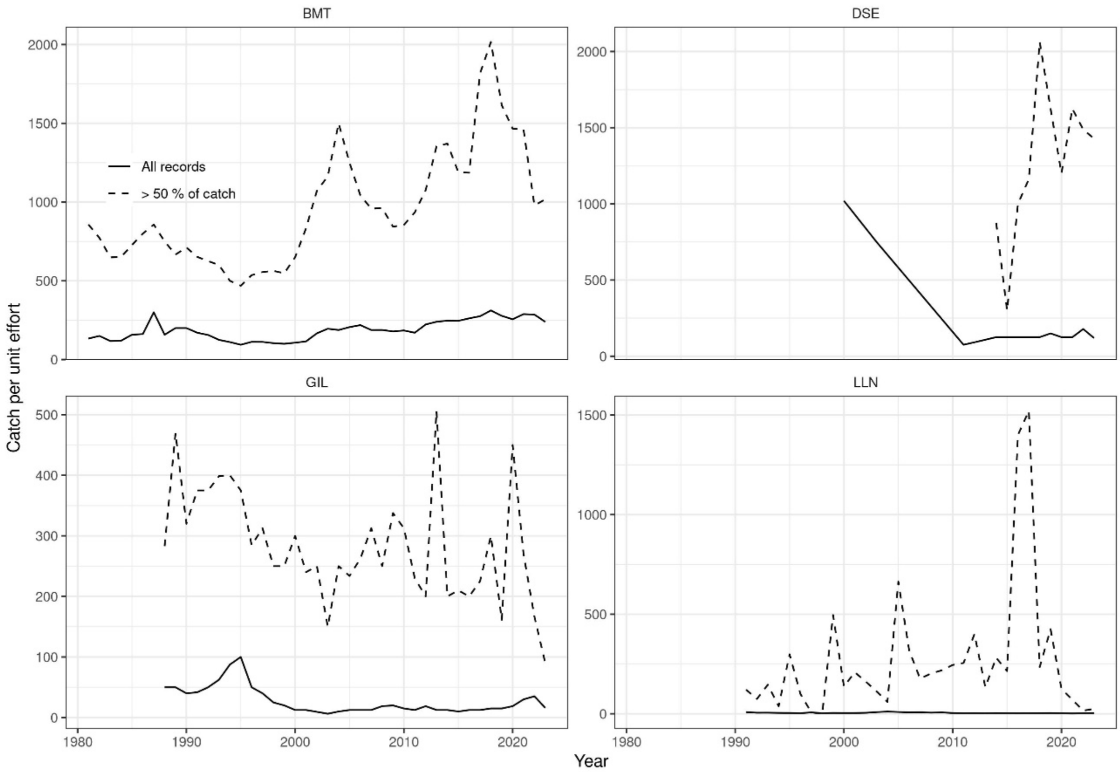


Figure 8.15. The CPUE in kg/effort unit for each record is compiled and the median for each year compiled. Bottom-trawl accounts for 80-92 % of the saithe catch and CPUE in kg/hours trawled.

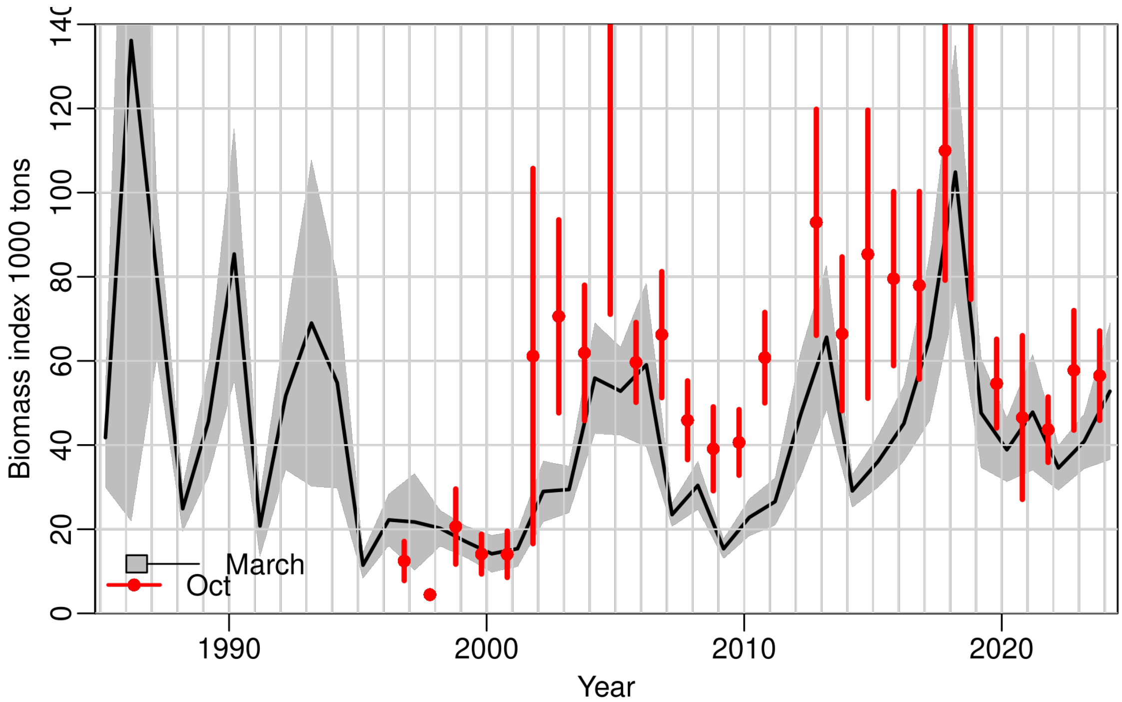


Figure 8.16. Saithe in Division 5.a. Biomass index from the groundfish surveys in March and October.

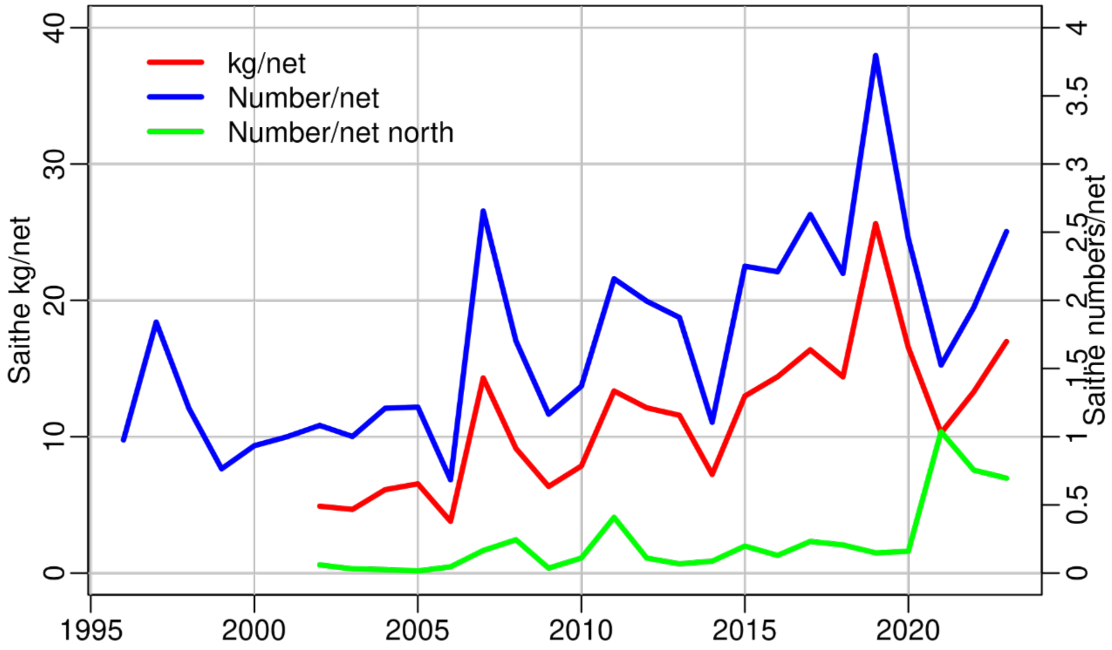


Figure 8.17. Saithe in Division 5.a. Indices from the gillnet survey in April 1996–2023. Saithe was not length measured in the survey before 2002 so catch in kg cannot be compiled.

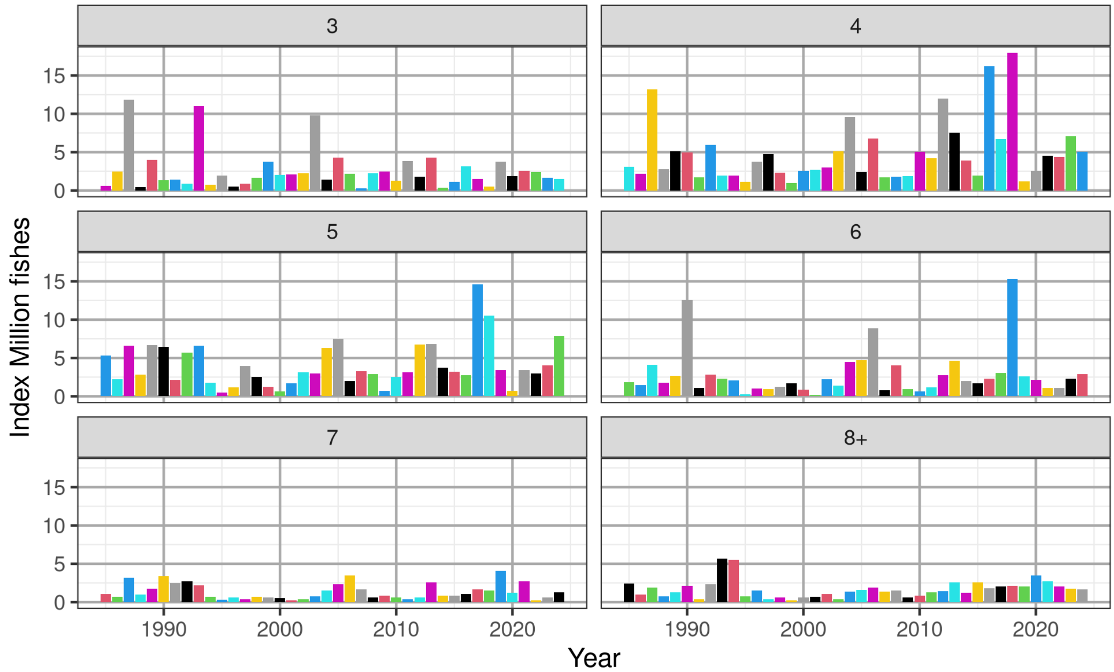


Figure 8.18. Saithe in Division 5.a. Survey indices by age from the spring survey. The colours follow year classes except of course for age 8+.

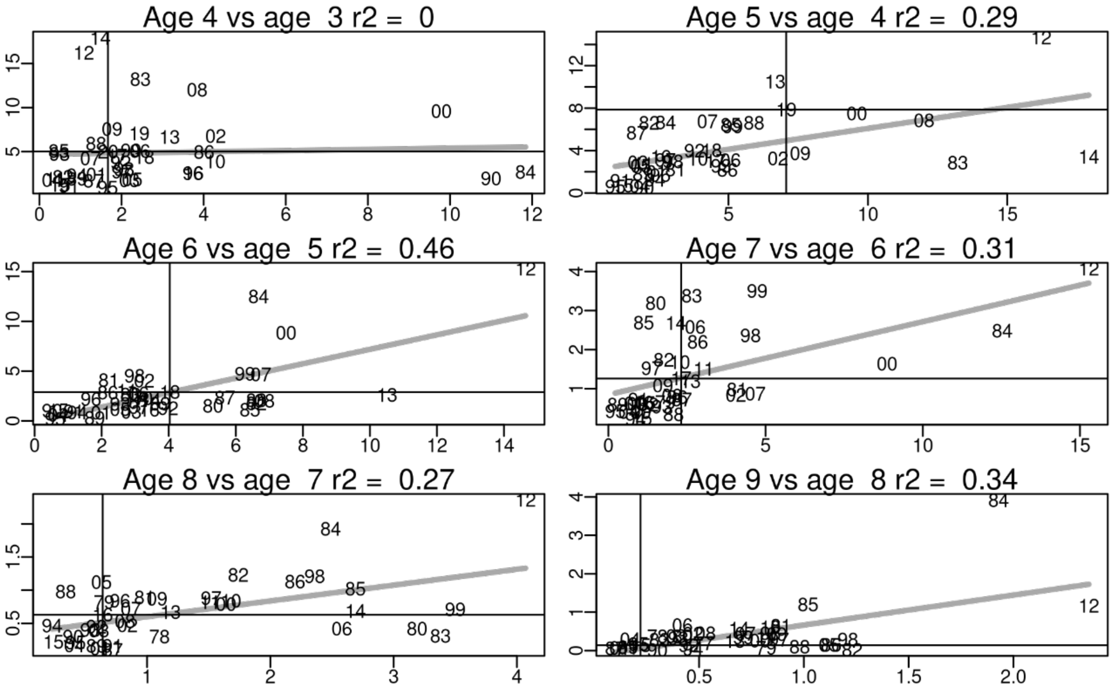


Figure 8.19. Saithe in Division 5.a. Survey indices by age from the spring survey plotted against indices of the same cohort one year earlier. The grey lines show the most recent values. The labels mean year classes.

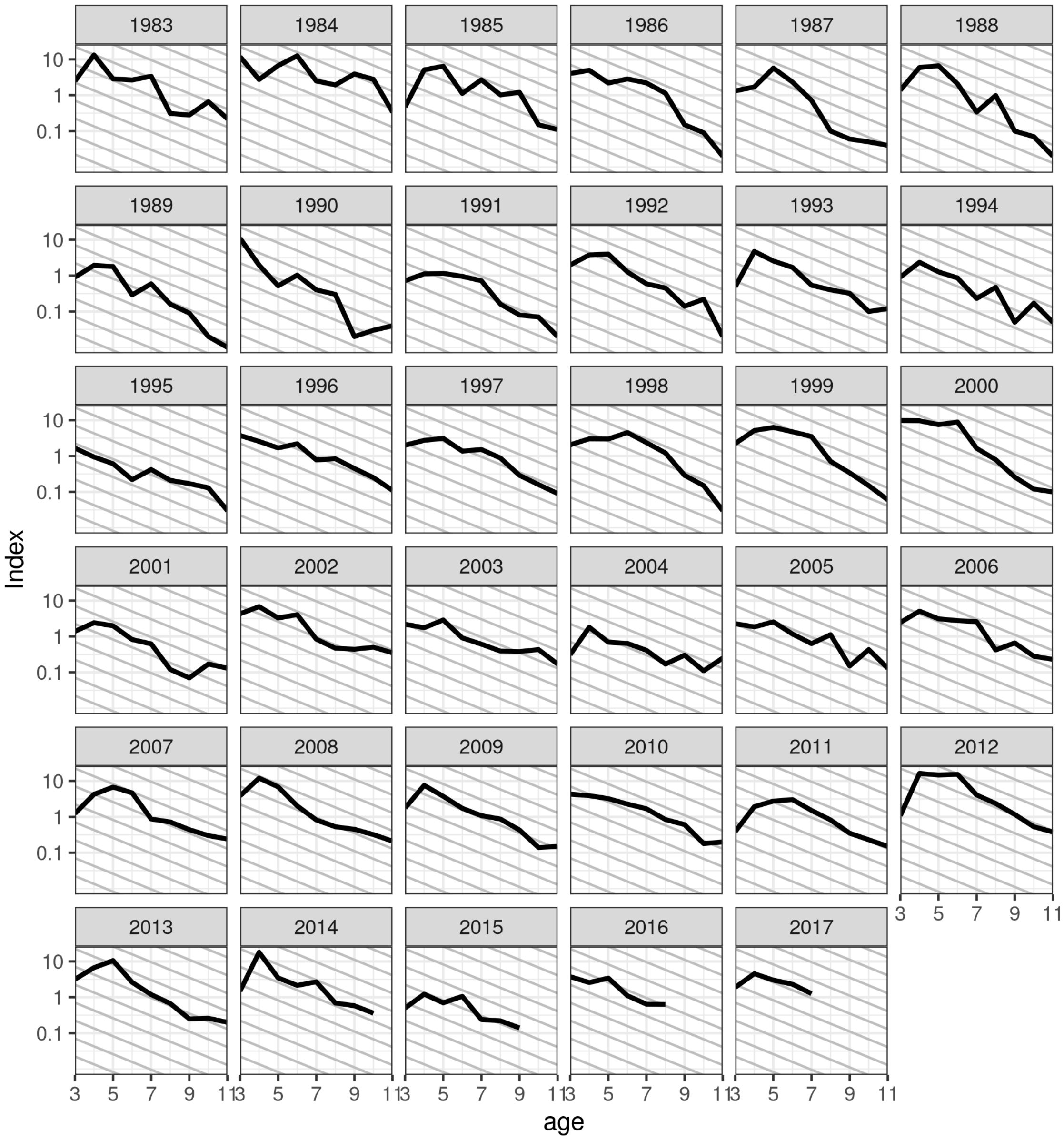
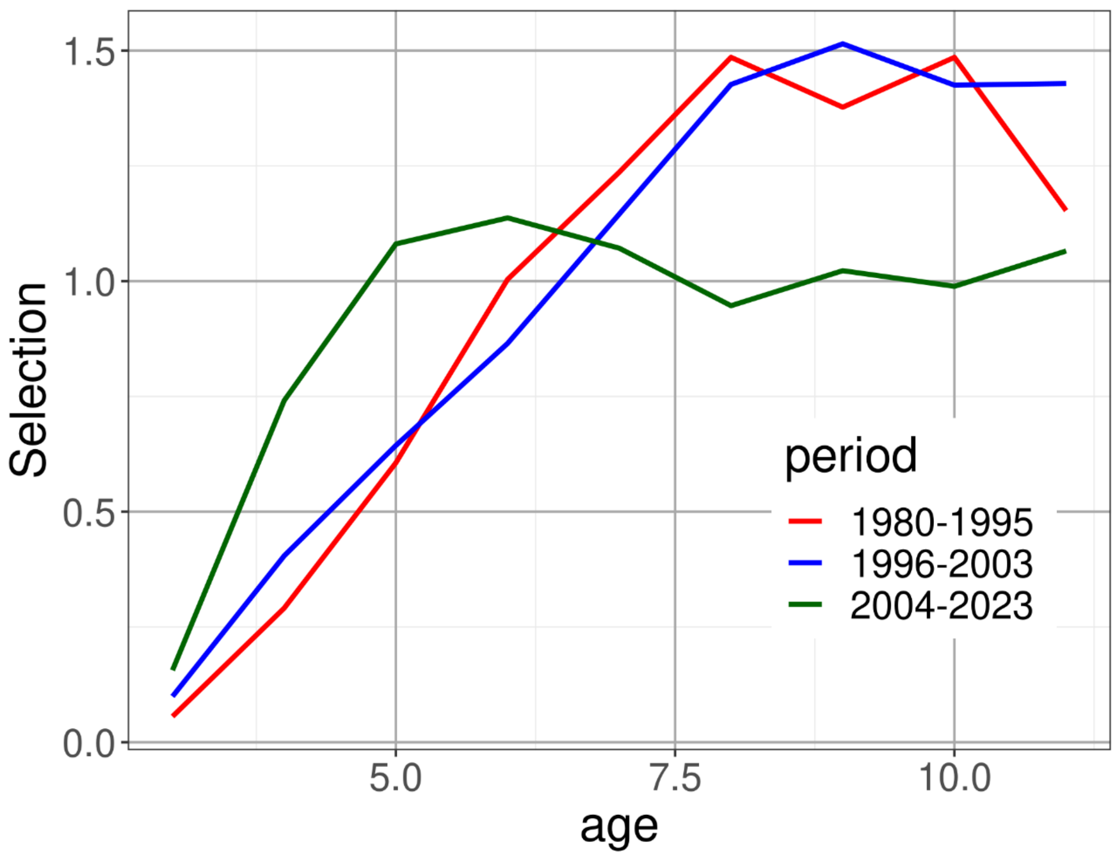


Figure 8.20. Saithe in Division 5.a. Survey indices by age from the spring survey plotted as catch curves for each year class. The grey lines correspond to Z = 0.5.



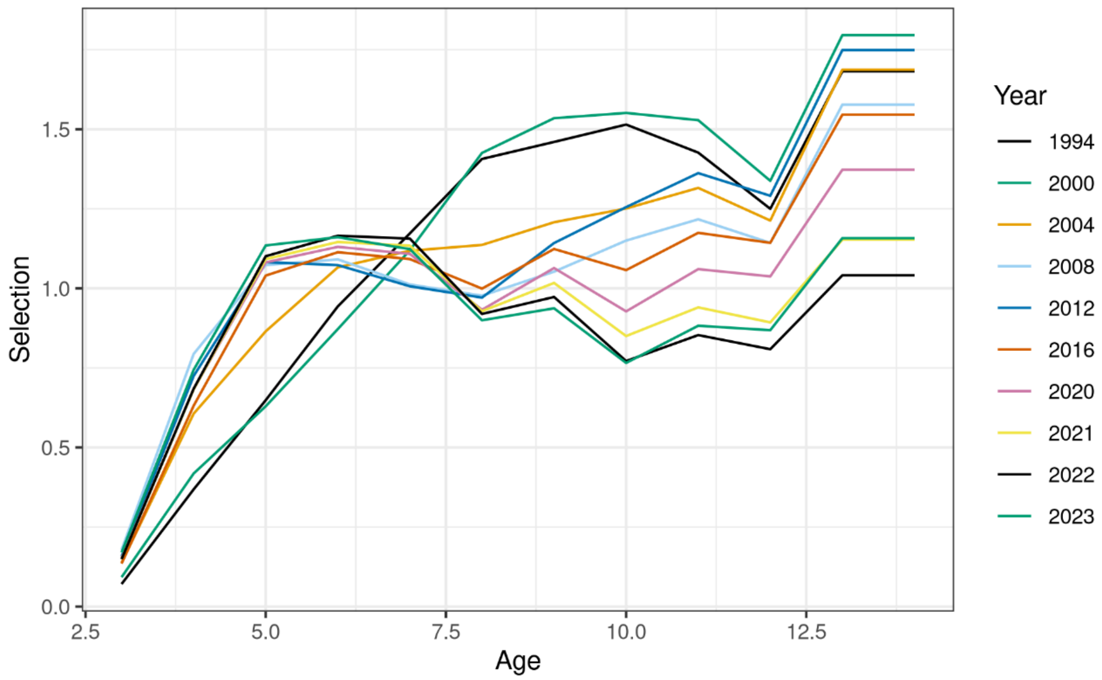


Figure 8.21. Upper figure. Estimated selectivity patterns for the 3 periods, 1980–1996, 1997–2003 and 2004–2020. Lower figure estimated selection from the SAM model. The timing of selection change around 2004 is also evident in the SAM model results.

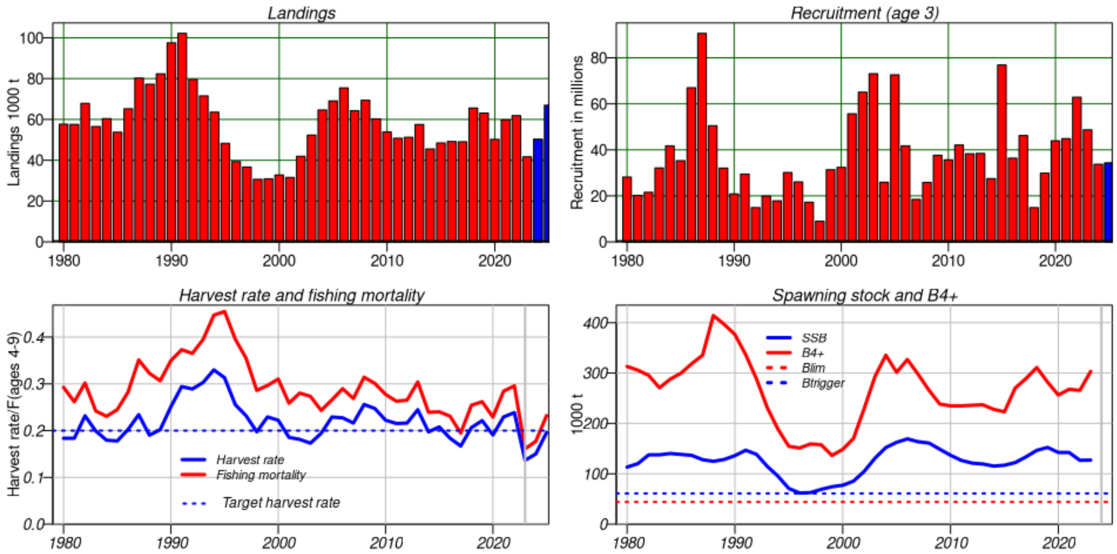


Figure 8.22. Saithe in Division 5.a. Results from the adopted benchmark (SPALY) model and short-term forecast

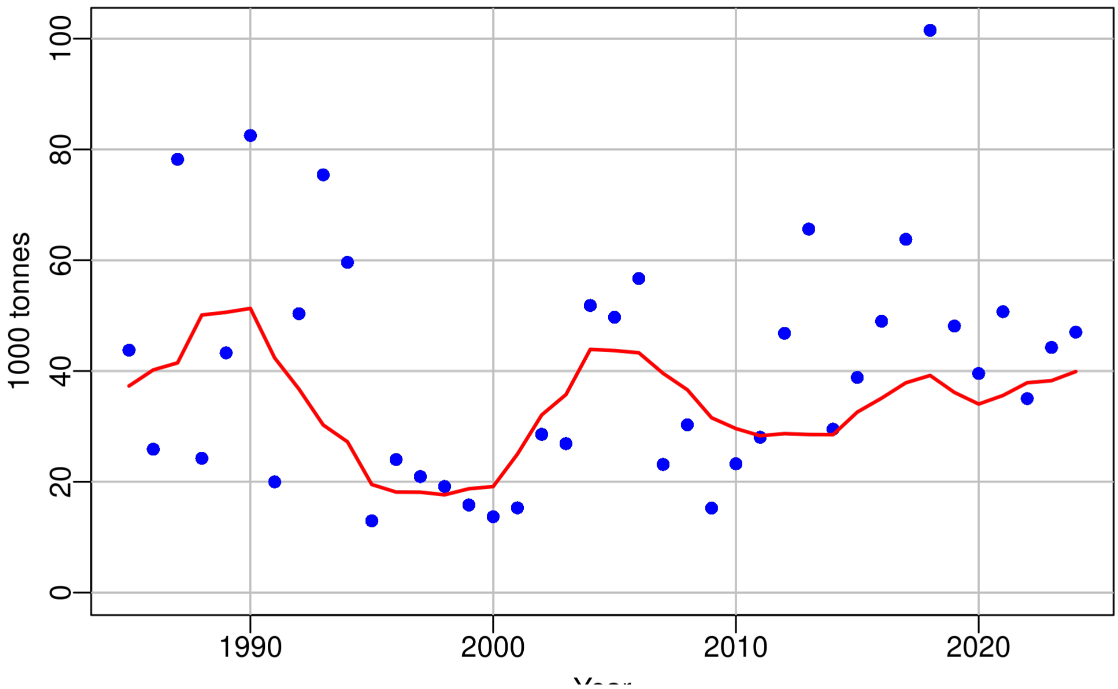


Figure 8.23. Saithe in Division 5.a. Observed and predicted survey biomass from the "SPALY model".

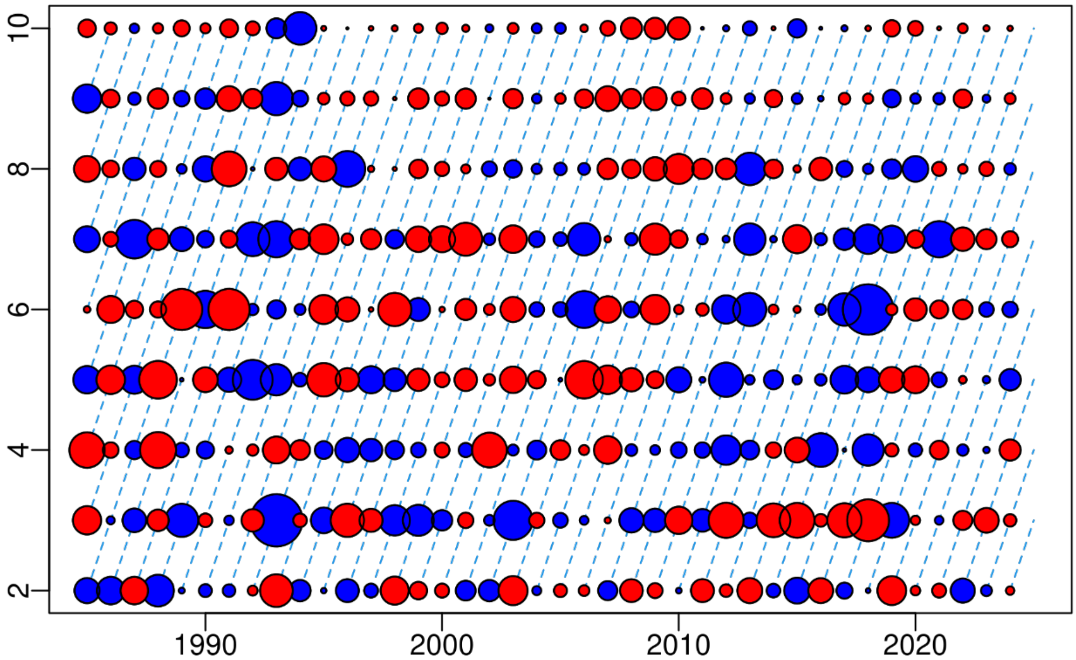


Figure 8.24. Saithe in Division 5.a. Survey residuals from the "Adopted model". The residuals are standardized.

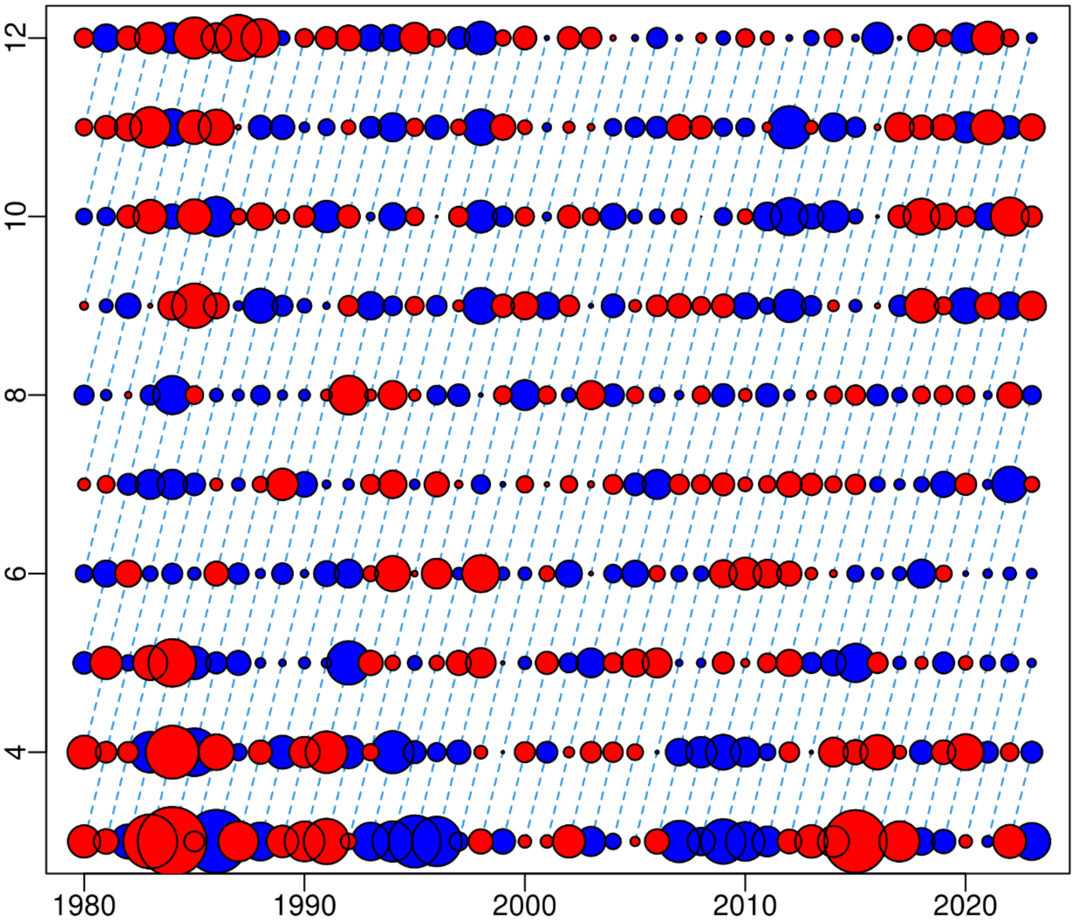


Figure 8.25. Saithe in Division 5.a. Catch residuals from the “Adopted model”.

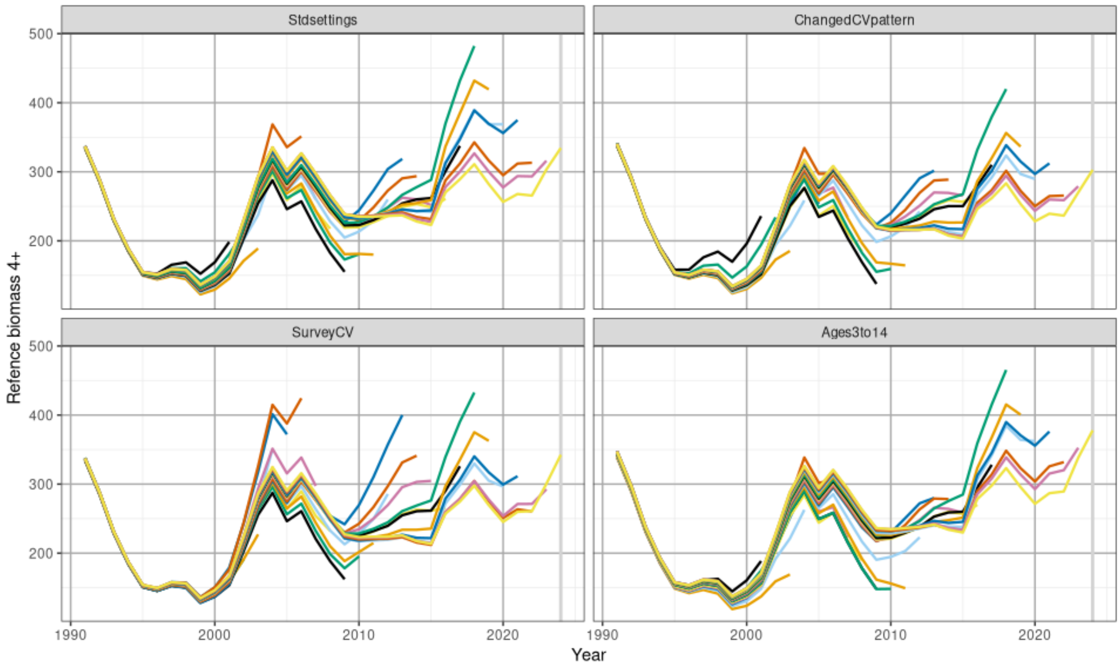


Figure 8.26. Saithe in Division 5.a. Retrospective pattern for the adopted assessment model (Oldsettings) and alternative configurations of the model. The figure shows estimate of B4+, the metric affecting advised catch. The grey vertical lines show the year 2021.

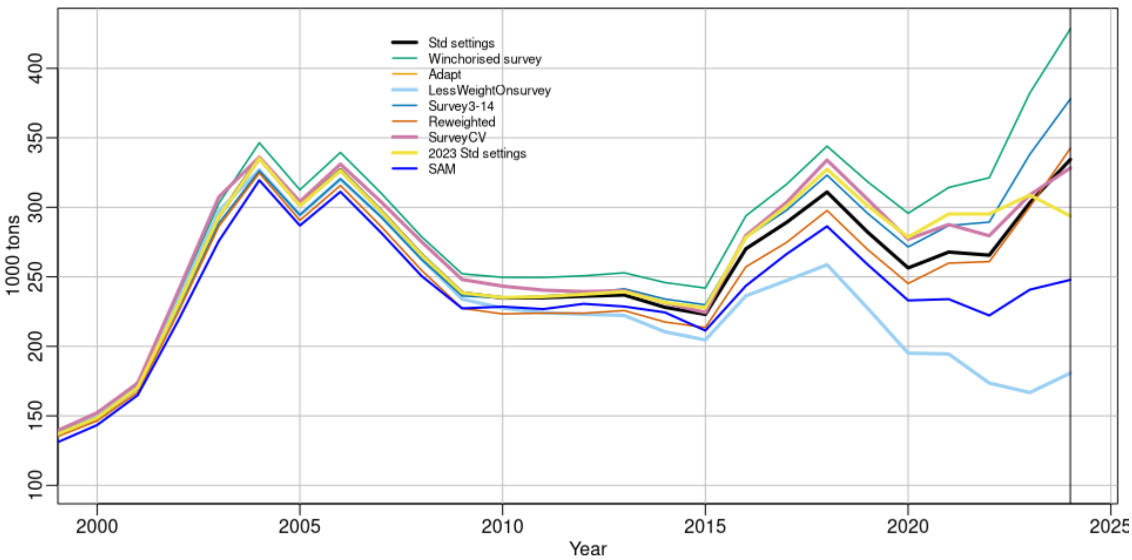


Figure 8.27. Saithe in Division 5.a. Comparison between the default separable model (Muppet) and alternative assessment models and model settings.

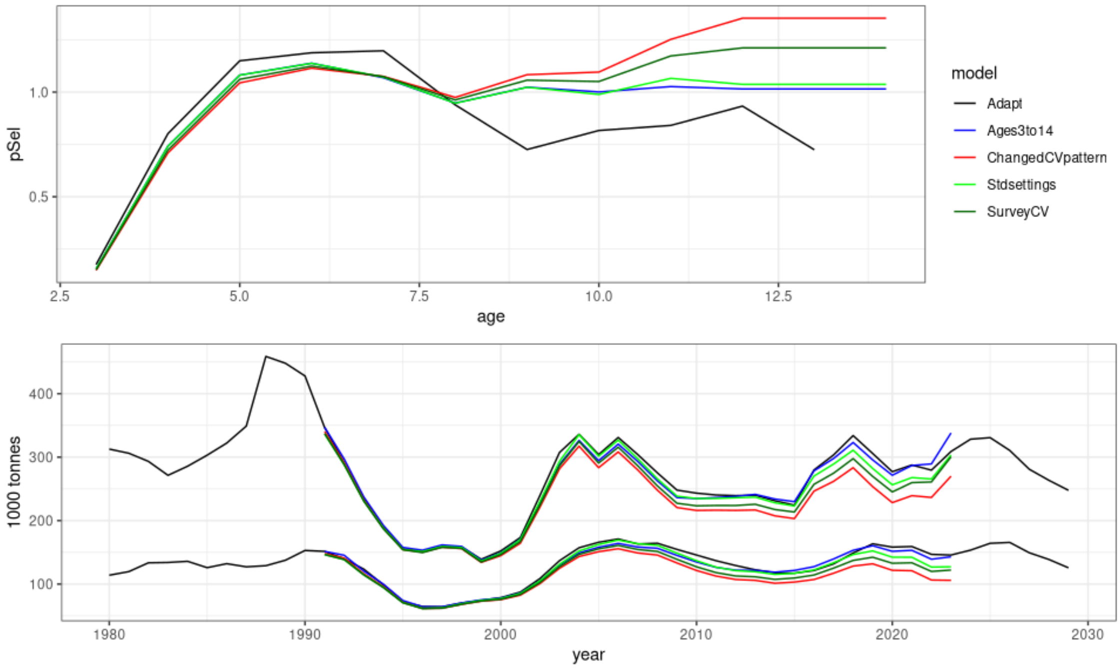


Figure 8.28. Saithe in Division 5a. Comparison between 2023 assessment results of the models shown in Figure 8.29. The Adapt model is added to the list shown there to see the "converged biomass". The lower figure shows B4+ and SSB.

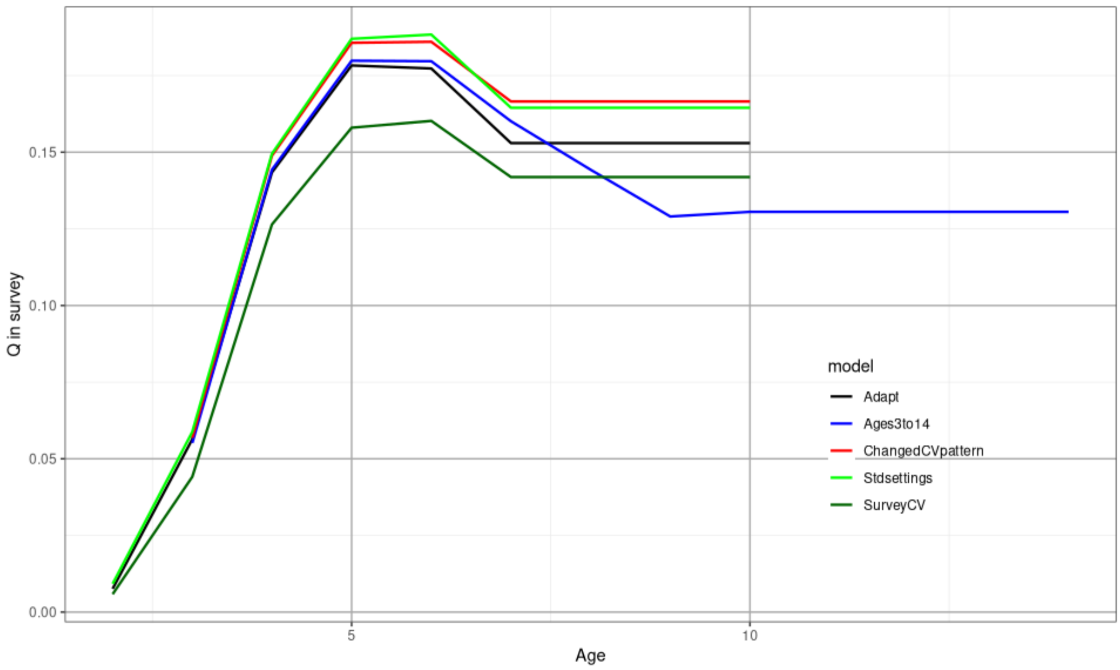


Figure 8.29. Saithe in Division 5a. Q by age in the March survey for the different models.

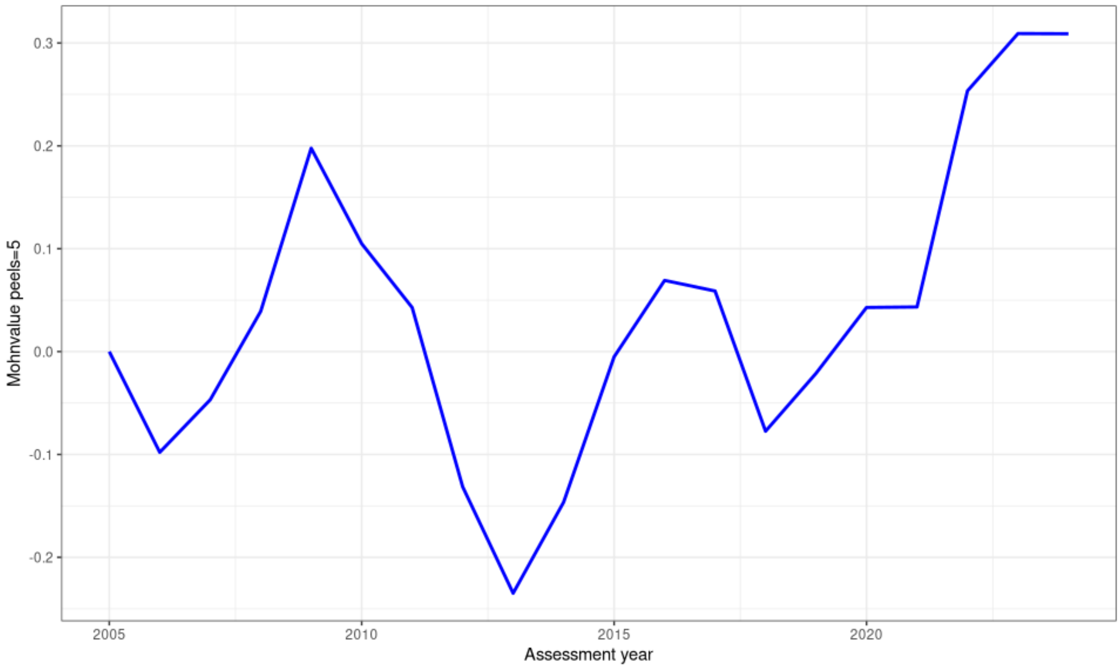


Figure 8.30. Saithe in Division 5a. Retrospective pattern of Mohns rho for B4+.

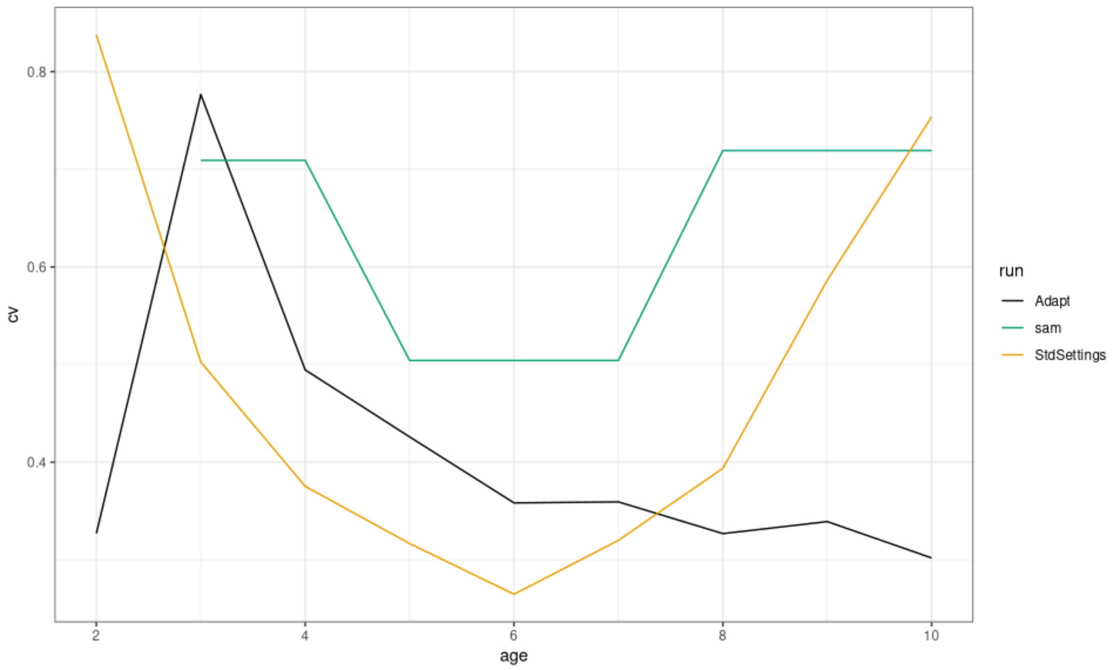


Figure 8.31. Saithe in Division 5a. Estimated CV from the survey by 3 assessment models.

9 Iceland grounds cod

cod.27.5a – *Gadus morhua* in Division 5.a

9.1 General information

Cod *Gadus morhua* is widely dispersed in Icelandic Waters, with higher abundance in northwestern, northern, and northeastern part of the shelf. Cod is considered demersal with moderately wide depth distribution which can vary from depths of few meters down to 600 m, occasionally even deeper. Adult cod has not much preference regarding bottom structure and can be found on various substrata; however, a large share of the cod juveniles prefer moderately sheltered, shallow kelp and seagrass environments. The ideal sea temperature for cod is around 4–7°C, nevertheless the temperature limits for this species are somewhat wider, and a significant proportion of the catch is taken where temperature is less than 2°C. Cod spawns all around Iceland by smaller regional spawning components, however the main spawning areas are situated in the south, southwest and west. Spawning starts early in the spring (March-April) on the main spawning grounds in the warmer waters in the south. In the past, spawning started later on in the colder waters in the north, but in recent years spawning time in the north has advanced significantly. North- and eastward pelagic egg- and larval drift mainly occurs clockwise to the nursery grounds situated in the north and northeastern area. The adult stock takes feeding migrations to the deeper waters in the northwest and southeast, but part stays in the shallow domains to feed. Cod is the most important exploited groundfish species in Iceland.

9.1.1 Fishery

Due to wide spatial distribution of cod in Icelandic Waters, the fishing grounds are scattered around the shelf and partially divided by gear type (Figure 9.5, Figure 9.6, Figure 9.7). Demersal trawl is the main fishing gear (Table 9.1, Figure 9.5). Main fishing grounds for demersal trawl are situated offshore in deeper relatively cold waters to the northwest, northeast, and east of the island. In recent years, the spatial distribution of demersal trawl fishery has been gradually contracting and aggregating at the previously mentioned trawl fishery hot spots (Figure 9.5). Longline accounts for the next largest portion of the catch in the cod fisheries and is widely distributed around the Icelandic shelf, with lowest reported catch in the south and southeast coast (Figure 9.6). The distribution pattern of the catches remains consistent between the years with occasional hot spots. Cod fisheries of the remaining fishing fleet, i.e. gillnets, demersal seine and jiggers, are widely distributed, but mainly take place in shallow waters (Figure 9.7).

Spatial distribution of the cod fishery has been relatively stable for the past years (Figure 9.8). Changes in depth and spatial distribution (Figure 9.3 and Figure 9.4) are partly caused by changes in gear composition (Figure 9.2). For cod, the average depth in bottom-trawl is 230 m, longline 160 m, but 80 m for demersal seine and gillnets. Mixed fisheries considerations do also affect spatial distribution of the fisheries. For example, cod TAC (Total Allowable Catch) was 50–80% of the cod TAC from 2003–2008 leading to increased fisheries in areas where cod was abundant. For comparison, TAC for cod has been 15–20% of the cod TAC in recent years. The long-term pattern is that gillnets and bottom-trawl were the most important gear with most of the bottom-trawl catches taken in the northwest, but the gillnet catches in the south and west during spawning time. The share of gillnets has declined continuously in recent decades, while that of longlines has increased (Figure 9.2). Longline fisheries have the widest spatial distribution of the fleets targeting cod (Figure 9.6), although most of the catches come from the west and northwest.

Introduction of large longliners with automatic baiting in recent decades has expanded the fishing area of longliners to deeper waters. In some areas, especially in the northwest and southeast, cod can be found in dense schools in certain hot spots, a fact exploited by captains when they want to catch large amount of cod in short time, e.g. just before landing. Condition and size of cod in different areas is also an issue regarding fishing areas, but all those factors are weighed against proximity to landing harbour.

In 2024, more than half of the cod catch was taken in bottom-trawl 54, around 26 on longlines, 6 by gillnets, 6 by jiggers, and 7 by demersal seine. The largest proportion of the catch in recent years was taken in the western and northwestern area, followed by the northeast and southwest areas. Cod was caught at similar depth as in previous years, but perhaps slightly more shallow (Figure 9.2).

Since 1994, the number of vessels reported as having landed over 10 tonnes of cod in total annually, has decreased. This decline is noticeable in all the fleets, as the number of vessels has dropped by more than half since 1994 (Table 9.1). However, total catches have been increasing steadily in the past few years (Table 9.1).

The number of vessels accounting for 95% of the annual catch of cod in Icelandic Waters reduced from almost 1500 to about 900 vessels in 1994–1999 (Figure 9.1, Table 9.1). This reduction occurred despite annual catch increasing by almost 100 thousand tonnes. In 1999–2008, the number of vessels accounting for 95% of the cod catch reduced with reduced total catches to about 400 vessels. Since 2009 the number of vessels has remained relatively constant between 250 and 500, although the most recent years are marked by having the smallest numbers of vessels.

9.1.1.1 Landing trends

Landings of cod in Icelandic Waters has been historically high since industrial fishing began, although a productivity shift in the 1980s has led to relatively less recruitment and lower sustainable yield in the following decades. Landings were around 350 000 to 450 000 tonnes prior to World War II and during the 1960s, but have ranged closer to 150 000 to 250 000 both as a result of the productivity shift and management action. Sharp reductions in foreign catches are visible during World War II and the 1970s, when the Icelandic EEZ was expanded to 200 nautical miles. Landings in 2023 amounted to 217157 tonnes. Foreign landings account for a small portion of this (2358.402 in 2024), attributable to bilateral agreements allowing Norwegian and Faroese vessels to land a small amount of cod and other demersal species (Figure 9.9).

9.1.2 Data available

In general, sampling is considered good from commercial catches from the main gears (demersal seines, longlines, gillnets and trawls). The sampling does seem to cover the spatial and seasonal distribution of catches (see Figure 9.10 and Figure 9.11). In 2020, sampling effort was reduced substantially, on-board sampling in particular, due to the COVID-19 pandemic. Although this reduction in sampling continued through 2022, sampling operations have returned to normal and current samples are still considered to be sufficiently representative of the fishing operations. Thus, it is not considered to substantially affect the assessment of the stock.

9.1.2.1 Landings and discards

All landings in 5a before 1982 are derived from the STATLANT database, and also all foreign landings in 5a to 2005. The years between 1982 and 1993 landings by Icelandic vessels were collected by the Fisheries Association of Iceland (Fiskifélagið). Landings after 1994 by Icelandic vessels are given by the Icelandic Directorate of Fisheries. Landings of foreign vessels (mainly Norwegian and Faroese vessels) are given by the Icelandic Coast Guard prior to 2014 but after 2014 this are also recorded by the Directorate. Discarding is banned by law in the Icelandic demersal fishery. Measures in the management system such as converting quota share from one species to another are used by the fleet to a large extent and this is thought to discourage discarding in mixed fisheries. In addition to prevent high grading and quota mismatch the fisheries are allowed to land fish that will not be accounted for in the allotted quota, provided that the proceedings when the landed catch is sold will go to the Ministry funds. A more detailed description of the management system can be found on https://www.responsiblefisheries.is/seafood-industry/fisheries-management.

9.1.2.2 Length compositions

The length distribution of landed catch has shifted towards larger cod in the last ten years (Figures Figure 9.12). The bulk of the length measurements is from the main fleet segments, i.e. trawls, longlines, gillnets and demersal seine (Table 9.2). The number of available length measurements by gear has fluctuated in recent years in relation to the changes in the fleet composition.

9.1.2.3 Age compositions

Table 9.3 shows the number of otoliths samples and number of age readings divided by gear type and Figure 9.11 shows the location of otolith sampling.

The age composition of the catch has shifted from younger to older fish in the last few decades (Figure 9.13), likely as a result of decreasing fishing pressure. The number of year classes contributing to the catches has increased in recent years as a result of the low fishing mortality in recent years (Figure 9.14).

9.1.2.4 Weight at age in the catch

The mean weight age in the catch (Figure 9.15) declined from 2001 to 2007, reaching then a historical low in many age groups. The weight at age have been increasing in recent years and are currently around the average weights observed over the period from 1985 in age groups 3 to 10, while around 10% below average in older age groups. The catch weight at age 3–10 in the final year (assessment year) is based on the relationship between spring survey and catch weights in in the previous year for ages 3–9, and for older ages, the values from the previous year are used (see short-term projections).

9.1.2.5 Natural mortality

No information is available on natural mortality. For assessment and advisory purpose, the natural mortality is set to 0.2 for all age groups.

9.1.3 Catch, effort and research vessel data

9.1.3.1 Catch per unit effort from commercial fisheries

Catch per unit effort data (Figure 9.16) shows that for hauls where the catch is composed of more than 50% cod the CPUE has been steadily increasing since 1990 for the main gear types. The CPUE from all catches from all gears is among the highest recorded. The catch per unit effort could not be estimated after 2020 as the effort data from several years were not available.

9.1.3.2 Icelandic survey data

The Icelandic spring groundfish survey (hereafter spring survey) has been conducted annually in March since 1985. In addition, the Icelandic autumn groundfish survey (hereafter autumn survey) was commenced in 1996. However, a full autumn survey was not conducted in 2011. Figure 9.17 shows both a recruitment index based on abundance of cod smaller than 55 cm, and trends in various biomass indices. Survey abundance by tow site (Figure 9.19) and changes in spatial distribution (Figure 9.18). The total biomass index in the spring survey has been high but fluctuating and with a slight decline over the last decade according to the spring survey index. The total spring (SMB) and autumn survey (SMH) measurements decreased significantly from the highest value observed in 2017 to the 2020 measurement, and have since increased again slightly (Figure 9.17). While the 2021 and 2022 spring survey measurement were on par with that observed in 2018 and 2019, the autumn survey measurement in 2021 continued to decline, it being the lowest observed since 2004. The 2020 survey indices were substantially below expectations for size classes that constitute the bulk of the fishable biomass, a trend which continued in 2021 in autumn survey indices but not 2021 spring survey indices. In general, the two surveys have shown similar trends through time (Figure 9.17) but the contrast through the increase and decline since the late 2000s is greater in the autumn survey. The discrepancy between the last two pairs of the spring (2021 and 2022)vs. the autumn biomass measurements (2020 and 2021) are the highest observed in the time-series. A greater decline is therefore observed in the autumn survey biomass index (Figure 9.17), although this difference between the two survey measurements has declined in most recent years of the survey.

Cod in the spring survey in 2024 was caught all around Iceland, with catch hot spots in offshore waters in the north and southwest, and in shallow waters in the south (Figure 9.19). The catch on continental slope to the west was similar to the previous year. Spatial distribution of the total biomass index of the catch in the spring survey, shows that the NW and NE areas are dominating in all years (Figure 9.18). However, some temporal changes have been occurring in recent years with the catch in the NE area decreasing and increasing in the W and SE area. In 2024 there was increase in almost all areas except for the northern areas.

Spatial distribution of cod in autumn survey in 2024 was similar as in previous years (Figure 9.18). The majority of cod in the autumn survey has been caught on the traditional fishing grounds in the northwest and northeast (Figure 9.18).

Length distributions from both surveys illustrate quite clearly age-groups division in the youngest age groups (Figure 9.20). Thereafter the division is not quite as clear, due to variability of individual growth and maturity, but some multimodal length distribution can be seen. The large year classes observable in the 2020 and 2021 length distributions are now beginning to enter the fishable stock.

Survey age-based indices of older fish are all relatively high in recent decade despite the pattern that several of the year classes showing high indices recently were showed low - moderate indices when younger (Figure 9.21). The 2020 spring survey anomaly are clearly apparent, e.g. for year classes 2014 and 2015 that are around the long-term average in 2019 (then ages 4 and 5) but roughly half of that in 2020 (then ages 5 and 6).

9.1.3.3 Stock weight at age

Mean weights in the spring survey for all ages of cod were below average during roughly 2000–2010. After this period, younger ages remained below average but older ages become mainly above average. The autumn survey shows a similar trend, but recent years have begun to show a switch toward lower weights at all ages (Figure 9.22).

9.1.3.4 Stock maturity-at-age

Maturity-at-age data are shown in Figure 9.23. Those data are obtained from the groundfish survey in March. Maturity by age has generally been below average at younger ages, indicating a shift toward older-maturing fish in recent decades.

9.1.4 Data analyses

9.1.4.1 Analytical assessment

A separable statistical catch-at-age model (sometimes referred to as MUPPET, described in Björnsson, Hjörleifsson, and Elvarsson (2019)) with four periods where the selection pattern is assumed to be constant. The last separable period is from 2007 to the present. The survey residuals are modelled as multivariate normal distribution to account for potential survey "year effects" - this being a feature in place since 2002. It is a statistical cohort model where fishing mortality can change gradually over time, constrained by a random walk. The same framework is used to carry the stock dynamics forward to evaluate reference points and HCR. This framework was benchmarked in 2021 through a harvest control rule evaluation (ICES (2021b)). The survey residuals are modelled as multivariate normal distribution to account for potential survey "year effects" - this being a feature in place since 2002.

The input to the analytical age-based assessment are catch-at-age 1955–2023 (age 3 to 14) and ages 1 to 14 (from the 1985–2024 spring (often referred to as SMB in this report) and ages 3 to 13 from the 1996–2023 autumn groundfish surveys (often referred to as SMH in this report). The method for deriving the catch-at-age is based on 20 métiers: two areas (north and south), two seasons (January–May and June–December) and five fleets (bottom-trawl, longline, hooks (jiggers), gillnet and Danish seine).The reference biomass (4+) upon which the TAC in the fishing year is set is the sumproduct of the population numbers at the beginning of the assessment year and catch weights in that year. The catch weights are not known and hence need to be predicted from stock weights measured in the spring survey, based on a relationship between catch and stock weights observed in the previous year. The mean weight age in the catch (Figure 9.15) declined from 2001 to 2007, reaching then a historical low in many age groups. The weights at age have been increasing in recent years and are at or above the average in the most important age groups. The variation in the pattern of weight at age in the catches is in part a reflection of the variation in the weight in the stock as seen in the measurements from the surveys (Figure 9.22).

9.1.4.2 Data used by the assessment

The assessment relies on four sources of data, that are described above. These are the two surveys, commercial samples and landings. The commercial data are used to compile catch-at-age data that enter the likelihood along with the survey at age from both surveys. Stock weights and catch weights at age are derived from the spring survey and catches respectively. The maturity data are similarly collected in the spring survey. Prior to 1985, when the spring survey started, stock weights and maturity-at-age were assumed constant at the 1985 values. A full description of the preparation of the data used for tuning and as input is given in the stock annex (see ICES (2021a)) and input data to the assessment are available on the MFRI website www.hafogvatn.is.

9.1.4.3 Diagnostics

The diagnostics (Figure 9.25) shows the large negative residuals in the spring survey 2020 for the most important age groups (ages 4 to 8), as well as smaller negative residuals for the surrounding years 2019 and 2021, especially for the autumn survey. The spring survey residuals are rather high for age groups 10 years and older in recent years, and especially high for age 8 in 2023 and 9 in 2024. A summarized diagnostic of the observedvs.predicted survey biomass (Figure 9.24) illustrates deviation between the model estimates and the point estimates. There are indications that interannual variability of survey measurements in both surveys has increased in recent years compared with that observed in the past. One of the ToR for this year was to evaluate the retrospective pattern of the assessment (Figure 9.28) and calculate the Mohn's rho values. The default 5-year peels resulted in the following values: 0.033 for recruitment, 0 for harvest rate, and for spawning-stock biomass. Leave-one-out analyses indicate that the assessment follows trends in the spring survey analysis the closest. Removal of the autumn survey series causes a slight increase in biomass estimates, removal of the spring survey series causes a more substantial decrease, as does following only the catch data (Figure 9.27).

9.1.4.4 Model results

The results of this year's assessment show that the spawning stock in this assessment year is estimated to be 377 kt. Weight and maturity-at-age used in the calculation of SSB are presented in Table 9.5. The values estimated in recent years are higher than have been observed during the last five decades. The reference biomass is estimated to be 1075 kt in 2024 and the harvest rate 0.182 in 2023. Year classes since the mid-1980s are estimated to be relatively stable but with the mean around 35% lower than observed in the period 1955 to 1985.

Results of the assessment are provided in the stock summary in Table 9.5 and Figure 9.26, as well as on the MFRI website www.hafogvatn.is. The reference biomass has been steady in recent years. The first estimates of the 2021 and 2022 year classes indicate that they are somewhat low, but they will not begin to enter the reference biomass until 2025.

Estimated spawning-stock biomass (SSB) has increased in recent years, although fluctuating, and it's peak in 2017 was larger than in almost 60 years. Harvest rate has declined and is at its lowest value in the assessment period. Recruitment since 1988 has been substantially lower than the average recruitment in the period 1955–1985. The increase in SSB is therefore primarily the result of lower harvest rate. It is estimated that the current fishable biomass is composed of several poor years of recruitment (e.g. 2013 and 2016), but also several good recruitment years (e.g. 2015 and 2019), indicating that variability of biomass levels can be expected to continue.

9.1.4.5 Short-term projections

Landings of Icelandic cod in 2023 are estimated to have been 217157 tonnes, the bulk taken by the Icelandic fleet. To perform short-term projections, estimates of catch for the current calendar year are needed. The projection this year assumes that the remainder of the TAC for the fishing year that ends on August 30. is caught along with the expected catch of the foreign fleet (3 kt). The projected stock status for the interim year and the output from the projection in Table 9.5.

Mean annual discard of cod over the period 2001–2012 was around 1% of landings in weight, but more recent data indicate that discarding may have increased slightly (MRI 2016). The method used for deriving these estimates assumes that discarding only occurs as high grading.

Following the management plan the advice for the coming fishing year (2024/2025) is based in the biomass of fish aged 4+ at the beginning of the calendar year (2024). Reference biomass is calculated using catch weights, so a deterministic projection of the growth of the catch in weight is needed. In recent years, the estimates of mean weights in the catch of age groups 3–9 in the assessment years have been based on a prediction from the spring survey weight measurements in that year using the slope and the intercept from a linear relationship between survey and catch weights in preceding year (for ages 10 and older the weights from the previous year are used).

Based on this, the mean weights at age in the catches in 2023 are predicted to be close to the long-term average for most age groups (Figure 9.15 and Table 9.5), although the weights in the spring survey in those age groups are below or at the long-term mean (Figure 9.22 and Table 9.6).

An alternative model based using all data from 1990 onwards to estimate and within each age group 3 to 9 (labelled 'alt') was explored in which the catch weight in the assessment year would be predicted using "each age" and the observed stock weights in the assessment year. This alternative model has in the past given much more plausible estimates of catch weights in last year's assessment (2023), although this year, the reference biomass in the terminal year was very similar (spaly = 1060550). A retrospective analysis indicated that the overall predictive power of the alternative reference biomass was better (cv of 0.035vs.0.050, bias -0.0020vs.-0.0049) using the alternative model Figure 9.29, Figure 9.30). The alternative model was discussed within the NWWG 2022 that the alternative model could be an improvement over the current spaly weight prediction model. However, it was decided that before implementation, it would be beneficial for the method to be externally reviewed either as a working document appended to next year's report, or through next benchmark, that for this stock will most likely occur in 2026 or 2027.

9.1.5 Management

9.1.5.1 History

The Ministry of Industries and Innovation is responsible for management of the Icelandic fisheries and implementation of legislation. Cod was included in the ITQ system in 1984, but effort management was also implemented during the first years of the TAC system, partly to help those that thought they got unfair share of the quota. This "additional effort" management system led to the catches exceeding TAC by 20–30% in the first years of the ITQ system. In 1990 the law was changed, and effort management eliminated except for the smallest coastal fleet that was managed by fishing days. At the same time, many limitations of the quota transfer were released and the fishing year from 1 September to 31 August was introduced. These laws took effect on 1 September 1991. In the first years, advice by MRI (Marine Research Institute) was based on reducing F (Fishing mortality) by 40%. TAC exceeded advice during those years and catch exceeded TAC. The cod stock reduced rapidly in the early nineties due to low recruitment and high fishing mortality. The need for more strict control of fisheries was apparent and 2–3 years of work by a group of fisheries scientist lead to an adoption of HCR (Harvest Control Rule) for the fishing year 1995/96. The HCR led to significant reduction in fishing mortality. Since the HCR was introduced, TAC has been set according to the HCR, but catch has exceeded TAC by 7.4% on the average, however somewhat less or close to 5% in recent years. The main explanation for catch exceeding advice is that catch in the effort control system exceeded predictions, but the predicted catch is subtracted from the calculated TAC according to the HCR. The current effort control system for the small boats that started in 2009, includes TAC constraint so catches should not exceed TAC by large amount (1–2%).

9.1.5.2 Harvest control rule

The primary essence of the rule is that the TAC for the next fishing year (starting 1. September in the assessment year and ending 31. August next year) is based on a multiplier on the reference biomass of four years and older in the assessment year (B4+). The rule has gone through some amendments and revisions over time. The last significant change occurred in 2007, when the harvest rate multiplier upon which the TAC for the next fishing season is based was changed from 0.25 to 0.20. The current rule has in addition a catch stabilizer. When the SSB in the assessment year is estimated to be above (265 kt) the decision rule is:

The TAC for the current fishing year (2022/2023) based on last year's assessment was 2.11309^{5}.

Following the benchmark 2021 the reference biomass upon which the advice is based was approximately 20% lower in recent years than based on setting prior to the benchmark. This in part is reflected in somewhat higher recent harvest rate than intended although it is still within the range expected in the HCR simulation. During the benchmark, reference points and the definition of how harvest rate is presented were also updated.

Figure 9.31 shows the net transfers of cod quota in the Icelandic ITQ system. Quota transfers from other species to cod are not allowed, and net transfers from cod to other species have been relatively low in recent fishing years (Figure 9.31, upper). Net transfers of unused cod quota from one fishing year to the next have usually been in the range of 0–7%.

9.1.5.3 Reference points

Prior to the 2021 benchmark the ICES reference points that matter for the advice (ICES 2021b) were set the same as in the HCR. Other fishing pressure reference points were set based on the conventional F. In the 2021 benchmark there was a requirement that reference points should be set in accordance with the guidelines and that fishing pressure should be set in the same units as used in the HCR. Since this stock has been fished for quite a while at a rate that is close to that resulting in MSY, the B_{pa} reference point was based on the 5% percentile of SSB with the stabilizer in the HCR being ignored. The resulting value was 265 kt. This may not be the most optimum approach because the influence of incoming age 4 weigh quite high in the reference biomass, something that is actually ameliorated in the HCR that uses a buffer. If advice is based on no buffer it may be better to base the reference biomass not on catch weights but stock weights, because then the influence of age four would be reduced.

9.1.5.4 On the measure of fishing pressure

Given the push to define fishing pressure in the same units as used in the HCR one may need to consider how one should derive the harvest rate. For the Icelandic cod this is more cumbersome than normally because the advice is not for a calendar year but fishing year. It was decided to use the following metric in the summary (Table 9.5) as well as the table in the advice sheet:

$$HR_y = \frac{1/3 * Catch_y + 2/3 * Catch_{y+1}}{B_{4+,y}}$$

where calendar year. This measure of fishing pressure is by no means the best one but reflects best the "intended" harvest rate as stipulated in the HCR. The fractions represent the proportion of the catch of the fishing year taken in the different.

9.1.6 Management considerations

All the signs from commercial catch data and surveys indicate that cod in 5.a is at present in a good state. This is confirmed in the assessment and the recent harvest control rule evaluation (ICES 2021b). The stock is in a high state; however, highly variable recruitment patterns in the past decade indicate that the stock size is expected to fluctuate in the future. As the harvest control rule has a built-in cap, these fluctuations will be dampened in advice.

9.1.7 References

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9.2 Figures and tables

Table 9.1. Cod in division 5a. Number of Icelandic vessels landing cod, and all landed catch divided by gear type.

Year	Nr. Danish Seine	Nr. Other	Nr. Long Line	Nr. Bottom Trawl	Danish Seine	Other	Long Line	Bottom Trawl	Total catch
2000	133	827	530	183	14930	17623	49946	103558	186057
2001	106	766	515	160	17015	17002	47172	99071	180260
2002	101	724	450	155	13584	19305	42405	87885	163179
2003	107	721	461	147	13375	16026	44654	88422	162477
2004	103	722	470	135	14228	14840	57397	95769	182234
2005	98	604	463	134	12770	8106	69444	84018	174338
2006	93	509	447	126	10358	5859	71037	82417	169671
2007	97	473	425	123	8711	4397	58943	71499	143550
2008	92	427	370	113	8441	4151	53843	58172	124607
2009	81	798	336	113	10370	8190	61005	79667	159232
2010	75	1008	286	111	8296	9372	57491	75609	150768
2011	65	1061	290	110	9106	12665	57711	73538	153020
2012	74	1099	305	118	9989	13417	67777	85265	176448
2013	71	1054	297	110	10092	15237	74835	101453	201617
2014	65	1012	292	110	10407	16355	77807	95830	200399
2015	67	943	266	103	11938	13957	79244	103530	208669
2016	60	956	246	99	15930	15299	84509	111016	226754
2017	67	832	221	94	15398	14945	75244	117891	223478
2018	63	813	201	83	15818	16221	78316	135030	245385
2019	44	794	190	81	14181	13592	78326	135661	241760
2020	43	839	158	81	16198	15884	68103	146788	246973
2021	53	841	145	87	17695	16014	69460	140773	243942
2022	60	850	120	83	16496	15172	62613	124950	219231
2023	61	867	99	81	15958	13286	54213	117211	200668

Table 9.2. Cod in division 5a. Number of samples and length measurements from landed catch.

Year	Bottom trawls Num. samples	Bottom trawls Num. lengths	Demersal seines Num. samples	Demersal seines Num. lengths	Gillnets Num. samples	Gillnets Num. lengths	Longlines Num. samples	Longlines Num. lengths
2000	766	172132	23	3265	27	4517	124	29780
2001	1131	170398	79	13660	541	39836	281	39915
2002	1233	162365	328	19270	1032	46109	367	46589
2003	1131	114366	428	13648	1214	33432	444	67124
2004	1239	107977	433	18281	780	28705	746	86231
2005	1092	101166	844	18605	916	38072	873	108923
2006	859	79264	680	16333	976	34720	923	115548
2007	946	75259	1013	16850	833	23972	596	96760
2008	849	67630	654	14430	875	23796	562	105976
2009	884	76100	988	16078	763	24751	741	87231
2010	806	77979	757	11241	849	26467	986	81958
2011	596	64643	921	7443	652	29408	765	56099
2012	604	54037	748	8928	646	22778	1124	98415
2013	661	73855	694	2840	765	4272	630	83238
2014	531	46615	262	5340	453	27415	691	96774
2015	554	65641	1018	6858	767	6565	1037	84003
2016	493	57116	1031	7182	797	26568	1060	97164
2017	518	67512	1270	8287	311	7413	368	77691
2018	264	48111	1368	6545	1004	16636	395	74874
2019	451	81165	330	4970	43	5754	292	56710
2020	191	35494	581	3915	226	12606	84	13242
2021	325	53645	900	6468	11	1133	38	4333
2022	228	38180	510	5804	546	1893	52	11348
2023	150	23230	70	3882	162	9741	34	4187

Table 9.3. Cod in division 5a. Number of samples and length measurements from landed catch.

Year	Bottom trawls Num. samples	Bottom trawls Num. otoliths	Demersal seines Num. samples	Demersal seines Num. otoliths	Gillnets Num. samples	Gillnets Num. otoliths	Longlines Num. samples	Longlines Num. otoliths
2000	766	10034	23	885	27	1051	124	2223
2001	1131	9200	79	500	541	2241	281	2830
2002	1233	8619	328	905	1032	2644	367	2846
2003	1131	8146	428	814	1214	1906	444	3409
2004	1239	9053	433	736	780	1375	746	2483
2005	1092	6503	844	1343	916	1258	873	3874
2006	859	5720	680	1452	976	2107	923	3656
2007	946	6094	1013	1842	833	1745	596	3748
2008	849	5024	654	1181	875	1539	562	2883
2009	884	5418	988	1333	763	1720	741	1972
2010	806	5880	757	1121	849	1505	986	3516
2011	596	5403	921	1417	652	1197	765	2779
2012	604	5757	748	1334	646	1557	1124	3895
2013	661	6194	694	1041	765	1790	630	3302
2014	531	5104	262	747	453	1162	691	2096
2015	554	4937	1018	1686	767	1632	1037	2128
2016	493	5015	1031	2006	797	1674	1060	2183
2017	518	3818	1270	2189	311	908	368	1119
2018	264	2369	1368	2073	1004	1290	395	945
2019	451	2828	330	966	43	300	292	1237
2020	191	1847	581	1397	226	437	84	775
2021	325	2171	900	2304	11	200	38	750
2022	228	1264	510	788	546	972	52	362
2023	150	1511	70	588	162	200	34	440

Table 9.4. Cod in division 5a. Cod in 5.a. Summary of the assessment and results of the short-term projections when the harvest control rule is applied. In 2024, the assessment includes estimates for SSB, B4+, and recruitment, whereas values for catch and harvest rate are based on intermediate year assumptions. Projections begin with 2025. Fishing year catches are only given for 2024 on.

Year	Calendar Year Catch	Fishing Year Catch	SSB	B4+	HR	Recruit. (age 3)
1955	539486		726863	2091220	0.242	151032.0
1956	461780		588192	1818970	0.256	143774.0
1957	454375		575094	1640420	0.303	161483.0
1958	508429		690445	1650990	0.290	215103.0
1959	436801		639696	1580900	0.295	303945.0
1960	474805		583802	1657780	0.246	153744.0
1961	387897		465511	1430570	0.269	195934.0
1962	393690		505861	1464380	0.275	125273.0
1963	408335		460580	1298970	0.329	173269.0
1964	417289		420221	1211060	0.333	197608.0
1965	376136		323049	1053000	0.346	219590.0
1966	346153		295853	1063480	0.321	233032.0
1967	343542		280743	1139740	0.321	320099.0
1968	399163		248564	1242600	0.319	171262.0
1969	388876		354360	1335840	0.338	239766.0
1970	459027		354965	1332990	0.341	179674.0
1971	436786		253213	1083980	0.380	193088.0
1972	393200		225793	979053	0.386	142012.0
1973	361881		245417	831019	0.443	278016.0
1974	362136		188988	909809	0.402	187117.0
1975	361758		175181	891382	0.395	259291.0
1976	331284		146066	948599	0.361	369462.0
1977	337924		199274	1298580	0.257	144156.0
1978	329859		212640	1308980	0.271	223896.0
1979	357435		308024	1409790	0.291	237555.0
1980	423297		370325	1510730	0.301	141783.0
1981	451034		275957	1254480	0.326	145073.0

Year	Calendar Year Catch	Fishing Year Catch	SSB	B4+	HR	Recruit. (age 3)
1982	386498		183093	987452	0.330	141066.0
1983	293409		144153	802754	0.358	227535.0
1984	282869		154353	913772	0.339	143502.0
1985	325493		169405	940339	0.373	140282.0
1986	366011		194963	866433	0.440	299764.0
1987	380240		145613	989352	0.386	250845.0
1988	372356		159668	978580	0.376	176924.0
1989	329697		161505	949862	0.363	97221.6
1990	320762		197665	816583	0.388	130695.0
1991	305691		156893	699315	0.399	113579.0
1992	267035		143236	566540	0.451	160730.0
1993	244266		114758	587416	0.344	129525.0
1994	171845		151164	568857	0.302	80894.8
1995	158645		172776	565297	0.313	142708.0
1996	178234		156771	679849	0.288	166140.0
1997	205340		191306	797531	0.289	92231.2
1998	250490		201671	739073	0.345	156564.0
1999	262623		178197	729258	0.334	76123.1
2000	230756		163610	590621	0.400	167692.0
2001	213547		159972	663695	0.329	155559.0
2002	195343		192648	713703	0.291	158211.0
2003	203923		189334	742223	0.298	180887.0
2004	232687		196477	811977	0.269	85207.6
2005	225649		226044	728900	0.278	154920.0
2006	199202		217507	691882	0.260	132604.0
2007	179458		202042	668181	0.233	95370.5
2008	151217		253816	672217	0.255	131337.0
2009	178911		234039	745824	0.234	117274.0
2010	168064		263775	794567	0.216	125821.0

Year	Calendar Year Catch	Fishing Year Catch	SSB	B4+	HR	Recruit. (age 3)
2011	171098		322624	840655	0.224	165795.0
2012	195313		358291	961248	0.223	176293.0
2013	228333		380761	1084670	0.205	125603.0
2014	219466		348359	1091120	0.208	174820.0
2015	228543		455212	1173130	0.208	148771.0
2016	247259		397722	1227700	0.201	99953.9
2017	247293		525256	1155880	0.224	156956.0
2018	270171		517051	1203980	0.220	167527.0
2019	270377		463460	1152390	0.232	116943.0
2020	266545		415044	1045480	0.256	146136.0
2021	255143		404690	1102950	0.227	130425.0
2022	224560		412477	1090690	0.207	169403.0
2023	206944		392593	1136840	0.182	139550.0
2024	200600	211983	377477	1075600	0.194	112024
2025	212239	212939	404273	1069480	0.199	125549
2026	212737	212524	419259	1060550	0.201	142138
2027	212871	213754	428230	1074920	0.199	132529

Table 9.5. Cod in division 5a. Comparison of the realized catches and the set TAC for the fishing operations in Icelandic Waters.

Year	ICES advice	Catch corresponding to advice	TAC	ICES catch for the fishing year	ICES catch for the calendar year
1988*	National advice	300 000	350 000		377 554
1989*	National advice	300 000	325 000		363 125
1990*	National advice	250 000	300 000		335 316
1991*	National advice	240 000	245 000		307 759
1991/1992	National advice	250 000	265 000	274 000	264 834
1992/1993	Reduce F by 40%	154 000	205 000	241 000	250 704
1993/1994	Reduce F by 40%	150 000	165 000	197 000	178 138
1994/1995	Reduce F by 50%	130 000	155 000	165 000	168 592

Year	ICES advice	Catch corresponding to advice	TAC	ICES catch for the fishing year	ICES catch for the calendar year
1995/1996	Apply catch rule	155 000	155 000	170 000	180 701
1996/1997	Apply catch rule	186 000	186 000	202 000	203 112
1997/1998	Apply catch rule	218 000	218 000	227 000	243 987
1998/1999	Apply catch rule	250 000	250 000	254 000	260 147
1999/2000	Apply catch rule	247 000	250 000	257 000	235 092
2000/2001	Apply catch rule	203 000	220 000**	221 000	236 702
2001/2002	Apply catch rule	164 000	190 000**	219 000	209 544
2002/2003	Apply catch rule	183 000	179 000**	202 000	207 246
2003/2004	Apply catch rule	210 000	209 000	227 000	228 342
2004/2005	Apply catch rule	205 000	205 000	217 000	213 867
2005/2006	Apply catch rule	198 000	198 000	207 000	197 202
2006/2007	Apply catch rule	187 000	193 000	191 000	171 646
2007/2008	Apply catch rule	152 000	130 000	143 000	147 676
2008/2009	Apply Fmax	< 124 000	160 000^	171 000	183 320
2009/2010	Apply Fmax	< 135 000	150 000^^	170 000	170 025
2010/2011	Apply catch rule	160 000	160 000	167 000	172 218
2011/2012	Apply catch rule	177 000	177 000	185 000	196 171
2012/2013	Apply catch rule	196 000	196 000	213 000	223 582
2013/2014	Apply catch rule	215 000	215 000	226 000	222 021
2014/2015	Apply catch rule	218 000	218 000	223 000	230 165
2015/2016	Apply catch rule	239 000	239 000	251 000	251 219
2016/2017	Management plan	244 000	244 000	237 644	243 945
2017/2018	Management plan	257 572	257 572	270 217	267 221
2018/2019	Management plan	264 437	264 437	265 385	263 025
2019/2020	Management plan	≤ 272 411	272 411	272 385	270 302
2020/2021	No advice requested***	-	256 593	272 137	265 740
2021/2022	Management plan	≤ 222 373	222 373	239 925	242 192
2022/2023	Management plan	≤ 208 846	208 846	219 803	218 181

Year	ICES advice	Catch corresponding to advice	TAC	ICES catch for the fishing year	ICES catch for the calendar year
2023/2024	Management plan	≤ 211 309	211 309	---	---
2024/2025	Management plan	≤ 213 214	---	---	---

*** Calendar year.**

**** Amended catch rule.**

***** Advice for 2020/2021 was issued by the Icelandic Marine and Freshwater Research Institute (MFRI; 256 593 tonnes).**

^ Initial TAC set to 130 000 tonnes according to the catch rule, raised to 160 000 tonnes in January 2009.

^^ Set according to the catch rule.

 # The values refer to the catches in the second year within the specified fishing year.

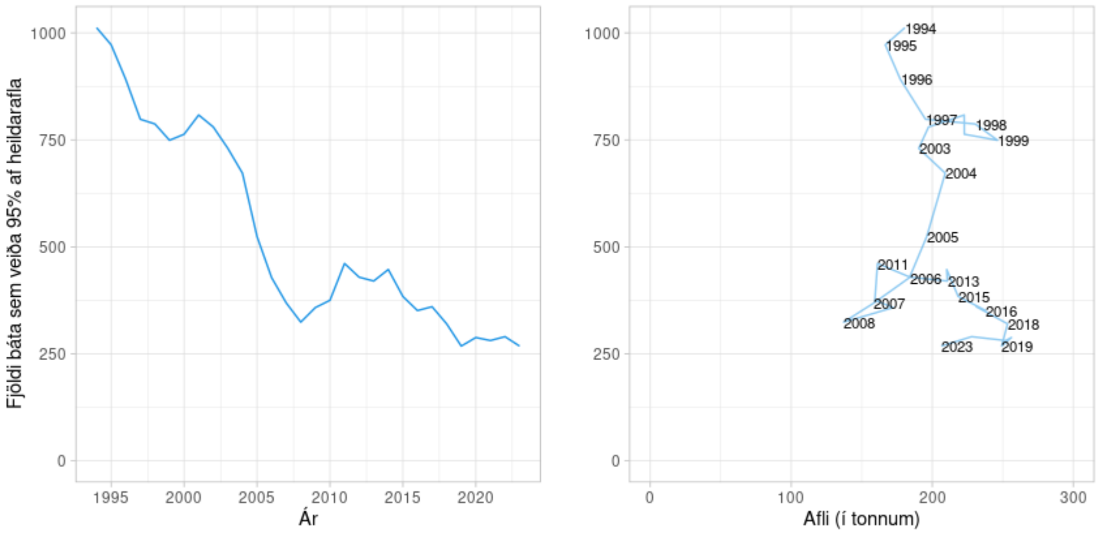

Figure 9.1. Cod in division 5a. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

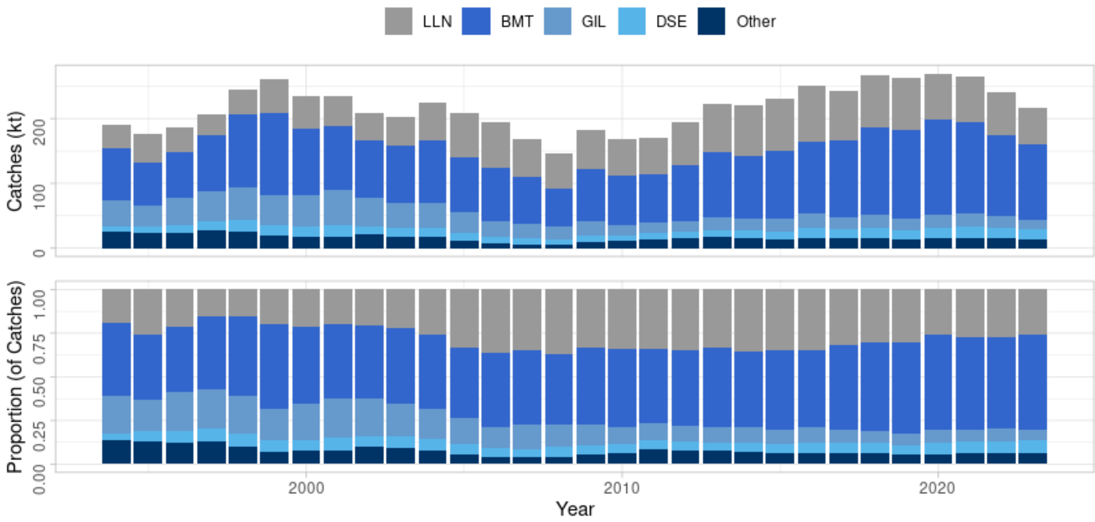

Figure 9.2. Cod in division 5a. Landings in tons and percent of total by gear and year

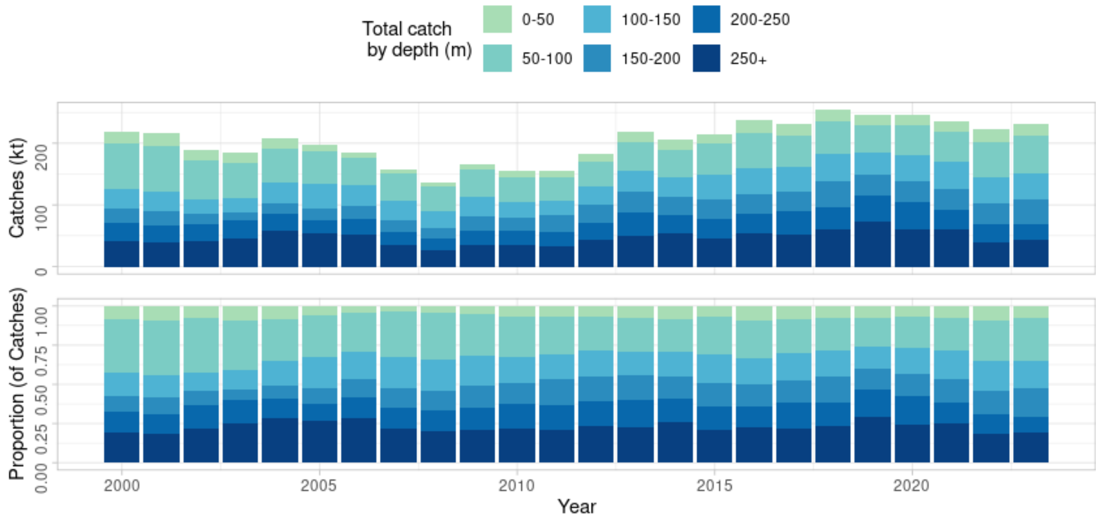

Figure 9.3. Cod in division 5a. Depth distribution of cod catches from bottom trawls, longlines, trawls and demersal seine from Icelandic logbooks

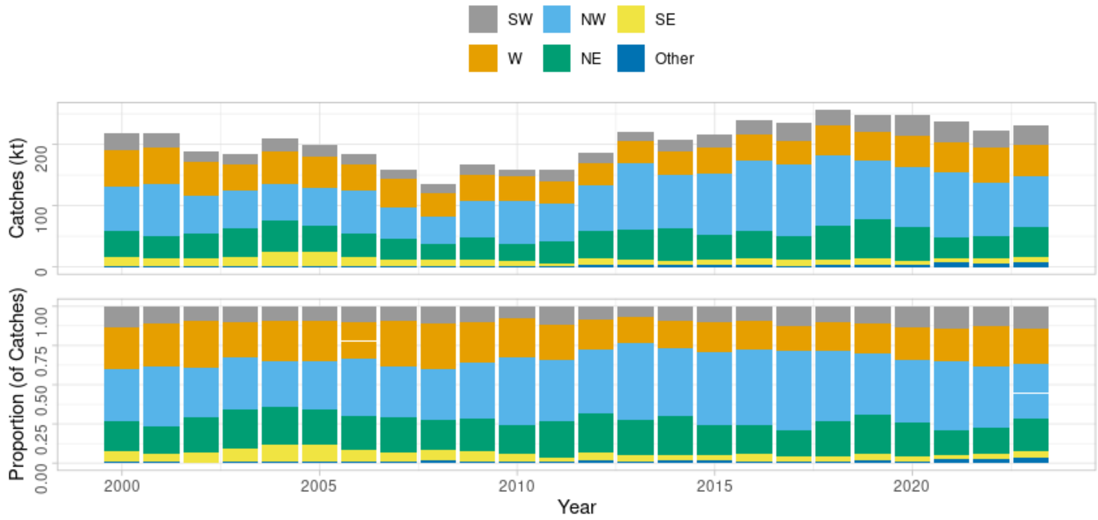

Figure 9.4. Cod in division 5a. Changes in spatial distribution of cod catches as recorded in Icelandic logbooks.

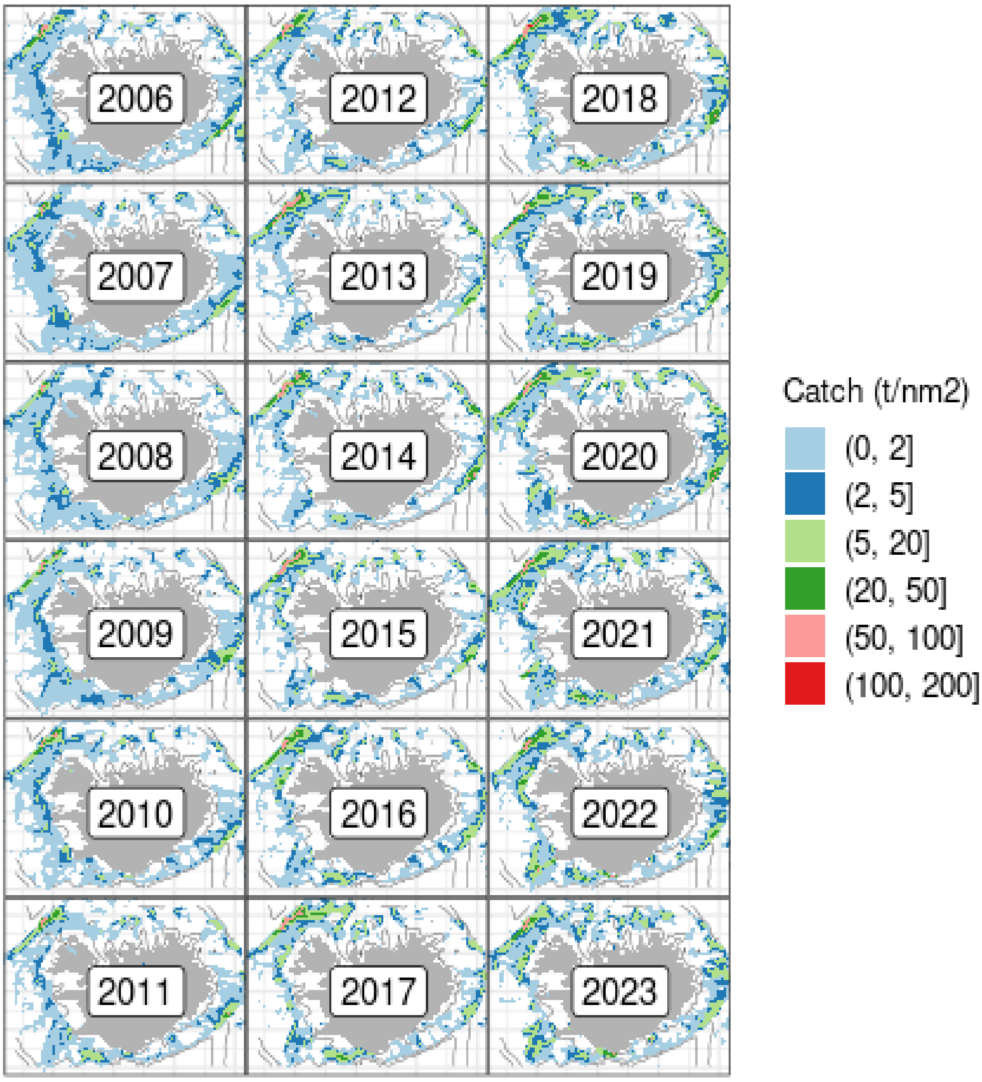

Figure 9.5. Cod in division 5a. Spatial distribution of catches by demersal trawls for selected years.

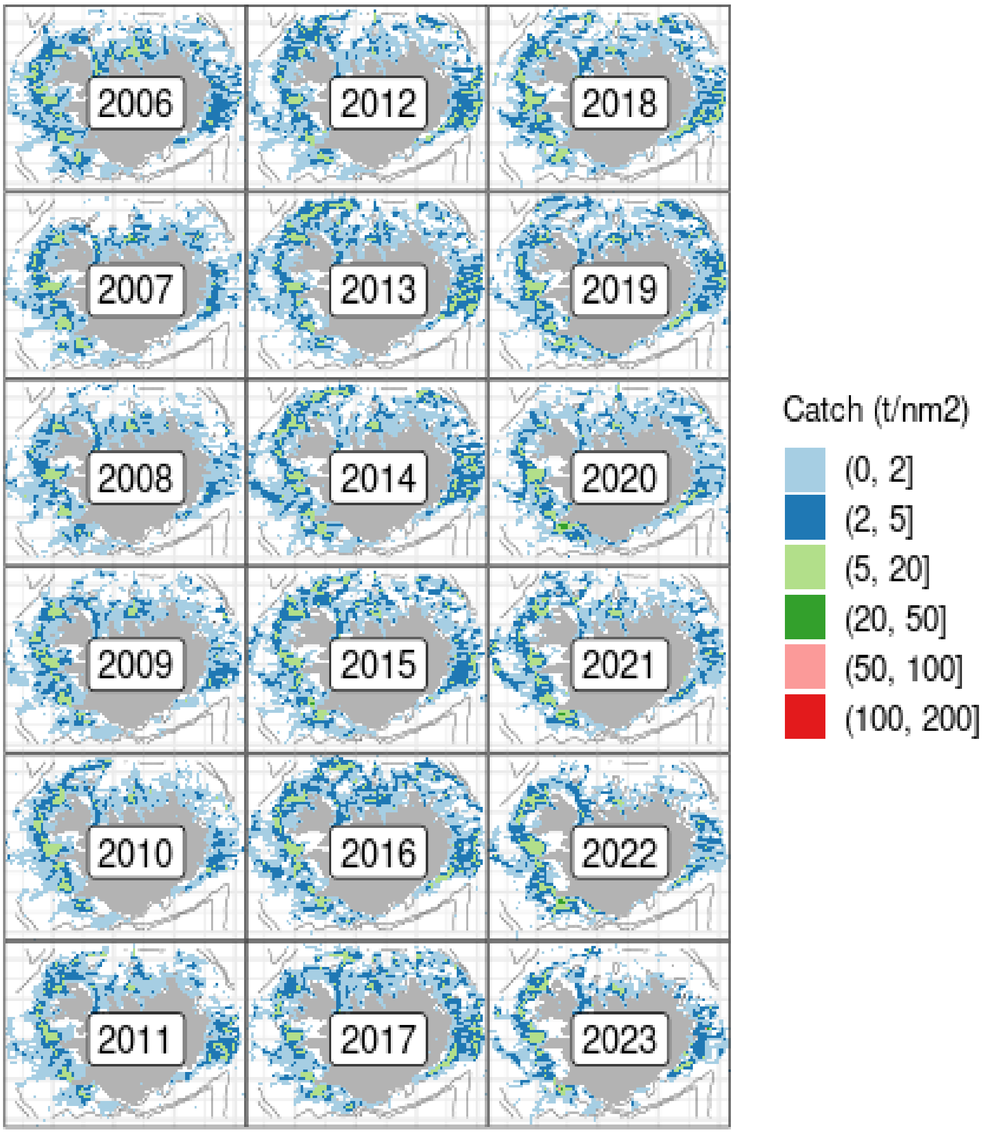

Figure 9.6. Cod in division 5a. Spatial distribution of catches by longlines for selected years.

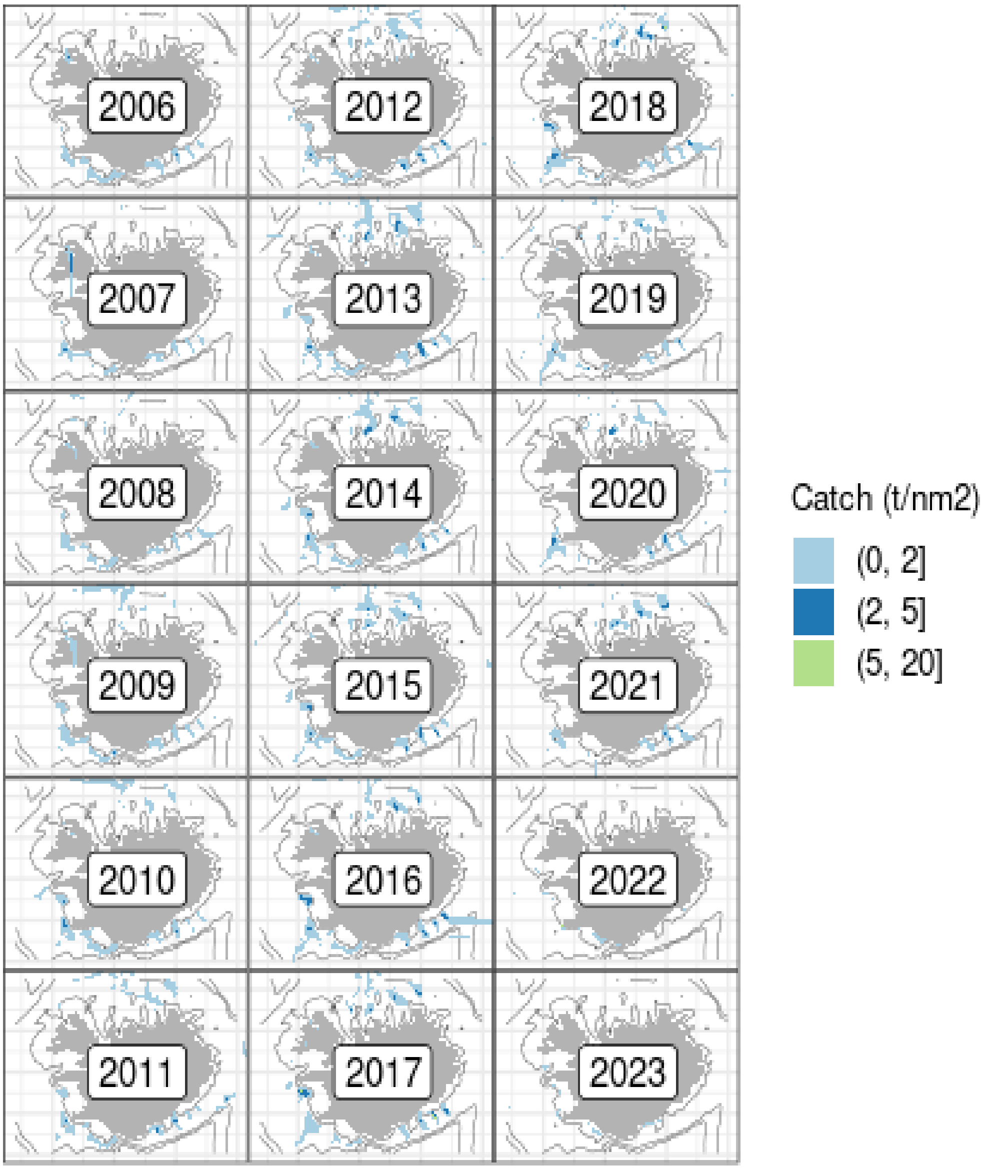

Figure 9.7. Cod in division 5a. Spatial distribution of catches by gillnets, demersal seine, and jiggers for selected years.

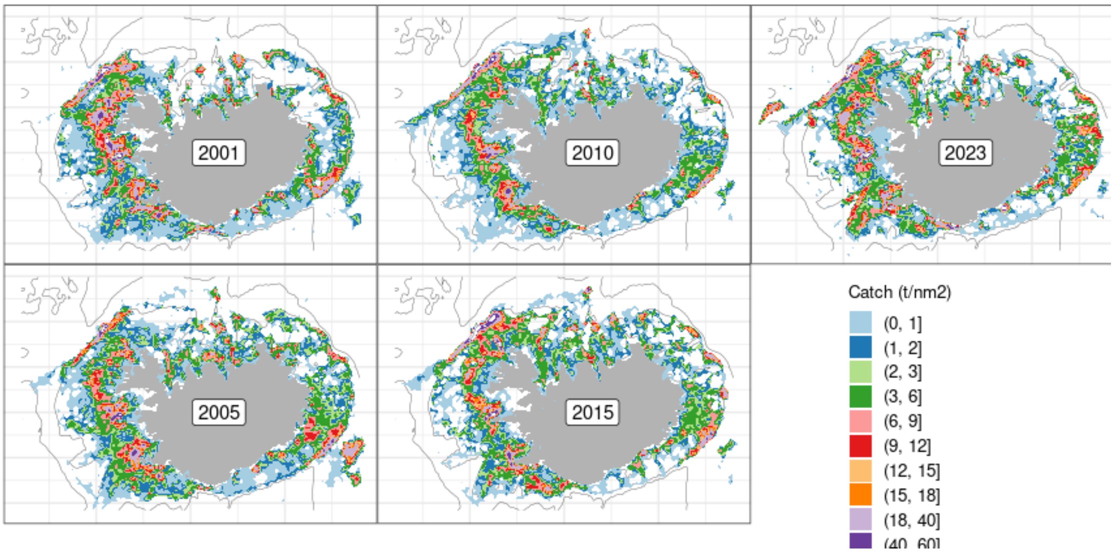

Figure 9.8. Cod in division 5a. Spatial distribution of catches by all gears for selected years.

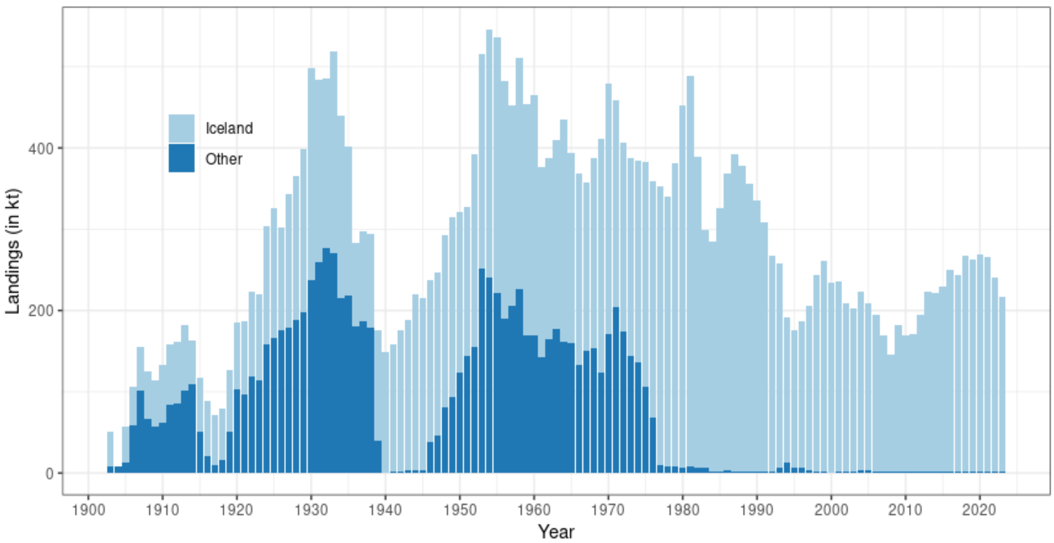

Figure 9.9. Cod in division 5a. Recorded landings since 1905.

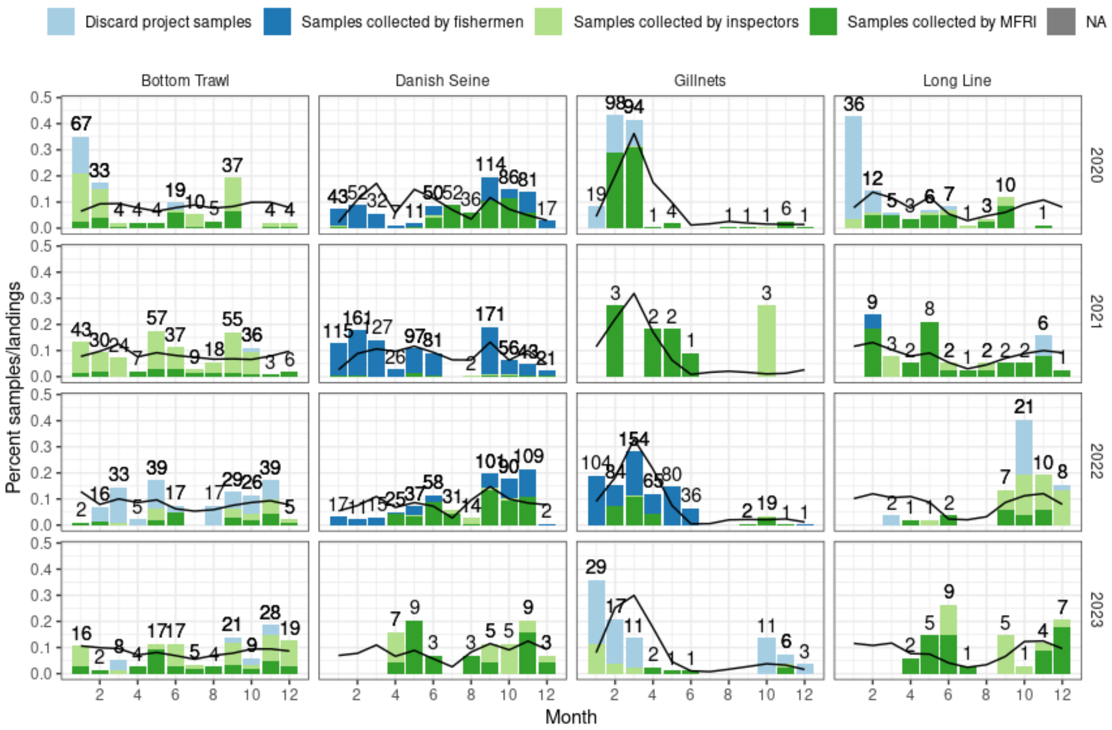

Figure 9.10. Cod in division 5a. Ratio of samples by month (bars) compared with proportion landings by month (solid black line) split by year and main gear types. Numbers of above the bars indicate number of samples by year, month and gear.

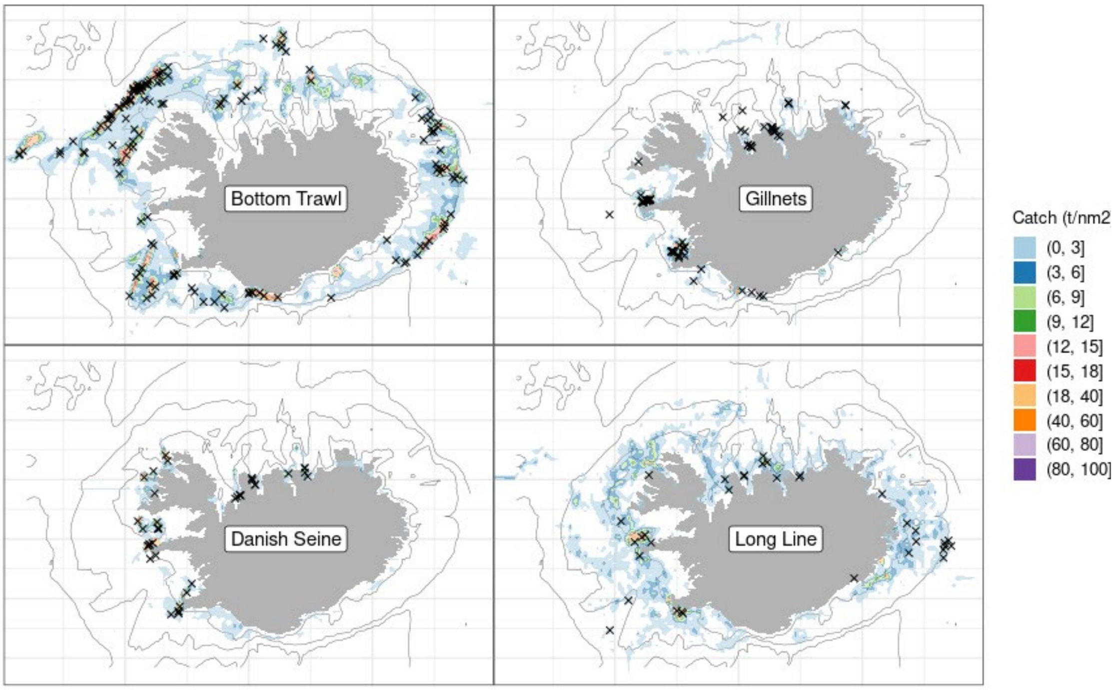

Figure 9.11. Cod in division 5a. Fishing grounds last year as reported in logbooks (contours) and positions of samples taken from landings (crosses) by main gear types.

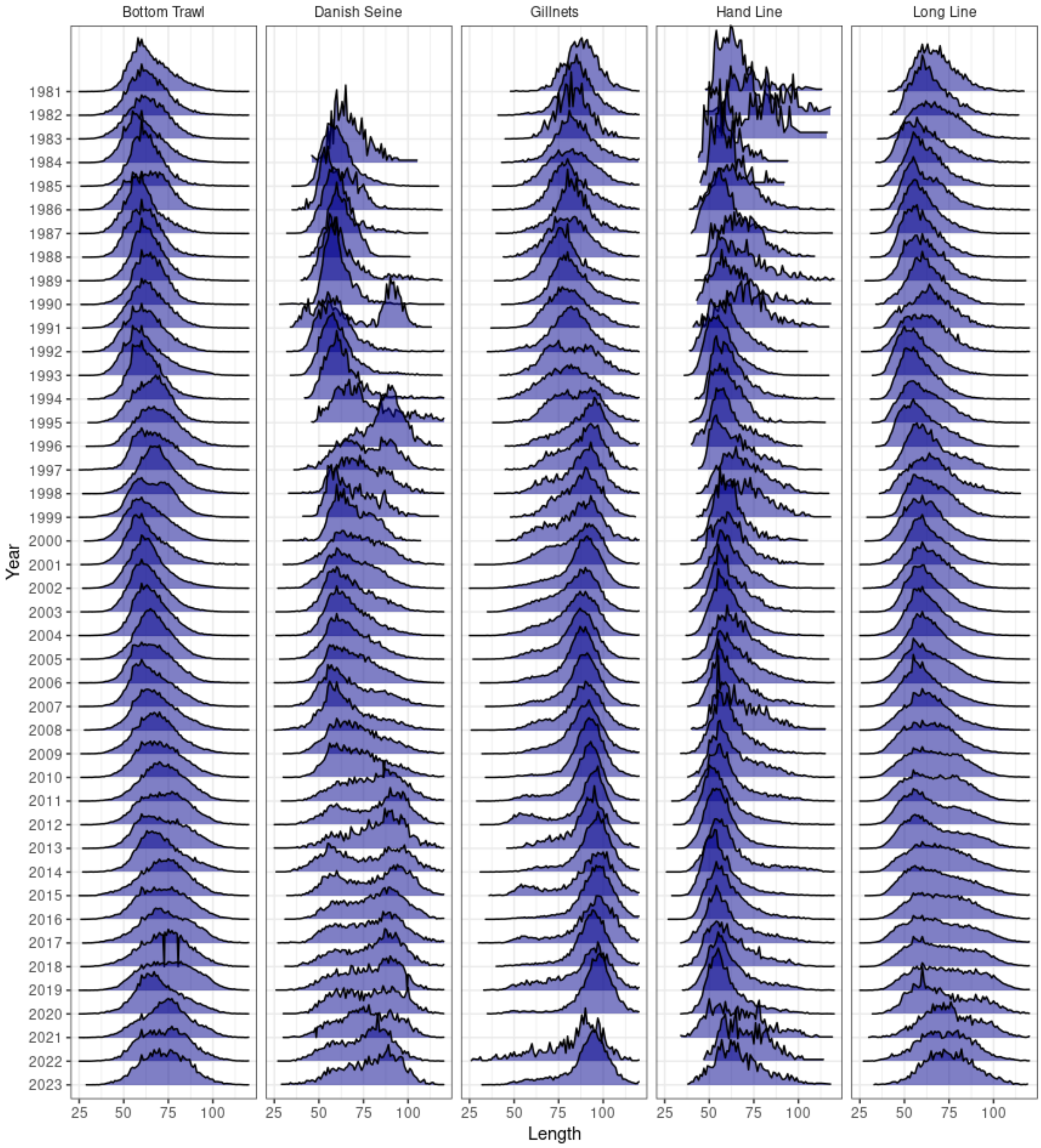

Figure 9.12. Cod in division 5a. Commercial length distributions by gear and year

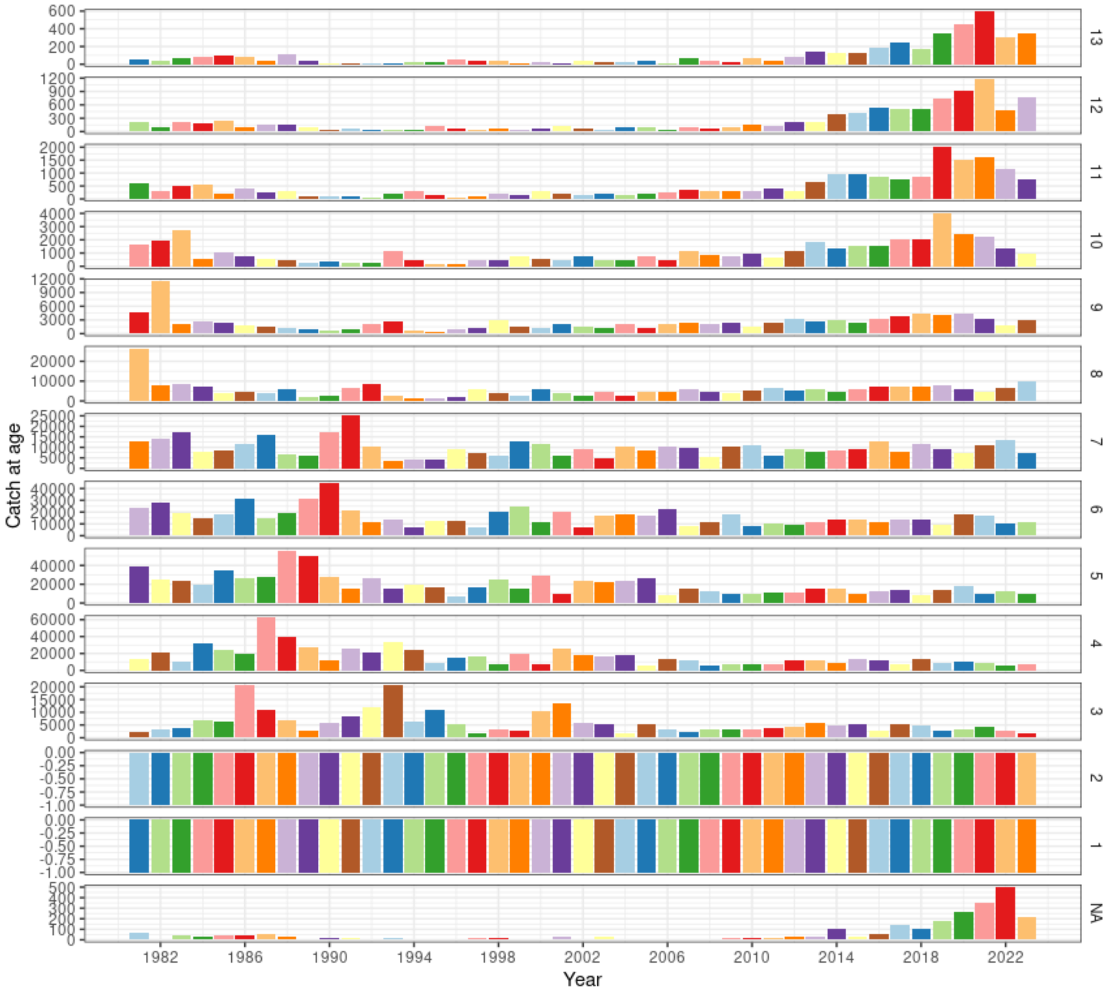

Figure 9.13. Cod in division 5a. Catch-at-age from the commercial fishery in Iceland waters. Bar size is indicative of the catch in numbers and bars are colored by cohort

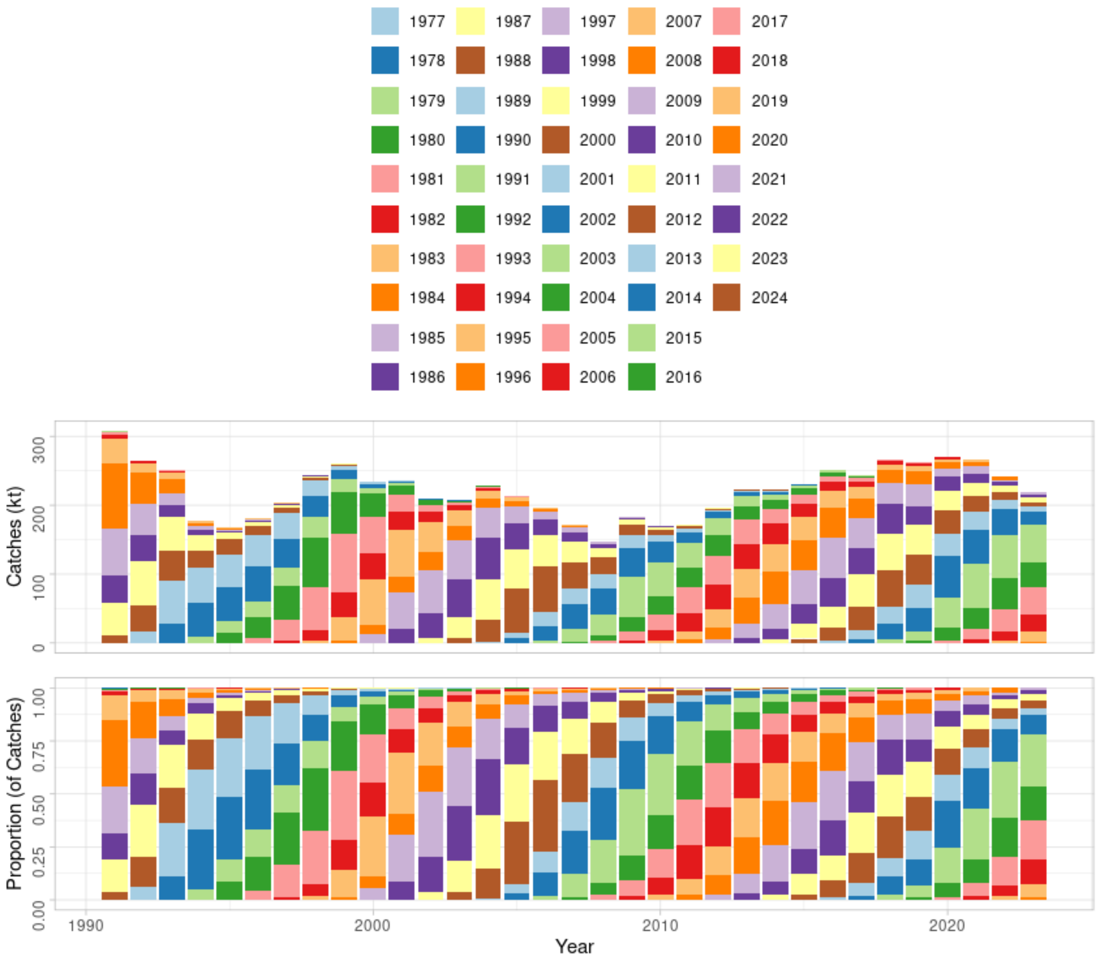

Figure 9.14. Cod in division 5a. Catch-at-age from the commercial fishery in Iceland waters. Biomass caught by year and age, bars are colored by cohort.

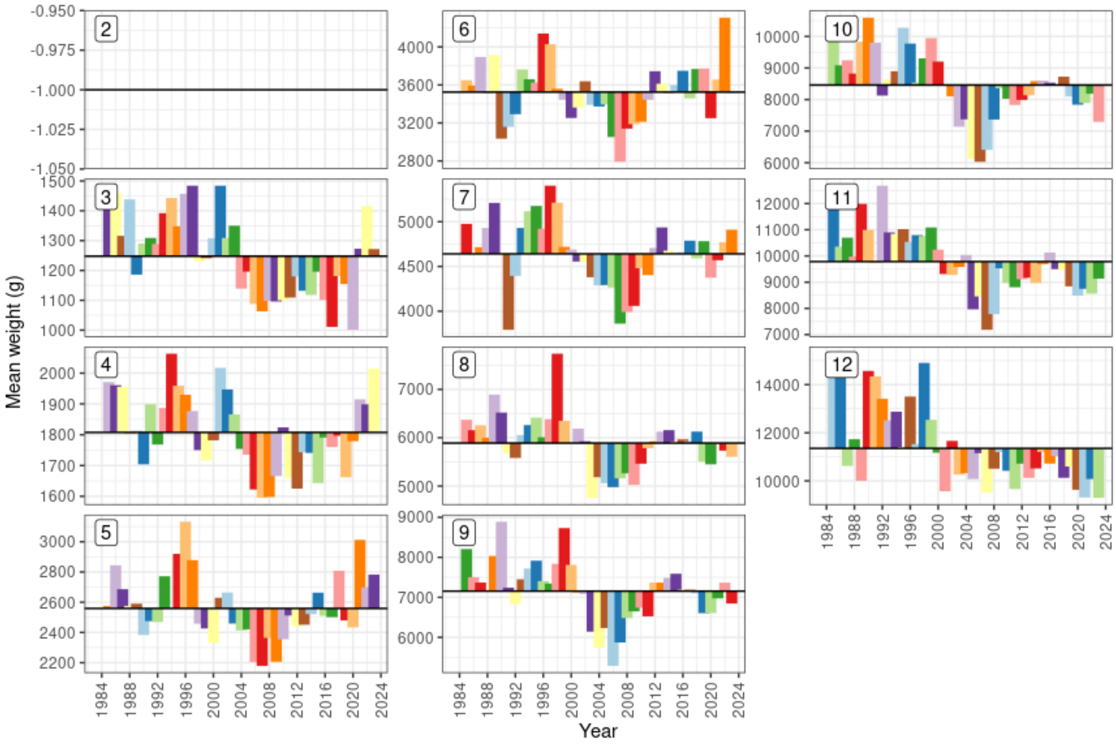

Figure 9.15. Cod in division 5a. Mean weight at age in the catch from the commercial fishery in Icelandic Waters. Bars are coloured by cohort.

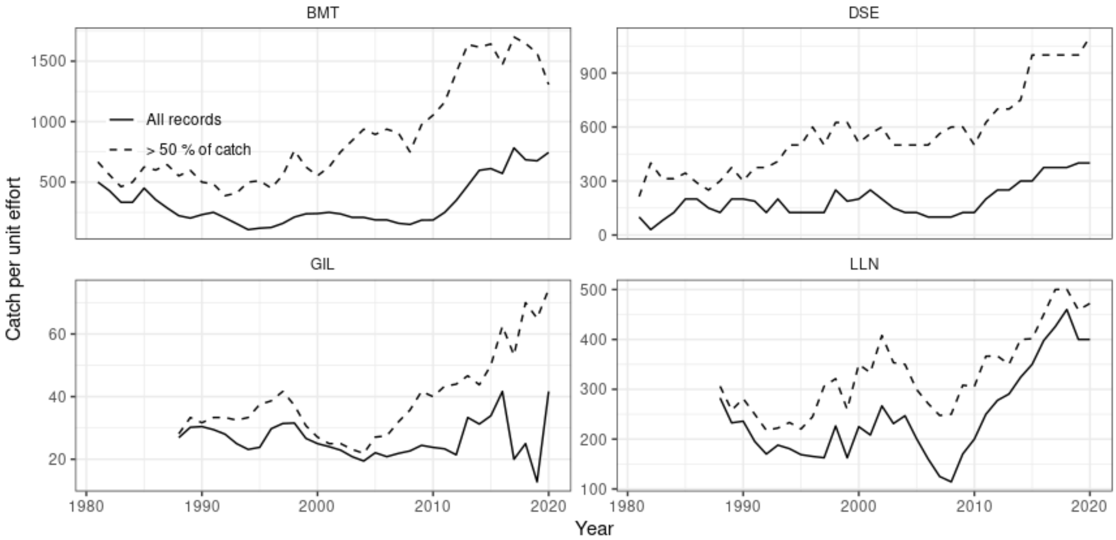

Figure 9.16. Cod in division 5a. Catch per unit effort in the most important gear types. The dashed lines are based on locations where more than 50% of the catch is cod and solid lines on all records where cod is caught. A change occurred in the longline fleet starting September 1999. Earlier only vessels larger than 10 BRT were required to return logbooks but later all vessels were required to return logbooks. Data are excluded for 2021 and 2022 due to effort data inconsistencies.

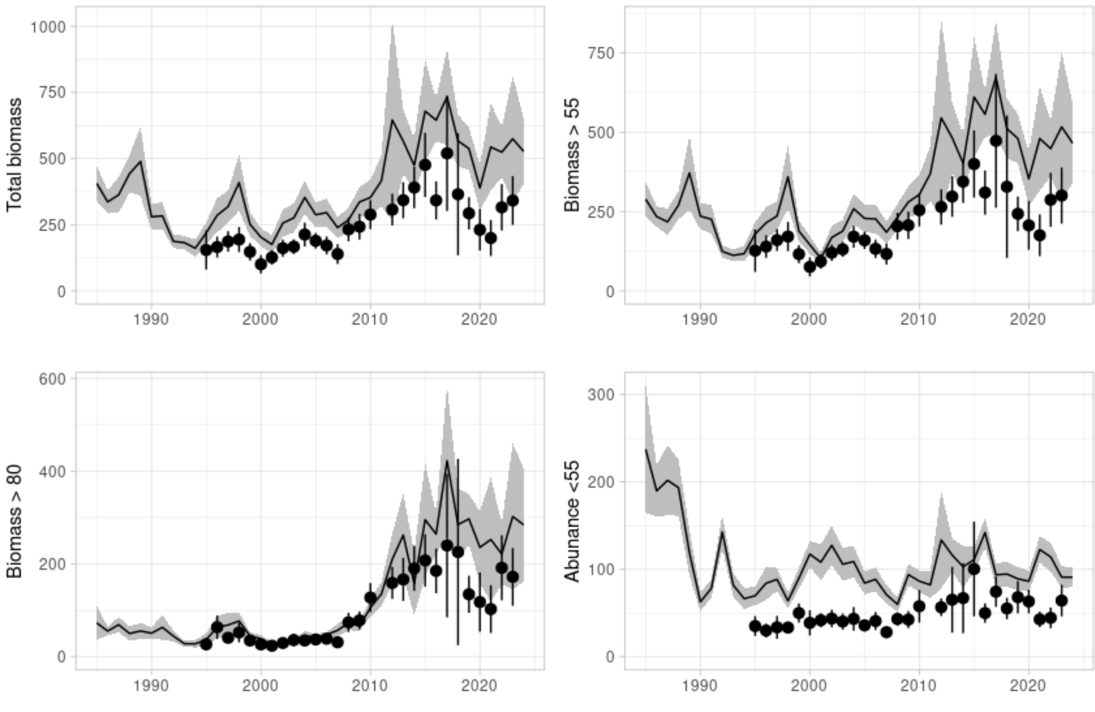

Figure 9.17. Cod in division 5a. Indices (total biomass, biomass> 45 cm, biomass> 60 cm and abundance <25 cm) in the Spring Survey (March) 1985 and onwards (line shaded area) and the autumn survey (point ranges).

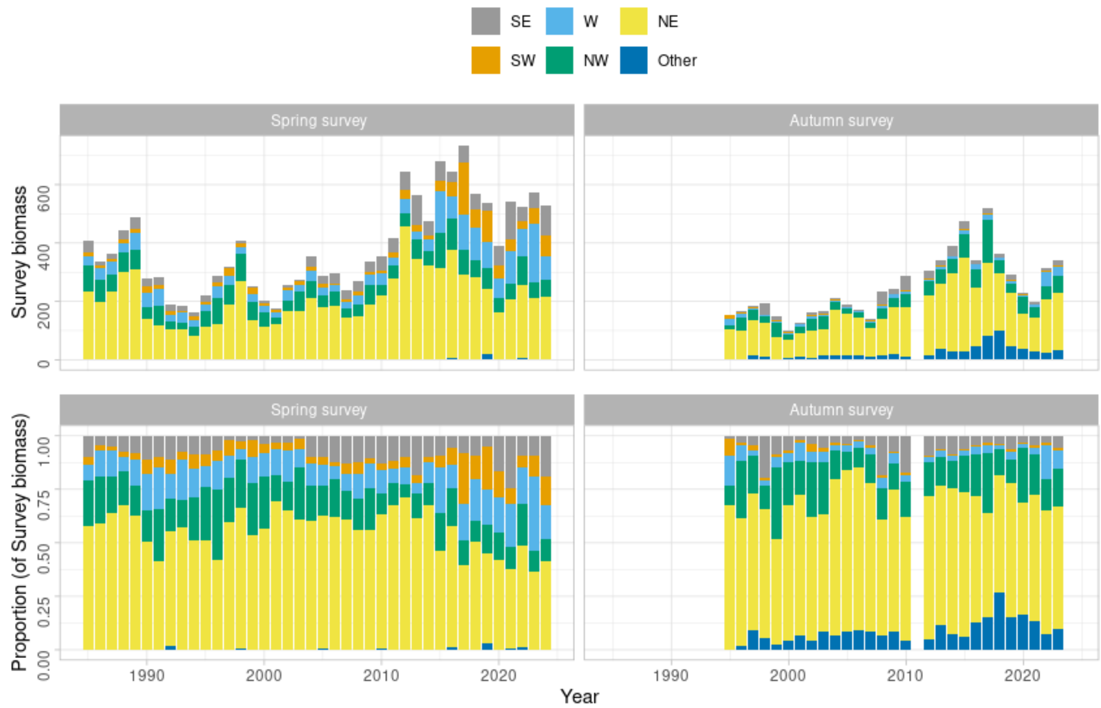

Figure 9.18. Cod in division 5a. Changes in geographical distribution of the survey biomass.

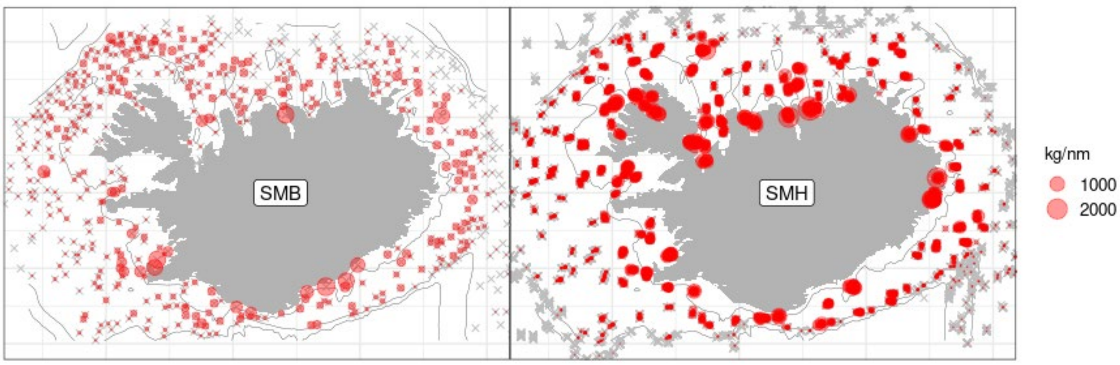

Figure 9.19. Cod in division 5a. Location of cod in the most recent March (SMB) and the Autumn (SMH) surveys, bubble sizes are relative to catch sizes, and crosses indicate stations where no cod was observed.

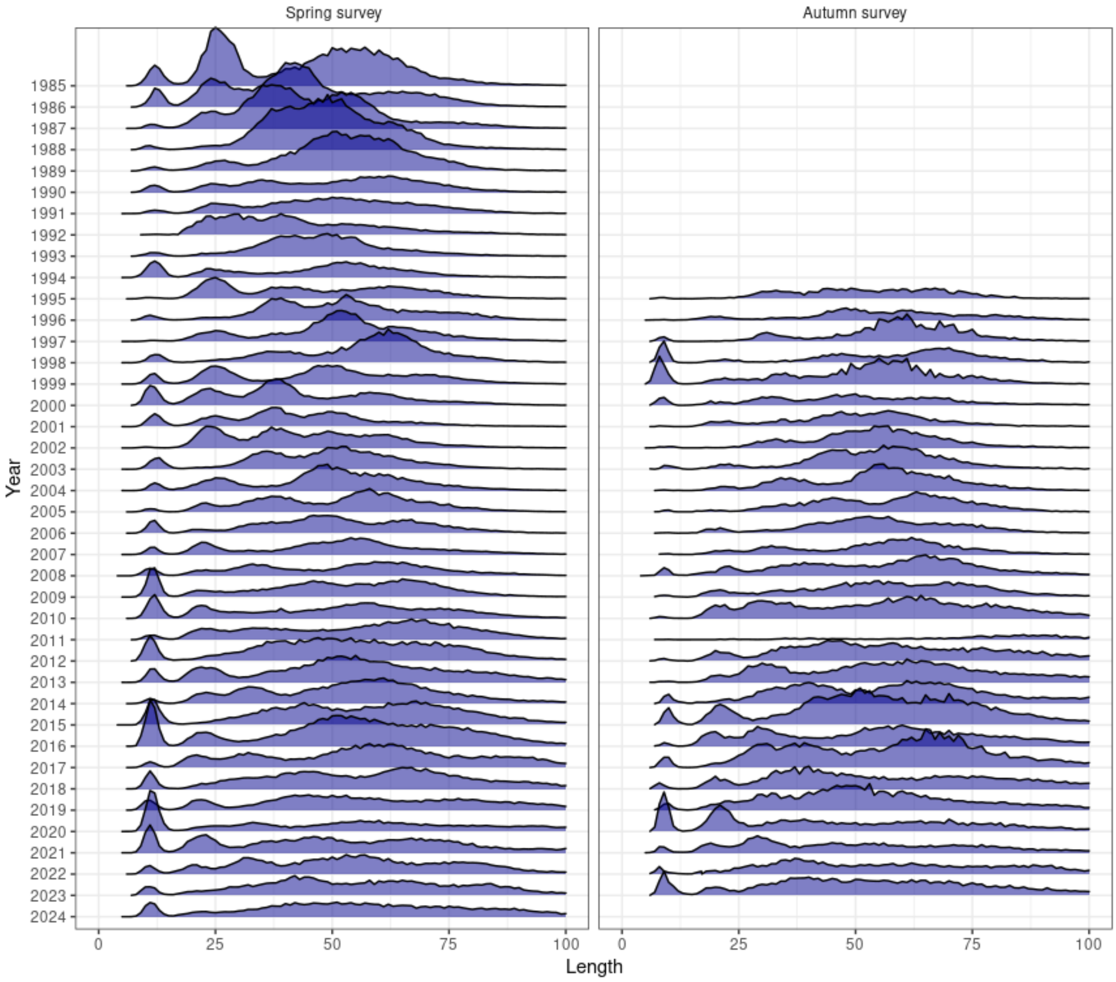

Figure 9.20. Cod in division 5a. Length disaggregated abundance indices from the March survey 1985 and onwards.

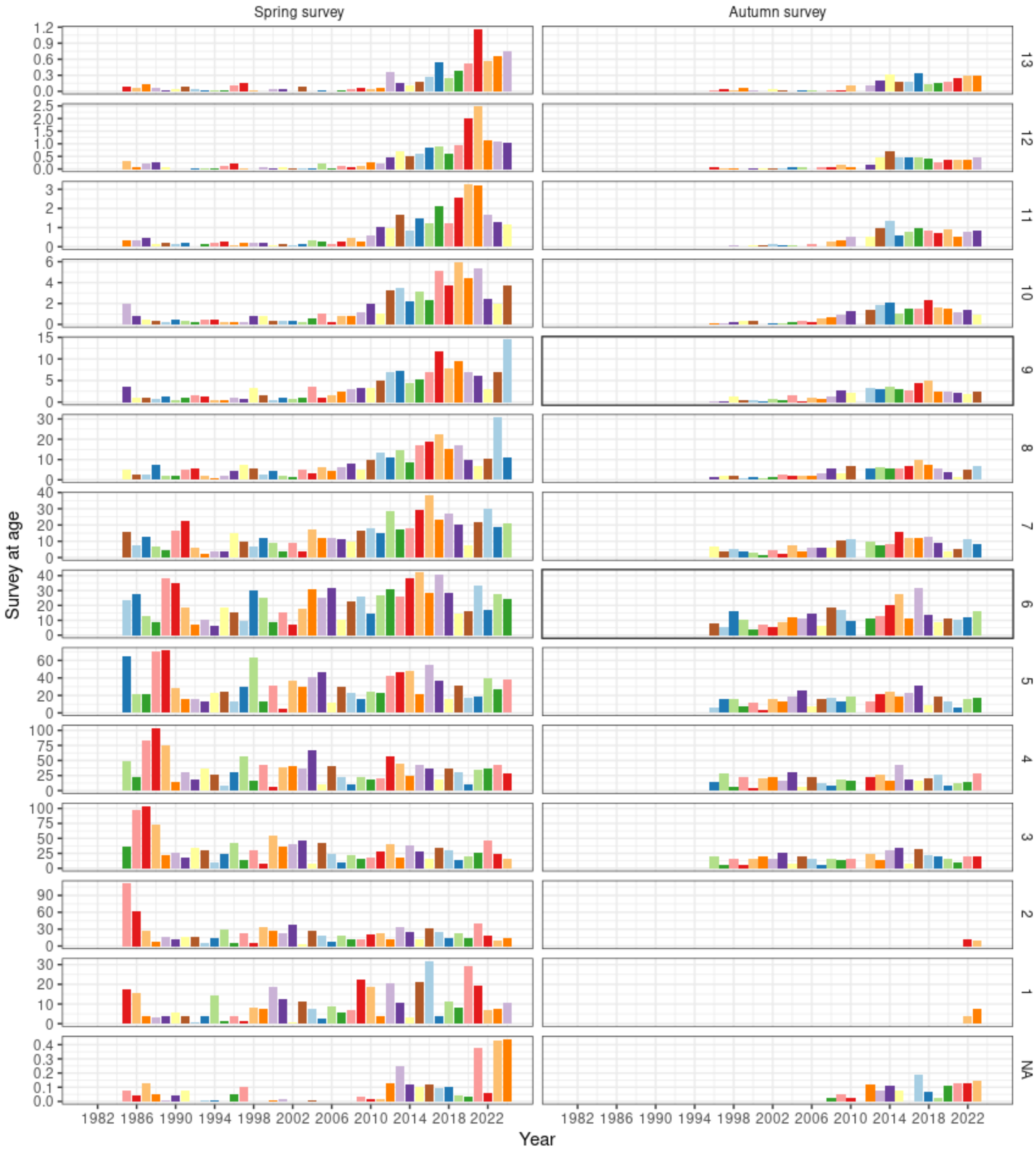

Figure 9.21. Cod in division 5a. Age disaggregated indices in the Spring Survey (left) and the autumn survey (rights). Bars indicated the deviation from the log mean index, fill colors indicate cohorts. Note different scales on y-axes.

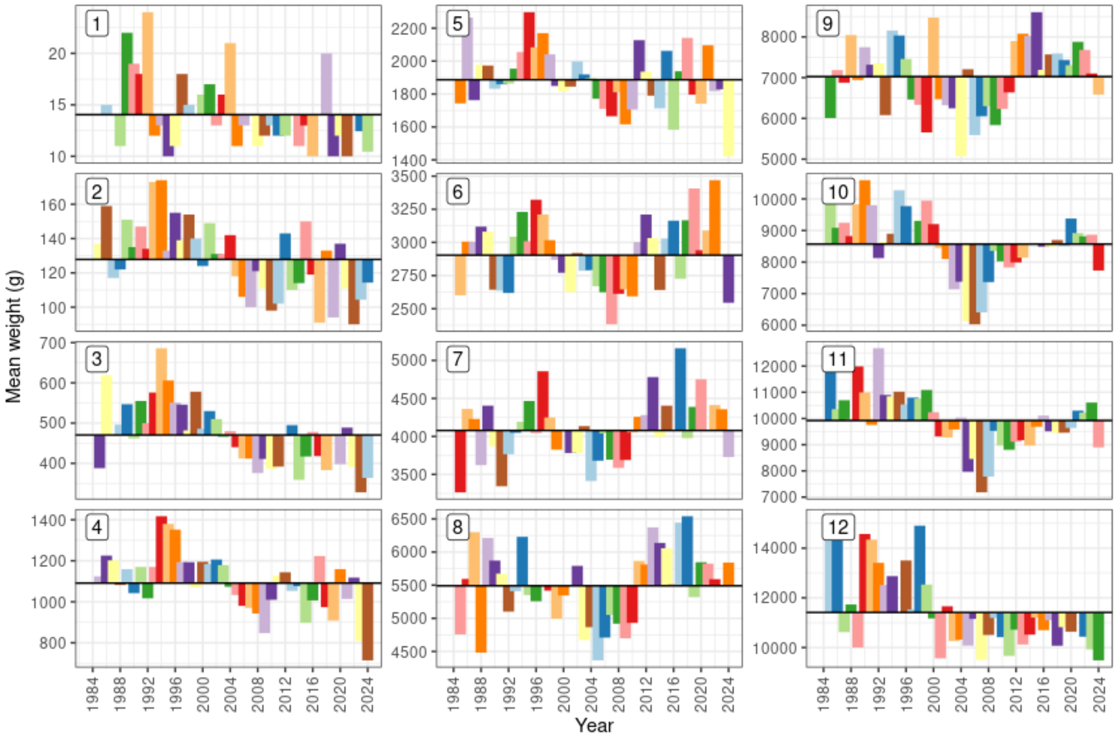

Figure 9.22. Cod in division 5a. Stock weights from the March survey in Icelandic Waters. Bars are coloured by cohort.

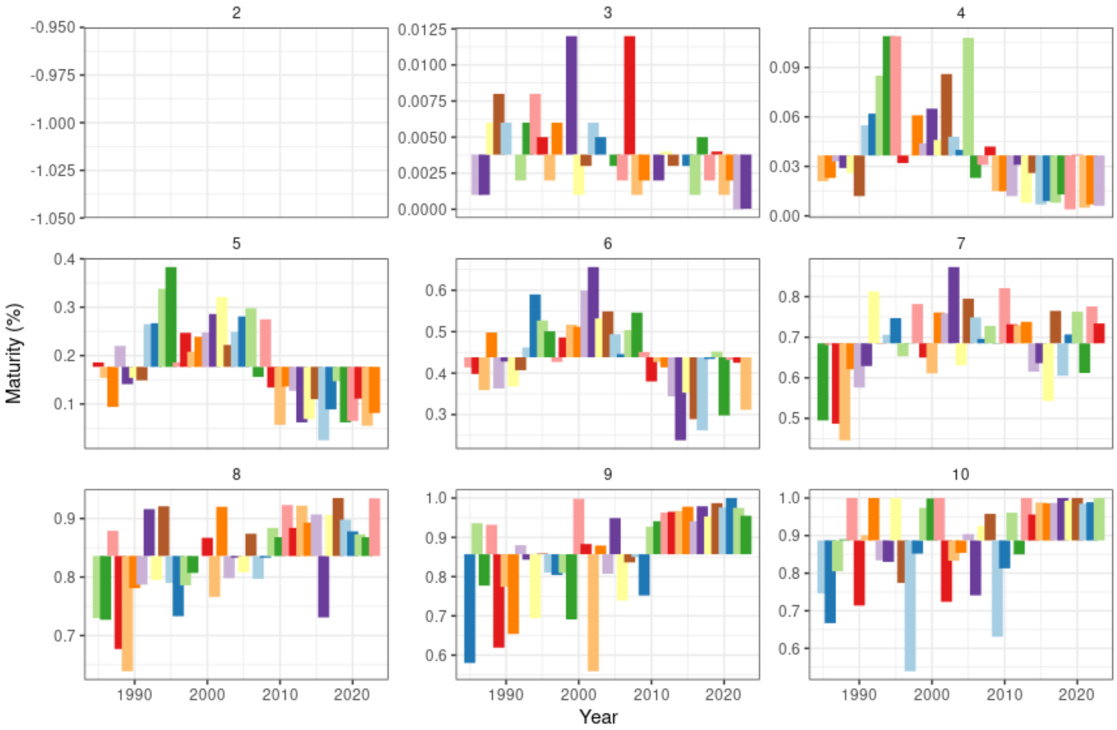

Figure 9.23. Cod in division 5a. Maturity-at-age in the survey. Bars are coloured by cohort. The values are used to calculate the spawning stock.

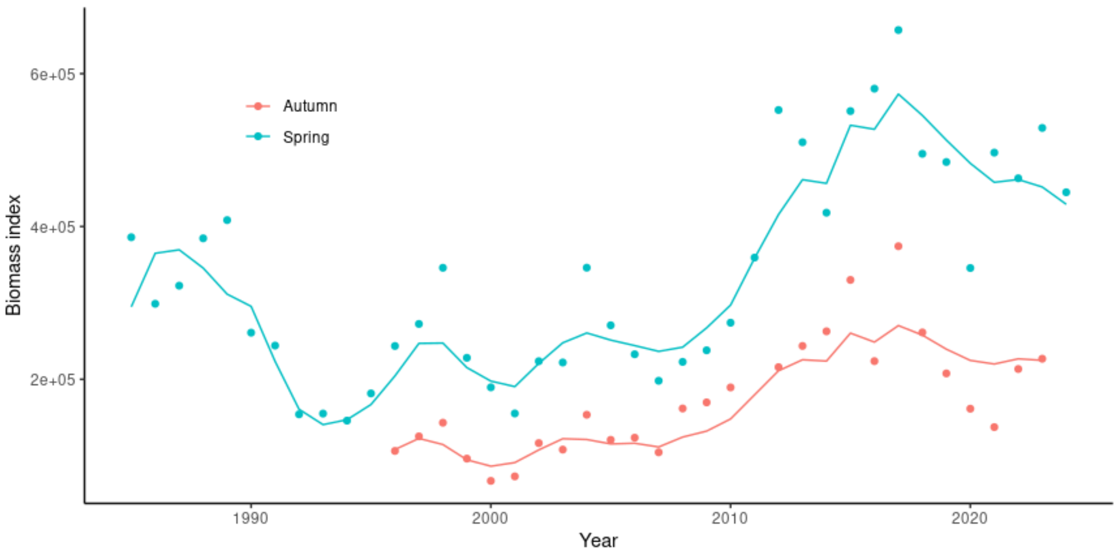

Figure 9.24. Cod in division 5a. Aggregated model fit to the total biomass indices. Note that residual correlation is estimated (see text for further details).

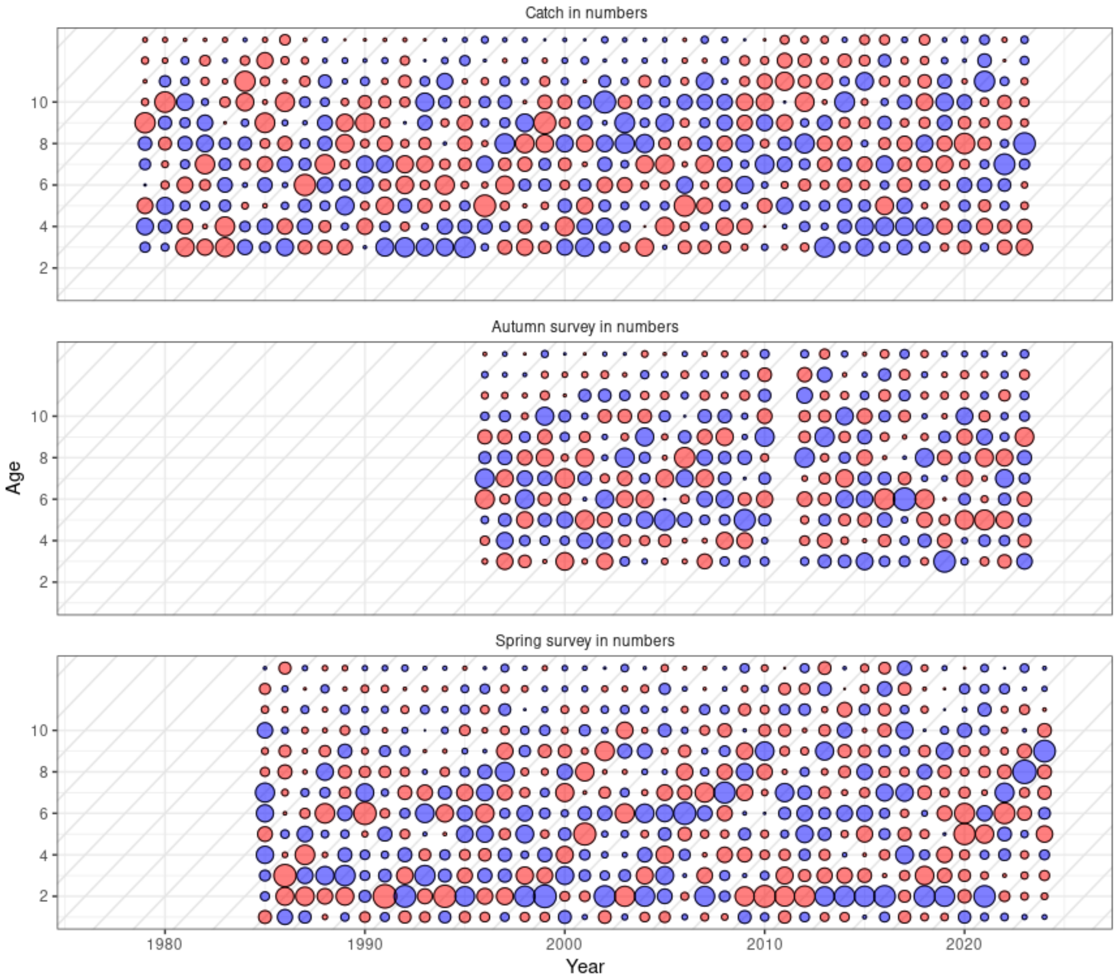

Figure 9.25. Cod in division 5a. Residuals from the model fit to survey and catch data based on the both the surveys. Red circles indicate negative residuals (observed < modelled), while blue positive. Residuals are proportional to the area of the circles.

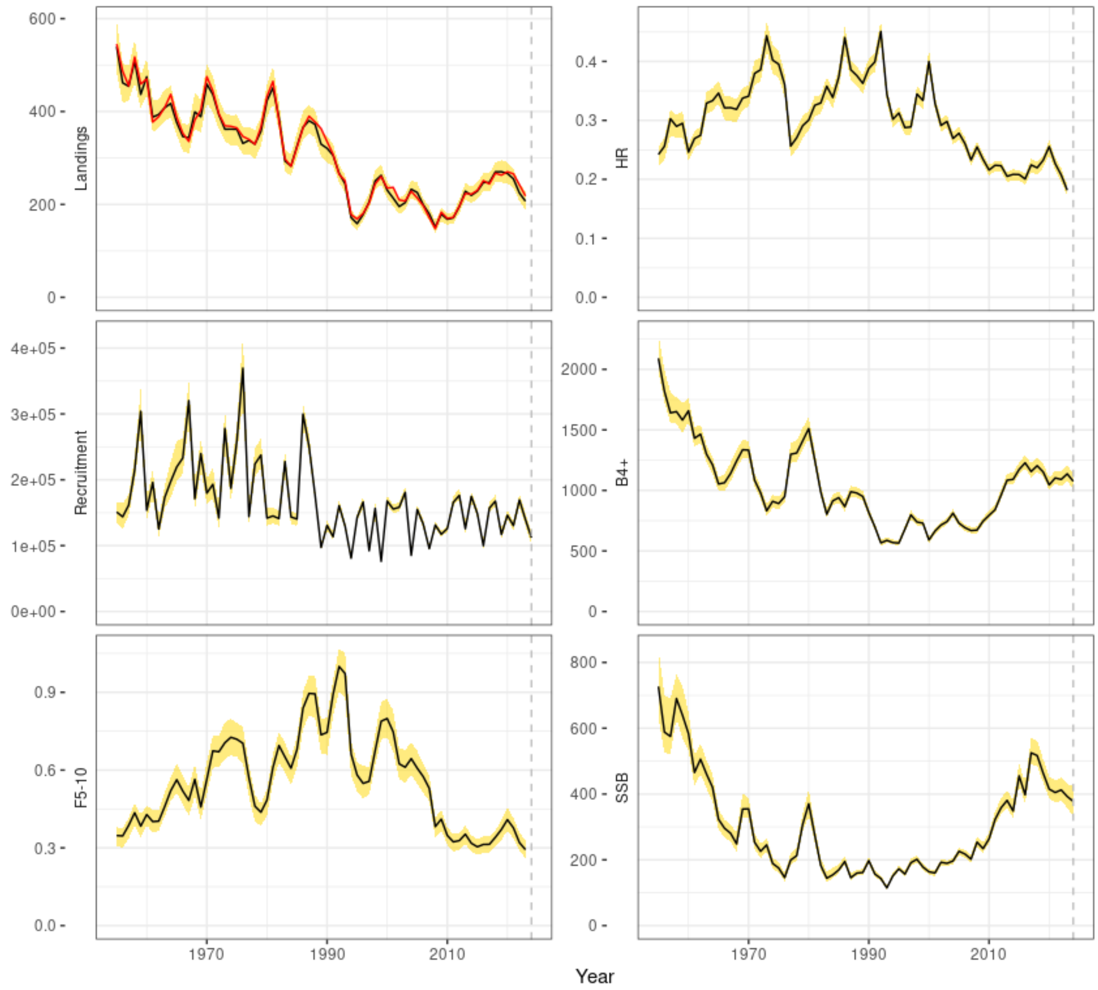

Figure 9.26. Cod in division 5a. Summary from assessment. Dashed vertical line indicates the assessment year and yellow shaded region the uncertainty as estimated by the model.

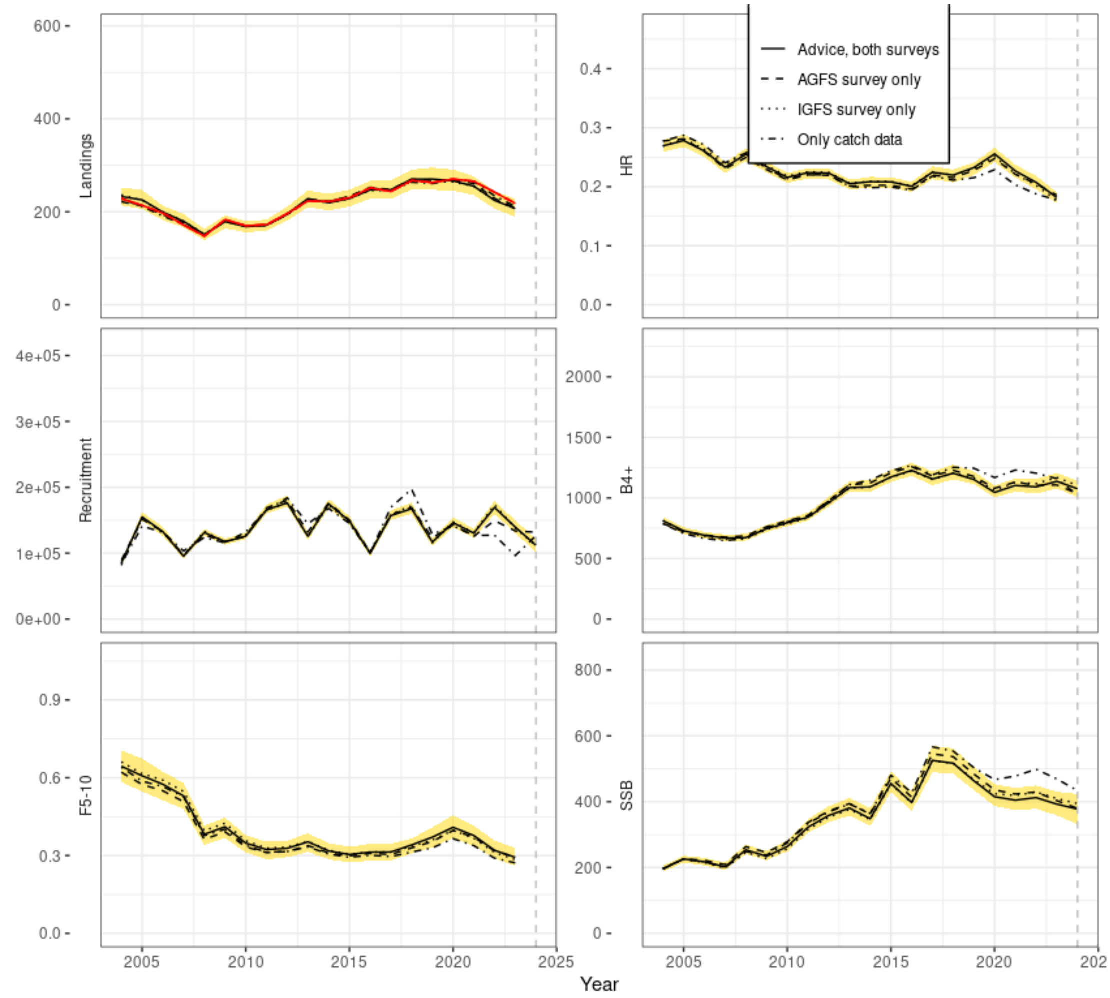

Figure 9.27. Cod in division 5a. Comparison of assessment results where either the spring survey or the autumn survey is omitted from the estimation.

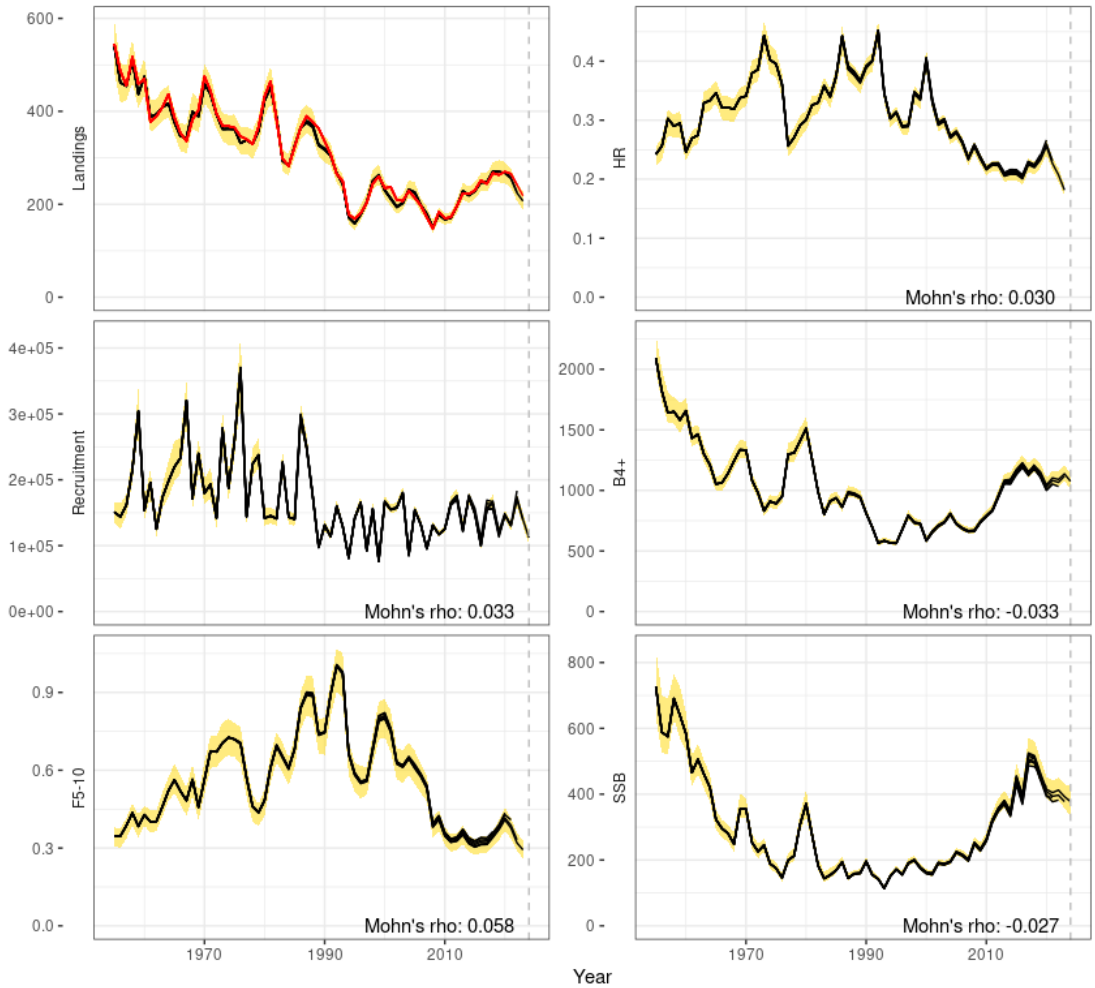

Figure 9.28. Cod in division 5a. Analytical retrospective analysis of the assessment of cod with a 5 year peel.

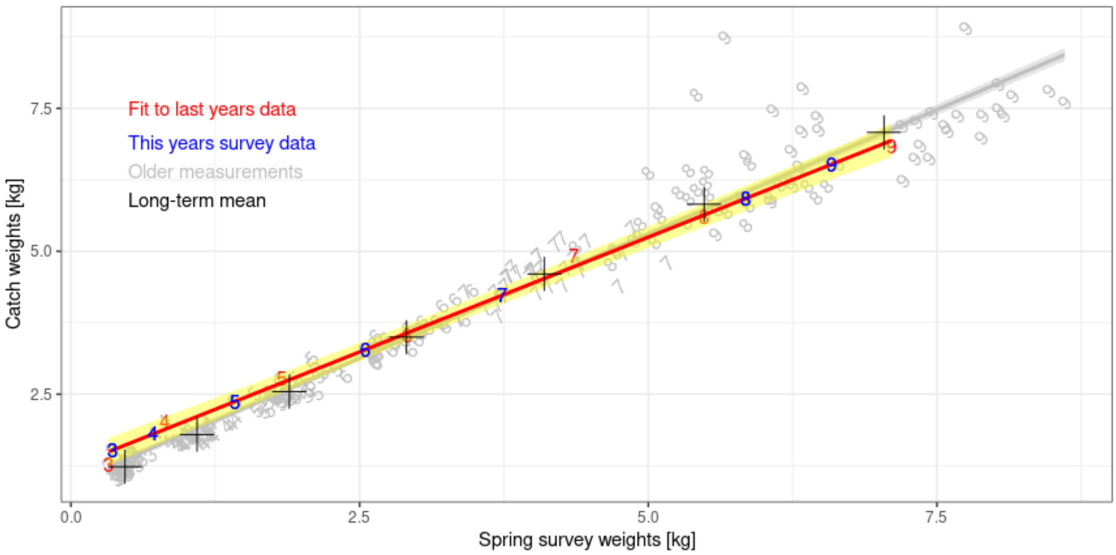

Figure 9.29. Cod in division 5a. Comparison of the short-term prediction of catch weights used in the calculation of reference biomass (blue) using a regression of catch weights on stock weights across ages from last year (red). Historical values and a regression based on all years of data represent the long-term average relationship in grey.

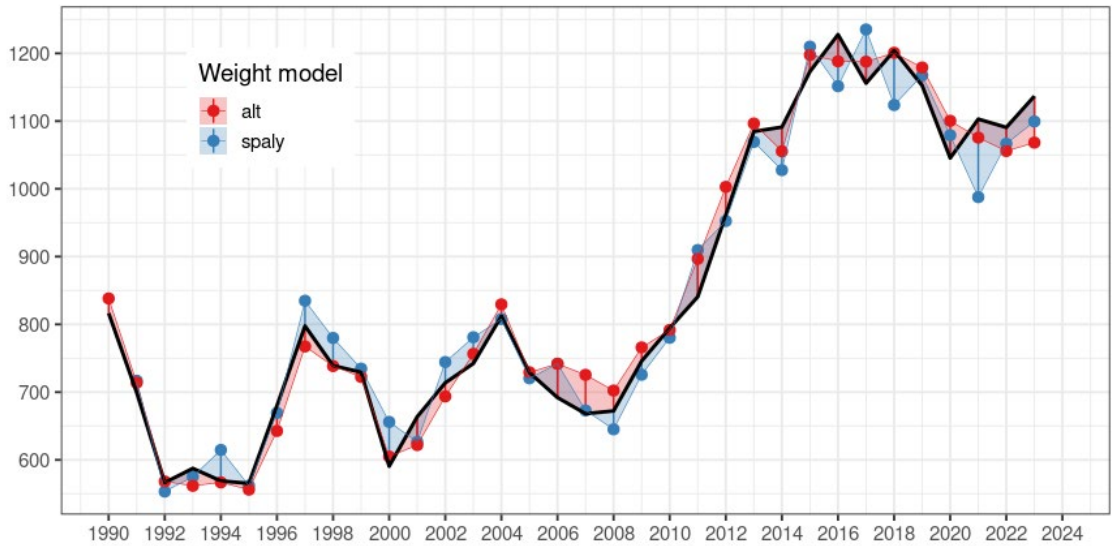

Figure 9.30. Cod in division 5a. Comparison of the short-term prediction of reference biomass using the standard procedure (spaly) vs. an alternate method (alt) to the realized value a year later (black line).

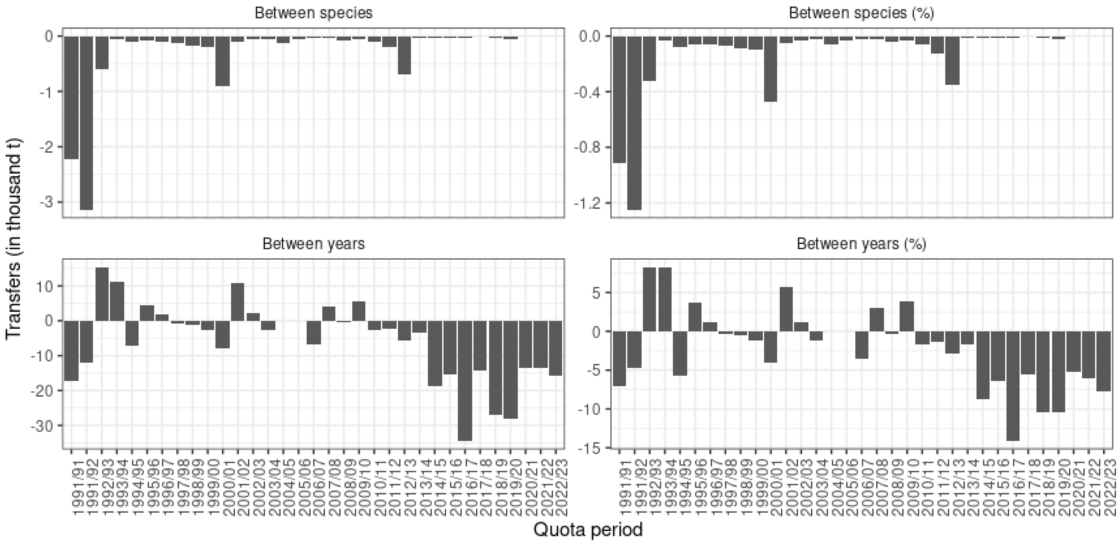

Figure 9.31. Cod in division 5a. An overview of the net transfers of quota between years and species transformations in the fishery in 5a.

10 Iceland grounds haddock

had.27.5a – *Melanogrammus aeglefinus* in Division 5.a

10.1 General information

Icelandic haddock (*Melanogrammus aeglefinus*) is fairly abundant in the coastal waters around Iceland and is mostly limited to the Icelandic continental shelf, while 0-group and juveniles from the stock are occasionally found in East Greenland waters (ICES Area 14). Apart from this, larval drifts links with other regions have not been found. In addition, minimal catches have been reported in area 14 (maximum of less than 10 tons in 2016). The nearest area to Iceland where haddock is found in reasonable abundance are in shallow Faroese waters, which constitutes as a separate stock. The two regions are separated by a wide and relatively deep ridge, an area where reporting of haddock catches is non-existent, both commercially and scientifically. Tagging studies (Jónsson, 1996) conducted between 1953 and 1965 showed no migrations of juvenile and mature fish outside Icelandic Waters, as most recaptures took place in the area of tagging (or adjacent areas) and on the spawning grounds south of Iceland. Information about stock structure (metapopulation) of haddock in Icelandic Waters is limited.

The species is found all around the Icelandic coast, principally in the relatively warm waters off the west and south coast, in shallow waters (10-200 m depth). Spawning has historically been limited to the southern waters. Haddock is also found off the north coast and in warm periods a large part of the immature fish have been found north of Iceland. In recent years a larger part of the fishable stock has been found off the north coast of Iceland than in the last two decades of the 20th century.

10.1.1 Fishery

The fishery for haddock in 5.a has not changed substantially in recent years, but the total number of boats that account for 95% of the fishery has been declining steadily (Figure 10.1 and Table 10.1). Around 250 longliners annually report catches of haddock, around 60 trawlers and 40 demersal seine boats. Most of haddock in 5.a is caught by trawlers and the proportion caught by that gear has decreased since 1995 from around 70% to 45% in 2017. However, for the last two years this proportion has increased slightly and is now around 60%. At the same time the proportion caught by longlines has increased from around 15% in 1995–2000 to 40% in 2011–2023. Catches in demersal seine have varied less and have been at around 15% of Icelandic catches of haddock in 5.a. Currently less than 2% of catches are taken by other vessel types, but historically up to 10% of total catches were by gillnetters, but since 2000 these catches have been low (Figure 10.2). Most of the haddock caught in 5.a by Icelandic vessels is caught at depths less than 200 m (Figure 10.3). The main fishing grounds for haddock in 5.a, as observed from logbooks, are in the south, southwestern and western part of the Icelandic shelf (Figure 10.4 and Figure 10.5). The main trend in the spatial distribution of haddock catches in 5.a according to logbook entries is the increased proportion of catches caught in the north and northeast.

10.1.1.1 Landing trends

Landings of Icelandic haddock in 2023 are estimated to have been 70 595 tonnes, see Figure 10.6. The landings in division 5.a. have decreased from 100 thous. tonnes between 2005–2008, which historically was very near the maximum levels observed in the 1960’s, to the current level which is slightly lower than observed between 1975 to early 2000’s.

Foreign vessel landings were a considerable proportion of the landings, but since the expansion of the EEZ landings of foreign vessels are negligible. Currently most of the foreign catch is caught by Faroese vessels, which in last year was 1750 tonnes, while Norwegian vessels land considerably less haddock.

10.1.2 Data available

In general sampling is considered good from commercial catches from the main gears (demersal seines, longlines and trawls). The sampling does seem to cover the spatial and seasonal distribution of catches (see Figure 10.7 and Figure 10.8). In 2020 sampling effort was reduced substantially, on-board sampling in particular, due to the COVID-19 pandemic. However, the reduced sampling during this period is considered to be sufficiently representative of the fishing operations and thus not considered to substantially affect the stock assessment. The sampling effort has since increased to near pre-pandemic levels.

10.1.2.1 Landings and discards

All landings in 5.a before 1982 are derived from the STATLANT database, and also all foreign landings in 5.a to 2005. The years between 1982 and 1993 landings by Icelandic vessels were collected by the Fisheries Association of Iceland (Fiskifélagið). Landings after 1994 by Icelandic vessels are given by the Icelandic Directorate of Fisheries. Landings of foreign vessels (mainly Norwegian and Faroese vessels) are given by the Icelandic Coast Guard prior to 2014 but after 2014 this are also recorded by the Directorate. Discarding is banned by law in the Icelandic demersal fishery. Based on annual discards estimates since 2001, discard rates in the Icelandic fishery for haddock due to highgrading are estimated very low in recent years (<3% in either numbers or weight, see MRI (2016) for further details) while historically discards may have been substantial in the early 1990s. Measures in the management system such as converting quota share from one species to another are used by the fleet to a large extent and this is thought to discourage discarding in mixed fisheries. In addition to prevent high grading and quota mismatch the fisheries are allowed to land fish that will not be accounted for in the allotted quota, provided that the proceedings when the landed catch is sold will go to the Fisheries Project Fund (*Verkefnasjóður sjávarútvegsins*). A more detailed description of the management system can be found on https://www.responsiblefisheries.is/seafood-industry/fisheries-management.

10.1.2.2 Length compositions

The bulk of the length measurements is from the three main fleet segments, i.e. trawls, longlines and demersal seine (Table 10.2). The number of available length measurements by gear has fluctuated in recent years in relation to the changes in the fleet composition.

Length distributions from the main fleet segments are shown in Figure 10.10. The sizes caught by the main gear types (bottom-trawl and longlines) appear to be fairly stable, primarily catching haddock in the size range between 40 and 70 cm. Gillnets tend to catch slightly larger fish and modes of the length distribution vary more depending on the availability of large haddock.

10.1.2.3 Age compositions

An overview of the sampled otoliths is shown in Table 10.3. Catch in numbers-at-age is shown in Figure 10.11. The catches in 2023 are mainly of the 2014 to 2017 year classes. The number of year classes contributing to the catches has increased in recent years; the result of low fishing mortality in recent years and the last year class contributing with more than 1% of total is 11 years old (Figure 10.12).

10.1.2.4 Weight at age in the catch

Mean weight at age in the catch is shown in Figure 10.13. Catch weights of the older year classes have been increasing in recent years, after being very low when the stock was large between 2005 and 2009. Higher mean weight at age is most apparent for the younger haddock from the small cohorts (2008–2013), which has resulted in a mean weight of the old fish above average. Mean weight of younger year classes in the catches has decreased but is still above average.

10.1.2.5 Natural mortality

No information is available on natural mortality. For assessment and advisory purpose, the natural mortality is set to 0.2 for all age groups.

10.1.3 Catch, effort and research vessel data

10.1.3.1 Catch per unit effort from commercial fisheries

Catch per unit effort data (Figure 10.14) shows that for hauls where the catch is composed of more than 50% haddock the CPUE has been steadily increasing since 1990 for the main gear types. The CPUE from all catches from bottom trawls and demersal seine is among the highest recorded while for longlines it is relatively low. This is in-line with fishers' perception that it is easy to catch haddock. This gives a different picture of the development of the stock than what is observed in surveys and assessment, much less increase after 2000 and much less decrease in recent years. However, it is worth noting that there is also a considerable change in the size composition of the stock, where the biomass of 60 cm and above is at the highest observed in the time-series, while the total biomass is close to it average value, suggesting that the CPUE may be more representative of larger fish.

There are also considerable differences in the CPUE by area, where the area north of Iceland has seen a continuous increase while the southern regions are more consistent with the total biomass index from the spring survey. Bycatch is of little concern as the haddock is commonly targeted in specific catch mixtures.

The catch per unit effort could not be estimated for 2022 as the effort data from that year were not available at the time of assessment.

10.1.3.2 Icelandic survey data

Information on abundance and biological parameters from haddock in 5.a is available from two surveys, the Icelandic groundfish survey in the spring and the Icelandic autumn survey.

The Icelandic groundfish survey in the spring, which has been conducted annually since 1985, covers the most important distribution area of the haddock fishery. The autumn survey commenced in 1996 and expanded in 2000 to include deep-water stations. It provides additional information on the development of the stock. The autumn survey has been conducted annually with the exception of 2011 when a full autumn survey could not be conducted due to a fisher strike. Although both surveys were originally designed to monitor the Icelandic cod stock, the surveys are considered to give a good indication of the haddock stock, both the juvenile population and the fishable biomass. A detailed description of the Icelandic spring and autumn groundfish surveys is given in the Stock Annex. Figure 10.15 shows both a recruitment index (abundance < 25 cm) and the trends in various biomass indices (total biomass, biomass > 60 cm and biomass > 45 cm). Changes in spatial distribution observed in the spring survey are shown in Figure 10.16). The shows that a larger proportion of the observed biomass now resides in the north (areas NW and NE). Changes in spatial distribution are shown in Figure 10.17 and survey length distributions in Figure 10.18 (abundance).

Both surveys show a high increase total biomass between 2002 and 2005 but considerable decrease from 2007–2010. The difference in perception of the stock between the surveys is that the autumn survey shows less contrast between periods of large and small stock. The 2015 estimate from the autumn survey exhibited substantially lower biomass compared to adjacent years. The contrast between the surveys appears to be stronger when looking at the biomass of 60 cm and larger, but both surveys show that the 60 cm$^+$ is at its maximum in recent years. A marked increase in total survey biomass was observed in autumn 2022 and spring 2023.

Age disaggregated indices from the March survey are shown in Figure 10.19. Similar to the biomass of 60 cm$^+$ the index of age 11$^+$ higher than seen before in March survey. This is assumed to be related to lower fishing mortality after the establishment of a management plan for haddock in 5.a. After a period of low recruitment the biomass for other age groups is near the geometric mean in both surveys.

10.1.3.3 Stock weight at age

Mean weight at age in the stock is shown in Figure 10.20. Stock weights are obtained from the groundfish survey in March and are also used as mean weight at age in the spawning stock. Both stock and catch weights of the older year classes have been increasing in recent years, after being very low when the stock was large between 2005 and 2009. Higher mean weight at age is most apparent for the younger haddock from the small cohorts (2008–2013), which has resulted in a mean weight of the old fish above average. Mean weight of younger year classes has decreased but is still above average.

10.1.3.4 Stock maturity-at-age

Maturity-at-age data are shown in Figure 10.21 and Figure 10.22. Those data are obtained from the groundfish survey in March. Maturity-at-age of the youngest age groups has been decreasing in recent years which is likely to be related to the distributional shift towards the north. Maturity by size has been decreasing and the most likely explanation is a large proportion of those age groups north of Iceland where the proportion of mature has always been low.

10.1.4 Data analyses

10.1.4.1 Analytical assessment

The stock was last benchmarked in 2019 as a part of a harvest control rule evaluation (WKICEMSE 2019), but the current assessment model had been run in parallel with the previous assessment since 2013. The management plan for haddock in 5.a based on this assessment was tested at the same meeting and subsequently implemented by the government of Iceland in the same year.

The assessment model used is a statistical catch–at-age model described in Björnsson, Hjörleifsson, and Elvarsson (2019). The model runs from 1979 onwards and ages 1 to 10 are tracked by the model, where the age of 10 is a plus group. Natural mortality is set to 0.2 for all age groups. Selection pattern of the commercial fleet is defined in terms of mean stock weights at age, rather than age, based on a logit selection function:

$$S_{a,y} = \frac{1}{1 + e^{-\alpha\left(\log(sW_{a,y}) - \log(W_{50})\right)}}$$

The rationale for this choice, compared to a more traditional age-based selection, is to account for observed changes in growth between year classes. Larger year classes tend to have lower mean weight compared to smaller year classes, as observed in Figure 10.13. As fishery selection is mainly size based, the assessment model using a size-based selection only requires two parameters to estimate the selection pattern. In contrast an age-based selection pattern would require parameter based on multiple selection time periods.

The weights to the survey data are based on a common multiplier to the variance estimates of each age group and survey obtained from a backwards calculation model (described in Björnsson, Hjörleifsson, and Elvarsson 2019), shown in Figure 10.23.

The ratio of fishing and natural mortality before spawning was set at 0.4 and 0.3 respectively as haddock is known to spawn in the period between April till the end of May.

10.1.4.2 Data used by the assessment

The assessment relies on four sources of data, that are described above. These are the two surveys, commercial samples and landings. The commercial data are used to compile catch-at-age data that enter the likelihood along with the survey at age from both surveys. Stock weights and catch weights at age are derived from the spring survey and catches respectively. The maturity data are similarly collected in the spring survey. Prior to 1985, when the spring survey started, stock weights and maturity-at-age were assumed constant at the 1985 values. A full description of the preparation of the data used for tuning and as input is given in the stock annex (see ICES (2019)).

10.1.4.3 Diagnostics

No concerning residual patterns are observed in the fit to data as illustrated in Figure 10.25. When looking at the combined fit (Figure 10.24) the figure shows the observed vs. predicted biomass from the surveys and it indicates that historically the autumn survey biomass has been closer to the prediction than corresponding values from the March survey, where the contrast in observed biomass is more than predicted from the assessment. The model accounts for this by estimating a stronger residual correlation for the spring survey (0.527) compared with the autumn survey (0.193). When contrasting the biomass levels before and after the mid 2000's peak the autumn survey suggests that the biomass level after the peak biomass is higher while the spring survey is at similar levels. Thus the model appears to fall in a region between the two surveys. Related to Figure 10.23 shows the estimated "catchability" and CV as a function of age for the surveys, showing that estimated CV is lower is generally lower for ages 2–6, whereas the CV increases faster by age for the autumn survey compared with the spring survey.

10.1.4.4 Model results

The results of the assessment indicate that the stock decreased from 2008–2011 when large year classes disappeared from the stock and were replaced by smaller year classes (Figure 10.26). From 2011 to 2017 the stock stabilized as a results of lower fishing mortality and since 2017 the stock biomass has increased rapidly as strong year classes have entered into the fishery. Fishing mortality is now estimated to be above the overall goal of the currently implemented HCR, while historically low. The baseline assessment does indicate that the stock size high and will remain in the coming years. The analytical retrospective (Figure 10.28) indicates an upwards revision in the most recent years. As this related to strong incoming recruitment to the fishable biomass the assessment is considered stable although the estimated 5-year Mohns's ρ fall slightly outside the acceptable range as illustrated in Figure 10.28.

Assessment in recent years has shown some difference between model runs where either or both of the two different tuning series, i.e. March and the October surveys, are omitted from the estimation, but currently this difference is mostly within the estimated uncertainty (Figure 10.27) but that has not always been the case. When the model is only fitted with catch data the reference biomass shows an opposite trend from the baseline assessment which is estimated to be decreasing. Last year's catch only assessment however indicated that biomass was increasing at a faster rate suggesting that the uncertainty of the estimate of the current state of the stock when the surveys are omitted increases substantially.

Estimated selection is illustrated in Figure 10.29, where substantial variations in selection at age is estimated by the model. Haddock in Icelandic Waters has exhibited substantial density-dependence in growth, as illustrated in Figure 10.32.

10.1.4.5 Short-term projections

Following the management plan the advice for the coming fishing year (2024/2025) is based in the biomass of 45 cm$^+$ at the beginning the next calendar year (2025). To arrive at this prediction a deterministic projection of the growth in weight and changes in maturity in the coming calendar year is needed. Growth in 2025 is predicted by the equation:

$$log\left(\frac{W_{a+1,y+1}}{W_{a,y}}\right) = \alpha + \beta log\left(W_{a,y0}\right) + \delta_y$$

where according to the stock annex the factor δ_y for the assessment year (Figure 10.32) is the average of the points estimates of the growth factor in the two preceding years. Growth has been high but variable in recent years but was much less in when the stock was larger in the early 2000s. Maturity, selection, catch weights at age and proportion of the biomass above 45cm$^+$ are then predicted from stock weights in 2024, see Figure 10.32 and Figure 10.33. When those values have been estimated the prediction is done by the same model as used in the assessment. The model works iteratively as the estimated TAC for the fishing year 2024/2025 has some effect of the biomass at the beginning of 2025, which the TAC is based on. This procedure is described in detail in the stock annex. A comparison of the predicted variables and observed/estimated values from the current assessment and last year's projection is shown in Figure 10.30 and Figure 10.31. This difference shown in Figure 10.30 is not considered to be related to the weight predictions for the advisory year as the assessment has consistently been revised upwards is the last years (Figure 10.28).

The projection this year assumes that the remainder of the TAC for the fishing year that ends on August 30. is caught. The projected stock status for the interim year is shown in Table 10.4 and the output from the projection in Table 10.5.

10.1.5 Management

The Icelandic Ministry of Food, Agriculture and Fisheries is responsible for management of the Icelandic fisheries and implementation of legislation. The Ministry issues regulations for commercial fishing for each fishing year (1 September–31 August), including an allocation of the TAC for each stock subject to such limitations. Haddock in 5.a has been managed by TAC since 1987. Landings have roughly followed the advice given by MFRI and the set TAC in all fishing years (Figure 10.34). Since the 2001/2002 the catches have exceeded more that 5% the set TAC in twelve fishing years. The largest overshoot in landings in relation to the advice/TAC was observed in the fishing year 2020/2021 when the landings of haddock exceeded the advice by 33%. The reasons for the implementation errors are related to the management system that allows for transfers of quota share between fishing years and conversion of TAC from one species to another (species transformation).

The TAC system does not include catches taken by Norway and the Faroe Islands by bilateral agreement. The level of those catches is known in advance but has until recently not been taken into consideration by the Ministry when allocating TAC to Icelandic vessels. There is no minimum landing size for haddock in 5.a. There are agreements between Iceland, Norway and the Faroe Islands relating to a fishery of vessels in restricted areas within the Icelandic EEZ. Faroese vessels are allowed to fish 5600 t of demersal fish species in Icelandic Waters which includes maximum 1200 tonnes of cod and 40 t of Atlantic halibut.

The effect of these species transformations and quota transfers is illustrated in Figure 10.35. The illustrates that when the biomass of haddock was high in the years between 2002 to 2007 the net transfers to haddock from other species increased. This may in part be explained by shifts in distribution of haddock, as illustrated in Figure 10.5, as the fisheries that traditionally target the northern area had lower amounts of haddock in their quota portfolio. However, looking over longer period quota transfer towards/from haddock has on the average been close to zero. With the establishment a management plan in 2013 the transfers between quota years have decreased substantially, while at the same time transfers from other species have increased. This is likely due to the fact that haddock is easy to catch, as demonstrated by high CPUE in recent years. The haddock quota may also be limiting in some mixed fisheries and that haddock may have been underestimated in last years could also contribute to transfer towards haddock. These effects were considered when the management plan was tested.

Figure 10.34 illustrates the difference between national TAC and landed catch in 5.a. The difference can be attributed to species transformation (in both directions), while for the 1999/2000 and 2020/2021 fishing years the government of Iceland increased TAC mid-season. Similarly, the TAC for the 2020/2021 fishing year was increased by 8 000 t and reduced by the same amount the following fishing year.

In 2023 the Ministry of Food, Agriculture and Fisheries initiated the process of reviewing the management plan for haddock in Icelandic Waters and it expected that it will be reviewed before the 2025/2026 fishing year.

10.1.6 Management considerations

All the signs from commercial catch data and surveys indicate that haddock in 5.a is at present in a good state. This is confirmed in the assessment. At WKICEMSE 2019 the harvest rate target applied by the HCR in the period between 2013 and 2018 was estimated to be no longer precautionary while a rate of 0.35 was in-line with both the precautionary and ICESs MSY approach. In 2023 the stock is estimated to have increased substantially and it is projected to increase in the coming year due to strong incoming cohorts (2019 and 2020 year classes) and the estimate of the 2021 year class is above average suggesting that the stock will remain in a good state in the near term. Analytical retrospective analysis of the assessment revealed a negative bias in the estimate of the SSB. While this is bordering on acceptable limits the robustness of the HCR was tested against model uncertainty of this magnitude.

10.1.7 References

Björnsson, Höskuldur, Einar Hjörleifsson, and Bjarki ór Elvarsson. 2019. "Muppet: Program for Simulating Harvest Control Rules." Reykjavik: Marine; Freshwater Research Institute. http://www.github.com/hoski/Muppet-HCR.

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10.2 Figures and tables

Table 10.1. Haddock in 5.a. Number of Icelandic vessels landing haddock, and all landed catch divided by gear type.

Year	Nr. Bottom Trawl	Nr. Other	Nr. Danish Seine	Nr. Long Line	Bottom Trawl	Other	Danish Seine	Long Line	Total catch
2000	164	504	117	479	23300	1740	3101	13089	41230
2001	146	631	91	447	22034	2050	3036	11982	39102
2002	144	548	91	417	30377	1990	3596	13638	49601
2003	136	550	96	435	36239	1664	4804	17284	59991
2004	131	656	95	449	50722	1787	8095	23198	83802
2005	126	488	90	449	53046	1573	10493	30767	95879
2006	116	416	93	436	45968	1217	12709	36237	96131
2007	109	345	94	407	57033	1080	12869	37199	108181
2008	102	311	91	362	51228	944	16457	33051	101680
2009	98	448	81	335	39078	608	15182	26571	81439
2010	94	623	67	279	29341	475	10138	23916	63870
2011	95	630	54	278	20718	473	6866	21175	49232
2012	98	699	56	289	20469	473	6048	18722	45712
2013	95	702	65	282	18829	398	4955	19197	43379
2014	84	654	47	283	13438	329	3776	15598	33141
2015	83	607	50	257	17337	360	4327	16432	38456
2016	82	580	53	237	17045	321	4456	14927	36749
2017	80	531	53	210	16456	343	4539	14447	35785
2018	71	494	58	194	26639	336	5585	15190	47750
2019	69	493	43	183	35947	302	6237	14650	57136
2020	73	536	42	149	32005	278	5079	16189	53551
2021	82	532	46	141	35961	264	5338	14411	55974
2022	73	513	57	114	39003	243	3929	13640	56815
2023	76	607	60	96	44514	311	6560	17427	68812

Table 10.2. Haddock in 5.a. Number of samples and length measurements from landed catch.

Year	Bottom Trawl Num. samples	Bottom Trawl Num. lengths	Danish Seine Num. samples	Danish Seine Num. lengths	Long Line Num. samples	Long Line Num. lengths
2000	344	66143	21	3114	88	14393
2001	359	71914	26	4098	168	30110
2002	467	85869	47	7644	212	32425
2003	422	71509	75	7094	210	31239
2004	503	82474	75	10416	252	35405
2005	514	94529	102	14880	375	53472
2006	500	74627	241	29862	747	75392
2007	837	102155	515	34922	531	87737
2008	813	83284	389	29477	572	88920
2009	630	56466	349	35176	406	63817
2010	470	59477	265	19727	344	56681
2011	357	53462	204	8494	237	43200
2012	349	41424	191	10270	306	60842
2013	267	34357	92	2597	237	43132
2014	155	13731	51	3157	217	37035
2015	187	26101	92	2816	222	41594
2016	163	21500	132	2540	202	37492
2017	200	23387	151	6417	232	42360
2018	134	21780	94	5611	231	35621
2019	295	50698	42	3266	187	25692
2020	109	17640	15	1552	64	8929
2021	139	22264	20	2112	38	4669
2022	124	18937	16	1942	34	3941
2023	129	23280	22	1933	28	3382

Table 10.3. Haddock in 5.a. Number of samples and otoliths collected from landed catch.

Year	Bottom Trawl Num. samples	Bottom Trawl Num. otoliths	Danish Seine Num. samples	Danish Seine Num. otoliths	Long Line Num. samples	Long Line Num. otoliths
2000	344	6773	21	800	88	2848
2001	359	5208	26	359	168	2755
2002	467	6510	47	750	212	2848
2003	422	7237	75	878	210	3499
2004	503	6786	75	698	252	2855
2005	514	6478	102	823	375	3520
2006	500	6447	241	1219	747	4806
2007	837	6602	515	1969	531	4451
2008	813	7637	389	2163	572	4464
2009	630	5449	349	1822	406	2800
2010	470	5458	265	1473	344	3199
2011	357	3522	204	1140	237	2675
2012	349	4448	191	1436	306	3204
2013	267	3039	92	750	237	2751
2014	155	1421	51	329	217	1550
2015	187	1924	92	324	222	1151
2016	163	1769	132	440	202	975
2017	200	1363	151	337	232	945
2018	134	1385	94	291	231	845
2019	295	1740	42	362	187	925
2020	109	1322	15	276	64	625
2021	139	1820	20	300	38	775
2022	124	1100	16	120	34	265
2023	129	1462	22	220	28	440

Table 10.4. Haddock in 5.a. The input data used for the advisory year prognosis of the Icelandic haddock in the assessment: the predicted weights, the selection pattern, M, proportion of M before spawning, and the number-at-age derived from Muppet run.

Age	Catch-at-age	Stock Maturity	Catch Weights	Stock Weights	Numbers-at-age	Selection
1	0.000	0.000	169.841	30.2014	69363.90	0.000
2	161.268	0.017	476.359	152.3550	54604.80	0.007
3	1159.530	0.129	887.111	404.2120	33683.70	0.063
4	9149.740	0.325	1245.940	688.8020	76974.70	0.184
5	14112.700	0.605	1737.650	1160.8900	70162.00	0.425
6	11451.500	0.767	2162.830	1636.6600	45302.80	0.618
7	762.789	0.882	2742.600	2375.7800	2759.51	0.791
8	2323.650	0.900	2889.030	2577.8400	7854.41	0.820
9	537.431	0.915	3047.630	2803.3400	1807.82	0.846
10	638.099	0.927	3193.150	3016.2300	2099.53	0.867

Table 10.5. Haddock in 5.a. Results of the short-term projections when a target harvest rate of 0.35 is applied.

Year	Calendar Year Catch	Fishing Year Catch	SSB	B45+	HR	Recruitment (age 2)
2024	73783	76774	127009	187073	0.394	44940.6
2025	78101	80756	143086	219356	0.356	52144.8
2026	78175	73013	151298	230722	0.339	56742.4
2027	70240	64695	142000	208635	0.337	56742.4

Table 10.6. Haddock in 5.a. ICES advice and official landings. All weights are in tonnes.

Year	ICES advice	Predicted catch corresp. to advice	Agreed TAC	ICES landings for the fishing year	ICES landings for the calendar year
1984*	National advice	< 55000	60000	---	48000
1985*	National advice	< 45000	60000	---	51000
1986*	National advice	< 50000	60000	---	48000
1987*	National advice	< 50000	60000	---	40760
1988*	National advice	< 60000	65000	---	54204
1989*	National advice	< 60000	65000	---	62885
1990*	National advice	< 60000	65000	---	67198
1991**	National advice	< 38000	48000	---	54692
1991/1992	National advice	< 50000	50000	48123	47121

Year	ICES advice	Predicted catch corresp. to advice	Agreed TAC	ICES landings for the fishing year	ICES landings for the calendar year
1992/1993	National advice	< 60000	65000	47255	48123
1993/1994	National advice	< 65000	65000	58443	59502
1994/1995	National advice	< 65000	65000	60829	60884
1995/1996	National advice	< 55000	60000	53972	56890
1996/1997	National advice	< 40000	45000	49764	43764
1997/1998	National advice	< 40000	45000	37811	41192
1998/1999	National advice	< 35000	35000	45146	45411
1999/2000	F reduced below F_{med}	< 35000	35000	41150	42105
2000/2001	F reduced below provisional F_{pa}	< 31000	30000	39143	39654
2001/2002	F reduced below provisional F_{pa}	< 30000	41000	41069	50498
2002/2003	F reduced below provisional F_{pa}	< 55000	55000	55269	60883
2003/2004	F reduced below provisional F_{pa}	< 75000	75000	77916	84828
2004/2005	F reduced below provisional F_{pa}	< 97000	90000	96617	97225
2005/2006	F reduced below provisional F_{pa}	< 110000	105000	99926	97614
2006/2007	F reduced below provisional F_{pa}	< 112000	105000	99763	109966
2007/2008	F reduced below provisional F_{pa}	< 120000	100000	109810	102872
2008/2009	F reduced below 0.35	< 83000	93000	88617	82045
2009/2010	F reduced below 0.35	< 57000	63000	67579	64169
2010/2011	F reduced below 0.35	< 51000	50000	50042	49433
2011/2012	F reduced below 0.35	< 42000	45000	49179	46208
2012/2013	F reduced below 0.35	< 32000	36000	40512	44097
2013/2014	TAC 0.4 × B45+cm,2014	< 38000	38000	39628	33900
2014/2015	TAC 0.4 × B45+cm,2015	< 30400	30400	36656	39646
2015/2016	TAC 0.4 × B45+cm,2016	< 36400	36400	40117	38109
2016/2017	TAC 0.4 × B45+cm,2017	< 34600	34600	36340	37062

Year	ICES advice	Predicted catch corresp. to advice	Agreed TAC	ICES landings for the fishing year	ICES landings for the calendar year
2017/2018	TAC 0.4 × B45+cm,2018	< 41390	41390	43700	49993
2018/2019	TAC 0.4 × B45+cm,2019	< 57982	57982	59382	58850
2019/2020	TAC 0.35 x B45+cm,2020	< 41823	41823	48991	54781
2020/2021	TAC 0.35 x B45+cm,2021	< 45389	45389	60672	57599
2021/2022	TAC 0.35 x B45+cm,2022	< 50429	41929	51986	58770
2022/2023	TAC 0.35 x B45+cm,2023	< 62219	62219	68881	70595
2023/2024	TAC 0.35 x B45+cm,2024	< 76415	76415	---	---

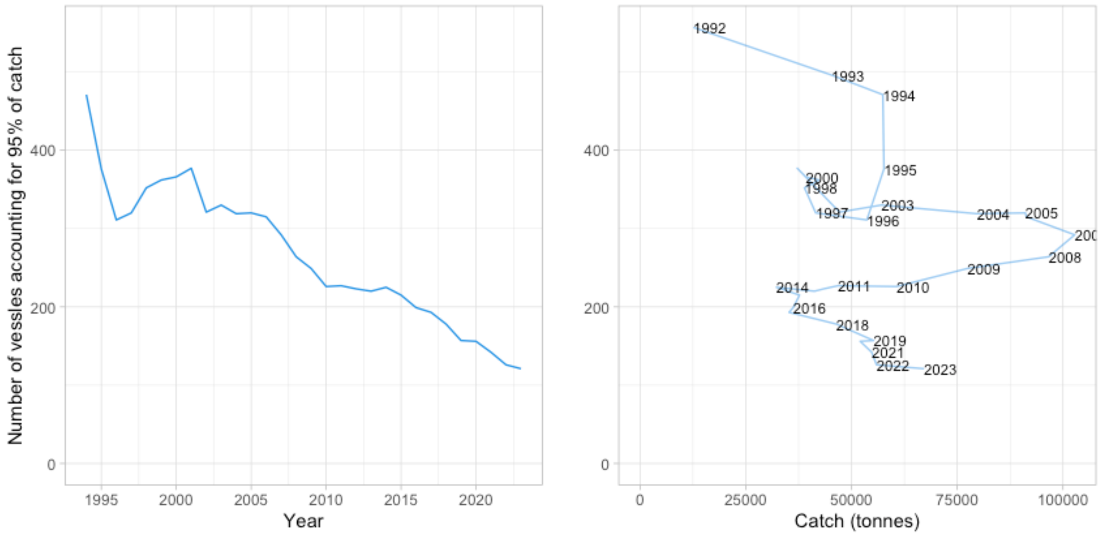

Figure 10.1. Haddock in 5.a. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

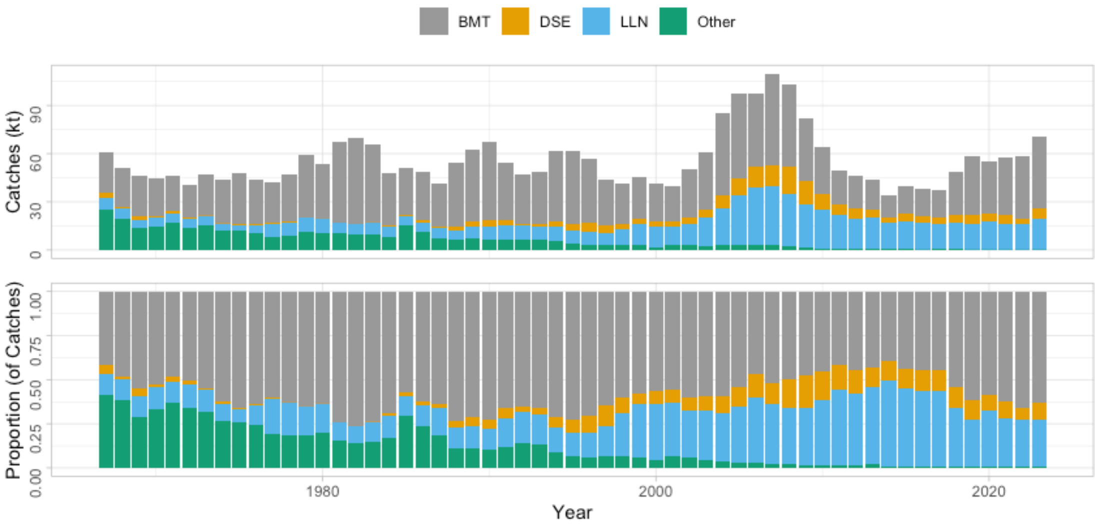

Figure 10.2. Haddock in 5.a. Landings in tons and percent of total by gear and year

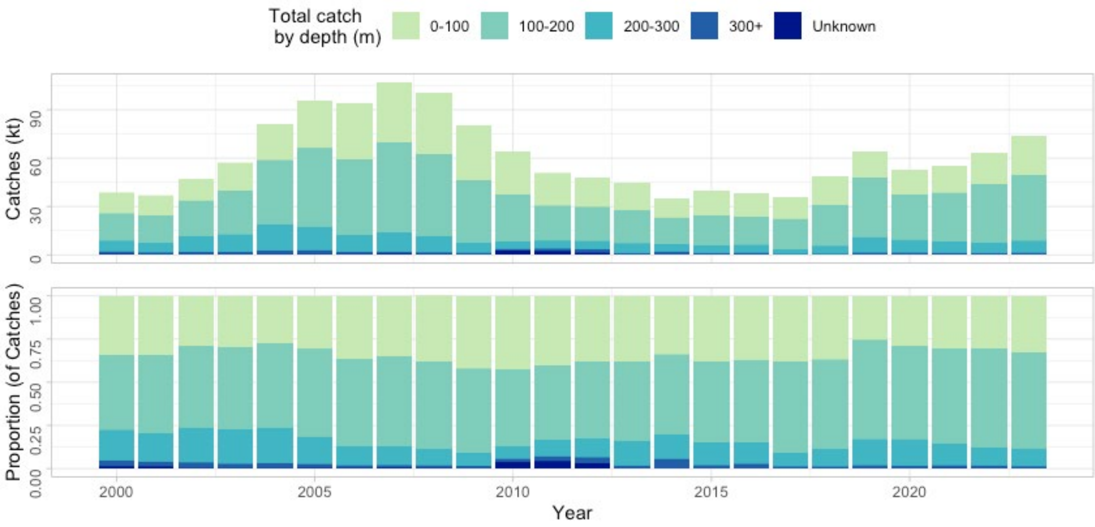

Figure 10.3. Haddock in 5.a. Depth distribution of haddock catches from bottom trawls, longlines, trawls and demersal seine from Icelandic logbooks

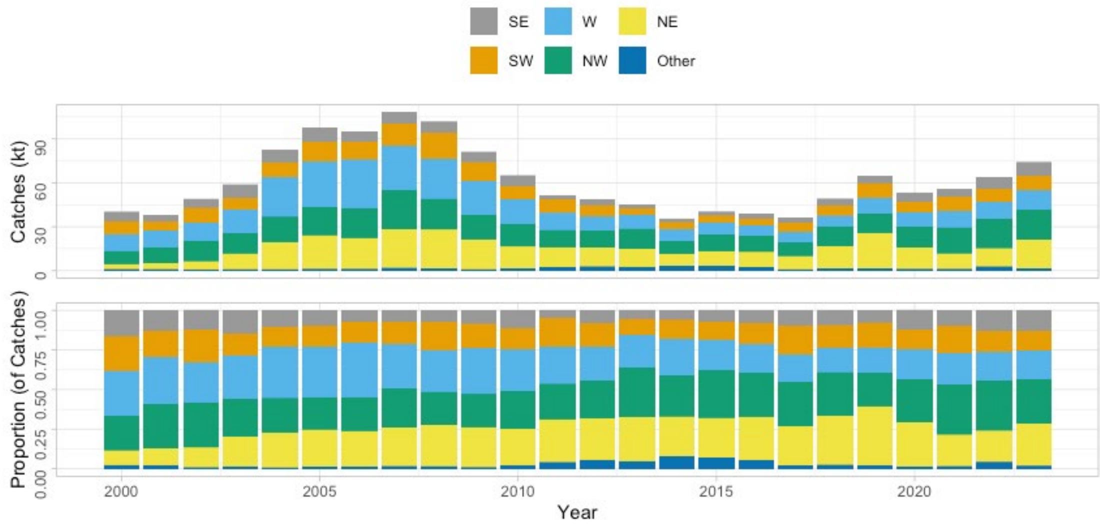

Figure 10.4. Haddock in 5.a. Changes in spatial distribution of haddock catches as recorded in Icelandic logbooks.

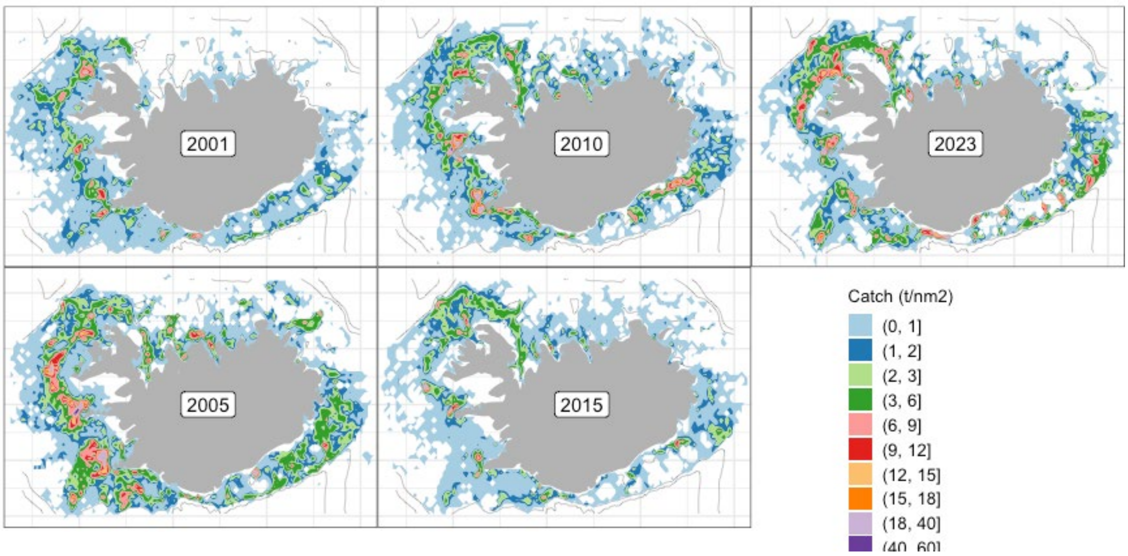

Figure 10.5. Haddock in 5.a. Spatial distribution of catches by all gears for selected years.

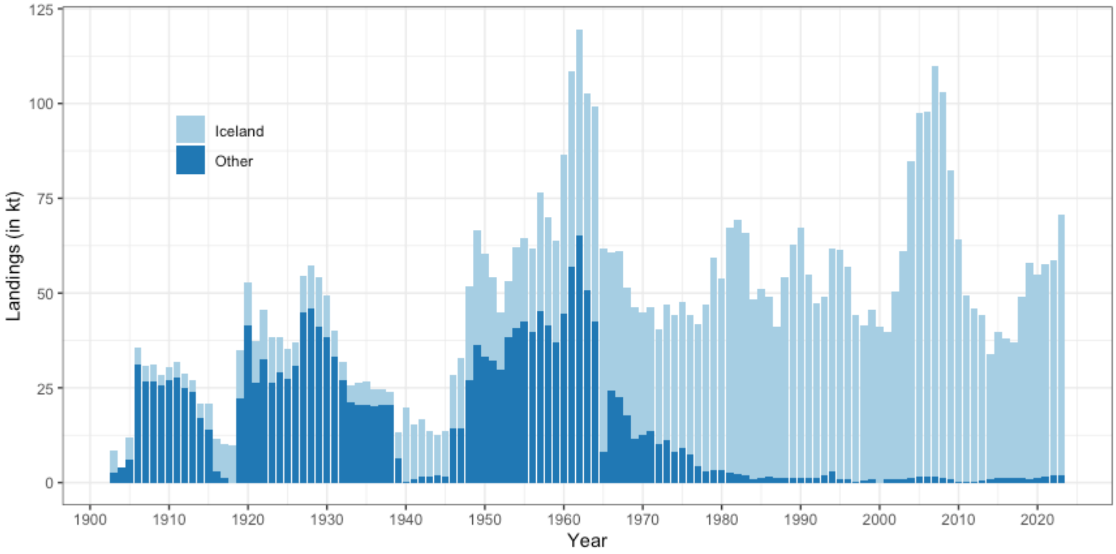

Figure 10.6. Haddock in 5.a. Recorded landings since 1905.

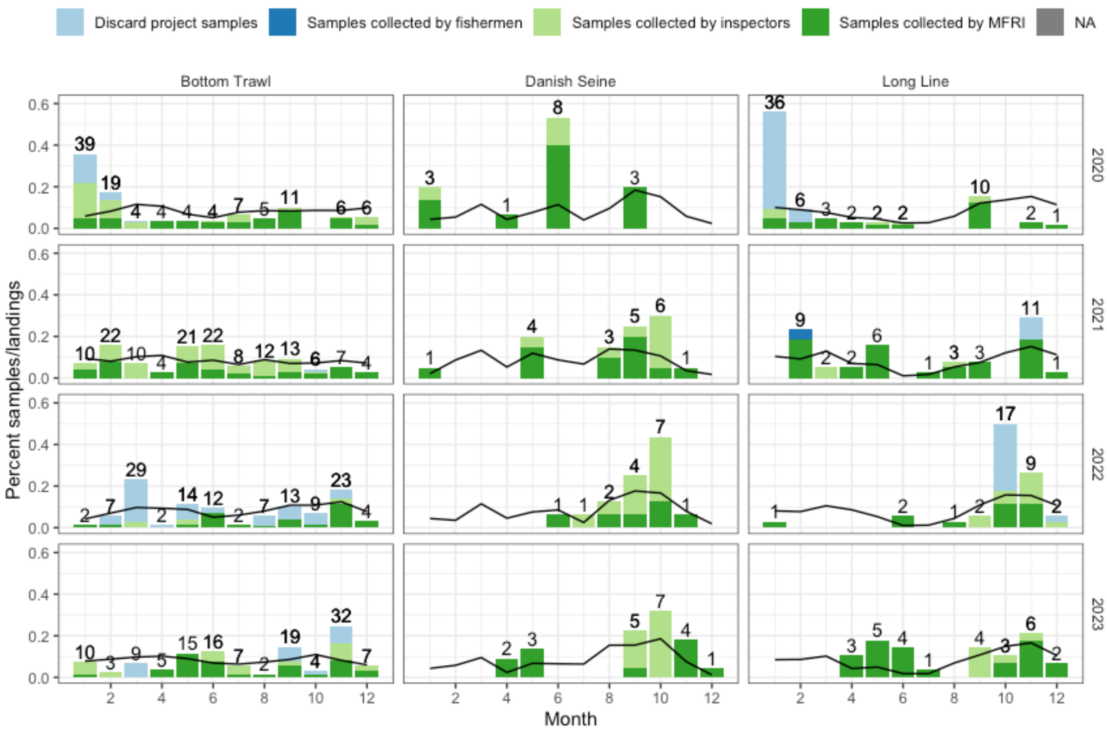

Figure 10.7. Haddock in 5.a. Ratio of samples by month (bars) compared with proportion landings by month (solid black line) split by year and main gear types. Numbers of above the bars indicate number of samples by year, month and gear.

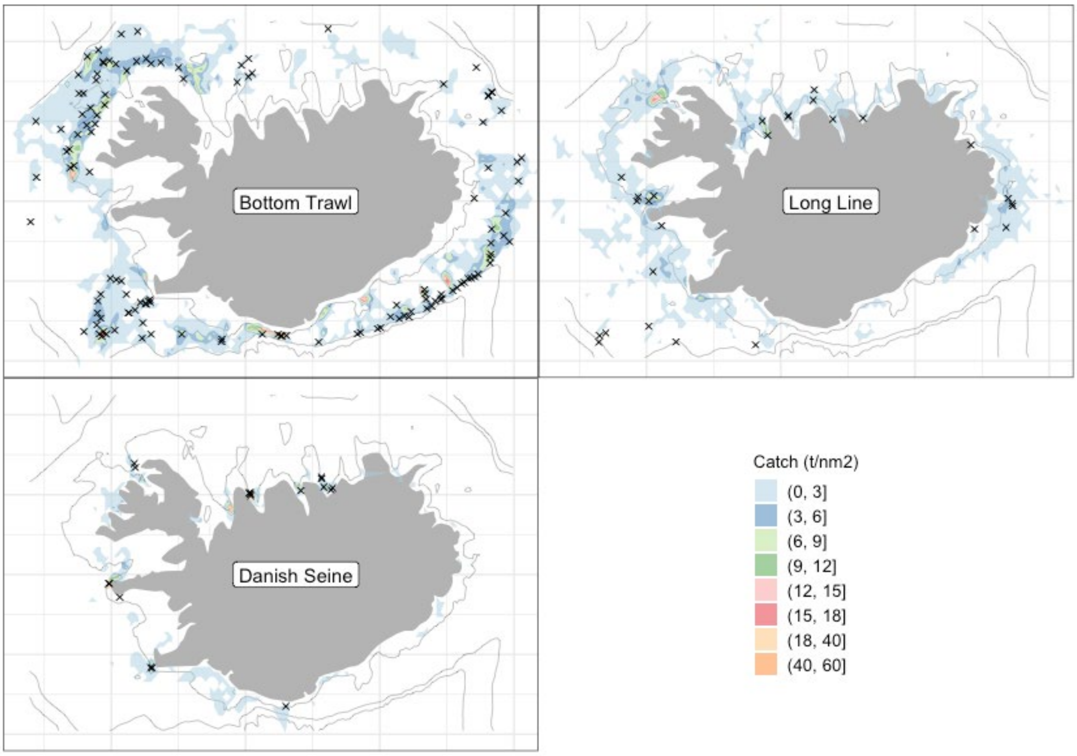

Figure 10.8. Haddock in 5.a. Fishing grounds last year as reported in logbooks (contours) and positions of samples taken from landings (crosses) by main gear types.

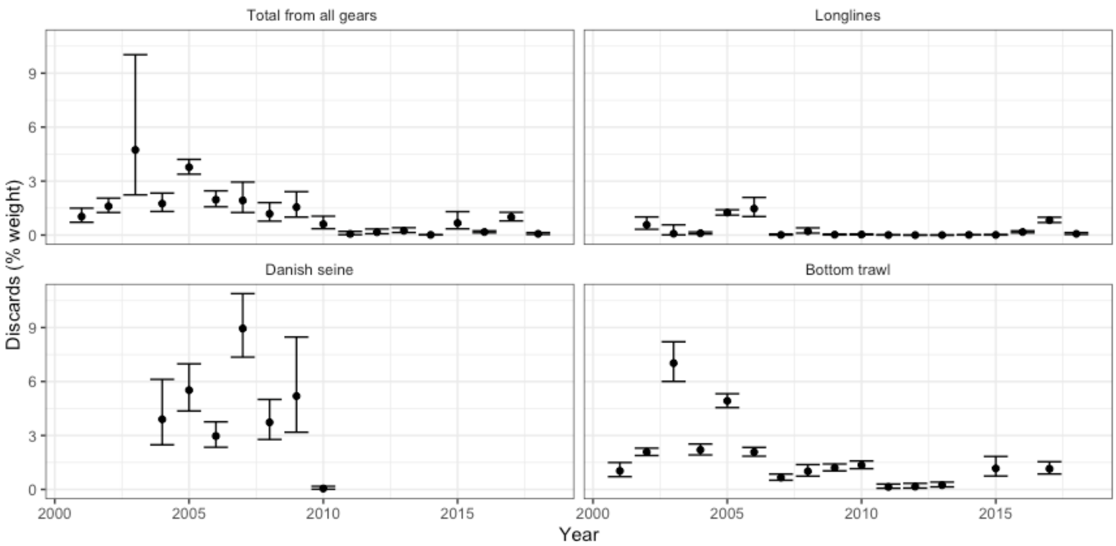

Figure 10.9. Haddock in 5.a. Estimates of annual discards by gear. Vertical lines indicate the 95 \% confidence interval while dots are the point estimates. No estimates are available since 2018.

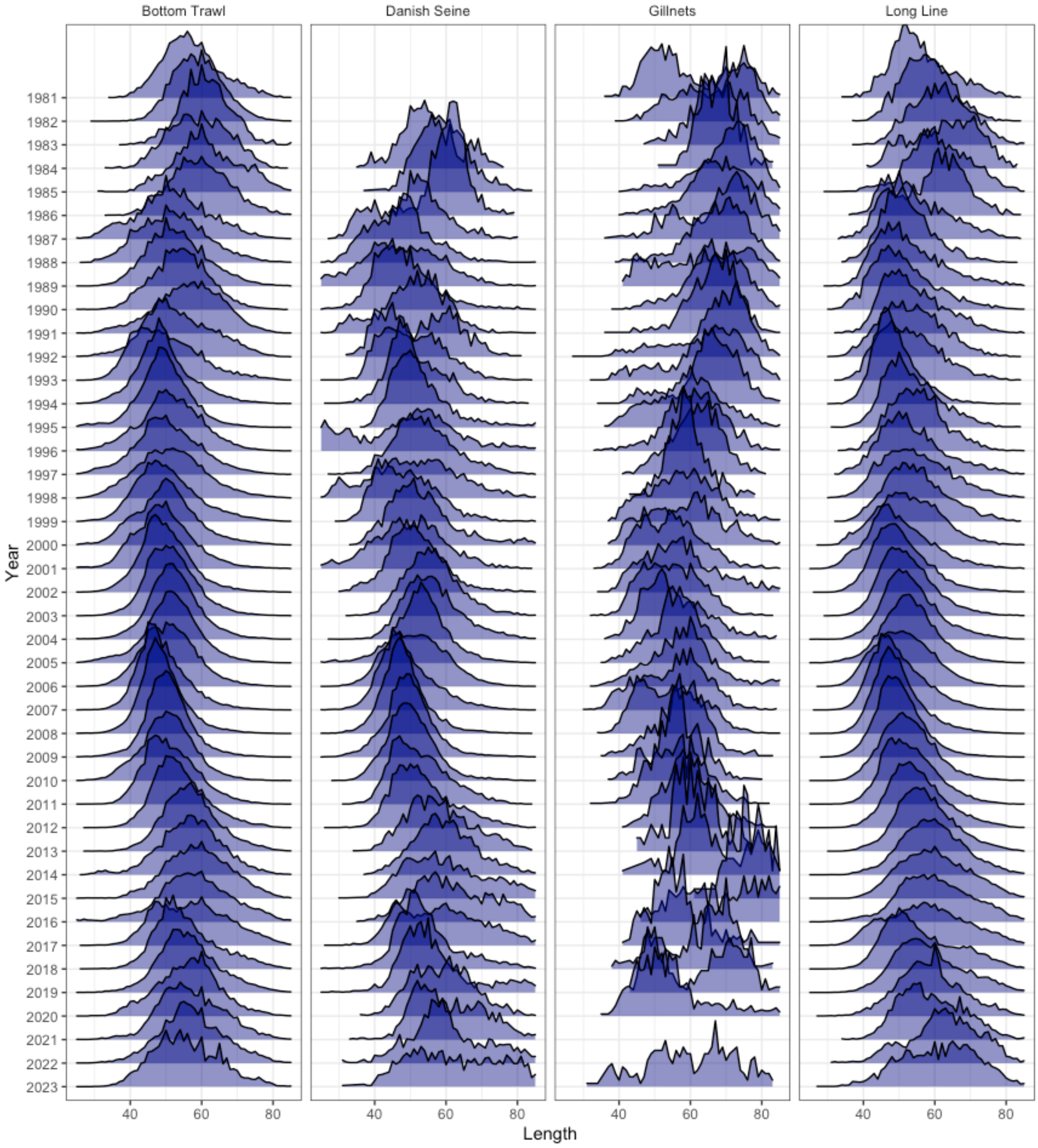

Figure 10.10. Haddock in 5.a. Commercial length distributions by gear and year

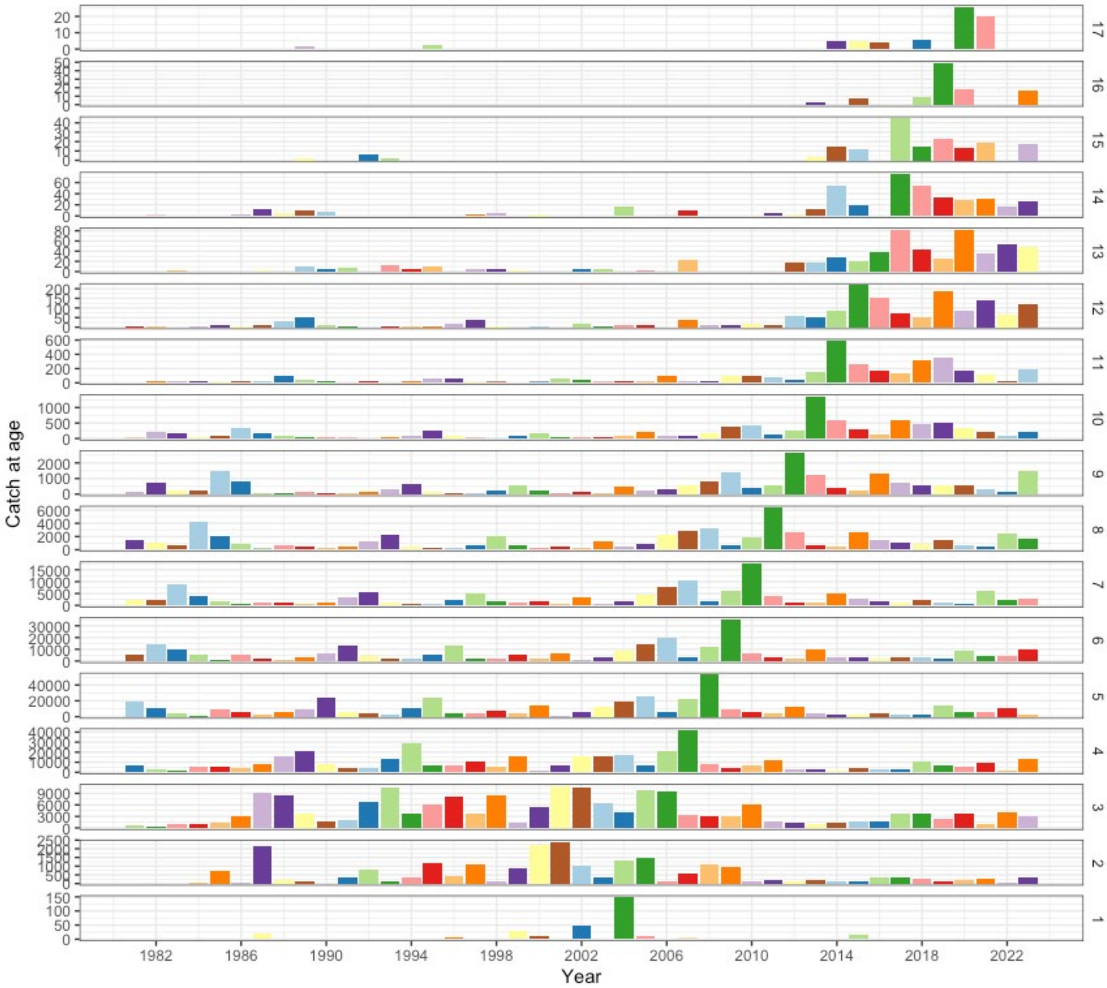

Figure 10.11. Haddock in 5.a. Catch-at-age from the commercial fishery in Iceland waters. Bar size is indicative of the catch in numbers and bars are colored by cohort.

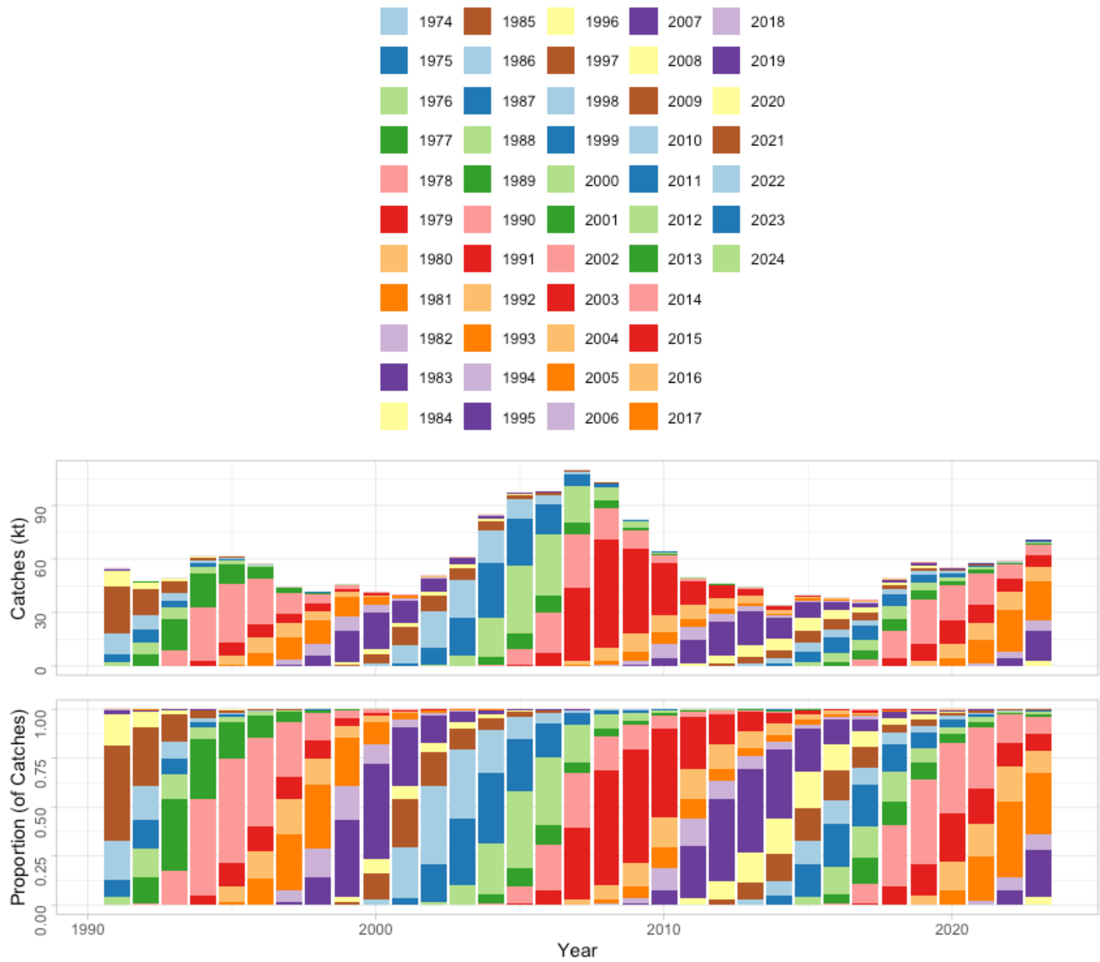

Figure 10.12. Haddock in 5.a. Catch-at-age from the commercial fishery in Iceland waters. Biomass caught by year and age, bars are colored by cohort.

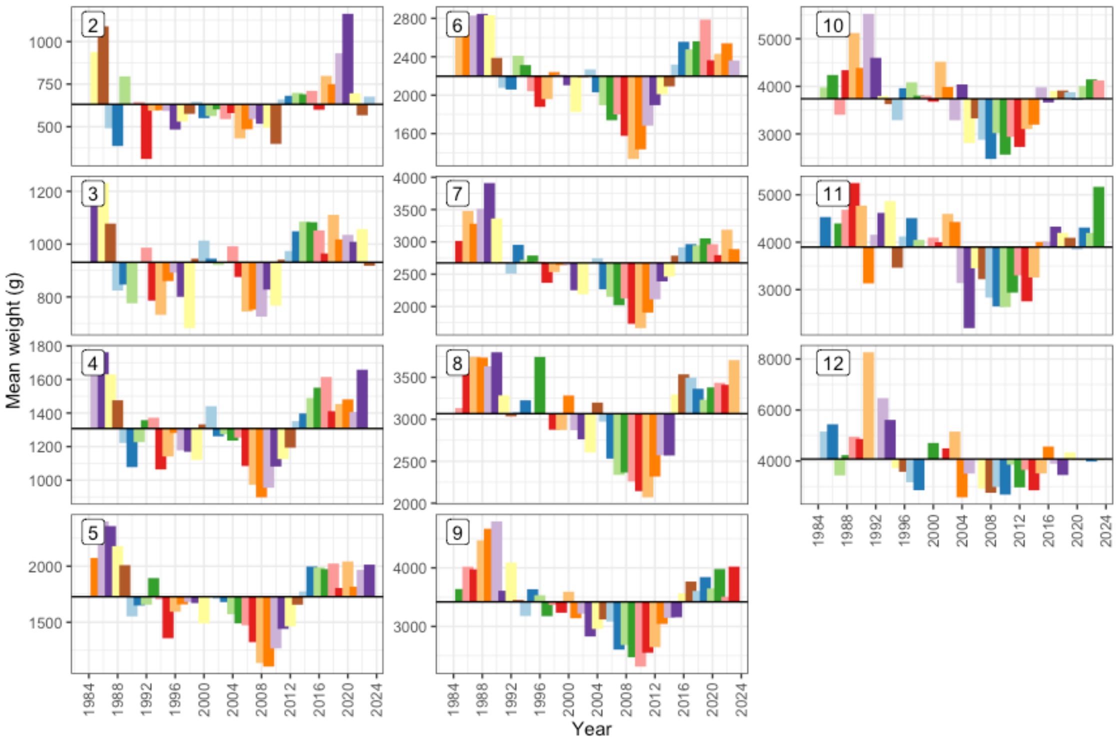

Figure 10.13. Haddock in 5.a. Mean weight at age in the catch from the commercial fishery in Icelandic Waters. Bars are coloured by cohort.

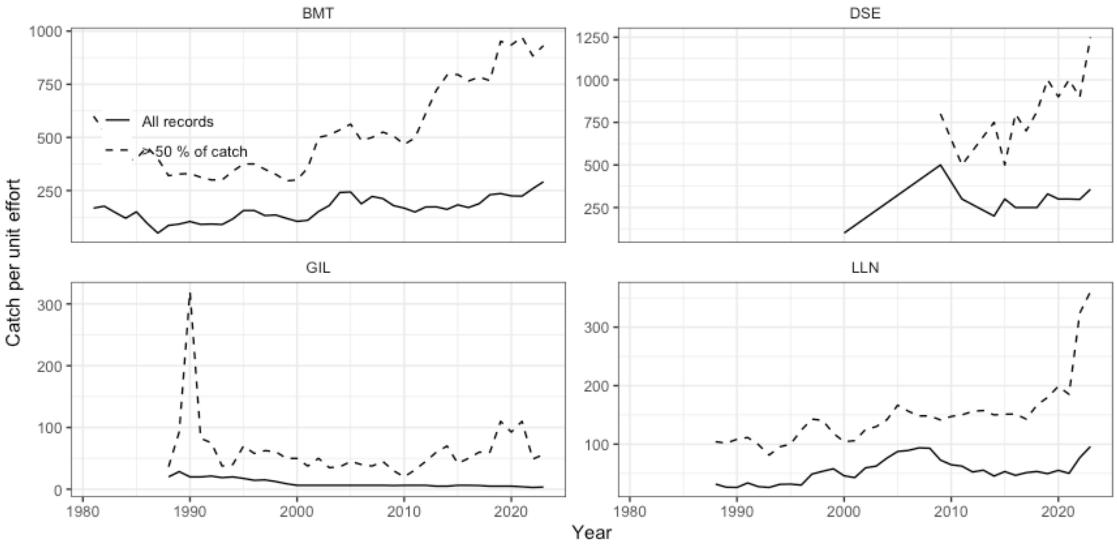

Figure 10.14. Haddock in 5.a. Catch per unit effort in the most important gear types. The dashed lines are based on locations where more than 50% of the catch is haddock and solid lines on all records where haddock is caught. A change occurred in the longline fleet starting September 1999. Earlier only vessels larger than 10 BRT were required to return logbooks but later all vessels were required to return logbooks. Effort data are not available for 2022.

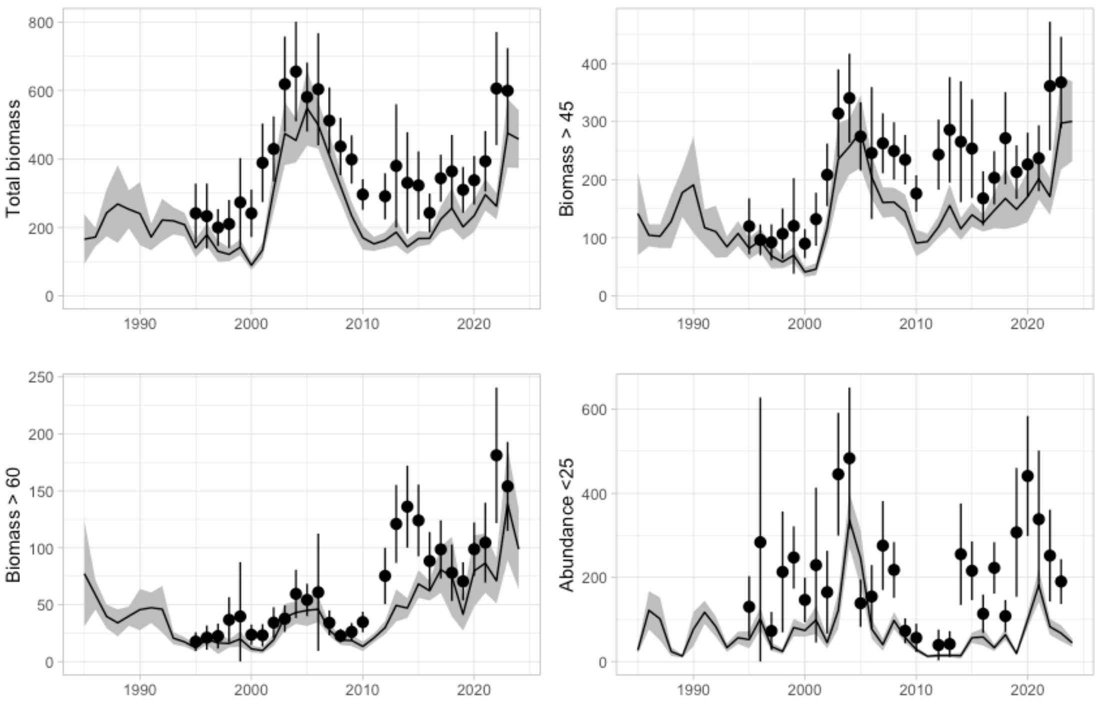

Figure 10.15. Haddock in 5.a. Indices (total biomass, biomass> 45 cm, biomass> 60 cm and abundance <25 cm) in the Spring Survey (March) 1985 and onwards (line shaded area) and the autumn survey (point ranges).

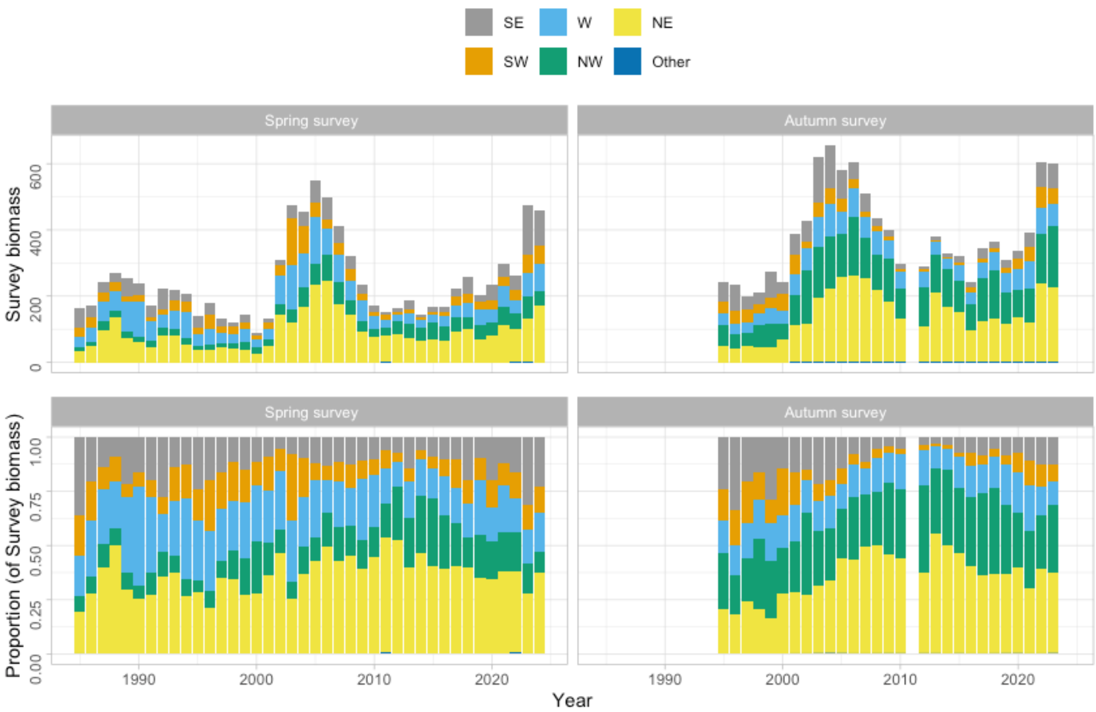

Figure 10.16. Haddock in 5.a. Changes in geographical distribution of the survey biomass.

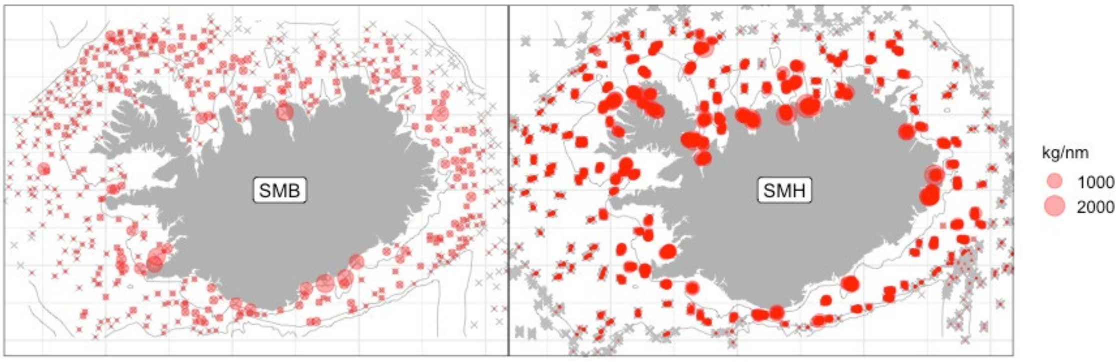

Figure 10.17. Haddock in 5.a. Location of haddock in the most recent March (SMB) and the Autumn (SMH) surveys, bubble sizes are relative to catch sizes, and crosses indicate stations where no haddock was observed.

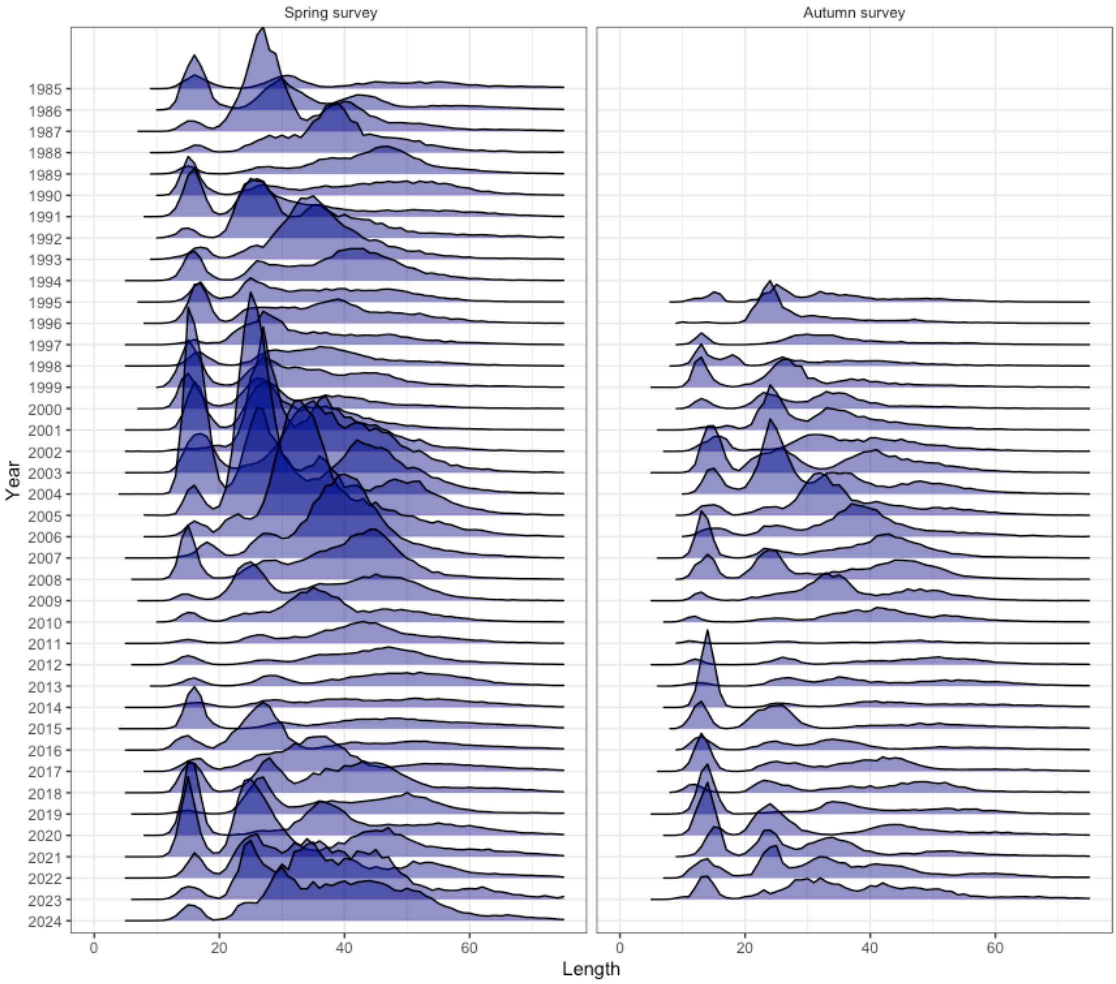

Figure 10.18. Haddock in 5.a. Length disaggregated abundance indices from the March survey 1985 and onwards.

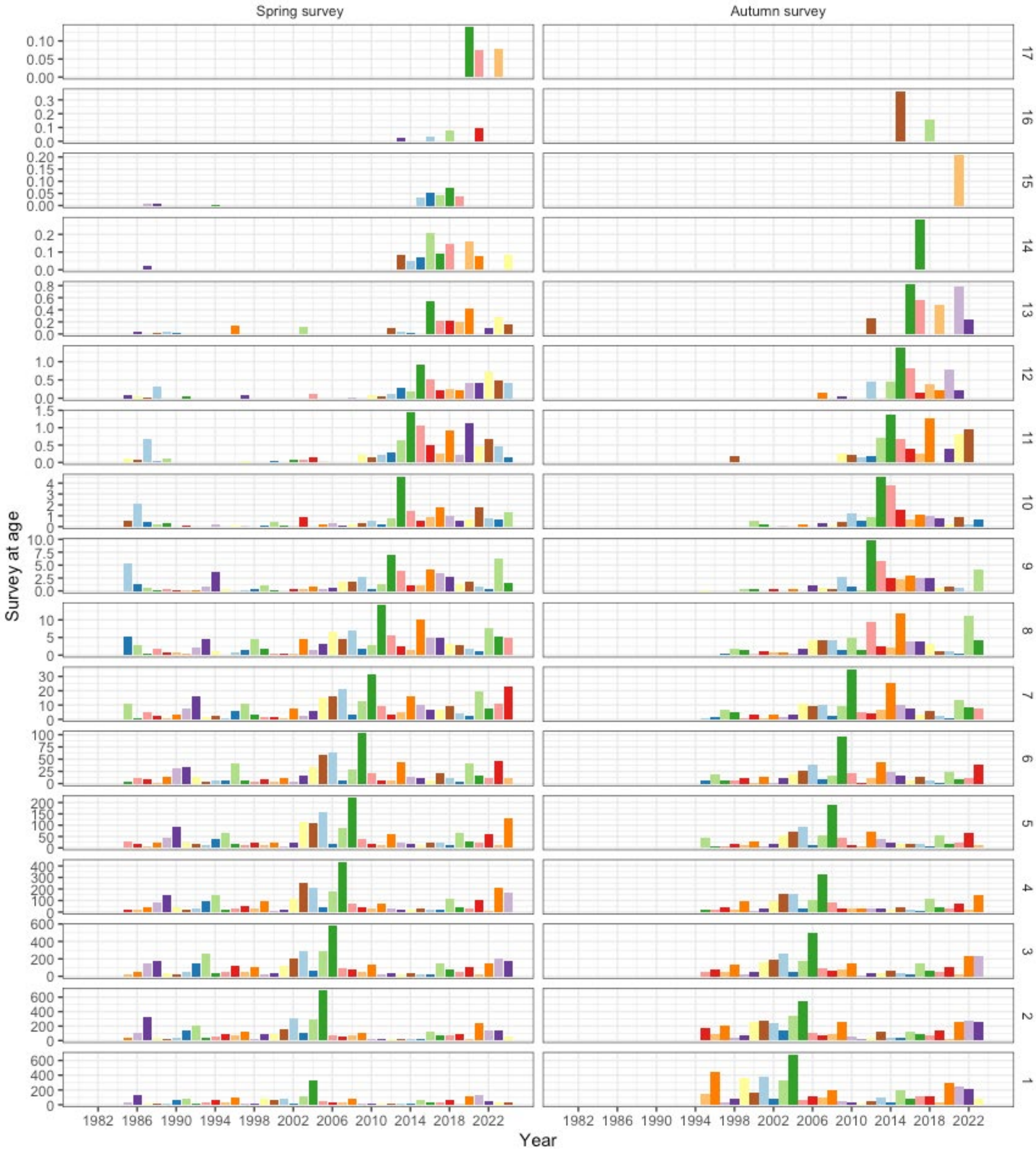

Figure 10.19. Haddock in 5.a. Age disaggregated indices in the Spring Survey (left) and the autumn survey (rights). Bars indicated the deviation from the log mean index, fill colors indicate cohorts. Note different scales on y-axes.

Figure 10.20. Haddock in 5.a. Stock weights from the March survey in Icelandic Waters. Bars are coloured by cohort.

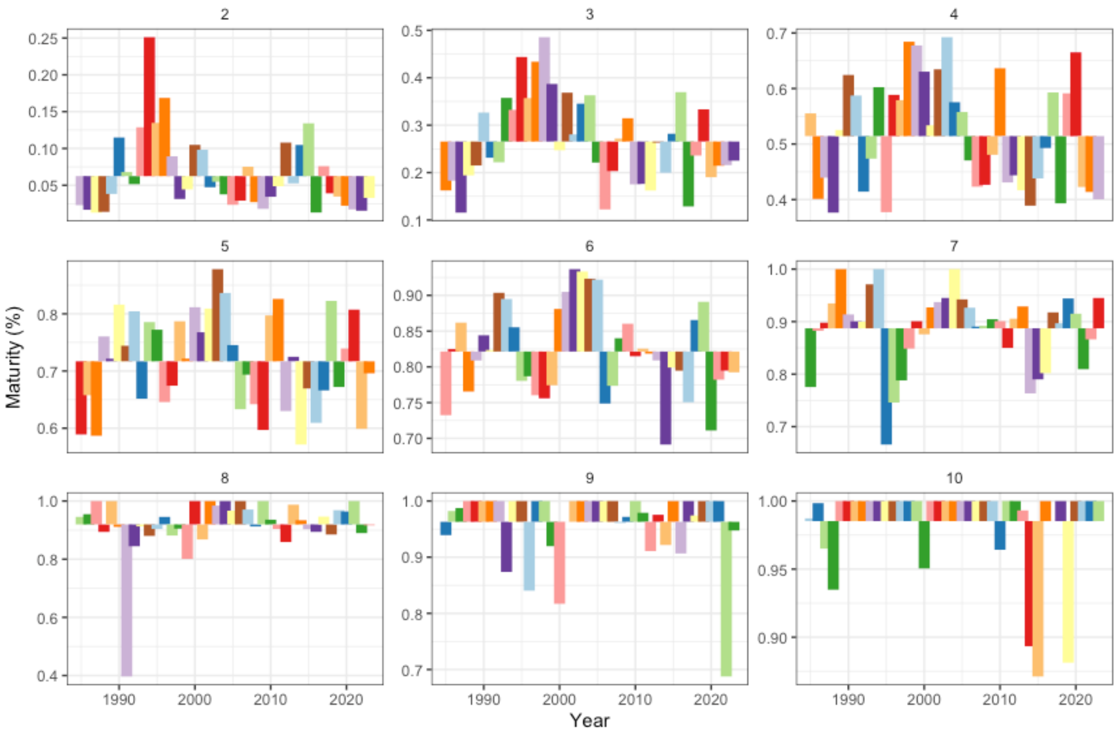

Figure 10.21. Haddock in division 5.a. Maturity-at-age in the survey. Bars are colored by cohort. The values are used to calculate the spawning stock.

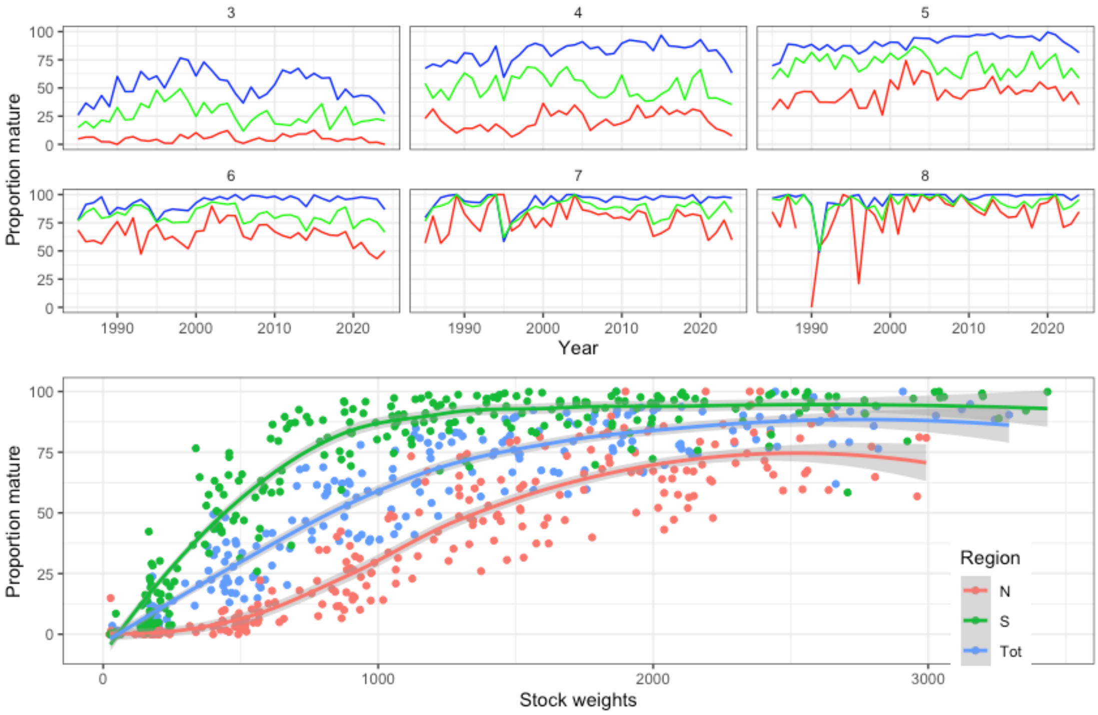

Figure 10.22. Haddock in 5.a. Geographical differences in proportion mature by year and age (top), and stock weights (below).

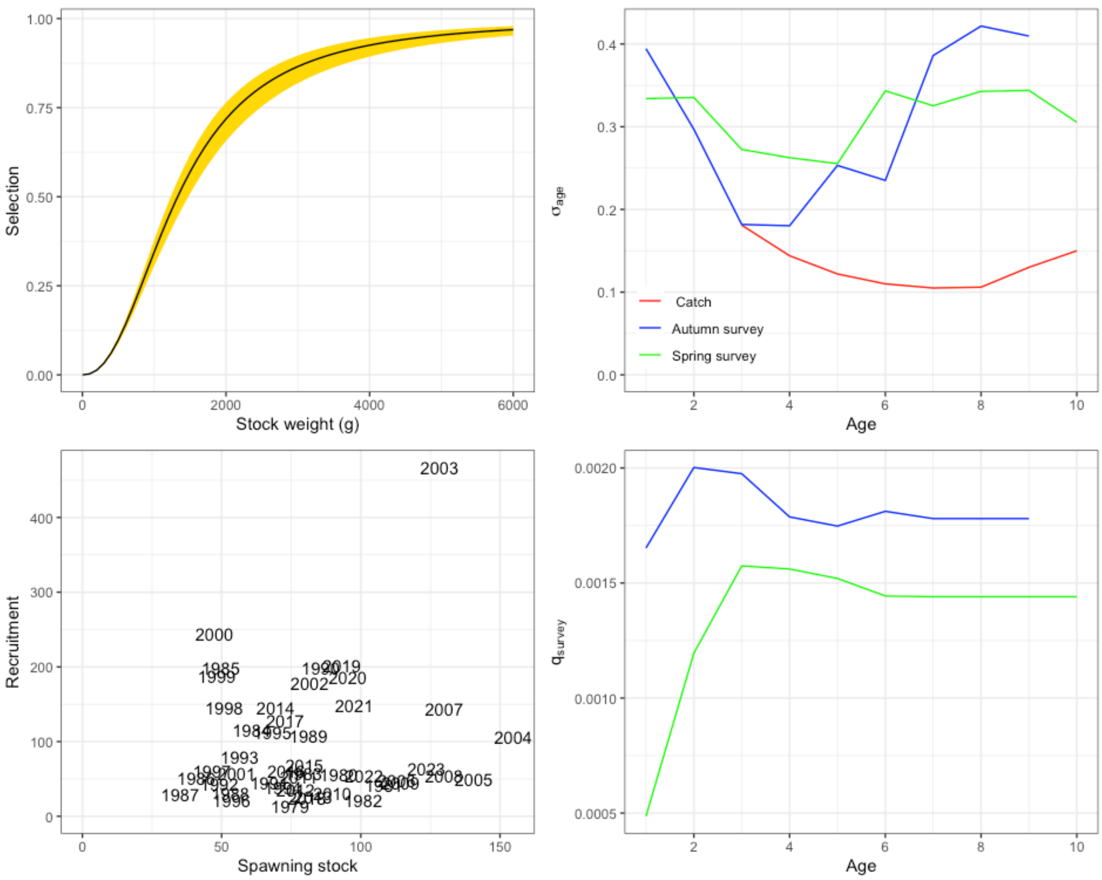

Figure 10.23. Haddock in 5.a. Estimated selection by weight, CV pattern, stock recruitment relationship and survey catch-ability.

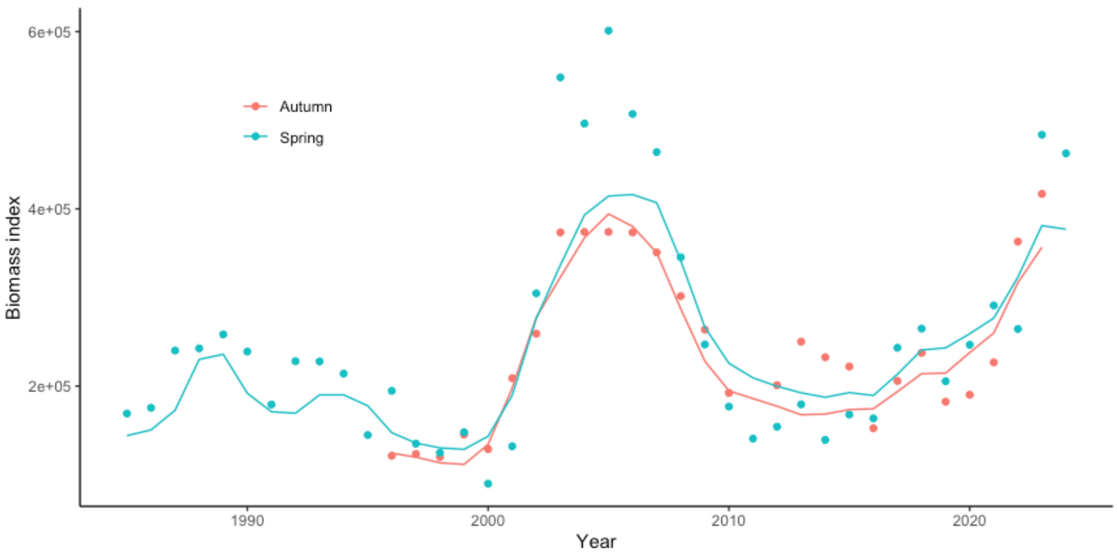

Figure 10.24. Haddock in division 5.a. Aggregated model fit to the total biomass indices. Note that residual correlation is estimated (see text for further details).

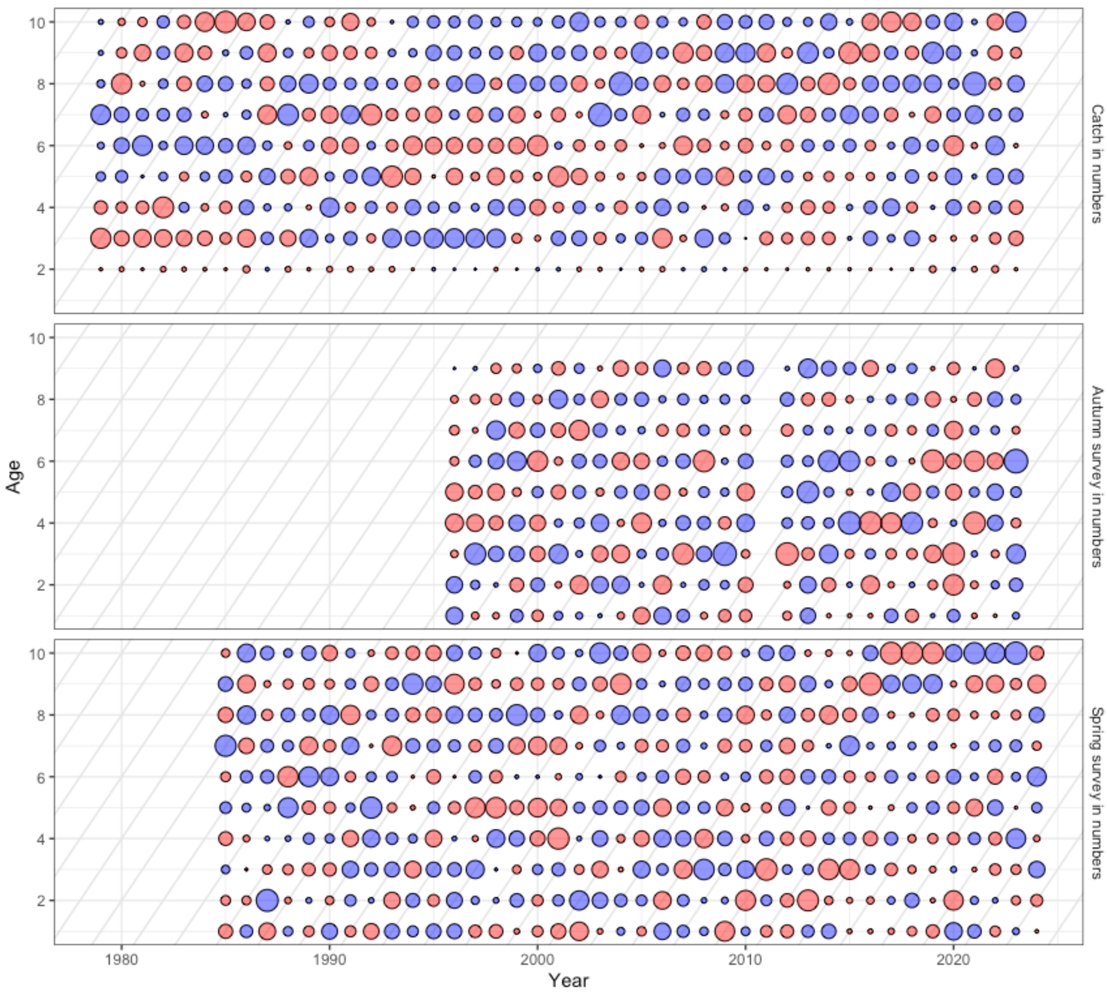

Figure 10.25. Haddock in division 5.a. Residuals from the model fit to survey and catch databased on the both the surveys. Red circles indicate negative residuals (observed < modelled), while blue positive. Residuals are proportional to the area of the circles.

Figure 10.26. Haddock in division 5.a. Summary from assessment. Dashed vertical line indicates the assessment year and yellow shaded region the uncertainty as estimated by the model.

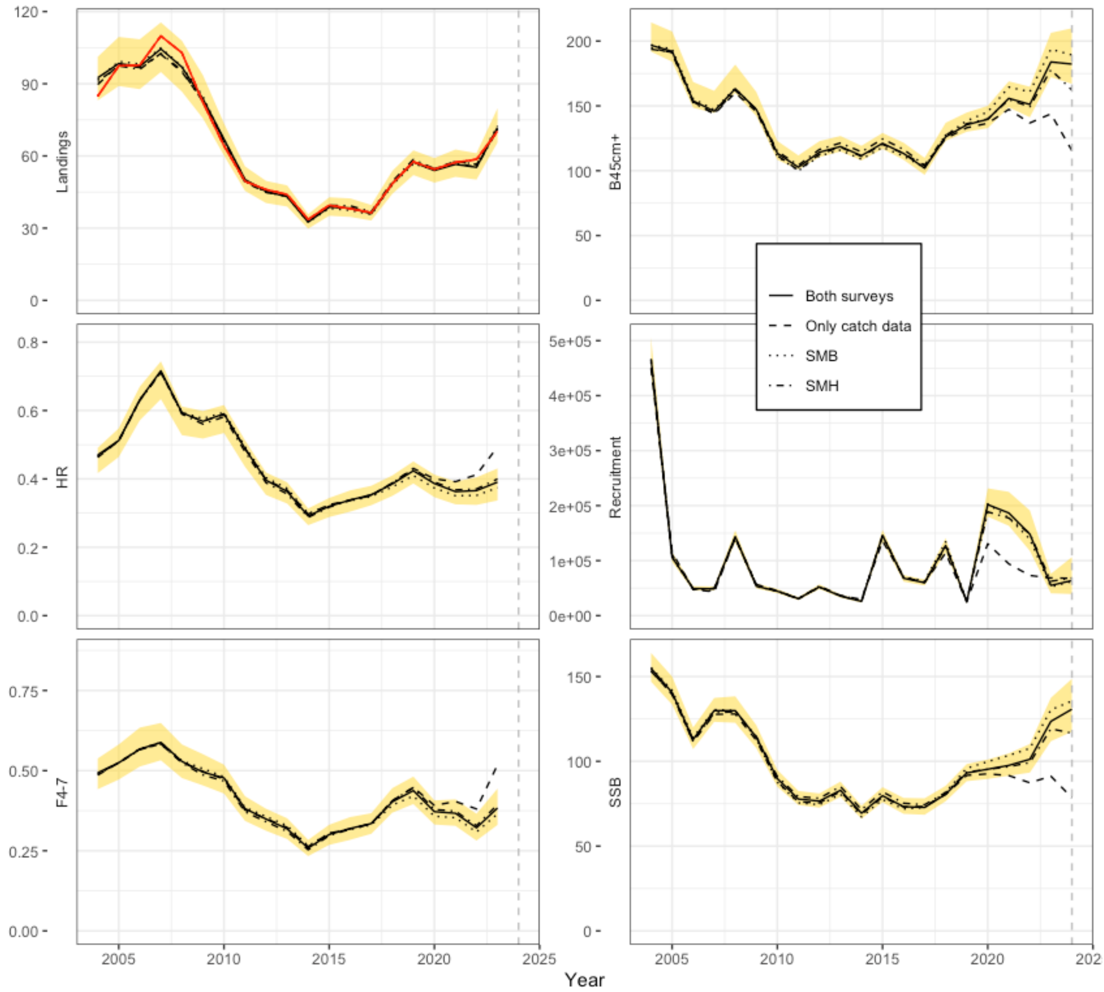

Figure 10.27. Haddock in 5.a. Comparison of assessment results where either the spring survey or the autumn survey is omitted from the estimation.

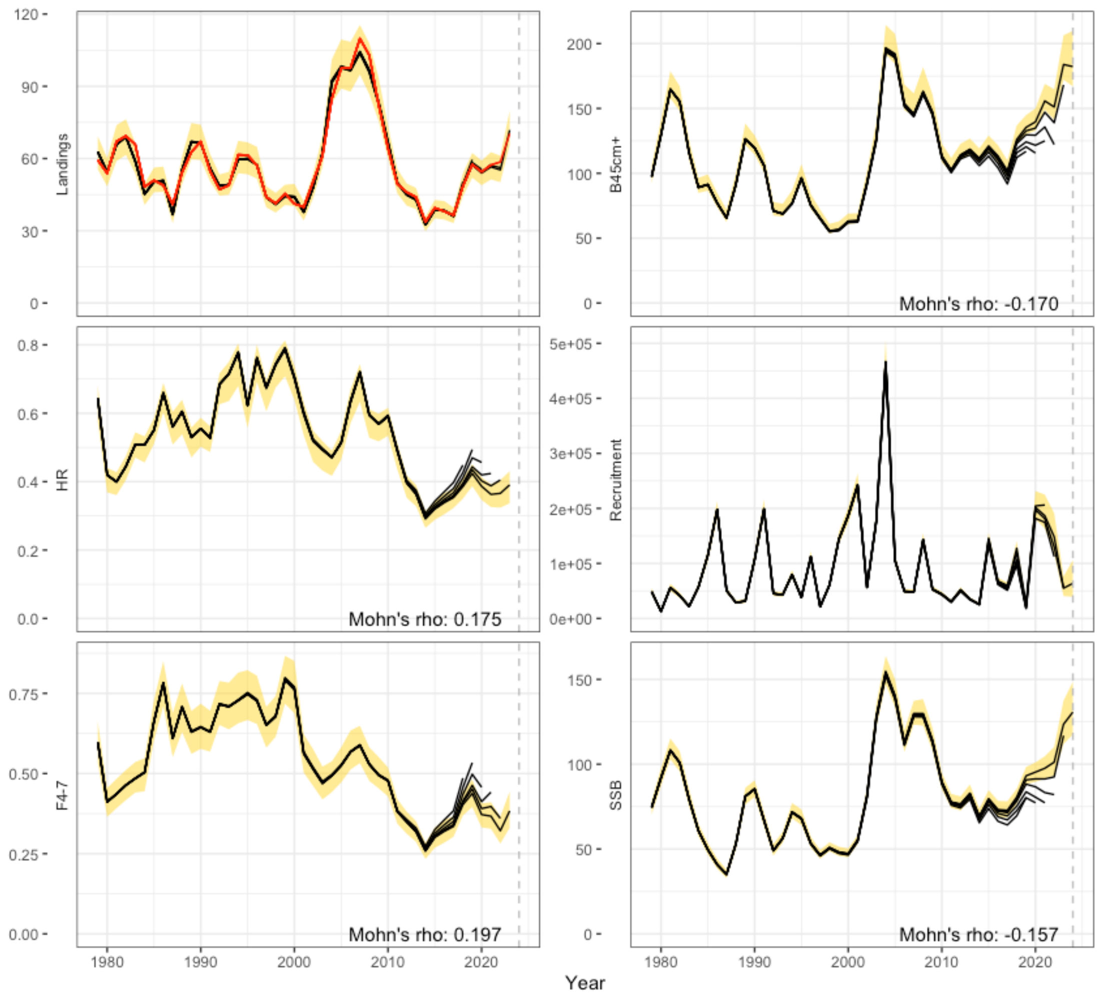

Figure 10.28. Haddock in division 5.a. Analytical retrospective analysis of the assessment of haddock with a 5 year peel.

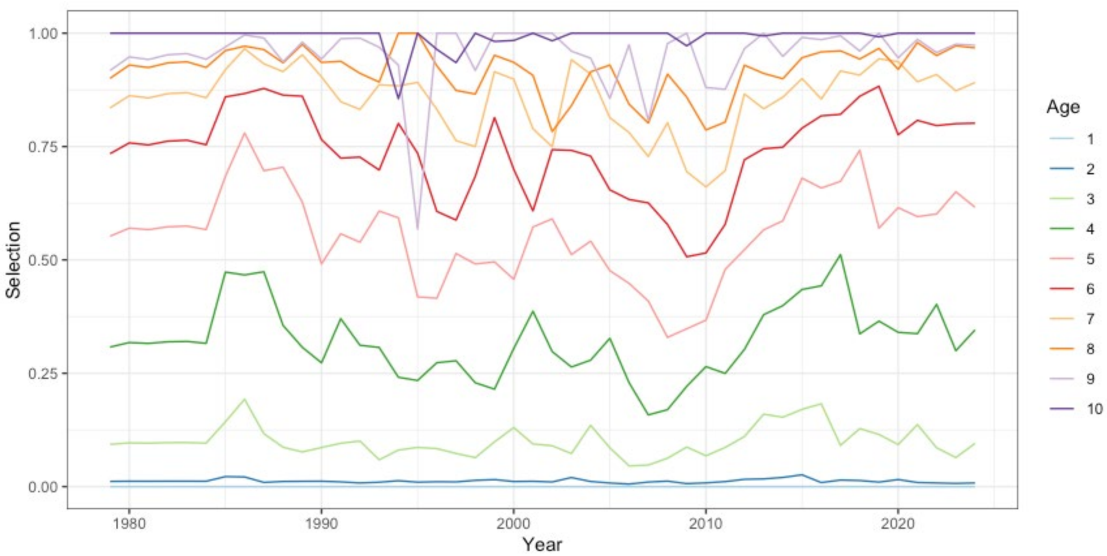

Figure 10.29. Haddock in 5.a. Estimated selection at age.

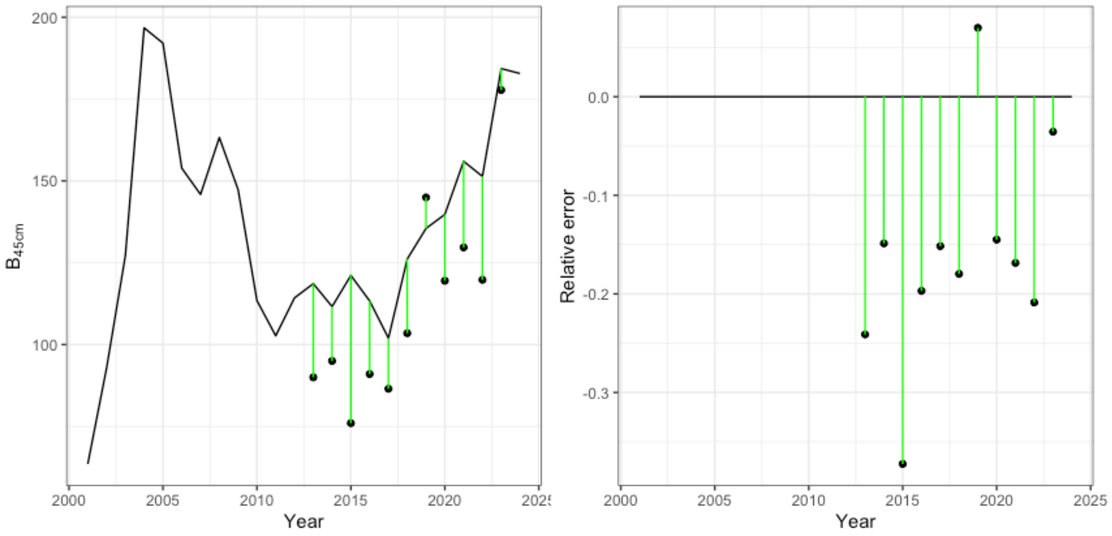

Figure 10.30. Haddock in 5.a. Comparison of the short-term prediction of reference biomass to the realized value a year later.

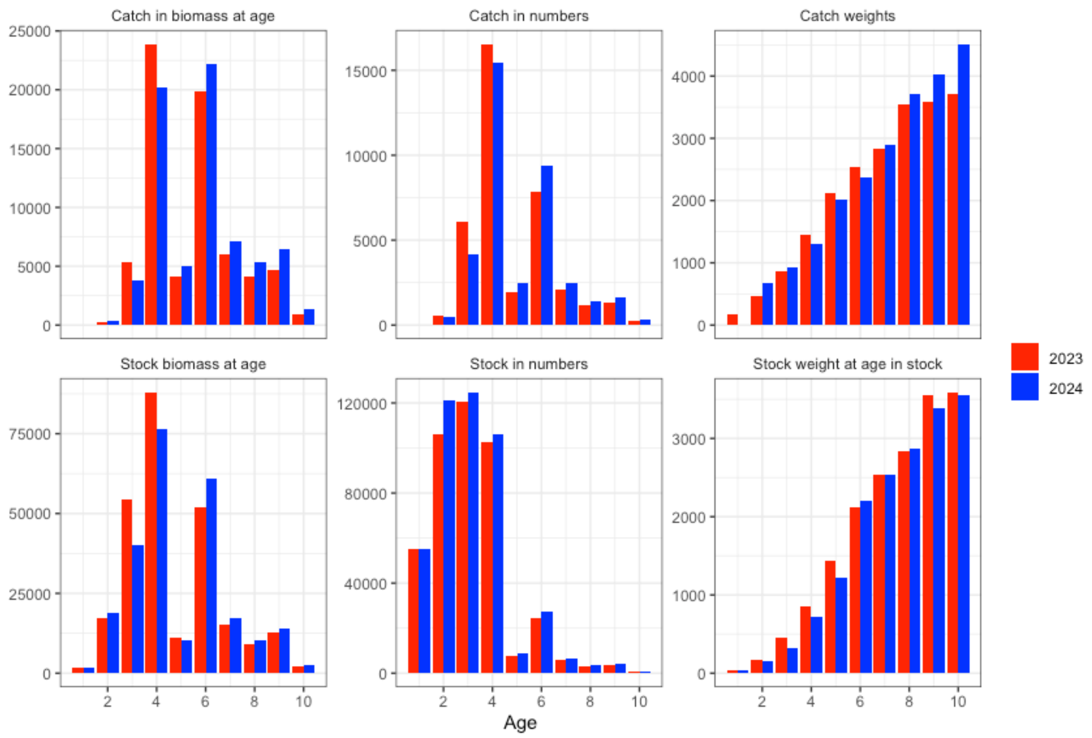

Figure 10.31. Haddock in 5.a. Comparison of some of the results of last year's assessment based on different tuning data and current assessment tuned with both the surveys.

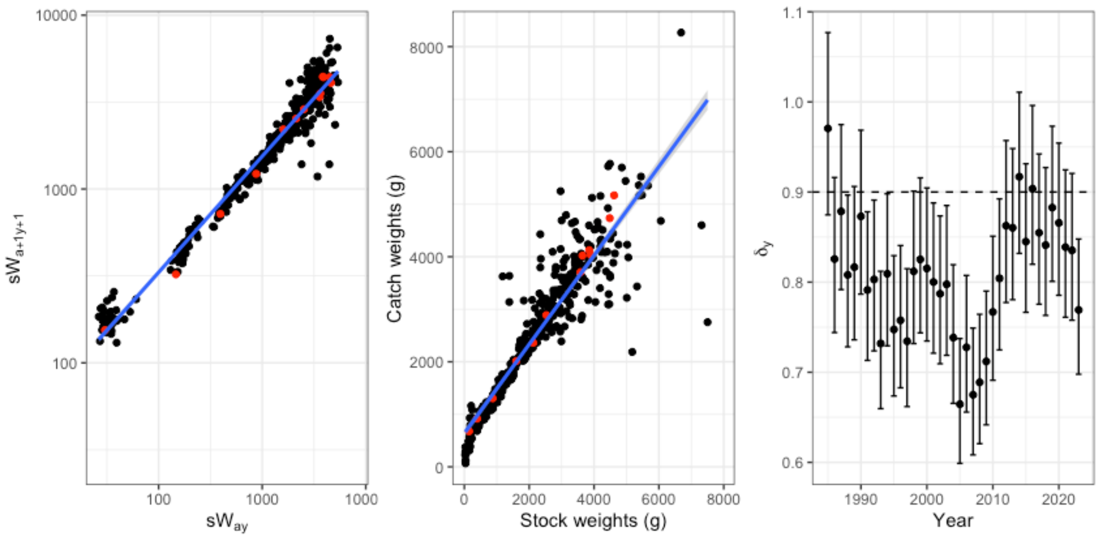

Figure 10.32. Haddock in 5.a. Input data to the prediction model, where the exponent of the year factor (growth multiplier) is estimated to derive the reference biomass in the advisory year, as described in the text.

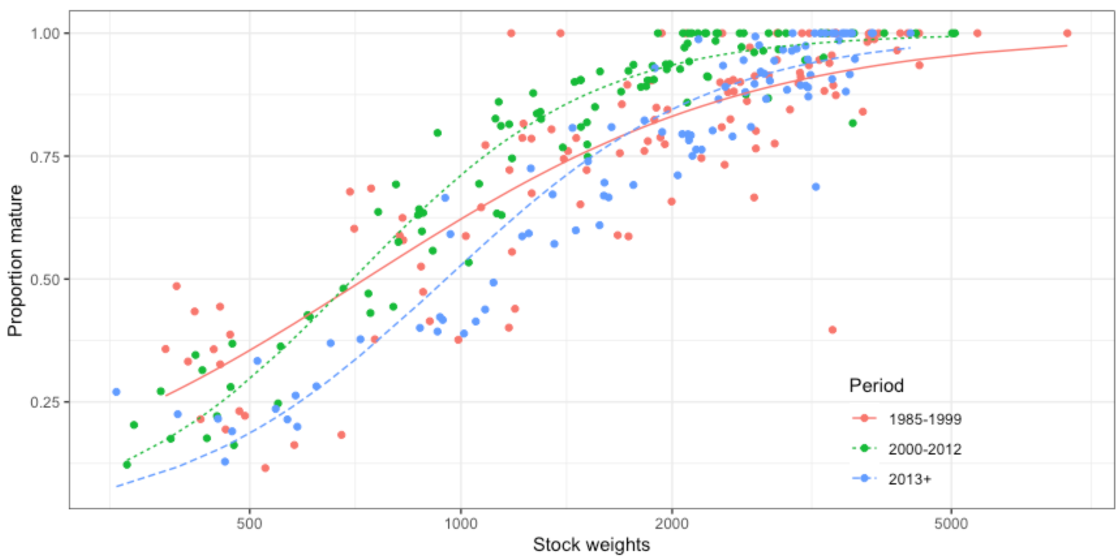

Figure 10.33. Haddock in 5.a. Maturity at weight as used in the projections.

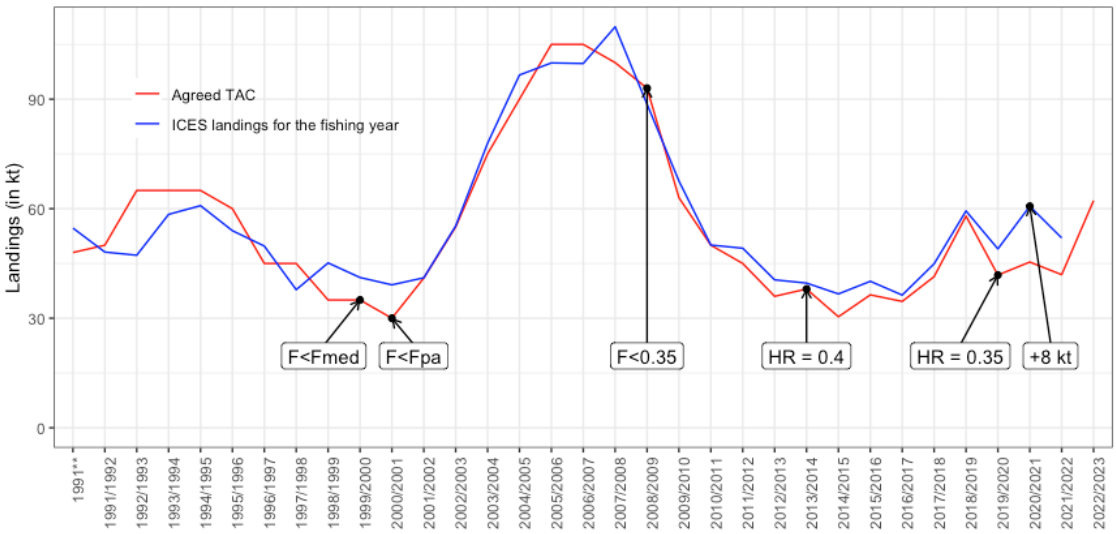

Figure 10.34. Haddock in 5.a. Comparison of the realized catches and the set TAC for the fishing operations in Icelandic Waters. Note that in the 1999/2000 fishing year the government of Iceland increased TAC mid-season

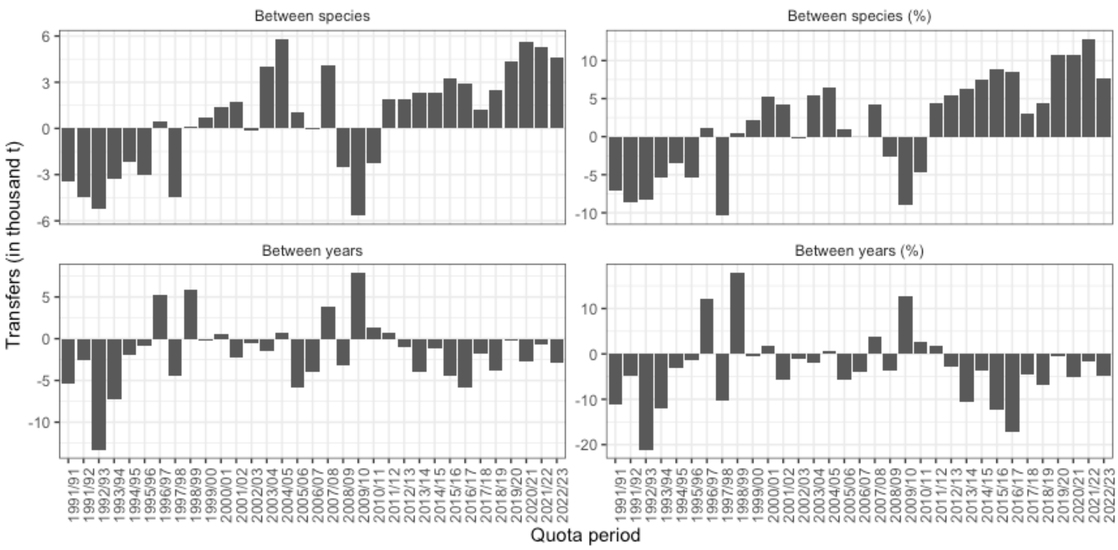

Figure 10.35. Haddock in 5.a. An overview of the net transfers of quota between years and species transformations in the fishery in 5.a.

11 Iceland grounds summer-spawning herring

her.27.5a – *Clupea harengus* in Division 5.a

11.1 Scientific data

11.1.1 Survey description

The scientific data used for assessment of the Icelandic summer-spawning (ISS) herring stock derives from annual acoustic surveys (IS-Her-Aco-4Q/1Q), which have been ongoing since 1973 (Table 11.1.1.1). These surveys are conducted in the period of October–January and March-April. The surveyed area each year is decided based on available information on the distribution of the stock in the previous and the current year, which include information from the fishery. Thus, the survey area varies spatially as the survey is focused on the adult and incoming year classes but is usually considered to cover the whole stock each year. However, in the winter 2023/2024 the autumn survey did not manage to cover the recently growing portion of the stock that resides in the east and are therefore lacking from the survey index. The reason for this unsuccessful survey is due to increasing ISSH and Norwegian spring-spawning herring (NSSH) mixing in the east of Iceland in recent years. To separate the measurements of the stocks, the autumn survey was delayed by several weeks in hopes that the NSSH had migrated out of Icelandic Waters and ISSH would remain in the area. When surveying the area, no herring was found in the east and it is assumed that the ISSH component accompanied the NSSH migrating east, at least to some extent. The autumn survey also targets juvenile herring on the south coast of Iceland, and this also resulted in no herring observed. However, a later survey targeting migrating capelin in February, did successfully measure herring juveniles in the southeastern areas and results from that survey were used for the assessment. Further details about the surveys can be found in a NWWG working document (Bjarnason, 2024).

Thus, the acoustic index for adult part of the Icelandic summer-spawning herring in winter 2023/2024 derives from one dedicated survey on RV Bjarni Sæmundsson in the end of March 2024 (B4-2024) and from a capelin survey (AH3-2024 and AMM3-2024) in the southeast of Iceland in February 2024.

In addition to getting an acoustic estimate on the adult part and on juveniles at age 2 (juvenile survey for age 1 was not conducted in the year 2023), the objective was also to get an estimate of the prevalence of *Ichthyophonus* infection in the stock. The instrument and methods in the surveys were the same as in previous years. The biological sampling in the survey is detailed in Table 11.1.1.2.

11.1.2 The survey results

The fishable part of the Icelandic summer-spawning herring stock was observed only in one area, west of Iceland in Kolluáll/Snæfellsnes in the end of March 2024 (Figure 11.1.2.1). The total acoustic estimate came to 2.51 billion in numbers and the total biomass index was 432 kt (Table 11.1.1.1). The fishable part of the stock (≥ 27 cm) accounted for 60% in number and 88% of the biomass, or 380 kt.

The annual survey aiming for the abundance of herring juveniles east and southeast of Iceland took place in November 2023 and was unsuccessful as stated above. An acoustic survey targeting capelin was conducted in February 2024 on the continental slope of southeast Iceland in the same areas as the autumn survey where juvenile herring was measured and the results from that survey was used (Figure 11.1.2.1). A considerable part of the adult herring stock was therefore not measured this year.

A widespread ichthyophoniasis epizootic infection has been occurring in ISS-herring since 2008. This is caused by the parasite *Ichthyophonus* sp. Results of comprehensive analyses for the period 2008–2014 imply that significant infection mortality took place in the first three years after the outbreak started (2009–2011) but not the years after (2012–2016; Óskarsson *et al.*, 2018b). The level of the mortality was estimated with series of runs of the NFT-Adapt assessment model, which gave the best fit to the data when applying infection mortality equivalent to 30% of the infected herring (heart inspection and survey abundance estimates provided $M_{infected}$) died annually in the first three years of the outbreak ($M_{year, age} = M_{fixed} + M_{infected, year, age} \times 0.3$; Table 11.3.2.1). Also, the separate model run in the assessment, Muppet, estimated the *Ichthyophonus* multiplier and it was very close to 0.3 (the value used in the assessment).

As a part of the 2024 WKICEHER workshop assessment (ICES 2024), the infection mortality was estimated by the Muppet model in a similar way as done by Óskarsson et al. (2018b). That model had been used previously also and returned the same multiplier as NFT-Adapt, or 0.3. The multiplier was estimated for the whole time-series (2008-2023) on basis of the interannual estimates of infection prevalence by the different age groups. Different from the previous estimation, the infection mortality was assumed to have taken place in all years, also in the years 2012-2016. This was considered appropriate because thorough inspection on development of the infection stages and prevalence of the infection has not been done for recent years. It means that instead of a sort of subjective approach, a simpler approach was taken. The resulting multiplier for the years 2008-2023, and for the coming years until revised again, is 0.22. The revised M for the stock is provided in Table 11.3.2.1.

The prevalence of the *Ichthyophonus* infection in the stock in 2023/24 was estimated in a same way as has been done since the initiation of the infection in the autumn 2008 (Óskarsson and Pálsson, 2018). The prevalence of infection shows a declining trend for all age classes for the past decade. The infection rate for the younger year classes (age 2-5) seems to be low, or <3.7% in the west (Figure 11.1.3.1.) There are still new infections taking place as seen with the younger ages, so infection mortality is assumed to take place in 2024, like in previous years. Thus, in the stock prognosis (Section 11.6), the abundance estimates from the final year of the assessment (1 January 2024) is lowered by this additional M as done in assessments for the past years. The level of M should then follow the results of the WKICEHER workshop (2024), where age specific $M_{infected}$ (estimated from the catch samples; Figure 11.1.3.1) is multiplied by 0.22 and the fixed M (0.1) added to it. The M for 2023 (Table 11.3.2.1) should be used in the prognosis in 2023 and in the analytical assessment from 2023 and onwards, until better more reliable estimates become available.

11.2 Information from the commercial fishery

The total landings of ISS herring in 2023/2024 season were 94 422 t including the summer catches in 2023 with no discards reported (Table 11.2.1 and in Figure 11.2.1). Including the summer catches in the subsequent fishing season, as done here, is a traditional handling of the catch data when assessing this stock. The quality of the herring landing data regarding discards and misreporting are consider adequate as implied in the Her-Vasu stock annex.

The recommended TAC for 2023/2024 fishing season (1 September–31 August; ICES, 2018) and TAC (Regulation No. 672, 2 July 2020) was 92.6 kt (Table 11.2.1). Officially, according to the Directorate of Fisheries (www.fiskistofa.is/veidar/aflaupplysingar/heildaraflamarksstada/), 1.8 kt had been caught in April 2024, above the TAC, but within the allowed limit due to transfer of quota between seasons.

The direct fishery in offshore areas west of Iceland in October-December contributed 69.1% (65 kt) of the total catches (Figure 11.2.2). The remaining 29.8% (28 kt) of the catch was taken in September-October in the east and the final 1.1% (1.5 kt) as bycatch in the fishery also in the east in June-August or limited summer fishery in the south (Figure 11.2.2).

11.2.1 Fleets and fishing grounds

The herring fishing season has taken minor changes in the last three decades as detailed in the stock annex. All seasonal restricted landings, catches and recommended TACs since 1985 are given in thousands of tonnes (kt) in Table 11.2.1.

All the catch in 2023/2024 was taken in pelagic trawls (Figure 11.2.1), which reflects that both the targeting and bycatch fisheries. During all fishing seasons from 2007/2008 to 2012/2013, most of the catches (~90%) were taken in inshore areas west off Iceland in Breiðafjörður, while prior to that they were mainly taken off the south-, southeast-, and the east coast. In 2013/2014 there was an indication for change in this pattern, with less proportion in Breiðafjörður, and then in 2014/2015 almost all the overwintering west of Iceland took place offshore, which has continued since. These changes in the stock distribution explain the dominance of pelagic trawl in the fishery, which is preferred by the fleet over purse-seine in offshore areas.

To protect juvenile herring (27 cm and smaller) in the fishery, area closures are enforced based on a regulation of the herring fishery set by the Icelandic Ministry of Fisheries (no. 376, 8 October 1992). No closure was enforced in this herring fishery in 2023/24. Normally, the age of first recruitment to the fishery is age-3, which is fish at length around 26–29 cm.

11.2.2 Catch in numbers, weight at age and maturity

Catch-at-age in 2023/2024:

The procedure for the catch-at-age estimations, as described in the Stock Annex, was followed for the 2023/24 fishing season. It involves calculations from catch data collected at the harbours by the research personnel (0%) or at sea by fishers (100%). This year, the calculations were accomplished by dividing the total catch into three cells confined by season and area. In the same way, weight-at-length relationships derived from the length and weight measurements of the catch samples were used. Based on difference in length-at-age, two length-age keys were applied. The catches of the Icelandic summer spawners in number-at-age for this fishing season as well as back to 1975 are given in Table 11.2.2.1. The geographical location of the catch and sampling in 2023/2024 is shown on Figure 11.2.2.

Weight at age:

As stated in the stock annex, the mean weight-at-age of the stock is derived from the catch samples (Table 11.2.2.2).

Proportion mature:

The fixed maturity ogives were used in this year’s assessment, as described in detail in the stock annex, where proportion mature-at-age 3 is set 20% and 85% for fish at age 4, while all older fish is considered mature.

11.3 Analytical assessment

11.3.1 Analysis of input data

Examination of catch curves for the year classes from 1989 to 2018 (Figure 11.3.1.1) indicates, in general, that the total mortality signal (Z) in the fully recruited age groups is around 0.4. It is under the assumption that the effort has been the same the whole time. In recent years the effort has changed a lot because of the infection and spatial distribution of the stock, and the mass mortality in 2012/2013, which makes any strong inference from the catch curves for those recent years less meaningful.

Catch curves were also plotted using the age disaggregated survey indices for each year class from 1989–2018 (Figure 11.3.1.2). Even if the total mortalities look at bit noisy for some year classes, they seem to be close to 0.4. There is an indication that the fish is fully assessable to the survey at age 3–5.

Increased mortality in the stock because of the *Ichthyophonus* outbreak cannot be detected clearly from the catch curves of the surveys. However, considering that F was reduced drastically at the beginning of the outbreak, similar Z means an increased M during that period, representing infection mortality.

11.3.2 Assessment

In accordance with the recommendation from the 2024 WKICEHER workshop (ICES, 2024), a statistical catch-at-age model was adopted for the 2024 assessment and the reference points were updated. The model is based on catch data from 1980–2023 (Table 11.2.2.1) and survey data from 1987-2023 (Table 11.1.1.1). Input data were not treated as a plus group. Other input data consisted of: (i) mean weight at age (Table 11.2.2.2); (ii) maturity ogive (Table 11.2.2.3); (iii) natural mortality, M, that was set to 0.1 for all age groups in all years, except for 2009–2023 where additional age dependent mortality was applied because of the *Ichthyophonus* infection (see Section 11.1.3; Table 11.3.2.1); (iv) proportion of M before spawning was set to 0.5; and (v) proportion of F before spawning was set to 0. Model setup and settings are described in the Stock Annex.

11.3.2.1 Model diagnostics.

Fits to the catch data and acoustic survey numbers-at-age indices can be found in Figure 11.3.2.1 and Figure 11.3.2.2. Catch data follow reasonably well with the model but younger age groups (<5) are not as well described by the model as the older age groups. For the herring survey data, the model fit is best for age groups 4-13 and gets noticeably better in later years.

Observation error residuals (Figure 11.3.2.3) for the herring acoustic survey are generally higher in the period 2000-2010 than other parts of the dataseries, underlining the inaccuracies in the survey at that time. Positive residuals, where the model estimates are smaller than seen in the survey, can be seen for 1994- and 1999-year classes for almost all age groups and negative residuals for the 2001- and 2003-year classes. Year blocks of positive residuals are apparent for the years ~2000 to 2006 (i.e. referring to 1 January). During these years, the stock was overwintering in offshore areas off the east and west coast, compare to mainly easterly distribution before and overwintering in inshore areas there after (from ~2006–2012). These positive blocks could therefore reflect changes in catchability of the survey for these years.

Since 2020, a series of positive survey residuals can be seen for recruiting herring, this is due to large year classes entering the stock. The residuals from the catch show no definitive trend other than that they are higher in earlier years of the series. Process residuals showed only a minor trend (Figure 11.3.2.4).

11.3.2.2 Stock overview.

Summary of the assessment is shown in Figure 11.3.2.6 and Table 11.3.2.2

The spawning-stock biomass was large around 2007 but steadily declined until 2017 despite small catches (Figure 11.3.2.6 This decrease was due to the *Ichthyophonus* infection mortality in 2009–2011 and 2016–2018 in addition to small year classes entering the stock since around 2005, particularly the 2011–2014-year classes. The 2017- 2019-year classes are large, and indices from the last fishing season 2023/24 indicate that the 2020-year class will also be above average and will enter the fishable stock in autumn 2024 at age 4. Consequently, SSB has been growing since 2020 but declined again in this year's assessment as the survey index does not depict the 2018- and 2019-year classes as large as previously thought. The information about recruitment is also poor which leads to high uncertainty around recruitment. Fishing mortality of herring in 27.5a has been quite variable since 1980, reaching a peak in late 80's and gradually reducing in the following years.

11.3.2.3 Retrospective pattern

The assessment model had relatively low Moh''s ρ statistic values for spawning-stock biomass and fishing mortality and the recruitment values (Table below) are within the recommended by Carvalho et al. 2021. Moh''s ρ statistical values quantify the extent of retrospective bias in stock assessment results and these low values indicate that the assessment model has relatively low retrospective bias.

R (age 2)	SSB	Fbar (5-10)
-0.03	-0.05	0.09

Analytical retrospective plots do not indicate any substantial deviations in assessment apart from the recruitment which has high uncertainty due to scarce information regarding recruiting year classes (Figure 11.3.2.7)).

Comparisons of different models:

The two models explored, SAM and Muppet, gave very similar results for development of the stock size for recent years, even if the levels are not the same (Figure 11.3.2.7). This indicates that the results are driven by the input data and not by the model used.

11.3.3 Final assessment and TAC advice based on a Management Plan

The assessment method was reevaluated in 2024 (ICES, 2024) and the stock is now assessed using a catch- at-age based assessment model (SAM). *Ichthyophonus* infection mortality was revaluated for the period 2009-2023, resulting in applying lower infection mortality than previously. In this update assessment, where the 2023/24 catch and survey data have been added to the input data, additional natural mortality was applied for 2024 because of the Ichthyophonus infection in the stock.

The effect of the SAM assessment model results in a downward revision of the reference biomass (age 4+) and in the spawning-stock biomass compared to the 2023 assessment but includes uncertainty estimates which the NFT-Adapt model was lacking. The results from the assessment model also indicate a downward revision in stock size from last year, due to the large 2017-2019 year-classes, who have now entered fully into the fishery, are not perceived as strong as previously suspected. Spawning-stock biomass for 2024 is estimated 412.1 kt and the reference biomass of age 4+ (B_{Ref}) is 428.2 kt at the beginning of the year 2024. As the SSB will be above MGT $B_{trigger}$ = 273 kt, the advised TAC according to the Iceland Management Plan is $HR_{MGT} \times B_{Ref}$ = 0.19 × 428 249 = 81 637 tonnes.

11.4 Reference points and the Management plan

11.4.1.1 Precautionary approach reference points:

The working group points out that managing this stock at an exploitation rate at or above $F_{0.1} = F_{MSY} = 0.22$ has been successful in the past for almost 30 years, despite biased assessments. At the 2024 WKICEHER workshop, the PA reference points for the stock were verified and revised (ICES 2024). On basis of the stock–recruitment relationship deriving from time-series ranging from 1947–2015, keeping $B_{lim} = 200$ kt was considered reasonable as the 2016 NWWG meeting (ICES, 2016) and the Study Group on Precautionary Reference Points for Advice on Fishery Management concluded also in February 2003. Other PA reference points were derived from B_{lim} and these data in accordance with the ICES Advice Technical Guidelines and became these: $B_{pa} = 273$ kt ($B_{pa} = B_{lim} \times e^{1.645\sigma}$, where $\sigma = 0.19$); $HR_{lim} = 0.34$ (HR that leads to SSB = B_{lim}, given mean recruitment); $HR_{pa} = 0.248$ (HR leading to P (SSB > Blim) > 95% with MSY Btrigger) (Table 11.6.2.2).

11.4.1.2 MSY based reference points:

At a NWWG meeting in 2011 an exploratory work, using the HCS program Version 10.3 (Skagen, 2012), was used to evaluate possible points based on the MSY framework that could be a basis for a management plan and Harvest Control Rule later (ICES, 2011b). Number of different runs was made with varying settings. The results implied that the MSY framework was confirmative with the currently used precautionary reference points. It means that the currently used $F_{0.1} = 0.22$ could be a valid candidate for F_{MSY}. During a Management Strategy Evaluation (MSE) for the stock in April 2017 and again in March 2024 (ICES, 2024, 2017b), results from simulations from both MSEs concluded that $F_{MSY} = 0.22$ is adequate.

11.4.1.3 Management plan

A Management Strategy Evaluation (MSE) for the stock took place in March 2024 (ICES, 2024). Three different HCRs were tested and all of them were considered precautionary, and, except for the advisory rule applied at that time ($F_{MGT} = 0.15$), in accordance with the ICES MSY approach. One of these HCR was later adopted by Icelandic Government as a Management plan for the stock. This HCR is based on reference biomass of age 4+ at the beginning of the assessment years ($B_{ref,\,Y}$), a spawning-stock biomass trigger (MGT $B_{trigger}$) is defined as 273 kt, and the harvest rate (HR_{MGT}) is set as 19% of the reference biomass age 4+ at the beginning of the assessment year. In the assessment year (Y) the TAC in the next fishing year (1 September of year Y to 31 August of year Y+1) is calculated as follows:

When SSB_Y is equal or above MGT $B_{trigger}$:

$TAC_{Y/y+1} = HR_{MGT} * B_{Ref,y}$

When SSB_Y is below MGT $B_{trigger}$:

$TAC_{Y/y+1} = HR_{MGT} * (SSB_y / \text{MGT } B_{trigger}) * B_{ref,y}$

In the MSE simulation, the ongoing *Ichthyophonus* epidemic was considered to continue and was accounted for. Consequently, this HCR is independent of estimated level of *Ichthyophonus* mortality and requires no further action during such epidemics.

The distribution of the realized harvest rate when the HCR is followed showed that the 90% expected range are within a harvest rate of 0.099–0.22. The recent realized harvest rates are within the above range.

11.5 State of the stock

The stock was at high levels around 2002 but showed a steady decline to 2017 despite a low fishing mortality. The reduction is a consequence of mortality induced by the *Ichthyophonus* outbreak in the stock in 2009–2011 and 2016–2018 in addition to small year classes entering the stock since around 2005, particularly the 2011–2014-year classes. The 2017- 2019-year classes are large and will be the foundation of the fishable stock in the coming years. Consequently, SSB has been growing since 2021, but because of a lowered survey index in 2023/2024 surveys, the SSB has shifted downwards in 2024.

11.6 Short-term forecast

11.6.1 The input data

The final SAM model which gave the number-at-age on 1 January 2024, was used for the prognosis. All input values for the prognosis are given in Table 11.6.1.1. Because of the expected *Ichthyophonus* mortality in the stock in spring 2024 (see Section 11.1.3), the SAM model outputs were reduced according to the infection ratios times 0.22 (Table 11.3.2.1) in accordance with the 2024 WKICEHER workshop results of added natural mortality (ICES 2024). The stock weights were estimated from the last year catch weights (see Stock Annex).

In summary, the basis for the stock projection is as follows: SSB (2024) = 412.1 kt; Biomass age 4+ (1 January 2024) = 428.2 kt; Catch (2023/24) = 94.4 kt; $WF_{5–10}$ (2023) = 0.253; HCR (2023) = 0.15.

11.6.2 Prognosis results

SSB at the beginning of the fishing season 2024/25 (approximately the same time as spawning in July 2024) is estimated to be 412 136 kt, which is above MGT $B_{trigger}$ of 273 kt. Consequently, advised TAC on basis of the new Management rule is 0.19 × Biomass 4+ (428 249 kt) = 81 367 kt. This results in $F_{W5–10}$ = 0.232 in 2024/25 and SSB = 401 000 kt in 2025 (Table 11.6.2.1). The results of different options are given in Table 11.6.2.1.

11.7 Medium term predictions

Because of the increased uncertainty of the assessment in relation to the development of the *Ichthyophonus* outbreak in the coming months and years, the uncertainty in size of the recruiting year classes, and the new management rule, no medium-term prediction is provided.

11.8 Uncertainties in assessment and forecast

11.8.1 Uncertainty in assessment

There are number of factors that could lead to uncertainty in the assessment. Two of them are addressed here. Additional natural mortality caused by the *Ichthyophonus* infection was set for the whole infection period 2008-2023 ($M_{infected, age, year}$ multiplied by 0.22 (see Section 11.1.3). This quantification of the infection mortality based on Óskarsson *et al*. (2018b) and revised at the 2024 WKICEHER workshop (ICES, 2024), was considered to improve the assessment, and reduce its uncertainty. Worth noticing, increasing M has been shown to increase the historical perception of the stocks size but has minor impacts on the assessment of the final year and the resulting advice. Further uncertainty regarding the assessment is the estimate of recruiting year-classes.

With no active juvenile survey (discontinued in 2018) the first glimpse of year-class strength is at age 3 in autumn. A dedicated juvenile survey would reduce this uncertainty.

11.8.2 Uncertainty in forecast

It is important to notice that the advice for 2024/2025 fishing season deriving from the Management plan is independent of the forecast and its uncertainty as it is only based on the reference biomass at the beginning of the assessment year. The uncertainty in the assessment mentioned above related to the apparent new infection in the stock and size of the recruiting year classes, apply also for the forecast.

11.8.3 Assessment quality

For a period in the 2000s, there was concerns regarding the assessment because of retrospective patterns of the results. No assessment was provided in 2005 due to data and model problems and in the two next consecutive years, ACFM rejected the assessment due to the retrospective pattern. In the assessments in 2007–2009 there was observed an improvement in the pattern from NFT-Adapt, while in 2010–2011, a retrospective pattern appeared again which was both related to the high M because of the *Ichthyophonus* infection but also due to new and more optimistic information about incoming year classes to the fishable stock (particularly the 2008-year class) and fishing pattern in recent year. The retrospective pattern in the current and last year's assessments is less than during these above-mentioned periods for SSB and F and Recruitment retros are improved in the new SAM model (Figure 11.3.2.4). Moreover, the Mohn's rhos are at the same time relatively low (<0.1) and therefore not of concern. Simultaneously the residuals from the survey have behaved better than before (Figure 11.3.2.3) with no strong year or year-class effect apparent. This together could be interpreted as indications for improvements in the assessment quality in recent years compared with the years before.

As stated in the 2017 NWWG report (ICES, 2017c), the revision of the infection mortality applied in the analytical assessment for the years 2009–2011 in accordance with the estimated mortality levels (Section 11.1.3), is also considered as an improvement of the assessment. Thus, the downward revision of the stock size over the period ~2003–2011 compared to the last year's assessment (Figure 11.3.2.2) is considered to provide more robust figure of development in the historical stock's size.

11.9 Comparison with previous assessment

This year's assessment was conducted with a new assessment model SAM. A comparison of the previous assessment model NFT-Adapt and SAM can be found in the 2024 WKICEHER report (ICES 2024). Additional natural mortality was applied, like previous years, because of the infection.

11.10 Management consideration

Inspections indicate still a high prevalence of heart lesions related to *Ichthyophonus hoferi* in the herring stock, particularly for older age groups. However, new infection has apparently been low in the most recent years as indicated with low infection prevalence for younger age groups (~ ≤5%). Hence, the outbreak that has been ongoing since 2008 might be ceasing or a growing tolerance is developing within the stock. At the 2024 WKICEHER workshop it was concluded that a re-evaluated induced mortality should be applied during the infection period 2008-2023 (see chapter 11.1.2).

11.11 Ecosystem considerations

The reason for the outbreak of *Ichthyophonus* infection in the herring stock that was first observed in the autumn 2008 is not known but is probably the effect of interaction between environmental factors and distribution of the stock (Óskarsson *et al.* 2009). It includes that outbreak of *Ichthyophonus* spores in the environment, which infect the herring via oral intake (Jones and Dawe, 2002), could be linked to the observed increased temperature off the southwest coast. Further research on the causes and origins of such an outbreak are ongoing at MFRI. It involves scanning for *Ichthyophonus* DNA in zooplankton species that the herring feeds on with PCR (Polymerase chain reaction) technique. Results from that work (MS thesis) can be expected in the in the near future, while preliminary results indicate that the source of the infection is widespread and is in various zooplankton groups and species. With respect to the impacts of the outbreak on the herring stock, recent analyses show that significant additional mortality took place over the first three years only (Óskarsson *et al.*, 2018b), despite a high prevalence of infection for the past decade. For how long time this outbreak will last is unknown as this is basically an unprecedented outbreak. The signs of the infection that is found in the stock will most likely remain for some years, even if no new infection will occur, and then decrease and disappear over some years as new year classes replace the older ones. The observed new infection, even if at a relatively low level, will however delay this process.

All general ecosystem consideration with respect to the stock can be found in the Ecosystem Overview for the Icelandic Ecoregion (ICES, 2017a).

11.12 Regulations and their effects

The fishery of the Icelandic summer-spawning herring is limited to the period 1 September to 1 May each season, according to regulations set by the Icelandic Fishery Ministry (**no. 770, 8 September 2006**). Several other regulations are enforced by the Ministry that effect the herring fishery. They involve protections of juvenile herring (27 cm and smaller) in the fishery where area closures are enforced if the proportion of juveniles exceeds 25% in number (no. 376, 8 October 1992). No such closures took place in 2023/2024. Another regulation deals with the quantity of bycatch allowed. Then there is a regulation that prohibits use of pelagic trawls within the 12 nautical miles fishing zone (**no. 770, 8 September 2006**), which is enforced to limit bycatch of juveniles of other fish species.

11.13 Changes in fishing technology and fishing patterns

There are no recent changes in fishing technology which may lead to different catch compositions. The fishing pattern in the seasons 2014/2015 to 2023/2024 was different from the previous seasons. Instead of fishing near only in a small inshore area off the west coast in purse-seine, the directed fishery took place in offshore areas west and east of Iceland by pelagic trawls. These changes are not considered to affect the selectivity of the fishery because the fishery is still targeting dense schools of overwintering herring in large fishing gears, getting huge catches in each haul and is by no means size selective.

Since around mid-2000s, Icelandic summer-spawning herring has been caught to varying degree mixed in the summer fishery for NE-Atlantic mackerel and Norwegian spring-spawning herring. Until that time, no summer fishery on this stock had taken place for decades. Part of this bycatch is on the stock components (e.g. juveniles and herring east of Iceland) that are not fished in the direct fishery on the overwintering grounds in the west. These bycatches are well sampled and contributes normally to less than 10% of the total annual catch but were as high as 30% in this year's fishery. Easterly distribution of the large incoming year classes from 2017, 2018 and 2019 explains this high level of bycatch, which contributed to 62% of the catches in the east. This is also reflected in the acoustic measurements where there is an increasing part of the stock in the east compared to west (Bjarnason, 2023).

The fishing pattern varies annually as noted in Section 11.2 and it is related to variation in winter distribution of the different age classes of the stock. This variation can have consequences for the catch composition, but it is impossible to provide a forecast about this variation.

11.14 Species interaction effects and ecosystem drivers

The WG have not dealt with this issue in a thoroughly and dedicated manner. However, some work has been done in this field in recent years in one way or another.

Regarding relevant research on species interaction, the main work relates to the increasing amount of Northeast Atlantic mackerel (NEAM) feeding in Icelandic Waters after 2006 (Astthorsson *et al.*, 2012; Nøttestad *et al.*, 2016). Surveys in the summers since 2010 indicate a high overlap in spatial and temporal distribution of NEAM and Icelandic summer-spawning herring (Óskarsson *et al.*, 2016). Moreover, the diet composition of NEAM in Icelandic Waters showed a clear overlap with those of the two herring stocks, i.e. Icelandic summer-spawning herring and Norwegian spring-spawning herring (Óskarsson *et al.*, 2016). Even if copepoda was important diet group for all the three stocks its relative contribution to the total diet was apparently higher for NEAM than the two herring stocks. Considering former studies of herring diet, this finding was unexpected, and particularly how little the copepoda contributed to the herring diet. This difference in the stomach content of NEAM and the two herring stocks indicated that there could be some difference in feeding ecology between them in Icelandic Waters, where NEAM preferred copepoda, or feed in the water column where they dominate over other prey groups, while the opposite would be for the herring and the prey Euphausiacea. Studies in the Nordic Seas have shown similar results (Langøy *et al.*, 2012; Debes *et al.*, 2012). The indication for difference in feeding ecology of the species is further supported by the fact that the body condition of the two herring stocks showed no clear decreasing trend since the invasion of NEAM started into Icelandic Waters. On the contrary the mean weights-at-age (and at-length) of the summer spawners have been high after 2010 (Óskarsson, 2019b) and for example record high in the autumn 2014 (Figure 11.6.1.1). It should though be noted that comparison of the diet composition of herring in recent years to earlier studies, mainly on NSS herring, indicate that the herring might have shifted their feeding preference towards Euphausiacea instead of Copepoda. That is possibly a consequence of increased competition for food with NEAM, where the herring is overwhelmed and shifts towards other preys.

The WG is not aware of documentations of strong signals from ecosystem or environmental variables that impact the herring stock and could possibly be a basis for implementing ecosystem drivers in the analytical basis for its advice. For example, recruitment in the stock has been positively, but weakly, linked to NAO winter index (North Atlantic Oscillation) and sea temperature (Óskarsson and Taggart, 2010), while indices representing zooplankton abundance in spring have not been found to impact the recruitment (Óskarsson and Taggart, 2010) or body condition and growth rate of the adult part of the stock (Óskarsson, 2008).

Considering these relations derived from the historical data, relatively warm waters around Icelandic (MRI 2016), and high positive NAO in recent years (http://www.cpc.ncep.noaa.gov/products/precip/CWlink /pna/nao.shtml), it was concluded in an earlier report (ICES, 2021) that we could expect a good recruitment in the stock. It seems to be coming about with the 2017-2019 -year classes.

11.15 Comments on the PA reference points

The reference points were revised in accordance with the ICES Technical Guidelines at the 2024 WKICEHER workshop (ICES, 2024). (Table 11.6.2.2).

11.16 Comments on the assessment

The assessment shows that the stock size was declining 2000–2018 due to a combination of *Ichthyophonus* mortality and series of below average and poor year classes entering the stock. The 2017- 2019-year classes which entered the reference biomass in autumn 2021 - 2023 caused an upward revision of the assessment but the acoustic index in the terminal year is below expectations and results in a downward revision this year.

There is compelling evidence of new infection by *Ichthyophonus* in the stock in winter 2023/24, even if less intense than in the years before. This called for applying additional infection mortality. If the low levels of new infection in the recent three years, and thereby low infection rate for the younger age groups, marks a cessation of the outbreak is unclear. This current outbreak adds uncertainty to the assessment and advice.

11.17 References

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11.17.1 Tables

Table 11.1.1.1. Icelandic summer-spawning herring. Acoustic estimates (in millions) in the winters 1973/74–2023/24 (age refers to the autumns). No surveys (and gaps in the time-series) were in 1976/77, 1982/83, 1986/87, 1994/95.

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1973/74	154.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	154
1974/75	5.000	137.000	19.000	21.000	2.000	2.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	186
1975/76	136.000	20.000	133.000	17.000	10.000	3.000	3.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	322
1977/78	212.000	424.000	46.000	19.000	139.000	18.000	18.000	10.000	0.000	0.000	0.000	0.000	0.000	0.000	886
1978/79	158.000	334.000	215.000	49.000	20.000	111.000	30.000	30.000	20.000	0.000	0.000	0.000	0.000	0.000	967
1979/80	19.000	177.000	360.000	253.000	51.000	41.000	93.000	10.000	0.000	0.000	0.000	0.000	0.000	0.000	1004
1980/81	361.000	462.000	85.000	170.000	182.000	33.000	29.000	58.000	10.000	0.000	0.000	0.000	0.000	0.000	1390
1981/82	17.000	75.000	159.000	42.000	123.000	162.000	24.000	8.000	46.000	10.000	0.000	0.000	0.000	0.000	666
1983/84	171.000	310.000	724.000	80.000	39.000	15.000	27.000	26.000	10.000	5.000	12.000	0.000	0.000	0.000	1419
1984/85	28.000	67.000	56.000	360.000	65.000	32.000	16.000	17.000	18.000	9.000	7.000	4.000	5.000	5.000	689
1985/86	652.000	208.000	110.000	86.000	425.000	67.000	41.000	17.000	27.000	26.000	16.000	6.000	6.000	1.000	1688
1987/88	115.544	401.246	858.012	308.065	57.103	32.532	70.426	36.713	23.586	18.401	24.278	10.127	3.926	4.858	1965
1988/89	635.675	201.284	232.808	381.417	188.456	46.448	25.798	32.819	17.439	10.373	9.081	5.419	3.128	5.007	1795
1989/90	138.780	655.361	179.364	278.836	592.982	179.665	22.182	21.768	13.080	9.941	1.989	0.000	0.000	0.000	2094
1990/91	403.661	132.235	258.591	94.373	191.054	514.403	79.353	37.618	9.394	12.636	0.000	0.000	0.000	0.000	1733
1991/92	598.157	1049.99	354.521	319.866	89.825	138.333	256.921	21.290	9.866	0.000	9.327	0.000	0.000	1.494	2850
1992/93	267.862	830.608	729.556	158.778	130.781	54.156	96.330	96.649	24.542	1.130	1.130	3.390	0.000	0.000	2395
1993/94	302.075	505.279	882.868	496.297	66.963	58.295	106.172	48.874	36.201	0.000	4.224	18.080	0.000	0.000	2525
1995/96	216.991	133.810	761.581	277.893	385.027	176.906	98.150	48.503	16.226	29.390	47.945	4.476	0.000	0.000	2197
1996/97	33.363	270.706	133.667	468.678	269.888	325.664	217.421	92.979	55.494	39.048	30.028	53.216	18.838	12.612	2022
1997/98	291.884	601.783	81.055	57.366	287.046	155.998	203.382	105.730	35.469	27.373	14.234	36.500	14.235	11.570	1924
1998/99	100.426	255.937	1081.50	103.344	51.786	135.246	70.514	101.626	53.935	17.414	13.636	2.642	4.209	8.775	2001
1999/00	516.153	839.491	239.064	605.858	88.214	43.353	165.716	89.916	121.345	77.600	21.542	3.740	11.149	0.000	2823

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
2000/01	190.281	966.960	1316.41	191.001	482.418	34.377	15.727	37.940	14.320	15.413	14.668	1.705	3.259	0.000	3284
2001/02	1047.64	287.004	217.441	260.497	161.049	345.852	62.451	57.105	38.405	46.044	38.114	21.062	3.663	0.000	2586
2002/03	1731.80	1919.36	553.149	205.656	262.362	153.037	276.199	99.206	47.621	55.126	18.798	24.419	24.112	1.377	5372
2003/04	1115.25	1434.97	2058.22	330.800	109.146	100.785	38.693	45.582	7.039	6.362	7.509	10.894	0.000	2.289	5268
2004/05	2417.12	713.730	1022.32	1046.65	171.326	62.429	44.313	10.947	23.942	12.669	0.000	1.948	11.088	0.000	5539
2005/06	469.532	443.877	344.983	818.738	1220.90	281.448	122.183	129.588	73.339	65.287	10.115	9.205	3.548	12.417	4005
2006/07	109.959	608.205	1059.59	410.145	424.525	693.423	95.997	123.748	48.773	0.955	0.000	0.000	0.000	0.480	3576
2007/08	90.231	456.773	289.260	541.585	309.443	402.889	702.708	221.626	244.772	13.997	22.113	68.105	10.136	2.800	3376
2008/09	149.466	196.127	416.862	288.156	457.659	266.975	225.747	168.960	29.922	26.281	17.790	9.881	0.974	3.195	2258
2009/10	151.066	315.941	490.653	554.818	271.445	327.275	149.143	83.875	156.920	36.666	13.649	8.507	1.458	5.590	2567
2010/11	106.178	280.582	228.857	304.885	296.254	138.686	301.285	60.997	141.323	97.412	37.006	0.000	4.019	0.000	1997
2011/12	704.863	977.323	434.876	313.742	272.140	239.320	154.581	175.088	84.582	92.435	89.376	17.638	6.808	4,989	3676
2012/13	178.500	781.083	631.421	166.627	126.961	142.044	110.084	97.000	74.340	69.473	43.376	38.450	7.458	0.773	2468
2013/14	15.919	314.865	218.715	344.981	151.631	132.767	120.756	118.377	89.555	74.602	48.695	44.637	31.096	11.598	1718
2014/15	152.422	90,269	330.084	260.919	259.079	187.905	111.955	91.629	37.855	76.680	30.366	10.619	22.799	10.108	1667
2015/16	381.900	164.221	174.507	312.350	225.836	215.207	93.743	62.753	75.339	41.961	15.696	26.756	20.159	5.401	1816
2016/17	97.036	220.642	137.217	151.937	262.488	136.801	241.382	61.220	55.869	62.805	11.435	20.135	13.733	0.313	1473
2017/18	32.749	22.947	95.097	171.664	201.944	319.933	209.174	255.348	75.813	34.505	83.460	54.903	25.370	28.115	1611
2018/19	306.295	137.402	67.933	201.362	101.946	110.810	167.397	163.804	73.346	30.040	29.950	38.499	9.138	7.271	1445
2019/20	1525	229.841	158.605	103.631	211.106	98.785	53.723	59.527	42.221	37.186	21.341	15.089	10.393	0.986	2568
2020/21	1399.76	1114.74	424.292	138.193	81.983	127.703	66.488	102.847	82.755	63.522	56.970	22.767	11.122	21.563	3802
2021/22	16.189	629.418	655.481	400.632	153.292	237.094	179.000	174.174	81.586	83.935	82.750	32.917	46.798	21.847	2795
2022/23	136.691	823.557	994.910	574.750	244.747	159.654	109.635	72.478	87.935	38.722	57.096	34.002	26.865	4.929	3366
2023/24	482.527	242.355	296.398	294.835	273.452	194.322	99.041	90.086	47.802	9.975	48.028	27.729	23.454	5.863	2513

Table 11.1.1.2. Icelandic summers-spawning herring. Number of fish aged (number of scales) and number of samples taken in the annual acoustic surveys in the seasons 1987/88–2023/24 (age refers to the former year, i.e. autumns). In 2000 seven samples were used from the fishery.

	Number of scales														N of samples		
Year/age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Total	West	East
1987/88	11	59	246	156	37	28	58	33	22	16	23	10	5	8	712	8	1	7
1988/89	229	78	181	424	178	69	50	77	42	29	23	13	7	12	1412	18	5	10
1989/90	38	245	96	132	225	35	2	2	3	3	2	0	0	0	783	8		8
1990/91	418	229	303	90	131	257	28	6	3	8	0	0	0	0	1473	15		15
1991/92	414	439	127	127	33	48	84	5	3	0	2	0	0	1	1283	15		15
1992/93	122	513	289	68	73	28	38	34	6	2	2	6	0	0	1181	12		12
1993/94	63	285	343	129	13	15	7	14	11	0	1	3	0	0	884	9		9
1994/95*																		
1995/96	183	90	471	162	209	107	38	18	8	14	18	2	0	0	1320	14	9	5
1996/97	24	150	88	351	141	137	87	32	15	10	7	14	4	2	1062	11	4	7
1997/98	101	249	50	36	159	95	122	62	21	13	8	15	8	5	944	14	7	7
1998/99	130	216	777	72	31	65	59	86	37	22	17	5	6	11	1534	17	10	7
1999/00	116	227	72	144	17	13	26	26	27	10	8	2	1	0	689	7	3	4
2000/01	116	249	332	87	166	10	7	21	8	14	11	3	1	0	1025	14	10	4
2001/02	61	56	130	114	62	136	25	24	17	21	17	10	3	0	676	9	4	5
2002/03	520	705	258	104	130	74	128	46	26	25	13	15	10	1	2055	22	12	10
2003/04	126	301	415	88	35	32	15	17	3	4	4	6	1	1	1048	13	8	5
2004/05	304	159	284	326	70	29	17	5	8	4	0	3	3	0	1212	13	4	9
2005/06	217	312	190	420	501	110	40	38	26	18	5	5	5	7	1894	22	14	8
2006/07	19	77	134	64	71	88	22	4	2	2	0	0	0	1	484	6	4	2
2007/08	58	288	180	264	85	80	104	19	15	2	2	6	1	3	1107	17	13	4
2008/09	274	208	213	136	204	123	125	97	18	13	9	7	4	17	1448	29	19	10
2009/10	104	100	105	116	60	74	34	19	36	8	3	4	2	2	667	17	10	7
2010/11	35	74	102	157	139	61	119	22	52	36	13	0	1	0	811	11	8	3
2011/12	229	330	134	115	100	106	74	87	45	48	51	10	3	3	1335	15	9	6
2012/13‡	42	266	554	273	220	252	198	165	126	114	69	61	12	2	2370	60	55‡	5

	Number of scales														N of samples		
Year/age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Total	West	East
2013/14	26	472	275	414	199	200	199	208	163	138	90	85	60	23	2552	45	37‡	8
2014/15	83	50	96	71	72	53	32	26	11	22	8	3	6	4	534	10	8	2
2015/16	229	112	131	208	148	123	47	32	32	22	13	7	12	4	1120	14	7	7§
2016/17	66	164	122	137	202	117	169	43	50	44	14	15	9	4	1162	14	12	2
2017/18	35	58	82	77	75	101	65	77	29	11	27	18	8	9	672	10	5	5
2018/19	28	39	31	98	50	53	77	75	36	15	15	21	5	4	547	7	5	2
2019/20	265	143	94	48	101	60	43	54	45	43	27	26	20	6	975	10	5	5
2020/21	248	215	116	68	59	104	52	79	55	44	35	13	6	8	1102	13	5	8
2021/22	39	89	588	258	254	113	138	87	78	49	34	24	19	8	1890	12	5	7
2022/23	214	306	410	388	127	118	120	90	83	83	61	41	37	15	2093	13	4	9
2023/24	48	529	652	396	192	208	84	110	65	54	29	25	14	8	2414	9	6	3

*** No survey ‡ Samples in the western part were mainly from the commercial catch as there was impossible to secure a usable research survey samples from Kolgrafafjörður where most of the herring was observed. § Three samples were taken in the east and south in this survey (B1-2016), while four were taken in the west and used also in the age–length key.**

Table 11.2.1. Icelandic summer spawners. Landings, catches, recommended TACs, and set National TACs in thousand tonnes.

Year	Landings	Catches	Recom. TACs	Nat. TACs	Year	Landings	Catches	Recom. TACs	Nat. TACs
1972	0.31	0.31			2007/2008	158.9	158.9	130	150
1973	0.254	0.254			2008/2009	151.8	151.8	130	150
1974	1.275	1.275			2009/2010	46.3	46.3	40	47
1975	13.28	13.28			2010/2011	43.5	43.5	40	40
1976	17.168	17.168			2011/2012‡	49.4	49.4	40	45
1977	28.925	28.925			2012/2013‡	72.0	72.0	67	68.5
1978	37.333	37.333			2013/2014‡	72.0	72.0	87	87
1979	45.072	45.072			2014/2015‡§	95.0	95.0	83	83
1980	53.268	53.268			2015/2016‡	69.7	69.7	71	71
1981	39.544	39.544			2016/2017‡	60.4	60.4	63	63
1982	56.528	56.528			2017/2018‡	35.0	35.0	39	39
1983	58.867	58.867			2018/2019‡	40.7	40.7	35.1	35.1
1984	50.304	50.304			2019/2020	30.0	30.0	34.6	34.6
1985	49.368	49.368	50	50	2020/2021	36.1	36.1	35.5	35.5
1986	65.5	65.5	65	65	2021/2022	70.1	70.1	72.2	72.2
1987	75	75	70	73	2022/2023	72.8	72.8	66.2	66.2
1988	92.8	92.8	90	90	2023/2024	94.4	94.4	92.6	92.6
1989	97.3	101	90	90	2024/2025			81.4	81.4
1990/1991	101.6	105.1	80	110					
1991/1992	98.5	109.5	80	110					
1992/1993	106.7	108.5	90	110					
1993/1994	101.5	102.7	90	100					
1994/1995	132	134	120	120					
1995/1996	125	125.9	110	110					

Year	Landings	Catches	Recom. TACs	Nat. TACs	Year	Landings	Catches	Recom. TACs	Nat. TACs
1996/1997	95.9	95.9	100	100					
1997/1998	64.7	64.7	100	100					
1998/1999**	87	87	90	70					
1999/2000	92.9	92.9	100	100					
2000/2001	100.3	100.3	110	110					
2001/2002	95.7	95.7	125	125					
2002/2003*	96.1	96.1	105	105					
2003/2004*	130.7	130.7	110	110					
2004/2005	114.2	114.2	110	110					
2005/2006	103	103	110	110					
2006/2007	135	135	130	130					

***Summer fishery in 2002 and 2003 included**

**** TAC was decided 70 thousand tonnes but because of transfers from the previous quota year the national TAC became 90 thousand tonnes.**

‡ Landings and catches include bycatch of Icelandic summer-spawning herring in the mackerel and NSS herring fishery during the preceding summer (i.e. from the fishing season before in June–August).

§ The landings and catches in 2014/2015 consist of transfer of 7 kt from the year before and 5 kt from the year to come, which explains the discrepancy to the TACs.

Table 11.2.2.1. Icelandic summer-spawning herring. Catch in numbers (millions) and total catch in weight (thousand tonnes) (1981 refers to season 1981/1982 etc).

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Catch
1975	1.518	2.049	31.975	6.493	7.905	0.863	0.442	0.345	0.114	0.004	0.001	0.001	0.001	0.001	13.280
1976	0.614	9.848	3.908	34.144	7.009	5.481	1.045	0.438	0.296	0.134	0.092	0.001	0.001	0.001	17.168
1977	0.705	18.853	24.152	10.404	46.357	6.735	5.421	1.395	0.524	0.362	0.027	0.128	0.001	0.001	28.925
1978	2.634	22.551	50.995	13.846	8.738	39.492	7.253	6.354	1.616	0.926	0.4	0.017	0.025	0.051	37.333
1979	0.929	15.098	47.561	69.735	16.451	8.003	26.04	3.05	1.869	0.494	0.439	0.032	0.054	0.006	45.072
1980	3.147	14.347	20.761	60.727	65.328	11.541	9.285	19.442	1.796	1.464	0.698	0.001	0.11	0.079	53.268
1981	2.283	4.629	16.771	12.126	36.871	41.917	7.299	4.863	13.416	1.032	0.884	0.760	0.101	0.062	39.544
1982	0.454	19.187	28.109	38.280	16.623	38.308	43.770	6.813	6.633	10.457	2.354	0.594	0.075	0.211	56.528
1983	1.475	22.499	151.718	30.285	21.599	8.667	14.065	13.713	3.728	2.381	3.436	0.554	0.100	0.003	58.867
1984	0.421	18.015	32.244	141.354	17.043	7.113	3.916	4.113	4.517	1.828	0.202	0.255	0.260	0.003	50.304
1985	0.112	12.872	24.659	21.656	85.210	11.903	5.740	2.336	4.363	4.053	2.773	0.975	0.480	0.581	49.368
1986	0.100	8.172	33.938	23.452	20.681	77.629	18.252	10.986	8.594	9.675	7.183	3.682	2.918	1.788	65.500
1987	0.029	3.144	44.590	60.285	20.622	19.751	46.240	15.232	13.963	10.179	13.216	6.224	4.723	2.280	75.439
1988	0.879	4.757	41.331	99.366	69.331	22.955	20.131	32.201	12.349	10.250	7.378	7.284	4.807	1.957	92.828
1989	3.974	22.628	26.649	77.824	188.654	43.114	8.116	5.897	7.292	4.780	3.449	1.410	0.844	0.348	101.000
1990	12.567	14.884	56.995	35.593	79.757	157.225	30.248	8.187	4.372	3.379	1.786	0.715	0.446	0.565	105.097
1991	37.085	88.683	49.081	86.292	34.793	55.228	110.132	10.079	4.155	2.735	2.003	0.519	0.339	0.416	109.489
1992	16.144	94.86	122.626	38.381	58.605	27.921	38.42	53.114	11.592	1.727	1.757	0.153	0.376	0.001	108.504
1993	2.467	51.153	177.78	92.68	20.791	28.56	13.313	19.617	15.266	4.254	0.797	0.254	0.001	0.001	102.741
1994	5.738	134.616	113.29	142.876	87.207	24.913	20.303	16.301	15.695	14.68	2.936	1.435	0.244	0.195	134.003
1995	4.555	20.991	137.232	86.864	109.14	76.78	21.361	15.225	8.541	9.617	7.034	2.291	0.621	0.235	125.851
1996	0.717	15.969	40.311	86.187	68.927	84.66	39.664	14.746	8.419	5.836	3.152	5.18	1.996	0.574	95.882
1997	2.008	39.24	30.141	26.307	36.738	33.705	31.022	22.277	8.531	3.383	1.141	10.296	0.947	2.524	64.682
1998	23.655	45.39	175.529	22.691	8.613	40.898	25.944	32.046	14.647	2.122	2.754	2.15	1.07	1.011	86.998
1999	5.306	56.315	54.779	140.913	16.093	13.506	31.467	19.845	22.031	12.609	2.673	2.746	1.416	2.514	92.896

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Catch
2000	17.286	57.282	136.278	49.289	76.614	11.546	8.294	16.367	9.874	11.332	6.744	2.975	1.539	1.104	100.332
2001	27.486	42.304	86.422	93.597	30.336	54.491	10.375	8.762	12.244	9.907	8.259	6.088	1.491	1.259	95.675
2002	11.698	80.863	70.801	45.607	54.202	21.211	42.199	9.888	4.707	6.52	9.108	9.355	3.994	5.697	96.128
2003	24.477	211.495	286.017	58.120	27.979	25.592	14.203	10.944	2.230	3.424	4.225	2.562	1.575	1.370	130.741
2004	23.144	63.355	139.543	182.45	40.489	13.727	9.342	5.769	7.021	3.136	1.861	3.871	0.994	1.855	114.237
2005	6.088	26.091	42.116	117.91	133.437	27.565	12.074	9.203	5.172	5.116	1.045	1.706	2.11	0.757	103.043
2006	52.567	118.526	217.672	54.800	48.312	57.241	13.603	5.994	4.299	0.898	1.626	1.213	0.849	0.933	135.303
2007	10.817	94.250	83.631	163.294	61.207	87.541	92.126	23.238	11.728	7.319	2.593	4.961	2.302	1.420	158.917
2008	10.427	38.830	90.932	79.745	107.644	59.656	62.194	54.345	18.130	8.240	5.157	2.680	2.630	1.178	151.780
2009	5.431	21.856	35.221	31.914	18.826	22.725	10.425	9.213	9.549	2.238	1.033	0.768	0.406	0.298	46.332
2010	1.476	8.843	22.674	29.492	24.293	14.419	17.407	10.045	7.576	8.896	1.764	1.105	0.672	0.555	43.533
2011	0.521	9.357	24.621	20.046	22.869	23.706	13.749	16.967	10.039	7.623	7.745	1.441	0.618	0.785	49.446
2012*	0.403	17.827	89.432	51.257	43.079	51.224	41.846	34.653	27.215	24.946	15.473	13.575	2.595	0.253	125.369
2013	6.888	46.848	24.833	35.070	17.250	18.550	19.032	21.821	15.952	15.804	10.081	9.775	6.722	2.486	72.058
2014	0.000	3.537	53.241	50.609	70.044	34.393	22.084	22.138	13.298	17.761	7.974	4.461	2.862	1.746	94.975
2015	0.089	6.024	29.89	53.573	43.501	43.015	15.533	10.76	8.664	8.161	6.981	2.726	2.467	1.587	69.729
2016	0.072	10.740	25.575	29.908	41.952	25.823	24.925	9.516	7.734	6.088	4.284	7.154	3.108	0.827	60.403
2017	1.262	5.236	31.855	18.113	10.239	15.506	10.223	8.830	5.676	3.399	1.616	2.220	1.533	1.596	35.034
2018	0.000	8.911	19.642	34.284	16.847	12.376	17.161	6.978	7.379	3.482	1.713	1.153	2.159	0.489	40.683
2019	0.461	4.601	15.845	12.970	16.084	12.244	6.944	9.531	6.167	4.732	2.983	2.808	2.200	1.866	30.038
2020	0.384	23.603	15.956	22.572	16.333	19.385	11.071	7.098	6.241	3.035	3.359	1.809	1.567	1.129	36.100
2021	12.440	21.018	88.992	37.291	37.244	17.231	21.230	13.155	11.781	7.270	5.213	3.549	2.771	1.583	70.084
2022	0.000	23.108	90.765	86.093	26.757	25.603	11.495	14.534	6.998	6.915	4.225	3.816	2.711	1.651	72.804
2023	0.000	8.178	75.892	90.608	56.330	26.616	29.871	11.921	16.204	9.236	8.009	4.399	3.936	2.218	94.422

*** Includes both the landings (73.4 kt) and the herring that died in the mass mortality (52.0 kt) in the winter 2012/13 in Kolgrafarfjörður.**

Table 11.2.2.2. Icelandic summer-spawning herring. The mean weight (g) at age from the commercial catch (1981 refers to season 1981/1982 etc.).

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1975	110	179	241	291	319	339	365	364	407	389	430	416	416	416
1976	103	189	243	281	305	335	351	355	395	363	396	396	396	396
1977	84	157	217	261	285	313	326	347	364	362	358	355	400	420
1978	73	128	196	247	295	314	339	359	360	376	380	425	425	425
1979	75	145	182	231	285	316	334	350	367	368	371	350	350	450
1980	69	115	202	232	269	317	352	360	380	383	393	390	390	390
1981	61	141	190	246	269	298	330	356	368	405	382	400	400	400
1982	65	141	186	217	274	293	323	354	385	389	400	394	390	420
1983	59	132	180	218	260	309	329	356	370	407	437	459	430	472
1984	49	131	189	217	245	277	315	322	351	334	362	446	417	392
1985	53	146	219	266	285	315	335	365	388	400	453	469	433	447
1986	60	140	200	252	282	298	320	334	373	380	394	408	405	439
1987	60	168	200	240	278	304	325	339	356	378	400	404	424	430
1988	75	157	221	239	271	298	319	334	354	352	371	390	408	437
1989	63	130	206	246	261	290	331	338	352	369	389	380	434	409
1990	80	127	197	245	272	285	305	324	336	362	370	382	375	378
1991	74	135	188	232	267	289	304	323	340	352	369	402	406	388
1992	68	148	190	235	273	312	329	339	355	382	405	377	398	398
1993	66	145	211	246	292	324	350	362	376	386	419	389	389	389
1994	66	134	201	247	272	303	333	366	378	389	390	412	418	383
1995	68	130	183	240	277	298	325	358	378	397	409	431	430	467
1996	75	139	168	212	258	289	308	325	353	353	377	404	395	410
1997	63	131	191	233	269	300	324	341	355	362	367	393	398	411
1998	52	134	185	238	264	288	324	340	348	375	406	391	426	456
1999	74	137	204	233	268	294	311	339	353	362	378	385	411	422
2000	62	159	217	268	289	325	342	363	378	393	407	425	436	430
2001	74	139	214	244	286	296	324	347	354	385	403	421	421	433
2002	85	161	211	258	280	319	332	354	405	396	416	433	463	460
2003	72	156	189	229	260	283	309	336	336	369	394	378	412	423
2004	84	149	213	248	280	315	331	349	355	379	388	412	419	425
2005	106	170	224	262	275	298	324	335	335	356	372	394	405	413
2006	107	189	234	263	290	304	339	349	369	416	402	413	413	467
2007	93	158	221	245	261	277	287	311	339	334	346	356	384	390
2008	105	174	232	275	292	307	315	327	345	366	377	372	403	434
2009	113	190	237	274	304	318	326	335	342	360	372	394	409	421
2010	87	204	243	271	297	315	329	335	341	351	367	366	405	416
2011	97	187	245	283	309	328	343	352	356	364	375	386	378	432
2012	65	206	244	282	301	320	333	344	350	359	364	367	373	391

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2013	95	182	238	271	300	322	337	349	360	365	362	375	377	394
2014		202	259	288	306	328	346	354	362	366	367	380	383	403
2015	107	203	249	275	299	313	329	347	352	358	361	368	380	378
2016	129	202	242	281	303	322	336	355	359	368	369	379	386	402
2017	95	192	252	281	303	324	341	350	367	376	384	389	395	402
2018		191	252	293	317	333	347	350	366	375	389	388	392	383
2019	103	175	244	282	305	308	328	340	349	357	360	366	374	374
2020	81	140	229	267	288	311	329	345	351	367	372	370	382	398
2021	90	154	212	253	272	296	314	325	337	356	352	361	372	364
2022		151	200	232	260	277	301	318	325	332	342	352	365	367
2023		167	221	251	279	298	310	339	351	359	368	384	383	403

Table 11.2.2.3. Icelandic summer-spawning herring. Proportion mature at age (1981 refers to season 1981/1982 etc.).

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1975	0	0.27	0.97	1	1	1	1	1	1	1	1	1	1	1
1976	0	0.13	0.9	1	1	1	1	1	1	1	1	1	1	1
1977	0	0.02	0.87	1	1	1	1	1	1	1	1	1	1	1
1978	0	0.04	0.78	1	1	1	1	1	1	1	1	1	1	1
1979	0	0.07	0.65	0.98	1	1	1	1	1	1	1	1	1	1
1980	0	0.05	0.92	1	1	1	1	1	1	1	1	1	1	1
1981	0	0.03	0.65	0.99	1	1	1	1	1	1	1	1	1	1
1982	0.02	0.05	0.85	1	1	1	1	1	1	1	1	1	1	1
1983	0	0	0.64	1	1	1	1	1	1	1	1	1	1	1
1984	0	0.01	0.82	1	1	1	1	1	1	1	1	1	1	1
1985	0	0	0.9	1	1	1	1	1	1	1	1	1	1	1
1986–2024	0	0.2	0.85	1	1	1	1	1	1	1	1	1	1	1

Table 11.3.2.1. Icelandic summer-spawning herring. Natural mortality-at-age for the different years (refers to the age in assessment) where the deviation from the fixed M = 0.1 is due to the *Ichthyophonus* infection for the period 2009-present (1987 refers to season 1987/1988 etc.).

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1987–2008	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2009	0.10	0.10	0.180	0.188	0.196	0.208	0.188	0.180	0.178	0.171	0.201	0.181	0.176	0.176
2010	0.10	0.10	0.211	0.214	0.206	0.197	0.205	0.188	0.176	0.184	0.176	0.176	0.176	0.176

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2011	0.10	0.10	0.142	0.202	0.197	0.192	0.181	0.189	0.196	0.188	0.174	0.181	0.176	0.176
2012	0.10	0.10	0.107	0.138	0.183	0.166	0.177	0.171	0.166	0.152	0.158	0.148	0.117	0.134
2013	0.10	0.10	0.107	0.107	0.156	0.194	0.195	0.200	0.183	0.163	0.165	0.143	0.154	0.142
2014	0.10	0.10	0.112	0.109	0.109	0.152	0.180	0.171	0.173	0.162	0.157	0.155	0.141	0.147
2015	0.10	0.10	0.100	0.105	0.107	0.114	0.162	0.177	0.194	0.192	0.195	0.167	0.167	0.176
2016	0.10	0.10	0.118	0.107	0.110	0.119	0.135	0.169	0.176	0.198	0.172	0.186	0.154	0.159
2017	0.10	0.10	0.124	0.138	0.149	0.158	0.155	0.173	0.162	0.197	0.207	0.175	0.158	0.164
2018	0.10	0.10	0.170	0.157	0.145	0.153	0.181	0.180	0.190	0.205	0.226	0.170	0.159	0.170
2019	0.10	0.10	0.126	0.132	0.148	0.175	0.149	0.149	0.157	0.188	0.160	0.170	0.170	0.170
2020	0.10	0.10	0.112	0.138	0.158	0.141	0.139	0.164	0.163	0.185	0.179	0.176	0.155	0.179
2021	0.10	0.10	0.115	0.133	0.117	0.139	0.161	0.145	0.162	0.142	0.181	0.170	0.170	0.170
2022	0.10	0.10	0.108	0.115	0.112	0.136	0.153	0.142	0.153	0.145	0.165	0.166	0.184	0.170
2023	0.10	0.10	0.102	0.110	0.117	0.121	0.118	0.142	0.124	0.146	0.143	0.147	0.146	0.162
2024*	0.10	0.10	0.109	0.107	0.106	0.114	0.129	0.139	0.149	0.136	0.153	0.159	0.159	0.159

***Based on prevalence of infection estimates in the winter 2023/24 (multiplied by 0.23 and added to 0.1) and should be applied in the prognosis in the 2024 assessment.**

Table 11.3.2.2. Icelandic summer-spawning herring. Assessment summary table. Recruitment in thousands. Weights are in tonnes. 'High' and 'Low' refer to 95% confidence intervals.

Year	Recruitment (Age 2)			SSB			Reference biomass (age 4+)	Landings	Harvest rate (Ages 4+)		
	Median	High	Low	Median	High	Low			Median	High	Low
1980	226391	137486	372787	208998	176637	247288	219781	53117	0.242	0.219	0.266
1981	921888	587547	1446483	179303	152151	211299	199018	38765	0.195	0.174	0.218
1982	300908	189421	478013	179300	154753	207740	190931	56296	0.295	0.263	0.331
1983	315887	198185	503492	220254	186956	259483	289189	57130	0.198	0.178	0.219
1984	500945	319235	786084	254720	213434	303992	280365	48755	0.174	0.153	0.197
1985	674822	425741	1069627	278641	237606	326762	303415	47436	0.156	0.140	0.175
1986	494654	314751	777383	287042	252698	326053	295753	64154	0.217	0.193	0.244
1987	285792	183213	445804	322298	279526	371615	342275	74798	0.219	0.198	0.242
1988	571287	369163	884077	350103	302058	405791	374578	92491	0.247	0.224	0.272

Year	Recruitment (Age 2)			SSB			Reference biomass (age 4+)	Landings	Harvest rate (Ages 4+)		
	Median	High	Low	Median	High	Low			Median	High	Low
1989	339521	231105	498797	344274	299607	395599	355145	98653	0.278	0.246	0.314
1990	863929	559003	1335188	337537	296766	383910	360219	103358	0.287	0.255	0.323
1991	877150	578087	1330929	313281	277365	353849	314508	101925	0.324	0.289	0.364
1992	658769	429225	1011068	348721	306662	396549	358426	103428	0.289	0.259	0.321
1993	815586	551869	1205324	436485	377771	504325	469128	101244	0.216	0.195	0.239
1994	273084	174542	427262	457675	399487	524338	476511	125727	0.264	0.240	0.290
1995	266282	170326	416297	434034	379994	495759	465892	125345	0.269	0.246	0.294
1996	752656	510371	1109962	334077	292200	381956	349380	97939	0.280	0.253	0.310
1997	345866	234770	509533	291413	254584	333570	291936	66576	0.228	0.204	0.255
1998	807477	541471	1204163	333151	290825	381637	362393	79898	0.220	0.198	0.245
1999	489880	318922	752480	332741	291339	380026	339032	94082	0.278	0.250	0.308
2000	567046	381964	841808	360047	315079	411432	382093	100063	0.262	0.238	0.289
2001	1629138	1085813	2444336	318254	278321	363917	332572	100500	0.302	0.272	0.336
2002	965403	646991	1440519	325373	283202	373823	304785	101982	0.335	0.289	0.387
2003	543839	349546	846128	422752	357402	500051	451888	112340	0.249	0.217	0.284
2004	1089317	731642	1621846	532734	447120	634743	572470	111822	0.195	0.176	0.217
2005	677991	438001	1049479	556640	470888	658008	561623	109191	0.194	0.174	0.217
2006	716573	461277	1113163	650692	555438	762282	696662	118143	0.170	0.148	0.194
2007	559330	357807	874354	593525	511265	689020	619541	154146	0.249	0.225	0.275
2008	468212	299262	732546	580663	496077	679672	611368	152206	0.249	0.227	0.273
2009	449879	303697	666423	502247	421493	598472	551279	45873	0.083	0.076	0.092
2010	640205	432598	947443	487572	414310	573789	534684	44390	0.083	0.076	0.091
2011	466260	297782	730058	490470	422746	569044	527600	51021	0.097	0.088	0.107
2012	588343	373353	927130	508573	442067	585084	551087	122549	0.222	0.201	0.246
2013	323844	203792	514618	435405	372662	508712	460977	64043	0.139	0.125	0.155
2014	344987	230194	517023	475291	405849	556615	515179	96562	0.187	0.171	0.206
2015	436981	292815	652126	400095	338598	472761	423639	70447	0.166	0.152	0.182

Year	Recruitment (Age 2)			SSB			Reference biomass (age 4+)	Landings	Harvest rate (Ages 4+)		
	Median	High	Low	Median	High	Low			Median	High	Low
2016	264841	176471	397463	367006	309315	435457	383547	59011	0.154	0.140	0.169
2017	395486	264472	591402	351550	294347	419870	383752	35752	0.093	0.085	0.102
2018	300518	198536	454886	347646	291470	414649	372443	40410	0.109	0.099	0.119
2019	846332	565645	1266305	312479	261751	373039	336663	29313	0.087	0.079	0.096
2020	706366	467229	1067899	322300	271168	383074	332504	35217	0.106	0.096	0.117
2021	691530	405127	1180405	384672	321827	459789	411300	70050	0.170	0.155	0.187
2022	356200	186163	681542	402029	326760	494637	427514	72471	0.170	0.154	0.186
2023	621438	255793	1509760	446153	345745	575720	480257	93672	0.195	0.178	0.213
2024	537005	200987	1434787	412137	297816	570340	428249				

Table 11.6.1.1. The input data used for prognosis of the Icelandic summer-spawning herring in the 2025 assessment: the predicted weights, the selection pattern, M, proportion of M before spawning, and the number-at-age derived from SAM.

Age (year class)	**Mean weights (kg)**	**M**	**Maturity ogive**	**Selection pattern**	**Mortality prop. before spawning**		**Number at age**
					F	M	1 January 2024
3 (2021)	0.154	0.10	0.200	0.132	0.000	0.500	568.6
4 (2020)	0.220	0.109	0.850	0.515	0.000	0.500	268.7
5 (2019)	0.262	0.107	1.000	1.000	0.000	0.500	393.0
6 (2018)	0.285	0.106	1.000	1.000	0.000	0.500	307.8
7 (2017)	0.307	0.114	1.000	1.000	0.000	0.500	208.5
8 (2016)	0.322	0.129	1.000	1.000	0.000	0.500	100.0
9 (2015)	0.331	0.139	1.000	1.000	0.000	0.500	69.4
10 (2014)	0.353	0.149	1.000	1.000	0.000	0.500	43.7
11 (2013)	0.363	0.136	1.000	1.000	0.000	0.500	44.8
12 (2012)	0.369	0.153	1.000	1.000	0.000	0.500	23.6
13 (2011)	0.377	0.159	1.000	1.000	0.000	0.500	22.9
14 (2010)	0.389	0.159	1.000	1.000	0.000	0.500	15.7
15 (2009)	0.388	0.159	1.000	1.000	0.000	0.500	10.3

Table 11.6.2.1. Icelandic summer-spawning herring. Catch options table for the 2024/2025 season according to the Management plan where the basis is: SSB (1 July 2024) 412.1 kt (accounted for $M_{infection}$ in 2023); Biomass age 4+ (1 January 2024) is 428.2 kt; Catch (2023/24) 94.4 kt; HR (2023) 0.15, and $WF_{5–10}$(2023) 0.253.

Rationale	Catches (2024/2025)	Basis	F (2024/2025)	Biomass of age 4+ (2025)	SSB 2025	%SSB change *	% TAC change **
Management plan	81.4	HR =0.19	0.232	406	401	-3	-14
MSY approach	94.6	HR_{MSY}=0.22	0.275	393	388	-5	>1
Zero catch	0	F=0	0.000	487	475	15	-100
HR_{pa}	106	HR_{pa}=0.248	0.314	382	378	-8	13
HR_{lim}	145	HR_{lim}=0.34	0.456	343	342	-15	54

***SSB 2025 relative to SSB 2024**

****TAC 2024/25 relative to landings 2023/24**

Table 11.6.2.2. Previous and revised reference points for herring in division 5.a following the WKICEHER workshop (ICES, 2024). Weights are in tonnes.

Framework	Reference point	Previous value	Revised value	Revised technical basis	Source
MSY approach	MSY $B_{trigger}$	273 000	273 000	Bpa	ICES (2024)
	HR_{MSY}	0.22*	0.221	Stochastic MSE simulations.	ICES (2024)
Precautionary approach	B_{lim}	200 000	200 000	Previous Blim value which is still considered compatible with current stock perception (ICES, 2017)	ICES (2017, 2024)
	B_{pa}	273 000	273 000	$B_{pa} = B_{lim} \times \exp(1.645 \times \sigma)$, where σ = 0.19	ICES (2024)
	HR_{lim}	0.61*	0.34	The harvest rate that leads to SSB = B_{lim}	ICES (2024)
	HR_{pa}	0.45*	0.248	Harvest rate leading to P (SSB > Blim) > 95% with MSY Btrigger	ICES (2024)
Management plan	MGT $B_{trigger}$	200 000	273 000	Stochastic simulations	ICES (2024)
	HR_{mgt}	0.15	0.19	Management plan	ICES (2024)

*** Fishing mortality (F) and not harvest rate.**

11.18 Figures

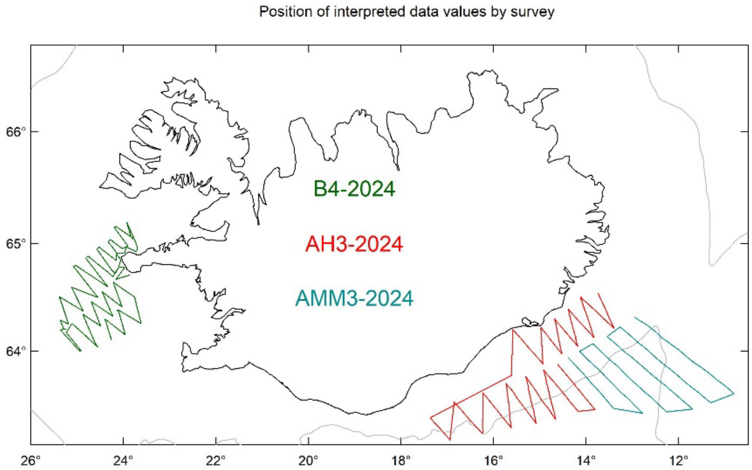

Figure 11.1.2.1. The survey tracks of three acoustic surveys on Icelandic summer-spawning herring in the southeast (AH3-2024 and AMM3-2024; younger part of the stock; red and blue) and in the west (B4-2024; adults; green) in 2023/24.

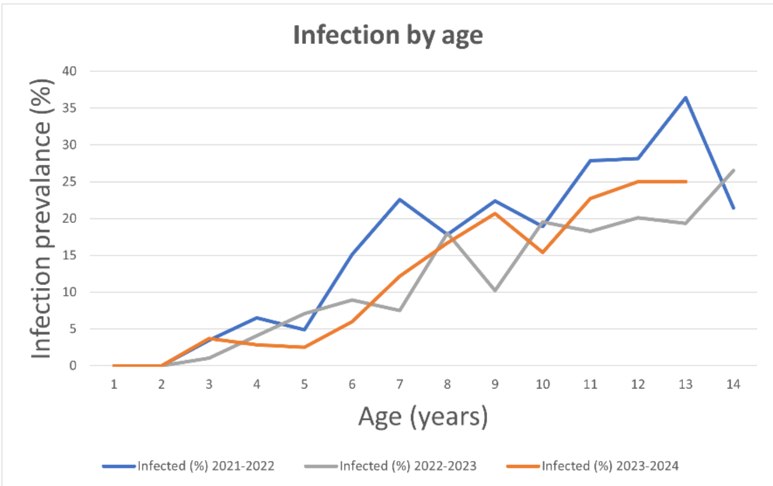

Figure 11.1.3.1. The prevalence of the Ichthyophonus infection followed for each age of Icelandic summer-spawning herring as estimated from catch samples west of Iceland in autumn (Oct.–Dec.) and samples southeast of Iceland from the acoustic survey (Oct). A comparison of the results from two last assessments (blue; 2021/2022 and orange; 2022/2023) and current (grey; 2023/2024) is shown. The age refers to autumn.

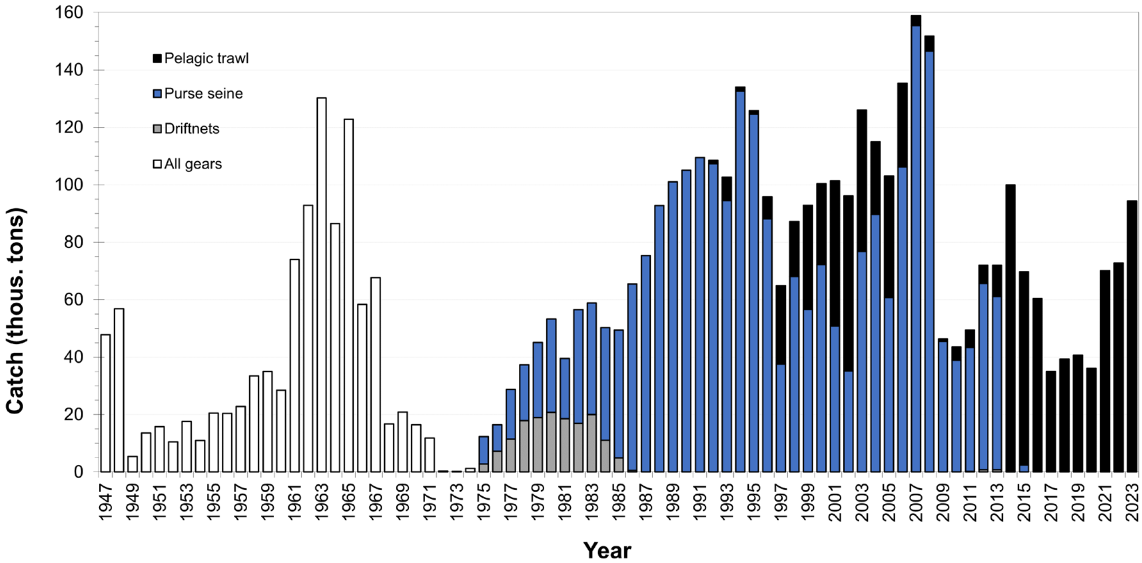

Figure 11.2.1. Icelandic summer spawning herring. Seasonal total landings (in thousand tonnes) during 1947–2023, referring to the autumns, by different fishing gears from 1975 onwards).

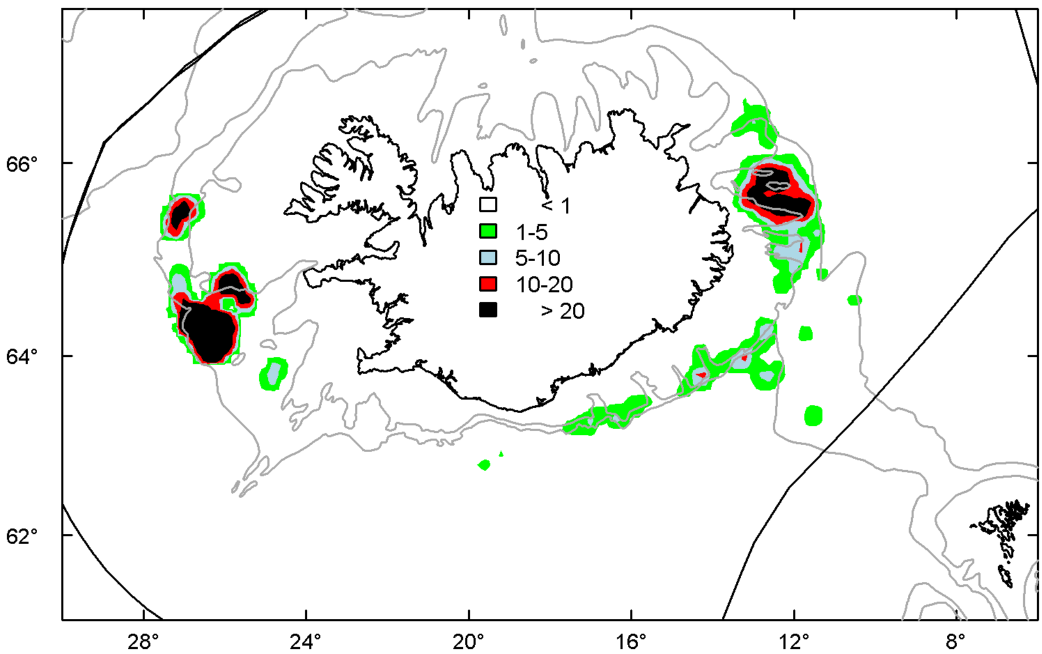

Figure 11.2.2. The distribution of the fishery (in tonnes) of Icelandic summer spawning herring during the fishing season 2023/24, including the bycatch (mackerel and Norwegian spring-spawning herring fishery) in July–September 2023.

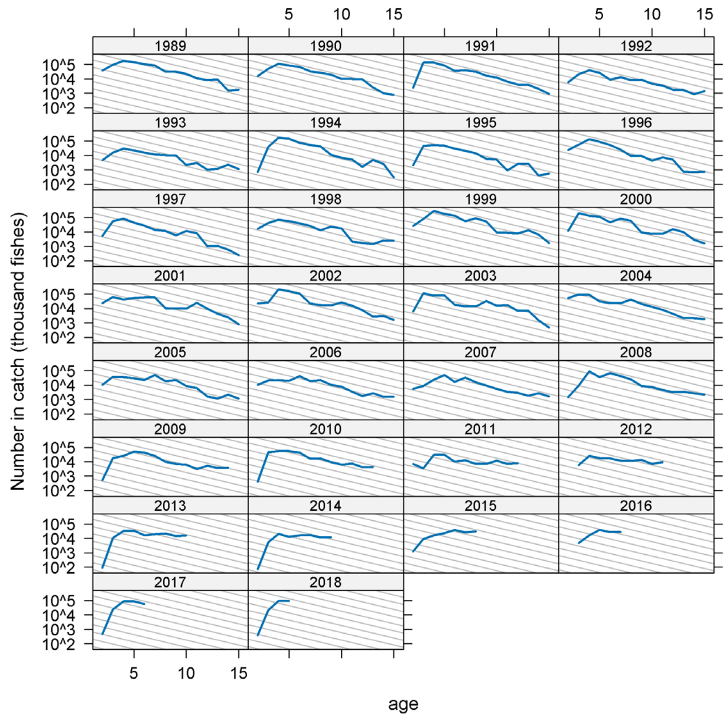

Figure 11.3.1.1. Icelandic summer-spawning herring. Catch curves (log_2 of catches) by year classes 1989–2018. Grey lines correspond to Z = 0.4. Note that the mass mortality in Kolgrafafjörður is added to the catches in 2012.

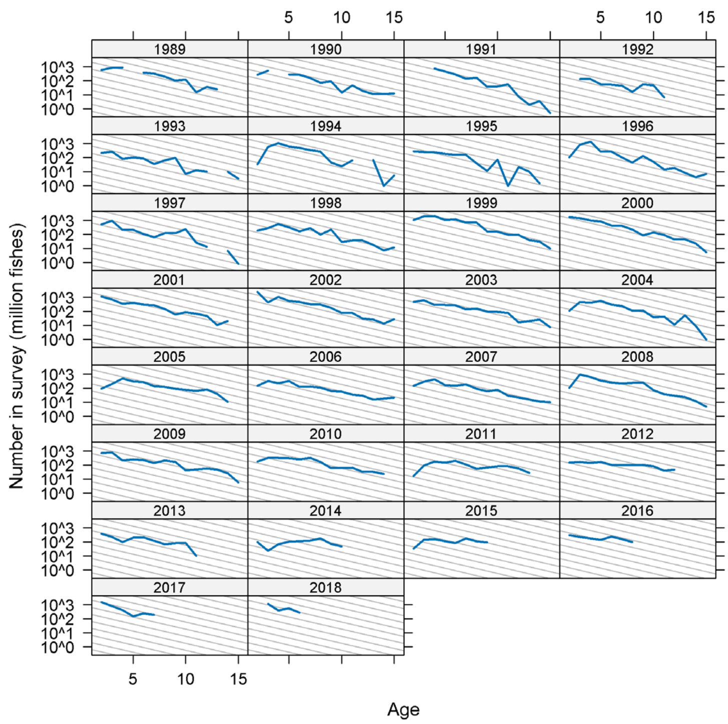

Figure 11.3.1.2. Icelandic summer spawning herring. Catch curves (log_2 of indices) from survey data by year classes 1989–2018. Grey lines correspond to Z = 0.4.

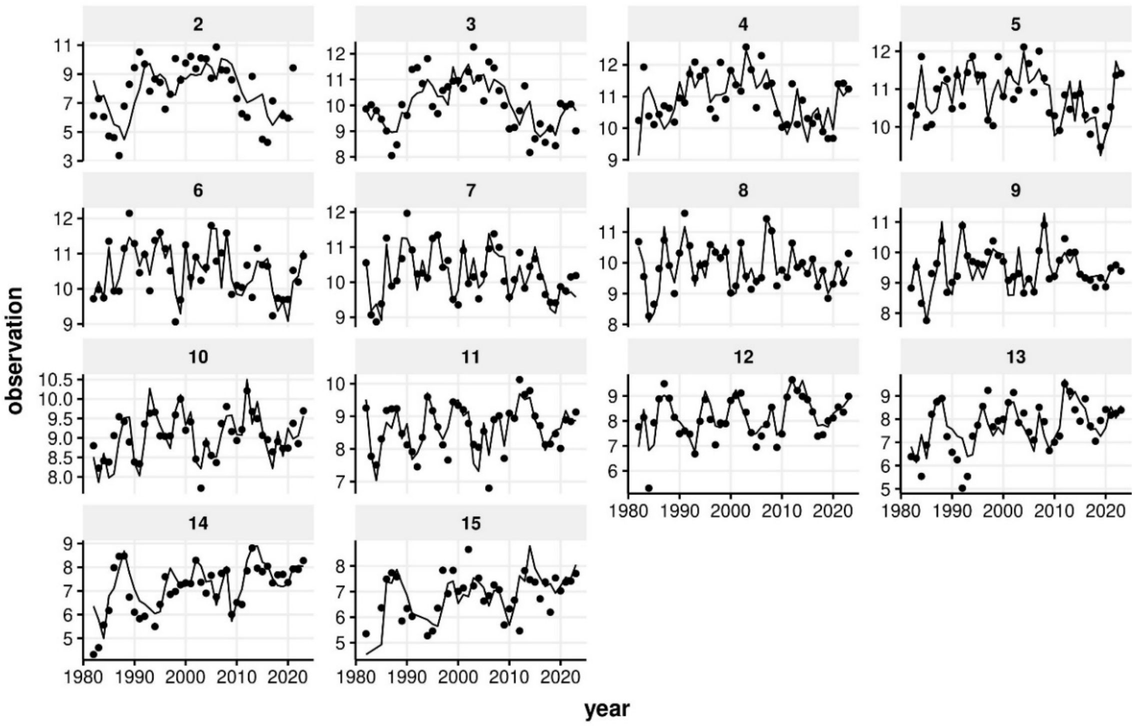

Figure 11.3.2.1. Herring in 27.5a. Fit to the catch numbers-at-age (2-15) input data to the assessment model.

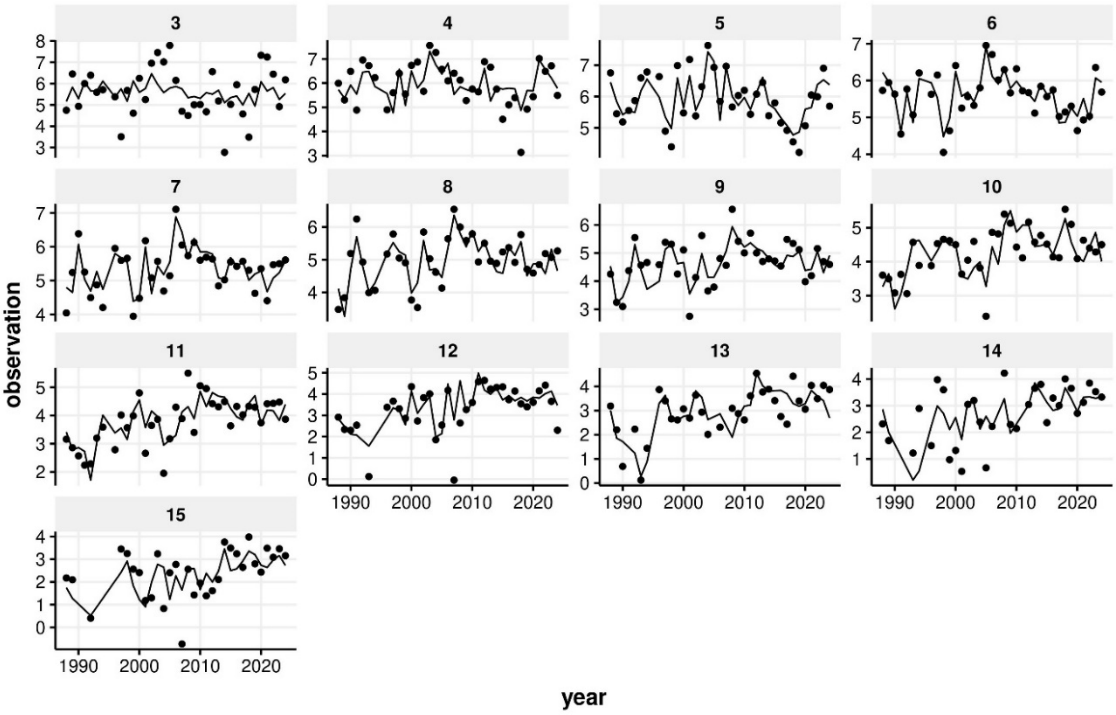

Figure 11.3.2.2. Herring in 27.5a. Fit to the acoustic survey numbers-at-age (3-15) input data to the assessment model.

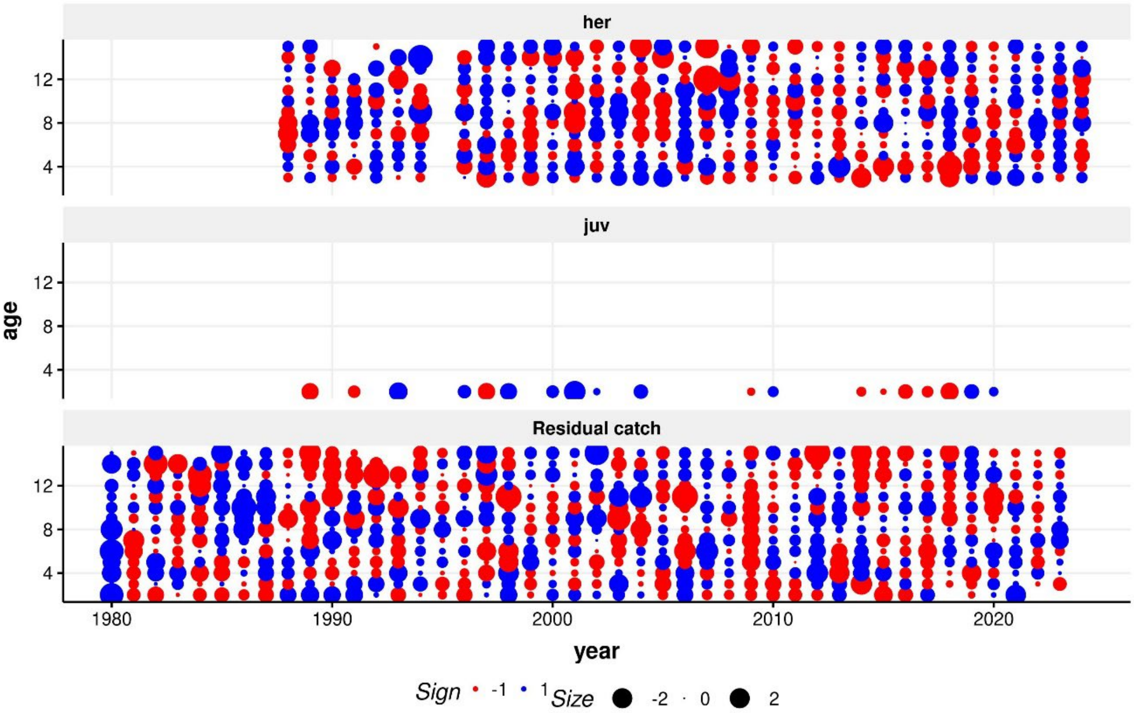

Figure 11.3.2.3. Herring in 27.5a. Observation error residuals from the assessment model

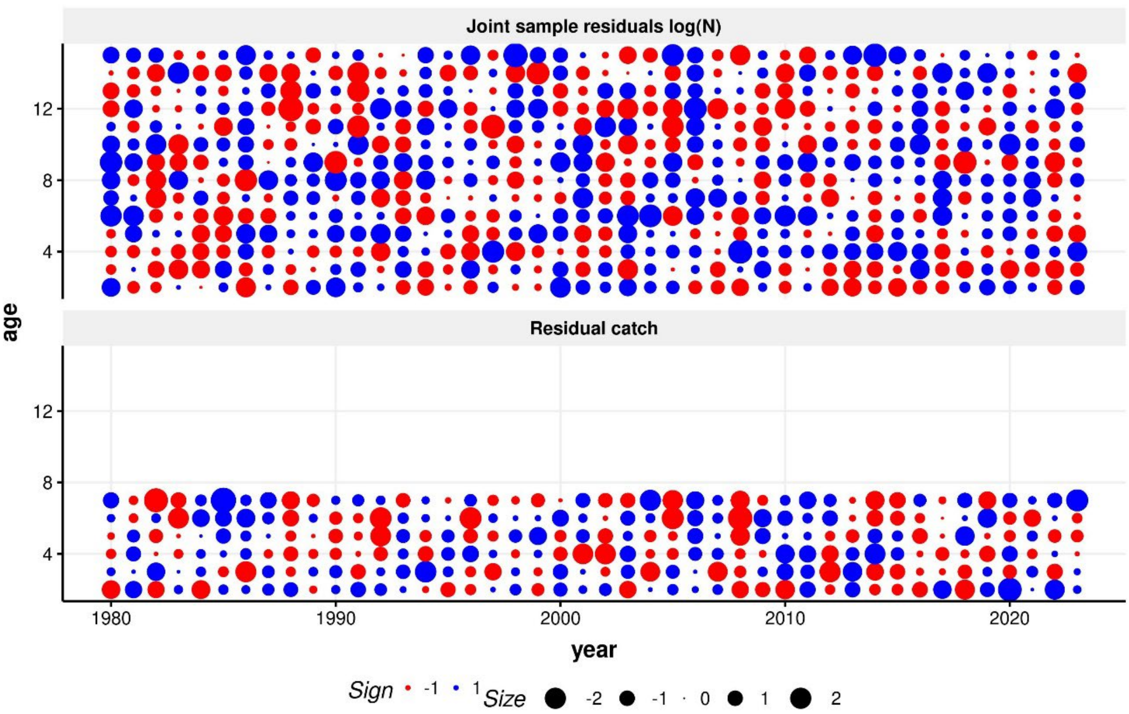

Figure 11.3.2.4. Herring in 27.5a. Joint sample residuals log(N) and residual catch from the assessment model

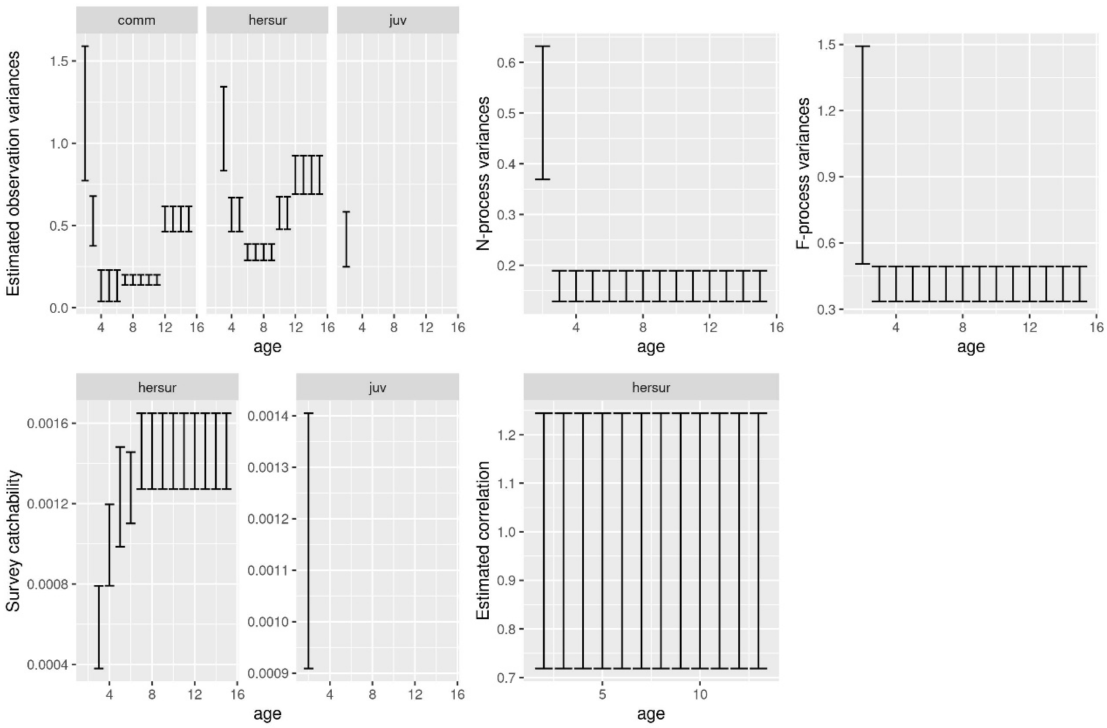

Figure 11.3.2.5. Herring in 27.5a. Illustration of estimated model parameters.

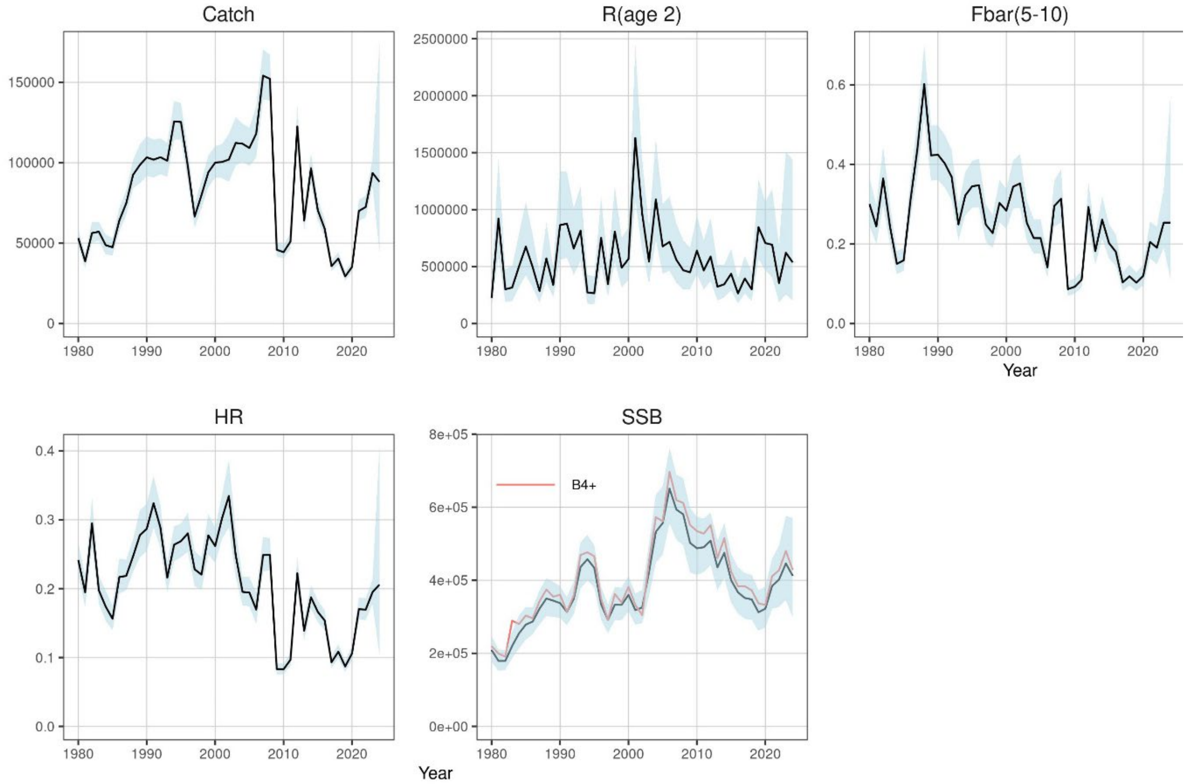

Figure 11.3.2.6. Herring in 27.5a. Assessment model results of population dynamics overview: estimated catch, recruitment (age 2), weighted average fishing mortality over ages 5–- 10 (Fbar), harvest rate of the reference biomass, and spawning-stock biomass (SSB) with reference biomass (B4+ in red). Note that the mass mortality in Kolgrafafjörður in the winter 2012/13 is included in harvest rate.

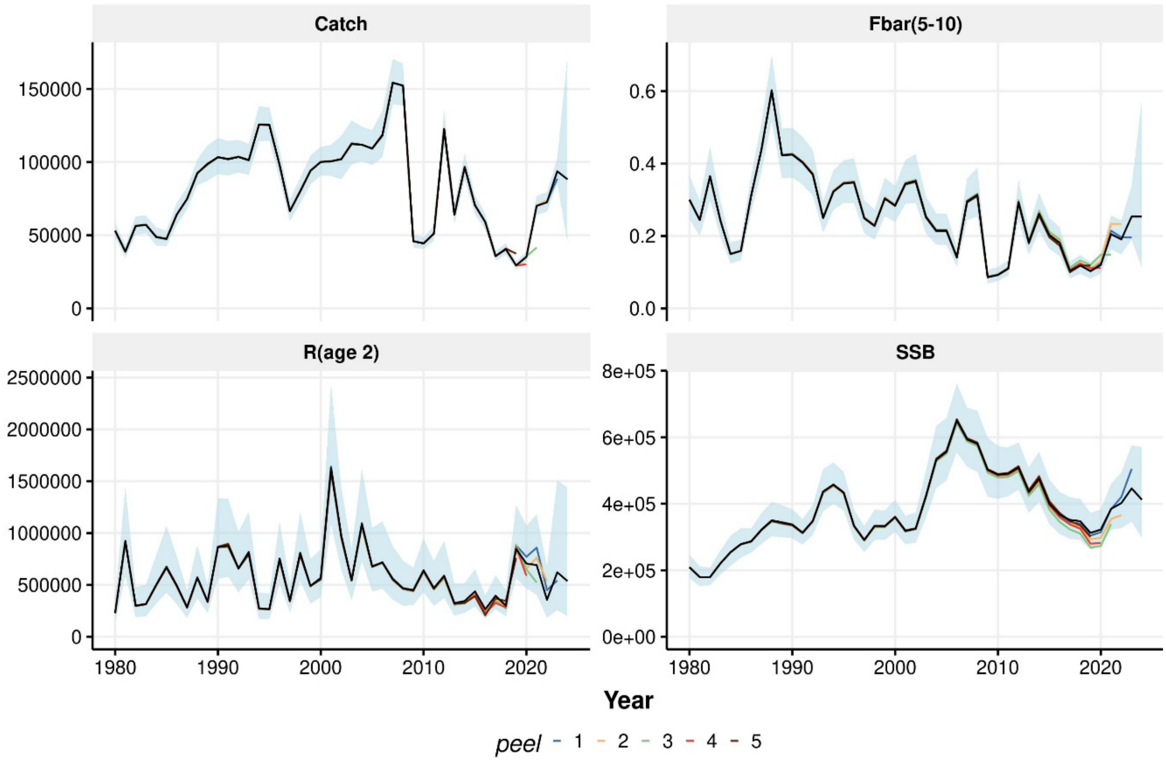

Figure 11.3.2.7. Herring in 27.5a. Retrospective analyses: estimated catch, average fishing mortality over ages 5 – 10 (Fbar), recruitment (R (age 2)), and spawning-stock biomass (SSB).

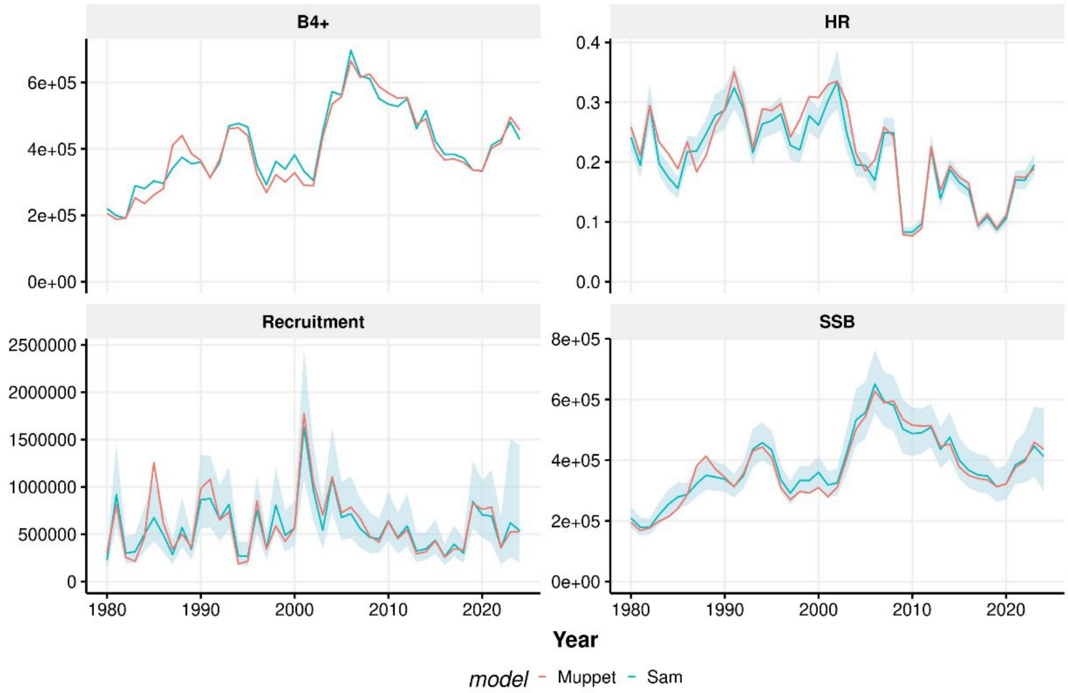

Figure 11.3.2.8. Herring in 27.5a. Model comparison between Sam model used in assessment and the Muppet model: Reference biomass (B4+), harvest rate (HR), recruitment (R (age 2)), and spawning-stock biomass (SSB).

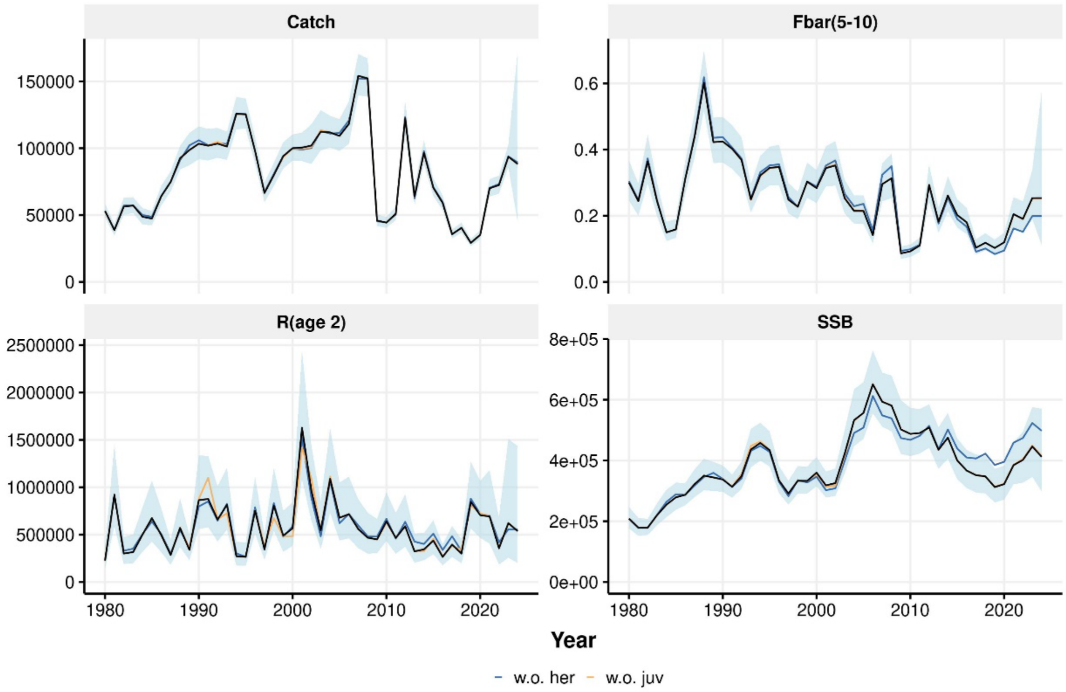

Figure 11.3.2.9. Herring in 27.5a. Leave-out estimates of herring SSB, catch, fishing mortality and recruitment-at-age 2.

12 Capelin in Iceland and Faroes grounds, East Greenland, and Jan Mayen area

cap.27.2a514 – *Mallotus villosus* in subareas 5 and 14 and Division 2.a west of 5°W 12

12.1 Stock description and management units

See Stock Annex.

12.2 Fishery-independent abundance surveys

The capelin stock in Iceland-East Greenland-Jan Mayen area has been assessed by acoustics annually since 1978. The surveys have been conducted in autumn (September–December) and in winter (January–February). An overview is given in the Stock Annex.

12.2.1 Autumn survey during August and September 2023

The survey was conducted with the aim of assessing both the immature and the maturing part of the stock (Bardarson *et al.*, 2023). Since 2010, the autumn surveys have started in September, a month earlier than in previous years because of difficulties in covering the stock due to drift ice and weather during later months. The survey was conducted by the research vessels Árni Friðriksson on behalf of MFRI and Tarajoq , on behalf of GINR.

The survey area was on the shelf and along the shelf edge of East Greenland from about 63°20’W towards about 72°30’N, also covering the Denmark Strait and the slope northwest to northeast of Iceland. The coverage was planned in 2018 and 2019 as a fixed transect layout with fixed stations for hydrography (CTD) and ecology (WPII and some Bongoes), with targeted pelagic trawl stations as capelin or other registrations are encountered. The Iceland Sea, Kolbeinsey ridge and Greenland basin were only briefly scouted due to time constraints and for same reason hydrographic measurements and zooplankton sampling were limited compared to previous years. On Árni a WBT-tube was deployed to study in-situ TS of capelin.

Tarajoq departed from Hafnarfjörður harbour just after midnight 23 August, initially operating pelagic trawl stations for a mackerel project and then heading to the first capelin assessment transect at the southwest extent of the survey area. From there Tarajoq followed paralell transects covering the East-Greenland continental shelf from Umivik towards Denmark Strait. Due to bad weather, Tarajoq went into Isafjordur harbour on 1 September and with an exchange of personnel planned on September 4th it was decided to use the time to calibrate the transducers. Tarajoq departed for the second half of the survey on September 4.

Arni departed from Hafnarfjörður on the 5 September and headed to Denmark Strait where both vessels operated along-transects covering Denmark Strait and shelf areas outside Scoresby Sund. On the first transect Arni deployed 5 drift boys for the NORSE project. The 8 September, both vessels had to halt operation for about 16 - 18 hours in Denmark Strait outside Kogurgrunn, due to bad weather. On 13 September Arni deployed a wave glider between Scoresby Sund and Jan Mayen for the international NORSE project. On the 12 September Tarajoq had to leave the project to assist stranded cruise ship, Ocean Explorer, in Alpefjord. Hence, Arni finished all transects from Scoresby towards Kong Oscar Fjord while only CTD and net samples on the eastern half of

Transect D (outside Kong Oscar Fjord) could be sampled due to time constraints and drift ice distribution. Planned transects and sampling scheme north of Kong Oscar Fjord could not be covered due to drift ice. Hence, the ice edge was followed with adapted zik-zak transects north to 72°33 N and then 1 sailing along coarse zik-zak transects southwards over the East Greenland-Jan Mayen ridge and Iceland basin. At 71°N and 15°09W Arni stopped and attempted an open water calibration of WBT-Tube echosounder but without success due to lack of tilt control of the instrument transducers. While covering the Iceland basin Arni could not always extend transects as planned to the west due to bad weather and the 18 September the vessel had to head to shelter in Axarfjordur bay and wait until 20 September for calmer weather. Then, coarse transects were sailed from shelf areas north of NE-Iceland and into the Icelandic basin heading towards Kolbeinsey-ridge. After finishing the last transect 18 nautical mile south of Kolbeinsey Island Árni headed towards Hafnarfjordur. While passing the Vestfirðir peninsula Arni stopped outside Talknafjordur fjord for potential assistance of rv Bjarni Saemundsson that had stranded close to the coast inside the fjord, then Arni escorted Bjarni to harbour in Hafnarfjörður where both vessels arrived on the morning of 23 September.

In general, in areas south of Scoresby, drift ice did not limit the coverage of the survey vessels although icebergs and a lack of benthic mapping occasionally limited extension of transects towards the Greenlandic coast. On the other hand, drift ice hindered the coverage of areas north of Kong Oscar Fjord.

Maturing capelin was mainly observed along the East Greenlandic continental shelf and shelf edges in Denmark Strait. In western Denmark Strait maturing capelin was mixed with immature capelin, but mainly maturing capelin was found further west. No important quantities of mature capelin were found east of Denmark Strait and that is a drastic change from observations during preceding years when mature capelin was found on or along the East Greenland continental shelf south, east and north of Scoresby. Further, no capelin was found by West Jan Mayen ridge or Kolbeinsey ridge. In general there were no signs of any important quantities of capelin east of Kolbeinsey ridge nor along Icelandic shelf edges. Juveniles (0-group) of various species, including capelin (although not quantified) were observed along the continental shelf north of Iceland. Immature capelin was found along the Greenlandic shelf, dominating in southwestern part of the survey area 3 and western Denmark Strait. Overall, the distribution of maturing capelin was not reaching as far east in autumn as in preceding years. Figures 12.2.1–12.2.3 show the cruise tracks, distribution, relative density and proportion mature of the capelin during the survey.

The total number of capelin amounted to 60 billion whereof the 1-group was about 47.6 billion. The total estimate of 2 group capelin was about 7.8 billion. The total biomass estimate was 658 000 tonnes of which about 274 000 tonnes were 2 years and older. About 9.5 % in numbers of the 1-group was estimated to be maturing to spawn, about 79.8 % of the 2 year old and 97.5 % of the 3 year old capelin appeared to be maturing. This gives about 309 000 tonnes of maturing 1 - 4 year old capelin.

Tables 12.2.1a and 12.2.1.b give the age disaggregated biomass, numbers and weights of the capelin stock components. Tables 12.2.2 and 12.2.3 show the historic time-series of abundance and mean weights by age and maturity in autumn. Based on the estimate of the maturing part of the stock the Marine and Freshwater Research Institute recommended intermediate TAC of 0 tonnes for the fishing season 2023/2024 (MFRI, 2023). This recommendation was in accordance with existing HCR and management plan between Iceland, Norway and Greenland (Anon, 2023).

12.2.2 Surveys in winter 2023/2024

Winter surveys were conducted in December 2023–February 2024 resulting in 4 separate coverages of stock components. The main objective of the winter surveys was to assess the maturing part of the stock with coverages designed for acoustic stock assessment. This was a coordinated collaboration of two Icelandic research vessels and several Icelandic and Greenlandic fishing vessels, where each coverage was based on combined acoustic and trawl data. Scientists from MFRI were on board each vessel performing acoustic stock estimates and all assessments were based on acoustic data from calibrated echosounders.

12.2.2.1 Winter surveys 1. Coverage in 9–13 December 2023

In November 2023 industry stakeholders approached Hafró/MFRI and commissioned an extra capelin survey at the beginning of December, to be conducted on RV-s Árni Friðriksson and Bjarni Sæmundsson supplemented with uncalibrated industry vessel scouting effort.

Prior to the survey, f/v Vilhelm Þorsteinsson contributed by conducting transects along the shelf edges northeast of Iceland from Vopnafjardargrunn westwards to Kolbeinsey ridge. . Vilhelm first encountered capelin in the proximity of Kolbeinsey ridge.

The main objective of the survey was acoustic assessment of the capelin stock in the Denmark Strait and north Iceland shelf area, with the aim of measuring the mature stock component. The survey was conducted by RV Bjarni Sæmundsson and RV Árni Friðriksson on 9–13 December. The resulting stock estimate was based on combined acoustic and trawl data from both research vessels. Figures 12.2.4–12.2.6 show the cruise tracks, distribution, relative density and proportion mature of the capelin during the survey.

The vessels managed to cover the planned survey area except for limited coverage in Denmark Strait and the northwestern edge of the survey area, due to drifting sea ice. A mixture of immature and mature capelin was observed in the western most part of the survey region while mature capelin dominated further east in the Denmark Strait and by Kolbeinsey ridge. Mature capelin had migrated few miles east across the Kolbeinsey ridge, but not much further.

Insignificant amount of capelin was observed in the area Vilhelm covered further east prior to the survey, which suggests that the planned survey area covered the eastern front of the potential spawning migration. Total SSB was estimated around 70 thous. tonnes, indicating that the spawning migration was in its early stages and that not all capelin observed on the autumn survey in September 2023 had migrated into Icelandic Waters. The survey wasn't used to change the advice but was nevertheless important for the overall strategy of timing and coverage in forthcoming surveys.

12.2.2.2 Winter surveys 2. Coverage in 16–22 January 2024

The main objective of the survey was acoustic assessment of the capelin stock in the Denmark Strait and north and east Iceland shelf area, with the aim of measuring the mature stock component The survey was conducted by RV Bjarni Sæmundsson and RV Árni Friðriksson and f/v Ásgrímur Halldórsson and Polar Ammassak on 6–22 January. (Bardarson *et al.*, 2024). 2–4 Scientists from MFRI were on board each vessel and all assessments were based on acoustic data from calibrated echosounders.

The survey area was on and along the shelf edge from Vikurall northwest of Iceland and eastwards along and outside shelf slopes north of Iceland and Eastfjords to Reyðarfjarðardjúp east of Iceland (Figures 12.2.6–12.2.8). The fishing vessels were funded by Fisheries Iceland.

Based on weather forecasts, three vessels (Árni Friðriksson, Bjarni Sæmundsson and Polar Ammassak) started in the Denmark Strait region progressing eastwards along and outside shelf edge areas, while Ásgrímur Halldórsson started east of Iceland heading west. This approach was chosen to finish the coverage in the west as early as possible before measurements in Denmark Strait would be hindered by forecasted wind and heavy seas. Due to southerly capelin observations along-transects west of Kolbeinsey ridge, Árni was assigned a transect south of the coverage in that region. There, Árni observed and sampled maturing capelin leading to the addition of two more parallel transects further south and shallower on the shelf or until the southern extent of the migration was reached.

Overall, the vessels managed to cover the planned survey area except the hindered coverage in Denmark Strait due to sea ice. In general good progress was maintained and the areas with the highest abundance were measured in good conditions.

In the western part of the survey area there was a mixture of mature and immature capelin where the immature component dominated while all observations and samples east of Hornbjarg were predominated by maturing capelin. North of Strandagrunn maturing capelin was mainly found by the ice edge and from there distributed towards the Kolbeinsey ridge. Another important component of the maturing capelin was found north of Melrakkaslétta and from there very low registrations of capelin reached east of Langanes peninsula while furthest to the east and south, off Austfirdir, hardly any capelin was found.

Furthest to east on the survey area, older and larger capelin predominated. Most of the biomass was measured while vessels were progressing with the direction of capelin migration, which might lead to slight overestimate of the stock size, but it is also very likely that there were unmeasured stock components in Denmark Strait due to survey restrictions caused by sea ice in that region potentially leading to severe overall underestimation of the capelin stock size.

The survey results gave capelin SSB of 84 000 tonnes but because of profound limitations of coverage due to sea ice this survey was not used to evaluate the capelin stock size or composition.

12.2.2.3 Winter surveys 3. Coverage in 5 – 18 February 2024

The main objective of the survey was acoustic assessment of the capelin stock in the Denmark Strait and north and east Iceland shelf areas, with the aim of measuring the mature stock component. The survey was initially planned to be conducted by RV Árni Friðriksson and f/v Ásgrímur Halldórsson and Polar Ammassak with assistance from RV Bjarni Sæmundsson while on survey making environmental measurements for another project (Bardarson *et al.*, 2024). Unfortunately, a few days before the survey a mechanical problem came up which ruled RV Árni Friðriksson out of participation in this project. Hence, f/v Heimaey was hired for the project. 2–5 Scientists from MFRI were on board each vessel and all assessments were based on acoustic data from calibrated echosounders.

The survey area was on and along the shelf edge from Vikurall northwest of Iceland and eastwards along and outside shelf slopes north of Iceland and Eastfjords to Hvalbakshalli southeast of Iceland (Figures 12.2.9 -12.2.11). The fishing vessels were originally funded by Fisheries Iceland while additional cost due to elimination of RV Árni Friðriksson was paid by MFRI.

Ásgrímur Halldórsson and Polar Ammassak started on parallel transects north of Melrakkaslétta, Ásgrímur heading east and Ammassak to the west. Heimaey began by surveying shelf areas north of Húnaflói bay and it was then planned to follow the shelf edge westwards but soon swapped planned routes with Ammassak such that Heimaey finished up all transects on the shelf north of Iceland while Ammassak continued westwards along the shelf edges. Both Heimaey and Ammassak then had to seek shelter in Ísafjörður before finishing the Denmark Strait region where Heimaey was measuring to the west while Ammassak was covering eastwards, partly repeating measurements made earlier in bad weather. Ásgrímur continued along the shelf edges east of Iceland and ended by ad hoc zik-zak coverage in bad weather along the shelf edge east of Iceland without observing any important quantities of capelin. Later, based on news of capelin observations of pelagic fishing vessels crossing the region southeast of Iceland, Polar Ammassak was directed to southeast Iceland and measured along with Bjarni Sæmundsson in the area from Hvalbakshalli to Seyðisfjarðardjúp.

Overall, the vessels managed to cover the planned survey area except where coverage was not possible in Denmark Strait due to sea ice. Weather and sea state was challenging during part of the survey and hence measurements had to be halted and part of measurements were repeated.

As before, immature capelin dominated in the Denmark Strait region mixed with mature capelin while the spawning migration of other maturing components had progressed such that no capelin was found alongshelf edges north and northeast of Iceland while a mature capelin of low abundance had reached southwest of Iceland. At the same time there were signs of scarce and scattered observations of capelin on shelf areas north of Iceland of such a low abundance that they were not sampled, but based on information from fishing boats it was mature capelin.

The survey results gave capelin SSB of 134 000 tonnes that along with autumn survey estimates gave basis to advice no fisheries.

12.2.2.4 Winter surveys 4. Coverage in 22 – 29 February 2024

The main objective of the survey was acoustic assessment of the capelin stock in the Denmark Strait and north and east Iceland shelf areas, with the aim of measuring the mature stock component with special emphasis on observing if additional components of the stock might be found given the limitations of coverage in earlier surveys. The survey was conducted by f/v Heimaey, Ásgrímur Halldórsson and Polar Ammassak on 22–29 February. (Bardarson *et al*., 2024). 1–3 Scientists from MFRI were on board each vessel and all assessments were based on acoustic data from calibrated echosounders.

The survey area was split in two, first focusing on the region northwest of Iceland, in Denmark Strait, where coverage of preceding winter surveys had been hindered by sea ice, and second covering the region southeast of Iceland where part of the mature component had been observed. Hence, there was no coverage of the regions north and northeast of Iceland where hardly any capelin had been observed in the preceding survey in early February (Figures 12.2.12–12.2.14). The survey was jointly funded by MFRI and Fisheries Iceland.

In Denmark Strait, there continued to be mainly immature capelin while small quantities of mature capelin were observed migrating south on shelf areas towards potential spawning grounds. Coverage was still limited due to sea ice in the Denmark Strait and adjacent areas but as time passes, the mature capelin is expected to have migrated further towards the spawning grounds in shallow waters. In the southeast, a considerable part of the mature capelin had migrated westwards onto shelf areas.

The survey results gave capelin SSB of 190 000 tonnes that along with earlier February survey and the autumn survey estimates gave basis to advice no fisheries.

Following the survey, close attention was given to observations of capelin migrating to spawning that might indicate addition to earlier estimates. This included news from fishing vessels in potential regions and from data gathered in groundfish bottom-trawl survey covering the whole Icelandic shelf where the RV Árni Friðriksson and Bjarni Sæmundsson also collected acoustic data west of Iceland, off Vestfirðir and northwest of Iceland. No signs of considerable additional spawning migration of capelin were observed.

Age disaggregated abundance in numbers and biomass is shown, combined for both February winter surveys, in tables 12.2.4.a and 12.2.4.b.

12.3 The fishery (fleet composition, behaviour and catch)

Initial catch quota for the 2023/2024 fishing season was 0 tonnes (ICES, 2023a.

The intermediate TAC advice based on the autumn survey 2023 recommended TAC = 0 tonnes (MFRI, 2023) and this advice was not changed in winter 2024. No fisheries took place in the 2023/2024 fishing season.

The total catches in numbers by age during summer/autumn since 1985 are given in Table 12.3.2 and for winter since 1986 in Table 12.3.3.

Initial and final TAC as well as landings for the fishing seasons since 1992/93 are given in Table 12.3.4 and total catch by season is shown in Figure 12.3.1.

12.4 Biological data

12.4.1 Growth

Seasonal growth pattern, with considerably increased growth rate during summer and autumn has been observed in this capelin stock in a study of the period 1979–1992. Where immature fish had slower growth during winter, the maturing fish had faster summer growth that continued throughout winter until spawning in March/April, followed by almost 100% spawning mortality (Vilhjalmsson, 1994). Further examination of the growth of immature capelin at age 1 in autumn to mature at age 2 in autumn the year after in the period 1979–2013 showed on average almost fourfold weight increase during one year (Gudmundsdottir and Sigurdsson, 2014). This considerable weight increase and seasonal pattern in growth the year before spawning should be taken into account when deciding the timing of the capelin fisheries.

Immature capelin has rather low fat content, usually less than 3–4%. The fat content rises from approximately 5% in summer to 20% in late autumn. In autumn and winter the fat content slowly declines, until the spawning migration begins in early January where the fat content drops drastically from about 15% to 5% in mid-April (Engilbertsson *et al.*, 2012).

12.5 Methods

The objective of the HCR for the stock is to leave at least 114 000 tonnes (= B_{lim}) for spawning (escapement strategy). The initial (preliminary), intermediate and final TACs are based on acoustic surveys.

a) The initial TAC advice for the subsequent fishing season is issued by ICES in June. It is based on the autumn survey abundance estimate of immature capelin.
b) The intermediate TAC advice is issued by MFRI in autumn based on the biomass estimate of maturing capelin.
c) The final TAC advice is issued by MFRI in January/February based on the biomass estimate of maturing capelin.

The initial (preliminary) quota follows a simple forecast that is based on a linear relation between historic observations of the abundance of juveniles from the acoustic autumn surveys and the corresponding final TACs nearly 1½ year later. Based on this rule, advice on the initial quota for the fishing season 2024/25 is given. Figure 12.7.2 shows the relation and the associated precautionary initial quota.

The intermediate and final TACs are set so that there is at least 95% probability that there will be at least 114 000 tonnes (= B_{lim}) of mature capelin left for spawning at the spawning time

(15 March). This was done for the first time in 2015/2016 by the Icelandic Marine Research Institute and was not evaluated by ICES.

The estimated SSB at spawning time (March-April) has been recompiled for 1981–2023 (Figure 12.6.1 and Table 12.7.1), using the model adopted in 2015 and 2023, i.e taking into account uncertainty in the acoustic measurements and using the predation model adopted in 2015. Uncertainty in acoustic measurements was recompiled for the years 2002–2006 and 2012–2014 by recalculating the acoustic indices and bootstrapping the results. Additionally, uncertainty was available for the years since 2015 when the advice has been given based on the new HCR. For earlier years the CV in the acoustic measurements was estimated by looking at survey reports as well as text from (Vilhjálmsson (1994)) The estimated CV was in the range of 0.15–0.25 and was included as a lognormal multiplier on available average values from the same sources.

These methods were endorsed by the benchmark working group WKICE in 2015 and WKCAPELIN 2022 with minor adjustments. See WKICE (ICES, 2015), WKCAPELIN (ICES, 2023b) and the Stock Annex for the capelin in the Iceland-East Greenland-Jan Mayen area.

Previously, (since early 1980s) the stock was managed according to an escapement strategy, leaving 400 000 tonnes for spawning (uncertainty of the estimates were not considered). To predict the TAC for the next fishing season a model was developed in the early 1990s (Gudmundsdottir and Vilhjalmsson, 2002). These models were not endorsed by the benchmark working group WKSHORT 2009.

12.6 Reference points

During WKICE, a B_{lim} of 150 000 tonnes was defined (ICES, 2015) and following WKCAPELIN B_{lim} was changed to 114 000 tonnes. No other reference points are defined for this stock.

12.7 State of the stock

The spawning-stock biomass (SSB) was estimated to 309 200 tonnes in September 2023 and 162 000 tonnes in January - February 2023. The predation model (ICES, 2015), accounting for catches (in this case winter catch of 0 t) and predation between surveys and spawning by cod, saithe and haddock, estimated that 123 000 tonnes were left for spawning in spring 2024 (Table 12.7.1). Given the uncertainty estimates, there was less than 95% probability that at least 114 000 tonnes was left for spawning. This was below B_{lim} within the sustainable HCR.

The acoustic estimate of immature capelin from the autumn survey in September 2023 was 44.8 billion. The estimate is below long-term average (Figure 12.7.1) and the initial advice according to the HCR is 0 tonnes in the fishing season 2024/25 (Figure 12.7.2) (ICES, 2023a).

12.8 Uncertainties in assessment and forecast

The uncertainty of the assessment and forecast depends largely on the quality of the acoustic surveys in terms of coverage, conditions for acoustic measurements and the aggregation (high patchiness leads to high variance) of the capelin.

The uncertainty is estimated by bootstrapping (see Stock Annex). The CV for the immature abundance was estimated to 0.26 in the 2023 autumn survey. The CV for the mature biomass was estimated to 0.34 in the 2023 autumn survey but in the two winter surveys in February used for the assessment in 2024 it was 0.54 and 0.52.

There was a good spatial coverage of the observed main distributions of the mature component of the stock in the autumn survey 2023. While the autumn survey was affected by time constrains and drift ice hindered the coverage of areas north of Kong Oscar Fjord the distribution of immature and mature components of the capelin stock seemed to have been covered. The final estimate was based on combination of the autumn survey and two winter surveys in February. The winter surveys had considerably lower SSB estimates than the autumn survey. During all winter surveys, the coverage was hindered by sea ice in Denmark Strait that might lead to underestimated stock size. However, repeated surveys in the period December to February did not show the arrival of additional component of mature capelin. Hence the stock estimates from last two winter surveys were used along with the autumn survey estimate to predict the status and development of the capelin stock. The final estimate did not involve repeated surveying with and against the migration direction. Although some components of the stock are likely to have been measured with the survey migration and others against it, there could be some bias due to migration direction. Comparison with previous assessment and forecast.

For the fishing season 2023/2024 0 t initial quota was advised and intermediate and final TAC were also set to 0tonnes. Low juvenile index in autumn 2024 predicts small fishable stock in 2024/2025.

12.9 Management plans and evaluations

See Section 12.5.

12.10 Management considerations

The fishing season for capelin has since 1975 started in the period from late June to July/August when surveys on the juvenile part of the stock the year before have resulted in the setting of an initial (preliminary) catch quota. During summer, the availability of plankton is at its highest and the fishable stock of capelin is feeding very actively over large areas between Iceland, Greenland and Jan Mayen, increasing rapidly in length, weight and fat content. By late September/beginning of October this period of rapid growth is over. The growth is fastest the first two years, but the weight increase is highest in the year before spawning (Vilhjálmsson, 1994).

Given the large weight increase in summer before spawning (Section 12.4) it is likely that there will be more biomass of maturing fish in autumn than in summer, although the level of natural mortality is not well known during this period. This should be considered for optimal timing of fishery in relation to yield and ecological impact. This is also supported by information for the Barents Sea capelin where it has been shown that fishing during autumn would maximize the yield, but from the ecosystem point of view a winter fishery were preferable (Gjøsæter *et.al.*, 2002). As the biology and role in the ecosystem of these two capelin stocks are similar, this is considered to be valid for the capelin in the Iceland-East Greenland-Jan Mayen area as well - until it is studied for this specific stock.

During the autumn surveys, juvenile and adult capelin is often found together. This should be considered during summer and autumn fishing because the survival rate of juvenile capelin that escapes through the trawlnet is unknown.

12.11 Ecosystem considerations

Capelin is an important forage fish and its dynamics are expected to have implications on the productivity of their predators (see further in Section 7.3).

The importance of capelin in East Greenlandic waters is not well documented but effort has been increased considerably during autumn surveys towards evaluation of capelin role in the ecosystem e.g. by research on feeding of capelin, estimates of prey availability, predators' distributions and environmental monitoring.

In Icelandic Waters, capelin is the main single item in the diet of Icelandic cod, a key prey to several species of marine mammals and seabirds and also important as food for several other commercial fish species (see e.g. Vilhjálmsson, 2002; Singh *et al.*, 2023).

12.12 Regulations and their effects

Over the years, the fishery has been closed during April–late June and the season has started in July/August or later, depending on the state of the stock.

Areas with high abundances of juvenile age 1 and 2 capelin (on the shelf region off NW-, N- and NE-Iceland) have usually been closed to the summer and autumn fishery.

It is permissible to transfer catches from the purse-seine of one vessel to another vessel, in order to avoid slippage. However, if the catches are beyond the carrying capacity of the vessel and no other vessel is nearby, slippage is allowed. In recent years, reporting of such slippage has not been frequent. Industrial trawlers do not have the permission to slip capelin in order to harmonize catches to the processing.

In Icelandic Waters, fishing with pelagic trawl is only allowed in limited area off the NE-coast (fishing in January) to protect juvenile capelin and to reduce the risk of affecting the spawning migration route (shuttering of migrating capelin schools by pelagic trawling has been hypothesized).

As a precautionary measure to protect juvenile capelin, the coastal states (Iceland, Greenland and Norway) have agreed that from 2021 fishing shall not start until 15 October.

12.13 Changes in fishing technology and fishing patterns

There were no catches in 2023/24, but historically a variable amount of the catches have been taken with pelagic trawl through the fishing seasons, related to the size of the TAC and when it is issued. Discards have been considered negligible.

12.14 Changes in the environment

Icelandic and East Greenlandic waters are characterized by highly variable hydrographical conditions, with temperatures and salinities depending on the strength of Atlantic inflow through the Denmark Strait and the variable flow of polar water from the north. A rise in ambient sea temperatures for the migrating and spawning capelin was especially abrupt around 2003, coinciding with a decrease in recruitment, and a change in nursery areas that may partly be a be a consequence of a change in spawning distribution (Jansen *et al.*, 2021). Including consequences on the progress of spawning migration (Singh *et al.*, 2020). The acoustic surveys in autumn 2010, 2012–onwards confirmed this change in distribution of immatures and maturing capelin. Fisheries data suggests that major part of the spawning still takes place on the usual grounds by the South and Southwest coasts of Iceland and possibly to increased extent by the North coast of Iceland.

A more detailed environmental description is in Section 7.3.

12.15 Recommendations

Studies of optimal harvesting of capelin should be conducted. These estimates should take account of ecological impact, growth, mortality and gear selection in relation to the timing of the fishery.

Profound changes in the distribution, migration and productivity of this capelin stock, likely caused by environmental changes, point out there is an urgent need for further biological studies i.e. regarding life history (including changes in spawning grounds, larval drift and migration at times not observed by autumn and winter surveys) and the role of capelin (predation/prey relationships) as a key species in the ecosystem.

The assessment and advice on the final TAC for capelin based on the autumn and winter surveys are issued directly to the Coastal States by the Icelandic Marine and Freshwater Research Institute. This process is not internationally peer reviewed prior to the release of the advice. Among the reasons for using this process is the need for fast advice once the survey results are available. The ICES ACOM procedure is more time consuming. NWWG has recommended that a fast track workflow based on online meetings is established if possible. The coastal states evaluated this recommendation in 2017 and concluded that a current regime for setting intermediate and final TAC should be maintained.

When planning acoustic surveys for capelin stock assessment, allocation of effort in terms of ship time, number of ships and manpower, should be sufficient for a likely full coverage in the first attempt given the demanding weather and ice conditions during autumn and winter surveys.

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12.17 Tables

Table 12.2.1.a Icelandic Capelin. Estimated stock size of the capelin total stock component in numbers (millions) by age (years) and length (cm), and biomass (thous. tonnes) from the acoustic survey in 23. August – 23. September 2023.

Length (cm)	Numbers-at-age (10^9)				Numbers (10^9)	Biomass (10^3t)	Mean weight (g)
	1	2	3	4			
8	46.40	0.00	0.00	0.00	46.40	92.79	2.00
8.5	463.96	0.00	0.00	0.00	463.96	1043.92	2.25
9	1299.10	0.00	0.00	0.00	1299.10	3447.25	2.65
9.5	2319.82	0.00	0.00	0.00	2319.82	7199.78	3.10
10	2055.99	0.00	0.00	0.00	2055.99	7765.81	3.78
10.5	2751.94	0.00	0.00	0.00	2751.94	12429.94	4.52
11	3166.76	0.00	0.00	0.00	3166.76	16709.34	5.28
11.5	4448.57	0.00	0.00	0.00	4448.57	27159.53	6.11
12	7258.71	246.53	0.00	0.00	7505.24	54390.76	7.25
12.5	6235.25	107.34	0.00	0.00	6342.60	53042.61	8.36
13	6789.27	382.98	0.00	0.00	7172.25	68288.35	9.52
13.5	3970.90	43.66	0.00	0.00	4014.56	44246.92	11.02
14	3301.32	473.04	14.55	0.00	3788.91	47609.55	12.57
14.5	2030.48	455.74	46.40	0.00	2532.62	36869.78	14.56
15	1105.29	1097.92	90.05	0.00	2293.27	36602.43	15.96
15.5	322.03	961.47	136.45	14.55	1434.51	26914.86	18.76
16	92.79	1133.36	354.73	0.00	1580.88	33706.02	21.32
16.5	0.00	1460.87	537.57	0.00	1998.45	46426.55	23.23

Length (cm)	Numbers-at-age (10^9)				Numbers (10^9)	Biomass (10^3t)	Mean weight (g)
	1	2	3	4			
17	0.00	741.30	834.95	14.55	1590.80	40905.02	25.71
17.5	0.00	430.23	791.29	14.55	1236.07	36170.84	29.26
18	0.00	209.21	672.13	0.00	881.34	27142.38	30.80
18.5	0.00	60.95	473.89	0.00	534.83	18388.98	34.38
19	0.00	14.55	221.02	0.00	235.57	8626.15	36.62
19.5	0.00	0.00	58.21	0.00	58.21	2225.30	38.23
20	0.00	0.00	14.55	0.00	14.55	642.04	44.12

Table 12.2.1.b Icelandic Capelin. Summary of the capelin stock components from the acoustic survey in 23. August – 23. September 2023. Age (years) aggregated spawning stock component summary. T = Total, S = Stock, N = Numbers (billions), W = Weight(grammes), L = Length(Cm), p = %

	Age				**Total**	**Mean**
	1	**2**	**3**	**4**		
TSN	47.66	7.82	4.25	0.04	59.77	
TSB	384.55	155.56	116.88	1.05	658.05	
MeanW	8.07	19.89	27.53	24.02		11.01
MeanL	12.17	15.60	17.29	16.63		12.98
TSNp	79.74	13.08	7.10	0.07		
SSN	4.53	6.24	4.14	0.04	14.95	
SSB	62.07	131.69	114.40	1.05	309.21	
MeanW	13.72	21.10	27.64	24.02		20.68
MeanL	14.19	15.91	17.31	16.63		15.78
SSNp	30.28	41.75	27.68	0.29		
ISN	43.13	1.58	0.11		44.82	
ISB	322.48	23.87	2.49		348.84	
MeanW	7.48	15.12	23.19			7.78
MeanL	11.95	14.39	16.42			12.05
ISNp	96.24	3.52	0.24			

Table 12.2.2. Icelandic Capelin. Abundance of age classes in numbers (10^9) measured in acoustic surveys in autumn.

Year	Month	Day	Age1 Imm.	Age1 Mat.	Age2 Imm.	Age2 Mat.	Age3 Imm.	Age3 Mat.	Age4 Mat.	Age5 Mat.
1978	10	16				60.0		13.9	0.4	
1979	10	14	10.0			49.7		9.1	0.4	
1980	10	11	23.5			19.5		4.8		
1981	11	26	21.0		1.1	11.9		0.6		
1982	10	2	68.0		1.7	15.0		1.6		
1983	10	3	44.1		8.2	58.6		5.6	0.1	
1984	11	1	73.8		4.6	31.9		10.3	0.3	
1985	10	8	33.8		12.6	43.7		14.4	0.4	0.1
1986	10	4	58.6		1.4	19.9		29.8	0.3	
1987	11	18	21.3		2.5	52.0		13.5		
1988	10	6	43.9		6.7	53.0		17.0	0.4	
1989	10	26	29.2		1.8	2.9		0.6		
1990	11	8	24.9		1.3	16.4		2.7	0.1	
1991	11	15	60.0		5.3	44.7		4.2		
1992	10	13	104.6		2.3	54.5		4.3	0.1	
1993	11	18	100.4		9.8	55.1		4.9		
1994	11	25	119.0		6.9	29.2		4.4		
1995	11	30	165.0		30.1	84.6		7.0		
1996	11	27	111.9		16.4	70.0		15.9		
1997	11	1	66.8		30.8	52.5		8.5		
1998	11	13	121.0		5.9	20.5		3.3		
1999	11	15	89.8		4.4	18.1		0.9		
2000	11	10	103.7		10.9	11.6	0.1	0.6		
2001	11	12	101.8		2.4	22.1	0.0	0.7		
2002	11	12	1.0		0.5					
2003	11	6	4.9		3.1	1.7	0.1	0.2		
2004	11	22	7.9		0.1	7.3		0.8	0.0	
2005	11									

Year	Month	Day	Age1 Imm.	Age1 Mat.	Age2 Imm.	Age2 Mat.	Age3 Imm.	Age3 Mat.	Age4 Mat.	Age5 Mat.
2006	11	6	44.7		0.3	5.2		0.4		
2007	11	7	5.7		0.1	1.3		0.0		
2008	11	17	7.5	5.1	0.4	12.1		1.8		
2009	11	24	13.0	2.4		5.0		0.7		
2010	10	1	91.6	9.6	6.3	25.8	0.1	0.8	0.02	
2011	11	29	9.0	0.6	3.6	19.9	0.05	2.1		
2012	10	3	18.5	0.9	2.0	21.2	0.07	11.4	0.1	
2013	9	17	60.1	0.6	6.9	25.0	1.3	6.9	0.1	
2014	9	16	57.0	1.0	3.3	26.5	0.2	7.6	0.1	
2015	9	16	5.0	0.4	1.2	21.2		6.7		
2016	9	10	8.7	0.5	0.7	4.5	0.0	0.9	0.01	
2017	9	7	24.6	1.3	1.5	35.5	0.0	5.1	0.05	
2018	9	6	10.3	1.5	0.4	8.8	0.0	1.0		
2019	9	12	81.5	1.8	1.1	6.1		0.6	0.0	
2020	9	7	139.8	0.8	6.5	13.5	0.0	1.44		
2021	9	6	84.8	1.0	45.9	87.6	0.8	7.7	0.03	
2022	8	27	28.7		11.2	22.8	0.9	11.7	0.04	
2023	8	23	43.13	4.53	1.58	6.24	0.11	4.14	0.04	

1987 - The number-at-age 1 was from survey earlier in autumn.
2005 - Scouting vessels searched for capelin. r/s ÁF measured. No samples taken for age determination. Estimated to be < 50 000 t.
2011 - Only limited coverage of the traditional capelin distribution area. 2001–2009 and 2016 – Not full coverage of stock.

Table 12.2.3. Icelandic Capelin. Mean weight (g) of age classes measured in acoustic surveys in autumn. (imm = immature, mat = mature). See footnotes in Table 12.2.2.

Year	Mon	Age1 Imm.	Age1 Mat.	Age2 Imm.	Age2 Mat.	Age3 Imm.	Age3 Mat.	Age4 Mat.	Age5 Mat.
1978	10				19.8		25.4	26.3	
1979	10	6.2			15.7		23.0	20.8	
1980	10	7.3			19.4		26.7		
1981	11	3.6		12.3	19.4		22.5		

Year	Mon	Age1 Imm.	Age1 Mat.	Age2 Imm.	Age2 Mat.	Age3 Imm.	Age3 Mat.	Age4 Mat.	Age5 Mat.
1982	10	3.8		8.5	16.5		24.1		
1983	10	5.1		9.5	16.8		22.5	23.0	
1984	11	2.9		8.3	15.8		25.7	23.2	
1985	10	3.8		8.5	15.5		23.8	29.5	31.0
1986	10	4.0		6.1	18.1		24.1	28.8	
1987	11	2.8		8.7	17.9		25.8		
1988	10	3.0		8.0	15.4		23.4	20.9	
1989	10	3.5		8.0	12.9		24.0		
1990	11	3.9		8.4	18.0		25.5	36.0	
1991	11	4.7		7.9	16.3		25.4		
1992	10	3.7		8.6	16.5		22.6	22.0	
1993	11	3.6		8.9	16.2		23.3		
1994	11	3.3		7.9	15.9		23.6		
1995	11	3.7		7.0	14.0		20.8		
1996	11	3.1		7.4	15.8		20.6		
1997	11	3.3		8.5	14.3		20.1		
1998	11	3.5		9.9	13.7		18.8		
1999	11	3.6		8.0	15.4		19.5		
2000	11	3.9		8.5	13.4	13.0	20.8		
2001	11	3.8		8.8	16.3	15.7	23.9		
2002	11								
2003	11	7.2		14.9	17.0	22.6	23.7		
2004	11	7.4		7.6	16.0		18.0	14.5	
2005									
2006	11	3.7		7.9	15.0		16.7		
2007	11	5.5		8.6	14.9		15.8		
2008	11	6.2	11.0	6.9	18.6		22.4		
2009	11	5.1	9.8		20.0		23.8		

Year	Mon	Age1 Imm.	Age1 Mat.	Age2 Imm.	Age2 Mat.	Age3 Imm.	Age3 Mat.	Age4 Mat.	Age5 Mat.
2010	10	5.8	12.9	12.2	19.0	12.9	24.0	21.2	
2011	11	6.8	11.4	11.1	18.7	15.8	24.4		
2012	10	6.5	16.0	15.3	22.0	22.4	28.0	26.6	
2013	9	5.8	12.6	10.9	18.0	11.2	20.9	23.6	
2014	9	4.2	9.9	12.7	18.3	16.6	21.2	25.0	
2015	9	8.5	12.3	13.4	18.4	21.5	23.1		
2016	9	9.0	15.1	13.1	25.5	11.5	31.7	39.2	
2017	9	8.0	12.6	15.0	22.2	22.3	27.2	33.2	
2018	9	8.8	12.9	16.5	21.7	21.2	27.1		
2019	9	7.3	13.4	14.5	24.0	15.7	27.1	28.4	
2020	9	4.8	10.0	10.8	22.0	31.3	26.7		
2021	9	5.2	6.9	13.1	18.6	21.7	25.5	29.1	
2022	9	5.8		14.7	19.5	21.9	28	39.6	
2023	8	7.48	13.72	15.12	21.1	23.19	27.64	24.02	

Table 12.2.4.a Icelandic Capelin. Estimated stock size of Iceland-Greenland-Jan Mayen capelin total stock in numbers (millions) by age (years) and length (cm), and biomass (thous. tonnes) from the acoustic surveys in 23. January – 23. February 2023.

	Numbers-at-age (10^9)						
Length (cm)	2	3	4	5	Total N	Total B	Mean weight (g)
8.5	33.14	0.00	0.00	0.00	33.14	44.40	1.34
9.5	66.27	0.00	0.00	0.00	66.27	197.49	2.98
10	140.21	0.00	0.00	0.00	140.21	447.70	3.19
10.5	410.48	0.00	0.00	0.00	410.48	1564.01	3.81
11	558.36	0.00	0.00	0.00	558.36	2497.40	4.47
11.5	910.23	0.00	0.00	0.00	910.23	4710.52	5.18
12	1251.96	0.00	0.00	0.00	1251.96	7605.32	6.07
12.5	2062.78	107.07	0.00	0.00	2169.85	15258.06	7.03
13	3380.79	73.94	0.00	0.00	3454.73	28310.20	8.19
13.5	3442.10	81.60	0.00	0.00	3523.70	32862.07	9.33

	Numbers-at-age (10^9)						
Length (cm)	2	3	4	5	Total N	Total B	Mean weight (g)
14	2636.58	402.82	0.00	0.00	3039.40	33002.06	10.86
14.5	1415.49	340.08	0.00	0.00	1755.57	21638.33	12.33
15	459.20	531.99	7.75	0.00	998.93	14298.06	14.31
15.5	219.66	418.64	38.36	0.00	676.65	11583.16	17.12
16	102.78	597.07	217.08	0.00	916.93	17361.60	18.93
16.5	120.12	605.44	123.19	0.00	848.76	17847.89	21.03
17	7.75	779.66	283.98	0.00	1071.39	25931.98	24.20
17.5	0.00	553.23	524.69	0.00	1077.92	28820.70	26.74
18	0.00	107.70	509.19	40.88	657.78	19847.41	30.17
18.5	0.00	53.85	444.39	61.22	559.46	18038.25	32.24
19	0.00	7.75	84.46	0.00	92.21	3177.98	34.47
19.5	0.00	0.00	30.61	0.00	30.61	1085.08	35.45

Table 12.2.4.b Icelandic Capelin. Summary of the capelin stock components from the acoustic surveys in 17. – 30. January 2021. Age (years) aggregated spawning stock component summary. T = Total, S = Stock, N = Numbers(billions), W = Weight(grammes), L = Length (Cm), p = %

	Age				Total	Mean
	2	3	4	5		
TSN	17.22	4.66	2.26	0.10	24.24	
TSB	152.04	88.60	62.34	3.15	306.13	
MeanW	8.83	19.01	27.54	30.88		12.63
MeanL	13.15	15.88	17.62	18.38		14.11
TSNp	71.02	19.22	9.34	0.42	100	
SSN	1.25	3.85	2.26	0.10	7.47	
SSB	17.92	78.56	62.34	3.15	161.97	
MeanW	14.34	20.39	27.54	30.88		21.69
MeanL	14.67	16.17	17.62	18.38		16.39
SSNp	17.25	52.00	29.47	1.28	100	
ISN	15.97	0.81	0	0	16.78	
ISB	134.12	10.04	0	0	144.16	

	Age				Total	Mean
	2	**3**	**4**	**5**		
MeanW	8.40	12.42	0	0		8.59
MeanL	13.03	14.50	0	0		13.10
ISNp	95.23	4.77	0	0	100	

Table 12.3.1 Capelin. The international catch since 1964 (thousand tonnes).

Year	Winter season					Summer and autumn season						Total
	Iceland	Norway	Faroes	Greenland	Season total	Iceland	Norway	Faroes	Greenland	EU	Season total	
1964	8.6	-	-		8.6	-	-	-		-	-	8.6
1965	49.7	-	-		49.7	-	-	-		-	-	49.7
1966	124.5	-	-		124.5	-	-	-		-	-	124.5
1967	97.2	-	-		97.2	-	-	-		-	-	97.2
1968	78.1	-	-		78.1	-	-	-		-	-	78.1
1969	170.6	-	-		170.6	-	-	-		-	-	170.6
1970	190.8	-	-		190.8	-	-	-		-	-	190.8
1971	182.9	-	-		182.9	-	-	-		-	-	182.9
1972	276.5	-	-		276.5	-	-	-		-	-	276.5
1973	440.9	-	-		440.9	-	-	-		-	-	440.9
1974	461.9	-	-		461.9	-	-	-		-	-	461.9
1975	457.1	-	-		457.1	3.1	-	-		-	3.1	460.2
1976	338.7	-	-		338.7	114.4	-	-		-	114.4	453.1
1977	549.2	-	24.3		573.5	259.7	-	-		-	259.7	833.2
1978	468.4	-	36.2		504.6	497.5	154.1	3.4		-	655	1,159.60
1979	521.7	-	18.2		539.9	442	124	22		-	588	1,127.90

Year	Winter season					Summer and autumn season						Total
	Iceland	Norway	Faroes	Greenland	Season total	Iceland	Norway	Faroes	Greenland	EU	Season total	
1980	392.1	-	-		392.1	367.4	118.7	24.2		17.3	527.6	919.7
1981	156	-	-		156	484.6	91.4	16.2		20.8	613	769
1982	13.2	-	-		13.2	-	-	-		-	-	13.2
1983	-	-	-		-	133.4	-	-		-	133.4	133.4
1984	439.6	-	-		439.6	425.2	104.6	10.2		8.5	548.5	988.1
1985	348.5	-	-		348.5	644.8	193	65.9		16	919.7	1,268.20
1986	341.8	50	-		391.8	552.5	149.7	65.4		5.3	772.9	1,164.70
1987	500.6	59.9	-		560.5	311.3	82.1	65.2		-	458.6	1,019.10
1988	600.6	56.6	-		657.2	311.4	11.5	48.5		-	371.4	1,028.60
1989	609.1	56	-		665.1	53.9	52.7	14.4		-	121	786,1
1990	612	62.5	12.3		686.8	83.7	21.9	5.6		-	111.2	798
1991	202.4	-	-		202.4	56	-	-		-	56	258.4
1992	573.5	47.6	-		621.1	213.4	65.3	18.9	0.5	-	298.1	919.2
1993	489.1	-	-	0.5	489.6	450	127.5	23.9	10.2	-	611.6	1,101.20
1994	550.3	15	-	1.8	567.1	210.7	99	12.3	2.1	-	324.1	891.2
1995	539.4	-	-	0.4	539.8	175.5	28	-	2.2	-	205.7	745.5
1996	707.9	-	10	5.7	723.6	474.3	206	17.6	15	60.9	773.8	1,497.40

Year	Winter season					Summer and autumn season						Total
	Iceland	Norway	Faroes	Greenland	Season total	Iceland	Norway	Faroes	Greenland	EU	Season total	
1997	774.9	-	16.1	6.1	797.1	536	153.6	20.5	6.5	47.1	763.6	1,561.50
1998	457	-	14.7	9.6	481.3	290.8	72.9	26.9	8	41.9	440.5	921.8
1999	607.8	14.8	13.8	22.5	658.9	83	11.4	6	2	-	102.4	761.3
2000	761.4	14.9	32	22	830.3	126.5	80.1	30	7.5	21	265.1	1,095.40
2001	767.2	-	10	29	806.2	150	106	12	9	17	294	1,061.20
2002	901	-	28	26	955	180	118.7	-	13	28	339.7	1,294.70
2003	585	-	40	23	648	96.5	78	3.5	2.5	18	198.5	846.5
2004	478.8	15.8	30.8	17.5	542.9	46	34	-	12		92	634.9
2005	594.1	69	19	10	692	9	-	-	-	-	9	701.1
2006	193	8	30	7	238	-	-	-	-		-	238
2007	307	38	19	12.8	376.8	-	-	-	-	-	-	376.8
2008	149	37.6	10.1	6.7	203.4	-	-	-	-	-	-	203.4
2009	15.1	-	-	-	15.1	-	-	-	-	-	-	15.1
2010	110.6	28.3	7.7	4.7	150.7	5.4	-	-	-	-	5.4	156.1
2011	321.8	30.8	19.5	13.1	385.2	8.4	58.5		5.2	-	72.1	457.3
2012	576.2	46.2	29.7	22.3	674.4	9	-	-	1	-	10	684.4
2013	454	40	30	17	541	-	-	-	-	-	-	541

Year	Winter season					Summer and autumn season						Total
	Iceland	Norway	Faroes	Greenland	Season total	Iceland	Norway	Faroes	Greenland	EU	Season total	
2014	111.4	6.2	8	16.1	141.7	-	30.5	-	5.3	9.7	45.5	187.2
2015	353.6	50.6	29.9	37.9	471.9	-	-	-	2.5	-	2.5	474.4
2016	101.1	58.2	8.5	3.3	171.1	-	-	-	-	-	-	171.1
2017	196.8	60.4	15	27.4	299.8	-	-	-	-	-	-	299.8
2018	186.3	74.5	14.3	11.4	286.5	-	-	-	-	-	-	286.5
2019	-	-	-	-	-	-	-	-	-	-	-	-
2020	-	-	-	-	-	-	-	-	-	-	-	-
2021	67	49.4	6.4	6.6	129.4	75.8	-	-	1.3	-	77.1	206.5
2022	433.8	122.3	29.5	26.6	612.1	4.3	-	-	0.6	-	4.9	617.0
2023*	325.7	50.4	22.8	46.3	445.2	-	-	-	-	-	-	-
2024	-	-	-	-	-	-	-	-	-	-	-	-

*** Preliminary, provided by working group members.**

Table 12.3.2 Icelandic capelin. The total international catch of capelin in the Iceland-East Greenland-Jan Mayen area by age group in numbers (billions) and the total catch by numbers and weight (thousand tonnes) in the autumn season (August–December) since 1985.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Total number	Total weight
1985	0.8	25.6	15.4	0.2		42.0	919.7
1986	+	10.0	23.3	0.5		33.8	772.9
1987	+	27.7	6.7	+		34.4	458.6
1988	0.3	13.6	5.4	+		19.3	371.4
1989	1.7	6.0	1.5	+		9.2	121.0
1990	0.8	5.9	1.0	+		7.7	111.2
1991	0.3	2.7	0.4	+		3.4	56.0
1992	1.7	14.0	2.1	+		17.8	298.1
1993	0.2	24.9	5.4	0.2		30.7	611.6
1994	0.6	15.0	2.8	+		18.4	324.1
1995	1.5	9.7	1.1	+		12.3	205.7
1996	0.2	25.2	12.7	0.2		38.4	773.7
1997	1.8	33.4	10.2	0.4		45.8	763.6
1998	0.9	25.1	2.9	+		28.9	440.5
1999	0.3	4.7	0.7	+		5.7	102.4
2000	0.2	12.9	3.3	0.1		16.5	265.1
2001	+	17.6	1.2	+		18.8	294.0
2002	+	18.3	2.5	+		20.8	339.7
2003	0.3	11.8	1	+		14.3	199.5
2004	+	5.3	0.5	-		5.8	92.0
2005	-	0.4	+	-		0.4	9.0
2006	-	-	-	-		-	-
2007	-	-	-	-		-	-
2008	-	-	-	-		-	-
2009	-	-	-	-		-	-
2010	0.01	0.23	0.02	-		0.25	5.4
2011	-	2.45	1.61	-	0.08	4.13	72.1

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Total number	Total weight
2012	-	0.2	0.2	-	-	0.4	10.4
2013	-	-	-	-	-	-	-
2014	0.01	2.22	0.6	0.02	-	2.8	45.5
2015	0.03	0.08	0.03			1.4	2.5
2016	-	-	-	-	-	-	-
2017	-	-	-	-	-	-	-
2018	-	-	-	-	-	-	-
2019	-	-	-	-	-	-	-
2020	-	-	-	-	-	-	-
2021	-	2.6	0.6	0.01	-	4.2	77.1
2022	-	0.05	0.11	0.00	-	0.16	4.9
2023	-	-	-	-	-	-	-

Table 12.3.3 Icelandic capelin. The total international catch of capelin in the Iceland-East Greenland-Jan Mayen area by age group in numbers (billions) and the total catch by numbers and weight (thousand tonnes) in the winter season (January–March) since 1986.

Year	age 1	age 2	age 3	age 4	age 5	Total number	Total weight
1986		0.1	9.8	6.9	0.2	17.0	391.8
1987		+	6.9	15.5	-	22.4	560.5
1988		+	23.4	7.2	0.3	30.9	657.2
1989		0.1	22.9	7.8	+	30.8	665.1
1990		1.4	24.8	9.6	0.1	35.9	686.8
1991		0.5	7.4	1.5	+	9.4	202.4
1992		2.7	29.4	2.8	+	34.9	621.1
1993		0.2	20.1	2.5	+	22.8	489.6
1994		0.6	22.7	3.9	+	27.2	567.1
1995		1.3	17.6	5.9	+	24.8	539.8
1996		0.6	27.4	7.7	+	35.7	723.6
1997		0.9	29.1	11	+	41.0	797.6
1998		0.3	20.4	5.4	+	26.1	481.3

Year	age 1	age 2	age 3	age 4	age 5	Total number	Total weight
1999		0.5	31.2	7.5	+	39.2	658.9
2000		0.3	36.3	5.4	+	42.0	830.3
2001		0.4	27.9	6.7	+	35.0	787.2
2002		0.1	33.1	4.2	+	37.4	955.0
2003		0.1	32.2	1.9	+	34.4	648.0
2004		0.6	24.6	3	+	28.3	542.9
2005		0.1	31.5	3.1	-	34.7	692.0
2006		0.1	10.4	0.3	-	10.8	230.0
2007		0.3	19.5	0.5	-	20.3	376.8
2008		0.5	10.6	0.4	-	11.5	202.4
2009		0.1	0.6	0.1	-	0.7	15.1
2010		0.7	5.3	0.9	0.01	6.9	150.7
2011		0.1	16.2	0.6	-	17.0	385.2
2012	0.02	0.6	25.0	6.1	0.02	31.8	674.4
2013	-	0.3	12.1	9.7	0.2	22.3	541.0
2014	-	0.1	4.8	1.3	+	6.1	141.8
2015	-	0.3	17.5	4.7	0.1	22.7	471.9
2016		0.4	5.5	2.0	0.02	8.0	171.1
2017		0.4	5.4	4.1	0.1	10.0	299.8
2018		0.6	10.4	0.9	0.01	11.91	286.5
2019	-	-	-	-	-	0	0
2020	-	-	-	-	-	-	-
2021	-	0.0	4.8	0.3	-	5.2	129.4
2022	-	0.2	22.6	1.5	0.01	24.3	612.1
2023			7.9	9.2	0.06	17.2	445.2
2024	-	-	-	-	-	-	-

Table 12.3.4. Initial quota and final TAC and landings by seasons.

Fishing season	Initial advice	Final TAC	Landings
1992/931	500	900	788
1993/94[1]	900	1250	1179
1994/95	950	850	842
1995/96[1]	800	1390	930
1996/97[1]	1100	1600	1571
1997/98	850	1265	1245
1998/99	950	1200	1100
1999/00	866	1000	934
2000/01	650	1090	1065
2001/02	700	1300	1249
2002/03	690	1000	988
2003/04[2]	555	900	741
2004/05[3]	335	985	783
2005/06	No fishery	235	238
2006/07	No fishery	385	377
2007/08	207	207	202
2008/09[4]	No fishery		15
2009/10	No fishery	150	151
2010/11	No fishery	390	391
2011/12	366	765	747
2012/13	No fishery	570	551
2013/14[1]	No fishery	160	142
2014/15	225[5]	580	517
2015/16	No fishery[5]	173	174
2016/17	No fishery[5]	299	300
2017/18	No fishery[5]	285	287
2018/19	No fishery[5]	0	0

Fishing season	Initial advice	Final TAC	Landings
2019/20	No fishery[5]	0	0
2020/21	170[5]	127	129
2021/22	400[5]	870	689
2022/23[6]	400[5]	460	450
2023/24	No fishery[5]	0	0

1) The final TAC was set on basis of autumn surveys in the season.

2) Indices from April 2003 were projected back to October 2002.

3) The initial quota was set on a basis of an acoustic survey in June/July 2004

4) No fishery was allowed, 15 000 t was assigned to scouting vessels.

5) Initial advice based on low probability of exceeding final TAC.

6) Preliminary landings.

Table 12.7.1 Icelandic capelin in the Iceland-East Greenland-Jan Mayen area since the fishing season 1978/79. (A fishing season e.g. 1978/79 starts in summer 1978 and ends in March 1979). Recruitment of 1-year-old fish (unit 10^9) as measured in autumn survey. Spawning-stock biomass ('000 t) is given at the time of spawning at the end of the fishing season. Landings ('000 t) are sum of total landings in the season.

Season (Summer/winter)	Recruitment	Landings	Spawning-stock biomass
1978/79	-	1195	600*
1979/80	22	980	300*
1980/81	23.5	684	106
1981/82	21	626	116
1982/83	68	0	206
1983/84	44.1	573	338
1984/85	73.8	896	315
1985/86	33.8	1312	156
1986/87	58.6	1334	365
1987/88	21.3	1116	257
1988/89	43.9	1036	139
1989/90	29.2	807	91
1990/91	27.2	313	245
1991/92	60	677	203
1992/93	104.6	788	294

Season (Summer/winter)	Recruitment	Landings	Spawning-stock biomass
1993/94	100.4	1178	307
1994/95	119	864	144
1995/96	165	930	380
1996/97	111.9	1570	426
1997/98	66.8	1246	272
1998/99	121	1100	230
1999/00	89.8	932	120
2000/01	103.7	1071	233
2001/02	101.8	1249	242
2002/03	-	988	10
2003/04	4.9	742	109
2004/05	7.9	784	226
2005/06	-	247	16
2006/07	44.7	377	217
2007/08	5.7	203	65
2008/09	12.6	150	261
2009/10	15.4	151	261
2010/11	101.2	391	204
2011/12	9.6	747	257
2012/13	19.4	551	301
2013/14	60.7	142	289
2014/15	58	518	342
2015/16	5.4	174	336
2016/17	9.2	300	356
2017/18	25.9	287	384
2018/19	11.8	0	166
2019/20	83.3	0	142
2020/21	140.6	129	374
2021/22	85.8	689	510

Season (Summer/winter)	Recruitment	Landings	Spawning-stock biomass
2022/23	28.7	450	356
2023/24	47.66	0	123

*** Based on historical stock estimates while later values are based on predation model in current HCR.**

12.18 Figures

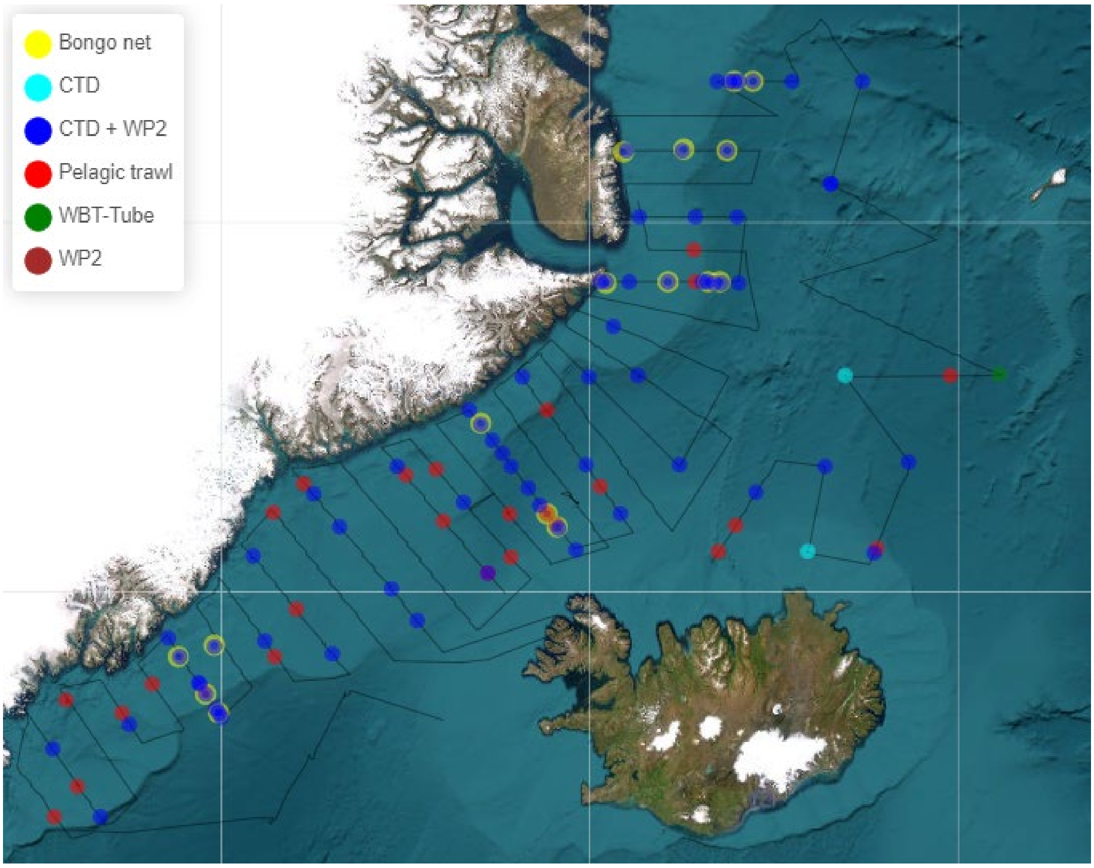

Figure 12.2.1. Icelandic capelin. Cruise tracks during an acoustic survey by RV Arni Fridriksson and Tarajoq during 23 August – 23 September 2023.

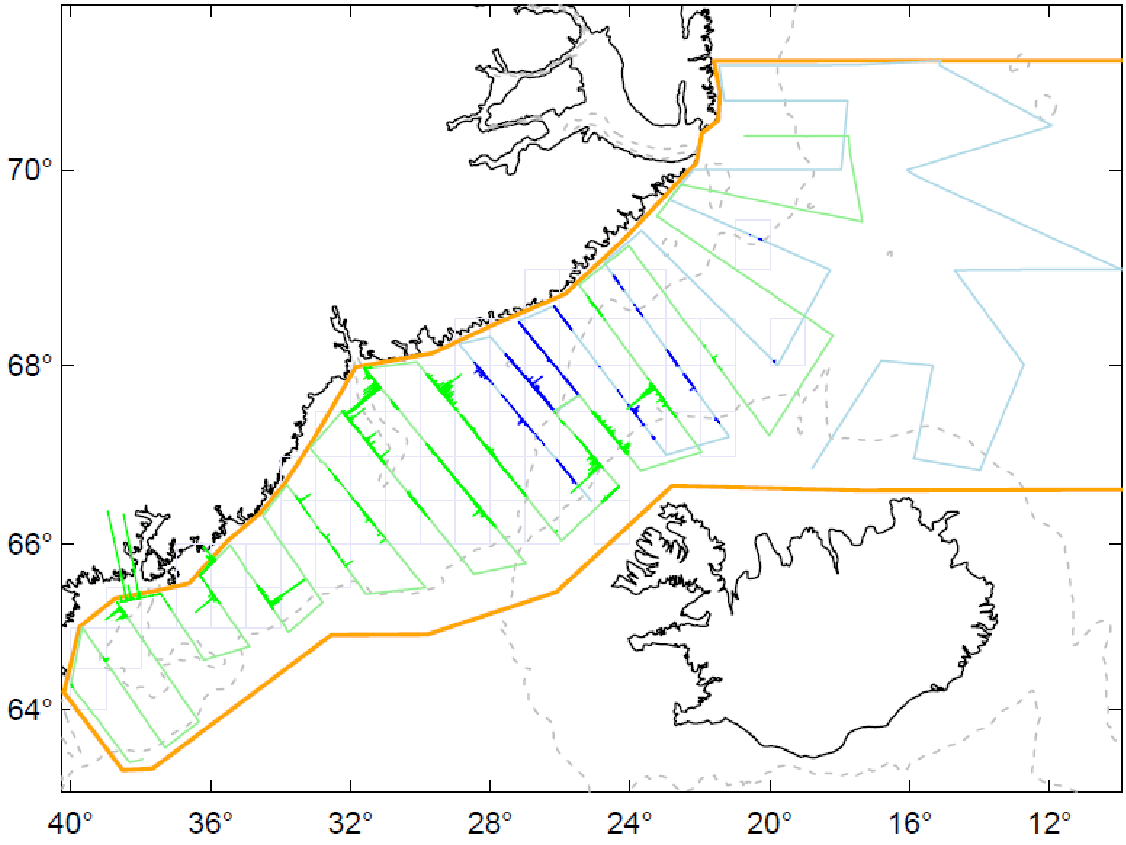

Figure 12.2.2. Icelandic capelin. Relative density and distribution of capelin shown as bars perpendicular to survey tracks showing capelin acoustic backscatter as NASC per 0.1 nautical mile. Tarajoq track and NASC light green, Árni Friðriksson track cyan, NASC blue, during 23 August – 23 September 2023.

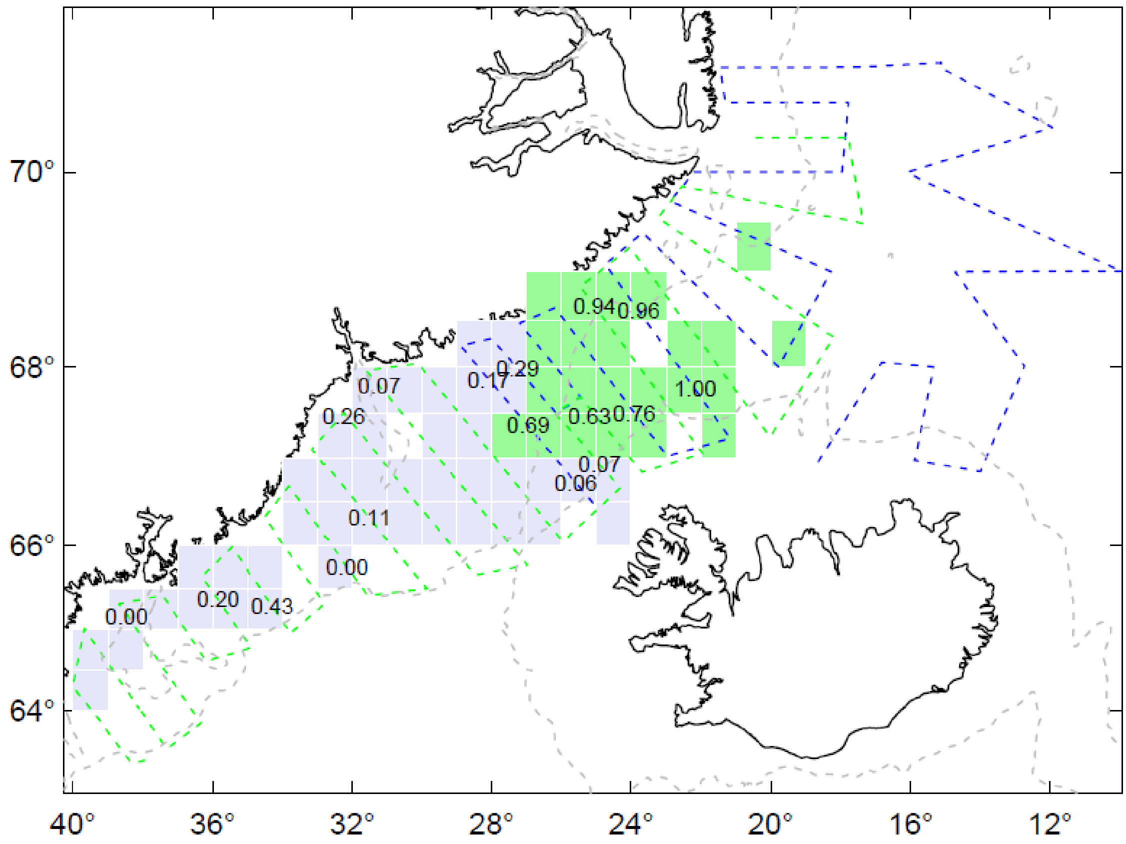

Figure 12.2.3 Icelandic capelin. Transects of the participating vessels and proportion mature within capelin samples and regional allocation in assessment during the autumn survey in 23 August – 23 September 2023.

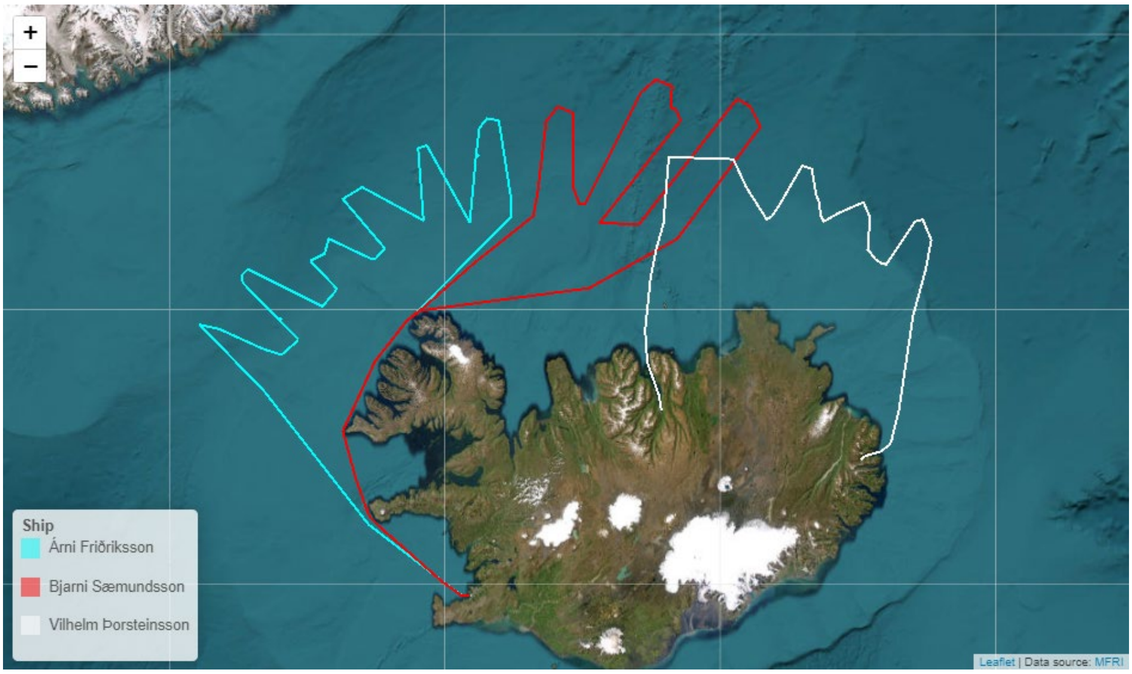

Figure 12.2.4. Icelandic capelin. Survey tracks of the participating vessels in December 2023.

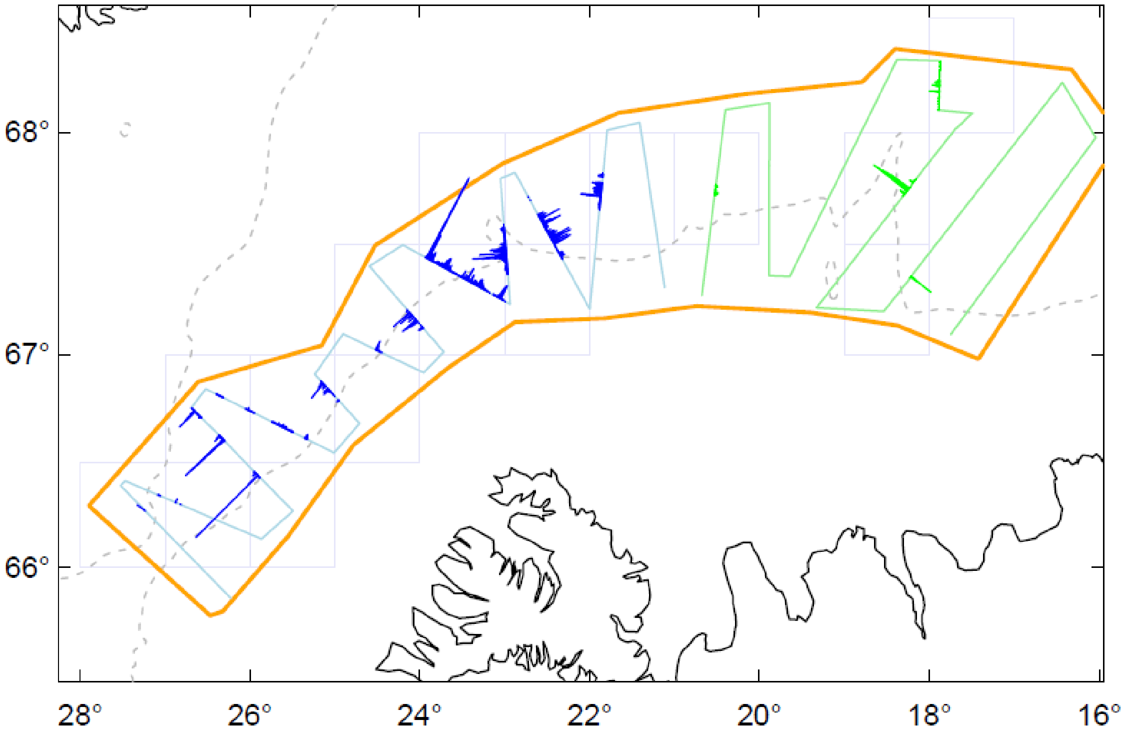

Figure 12.2.5. Icelandic capelin. Capelin distribution as relative density of acoustic backscatter during the survey in December 2023. Bars perpendicular to survey tracks show capelin acoustic backscatter as NASC per 0.1 nautical mile. Bjarni Sæmundsson track light green, NASC dark green, Árni Friðriksson track cyan, NASC blue.

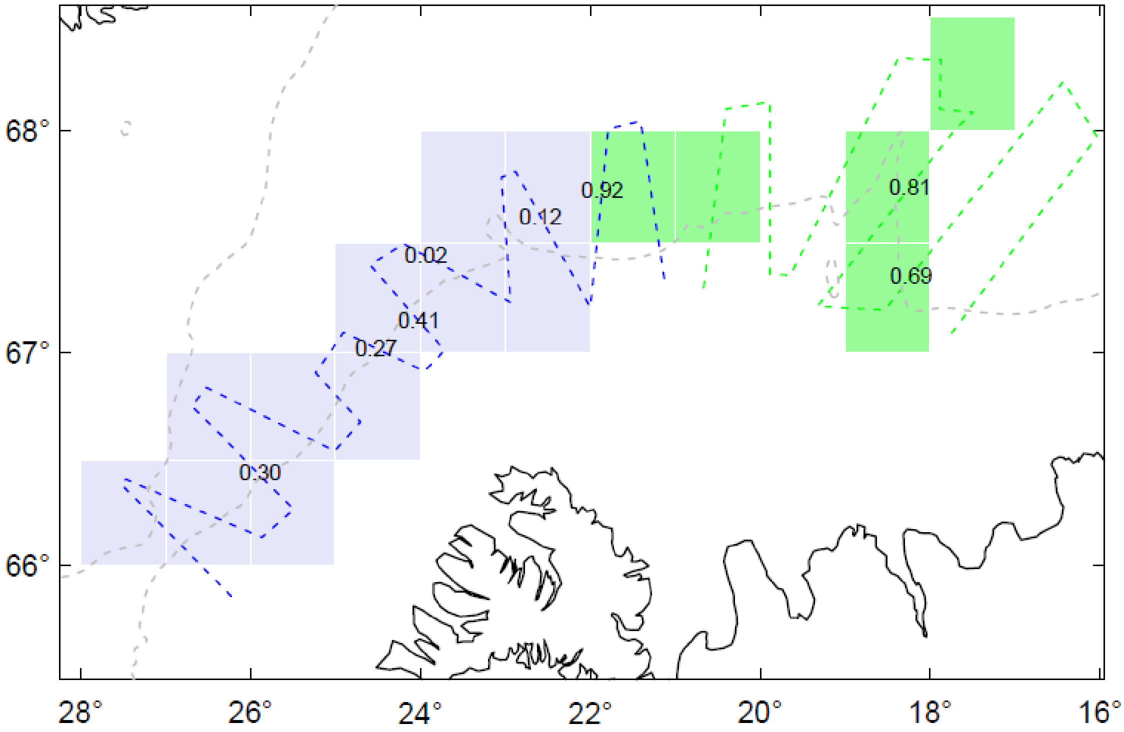

Figure 12.2.6 Icelandic capelin. Transects of the participating vessels and proportion mature within capelin samples and regional allocation in assessment during the survey in December 2023.

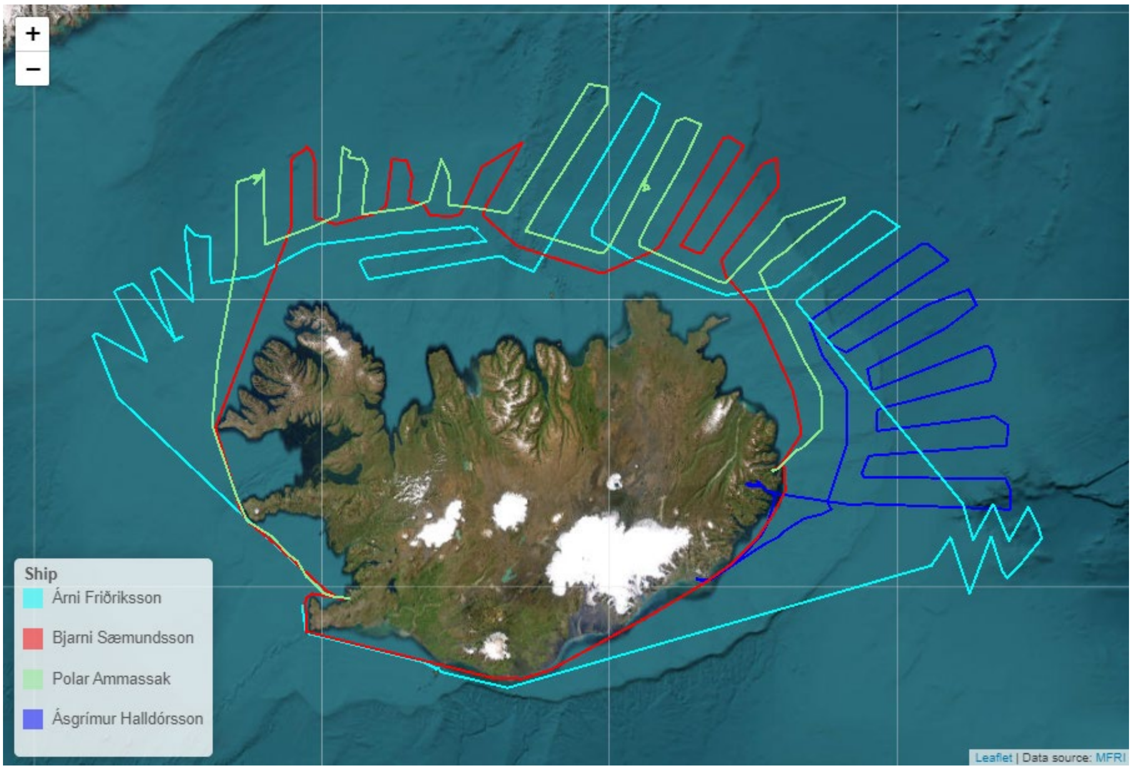

Figure 12.2.6. Icelandic capelin. Survey tracks of the participating vessels during the survey in 16 - 26 January 2024.

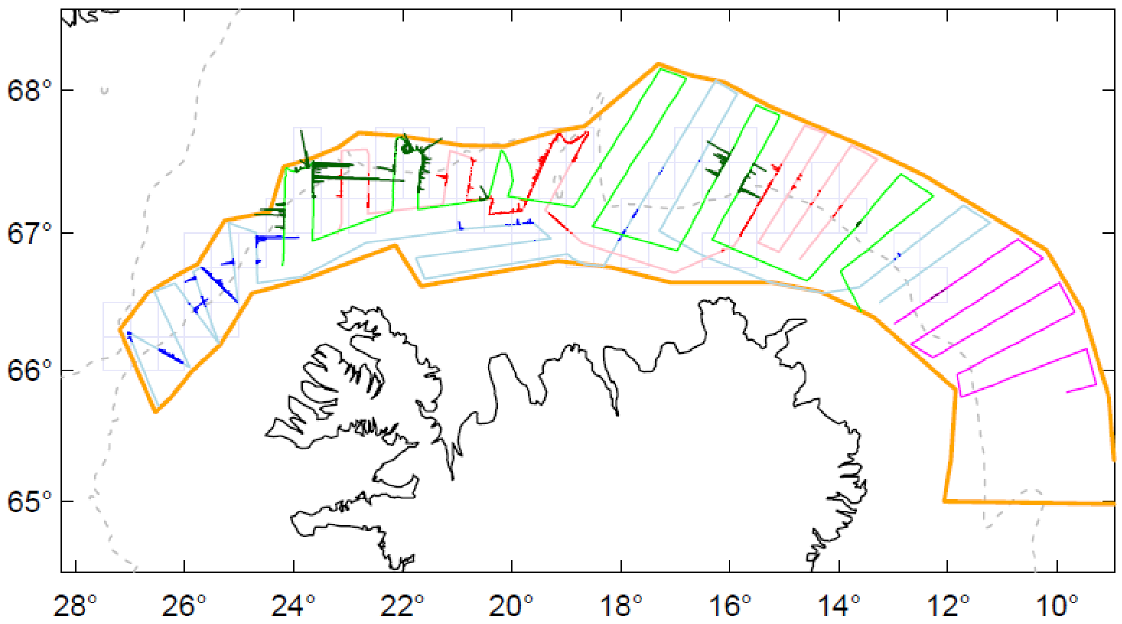

Figure 12.2.7. Icelandic capelin. Capelin distribution as relative density of acoustic backscatter during the survey in 16 - 26 January 2024. Bars perpendicular to survey tracks show capelin acoustic backscatter as NASC per 0.1 nautical mile.

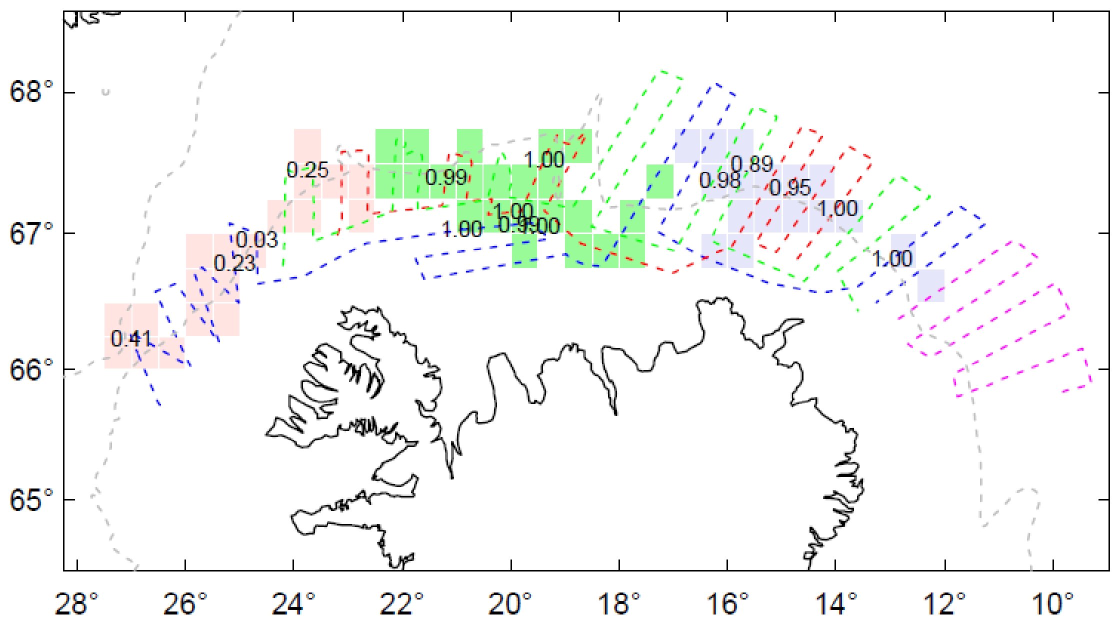

Figure 12.2.8. Icelandic capelin. Transects of the participating vessels and proportion mature within capelin samples and regional allocation in assessment during the survey in 16 - 26 January 2024.

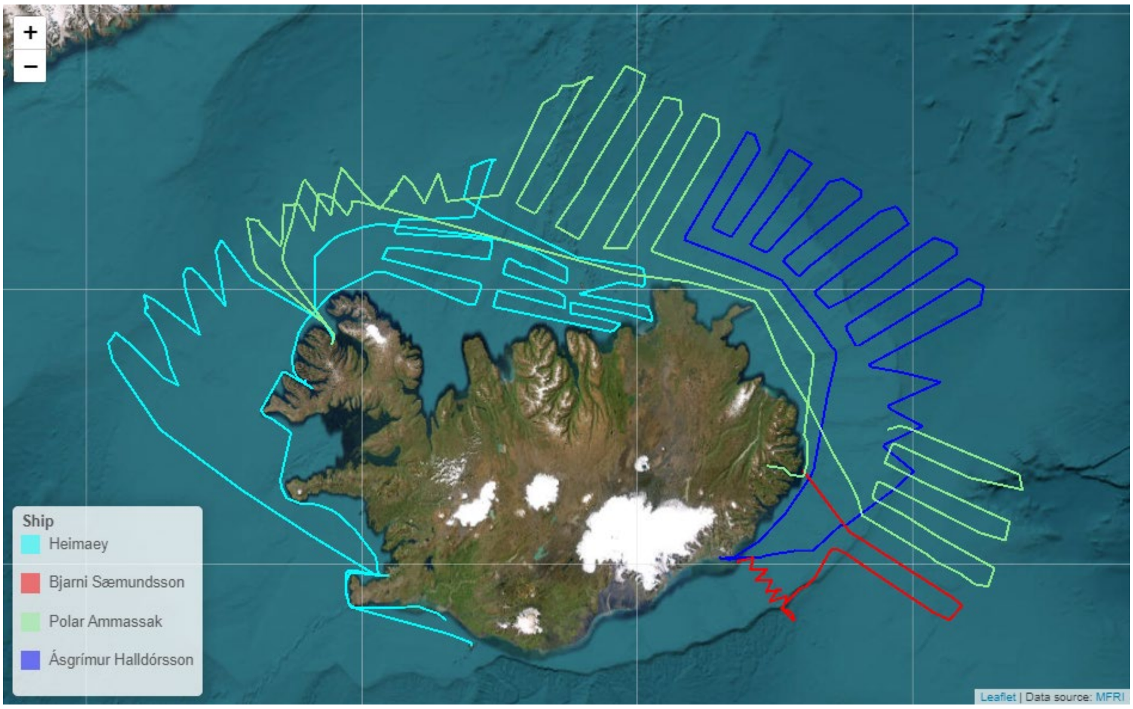

Figure 12.2.9. Icelandic capelin. Survey tracks of the participating vessels during the survey in 5 - 18 February 2024.

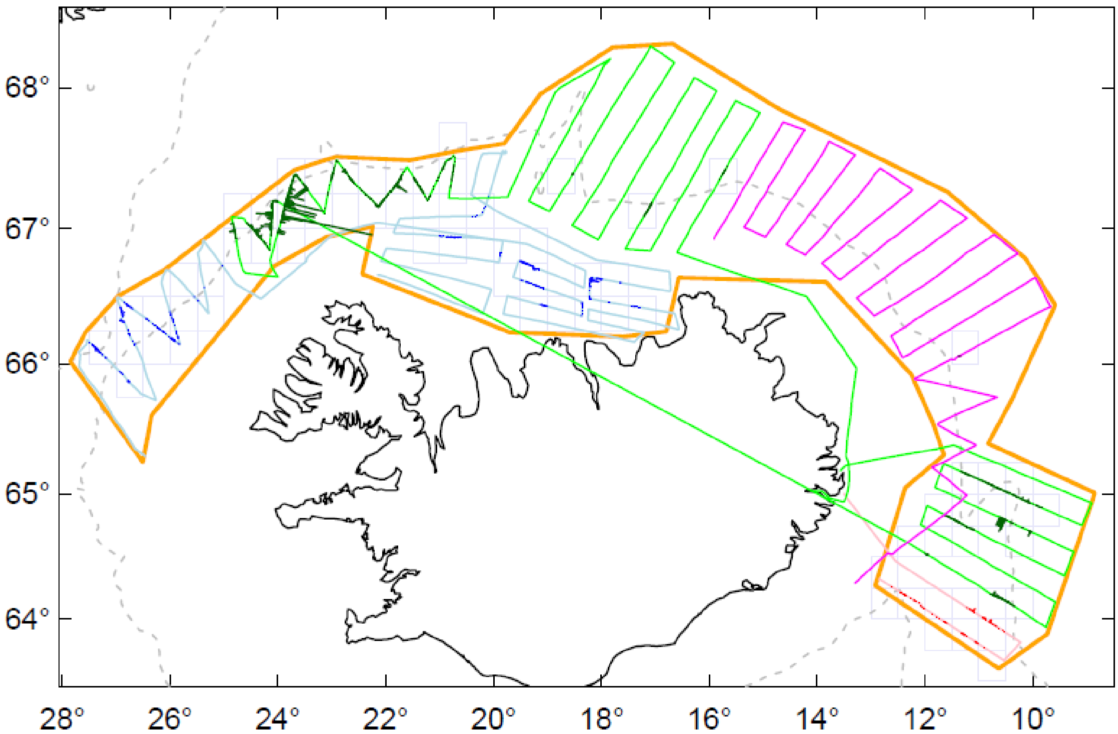

Figure 12.2.10. Icelandic capelin. Capelin distribution as relative density of acoustic backscatter during the survey 5 - 18 February 2024. Bars perpendicular to survey tracks show capelin acoustic backscatter as NASC per 0.1 nautical mile.

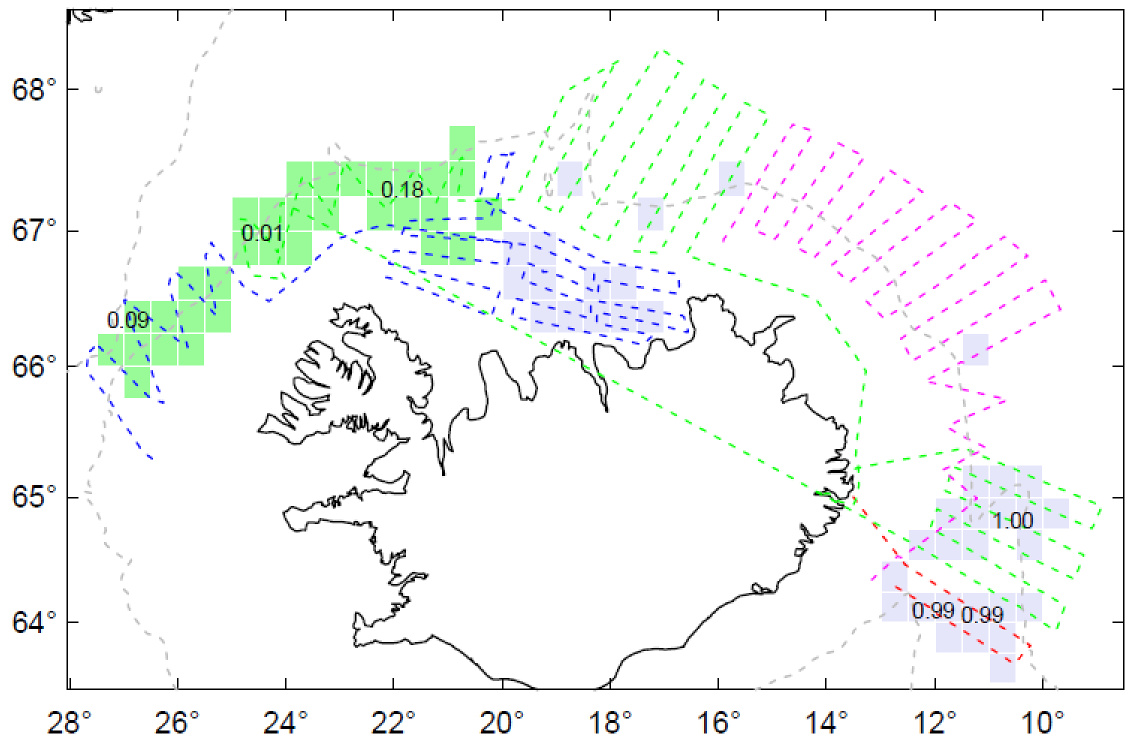

Figure 12.2.11. Icelandic capelin. Transects of the participating vessels and proportion mature within capelin samples and regional allocation in assessment during the survey in 5 - 18 February 2024.

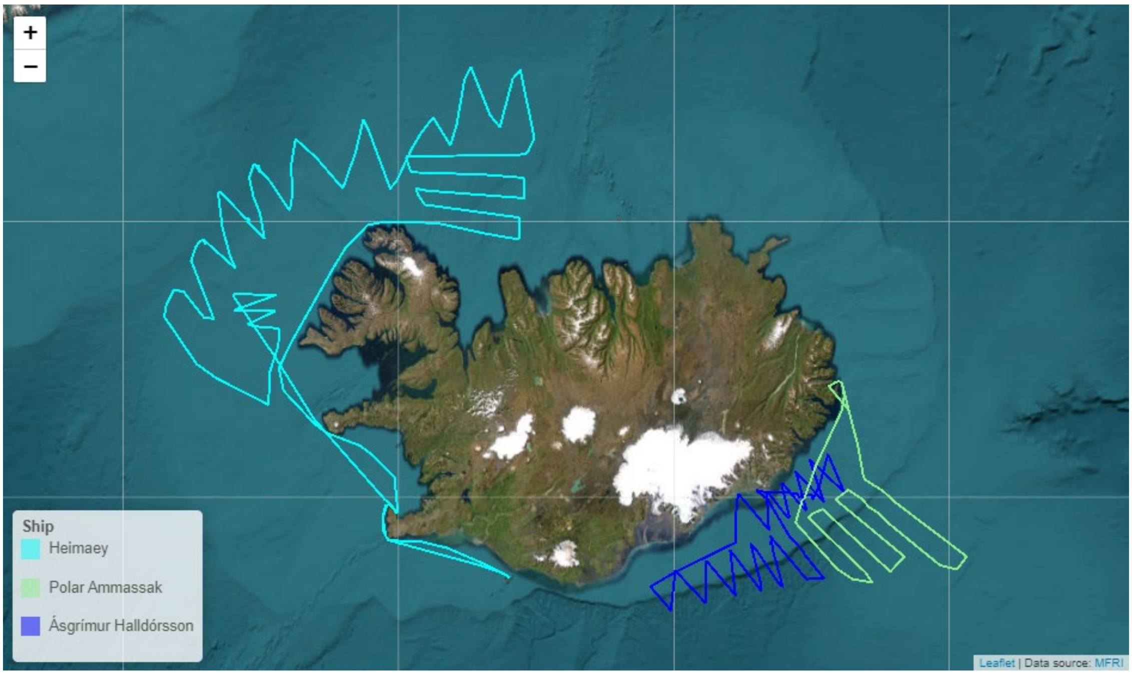

Figure 12.2.12. Icelandic capelin. Survey tracks of the participating vessels during the survey in 22 - 29 February 2024.

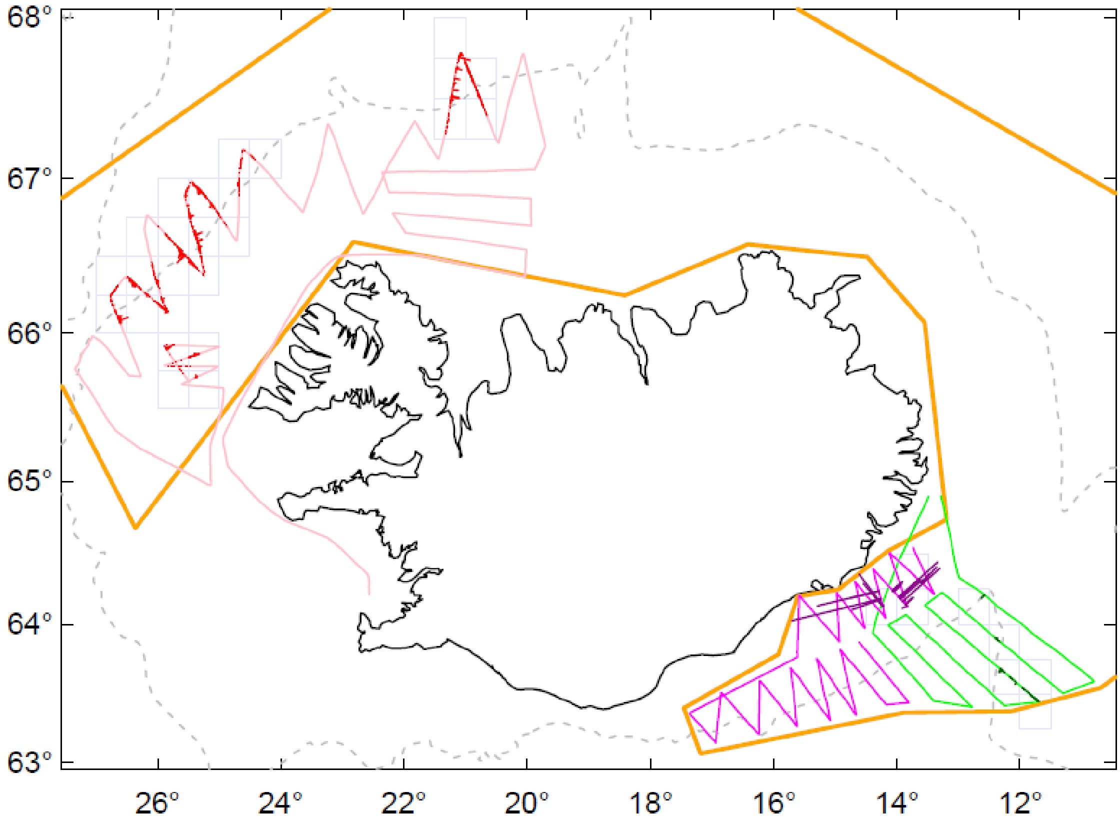

Figure 12.2.13. Icelandic capelin. Capelin distribution as relative density of acoustic backscatter during the survey 22 - 29 February 2024. Bars perpendicular to survey tracks show capelin acoustic backscatter as NASC per 0.1 nautical mile.

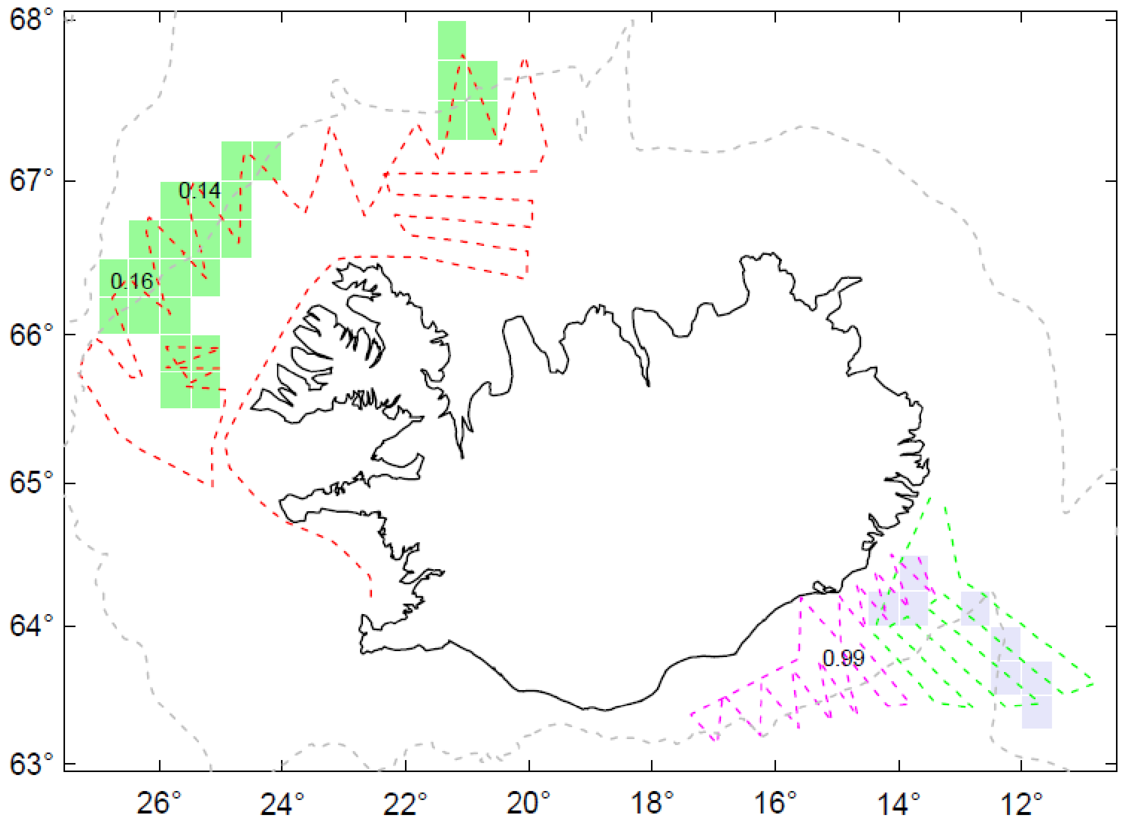

Figure 12.2.14. Icelandic capelin. Transects of the participating vessels and proportion mature within capelin samples and regional allocation in assessment during the survey in 22 - 29 February 2024.

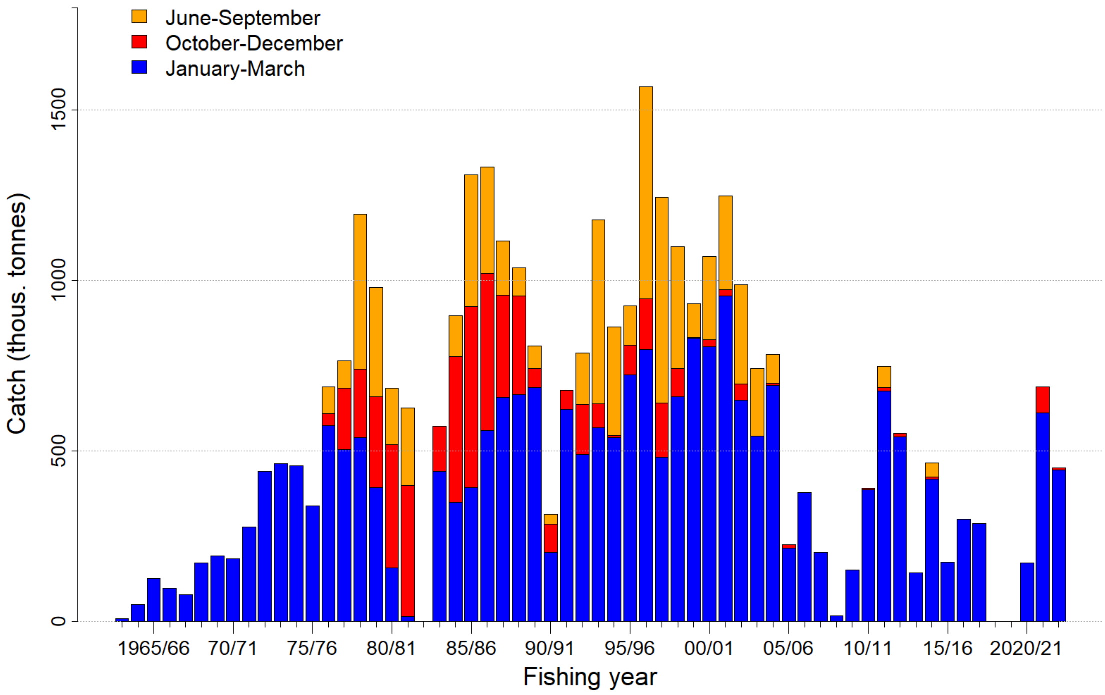

Figure 12.3.1. Icelandic capelin. The total catch (in thousand tonnes) of the Icelandic capelin since 1963/64 by season.

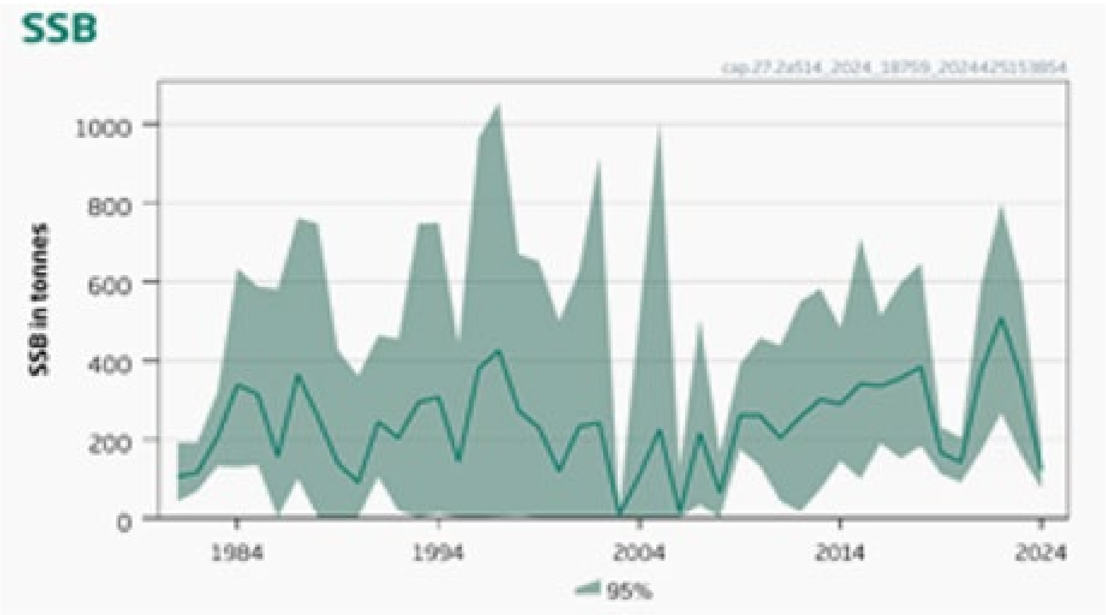

Figure 12.6.1. Icelandic capelin. 5th, 25th, 50th, 75th and 95th percentile of the spawning stock at spawning time (March-April) since 1981. Blim = 114 kt.

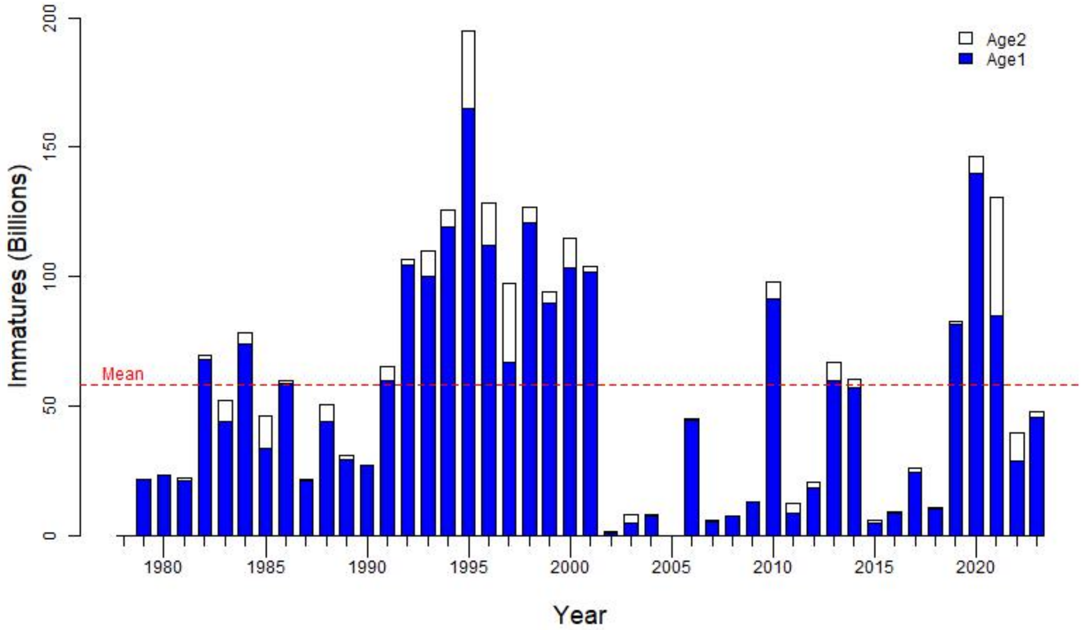

Figure 12.7.1. Icelandic capelin. Indices of immature 1 and immature 2 years old capelin from acoustic surveys in autumn since 1979.

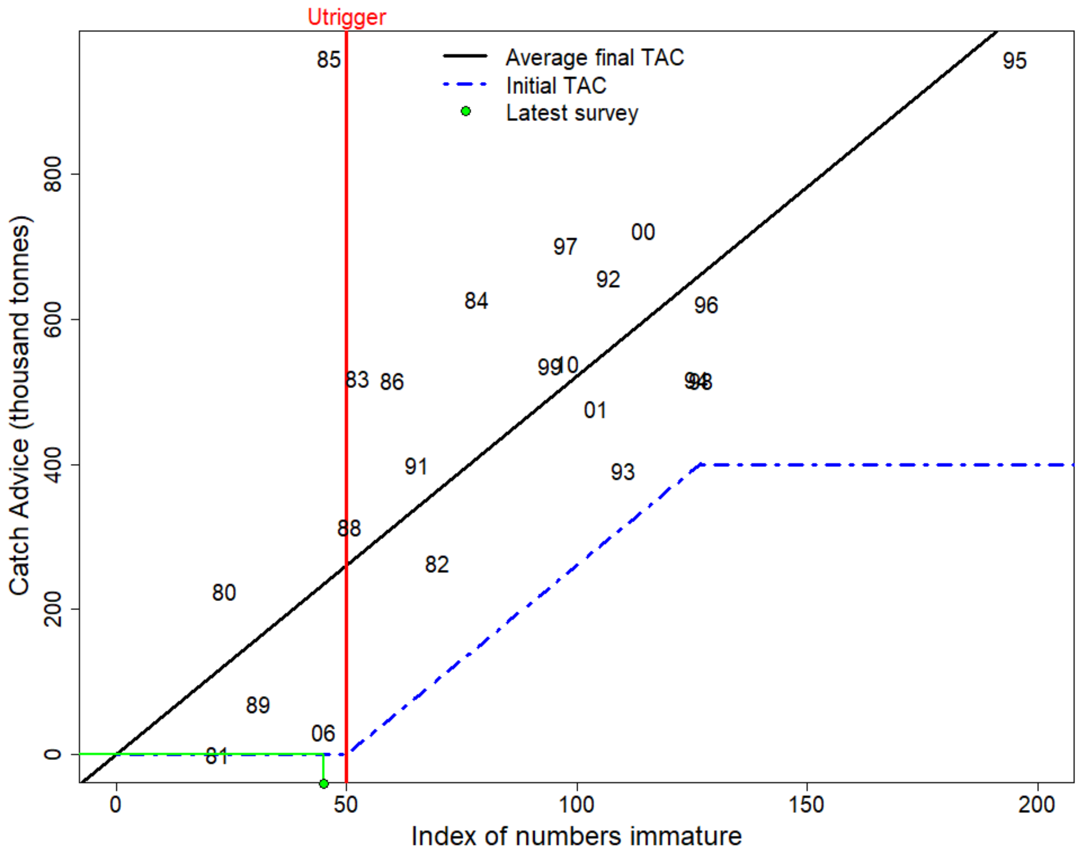

Figure 12.7.2 Icelandic Capelin. Catch advice according to the proposed stochastic HCR, based on the measured number of immature capelins about 15 months earlier. The figure shows the estimated final TAC (black unbroken line) and the initial (preliminary) TAC (blue dashed line). The latter is set using a Utrigger (red vertical line) of 50 billion immature fish, with a cap on the initial (preliminary) TAC of 400 kt. The green lines show the index value from the autumn survey 2022, with the corresponding initial TAC for 2023/2024 shown on the y-axis. (The figure adapted from stock-annex, WKICE 2015).

13 West Greenland offshore spawning cod (WOSC)

cod.21.1.osc – *Gadus morhua* in NAFO Subarea 1 – offshore spawning stock

13.1 Stock description and management units

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023a). The new methods utilize genetics and information from tagging to separate the cod into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks were assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022. It is therefore the first assessment for this stock. Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

Reference points were re-estimated at NWWG 2024.

13.2 Scientific data

13.2.1.1 Historical trends in landings and fisheries

The fishery for cod in Greenlandic waters started at the beginning if the 19th century and developed into a large fishery of more than 400 000 tonnes in the 1960s. After this historic height the fishery reduced to between 50 000–100 000 tonnes in the 1970s and 80s and thereafter collapsed in the 90ies.

For further information see stock annex.

13.2.1.2 The present fishery

The catch of the WOSC stock started from almost zero in 2000. In 2001 there were no samples from the fishery and hence no split by stock can be made for this year. The catch steadily increased from below 2000 tonnes pr year to a maximum of 12 000 tonnes in 2016 and 2017 (table 13.2.1). Hereafter the catches have declined to 4000 tonnes until 2021 and have since increased to 8 000 tonnes in 2023. The WOSC stock is mainly distributed in the mid and northern part of West Greenland corresponding to NAFO divisions 1A-1D where in average 90% of the total catch of WOSC is caught (table 13.2.1).

The WOSC stock is mainly caught in the inshore fishery (average 95%, figure 13.2.1). The most important gear in the inshore fishery is poundnets (taking app. 60-80% of the annual catches) anchored at the shore and fishing the upper 20 m. Due to the ice conditions and vertical migration of cod, poundnets are not used during November-April. The inshore fishery uses longlines, jigs and gillnets in autumn and winter. The catches usually peak in summer and are lowest during late winter or early spring, when the lumpfish fishery dominates. About half of the catches are taken by small dinghies. The other half of the catches are taken by larger vessels (cutters).

The offshore fleet consists of larger vessels where bottom-trawl and longline is the main gear used. The offshore fishery has been at a low level in recent years and was zero in 2022. In 2023 a trial TAC of 1 500 tonnes was introduced and allocated with 500 tonnes to NAFO division 1D and 1 000 tonnes to NAFO division 1E (Retzel 2024).

13.2.1.3 Catch-at-age

Yearly catch-at-age is calculated from the commercial catch.

For further information see stock annex.

13.2.1.4 Weight-at-age

Yearly catch mean weight at age is calculated from the commercial catch.

Yearly stock mean weight at age is calculated from the Greenland bottom-trawl survey.

For further information see stock annex.

13.2.1.5 Maturity-at-age

Maturity-at-age is fixed between years.

For further information see stock annex

13.2.1.6 Gillnet survey

An annual multimesh gillnet survey designed to target cod aged 2 and 3 years old have been conducted in the inshore areas NAFO 1B (Sisimiut) and NAFO 1D (Nuuk) since 1987. Full description of the survey is given in (Retzel et al., 2023). Catches from the gillnet survey are split into the three genetically distinct cod stocks. For the WOSC stock a CPUE index combined for both areas are calculated for the years 2002-2023 (details are given in (Buch et al. 2023b).

13.2.1.7 Bottom-trawl surveys

Abundance indices in summer-autumn was derived from a geostatistical model fitted to catch data from the Greenland Groundfish Survey (G2064) and German Groundfish Survey (G4355) conducted during summer and autumn in Greenlandic waters. Catch data were split by stock based on genetics (See section on ‘Genetics and stock splitting’ below). A complete description of the data and model can be found in WD5 and WD03 from WKGREENCOD respectively, as well as in the stock annex.

The data were compiled from two bottom-trawl surveys. Namely “SF” (G2064) conducted between 28 May – 4 October from 2005—2023 by the Greenlandic Institute of Natural Resources, and “GGS” (G4355) conducted between 22 September– 15 November from 2000—2020 by the Thünen Institute for Sea Fisheries.

All surveys sample the fish community on the continental shelf and upper shelf slope.

Trawl operations have largely been standardized on each of the surveys, but differ substantially between the two. A survey effect was therefore included in the model in addition to the effect of effort (swept-area in nmi^2).

In 2018 only West Greenland was covered and no surveys were conducted 2021. These years were excluded accordingly. Figure 13.2.7.1 provides an overview of the distribution and number of samples.

INLA (Integrated Nested Laplace Approximation) was used to fit a spatially explicit statistical model. INLA is a Bayesian statistical method for fast fitting of complex statistical models such as generalized additive models (GAM) with spatial correlations (Lindgren et al., 2015; Rue et al., 2009). Based on simulations with the model, spatial distributions and time-series for each age and stock was estimated.

The spatial distributions of mean density indices were mapped by age in Figure 13.2.7.2. The time-series of spatially integrated density indices that were used in the assessment as relative abundance indices of cod at age (Figures 13.2.7.3) were found to have good internal consistency (Figure 13.2.7.4).

In 2022 the GGS survey was not conducted and in 2023 the survey was not completed. From 2025 the Thünen institute will change the timing of the GGS survey from autumn to summer. This must initially be considered as a new survey. The model will need more than one year of data to estimate the new survey effect. It must therefore be expected that only SF will be used by NWWG in 2026 and 2027.

13.2.1.8 Genetics and stock splitting

Commercial and survey catch data are split into separate spawning stock units using a Generalized Additive Model (GAM) on genetic assigned samples. In order to improve sampling coverage for the years 2008 and 2010 archived samples were analysed in 2023. These samples showed higher than previously seen presence of the Icelandic inshore spawning cod stock (ISI) in the inshore areas 1E and 1F (figure 13.2.1.8.1). Previously it was decided to exclude the ISI stock from the stock splitting (see ICES 2023a: WKGREENCOD WD 01 and WD 05), the basis for this was that we were seeing only few occurrences and without patterns. The period 2008-2010 had a large fishery in the areas where the new samples showed high prevalence of ISI, this raised concerns that the split of catches for this period were incorrect. The areas were the inshore area of NAFO divisions 1E and 1F. The proportion of WOSC in this area is very small and the new data has very little effect on the proportion of WOSC in these areas.

It was decided that for the splitting model ISI was merged with East Greenland Iceland offshore spawning cod stock (EGIOSC). This was done in order to account for the presence of this stock historically and any future incoming ISI cohorts. The number of ISI individuals observed in Greenland waters are at such a low level that it is difficult to include it as a separate stock in the split model. Merging the stock with the EGIOSC stock are also in line with previous studies (Christensen et al 2022) and in Iceland the two stocks are combined for the assessment (ICES 2023b). Continuous sampling will allow monitoring of this stock, should it become prevalent in large numbers this decision can be re-evaluated.

The number of samples for the split in 2024 is 11 083 (data added: 1300 samples from 2023 + 777 from 2008 and 2010 + 437 ISI) (Retzel & Buch 2024). The consequence of the addition of genetic data and the inclusion of ISI as EGIOSC was explored in several sensitivity runs in SAM on the 2023 assessment (Buch et al., 2024). The SAM output showed little effect on the assessment.

For further information on GAM model see stock annex.

13.3 Stock assessment

The stock was benchmarked in 2023 (ICES, 2023a). It was decided to use the SAM model (Nielsen and Berg, 2014) to perform an analytical assessment. This is considered a vast improvement, as the data are now split into stock components based on genetics.

13.3.1.1 Model diagnostics

The model fits the data well but does not capture the high catches in 2016, 2017 and 2023 (Figure 13.3.1). Retrospective analysis showed stability when removing data, with all peels for SSB and F within the confidence intervals and Mohn’r rho values were low (Figures 13.3.2-4).

Overview of assessment given in Table 13.3.1.

13.3.1.2 State of the stocks

SSB is currently below MSY $B_{trigger}$ and has only been above MSY $B_{trigger}$ in 2015-2017, SSB is above Bpa and Blim. F has been above Fmsy for the entire assessment period (2000-2023).

13.3.1.3 Quality of the assessment

The stock was benchmarked in 2023. A new model was adopted for the assessment (SAM), this was fitted to data for genetic stock components. This has increased the quality of the assessment by taking stock specific dynamics into account.

13.4 Reference points

Reference points was estimated and accepted at NWWG 2024 (this was recommended by WKGREENCOD (ICES, 2023a).) The estimations were conducted in EQSIM according to ICES guidelines (see ICES (2021) for details). Final reference points are shown in Table 13.5.1. However, F_{pa} and F_{lim} was not defined. Re-estimation of reference points are proposed to take place in connection with the 2026 assessment.

For estimating B_{lim} a categorization of the stock–recruitment relationship into type is required (ICES, 2021). The group agreed to use the average SSB of the three years with highest recruitment. This gave a B_{lim} of 3050.

Data from the SAM assessment agreed at NWWG 2024 were used for the simulations. The Eqsim software was used to define PA and MSY reference points.

The number of simulations were set to 1500. Recruitment in 2021-2023 was omitted due to high uncertainty for the estimates. For assessment error sigmaF was default value of 0.2 and sigmaSSB was set to the default value of 0.2. The default values were used for forecast errors: cvF=0.212, phiF=0.423, cvSSB=0 and phiSSB=0. For weight at age the last 5 years were used. For selectivity the last 10 years were used. For the simulations segmented regressions (with breakpoint fixed at Blim) and Beverton–Holt were used (Figure 13.4.1). The estimated reference points are given in the table below. Due to very high estimate of Fpa and F_{lim}, it was decided to not report on these values. Following WKGREENCOD (ICES, 2023a) the benchmark oversight group proposed using 50% of Bmsy as MSY $B_{trigger}$, rather than the values calculated in the benchmark, and this proposal was endorsed by ACOM on the ACOM forum (April 21, 2023). This method was applied and has been carried over for this stock, the rational for keeping this more precautionary basis for MSY $B_{trigger}$ was that historically this stock has been at a very high level and it remains uncertain is the stock will be able to reach these historical levels following the regime shift in the late 1990s.

13.5 Short-term forecast

13.5.1.1 Input data

The SAM model provides predictions that carry the signals from the assessment into the short-term forecast. The forecast procedure starts from the last year's estimate of the state (log(N) and log(F)). One thousand replicates of the last state are simulated from the estimated joint distribution. Each of these replicates are then simulated forward according to the assumptions and parameter estimates found by the assessment model.

In the forward simulations, a 5-year average (up to the assessment year) of proportion mature, and natural mortality are used. Stock and catch weight used in the short term forecast are estimated within SAM. Recruitment is resampled from 2014-2023. In each forward simulation step the fishing mortality is scaled, such that the median of the distribution is matching the requirement in the scenario (e.g. hitting a specific mean F value, a specific catch or level of SSB).

For the interim year it was assumed that F in 2024 will be the same as F in 2023 (Table 13.7.1).

13.5.1.2 Results

The results from the assessment can be found on stockassessment.org (run: NWWG24_WOSC).

The forecasts from the different scenarios are presented in Table 13.7.2. Fishing at F= Fmsy in 2025 will result in catches of 3238 t. Recently the catches have been above the ICES advice, and an F status quo will result in catches of 7383 t.

13.6 Uncertainties in assessment and forecast

The TAC in the intermediate year is known at the time of the assessment meeting. This TAC is valid for the mixed fishery and does not reflect the expected catch of solely the WOSC stock. For 2024 catch is assumed to be similar to catch in 2023. In future years advice will be given by stock and TAC will likely be set by area. The genetic split between stock can be used to split TACs into stocks to get likely estimates of catch by stock for the intermediate years.

Estimation of reference points are associated with some uncertainty due to the short time-series.

The assessment methods recalculates the entire time-series every year, so minor revisions of estimates from all years are expected.

13.7 Comparison with previous assessment and forecast

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023a). The new methods utilize genetics and information from tagging to separate the cod into four stocks that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks was assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022.

The SSB for this stock are estimated higher than in the 2023 assessment, this is due to the incoming 2019 yearclass which are now entering the fisheries. The recruitment for the 2019 yearclass is estimated higher.

13.8 Management plans and evaluations

There is no management plan for this stock.

13.9 Management considerations

Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

13.10 Ecosystem considerations

The gear used for this fishery have little effect on the ecosystem, especially the main gear (pound-net).

13.11 Regulations and their effects

The fishery has never been limited by a TAC, as the TAC has always been set well above the fleet capacity or raised when reached. In 2023 the TAC was raised from 17 000 tonnes to 23 000 tonnes in autumn. Therefore, it is unknown what the effect would be of limiting the fishery.

13.12 References

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13.13 Tables

Table 13.2.1. Catch (tonnes) of the West Greenland offshore spawning cod stock (WOSC) by NAFO divisions in West Greenland. *No samples from the fishery in 2001.

	Nafo Division						
Year	1A	1B	1C	1D	1E	1F	Total
2000	80	48		48			176
2001*							
2002	211	594	106	34	2	13	960
2003	605	570	79	52		15	1321
2004	529	613	96	100	3	8	1349
2005	300	562	233	84	16	10	1205
2006	359	693	362	316	33	46	1809
2007	392	601	269	395	124	114	1895
2008	463	898	321	512	100	182	2476
2009	175	350	253	287	72	84	1221
2010	313	943	382	274	89	22	2023
2011	342	649	659	478	83	37	2248
2012	367	359	449	560	157	59	1951
2013	809	798	668	784	201	58	3318
2014	1618	1870	948	912	86	83	5517
2015	2066	2116	1701	1952	711	357	8903
2016	2845	3189	2733	2412	567	421	12167
2017	2862	3515	3104	1555	311	547	11894
2018	1165	2264	2520	2487	576	488	9500
2019	1083	984	1459	2424	88	254	6292
2020	787	718	1219	1903	27	103	4757
2021	677	914	1249	1249	17	66	4172
2022	1021	815	1891	1433	16	22	5198
2023	1552	1359	2330	2275	298	64	7878

Table 13.3.1 Assessment summary. 'High' and 'Low' correspond to 95% confidence intervals. Weights are in tonnes, recruitment in thousands. *No sampling for 2001 catches, therefore not included.

Year	Recruit-ment Age 2	97.50%	2.50%	SSB tonnes	97.50%	2.50%	Total Catch tonnes	F Ages 5-8	97.50%	2.50%
2000	1575	2498	993	180	337	96	98	0.70	1.12	0.44
2001	1192	1750	812	379	608	237	*	0.74	1.11	0.50
2002	1758	2544	1215	771	1154	515	1183	0.83	1.16	0.59
2003	1543	2267	1050	1038	1488	724	1159	0.94	1.25	0.71
2004	1727	2549	1171	1076	1461	792	1403	1.02	1.33	0.79
2005	3279	4628	2323	1152	1569	845	1519	0.99	1.30	0.76
2006	3414	4850	2403	1059	1399	802	1863	0.89	1.19	0.67
2007	2988	4121	2166	1392	1833	1057	1907	0.86	1.15	0.64
2008	2736	3779	1981	2009	2727	1481	2432	0.80	1.05	0.61
2009	2917	3958	2149	2444	3288	1817	1275	0.69	0.91	0.53
2010	4842	6387	3671	2948	3848	2258	2376	0.73	0.94	0.56
2011	8773	11332	6791	3437	4376	2700	2704	0.71	0.91	0.55
2012	11628	15441	8756	4625	5740	3727	1768	0.64	0.82	0.50
2013	12574	17272	9155	7042	8639	5741	2789	0.63	0.80	0.49
2014	8799	11933	6488	11770	14502	9553	5428	0.67	0.85	0.53
2015	6894	9075	5238	16550	20923	13092	7924	0.70	0.88	0.56
2016	7935	10570	5957	17200	22340	13243	12739	0.81	1.00	0.66
2017	4436	6027	3266	14078	18269	10849	12070	0.98	1.20	0.79
2018	6594	8841	4918	10440	12959	8411	7015	1.05	1.30	0.86
2019	4929	7075	3434	8072	9997	6518	4306	1.02	1.25	0.83
2020	5049	7797	3270	7058	8878	5612	4041	0.97	1.21	0.78
2021	10133	19720	5206	6733	8590	5277	4068	0.92	1.18	0.72
2022	7333	17207	3125	6704	9090	4944	4221	0.85	1.16	0.62
2023	6462	20066	2081	7098	10929	4610	6081	0.88	1.29	0.59
2024	6594			8389	15297	4521				

Table 13.5.1 Reference points

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	15 411 t	0.5*Bmsy	NWWG 2024
	F_{MSY}	0.25	EQSim analysis based on the recruitment period 2000–2020.	NWWG 2024
Precautionary approach	B_{lim}	3 050 t	Average SSB of the three years with low SSB and high recruitmet	NWWG 2024
	B_{pa}	4 238 t	B_{lim}*exp(sigmaSSB*1.645), sigmaSSB=0.2	NWWG 2024
	F_{lim}	NA	Equilibrium F, which will maintain the stock above Blim with a 50% probability.	
	F_{pa}	NA	The fishing mortality including the advice rule that, if applied as a target in the ICES MSY advice rule (AR) would lead to SSB ≥ Blim with a 95% probability (also known as Fp05).	
Management plan	SSBmgt	-		
	Fmgt	-	-	

Table 13.7.1 Values in the forecast and for the interim year.

Variable	Value	Notes
$F_{ages\ 5\text{-}8}$(2024)	0.679	$F_{2024} = F_{2023.}$
SSB (2025)	15 648	Short-term forecast; tonnes.
$R_{age\ 2}$ (2024)	9 161	Median recruitment, resampled from the years 2014–2023; thousands.
$R_{age\ 2}$ (2025)	9 412	Median recruitment, resampled from the years 2014–2023; thousands.
Catch (2024)	7073	Based on $F_{ages\ 5\text{-}8}$ 2024; tonnes.

Table 13.7.2 Catch scenarios for 2025 assuming $F_{2024} = F_{2025}$. All weights are in tonnes.

Rationale	Catch (2024)	F (2024)	SSB (2025)	% SSB change*	% advice change**
MSY approach: F_{MSY}	3238	0.25	20652	32	35
$F_{2025} = 0$	0	0	24919	59	-100
$F_{2025} = F_{2024}$	7383	0.68	15500	-1	208

* SSB_{2026} relative to SSB_{2025}.** Advised catch for 2025 relative to advised catch for 2024 (2398 tonnes).

13.14 Figures

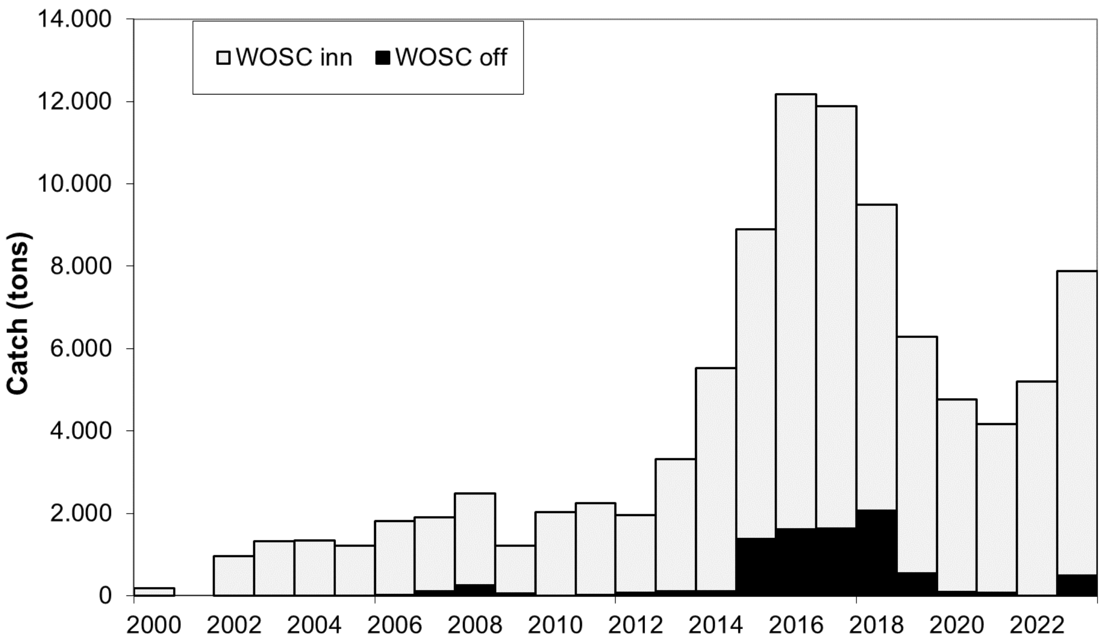

Figure 13.2.1 Catch of the West Greenland offshore spawning cod stock (WOSC) in the inshore and offshore area in West Greenland. No samples from the fishery in 2001.

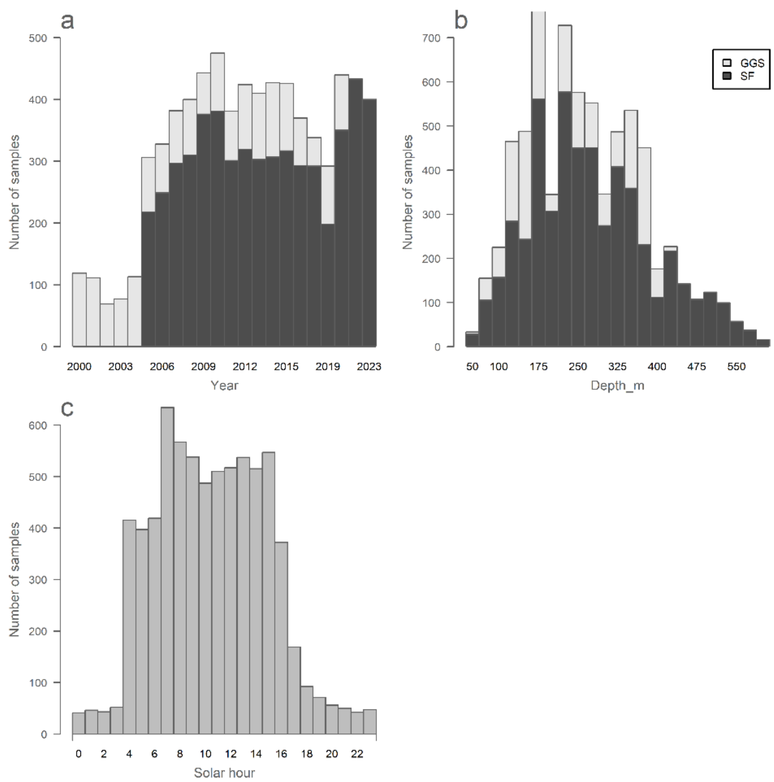

Figure 13.2.7.1. Overview of the distribution and number of bottom-trawl samples.

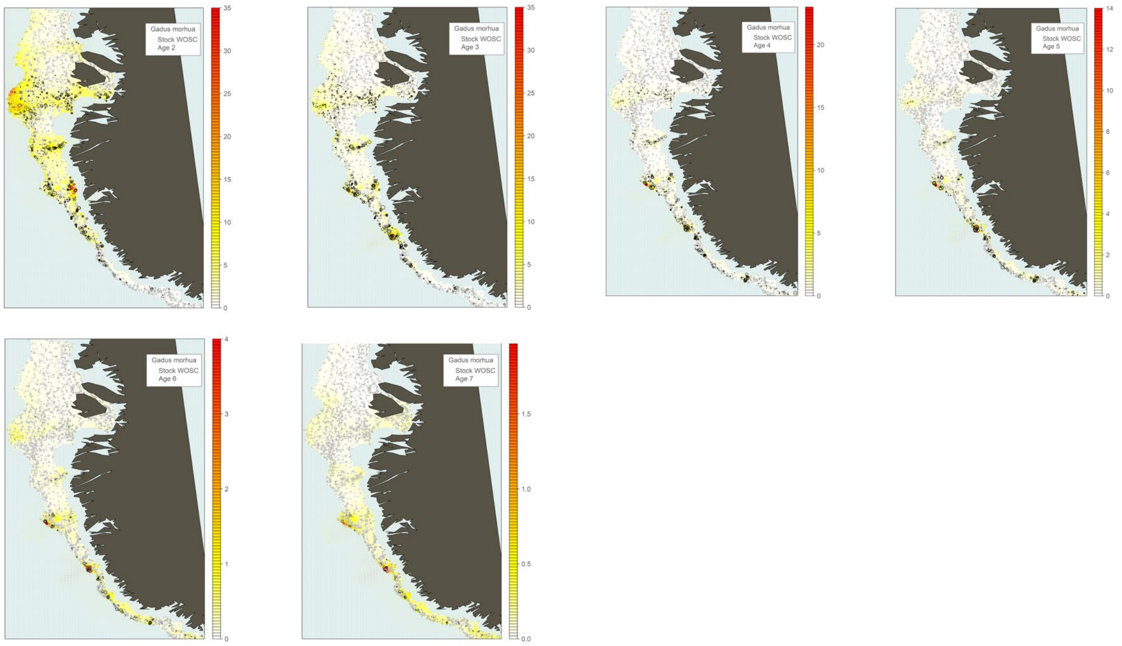

Figure 13.2.7.2. Spatial distribution by age estimated by the model (color scales), overlaid by catch rate observations from the bottom-trawl surveys (catch rates are proportional to the areas of the black circles), grey crosses indicates zero catches.

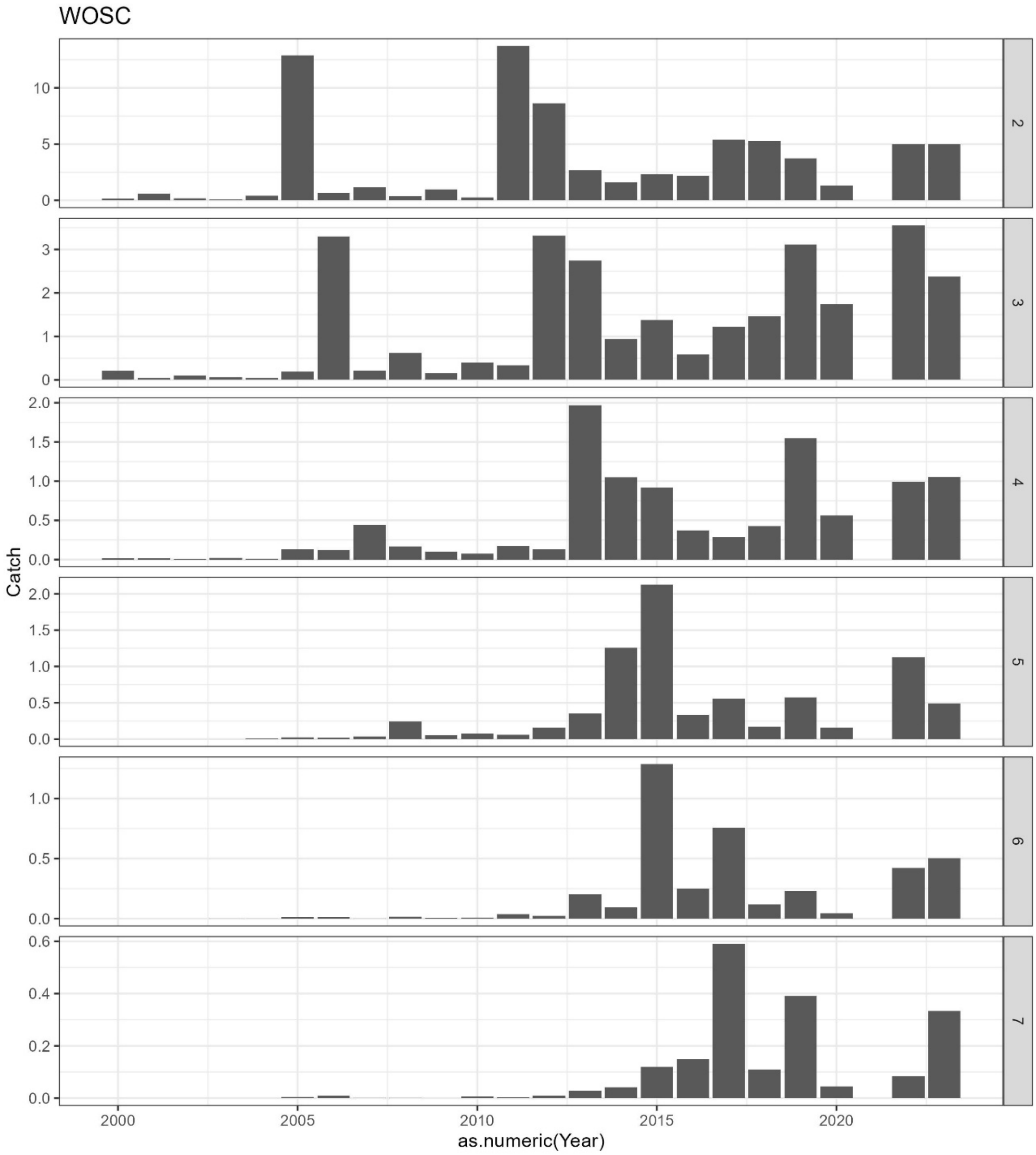

Figure 13.2.7.3. Bottom-trawl survey catch rate indices by age estimated by the INLA model.

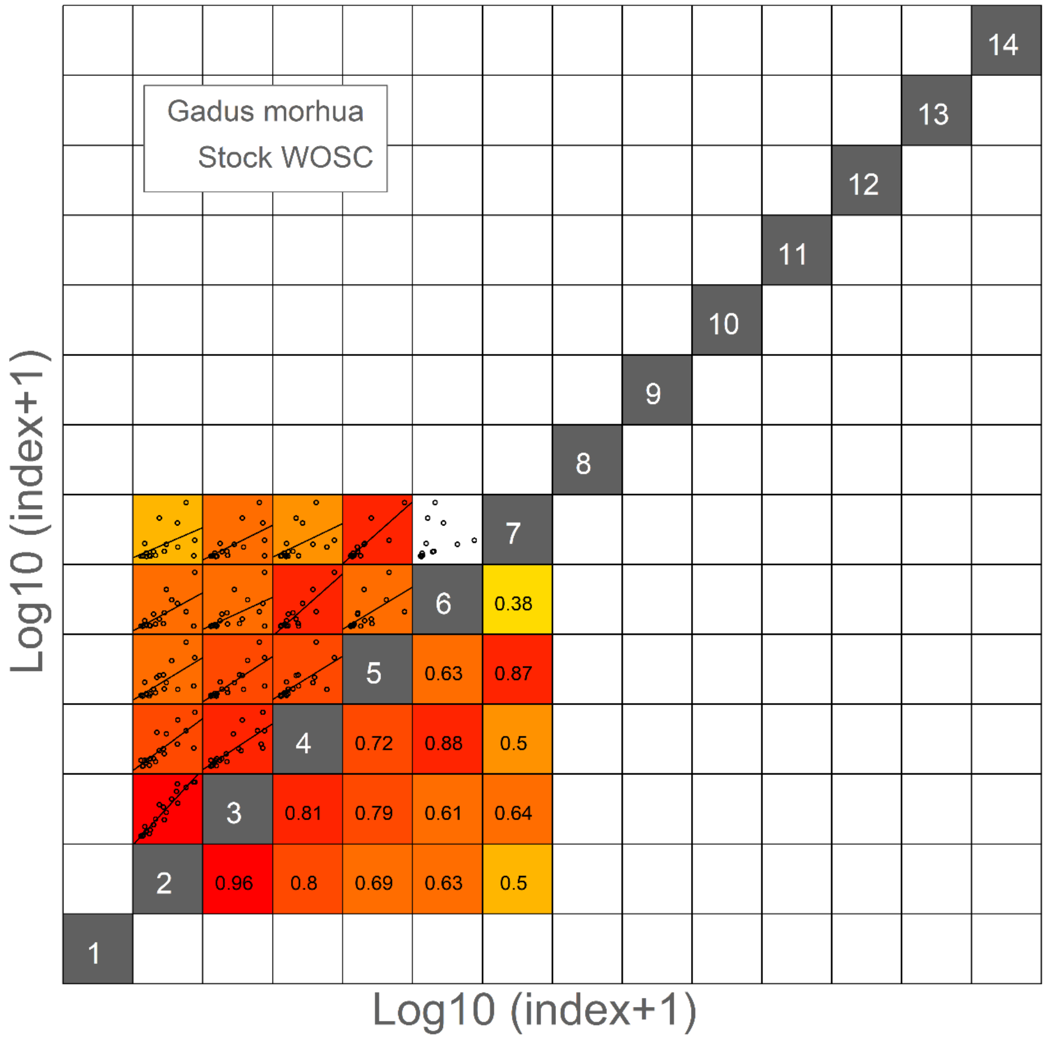

Figure 13.2.7.4. Internal consistency. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (p<0.05) are indicated by regression lines in the upper left half. Correlation coefficients (r) are given in the lower right half.

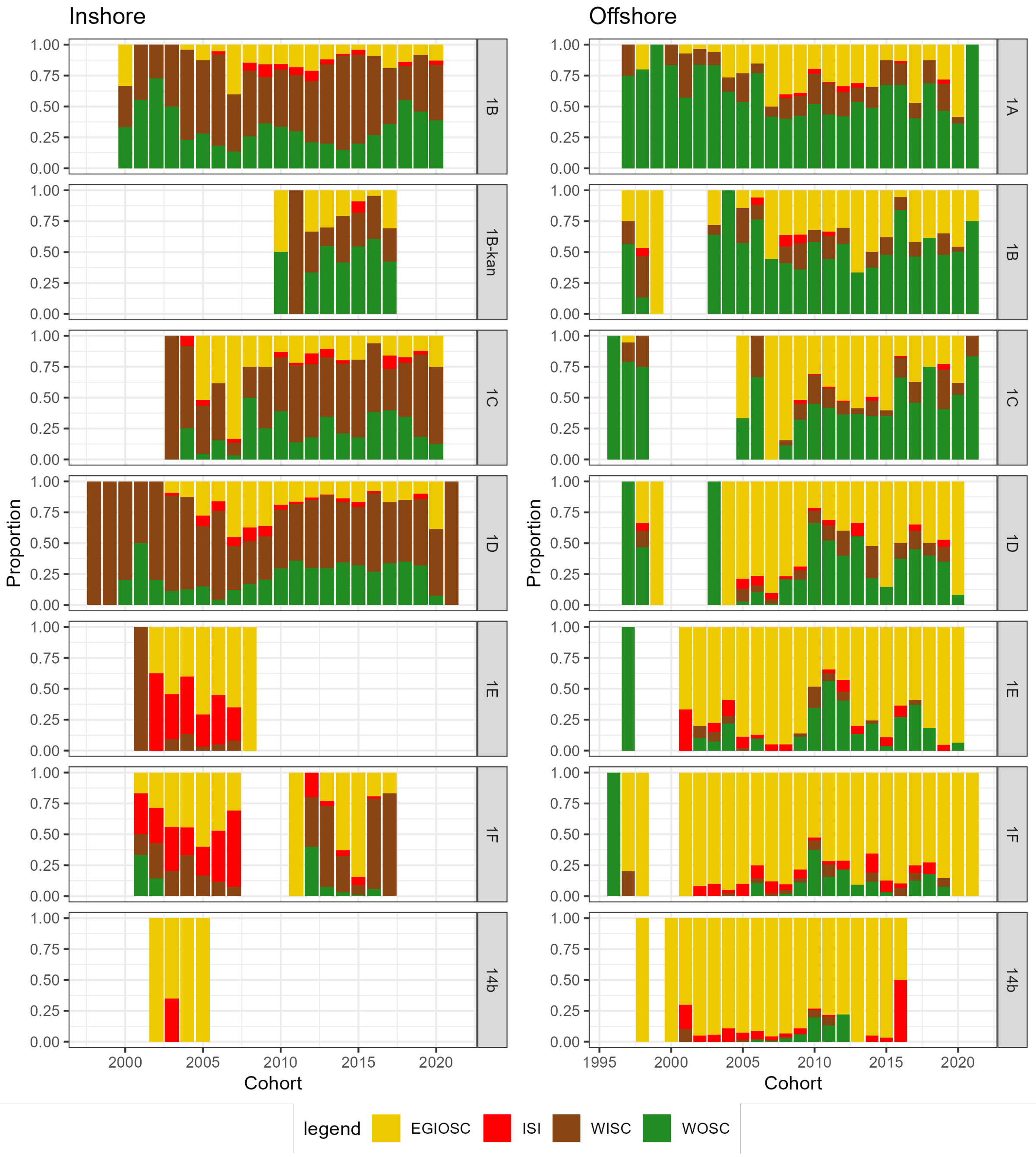

Figure 13.2.1.8.1. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2022 by area and cohort.

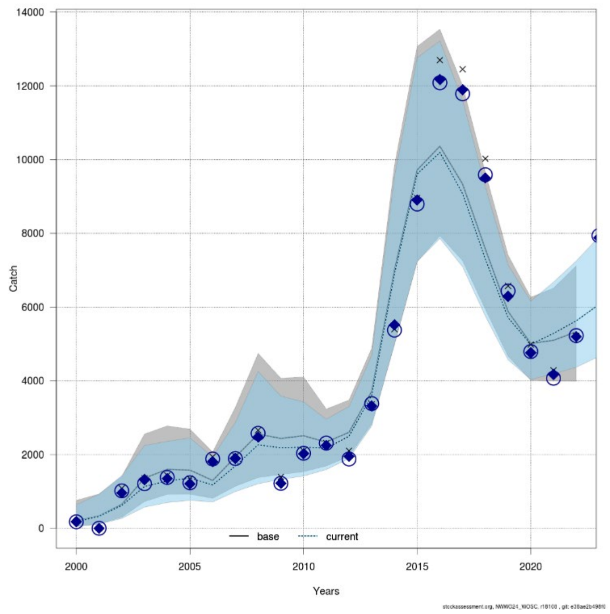

Figure 13.3.1. Estimated catch and with observed catch shown as crosses. Grey is the 2023 assessment and blue is the updated 2024 assessment.

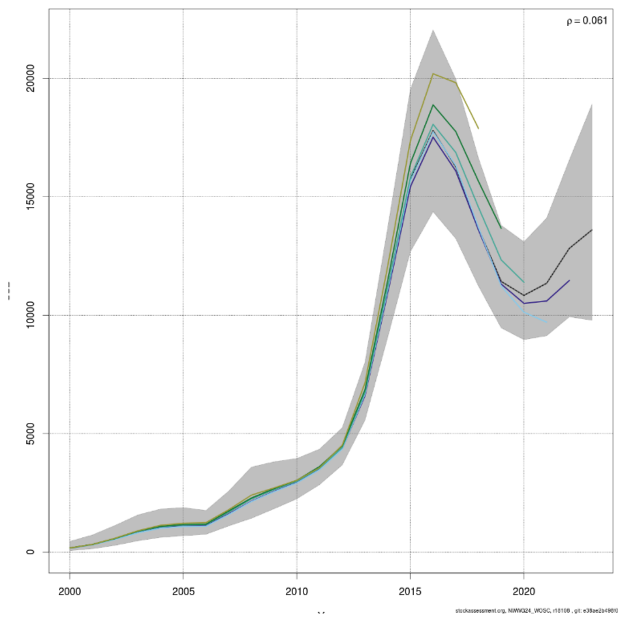

Figure 13.3. 2 Retrospective plot of SSB.

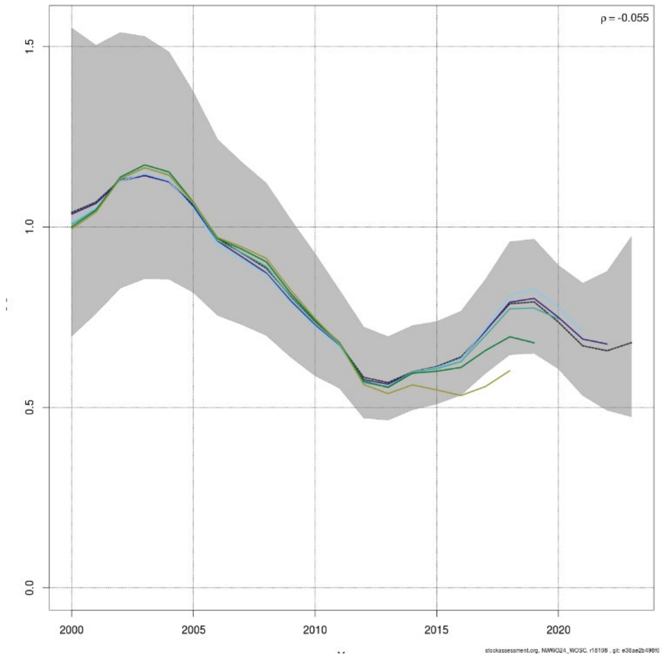

Figure 13.3.3. Retrospective plot of F4-7.

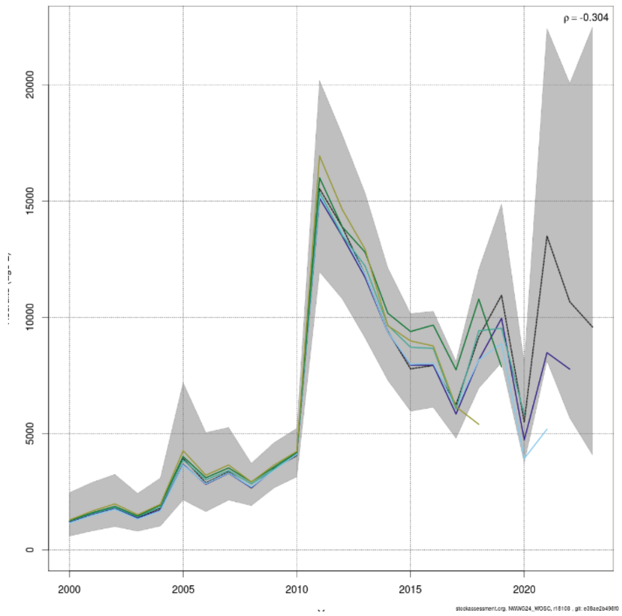

Figure 13.3.4. Retrospective plot of Recruits.

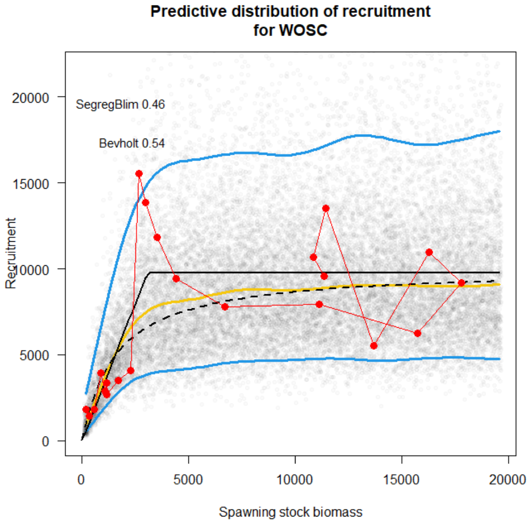

Figure 13.4.1 SSB-recruitment relationship estimated by simulation using EqSim with fitted SSB-recruitment relationships. The solid line gives the fitted model and the blue lines indicated the interval in which 95% of the simulations fall.

14 Southwest Greenland inshore spawning cod

cod.21.1d-f – *Gadus morhua* in NAFO Subarea 1 d-f

The West Greenland inshore spawning cod stock are split into two stock components (cod.21.1a-c and cod.21.1d-f) for the assessments. The procedure is documented in separate report chapters and stock annexes exist for each of these components. At the ADGANW 15-19 May 2023 it was decided that advice is given for the entire West Greenland Inshore spawning cod stock (cod.21.1.isc), this is done by presenting the advice for both stock components in a single advice sheet.

14.1 Stock description and management units

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023c). The new methods utilize genetics and information from tagging (Retzel & Nielsen 2024) to separate the cod into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks were assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022. Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

Reference points were re-estimated at NWWG 2024 (Buch et al. 2024b).

14.2 Scientific data

14.2.1.1 Historical trends in landings and fisheries

The fishery for cod in Greenlandic waters started at the beginning if the 19th century and developed into a large fishery of more than 400 000 tons in the 1960ies. After this historic height the fishery reduced to between 50 000 – 100 000 tons in the 1970ies and 80ies and thereafter collapsed in the 1990s.

For further information see stock annex

14.2.1.2 The present fishery

The catch of S-WISC started from almost zero in 2000. In 2001 there were no samples from the fishery and hence no split by stock can be made for this year. The catch steadily increased to 5 000 tons in 2019 (table 14.2.1). Hereafter, it declined to 2 600 tons in 2022 and then doubled to 5 000 tons in 2023. Until 2013, 70% of the catches were caught in Mid Greenland (NAFO division 1D), the rest in South Greenland (NAFO divisions 1E-1F). Since 2013, the proportion caught in NAFO division 1D has increased to approximately 90%.

The S-WISC is mainly caught in the inshore fishery (average 95%, figure 14.2.1). The most important gear in the inshore fishery is poundnets (taking approx. 60-80% of the annual catches) anchored at the shore and fishing the upper 20 m. Due to the ice conditions and vertical migration of cod, poundnets are not used during November-April. The inshore fishery uses longlines, jigs and gillnets in autumn and winter. The catches usually peak in summer and are lowest during late winter or early spring, when the lumpfish fishery dominates. About half of the catches are taken by small dinghies. The other half of the catches are taken by larger vessels (cutters).

14.2.1.3 Catch-at-age

Yearly catch-at-age is calculated from the commercial catch.

For further information see stock annex.

14.2.1.4 Weight-at-age

Yearly catch mean weight at age is calculated from the commercial catch and the gillnet survey as samples from the commercial fishery is low and sporadic.

Yearly stock mean weight at age is calculated from the Greenland gillnet survey.

For further information see stock annex.

14.2.1.5 Maturity-at-age

Maturity-at-age is fixed between years.

For further information see stock annex

14.2.1.6 Gillnet survey

An annual multimesh gillnet surveys designed to target cod aged 2 and 3 years old have been conducted in the inshore areas NAFO 1D (Nuuk) since 1987. Full description of the survey is given in (Retzel et al., 2023). Catches from the gillnet survey are split into the three genetically distinct cod stocks. For the WISC stock a CPUE index for area 1D are calculated for the years 2002-2023 (details are given in (Buch et al. 2023b).

Stock weight-at-age are based on data collected on the gillnet survey, only data from the WISC stock was used.

14.2.1.7 Genetics and stock splitting

Commercial and survey catch data are split into separate spawning stock units using a Generalized Additive Model (GAM) on genetic assigned samples. In order to improve sampling coverage for the years 2008 and 2010 archived samples were analysed in 2023. These samples showed higher than previously seen presence of the Icelandic inshore spawning cod stock (ISI) in the inshore areas 1E and 1F (figure 14.2.1.7.1). Previously it was decided to exclude the ISI stock from the stock splitting (see ICES 2023a: WKGREENCOD WD 01 and WD 05), the basis for this was that we were seeing only few occurrences and without patterns. The period 2008-2010 had a large fishery in the areas where the new samples showed high prevalence of ISI, this raised concerns that the split of catches for this period were incorrect. These areas are in the southern part of West Greenland (NAFO division 1E and 1F) and could have a potential effect on the proportion of S-WISC as this is stock is in this areas.

It was decided that for the splitting model ISI was merged with East Greenland Iceland offshore spawning cod stock (EGIOSC). This was done in order to account for the presence of this stock historically and any future incoming ISI cohorts. The number of ISI individuals observed in Greenland waters are at such a low level that it is difficult to include it as a separate stock in the split model. Merging the stock with the EGIOSC stock are also in line with previous studies (Christensen et al 2022) and in Iceland the two stocks are combined for the assessment (ICES 2023b). Continuous sampling will allow monitoring of this stock, should it become prevalent in large numbers this decision can be re-evaluated. The new catch estimates for S-WISC show a decrease in the S-WISC catch until 2017, especially in the period 2009-2014, compared to the old splitting (figure 14.2.1.7.2).

The number of samples for the split in 2024 is 11 083 (data added: 1300 samples from 2023 + 777 from 2008 and 2010 + 437 ISI) (Retzel & Buch 2024). The consequence of the addition of genetic data and the inclusion of ISI as EGIOSC was explored in several sensitivity runs in SAM on the 2023 assessment (Buch et al. 2024a). The SAM output showed little effect on the assessment.

For further information on GAM model see stock annex.

14.3 Stock assessment

The stock was benchmarked in 2023 (ICES, 2023). It was decided to use the SAM model (Nielsen and Berg, 2014) to perform an analytical assessment. This is considered a vast improvement, as the data are now split into stock components based on genetics.

14.3.1.1 Model diagnostics

The model fits the data well (Figure 14.3.1). Retrospective analysis showed stability when removing data, with most peels within the confidence intervals and Mohn'r rho values were low (Figures 14.3.2-4). The model are not able to fully estimate the increase in catches in 2023 (Buch et al. 2024b)

Overview of assessment given in Table 14.3.1.

14.3.1.2 State of the stocks

SSB has been above MSY Btrigger since 2014, and above Blim since 2012. F has been above Fmsy for the entire assessment period (2000-2023).

14.3.1.3 Quality of the assessment

The stock was benchmarked in 2023. A new model was adopted for the assessment (SAM), this was fitted to data for genetic stock components (Buch et al 2023a). This has increased the quality of the assessment by taking stock specific dynamics into account.

14.3.1.4 Reference points

Reference points was estimated and accepted at NWWG 2024 (this was recommended by WKGREENCOD (ICES, 2023a).) The estimations were conducted in EQSIM according to ICES guidelines (see ICES (2021) for details). Final reference points are shown in Table 15.5.1. However, F_{lim} was not defined (Buch et al. 2024b). Re-estimation of reference points are proposed to take place in connection with the 2026 assessment.

Following ICES guidelines the stock–recruitment relationship appears to follow a type 2 stock type, where B_{lim}= segmented regression breakpoint, however this gave a Blim that the group considered to be too low when inspecting the data. It was therefore decided to set Blim as the average of three years where recruitment started to increase above the initial scatter of poor to moderate recruitment in 2002-2011 (recruitment-at-age 2 in 2012-2014, and the corresponding SSB in 2010-2012). This gave a B_{lim} of 2462. Following initial runs, it was decided to exclude recent recruitment estimates due to very high uncertainty (recruitment in 2021-2023, SSB in 2019-2021), this is in line with ICES guidelines and the procedures followed for this stock since the benchmark.

Data from the latest SAM assessment (Buch et al. 2024b) were used for the simulations. The Eqsim software was used to define PA and MSY reference points.

The number of simulations were set to 1500. For assessment error sigmaF was default value of 0.2 and sigmaSSB was set to 0.216 from SAM. The default values were used for forecast errors: cvF=0.212, phiF=0.423, cvSSB=0 and phiSSB=0. For weight at age the last 5 years were used. For selectivity the last 10 years were used. The estimated reference points are given in the table below.

The breakpoint in the segmented was fixed to Blim. This resulted in a poor fit to the data with recruitments above the estimated recruitments for SSBs larger Blim. It was therefore decided to fix the slope for the segmented regression, to 2.1 which was the level where the horizontal part for large SSBs was equal to the average recruitment of the years 2012 (first year used to estimate Blim) to 2020 (last year in time-series used in the simulations). Fixing both the slope and breakpoint of the segmented regression resulted in the segmented regression getting nearly zero influence (compared to Ricker and Beverton–Holt) in the simulations (Figure 14.3.1.4.1). The Beverton–Holt model had the best fit resulting in a weight of 0.58, and the Ricker model had nearly as good a fit with the weight being estimated to 0.41. This indication of density-dependence was discussed by NWWG 2024. This stock is mainly within the large fjord complex around Nuuk, where it stays from recruitment to spawning and death without performing migrations to other fjords. It shares its habitat with juveniles from the two offshore spawning stocks that use the fjord as nursery area. As the stock size grew to the current high level, the weight-at-age decreased indicating reduced growth and/or condition. This pattern is consistent across ages and years and the effect is substantial (40-61% since 2018 relative to prior to 2013). Decreasing food availability is the most likely reason. The main prey is capelin (Grønkjær et al., 2019; unpublished stomach content analysis from 2023). Capelin has been observed to be decreasing in abundance (Merkel et al., 2021; unpublished acoustic surveys) and another predator have been negatively affected by this reduction (Merkel et al., 2021). In conclusion, it appears likely that cod from this stock, in conjunction with the juveniles from the two offshore stocks, are fully utilizing the current carrying capacity and that density-dependent effects may also be affecting the recruitment. The group therefore found no reason for removing the ricker model from the stock–recruitment assemble model.

Due to uncertainty in the estimates of reference points, and a large estimate of Fmsy, relative to other cod stocks, the group decided to give advice based on F ranging from the lowest F that leads to average catches at 95% of catches with Fmsy, and up to Fmsy.

The benchmark oversight group (BOG) proposed using 50% Bmsy as MSY Btrigger, rather than the values calculated at WKGREENCOD, and this proposal was endorsed by ACOM on the ACOM forum (April 21, 2023) (ICES, 2023b). During revision of reference points at NWWG 2024 it was decided to follow normal ICES guidelines of using Bpa as basis for MSY Btrigger. The reason for changing the procedure was a scrutinization of the minutes from BOG where the group interpreted that the recommendation was primarily intended for the West Greenland Offshore Spawning Cod (WOSC) as this stock has a higher production potential than the Inshore stocks.

14.4 Short-term forecast

14.4.1.1 Input data

The SAM model provides predictions that carry the signals from the assessment into the short-term forecast. The forecast procedure starts from the last year's estimate of the state (log(N) and log(F)). One thousand replicates of the last state are simulated from the estimated joint distribution. Each of these replicates are then simulated forward according to the assumptions and parameter estimates found by the assessment model.

In the forward simulations, a 5-year average (up to the assessment year) of proportion mature, and natural mortality are used. Stock and catch weight used in the short-term forecast are estimated within SAM. Recruitment is resampled from 2014-2023. In each forward simulation step the fishing mortality is scaled, such that the median of the distribution is matching the requirement in the scenario (e.g. hitting a specific mean F value, a specific catch or level of SSB).

For the interim year it was assumed that F in 2024 will be the same as F in 2023 (Table 14.7.1).

14.4.1.2 Results

The results from the assessment can be found on stockassessment.org (run: NWWG24_S-WISC).

The forecasts from the different scenarios are presented in Table 14.7.2. Fishing at F= 0.54 in 2024 will result in catches of 2304 t. And fishing at F= 0.27 ($F_{MSYlower}$) in 2024 will result in catches of 1285 t. Recently the catches have been above the ICES advice, and an F status quo will result in catches of 3367 t.

14.5 Uncertainties in assessment and forecast

The TAC in the intermediate year is known at the time of the assessment meeting. This TAC is valid for the mixed fishery and does not reflect the expected catch of solely the inshore stock. For 2024 catch is assumed to be similar to catch in 2023. In future years advice will be given by stock and TAC will likely be set by area. The genetic split between stock can be used to split TACs into stocks to get likely estimates of catch by stock for the intermediate years.

Estimation of reference points are associated with some uncertainty due to the short time-series.

The assessment methods recalculates the entire time-series every year, so minor revisions of estimates from all years are expected.

14.6 Comparison with previous assessment and forecast

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023a). The new methods utilize genetics and information from tagging to separate the cod into four stocks that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks were assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022. Management plans and evaluations
There is no management plan for this stock.

14.7 Management considerations

Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

14.8 Ecosystem considerations

The gear used for this fishery have little effect on the ecosystem, especially the main gear (pound-net).

14.9 Regulations and their effects

The fishery has never been limited by a TAC, as the TAC has always been set well above the fleet capacity or raised when reached. In 2023 the TAC was raised from 17 000 tons to 23 000 tons in autumn. Therefore, it is unknown what the effect would be of limiting the fishery.

14.10 References

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14.11 Tables

Table 14.2.1. Catch (tons) of the Southern West Greenland inshore spawning cod stock (S-WISC) by NAFO divisions in West Greenland. *No samples from the fishery in 2001.

	NAFO division			
Year	**1D**	**1E**	**1F**	**Total**
2000	136		2	138
2001*				
2002	90	4	79	173
2003	125	1	95	221
2004	268	7	46	321
2005	245	46	51	342
2006	620	71	211	902
2007	774	151	526	1451
2008	1283	68	312	1663
2009	791	196	233	1220
2010	715	244	108	1067
2011	1205	221	153	1579
2012	1917	339	88	2344
2013	1879	258	74	2211
2014	1763	146	76	1985
2015	3117	263	172	3552
2016	2782	204	161	3147
2017	2122	117	194	2433
2018	3660	196	269	4125
2019	4460	60	470	4990
2020	3712	66	464	4242
2021	2353	32	300	2685
2022	2439	29	133	2601
2023	4592	131	213	4936

Table 14.3.1 Assessment summary. 'High' and 'Low' correspond to 95% confidence intervals. Weights are in tonnes, recruitment in thousands.

Year	Recruitment Age 2 thousands	97.50%	2.50%	SSB tonnes	97.50%	2.50%	Total Catch tonnes	F Ages 4-7	97.50%	2.50%
2000	288	456	182	167	377	74	138	0.741	1.287	0.426
2001	331	483	227	151	281	82		0.755	1.226	0.465
2002	270	393	185	170	251	115	173	0.736	1.109	0.488
2003	507	739	348	219	303	158	220	0.751	1.088	0.519
2004	1160	1654	813	271	369	199	321	0.756	1.086	0.527
2005	2763	3782	2018	346	452	265	341	0.782	1.094	0.559
2006	3643	4769	2783	577	746	447	902	0.808	1.106	0.591
2007	3124	4090	2386	971	1288	732	1452	1.172	1.559	0.881
2008	1407	1940	1021	1293	1722	971	1664	1.04	1.364	0.793
2009	3192	4163	2447	1663	2176	1271	1220	0.85	1.128	0.641
2010	2551	3382	1924	2057	2654	1595	1066	0.804	1.048	0.616
2011	3230	4161	2508	2300	2898	1826	1579	0.819	1.058	0.634
2012	4353	5558	3408	3029	3838	2391	2345	0.781	1.005	0.607
2013	6136	7708	4884	3322	4109	2685	2210	0.774	1.012	0.592
2014	5967	7548	4716	3980	4897	3234	1985	0.718	0.946	0.545
2015	6831	8640	5401	4952	6081	4033	3552	0.747	0.975	0.573
2016	7872	9814	6314	5726	7005	4680	3147	0.688	0.896	0.528
2017	5621	7079	4463	6303	7720	5146	2432	0.651	0.861	0.492
2018	5699	7412	4381	6742	8338	5452	4123	0.813	1.035	0.639
2019	6866	9055	5207	6533	8052	5300	4991	0.98	1.256	0.765
2020	3051	4522	2059	5906	7142	4884	4241	0.94	1.215	0.728
2021	6646	11448	3858	5706	6972	4670	2685	0.736	0.988	0.549
2022	4066	9045	1828	6094	7769	4780	2601	0.754	1.052	0.541
2023	2949	9499	916	5735	7908	4159	4936	0.903	1.382	0.59
2024**	5699			5348	8684	2585				

Table 14.5.1 Reference points

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	3421 t	B_{pa}	NWWG 2024
	F_{MSY}	0.54	Stochastic simulations (EqSim) using segmented regression, Ricker and Beverton–Holt.	NWWG 2024
	$F_{MSYlower}$	0.27	Consistent with lower range resulting in no more than 5% reduction in long-term yield compared to MSY	NWWG 2024
Precautionary approach	B_{lim}	2462 t	From segmented regression breakpoint	NWWG 2024
	B_{pa}	3421 t	B_{lim}*exp(sigmaSSB*1.645), sigmaSSB = 0.211	NWWG 2024
	F_{lim}	NA	Equilibrium F, which will maintain the stock above B_{lim} with a 50% probability.	NWWG 2024
	F_{pa}	1.38	The fishing mortality including the advice rule that, if applied as a target in the ICES MSY advice rule (AR) would lead to SSB ≥ B_{lim} with a 95% probability (also known as F_{p05}).	NWWG 2024
Management plan	SSB_{mgt}	-	-	
	F_{mgt}	-	-	

Table 14.7.1 Values in the forecast and for the interim year.

Variable	**Value**	**Notes**
$F_{ages\ 5–8}$ (2024)	0.903	$F_{2024} = F_{2023}$
SSB (2025)	4777	Short-term forecast; tonnes
$R_{age\ 2}$ (2024)	5699	Median recruitment, resampled from the years 2014–2023; thousands
$R_{age\ 2}$ (2025)	5699	Median recruitment, resampled from the years 2014–2023; thousands
Catch (2024)	3734	Based on $F_{ages\ 5–8}$ (2023) = 0.903; tonnes

Table 14.7.2 Catch scenarios for 2024 assuming $F_{2022} = F_{2023}$. All weights are in tonnes.

Rationale	**Catch (2025)**	**F (2025)**	**SSB (2026)**	**% SSB change***	**% advice change****
ICES advice basis					
MSY approach: F_{MSY}	2304	0.54	5195	9	-2
MSY approach: $F_{MSYlower}$	1285	0.27	6022	26	-45

Rationale	Catch (2025)	F (2025)	SSB (2026)	% SSB change*	% advice change**
Other scenarios					
$F_{2025} = 0$	0	0	4777	49	-100
$F_{2025} = F_{2024}$	3367	0.903	4271	-11	34

*** SSB_{2026} relative to SSB_{2025}.**

**** Advised catch for 2025 relative to advised catch for 2024 (2349 tonnes).**

14.12 Figures

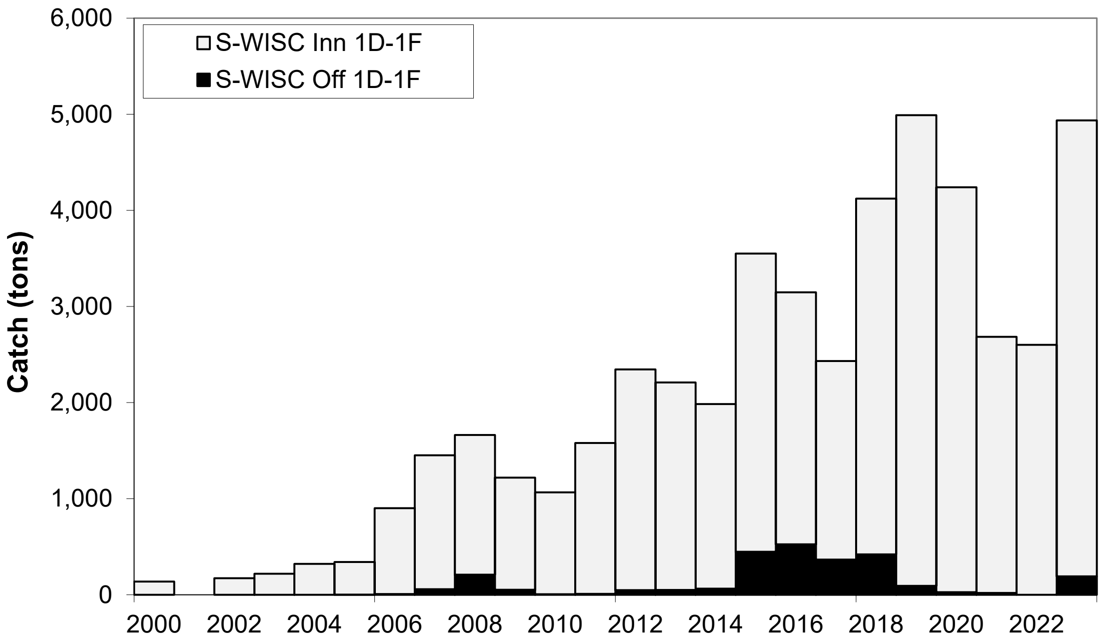

Figure 14.2.1 Catch of the Southern West Greenland inshore spawning cod stock (S-WISC) in the inshore and offshore area in West Greenland. No samples from the fishery in 2001.

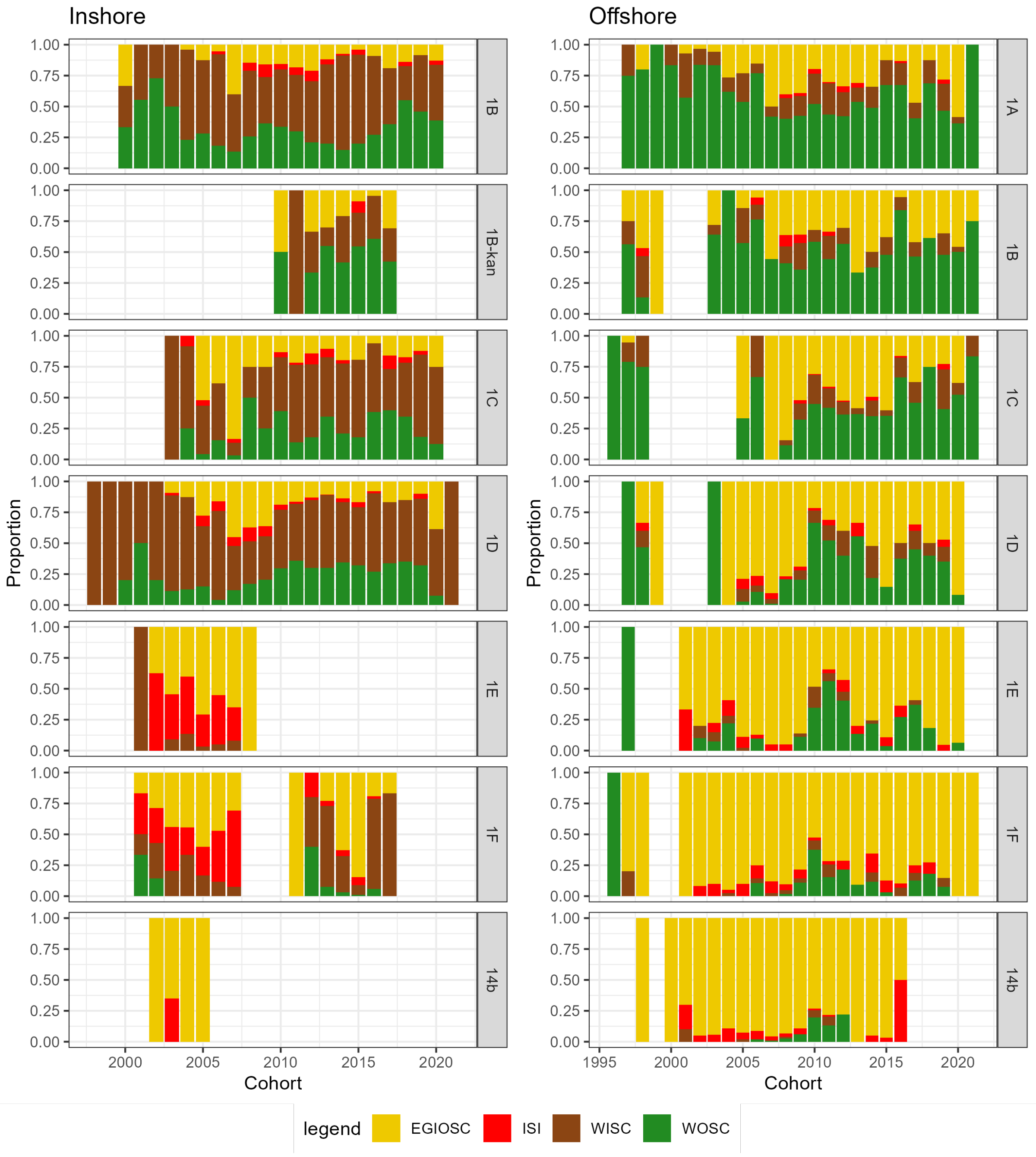

Figure 14.2.1.7.1. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2022 by area and cohort.

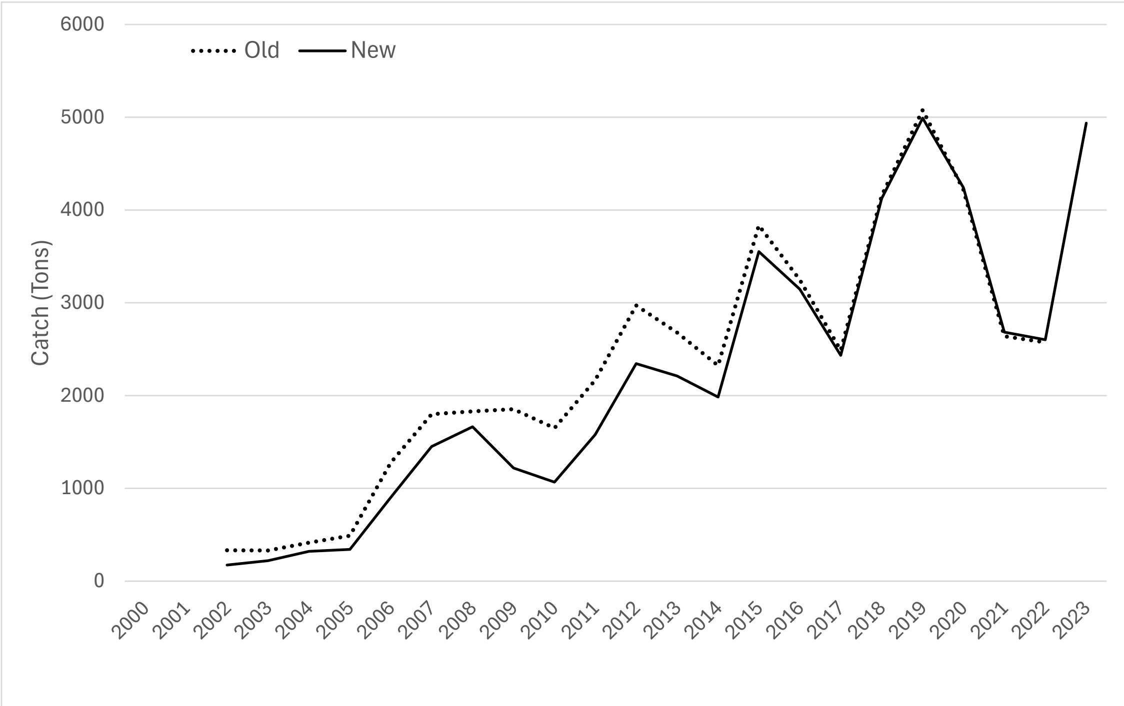

Figure 14.2.1.7.2. Total catch of S-WISC from the split done in 2023 (old – end year 2022) and 2024 (new – end year 2023).

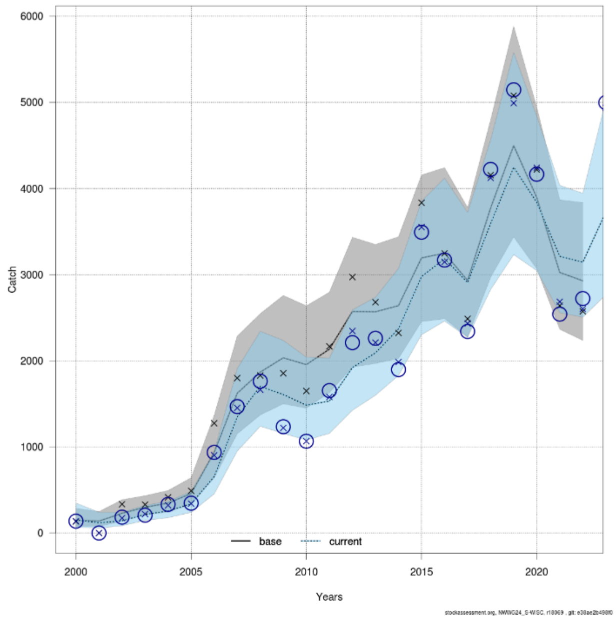

Figure 14.3.1. Estimated catch and with observed catch shown as crosses.

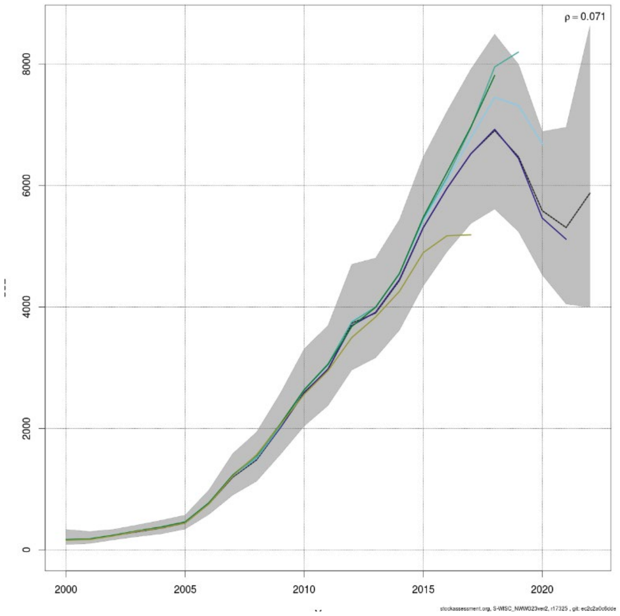

Figure 14.3. 2 Retrospective plot of SSB.

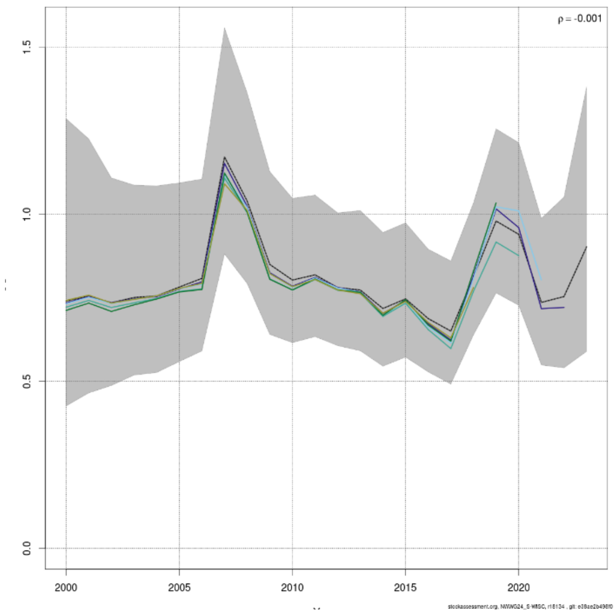

Figure 14.3.3. Retrospective plot of F5-8.

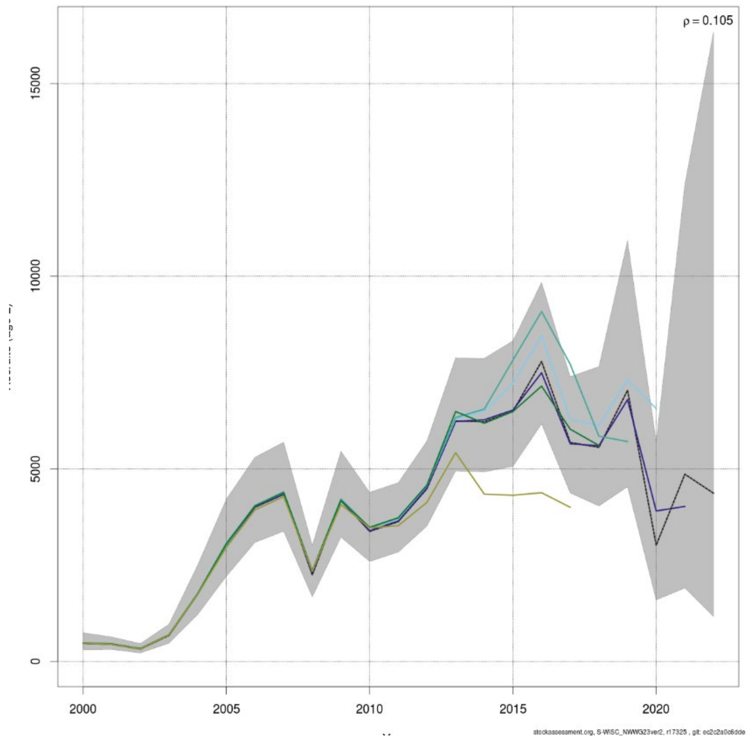

Figure 14.3.4. Retrospective plot of Recruits.

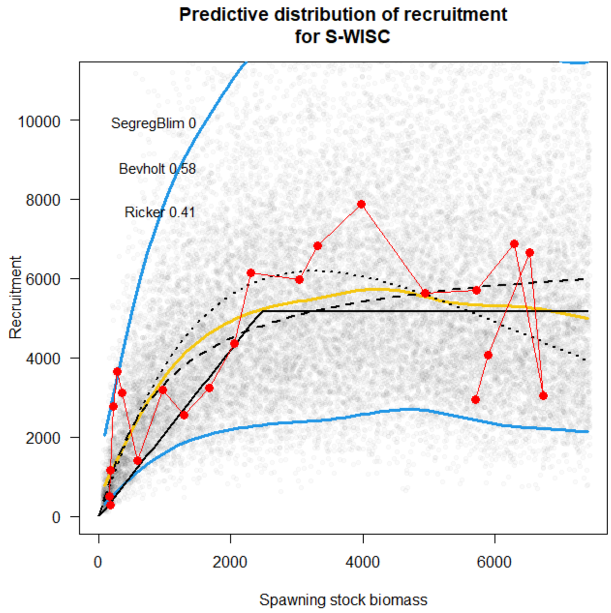

Figure 14.3.1.4.1 SSB-recruitment relationship estimated by simulation using EqSim with fitted SSB-recruitment relationships. Dashed: Ricker curve. Dotted: Beverton–Holt curve. Solid: Segmented regression (with breakpoint fixed to Blim and slope fixed to 2.1). The curve fits are indicated.

15 Northwest Greenland inshore spawning cod

cod.21.1a-c – *Gadus morhua* in NAFO Subarea 1a-c

The West Greenland inshore spawning cod stock are split into two stock components (cod.21.1a-c and cod.21.1d-f) for the assessments. The procedure is documented in separate report chapters and stock annexes exist for each of these components. At the ADGANW 15-19 May 2023 it was decided that advice is given for the entire West Greenland Inshore spawning cod stock (cod.21.1.isc), this is done by presenting the advice for both stock components in a single advice sheet.

15.1 Stock description and management units

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023a). The new methods utilize genetics and information from tagging (Retzel & Nielsen 2024) to separate the cod into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks was assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022. Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

Reference points were re-estimated at NWWG 2024.

15.2 Scientific data

15.2.1.1 Historical trends in landings and fisheries

The fishery for cod in Greenlandic waters started at the beginning if the 19th century and developed into a large fishery of more than 400 000 tons in the 1960ies. After this historic height the fishery reduced to between 50 000 – 100 000 tons in the 1970ies and 80ies and thereafter collapsed in the 90ies.

For further information see stock annex

15.2.1.2 The present fishery

The catch of N-WISC started from almost zero in 2000. In 2001 there were no samples from the fishery and hence no split by stock can be made for this year. The catch steadily increased from 2,000 tons pr year to a maximum of 12 000 tons in 2016 and 2017 (table 15.2.1). Hereafter the catches declined to app. 4 000 tons in 2019-2022. In 2023 the catches increased to 6 000 tons.

The N-WISC is mainly caught in NAFO divisions 1B and 1C where in average 90% of the total catch of N-WISC is caught. Especially in later years the proportions of the catch in 1C have increased to almost 60%.

The N-WISC is caught in the inshore fishery (average 99%, figure 15.2.1). The most important gear in the inshore fishery is poundnets (taking app. 60-80% of the annual catches) anchored at the shore and fishing the upper 20 m. Due to the ice conditions and vertical migration of cod, poundnets are not used during November-April. The inshore fishery uses longlines, jigs and gillnets in autumn and winter. The catches usually peak in summer and are lowest during late winter or early spring, when the lumpfish fishery dominates. About half of the catches are taken by small dinghies. The other half of the catches are taken by larger vessels (cutters). Catches in NAFO division 1A are mainly from the Disco Bay area and cod are here mainly caught as bycatch in the Greenland halibut fishery which uses longlines and gillnets.

15.2.1.3 Catch-at-age

Yearly catch-at-age is calculated from the commercial catch.

For further information see stock annex.

15.2.1.4 Weight-at-age

Yearly catch mean weight at age is calculated from the commercial catch and the gillnet survey as samples from the commercial fishery is low and sporadic.

Yearly stock mean weight at age is calculated from the Greenland gillnet survey.

For further information see stock annex.

15.2.1.5 Maturity-at-age

Maturity-at-age is fixed between years.

For further information see stock annex

15.2.1.6 Gillnet survey

An annual multimesh gillnet surveys designed to target cod aged 2 and 3 years old have been conducted in the inshore areas NAFO 1B (Sisimiut) since 1987. Full description of the survey is given in (Retzel et al., 2023). Catches from the gillnet survey are split into the three genetically distinct cod stocks. For the WISC stock a CPUE index for area 1B are calculated for the years 2002-2023 (details are given in (Buch et al. 2023b).

Stock weight-at-age are based on data collected on the gillnet survey, only data from the WISC stock was used.

15.2.1.7 Genetics and stock splitting

Commercial and survey catch data are split into separate spawning stock units using a Generalized Additive Model (GAM) on genetic assigned samples. In order to improve sampling coverage for the years 2008 and 2010 archived samples were analysed in 2023. These samples showed higher than previously seen presence of the Icelandic inshore spawning cod stock (ISI) in the inshore areas 1E and 1F (figure 15.2.1.7.1). Previously it was decided to exclude the ISI stock from the stock splitting (see ICES 2023a: WKGREENCOD WD 01 and WD 05), the basis for this was that we were seeing only few occurrences and without patterns. The period 2008-2010 had a large fishery in the areas where the new samples showed high prevalence of ISI, this raised concerns that the split of catches for this period were incorrect. These areas are in the southern part of West Greenland (NAFO division 1E and 1F) and has therefore no effect on the proportion of the N-WISC stock.

It was decided that for the splitting model ISI was merged with East Greenland Iceland offshore spawning cod stock (EGIOSC). This was done in order to account for the presence of this stock historically and any future incoming ISI cohorts. The number of ISI individuals observed in Greenland waters are at such a low level that it is difficult to include it as a separate stock in the split model. Merging the stock with the EGIOSC stock are also in line with previous studies (Christensen et al 2022) and in Iceland the two stocks are combined for the assessment (ICES

2023b). Continuous sampling will allow monitoring of this stock, should it become prevalent in large numbers this decision can be re-evaluated.

The number of samples for the split in 2024 is 11 083 (data added: 1300 samples from 2023 + 777 from 2008 and 2010 + 437 ISI) (Retzel & Buch 2024). The consequence of the addition of genetic data and the inclusion of ISI as EGIOSC was explored in several sensitivity runs in SAM on the 2023 assessment (Buch et al. 2024a). The SAM output showed little effect on the assessment.

For further information on GAM model see stock annex.

15.3 Stock assessment

The stock was benchmarked in 2023 (ICES, 2023a). It was decided to use the SAM model (Nielsen and Berg, 2014) to perform an analytical assessment. This is considered a vast improvement, as the data are now split into stock components based on genetics.

15.3.1.1 Model diagnostics

The model fits the data well but does not capture the high catches in 2016, 2017 and 2023 (Figure 15.3.1). Retrospective analysis showed stability when removing data, but with a tendency to underestimate SSB and overestimate F (Figures 15.3.2-4). There was also a tendency to underestimate recruitment, indicating that the model do not capture incoming cohorts fully at the recruitment age. For F there was a big downward revision following the addition of the 2023 data, this revision is related to the increase in catches particularly for age 4 which results in an upwards revision in recruitment and SSB.

Overview of assessment given in Table 15.3.1.

15.3.1.2 State of the stocks

SSB is above MSY Btrigger since 2012, and above Blim. F has been above Fmsy for the entire assessment period (2000-2023).

15.3.1.3 Quality of the assessment

The stock was benchmarked in 2023. A new model was adopted for the assessment (SAM), this was fitted to data for genetic stock components. This has increased the quality of the assessment by taking stock specific dynamics into account.

15.4 Reference points

Reference points was estimated and accepted at NWWG 2024 (this was recommended by WKGREENCOD (ICES, 2023a).) The estimations were conducted in EQSIM according to ICES guidelines (see ICES (2021) for details). Final reference points are shown in Table 15.5.1. However, F_{pa} and F_{lim} was not defined (Buch et al. 2024b). Re-estimation of reference points are proposed to take place in connection with the 2026 assessment.

For estimating B_{lim} a categorization of the stock–recruitment relationship into type is required (ICES, 2021). The group agreed to use the average SSB of the three years with highest recruitment. This gave a B_{lim} of 2943 t.

Data from the SAM assessment agreed at NWWG 2024 (Buch et al. 2024b) were used for the simulations. The Eqsim software was used to define PA and MSY reference points.

The number of simulations were set to 1500. Recruitment in 2021-2023 was omitted due to high uncertainty for the estimates. For assessment error sigmaF was default value of 0.2 and sigmaSSB was set to 0.216 from SAM. The default values were used for forecast errors: cvF=0.212, phiF=0.423, cvSSB=0 and phiSSB=0. For weight at age the last 5 years were used. For selectivity the last 10 years were used. For the simulations segmented regression (with breakpoint fixed at B_{lim}) and Beverton–Holt were used (Figure 15.4.1). The estimated reference points are given in the table below. Due to very high estimate of Fpa and F_{lim}, it was decided to not report on these values.

The benchmark oversight group (BOG) proposed using 50% Bmsy as MSY Btrigger, rather than the values calculated at WKGREENCOD, and this proposal was endorsed by ACOM on the ACOM forum (April 21, 2023) (ICES, 2023b). During revision of reference points at NWWG 2024 it was decided to follow normal ICES guidelines of using Bpa as basis for MSY Btrigger. The reason for changing the procedure was a scrutinization of the minutes from BOG where the group interpreted that the recommendation was primarily intended for the West Greenland Offshore Spawning Cod (WOSC) as this stock has a higher production potential than the Inshore stocks.

15.5 Short-term forecast

15.5.1.1 Input data

The SAM model provides predictions that carry the signals from the assessment into the short-term forecast. The forecast procedure starts from the last year's estimate of the state (log(N) and log(F)). One thousand replicates of the last state are simulated from the estimated joint distribution. Each of these replicates are then simulated forward according to the assumptions and parameter estimates found by the assessment model.

In the forward simulations, a 5-year average (up to the assessment year) of proportion mature, and natural mortality are used. Stock and catch weight used in the short-term forecast are estimated within SAM. Recruitment is resampled from 2014-2023. In each forward simulation step the fishing mortality is scaled, such that the median of the distribution is matching the requirement in the scenario (e.g. hitting a specific mean F value, a specific catch or level of SSB).

For the interim year it was assumed that F in 2024 will be the same as F in 2023 (Table 15.7.1).

15.5.1.2 Results

The results from the assessment can be found on stockassessment.org (run: NWWG24_NWISC).

The forecasts from the different scenarios are presented in Table 15.7.2. Fishing at F= 0.27 in 2025 will result in catches of 2151 t. Recently the catches have been above the ICES advice, and an F status quo will result in catches of 5402 t.

15.6 Uncertainties in assessment and forecast

The TAC in the intermediate year is known at the time of the assessment meeting. This TAC is valid for the mixed fishery and does not reflect the expected catch of solely the inshore stock. For 2024 catch is assumed to be similar to catch in 2023. In future years advice will be given by stock and TAC will likely be set by area. The genetic split between stock can be used to split TACs into stocks to get likely estimates of catch by stock for the intermediate years.

Estimation of reference points are associated with some uncertainty due to the short time-series.

The assessment methods recalculate the entire time-series every year, so minor revisions of estimates from all years are expected.

15.7 Comparison with previous assessment and forecast

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023a). The new methods utilize genetics and information from tagging to separate the cod into four stocks that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks was assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022.

The addition of the 2023 data resulted in an upward revision of both SSB and recruitment of the 2019 cohort, this is largely related to the 2019 being present in the catches in large numbers and a general big increase in catches for 2023.

15.8 Management plans and evaluations

There is no management plan for this stock.

15.9 Management considerations

Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

15.10 Ecosystem considerations

The gear used for this fishery have little effect on the ecosystem, especially the main gear (pound-net).

15.11 Regulations and their effects

The fishery has never been limited by a TAC, as the TAC has always been set well above the fleet capacity or raised when reached. In 2023 the TAC was raised from 17 000 tons to 23 000 tons in autumn. Therefore, it is unknown what the effect would be of limiting the fishery.

15.12 References

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15.13 Figures and Tables

Table 15.2.1. Catch (tons) of the Northern West Greenland inshore spawning cod stock (N-WISC) by NAFO divisions in West Greenland. *No samples from the fishery in 2001.

	NAFO division			
Year	1A	1B	1C	Total
2000	32	66		98
2001*				
2002	75	861	247	1183
2003	250	742	167	1159
2004	233	948	222	1403
2005	129	856	534	1519
2006	194	1017	653	1864
2007	156	1146	605	1907
2008	158	1546	729	2433
2009	54	671	550	1275
2010	120	1516	740	2376
2011	94	1288	1323	2705
2012	136	640	992	1768
2013	317	1215	1258	2790

	NAFO division			
Year	1A	1B	1C	Total
2014	783	2917	1728	5428
2015	928	3750	3246	7924
2016	1391	5402	5946	12739
2017	1502	5060	5507	12069
2018	590	2907	3518	7015
2019	502	1460	2344	4306
2020	305	1233	2503	4041
2021	234	1526	2309	4069
2022	341	1168	2712	4221
2023	544	1957	3579	6080

Table 15.3.1 Assessment summary. 'High' and 'Low' correspond to 95% confidence intervals. Weights are in tonnes, recruitment in thousands.

Year	Recruitment Age 2	97.50%	2.50%	SSB tonnes	97.50%	2.50%	Total Catch tonnes	F Ages 5-8	97.50%	2.50%
2000	993	1575	2498	96	180	337	98	0.44	0.70	1.12
2001	812	1192	1750	237	379	608		0.50	0.74	1.11
2002	1215	1758	2544	515	771	1154	1183	0.59	0.83	1.16
2003	1050	1543	2267	724	1038	1488	1159	0.71	0.94	1.25
2004	1171	1727	2549	792	1076	1461	1403	0.79	1.02	1.33
2005	2323	3279	4628	845	1152	1569	1519	0.76	0.99	1.30
2006	2403	3414	4850	802	1059	1399	1863	0.67	0.89	1.19
2007	2166	2988	4121	1057	1392	1833	1907	0.64	0.86	1.15
2008	1981	2736	3779	1481	2009	2727	2432	0.61	0.80	1.05
2009	2149	2917	3958	1817	2444	3288	1275	0.53	0.69	0.91
2010	3671	4842	6387	2258	2948	3848	2376	0.56	0.73	0.94

Year	Re-cruit-ment Age 2	97.50%	2.50%	SSB tonnes	97.50%	2.50%	Total Catch tonnes	F Ages 5-8	97.50%	2.50%
2011	6791	8773	11332	2700	3437	4376	2704	0.55	0.71	0.91
2012	8756	11628	15441	3727	4625	5740	1768	0.50	0.64	0.82
2013	9155	12574	17272	5741	7042	8639	2789	0.49	0.63	0.80
2014	6488	8799	11933	9553	11770	14502	5428	0.53	0.67	0.85
2015	5238	6894	9075	13092	16550	20923	7924	0.56	0.70	0.88
2016	5957	7935	10570	13243	17200	22340	12739	0.66	0.81	1.00
2017	3266	4436	6027	10849	14078	18269	12070	0.79	0.98	1.20
2018	4918	6594	8841	8411	10440	12959	7015	0.86	1.05	1.30
2019	3434	4929	7075	6518	8072	9997	4306	0.83	1.02	1.25
2020	3270	5049	7797	5612	7058	8878	4041	0.78	0.97	1.21
2021	5206	10133	19720	5277	6733	8590	4068	0.72	0.92	1.18
2022	3125	7333	17207	4944	6704	9090	4221	0.62	0.85	1.16
2023	2081	6462	20066	4610	7098	10929	6081	0.59	0.88	1.29
2024		6594		4521	8389	15297				

Table 15.5.1 Reference points

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	4197	Bpa	NWWG 2024
	F_{MSY}	0.27	Stochastic simulations (EqSim) using segmented regression and Beverton–Holt.	NWWG 2024
Precautionary approach	B_{lim}	2943	Average SSB of the three years with low SSB and high recruitment.	NWWG 2024
	B_{pa}	4197	$B_{lim} \times \exp(\sigma \times 1.645)$; $\sigma = 0.216$	NWWG 2024
	F_{lim}	-	Not defined	NWWG 2024
	F_{pa}	-	Not defined	NWWG 2024
Management plan	SSB_{mgt}	-	-	
	F_{mgt}	-	-	

Table 15.7.1 Values in the forecast and for the interim year.

Variable	Value	Notes
$F_{ages\ 5–8}$ (2024)	0.875	$F_{2024} = F_{2023}$
SSB (2025)	8527	Short-term forecast; tonnes
$R_{age\ 2}$ (2024)	6594	Median recruitment, resampled from the years 2014–2023; thousands
$R_{age\ 2}$ (2025)	6594	Median recruitment, resampled from the years 2014–2023; thousands
Catch (2024)	5256	Based on $F_{ages\ 5–8}$ (2024); tonnes

Table 15.7.2 Catch scenarios for 2025 assuming $F_{2024} = F_{2023}$. All weights are in tonnes.

Rationale	Catch (2024)	F (2024)	SSB (2025)	% SSB change*	% advice change**
ICES advice basis					
MSY approach: F_{MSY}	2151	0.27	11613	36	188
Other scenario					
$F_{2025} = 0$	0	0	14234	67	-100
$F_{2025} = F_{2024}$	5402	0875	7839	-8	624

*** SSB_{2026} relative to SSB_{2025}.**

**** Adviced catch for 2025 relative to adviced catch for 2024 (746 tonnes).**

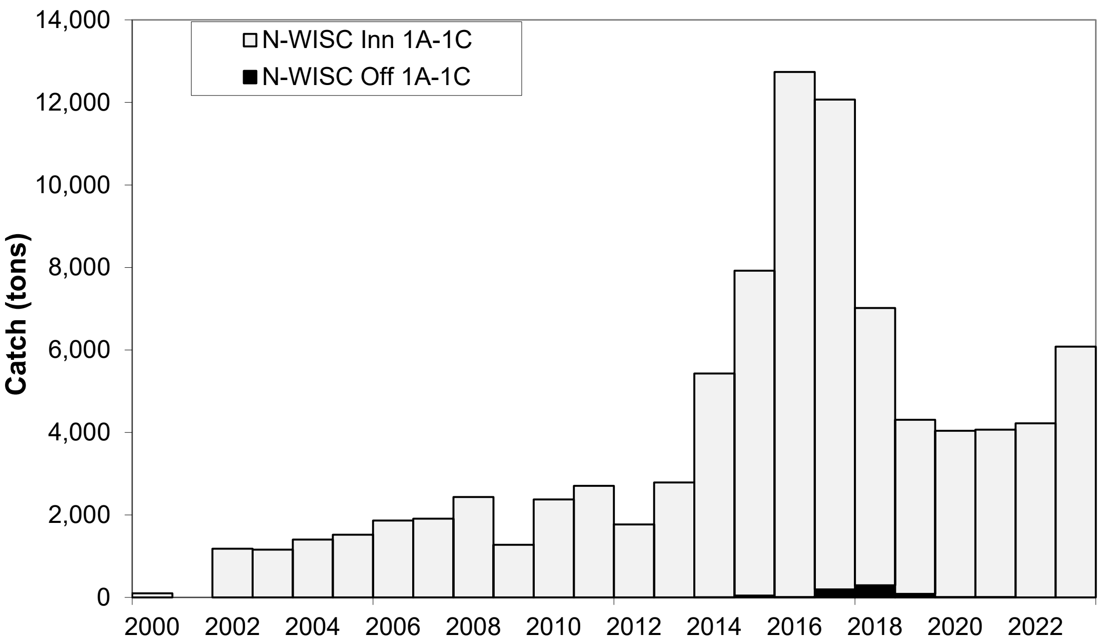

Figure 15.2.1 Catch of the Northern West Greenland inshore spawning cod stock (N-WISC) in the inshore and offshore area in West Greenland. No samples from the fishery in 2001.

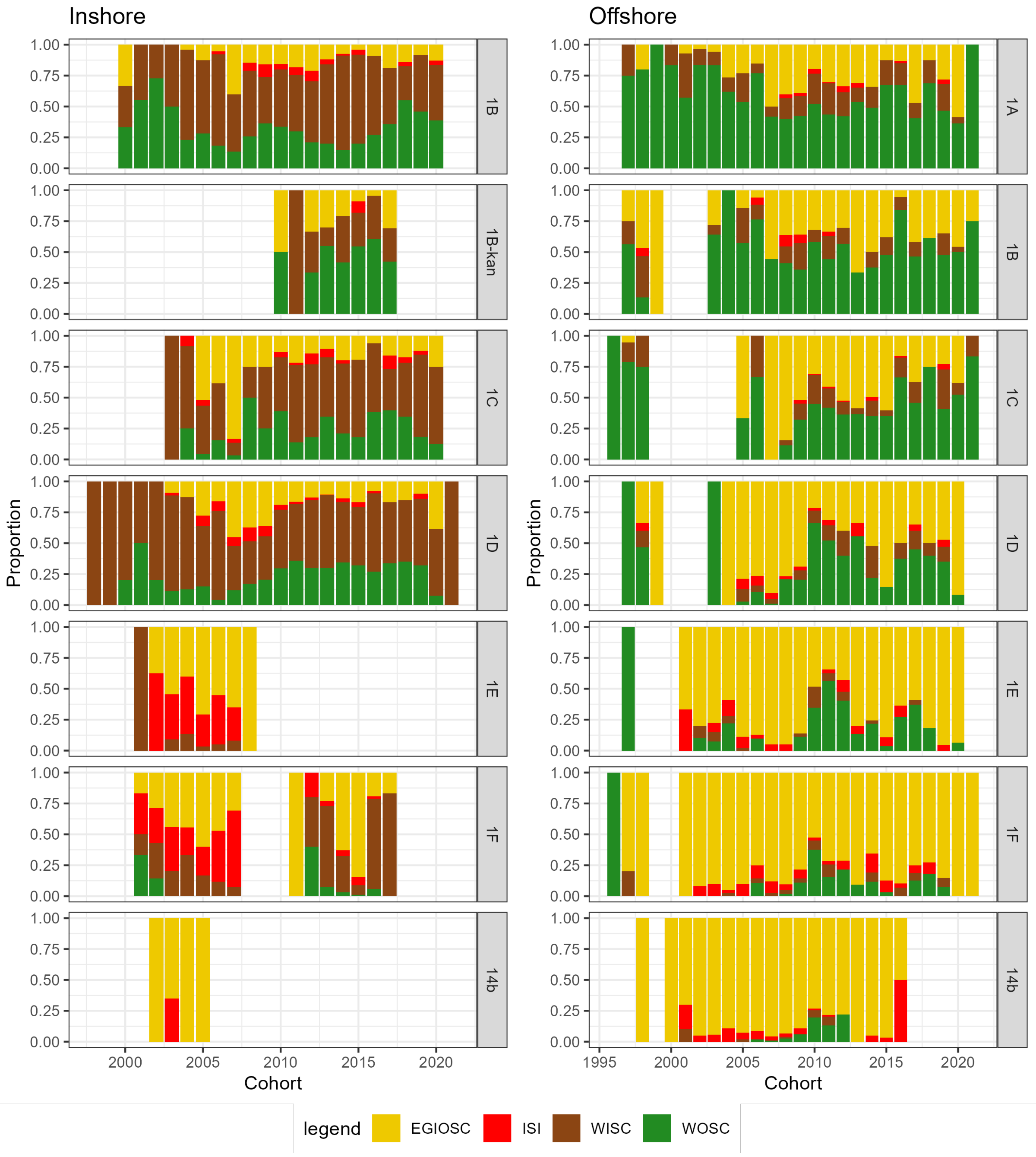

Figure 15.2.1.7.1. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2022 by area and cohort.

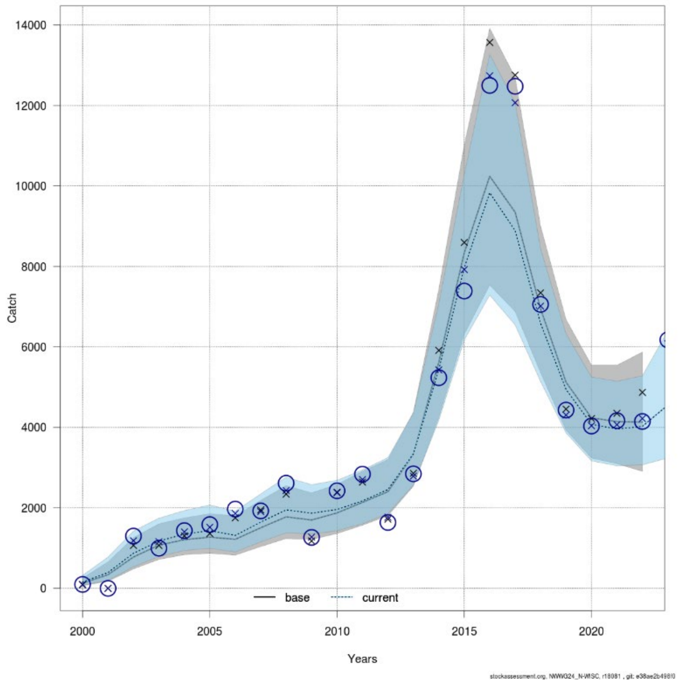

Figure 15.3.1. Estimated catch and with observed catch shown as crosses. Grey is the 2023 assessment and blue is the updated 2024 assessment.

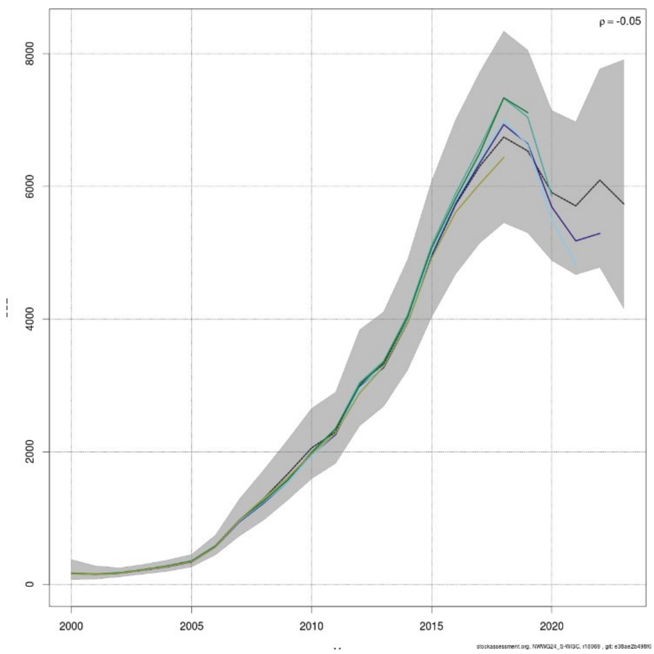

Figure 15.3. 2 Retrospective plot of SSB.

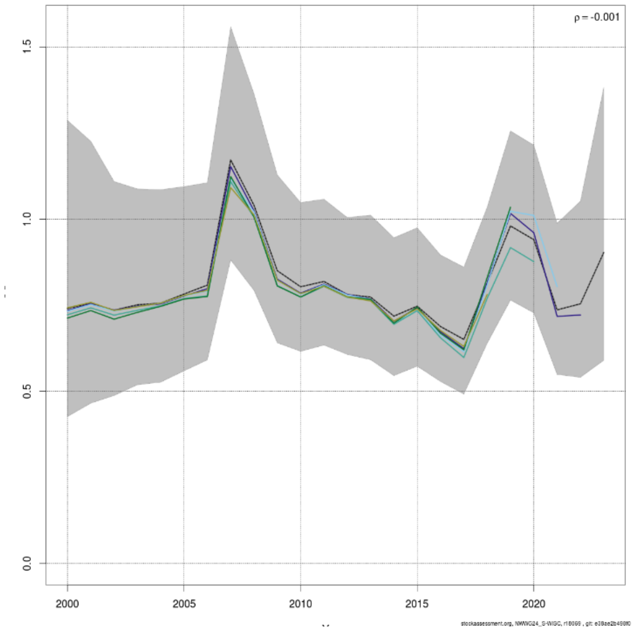

Figure 15.3.3. Retrospective plot of F4-7.

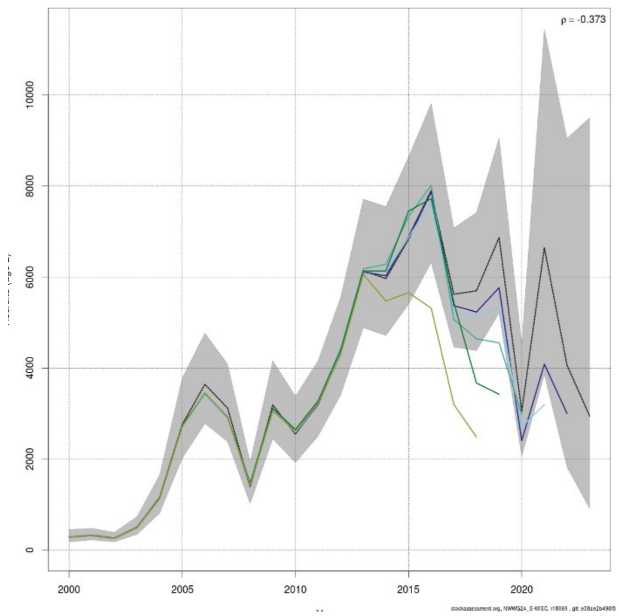

Figure 15.3.4. Retrospective plot of Recruits.

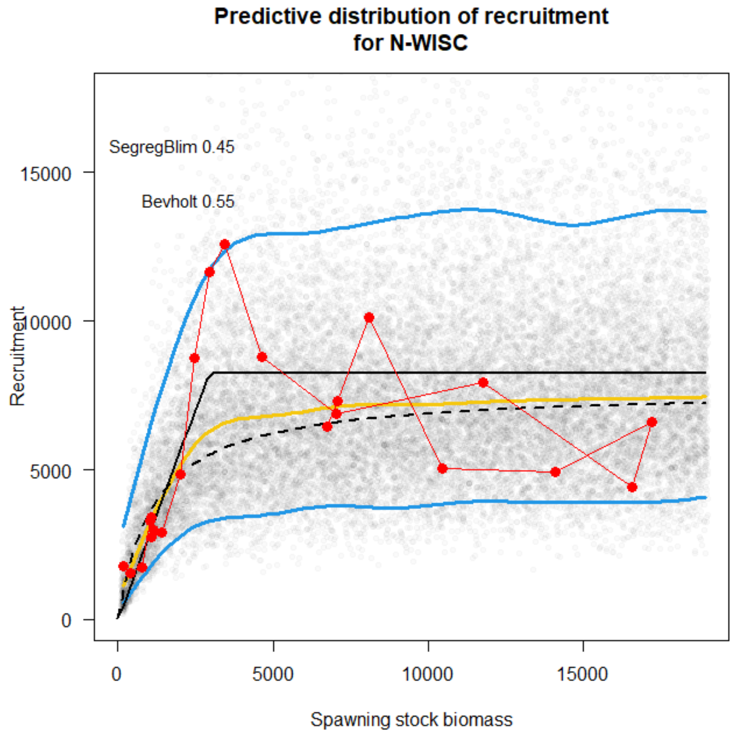

Figure 15.4.1 SSB-recruitment relationship estimated by simulation using EqSim with fitted SSB-recruitment relationships. Dashed: Ricker curve. Dotted: Beverton–Holt curve. Solid: Segmented regression. The curve fits are indicated.

16 East Greenland-Iceland offshore spawning cod (EGI-OSC)

cod.21.27.1.14 – *Gadus morhua* in NAFO Subarea 1 and ICES Subarea 14

At the ADGANW 15-19 May 2023 this stock was changed to a category 5 stock. Advice for 2024 is based on catch in 2022. Since this was the first year the approach was applied a precautionary buffer of 20% was added. The final advice is that catches in 2024, 2025 and 2026 should be no more than 23 518 tonnes.

16.1 Stock description and management units

The cod stocks in Greenland were benchmarked in 2023 (ICES, 2023a). The new methods utilize genetics and information from tagging to separate the cod into four stocks (cod.21.1.osc, cod.21.1a-c, cod.21.1d-f, and cod.21.27.1.14) that are considered reproductively isolated on the time-scale relevant to management advice. The time-series was shortened to start in 2000 because the productivity of the stocks was assumed to have changed and genetic data were limited before year 2000. The four stocks are not directly comparable to the three stocks ICES gave advice for from 2015 to 2022. It is therefore the first assessment for this stock. The assessment method includes annual recalculation of the entire time-series of catches, through the incorporation of additional genetic data.

Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

16.2 Scientific data

16.2.1 Historical trends in landings and fisheries

The fishery for cod in Greenlandic waters started at the beginning of the 19th century and developed into a large fishery of more than 400 000 tons in the 1960ies. After this historic height the fishery reduced to between 50 000 – 100 000 tons in the 1970ies and 80ies and thereafter collapsed in the 1990s.

For further information see stock annex.

16.2.2 The present fishery

The catch of the EGIOSC stock started from almost zero in 2000. In 2001 there were no samples from the fishery and hence no split by stock can be made for this year. The catch increased to almost 19 000 tons in 2008, primarily fished in NAFO division 1F in West Greenland (table 16.2.1). The catch hereafter decreased to between 6 000-13 000 tons in the period 2009-2014. In the following years 2015-2020 catches were between 20 000-25 000 tons. In 2021 catches increased to 28 500 tons and 30 000 tons in 2022. Due to a TAC increase both in the inshore fishery in West Greenland and on Dohrn Bank the catches were record high with 37 000 tons in 2023.

In West Greenland the EGIOSC stock is caught at different proportions from north to south (table 16.2.1). In general, largest proportions are caught in the mid- and southern part covering NAFO divisions 1D, 1E and 1F with average 60%, especially in the years around the high catch in 2008 (2007-2009) where 80% was caught in the southernmost part corresponding to NAFO division 1E and 1F.

At the beginning of the time-series until 2007 catches of the EGIOSC stock was only caught in the inshore area averaging 70% of the total catch followed by catches in East Greenland with average 30% (Figure 16.2.1). Since 2016 catches of the EGIOSC stock have been higher in East Greenland especially in the latest years where catches from the commercial fishery in the Dohrn Bank area (Q1-Q2, figure 16.2.2) has constituted a considerable part of the total catch, and this has further increased to app. 70% in the recent period (2021-2023) (Table 16.2.1).

16.2.2.1 Catch-at-age

Yearly catch-at-age is calculated from the commercial catch, but not used in assessment.

For further information see stock annex.

16.2.2.2 Weight-at-age

Yearly catch mean weight at age is calculated from the commercial catch, but not used in assessment.

Yearly stock mean weight at age is calculated from the Greenland bottom-trawl survey, but not used in assessment.

For further information see stock annex.

16.2.2.3 Maturity-at-age

Maturity-at-age is fixed for two periods: 2000-2017 and 2018-present, but not used in assessment.

For further information see stock annex

16.2.3 Bottom-trawl surveys

Abundance indices in summer-autumn was derived from a geostatistical model fitted to catch data from the Greenland Groundfish Survey (G2064) and German Groundfish Survey (G4355) conducted during summer and autumn in Greenlandic waters. Catch data were split by stock based on genetics (See section on ‘Genetics and stock splitting’ below). A complete description of the data and model can be found in WD5 and WD03 from WKGREENCOD respectively, as well as in the stock annex.

The data were compiled from two bottom-trawl surveys. Namely “SF” (G2064) conducted between 28 May – 4 October from 2005—2023 by the Greenlandic Institute of Natural Ressources, and “GGS” (G4355) conducted between 22 September – 15 November from 2000—2020 by the Thünen Institute for Sea Fisheries. In 2022 and 2023 the GGS survey was not conducted.

All surveys sample the fish community on the continental shelf and upper shelf slope.

Trawl operations have largely been standardized on each of the surveys, but differ substantially between the two. A survey effect was therefore included in the model in addition to the effect of effort (swept-area in nmi^2).

In 2018 only West Greenland was covered and no surveys were conducted 2021. These years were excluded accordingly. Figure 16.2.3.1 provides an overview of the distribution and number of samples.

INLA (Integrated Nested Laplace Approximation) was used to fit a spatially explicit statistical model. INLA is a Bayesian statistical method for fast fitting of complex statistical models such as generalized additive models (GAM) with spatial correlations (Lindgren et al., 2015; Rue et al., 2009). Based on simulations with the model, spatial distributions and time-series for each age and stock was estimated.

The spatial distributions of mean density indices were mapped by age in Figure 16.2.3.2. The time-series of spatially integrated density indices of cod at age (Figures 16.2.3.3) were found to have good internal consistency (Figure 16.2.3.4).

16.2.4 Genetics and stock splitting

Commercial and survey catch data are split into separate spawning stock units using a Generalized Additive Model (GAM) on genetic assigned samples. In order to improve sampling coverage for the years 2008 and 2010 archived samples were analysed in 2023. These samples showed higher than previously seen presence of the Icelandic inshore spawning cod stock (ISI) in the inshore areas 1E and 1F (figure 16.2.4.1). Previously it was decided to exclude the ISI stock from the stock splitting (see ICES 2023a: WKGREENCOD WD 01 and WD 05), the basis for this was that we were seeing only few occurrences and without patterns. The period 2008-2010 had a large fishery in the areas where the new samples showed high prevalence of ISI, this raised concerns that the split of catches for this period were incorrect. These areas are in the inshore southern part of West Greenland (NAFO division 1E and 1F) and could have a potential effect on the split for EGIOSC as this is stock is high in proportion in these areas.

It was decided that for the splitting model ISI was merged with EGIOSC. This was done in order to account for the presence of this stock historically and any future incoming ISI cohorts. The number of ISI individuals observed in Greenland waters are at such a low level that it is difficult to include it as a separate stock in the split model. Merging the stock with the EGIOSC stock are also in line with previous studies (Christensen et al 2022) and in Iceland the two stocks are combined for the assessment (ICES 2023b). Continuous sampling will allow monitoring of this stock, should it become prevalent in large numbers this decision can be re-evaluated. The new catch estimates for EGIOSC show a minor increase in the EGIOSC catch (figure 16.2.4.2).

The number of samples for the split in 2024 is 11 083 (data added: 1300 samples from 2023 + 777 from 2008 and 2010 + 437 ISI) (Retzel & Buch 2024).

For further information on GAM model see stock annex.

16.3 Stock assessment

The stock was benchmarked in 2023 (ICES, 2023a). It was decided to use the SAM model (Nielsen and Berg, 2014) to perform an analytical assessment. However, at the ADGANW 15-19 May 2023 this stock was changed to a category 5 stock.

16.3.1.1 State of the stocks

It is not possible to assess stock and exploitation status relative to MSY and precautionary approach reference points.

16.3.1.2 Quality of the assessment

The stock was benchmarked in 2023 (ICES, 2023a). The assessment model developed in the benchmark was unable to fit the observed data (up to 92% of the catches for some ages; these are thought to predominantly come from the Dohrn Bank). The model is, therefore, not currently considered to be a robust basis for the advice.

16.4 Reference points

It was not possible to estimate reference points for the stock component.

16.5 Management plans and evaluations

There is no management plan for this stock.

16.6 Management considerations

Cod from this stock mix with the other three stocks outside the spawning season and are therefore targeted by a mixed fishery in West Greenland. It is recommended that management actions, such as area-based TACs, can be evaluated in relation to advised catch levels for all stocks.

16.7 Ecosystem considerations

The gear used for this fishery in West Greenland have little effect on the ecosystem, especially the main gear (poundnet). However, as 70% of the fishery occurs on Dohrn Bank, primarily with trawlers, some effect on the ecosystem is expected.

16.8 Regulations and their effects

The fishery in West Greenland has never been limited by a TAC, as the TAC has always been set well above the fleet capacity or raised when reached. In 2023 the TAC was raised from 17 000 tons to 23 000 tons in autumn.

In East Greenland TAC for the Dohrn Bank area was increased to 25 000 tons in 2023, compared to 20 000 tons in 2022. South of Dohrn Bank TAC of 7 900 tons is set for 2023 which is the same as in 2022.

16.9 References

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16.10 Figures and Tables

Table 16.2.1. Catch (tons) of the East Greenland Iceland offshore spawning cod stock (EGIOSC) by NAFO divisions in West Greenland and survey area in East Greenland. *No samples from the fishery in 2001.

	NAFO Division						ICES 14b			
Year	1A	1B	1C	1D	1E	1F	Q3-Q6	Q1-Q2 (Dohrn Bank)	North of Q1Q2	Total
2000	47	29	0	148	0	10	63	0	0	297
2001*										
2002	140	405	169	96	19	748	398	0	0	1975
2003	324	307	110	115	2	400	485	0	0	1743
2004	378	461	168	273	29	271	778	0	0	2358
2005	213	417	411	288	223	431	819	0	0	2802
2006	197	373	366	561	315	2295	2042	0	0	6149
2007	189	372	431	704	819	5761	3192	2	0	11470
2008	249	623	488	1399	583	12019	3255	3	0	18619
2009	97	267	387	931	880	4755	1587	55	0	8959
2010	126	532	485	806	1127	1017	2268	120	0	6481
2011	131	427	868	1222	978	1399	4478	93	0	9596
2012	128	228	674	1962	1748	1623	2360	1581	0	10304
2013	375	546	867	2255	1258	1480	1960	2144	0	10885
2014	682	1355	1111	1974	471	1755	3454	2606	0	13408
2015	1094	2046	1822	2498	2712	3536	6358	5413	34	25513
2016	1692	2875	2657	2009	1079	1910	8645	3838	14	24719
2017	1433	2536	2889	1119	480	1951	7693	5970	76	24147
2018	458	1251	2145	1571	776	1449	7856	5305	88	20899
2019	403	480	1064	1845	169	2012	4959	12156	44	23132
2020	290	373	861	1797	130	2212	4783	10459	16	20921

	NAFO Division						ICES 14b			
Year	1A	1B	1C	1D	1E	1F	Q3-Q6	Q1-Q2 (Dohrn Bank)	North of Q1Q2	Total
2021	222	470	755	995	45	455	5889	19696	51	28578
2022	295	497	1103	942	28	194	6917	20027	37	30040
2023	583	662	1397	1785	433	405	6866	24902	239	37272

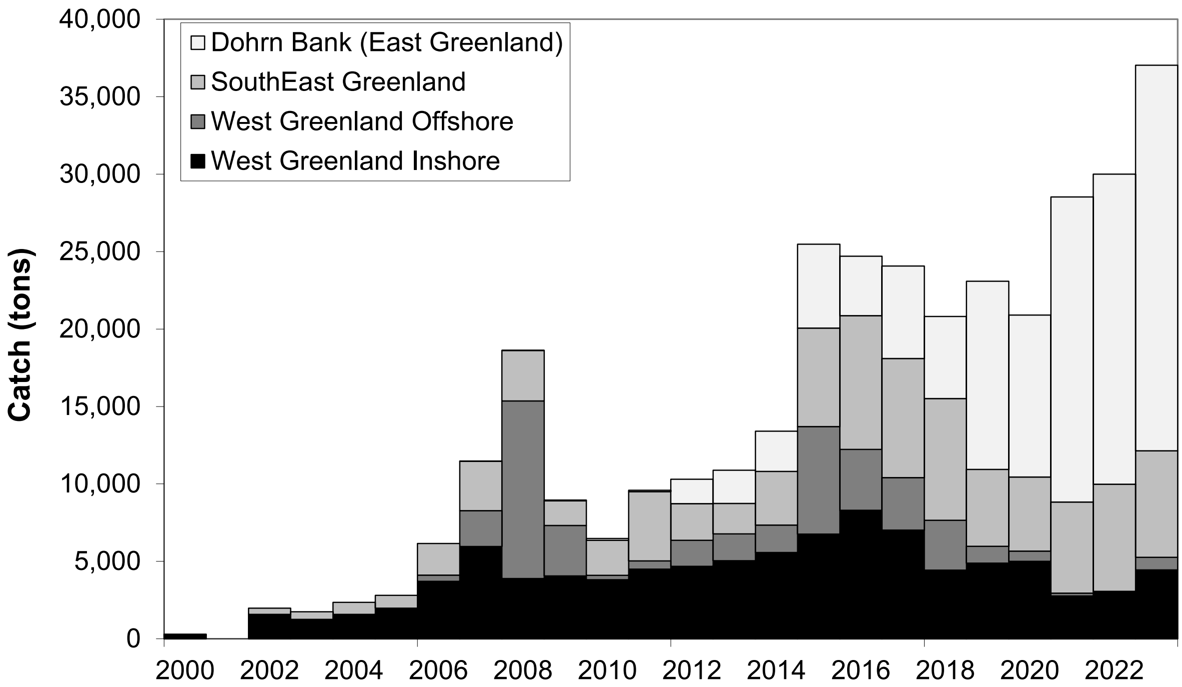

Figure 16.2.1 Catch of the East Greenland Iceland offshore spawning cod stock (EGIOSC) in the inshore and offshore area in West Greenland and East Greenland Dohrn Bank and South of Dohrn Bank. No samples from the fishery in 2001.

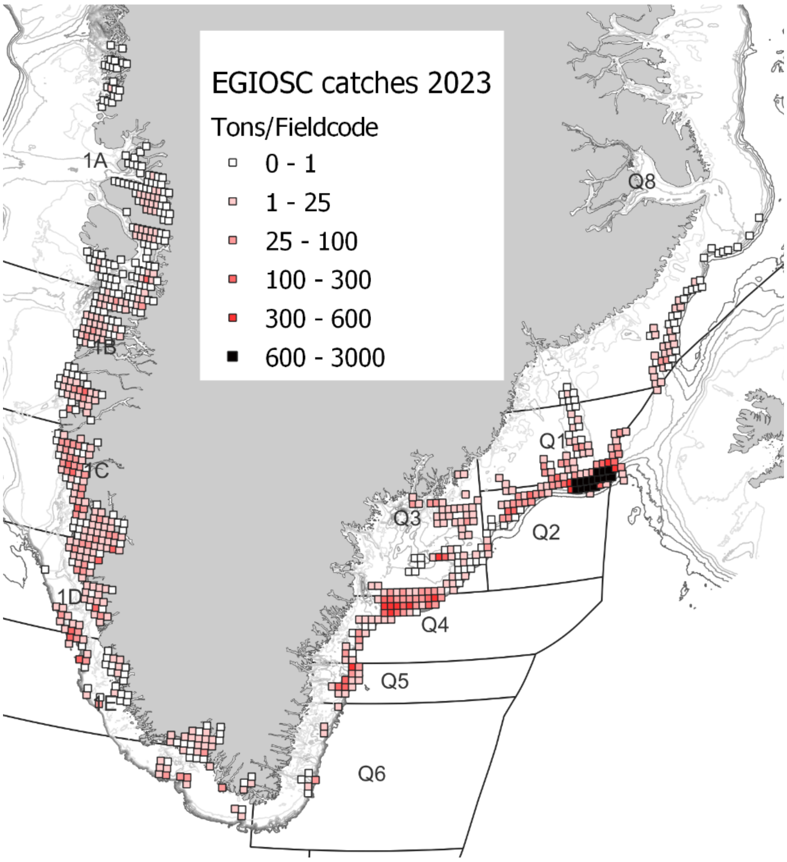

Figure 16.2.2 Distribution of commercial catches of cod of the East Greenland Iceland offshore spawning cod in tons by field code in Greenland waters. Survey strata Q1-Q6 and NAFO subareas 1A-1F in Greenland are given on the map.

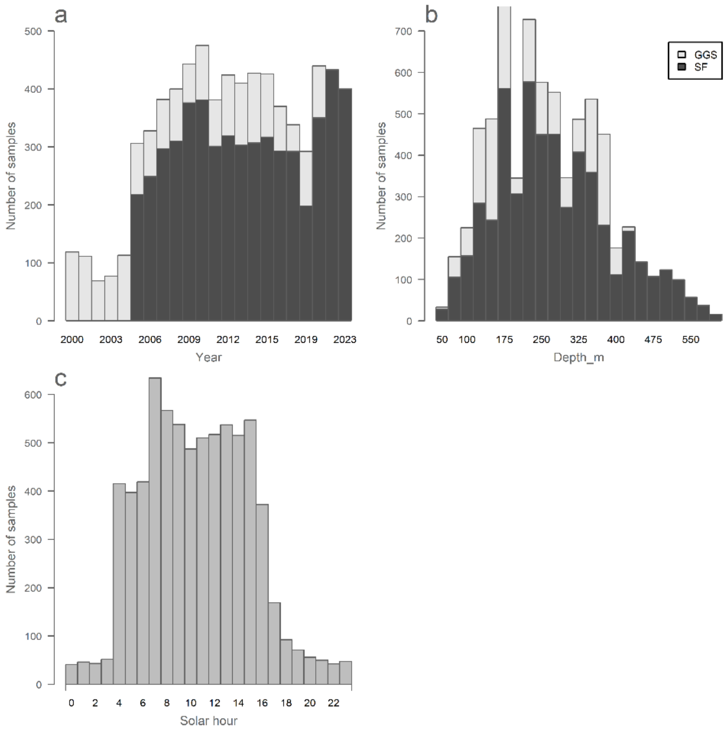

Figure 16.2.3.1 Overview of the distribution and number of bottom-trawl samples.

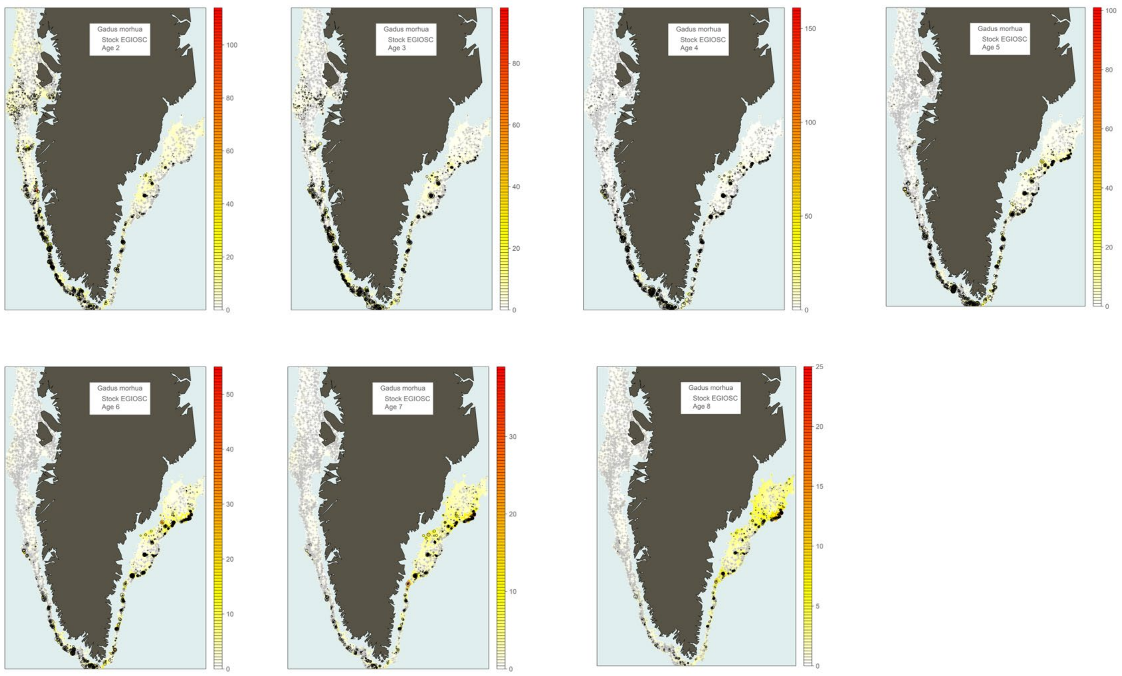

Figure 16.2.3.2. Spatial distribution by age estimated by the model (color scales), overlaid by catch rate observations from the bottom-trawl surveys (catch rates are proportional to the areas of the black circles), grey crosses indicates zero catches.

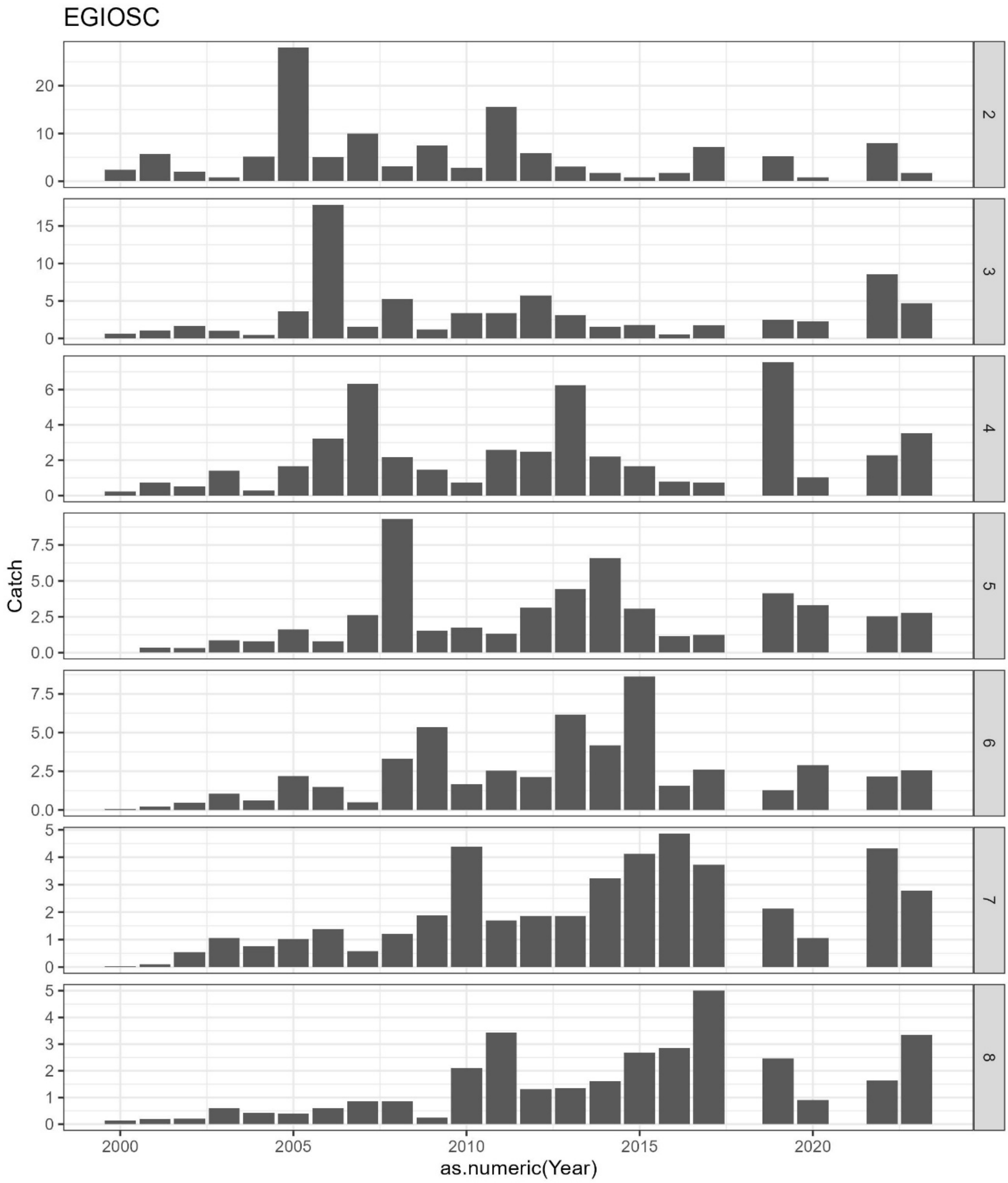

Figure 16.2.3.3. Bottom-trawl survey catch rate indices by age estimated by the INLA model.

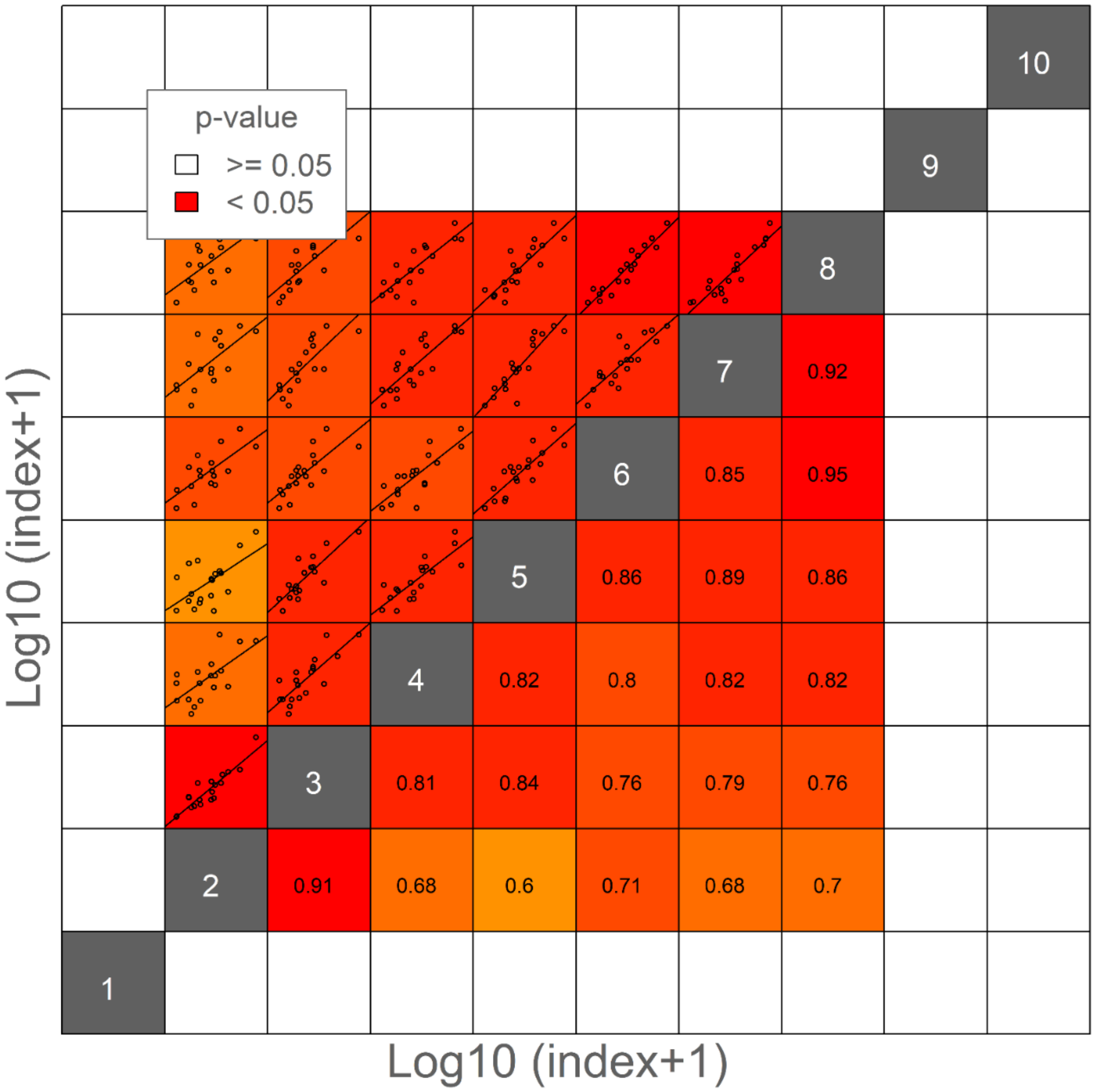

Figure 16.2.3.4. Internal consistency. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (p<0.05) are indicated by regression lines in the upper left half. Correlation coefficients (r) are given in the lower right half.

Figure 16.2.4.1. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2022 by area and cohort.

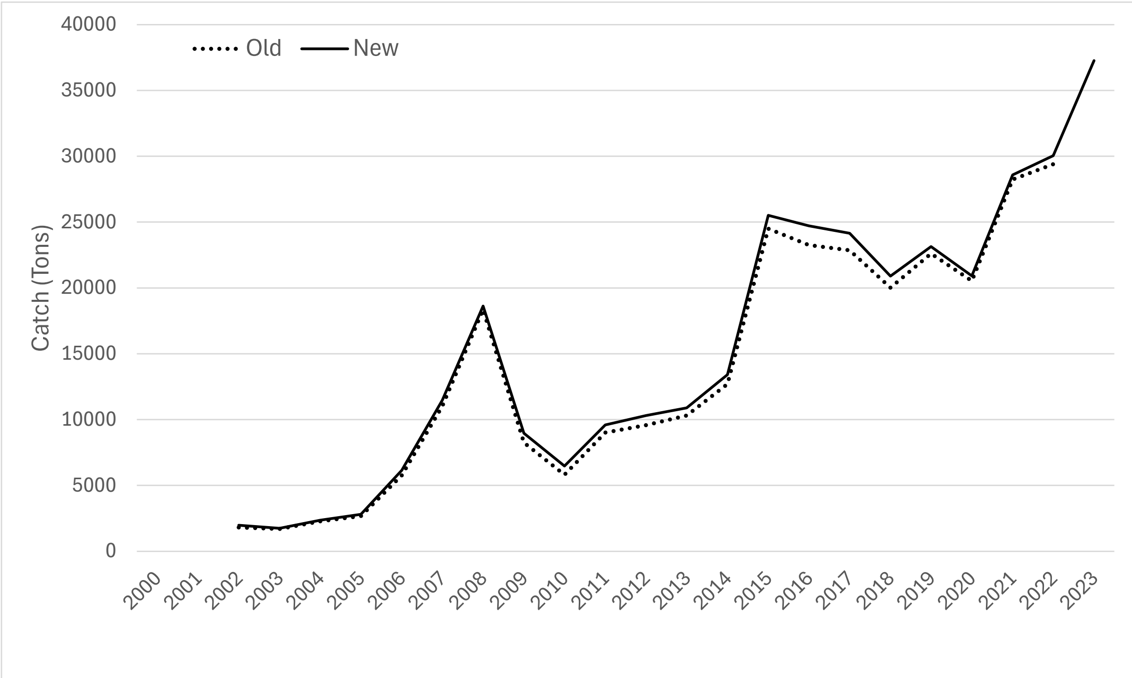

Figure 16.2.4.2. Total catch of EGIOSC from the split done in 2023 (old – end year 2022) and 2024 (new – end year 2023).

17 Greenland halibut (Iceland and Faroes grounds, West of Scotland, North of Azores, and East of Greenland)

ghl.27.561214 – *Reinhardtius hippoglossoides* in subareas 5, 6, 12, and 14

17.1 General information

Greenland halibut in ICES subareas 5, 6 12 and 14 (East-Greenland, Iceland, Faroe-islands) are assessed as one stock. In Icelandic Waters, it is found on the continental shelf around Iceland with the highest abundance west, north and east off the coast in deeper and colder waters. It is mainly found on a muddy substratum at depths ranging from 200-1500 m. The main spawning grounds are located west off the coast at around 1000 m depth and eggs and larvae drift between Iceland and the east coast of Greenland until juveniles seek bottom post metamorphosis. After spawning, Greenland halibut migrates further north and east to their main feeding grounds. No juvenile grounds are known within the assessment area, and migration is known to occur from adjacent management units.

In the waters of East Greenland it is mainly found at depths greater than 600 m on the steep continental slope from Cape Farewell in the south to Ittoqqortoormiit (70oN) in the North. Only limited spawning is observed and as in Icelandic Waters very few juveniles occur in the area. However, larvae have regularly been observed in years when the area were monitored. Around the Faroe Islands it is mainly found North and East of the islands at 200 to 600 m.

Recent investigations on Greenland halibut stock connectivity in the North Atlantic suggest that the present stock might be associated to both of the neighboring stocks, namely the Northeast Arctic stock in SA 1 and 2 and the Davis Strait/Baffin Bay stock in NAFO SA 0+1 (Albert and Vollen, 2015; Gislason et al., 2023, Westgaard et al., 2017; Vihtakari et al., 2022, Ubeda et al. 2023). The association means that the SA 5, 6 12 and 14 stock might be a mix of the two neighboring stocks and at the same time receive recruits from them (SA 1+2) and contribute recruits to them (NAFO 0+1). The investigations are still ongoing and therefore no firm conclusion can be drawn at present.

17.2 Fishery

Historically, most of the fishery has been conducted as a trawl fishery, however, in the last decade a gillnet fishery has developed in Iceland. Spatial distribution of the 2023 fishery and historic catch and effort in the trawl fishery in Subareas 5, 6, 12 and 14 is provided in Figure 17. 1 and Figure 17. 2. Fishery in the entire area did in the past occur in a seemingly continuous belt on the continental slope from the slope of the Faroe plateau to southeast of Iceland extending north and west of Iceland and further south to southeast Greenland. Fishing depth ranges from 350-500 m southeast, east and north of Iceland to about 1000 m at East Greenland.

In 2001–2008 a directed and a bycatch fishery by Spain, France, Lithuania, UK and Norway developed in the Hatton Bank area of Division 6.b, however, most of these fisheries ceased after 2008. Currently UK and France have a small fishery in the area. All catches in Subareas 6 and 12 are assumed to derive from the fishing on Hatton Bank area.

17.3 Landing trends

In 1980–1990, about 75–90% of catches were caught by Iceland (Figure 17. 3). Since 1990, the Icelandic proportion has decreased, and has in recent years been 50–60%. Highest catches were recorded in 1986, about 60 thous. tonnes. Landings in Icelandic Waters (usually allocated to Division 5a) have historically been predominated by the total landings in areas 5+14 (Icelandic Waters), but since the mid-1990s fisheries in Subarea 14 (Greenland waters) and Division 5b (Faroese waters) have developed. Landings have since 1997 been between 20-31 thous. tonnes (Figure 17. 4).

Demersal trawl has been the main fishing gear for Greenland halibut in Icelandic Waters, followed by gillnets, while a small proportion of the catch is taken on longlines and in shrimp trawls. Since 2015, landings by gillnets have, however, increased, reaching 62% of total catch in 2019 (Figure 17. 5). The Greenland halibut trawl fishery is considered clean with respect to bycatches. The mandatory use of sorting grids in the shrimp fishery in Icelandic and Greenland waters since 2002 is observed to have reduced bycatches of Greenland halibut considerably. Greenland halibut is caught in relatively deep waters, with most of the catch (70%) taken between 400-800 meters depth. In 2003, most of Greenland halibut was caught at 800 meters or deeper (73%), but since then, catch has increased steadily in more shallow waters (Figure 17. 6). Changes in depth range where Greenland halibut was caught seem to be reasonably synchronized with changes in fleet and therefore gear structure that target Greenland halibut in most recent years (Figure 17. 5 and Figure 17. 6).

The number of vessels accounting for 95% of the catch of Greenland halibut in Icelandic Waters changed from about 75 vessels in 1994-1998 to little less than 20 (Figure 17. 7). This change coincided with reduced catches. Since 1998,the number of vessels accounting for 95% of the catch has been relatively constant despite variable annual catches, with the smallest number of vessels observed in 2018. In Greenland the number of vessels has also been continuously lowered to about less than 20 in recent years.

17.3.1 Catch per unit effort

Estimates of catch per unit effort (CPUE) for the Icelandic trawl fleet directed at Greenland halibut for the period 1985–onwards is provided in Figure 17. 8. The overall CPUE index for the Icelandic fishery is compiled as the average of the standardized indices from the whole area. Catch rates of Icelandic bottom trawlers decreased for all fishing grounds during 1990–1996 but peaked again in 2001. Since 2003, CPUE has been relatively stable.

An analysis of the CPUE by area is shown in Figure 17. 9. The CPUE west of Iceland showed a substantial drop in the period but after that the CPUE in the western area followed similar trends as other areas around Iceland.

17.4 Sampling from Greenland halibut landings

17.4.1 Area 5a

In general sampling is considered good from commercial catches in Icelandic Waters from the main gears (gillnets, longlines and trawls). The sampling does seem to cover the spatial and seasonal distribution of catches (see Figure 17. 11 and Figure 17. 10). In 2020 sampling effort was reduced substantially, on-board sampling in particular, due to the COVID-19 pandemic. This reduction in sampling is, however, considered not to substantially affect the assessment of the stock in the short term. Sampling effort has now started to increase.

The bulk of the length measurements in Icelandic Waters are from the three main fleet segments, i.e. trawls, longlines and gillnets. The number of available length measurements by gear has fluctuated in recent years in relation to the changes in the fleet composition.

Length distributions from the main fleet segments are shown in Figure 17. 12. The sizes caught by the main gear types (bottom-trawl and gillnets) appear to be fairly stable, primarily catching halibut in the size range between 40 and 80 cm while gillnets tend to catch slightly larger fish.

There has been a gradual shift towards larger fish in the length distribution of landed catch (Figure 17. 12) following periods of poorer recruitment.

17.4.2 Areas 14b (East Greenland) and 5b (Faroese waters)

Samples collected from the fishing grounds in Faroe Islands (5a) and east of Greenland (14b) are shown in Figure 17. 13. Fish caught at Faroe Islands seem to be smaller than those caught in Iceland and in East Greenland and are comprised of a broader size interval. Both for 5a and 14b size composition seem rather stable.

17.4.3 Other areas

No samples are available and reported catches have been negligible in recent years.

17.4.4 Bycatch and discard

The Greenland halibut trawl fishery is mostly a clean fishery with little bycatches. Eventual bycatches are mainly beaked redfish and cod. Southeast of Iceland the cod fishery and a minor Greenland halibut fishery coincide spatially. In East Greenland where fishery is located on the steep slope, fishing grounds for cod and redfish are close to the Greenland halibut fishing grounds, but nevertheless the catches from single hauls are clean catches of Greenland halibut in 5, 6, 12 and 14.

The mandatory use of sorting grids in the shrimp fishery in Iceland since the late 1980s and in Greenland since 2002 was observed to have reduced bycatches considerably. Based on few samples in 2006–2007, scientific staff observed bycatches of Greenland halibut to be less than 1% compared to about 50% by weight observed before the implementation of sorting grids (Sünksen, 2007). No information has since been available but the fishery in Division 14b generally report discard rates less than 1% by weight in logbooks.

17.5 Survey information

Three surveys are conducted in the distribution area of the Greenland halibut stock; in East Greenland (14.b), in Iceland waters (5.a) and in Faroese waters (5.b). The total surveyed area is provided in Figure 17. 14.

17.5.1 Surveys in East Greenland and around Iceland

The two surveys in 5.a and 14.b are combined to one index and used as biomass index input for the assessment model. In the years between 2017 and 2021 no survey data were available from East Greenland (area 14.b), for those years the 2016 estimate was used to fill in the combined survey estimate. A relative comparison of the two surveys is provided in Figure 17. 15.

The Icelandic autumn groundfish survey (hereafter autumn survey) was commenced in 1996. Spatial distribution and abundance in recent years are shown in Figure 17. 14 and Figure 17. 15 while Figure 17. 16 shows trends in various biomass indices, and a recruitment index based on abundance of Greenland halibut ≤ 40 cm. Survey length distributions are shown in Figure 17. 17. In the recent years, Greenland halibut were mainly caught on the continental slope southeast, north, and northwest of the country (Figure 17. 15).

Since the survey was commenced in 1996, the distributional pattern has remained quite stable, with the greatest biomass index in the northeast and northwest. Since 1996, biomass index in the west has been steadily decreasing, while increasing in the southeast (Figure 17. 15).

The Greenland deep-water stratified bottom-trawl survey in ICES division 14b, that is combined with the Icelandic survey, is conducted annually by the Greenland Institute of Natural Resources. The survey covers depth from 400 to 1500 m. The survey has been conducted from 1998 to 2016 (no survey was conducted in 2001) using RV Paamiut and an Alfredo II bottom-trawl gear. RV Paamiut was retired in 2017. Since 2022 the survey is conducted with the new vessel RV Tarajoq using a new trawl gear, a Bacalao 476. More details on the survey is provided in the stock annex.

Biomass indices for the total stock of Greenland halibut and Greenland halibut larger than 40 cm (harvestable part of the stock), that are based on the combined Icelandic and Greenlandic autumn surveys, showed an increase from 1996-2001. After peaking in 2001, indices dropped but increased steadily from 2004 till 2017 when the stock started to decrease (Figure 17. 16). The same holds for the index of Greenland halibut larger than 60 cm. The index of juvenile abundance (<40 cm) has fluctuated between years, peaking in 2002 but remained low in the past six years (Figure 17. 16). Between 2016 and 2022 the East Greenland area has not been surveyed, and for the indices the values from 2016 are used for the period with no survey.

Length distributions from the Icelandic autumn survey shows more dynamics in observed sizes compared to catch samples (Figure 17. 17), and average size has be decreasing in recent years.

Age distribution of the sexes of Greenland halibut from the autumn survey 2015-onwards show that the greatest proportion males are between 9 and 10 years old and range between 4-16 years. The greatest proportion of females are 11-13 years old and range from 3 to 22 years (Figure 17. 18).

It is worth noting that ageing recently resumed after a long period where otoliths were sampled but not age read. Recent advances in age reading techniques suggested that older age reading methods used previously were biased and thus older age-readings are not considered representative of the age structure in the population. Further, otoliths sampled prior to 2015 were not stored in a manner compatible with the newer age-reading method. It is therefore uncertain whether data on the historic age structure will ever be available.

According to the length distribution by age of Greenland halibut, it reaches 60 cm at the roughly the age of 12 on the average (Figure 17. 19). The growth of Greenland halibut appears to be similar between the sexes, while female exhibit larger variability of size. It is noteworthy that males tend to be on average smaller in the catches than females, although both sexes seem to have similar mean length-at-age. This may suggest differences in behavior of the sexes, such as catchability with respect to gear and/or natural mortality.

17.5.2 Faroese survey

The annual Greenland halibut survey in Faroese waters was started in 1995. The samples taken using a commercial trawl and the survey design varies between years. The average tow time has increased steadily from an average of 3 hours in 1995 to nearly 7.5 hours in 2020.

Ageing resumed in 2015 and information is available from four years (2015 to 2017 and 2021). Preliminary results from an ageing workshop on Greenland halibut ototliths suggest that further calibration between labs is needed to ensure that they are appropriate (Windsland pers. comm).

17.5.2.1 Maturity data

Information on maturity for Greenland halibut is sparse, and the maturity scale used in the surveys is considered to be imprecise. A gonadsomatic index (GSI) value above 1% is considered be a good indicator of maturity (Kennedy pers comm). Information on gonad size is available from the Icelandic autumn survey (Figure 17. 21). Work has started to update the maturity scale used in the survey.

17.6 Updates to reference points

This year all reference point were estimated and revised. This re-estimate was needed after an error was discovered during the update assessment of Greenland halibut and beaked redfish. The routine that collated SSB from the model output incorrectly calculated mean weight at length resulting in a downward bias in total and spawning-stock biomass estimates (Figure 17. 23). As the estimate of B_{lim} for GHL was based on B_{loss} it was affected by this error and thus the biomass and fishing pressure reference points needed to be revised. Figure 17. 22 illustrates the difference between last years estimates and the corrected last years assessment.

The revision of reference points followed the same procedure as used at WKBNORTH and resulted in higher estimated of B_{lim} and B_{pa} and lowered estimates of F_{lim} and F_{pa} (see Table 17. 1. F_{msy} was also lowered from 0.24 to 0.22. This is not related to precautionarity, as the estimate F_{pa} is higher but only minor pertubations in yield as the range of fishing mortalities that have expected yields within 5% of the MSY is wide (see Figure 17. 24).

17.7 Stock assessment

The stock was benchmarked in 2023 (WKBNORTH) where the basis for advice was changed and reference points were updated. The approved assessment is an age–length based assessment model (GADGET) incorporating available data on the population dynamics. An overview of the settings are listed below:

- Start year 1985
  - Two time-steps, equal in length, within the year
- Age range: 1 to 20^{+}
- Size range: 4 – 100 cm, 1 cm length groups
- Growth: Length based von Bertalanffy size update (k, L_{∞})
- Beta-binomial size dispersal with a maximum length group growth set as 15 cm (β)
- Length – weight relationship estimated externally
- Natural mortality set as 0.15
- Initial population and recruitment:
  - Annual recruitment occurs in the first time-step, one parameter per year R_y.

- Mean length and standard deviation at recruitment is estimated
- Initial population at age is set as $S \times \mathrm{n}_a \times e^{-a(M_a+\hat{F})}$
- Initial mean length-at-age is defined using the Von B growth curve, and initial numbers at length are dispersed assuming a normal distribution around the mean length with a fixed CV.

- Fishing split by fleet:
  - 6 fleets, 1 survey, 3 bottom-trawl (Greenland, Iceland and Faroese), gillnet and longlines in Iceland
  - Logit selectivity for each fleet (α_f, $l_{50,f}$)
- Maturity at length estimated externally based on autumn survey samples
- Likelihood functions:
  - Survey indices are fit assuming that $\log(I) = \alpha + \beta\log(\hat{I})$, where I and $\hat{I}$ are observations and model predictions respectively. α and β are estimated using linear regression.
  - Composition data are assumed randomly sampled and fit using sums of squares of proportions
- Uncertainties are estimated using a spatial bootstrap for the composition data and simulated survey indices based on estimated survey CV.

17.7.1 Input data

The Gadget assessment of Greenland halibut relies on a number of disparate datasets, ranging from survey indices from the autumn survey, landings by gear and area, to catch composition data from the various fleets that target Greenland halibut in 5, 6, 12 and 14. An overview is shown in Figure 17. 25.

The model fit to the observed biomass index from the combined Iceland and Greenland autumn survey is shown in Figure 17. 26. The model appears to capture the main trends in the index, although in order to do that a non-linear relationship between the model biomass and the observed survey biomass is assumed.

The model estimated catch composition is illustrated in Figure 17. 27 to Figure 17. 34, with residual plot shown in Figure 17. 35). In general the fit is best to the autumn survey data. Other datasets that have had fairly consistent sampling through the years, such as the bottom-trawl samples, show no discernible patterns in the residuals, with the Icelandic bottom-trawl and gillnet samples exhibit the lowest deviation in residuals. Observed longline size distributions, however, are fairly inconsistent from year to year and the model seems therefore to have higher propensity to ignore that dataset.

17.7.2 Model results

The results from the model are shown in Figure 17. 36. The total and spawning-stock biomass are estimated to have decreased since its highest value at the start of the model period and reached its lowest point in SSB around 2005. The stock biomass increased to 2015 due to incoming recruitment but has since then deacreased and the assessment suggests that the spawning-stock biomass at the start of 2024 is below $\mathrm{B}_{trigger}$. Fishing mortality appears to fluctuate without trend. Analytical retrospective analysis is shown in Figure 17. 37. These results indicate a potential for bias, as indicated by the Mohn's ρ. This can be explained by the exclusion of age data when a year of data are removed, as the model only has age observations for the last nine years.

The recruitment is estimated to fall outside the uncertainty bounds in the current assessment, suggesting that little observations are available on the recruitment-at-age 5.

Estimated selection by fleet is shown in Figure 17. 38. The estimated selectivities range considerably, with the Faroese bottom-trawl fleet catching the smallest fish while longline and gillnet boats in Iceland the largest.

17.7.3 Conclusions

Overall the gadget model presented here captures the overall trends in the data, and despite minor mis-fits the model is usable for assessing the stock and to base advice to managers.

In a complicated model such as the gadget model that has many parameters and many datasets of varying quality it is to be expected that not all data contributes in the same direction and with various trends which will cause problems with fit to some datasets.

The main problem encountered when building the model during the benchmark were strong year factors in the autumn survey. Although fitting to a single survey seems improve the retrospective estimates it does cause some concern. However as more age data becomes available in the coming years it is expected that this issue will be easier to reconcile within the model.

17.8 Short-term prognosis

Short-term forecasts for Greenland halibut are done in Gadget using the settings described below.

- F and M before spawning: NA
- Weight-at-age in the stock: GADGET uses a weight–length relationship and von Bertalanffy growth estimated internally (no weights-at-age are supplied to GADGET)
- Weight-at-age in the catch: GADGET uses a weight–length relationship and von Bertalanffy growth estimated internally (no weights-at-age are supplied to GADGET)
- Exploitation pattern: selectivity pattern by length and fleet weighted by a three year average catch proportion
- Landings: logistic selection-at-length by fleet, with parameters estimated within GADGET. Catch proportions by fleet are assumed fixed based on last three years.
- Intermediate year assumptions: Advice (and TAC) constraint (catch of 21 590 t)
- Stock–recruitment model used: Constant, estimated by the model (as the assessment model estimates recruitment-at-age 1 internally.
- Catch scenarios: F=Fmsy, F=0 and F=Fsq

The results of the prognosis are shown in Table 17. 2.

17.9 Management

Available biological information and information on distribution of the fisheries suggest that Greenland halibut in East Greenland, Iceland and Faroe Islands might be separated into subpopulations but that they do mix between these. Recent information of tagging experiments in the Barents Sea suggests high mixing between the Barents Sea and Iceland and also connectivity to West Greenland. This connectivity is not accommodated for in the present assessment.

Figure 17. 39 shows the Icelandic national TAC, and catches since the 1991/1992 fishing year. In 2014, the Greenland and Iceland entered a five-year bilateral agreement to limit the fishing

pressure of the Greenland halibut stock in East-Greenland, Iceland and Faroes to F_{msy}. According to this agreement 56.4% of the TAC was allocated to Iceland and 37.6% to Greenland. This agreement was renewed in 2023. Other countries, notably the Faroe Islands, are not party to this agreement.

In recent fishing years, landings have been similar to the advised TAC. Figure 17. 40 shows the net transfers in the Icelandic ITQ-system since 1991 to Greenland halibut in 5, 6, 12 and 14. Upon till the 2022/2023 fishing year the Icelandic management system allowed for transfers of quota share of Greenland halibut between fishing years and conversion of TAC from one species to another (species transformation) based on value equivalents. In this period, transfers to Greenland halibut from other species (positive values) and transfers from Greenland halibut to other species (negative values) fluctuated but were mostly been from Greenland halibut to other species. With the most recent revision of the agreement between Iceland and Greenland on quota share transfers of quota between years and species transformations were no longer allowed for Greenland halibut.

17.9.1 Data consideration and Assessment quality

The fishery for Greenland halibut in the vast stock area from East Greenland to west of the British Isles is conducted by an international fleet and catch recordings are therefore dependent on reporting from many nations. Although it is believed that reporting is reliable the many data sources do not always agree exactly. In example logbook information, reporting's to national authorities, data submissions to ICES, EuroStat and FAO often deviate and there are difficulties associated with choosing what is believed to be the correct number. Even data within ICES do not agree even though the source is the same, namely EuroStat. Thus ICES Catch dataset 2006-2020 has huge deviations from its database 1950-2010 in its 5 overlapping years. An effort has been made to correct obvious deviations back in time, but this work is expected to continue and revisions of historic catch data are therefore foreseen. For the forthcoming years logbook data that agrees with reporting on catch from quota will superimpose other official reporting.

With the change to an age and length-based assessment more requirements will be put on biological sampling and sampling from the fisheries. This is especially the case for SA 14 (East Greenland) where sampling have been inadequate so far. Ageing of Greenland halibut ceased for many of the marine institutes in Greenland, Iceland, Faroe Island and Norway around 2000 due to reading difficulties and lack of inter-calibration. A new method has been agreed upon and cooperation between institutes has been initiated on age calibration. With respect to this stock Iceland has now progressed so far that an ALK is available for the 9 previous years. The Greenland institute of Natural Resources has also initiated age reading. Otolith collected prior to early 2010s were not collected in a manner compatible with the newer age-reading method and it is unlikely that the age of those older otoliths can be reliably determined in the coming years.

17.10 References

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17.11 Figures and Tables

Table 17. 1: Greenland halibut in 5, 6, 12 and 14. Comparison of estimated reference points to last years estimate.

	Updated Value	2023 benchmark	Basis
MSY approach			
F_{msy}	0.22	0.24	F leading to MSY
$B_{trigger}$	24895	21402	B_{pa}
Precautionary approach			
B_{lim}	18213	15657	Lowest observed stock biomass
B_{pa}	24895	21402	Blim x exp(1.645 $sigma_{SSB}$)
F_{lim}	0.41	0.5	F leading to P(SSB < B_{lim}) = 0.5
F_{pa}	0.29	0.38	F, when ICES AR is applied, leading to P(SSB > Blim) = 0.05
MSY	25567	26554	Avg. MSY

Due to this update of the reference point last years advice needed also to be corrected based on the updated F_{msy} and $B_{trigger}$ values.

Table 17. 2: Greenland halibut in 5, 6, 12 and 14. Overview of the catch options.

	Recruitment	Catch	SSB	Fbar
Status Quo				
2023	46768689	25425	25204	0.33
2024	50179813	21590	23871	0.28
2025	49516494	23164	23971	0.29

	Recruitment	Catch	SSB	Fbar
2026	47985852	25246	25142	0.29
Zero catch				
2023	46768689	25425	25204	0.33
2024	50179813	21590	23871	0.28
2025	49516494	0	23971	0.00
2026	48003734	0	29826	0.00
F_{msy}				
2023	46768689	25425	25204	0.33
2024	50179813	21590	23871	0.28
2025	49516494	17890	23971	0.21
2026	47990220	20967	26287	0.22

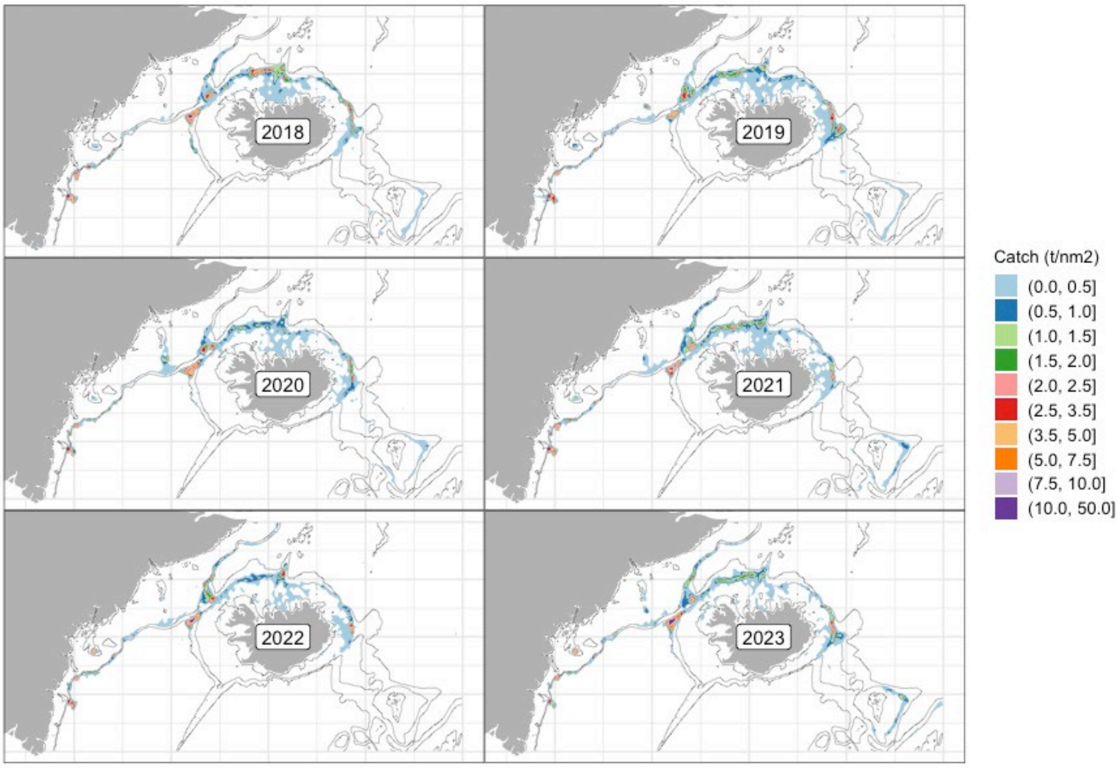

Figure 17. 1: Greenland halibut in 5, 6, 12 and 14. Geographical distribution of the fishery in division 5, 6, 12 and 14 from

last six years. The 100 m, 500m and 1000 m depth contours are shown. Reported catch from logbooks, note that logbook data from the Faroe Islands is incomplete.

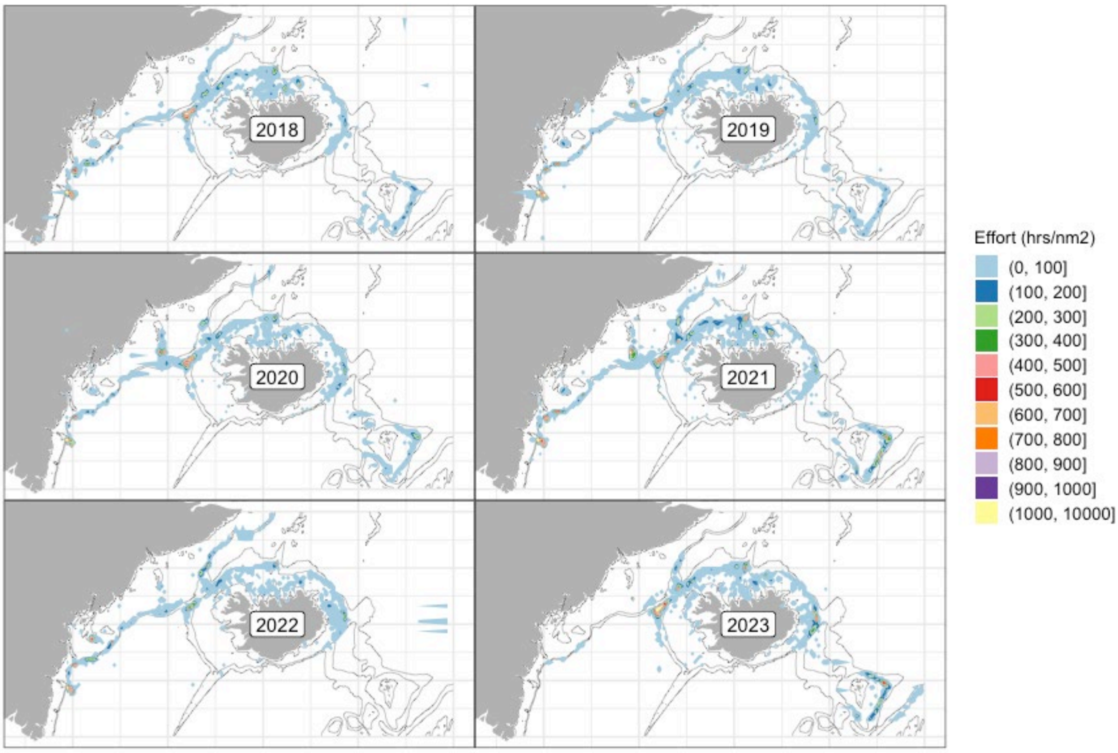

Figure 17. 2: Greenland halibut in 5, 6, 12 and 14. Geographical distribution of the fishery in division 5, 6, 12 and 14 from last six years. The 100 m, 500m and 1000 m depth contours are shown. Reported effort from logbooks, note that logbook data from the Faroe Islands is incomplete.

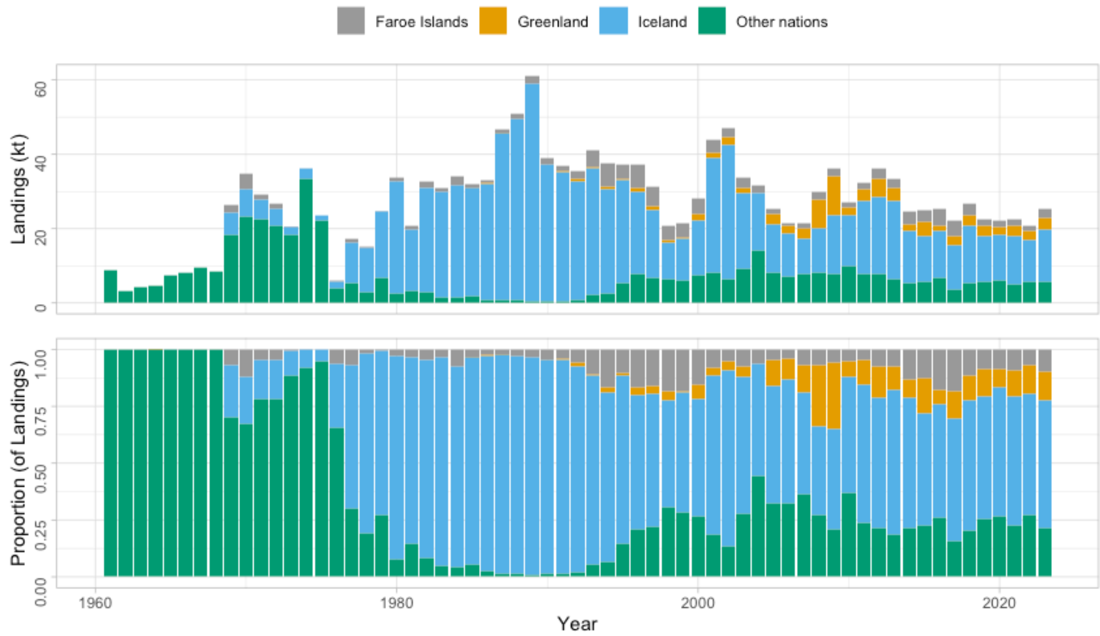

Figure 17. 3: Greenland halibut in 5, 6, 12 and 14. Landings from ICES Subareas 5,6,12 and 14 by nations (Greenland, Iceland, and Faroe Islands) in 1961-2020. All gears combined.

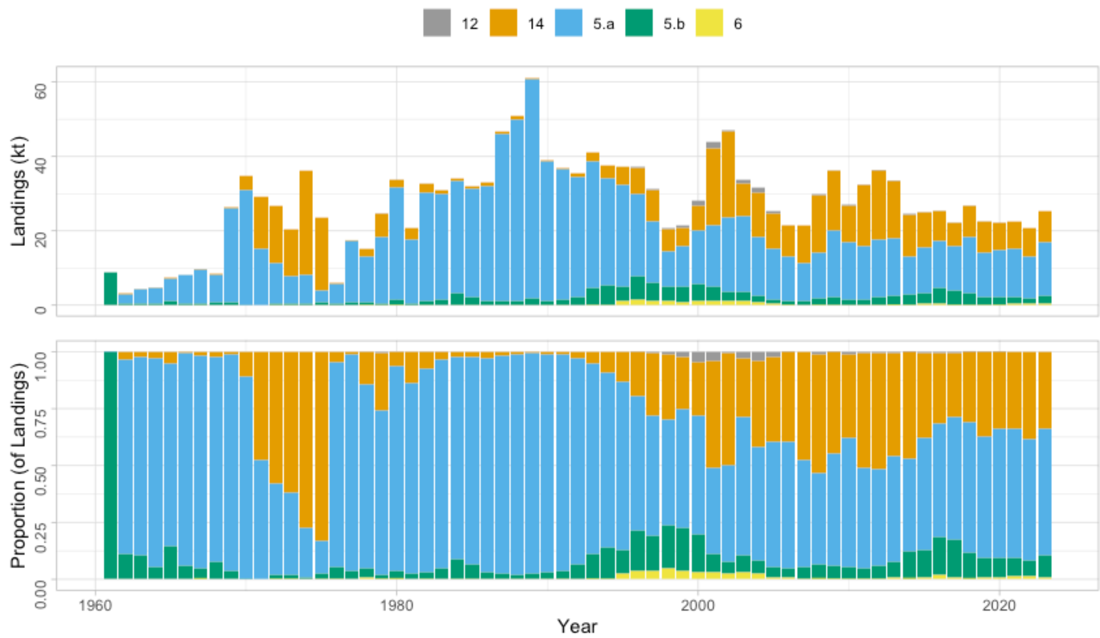

Figure 17. 4: Greenland halibut in 5, 6, 12 and 14. Spatial distribution of catch between ICES Subareas 5.a, 5.b, 6, 12 and 14 in 1961-2020. All gears combined

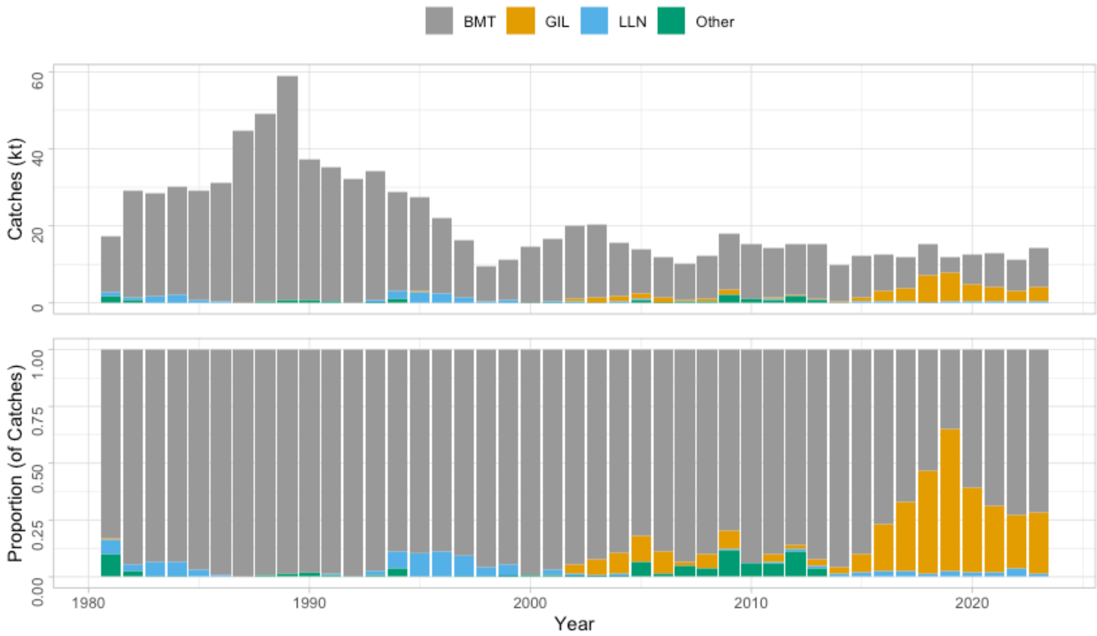

Figure 17. 5: Greenland halibut in 5, 6, 12 and 14. Total catch (landings) by fishing gear since 1994 in Icelandic Waters, according to statistics from the Directorate of Fisheries.

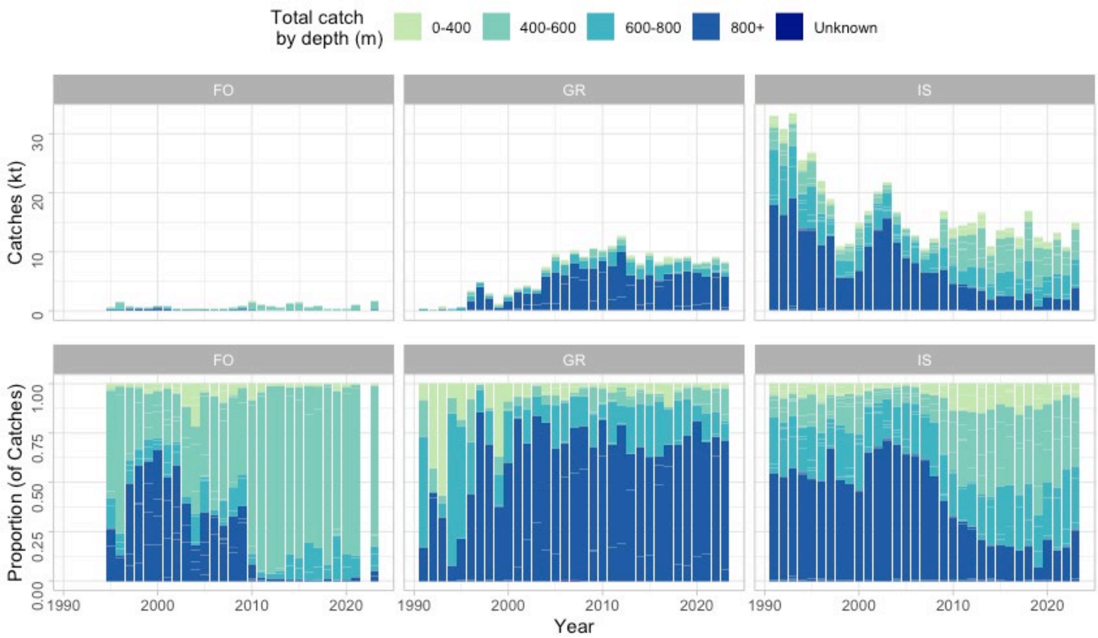

Figure 17. 6: Greenland halibut in 5, 6, 12 and 14. Depth distribution of catches in Faroese (FO), Greenlandic (GR) and Icelandic (IS) waters according to combined logbooks, note that logbook data from the Faroe Islands is incomplete.

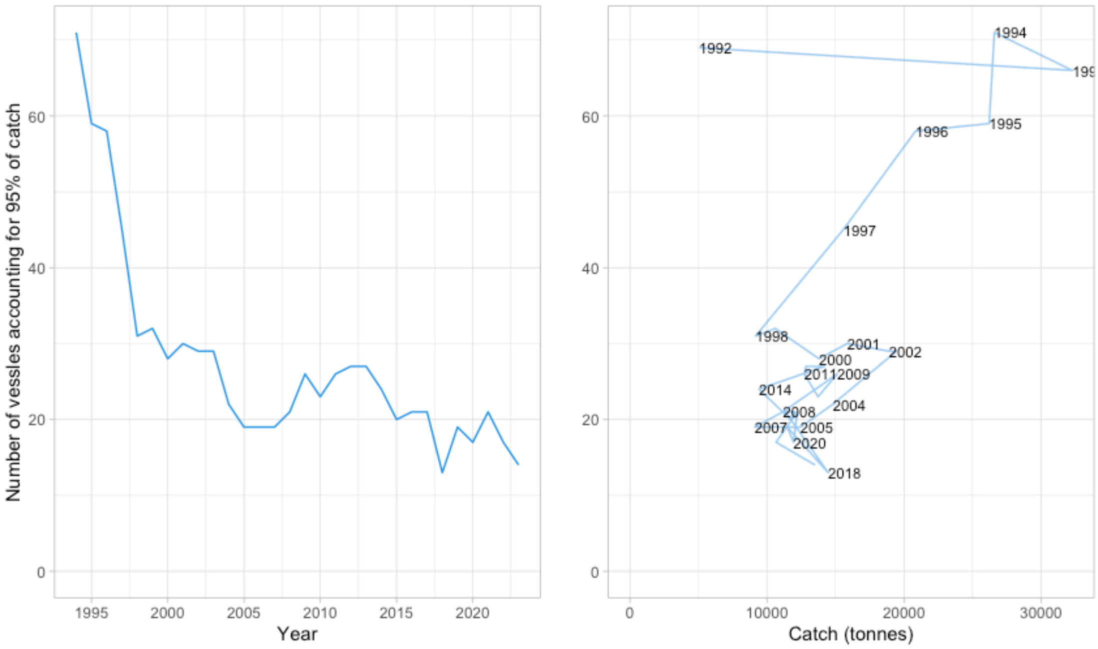

Figure 17. 7: Greenland halibut in 5, 6, 12 and 14. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

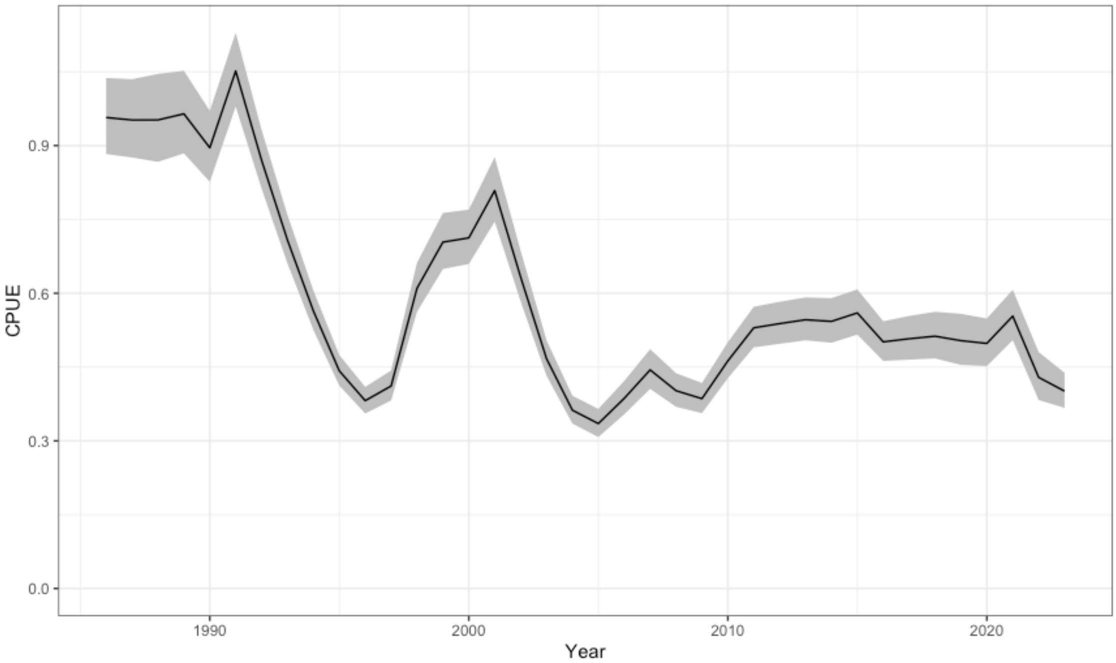

Figure 17. 8: Greenland halibut in 5, 6, 12 and 14. Catch per unit effort (CPUE, log-transformed) from the Icelandic trawler fleet in 5a. 95% CI indicated. Effort data are not available from 2022.

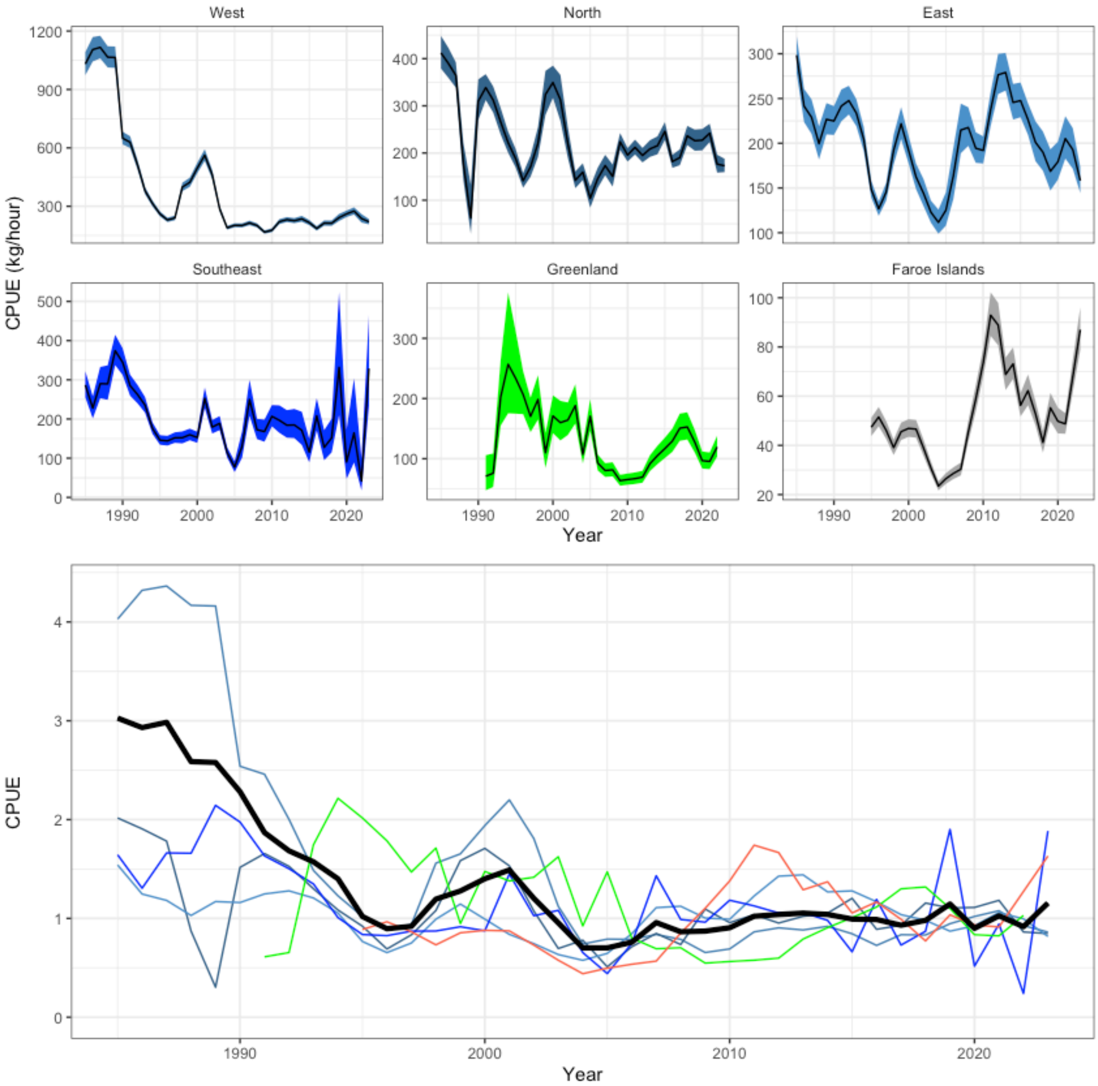

Figure 17. 9: Greenland halibut in 5, 6, 12 and 14. Upper 6 panels. Catch per unit effort (CPUE) from the Icelandic trawler fleet in 5a, split by area indicated by the overlayed of Iceland, and from Faroese (5b) and Greenlandic (12 and 14) waters. 95% CI indicated. Lower panel shows the normalized CPUE by area, total average is indicated (black line)

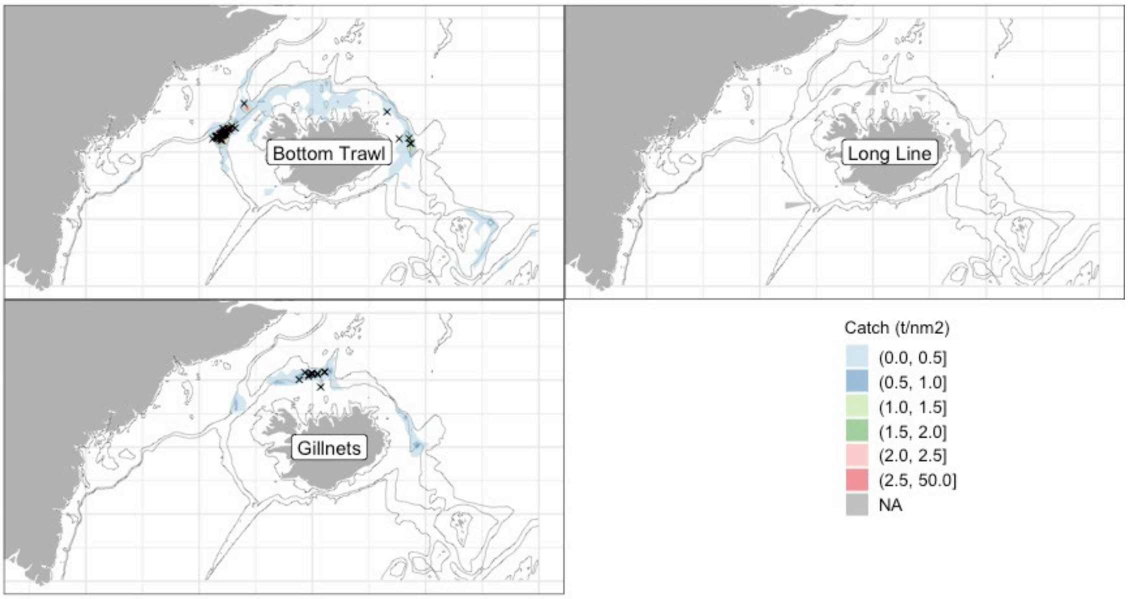

Figure 17. 10: Greenland halibut in 5, 6, 12 and 14. Fishing grounds in 2023 as reported in logbooks and positions of samples taken from landings (asterisks). Note that sampling locations are only available from Icelandic sources

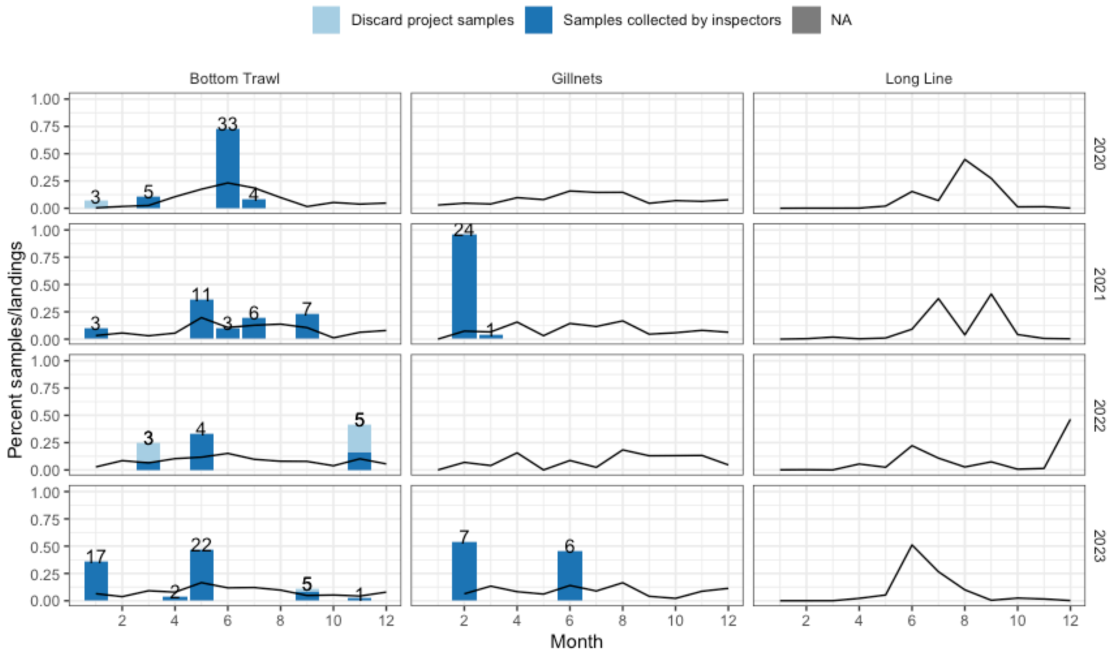

Figure 17. 11: Greenland halibut in 5, 6, 12 and 14. Ratio of samples by month (blue bars) compared with landings by month (solid black line) split by year and main gear types. Numbers of above the bars indicate number of samples by year, month and gear. Each sample typically consists of 50 fish.

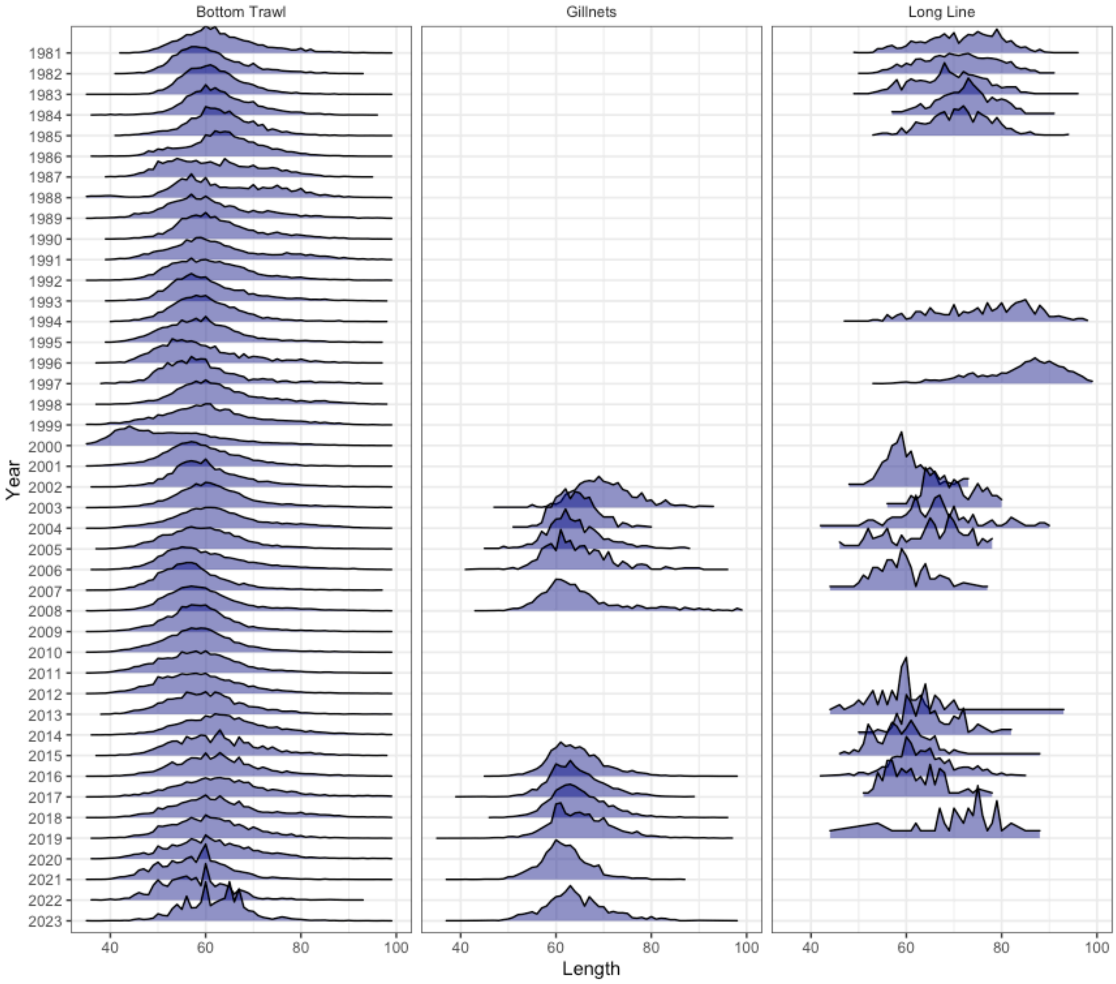

Figure 17. 12: Greenland halibut in 5, 6, 12 and 14. Commercial length distributions by gear and year

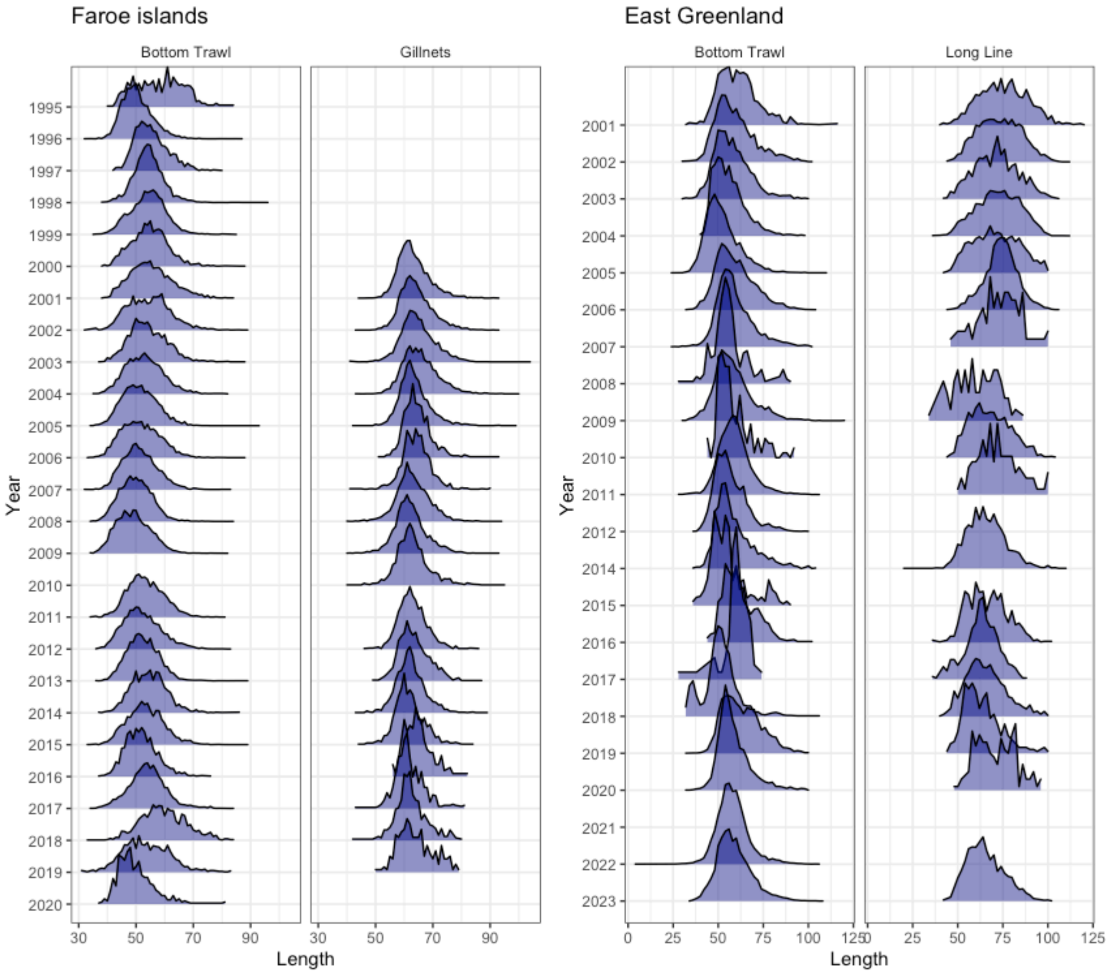

Figure 17. 13: Greenland halibut in 5, 6, 12 and 14. Commercial length distributions by gear and year in Faroese and Greenlandic waters, note different y-axis.

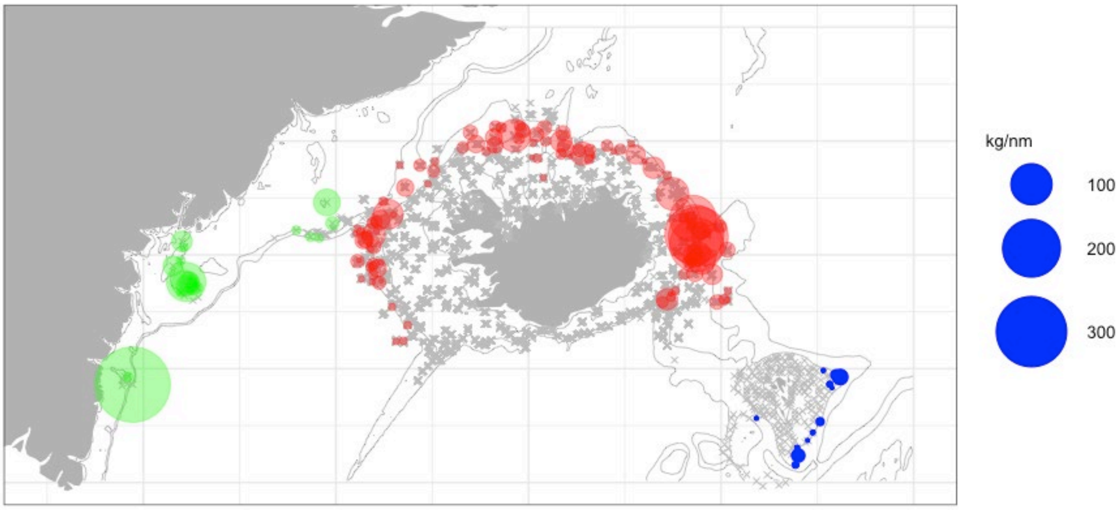

Figure 17. 14: Greenland halibut in 5, 6, 12 and 14. Spatial distribution of Greenland halibut in the Icelandic autumn survey (red), Greenlandic Greenland halibut survey (green) and Faroese surveys (blue). Size of the points indicates catch at the location, grey crosses the stations were no halibuts were observed.

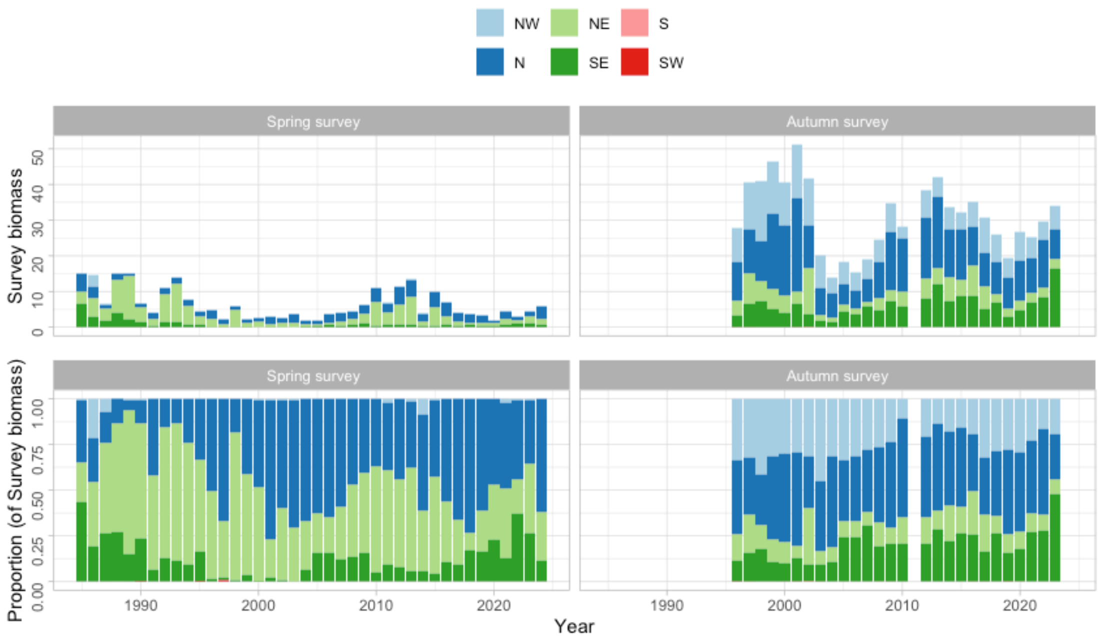

Figure 17. 15: Greenland halibut in 5, 6, 12 and 14. Spatial distribution of the biomass index from the spring and autumn surveys. Note that the autumn survey extends into deeper waters.

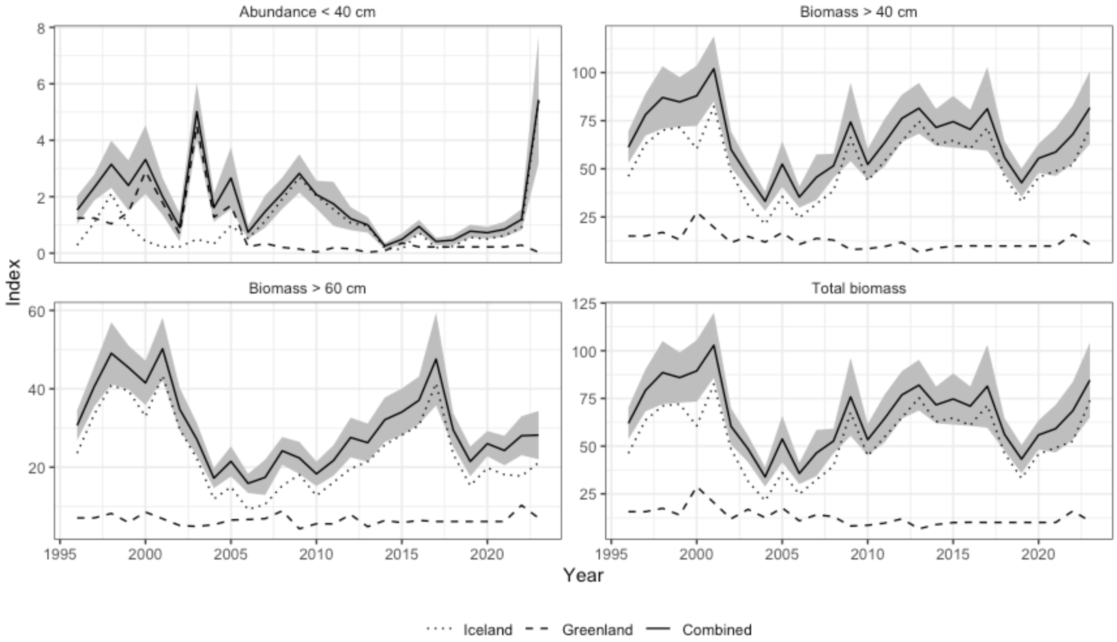

Figure 17. 16: Greenland halibut in 5, 6, 12 and 14. Indices from Iceland (smaller dots) Greenland (larger dots) and combined (straight line) with 95% CI indicated. Harvestable biomass indices (>40 cm) (upper right), juvenile abundance indices (<40 cm) (upper left), biomass indices of larger ind. (>60cm) (lower left) and total biomass indices (lover right)

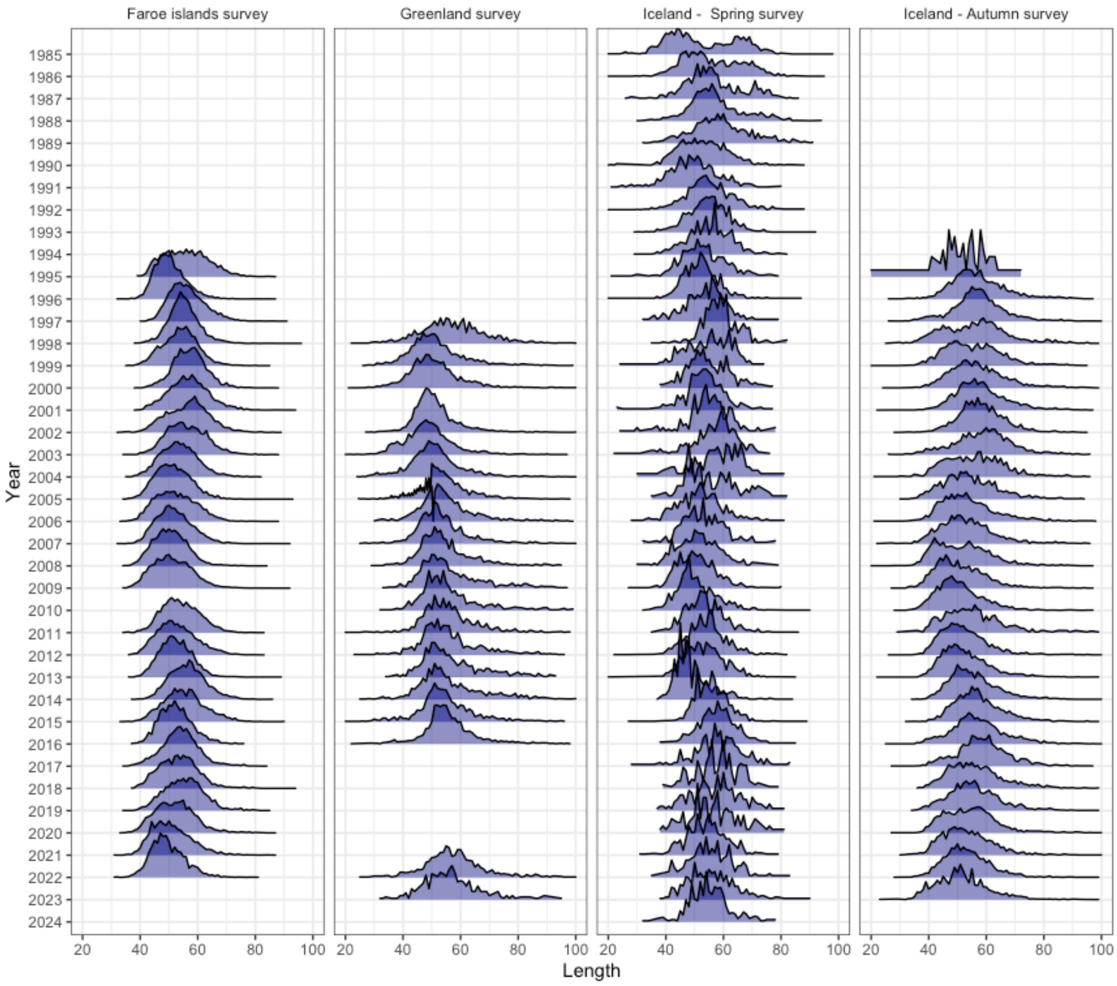

Figure 17. 17: Greenland halibut in 5, 6, 12 and 14. Mean length and 95% CI (upper) and length distribution (lower) of females and males from the autumn survey since 1996

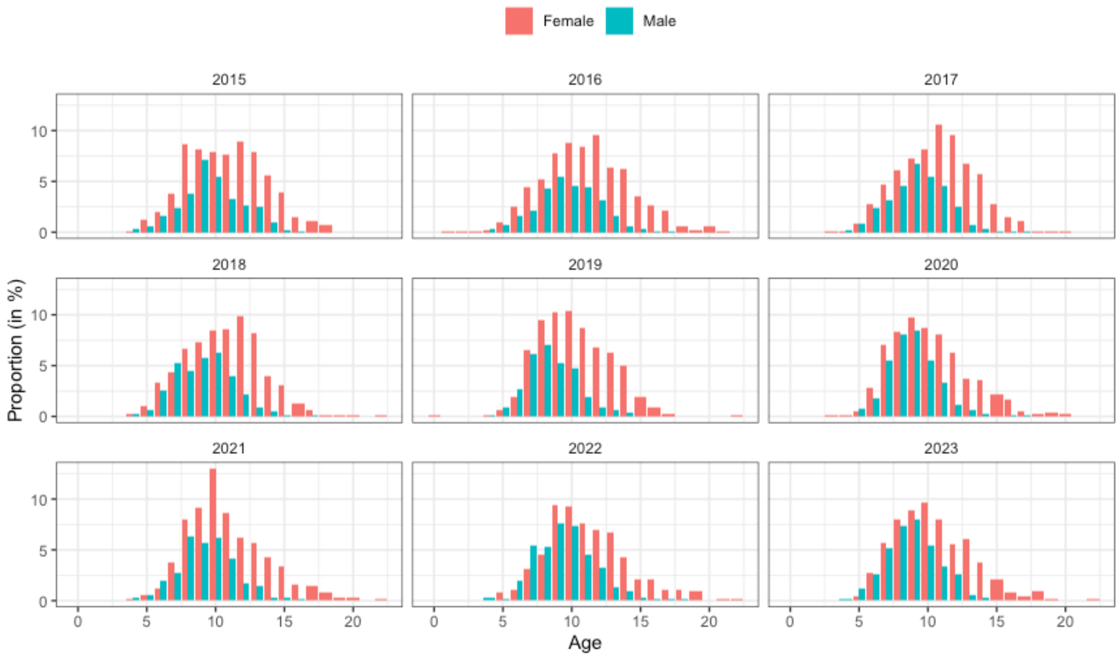

Figure 17. 18: Greenland halibut in 5, 6, 12 and 14. Proportion by age from the autumn survey from 2015

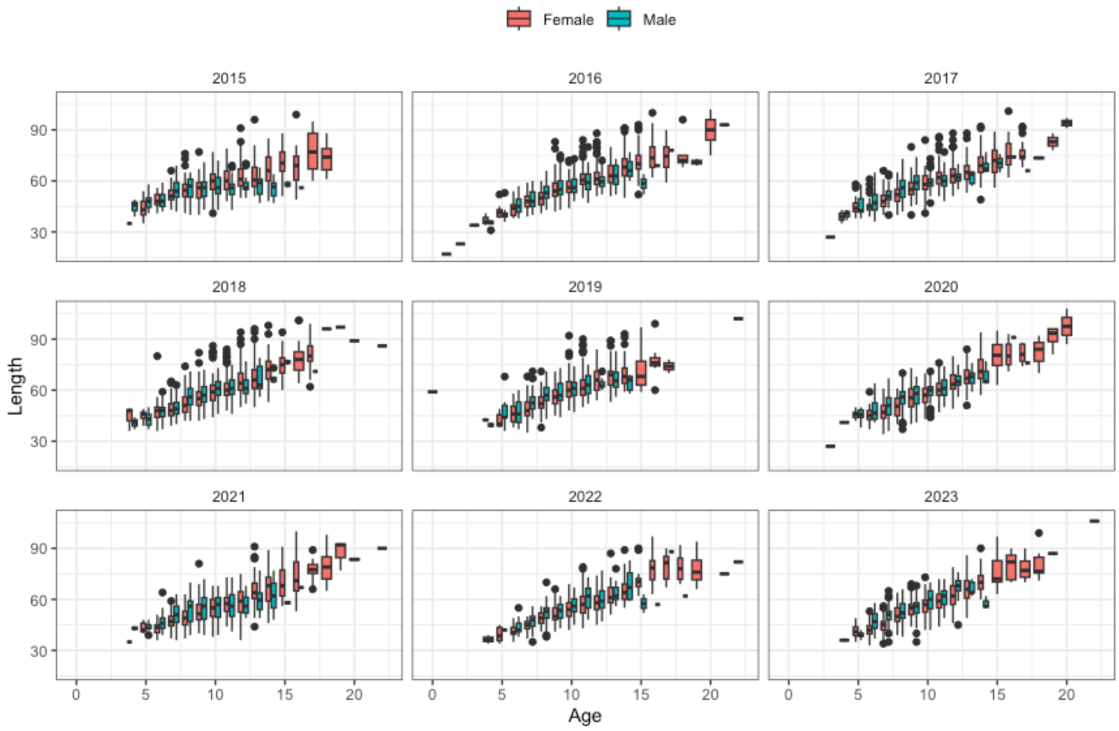

Figure 17. 19: Greenland halibut in 5, 6, 12 and 14. Distribution of length-at-age by sex from the autumn survey

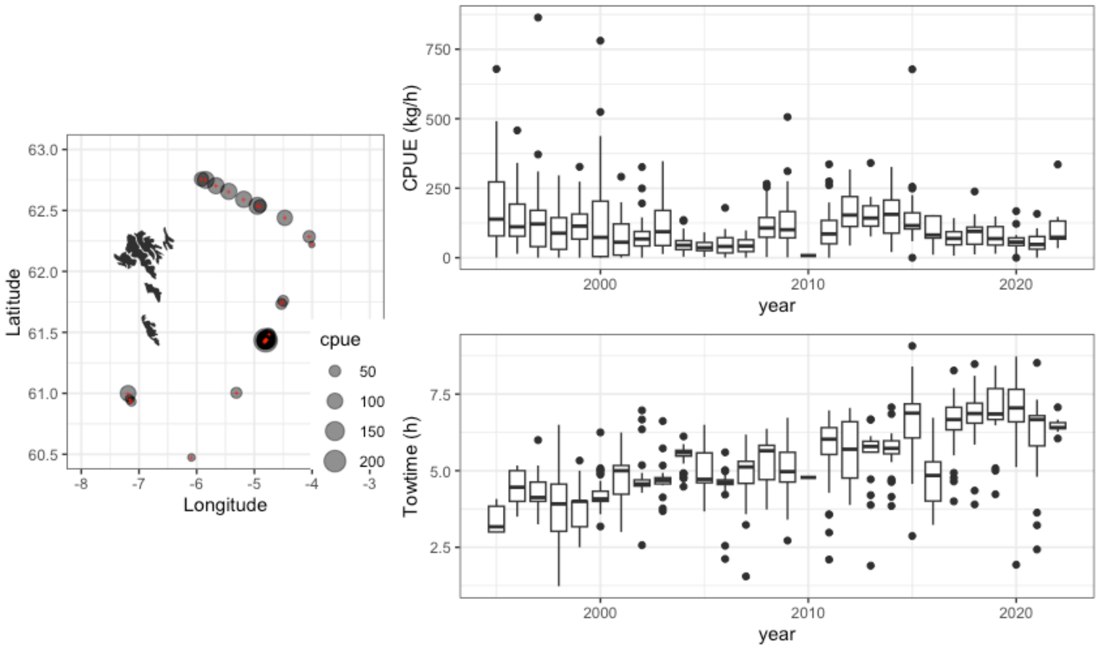

Figure 17. 20: Greenland halibut in 5, 6, 12 and 14. Tow stations in the Faroese Greenland halibut survey in 2018. Boxplot of the catch per unit effort (top panel) and towtime (bottom panel) by year in the Faroese survey.

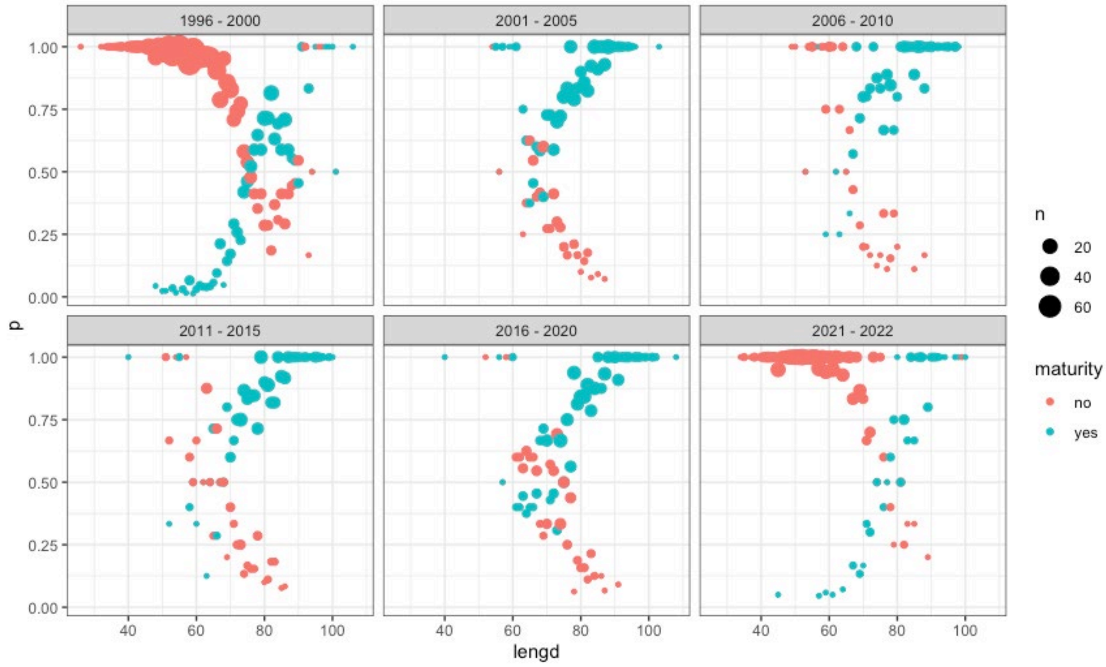

Figure 17. 21: Greenland halibut in 5, 6, 12 and 14. Observed propotion female mature by length the Icelandic autumn survey based on GSI > 1%.

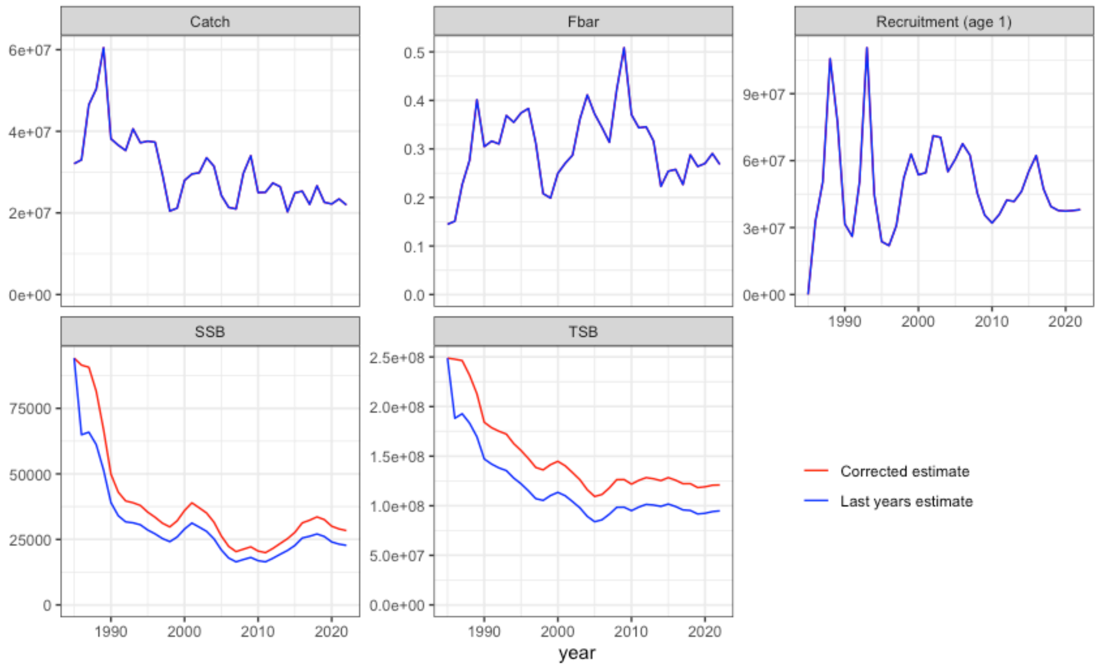

Figure 17. 22: Greenland halibut in 5, 6, 12 and 14. Comparison of last years model assessment of stock status with the corrected output from the same assessment (see text for further details).

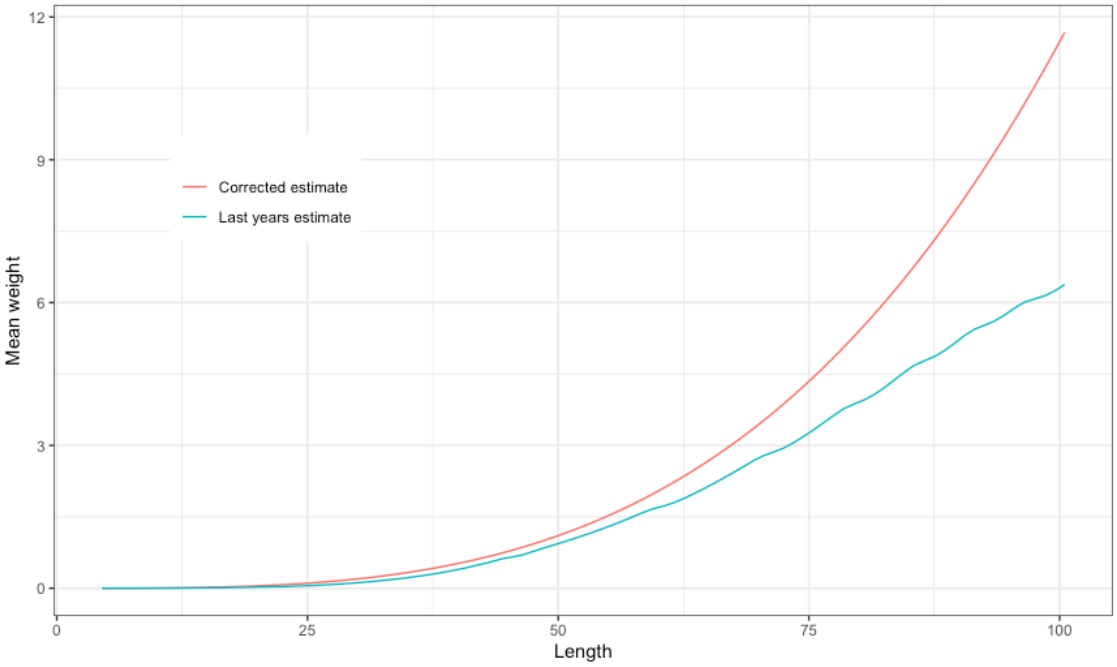

Figure 17. 23: Greenland halibut in 5, 6, 12 and 14. Comparison of last years model assessment of mean weight at length to the corrected output from the same assessment (see text for further details).

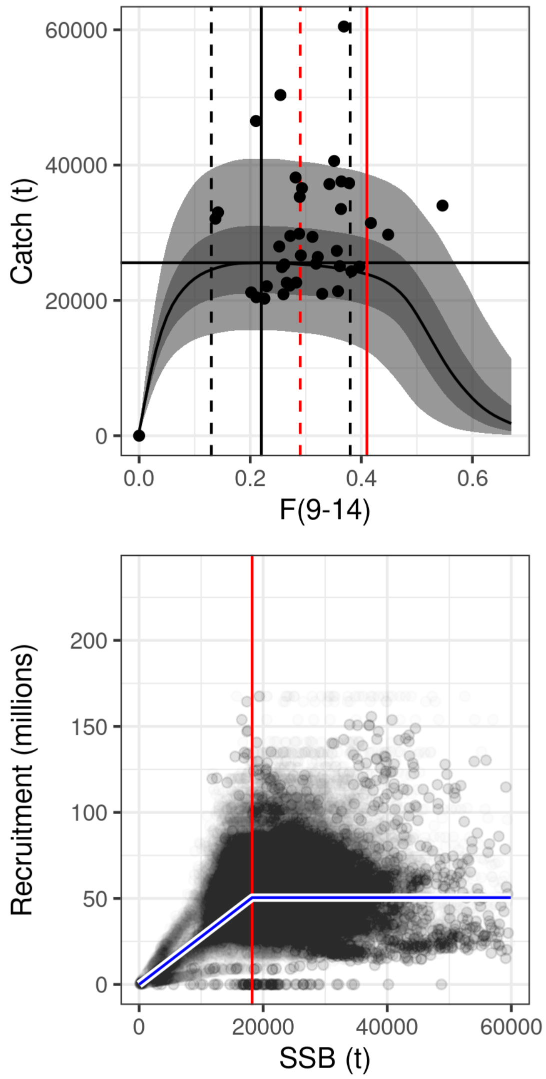

Figure 17. 24: Greenland halibut in 5a. Equilibrium catch, recruitment, SSB and risk from forward projections.

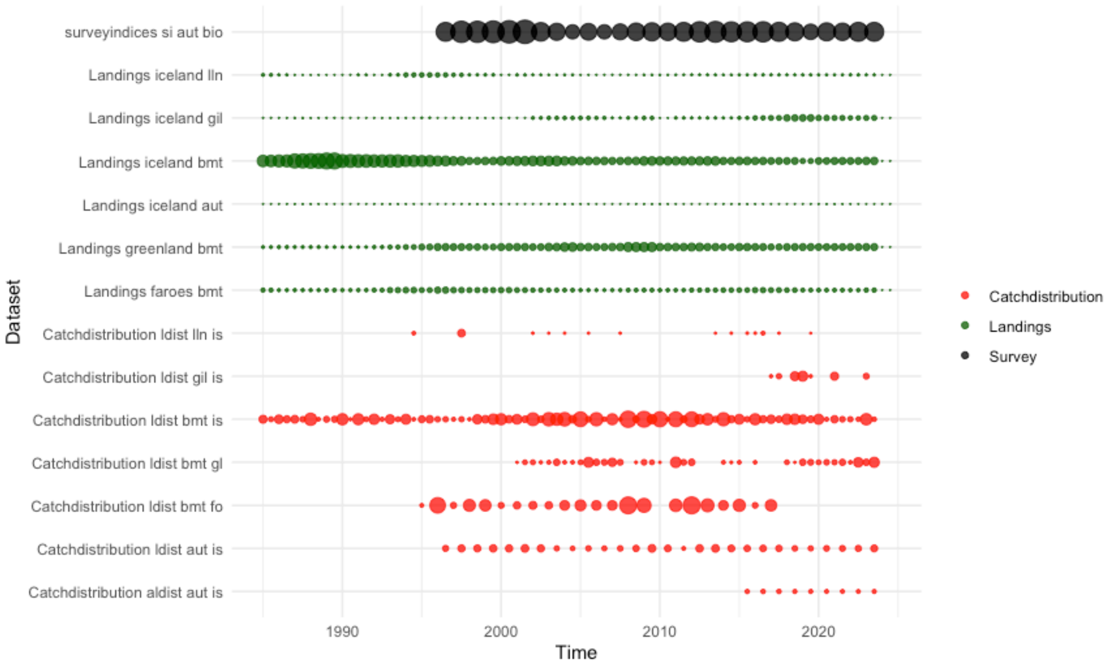

Figure 17. 25: Greenland halibut in 5, 6, 12 and 14. Overview of the datasets used and when they are available. Size of the bubbles indicate number of data points.

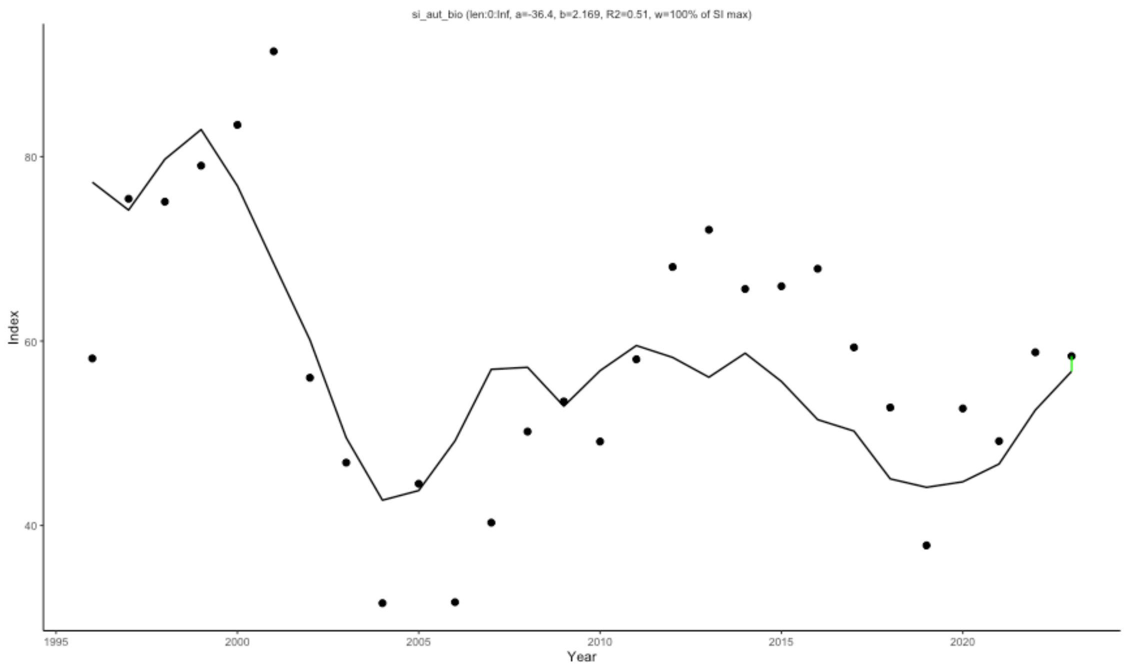

Figure 17. 26: Greenland halibut in 5, 6, 12 and 14. Observed survey index (dots) compared to the fitted model (solid line).

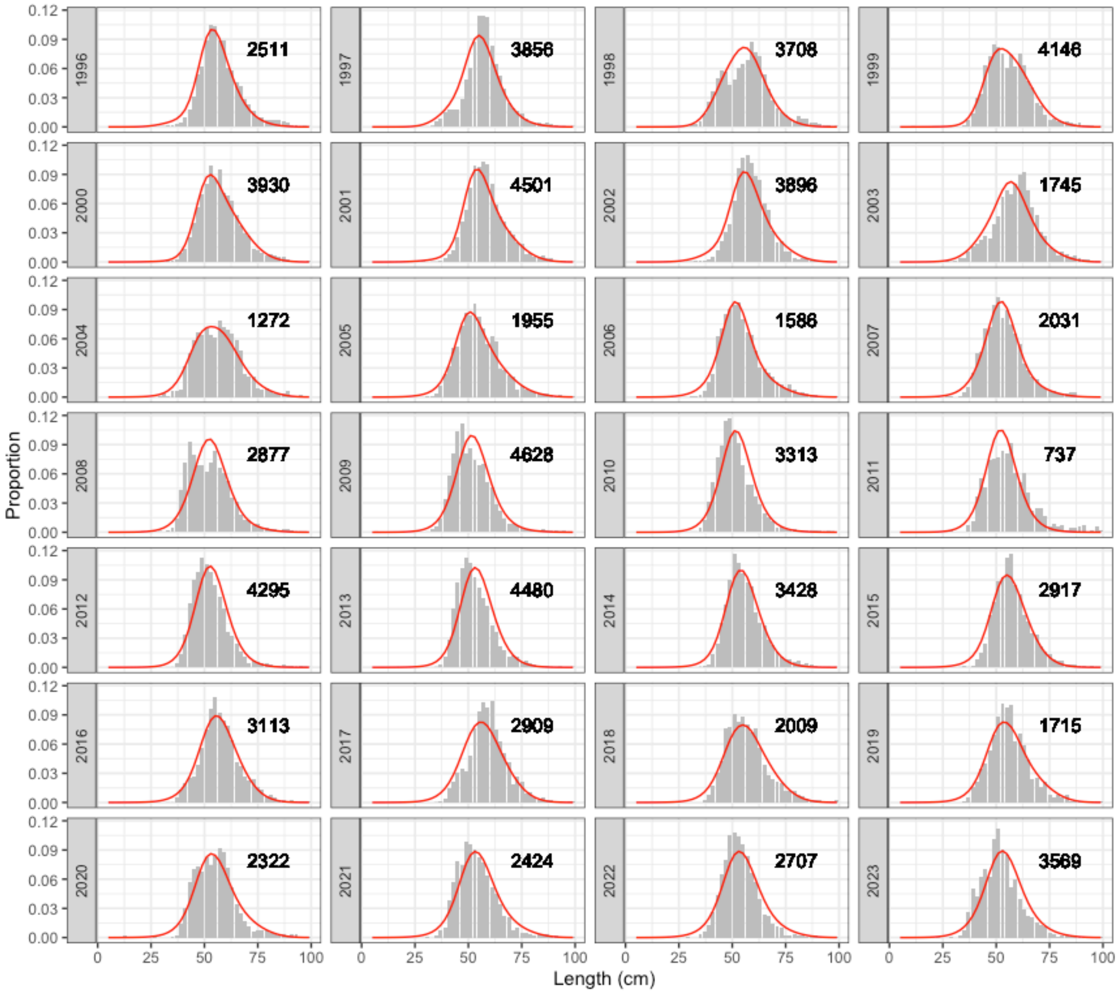

Figure 17. 27: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated size distribution from the autumn survey catches. Observations are shown as grey bars while the estimated proportions by a red line. Number of fish sampled by year is indicated on each panel.

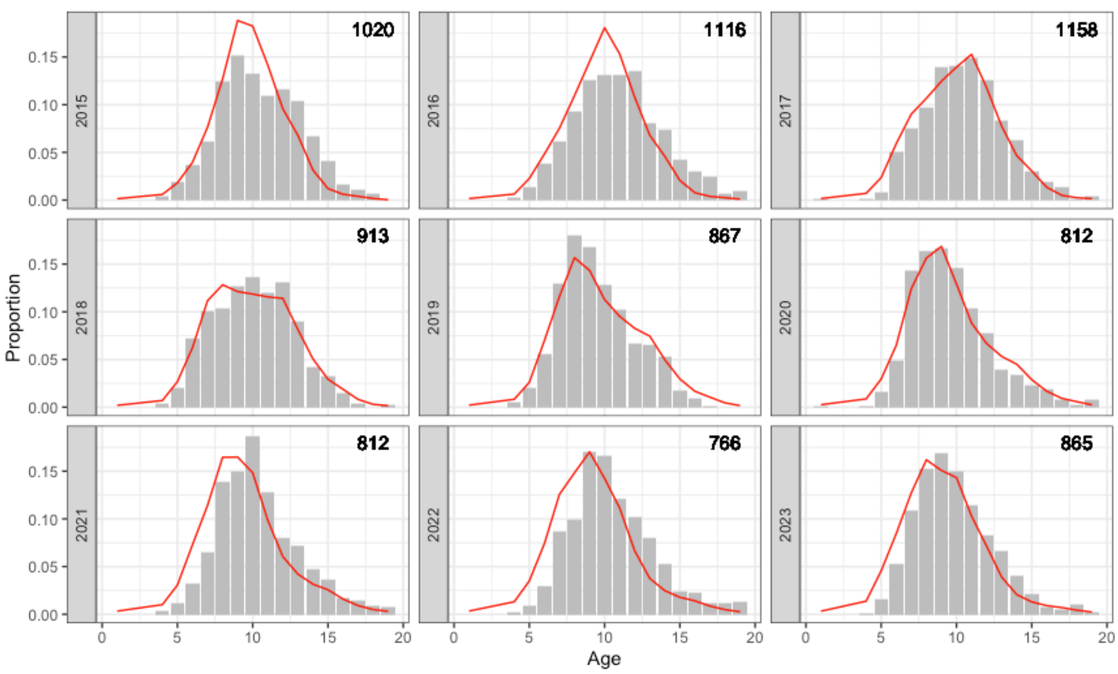

Figure 17. 28: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated age distribution from the autumn survey catches. Observations are shown as grey bars while the estimated proportions by a red line. Number of fish sampled by year is indicated on each panel.

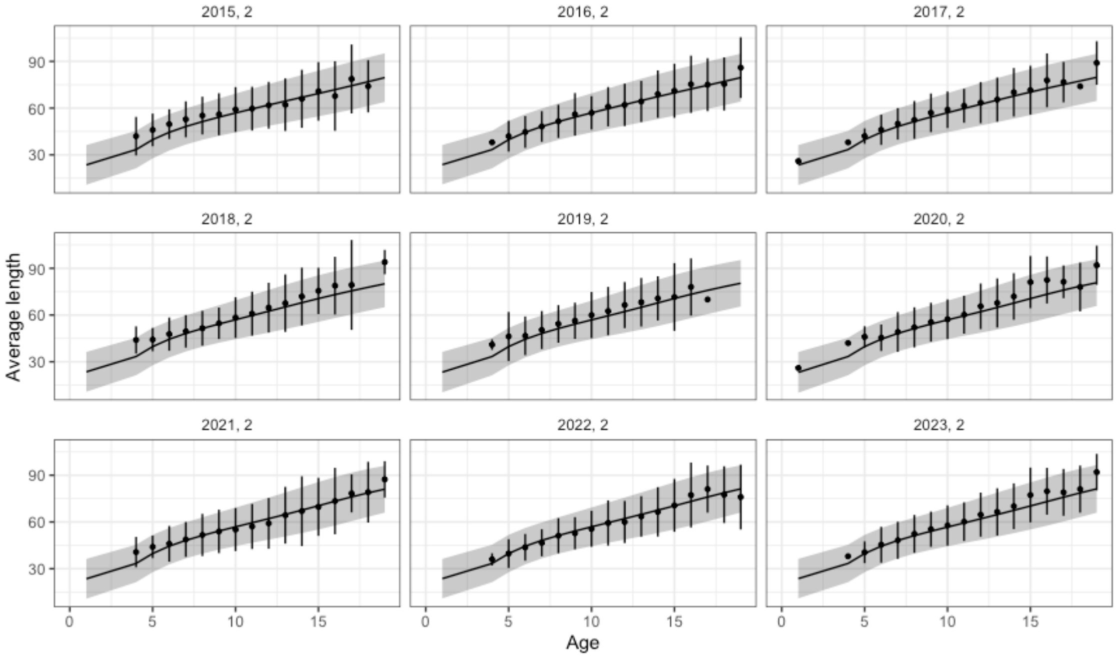

Figure 17. 29: Greenland halibut in 5, 6, 12 and 14. Comparison of the estimated growth from the assessment model to the observed values from the Icelandic autumn survey

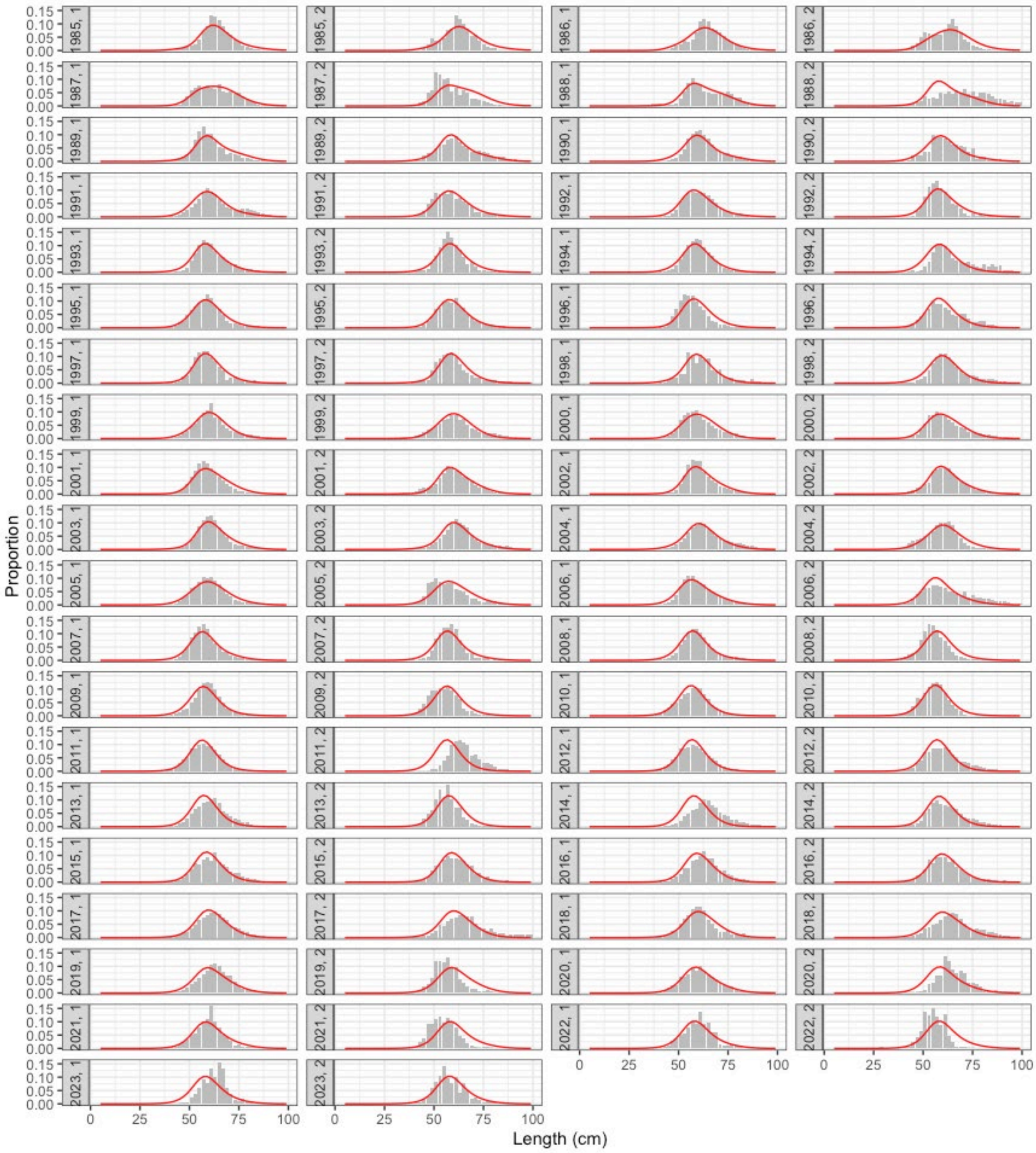

Figure 17. 30: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated size distribution from the commercial bottom-trawl catches in Iceland. Observations are shown as grey bars while the estimated proportions by a red line.

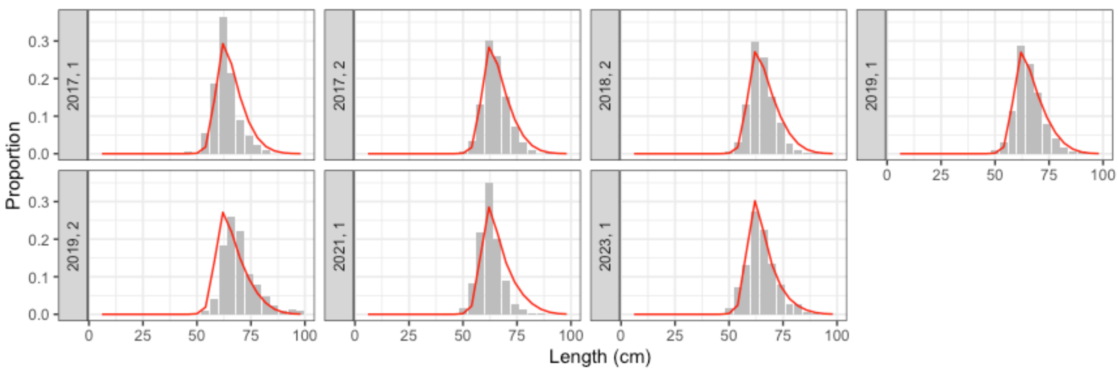

Figure 17. 31: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated size distribution from the commercial gillnet catches in Iceland. Observations are shown as grey bars while the estimated proportions by a red line.

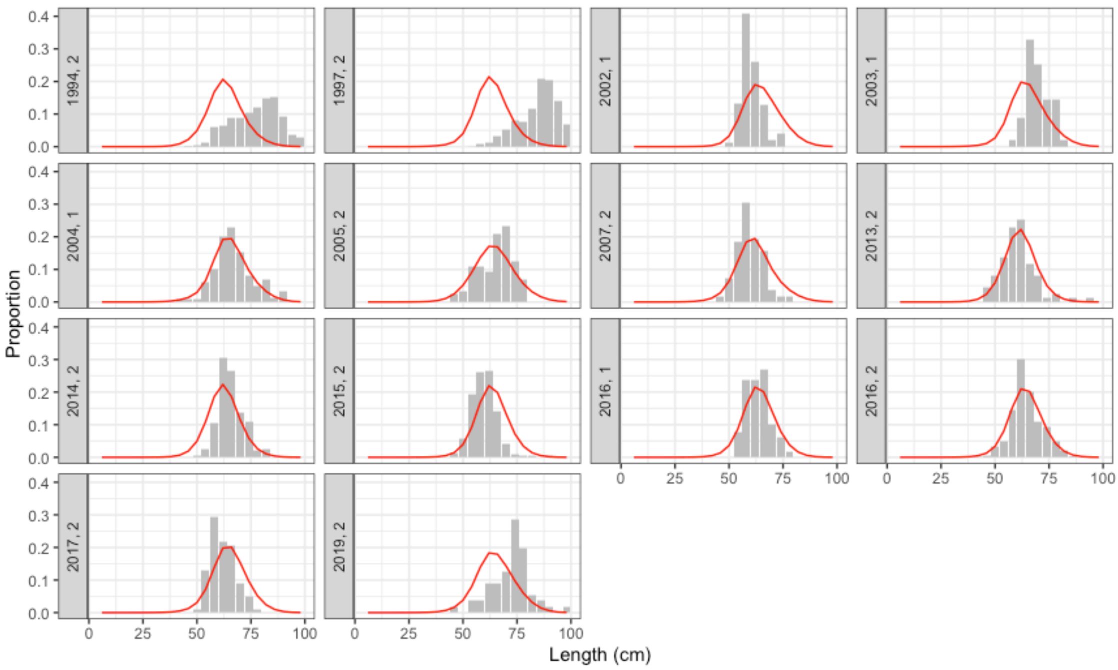

Figure 17. 32: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated size distribution from the commercial longline catches in Iceland. Observations are shown as grey bars while the estimated proportions by a red line.

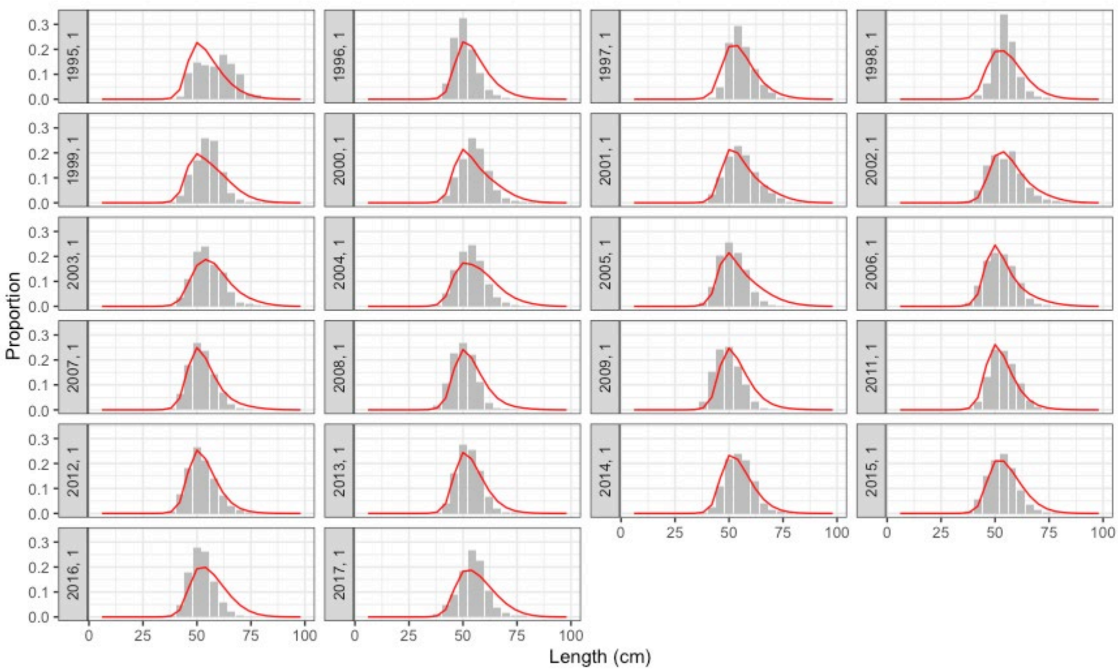

Figure 17. 33: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated size distribution from the commercial bottom-trawl catches in Faroe Islands. Observations are shown as grey bars while the estimated proportions by a red line.

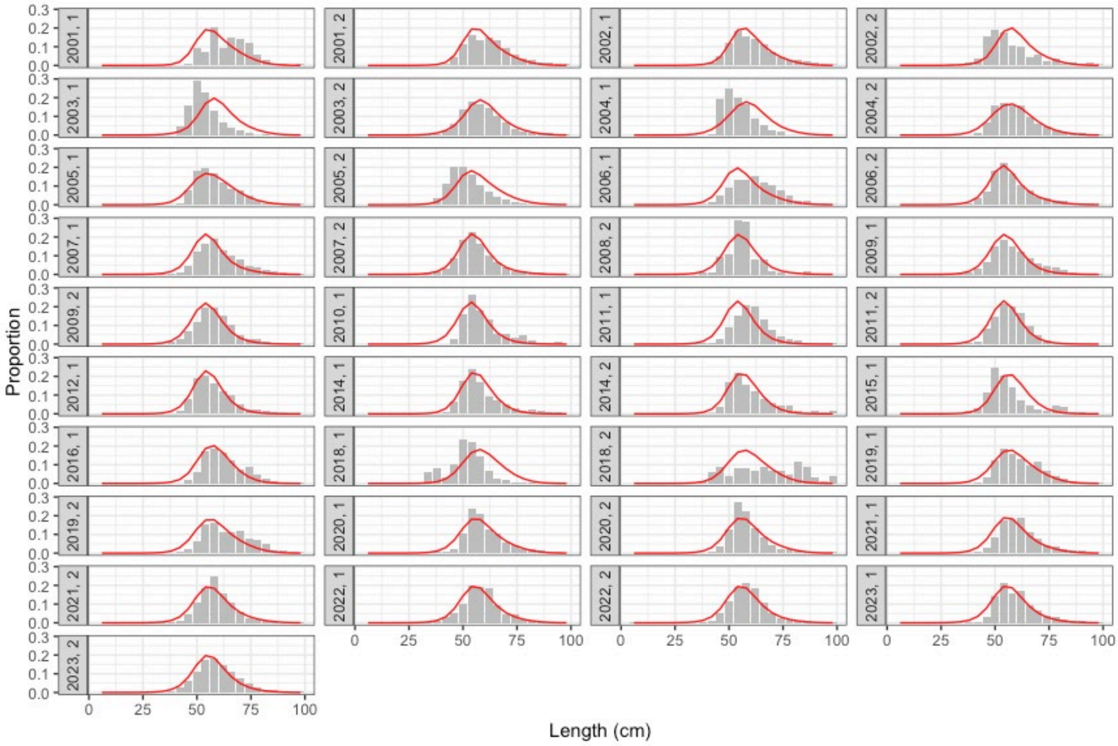

Figure 17. 34: Greenland halibut in 5, 6, 12 and 14. Comparison of the observed and estimated size distribution from the commercial bottom-trawl catches in Greenland. Observations are shown as grey bars while the estimated proportions by a red line.

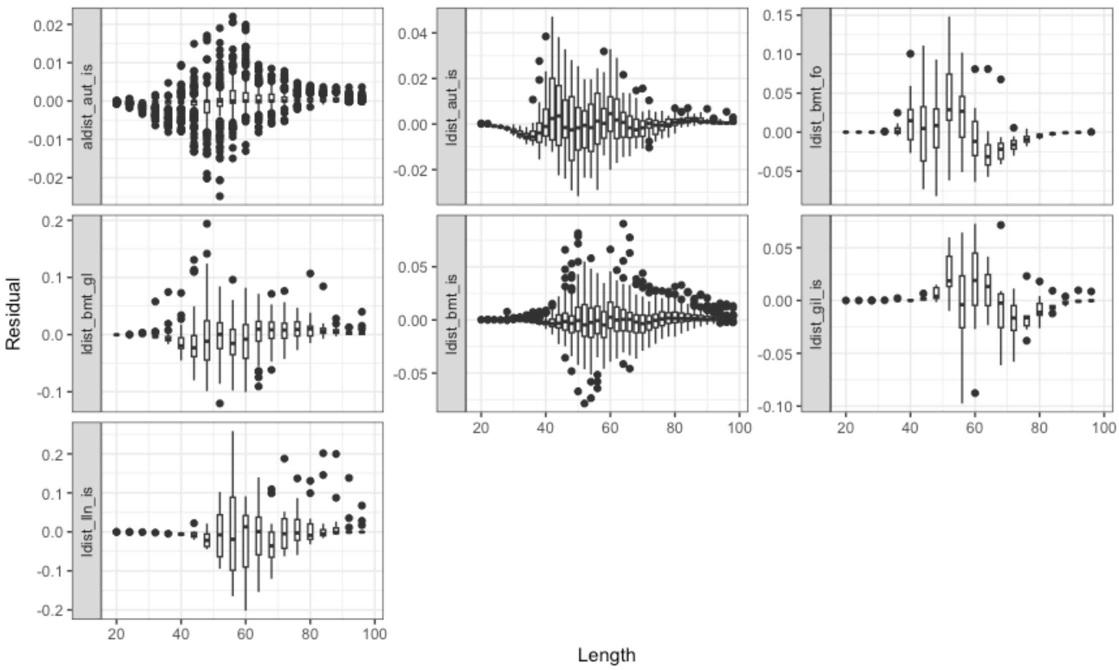

Figure 17. 35: Greenland halibut in 5, 6, 12 and 14. Model residuals by catch composition likelihood components

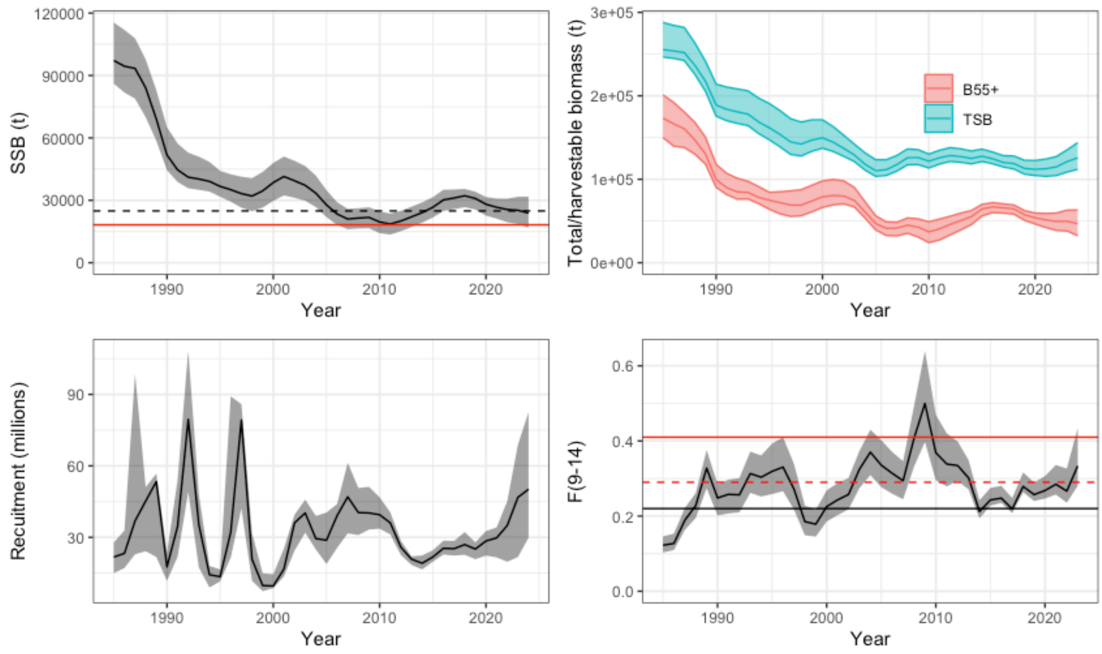

Figure 17. 36: Greenland halibut in 5, 6, 12 and 14. Estimates of total stock biomas, spawning-stock biomass, fishing mortality and recruitment (age 5) from the best model. Black line represents the point estimates and yellow ribbon the 90% confidence intervals. Upper left panel: dashed line indicate MSY Btrigger and red line indicate Blim.Lower right panel: red line indicate Flim, dashed red line indicate Fpa and black line indicate Fmsy.

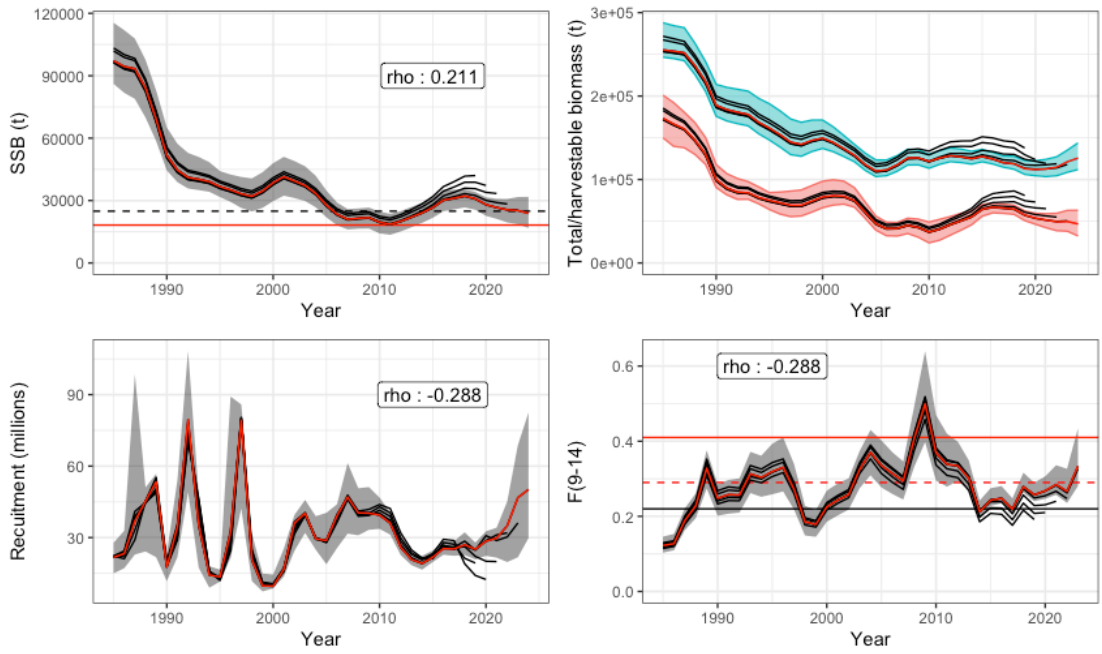

Figure 17. 37: Greenland halibut in 5, 6, 12 and 14. Analytical retrospective estimates of total stock biomas, spawning-stock biomass, fishing mortality and recruitment from the best model. Colored lines represent the peeled point estimates and yellow ribbon the 90% confidence intervals. For reference points indications see Figure 17.36 caption.

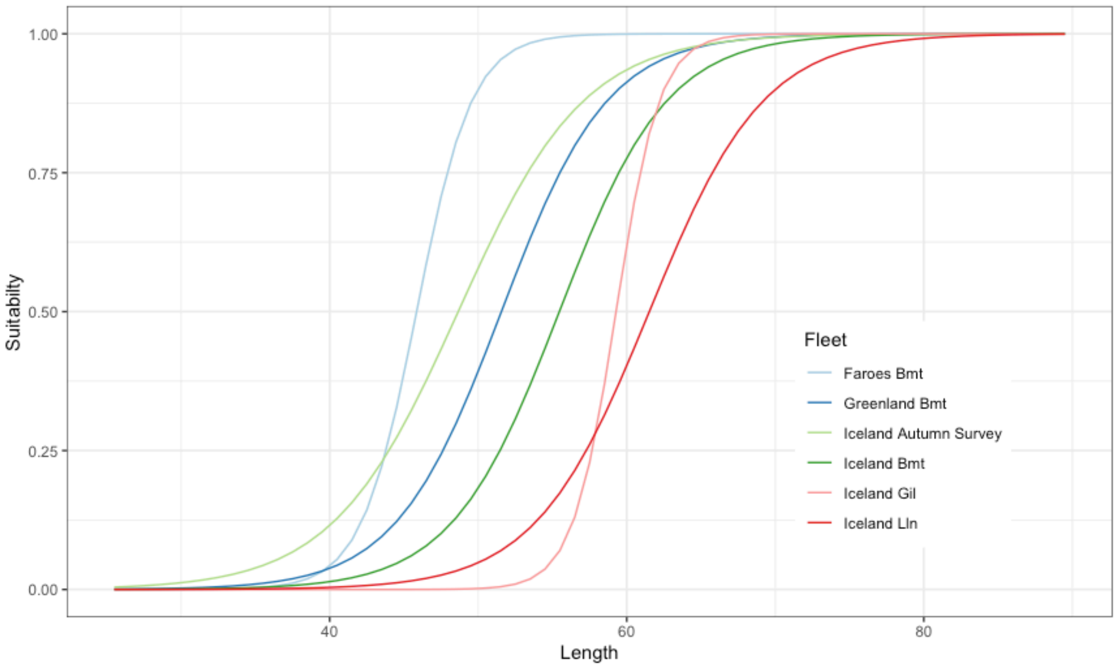

Figure 17. 38: Greenland halibut in 5, 6, 12 and 14. Estimated selection functions by fleet.

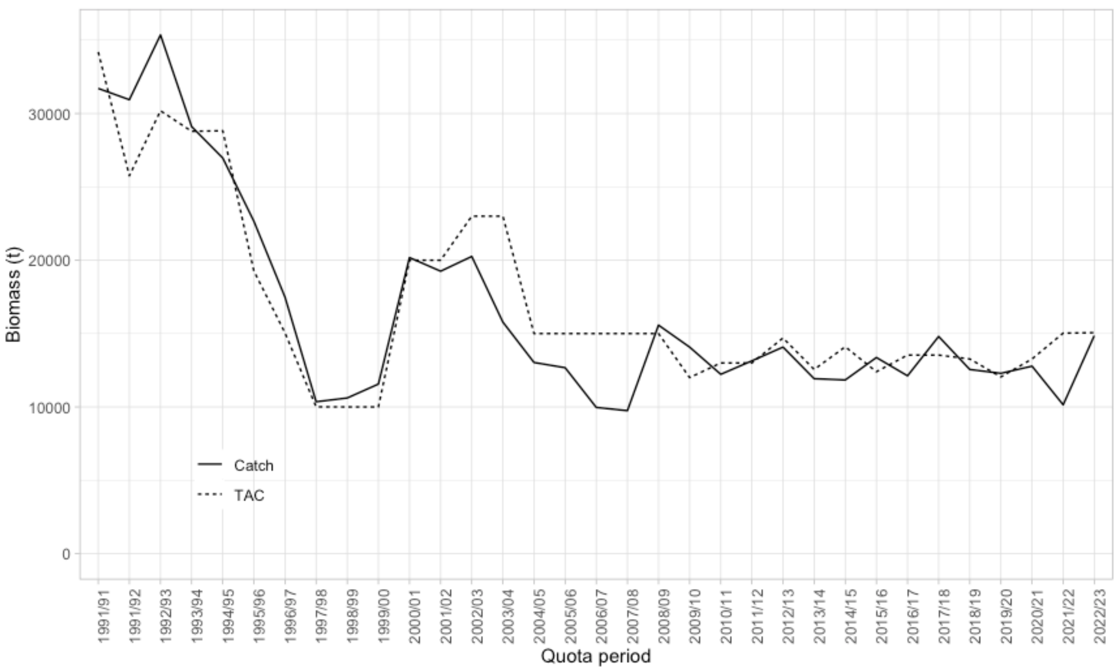

Figure 17. 39: Greenland halibut in 5, 6, 12 and 14. Recommended Icelandic national total allowable catch (TAC) compared with catches in Icelandic Waters.

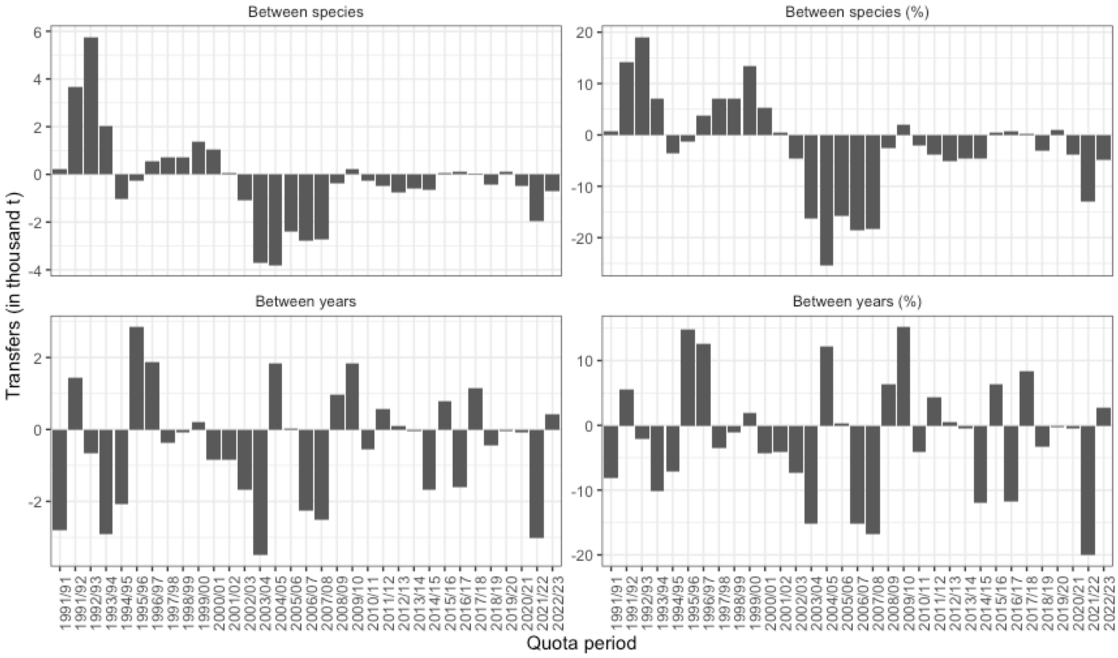

Figure 17. 40: Greenland halibut in 5, 6, 12 and 14. Net transfers of quota to and from Greenland halibut in the Icelandic ITQ system by fishing year. Between species (upper): Positive values indicate a transfer of other species to Greenland halibut, but negative values indicate a transfer of Greenland halibut quota to other species. Between years (lower): Net transfer of quota for a given fishing year.

18 Redfish in subareas 5, 6, 12, and 14

This chapter deals with fisheries directed to *Sebastes* species in subareas 5, 6, 12 and 14 (sections and 18.7), and the abundance and distribution of juveniles (Section 18.2.1), among other issues.

The "Workshop on Redfish Stock Structure" (WKREDS, 22–23 January 2009, Copenhagen, Denmark; ICES 2009) reviewed the stock structure of *Sebastes mentella* in the Irminger Sea and adjacent waters. ACOM concluded, based on the outcome of the WKREDS meeting, that there are three biological stocks of *S. mentella* in the Irminger Sea and adjacent waters:

- a 'Deep Pelagic' stock (NAFO 1–2, ICES 5, 12, 14 > 500 m) – primarily pelagic habitats, and including demersal habitats west of the Faroe Islands;
- a 'Shallow Pelagic' stock (NAFO 1–2, ICES 5, 12, 14 < 500 m) – extends to ICES 1 and 2, but primarily pelagic habitats, and includes demersal habitats east of the Faroe Islands;
- an 'Icelandic Slope' stock (ICES 5.a, 14) – primarily demersal habitats.

This conclusion is primarily based on genetic information, i.e. microsatellite information, and supported by analysis of allozymes, fatty acids and other biological information on stock structure, such as some parasite patterns. The Russian Federation maintains the point of view that there is only one stock of *S. mentella* in the pelagic waters of the Irminger Sea. Accordingly, the Russian Federation presented alternative approaches to stock assessment as well as environmental influence on stock dynamics. Briefly, it is claimed that the current survey-based assessment does not adequately reflect stock status and that environmental factors – temperature causes major distributional changes of redfish – affect stock status more than fisheries and the use of the current management areas is rejected (see WD22, WD23 and Annex 7). The other NWWG members did not agree with the Russian Federation's view on stock structure and did not consider the presented assessment approach sufficiently documented.

The adult redfish on the Greenland shelf has traditionally been attributed to several stocks, and there remains the need to investigate the affinity of adult *S. mentella* in this region. Recent studies confirm the connectivity between *S. mentella* in East-Greenland and other areas (Saha *et al.,* 2016). Further studies are needed to understand e.g. the connection between the slope stocks in both East-Greenland, Iceland and the Faroe Islands.

ICES past advice for *S. mentella* fisheries was provided for two distinct management units, i.e. a demersal unit on the continental shelves and slopes and pelagic unit in the Irminger Sea and adjacent waters. However, based on the new stock identification information, ICES recommended three potential management units that are geographic proxies for biological stocks that were partly defined by depth and whose boundaries are based on the spatial distribution pattern of the fishery to minimize mixed-stock catches (Figure 18.1.1):

- Management Unit in the northeast Irminger Sea: ICES Subareas 5.a, 12, and 14.
- Management Unit in the southwest Irminger Sea: NAFO Areas 1 and 2, ICES Subareas 5.b, 12 and 14.
- Management Unit on the Icelandic slope: ICES Subareas 5.a and 14, and to the north and east of the boundary proposed in the MU in the northeast Irminger Sea.

The pelagic fishery in the Irminger Sea and adjacent waters shows a clear distinction between two widely separated grounds fished at different seasons and depths. Spatial analysis of the pelagic fishery catch and effort by depth, inside and outside the boundaries proposed for the management units in the northeast Irminger Sea, indicate that the boundaries effectively delineate the pelagic fishery in the northeast Irminger Sea from the pelagic fishery in the southwest Irminger Sea, with a small portion of mixed-stock catches. In the last decade the majority (more than 90%) of the catches have been taken in the northeast Irminger Sea. The northeastern fisheries on the pelagic *S. mentella* occur at the start of the fishing season at depths below 500 m and overlap to some extent with demersal fisheries on the continental slopes of Iceland (Sigurdsson *et al.*, 2006).

A schematic illustration of the relationship between the management units and biological stocks is given in Figure 18.1.2.

For the above-mentioned reasons, the group now provides advice for the following *Sebastes* units:

- the *S. norvegicus* on the continental shelves of ICES divisions 5.a, 5.b and subareas 6 and 14 (Section 19);
- the demersal *S. mentella* on the Icelandic slope (Section 20);
- the shallow and deep pelagic *S. mentella* units in the Irminger Sea and adjacent waters (sections 21 and 22, respectively);
- the Greenland shelf *S. mentella* (Section 23).

18.1 Environmental and ecosystem information

Species of the genus *Sebastes* are common and widely distributed in the North Atlantic. They are found off the coast of Great Britain, along Norway and Spitsbergen, in the Barents Sea, off the Faroe Islands, Iceland, East and West Greenland, and along the east coast of North America from Baffin Island to Cape Cod. All *Sebastes* species are viviparous. Copulation occurs in autumn-early winter and larvae extrusion takes place in late winter–late spring/early summer. Little is known about the copulation areas.

The increase of water temperature in the Irminger Sea may have an effect on spatial and vertical distribution of *S. mentella* in the feeding area (Pedchenko, 2005). The abundance and distribution of pelagic *S. mentella* in relation to oceanographic conditions were analyzed in a special multi-stage workshop (ICES, 2012). Based on 20 years of survey data, the results reveal the average relation of pelagic redfish to their physical habitat in shallow and intermediate waters: The most preferred latitude, longitude, depth, salinity and temperature for *S. mentella* are approximately 58°N, 40°W, 300 m, 34.89 and 4.4°C, respectively. The spatial distribution of *S. mentella* in the Irminger Sea mainly in waters < 500 m (and thus mainly relating to the "shallow" stock) appears strongly influenced by the Irminger Current Water (ICW) temperature changes, linked to the Subpolar Gyre (SPG) circulation and the North Atlantic Oscillation (NAO). The fish avoid waters mainly associated with the ICW (> 4.5°C and > 34.94) in the northeastern Irminger Sea, which may cause displacement of the fish towards the southwest, where fresher and colder water occurs.

Results based on international redfish survey data suggest that the interannual distribution of fish above 500 m will shift in a southwest/northeast direction depending on integrated oceanographic conditions (ICES, 2012).

18.2 Environmental drivers of productivity

18.2.1 Abundance and distribution of 0 group and juvenile redfish

Available data on the distribution of juvenile *S. norvegicus* indicate that the nursery grounds are located in Icelandic and Greenland waters. No nursery grounds have been found in Faroese waters. Studies indicate that considerable amounts of juvenile *S. norvegicus* off East Greenland are mixed with juvenile *S. mentella* (Magnússon *et al.*, 1988; 1990, ICES CM 1998/G:3). The 1983 Redfish Study Group report (ICES CM 1983/G:3) and Magnússon and Jóhannesson (1997) describe the distribution of 0-group *S. norvegicus* off East Greenland. The nursery areas for *S. norvegicus* in Icelandic Waters are found all around Iceland but are mainly located west and north of the island at depths between 50 and 350 m (ICES CM 1983/G:3; Einarsson, 1960; Magnússon and Magnússon, 1975; Pálsson *et al.*, 1997). As they grow, the juveniles migrate along the north coast towards the most important fishing areas off the west coast.

Indices for 0-group redfish in the Irminger Sea and at East Greenland areas were available from the Icelandic 0-group surveys from 1970–1995. Thereafter, the survey was discontinued. Above average year-class strengths were observed in 1972, 1973–1974, 1985–1991, and in 1995.

There are very few juvenile demersal *S. mentella* in Icelandic Waters (see Section 20), and the main nursery area for this species is located off East Greenland (Magnússon *et al*., 1988; Saborido-Rey *et al*., 2004). Abundance and biomass indices of redfish smaller than 17 cm from the German annual groundfish survey, conducted on the continental shelf and slope of West and East Greenland down to 400 m, show that juveniles were abundant in 1993 and 1995–1998 (Figure 18.2.1). The 1999–2006 survey results indicate low abundance and were similar to those observed in the late 1980s. Since 2008, the survey index has been very low and was in 2013–2016 the lowest value recorded since 1982. Juvenile redfish were only classified to the genus *Sebastes* spp., as identification of small specimens to species level is difficult due to very similar morphological features. Observations on length distributions of *S. mentella* fished deeper than 400 m indicate that a part of the juvenile *S. mentella* on the East Greenland shelf migrates into deeper shelf areas and into the pelagic zone in the Irminger Sea and adjacent waters (Stransky, 2000), with unknown shares.

18.3 Ecosystem considerations

Information on the ecosystems around the Faroe Islands is given in Section 2, in Icelandic Waters in Section 7 and Greenland waters in Section 13.

Analysis of the oceanographic situation in the Irminger Sea during the 2013 international survey and long-term data including 2003, allows the following conclusions:

Strong positive anomalies of temperature observed in the upper layer of the Irminger Sea with a maximum in 1998 are related to an overall warming of water in the Irminger Sea and adjacent areas in 1994–2013. These changes were also observed in the Irminger Current above the Reykjanes Ridge (Pedchenko, 2000), off Iceland (Malmberg *et al*., 2001) and in the Labrador Sea water (Mortensen and Valdimarsson, 1999). Thus, temperature and salinity in the Irminger Current have increased since 1997 to the highest values seen for decades.

The 2003 survey detected high temperature anomalies within the 0–200 m layer in the Irminger Sea and adjacent waters. At 200–500 m depth and deeper waters, positive anomalies were observed in most of the surveyed area. However, increasing temperature as compared to the survey in June–July 2001 was detected only north of 60°N in the flow of the Irminger Current above the Reykjanes Ridge and the northwestern part of the Irminger Sea. These changes in oceanographic conditions might have an effect on the seasonal distribution of redfish and its aggregations in the layer shallower than 500 m in the survey area (ICES, 2003).

In June/July 2005 and 2007, water temperature in the shallower layer (0–500 m) of the Irminger Sea was higher than normal (ICES, 2005; ICES, 2007). As in the surveys 1999–2003, the redfish were aggregating in the southwestern part of the survey area, partly influenced by these hydrographic conditions. Favourable conditions for aggregation of redfish in an acoustic layer have been marked only in the southwestern part of the survey area with temperatures between 3.6–4.5°C, as confirmed by the survey results obtained in 2009 (ICES, 2009b). The hydrography in the survey of June/July 2013 shows that temperature in the survey area is above average but it was lower than in 2011 in most of the surveyed area, except for the Irminger Current (ICES, 2013a).

18.4 Description of fisheries

There are three species of commercially exploited redfish in ICES Subareas 5, 6, 12, and 14: *S. norvegicus* (in publication both names *S. norvegicus* and *S. marinus* can be found, but according to Fernholm and Wheeler (1983) the first name is the correct name), *S. mentella* and *S. viviparus*.

S. viviparus has only been of a minor commercial value in Icelandic Waters and it is exploited in two small areas south of Iceland at depths of 150–250 m. The landings of *S. viviparus* decreased from 1160 t in 1997 to 2–9 t in 2003–2006 (Table 18.4.1) due to decreased commercial interest in this species. The landings in 2009 amounted to 37 t, more than a twofold increase compared with 2008. After a directed fishery developed in 2010, with a total catch of 2600 t, the MRI (now MFRI) advised on a 1500 t TAC for the 2012–2013 fishing year. Annual catches 2012–2015 were about 500 t but have since then decreased and were 117 t in 2018.

The group has in the past included the fraction of *S. mentella* that are caught with pelagic trawls above the western, southwestern and southern continental slope of Iceland as part of the landing statistics of the demersal *S. mentella*. This practice has been in accordance with Icelandic legislation, where captains are obligated to report their *S. mentella* catch as either "pelagic redfish" or as "demersal redfish/Icelandic slope *S. mentella*" depending in which fishing area they fish. According to this legislation, all catch outside the Icelandic EEZ and west of the 'redfish line' (red line shown in Figure 18.1.1, which is drawn approximately over the 1000 m isoclines within the Icelandic EEZ) shall be reported as pelagic *S. mentella*. All fish caught east of the 'redfish line' shall be reported as Icelandic slope *S. mentella*. Most of the catches since 1991 have been taken by bottom trawlers along the shelf west, southwest, and southeast of Iceland at depths between 500 and 800 m. The Group accepts this praxis as a pragmatic management measure but notes that there is no biological information that could support this catch allocation.

As the Review Group in 2005 noted that this issue needed more elaboration, detailed portrayals of the geographical, vertical, and seasonal distribution of the Icelandic slope *S. mentella* fisheries with different gears are presented here, as done previously (see below). Quantitative information on the fractions of the pelagic catches of Icelandic slope *S. mentella* is given in chapter 20. The proportion of the total Icelandic slope *S. mentella* catches taken by pelagic trawls has ranged since 1991 between 0% and 44% (Table 20.3.2) and is on average 15%. With exception of 2007, no Icelandic slope *S. mentella* has been caught with pelagic trawls since 2004. The geographic distribution of the Icelandic fishery for *S. mentella* since 1991 was in general close to the redfish line, off South Iceland, and has expanded into the NAFO Convention Area since 2003 (Figure 18.4.1). The pelagic catches of Icelandic slope *S. mentella* were taken in similar areas and depths as the bottom trawl catches (Figure 18.4.2). The vertical and horizontal distribution of the pelagic catches focused, however, on smaller areas and shallower depth layers than the bottom trawl catches. The seasonal distribution by depth (Figure 18.4.3) shows that the pelagic catches of Icelandic slope *S. mentella* were in general taken in autumn and overlapped in June with the traditional pelagic fishery only in 2003 and 2007. The bottom trawl catches of the Icelandic slope *S. mentella* were mainly taken in the first quarter of the year and during autumn/winter. The length distributions of the Icelandic slope *S. mentella* catches in Iceland by gear and area are given in Figure 18.4.4. During 1994–1999 and in 2003, the fish taken with pelagic trawls were considerably larger than the fish caught with bottom trawls, but they were of similar length during 2000–2002. The fish caught in the northeastern area were on average about 5 cm larger than those caught in the southwestern area. The length distribution also shows that the fish caught in northeast area since 2011 is smaller than during the period 1998–2010 and have now a size similar to that registered at the beginning of the fishery.

18.5 Demersal *S. mentella* in 5.b and 6

18.5.1 Demersal *S. mentella* in 5.b

18.5.1.1 Surveys

The Faroese spring and summer surveys in Division 5.b are mainly designed for species inhabiting depths down to 500 m and do not cover the vertical distribution of demersal *S. mentella* fully. Therefore, the surveys are not used to evaluate the stock status.

18.5.1.2 Fisheries

In Division 5.b, landings gradually decreased from 15 000 t in 1986 to about 5000 t in 2001 (Table 18.6.1). Between 2002 and 2011 annual landings varied between 1100 and 4000 t. In 2012, landings decreased drastically from 1126 t in 2011 to 263 t but has since then increased and were 863 t in 2021.

Length distributions from the landings in 2001–2018 indicate that the fish caught in 5.b in 2018 are between 35–50 cm and the mode of the distribution is around 42 cm (Figure 18.7.1).

Non-standardized CPUE indices in Division 5.b were obtained from the Faroese otter board (OB) trawlers (> 1000 HP) towing deeper than 450 m and where demersal *S. mentella* composed at least 70% of the total catch in each tow. The OB trawlers have in recent years landed about 50% of the total demersal *S. mentella* landings from 5b. CPUE decreased from 500 kg/hour in 1991 to 300 kg/hour in 1993 and remained at that level until 2013, when it reached a historical low (Figure 18.7.2). The CPUE has since remained at that level. Data for 2018–2020 were not available.

Fishing effort has decreased since the beginning of the time-series and has remained very low since 2008.

18.5.2 Demersal *S. mentella* in 6

18.5.2.1 Fisheries

In Subarea 6, the annual landings varied between 200 t and 1100 t in 1978–2000 (Table 18.6.1). The landings from 6 in 2004 were negligible (6 t), the lowest recorded since 1978. They increased again to 111 t in 2005 and 179 t in 2006. The reported landings in 2008 were 50 t and no catches have been taken since 2009.

18.6 Regulations (TAC, effort control, area closure, mesh size etc.)

Management of redfish differs between stock units and is described in sections 19.14 for *S. norvegicus*, Section 20.7 for Icelandic slope *S. mentella*, Section 21.10 for shallow pelagic *S. mentella*, Section 22.10 for deep pelagic *S. mentella*, and Section 23 for Greenland slope *S. mentella.*

The allocation of Icelandic *S. mentella* catches to the pelagic and demersal management unit has been based on the "redfish line" (see Section 18.4).

18.7 Mixed fisheries, capacity, and effort

The official statistics reported to ICES do not divide catch by species/stocks, and since the Review Group in 2005 recommended that "multispecies catch tables are not relevant to management of redfish resources", these data are not given here and the best estimates on the landings by species/stock unit are given in the relevant chapters. Preliminary official landings data were provided by the ICES Secretariat, NEAFC and NAFO, and various national data were reported to the Group. The Group, however, repeatedly faced problems in obtaining catch data, especially with respect to pelagic *S. mentella*. Detailed descriptions of the fisheries are given in the respective sections: *S. norvegicus* in Section 19.3, Icelandic slope *S. mentella* in Section 20.3, shallow pelagic *S. mentella* in Section 21.2, deep pelagic *S. mentella* in Section 22.2 and Greenland slope *S. mentella* in Section 23.3.

Information from various sources is used to split demersal landings into two redfish species, *S. norvegicus* and *S. mentella* (see stock annexes for Icelandic slope *S. mentella* and *S. norvegicus*). In Division 5.a, if no direct information is available on the catches for a given vessel, the landings are allocated based on logbooks and samples from the fishery. According to the proportion of biological samples from each cell (one fourth of ICES statistical square), the unknown catches within that cell are split accordingly and raised to the landings of a given vessel. For other areas, samples from the landings are used as basis for dividing the demersal redfish catches between *S. norvegicus* and *S. mentella*.

18.8 References

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18.9 Figures and Tables

Table 18.4.1. Landings of *S. viviparus* in Division 5.a 1996–2021.

Year	Landings (t)
1996	22
1997	1159
1998	994
1999	498
2000	227
2001	21
2002	20
2003	3
2004	2
2005	4
2006	9
2007	24
2008	15
2009	37
2010	2602
2011	1427
2012	535
2013	532
2014	550
2015	468
2016	234
2017	161
2018	117
2019	143
2020	118
2021	96

Table 18.6.1. Nominal landings (tonnes) of demersal *S. mentella* 1978–2021 in ICES divisions 5.b and 6.

Year	5.b	6
1978	7767	18
1979	7869	819
1980	5119	1109
1981	4607	1008
1982	7631	626
1983	5990	396
1984	7704	609
1985	10560	247
1986	15176	242
1987	11395	478
1988	10488	590
1989	10928	424
1990	9330	348
1991	12897	273
1992	12533	134
1993	7801	346
1994	6899	642
1995	5670	536
1996	5337	1048
1997	4558	419
1998	4089	298
1999	5294	243
2000	4841	885
2001	4696	36
2002	2552	20
2003	2114	197
2004	3931	6
2005	1593	111
2006	3421	179

Year	5.b	6
2007	1376	1
2008	750	50
2009	1077	0
2010	1202	0
2011	1126	0
2012	263	0
2013	398	0
2014	370	0
2015	537	0
2016	717	0
2017	375	0
2018	438	0
2019	367	0
2020	427	0
2021[1)]	863	0

1) Provisional

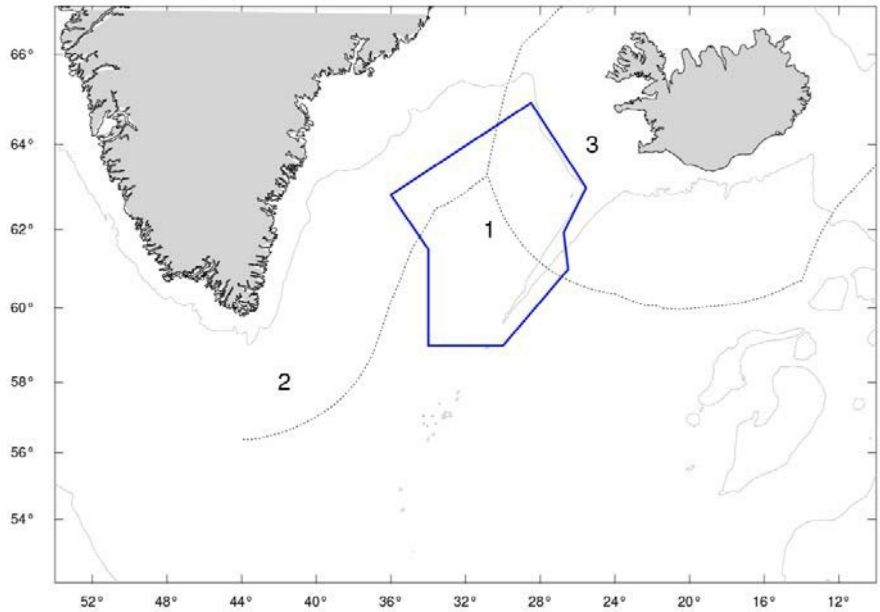

Figure 18.1.1 Potential management unit boundaries. The polygon bounded by blue lines, i.e. 1, indicates the region for the 'deep pelagic' management unit in the northwest Irminger Sea, 2 is the "shallow pelagic" management unit in the southwest Irminger Sea, and 3 is the Icelandic slope management unit.

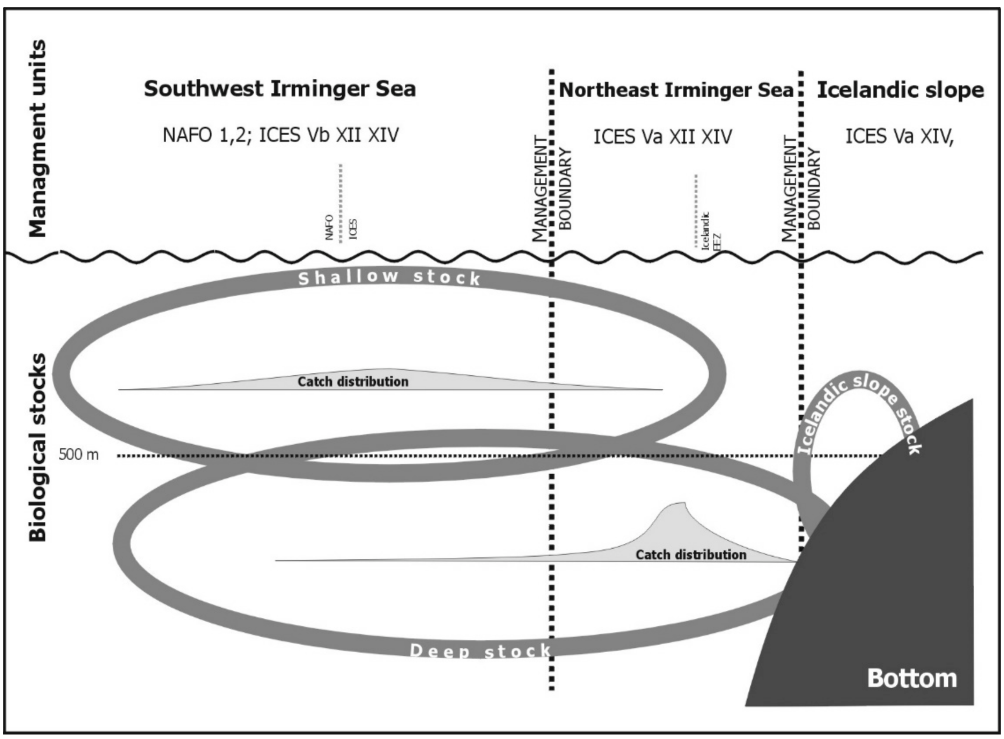

Figure 18.1.2 Schematic representation of biological stocks and potential management units of *S. mentella* in the Irminger Sea and adjacent waters. The management units are shown in Figure 18.1.1. Included is a schematic representation of the geographical catch distribution in recent years. Note that the shallow pelagic stock includes demersal *S. mentella* east of the Faroe Islands and the deep pelagic stock includes demersal *S. mentella* west of the Faroe Islands.

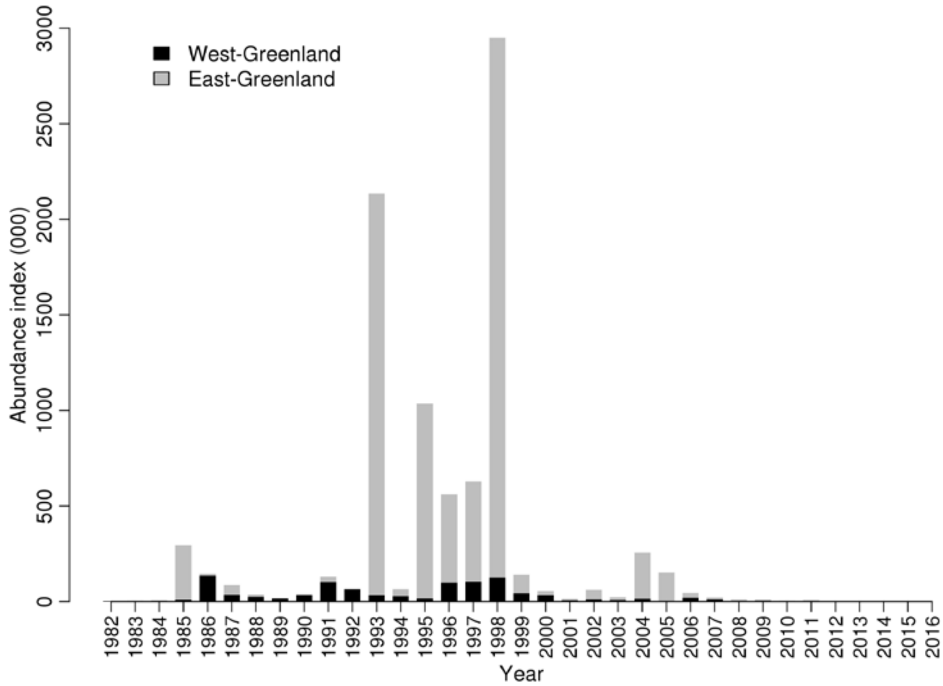

Figure 18.2.1 Survey abundance indices of *Sebastes spp.* (<17 cm) for East and West Greenland from the German ground-fish survey 1982–2016. No data were available in 2017–2020.

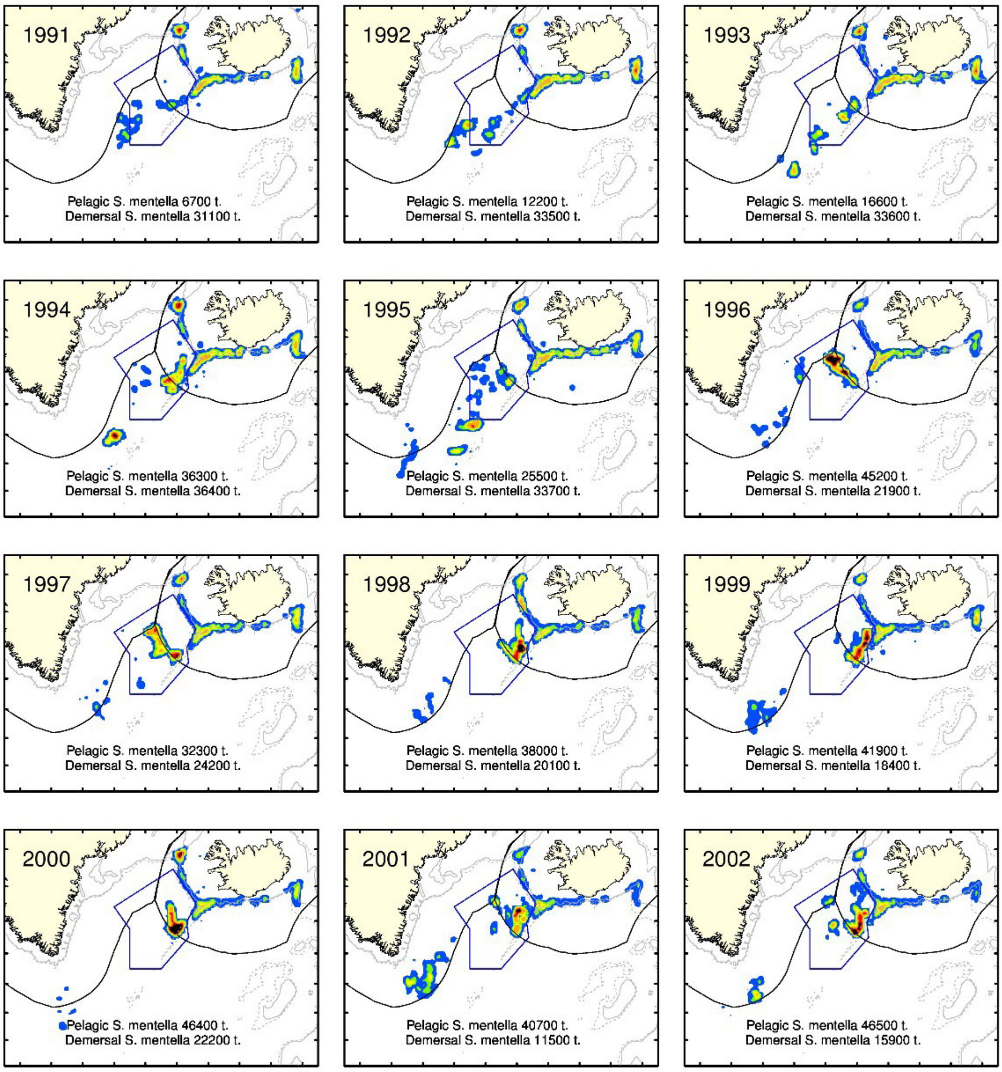

Figure 18.4.1Geographical distribution of the Icelandic catches of *S. mentella* 1991–2002. The colour scale indicates catches (tonnes per NM2). Not updated for 2019–2020.

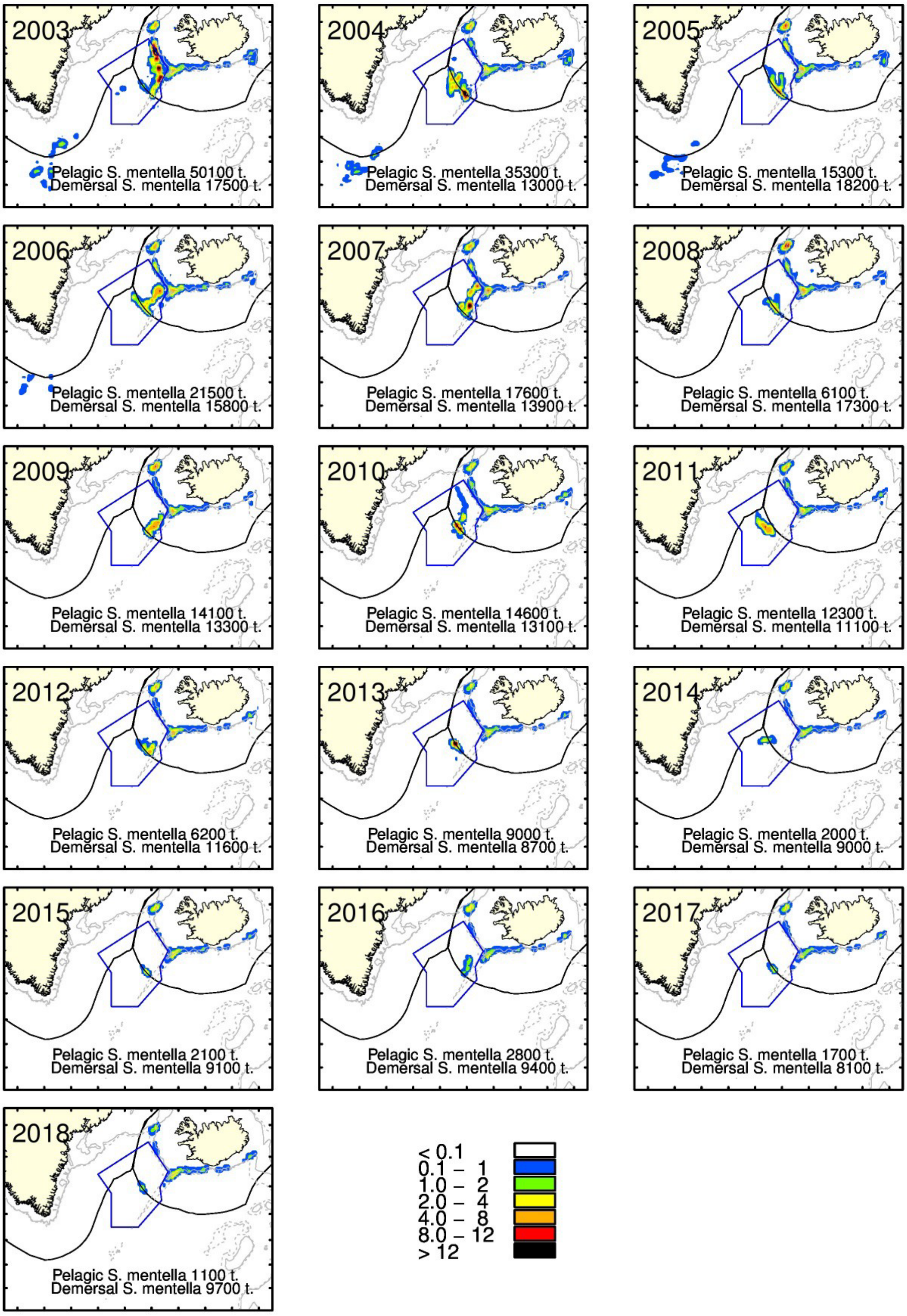

Figure 18.4.1 *cont.* Geographical distribution of the Icelandic catches of *S. mentella* 2003–2018. The colour scale indicates catches (tonnes per NM²). Not updated for 2019–2020.

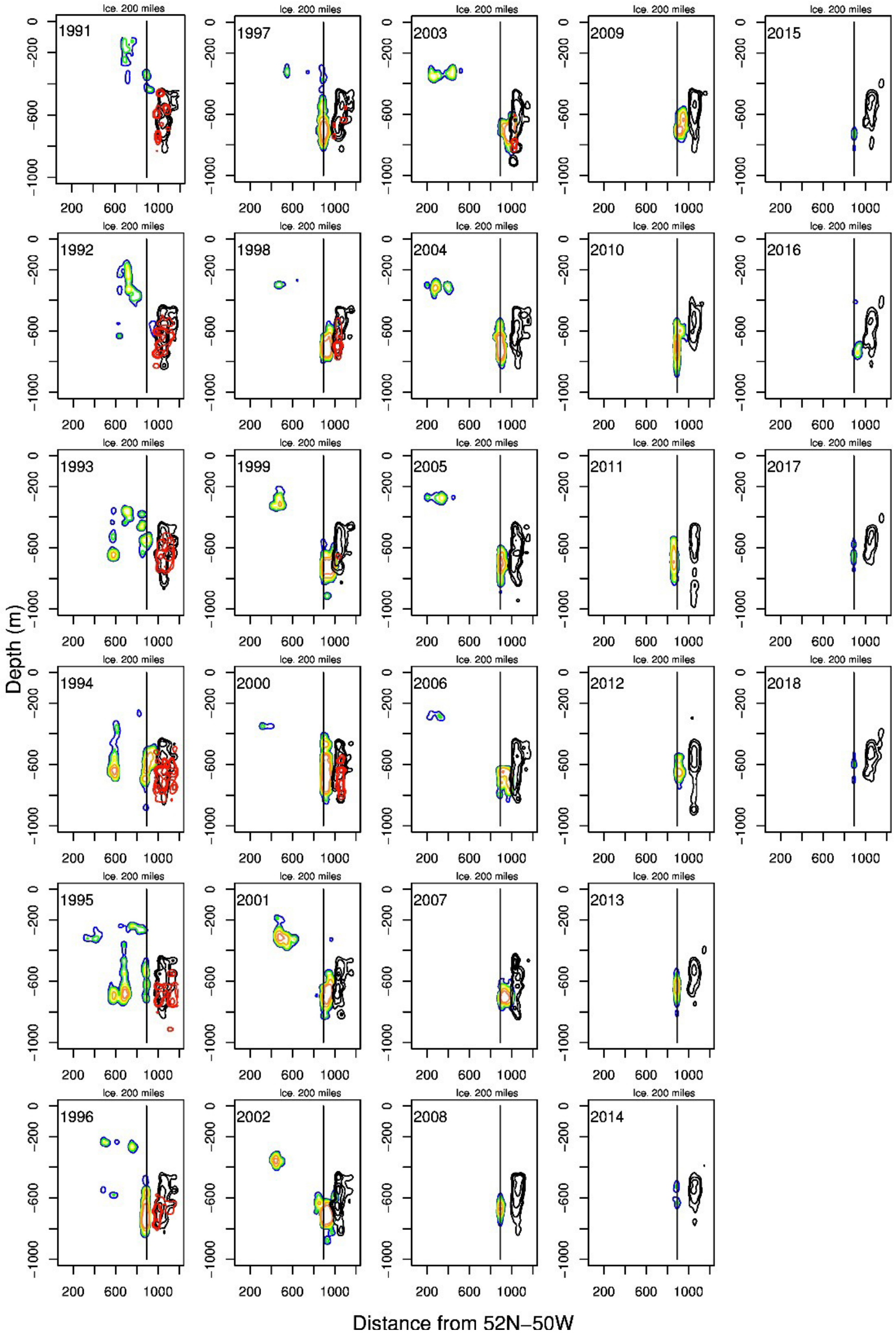

Figure 18.4.2 Distance-depth plot for Icelandic *S. mentella* catches, where distance (in NM) from a fixed position (52°N 50°W) is given. The contour lines indicate catches in a given area and distance. The coloured contours represent the fishery on pelagic *S. mentella*, the black contours indicate bottom trawl catches of demersal *S. mentella*, and the red contours represent catches of demersal *S. mentella* taken with pelagic trawls. Not updated for 2019–2020.

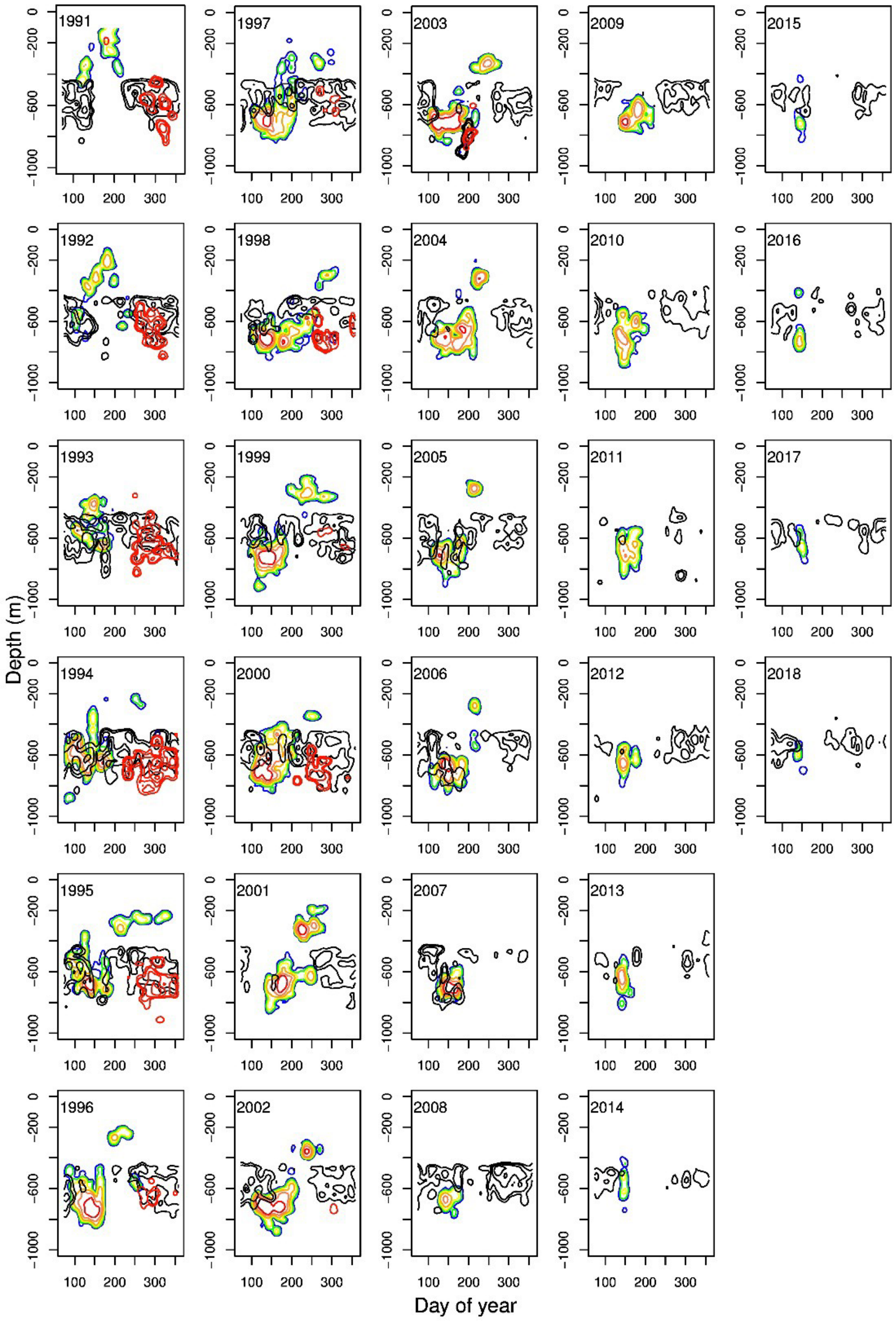

Figure 18.4.3 Depth-time plot for Icelandic *S. mentella* catches 1991–2016 where the y-axis is depth, the x-axis is day of the year and the colour indicates the catches. The coloured contours represent the fishery on pelagic *S. mentella*, the black contours indicate bottom trawl catches of demersal *S. mentella*, and the red contours represent catches of demersal *S. mentella* taken with pelagic trawls. Not updated for 2019–2020.

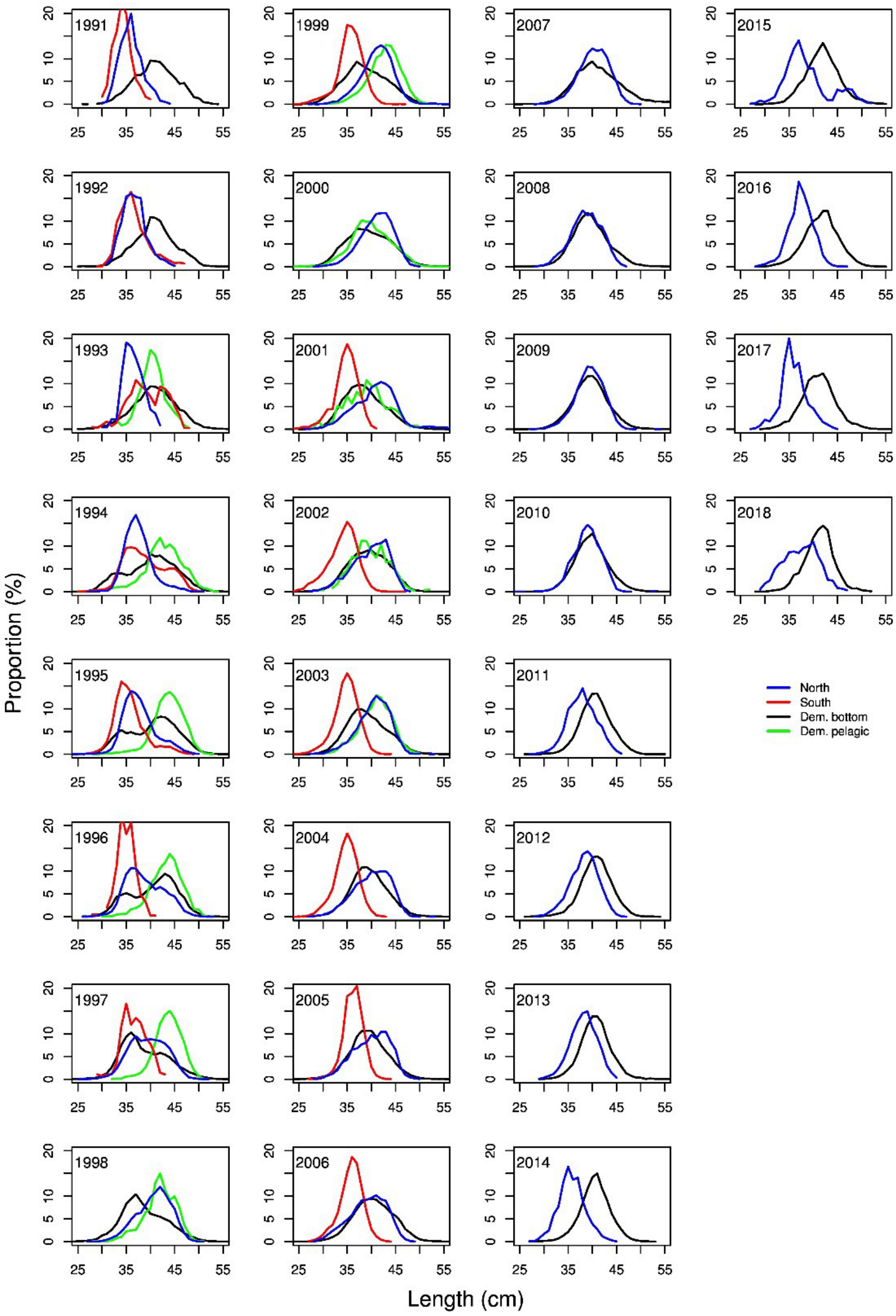

Figure 18.4.4 Length distributions from different Icelandic *S. mentella* fisheries, 1991–2018. The blue lines represent the fishery on pelagic *S. mentella* in the northeastern area, the red lines the pelagic fishery in the southwestern area, the black lines indicate bottom trawl catches of demersal *S. mentella*, and the green lines represent catches of demersal *S. mentella* taken with pelagic trawls. Not updated for 2019–2020.

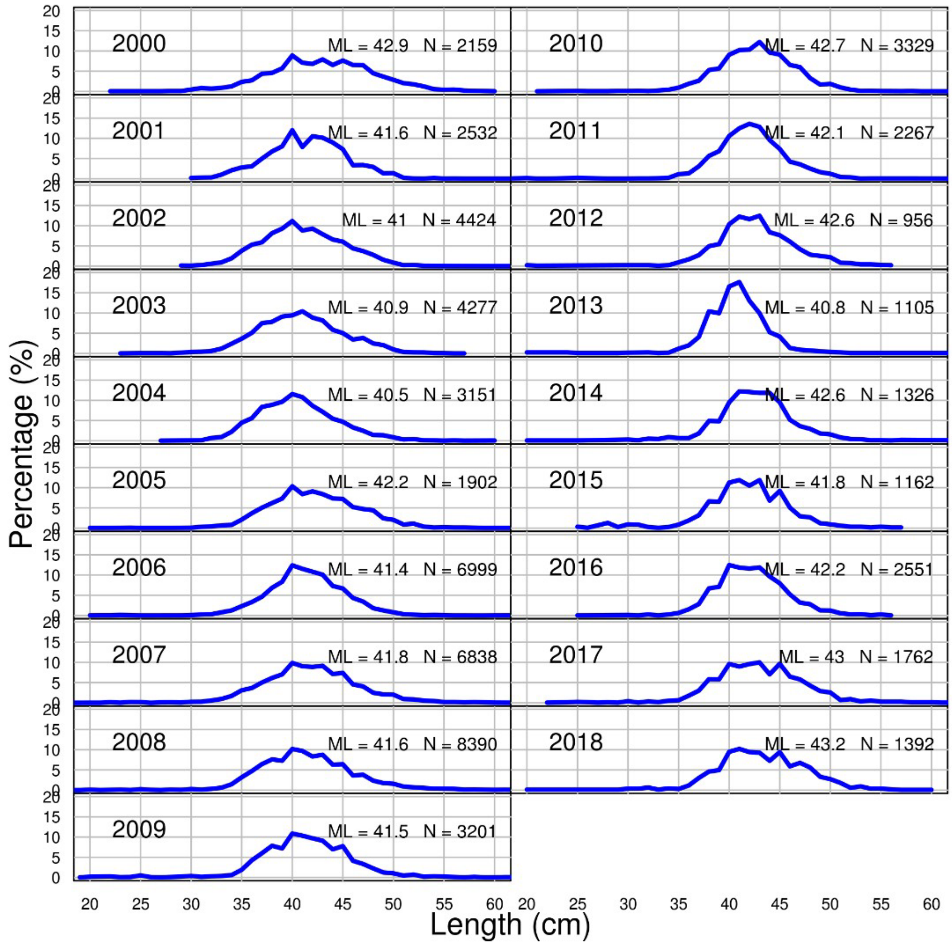

Figure 18.7.1 Length distribution of demersal *S. mentella* from landings of the Faroese fleet in Division 5.b 2000–2018. Not updated for 2019–2021.

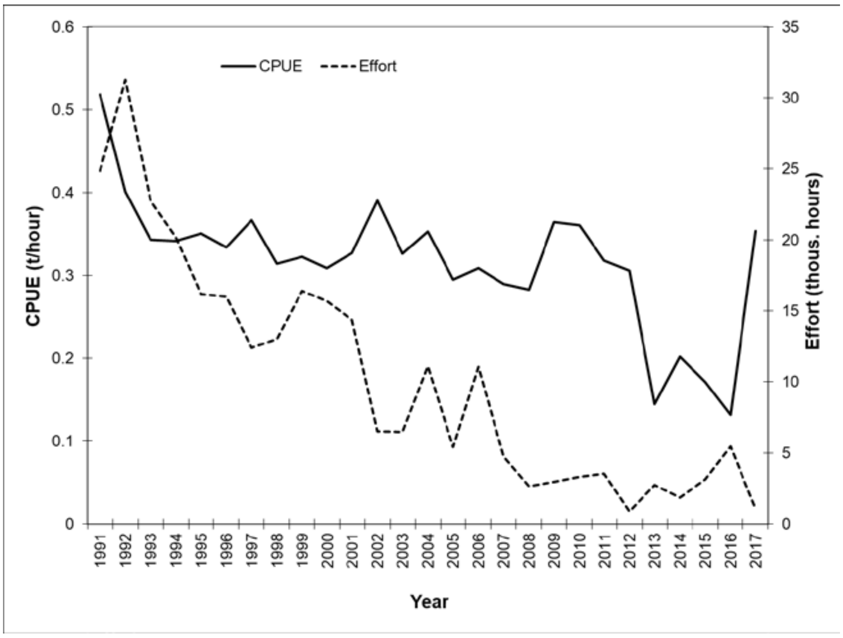

Figure 18.7.2 Demersal *S. mentella*, CPUE (t/hour) and fishing effort (in thousands hours) from the Faroese CUBA fleet 1991–2017 and where 70% of the total catch was demersal *S. mentella*. Not updated for 2018–2021.

19 Golden redfish (*Sebastes norvegicus*) in subareas 5, 6 and 14

19.1 Stock description and management units

Golden redfish (*Sebastes norvegicus*) in ICES Subareas 5 and 14 (Greenland Sea, Icelandic Waters, and Faroes Ecoregions) have been considered as one management unit. Catches in ICES Subarea 6 have traditionally been included in this report and the group continues to do so. Data from ICES Subarea 6 is, however, not used in the assessment.

19.2 Scientific data

This section describes results from various surveys conducted annually on the continental shelves and slopes of ICES Subareas 5 and 14. Detailed description of the survey design and the calculation of the survey indices for golden redfish in are given in the Stock Annex (reg-5614 SA). The calculation of the survey indices includes length dependent diel vertical migration of the species.

19.2.1 Division 5.a (Icelandic Waters Ecoregion)

Information on abundance and biological parameters from golden redfish in 5.a is available from two surveys, the Icelandic groundfish survey in the spring (IS-SMB) and the Icelandic autumn survey (IS-SMH). The spring survey has been conducted annually in March since 1985 and the autumn survey has been conducted annually in October since 1996. The autumn survey was not conducted in 2011.

The total biomass of golden redfish as observed in the spring survey decreased from 1988 to a record low in 1995 (Figure 19.1 and Table 19.1). From 2000 to 2016 the biomass increased to the highest value in the time-series and has, since then, with some fluctuation, been at that level. The total biomass index from the autumn survey shows similar trend as in the spring survey until 2019 but decreased sharply in 2020-2022 but increased again in 2023 (Figure 19.1).

Length disaggregated indices from the spring survey shows that the peaks in length 4–11 cm, which can be seen first in 1987 (the 1985 cohort) and then in 1991–1992 (the 1990 cohort) (Figure 9.1), reached the fishable stock approximately 10 years later (Figure 19.2). The increase in the survey index between 1995 and 2005 reflects the recruitment of these two strong year classes. During the 1999–2008 period the abundance of small redfish was lower than in 1986–1990, highest in 2000-2003 (Figure 19.1). In 2009-2020, very little of small redfish (4-11 cm) was observed in the spring survey. In 2021-2023 the index has increased to a similar level as it was at the turn of the century but decreased again in 2024 (Figure 19.1). This increase in small golden redfish reflects the increase in abundance of 12–29 cm fish.

The modes of the length distribution in both surveys have shifted to the right and is narrower. The abundance of golden redfish smaller than 30 cm has decreased since 2006 in both surveys (Figures 19.1-19.3).

The sharp increase in the survey indices since 2005 reflects the recruitment of the year-classes from 1996–2007 (Figure 19.4). The year classes 1996–2002 are gradually disappearing from the stock and the 2003–2008 cohorts are now the most abundant year classes in the stock. The age disaggregated abundance indices indicate that the 2009–2019 cohorts are small.

19.2.2 Division 5.b (Faroes Ecoregion)

In Division 5.b, the biomass indices of golden redfish are available from the Faroes spring groundfish survey 1994–2024 and the summer groundfish survey 1996–2023. Both survey indices show similar trends with sharp declines between 1998 and 1999 and have, since then, been at low level (Figure 19.5). The modes of the length distribution are between 40-45 cm and fish smaller the cm is rarely seen (Figures 19.6 and 19.7). The fish caught in these surveys are on the average larger than the fish caught in the Icelandic surveys and the surveys conducted in East Greenland waters.

19.2.3 Subarea 14 (Greenland Sea Ecoregion)

Information on abundance and biological parameters from golden redfish in subarea 14 is available from two surveys, the German Groundfish Survey and the Greenland Shallow Water Survey. Only information from the German survey is used in the assessment.

The German Groundfish Survey has been conducted annually in the autumn from 1982 to 2017 and in 2019-2020 covering shelf areas and the continental slopes off East Greenland. The survey was not conducted in 2018 and in 2021-2023. Abundance and biomass indices for golden redfish (fish >17 cm) are illustrated in Figure 19.8. After a severe depletion of the stock in the early 1990s, the survey estimates significantly increased from 2003 to 2016, both in biomass and abundance. In the years 2014–2016 the biomass index was at the highest level in the time-series but dropped from 2017 to 2020 to a similar level as in 2006 (Figure 19.8*a*). It should be noted that the CV for the indices is high, and the increase is driven by few very large hauls. In 2010–2020, the biomass of pre-fishery recruits (17–30 cm) has decreased compared to previous five years and in 2017-2020 very little of 17–30 cm fish was observed (Figure 19.8*c*).

The Greenland Shallow Water Survey 2008-2023 (the survey was not conducted in 2017-2019 and in 2021) covers the shelf area off East Greenland down to 600 m. Throughout the time-series, index values have been highly variable (Figure 19.10). The indices increased from very low level in the years 2008-2010 to the highest level in the 2011-2016 period. This increase was driven by the income of small fish (<30 cm) which can be followed until 2016 where the fish ranged from 25-40 cm with a mode around 30 cm (Figure 9.11). Both abundance and biomass indices decreased in 2020-2023 to a similarly low levels as in the years 2008-2010 but there is an increase in small redfish <25 cm in 2022 and 2023 (Figure 9.11).

Abundance indices of redfish smaller than 18 cm (not classified to species) from the German annual groundfish survey show that juveniles were abundant in 1993 and 1995–1998 (Figure 19.12). The juvenile index was very low in the years 2008-2020. The Greenland Shallow Water Survey also shows that very little juvenile redfish (<18 cm, not classified to species) were present in the 2013-2016 surveys (Figure 19.12). Juveniles were more abundant in the Greenland survey in 2022 and 2023 than they have been for more than a decade (Figure 19.12). Juvenile redfish in these two surveys were only classified to the genus *Sebastes* spp. as species identification of small specimens is difficult due to very similar morphological features. This increasing trend of juveniles in the Greenland Shallow Water Survey indicates potentially better recruitment of either *S. mentella* or *S. norvegicus* (or both) in the future.

19.3 Fishery

19.3.1 Landings

Total landings of golden redfish decreased gradually by more than 70% in 1982–1994 or from 130 429 t in 1982 to 43 515 t in 1994 (Table 19.2 and Figure 19.13). In the years 1995–2016, the annual landings varied between 33 451 t and 59 698 t, highest in 2016. Since then, the landings have decreased and in 2023 were 35 988 t about 3 000 t more than in 2022. This recent decrease in annual landings is directly related to decreased golden redfish TAC in East Greenland and Iceland. About 90–95% of the golden redfish catch has been taken in Icelandic Waters (ICES Division 5.a).

Landings of golden redfish in Icelandic Waters declined from 97 899 t in 1982 to 38 669 t in 1994 (Table 19.2). Since then, landings have varied between 30 037 t and 54 041 t, highest in 2016 and lowest in 2022. The landings were 32 192 t in 2023, 2155 t more than in 2022. The landings for the 2022/2023 fishing year were 24% higher than allocated quota of 22 614 t. The reasons for the implementation errors are related to the management system that allow for transfers of quota share between fishing years and conversion of TAC from one species to another. This conversion of TAC from one species to golden redfish will not be allowed from the 2023/2024 fishing season.

Between 90–95% of the golden redfish catch in in Icelandic Waters is taken by bottom trawlers targeting the species. The remaining catches are caught as bycatch in the gillnet, longline, and lobster fisheries. In 2023, as in previous years, most of the catches were taken along the shelf southwest, west, and northwest of Iceland (Figure 19.14). Larger proportion of the catches is now taken along the shelf northwest of Iceland and less south and southwest.

In Faroese waters, annual landings decreased from 9194 t in 1985 to less than 200 t in 2016 (Table 19.2). After an increase of landings in 2017-2020 landings to an annual average of 1250 t, the annual landings decreased substantially in 2021–2023 and were on average 162 t. Most of the golden redfish caught in Faroese waters is taken by pair and single trawlers (vessels larger than 1000 HP).

In East Greenland waters, the landings of golden redfish reached a record high of 30 962 t in 1982 but decreased rapidly within the next three years and to 2117 t in 1985 (Figure 19.13 and Table 19.2). During the period 1985–1994, the annual landings varied between 687 and 4255 t. There was little or no direct fishery for golden redfish in the years 1995–2009 and annual landings were 200 t or less, mainly taken as bycatch in the shrimp fishery. In 2010, landings of golden redfish increased considerable and were 1650 t. This increase was mainly dure to increased *S. mentella* fishery in the area. Annual landings 2010–2023 have been between 1000 t and to 5442 t. The landings in 2023 were 3073 t, 863 t more than in 2022.

Annual landings from Subarea 6 increased from 1978 to 1987 followed by a gradual decrease to 1992 (Table 19.2). From 1995 to 2004, annual landings have ranged between 400 and 800 t, but in 2006–2021 very little was landed from this area. Catches Subarea 6 in 2023 were close to 500 t but they have not been divided into species.

19.3.2 Discard

Comparison of sea and port samples from the Icelandic discard sampling program does not indicate significant discarding due to high grading in recent years (Pálsson *et al* 2010), possibly due to area closures of important nursery grounds west off Iceland. Substantial discard of small redfish took place in the deep-water shrimp fishery from 1986 to 1992 when sorting grids became mandatory. Since then, the discard has been insignificant both due to the sorting grid and much less abundance of small redfish in the region.

Discard of redfish species in the shrimp fishery in ICES Division 14.b is currently considered insignificant (see Section 18).

19.3.3 Biological data from commercial fishery

The table below shows the fishery related sampling by gear type and ICES divisions in 2023.

Area	Nation	Gear	Landings (t)	Samples	No. length measured	No. Age read
5.a	Iceland	Bottom trawl	32 192	68	10 324	613
5.b	Faroe Islands	Bottom trawl	182		238	
14	Greenland	Bottom trawl	3073		2347	

In general sampling is considered good from commercial catches in Icelandic Waters. The sampling does seem to cover the spatial and seasonal distribution of catches (Figures 19.15 and 19.16). In 2020 sampling effort was reduced substantially, especially the on-board sampling, due to the COVID-19 pandemic. This reduction in sampling is, however, considered to be sufficiently representative of the fishing operations and thus not considered to substantially affect the assessment of the stock.

19.3.4 Landings by length and age

The length distributions from the Icelandic commercial trawler fleet in 1976–2023 show that most of the fish caught are between 30 and 45 cm (Figure 19.17). The modes of the length distribution range between 35 and 42 cm and have over the past decade shifted to the right. The length distributions in 2012–2023 are narrower than previously, with less than average of small fish (<35 cm) caught, and the mean length has increased by almost 5 cm.

Catch-at-age data from the Icelandic fishery in Division 5.a show that the 1985-year class dominated the catches from 1995–2002 (Figure 19.18). The strong 1990 cohort dominated the catch in 2003–2007 contributing between 25–30% of the total catch in weight. In 2007–2010 the 1996–1999 cohorts dominated in the catches but are now gradually decreasing. The 2004–2009 cohorts (ages 14–19) were the most dominant year classes in the fishery in 2023. There is a substantial decrease of 7–10-year-old fish in the catch, compared to recent previous years, an additional indicator of low recruitment in recent year observed in all surveys conducted in East Greenland and Icelandic Waters.

Length distribution from the German commercial fleet in East Greenland indicates similar trend as observed in Icelandic Waters (Figure 19.19).

Length distribution from the Faroese commercial catches 2001–2020 and 2023 shows that the fish caught are on average larger than 40 cm with modes between 45 cm and 50 cm (Figure 19.20).

19.3.5 CPUE

The un-standardized CPUE index from the Icelandic bottom-trawl fleet operating in Division 5.a has increased sharply from 2006 to the highest level in the time-series in 2017-2019 (Figure 19.21. CPUE has in since then decreased although it remains high. Data were not available for 2022. Effort towards golden redfish has gradually decreased since 1986 and is now at the lowest level recorded (Figure 19.21). CPUE derived from logbooks is not considered indicative of stock trends however the information contained in the logbooks on effort, spatial and temporal distribution the fishery is of values.

CPUE from other areas are not available.

19.4 Analytical assessment

The stock was benchmarked in February 2023 (WKBNORTH 2023, ICES 2023) which resulted in changes in the assessment method (SAM model) and updated reference points. The Gadget model development was discontinued as it was apparent that there was a long enough time-series of age data to run an age-based assessment.

The model setup and model are described in the Stock Annex.

19.4.1 Survey indices

A designed method (Cochran, 1977) is used to calculate the survey indices for golden redfish for each of five surveys conducted in the Greenland Waters, Icelandic Waters, and the Faroes Ecoregions. In the SAM model input data, two length disaggregated survey indices were made in order to cover the full range of the stock:

1. Spring survey index
    - Icelandic spring survey 1985–2024.
    - German autumn survey index 1984–2020, which the year was shifted by one year (y + 1). For 2018 (missing) the average of 2017 and 2019 was used, and for 2021–2023 (missing) the index for 2020 was applied.
    - Faroese spring survey 1994–2024. The indices for 1985–1993 were the averages of 1994–1999.
2. Autumn survey index:
    - Icelandic autumn survey 1996–2023. For 2011 (missing) the average of 2010 and 2012 was used.
    - German autumn survey 1996–2020 from East Greenland. For 2018 (missing) the average of 2017 and 2019 was used, and for 2021–2023 (missing) the index for 2020 was applied.
    - Faroese summer survey 1996–2023.

Figure 19.22 shows the two combined survey indices divided by area. The survey index is mainly driven by the Icelandic survey indices.

19.4.2 Stock weights

Although golden redfish rarely attain sizes over 60 cm and 2 kg in the surveys and commercial catches, their growth is highly variable from year to year, leading to a wide range of ages possible from roughly 30 cm. Age–length keys are therefore highly variable, and this is thought to be the result of variable growth rather than ageing error, as ageing consistency is anecdotally good. Despite temporal differences in growth, the length-weight relationship is highly stable, so there is likely little variation in condition.

Fish weights at length are available from both surveys and commercial data (Figures 19.23 and 19.24). Stock weights were calculated as the mean weight at age taken from the combined spring survey, after converting lengths to weights using an estimated power relationship from fish with both length and weight data collected in both survey and commercial samples. Weights are calculated as the mean weight expected from the length distribution observed for that year. Before 1985, survey data were replaced with catch weight data, which are available from 1980. Where weights at a certain age were missing. which occurred only in very rare cases, data from the other data sources were used to fill the gap. To reduce variation among years, stock weights were calculated as a moving average of the current and previous year.

19.4.3 Maturity

Maturity at length is stable rather stable among years and regions, so a fixed maturity ogive is applied to length distributions and then averaged within ages after the ALK is applied. In the past Gadget model, a fixed ogive has been used: P = 1/(1+exp(-0.3122*(length + 1.5 - 33.54)). To help compare between modelling frameworks, this ogive was maintained. The updated ogive was based on fitting a maturity-at-length ogive to length data pooled across all years, using maturity data taken from the spring survey. The updated ogive is the one proposed to be used here: although changing the maturity ogive has no impact on model estimation, it does have an impact on calculation of spawning-stock biomass and therefore reference point generation. All reference points calculated are based on using the updated maturity ogive. To reduce variation among years, maturity-at-age was taken as the average between this and the previous year for ages less than 15 and the average over this and the three years prior for ages 15 and greater. Maturity-at-age is shown in Figure 19.25.

19.4.4 Natural mortality

In the previous Gadget model, natural mortality, M, was set to 0.05 with the plus age group set to 0.1. The same procedure is done in this model, so that all profile likelihoods include a plus group with a natural mortality value set to 0.1.

19.4.5 Assessment

The SAM model runs from 1966 onwards and ages 6 to 25+ are tracked by the model, treating age 25 as a plus group. Observations in SAM are assumed to arise from a multivariate normal process with an expected value derived from the model. SAM allows for the investigation of how to treat patterns in the residuals by defining different parameters by age for observation residual variances and correlations for all datasets. Furthermore, the user can define age groups for survey catchabilities, and related power relationships, and process variances for the $\log(N)$ and $\log(F)$ residuals.

SAM model development began with ALK refinement and choice of model age structure that emphasized correlations among consecutive cohort observations within catch-at-age and survey index data. The youngest ages observed in the catches were discarded due to high noise (ages 5 and 6), and the model begins at the earliest age that golden redfish start appearing in the surveys consistently (age 6).

19.4.5.1 Data and model settings

Below is a brief description of the data used in the model and the model settings is given. A more detailed description is given in the Stock annex.

- The simulation period is from 1966 to 2024.
- Two survey indices for the whole area used.
    - Spring survey length data from 1985–2024. As little age data are available for the spring survey, it was inputted as a single total biomass series.
    - Autumn survey length and age data from 1996–2023.
- Age ranges in the model spanned ages 6–25+.
    - Although age data range to 60, individual ages detected can be sparse by year in the range 25–60.
- Age–length keys (ALKs) for the surveys were created and applied within regions (east vs. west) to account for regional growth differences from autumn survey data.

  - The east ALK was applied to length data from Faroese surveys and the west ALK was applied to length data from Greenlandic surveys.
- ALKs generated from commercial samples were applied within biannual periods (January-June and July-December, but not by region) to catch length distributions.
- All ALKs were created using 2 cm length bins from 6–60 cm, with longer bins at lengths 0–6, 61–70, and 70+.
- Catch-at-age and total landings are available from 1966, but only those from 1995 onwards are used due to available age data.
- An ALK generated by pooling data from the years 1995–2003 was applied to length distribution data in 1966 and 1972.
- Annual ALKs were created from 1995 onwards to account for time-variable growth. These ALKs are time-specific (biannual, January-June and July-December) and applied to the approximate amount of catch from the corresponding period. This was done to account for differences in growth patterns between sampling times.
- Total catch-at-age over sectors is used in the tuning.
- Only Icelandic commercial length distribution data were used.
  - These total catches-at-ages were scaled according to total landings across all countries and areas fished within the stock.
- Recruitment was set at age 6.
- Natural mortality (M) was set to 0.05, except for the oldest age (25+) which was set to 0.1.

19.4.5.2 Results of the assessment model

Summary of the assessment is shown in Figure 19.26 and Table 19.2.

Population dynamics of the golden redfish estimated in this model show a clear trend of dynamic recruitment period from 1990–2013. Relatively high recruitment during 2000–2013 corresponds to increased spawning-stock biomass (SSB) and catches after 2010 (Figure 19.25). However, recruitment has decreased greatly since 2014 and shows a prolonged period of low recruitment. It is difficult to suggest whether this indicates a productivity shift or a long low period in a highly autocorrelated recruitment series. Fishing mortality has declined since 1990 but has been rather steady in recent years. The spawning-stock biomass observed over the past decade in this model is higher than that observed in the previous Gadget model, largely because of variable growth: a large number of relatively old fish in the stock are better accounted for in this model, increasing the numbers of old spawners. Faster growth of smaller fish indicates a greater contribution of smaller fish to the spawning biomass as well. Any trends prior to the onset of age data (1996) should be taken with caution due to a lack of data supporting the model during this period.

19.4.5.3 Retrospective analysis

The analytical retrospective pattern (five-year peel) of the assessment is presented in Figure 19.27. The newest run shows upward revision of SSB compared to previous assessment and it is related to the increased biomass in the autumn survey in 2023.

The table below shows the Mohn's rho values for SSB, F and recruitment for this five-year peel:

Variable	Value
F_{bar}	0.158
SSB	-0.038
Recruitment	-0.325

The Mohn's rho values for F_{bar} and the spawning-stock biomass are relatively low or 3.8% and 1.6% respectively. Mohn's rho for recruitment is on the other hand higher (33%) and is likely a result of high uncertainty due to low selectivity at the smallest age (6) detectable by the surveys. Mohn's ρ values are within the range recommended by Carvalho et al. [2] (< 0.2).

19.4.5.4 Diagnostics

Fits to the survey numbers-at-age indices and the catch-at-age data can be found in Figures 19.28 and 19.29 and to the spring survey index in Figure 19.30. The fit to total catch and landings data are shown in Figure 19.31. Catch and spring survey data are followed the closest by the model, whereas fits to the autumn survey series are slightly noisier but follow a similar pattern. Fits to landings data are quite variable, but more recent fits catch-at-age data are better.

Neither observation nor process residuals show obvious trends (Figures 19.32 and 19.33).

An overview of model parameter estimates is shown in Figure 19.34. Parameters with similar values were joined across ages within data sources if estimates overlapped substantially; therefore, those left show appreciable differentiation.

19.4.5.5 Leave-one-out analysis

Figure 19.34 shows the results comparing the full model estimates with estimates where the landings has been omitted from the observation likelihood. When leaving out the spring and autumn survey the model did not converge.

19.5 Reference points

During the 2023 Benchmark meeting, reference points were updated (Table 19.3). In line with ICES technical guidelines, the MSY $B_{trigger}$ is set to be set at B_{pa} in simulations with the ICES advice rule implemented (i.e. constant target fishing rate above $B_{trigger}$, which is scaled down by the ratio SSB/$B_{trigger}$ when SSB < $B_{trigger}$). Maximum yield is estimated to be obtained at an F of 0.112. F_{p05}, i.e. the maximum F that has less than 5% chance of SSB going below B_{lim} when the advice rule is applied, is more than the F maximizing yield 0.112, thus not limiting the estimate of F_{MSY}.

19.6 State of the stock

The results from SAM assessment model indicate that fishing mortality has been low and below F_{MSY} since 2009 (Figure 19.26). Total biomass and SSB has been decreasing since 2016 but remain high (Figure 19.26). Results from surveys in Iceland and East Greenland indicate that cohorts from 2009 to ca. 2019 are poor. There are, however, indications in the 2021-2023 surveys in both areas of increased number of small golden redfish (< 12 cm). The accuracy of the surveys as an indicator of recruitment is not known but recruitment in the next few years is expected to be poor.

19.7 Short-term forecast

Short-term projections are performed using the standard procedure in SAM using the **forecast** function. Three-year averages are used for stock and catch weights, and maturity. From this projection the advice is derived. As recruitment over the past 8 years has been consistently lower than historical values, the stock is projected as the mean recruitment over the previous 5 years, continuing current practice from recent years. Catches in 2024 were set as the TAC for 2024.

The results from the short-term prognosis with different fishing mortality is shown in Table 19.4. The results indicate that when fishing according to the ICES MSY approach the SSB is expected to decrease but is well above MSY $B_{trigger}$ (Table 19.3).

19.8 Medium-term forecast

No medium-term forecast was carried out.

19.9 Uncertainties in assessment and forecast

It is clear that large changes in growth have occurred in recent years in golden redfish, both for older and younger fish. It is possible that these changes could be due to density-dependence, but ecosystem shifts have also been observed in other species around Iceland. If it becomes clear that growth shifts as expected during the decline of the stock expected over the next 5-10 years, then growth may be predicted by a cohort or annual effect, and this may improve short-term forecasts and how closely actual harvest rates result from those expected under implementation of the ICES advice. As these changes in growth have likewise modified our current view of spawning-stock biomass, it would also be prudent to know whether the changing age structure of the spawning-stock biomass affects recruitment.

It is not 100% clear whether survey selectivity patterns vary logistically with age or are more dome-shaped, as both configurations gave a similar fit to the data, but different views of total-stock biomass. As changes in growth have recently coincided with shifts in commercial selectivity that appear to be due to spatial shifts in fishing effort, it may also be useful to research whether density-dependent shift in growth is spatially explicit.

19.10 Comparison with previous assessment and forecast

In 2014–2022, the Gadget model (Globally applicable Area Disaggregated General Ecosystem Toolbox) was used for the assessment of golden redfish. Several issues have come up regarding this assessment framework, prompting a need for this benchmark. First, length-based survey indices of different length ranges are in disagreement with each other. That is, if the assessment is to fit the index of the smallest length range of golden redfish, then it will have to disregard patterns in the largest length range, and vice versa. Second, this disagreement in length indices is also apparent in length distribution data as narrowed distributions with little recruitment visible in recent years, but also little indication of larger sized fish, despite its high longevity. Finally, growth appears to differ slightly by region, but length-at-age data are highly variable and shows a trend toward larger fish at smaller ages in recent years. It is possible this is a result of density-dependent somatic growth.

Age-based models give more stable results than then Gadget counterpart when differences in growth are accounted for by applying region- and time-specific age–length keys (ALKs) while generating total catch and survey data.

19.11 Basis for advice

ICES MSY approach agreed during the WKBNORTH meeting (ICES 2023).

19.12 Management consideration

In 2009 a fishery targeting redfish was initiated in Subarea 14 with annual catches of between 6000 and 8500 t in 2010–2020, highest in 2015 and lowest in 2018. The fishery does not distinguish between species, but based on survey information, golden redfish is estimated to be between 1000 and 2700 in 2010–2015 but increased to 3000–5400 t in 2016–2020.

Subarea 14 is an important nursery area for the entire resource. Measures to protect juvenile in Subarea 14 should be continued (sorting grids in the shrimp fishery).

No formal agreement on the management of *S. norvegicus* exists among the three coastal states, Greenland, Iceland, and the Faroe Islands. An agreement was made between Iceland and Greenland in July 2023 on the management of the golden redfish fishery based on the ICES management plan applied in 2023. The management strategy is to maintain the exploitation rate at the rate which is consistent with the precautionary approach and that generates maximum sustainable yield (MSY) in the long term. The agreement is from the beginning of 2024. The new agreement stated that each year 91% of the TAC is allocated to Iceland and 11% is allocated to Greenland. Furthermore, 300 t are allocated each year to other areas before allocation to Iceland and Greenland.

In Greenland and Iceland, the fishery is regulated by a TAC and in the Faroe Islands by effort limitation. The regulation schemes of those states have previously resulted in catches more than TACs advised by ICES.

Since 2009, surveys of redfish in the stock area have consistently shown very low abundance of young redfish (<30 cm). Biomass (SSB and the harvestable biomass) increased from 1995 to 2015 because of recruitment of several strong year-classes to the stock. Since then, the biomass has declined. The absence of any indications of any incoming cohorts raises concerns about the future productivity of the stock.

19.13 Regulation and their effects

In the late 1980s, Iceland introduced a sorting grid with a bar spacing of 22 mm in the shrimp fishery to reduce the bycatch of juveniles in the shrimp fishery north of Iceland. This was partly done to avoid redfish juveniles as a bycatch in the fishery, but also juveniles of other species. Since the large year classes of golden redfish disappeared out of the shrimp fishing area, there in the early 1990s, observers report small redfish as being negligible in the Icelandic shrimp fishery. If the sorting grids work where the abundance of redfish is high is a question but not a relevant problem now in 5.b as abundance of small redfish is low and shrimp fisheries limited.

There is no minimum landing size of golden redfish in Division 5.a. However, if more than 20% of a catch observed on board is below 33 cm a small area can be closed temporarily. A large area west and southwest of Iceland is closed for fishing to protect young golden redfish.

There is no regulation of the golden redfish in Division 5.b.

Since 2002 it has been mandatory in the shrimp fishery in Subarea 14 to use sorting grids to reduce bycatches of juvenile redfish in the shrimp fishery.

19.14 References

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19.15 Figures and Tables

Table 19.1. Official landings (in tonnes) of golden redfish, by area, 1966–2023 as officially reported to ICES. Landings statistics for 2023 are provisional. Note that the catch in ICES Division 6 is not used in the assessment.

Year	Area				Total
	5.a	5.b	6	14	
1966	59 245	54		23 290	82 589
1967	47 413	64		33 198	80 675
1968	45 089	99		23 079	68 267
1969	48 391	33		30 367	78 792
1970	42 662	33		18 162	60 857
1971	47 498	24		20 436	67 958
1972	36 857	53		13 970	50 880
1973	33 605	206		7899	41 710
1974	36 219	473		13 978	50 670
1975	40 029	963		20 915	61 907
1976	40 519	109		53 545	94 172
1977	38 507	767		14 433	53 707
1978	31 300	2039	313	15 477	49 129
1979	56 616	4805	6	15 787	77 214
1980	62 052	4920	2	22 203	89 177
1981	75 828	2538	3	23 608	101 977
1982	97 899	1810	28	30 692	130 429
1983	87 412	3394	60	15 636	106 502
1984	84 766	6228	86	5040	96 120
1985	67 312	9194	245	2117	78 868
1986	67 772	6300	288	2988	77 348
1987	69 212	6143	576	1196	77 127
1988	80 472	5020	533	3964	89 989
1989	51 852	4140	373	685	57 050
1990	63 156	2407	382	687	66 632
1991	49 677	2140	292	4255	56 364

Year	Area				Total
	5.a	5.b	6	14	
1992	51 464	3460	40	746	55 710
1993	45 890	2621	101	1738	50 350
1994	38 669	2274	129	1443	42 515
1995	41 516	2581	606	62	44 765
1996	33 558	2316	664	59	36 597
1997	36 342	2839	542	37	39 760
1998	36 771	2565	379	109	39 824
1999	39 824	1436	773	7	42 040
2000	41 187	1498	776	89	43 550
2001	35 067	1631	535	93	37 326
2002	48 570	1941	392	189	51 092
2003	36 577	1459	968	215	39 219
2004	31 686	1139	519	107	33 451
2005	42 593	2484	137	115	45 329
2006	41 521	656	0	34	42 211
2007	38 364	689	0	83	39 136
2008	45 538	569	64	80	46 251
2009	38 442	462	50	224	39 178
2010	36 155	620	220	1653	38 648
2011	43 773	493	83	1005	45 354
2012	43 089	491	80	1973	45 633
2013	51 330	372	92	1485	53 279
2014	47 775	202	60	2706	50 743
2015	48 769	270	44	2562	51 645
2016	54 036	179	50	5442	59 707
2017	50 119	1418	93	4511	56 141
2018	48 014	1129	80	4004	53 227
2019	44 746	1119	101	2665	48 631

Year	Area				Total
	5.a	5.b	6	14	
2020	40 688	1304	100	4105	46 197
2021	39 616	178	100	3532	43 426
2022	30 037	128	498	2210	32 873
2023[1)]	32 192	182	541	3073	35 988

Table 19.2. Golden redfish in 5, 6, 12, and 14. Assessment summary. Catches from ICES Subarea 6 are not included in the assessment Weights are in tonnes. Recruitment in thousands. 'High' and 'Low' refer to 95% confidence intervals.

Year	Recruitment (Age 6)			SSB			Landings	Fishing mortality (Ages 9-19)		
	Median	High	Low	Median	High	Low		Median	High	Low
1966	170890	70088	416669	236036	170640	326494	82589	0.171	0.130	0.226
1967	128723	65522	252886	220779	156682	311097	80675	0.188	0.141	0.252
1968	122197	63722	234331	206800	143644	297724	68267	0.177	0.128	0.245
1969	144824	69245	302894	197743	133769	292312	78792	0.204	0.141	0.295
1970	163418	78452	340403	189549	124530	288517	60857	0.176	0.115	0.269
1971	171588	66324	443921	188624	121054	293909	67958	0.191	0.119	0.308
1972	149864	44582	503770	190829	120820	301404	50881	0.148	0.088	0.249
1973	144381	44902	464250	202150	128768	317353	41710	0.115	0.067	0.198
1974	149802	47116	476285	218625	141305	338252	50634	0.132	0.078	0.224
1975	164489	47583	568618	230978	150696	354029	61907	0.163	0.096	0.278
1976	151378	45300	505861	235571	153920	360536	94171	0.189	0.110	0.327
1977	177784	75507	418599	236995	156663	358517	53708	0.121	0.071	0.206
1978	175101	77098	397681	252165	172934	367698	48816	0.099	0.060	0.161
1979	134558	61881	292593	271487	194336	379268	77208	0.13	0.084	0.203
1980	115396	54059	246327	280876	208039	379214	89174	0.156	0.106	0.229
1981	124826	58907	264508	281325	214932	368227	101975	0.18	0.129	0.251
1982	76249	35816	162330	270810	212396	345287	130401	0.228	0.169	0.308
1983	65265	30754	138501	250145	199175	314160	106443	0.207	0.157	0.273
1984	69502	33736	143187	234206	189029	290180	96033	0.191	0.147	0.248
1985	81206	40864	161373	218916	178327	268744	78622	0.164	0.130	0.207

Year	Recruitment (Age 6)			SSB			Landings	Fishing mortality (Ages 9-19)		
	Median	High	Low	Median	High	Low		Median	High	Low
1986	160213	82665	310506	208101	171106	253095	77062	0.17	0.136	0.213
1987	135089	72409	252026	198718	164685	239784	76552	0.178	0.143	0.221
1988	74607	40998	135769	181922	151183	218912	89456	0.228	0.182	0.285
1989	50300	28249	89565	164795	137558	197426	56678	0.179	0.145	0.220
1990	67026	39302	114306	154385	130609	182488	66246	0.214	0.177	0.260
1991	198760	122705	321957	135281	115364	158637	56072	0.205	0.172	0.245
1992	87304	54292	140389	123684	106128	144145	55671	0.214	0.179	0.257
1993	51681	32694	81694	114410	98749	132555	50249	0.203	0.169	0.244
1994	55638	35990	86010	110480	95507	127802	42386	0.177	0.148	0.212
1995	59342	38777	90811	115872	100339	133810	44160	0.154	0.131	0.180
1996	139637	92718	210300	122566	106409	141177	35933	0.134	0.114	0.157
1997	83023	55747	123644	127573	110990	146633	39218	0.132	0.113	0.155
1998	36689	24539	54854	142131	123536	163526	39445	0.132	0.113	0.155
1999	42818	28758	63754	152391	132154	175728	41267	0.128	0.109	0.151
2000	110593	74675	163789	148862	129193	171524	42773	0.131	0.112	0.155
2001	45034	30210	67133	152139	131958	175407	36791	0.101	0.086	0.120
2002	211865	140524	319425	150777	131153	173336	50700	0.139	0.118	0.164
2003	155839	103992	233536	155543	134801	179476	38252	0.121	0.102	0.143
2004	202028	136182	299711	168476	146056	194338	32933	0.096	0.081	0.114
2005	119972	81298	177042	175697	152146	202894	45192	0.118	0.100	0.139
2006	175145	119263	257212	186164	160808	215518	42211	0.103	0.087	0.122
2007	215455	146108	317716	200202	172808	231938	39136	0.093	0.078	0.110
2008	128691	87285	189740	214125	184843	248044	46187	0.106	0.089	0.126
2009	149350	101063	220708	222874	192069	258619	39128	0.088	0.074	0.105
2010	222450	148828	332492	237834	205096	275797	38425	0.077	0.065	0.093
2011	165364	109347	250078	263284	227189	305113	45272	0.077	0.065	0.093
2012	101154	67923	150644	292228	252558	338128	45553	0.073	0.061	0.086
2013	206915	140005	305802	319474	276176	369561	53186	0.081	0.068	0.096

Year	Recruitment (Age 6)			SSB			Landings	Fishing mortality (Ages 9-19)		
	Median	High	Low	Median	High	Low		Median	High	Low
2014	89149	59114	134443	330222	285824	381516	50683	0.072	0.060	0.085
2015	47867	31632	72434	355776	307448	411699	51602	0.070	0.059	0.083
2016	11342	7024	18314	373542	322719	432369	59657	0.076	0.064	0.090
2017	29669	19163	45935	384722	331549	446423	56044	0.076	0.064	0.091
2018	83639	53193	131512	374623	321230	436891	53147	0.072	0.060	0.086
2019	10696	6323	18096	351196	300051	411058	48529	0.067	0.056	0.08
2020	15795	9340	26711	336763	285830	396773	46097	0.068	0.056	0.081
2021	48420	27288	85917	336188	284330	397504	43318	0.064	0.053	0.077
2022	50200	25415	99155	327300	275669	388601	32375	0.060	0.050	0.072
2023	42679	17932	101578	331688	277286	396765	35446	0.069	0.056	0.085
2024	31698	9523	105512	315682	259150	384546				

Table 19.3 Golden redfish in subareas 5, 6, 12, and 14. Reference points, values, and their technical basis. All weights are in tonnes.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	154 094	B_{pa}	ICES (2023a)
	F_{MSY}	0.112	Fishing mortality that leads to MSY; estimated using stochastic simulations.	ICES (2023a)
Precautionary approach	B_{lim}	110 893	B_{loss}. Lowest SSB (1994)	ICES (2023a)
	B_{pa}	154 094	B_{lim} x exp(0.2×1.645)	ICES (2023a)
	F_{lim}	0.167	Fishing mortality that in stochastic equilibrium will result in median SSB at B_{lim}	ICES (2023a)
	F_{pa}	0.114	Maximum F at which the probability of SSB falling below B_{lim} is <5%	ICES (2023a)

Table 19.4 Assumption and output from short-term prognosis. All weights are in tonnes. Landings for 2024 is assumed to be the same as the quota set for Iceland and Greenland.

SSB (2025)	F_{9-19} (2024)	Landings (2024)	$R_{age\ 6}$ (2024)	SSB (2024)
281 192	0.098	41 286	31 698	315 682

Basis	Total catch (2025)	F_{9-19} (2025)	SSB (2026)
MSY	46 911	0.112	258 906
Other catch options			
F_0	0	0	290 762
$F_{sq} = F_{2023}$	29 774	0.069	276 983

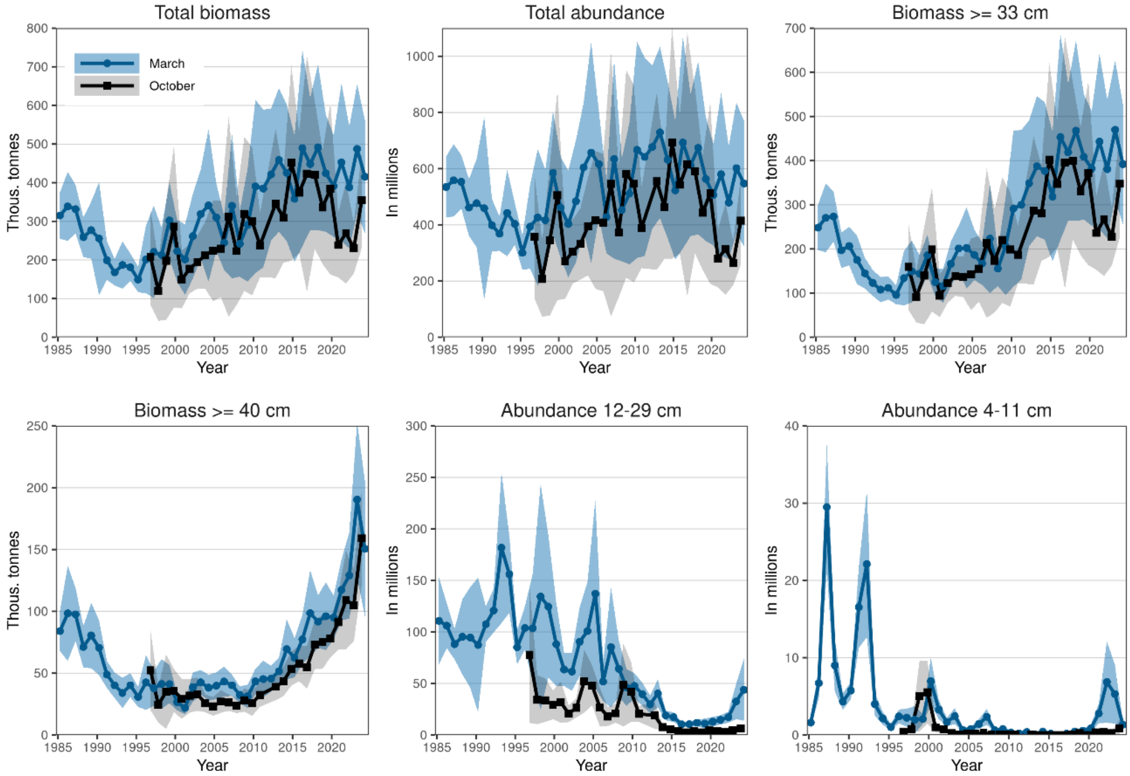

Figure 19.1 Indices of golden redfish in ICES Division 5.a (Icelandic Waters) from the groundfish surveys in March 1985–2024 (blue line and shaded area) and October 1996–2023 (black lines and shaded areas). The shaded areas represent 95% CI.

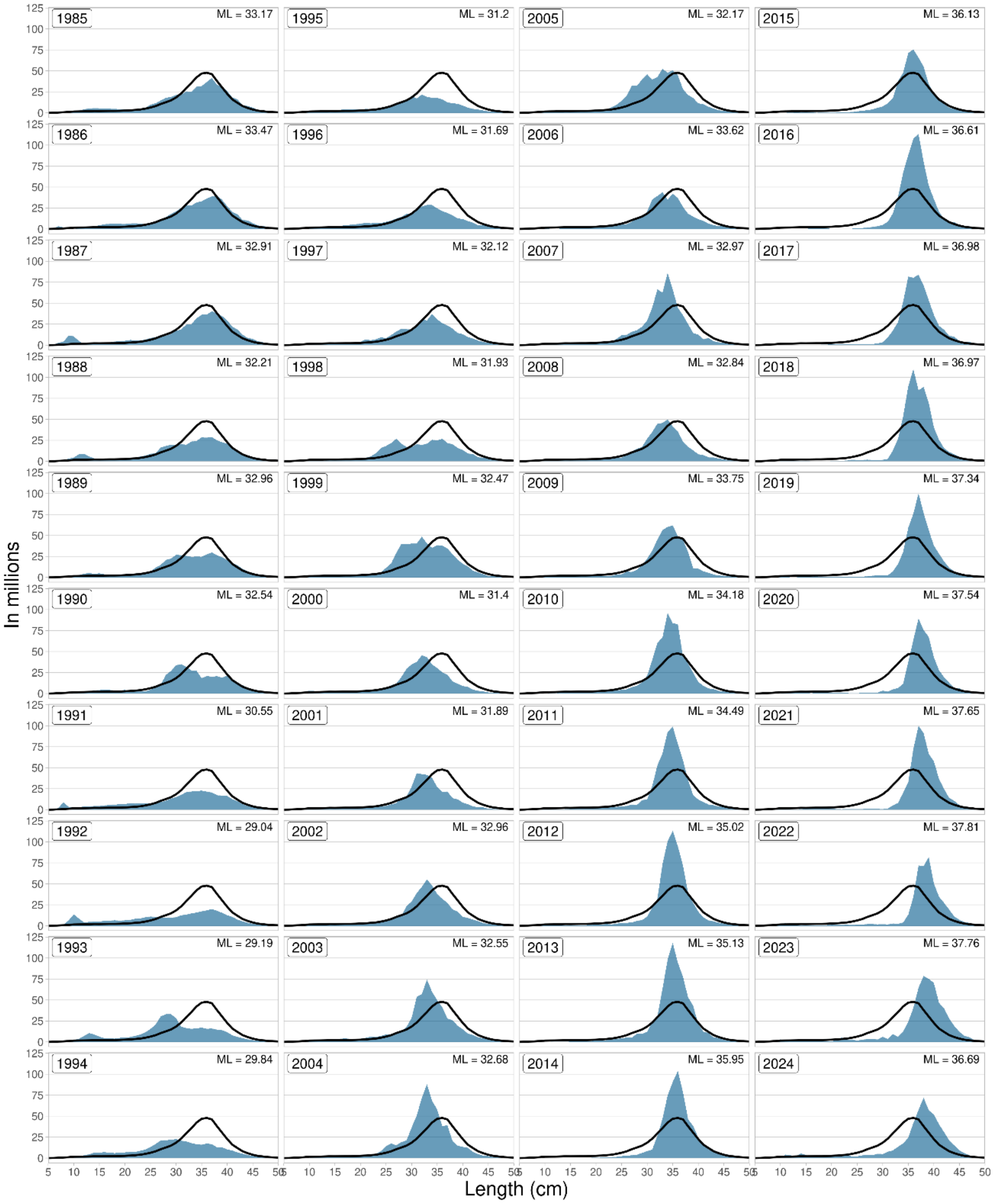

Figure 19.2. Length disaggregated abundance indices (blue area) of golden redfish from the bottom-trawl survey in March 1985-2024 conducted in Icelandic Waters. The black line is the mean of the total indices 1985–2024.

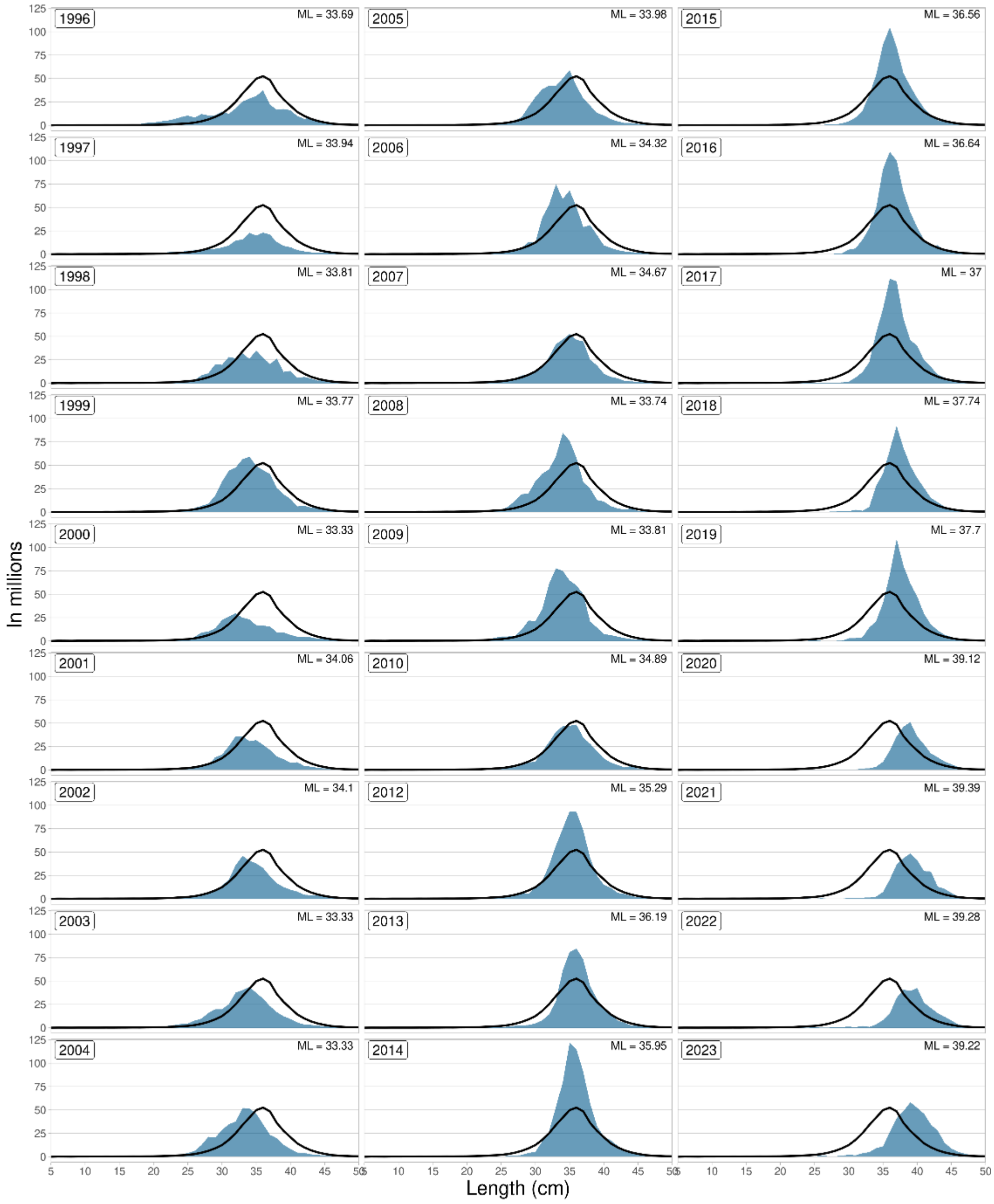

Figure 19.3. Length disaggregated abundance indices (yellow area) of golden redfish from the bottom-trawl survey in October 1996–2023 conducted in Icelandic Waters. The blue line is the mean of total indices 1996–2023. The survey was not conducted in 2011.

Figure 19.4. Age disaggregated abundance indices of golden redfish in the bottom-trawl survey in October conducted in Icelandic Waters 1996–2023. The survey was not conducted in 2011.

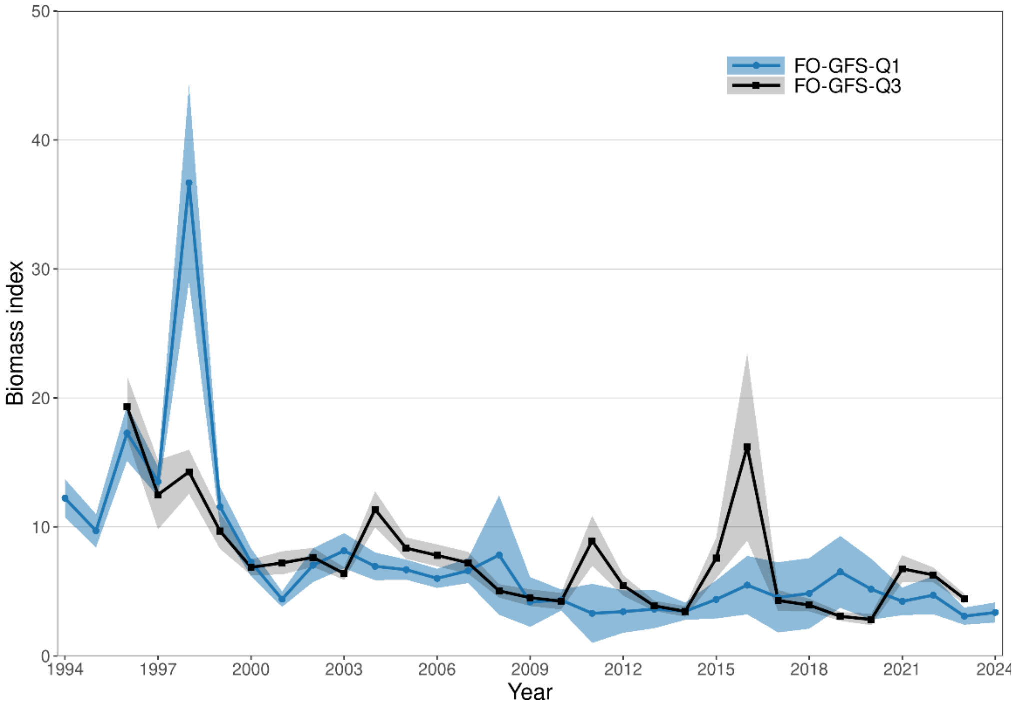

Figure 19.5. Survey biomass index of golden redfish in the Faroes spring groundfish survey 1994–2024 (blue line and shaded area) and the summer groundfish survey 1996–2023 (black line and shaded area) in ICES Division 5.b.

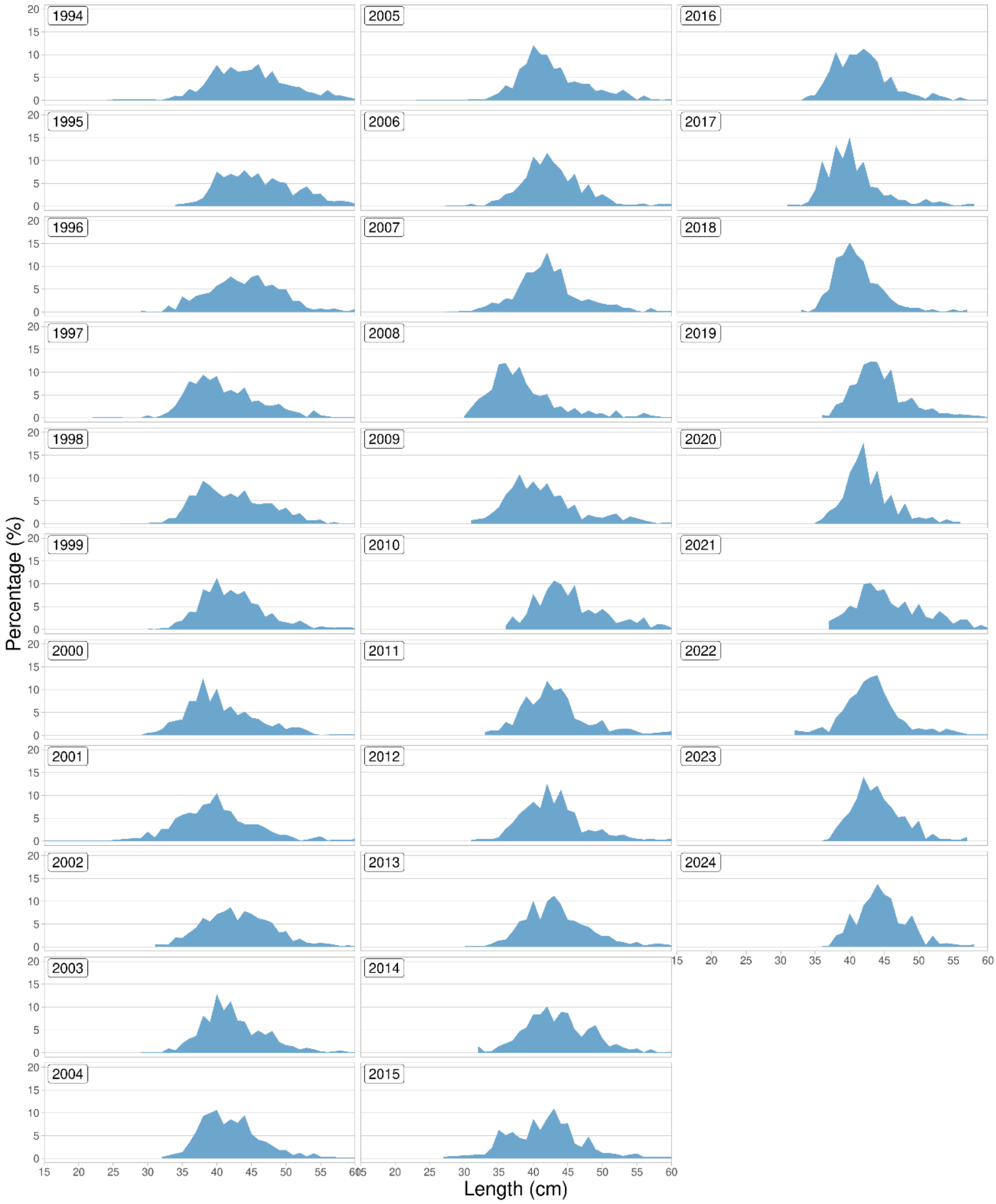

Figure 19.6. Length distribution (yellow area) of golden redfish in the Faroes spring groundfish survey 1994–2024.

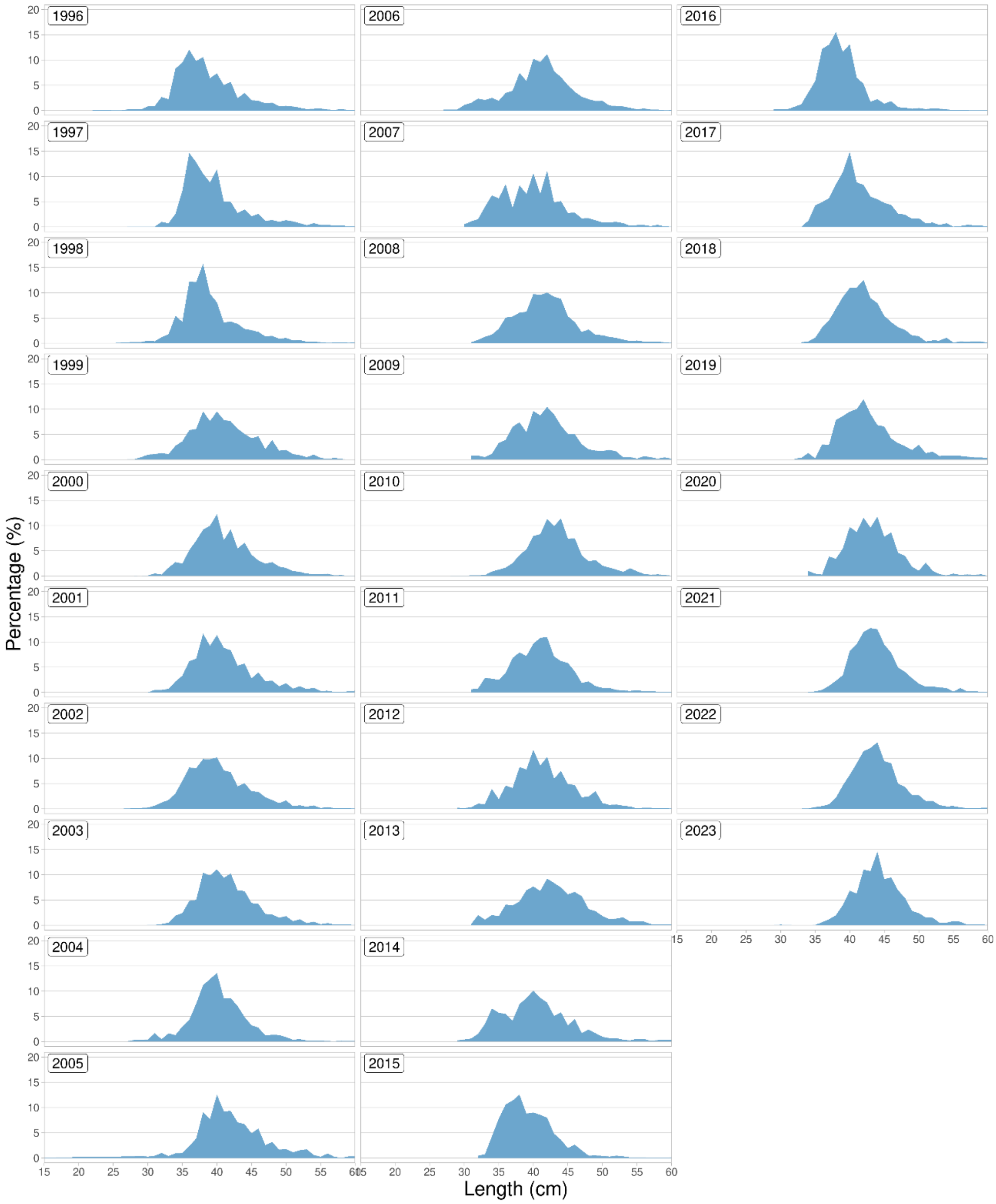

Figure 19.7. Length distribution (yellow area) of golden redfish in the Faroes summer groundfish survey 1996–2023.

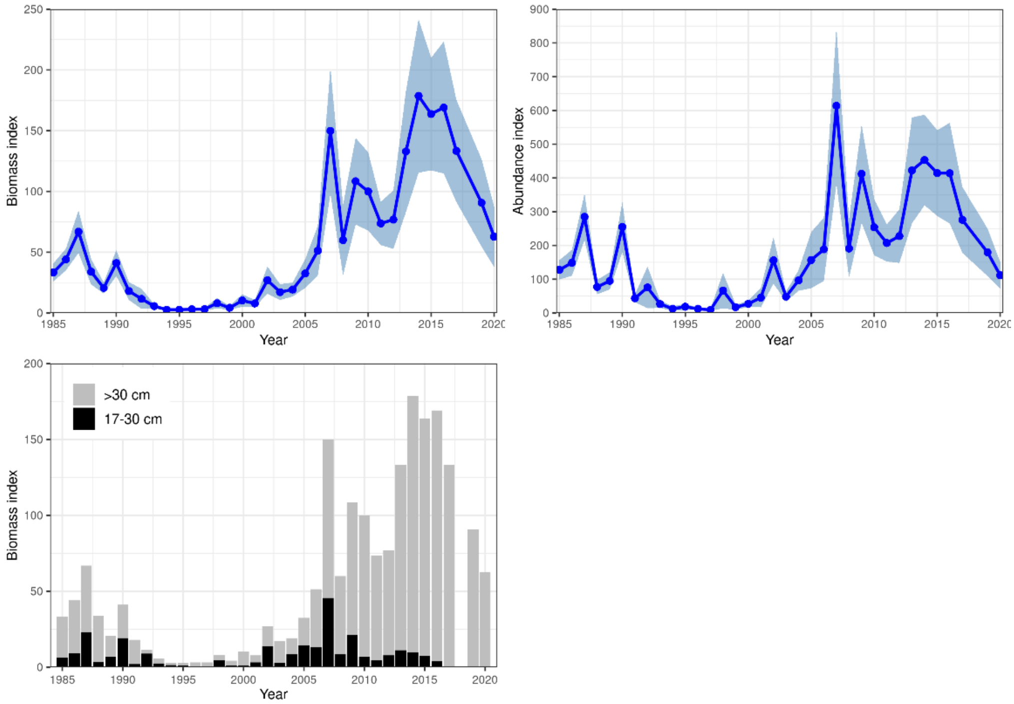

Figure 19.8. Golden redfish (> 17 cm). Survey abundance indices for East Greenland (ICES Subarea 14) from the German groundfish survey 1985–2020. a) Total biomass index, b) total abundance index, c) biomass index divided by size classes (17–30 cm and > 30 cm). The survey was not conducted in 2018, 2021-2023.

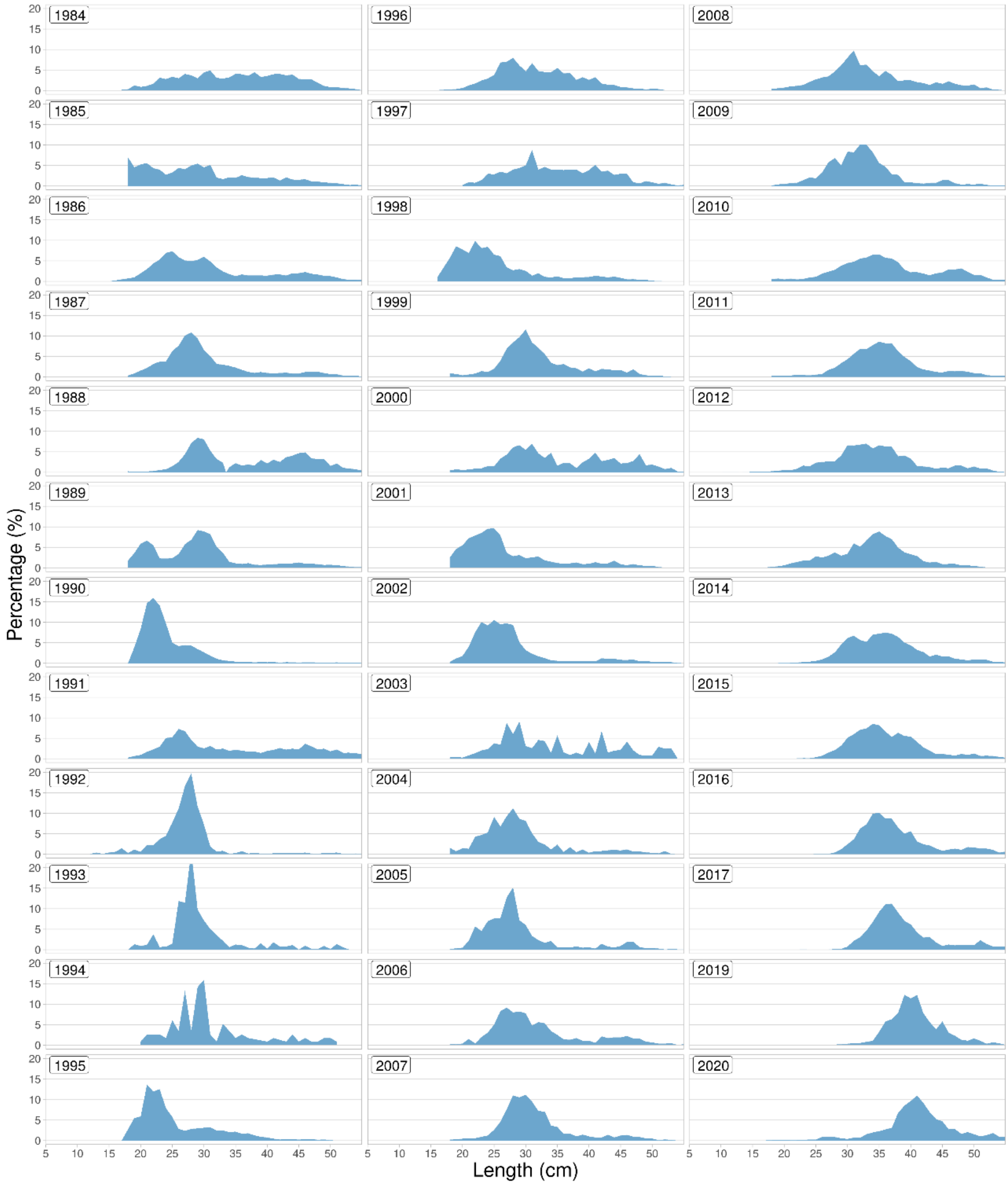

Figure 19.9. Golden redfish (>17 cm). Length frequencies for East Greenland (ICES Subarea 14) 1984–2020. The survey was not conducted in 2018, 2021-2023.

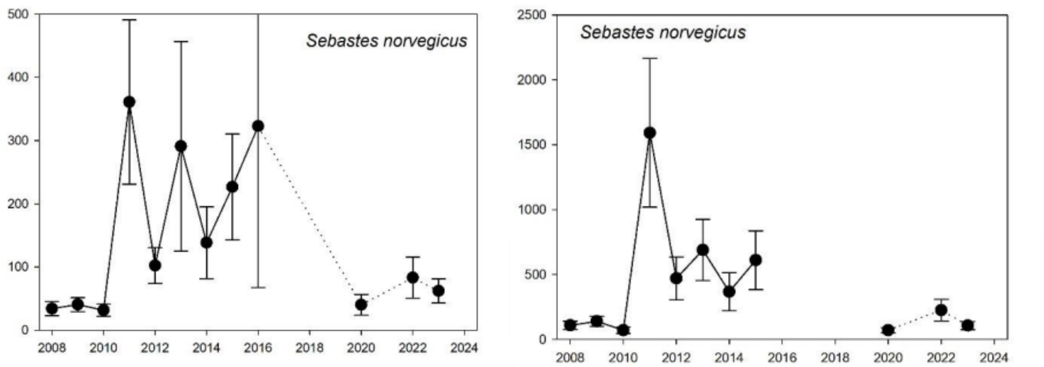

Figure 19.10. Golden redfish. Survey biomass (left) and abundance (right) indices for East Greenland (ICES Subarea 14) from the Greenland Shallow Water Groundfish Survey 2008–2023. The survey was not conducted in 2017-2019 and in 2021.

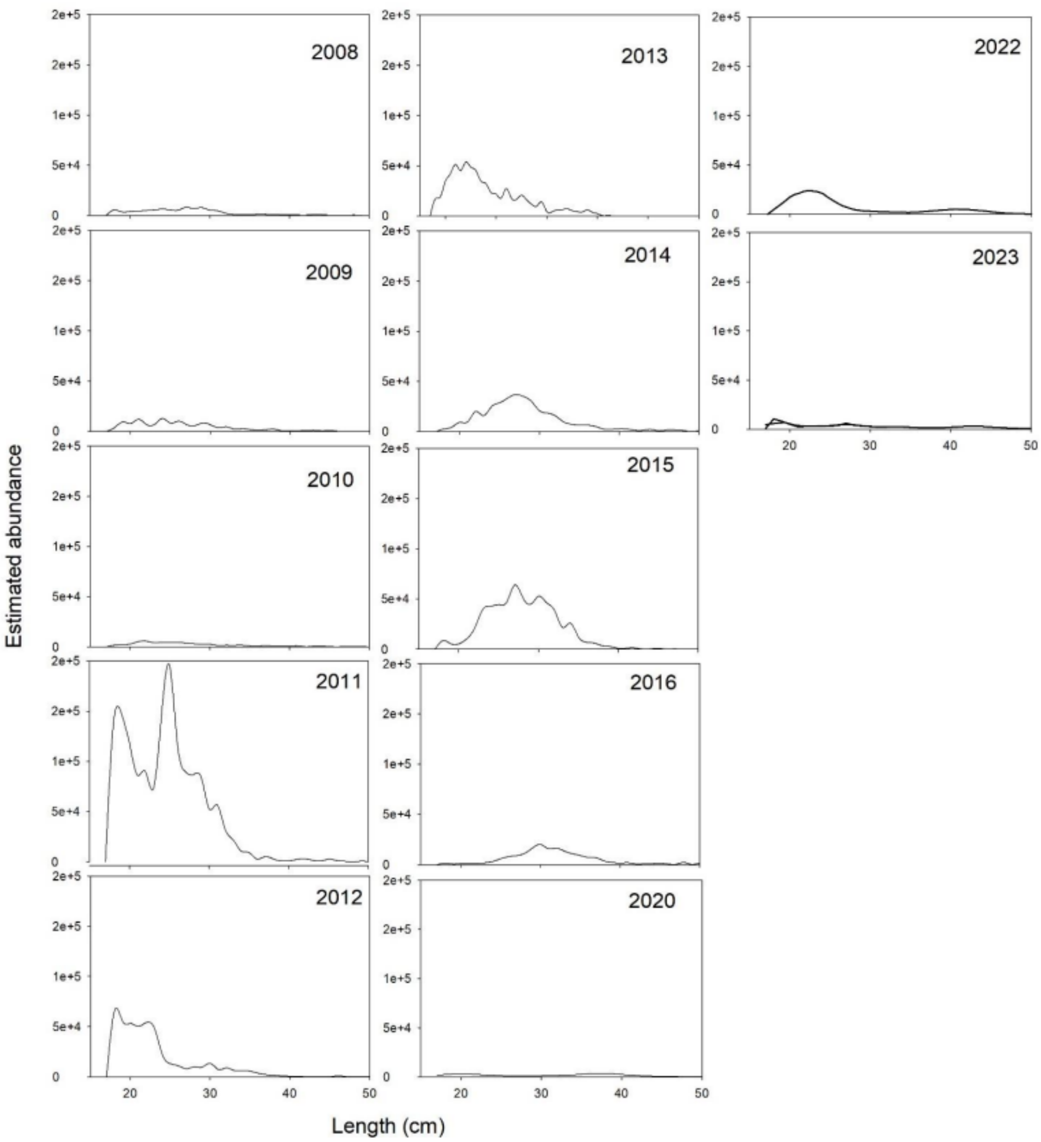

Figure 19.11. Golden redfish. Length distributions from the Greenland Shallow Water Groundfish Survey 2008–2023 off East Greenland. The survey was not conducted in 2017-2019 and in 2021.

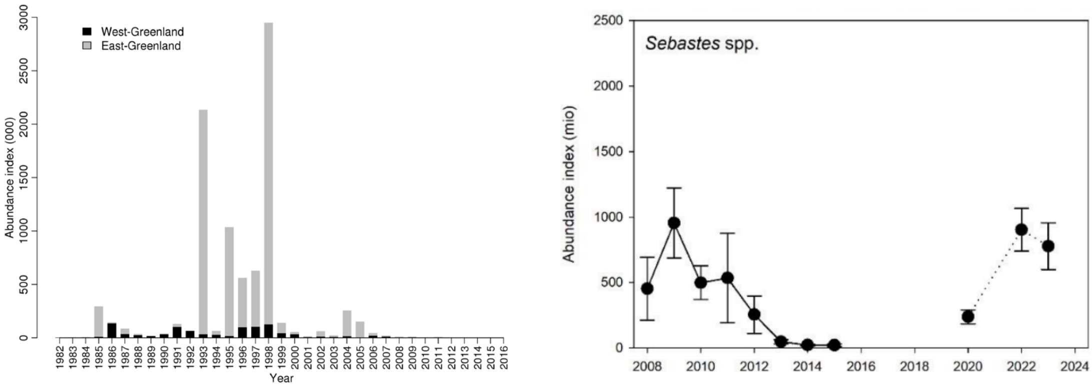

Figure 19.12. Survey abundance index of small unidentified redfish species (*Sebastes* spp. <18 cm) in East Greenland (ICES Subarea 14) from the German Groundfish Survey 1982-2018 (left) and the Greenland Shallow Water Groundfish Survey 2008–2023 (left).

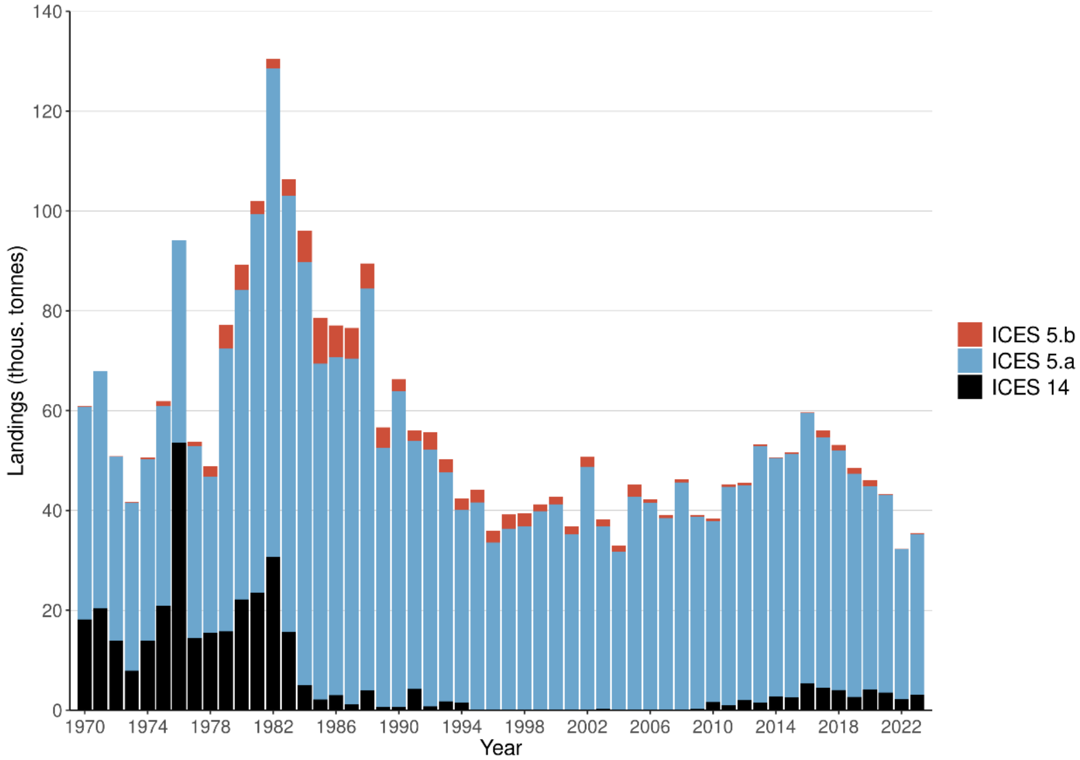

Figure 19.13. Nominal landings of golden redfish in tonnes by ICES divisions 1970–2023. Landings statistics for 2023 are provisional.

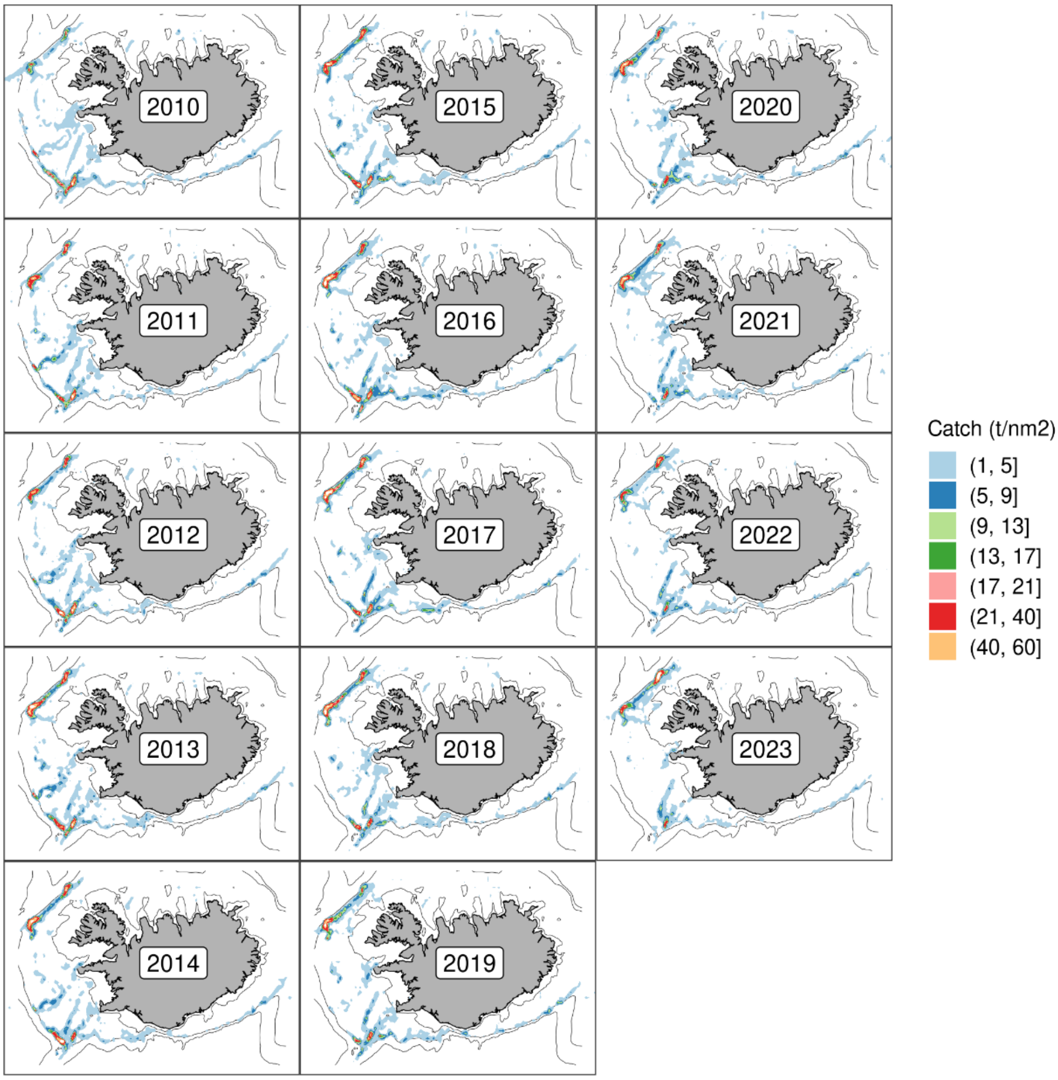

Figure 19.14. Geographical distribution of golden redfish catches in Division 5.a 2010–2023.

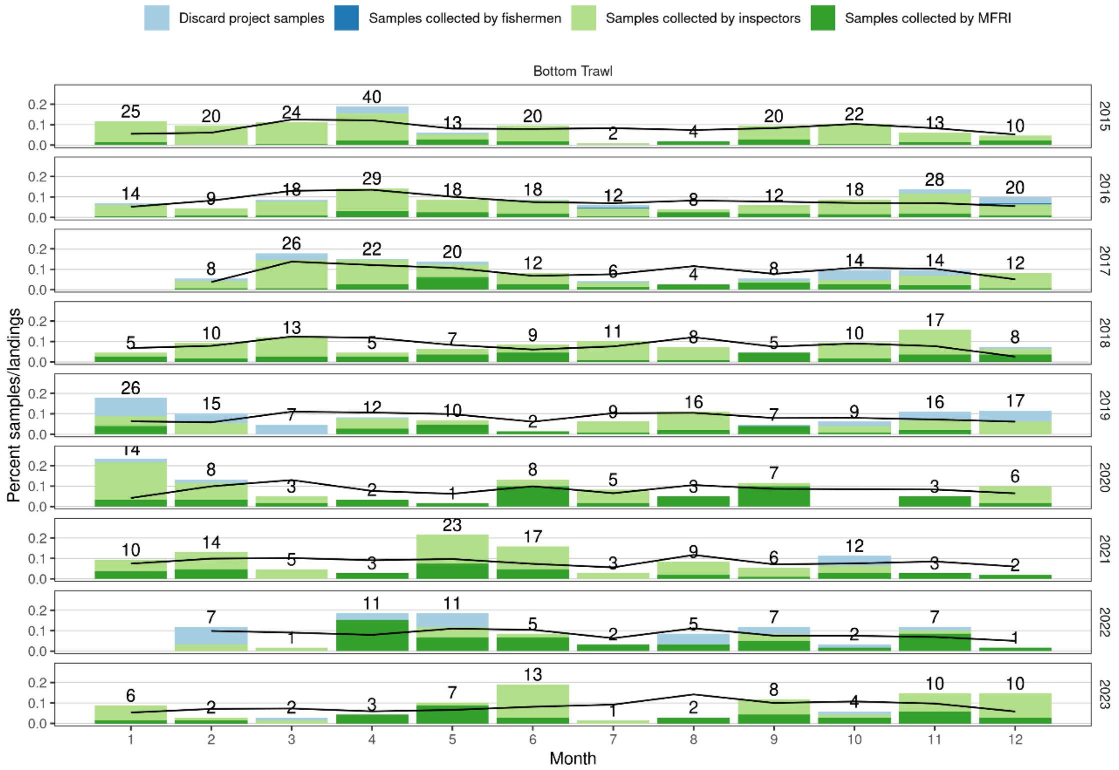

Figure 19.15. Ratio of samples by month (blue bars) compared with landings by month (solid black line) split by year of golden redfish in Icelandic Waters. Numbers of above the bars indicate number of samples by year and month.

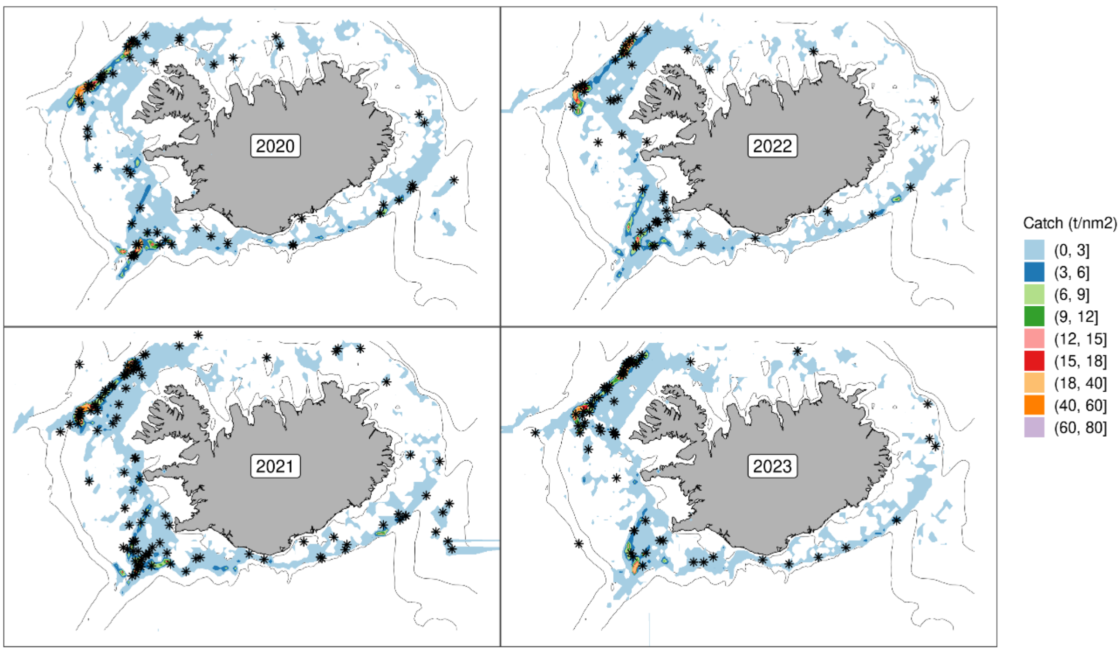

Figure 19.16. Fishing grounds of golden redfish in Icelandic Waters in 2020–2023 as reported in logbooks (contours) and positions of samples taken from landings (crosses) by year.

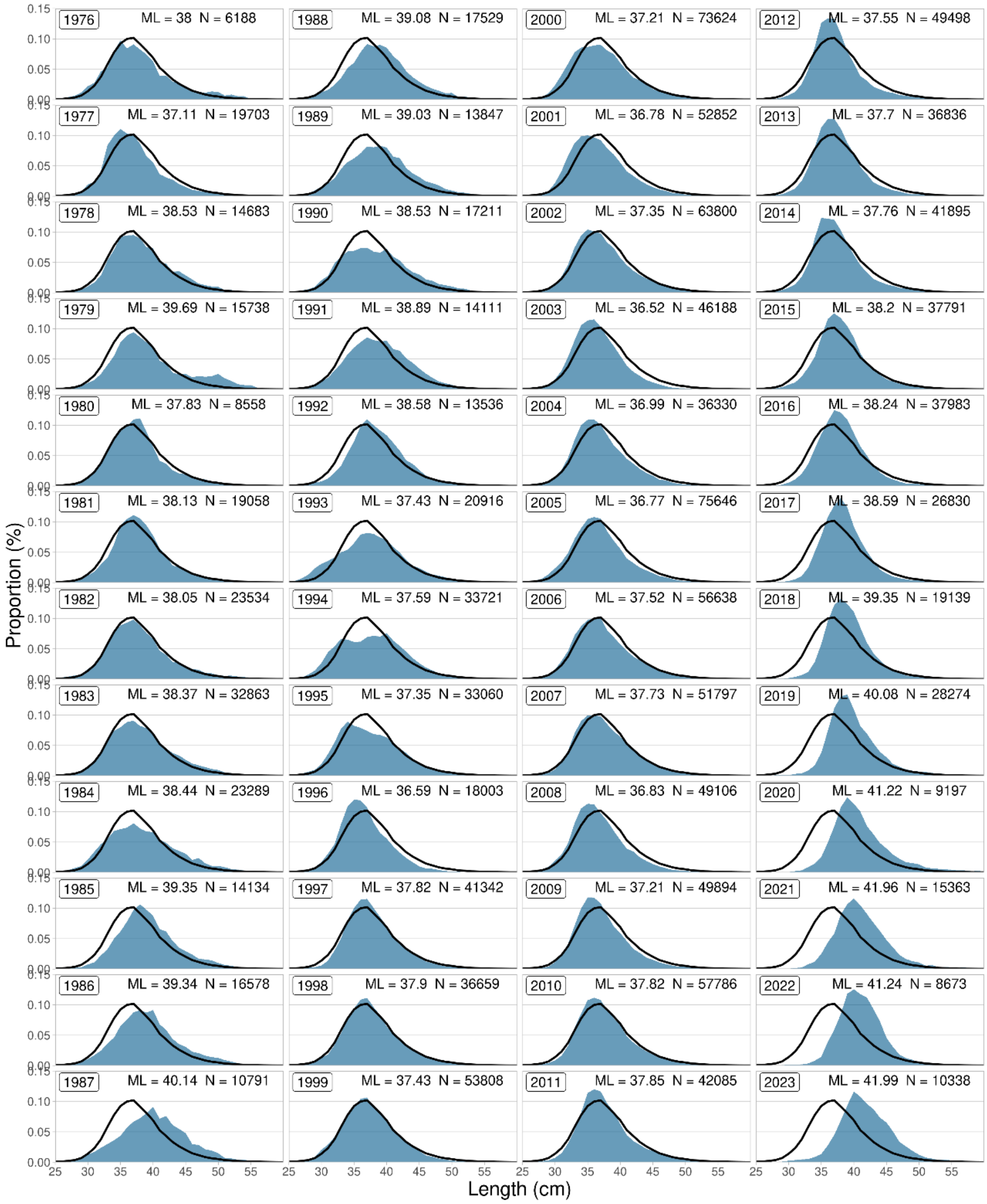

Figure 19.17. Length distribution (blue shaded area) of golden redfish in Icelandic Waters (ICES Division 5.a) in the commercial landings of the Icelandic bottom-trawl fleet 1976–2023. The black line is the mean of the years 1976–2023.

Figure 19.18. Catch-at-age of golden redfish in numbers in ICES Division 5.a 1995–2023.

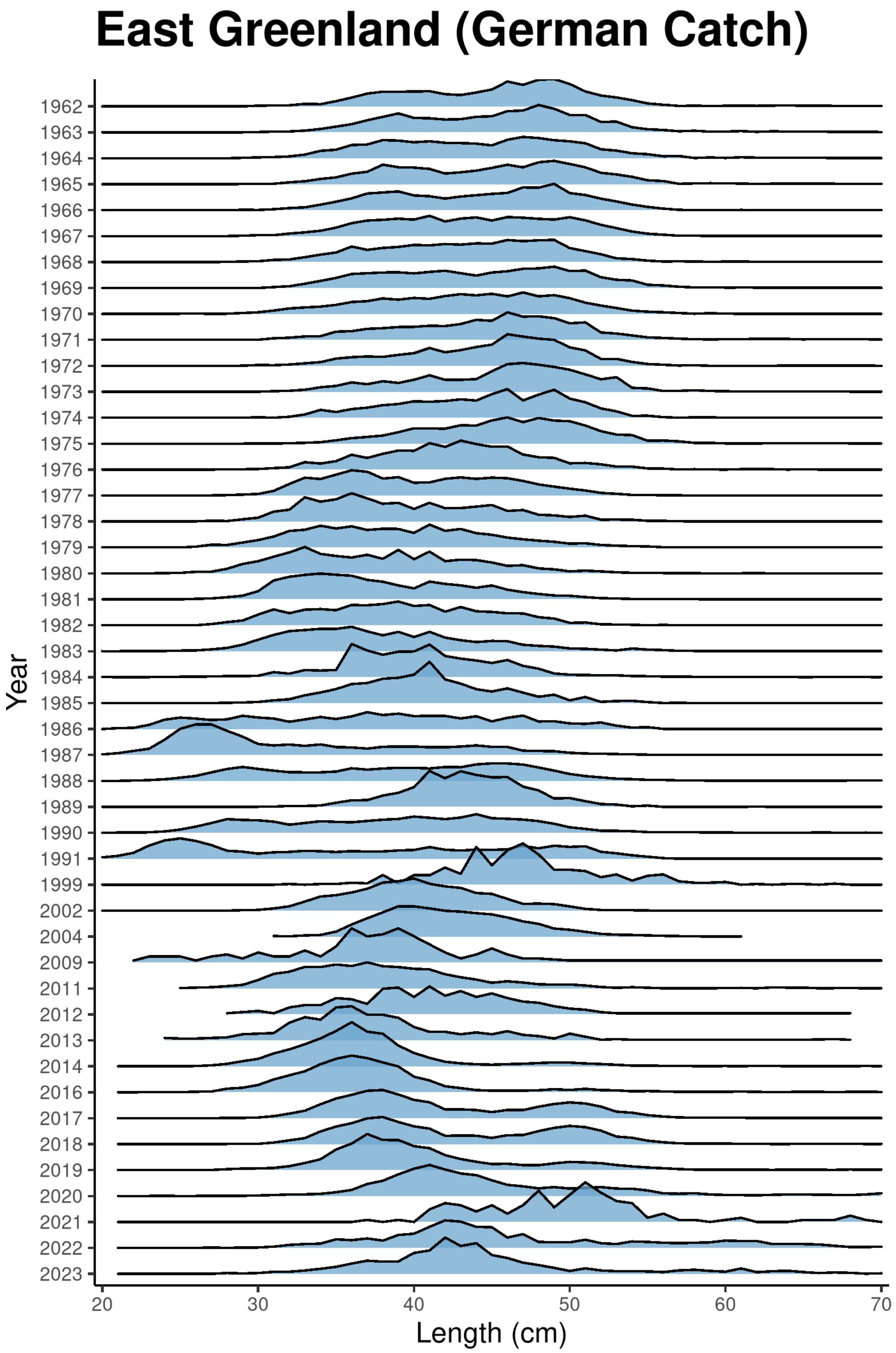

Figure 19.19. Length distribution of golden redfish from German catches in ICES Division 14.b (East Greenland) in 1962–2023.

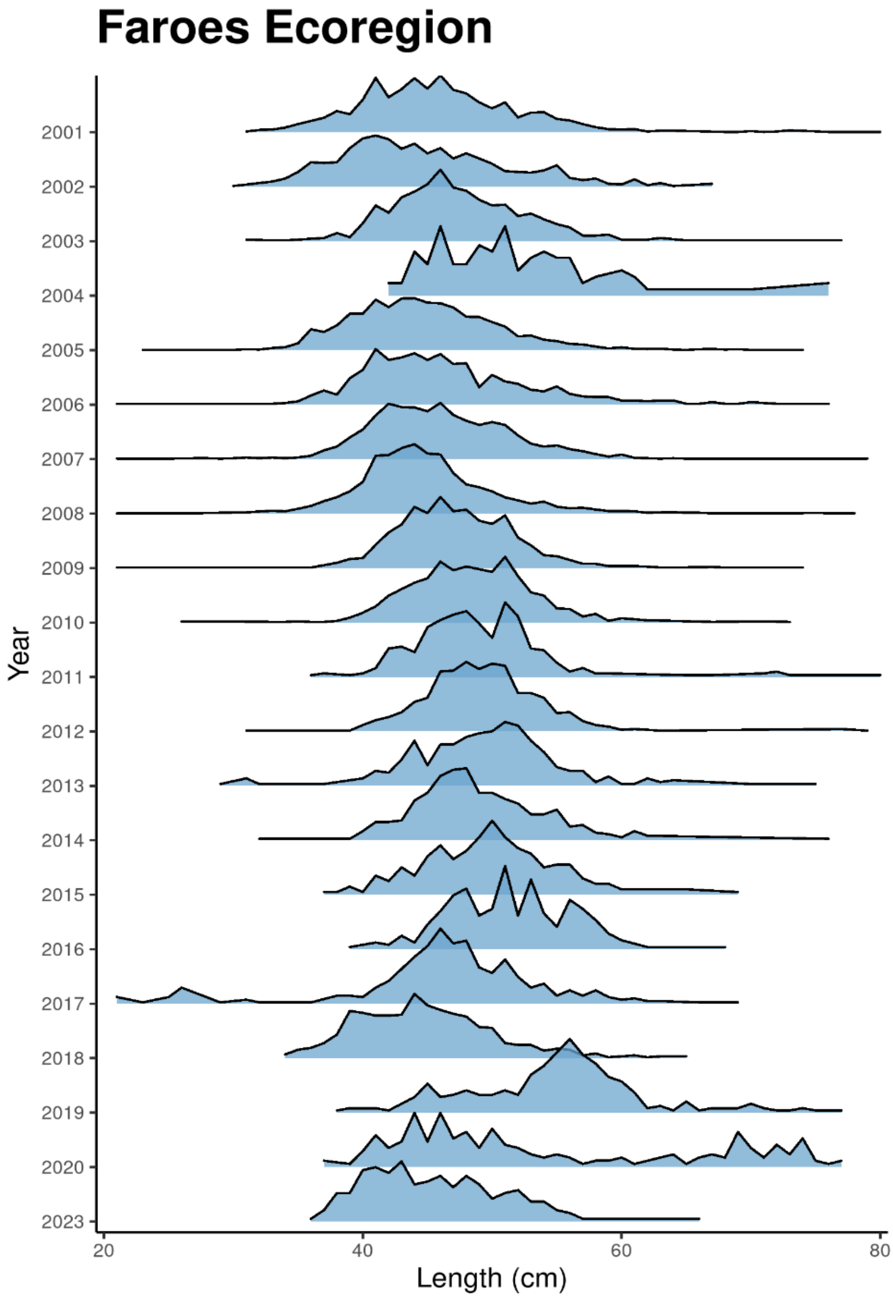

Figure 19.20. Length distribution of golden redfish from Faroese catches in ICES Division 5.b in 2001–2020 and 2023.

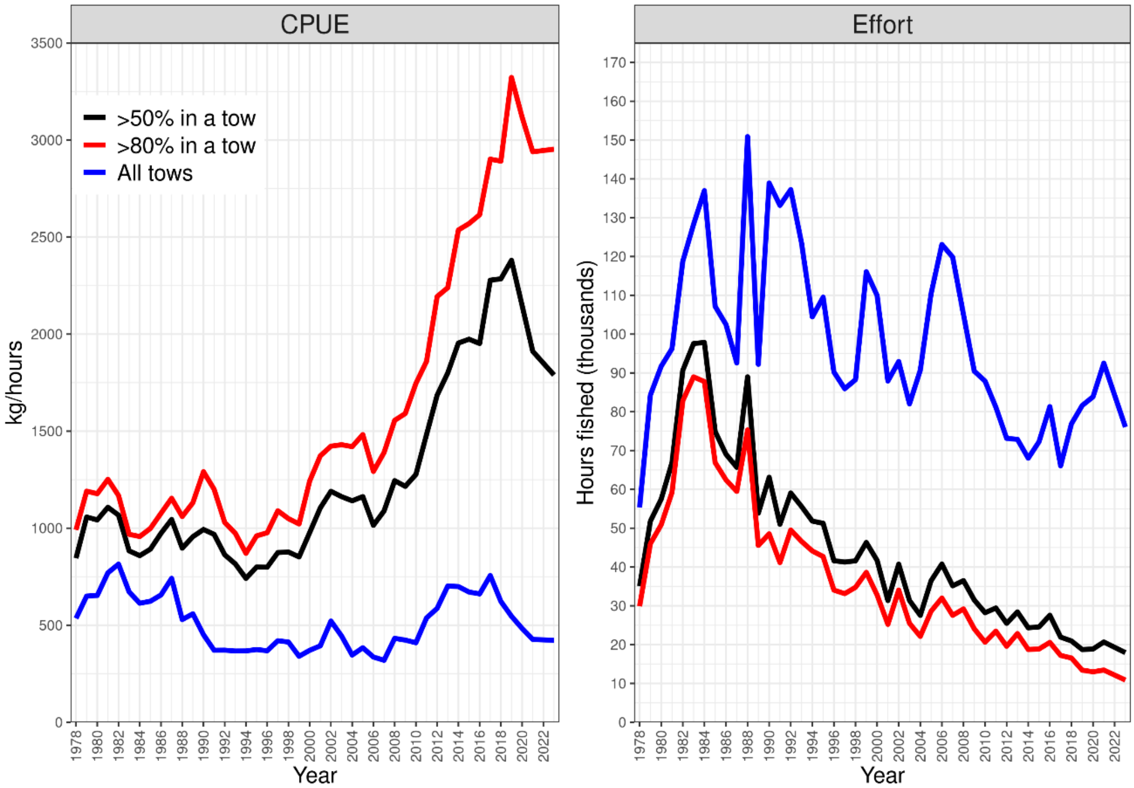

Figure 19.21. CPUE of golden redfish from Icelandic trawlers 1978–2023 where golden redfish catch composed at least 50% of the total catch in each haul (black line), 80% of the total catch (red line) and in all tows where golden redfish was caught (blue line). The figure shows the raw CPUE index (sum(yield)/sum(effort)) and effort. Data were not available for 2022.

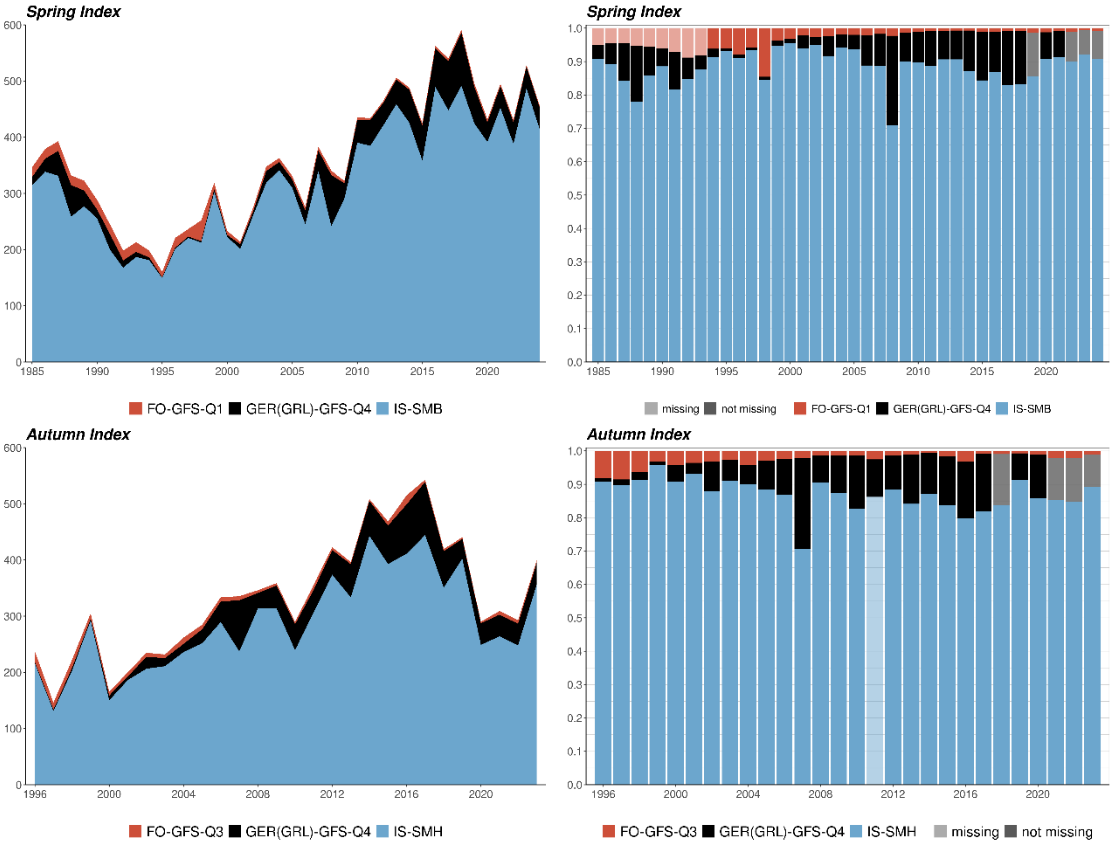

Figure 19.22. Golden redfish. Combined survey indices for the spring and autumn surveys. Lighter shaded columns means that survey data are missing. How missing data are treated is described in the text.

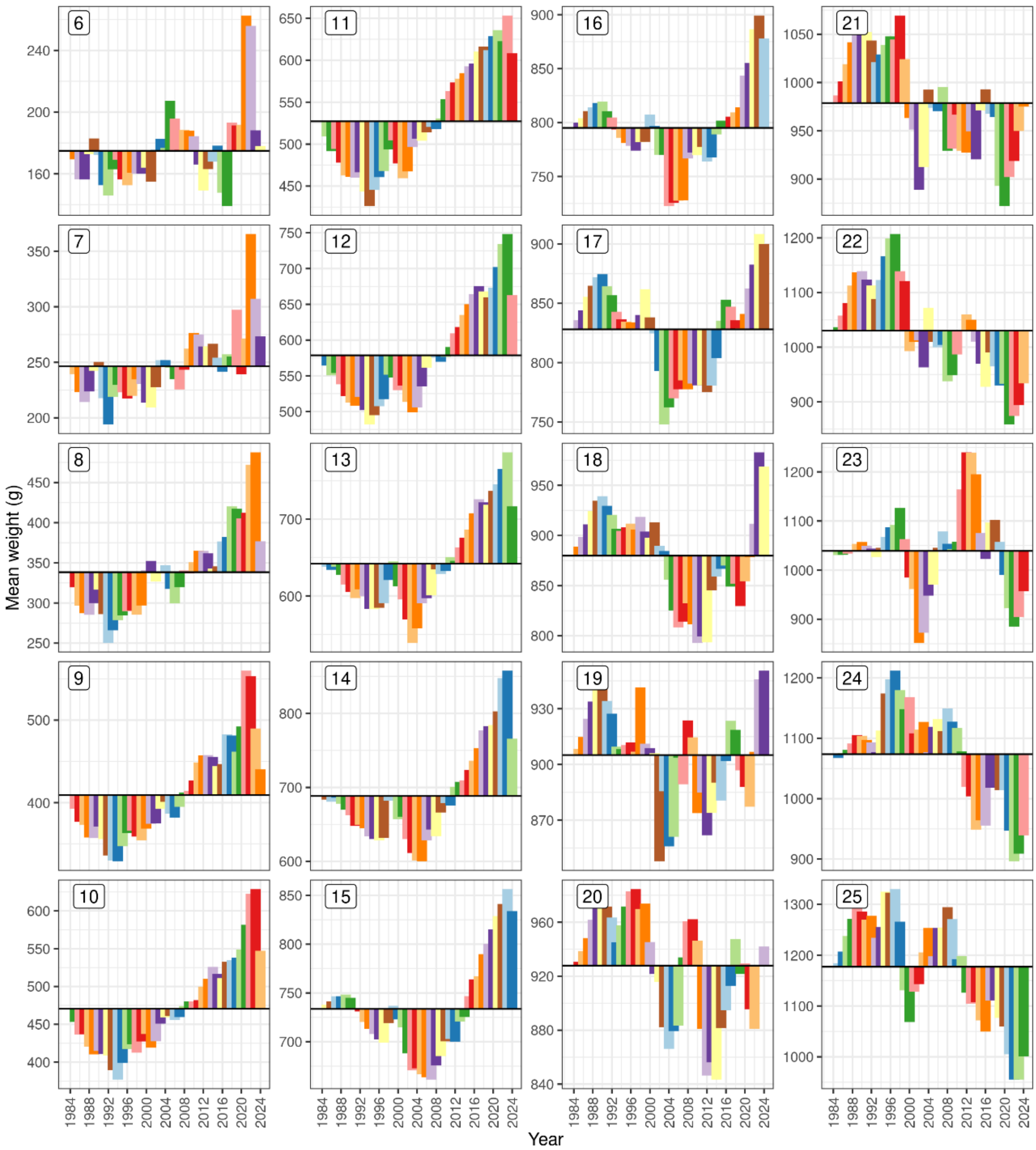

Figure 19.23. Golden redfish. Weight at age observed in the spring survey.

Figure 19.24. Golden redfish. Weight at age observed in the catches.

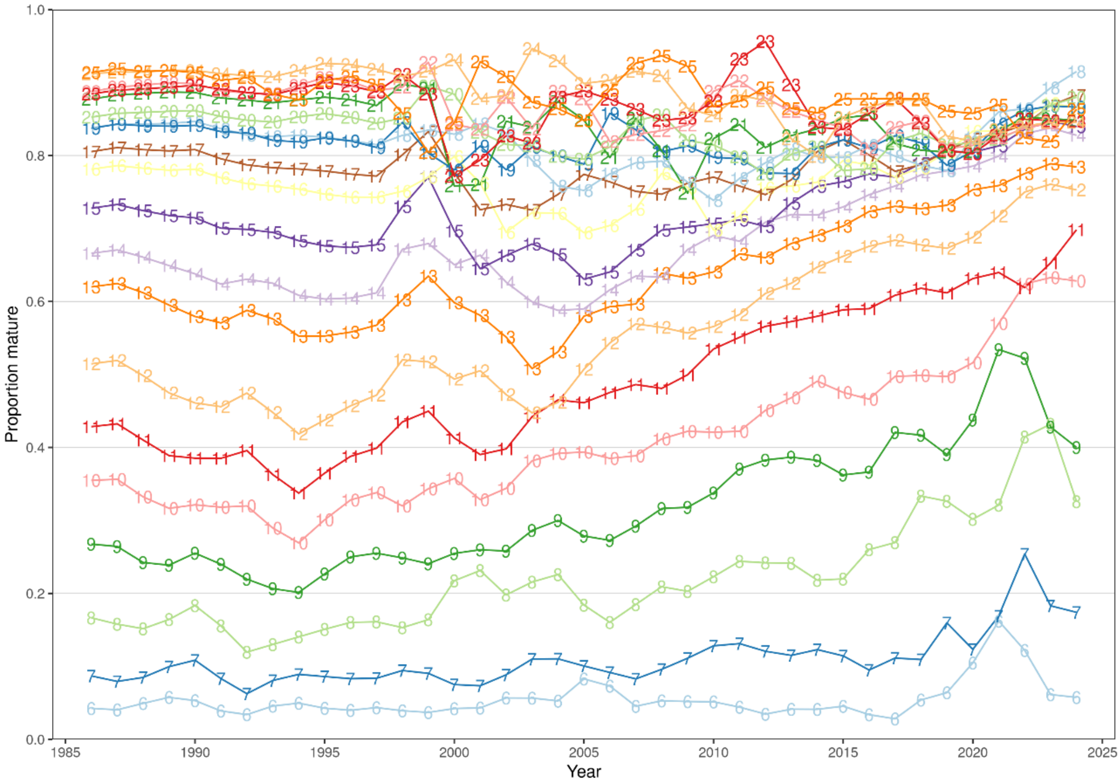

Figure 19.25. Golden redfish. The proportion mature at age from the autumn survey and commercial data.

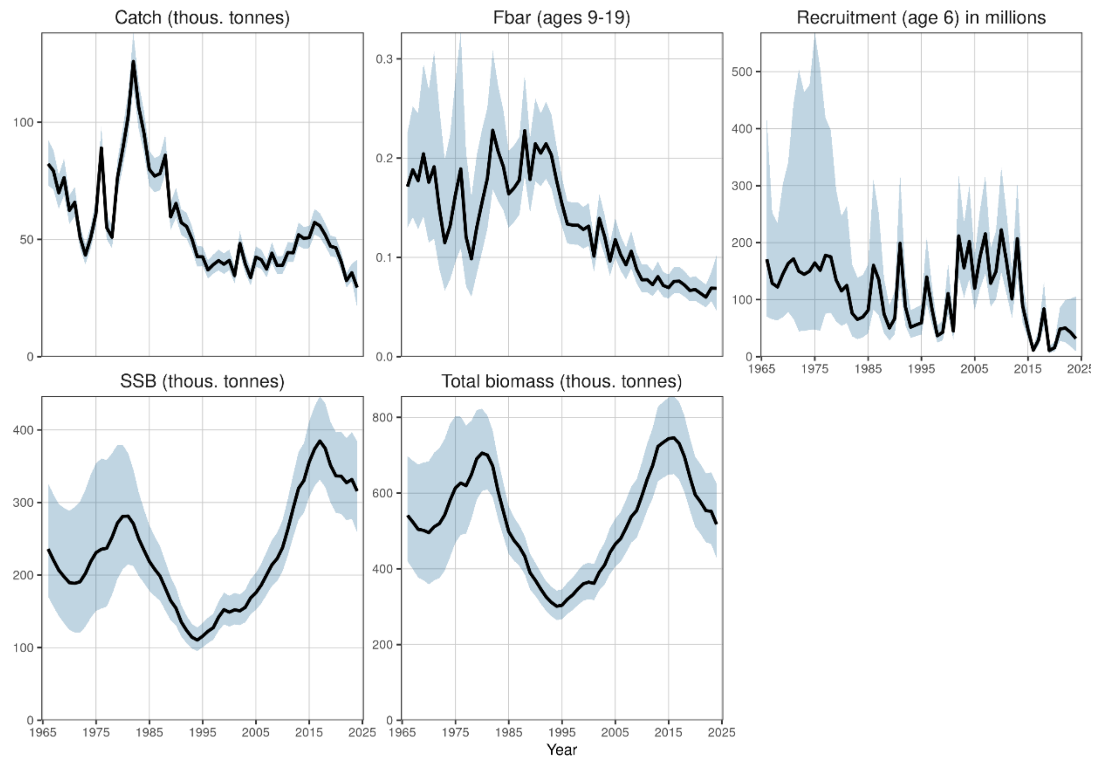

Figure 19.26. Summary from the assessment in 2024.

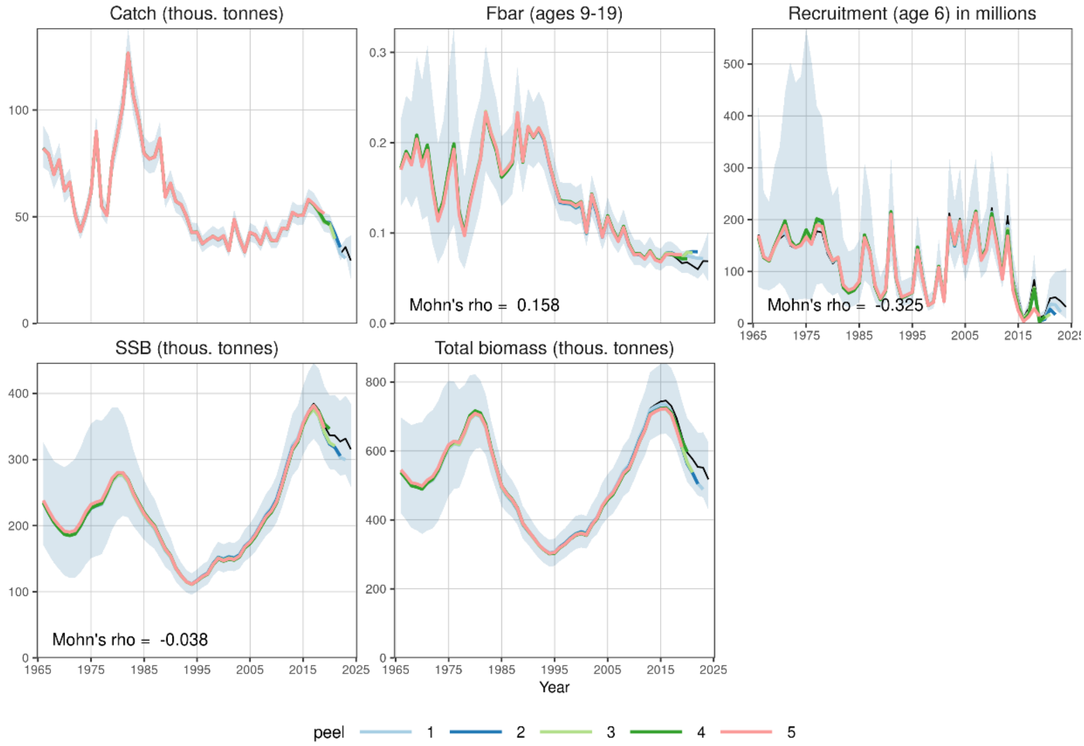

Figure 19.27. Analytical retrospective pattern of the base run.

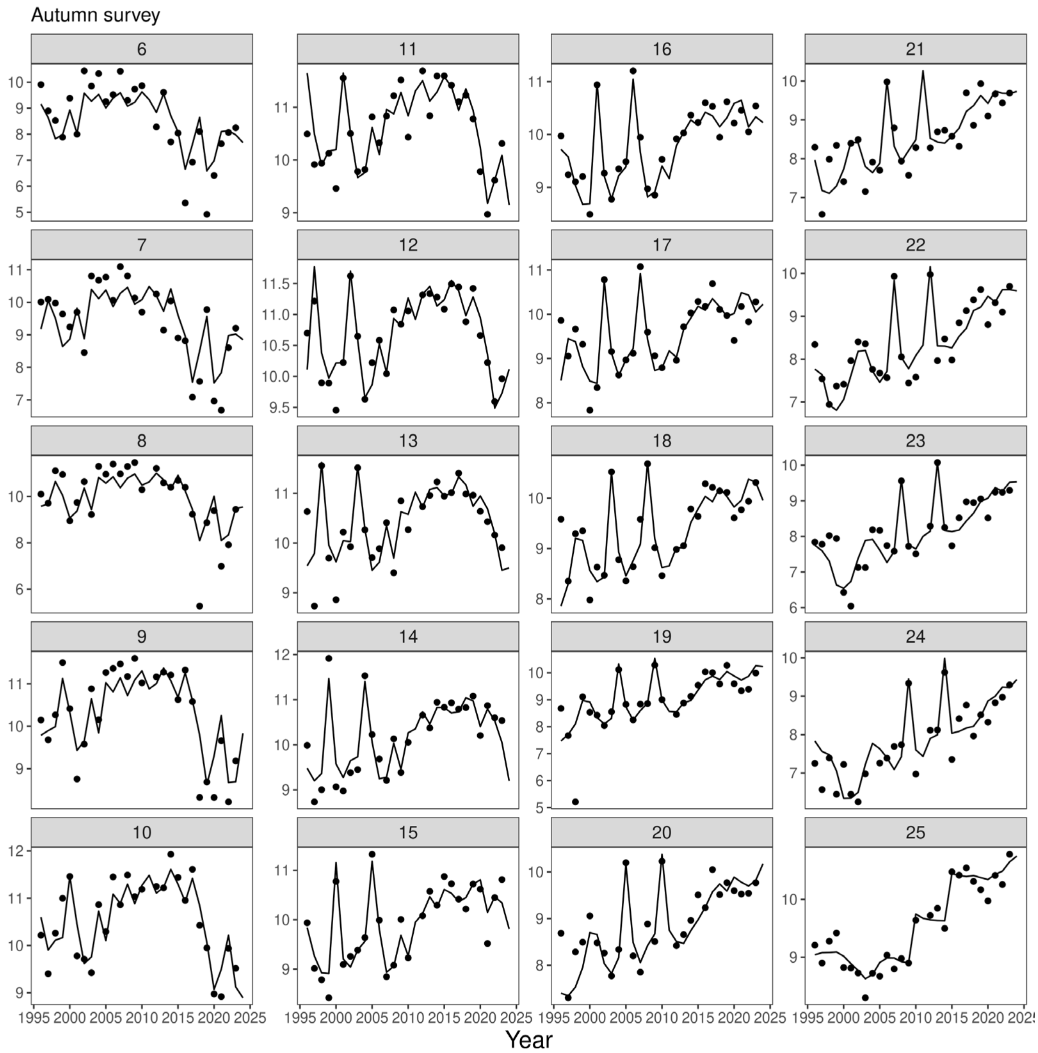

Figure 19.28. Fit to the numbers-at-age input data in the autumn survey to the proposed SAM model.

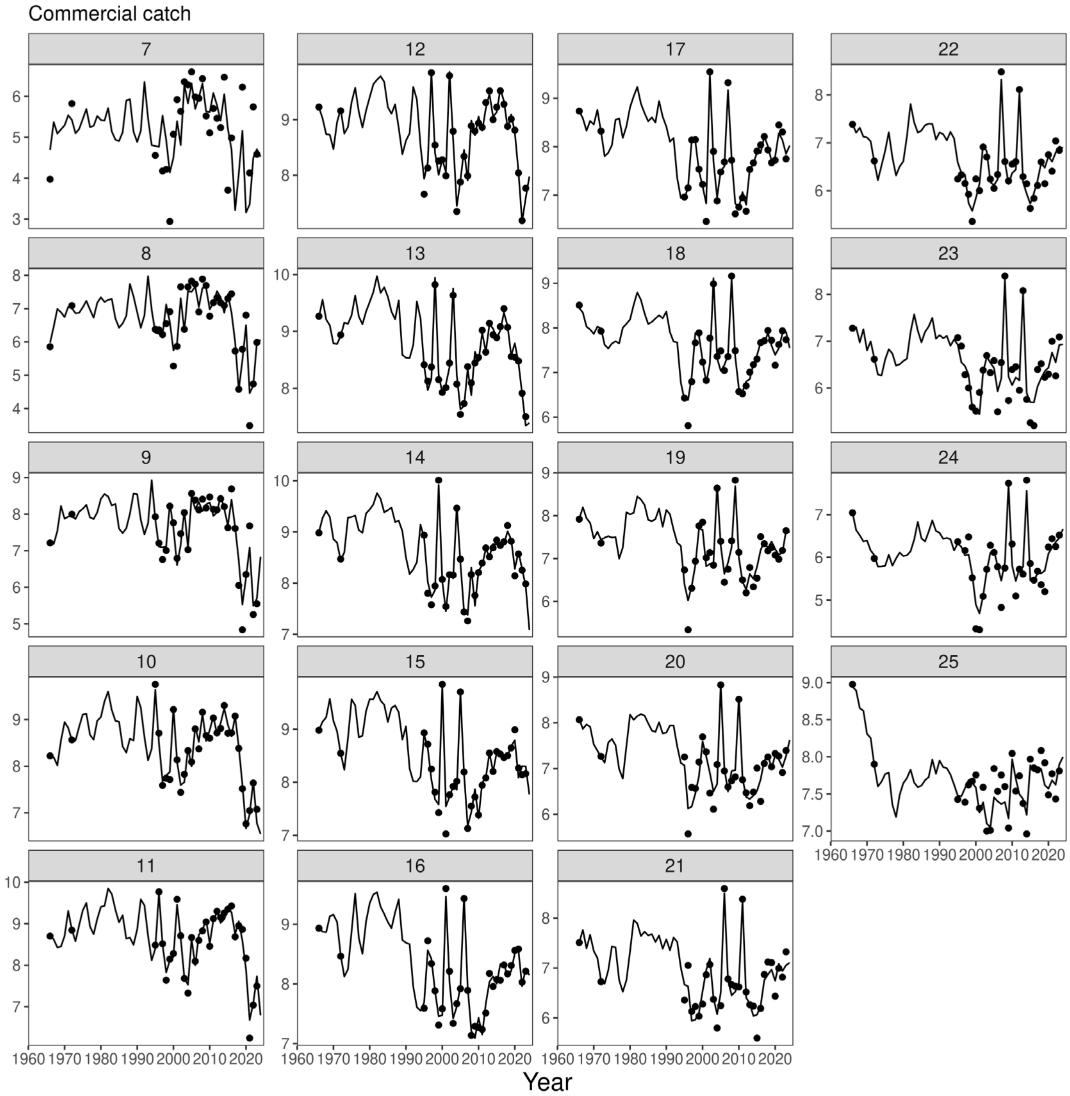

Figure 19.29. Fit to the numbers-at-age input data in the commercial catches to the proposed SAM model.

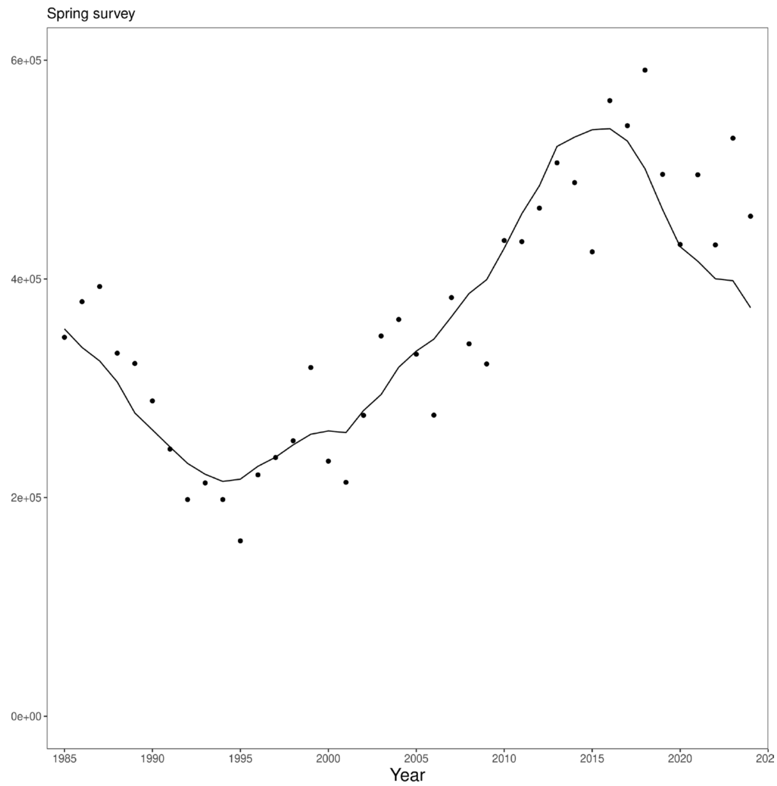

Figure 19.30. Fit to the spring survey data to the proposed SAM model.

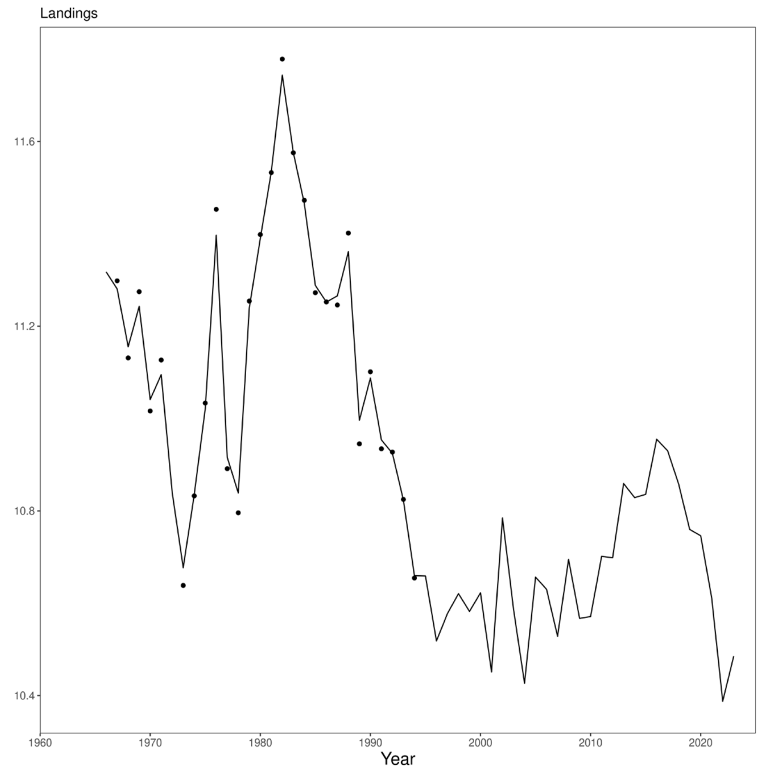

Figure 19.31. Fit to the landings input data to the proposed SAM model.

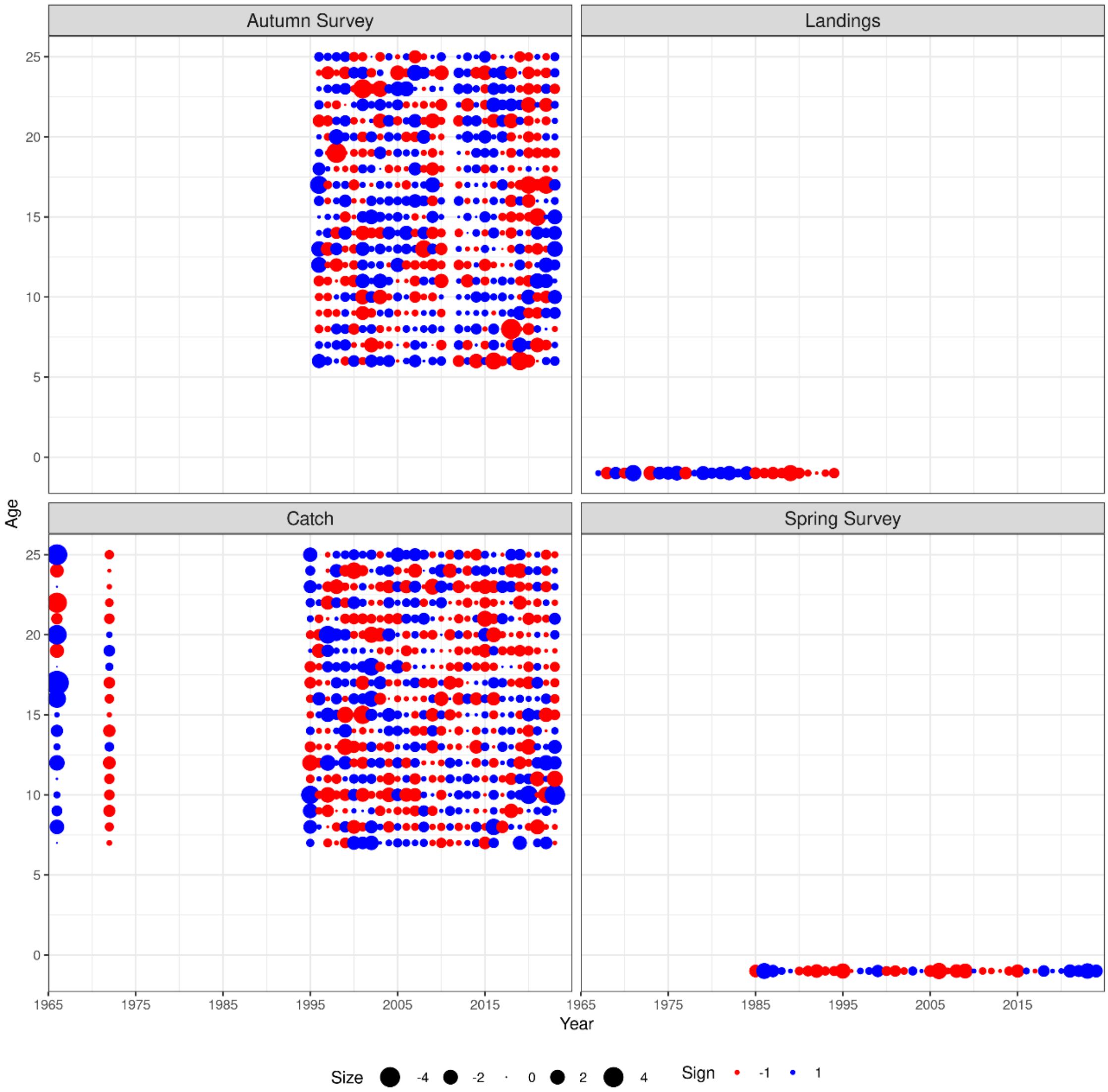

Figure 19.32. Residuals from the fit between model and survey indices. The red circles indicate positive residuals (survey results exceed model prediction). Largest residuals correspond to log(obs/mod) = 1.

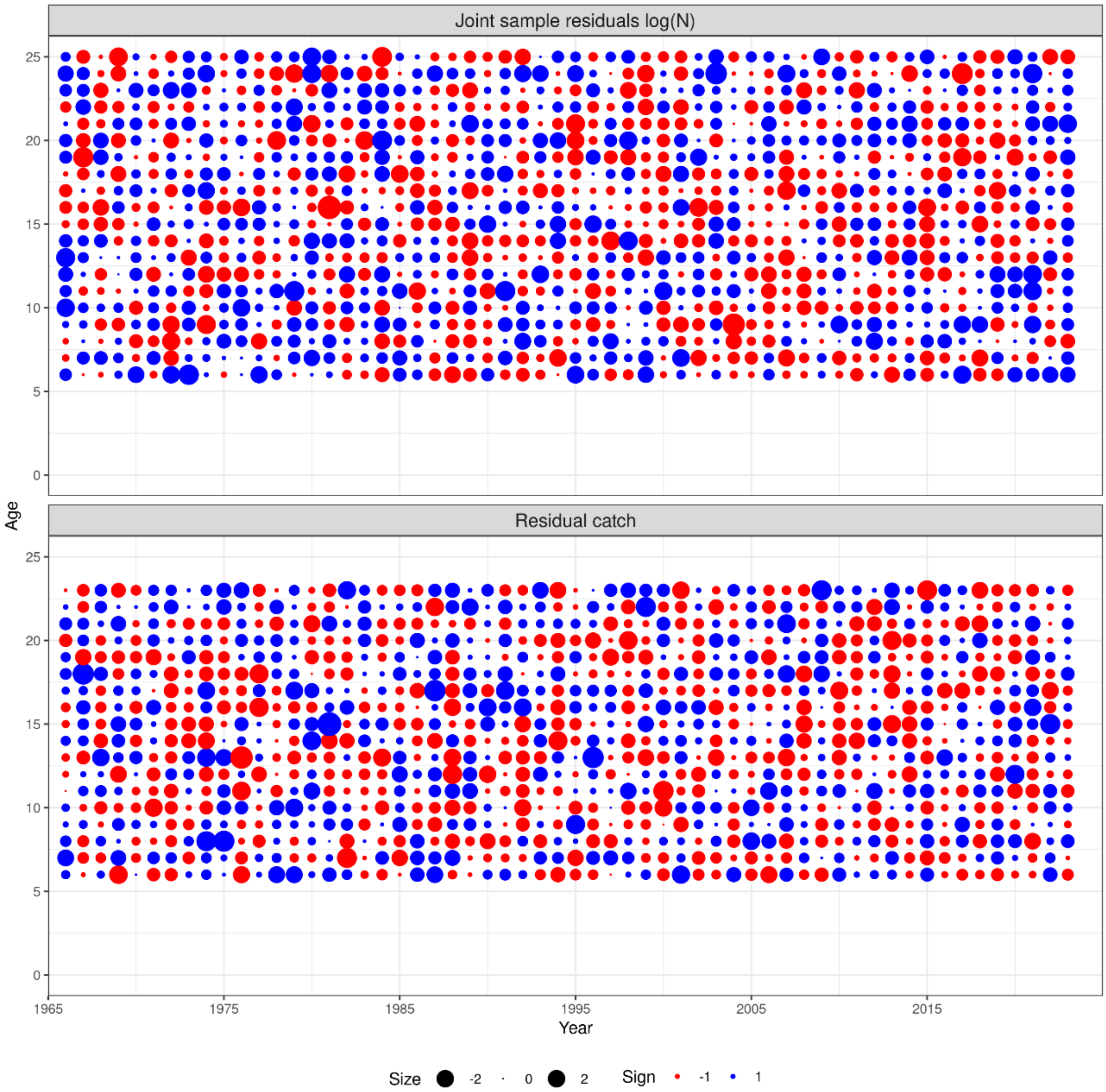

Figure 19.33. Residuals from the fit between model and survey indices. The red circles indicate positive residuals (survey results exceed model prediction). Largest residuals correspond to log(obs/mod) = 1.

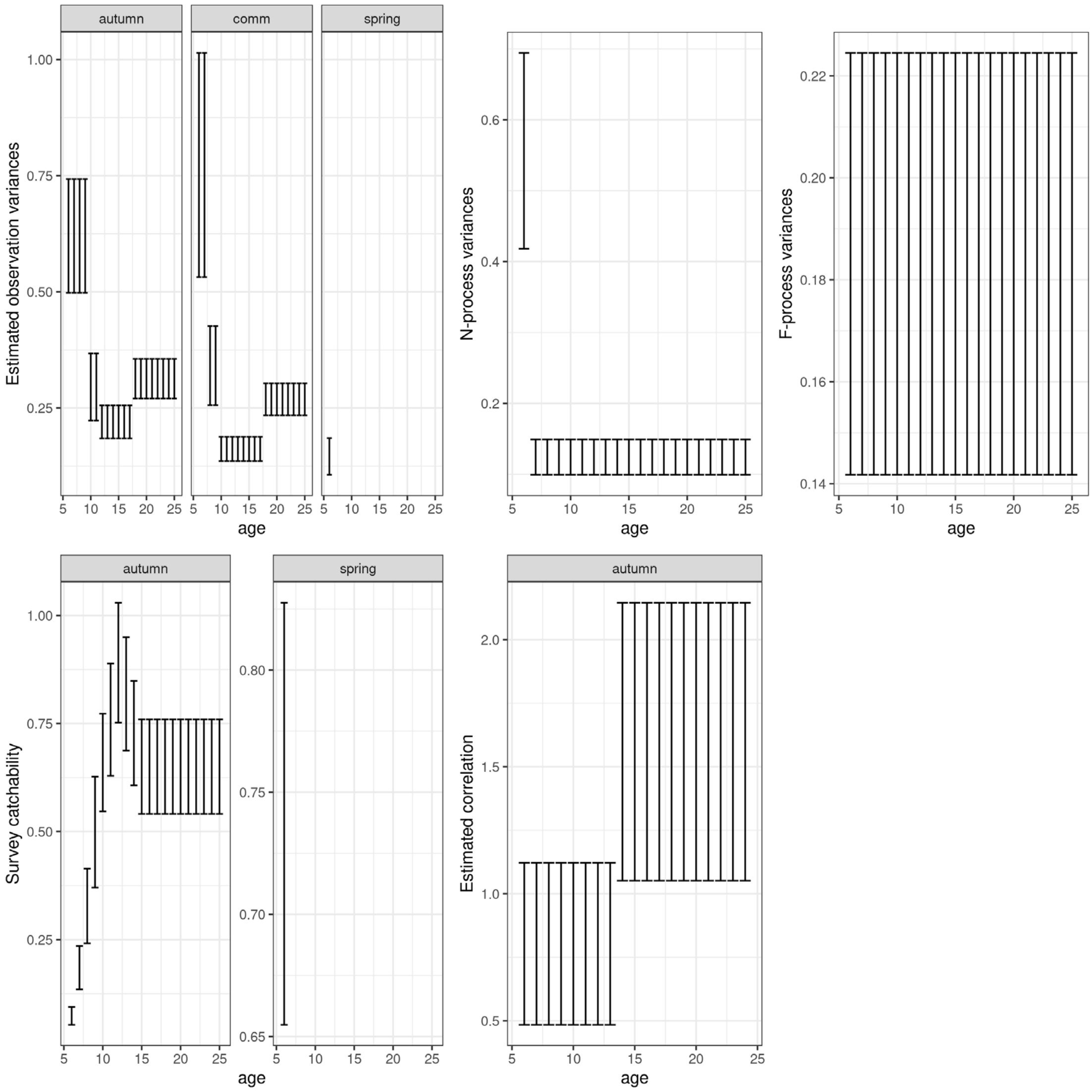

Figure 19.34: Golden redfish. Overview of model parameter estimates.

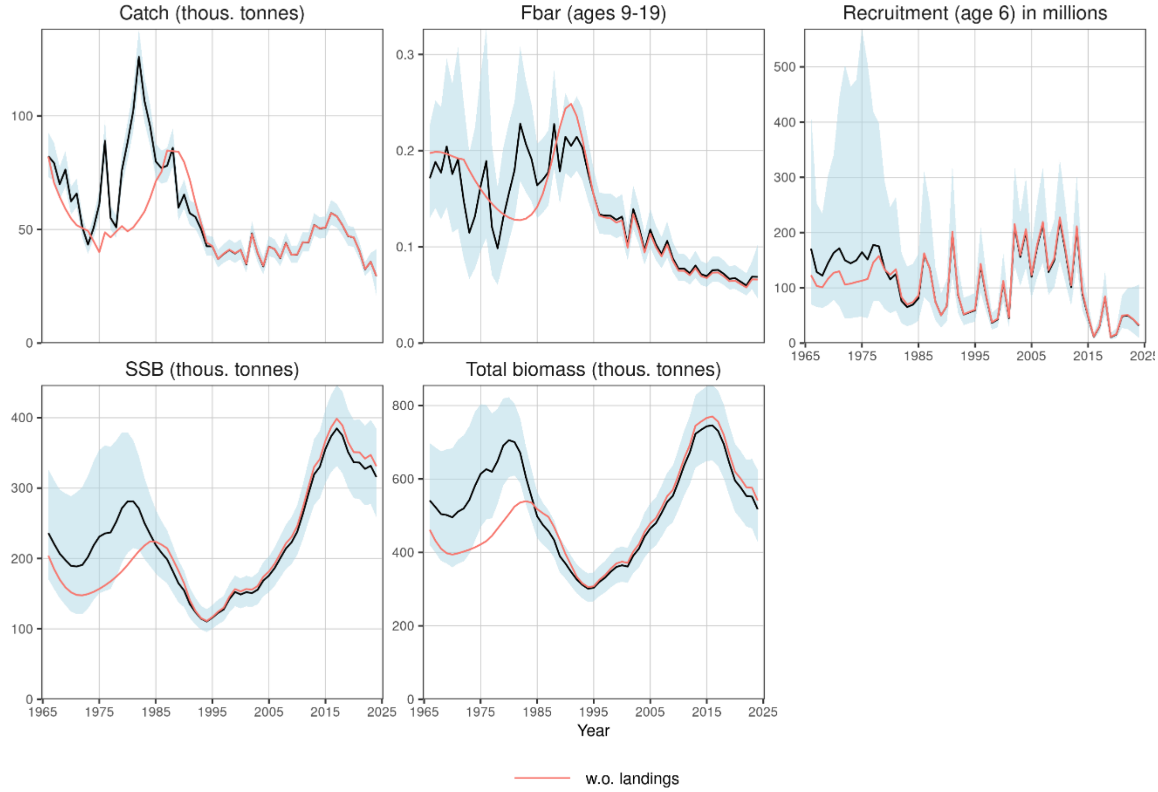

Figure 19.35: Golden redfish. Leave-out estimates of SSB, total biomass, catch, F and recruitment.

20 Icelandic slope beaked redfish (East of Greenland, Iceland grounds)

reb.27.5a14 – *Sebastes mentella* in Subarea 14 and Division 5.a

20.1 Stock description and management units

The stock structure of beaked redfish (*Sebastes mentella*) in the Irminger Sea and adjacent water is described in Chapter 18 and Stock Annex (smn-con SA). Beaked redfish on the continental shelf and slope of Iceland (the Icelandic Waters Ecoregion, which is defined to be within the Icelandic 200 NM EEZ and includes 5.a and part of Subarea 14.b.2; see Figure 20.1) is treated as separate biological stock and management unit. Only the fishable stock (fish larger than 30 cm) is found in Iceland Sea ecoregion. The East Greenland shelf is most likely a common nursery area for the three biological stocks described in Chapter 18, including the Icelandic slope one.

20.2 Scientific data

The Icelandic autumn survey (IS-SMH) on the continental shelf and slope in Icelandic Waters covers depths down to 1500 m. Data on Icelandic slope beaked redfish are available from 2000–2023. The survey was not conducted in 2011. Description of the autumn survey, including index calculations, is given in Stock Annex (smn-con SA).

The total biomass and abundance indices were highest in 2000 and 2001, declined in 2002 and have, since then, fluctuated at that level without clear trend (Figure 20.2). The biomass index of fish 45 cm and larger has, however, increased from the lowest value in 2007 to the highest one in 2021 but has since then decreased (Figure 20.2). The abundance index of fish 30 cm and smaller (recruits) has been at very low level since 2010. No fish smaller than 30 cm was observed in the 2021 and 2022 surveys and very little in 2023 (Figure 20.2).

The length of the Icelandic slope beaked redfish in the autumn survey is between 25 cm and more than 50 cm (Figure 20.3). Since 2000, the mode of the length distribution has shifted to the right or from 36-39 cm in 2000 to about 42-45 cm in 2012-2023 (Figure 20.3). During this period the mean length of the fish caught has increased from 37.4 cm in 2000 to 43.2 cm in 2022. This is a large increase in mean length for a species which annual growth is around 1-2 cm and where very few individuals larger than 50 cm are observed. This confirms the recruitment failure.

Otoliths from the autumn survey have been sampled since 2000 and otoliths from the 2000, 2006, 2009, 2010, 2014, 2017-2019 and 2021 surveys have been age read (Figure 20.4). The age reading shows that the stock consists of many cohorts and the age ranges from 5 to over 50 years. The 1985 and 1990 cohorts were large and were still relatively strong in the 2021 survey. No fish 10 years old and younger were observed in the 2021 survey, yet another indication of a recruitment failure.

20.3 Information from the fishery

20.3.1 Landings

Total annual landings of Icelandic slope beaked redfish from the Icelandic Waters Ecoregion 1950–2023 are presented in Table 20.3 and Figure 20.5.

During the 1950-1977 period, before the extension of the Icelandic EEZ to 200 NM, Icelandic slope beaked redfish was mainly fished by West-Germany. The catches peaked in 1953 to about 87 000 t but gradually decreased to about 23 000 t in 1977. After the extension of the Icelandic EEZ in 1978 the fishery has almost exclusively been conducted by Icelandic vessels. Annual landings gradually decreased from 57 000 t in 1994 to 17 000 t in 2001 and were at that level until 2010. Annual landings in the years 2011-2022 were between 8300 and 12 000 t. The total catch in 2023 were 6676 t, a decrease of 2781 t from previous year.

20.3.2 Fisheries and fleets

The fishery for Icelandic slope beaked redfish in Icelandic Waters is a directed bottom-trawl fishery along the shelf and slope west, southwest, and southeast of Iceland at depths between 500 and 800 m (Figure 20.6). The proportion of Icelandic slope beaked redfish catches taken by pelagic trawls 1991-2000 varied between 10 and 44% of the total landings. In 2001-2023, no pelagic fishery occurred, or it was negligible except in 2003 and 2007 (see Stock Annex).

The total number of boats that account for 95% of fishery have been declining steadily (Figure 20.7). In 1995 about 50 vessels fished for the stock but were around 20 in 2022.

20.3.3 Sampling from the commercial fishery

The table below shows the 2023 biological sampling from the catch and landings of Icelandic slope beaked redfish in Icelandic Waters. Location of sampling in relation to the location of the fishery 2020-2023 is shown in Figure 20.9.

Division/ Subarea	Nation	Gear	Landings (t)	No. samples	No. length measured
5.a/14	Iceland	Bottom trawl	6676	19	1880

20.3.4 Length distribution from the commercial catch

Length distributions of Icelandic slope beaked redfish from the bottom-trawl fishery show an increase in the number of small fish in the catch in 1994 compared to previous years (Figure 20.10). The peak of about 32 cm in 1994 can be followed by approximately 1 cm annual growth in 1996-2002. The fish caught in 2004-2023 peaked around 39-42 cm. The length distribution of Icelandic slope beaked redfish from the pelagic fishery, where available, showed that in most years the fish was on average bigger than taken in the bottom-trawl fishery (Figure 20.10).

20.3.5 Catch per unit effort

Trends in non-standardized CPUE (kg/hour) and effort (thousand hours fished) are shown in Figure 20.11. The figure shows CPUE and effort in all bottom-trawl tows where of Icelandic slope beaked redfish was caught and were more than 50% and 80% of individual tows. CPUE of tows where more than 50% and 80% gradually decreased from 1978 to a record low in 1994. Since then, CPUE has been steadily increasing and was in 2021 highest level in the time-series. From 1991 to 1994, when CPUE decreased, the fishing effort increased drastically. Since then, effort has decreased and is now at similar level as in 1980. CPUE and effort data were not available for 2022.

20.3.6 Discard

Although no direct measurements are available on discards, it is believed that there are no significant discards of Icelandic slope beaked redfish in the Icelandic redfish fishery.

20.4 Management

Ministry of Food, Agriculture and Fisheries (MFAF) in Iceland is responsible for management of the Icelandic fisheries, including the Icelandic slope beaked redfish fishery, and for the implementation of the legislation in the Icelandic Exclusive Economic Zone (EEZ). There is, however, no explicit management plan for the Icelandic slope beaked redfish.

The Ministry issues regulations for commercial fishing for each fishing year (1 September–31 August), including allocation of the TAC for each of the stocks subject to such limitations. Redfish (golden redfish (Chapter 19) and Icelandic slope beaked redfish) has been within the ITQ system from the beginning. Icelandic authorities gave, however, until the 2010/2011 fishing year a joint quota for these two species, and Icelandic fishermen were not required to divide the redfish catch into species. MFRI has since 1994 provided a separate advice for the species. The separation of quotas was implemented in the fishing year that started 1 September 2010.

20.5 Analytical assessment

The stock was benchmarked in 2023 (ICES, 2023) and is now assessed as a category 1 stock using an age- and length-based assessment model (Gadget). During the meeting the reference points were defined. The model setup and settings are described in the Stock Annex.

An error in the procedure for calculating biomass from the model output was found in 2024, which affected the estimates of total biomass and spawning-stock biomass, and thus the reference points B_{lim} and B_{pa}. Correcting the biomass levels therefore necessitates re-calculation of the stock's reference points. The error did not affect estimated recruitment levels nor exploitation rates. The results are described in more details in Chapter 20.11

20.5.1 Maturity

Maturity-at-age are shown Figure 20.12. Males mature at earlier age than females. Most of the fish is mature at age around 20 years old.

20.5.2 Natural mortality

Natural mortality M for long-lived species is considered low. In the assessment model presented here, M was set as 0.05.

20.5.3 Assessment

20.5.3.1 Data

The model uses multiple disparate datasets. The input data includes:

- Length disaggregated survey indices from the Autumn Survey IS-SMH (2000-2023, excluding 2011).
- Length distributions from the Icelandic commercial bottom-trawl fleet (1975-2023).
- Landings per 6-month period from Iceland (1975-2023).
- Age–length distributions from the Autumn Survey.
- Maturation data from the Autumn survey.

An overview of the input data and their annual availability is shown in Figure 20.13.

20.5.3.2 Overview of model settings

- The model runs from 1975 to 2024. Each year is divided into two 6-month time-steps.
- Two substocks are modelled:
  - An immature stock that has an age range of 3-20 years.
  - A mature stock that has an age range of 5-50 years.
- The oldest age is treated as a plus group (50 years and older).
- Movement from the immature stock to mature stock occurs via:
  - Maturation (using a length-based ogive)
  - Ageing (20-year-old fish automatically move to the mature stock at the end of the year).
- Modelled length ranged from 5-60 cm (with no mature individual 50 cm). Each length group was 1 cm.
- Recruitment to the immature stock occurs at age 3.
- The length increments in the survey were 10-30 cm, 30-35 cm, 34-40 cm, 41-45 cm and 46-55 cm (in total five length bins).
- One commercial fleet (bottom trawl).

20.5.3.3 Overview of model processes

- Natural mortality:
  - Natural mortality, M_a, fixed at 0.05 for all ages. The value chosen was based on settings in other redfish stocks.
- Growth:
  - Length-based von Bertalanffy growth function, k, L_∞, informed by age–length frequencies.
  - Parameter β of the beta-binomial distribution controlling the spread of the length distribution.
  - Maximum length group growth was set to 5 cm per time-step.
  - Length-weight relationship α_s, β_s, were fixed based on the means of log-linear regression of Autumn survey data.
- Maturity:
  - The logistic length-based maturity ogive α_m, l_{50} was estimated from Autumn survey data.
- Recruitment:

- Annual recruitment occurs in the first time-step, one parameter per year, R_y, and $y \in (1970, 2020)$.
- Recruitment scalar, R_c, is multiplied against all R_y to help optimization.
- Mean length at recruitment, l_0, is estimated.
- Length at recruitment has a CV of 0.1, based on Autumn survey.

- Initial population:
  - Total initial abundance of both stocks, N_0, is estimated.
  - Initial numbers-at-age calculated via $N_{0,a} = N_0 \times e^{-a(Ma+F0)}$
  - The additional mortality parameter F_0 determines the steepness of the initial numbers-at-age reflecting previous effects of fishing (estimated).
  - Initial numbers-at-age is subsequently split between stocks using an age-based ogive. The age at which 50% of the stock was mature, a_{50}, was estimated from the Autumn survey data and was fixed in the model, the alpha parameter of the ogive α_a was estimated.
  - Initial mean length-at-age were based on the von Bertalanffy growth function (see above).
  - Variance in initial length-at-age was fixed and based on length distributions obtained in the autumn survey for each stock.
- Fleet operation:
  - Two fleets: commercial bottom trawl and Autumn survey fleet.
  - Logistic fleet selection, α_f, l_{50}; one set for each of the fleets (Autumn survey or Commercial).

20.5.3.4 Length-weight relationship

The conversion from length to weight uses the following formula:

$$W_l = \alpha * l^{\beta}$$

In the model, the alpha and beta parameters are fixed and estimated from biological information collected during the Icelandic autumn survey. The observed values and estimated relationship are shown in Figure 20.14.

20.5.3.5 Likelihood data

Table 20.1 shows the datasets that are used as likelihood components in the model.

20.5.4 Diagnostics and model fit

Survey indices can be variable for the Icelandic slope beaked redfish due to its tendency to be influenced by a few very large hauls. The index data used as input here are the total raw numbers of fish caught (within length slices) in the entire autumn survey. Although they are expected to represent the entire stock, they are also expected to be highly variable because no treatment or data preprocessing has been performed to reduce this variability. This variability is reflected in the model's fit to the survey index data (Figure 20.15). In general, the model appears to follow the stock trends historically, although abundance is underestimated from 2000 to 2003 for the 10-30 cm, 30-35 cm, and 35-40 cm length groups. The terminal estimates do not deviate from the observed value for the for any of the length groups (Figure 20.15).

20.5.4.1 Length- and age–length distributions

The model estimated catch composition is illustrated in Figure 20.16 to Figure 20.19, with corresponding residual plots for each catch composition component shown in Figure 20. The model fits both length distributions good (Figure 20.16 and Figure 20.18), although in some years, it is noticeable that the model is not capturing the peaks (ca. 40-45 cm fish) in the Autumn survey data (see 2012 to 2015 in Figure 20.16). The fits to the age distribution data from the autumn survey show that the fit is not particularly good for the oldest ages (30+) where the model underestimates these ages (Figure 20.17). Furthermore, the model overestimates certain age classes which can be followed through years, first in 2009 as 12-19 years old fish and then again in 2017 and 2018 as 20-28 years old fish. The fit to the commercial age–length distributions is worse; however, this is likely because there are few age readings in each time-step (Figure 20.19). There are no discernible patterns in the residuals for any of the catch composition components (Figure 20.20).

20.5.4.2 Growth

For the Autumn survey, the growth patterns predicted by the model closely follow the observed growth from approximately age 10 onwards; however, prior to age 10, growth is underestimated (Figure 20.21). This noticeable shift is consistent between years suggesting that allowing for age specific variation in growth will improve the model. The model also fits the growth data from the bottom trawl consistently, although a similar trend of underestimating the growth rate in the younger ages is also apparent in 2001 and 2002 (Figure 20.22). This suggests that the model is overestimating the recruitment length, although it should be noted that (1) the age–length data are sparser for the younger ages, and (2) that because the stock does not enter the fishery until later ages, the beta-binomial length update will have created plausible standard deviations in the length-at-age by that time.

20.5.4.3 Maturation

The model's fit to the maturation data are shown in Figure 20.23.

20.5.4.4 Selection by fleet

Estimated length-based selection by fleet is shown in Figure 20.24.

20.5.4.5 Model results

Annual output from the final model is shown in Figure 20.25. A steep decline in the spawning stock is seen from the late 1980s to the early 2000s. This is followed by a period of stability in the 2000s and a gradual decline in the 2010s. The SSB is currently at its lowest point in the time-series. Since a recruitment spike in 2003, annual recruitment has also steadily declined, and furthermore, since 2010 recruitment has remained at exceptionally low values resulting in a declining total stock size and a stock composition that is increasingly dominated by older, mature fish. Fishing mortality has declined since the 1990s and was fairly stable around 0.9 from 2013–2019 and 1.1 from 2020–2022.

20.5.4.6 Retrospective analysis

The analytical retrospective analysis is shown in Figure 20.16. The model is consistent for the first three peels. An upward revision in biomass (and thus downward revision in F) occurs on the 4th peel 5th peel. This suggests uncertainty in the model output; however, it should be noted that the larger revisions also coincide with the removal of age data. Notably, the last three years of age data from the Autumn survey are removed in the 4th and 5th peels (Figure 20.16).

The table below shows the Mohn's rho values for SSB, F and recruitment for this five-year peel:

Variable	Value
F_{bar}	-0.078
SSB	0.084

Variable	Value
Recruitment	305

The Mohn's rho values for F_{bar} and the spawning-stock biomass are relatively low or 7.8% and 8.4% respectively. Mohn's rho for recruitment is on the other hand very higher (305%) and is a result of high uncertainty due to low selectivity at the smallest age (3) detectable by the surveys. Mohn's ρ values are within the range recommended by Carvalho et al. [2] (< 0.2).

20.5.4.7 Conclusion

Overall, the gadget model presented here captures the overall trends in the data and offers a significant improvement over the current category 3 'survey trend' empirical rule used in assessments. The main issues identified with the model, for instance, the consistent trend in the analytical retrospective analysis, and the fits to the age–length distributions (particularly to younger ages) will likely improve as more age data becomes available in the coming years.

20.6 Reference points

Note that the reference points were corrected in this year's assessment because of an error in the last year's assessment (see chapter 20.11) In line with ICES technical guidelines, the MSY $B_{trigger}$ is set as B_{pa} because this is the first time the reference points are evaluated. Maximum sustainable yield is estimated to be obtained at an F of 0.061. F_{p05}, i.e. the maximum F that has less than 5% chance of going below B_{lim} when the advice rule is applied, is 0.041. This value is less than F_{MSY}, therefore the suggested F_{target} is set to F_{p05} = 0.041. The re-evaluated estimate for F_{target} is lower than the original F_{target} that equalled 0.061 and was also set to F_{p05}.

20.7 State of the stock

The Group concludes that the state of the stock is at a low level. Since 2007, survey estimates of *S. mentella* have consistently shown very low abundance of pre-fishery juveniles (< 30 cm). This raises concerns about the productivity of the stock. Without substantial recruitment biomass levels will likely continue to decline.

20.8 Short-term forecast

Maturity, growth, and the length-weight relationship in the forecast are based on the processes estimated within the model. Similarly, the commercial fleet selectivity is the same as estimated by the model. Intermediate catch is equal to the leftover of the current fishing year (January-August) and for September-December F=F_{MSY}. Recruitment in the forecast is the average of the last five years (2019-2023).

20.9 Medium-term forecast

No medium-term forecast was carried out.

20.10 Uncertainties in assessment and forecast

Only the fishable biomass of the stock is found in Icelandic Waters and recruitment comes most likely from East Greenland. Connection of the Icelandic slope stocks with the stocks found in East Greenland (Chapter 21) and the deep pelagic stock (Chapter 18) is not known. Currently, little age data are available, therefore, when years are removed in the retrospective analysis the model results substantially. We anticipate reduced uncertainty when more age data are added.

20.11 Comparison with previous assessment and forecast

Figure 20.17 shows biomass trajectories before and after the correction. There is an upward revision in the estimated SSB and TB. The difference is largest (~12%) when the SSB stabilized from 2000 to 2008. However, throughout the time-series the uncorrected estimates of SSB and TB both fall within the uncertainties (yellow shaded area) of the respective revised estimates Figure 1. Furthermore, the corrected terminal estimates of both SSB and TB are very similar to the uncorrected equivalents (3% increase) so the status of the fishery and the advice for the 2023-2024 fishing year remain unchanged Figure 20.17.

20.12 Basis for advice

ICES MSY approach agreed during the WKBNORTH meeting (ICES 2023).

20.13 Management considerations

S. mentella is a slow growing, late maturing deep-sea species and is therefore considered vulnerable to overexploitation and advice must be conservative.

The advice is given by calendar year, though the fishing year runs from 1 September to 31 August of the following year.

20.14 Regulation and their effects

There are no explicit management for Icelandic slope beaked redfish. The species is managed under the ITQ system. A general description of management and regulation of fish populations in Icelandic Waters is given in the stock annex for the stock (smn-con SA) with emphasis on Icelandic slope beaked redfish where applicable.

Icelandic authorities gave until the 2010/2011 fishing year a joint quota for golden redfish (*S. norvegicus*) and Icelandic slope beaked redfish. The separation of quotas was implemented in the fishing year that started September 1, 2010.

20.15 References

ICES. 2023. BWKNORTH 2023

20.16 Figures and Tables

Table 20.1. Overview of the likelihood data used in the model. Survey indices are calculated from the length distributions and are disaggregated (sliced) into five groups.

Component name	Quarters	Year range	Delta 1	Type
aldist.aut	2	2000-2023	1 cm	Age- length distribution
aldist.comm	Both periods	1998-2023	1 cm	Age- length distribution
ldist.aut	2	2000-2023	1 cm	Length distribution

Component name	Quarters	Year range	Delta 1	Type
ldist.comm	Both periods	1976-2023	1 cm	Length-distribution
matp.aut	2	2000-2023		Ratio of immature:mature by length group
si.10-30.aut	2	2000-2023	10-30 cm	Survey index
si.30-35.aut	2	2000-2023	30-35 cm	Survey index
si.35-40.aut	2	2000-2023	35-40 cm	Survey index
si.40-45.aut	2	2000-2023	40-45 cm	Survey index
si.45-55.aut	2	2000-2023	45-55 cm	Survey index

Table 20.2: Reference points from stochastic simulations. Note that the reference points corrected.

Framework	Reference points	Value	Old values	Technical basis
MSY approach	MSY $B_{trigger}$	217 563 t	192 119 t	B_{pa}
	F_{MSY}	0.041	0.061	Stochastic simulations.
Precautionary approach	B_{lim}	156 568 t	138 257 t	Median SSB for 2000-2005
	B_{pa}	217 563 t	192 119 t	$B_{lim} * exp(1.645 * sigma)$
	F_{lim}	0.07	0.79	Equilibrium F that will maintain SSB above B_{lim} with a 50% probability
	F_{pa}	0.041	0.061	F, when ICES AR is applied, leading to P(SSB > B_{lim}) = 0.05

Table 20.3: Nominal landings (in tonnes) of Icelandic slope beaked redfish 1950–2023 from the Iceland Sea ecoregion (ICES Division 5.a and Subarea 14 within the Icelandic EEZ).

Year	Iceland	Others	Total
1950	1458	36 269	37 727
1951	1944	45 825	47 769
1952	885	55 554	56 439
1953	658	86 011	86 669
1954	577	75 972	76 459
1955	654	52 784	53 438
1956	674	40 047	40 721
1957	558	35 993	36 551
1958	409	43 820	44 229
1959	398	40 175	40 573

Year	Iceland	Others	Total
1960	407	38 428	38 836
1961	307	31 534	31 841
1962	264	35 122	35 386
1963	456	38 338	38 794
1964	362	45 414	45 776
1965	473	55 930	56 403
1966	332	47 491	47 823
1967	357	47 313	47 670
1968	494	50 892	51 386
1969	486	38 358	39 345
1970	500	35 800	36 300
1971	495	34 376	34 871
1972	593	39 874	40 468
1973	794	35 251	36 045
1974	806	32 103	32 909
1975	1404	29 301	30 705
1976	715	28 632	29 346
1977	590	22 427	23 018
1978	3693	209	3902
1979	7448	246	7694
1980	9849	348	10 197
1981	19 242	447	19 689
1982	18 279	213	18 492
1983	36 585	530	37 115
1984	24 271	222	24 493
1985	24 580	188	24 768
1986	18 750	148	18 898
1987	19 132	161	19 293
1988	14 177	113	14 290

Year	Iceland	Others	Total
1989	40 013	256	40 269
1990	28 214	215	28 429
1991	47 378	273	47 651
1992	43 414	0	43 414
1993	51 221	0	51 221
1994	56 674	46	56 720
1995	48 479	229	48 708
1996	34 508	233	34 741
1997	37 876	0	37 876
1998	32 841	284	33 125
1999	27 475	1115	28 590
2000	30 185	1208	31 393
2001	15 415	1815	17 230
2002	17 870	1175	19 045
2003	26 295	2183	28 478
2004	16 226	1338	17 564
2005	19 109	1454	20 563
2006	16 339	869	17 208
2007	17 091	282	17 373
2008	24 123	0	24 123
2009	19 430	0	19 430
2010	17 642	0	17 642
2011	11 738	0	11 738
2012	11 965	0	11 965
2013	8761	0	8761
2014	9500	0	9500
2015	9311	0	9311
2016	9536	0	9536
2017	8371	0	8371

Year	Iceland	Others	Total
2018	9995	0	9995
2019	8716	0	8716
2020	11 375	0	11 375
2021	10 588	0	10 588
2022	9457	0	9457
2023	6676	0	6676

Table 20.4: Results from the assessment. All weights are in tonnes. Recruitment is in millions

Year	Recruitment			SSB			Total catch	F		
	Low	Age 3	High	Low	SSB	High		Low	Fully selected	High
1975				235769	295686	352307	30705	0.114	0.133	0.175
1976	162	199	244	213468	271773	331074	29347	0.114	0.135	0.181
1977	131	164	189	200241	258707	322223	23017	0.093	0.111	0.150
1978	91	115	130	193767	252547	319087	3902	0.0154	0.0186	0.025
1979	57	87	100	210550	271662	342232	7694	0.029	0.035	0.046
1980	28	45	63	230161	293949	369377	10198	0.037	0.044	0.058
1981	12	22	38	252419	318212	397739	19689	0.069	0.083	0.109
1982	0.004	5.98	19.2	269743	336132	416816	18492	0.063	0.075	0.098
1983	32	46	71	289216	354448	433518	37115	0.127	0.150	0.194
1984	0.003	5.34	17.9	291552	353543	429559	24493	0.083	0.098	0.125
1985	0.003	6.41	17.5	300934	359821	431557	24768	0.082	0.096	0.120
1986	6.12	10.8	17.2	308117	363485	430956	18897	0.062	0.070	0.086
1987	24	32	40	316700	368174	431155	19293	0.062	0.069	0.082
1988	142	159	182	321194	368246	426267	14290	0.045	0.050	0.057
1989	30	37	44	324772	369083	421976	40268	0.128	0.142	0.159
1990	23	30	37	302213	343658	391495	28430	0.094	0.104	0.115
1991	33	38	42	293519	333453	380843	47651	0.168	0.186	0.21
1992	41	48	54	267220	305490	351663	43414	0.167	0.186	0.21
1993	113	120	132	244540	281150	325287	51221	0.22	0.25	0.28
1994	53	57	63	216550	251383	292597	56720	0.28	0.33	0.38

Year	Recruitment			SSB			Total catch	F		
	Low	Age 3	High	Low	SSB	High		Low	Fully selected	High
1995	47	50	56	182863	215960	254831	48708	0.28	0.34	0.40
1996	49	53	58	159065	191239	229922	34741	0.23	0.28	0.34
1997	42	46	51	149334	180542	218930	37876	0.27	0.34	0.42
1998	42	46	53	137855	167649	205750	33125	0.26	0.33	0.42
1999	41	45	49	131286	159593	197832	28590	0.24	0.30	0.39
2000	41	44	50	128770	155597	194178	31394	0.28	0.35	0.45
2001	37	40	46	123791	149233	188358	17231	0.152	0.189	0.24
2002	29	33	38	129796	154377	194545	19045	0.167	0.20	0.25
2003	24	27	32	133611	157506	198959	28478	0.25	0.30	0.37
2004	20	25	34	128678	151832	194549	17564	0.153	0.187	0.22
2005	29	33	38	131808	154579	198675	20563	0.176	0.21	0.25
2006	32	40	50	131678	154261	199381	17208	0.144	0.176	0.20
2007	33	38	47	132020	154555	201079	17372	0.142	0.175	0.20
2008	18	23	29	131168	153811	201959	24125	0.191	0.24	0.27
2009	22	25	28	123792	146828	197274	19429	0.156	0.199	0.23
2010	17.2	18.7	23	120023	143727	197041	17642	0.140	0.183	0.21
2011	4.13	6.4	9.68	117560	141963	197531	11738	0.090	0.119	0.138
2012	0.0027	0.0031	3.25	119144	144193	201516	11965	0.089	0.119	0.138
2013	0.0029	1.86	7.12	119749	145264	203820	8761	0.063	0.084	0.098
2014	0.0026	0.0030	1.33	121685	147801	206858	9500	0.066	0.089	0.104
2015	5.01	7.55	11.2	121320	147817	206472	9311	0.063	0.085	0.099
2016	1.80	2.54	4.48	119526	146331	203883	9536	0.063	0.086	0.101
2017	2.1	3.28	6.12	115984	142972	199012	8371	0.055	0.075	0.088
2018	0.0027	0.003	0.0052	112261	139536	193908	9995	0.066	0.090	0.107
2019	0.383	0.893	2.87	106006	133392	185938	8716	0.058	0.080	0.097
2020	0.0026	0.0029	0.0872	100094	127422	178126	11375	0.079	0.110	0.134
2021	0.0025	0.0029	0.0039	90971	117981	166758	10588	0.077	0.108	0.136
2022	0.0026	0.003	0.0043	81926	108585	155504	9457	0.072	0.104	0.133

Year	Recruitment			SSB			Total catch	F		
	Low	Age 3	High	Low	SSB	High		Low	Fully selected	High
2023	2.73	4.88	10.8	73583	99823	144873	6676	0.054	0.078	0.103
2024	2.73	4.88	10.8	67523	93350	136657				

Table 20.5: Beaked redfish in Subarea 14 and Division 5.a, Icelandic slope stock. Values in the forecast and for the interim year.

Variable	Value	Notes
F (2024)	0.014	Based on assumed catch in 2024
SSB (2025)	93 350	Short-term forecast; tonnes
$R_{age\ 3}$ (2024)	2.1	From the assessment; millions
$R_{age\ 3}$ (2025)	3.8	Resampled from the years 2020–2024; millions
Total catch (2024)	1500	Based on catches in the first eight months of the 2023/24 fishing year; tonnes.

Table 20.6. Beaked redfish in Subarea 14 and Division 5.a, Icelandic slope stock. Annual catch scenarios. All weights are in tonnes.

Basis	Total catch (2025)	F (2025)	SSB (2026)	% SSB change*	% advice change**
ICES advice basis					
MSY	0	0	91 426	-2.1	0
Other scenarios					
$F_{sq} = F_{2023}$	2575	0.078	90 111	-3.5	Inf.
F_{MSY}	1344	0.04	90 752	-2.8	Inf.

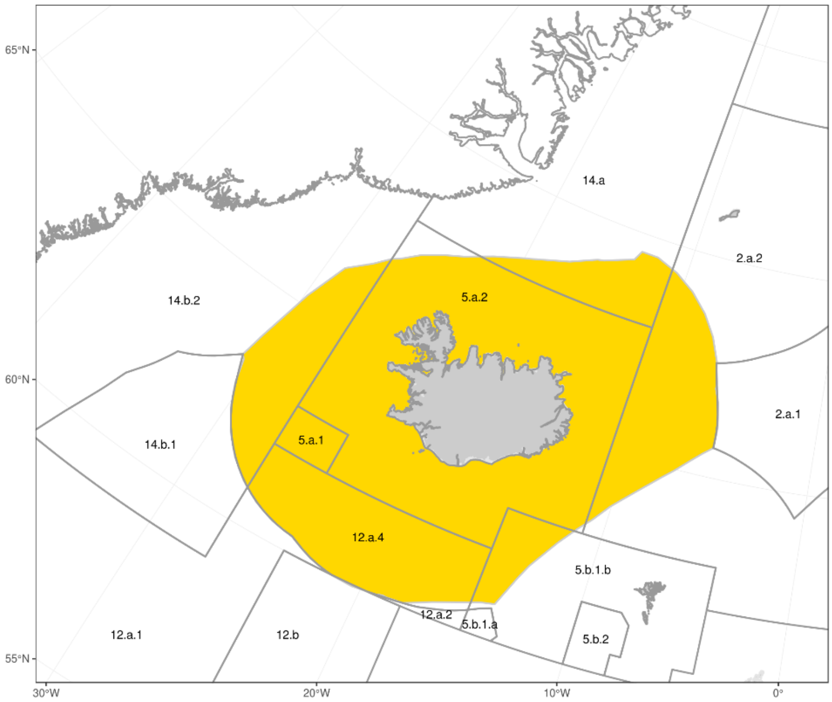

Figure 20.1. The Iceland Sea ecoregion (in yellow) as defined by ICES. The relevant ICES statistical areas are shown.

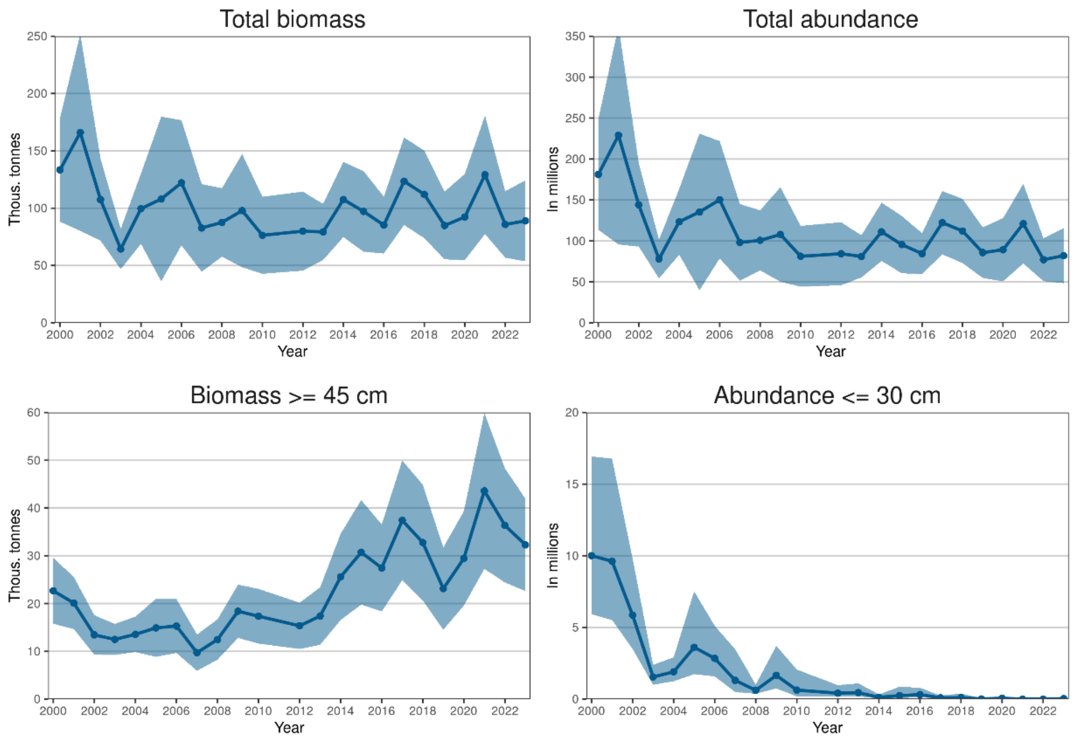

Figure 20.2. Survey indices of the Icelandic slope beaked redfish in the autumn survey in Icelandic Waters (ICES Division 5.a and part of Subarea 14) 2000–2023. No survey was conducted in 2011. The figure shows the total biomass index, total abundance index in millions of fish, biomass index of fish 45 cm and larger and abundance index of fish 30 cm and smaller.

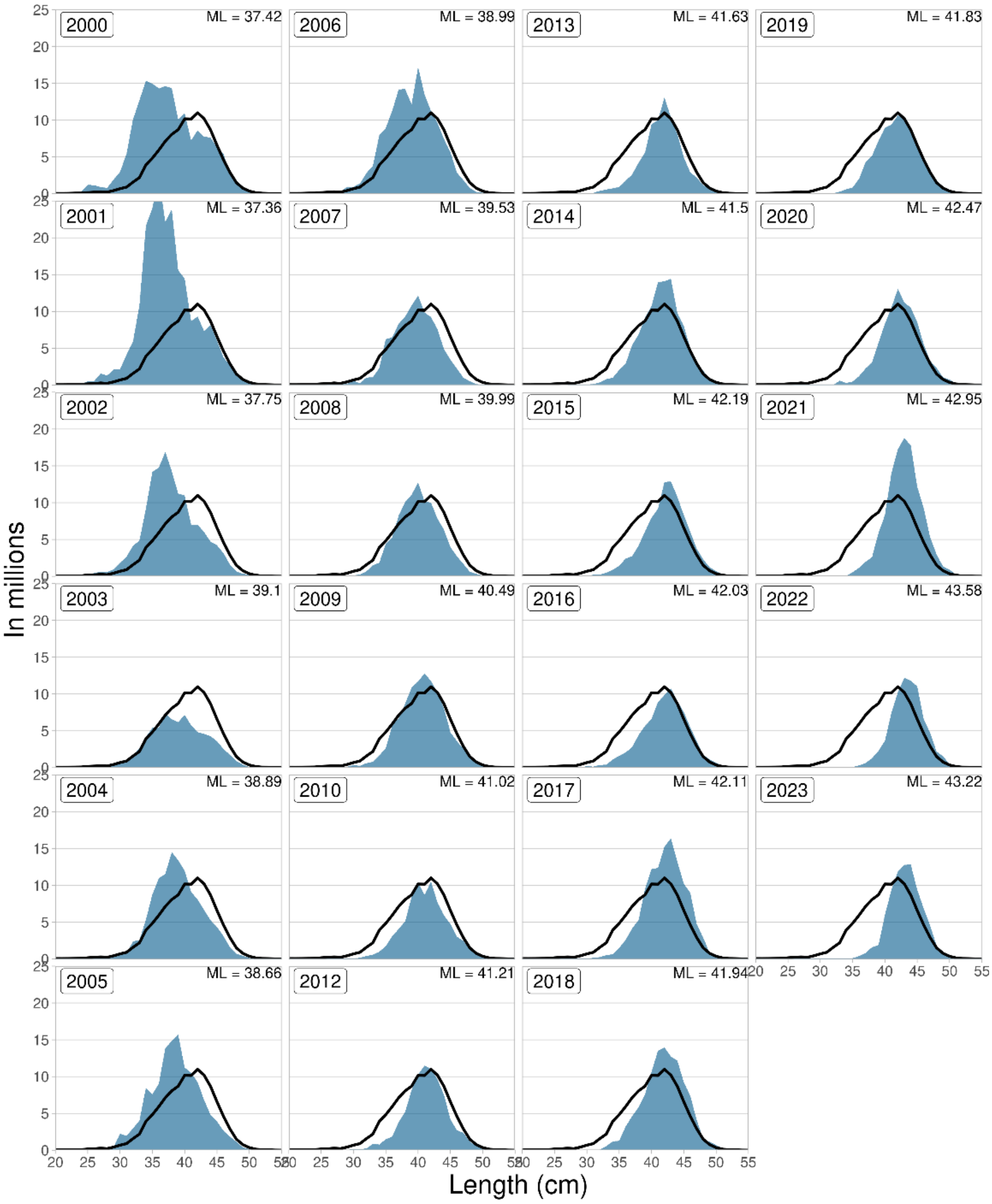

Figure 20.3. Length distribution of Icelandic slope beaked redfish in the Autumn Groundfish Survey in October 2000–2022 in Icelandic Waters (ICES Division 5.a and part of Subarea 14). No survey was conducted in 2011. The blue line is the mean of 2000–2023.

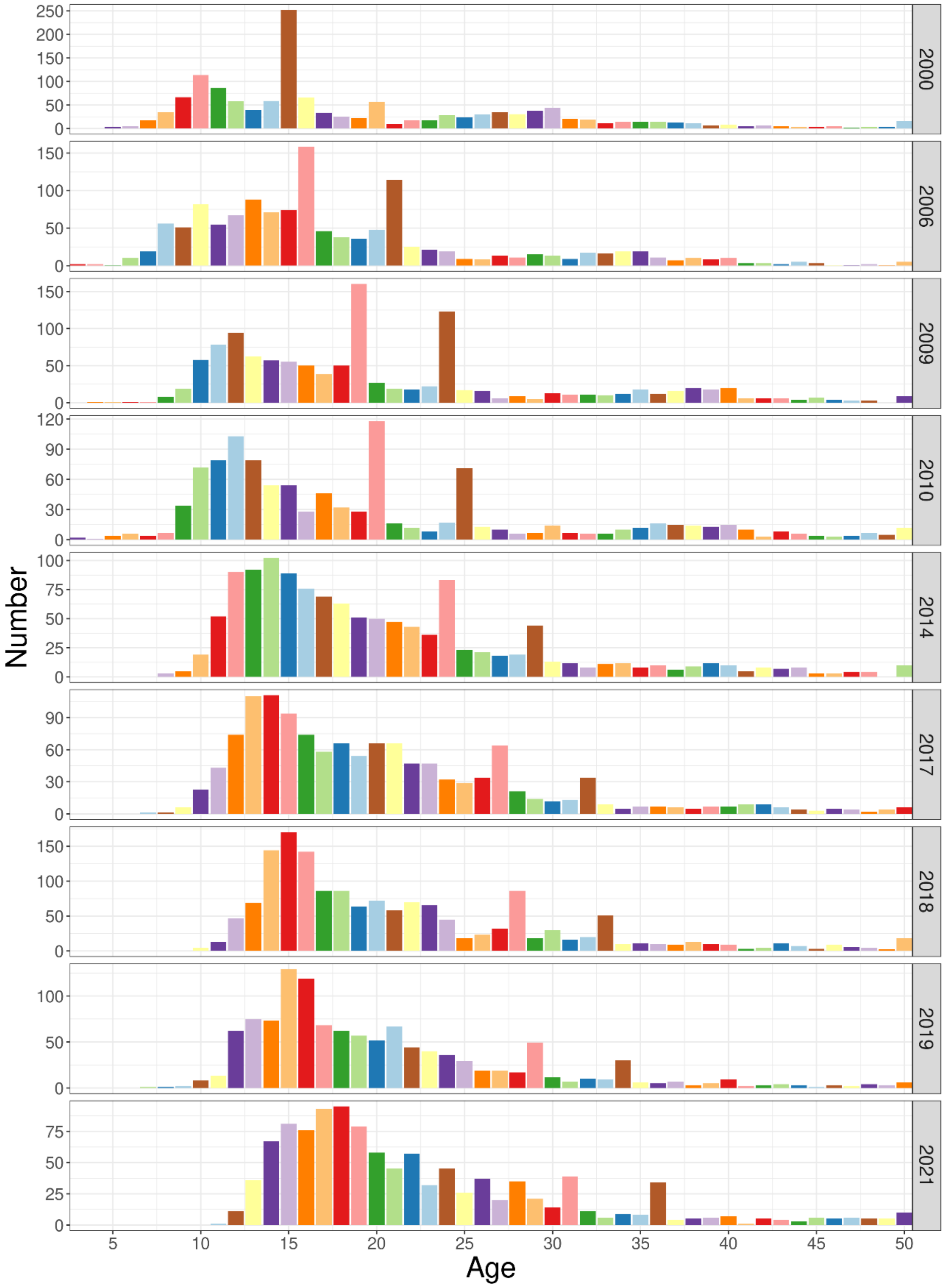

Figure 20.4. Age distribution of Icelandic slope beaked redfish from the Autumn Survey in 2000 (n = 1405), 2006 (n = 1304), 2009 (n = 1205), 2010 (n = 1101), 2014 (n = 1258), 2017 (n = 1299), 2018 (n = 1569), 2019 (n = 1176) and 2021 (n = 1108). The age class 50 are the combined age classes of 50 years and older.

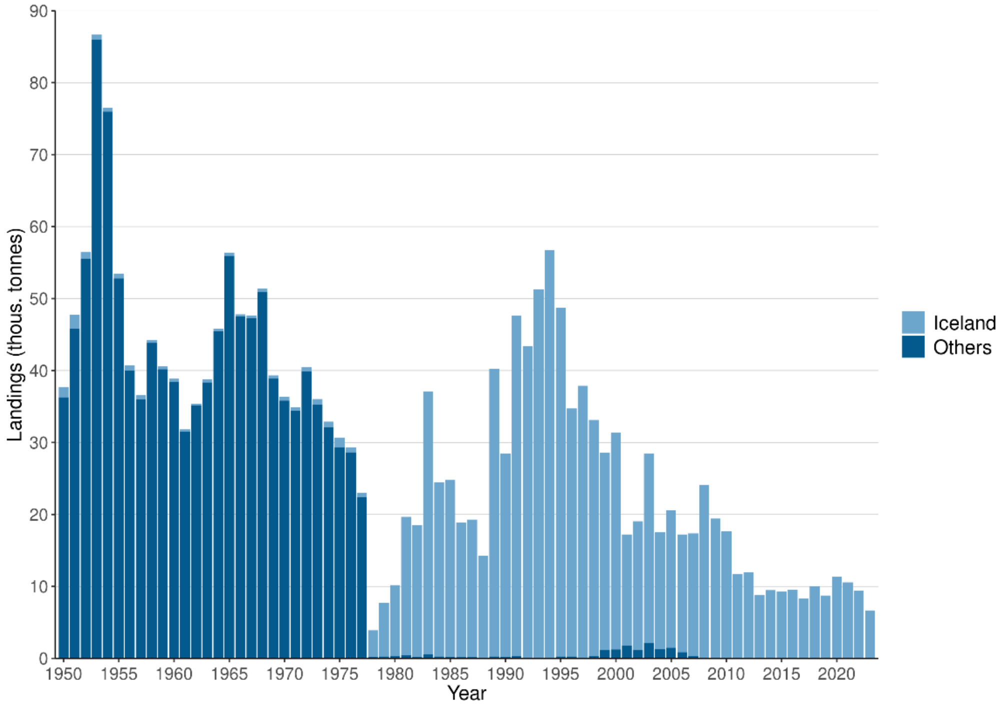

Figure 20.5. Nominal landings (in tonnes) of Icelandic slope beaked redfish from Icelandic Waters (ICES Division 5.a and Subarea 14 within the Icelandic EEZ) 1950–2023.

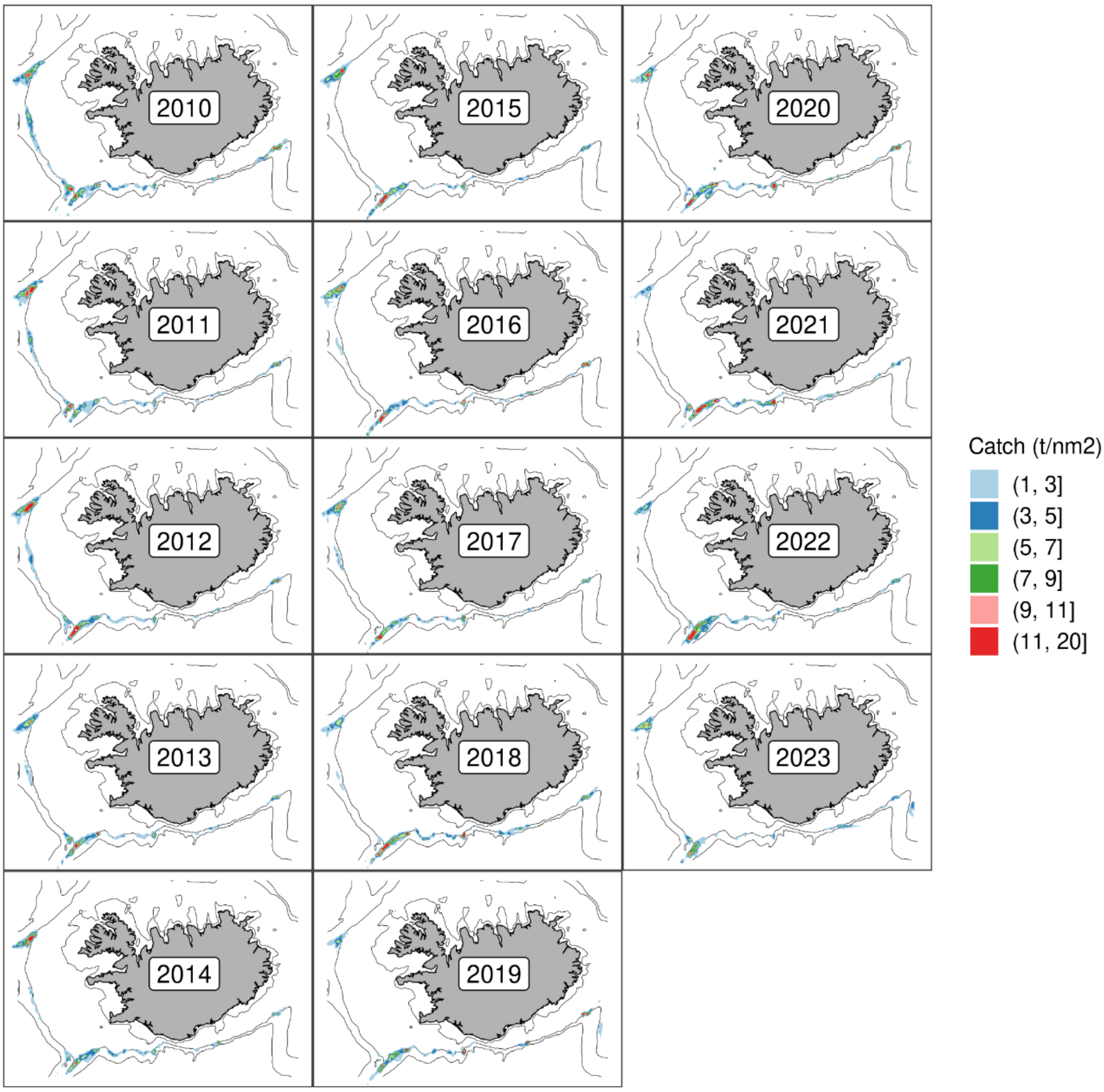

Figure 20.6. Geographical location of the Icelandic slope beaked redfish catches (t/nmi², coloured area) in Icelandic Waters (ICES Division 5.a and Subarea 14 and within the Icelandic EEZ) 2010–2023 as reported in logbooks (rep. catch) of the Icelandic fleet using bottom trawl. The black solid line indicates the boundaries of the Icelandic EEZ.

Figure 20.7. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

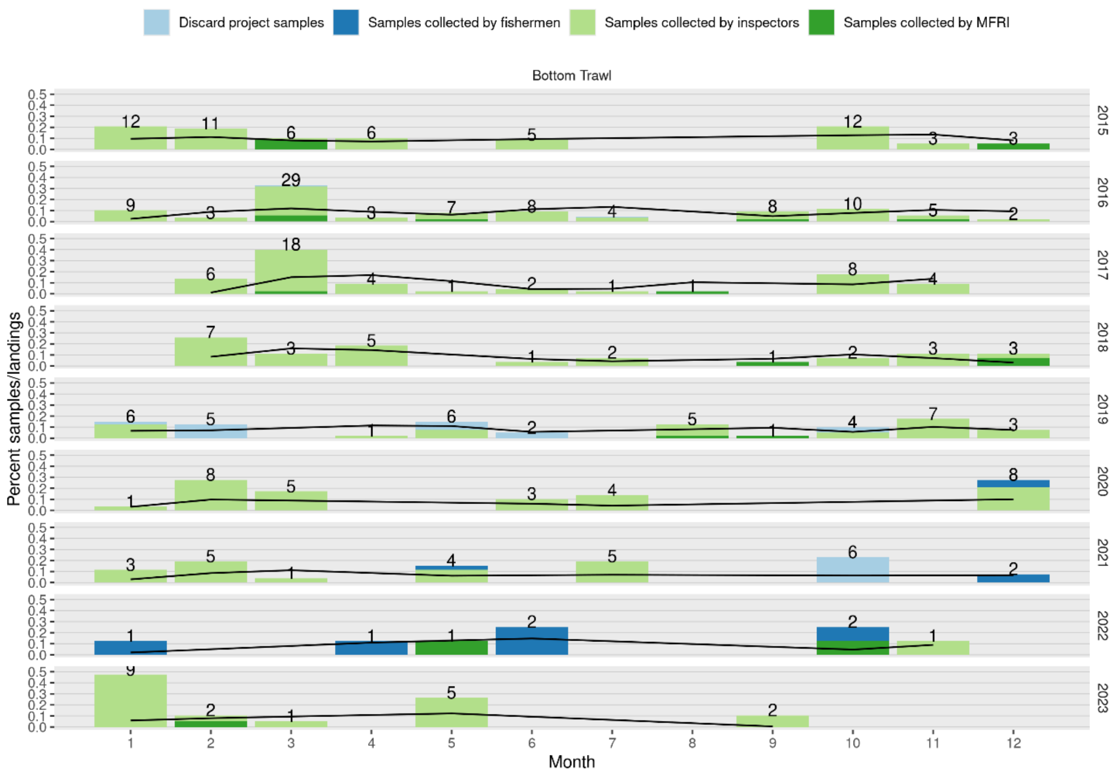

Figure 20.8. Ratio of samples by month (blue bars) compared with landings by month (solid black line) split by year of Icelandic slope beaked redfish in Icelandic Waters. Numbers of above the bars indicate number of samples by year and month.

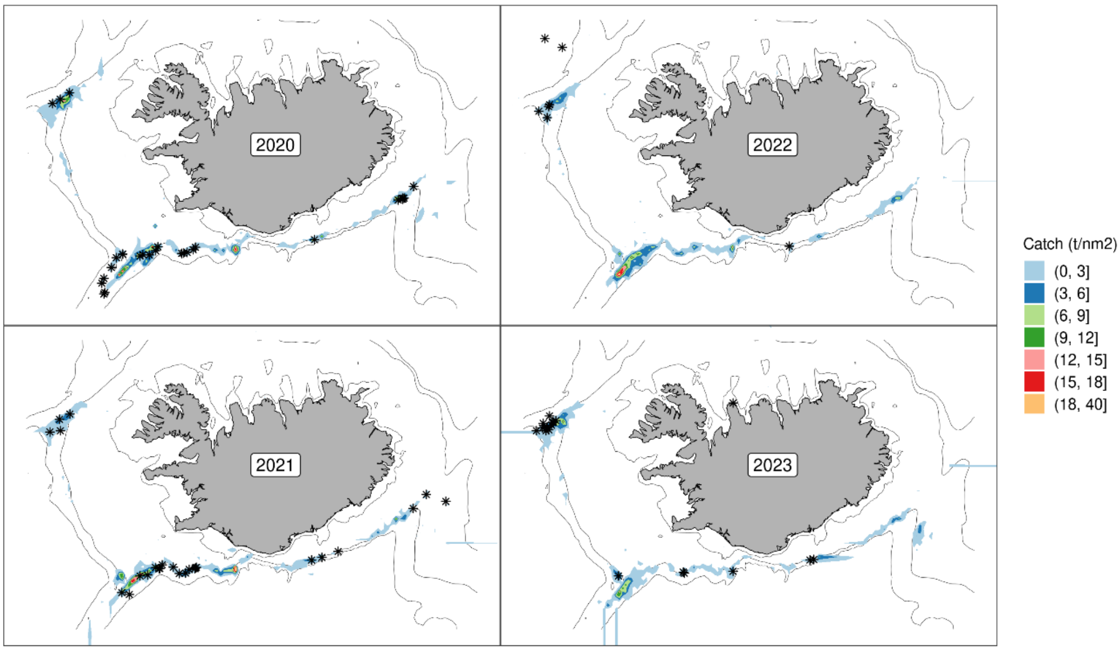

Figure 20.9. Fishing grounds of Icelandic slope beaked redfish in the years 2020–2023 as reported in logbooks (contours) and positions of samples taken from landings (stars) by year.

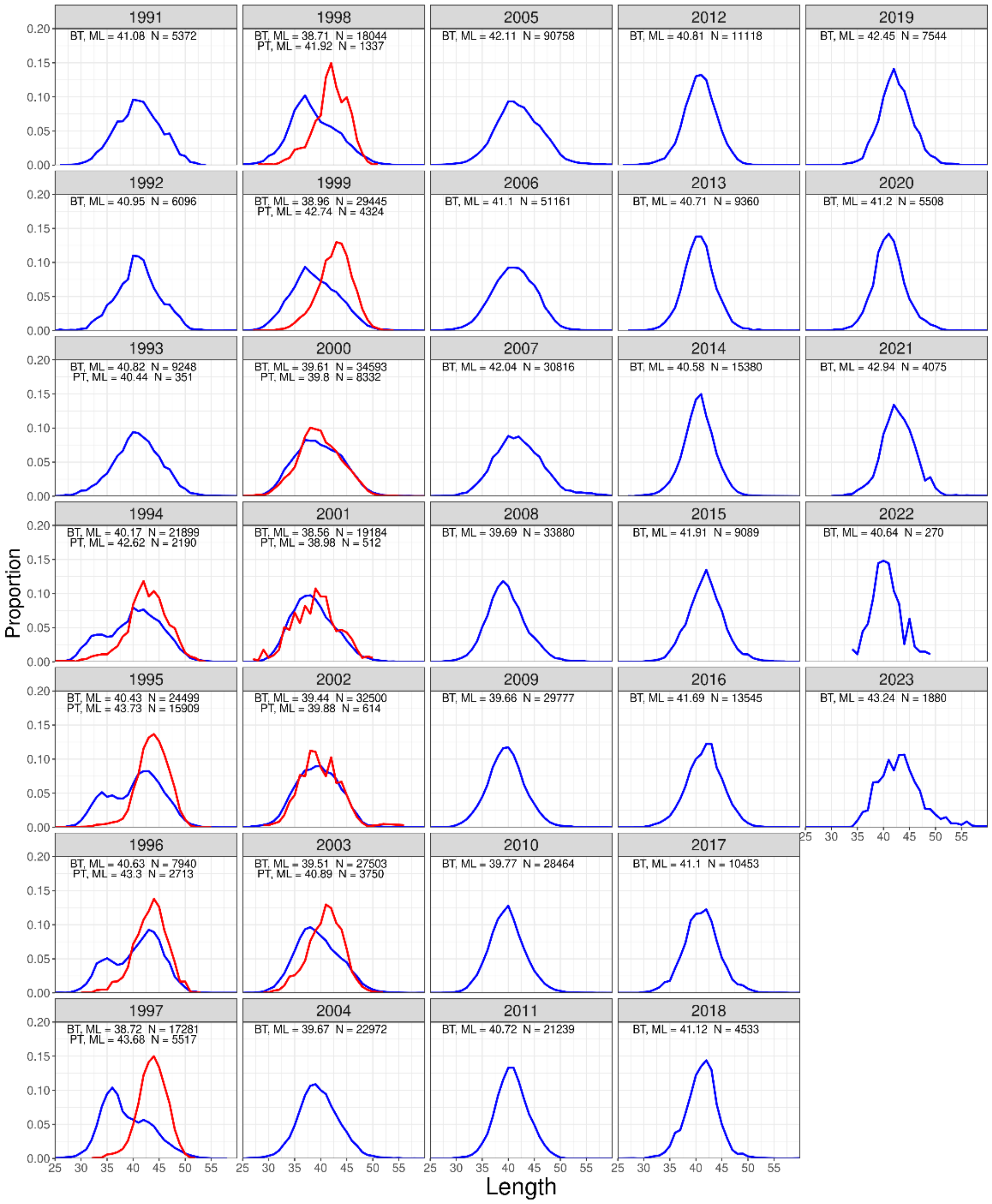

Figure 20.10. Length distributions of Icelandic slope beaked redfish from the Icelandic landings taken with bottom trawl (blue line) and pelagic trawl (red line) in Icelandic Waters (ICES Division 5.a and Subarea 14) 1991–2023.

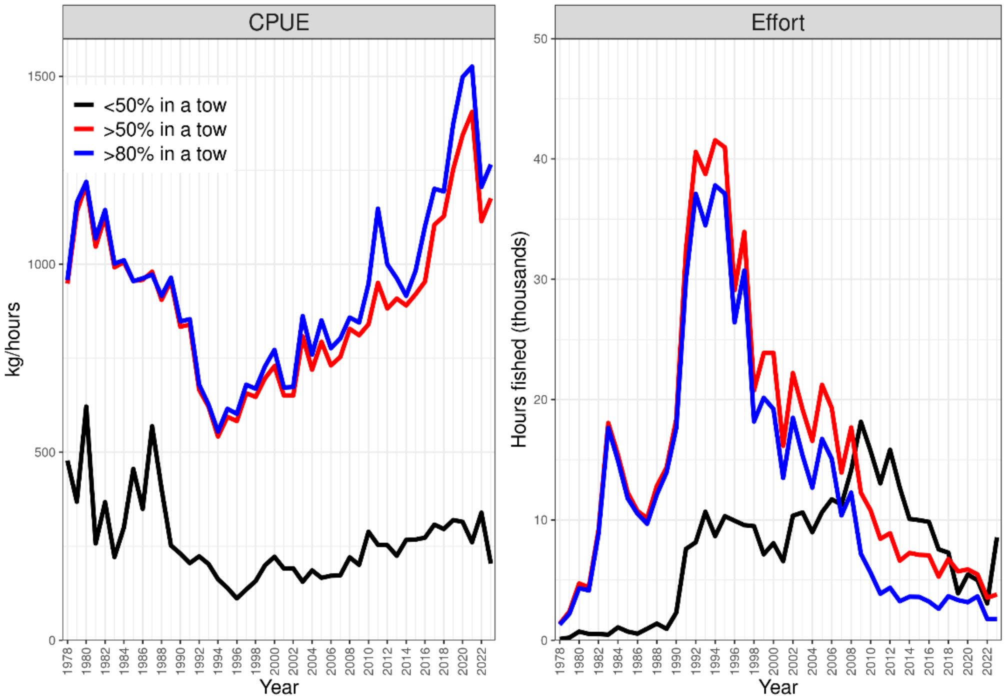

Figure 20.11. Non-standardized CPUE (kg/hour) and effort (thousand hours fished) of Icelandic slope beaked redfish from the Icelandic bottom trawl fishery in Icelandic Waters (ICES Division 5.a and Subarea 14 within the Icelandic EEZ) 1978–2021. The black lines show CPUE/effort where more than the 50% of the catch in individual tows were Icelandic slope beaked redfish, the red lines where more than 80% of the catch in individual tows were Icelandic slope beaked redfish, and the blue lines all tows where Icelandic slope beaked redfish was caught. The data for 2022 was not available.

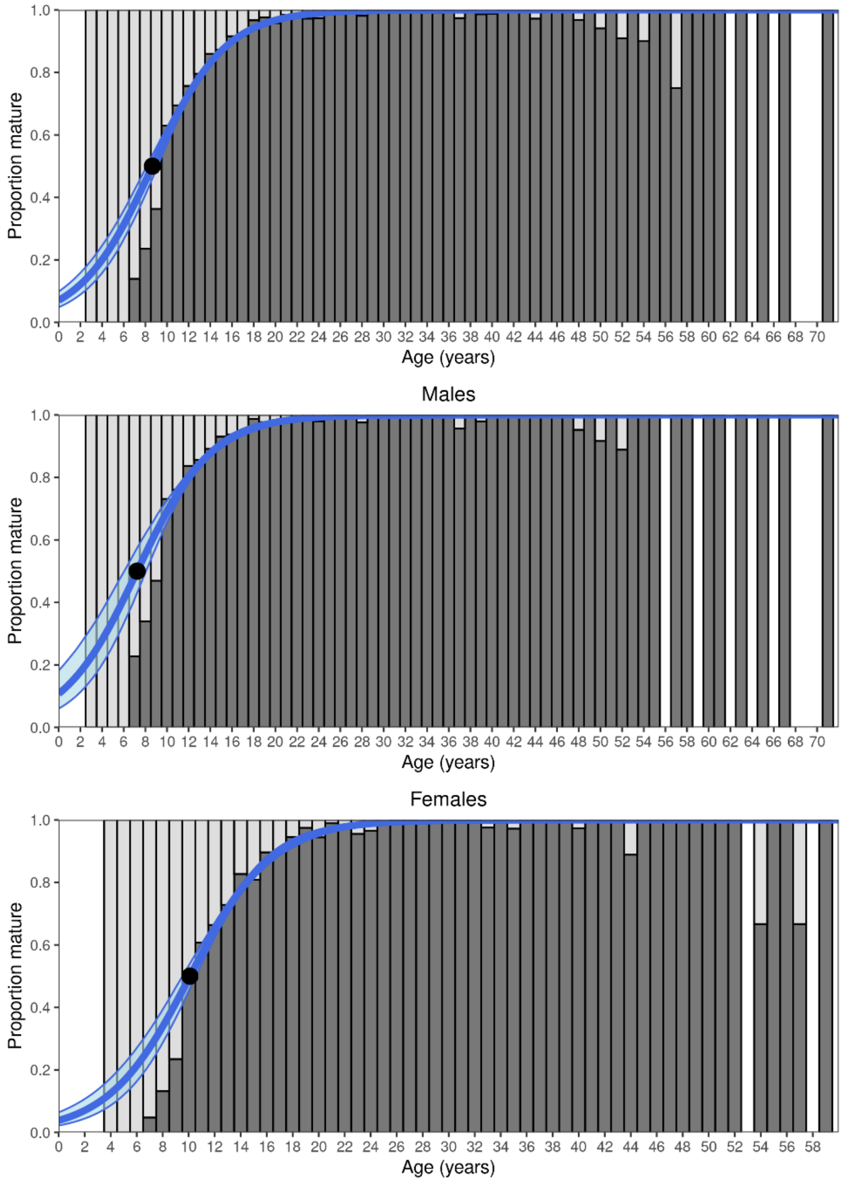

Figure 20.12. Icelandic slope beaked redfish. Maturity-at-age in the Autumn survey of both sexes combined (top), males (middle) and females) 2000-2022. All years combined. The blue line indicates the maturity curve and the black point age at which 50% is mature.

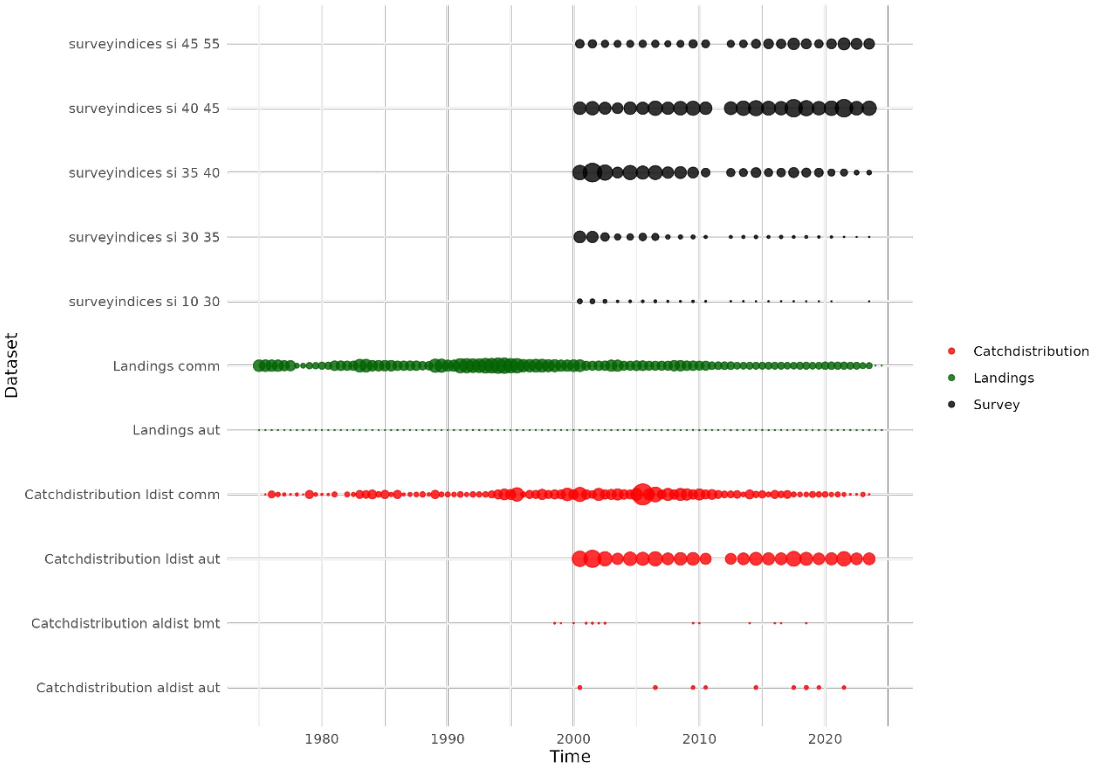

Figure 20.13. Icelandic slope beaked redfish. Overview of the datasets used in the Gadget model and when they are available.

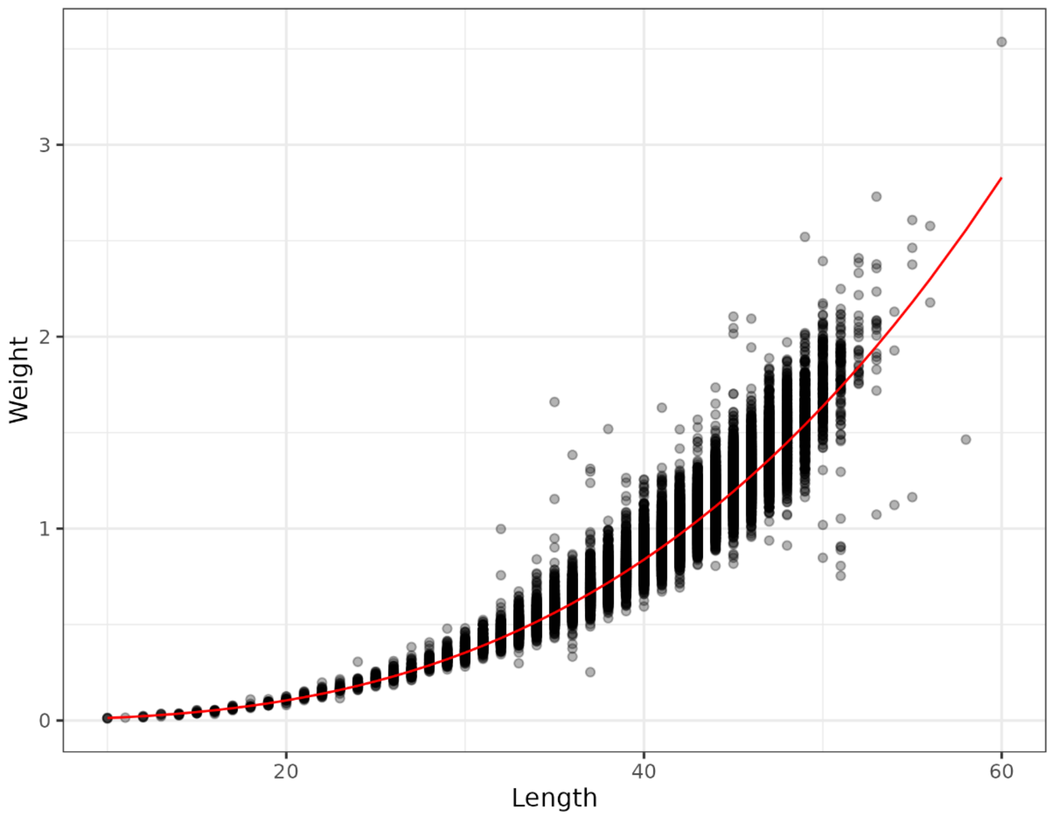

Figure 20.14. Icelandic slope beaked redfish. Observed length–weight relationship (dots) and the fitted relationship (red line).

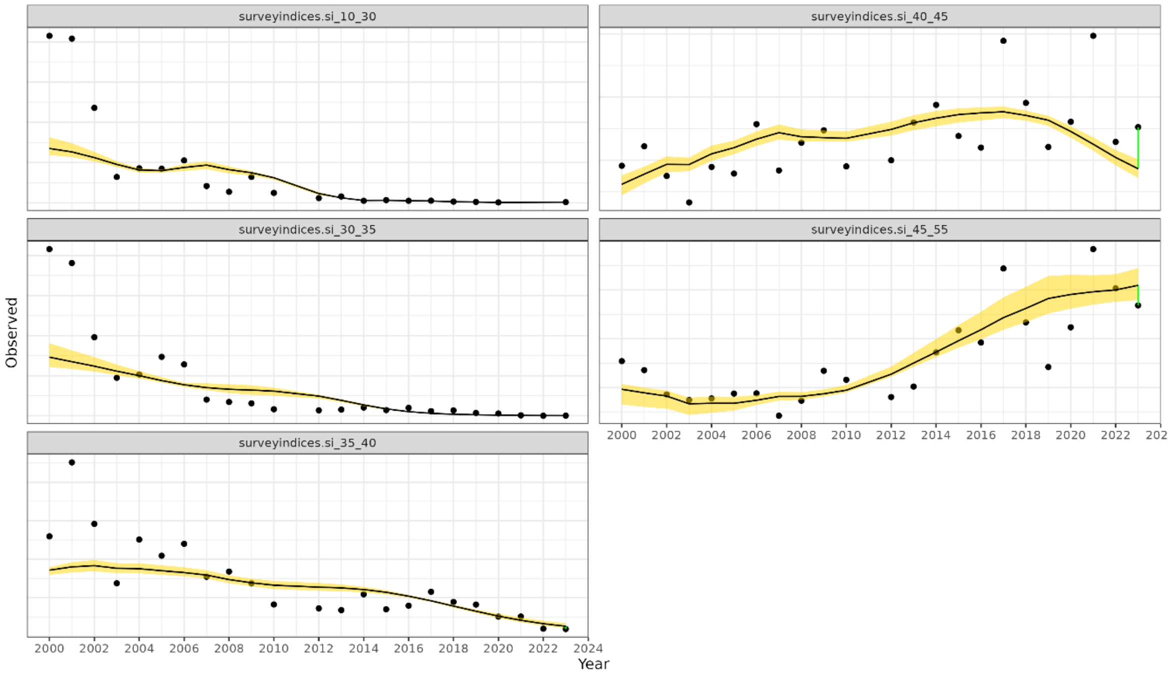

Figure 20.15. Icelandic slope beaked redfish. Autumn survey index number fits (lines) to data (points). The yellow ribbon shows the 90% confidence intervals. The vertical green lines highlight the difference between the observed and predicted values in the terminal year.

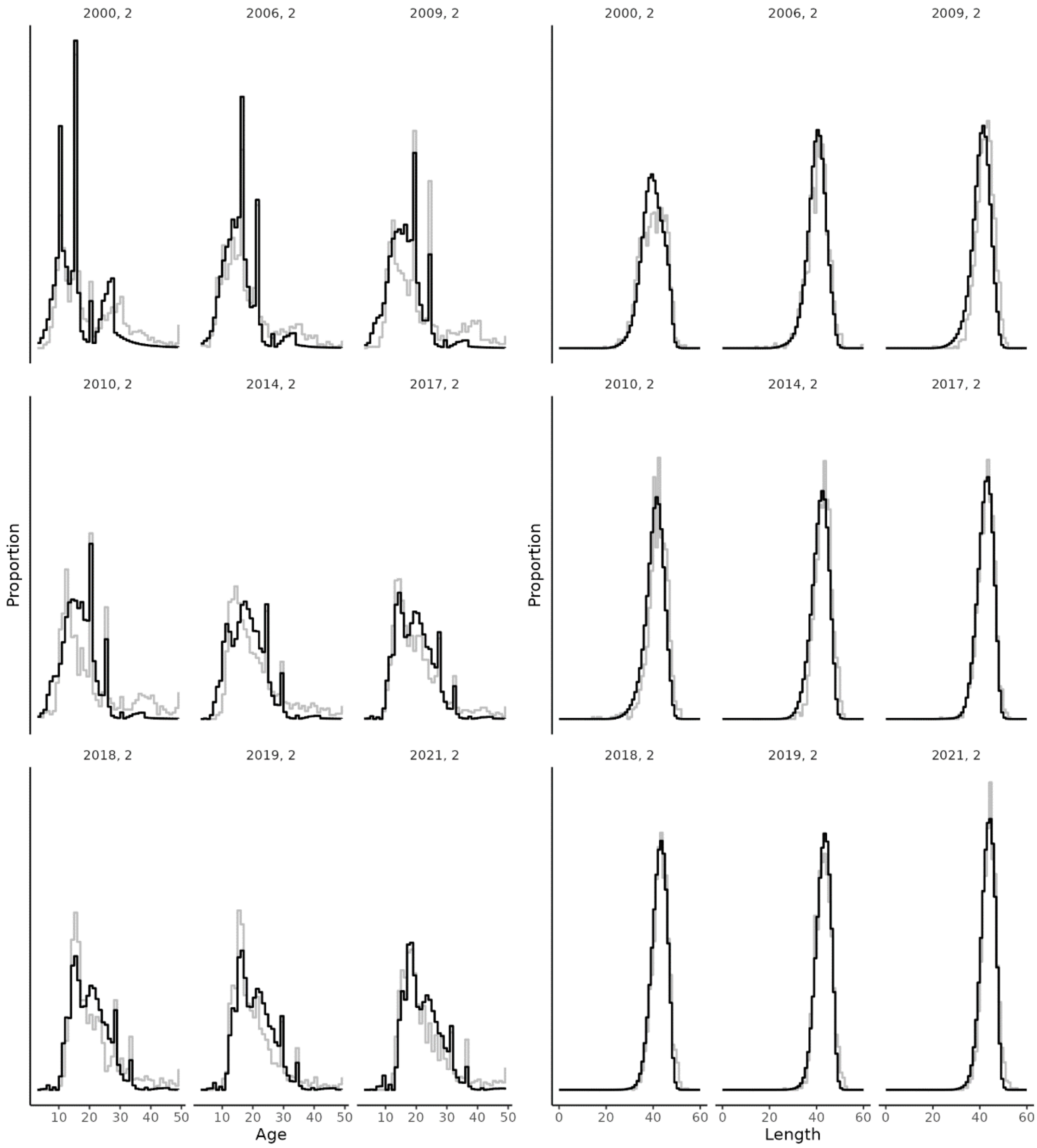

Figure 20.16. Icelandic slope beaked redfish. Comparison of autumn survey age distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

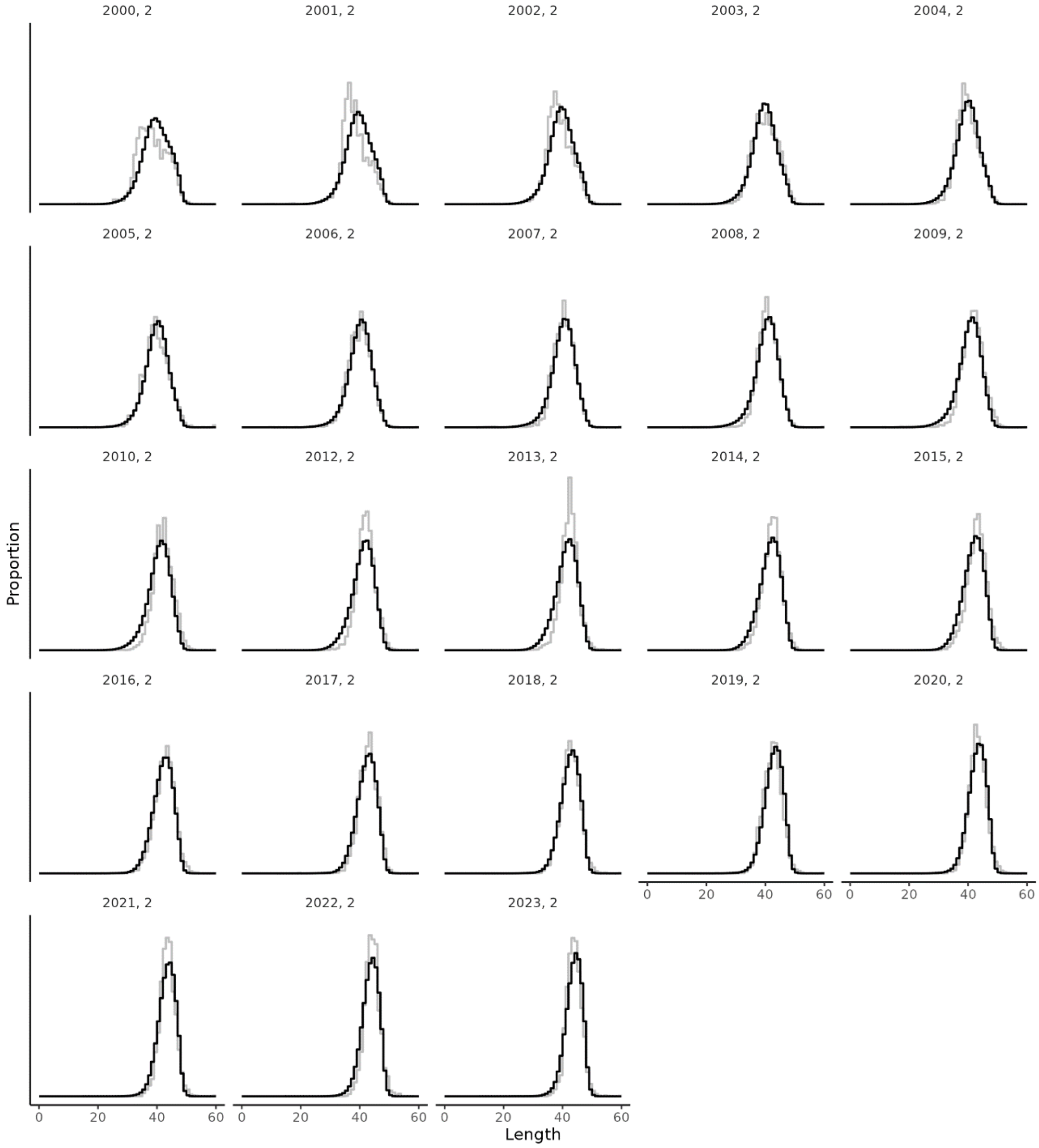

Figure 20.17. Icelandic slope beaked redfish. Comparison of autumn survey length distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

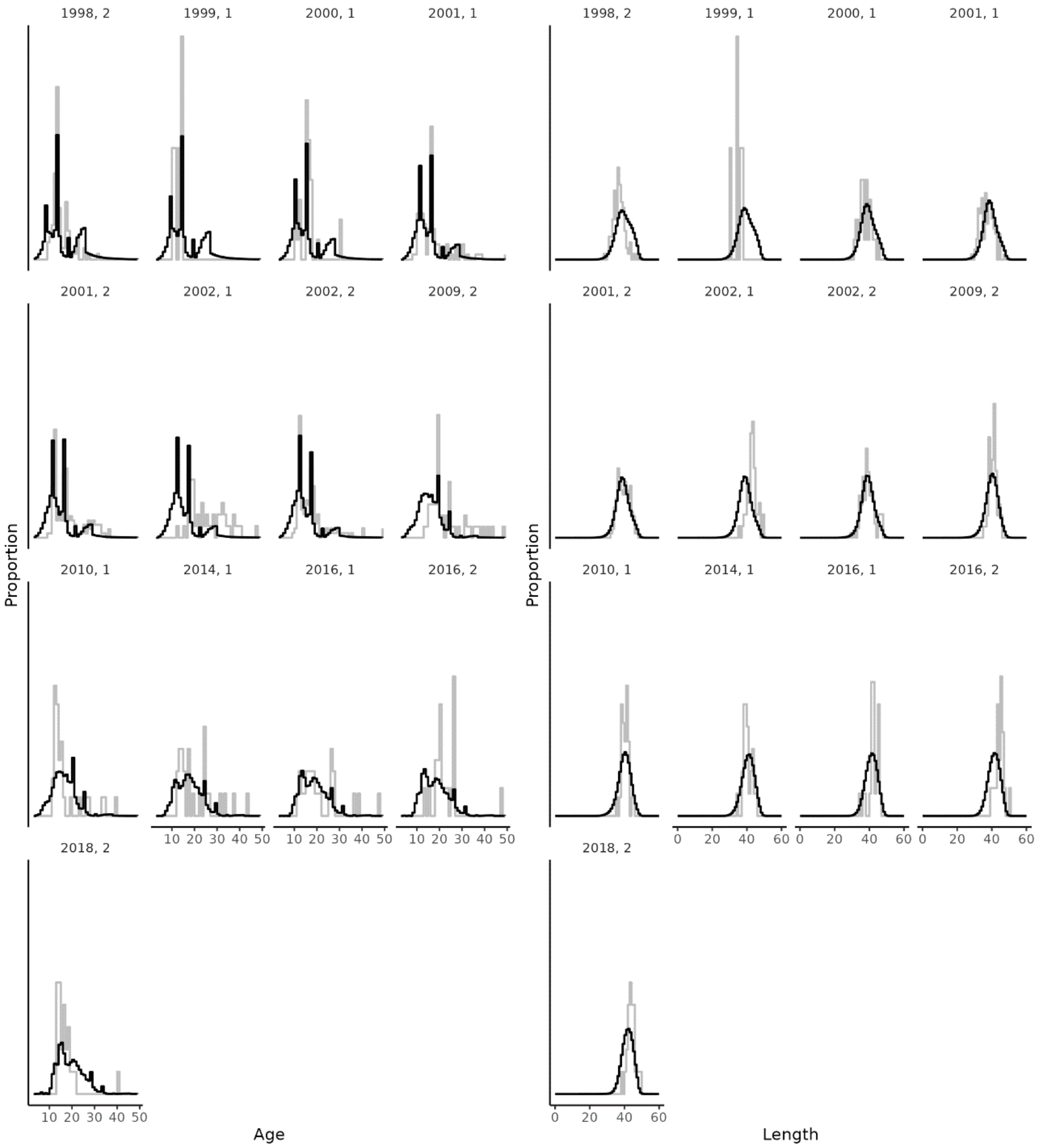

Figure 20.18. Icelandic slope beaked redfish. Comparison of commercial sample age–length distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

Figure 20.19. Icelandic slope beaked redfish. Comparison of commercial sample length distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

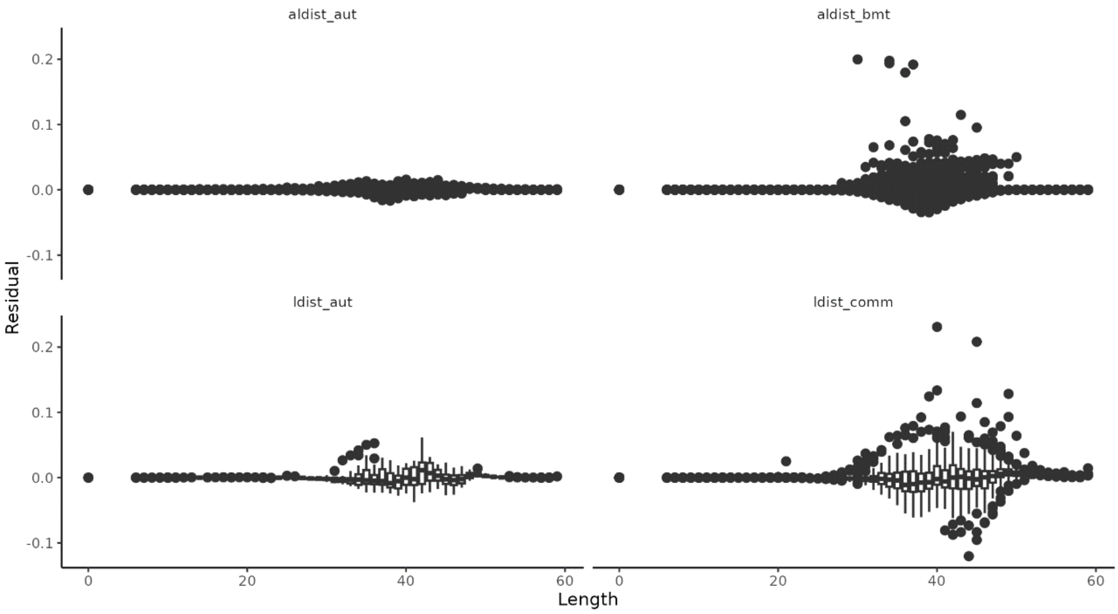

Figure 20.20: Icelandic slope beaked redfish. Model residuals for each catch composition likelihood component.

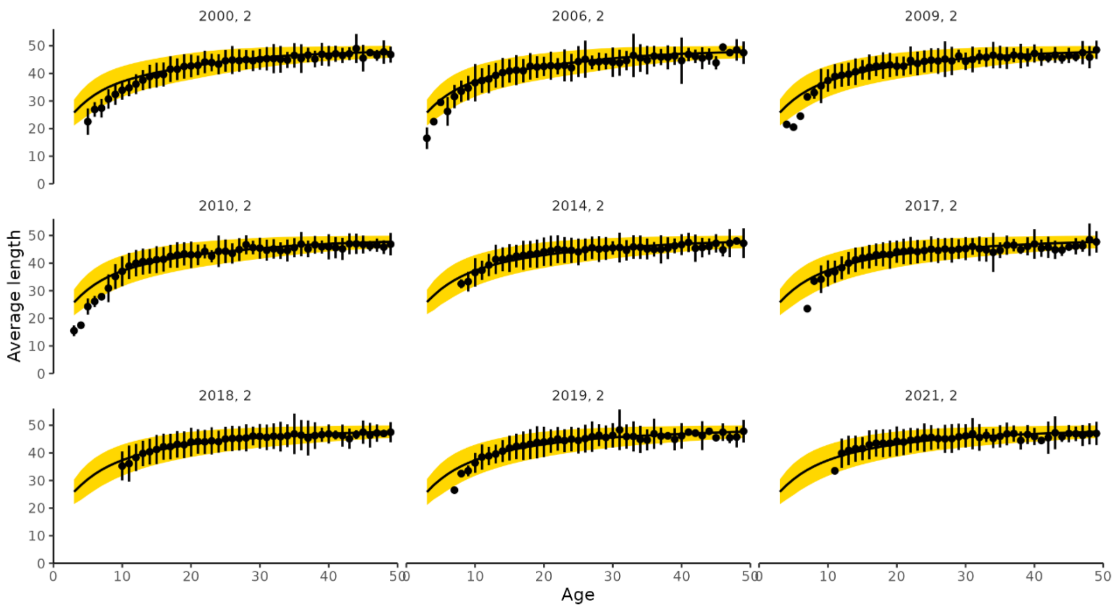

Figure 20.21. Icelandic slope beaked redfish. Model growth estimations for the Autumn survey. Yellow bands and the black line show where the mean and 90% confidence intervals of the of model predictions, whereas the points and error bars show the mean and 90% confidence intervals of the data.

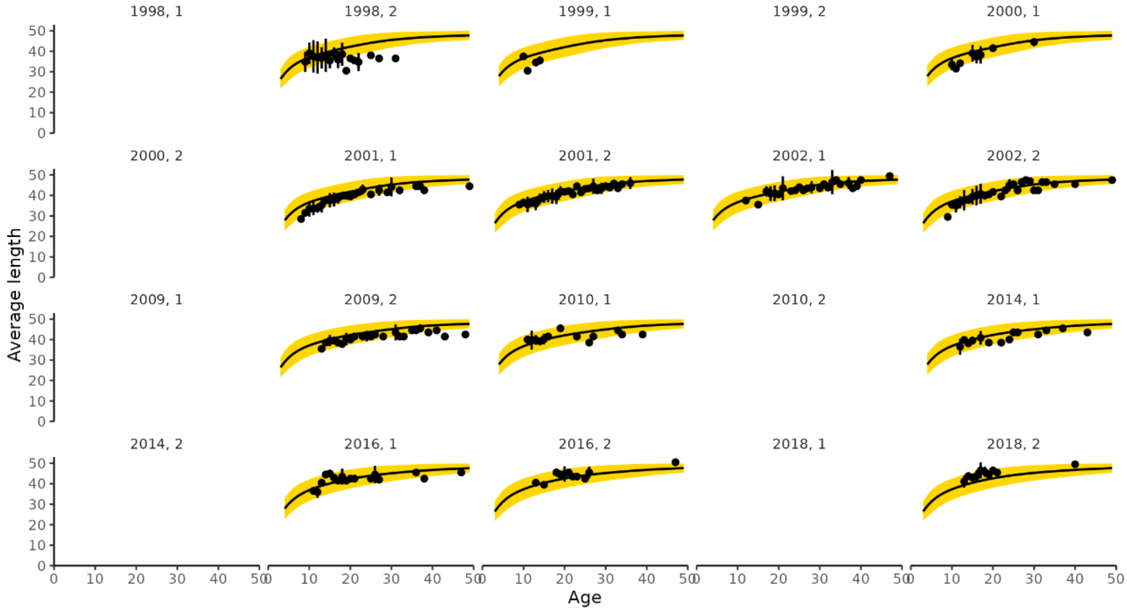

Figure 20.22. Icelandic slope beaked redfish. Model growth estimations for the commercial fleet. Yellow bands and the black line show where the mean and 90% confidence intervals of the of model predictions, whereas the points and error bars show the mean and 90% confidence intervals of the data.

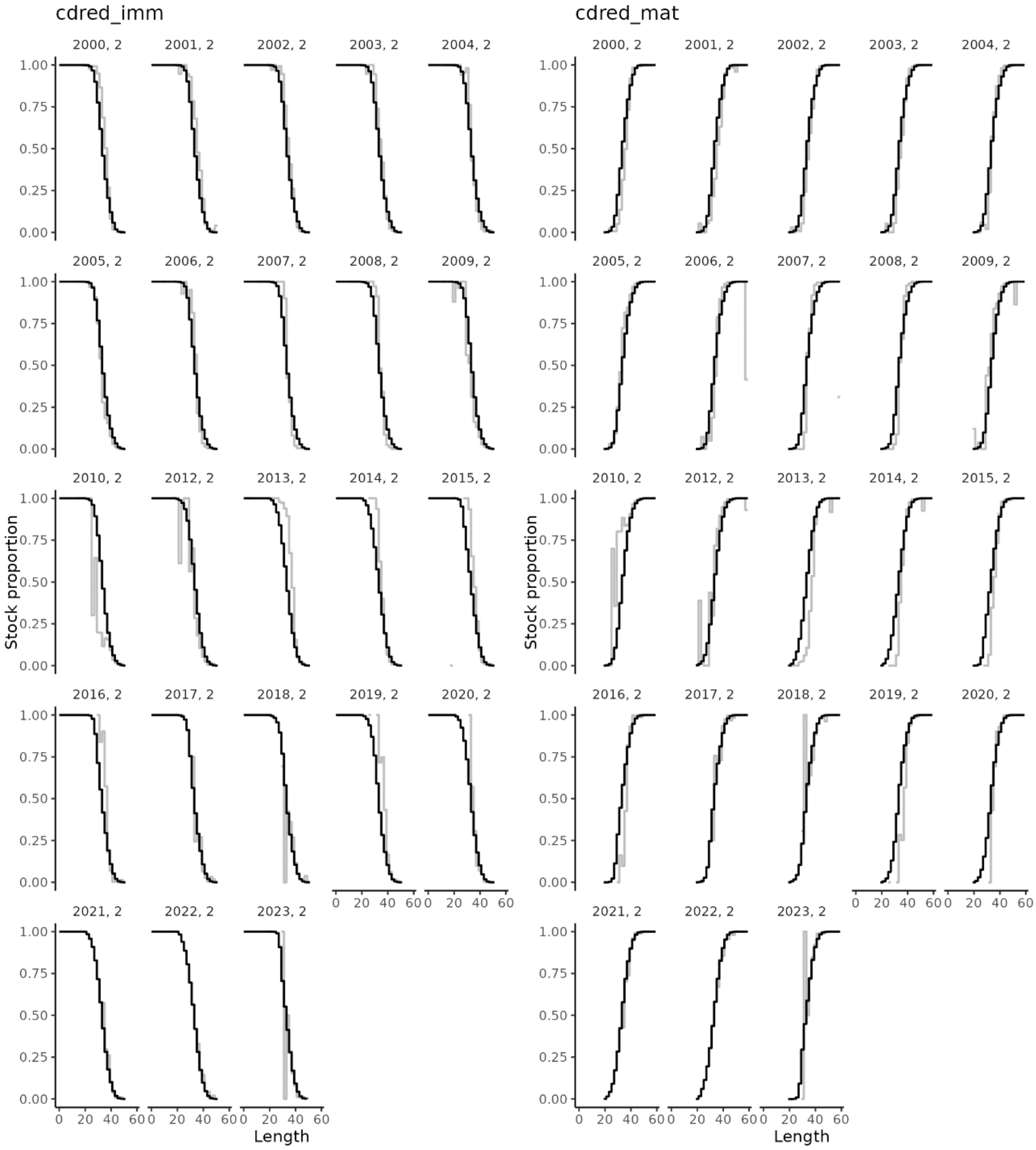

Figure 20.23. Icelandic slope beaked redfish. Observed (grey lines; Autumn survey) and estimated (black lines) proportions for the immature (left, cred_imm) and mature (right, cred_mmat) substocks per length interval.

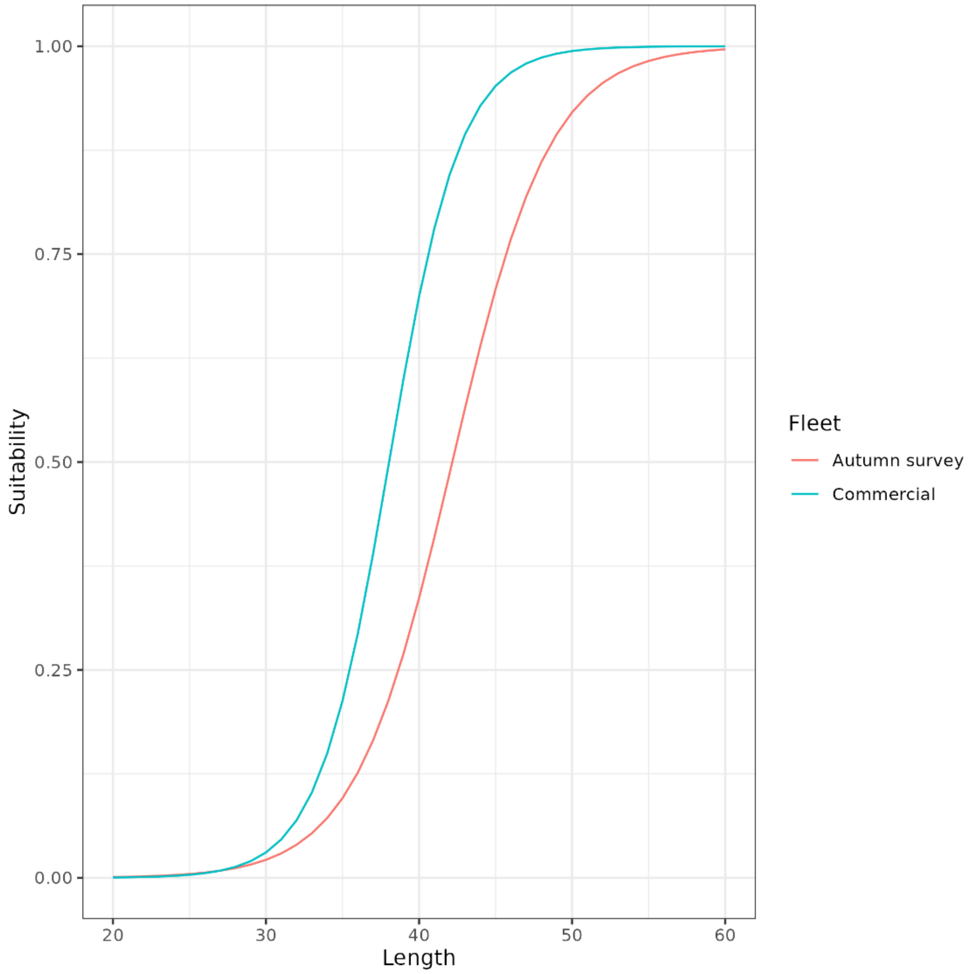

Figure 20.24. Icelandic slope beaked redfish. Selection (suitability) by length for the autumn survey and commercial bottom-trawl fleet.

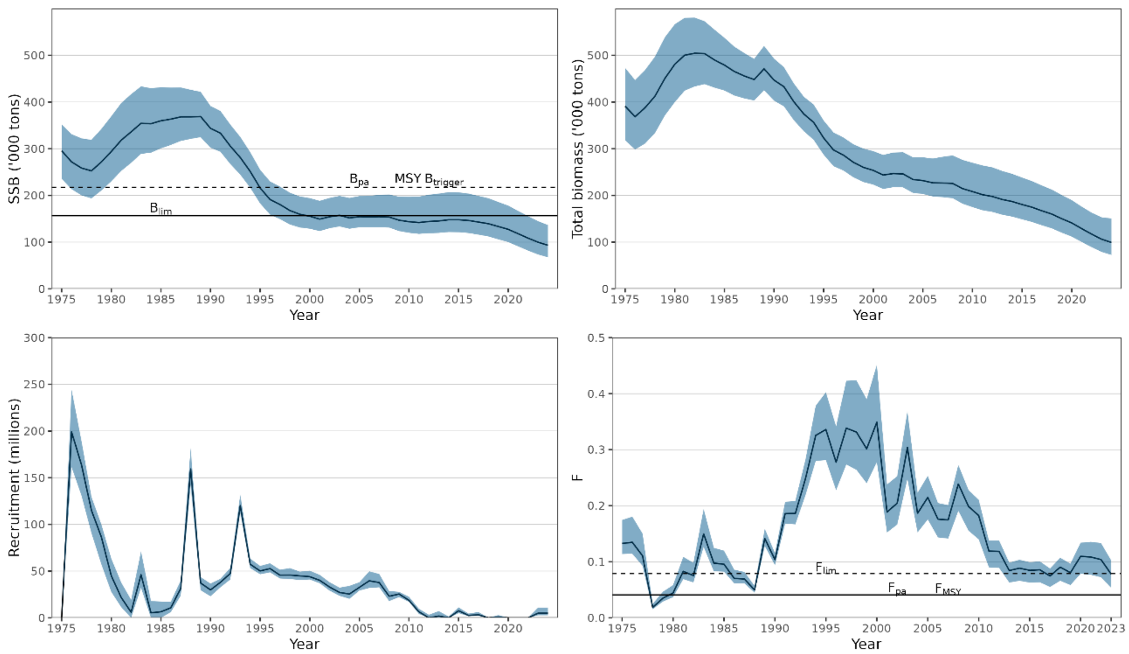

Figure 20.25. Icelandic slope beaked redfish. Summary from the assessment.

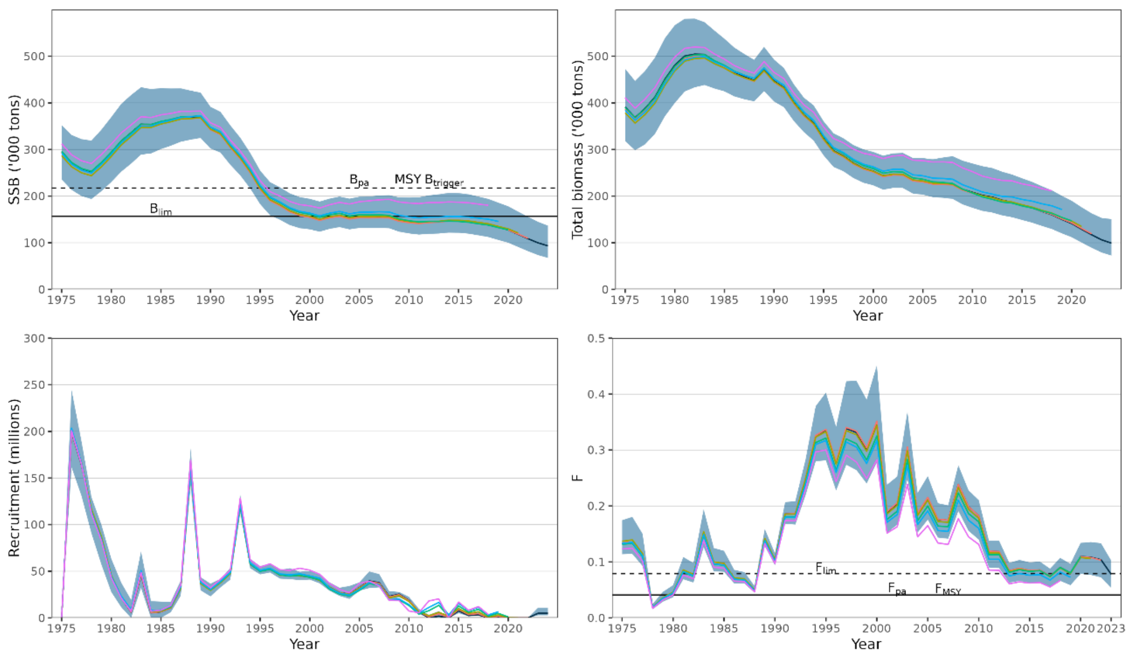

Figure 20.26. Icelandic slope beaked redfish. Retrospective plots illustrating stability in model estimates over a 5-year 'peel' in data. Results of spawning-stock biomass, fishing mortality F, and recruitment (age 3) are shown.

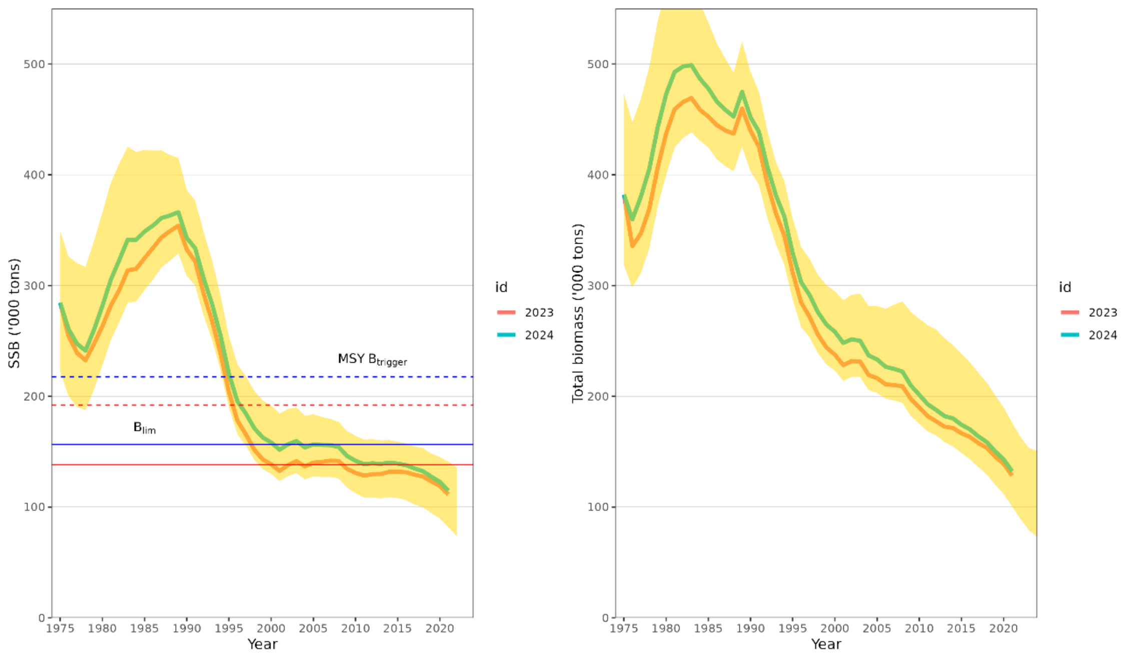

Figure 20.27. Icelandic slope beaked redfish. Comparison of estimates of total-stock biomass and spawning-stock biomass in the 2023 and 2024 assessments. The blue line shows the re-evaluated model outputs, the red line shows the original model outputs from the 2023 benchmark. The original and revised values for Bl_{im} and B_{pa}/MSY $B_{trigger}$ reference points are shown in red and blue respectively. The dotted red/blue lines show B_{pa}/MSY $B_{trigger}$, the solid red/blue lines show B_{lim}.

21 Shallow pelagic beaked redfish[1] (Iceland and Faroe grounds, North of Azores, and East of Greenland)

reb.2127.sp – *Sebastes mentella* in ICES subareas 5, 12, 14, and NAFO subareas 1 and 2

This section was not updated during the NWWG meeting in May 2022 or May 2023 due to the temporary suspension of all Russian Federation delegates, members, and experts from participation in ICES activities.

Please see the NWWG 2021 report for most updated information on this stock:

ICES. 2021. Northwestern Working Group (NWWG). ICES Scientific Reports. 3:52. 766 pp. https://doi.org/10.17895/ices.pub.8186

[1] < 500 m.

22 Deep pelagic beaked redfish[1] (Iceland and Faroe grounds, North of Azores, and East of Greenland)

reb.2127.dp – *Sebastes mentella* in ICES subareas 5, 12, 14, and NAFO subareas 1 and 2

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[1] > 500 m.

23 Beaked redfish (*Sebastes mentella*) in Division 14.b, demersal (Southeast Greenland)

reb.27.14b – *Sebastes mentella* in Division 14.b

23.1 Stock description and management units

See Section 18 for description of the stock structure of *S. mentella* in the Irminger Sea and adjacent waters. ICES has advised separately for *S. mentella* found demersal in ICES 14.b since 2011 and will do so until all available information on stock origin in this area is analysed and a new procedure is agreed upon.

23.2 Scientific data

Indices were available from three surveys in 14.b. A German survey directed towards cod in Greenlandic waters (0–400 m) (Fock *et al.*, 2013), the Greenland deep-water survey (400–1500 m) targeting Greenland halibut and the Greenland shrimp and fish survey in shallow water (0–600 m), which has been conducted since 2008 (Christensen and Hedeholm, 2018). The Greenland shrimp and fish survey is used in the assessment but was not conducted in 2017, 2018, 2019, and 2021 (Table 23.2.1). The Greenland halibut survey has been conducted since 1998 but not from 2016 to 2021 due to lack of research vessel. The German survey on the slope in 14.b has since 1982 been covering the slopes in East Greenland waters but was not conducted in 2018, 2021, and 2022, and only few stations were taken in 2023. This survey operates at depths of 400 m and shallower and does therefore not cover the full depth distribution of the species. The German survey was re-stratified in 2009 (see Stock Annex).

In the German survey, a large number of *Sebastes* spp. smaller than 17 cm was found from 1993–1998 (data not shown). This coincided with a large increase in the amount of 17–30 cm large *S. mentella* from 1995–1998 (Figure 23.2.1). From 1998 to 2003 the total biomass increased as a result of many small fish (< 17 cm) in the German survey, followed by a few years of high biomass estimates for *S. mentella* from 2003–2009. This increase occurred in one particular stratum only (i.e. stratum 8.2). From 2009 onward, a declining trend in both biomass and abundance was observed, with 2020 representing the lowest biomass for the last 20 years (Figure 23.2.1). Since 2013 and onwards, both biomass and abundance indices have been very low, but no new data are available from this survey since 2020. In the same period (2003-2020), the amount of small fish (17–30 cm) has steadily declined causing an increase in the amount of larger fish (Figure 23.2.1) until the overall biomass declines in 2010 and 2011. The depletion of the small size group has led to a progressive decline in the juvenile biomass index to a current low level, and no new recruits have been seen in the survey between 2012 and 2020. This pattern is also reflected in the abundance estimates (Figure 23.2.1). The modal size of the adult fish has increased from 25 cm in 2001 to around 37 cm in 2010 but declined slightly in 2011. The distribution has become flat with no clearly defined mode in 2013–2019 (Figure 23.2.2).

The Greenland deep-water survey has since 1998, except in 2001 and 2017-2021, surveyed the slopes of East Greenland from 400 to 1500 m with the majority of stations deeper than 600 meters targeting Greenland halibut. The biomass indices in the Greenland deep-water survey peaked in 2012 and were at a relatively constant level since 2010 (Figure 23.2.3). The overall length distribution from the entire area in 2013 and 2014 shows a mode around 31 cm. In 2015 and 2016, the mode increased slightly. In 2022 and 2023 the mode increased further and a second (small) peak became apparent at around 20 cm (Figure 23.2.4). The survey was aborted in 2017 due to vessel breakdown and in 2018-2021 no research vessel was available for the survey. The survey biomass index has not been used as the depth range is outside the depths of the targeted fishery.

The Greenland shrimp and fish survey in shallow water in East Greenland started in 2007, and surveys the East Greenland shelf and shelf edge at depths between 0–600 m. However, 2007 was mostly exploratory and is not reported. In general, survey estimates of schooling fish are associated with large uncertainties due to their patchy distribution. This, in conjunction with the relatively short time-series, makes overall conclusions regarding stock trends based solely on this survey tentative. It is, however, the survey with the best coverage of redfish depth distribution. The 2016 biomass estimate for *S. mentella* increased from 61 kt to 164 kt from 2015 to 2016 (Figure 23.2.5). However, the estimate has large uncertainties since one haul accounted for 70% of the total biomass estimate. The haul was taken in area Q2 close to Icelandic Waters. In 2017, 2018 and 2019, surveys have been missing but in 2020 a full survey revealed the lowest biomass indices (18.4 kt) throughout the time-series. No survey was conducted in 2021 due to lack of research vessel. In 2022, the survey biomass index (33.3 kt) was the second lowest in the time-series (Figure 23.2.5, Table 23.2.1). In 2023, decreased slightly compared to 2022. The 2020, 2022, and 2023 Greenland survey was carried out day and night, which is different from previous years where hauls were made only during daytime (08.00-20:00 UTC).

Overall, the trends from the German survey (until 2020) and from the Greenland shrimp and fish survey (2020, 2022, 2023) indicate that biomass in recent years is low. The accuracy of the surveys as an indicator of recruitment is not known, but the abundance of juveniles indicates that there was a long period of poor recruitment resulting in very few juveniles from around 2012 to 2019. An experimental fishery in 2019 partly focusing on juvenile redfish confirmed that the abundance of juvenile redfish was at a very low level (Christensen, 2020b). In 2020, 2022, and 2023, higher abundances of juvenile redfish were found in the Greenland survey, but it remains unclear when and to what extent these will contribute to the fishable biomass of this stock (Figure 23.2.5).

23.2.1 Landings

From the Greenland and German surveys, it is certain that the demersal redfish found on the Greenland slope is a mixture of *S. norvegicus* and *S. mentella*. Only negligible amounts are considered to be *Sebastes viviparus*. Before 2016, *S. mentella* dominated the catches, but the proportion started to decline in 2014 (Figure 23.2.1.1) and in 2016, the split changed and for the first time *S. norvegicus* was dominating (Figure 23.2.1.1). In 2019, *S. mentella* was again dominating the catches estimated from the logbooks. In 2020, the proportion shifted back again and *S. norvegicus* dominated. The shift was supported by Greenland shallow water survey (79:31), logbooks (60:40) as well as samples from the commercial fishery (71:29) analysed at Greenland Institute of Natural Resources. In 2021, no survey data were available for evaluating and neither were samples from the commercial fishery available for analysis at the Greenland Institute of Natural Resources. Like previous year, the proportion according to logbooks in 2021 was that *S. norvegicus* dominated over *S. mentella* (78:22). In 2022, a ratio of 29:71 was estimated from survey data, while 21:79 was estimated from logbooks, and 70:30 from commercial samples. The split estimated from survey data were considered most objective and realistic and used to estimate catch proportions of both species in 2022. In 2023, the split was made based on survey data again, which indicated the same ratio as in 2022, i.e. 29:71 (*S.mentella*:*S.norvegicus*). These proportions were also roughly supported by logbook data (26:74). Prior to 1974, all catches were reported as *S. norvegicus* and the split was determined by working groups on a yearly basis.

Catch depth has in the later years declined compared to earlier. In 2016, the catches were taken at a depth of 300–400 m. In 2017 and 2018 catch depth declined even further and in 2019 an increasing part of the catch was taken at a depth of 300-350 m. In 2011–2012 all catches were taken at 350–400 m (Figure 23.2.1.2).

Total annual landings of demersal *S. mentella* from Division 14.b since 1974 are presented in Table 23.2.1.1. From 1976–1994 annual landings were at a relatively high level with landings ranging between 2000 and 20 000 tonnes with a very high peak at nearly 60 000 t in 1976. This fishery was ended abruptly in 1995 due to large amounts of very small redfish in the catches. From 1998–2002 the landings ranged from 1000 to 2000 tonnes and from 2003 to 2008 landings remained at lower levels (<500 tonnes). In 2009, an exploratory fishery landed 895 tonnes of *S. mentella*. This was a large increase compared to 2008 and for the first time in ten years the fishery was limited by a TAC. Over the past 10 years, there has been a decreasing trend in landings of demersal *S. mentella* with the lowest level of 902 tonnes being reached in 2022. In 2023, catches increased slightly to 1255 tonnes.

In 2010, a quota on 5000 tonnes demersal redfish (mixed *S. mentella* and *S. norvegicus*) was initially given and of these, 400 tonnes were allocated to the Norwegian fleet. After this amount was fished, a research quota of 1000 tonnes were given to a Greenland vessel. Since 2010, the catches have been around 8300 tonnes (*S. mentella* and *S. norvegicus* combined) (Figure 23.2.1.3). In 2017, total catches decreased to 7568 tonnes and in 2018 the catch decreased further to 5976 tonnes. However, in 2019 a notable increase in the catches occurred and the total catch was 6663 tonnes (Figure 23.2.1.3), while it dropped to 5782 tonnes, 4825 tonnes, and 3112 tonnes in 2020, 2021, and 2022, respectively. In 2023, the mixed catch increased to 4328 tonnes. Since 2011 the mixed TAC has been 8500 tonnes until 2017 where the TAC started to decrease. In 2019, the mixed TAC was 5274 tonnes and in 2020 it was 5271 tonnes. In 2021 the mixed TAC was 4748 tonnes and in 2022 it was 3186 tonnes. In 2023 the TAC was raised to 5109 tonnes.

In 2010, there was no jurisdiction that clearly delimited the pelagic stocks from the redfish found on the shelf. A few vessels benefitted from this by fishing their pelagic quota on the shelf (2179 tonnes) making catches on the shelf exceed the TAC. This led to the introduction of a "redfish line" that separates the demersal slope stock from the pelagic stocks (see Stock Annex).

23.2.2 CPUE and bycatch CPUE

A redfish bycatch CPUE was introduced at the redfish 2012 benchmark (WKRED). This is based on catches from the Greenland halibut directed fishery and include both *S. mentella* and *S. norvegicus* (Christensen 2020a), which covers redfish distribution better than data from the redfish directed fishery and covers a longer period (1999–2023). The Greenland halibut fishery is not as spatially restricted as the redfish fishery; thus, it will not be as sensitive to local changes as the redfish directed CPUE. The CPUE is fluctuating with an overall very slight increasing trend since 2015 (Figure 23.2.2.1).

The CPUE from the redfish directed fishery declined from 2010 to 2023 (Figure 23.2.2.2). Until 2015, the fishery was conducted in a geographically limited area between 63.5°N and 65°N, where approximately 90% of the catches are taken. Thereafter it also included more southern areas (Figure 23.2.3.1). Accordingly, the CPUE series can only be used as an index on local stock development. Both the Greenland shallow water survey (0–600 m) and the German survey (0–400 m) show that the main fishing area coincides with the area of highest overall abundance.

23.2.3 Fisheries and fleets

The fishery for *S. mentella* on the slopes in 14.b is mainly conducted with bottom trawl, only about 5% were caught with longlines in 2023. The area where *S. mentella* is caught, is closely related to the area where fishery for Greenland halibut and cod takes place (Figure 23.2.3.1). The majority of the catches are taken at depths from 300 m to 400 m (Figure 23.2.1.2).

The directed fishery was stopped in 1995, but in 1998 Germany restarted a directed fishery for redfish with annual landings of approximately 1000 tonnes in 1998–2001 increasing to 2100 tonnes in 2002 (Bernreuther *et al.,* 2013). Samples taken from the German fleet indicated that substantial quantities of the redfish caught, especially in 2002, were juveniles, i.e. fish less than 30 cm. There was very little demersal redfish fishery in 14.b in 2003–2004 (less than 500 tonnes). This continued in 2005–2008 and most *S. mentella* were caught as bycatch in the Greenland halibut fishery.

After the German fleet stopped fishing in 2002 the majority of the catches have been taken by the British, Faroese, Norwegian and Greenland fleet. The British fishery took place from 2001–2005 and since 2006 only Greenland, Norway, Germany, and the EU have had any significant catches (Table 23.2.3.2).

In 2009, three Greenland vessels started a fishery targeting demersal redfish. Each was given an explorative quota of 250 tonnes. This fishery was very successful and led to an increased fishery in 2010 (seven boats), 2011 (15 boats) and 2012 (21 boats). However, in 2012, 95% of the catch was taken by six vessels and 97% by five vessels in 2013.

On the steep slopes very little horizontal distance separates the distribution of cod, redfish and Greenland halibut (Figure 23.2.3.2). The part of the fleet with both quotas for redfish and Greenland halibut takes advantage of this by shifting between very short hauls targeting redfish and long hauls directed to Greenland halibut and thereby avoiding time where the vessel is not fishing due to processing of the catch.

23.2.4 Bycatch/discard in the shrimp fishery

To minimize bycatch of fish species in the fishery for shrimp the trawls have since 2002 been equipped with grid separators (G.H., 2001). However, the 22 mm spacing between the bars in the separator allows small fish to enter the codend. In a study on the amount of bycatch in the shrimp fishery the mean length of the redfish that entered the codend was 13–14 cm. The same study also documented that redfish by weight accounted for less than 1% of the amount of shrimp that were caught (Sünksen, 2007). Coinciding with the introduction of these separator grids the amount of juvenile redfish caught by the shrimp fishery dropped from annual 100–200 tonnes to a lower level near 100 tonnes. Since 2006, limited shrimp fishery has taken place in ICES 14.b and the current level of bycatch must be considered negligible with 1 and 6 tonnes, respectively, in the last two years (Table 23.2.4.1). From 1999–2009, the fishery started in April–May due to poor winter conditions such as ice and wind that prevent fishing. Only in 2000 and 2002, the fishery started already in February (Table 23.2.4.2). Since 2010, the fishery has started already in January and in 2018 February was the month with the highest landings. In 2019, the fishery was relatively high already in March, but most of the catch was fished in May and June. In 2023 large catches was taken in April, July, August, October, and December (Table 23.2.4.2). The depth distribution of cod and redfish overlap (Figure 23.2.3.2) and therefore the fishery for redfish led to a bycatch of cod of 96 tonnes in 2013. The vessels are allowed a 10% bycatch of cod.

23.3 Methods

No analytical assessment was conducted.

23.4 Reference points

MSY proxy reference points need to be defined for the Greenlandic *S. mentella* demersal stock. ICES suggested four methods for this purpose, and all methods were tested on the stock. The conclusion was that based on the caveats listed below and the declines seen in surveys, especially on recruitment over the past decade, the determination of the stock status in relation to reference points should not be based solely on any of the indicators presented here, but rather a holistic view combining surveys and expert judgment with the results presented in Hedeholm and Christensen (2017).

The caveats to consider in relation to the Greenlandic *S. mentella* demersal stock when concluding on the length-based indicators and the SPiCT model:

- If there are few year classes in the fishery, which is currently the case for the present stock, the effect of overfishing the stock is more likely observed on biomass rather than length, especially on a slow growing species. There is no ageing done for this stock, therefore it is not possible to see if this is the case.
- *Sebastes mentella* is a slow growing species, thus the effect of the fishery on length may be very subtle. The relatively short time-series on length distributions available for this analysis and the limited number of samples per year entails that any effect is easily missed.
- The schooling behaviour of *S. mentella* in connection with the points made above means that the fishery can target a diminishing stock in a small area without seeing any effect on the length distribution. Indeed, the fishery is conducted with limited spatial extent.
- Several redfish stocks are present on the East Greenland slope, but in unknown quantities. Any changes in length could just as well be related to migration, timing of sampling, and latitude of sampling rather than to actual stock changes.
- Based on the three length-based methods the exploitation pattern appears reasonable. However, results from all three methods should be interpreted with some caution due to lack of knowledge of important input parameters (L_{inf}, M and k) for the specific stock (values from FishBase are used).

23.5 State of the stock

The Greenland shrimp and fish survey in shallow waters and the German groundfish survey are the two main data sources for biomass indices of *S. mentella*. In addition, the Greenland deep-water survey aimed for Greenland halibut is available for the deeper part of the *S. mentella* distribution. The different surveys' time-series suffer from periods with no surveys (i.e. the Greenland survey and, recently, the German survey) and insufficient depth coverage of the species distribution (i.e. the German survey). CPUE from the fishery is also available and shows fluctuating trends. CPUE is, however, considered less reliable as biomass indicator since the species tends to have a schooling behaviour, which enables the fishery to keep constant catch rates even when stock biomass is decreasing.

The shallow Greenland and German surveys show a decline in the *S. mentella* biomass since 2010 to record low levels in recent years (20217-2023) (Figures 23.2.1 and 23.2.5). In both surveys, juveniles (*Sebastes* spp.) were near absent from 2013 to 2019. Increased juvenile abundance was detected in 2020, 2022 and 2023 in the Greenland survey with a slight decrease from 2022 to 2023 apparent. It remains unknown to which redfish stock these juvenile redfish will recruit and if, when, and to what extent they will enter the fishable biomass. The CPUE in the redfish directed fishery has vaguely declined since 2010. Length distributions from the surveys confirm that some smaller redfish are becoming apparent.

The signals from surveys and the fishery suggest a low stock and also that recruitment has been low for several years. Given the slow growth and late maturation of this species, the present exploitation is of concern. A complete cease of the fishery is therefore necessary in order to evaluate any stock rebuilding in the coming years. Because a mixed TAC for this stock and *S. norvegicus* is set, a recovery plan for this stock must be developed. Areas where mixed quota fishing still captures demersal *S. mentella* should be identified and closed to fishing. A rebuilding will also require more incoming year classes to the stock.

The advice for demersal *S. mentella* in east Greenland is based on the ICES category 3, Data Limited Stock (DLS), approach including biomass indices from the Greenland shrimp and fish survey. Due to the lack of a survey estimates from the Greenland Shallow Water survey in 2017–2019, the advice for 2020 was given based on a category 5 approach. In 2021–2024, the advice follows the ICES framework for category 3 stocks with extremely low biomass (method 3.1.4) and therefore the advice is 0 catch in 2025. The stock will be benchmarked in 2026.

23.6 Management considerations

Sebastes mentella is a slow growing, late maturing deep-sea species and is therefore considered vulnerable to overexploitation and advice must be conservative. The fact that the fishery is targeting a localized aggregation of fish is cause for concern as is the near-absence of juveniles in the area until 2021. Given the biology of the species and the uncertainty in the biomass trend, any advice should consider this a hot spot fishery as it is potentially detrimental to this local and potentially important aggregation of larger fish. A complete cease of the fishery is necessary and in addition closure of areas, where *S. mentella* is still caught under a mixed TAC, should be considered.

23.7 References

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23.8 Figures and tables

Table 23.2.1 Relative biomass index of demersal *S. mentella* in ICES division 14.b based on the Greenland Groundfish Survey (GRL-GFS; G2064). No survey index estimates are available for 2017-2019 and 2021.

Year	Relative biomass index	Relative biomass index high	Relative biomass index low
2008	1.95	2.8	1.05
2009	1.86	2.5	1.22
2010	2.3	3.1	1.50
2011	0.97	1.20	0.73
2012	0.79	1.01	0.57
2013	1.27	1.89	0.65
2014	0.53	0.65	0.41
2015	0.48	0.61	0.35
2016	1.28	2.3	0.30
2017			
2018			
2019			
2020	0.1444	0.167	0.122
2021			
2022	0.26	0.40	0.121
2023	0.201	0.23	0.171

Table 23.2.1.1 Nominal landings (tonnes) of demersal *S. mentella* 1974–2023 ICES division 14.b.

Demersal S. mentella			
1974	0	2013	6761
1975	4400	2014	4608
1976	59 700	2015	5977
1977	0	2016	3061
1978	5403	2017	3027
1979	5131	2018	1972
1980	10 406	2019	3998
1981	19 391	2020	1677

Demersal S. mentella			
1982	12 140	2021	1302
1983	15 207	2022	902
1984	9126	2023	1255
1985	9376		
1986	12 138		
1987	6407		
1988	6065		
1989	2284		
1990	6097		
1991	7057		
1992	7022		
1993	14 828		
1994	19 305		
1995	819		
1996	730		
1997	199		
1998	1376		
1999	853		
2000	982		
2001	901		
2002	2109		
2003	446		
2004	482		
2005	267		
2006	202		
2007	226		
2008	92		
2009	895		
2010	6613		
2011	7376		

Demersal S. mentella	
2012	6243

Table 23.2.3.2 Landings (tonnes) of demersal redfish (*S. mentella* and *S. norvegicus*) caught in ICES 14.b by nation.

Year	DEU	ESP	EU	FRO	GBR	GRL	ISL	NOR	POL	RUS	UNK	Sum
1999											853	853
2000	884		11			19		65			3	982
2001	782				11	9		99				901
2002	1703			48	16	246	29	32		36		2109
2003	3	2	2	20	155	232		32				446
2004	5	1	79	12	221	93		68	3			482
2005	2		4	38	96	72		56				267
2006	1					152		48				202
2007	7		15	138		35		30				226
2008	1		8	50	5	5		23				92
2009				203		822		93				1118
2010	10		12	381		5672		2190		1		8266
2011	1262		26	2		6757		334		1		8381
2012	1810		5	32		5964	1	403		1		8216
2013	1957			32	30	5863		356		8		8246
2014	1973		0.2	13		4611	98	613		5		7314
2015	1987			74		4979	208	822		469		8539
2016		-	1759	25	2	5859	-	858	-	-	-	8503
2017	1060		537	31		4736		787		418		7568
2018	418		1295	48		3276		489		450		5976
2019	976		1021	5		3410		985		266		6663
2020			2050	9		2399		1069		256		5782
2021	808		894	32		2051		1002		38		4825
2022			1185	6		1044		823		54		3112
2023			1007	32		2567		722				4328
Sum	15 649	3	9909	1231	536	60 667	336	11 998	3	2003	856	103 397

Table 23.2.4.1 Discarded bycatch (tonnes) of *Sebastes* spp. from the shrimp fishery in ICES 14.b.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
1999	6	16	17	5	1	13	2	48	22	30	40	33	234
2000	10	3	31	17	15	4	21	78	28	18	9	6	239
2001	7	9	10	16	9	11	4	5	3	3	28	6	111
2002	3	11	9	6	1	0	0	5	4	8	3	5	55
2003	5	6	8	5	5	8	8	15	2	10	12	4	88
2004	7	10	17	13	4	2	27	20	7	2	9	0	118
2005	7	14	16	8	7	5	6	21	14	4	5	20	126
2006	6	2	4	1	3	5	2	4	4	0	0	4	35
2007	7	3	2	1	0	0	0	0	0	0	0	0	14
2008	0	2	2	0	0	1	0	0	0	0	0	1	7
2009	1	2	11	1	0	0	0	0	0	0	0	0	16
2010	1	2	2	1	1	0	1	0	0	0	0	2	10
2011	0	0	0	0	1	0	0	0	0	0	0	0	3
2012	0	0	1	1	1	0	0	0	0	0	0	0	4
2013	0	1	1	0	0	0	0	0	0	0	0	0	2
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	1	0	0	0	0	0	0	0	0	0	1
2023	0	2	3	1	0	0	0	0	0	0	0	0	6
Sum	60	83	135	76	48	49	71	196	84	75	106	81	1069

Table 23.2.4.2 Landings (tonnes) of demersal redfish (*S. mentella* and *S. norvegicus*) caught in ICES 14.b. by month.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
1999		10		108		4	42	10	15	34	481	149	853
2000	18	238	286	260	10	4	79	72	13	0	3		982
2001			1				108	2		184	369	236	901
2002		183	445	354	390	50	472	35	44	59	77		2109
2003			9	4	26	27	135	195	20	16	12		446
2004				35	41	63	75	48	64	96	25	35	482
2005			1	15	66	24	80	29	13	18	19		267
2006		3	7	50	14	39	20	61	2	1	1	2	202
2007	6	13	8	8	14	42	4	106	16	7	1	1	226
2008	4	3	1	6	12	11	31	12	10	2			92
2009				1	84	346	148	105	128		288	17	1118
2010	799	786	708	1058	2149	2100	108	134	88	301	36		8266
2011	419	1396	1661	1017	268	250	236	598	255	583	1223	475	8381
2012	899	2197	628	852	577	699	966	143	44	23	474	712	8215
2013			709	1290	925	1423	1218	1086	723	227	119	527	8246
2014	10	421	206	1210	1187	1709	231	401	376	448	632	479	7314
2015	543	786	1016	451	507	1611	1160	1024	504	393	74	467	8539
2016	306	214	1130	1185	1426	1864	1298	559	466	38	14	1	8501
2017	373	1977	1368	751	308	513	1111	249	38	651	102	124	7568
2018	798	1273	819	779	367	189	1049	22	176	234	225	45	5976
2019	23	211	1102	653	1359	1316	601	520	365	379	36	98	6663
2020	22	354	510	17	129	2189	731	705	439	309	310	67	5782
2021	113	164	369	275	284	1090	846	1184	235	10	127	124	4825
2022	305	257	186	346	246	726	154	317	254	128	69	124	3112
2023	267	163	109	583	152	239	546	404	237	491	259	876	4328
Sum	4905	10 649	11 280	10 541	10 541	16 528	11 450	8021	4524	4632	4976	4559	103 394

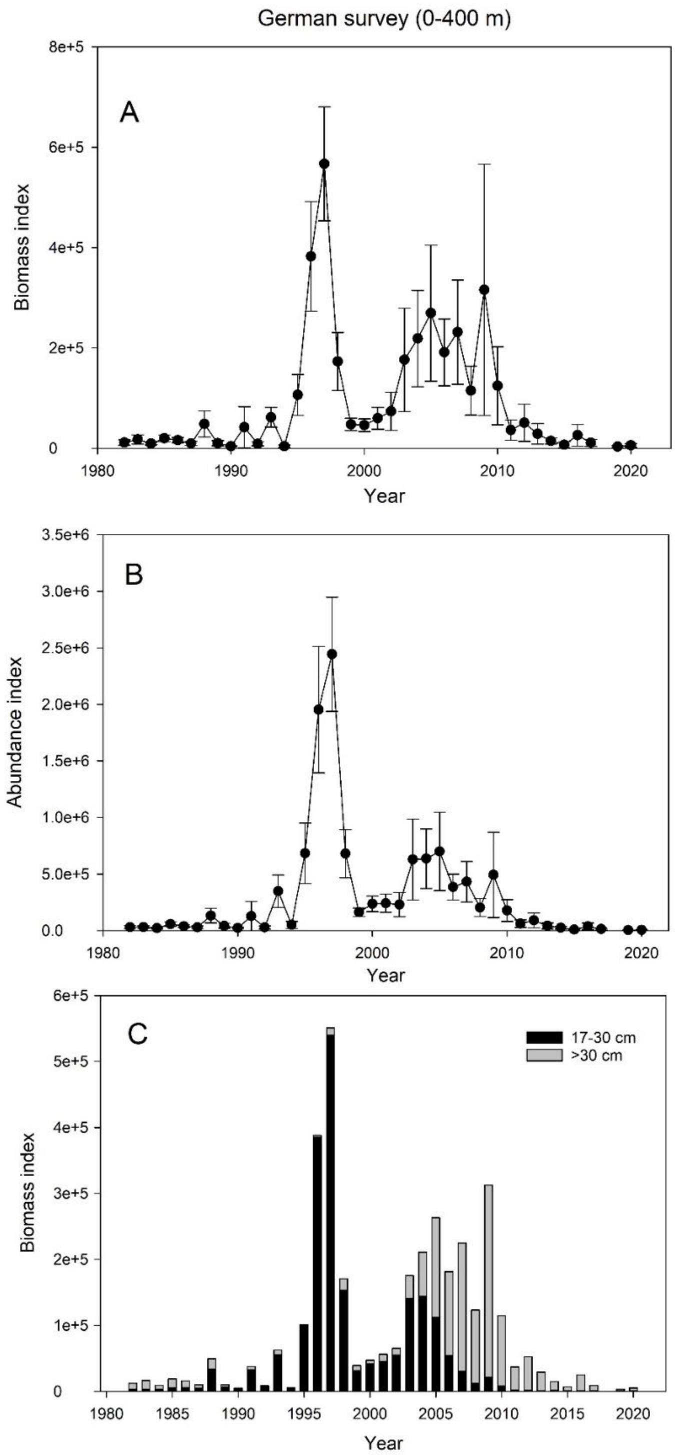


Figure 23.2.1. Indices from the German East Greenland survey of *S. mentella* larger than 17 cm. Biomass (A), abundance (B), and biomass split on length (C). On figure (C) the grey bars represent the biomass of *S. mentella* larger than 30 cm and the dark bars biomass in fish from 17–30 cm. No survey was conducted in 2018 and 2021-2022 and only few stations were taken in 2023.

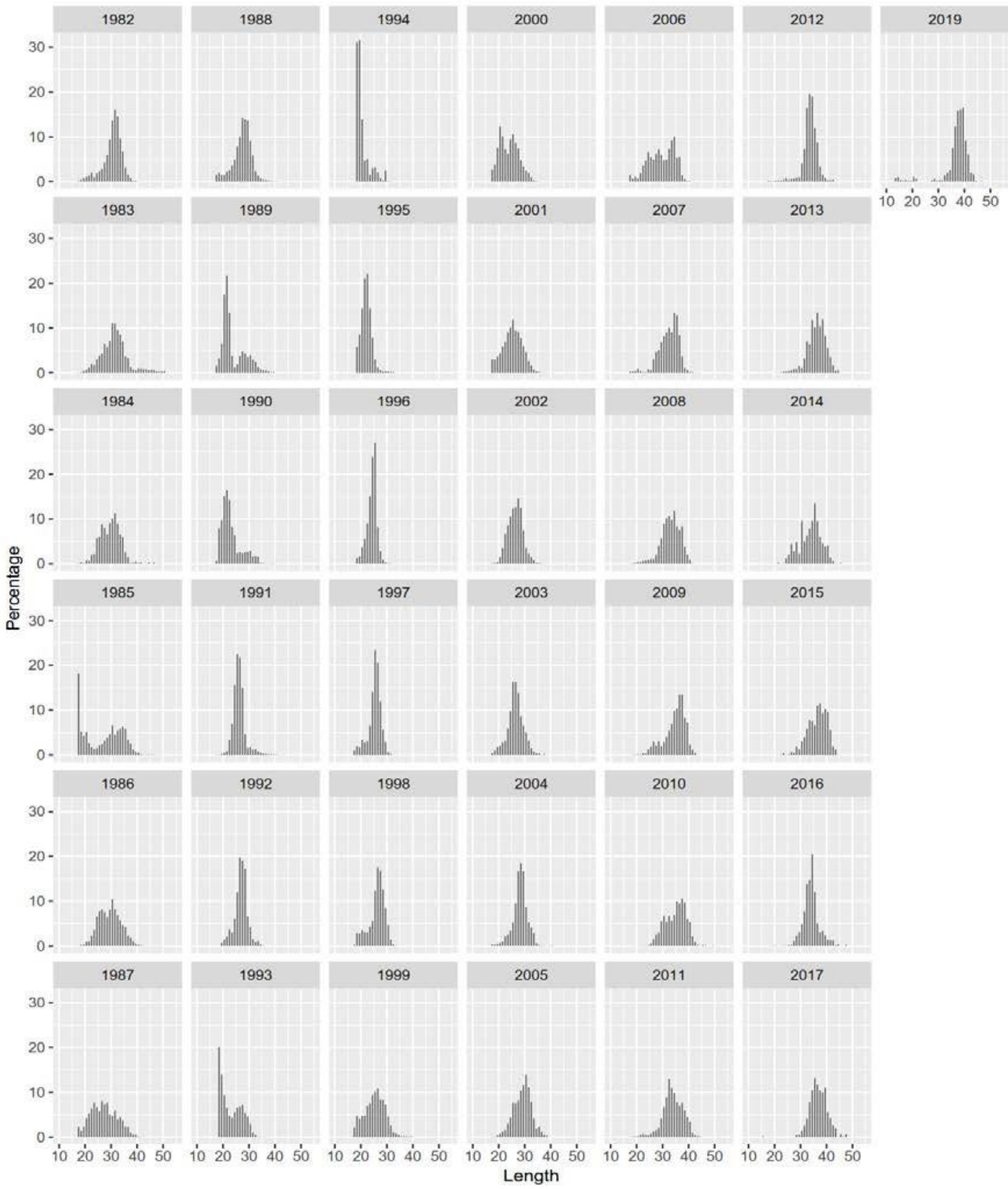


Figure 23.2.2. Length distributions from the German East Greenland survey 1985–2019. In 2018 and 2021-2022 no survey was conducted and only few stations were taken in 2023.

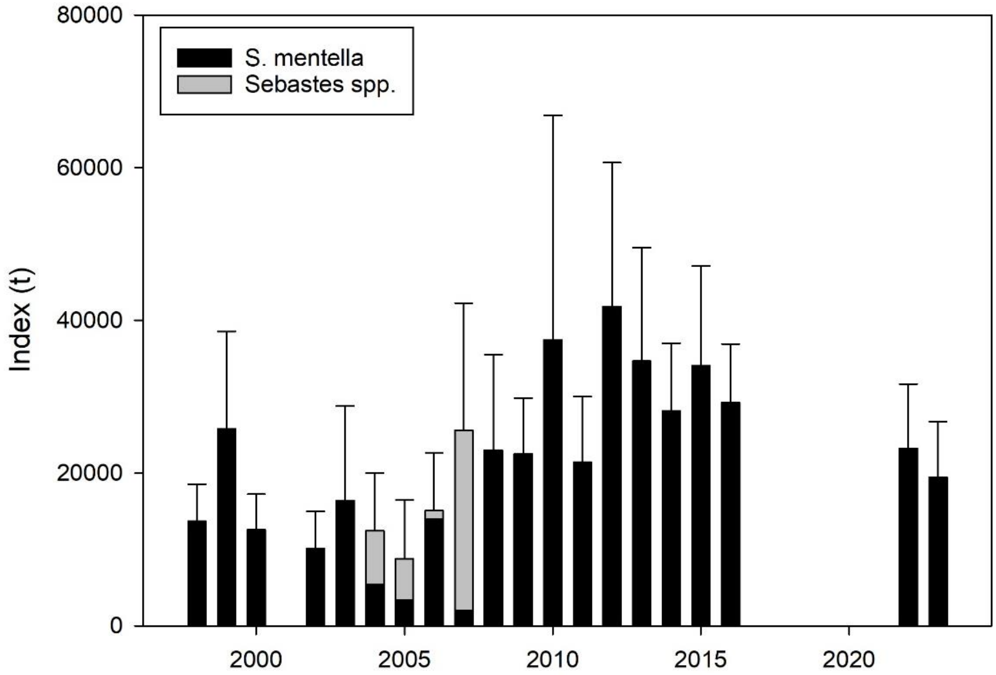


Figure 23.2.3. Biomass of *S. mentella* and *Sebastes* spp. derived from the Greenland deep-water survey. Bars indicate 2SE of the biomass of *S. mentella* including *Sebastes* spp. No survey in 2001. In 2004, 2005 and 2007 a large proportion of the redfish were not determined to species and only reported as "*Sebastes* spp". Considering the depth these are most likely *S. mentella*. In 2017, the survey was aborted due to vessel break down and in 2018-2021 no survey was conducted.

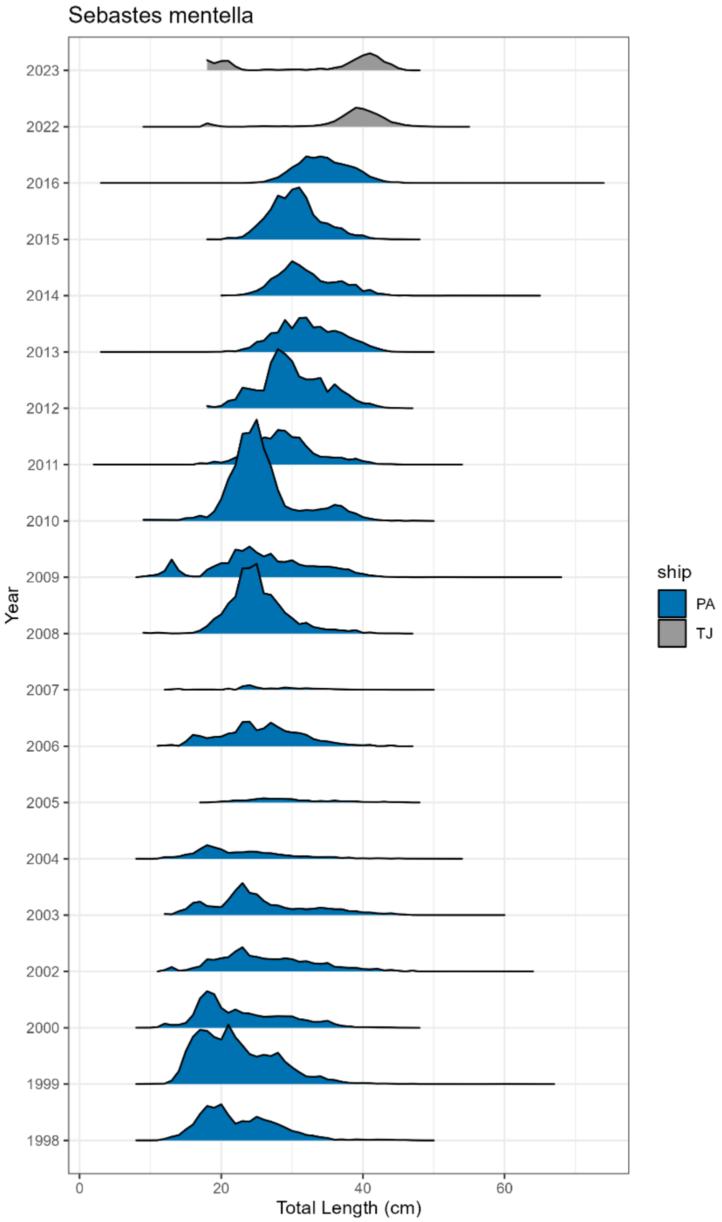


Figure 23.2.4. Overall length distribution of *Sebastes mentella* (number per km²) from the deep Greenland survey. In 2017, the survey was aborted due to vessel break down and in 2018-2021 no survey was conducted.

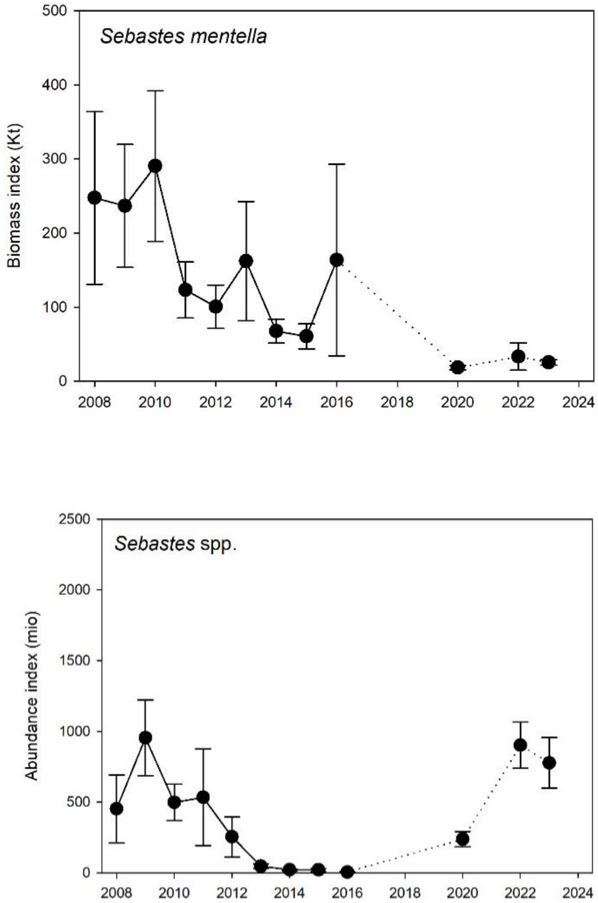


Figure 23.2.5: Biomass (kg*106, kt) (±SD) indices for S. mentella (top) and abundance (millions, mio,) (±SD) indices for Sebastes spp. (<18 cm) (bottom) off East Greenland in 2008–2016, 2020, and 2022-2023 from the Greenlandic shallow water survey. All surveyed areas are combined (Q1–Q6). In 2017, the survey was aborted due to vessel break down and in 2018, 2019, and 2021 no survey was conducted, therefore no data are shown (dotted line).

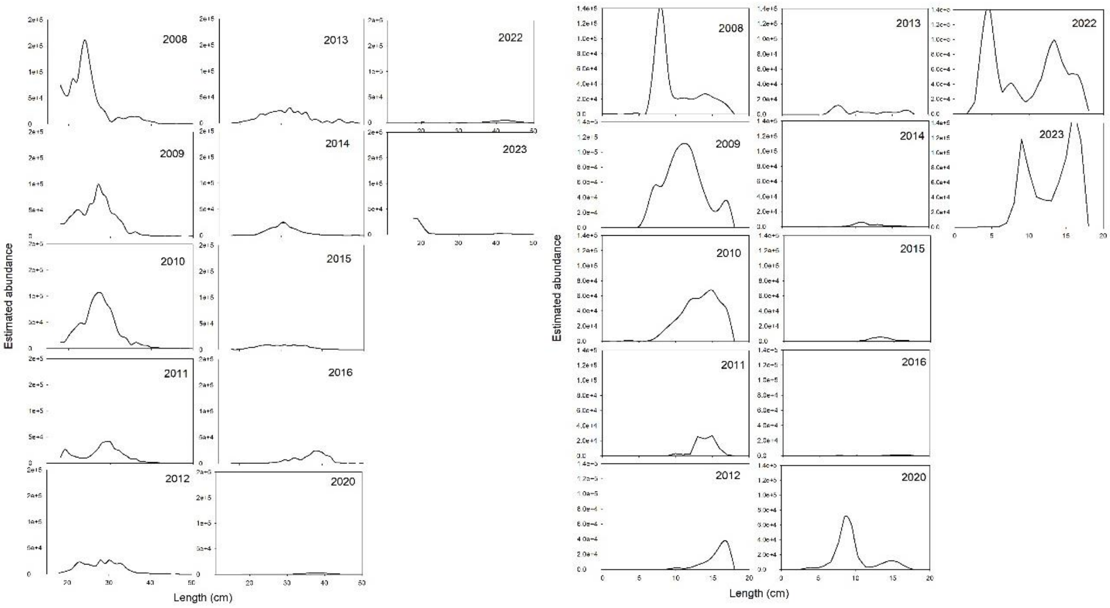
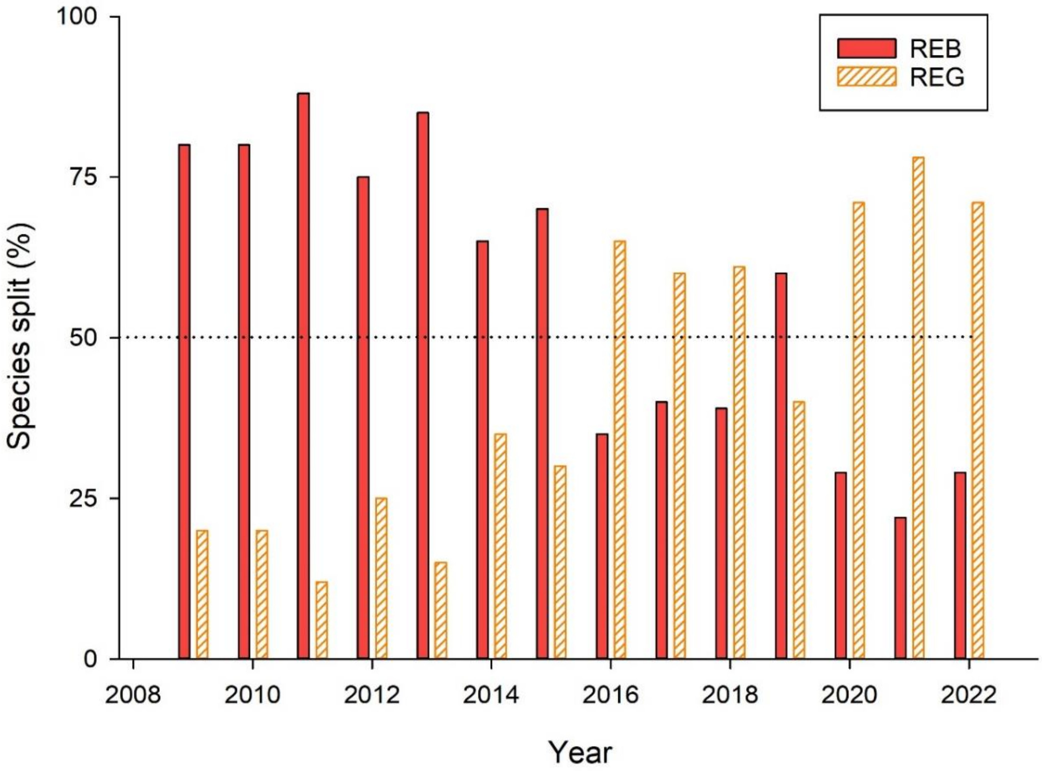


Figure 23.2.6. Overall length distributions for *S. mentella* (left) and *Sebastes* spp. <18 cm (right) from the Greenland shallow water survey. All surveyed areas combined (Q1–Q6). In 2017, the survey was aborted due to vessel break down and in 2018, 2019, and 2021 no survey was conducted.



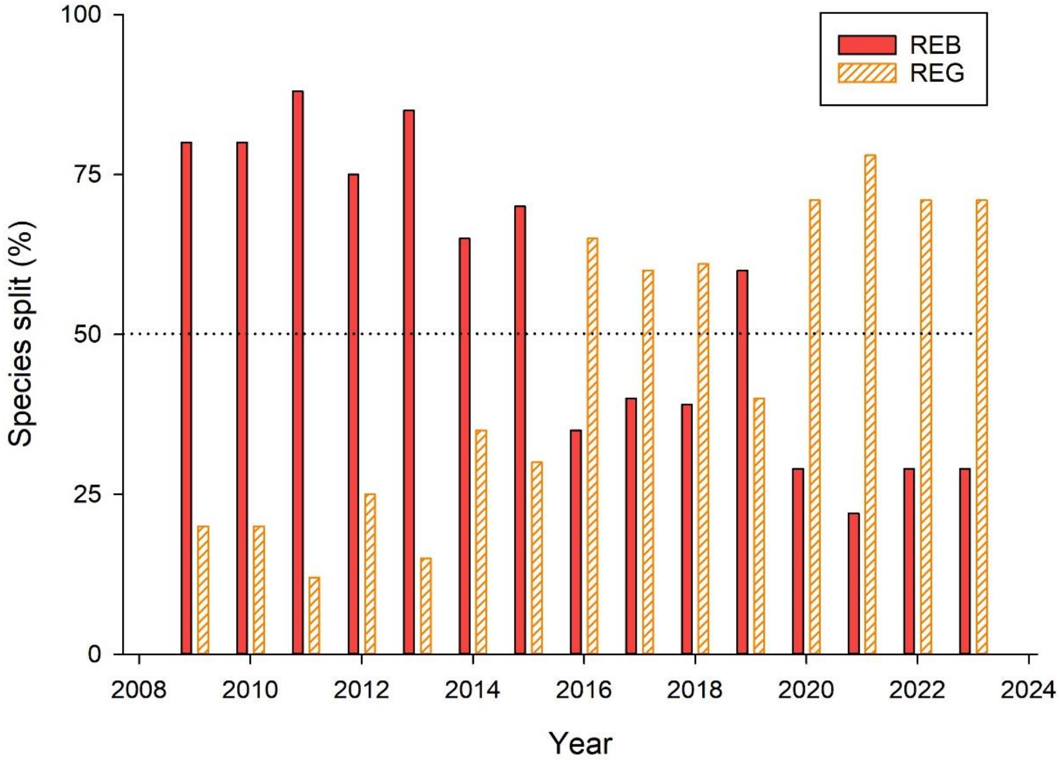


Figure 23.2.1.1. Development in split of *S. mentella* (REB) and *S. norvegicus* (REG) in the fisheries on the Greenland slope.

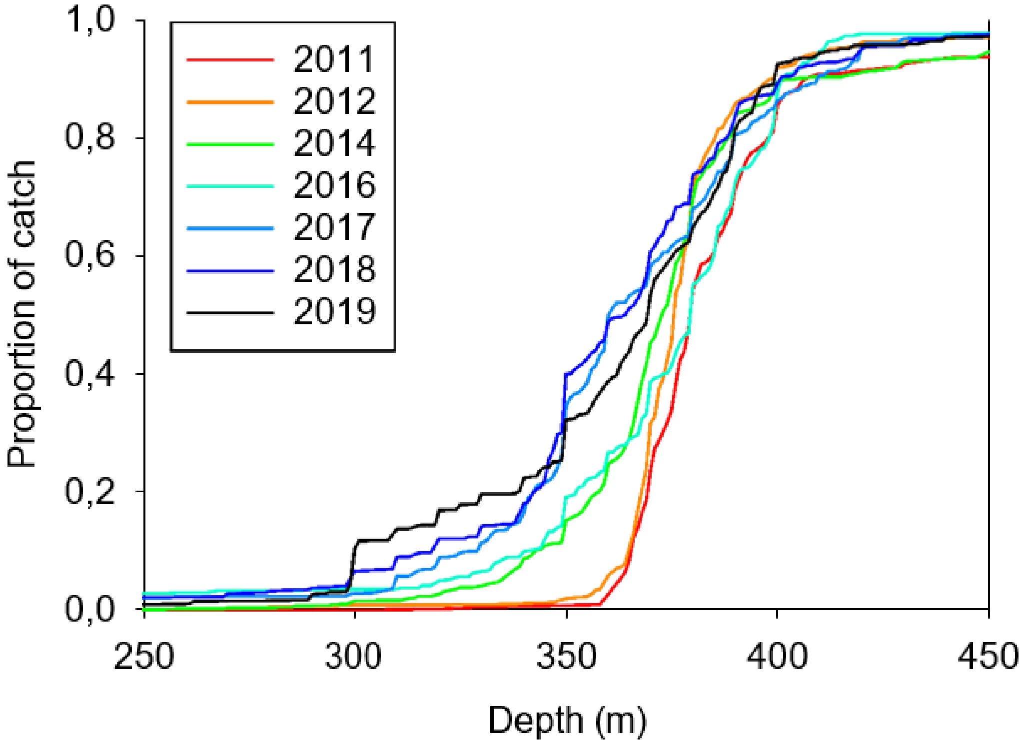
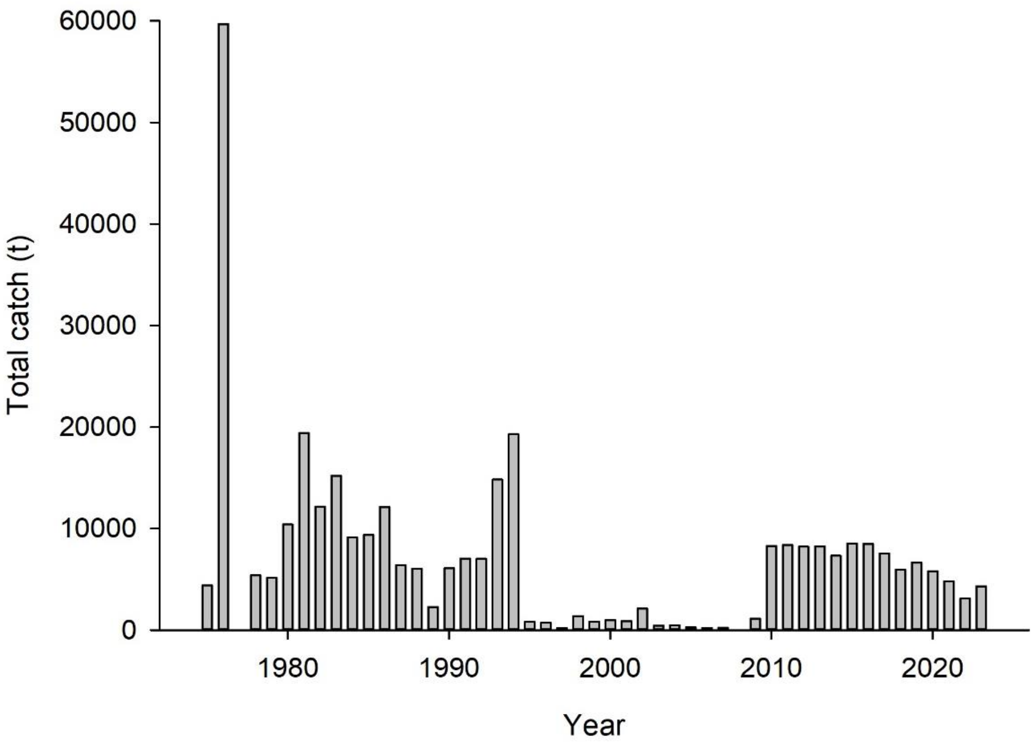


Figure 23.2.1.2 Development in catch depth of *Sebastes* (*S. mentella* and *S. norvegicus* combined). Not updated in 2023.



Figured 23.2.1.3 Total landings of redfish (mixed) in subarea 14.b.

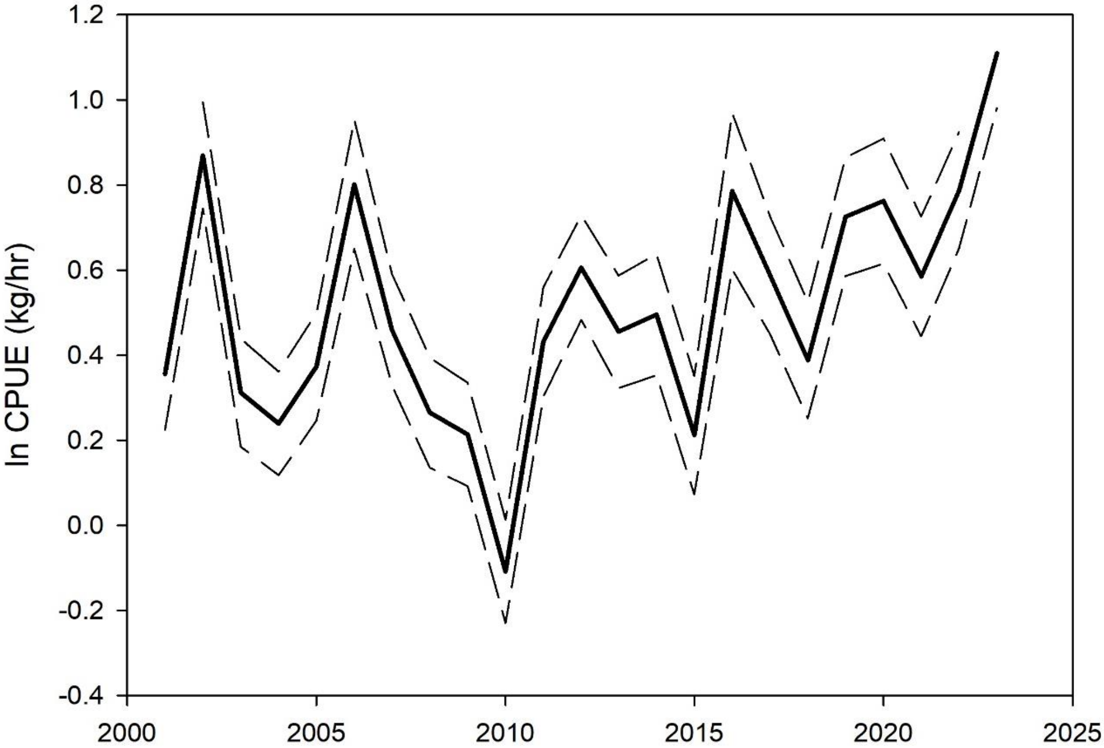


Figure 23.2.2.1 Standardized redfish bycatch CPUE in the Greenland halibut directed fishery in ICES 14.b as a function of year. CPUE was estimated from the GLM model: lnCPUE = year + ICES Subdivision + depth. Dashed lines represent 2*standard error. Only hauls made below 1000 m were used in the analyses.

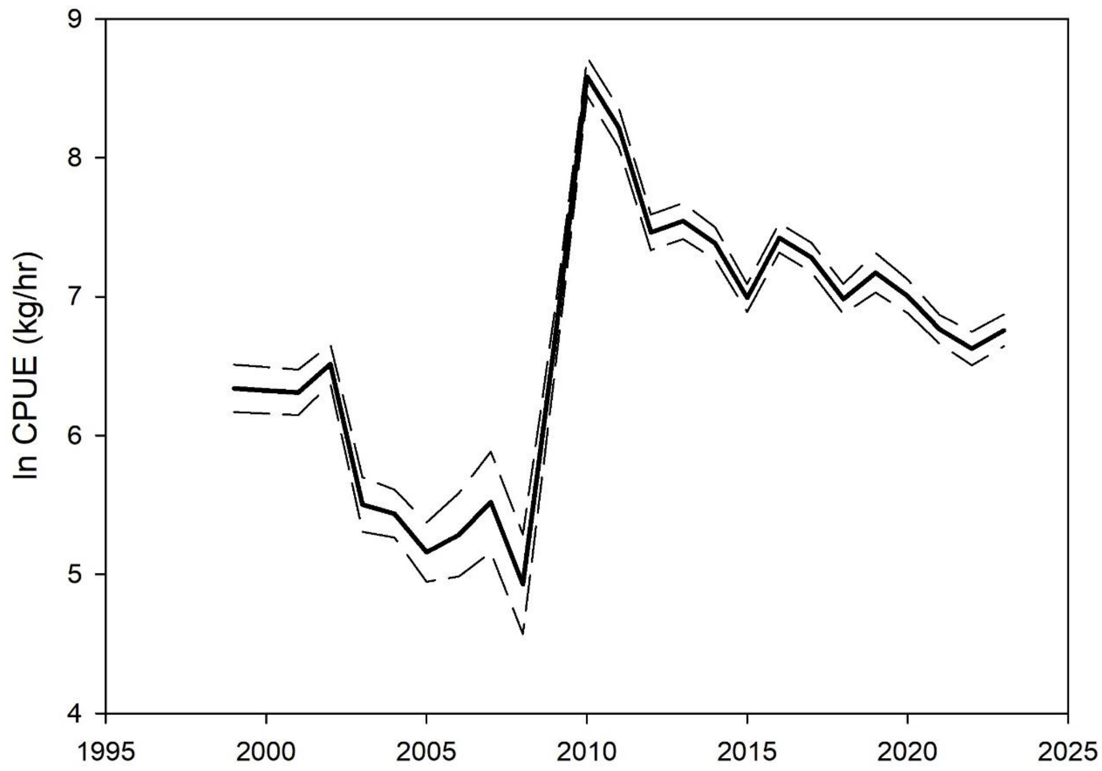


Figure 23.2.2.2 Standardized redfish CPUE in the redfish directed fishery ICES 14.b as a function of year. CPUE was estimated from the GLM model: lnCPUE = year + ICES Subdivision + depth. Dashed lines represent 2*standard error.

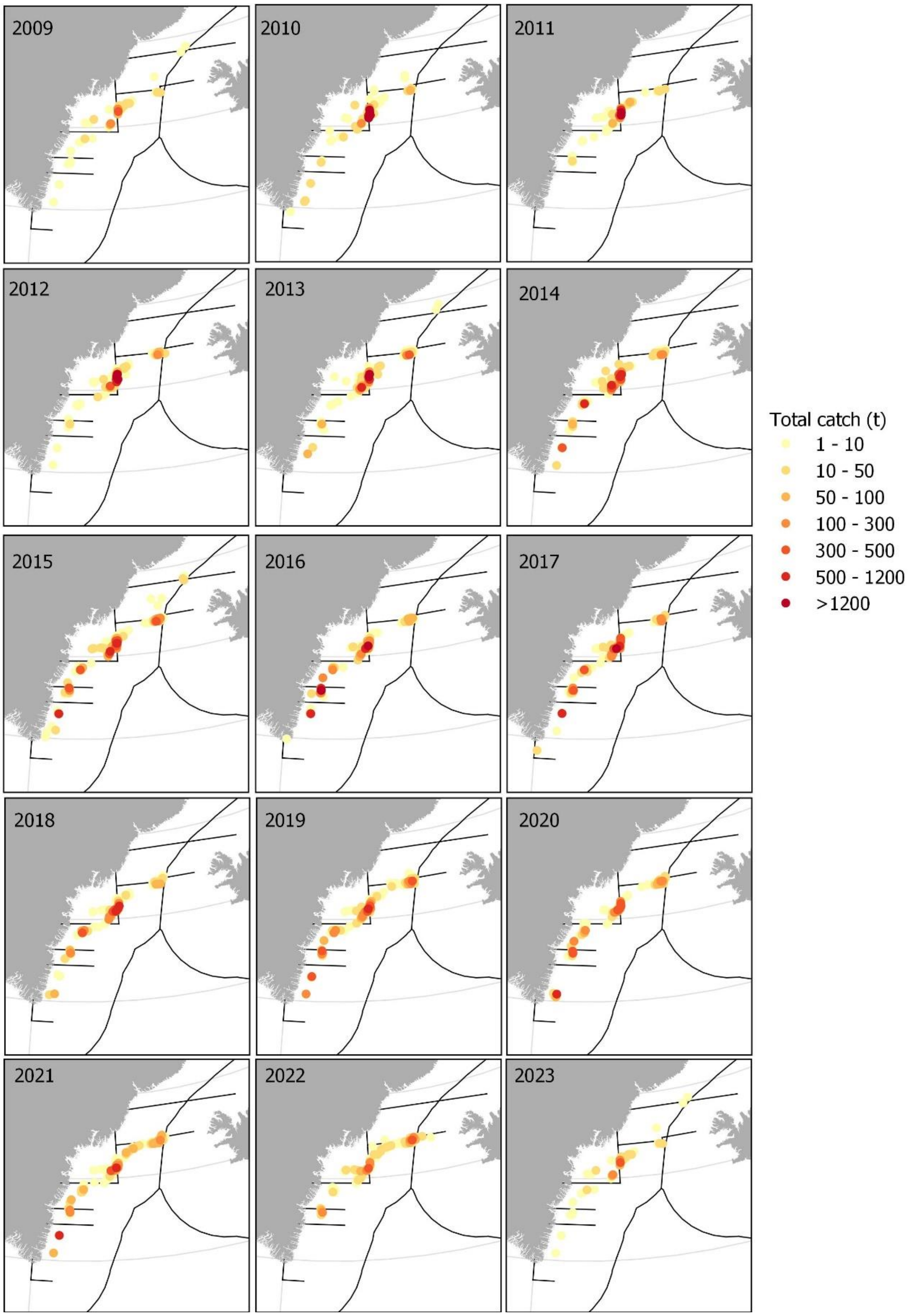


Figure 23.2.3.1 Distribution of annual catches of demersal redfish (*S. mentella* and *S. norvegicus*) between 2009 and 2023 in ICES 14.b.

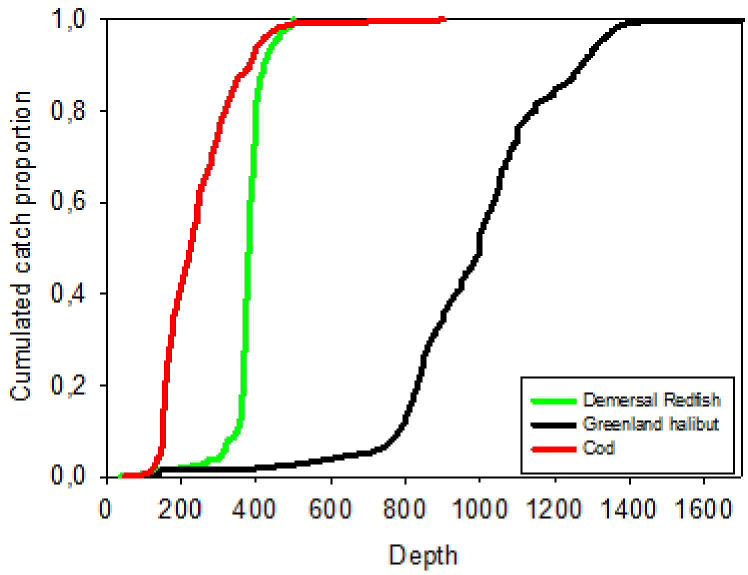


Figure 23.2.3.2. Lines represent the share of the total commercial catch caught at a given depth from 1999–2011 in Atlantic cod (*G. morhua*), demersal redfish (mixed *S. mentella* and *S. norvegicus*), and Greenland halibut *(R. hippoglossoides*).

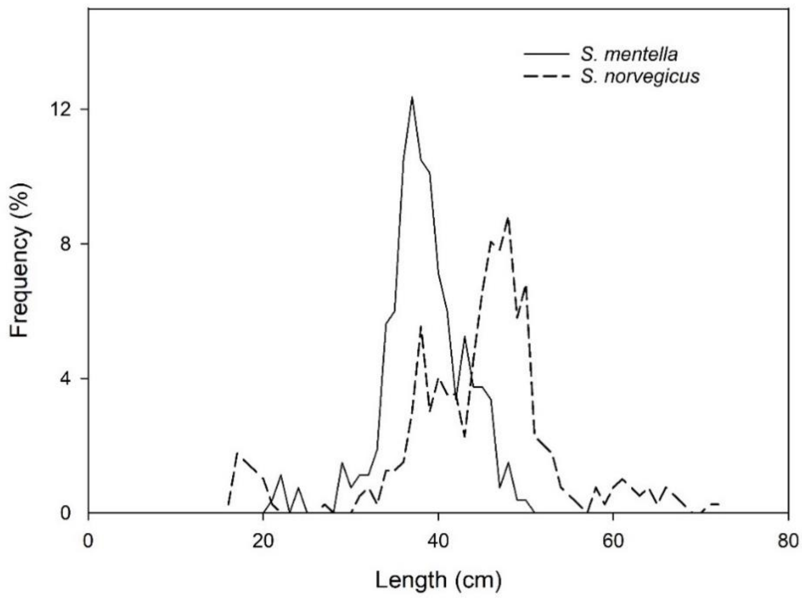


Figure 23.2.5.1: Length distribution of 672 redfish analysed by the Greenland Institute of Natural Resources in 2020 separated into *S. mentella* (N=273) and *S. norvegicus* (N=399).

24 Iceland grounds plaice

ple.27.5a – *Pleuronectes platessa* in Division 5.a

24.1 General information

Icelandic plaice (*Pleuronectes platessa*) is found on the continental shelf around Iceland with the highest abundance in the southwest and west of the island. It is mainly found on a sandy or muddy substratum, occurring at depths ranging from the coast down to 200 meters, sometimes even deeper (Jónsson & Pálsson, 2013). Sexual dimorphism occurs in plaice, as females grow larger than males and mature at larger size. Only a small proportion of males become longer than 45 cm, but about the same proportion of females grow larger than 55 cm. Size at sexual maturity differs between the sexes, whereas at the length of 33 cm about half the males have reached maturity, but females reach that level at 38 cm length. Spawning occurs mostly at 50–100 m depth in the relatively warm waters south and west of Iceland, but there is small-scale spawning off the northwest and north coast (Sigurðsson, 1989; Sólmundsson *et al*., 2005). After metamorphosis, the 0-group juveniles seek bottom in shallow waters and spend the first summer just below the tidemark (Pálsson & Hjörleifsson, 2001).

Genetic studies (Le Moan, Bekkevold, and Hemmer-Hansen 2021), (Hoarau *et al*., 2004) suggest that plaice found on the Icelandic and Faroese shelf areas are genetically different from plaice found elsewhere. Sigurdsson (1982) observed long distance migrations to the Barents Sea. Similar migrations were not observed in recent tagging studies in Icelandic Waters (Solmundsson, Palsson, and Karlsson, 2005) and the validity of these older observations are considered questionable (Sigurdsson pers. comm). Furthermore, the older observations conflict with the results from Le Moan, Bekkevold, and Hemmer-Hansen (2021).

Tagging data suggests considerable movement within Icelandic Waters, this is in accordance with the observed distributional shifts between the spring and autumn surveys and suggests that substock structure for plaice in Icelandic Waters is negligible.

24.2 Fishery

Main fishing grounds for plaice are in the west and southwest of Iceland, with smaller fishing areas in the southeast and several fjords in the north (Figure 24.1 and Figure 24.2). Demersal seine is the main fishing gear for plaice (59–71% since 2011) in area 5a followed by demersal trawl (23–37%), while a small proportion of the catch is taken in gillnets and longline (Figure 24.4). Seiners dominate the coastal plaice fishery, but trawlers catch them deeper and further offshore. Plaice fishing grounds in 2015–2023, as reported by mandatory logbooks, are shown in Figure 24.1.

Since 2000, the main fishing grounds of plaice have been on the southwestern, western and northwestern part of the Icelandic shelf (Figure 24.2). Spatial distribution of the Icelandic plaice fishery has been relatively stable, with around 60% of the plaice caught on the western and northwestern part of the shelf. In the last decade, reported catches have increased in the southwestern part but decreased again in the last 5 years to previous proportions. On the contrary, an increase in reported caches was observed in western and northwestern part of the shelf during that period. Plaice is caught in relatively shallow water, with most of the catch (60–80%) taken at depths of 21–80 m (Figure 24.3).

Since 2000, the number of vessels reporting catches of plaice annually has decreased, whereas total catches have been increasing in the past few years. This decrease is most noticeable in the demersal seiner fleet, where the number dropped from 92 vessels in 2004, to 37 in 2021. The number of trawlers has remained relatively stable since 2010 (Table 24.1). Total annual catch of plaice has been relatively stable (4900–8300 t) over the last 20 years. In 2023, a total of 6631 t of plaice was caught, about 645 t less than in the previous year.

24.2.1 Landings trends

Plaice fishery in 5a has been considered stable in last two decades and annual landings have been between 5 and 8 thousand tonnes (Figure 24.5). Landings of plaice in 2023 are estimated to have been 6631 tonnes, see Figure 24.5 and Table 24.1. Landings in division 5.a. have decreased from around 14.5 thous. tonnes in 1985, which historically was the maximum level observed to the current level. Landings by foreign vessels were considerable before the Icelandic EEZ was expanded to 200 nautical miles in 1975, afterwards landings were primarily conducted by the Icelandic fleet. Foreign vessels were the most significant with regards to landed plaice before WW2, but during the war period the Icelandic fleet picked up and took over the majority of fisheries in Icelandic Waters. Through years 1946–1973 the landings were divided between both foreign and Icelandic fleet.

24.3 Data available

Sampling of biological data from main gears (demersal seine and bottom-trawl) in commercial catches is considered good in general. The sampling does cover the spatial distribution of catches to a satisfactory extent. The sampling coverage by gear in 2023 is shown in Figure 24.6 and overview of the number of samples is shown in Figure 24.7. Due to the COVID-19 pandemic in 2020, researchers from MRFI and inspectors from Directorate of Fisheries in Iceland had difficult time obtaining necessary samples for biological measurements from the fisheries, therefore sampling locations and numbers were fewer than usual during that year.

24.3.1 Landings and discards

All landings in 5.a before 1982 are derived from the STATLANT database, and also all foreign landings in 5.a to 2005. The years between 1982 and 1993 landings by Icelandic vessels were collected by the Fisheries Association of Iceland (Fiskifélagið). Landings after 1994 by Icelandic vessels are given by the Icelandic Directorate of Fisheries. Landings of foreign vessels (mainly Norwegian and Faroese vessels) are given by the Icelandic Coast Guard prior to 2014 but after 2014 this are also recorded by the Directorate (Figure 24.5). Discarding is banned by law in the Icelandic demersal fishery. Discard rates in the Icelandic fishery for plaice are estimated negligible at least since 2001. Measures in the management system such as converting quota share from one species to another are used by the fleet to a large extent and this is thought to discourage discarding in mixed fisheries. In addition to prevent high grading and quota mismatch the fisheries are allowed to land fish that will not be accounted for in the allotted quota, provided that the proceedings when the landed catch is sold will go to the Fisheries Project Fund (Verkefnasjóður sjávarútvegsins). A more detailed description of the management system can be found on the website[1].

[1] https://www.responsiblefisheries.is/seafood-industry/fisheries-management/statement-on-responsible-fisheries

24.3.2 Length composition

An overview of available length measurements from 5.a is given in Table 24.2. Most of the measurements are from the two main fleet segments, i.e. trawls and demersal seine. Length distributions from the main fleet segments are shown in Figure 24.8. The sizes caught by the main gear types (bottom-trawl and Danish seine) appear to be stable, primarily catching plaice in the size range between 35 and 55 cm. There has been a gradual shift towards larger fish in the length distribution in both fleets. As a result, the average length in the samples taken from commercial catch has increased from 35 cm in 1991 to 43.1 cm in 2016.

24.3.3 Age composition

Table 24.3 gives an overview of otolith sampling intensity by gear types in 5.a. Since 2000 catch-at-age has been stable with 4-8 years old plaice dominating the catch (Figure 24.9). In the last decade older age groups are also visible in the catch.

24.3.4 Weight at age

Mean weight at age in commercial catches is shown in Figure 24.10. Mean weight at age has been increasing in all age groups since 1995.

24.3.5 Natural mortality

No information is available on natural mortality. For assessment and advisory purpose, the natural mortality is set to 0.15 for all age groups.

24.3.6 Catch, effort and research vessel data

24.3.6.1 Catch per unit effort (CPUE) and effort data from commercial fisheries

CPUE estimates of plaice in Icelandic Waters are not considered representative of stock abundance as changes in fleet composition and technical improvements have not been accounted for when estimating CPUE. Non-standardized estimates of CPUE in demersal seine (kg/set) is calculated as the total weight in sets in which plaice was more than 50% of the catch. CPUE gradually increased from 250 kg/set to over 700 kg/set in 2016 (Figure 24.11). CPUE of plaice in demersal seine has been fluctuating around that level in the last few years. CPUE of demersal trawl (kg/hour), in hauls where plaice is more than 50% of the catch, remained relatively stable between 150-200 kg/hour until 2005. CPUE of plaice has in trawl, like in the demersal seine fishery, gradually increased from 200 kg/hour in 2004 to just under 600 kg/hour in 2015 and has fluctuated between 400 and 600 kg/hour since.

24.3.7 Icelandic survey data

Information on abundance and biological parameters from plaice in 5.a is available from two surveys, the Icelandic groundfish spring survey and the Icelandic groundfish autumn survey. The Icelandic spring groundfish survey, which has been conducted annually in March since 1985, covers the most important distribution area of the plaice fishery. In addition, the Icelandic autumn groundfish survey was commenced in 1996. The autumn survey was not conducted in 2011. The spring survey is considered to measure changes in abundance/biomass better than the autumn survey. It does not, however, adequately cover the main recruitment grounds for plaice, as recruitment takes place in shallow water in habitats unsuitable for demersal trawling. In addition to these two major surveys, there was a designated flatfish survey with beam trawl, conducted annually in July/August from 2016 to 2022, with the aim to cover most of the recruitment grounds of plaice and other flatfish species. This survey was discontinued in 2023.

Figure 24.12 shows trends in various biomass indices and a recruitment index based on abundance of plaice smaller than 20 cm. Survey length-disaggregated abundance indices are shown in Figure 24.15 and changes in spatial distribution in Figure 24.13. Total biomass index of plaice and plaice larger than 30 cm (harvestable part of the stock), decreased rapidly in the first years of the spring survey and were at the lowest level in 1997–2002. In 2003–2016 the indices gradually increased and stabilized. Since 2017 there have been minor annual fluctuation in the indices, but they are still fairly stable. This year's spring survey biomass index is in correspondence with the biomass from early 1990. The indices are now only one-third to half of what they were in the first four years of the time-series. The index of plaice larger than 50 cm in the spring survey also decreased to lowest levels in 1997-2002 but has increased and has been in recent years at similar level as at the beginning of the time-series. The index of juvenile abundance (<20 cm) has maintained at the low level since 1998 with occasional small peaks. Trends in the autumn survey are similar to those observed from the spring survey with exception of year 2022, also standard deviations in autumn survey measurements are higher.

Mean weight at age in SMB is shown in Figure 24.16. Mean weights at age from SMB are also used as mean weight at age in the spawning stock, approximated from lengths. For stock weights for age 9 are smoothed using a running 3-year average. Prior to 1985 the stock weights are assumed fixed at 1985 levels.

Maturity-at-age data from SMB are given in Figure 24.17. Based on guidelines from PGCCDBS (ICES, 2017) it was decided to use mature females as the basis for maturity-at-age. Prior to 1985 the proportion mature is assumed fixed at 1985 levels. Maturity-at-age is estimated from yearly maturity at length ogives estimated using logistic regression treating individuals as fixed effects. Maturity-at-age was smoothed with a 3-year running average.

Plaice is mainly caught in the northwest area as well as on the main spawning grounds off the western part of the country in the spring survey and on the species main feeding grounds in the northwest of the country in the autumn survey (Figure 24.14). Spatial distribution of plaice catch in the surveys shows some temporal changes, particularly between catches taken in the west and northwest areas (Figure 24.13). This could be due to annual variation in timing of plaice moving to their traditional spawning grounds in the western part of the country as the survey takes place around that same time every year.

24.4 Data analyses

24.4.1 Analytical assessment

24.4.1.1 Model fit

The model fit to survey indices and catch-at-age data are shown in Figure 24.19. Generally, except for the youngest age classes, the SAM model follows the catch-at-age and spring survey data.

Figure 24.20 shows the estimated model parameters. Observation variances are lowest for the spring survey and commercial catches for ages 5 to 8 and 7 to 8 respectively, with the highest variances at either ends of the age range. Survey variances are in general higher than that of the commercial catches. Strong positive correlations were estimated between ages for the commercial catches, less for survey catches. Process variances were fixed across all ages for both $\log(N)$ and $\log(F)$, with populations variances estimated at 0.06.

Survey catchability showed an increasing trend with age, peaking at the age of 10, while slightly lower at 11 and 12.

24.4.2 Stock overview

Population dynamics of plaice estimated by this model (Figure 24.21) show a clear reduction in the level of recruitment (at age 3) in 1993, and subsequently we see an increase in fishing mortality and reduction in total catches. Spawning-stock biomass (SSB) was at its lowest value at the turn of the century. In recent years recruitment is seen to be stable at the post 1993 levels whereas fishing mortality has been reduced and SSB increased. Catches have remained stable, slightly decreasing.

24.4.3 Analytical retrospective

The proposed model had low Mohn's ρ statistic values for spawning-stock biomass, fishing mortality, and recruitment. Analytical retrospective plots do not indicate any substantial deviations in assessment (Figure 24.22). These Mohn's ρ values are well within the range recommended by Carvalho *et al.* (2021).

24.4.4 Short-term forecast

Short-term projections are performed using the standard procedure in SAM using the `forecast` function. Three-year averages are used for stock and catch weights, and maturity. From this projection the advice is derived. The advice is based on the Icelandic fishing year starting in September each year. This causes a mismatch between the assessment model, which is based on the calendar year. So, to provide advice for the fishing year, the standard projection procedure in SAM will need to be adapted to accommodate these differences. So given the assessment in year y the interim year catches are based on the following fishing mortality:

$$F_y = \left(\frac{8}{12}F_{sq} + \frac{4}{12}F_{mgt}\right)$$

and therefore the total catches for year y will be:

$$C_y = \frac{F_y}{F_y + M}\left(1 - e^{-(F_y+M)}\right)B_y$$

and the part of the catch in the fishing year y-1/y will be

$$\frac{\frac{8}{12}F_{sq}}{\left(\frac{8}{12}F_{sq} + \frac{4}{12}F_{mgt}\right)}C_y$$

and the catch in fishing year y/y+1 will be:

$$C_{y/y+1} = \frac{\frac{4}{12}F_{mgt}}{\left(\frac{8}{12}F_{sq} + \frac{4}{12}F_{mgt}\right)}C_y + \frac{8}{12}C_{y+1}$$

where,

$$C_{y+1} = \frac{F_{mgt}}{F_{mgt} + M}\left(1 - e^{-(F_{mgt}+M)}\right)B_y$$

The results from the short-term prognosis are shown in Table 24.4.

24.5 Management

The Ministry of Food, Agriculture and Fisheries is responsible for management of the Icelandic fisheries and implementation of legislation. The Ministry issues regulations for commercial fishing for each fishing year (1. September – 31. August), including an allocation of the TAC for each stock subject to such limitations. Plaice was included in the ITQ system in the 1991/1992 quota year and as such subjected to TAC limitations. For the first six years, the TAC was set higher than recommended by Marine Research Institute (MRI), but this practice stopped in the 2010/2011 quota year (Table 24.5). One reason for this practice was that no formal harvest rule existed for this stock. Through this period the landings have been fluctuating between the over- or undershoot of the set TAC. This is related to the management system that allows for transfers of quota share between fishing years and conversion of TAC from one species to another (species transformation).

Figure 24.23 shows the net transfers in the Icelandic ITQ-system. From 2002-2008 there was a net transfer of other species being transferred to plaice quota (positive values in the figure). However, from 2009-2015, this was reversed, and plaice quota was transferred to other species. In recent years species-transfer of quota trough plaice has been low, except for 2020/2021 when around 1500 t were transferred from quotas of other species to plaice. Net transfer of plaice quota between fishing years has varied between years, and ranges from 10 to −12%.

24.5.1 Management considerations

All the signals from commercial catch and survey data indicate that plaice in Iceland is at present in a good state. This is also confirmed in the assessment. Considerable uncertainty is present in the model due to limited information on recruitment from spring survey.

24.6 References

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Solmundsson, Jon, Jonbjorn Palsson, and Hjalti Karlsson. 2005. “Fidelity of mature Icelandic plaice (Pleuronectes platessa) to spawning and feeding grounds.” ICES Journal of Marine Science. https://doi.org/10.1016/j.icesjms.2004.11.012

24.7 Figures and tables

Table 24.1. Plaice in 5a. Number of Icelandic vessels landing plaice, and all landed catch divided by gear type.

Year	Nr. Bottom Trawl	Nr. Danish Seine	Nr. Other	Bottom Trawl	Danish Seine	Other	Total catch
2000	134	125	450	1747	3070	442	5259
2001	127	95	521	1402	2924	600	4926
2002	118	96	420	1270	3426	446	5142
2003	115	95	389	1295	3590	372	5257
2004	108	95	399	1375	4037	294	5706
2005	105	88	352	1638	3909	255	5802
2006	99	87	365	2449	3720	212	6381
2007	98	82	355	2232	3311	267	5810
2008	93	80	322	2605	3836	285	6726
2009	85	70	315	2125	3889	310	6324
2010	85	61	328	2038	3647	299	5984
2011	80	55	357	1655	3021	267	4943
2012	88	54	374	1410	4079	437	5926
2013	87	56	317	1583	4040	364	5987
2014	74	45	317	1380	4239	308	5927
2015	74	50	319	2001	4403	350	6754
2016	73	44	280	2120	4896	430	7446
2017	71	48	282	1765	4579	351	6695
2018	66	47	257	2436	5584	321	8341
2019	63	44	276	2231	4287	316	6834
2020	65	41	213	2474	4682	350	7506
2021	63	37	238	3604	4719	355	8678
2022	64	40	210	2746	4303	227	7276
2023	56	41	237	2456	3939	237	6631

Table 24.2. Plaice in 5a. Number of samples and length measurements from landed catch.

Year	Bottom Trawl Nr. lengths	Bottom Trawl Nr. samples	Danish Seine Nr. lengths	Danish Seine Nr. samples
2000	4261	33	7185	49
2001	1003	9	7517	51
2002	2392	18	11263	69
2003	3278	21	13804	96
2004	3834	28	21216	150
2005	5251	35	20583	139
2006	8102	60	19222	135
2007	6837	49	17073	124
2008	11359	77	17471	129
2009	7201	50	19106	136
2010	9608	62	17387	126
2011	7609	55	16857	110
2012	5723	39	18329	129
2013	4688	31	16647	115
2014	2531	21	7271	53
2015	4142	33	5997	44
2016	4757	32	8075	58
2017	3527	28	6231	52
2018	3506	24	5666	43
2019	4838	36	5990	47
2020	2788	27	3031	24
2021	6922	53	5067	42
2022	4507	34	3211	26
2023	4474	41	3486	31

Table 24.3. Plaice in 5a. Number of samples and otoliths collected from landed catch.

Year	Bottom Trawl Nr. otol.	Bottom Trawl Nr. samples	Danish Seine Nr. otol.	Danish Seine Nr. samples
2000	1507	33	2400	49

Year	Bottom Trawl Nr. otol.	Bottom Trawl Nr. samples	Danish Seine Nr. otol.	Danish Seine Nr. samples
2001	350	9	2250	51
2002	599	18	2424	69
2003	550	21	3149	96
2004	820	28	3701	150
2005	1000	35	3036	139
2006	1450	60	3200	135
2007	1500	49	3199	124
2008	1850	77	3099	129
2009	1250	50	3180	136
2010	2016	62	3951	126
2011	2452	55	4200	110
2012	1835	39	5199	129
2013	1350	31	5010	115
2014	575	21	900	53
2015	670	33	800	44
2016	573	32	1125	58
2017	550	28	974	52
2018	400	24	880	43
2019	476	36	750	47
2020	550	27	550	24
2021	1225	53	900	42
2022	560	34	470	26
2023	620	41	598	31

Table 24.4. Plaice in 5a. Results from the short-term prognosis

	fbar	rec	ssb	catch
2024	0.277	16236	20279	7322
2025	0.300	16426	19369	7852
2026	0.300	16426	18638	7554

Table 24.5. Plaice in 5a. National and ICES advice and official landings. All weights are in tonnes.

Year	Rec. TAC	National TAC	Catch
1991/92	10 000	11 000	10 175
1992/93	10 000	13 000	15 474
1993/94	10 000	13 000	12 465
1994/95	10 000	13 000	11 320
1995/96	10 000	13 000	11 197
1996/97	10 000	12 000	10 516
1997/98	9000	9000	8241
1998/99	7000	7000	7711
1999/00	4000	4000	4975
2000/01	4000	4000	4946
2001/02	4000	5000	4420
2002/03	4000	5000	5427
2003/04	4000	4500	5861
2004/05	4000	5000	6193
2005/06	4000	5000	5659
2006/07	5000	6000	6144
2007/08	5000	6500	6624
2008/09	5000	6500	6368
2009/10	5000	6500	6389
2010/11	6500	6500	4846
2011/12	6500	6500	5819
2012/13	6500	6500	5935
2013/14	6500	6500	6036
2014/15	7000	7000	6230
2015/16	6500	6500	7612
2016/17	7330	7330	6373
2017/18	7103	7103	8208
2018/19	7132	7132	7096
2019/20	6985	6985	7177

Year	Rec. TAC	National TAC	Catch
2020/21	7037	7037	9082
2021/22	7805	7805	7306
2022/23	7663	7663	7264
2023/24	7830	7830	---

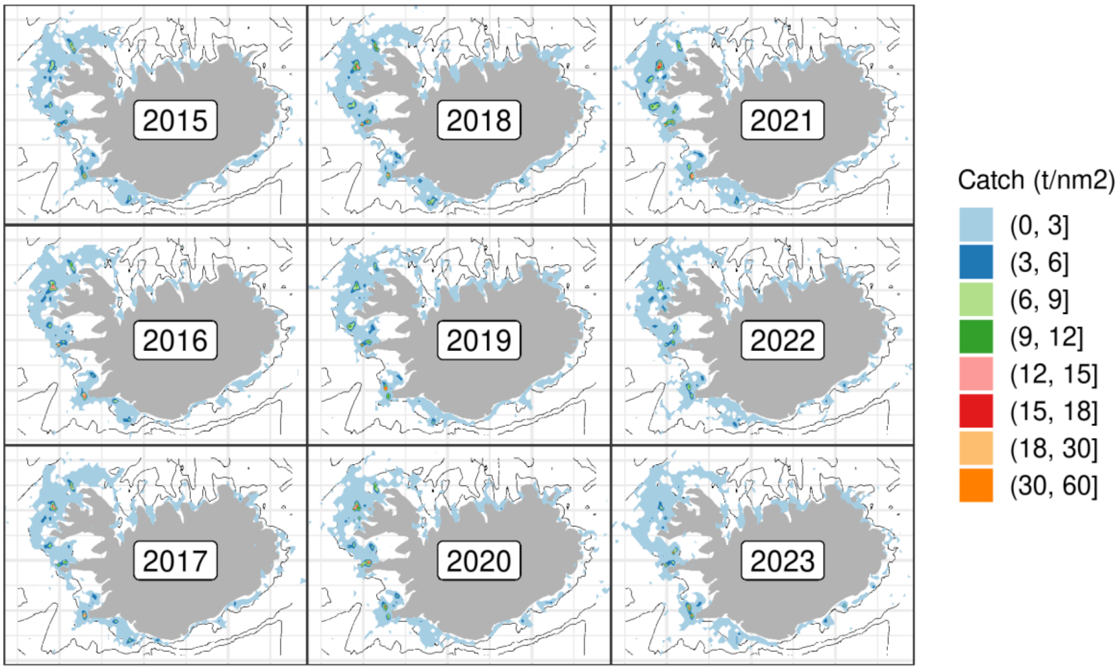

Figure 24.1. Plaice in 5a. Spatial distribution of catches by all gears according to logbooks.

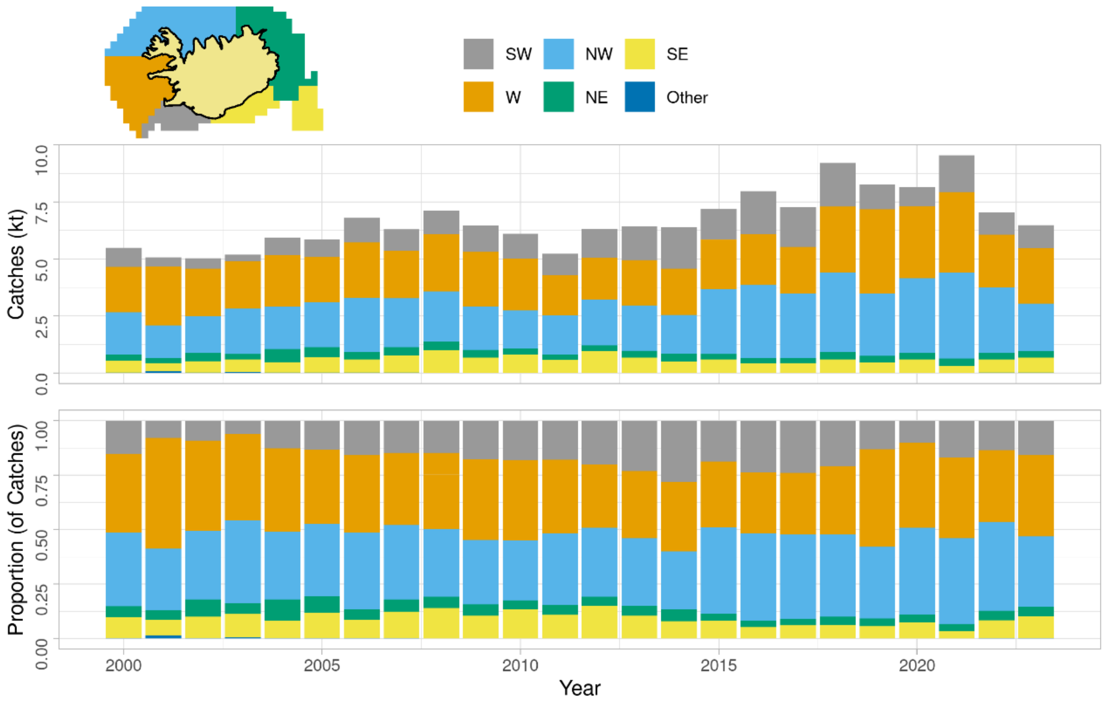

Figure 24.2. Plaice in 5a. Changes in spatial distribution of plaice catches as recorded in Icelandic logbooks.

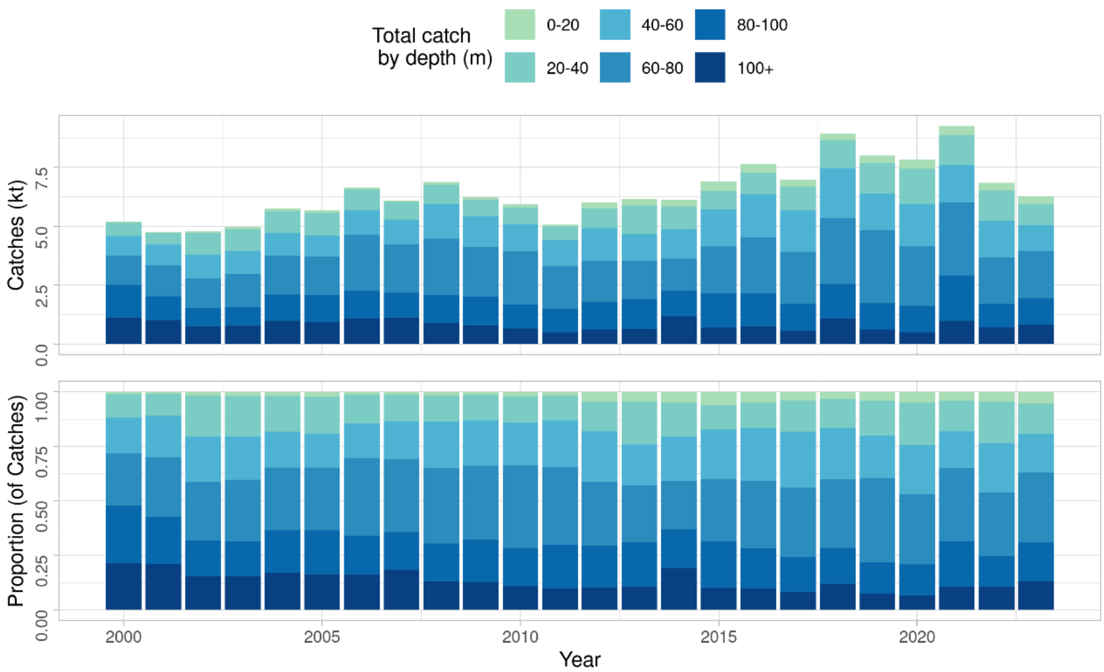

Figure 24.3. Plaice in 5a. Depth distribution of plaice from demersal trawl and seine according to Icelandic logbooks.

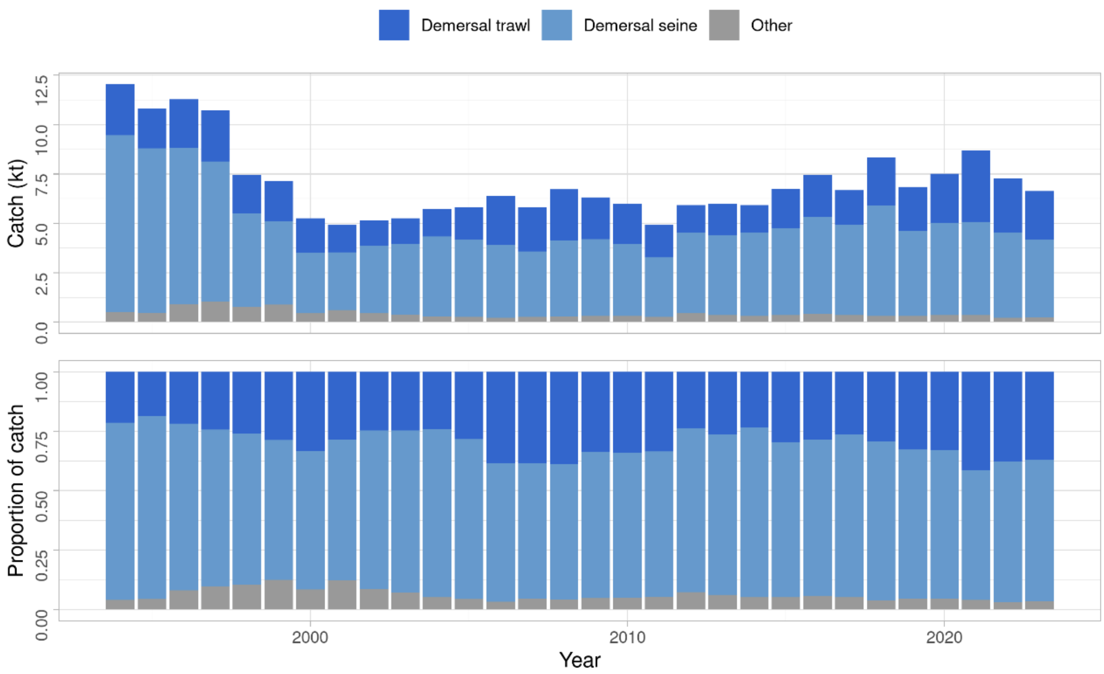

Figure 24.4. Plaice in 5a. Landings in tonnes and percent of total by gear and year.

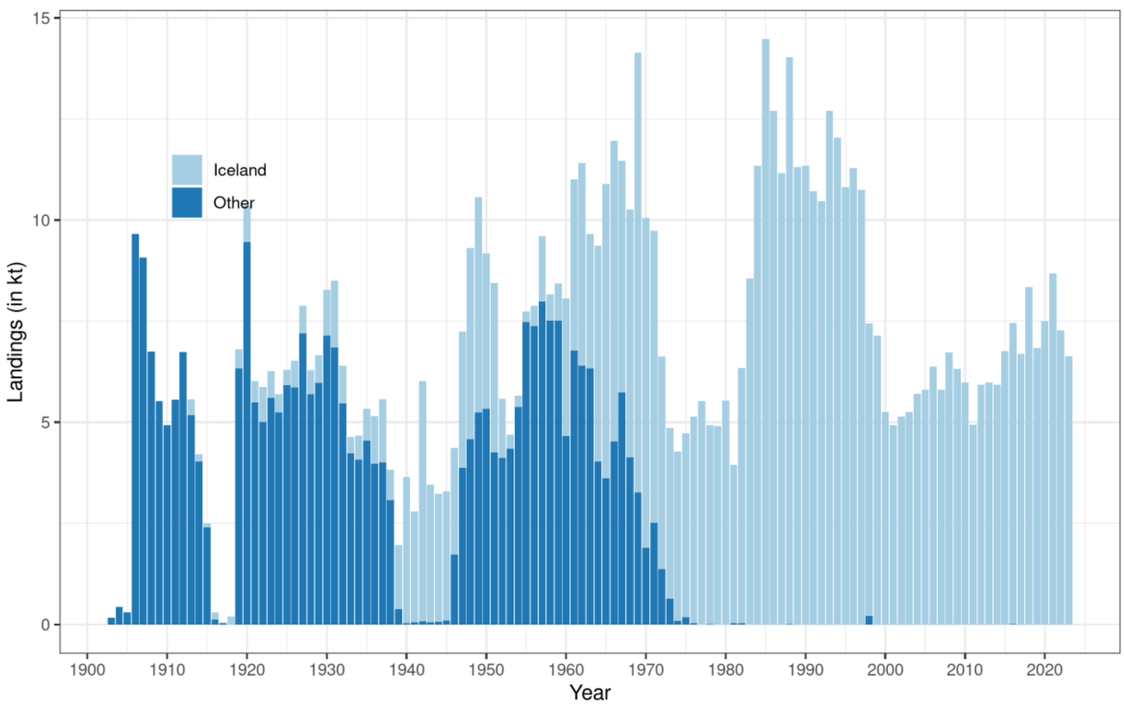

Figure 24.5. Plaice in 5a. Recorded landings since 1905.

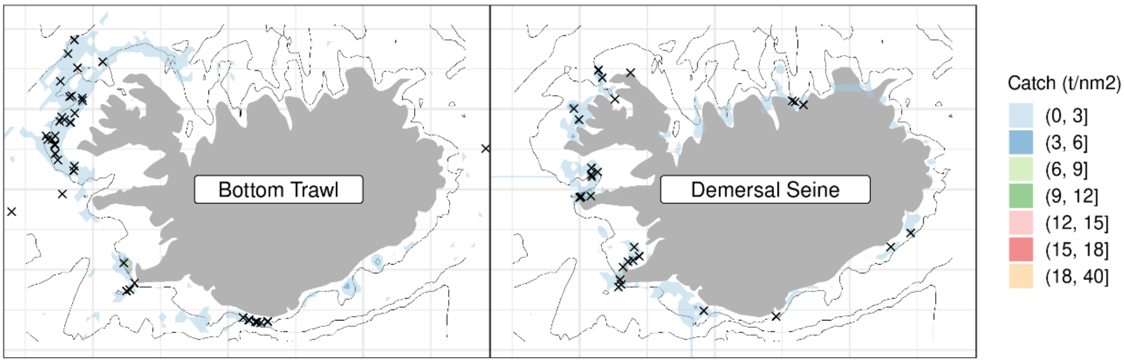

Figure 24.6. Plaice in 5a. Fishing grounds in 2023 as reported in Icelandic logbooks (colours) and positions of samples taken from landings (asterisks) by main gear types.

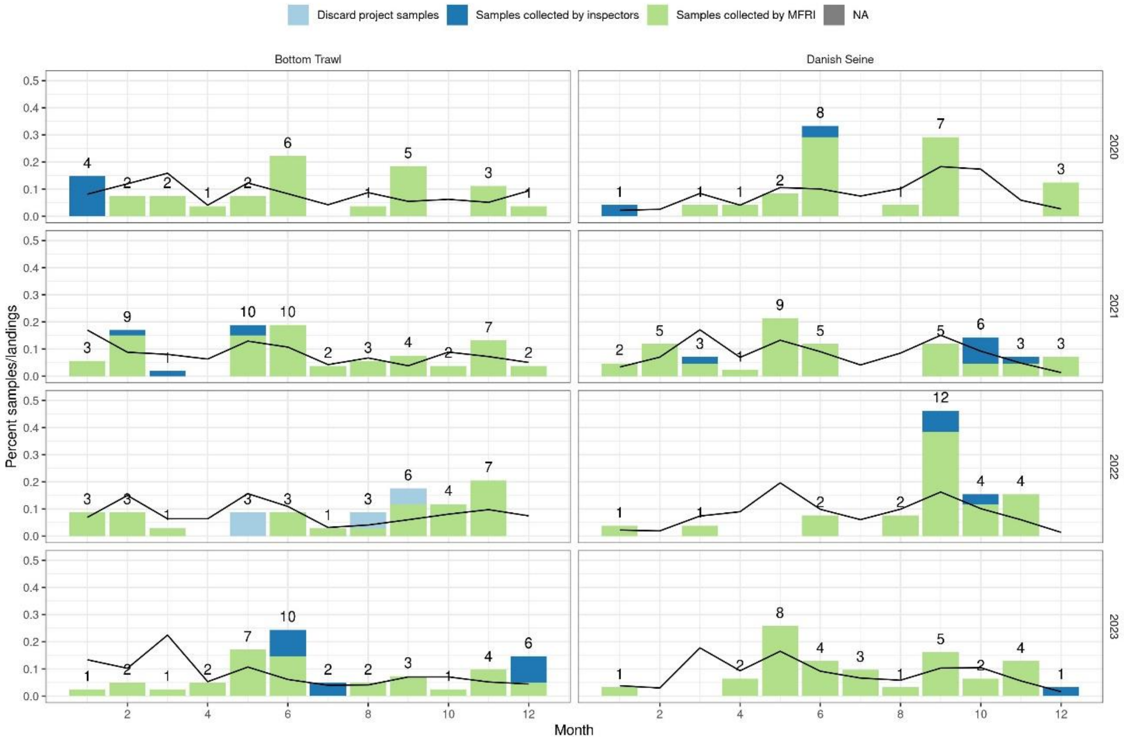

Figure 24.7. Plaice in 5a. Ratio of samples by month (blue bars) compared with landings by month (solid black line) split by year and main gear types. Numbers above the bars indicate the number of samples by year, month and gear.

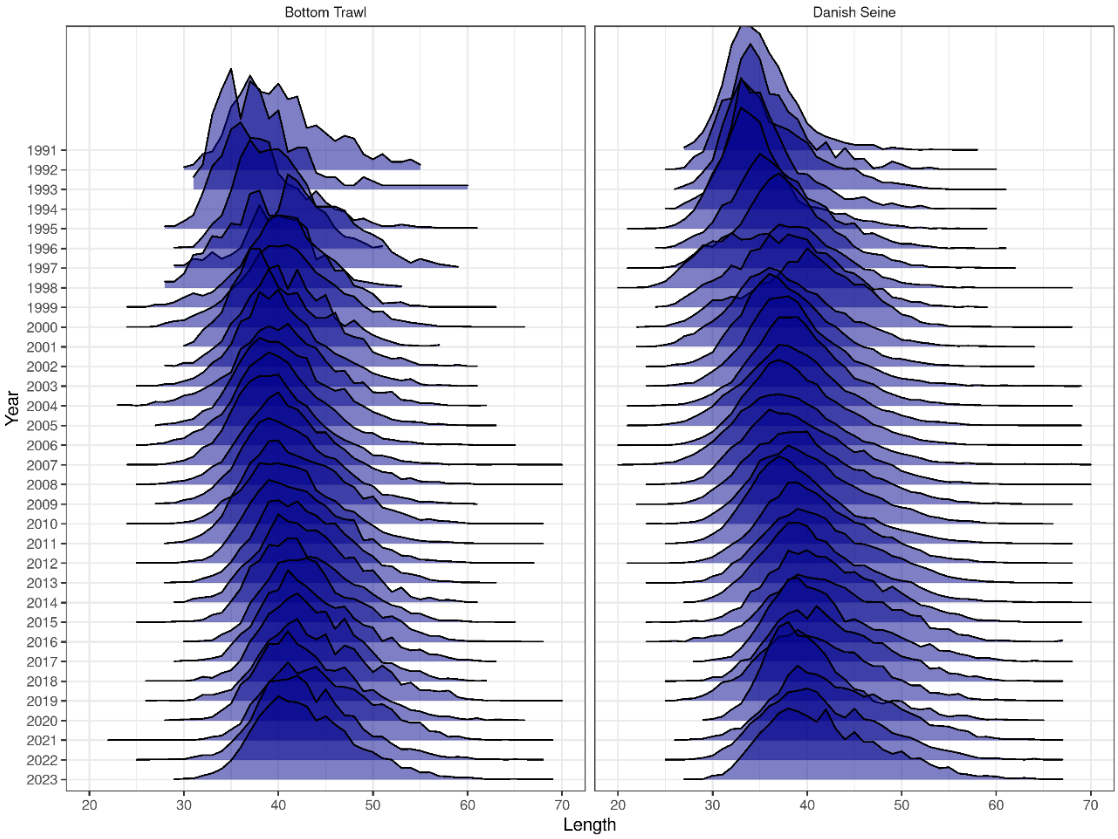

Figure 24.8. Plaice in 5a. Commercial length distributions by gear and year

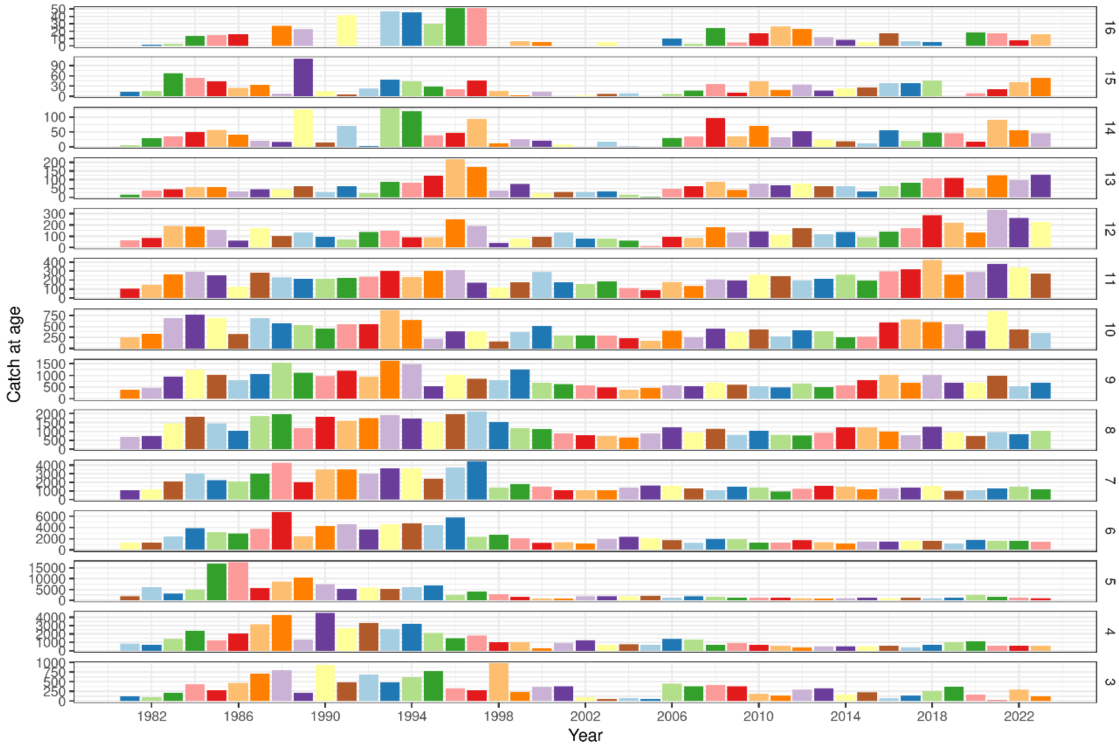

Figure 24.9. Plaice in 5a. Catch-at-age from the commercial fishery in Iceland waters. Bar size is indicative of the catch in numbers and bars are coloured by cohort.

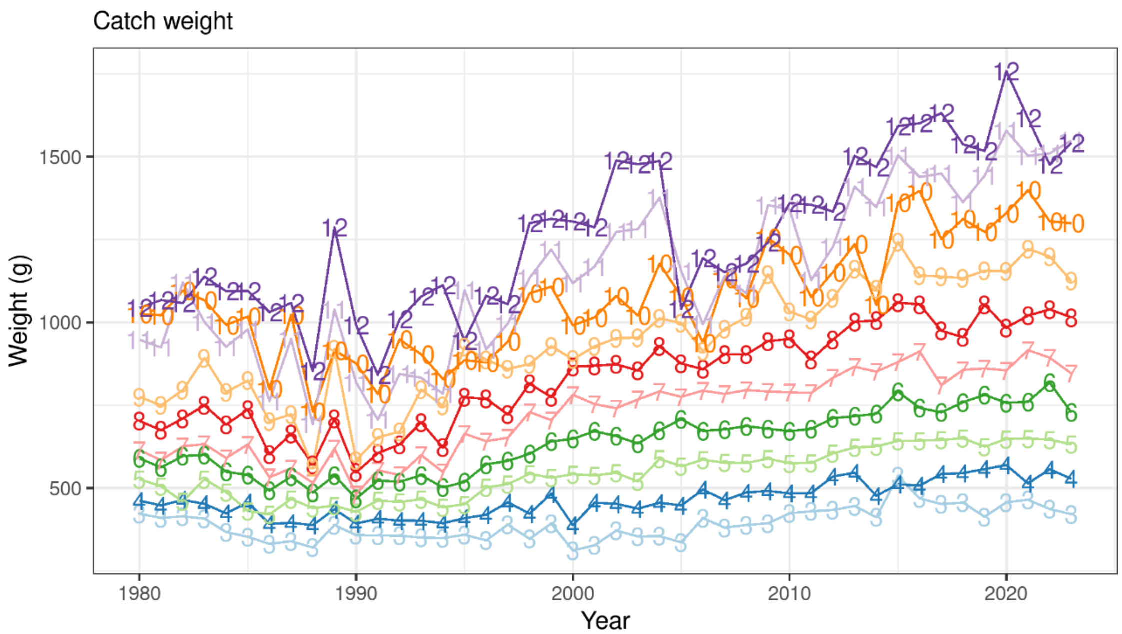

Figure 24.10. Plaice in 5a. Catch weights from the commercial fishery in Icelandic Waters.

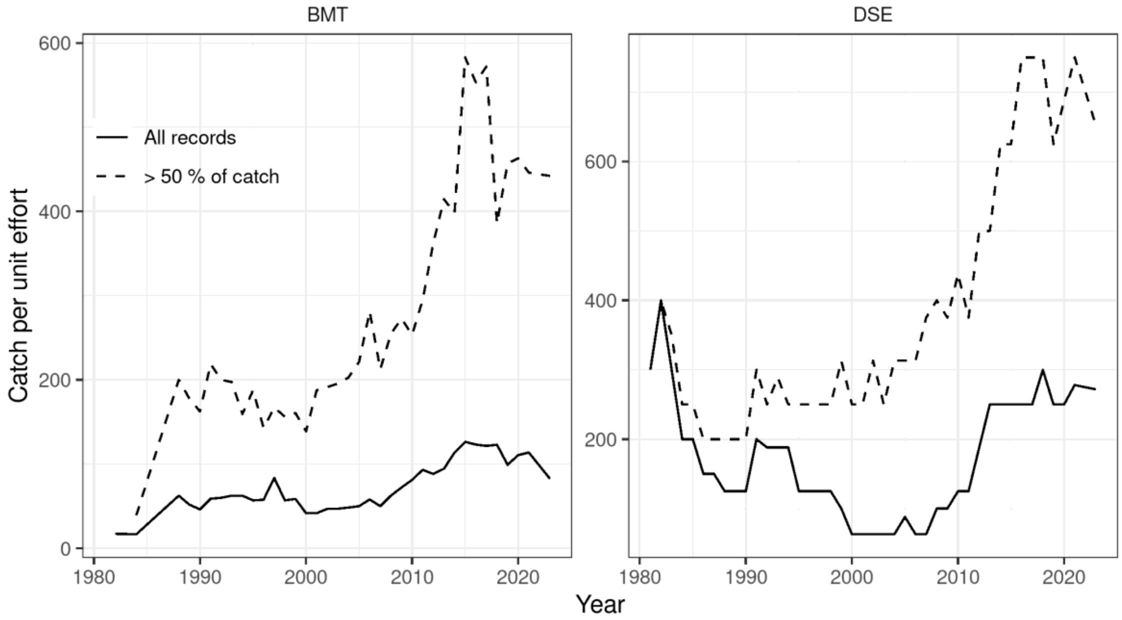

Figure 24.11. Plaice in 5a. Catch per unit effort in the most important gear types. The dashed lines are based on locations where more than 50% of the catch is plaice and solid lines on all records where plaice is caught. Effort data are not available for 2022.

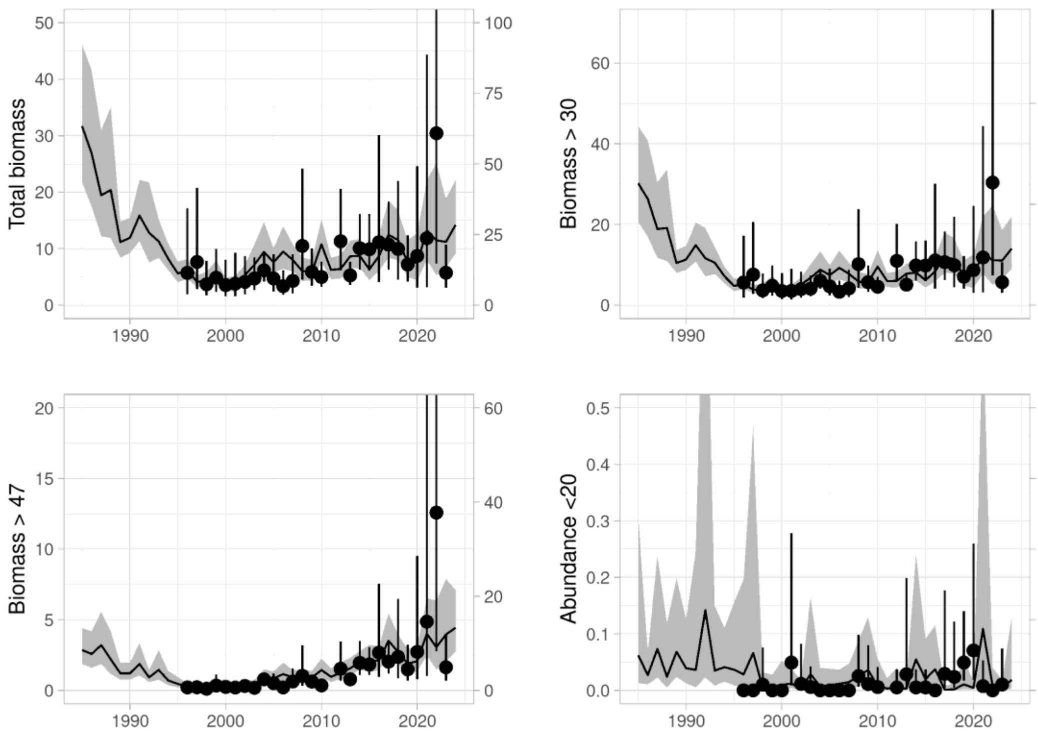

Figure 24.12. Plaice in 5a. Indices in the spring survey (March) 1985 and onwards (line shaded area) and the autumn survey (point ranges).

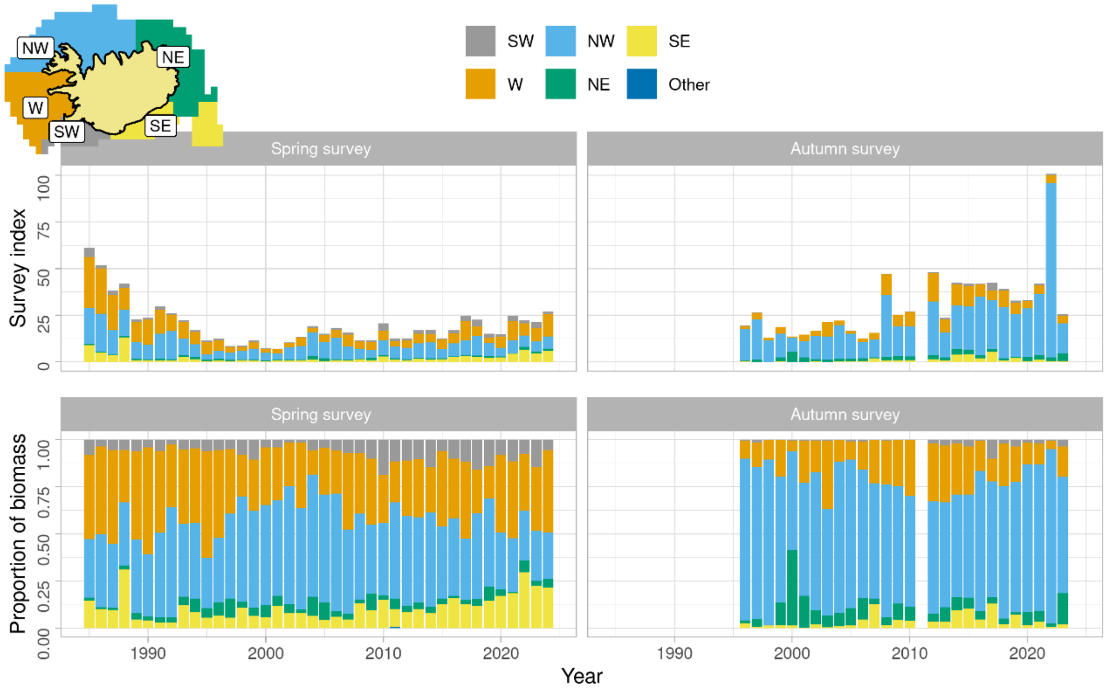

Figure 24.13. Plaice in 5a. Changes in geographical distribution of the survey biomass.

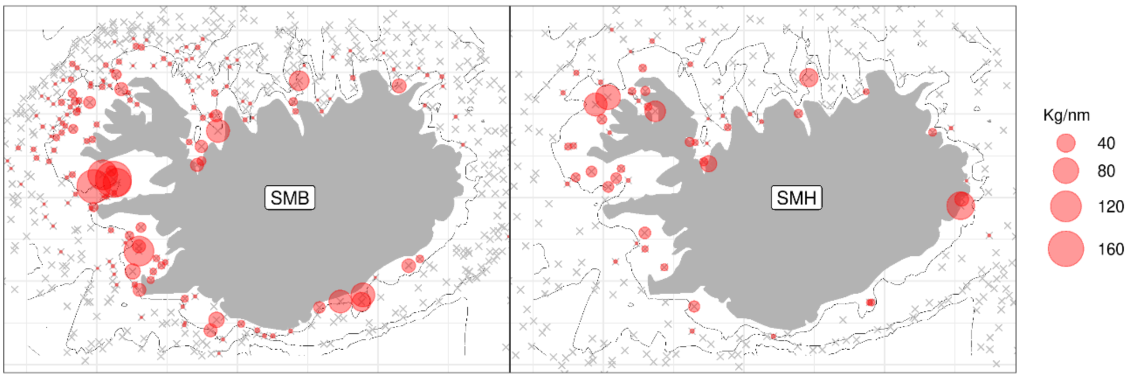

Figure 24.14. Plaice in 5a. Location of plaice in the most recent spring (SMB) and autumn (SMH) surveys, bubble sizes are relative to catch sizes.

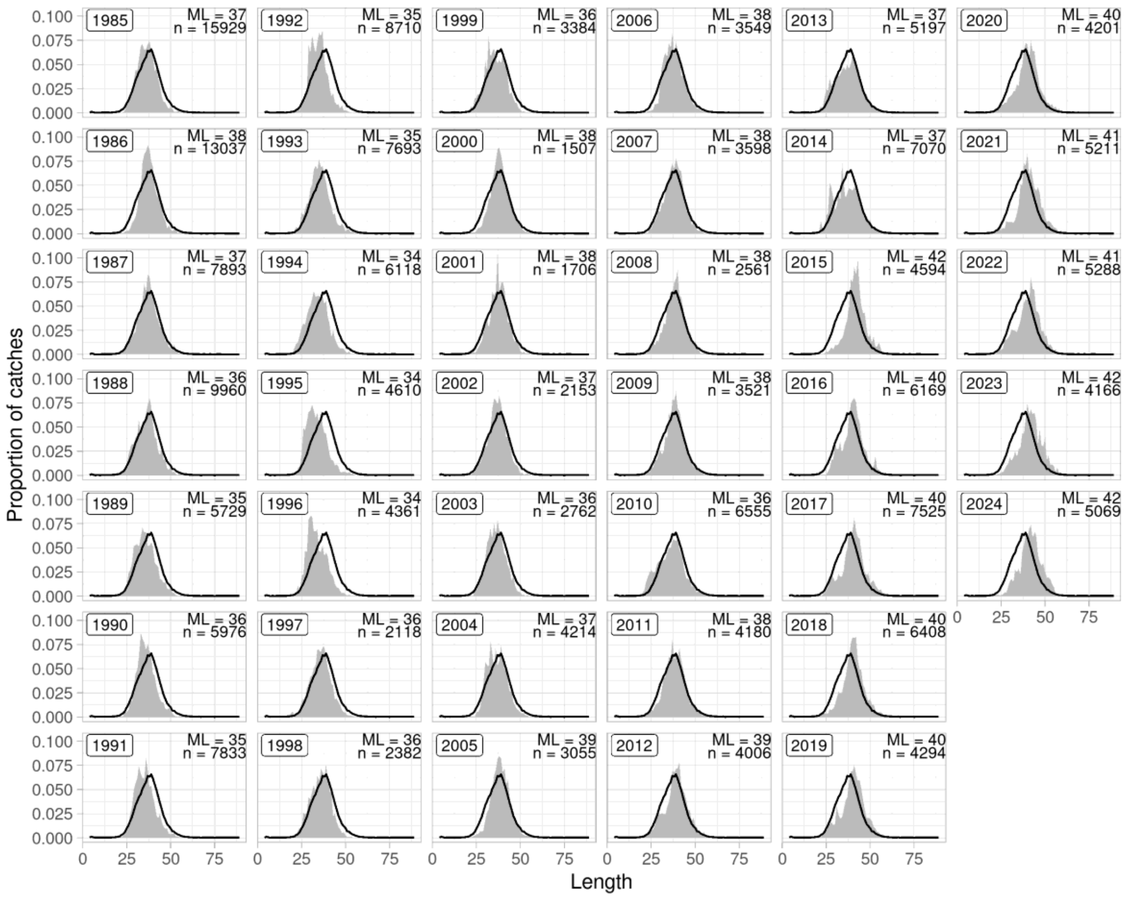

Figure 24.15. Plaice in 5a. Length disaggregated abundance indices from the spring survey 1985 and onwards.

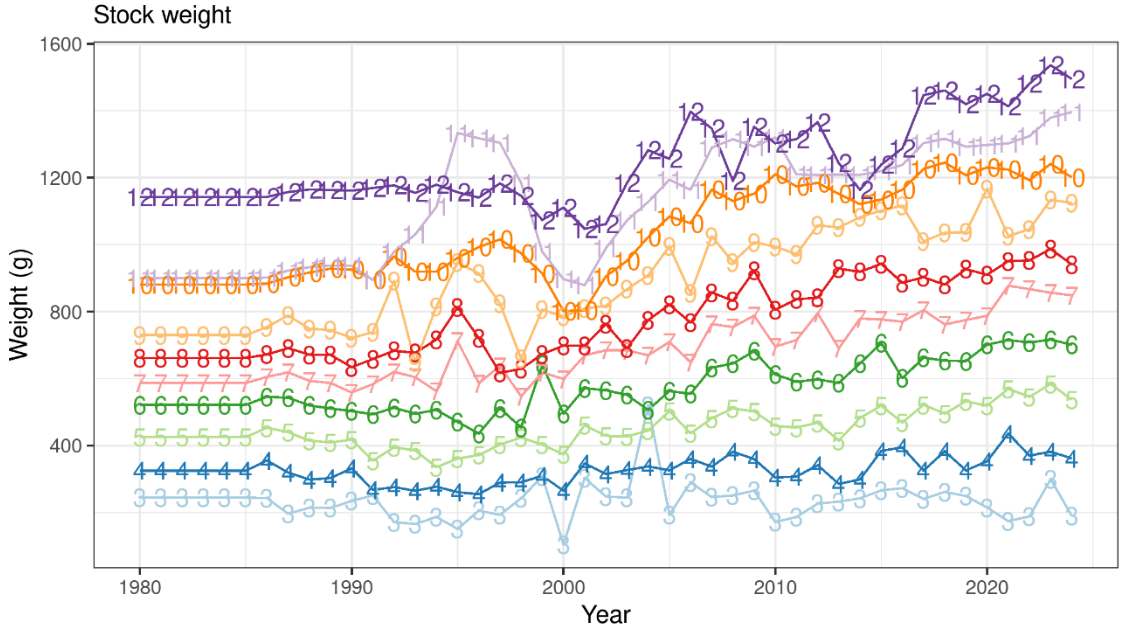

Figure 24.16. Plaice in 5a. Weight at age observed in the spring survey.

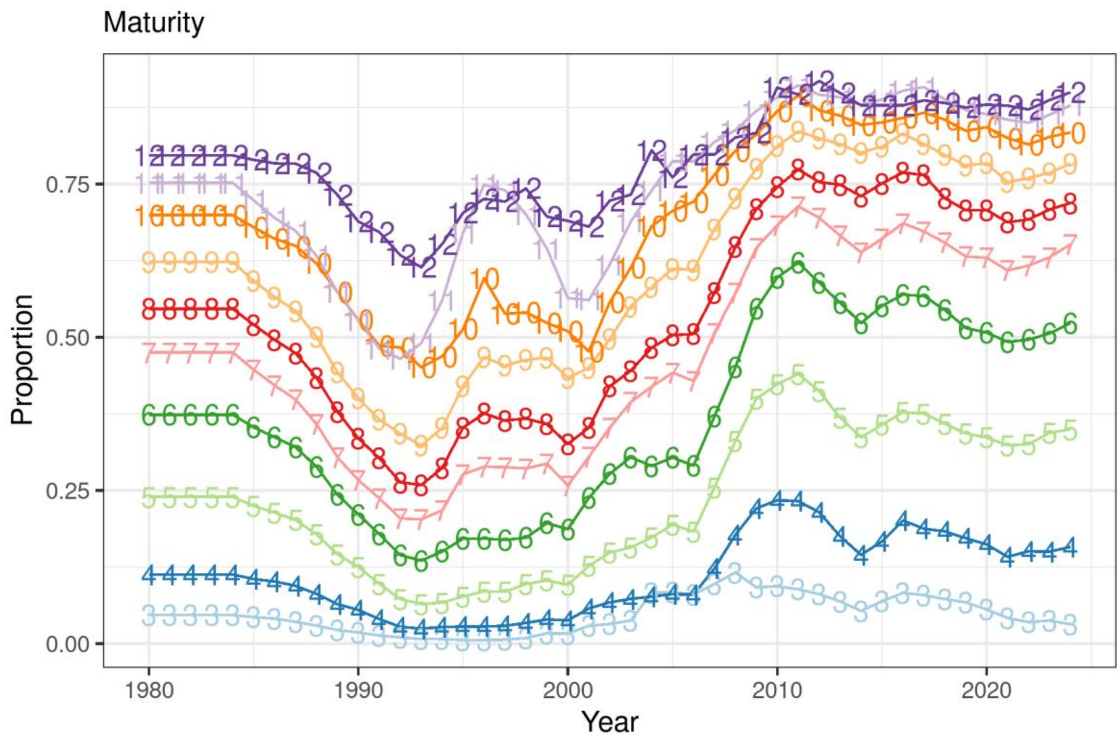

Figure 24.17. Plaice in 5a. Maturity-at-age observed in the spring survey.

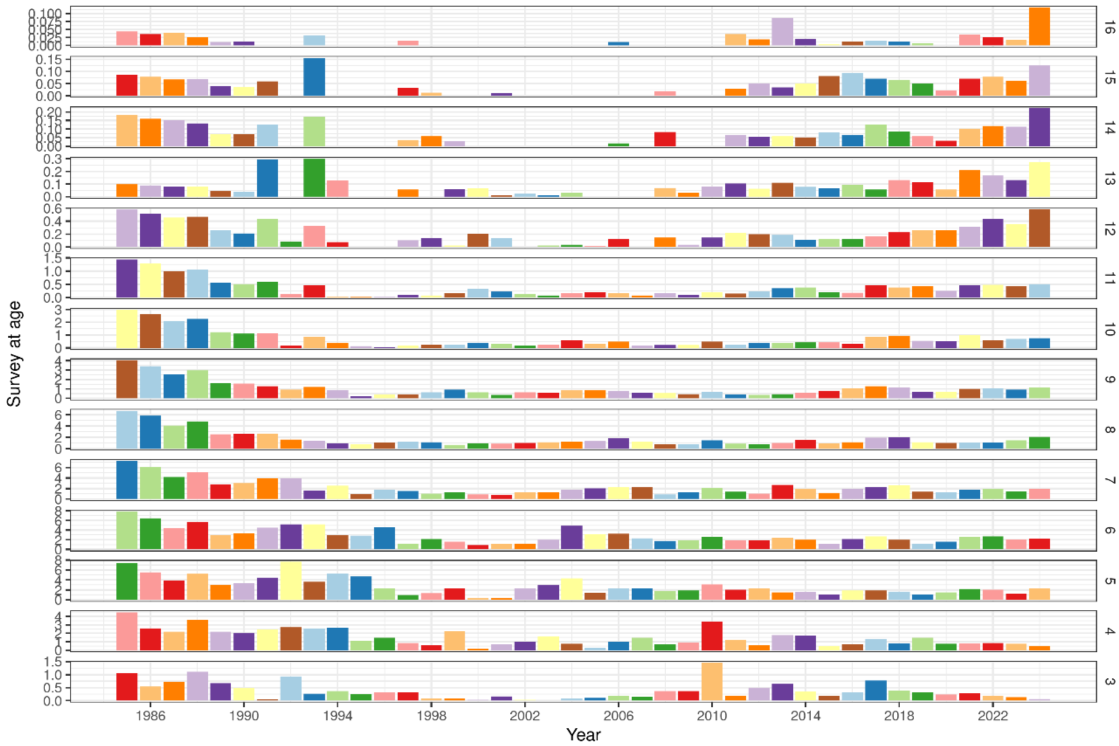

Figure 24.18. Plaice in 5a. Age disaggregated indices in the spring survey, colored by cohorts.

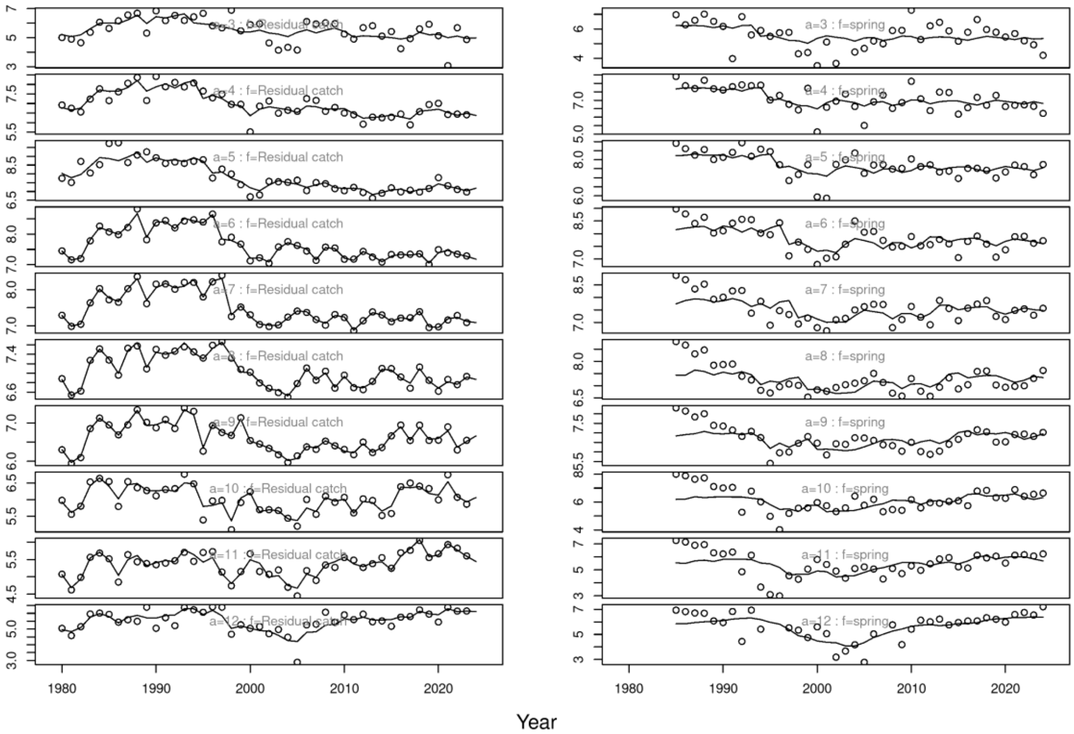

Figure 24.19. Plaice in 5a. Illustration of the model fit to the commercial catch (left) and survey data (right) by age. Points indicate the log observations while the solid line the model fit.

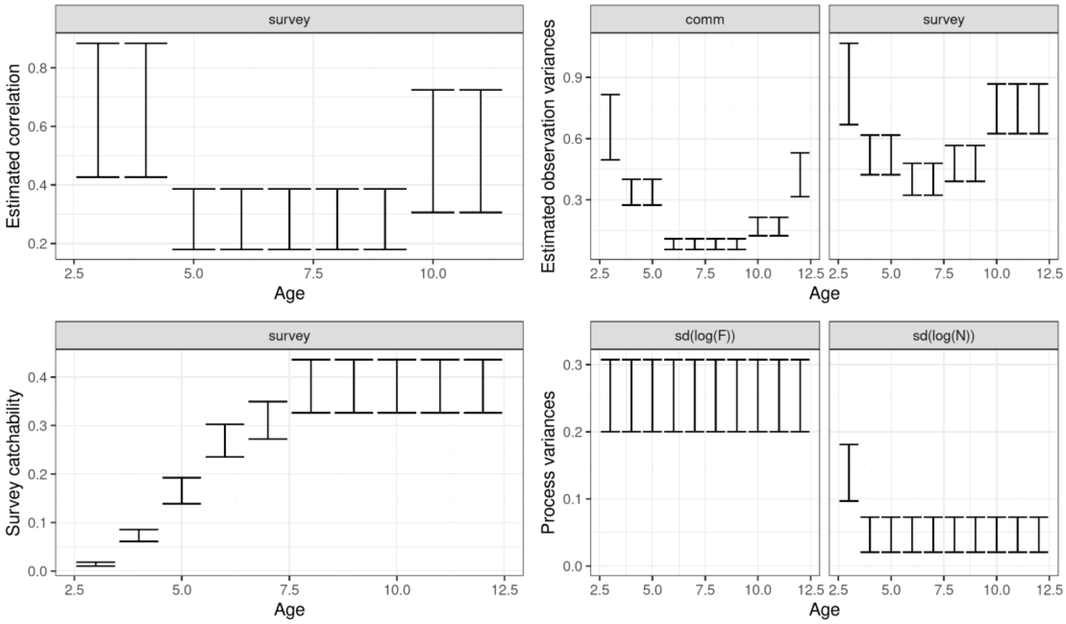

Figure 24.20. Plaice in 5a. Illustration of estimated model parameters.

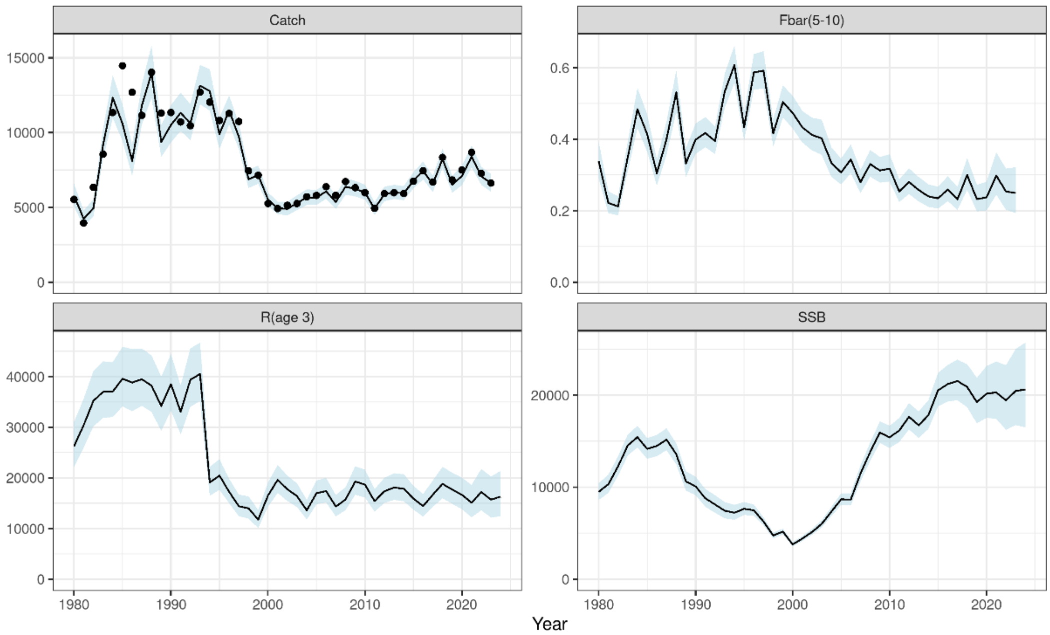

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Figure 24.21. Plaice in 5a. Estimates of spawning-stock biomass, fishing mortality (weighted average of ages 5 to 10), recruitment and landings from the best model.

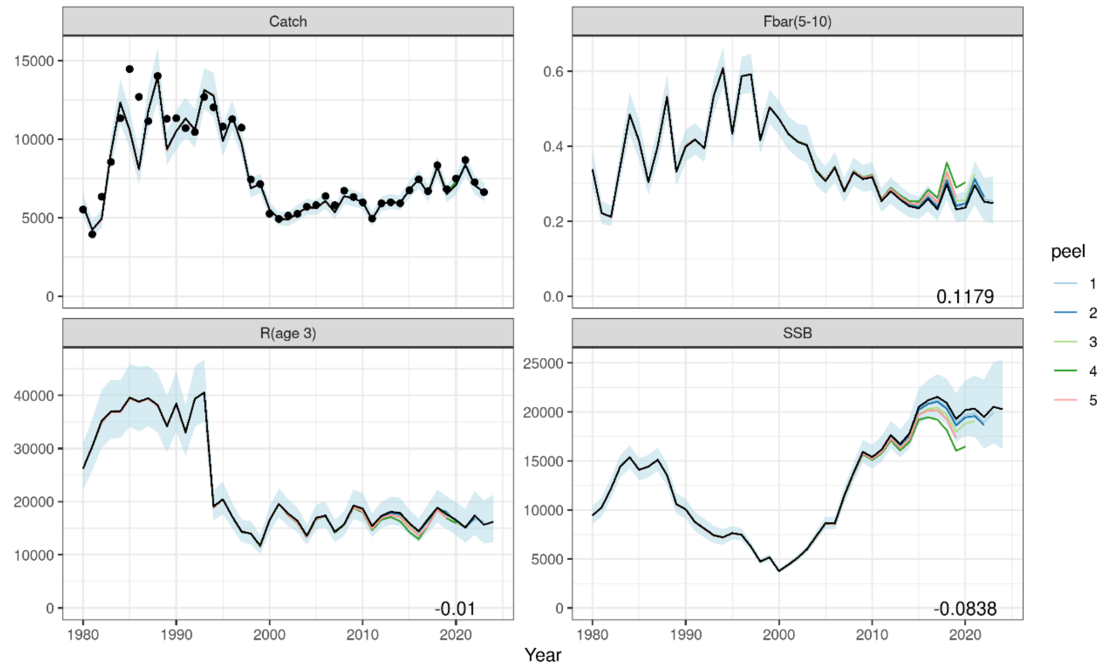


Figure 24.22. Plaice in 5a. Analytical retrospective estimates of SSB, catch, F and recruitment. Mohn's rho is indicated in the bottom right corner.

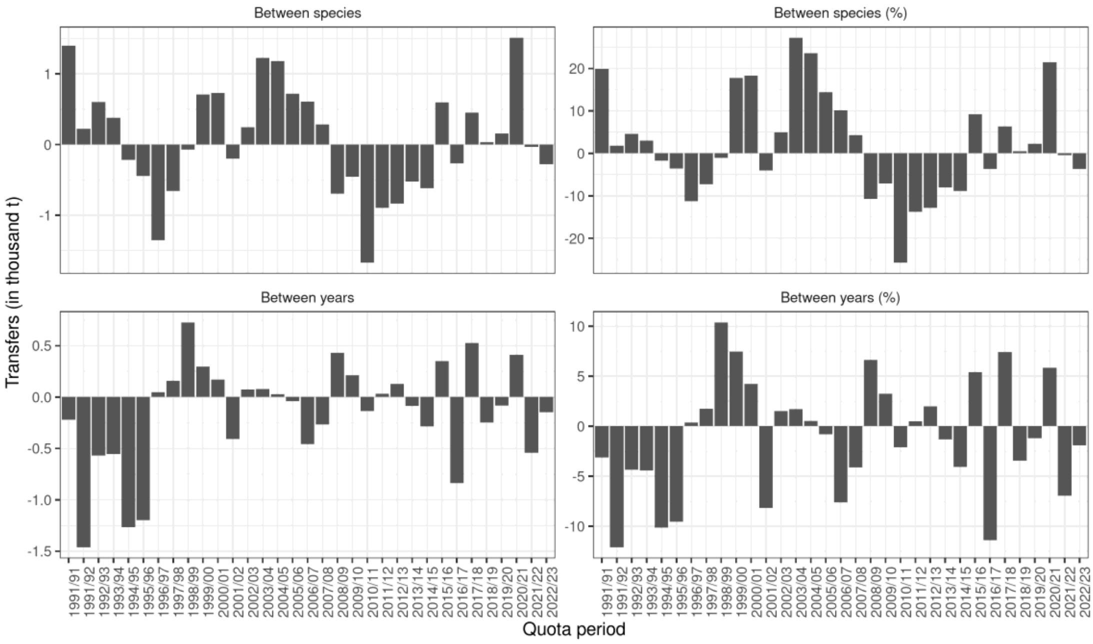


Figure 24.23. Plaice in 5a. An overview of the net transfers of quota between years and species transformations in the fishery in 5a.

24.8 Input data

24.8.1 Survey at age

year	3	4	5	6	7	8	9	10	11	12
1985	1.068	4.484	7.367	7.873	7.216	6.719	4.047	2.972	1.437	0.579
1986	0.537	2.595	5.490	6.499	6.059	5.827	3.437	2.653	1.280	0.515
1987	0.732	2.189	3.846	4.460	4.180	4.062	2.524	2.076	0.998	0.453
1988	1.113	3.584	5.225	5.695	5.075	4.770	2.981	2.276	1.048	0.464
1989	0.677	2.166	3.013	3.058	2.764	2.543	1.623	1.230	0.558	0.255
1990	0.482	2.016	3.401	3.337	3.010	2.618	1.564	1.109	0.511	0.211
1991	0.053	2.458	4.471	4.507	3.875	2.672	1.271	1.155	0.591	0.440
1992	0.935	2.735	7.620	5.248	3.935	1.617	0.914	0.194	0.128	0.085
1993	0.269	2.598	3.596	5.179	1.588	1.387	1.185	0.880	0.462	0.327
1994	0.365	2.684	5.332	3.049	2.552	0.907	0.857	0.411	0.040	0.079
1995	0.244	1.115	4.694	2.861	0.979	0.812	0.222	0.145	0.022	0.000
1996	0.313	1.462	2.249	4.580	1.754	1.051	0.387	0.056	0.020	0.000
1997	0.320	0.865	0.937	1.243	1.505	1.175	0.402	0.178	0.095	0.107
1998	0.074	0.620	1.313	2.136	1.032	1.111	0.635	0.260	0.072	0.136
1999	0.081	2.235	2.265	1.604	1.306	0.686	0.900	0.266	0.159	0.024
2000	0.033	0.169	0.378	0.883	0.888	0.922	0.641	0.389	0.332	0.205
2001	0.166	0.724	0.353	1.131	0.785	0.874	0.346	0.310	0.226	0.134
2002	0.038	1.041	2.295	1.198	1.217	1.017	0.620	0.203	0.135	0.000
2003	0.000	1.589	2.961	1.962	1.289	1.139	0.601	0.265	0.079	0.026
2004	0.084	0.759	4.314	4.925	1.805	1.213	0.849	0.616	0.164	0.033
2005	0.107	0.247	1.395	3.154	2.060	1.342	0.838	0.321	0.187	0.016
2006	0.178	1.004	2.223	3.257	2.266	1.815	0.739	0.489	0.159	0.126
2007	0.147	1.487	2.272	2.283	2.247	1.250	0.589	0.202	0.074	0.000
2008	0.363	0.679	1.771	1.754	0.892	0.806	0.562	0.235	0.166	0.147
2009	0.367	0.958	1.845	1.808	1.227	0.714	0.421	0.223	0.112	0.035
2010	1.457	3.376	3.103	2.661	2.078	1.470	0.666	0.478	0.203	0.145
2011	0.196	1.197	2.036	1.852	1.350	0.872	0.412	0.266	0.144	0.222

year	3	4	5	6	7	8	9	10	11	12
2012	0.500	0.595	2.243	1.933	0.997	0.710	0.357	0.386	0.238	0.199
2013	0.636	1.776	1.510	2.371	2.644	1.029	0.421	0.371	0.344	0.186
2014	0.355	1.737	1.584	1.991	1.915	1.512	0.604	0.420	0.384	0.114
2015	0.175	0.483	1.056	1.157	1.179	0.961	0.782	0.443	0.188	0.122
2016	0.323	0.706	1.845	2.189	1.942	1.139	1.056	0.310	0.171	0.122
2017	0.767	1.300	1.850	2.703	2.280	1.968	1.288	0.888	0.460	0.165
2018	0.389	0.819	1.652	1.980	2.631	2.009	1.154	0.932	0.374	0.226
2019	0.323	1.467	1.082	1.179	1.396	1.127	0.677	0.553	0.428	0.266
2020	0.233	0.760	1.511	1.574	1.229	1.026	0.686	0.528	0.252	0.265
2021	0.295	0.818	2.211	2.644	1.779	1.067	1.008	0.983	0.462	0.308
2022	0.179	0.837	2.038	2.687	1.888	1.092	1.032	0.609	0.481	0.429
2023	0.137	0.769	1.298	2.044	1.463	1.480	0.913	0.703	0.435	0.355
2024	0.067	0.506	2.289	2.253	1.932	2.052	1.124	0.767	0.512	0.585

24.8.2 Catch-at-age

year	3	4	5	6	7	8	9	10	11	12
1980	149.651	1012.992	2316.221	1723.328	1464.051	977.249	544.455	395.247	160.157	104.056
1981	133.574	856.559	1830.845	1288.402	1075.461	691.460	381.419	259.333	101.776	64.666
1982	104.644	704.047	6064.394	1340.353	1140.952	751.625	442.983	331.136	145.936	83.324
1983	214.889	1381.932	3142.708	2395.701	2068.615	1441.409	945.766	688.331	260.890	190.874
1984	429.662	2366.978	5036.678	3860.475	3064.618	1835.405	1244.656	765.795	294.200	184.961
1985	280.757	1275.173	16909.398	3201.505	2249.911	1449.143	1040.416	697.825	249.527	156.252
1986	472.323	2019.768	17557.517	2924.465	2101.065	1052.979	803.247	328.155	127.546	59.381
1987	707.396	3170.527	5680.789	3697.968	3055.403	1860.088	1042.375	694.608	281.004	170.285
1988	797.433	4296.351	8758.607	6742.540	4270.193	1952.205	1544.999	577.272	228.691	103.806
1989	203.167	1284.952	10474.443	2471.736	2019.663	1202.564	1116.311	529.624	217.591	135.802
1990	937.845	4531.179	7485.753	4289.676	3476.620	1818.354	967.021	452.549	210.255	95.268
1991	480.459	2644.625	5421.288	4626.631	3484.862	1604.973	1195.831	549.203	220.667	73.815
1992	686.790	3314.425	5842.937	3653.003	3015.036	1749.640	948.028	562.272	236.017	137.110

year	3	4	5	6	7	8	9	10	11	12
1993	486.097	2622.337	5431.957	4564.765	3642.233	1915.716	1624.004	869.157	300.639	149.393
1994	622.084	3224.822	6104.090	4752.711	3636.942	1721.288	1486.682	649.739	231.669	91.655
1995	790.278	2108.143	6695.912	4412.016	2428.724	1511.548	525.263	218.271	299.431	92.110
1996	334.811	1479.961	2359.080	5733.048	3701.003	1981.788	1025.426	388.238	307.378	252.455
1997	290.623	1799.233	3913.331	2313.836	4426.466	2139.275	854.744	394.070	170.071	191.289
1998	984.376	1051.650	2959.209	2691.300	1414.245	1508.134	793.363	163.025	114.627	39.957
1999	238.068	1051.701	1609.220	2149.315	1839.988	1188.519	1256.992	369.402	172.662	82.314
2000	363.484	247.307	808.537	1245.538	1482.725	1120.700	692.759	512.651	288.368	94.258
2001	384.497	955.002	897.363	1377.886	1132.262	892.687	632.790	296.911	172.762	134.905
2002	103.157	1249.843	1946.618	1152.989	1070.166	798.429	563.118	297.541	159.424	77.361
2003	62.684	660.635	1902.250	1957.764	1120.215	727.581	478.178	290.376	180.577	79.591
2004	76.169	769.270	1847.295	2331.344	1390.034	662.170	390.319	229.932	109.789	62.321
2005	63.368	727.086	2079.065	2054.237	1643.061	881.286	463.903	180.944	85.493	12.937
2006	450.213	1416.547	1147.145	1717.482	1582.723	1222.064	586.854	405.189	177.558	95.208
2007	381.665	1289.972	1819.083	1264.223	1301.014	946.813	549.562	259.030	133.716	82.924
2008	411.397	729.110	1704.594	1948.922	1113.918	1144.415	681.038	446.196	208.638	177.453
2009	388.550	893.124	1282.121	1893.878	1493.537	800.442	603.202	372.317	194.603	133.340
2010	190.911	664.825	1143.335	1314.568	1374.999	1051.678	548.502	431.602	259.095	145.968
2011	134.694	608.730	1383.611	1317.939	952.442	807.546	478.117	269.745	240.283	112.849
2012	294.596	371.183	1030.073	1696.094	1258.349	775.669	665.275	413.083	194.379	171.816
2013	335.426	538.641	746.033	1408.124	1606.161	923.147	505.764	393.805	216.711	116.493
2014	165.134	520.346	990.426	1194.753	1477.128	1214.309	577.453	249.800	258.118	136.150
2015	225.359	534.656	1345.554	1535.088	1223.771	1209.478	782.999	265.200	189.746	89.520
2016	69.402	630.267	1067.243	1509.588	1353.263	1012.661	1037.960	596.449	297.150	140.469
2017	138.830	358.149	1173.948	1545.151	1366.431	798.914	692.751	666.712	318.864	172.230
2018	270.777	716.650	1058.978	1564.904	1617.526	1248.785	1033.725	605.572	422.851	286.577
2019	372.947	1039.269	1297.808	1105.900	1042.619	943.283	693.715	563.467	258.721	222.317
2020	169.758	1106.263	2406.177	1797.119	1061.200	748.762	699.383	400.265	289.013	135.297
2021	21.621	614.808	1522.455	1625.426	1283.928	961.912	988.335	855.284	376.181	336.291

year	3	4	5	6	7	8	9	10	11	12
2022	293.275	629.213	1225.714	1550.798	1454.956	861.111	541.538	432.911	338.603	262.494
2023	130.104	608.046	1058.697	1463.101	1195.417	1024.779	696.202	351.781	270.879	223.346

24.8.3 Catch weights

year	3	4	5	6	7	8	9	10	11	12
1980	423	463	527	590	615	703	775	1026	948	1044
1981	410	448	505	562	584	675	750	1022	924	1067
1982	415	465	460	597	626	710	796	1096	1120	1058
1983	408	452	527	600	633	750	893	1067	1001	1138
1984	367	424	488	550	591	692	790	992	926	1094
1985	353	457	431	540	632	737	825	1018	979	1095
1986	332	392	421	493	533	602	702	799	762	1031
1987	340	396	467	535	560	664	723	1023	950	1059
1988	321	388	440	487	516	571	565	731	693	853
1989	388	436	447	538	619	710	920	916	1039	1286
1990	358	393	428	468	482	547	584	876	819	992
1991	357	408	463	523	554	605	653	784	706	842
1992	357	402	458	519	540	632	670	949	844	1009
1993	351	402	466	539	600	698	798	904	833	1078
1994	349	394	443	502	549	623	748	830	785	1113
1995	359	409	451	518	664	774	926	886	1098	944
1996	342	420	502	572	642	769	888	879	919	1081
1997	390	457	512	582	652	722	860	942	997	1055
1998	347	423	543	603	730	815	874	1088	1134	1299
1999	393	483	531	641	705	775	928	1108	1220	1312
2000	312	388	542	649	782	867	888	991	1118	1305
2001	327	456	539	672	754	869	928	1015	1168	1287
2002	372	453	546	657	741	874	952	1080	1273	1488
2003	354	438	520	634	768	855	954	1021	1282	1477

year	3	4	5	6	7	8	9	10	11	12
2004	355	456	588	674	792	928	1012	1178	1377	1487
2005	337	448	566	708	776	876	998	1078	1155	1041
2006	410	496	586	673	794	859	913	938	995	1194
2007	381	464	577	677	784	904	980	1132	1140	1152
2008	389	487	576	687	796	903	1016	1073	1088	1178
2009	394	491	589	679	792	943	1145	1255	1354	1241
2010	424	484	575	672	789	950	1033	1204	1341	1360
2011	430	485	576	679	787	888	1008	1076	1128	1355
2012	434	535	605	711	833	948	1073	1152	1228	1334
2013	446	547	622	717	866	1002	1162	1236	1410	1503
2014	412	477	626	724	852	1006	1101	1053	1348	1469
2015	536	512	642	791	880	1060	1242	1362	1504	1592
2016	469	508	643	742	912	1054	1141	1397	1439	1601
2017	452	542	646	729	811	975	1139	1252	1449	1632
2018	456	545	650	759	857	955	1133	1312	1363	1538
2019	414	557	625	781	861	1054	1156	1273	1443	1517
2020	457	570	648	757	855	984	1155	1330	1578	1758
2021	465	514	650	761	917	1020	1222	1399	1503	1616
2022	437	557	646	818	893	1039	1199	1305	1510	1476
2023	421	528	632	729	846	1015	1125	1299	1549	1542

24.8.4 Stock weights

year	3	4	5	6	7	8	9	10	11	12
1980	245	325	425	522	587	662	729	881	900	1142
1981	245	325	425	522	587	662	729	881	900	1142
1982	245	325	425	522	587	662	729	881	900	1142
1983	245	325	425	522	587	662	729	881	900	1142
1984	245	325	425	522	587	662	729	881	900	1142
1985	245	325	425	522	587	662	729	881	900	1142

year	3	4	5	6	7	8	9	10	11	12
1986	243	355	453	545	605	672	754	884	902	1143
1987	196	319	440	543	619	691	789	903	923	1157
1988	214	298	415	520	593	672	749	917	932	1165
1989	213	303	409	510	587	671	745	928	938	1163
1990	234	332	417	503	558	634	721	925	937	1161
1991	251	267	355	493	584	658	739	896	894	1169
1992	171	276	395	513	620	683	892	965	979	1177
1993	166	265	385	495	604	677	648	919	1031	1155
1994	187	277	335	506	562	716	815	920	1113	1179
1995	151	261	361	471	712	812	947	960	1333	1156
1996	206	255	372	436	586	721	914	993	1318	1141
1997	193	289	403	511	638	617	824	1016	1304	1183
1998	243	290	424	454	547	629	659	974	1184	1146
1999	308	310	403	641	618	673	806	913	979	1074
2000	105	265	373	495	599	699	785	801	897	1111
2001	303	347	461	571	669	699	809	804	879	1047
2002	248	315	429	565	685	763	818	905	989	1061
2003	245	327	427	551	685	690	867	952	1072	1184
2004	519	338	444	506	669	775	909	1023	1128	1282
2005	193	326	503	563	709	821	995	1085	1194	1256
2006	290	360	436	554	649	767	854	1064	1164	1397
2007	246	337	481	633	763	857	1025	1164	1290	1346
2008	251	381	511	645	754	832	948	1130	1315	1190
2009	265	359	502	682	788	922	1007	1153	1293	1352
2010	172	305	458	612	695	805	994	1210	1320	1303
2011	187	307	454	591	715	837	972	1174	1210	1315
2012	227	341	468	597	795	842	1058	1185	1208	1366
2013	232	285	415	587	690	928	1051	1151	1209	1243
2014	242	299	482	645	780	919	1082	1121	1209	1163

year	3	4	5	6	7	8	9	10	11	12
2015	266	384	519	706	776	943	1102	1135	1220	1239
2016	273	395	469	601	770	886	1116	1164	1238	1288
2017	240	325	522	662	804	903	1010	1226	1303	1446
2018	261	383	495	654	762	880	1035	1245	1316	1461
2019	249	326	532	652	775	927	1037	1207	1292	1420
2020	215	353	519	701	787	910	1167	1230	1298	1450
2021	174	436	569	715	877	951	1026	1224	1303	1413
2022	188	370	545	708	867	953	1046	1193	1324	1481
2023	299	382	584	716	856	987	1134	1241	1379	1536
2024	190	361	537	701	849	941	1125	1201	1396	1495

24.8.5 Maturity

year	3	4	5	6	7	8	9	10	11	12
1980	0.047	0.113	0.240	0.374	0.475	0.546	0.623	0.699	0.752	0.797
1981	0.047	0.113	0.240	0.374	0.475	0.546	0.623	0.699	0.752	0.797
1982	0.047	0.113	0.240	0.374	0.475	0.546	0.623	0.699	0.752	0.797
1983	0.047	0.113	0.240	0.374	0.475	0.546	0.623	0.699	0.752	0.797
1984	0.047	0.113	0.240	0.374	0.475	0.546	0.623	0.699	0.752	0.797
1985	0.043	0.105	0.224	0.353	0.447	0.520	0.592	0.680	0.723	0.790
1986	0.041	0.101	0.214	0.337	0.422	0.496	0.566	0.661	0.695	0.784
1987	0.035	0.094	0.202	0.321	0.398	0.474	0.543	0.649	0.674	0.783
1988	0.029	0.081	0.178	0.289	0.358	0.434	0.501	0.620	0.633	0.768
1989	0.022	0.064	0.146	0.243	0.304	0.378	0.442	0.574	0.574	0.732
1990	0.018	0.055	0.125	0.210	0.267	0.335	0.400	0.528	0.527	0.689
1991	0.013	0.040	0.097	0.178	0.237	0.303	0.365	0.486	0.481	0.672
1992	0.010	0.027	0.073	0.144	0.204	0.263	0.343	0.483	0.465	0.634
1993	0.007	0.024	0.065	0.135	0.203	0.259	0.323	0.451	0.490	0.614
1994	0.007	0.027	0.067	0.150	0.218	0.286	0.352	0.468	0.560	0.652
1995	0.006	0.028	0.077	0.171	0.277	0.352	0.421	0.513	0.671	0.703

year	3	4	5	6	7	8	9	10	11	12
1996	0.006	0.028	0.085	0.171	0.289	0.376	0.467	0.596	0.749	0.726
1997	0.006	0.029	0.085	0.169	0.288	0.364	0.454	0.538	0.740	0.721
1998	0.009	0.034	0.097	0.173	0.286	0.367	0.463	0.540	0.701	0.743
1999	0.017	0.039	0.103	0.196	0.294	0.358	0.466	0.523	0.645	0.697
2000	0.016	0.038	0.096	0.187	0.258	0.326	0.434	0.510	0.564	0.690
2001	0.029	0.057	0.127	0.238	0.304	0.352	0.450	0.477	0.561	0.680
2002	0.032	0.067	0.149	0.277	0.353	0.420	0.497	0.557	0.618	0.723
2003	0.038	0.073	0.157	0.304	0.394	0.445	0.550	0.613	0.689	0.733
2004	0.083	0.077	0.173	0.290	0.419	0.483	0.582	0.681	0.740	0.805
2005	0.084	0.081	0.194	0.304	0.442	0.503	0.612	0.706	0.787	0.761
2006	0.080	0.080	0.183	0.290	0.429	0.505	0.610	0.721	0.787	0.798
2007	0.097	0.123	0.255	0.371	0.507	0.573	0.677	0.765	0.819	0.798
2008	0.116	0.177	0.330	0.451	0.573	0.647	0.726	0.804	0.838	0.826
2009	0.092	0.221	0.399	0.547	0.646	0.710	0.775	0.831	0.869	0.834
2010	0.094	0.234	0.423	0.598	0.683	0.745	0.812	0.869	0.892	0.908
2011	0.089	0.233	0.440	0.622	0.714	0.774	0.836	0.895	0.911	0.896
2012	0.081	0.214	0.412	0.589	0.695	0.753	0.825	0.870	0.896	0.918
2013	0.069	0.175	0.368	0.556	0.666	0.749	0.815	0.862	0.891	0.899
2014	0.053	0.145	0.337	0.523	0.638	0.730	0.801	0.846	0.879	0.879
2015	0.069	0.167	0.357	0.551	0.661	0.751	0.811	0.851	0.888	0.879
2016	0.083	0.201	0.378	0.569	0.686	0.769	0.832	0.858	0.902	0.879
2017	0.079	0.187	0.375	0.567	0.673	0.764	0.815	0.866	0.908	0.887
2018	0.072	0.183	0.359	0.544	0.654	0.727	0.797	0.855	0.888	0.882
2019	0.067	0.172	0.343	0.515	0.632	0.707	0.781	0.837	0.871	0.875
2020	0.056	0.162	0.336	0.507	0.630	0.708	0.784	0.843	0.864	0.880
2021	0.042	0.142	0.323	0.493	0.609	0.688	0.753	0.825	0.855	0.878
2022	0.035	0.150	0.326	0.496	0.617	0.692	0.760	0.815	0.850	0.872
2023	0.037	0.150	0.344	0.506	0.630	0.708	0.768	0.827	0.863	0.887
2024	0.031	0.158	0.350	0.523	0.652	0.719	0.784	0.834	0.879	0.900

24.8.6 Landings

Year	Landings
1980	5530
1981	3951
1982	6340
1983	8553
1984	11342
1985	14473
1986	12705
1987	11157
1988	14032
1989	11307
1990	11343
1991	10713
1992	10464
1993	12702
1994	12040
1995	10813
1996	11281
1997	10743
1998	7443
1999	7145
2000	5259
2001	4925
2002	5143
2003	5258
2004	5707
2005	5802
2006	6382
2007	5810

Year	Landings
2008	6725
2009	6323
2010	5984
2011	4943
2012	5927
2013	5988
2014	5927
2015	6754
2016	7451
2017	6694
2018	8341
2019	6835
2020	7506
2021	8677
2022	7276
2023	6631

Annex 1: List of participants

Northwestern Working Group 22–26 April 2024

Name	Institute	Country	E-mail
Anja Retzel	Greenland Institute for Natural Resources	Greenland	AnRe@natur.gl
Birkir Bardarson	Marine and Freshwater Research Institute	Iceland	birkir.bardarson@hafogvatn.is
Bjarki Thor Elvarsson	Marine and Freshwater Research Institute	Iceland	bjarki.elvarsson@hafogvatn.is
Einar Hjörleifsson	Marine and Freshwater Research Institute	Iceland	einar.hjorleifsson@hafogvatn.is
Pamela J. Woods	Marine and Freshwater Research Institute	Iceland	pamela.woods@hafogvatn.is
Frank Farsø Riget	Greenland Institute for Natural Resources	Greenland	frri@natur.gl
Helga Bára Mohr Vang (co-chair)	Faroe Marine Research Institute	Faroe Islands	helgab@hav.fo
Höskuldur Björnsson	Marine and Freshwater Research Institute	Iceland	hoskuldur.bjornsson@hafogvatn.is
Jesper Boje	The National Institute of Aquatic Resources Sec- tion for Fisheries Advice	Denmark	jbo@aqua.dtu.dk
Adriana Nogueira	Greenland Institute for Natural Resources	Greenland	adno@natur.gl
Henrik Christiansen	Greenland Institute for Natural Resources	Greenland	hech@natur.gl
Karl-Michael Werner	Johann Heinrich von Thünen Institute, Institute for Sea Fisheries	Germany	karl-michael.werner@thuenen.de
Karolin Adorf	Johann Heinrich von Thünen-Institute, Institute for Sea Fisheries	Germany	kadorf@uni-bremen.de
Kristján Kristinsson	Marine and Freshwater Research Institute	Iceland	kristjan.kristinsson@hafogvatn.is
Sigurvin Bjarnason	Marine and Freshwater Research Institute	Iceland	sigurvin.bjarnason@hafogvatn.is
Petur Steingrund	Faroe Marine Research Institute	Faroe Islands	peturs@hav.fo
Neil Campbell	ICES Secretariat	Denmark	neil.campbell@ices.dk
Tanja B Buch	Greenland Institute for Natural Resources	Greenland	tabb@natur.gl
Teunis Jansen (Co-Chair)	Greenland Institute for Natural Resources and DTU AQUA	Greenland	tej@aqua.dtu.dk

Annex 2: NWWG – Northwestern Working Group

Approved in Resolutions meeting on 31 October 2023

2023/AT/FRSG05 The **Northwestern Working Group** (NWWG), chaired by Helga Bára Mohr Vang*, Faroe Islands, and Teunis Jansen, Denmark, will meet in ICES HQ, 22–26 April 2024 to:

a) Address generic ToRs for Regional and Species Working Groups for all stocks except those listed in ToRs b);

and online in October/November 2024 (*dates to be decided in April 2024*) to:

b) Address generic ToRs for Regional and Species Working Groups, for Cod (*Gadus morhua*) in Subdivision 5.b.1 (Faroe Plateau), Cod in Subdivision 5.b.2 (Faroe Bank,) Haddock (*Melanogrammus aeglefinus*) in Division 5.b (Faroes grounds) and Saithe (*Pollachius virens*) in Division 5.b (Faroes grounds).

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant to the meeting must be available to the group on the dates specified in the 2024 ICES data call.

NWWG will report by 15 May and 10 November 2024 for the attention of ACOM.

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

Annex 3: Working documents

WD #	WD Title	Authors
01	WD01_HER_5a_acoustic_NWWG2024	Sigurvin Bjarnason
02	WD02_GHL_new_ref_points	Bjarki Þór Elvarsson
03	WD03_Greenland Cod commercial data 2023	Anja Retzel
04	WD04_Greenland cod Sensitivity of 2023 assessment with new genetic data	Tanja Buch, Anja Retzel, Teunis Jansen, Søren Post
05	WD05_Greenland cod Genetic data used in 2024 assessment	Tanja Buch, Anja Retzel
06	WD06_SAM assessment and EqSim for the West Greenland inshore stock N_WISC	Tanja Buch, Teunis Jansen, Anders Nielsen, Anja Retzel, Søren Post
07	WD07_SAM assessment and EqSim for the West Greenland inshore stock S-WISC	Tanja Buch, Teunis Jansen, Anders Nielsen, Anja Retzel, Søren Post
08	WD08_SAM assessment and EqSim for the West Greenland offshore stock WOSC	Tanja Buch, Teunis Jansen, Anders Nielsen, Anja Retzel, Søren Post
09	WD09_West Greenland Inshore north south spawning populations	Anja Retzel, Einar Eg Nielsen
10	WD10_Sloperedfish_refpoints	William E. Butler, Bjarki Þ. Elvarsson, and Kristján Kristinsson
11	WD11_Redfish_14b_survey_NWWG-2024	Henrik Christiansen
12	WD12_Redfish_14b_fisheries_NWWG-2024	Henrik Christiansen
13	WD13_ Greenland_GHL_survey_NWWG-2024	Henrik Christiansen, Adriana Nogueira, Jesper Boje

ICES Northwestern Working Group, 22 - 26 April 2024, Working Document No. 01

Results of acoustic measurements of Icelandic summer-spawning herring (ISSH) in the winter 2023/2024

Sigurvin Bjarnason (sigurvin.bjarnason@hafogvatn.is)
Marine and Freshwater Research Institute, Fornubúðir 5, 220, Hafnafjordur, Iceland

Table of Content:

Prologue

This is a compilation of results of three surveys in the winter 2023/24 (Table 1) that had the main objective to measure the stock size of Icelandic summer-spawning herring acoustically and estimate the prevalence of *Ichthyophonus* infection in the stock. The survey design and performance were different from recent years. Usually, a dedicated autumn survey (B11-2023) targets the fishable stock in the east and juveniles located south of Iceland, but this year no acoustic measurements were successful in the east and are therefore lacking. The reasons for this lack is related to ISSH and Norwegian spring spawning herring (NSSH) mixing in the east of Iceland, and it is assumed that the ISSH component accompanied the NSSH migrating east, at least to some extent. Further details about the surveys can be found in the survey reports attached as Annex 1, but only the most relevant results from the surveys are introduced here and their results combined. Most recent results on the estimates of prevalence of *Ichthyophonus* infection can be found in Óskarsson (2019).

Results of the acoustic measurements and discussion

The fishable stock

The acoustic index for adult part of the Icelandic summer-spawning herring in the winter 2023/2024 derives from one dedicated survey on RV Bjarni Sæmundsson in the end of March 2024 (B4-2024) and from a capelin survey (AH3-2024 and AMM3-2024) in the south-east of Iceland in February 2024 (Fig. 1; Table 1 and Table 2). The main herring area west of Iceland was surveyed in the first survey, while the limited areas south of Iceland in the latter one. The areas east of Iceland were however surveyed in a dedicated survey but no herring was found. Thus, the final acoustic abundance index includes the areas in the and south from the February survey and in the west from the March survey.

The total acoustic estimate of Icelandic summer-spawning herring this winter, according to these three surveys came to 2.5 billion in numbers and the total biomass index was 432 kt (Table 3 and Table 4). The fishable part of the stock (≥27 cm) accounted for 60% in number and 88% of the biomass, or 380 kt. When only considering age 3+, the three most numerous year classes were those from 2019 (17,9%), 2018 (18,8%) and 2017 (16.5% Table 4).

The biomass estimates from the surveys were based on mean weights from samples collected at each survey area and period. The mean weights for the herring sampled southeast of Iceland in February (AH3-2024 and AMM3-2024) were smaller than the herring sampled in the west in March (B3-2023) and both were lighter than the catch samples (Fig. 2). Also, two age-at-length keys were applied, as they provided different results as presented by the mean length-at-age (Fig. 2). The mean length-at-age from the catch samples was slightly lower, which might be partly explained by earlier sampling (July-December).

After a large upward revision last year, the total abundance index decreases significantly this year (Fig. 3) This is mainly due to an increasing part of the stock found in the east compared to west and the unsuccessful autumn survey to measure this stock component. Recent recruitment to the fishable stock has been good but ongoing *Ichthyophonus* infection still causes mortality. When the abundance indices for the different year classes in the most recent five years are followed (Figure 4) the indices from 2023/24 show a missing stock component that we know from the catch samples, were in the east. It is also clear that the 2017–2019-year classes are dominating the recent surveys.

When the age composition from the acoustic surveys in 2023/2024 is compared to the catch composition in the main distribution area of the stock in the west in same winter, there are some differences (Fig. 5). Generally, there was more of younger fish in the survey, especially for age 1-3. This is to be expected as the fisheries target the larger herring, however age 3 in catches is higher than the survey in the west indicating that a large 2020-year class could emerge. Catches in the east show a similar trend to the catches in the west. Number at age 6 (2017-year class) in the spring survey was much higher in the acoustic than in the catches in 2023, which makes the biggest discrepancy between the catches and the acoustic. What could be the reason for these discrepancies mentioned above? All of these are probably mainly related to (a) the uneven (unknown) uncertainty in the annual survey indices, (b) bias in the sampling in the surveys and catches, and/or (c) distribution of the stock (e.g. catch composition in the autumn vs. acoustic measurements). Despite efforts in the surveys and catch samplings every year to minimize these unwanted impacts, they exist and are accepted.

The total survey coverage in the spring 2024 was generally good. However, as stated above, a large component of the fishable stock was not measured in the east during autumn. Anyhow, considering the different factors affecting quality of survey abundance indices, such as weather condition, horizontal and vertical distribution of the stock, number and size of schools, density of survey tracks, and coverage of survey, the measurements in March west of Iceland, and in February southeast of Iceland can be considered of good quality. Thus, the combined survey index for 2023/24 is adequate for being used in analytical assessment for the stock.

Juveniles

The annual survey aiming for the abundance of herring juveniles in the fjords northwest and north of Iceland has not been conducted since 2018.

The juvenile survey was specially aimed for assessing the number-at-age 1, which has been shown to give a signal of year class strength later at age 3 (Gudmundsdottir et al. 2007). The herring juvenile surveys have been conducted in a comparable way since 1980, with several gaps in the time series. This survey gives valuable insight into juvenile herring and is recommended to be reinstated.

Calibration of the echosounders onboard RV Bjarni Sæmundsson took place prior to the fall survey in November 2023. The instrument changes since the previous calibration were insignificant but were accounted for in the results above.

References

Guðmundsdóttir, Á., G.J. Óskarsson, and S. Sveinbjörnsson 2007. Estimating year-class strength of Icelandic summer-spawning herring on the basis of two survey methods. ICES Journal of Marine Science, 64: 1182–1190.

Óskarsson, G.J. 2019. Estimation on number-at-age of the catch of Icelandic summer-spawning herring in 2018/2019 fishing season and the development of Ichthyophonus sp. infection in the stock. ICES North Western Working Group, 25 April – 1 May 2019, Working Document No. 05. 17 pp.

Tables

Table 1. Overview over acoustic surveys targeting Icelandic summer-spawning herring in the winter 2023/2024.

No.	Survey code	Period	Area	The target	Used in 2024 abundance indices
1	AMM3-2024 and AH3-2024	22 – 26 February 2024	South-east of Iceland	The fishable stock/juveniles	Yes
2	B4-2023	22-26 March 2024	West of Iceland (Kolluáll and Jökuldýpi)	The fishable stock	Yes

Table 2. The results of the acoustic surveys (No. refers to the survey number in Table 1) by areas in the autumn and winter 2023/2024 aimed at the fishable stock, which the compiled acoustic index is based on.

No.	Area	EA-value	Total area (nm²)	Size of rectangles in minutes (lat. × lon.)	Number of trawl hauls
1	Stokksnesgrunn og Lónsdýpi	426377	133	5 x 10	3*
2	Kolluáll (grunnt-A1)	43886	60,1	5 x 10	1
2	Snæfellsnes (grunnt-A2)	132494	94,9	5 x 10	1
2	Kolluáll (djúpt- A3)	756108	805	5 x 10	3
2	Jökuldýpi -A4	185877	216	5 x 10	1
	Total	154 474 2	1154		9

*samples used from other surveys (See Annex 1)

Table 3. Results of the acoustic measurements of Icelandic summer-spawning herring for the different areas and totally in the autumn and winter 2023/2024 by different length groups.

Survey	AMM3-2024 and AH3-2024		B4-2024			
Area	Southeast areas*		Kolluáll/Jökuldjúp		All areas combined	
Length (cm)	Numb. (10⁶)	Biomass (t)	Numb. (10⁶)	Biomass (t)	Numb. (10⁶)	Biomass (t)
10	4.1	22.9	0.0	0.0	4.1	22.9
11	23.3	180.6	0.0	0.0	23.3	180.6
12	61.7	626.0	0.0	0.0	61.7	626.0
13	63.1	827.7	0.0	0.0	63.1	827.7
14	43.9	733.8	0.0	0.0	43.9	733.8
15	96.0	2003.0	0.0	0.0	96.0	2003.0
16	102.8	2645.5	0.0	0.0	102.8	2645.5
17	54.8	1714.3	0.0	0.0	54.8	1714.3
18	31.5	1187.6	0.0	0.0	31.5	1187.6
19	21.9	989.3	0.0	0.0	21.9	989.3
20	42.5	2249.6	0.0	0.0	42.5	2249.6
21	97.8	6049.6	5.9	353.1	103.7	6402.7
22	131.8	9617.0	0.0	0.0	131.8	9617.0
23	71.2	5983.6	5.9	467.3	77.1	6450.9
24	17.0	1690.4	5.9	532.7	22.8	2223.1
25	41.9	4745.1	0.0	0.0	41.9	4745.1
26	64.9	8556.9	0.0	0.0	64.9	8556.9
27	75.0	11021.3	10.5	1518.9	85.6	12540.2
28	17.0	2807.2	4.7	642.9	21.7	3450.1
29	62.1	11273.6	40.6	6776.4	102.7	18050.0
30	63.5	13111.2	143.5	28204.5	207.0	41315.7
31	2.7	582.9	172.0	38301.9	174.7	38884.8
32	1.4	337.6	260.9	64038.3	262.3	64375.9
33	0.0	0.0	215.7	58509.6	215.7	58509.6
34	1.4	411.2	193.6	55669.2	195.0	56080.4
35	0.0	0.0	101.2	31450.4	101.2	31450.4
36	0.0	0.0	87.5	30197.8	87.5	30197.8
37	0.0	0.0	63.5	22971.3	63.5	22971.3
38	0.0	0.0	6.8	2676.6	6.8	2676.6
39	0.0	0.0	1.0	389.0	1.0	389.0
40	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1193.4**	**89368.0**	**1319.1**	**342699.9**	**2513**	**432068**
<27 cm	970.3	49823.1	17.6	1353.1	987.9	51176
>26 cm	223.1	39545	1301.5	341347	1524.7	380892

Table 4. Results of the acoustic measurements of Icelandic summer-spawning herring, west south/east of Iceland and total in the winter/autumn 2023/2024 by different age groups.

		AH3-2024 and AMM3-2024		B4-2024					
		Southeast areas*		Kolluáll/Jökuldjúp		Total		Proportion (%)	
Age (years)	Year class	Numb. (10^6)	Biomass (t)	Numb. (10^6)	Biomass (t)	Numb. (10^6)	Biomass (t)	Number %	Biomass %
1	2022	375.7	7280.6	0.0	0.0	375.7	7280.6	15.0	1.7
2	2021	470.8	27550.1	11.7	820.4	482.5	28370.5	19.2	6.6
3	2020	195.5	25969.5	46.9	7292.2	242.4	33261.7	9.6	7.7
4	2019	125.7	23051.3	170.7	34575.9	296.4	57627.2	11.8	13.3
5	2018	25.7	5516.6	269.1	62222.5	294.8	67739.1	11.7	15.7
6	2017	0.0	0.0	273.5	69406.8	273.5	69406.8	10.9	16.1
7	2016	0.0	0.0	194.3	53965.2	194.3	53965.2	7.7	12.5
8	2015	0.0	0.0	99.0	29173	99.0	29173.0	3.9	6.8
9	2014	0.0	0.0	90.1	28460.7	90.1	28460.7	3.6	6.6
10	2013	0.0	0.0	47.8	16133.6	47.8	16133.6	1.9	3.7
11	2012	0.0	0.0	10.0	3139.3	10.0	3139.3	0.4	0.7
12	2011	0.0	0.0	48.0	16606.2	48.0	16606.2	1.9	3.8
13	2010	0.0	0.0	27.7	9912.8	27.7	9912.8	1.1	2.3
14	2009	0.0	0.0	23.5	8621.9	23.5	8621.9	0.9	2.0
15	2008	0.0	0.0	5.9	1980.4	5.9	1980.4	0.2	0.5
16	2007	0.0	0.0	1.0	389	1.0	389.0	0.0	0.1
17	2006	0.0	0.0	0.0	0.0				
18	2005	0.0	0.0	0.0	0.0				
19	2004	0.0	0.0	0.0	0.0				
20	2003	0.0	0.0	0.0	0.0				
Total		**1193.4**	**89368.0**	**1319.1**	**342699.9**	**2513**	**432068**	**100**	**100**
3+		346.9	54537.4	1307.4	341879.5	1654.3	396416.9	65.8	91.7
4+		151.4	28567.9	1260.5	334587.3	1411.9	363155.2	56.2	84.1

Figures

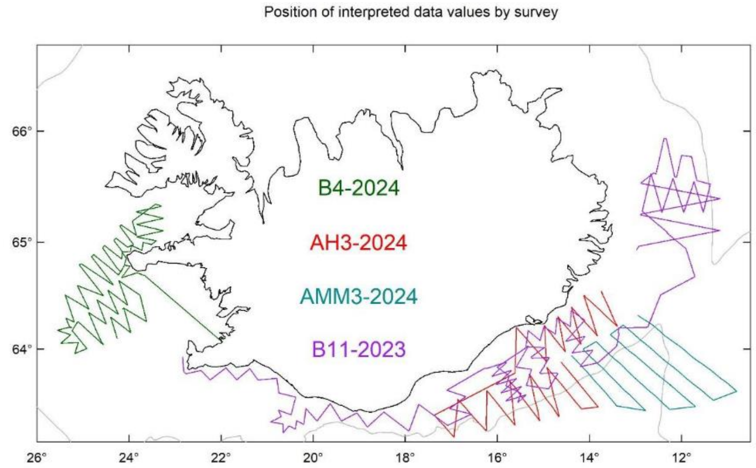
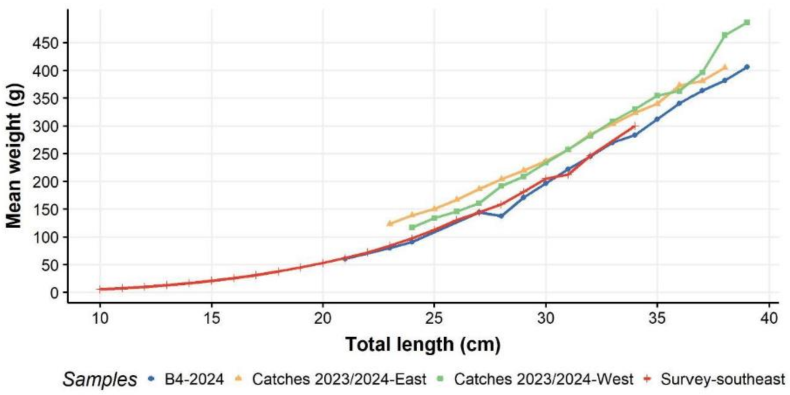


Figure 1. The survey tracks in the acoustic measurements of Icelandic summer-spawning herring in the east and southeast (B11-2023; purple), southeast (AH3-2024; red and AMM3-2024; cyan) and in the west (B4-2024; darkgreen). (See also Table 2 and Table 3).



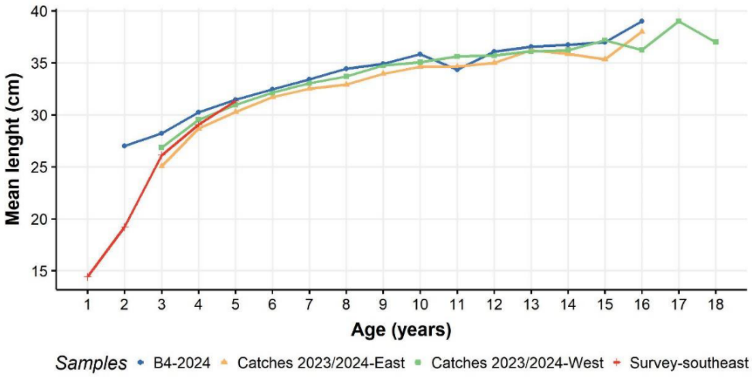


Figure 2. Mean weight-at-length for the two surveys used in the acoustic estimation of Icelandic summer-spawning herring biomass in the winter 2023/2024 (upper) and mean length-at-age (lower), compared to estimates from the catches (east and west) in 2023/24.

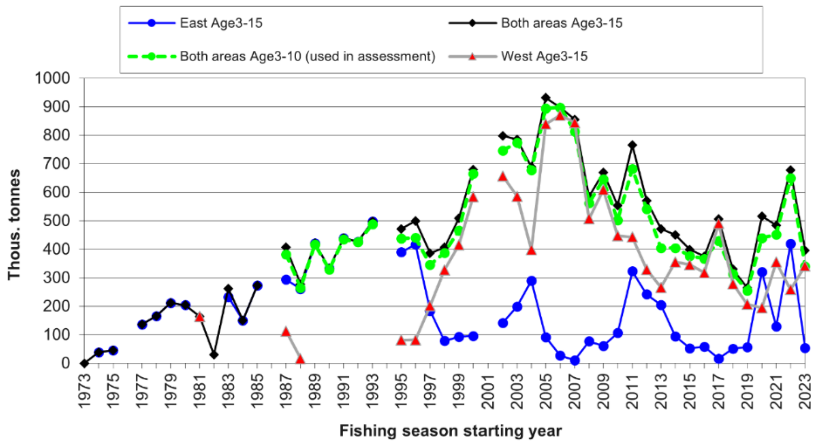


Figure 3. Comparison of total acoustical biomass indices of Icelandic summer-spawning herring over the autumns 1973/74 to 2023/24 (referring to the autumns) for age 3+ in the west, east (and south) and total, and then age 3-10 (the age groups used for tuning in the assessment).

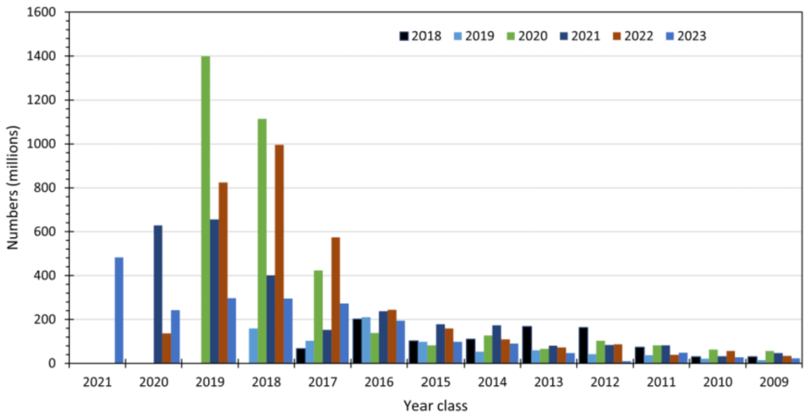


Figure 4. Comparison of survey indices (in millions) of Icelandic summer-spawning herring by year classes as measured in acoustic surveys in the last six autumns (2018 to 2023).

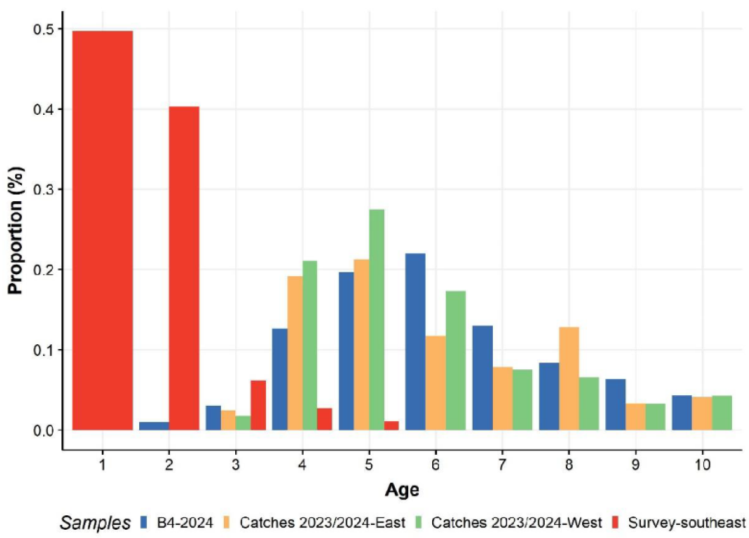


Figure 5. Proportion of the different age groups of Icelandic summer-spawning herring for the for the catches in the west 2023/2024, the catches in the east 2023/24 in comparison to the age composition in the stock according to the acoustic measurements in southeast (AH3-2024 and AMM3-2024) and spring survey (B4-2024). Age is relative to autumn 2023.

Annex 1: Survey report of B4-2024, AMM3-2024 and AH3-2024 acoustic measurements of Icelandic summers-spawning herring west and south-east of Iceland

Hafnarfjörður 5. apríl 2024

HAFRANNSÓKNASTOFNUN
Rannsókna- og ráðgjafarstofnun hafs og vatna

Leiðangursskýrsla B4-2024: Bergmálsmælingar íslenskrar sumargotssíldar í Kolluál, Jökuldýpi og Breiðafirði á RS Bjarni Sæmundsson, 22. mars – 26. mars 2024 ásamt niðurstöðum úr síldarmælingum í loðnuleiðangri AMM3-2024 og AH3-2024

Verkefnisnr. 9124

Sigurvin Bjarnason

Samantekt:

- Yfirferðasvæði 5 daga leiðangursins í Kolluál, Jökuldýpi, Breiðafjörð og um grunnin á Snæfellsnesi sýndu að dreifing síldarinnar var sambærilegt við undanfarin ár.
- Heildarmagnið sem mældist í yfirferðinni einu var um 340 þús. tonn og var það nánast allt fullorðin síld.
- Í fjölda mældist mest af 2017 og 2018 árganginum (20,4% og 20,7%) en árgangar frá 2016 (14,7%) og 2019 (12,9%) fylgdu þar á eftir (tafla 3). Aukning var af eldri síld (9+ ára; um 19% af fjölda en var 12% í leiðangrinum 2023).
- Niðurstöður leiðangursins sýnir að 2018 árgangurinn, sem mælst hefur stór undanfarin ár ásamt 2017 árganginum, er að fullu genginn inní veiðistofn og verða megin uppistaða veiðistofns á komandi árum.
- Engin mæling náðist fyrir austan og sunnan land haustið 2023 en þó tókst að mæla ungsíld ásamt parti af 2019 árganginum á Stokksnesgrunni og í Lónsdýpi í loðnuleiðangri í febrúar 2024. Niðurstöður þeirra mælinga verða notaðar í stofnmati (Viðauki 2).

1. Markmið leiðangursins

Markmið leiðangursins er að bergmálsmæla veiðistofn íslensku sumargotssíldarinnar á helstu vetursetustöðvum stofnsins vestan Íslands og verða niðurstöðurnar notaðar við mat á stærð stofnsins vorið 2024, ásamt niðurstöðum leiðangurs austan lands og aflagögnum. Jafnframt er markmiðið að meta *Ichthyophonus* sýkingarhlutfall í stofninum með sýnatökum.

2. Mönnun leiðangurs í B4-2024

Rannsóknarfólk

Sigurvin Bjarnason, leiðangursstjórn, tækjavakt
Thassya Christina dos Santos Schmidt, tækjavakt
Svandís Eva Aradóttir, sýnavinnsla
Ragnhildur Ólafsdóttir, sýnavinnsla

Skipstjóri

Guðmundur Sigurðsson

3. Gangur leiðangurs, vinnutilhögun og mælingar

Farið var frá Hafnarfirði kl. 10:00, 22. Mars í nokkuð leiðinlegu veðri en lægja átti um kvöldið. Þegar komið var í Kolluálinn var grynnsta svæðið krussað þar sem sterkur vindstrengur lág utar í ánum. Í framhaldi var farið fyrir Snæfellsnes og inní Breiðafjörð þar sem var einnig mælt og tekið sýni. Lítið mældist í Breiðafirði og einungis hrygnandi loðna fékkst í sýnum. Þaðan var krussað út Kolluál og sýni tekin þar sem síld fannst. Í framhaldinu var siglt inn Jökuldýpi þar sem síld var að finna og einnig í Jökuldýpinu.. Austan kaldi var á svæðinu og allan leiðangurinn sem aftraði sýnatöku í eitt skipti djúpt í Kolluál. Mælingar kláruðust á þriðjudegi ásamt sýnatöku og núllpunktur fannst í allar áttir og því svæðið vel afmarkað. Skipið kom í höfn í Hafnarfirði á þriðjudagseftirmiðdag 26. mars.

Bergmálsmælingarnar voru gerðar með og zigzag leggjum til þess að nýta skipatímann sem best. Með þeirri aðferð var siglt eftir fyrirfram ákveðnum leitarlínum með jafnri fjarlægð milli lína (hönnuð í HafróStox pakkanum í R). Túlkun bergmálsgagna var gerð í LSSS. Að öllu jöfnu voru túlkanir vistaðar á 0,1 mílna millibili. Meðaltal bergmálsgilda var reiknað í viðeigandi stærð af reitum að teknu tilliti til fjarlægðar milli leitarlína.

Kvörðun bergmálstækja var gerð í nóvember 2023 í Hvalfirði og hafði næmni breyst lítillega frá kvörðun einu ári fyrr (sjá viðauka 3). Breytingar á mælunum voru gerðar um borð og hafa því ekki áhrif á niðurstöðu þessa leiðangurs.
Alls voru sigldar um 967 mílur og tekin alls 7 togsýni (tafla 1) þessa 5 daga.

3.1.2. Fisksýnataka

Sýnum var safnað eftir þörfum með flotvörpu á hefðbundinn hátt. Teknir voru 50 síldar á stöð í "kvörnun" og 200 í lengdarmælingu (ef afli leyfði). Í viðbót við hefðbundnar mælingar/ákvarðanir (fitumæling (fyrstu 25 í stöð), lengd, þyngd, kyn, kynþroska stig, þyngd kynkirtla og hreistur fyrir aldursgreiningar) voru hjörtu sílda sett í kvarnabakka til þess að ákvarða hugsanlega *Ichthyophonus* sýkingu undir víðsjá. Aðrar fisktegundir sem fengust í sýnum voru ýmist kvarnaðar og/eða lengdarmældar.

4. Niðurstöður

4.1 Bergmálsmælingar

Í leiðangrinum B4-2024 var vart við síld á fjórum mismunandi svæðum; grunnt í Kolluál (svæði 1), á grunninum við Snæfellsnes (svæði 2) og djúpt í Kolluál (svæði 3) og Jökuldýpi (svæði 4, sjá mynd 2 og Viðauki 1). Niðurstöður leiðangursins gefa til kynna að megin útbreiðsla síldarinnar væri í Kolluál (rúmlega 70% af heildarendurkasti, sjá töflu 2). Það litila sem mældist í Breiðafirði var allt sett á hrygnandi loðu þó svo að lóðningar sem þar fengust líktust síldarlóði, kom rúm 2 tonn af loðnu í netin við sýnatöku. Á þessum tíma árs er loðnan að hrygna og safnast saman í þéttar torfur sem minna á síldartorfur. Því er mikilvægt að ná mörgum sýnum af svæðinu til þess að vera viss um að síld sé að ræða Á síðasta degi leiðangursins mældist töluvert af síld í Jökuldýpi (rúm 50 þús tonn) en ekki hefur alltaf gefist tími til þess að fara yfir það svæði í þessum leiðangri. Í framtíðarleiðöngrum er því mikilvægt að mælt sé einnig í Jökuldýpi. Veðrið aftraði ekki við yfirferð leiðangursins, þó svo að það stjórnaði nokkuð í hvaða röð svæðin voru mæld. Þrátt fyrir það er talið er að leiðangurinn hafi náð yfir megin útbreiðslu síldarinnar og nýtist í stofnmat.

Við útreikninga á magni síldar var notaður einn aldurslengdarlykill sem náði yfir öll svæði (Tafla 3) á meðan að lengdardreifingar og meðalþyngdir byggðust á sýnum frá hverju svæði fyrir sig.

Útreikningar á bergmálsmælingum voru gerðir með því að reikna NASC gildi á reiti 5 mín lengdagráða og 10 mín breiddargráða innan hvers yfirferðasvæðis, sem eru síðan lögð saman fyrir heildarmat (tafla 2). Síld fékkst í sex af sjö togum og var lengdardreifing þeirra ólík þar sem eldri síld fannst á einni stöð (mynd 3). Lengdardreifingin sýna í leiðangri var svipuð lengdardreifingu aflasýna haustsins 2023 þar sem megin uppistaða veiða var 29-34 cm síld og því er líklegt að leiðangurinn hafi náð yfir veiðihluta stofnsins (mynd 3).
Ekki er hægt að greina mun milli svæða á meðalþyngdum eftir lengd, nema að aflasýnin eru markvert þyngri en það má rekja til þess að síldin í mars er í vetrardvala og ekki að éta og gengur því á fituforða sinn á þessu 4-5 mánaða tímabili sem er á milli veiða og þessa leiðangurs (Mynd 4).
Heildarmælingin var upp á tæp 343 þúsund tonn í leiðangrinum og var það nánast allt hluti af veiðstofninum (≥4 ára; tafla 3). Í fjölda mældist mest af 2017 og 2018 árganginum (20,4% og 20,7%) en árgangar frá 2016 (14,7%) og 2019 (12,9%) fylgdu þar á eftir (tafla 3). Aukning var af eldri síld (9+ ára; um 19% af fjölda en var 12% í leiðangrinum 2023).

4.2. Ichthyophonus sýking

Aflasýni eru notuð við mat á sýkingarhlutfalli fyrir veiðistofn, því var ekki gerð greining á þeim í þessum leiðangri

5. Umræða

Eins og áður kom fram var yfirferð leiðangursins nokkuð góð þrátt fyrir leiðinlegt veður og samfellan í mælingum ásættanleg. Það verður þó að teljast að þetta er óheppileg tímasetning fyrir leiðangurinn þar sem hrygnandi loðna er að ganga inná svæðið í lok mars öllu jafna og eins og var fjallað um voru þéttir lóðningar í Breiðafirði allir settir á loðnu. Ástæða er til þess að reyna fara fyrr í þennan leiðangur á næsta ári vegna þessa. Að öðru leiti telur höfundur að leiðangurinn hafi náð yfir megin útbreiðslusvæði síldar og því er mælt með að mælingin verði notuð í stofnmati. Mesta magn af síld var að finna í Kolluál og á grunninum í kringum

Snæfellsnes, líkt og í fyrra. Umfram það sem var mælt í fyrra, mældist nokkur slatti í Jökulsdýpi og því ástæða til þess að hafa það svæði inni í framtíðarleiðöngrum. Sýni úr leiðangrinum sýndu sterklega 2017 og 2018 árgangana en 2019 árgangurinn er undir væntingum og má ætla að meira magn af þeim árgangi sé að finna í hluta stofnsins sem heldur sig til fyrir austan land en náðist ekki að mæla þetta árið nema að litlu leiti (sjá viðauka 2) en nýtist þó í stofnmati. Nýtt í þessum leiðangri var að minnka sýnasöfnun úr 100 kvörnuðum síldum niður í 50 síldar. Á móti kom að sýnasöfnun var með ágætum og samanburður við sýnatöku úr afla bendir til þess að þau eru sambærileg leiðangurssýnum og lýsa því stofninum ágætlega.
Mælingar síðustu ára hafa gefið til kynna að 2017 og 2018 árgangurinn verði stórir og niðurstöður leiðangursins gefa til kynna að þeir sé að fullu genginn inn í veiðihluta stofnsins.

Töflur

Tafla 1. Yfirlit yfir fiskmælingar fimm togsýna eftir tegundum og mælingum í B4-2024.

Fjöldi stöðva	Tegund	Nr.	Mældir	Vigtað	Kyngreint	Aldursgreint
6	Sumargotssíld	30	1500	300	300	300
2	Loðna	31	200	200	200	200
1	Hrognkelsi	48	1			
1	Gullkarfi	5	48			
1	Ufsi	3	1			
1	Lýsa	4	1			
1	Ýsa	2	1			
7			1752	500	500	500

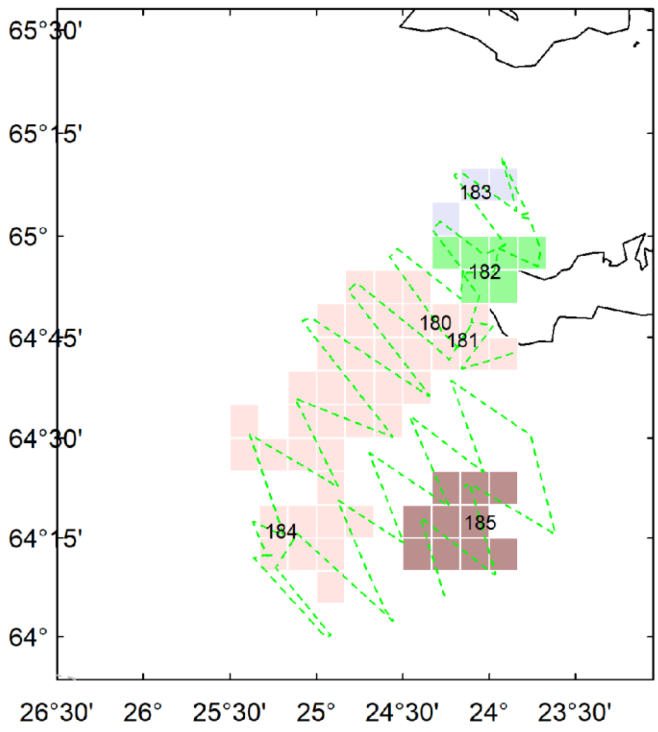
Tafla 2. Niðurstöður bergmálsmælinga á íslenskri sumargotssíld í B4-2024 eftir svæðum.

Undirsvæði	Heildarendurvarp (EA)	Stærð svæðis (nm^2)	Fjöldi fiska (milljarðar)	Lífmassi (t)
Kolluáll (grunnt-A1)	43886	60,1	47,9	13.674
Snæfellsnes (grunnt-A2)	132494	94,9	158	39.877
Kolluáll (djúpt-A3)	756108	805	880	235.205
Jökuldýpi -A4	185877	216	234	53.944

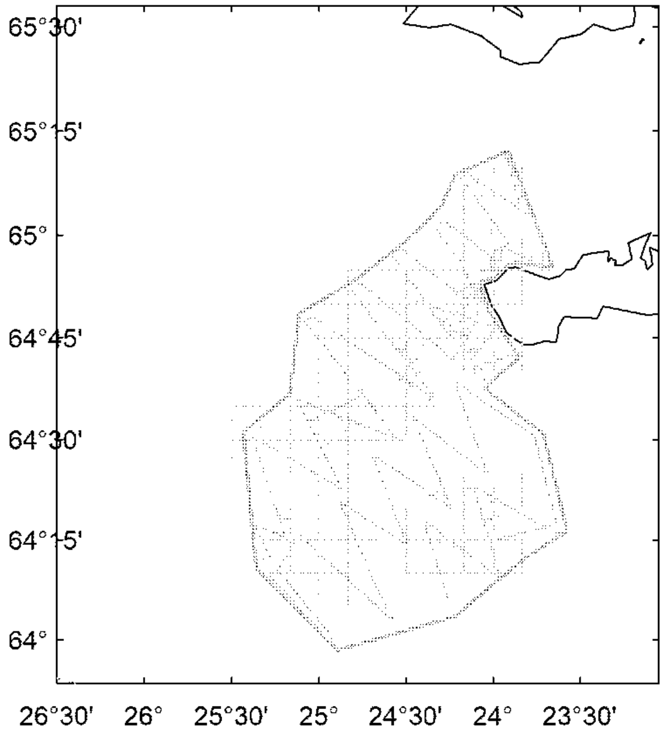
Tafla 3. Niðurstöður um fjölda fiska (N – fjöldi í milljörðum) og lífmassa (B) frá bergmálsmælingum á íslenskri sumargotssíld í B4-2024 eftir lengd og aldri fiska ásamt aldurs-lengdarlykli. Aldur miðast við haustið 2023.

Length (cm)/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total N	Total B (t)	Mean weight (g)
21	6															6	353.1	60.2
23	6															6	467.3	79.7
24		6														6	532.7	90.9
27		5	6													11	1518.9	144.1
28		5														5	642.9	137.4
29		27	14													41	6776.4	166.9
30		5	92	47												143	28204.5	196.6
31			50	79	40	3										172	38301.9	222.7
32			9	126	99	27										261	64038.3	245.4
33				17	117	64	12			6						216	58509.6	271.2
34					17	83	38	49	6							194	55669.2	287.5
35						18	48	16	8	4	7	1				101	31450.4	310.8
36							1	24	23		18	10	12			87	30197.8	345.2
37								1	12		23	16	6	6		63	22971.3	361.9
38												1	6			7	2676.6	392.4
39															1	1	389.0	406.4
Total N	12	47	171	269	273	194	99	90	48	10	48	28	23	6	1	1319	342699.9	
Percentage (%)	0.9	3.6	12.9	20.4	20.7	14.7	7.5	6.8	3.6	0.8	3.6	2.1	1.8	0.4	0.1			
Total B (t)	820.4	7292.2	34375.8	62222.5	69406.8	53965.2	29173.0	28460.7	16133.6	3139.3	16606.2	9912.8	8621.9	1980.4	389.0			
Mean weight (g)	70.0	155.6	202.6	231.2	253.8	277.7	294.6	315.9	337.5	314.7	345.8	357.5	367.6	337.8	406.4	259.8		
Mean length (cm)	22.0	28.2	30.2	31.4	32.4	33.4	34.4	34.7	35.8	33.8	36.3	36.6	36.8	37.0	39.0	32.6		

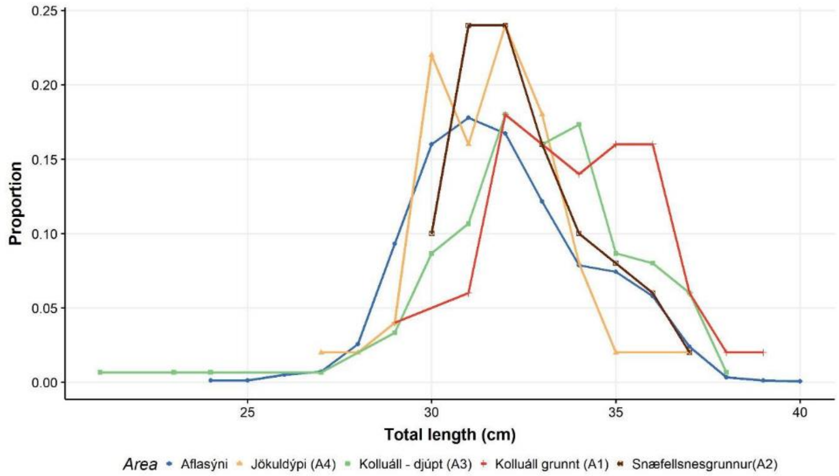
Myndir



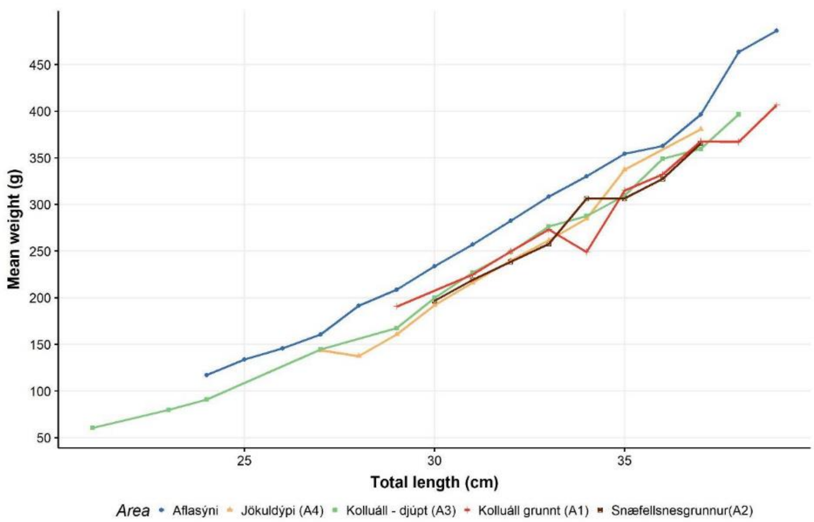
Mynd 1. Leiðangurslínur í B4-2024 ásamt svæðisskiptingu (Kolluáll grunnt- blátt (A1), Snæfellsnes- grænt (A2), Kolluáll djúpt- bleikt (A3) og Jökuldýpi -vínrautt (A4)). Númerin tákna stöðvar (6).



Mynd 2. Leiðarlínur og dreifing síldar samkvæmt bergmálsgildum (stöplarit) fyrir íslenska sumargotssíld í B4-2024.

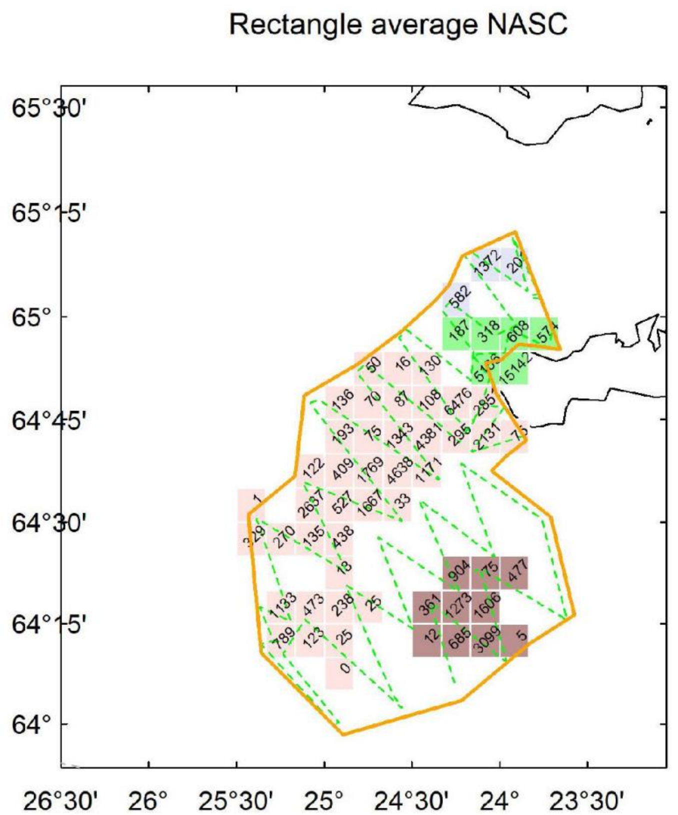


Mynd 3. Lengdardreifingar síldar eftir svæðum (A1-4) í B4-2024 ásamt aflasýnum að hausti fyrir vestan land.

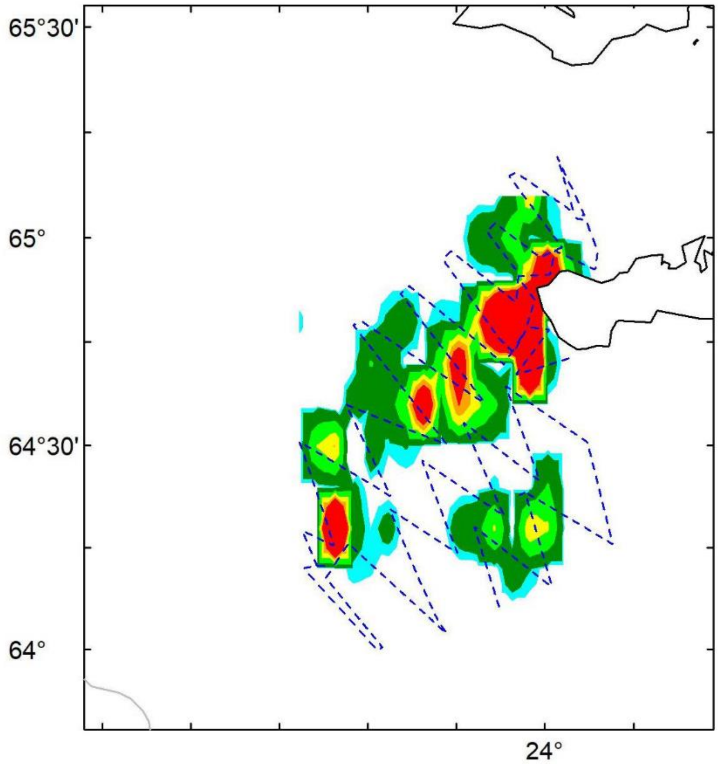


Mynd 4. Lengdar-þyngdarsamband síldar eftir svæðum (A1-4) í B4-2024 ásamt aflasýnum að hausti fyrir vestan land.

Viðauki 1 -Myndir af bergmálsgildum



Mynd 5. Leiðarlínur og dreifing síldar samkvæmt bergmálsgildum (NASC gildi innan reita) fyrir íslenska sumargotssíld í B4-2024.



Mynd 6. Leiðarlínur og dreifing síldar samkvæmt bergmálsgildum (contour litir) fyrir íslenska sumargotssíld í B4-2024.

Viðauki 2 – Síldarmælingar í Loðnuleiðangri við Stokknesgrunn og Lónsdýpi

Bakrunnur leiðangra, vinnutilhögun og mælingar

Síldarleiðangur að hausti B11-2023 var farinn í nóvember 2023 og markið hans er að mæla ungsíld í djúpunum á suður og austurlandi og jafnframt hefur færst í aukin síðustu ár að mæla hluta af íslenska sumargotssíldar veiðistofninum sem blandist við norsk-íslensku síldina á grunninum austan við Ísland áður en hún heldur austur í haf á hrygningaslóðir sínar við Noregsströnd. Ákveðið var að fara seinna í þennan leiðangur en fyrri ár í þeirri von um að stofnarnir hefðu aðskilist og íslenska sumargotssíldin yrði eftir á grunninum fyrir austan land. Í leiðangrinum í nóvember fannst þó engin síld fyrir austan og ljóst að sumargotssíldin hafði haldið austur með þeirri norsku og engin mæling fékkst í kjölfarið. Að sama skapi fannst lítið sem engin síld í djúpunum fyrir sunnan land og því bar leiðangurinn B11-2023 engan árangur í síldarmælingum.

Tími fékkst þó til þess að skoða djúpin betur snemma á árinu 2024 í hydroleiðangri á Bjarna Sæmundssyni og náðust 2 sýni af ungsíld í B2-2024. Aftur á móti var skipið á svæðinu að nóttu til þannig að ekki fékkst áreiðanleg mæling í þeim leiðangri. Viku seinna náðist mæling og eitt sýni til viðbótar í loðnuleiðangri við suðausturland í leiðöngrunum á Ásgrími Halldórssyni (AH3-2024) og Polar Ammasak (AMM3-2024) og verða niðurstöður þeirra mælinga kynntar hér (tafla 4).

Tafla 4. Niðurstöður bergmálsmælinga á íslenskri sumargotssíld í AH3-2024 og AMM3-2024.

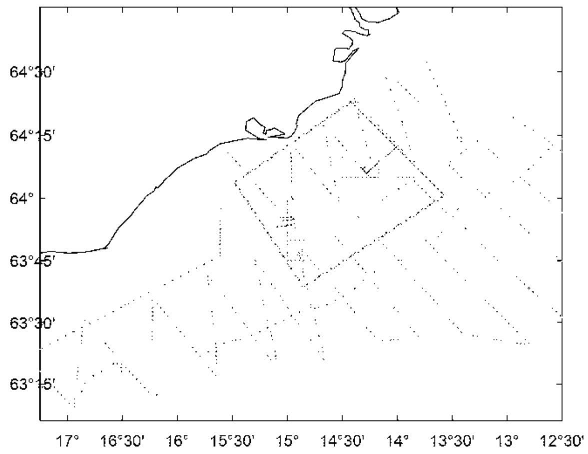
Undirsvæði	Heildarendurvarp (EA)	Stærð svæðis (nm^2)	Fjöldi fiska (milljarðar)	Lífmassi (t)
Stokksnesgrunn og Lónsdýpi	426377	133	1193	89.368

Niðustöður

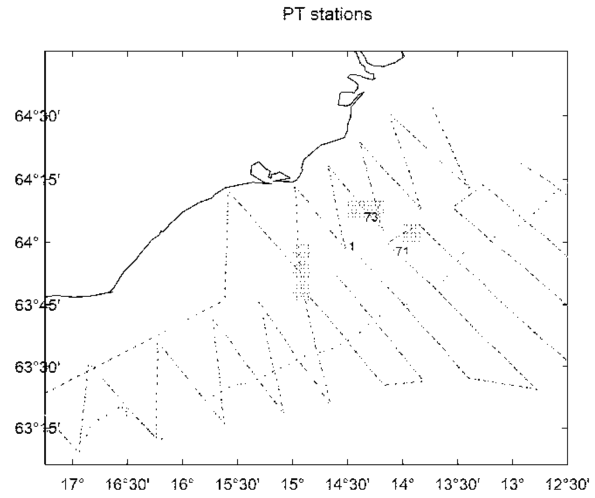
Sýnin tvö sem voru tekin í Lónsdýpi í leiðangri B2-2024 voru mest megins ungsíld og þótti höfundi eðlilegast að mælingin sem var á því svæði viku seinna myndi endurspegla þau sýni. Sýni sem fékkst á Ásgrími Halldórssyni vestar á svæðinu voru svo notaðar fyrir mælingarnar vestar á svæðinu en þar var aðeins stærri síld (Mynd 8). Ásgrímur Halldórsson mældi grunnin í þessum leiðangri og var þar að leiðandi í meiri síldargildum þarsem síldin heldur sig oftar á grunninum eða í kringum djúpin á suðurlandi (Mynd 7).
Í heildina mældust rúm 89 þús.tonn af síld og af því var 28500 tonn 4 ára og eldri síld (tafla 5). Í langmestum fjölda mældist 2021 árgangurinn (39%) en aðeins 12.5% af árgöngum 2020 og eldri sem teljast í veiðistofni.

Tafla 5. Niðurstöður um fjölda fiska (N – fjöldi í milljörðum) og lífmassa (B) frá bergmálsmælingum á íslenskri sumargotssíld í AMM3-2024, AH3-2024 og sýni frá B2-2024 eftir lengd og aldri fiska ásamt aldurs-lengdarlykli. Aldur miðast við haustið 2023.

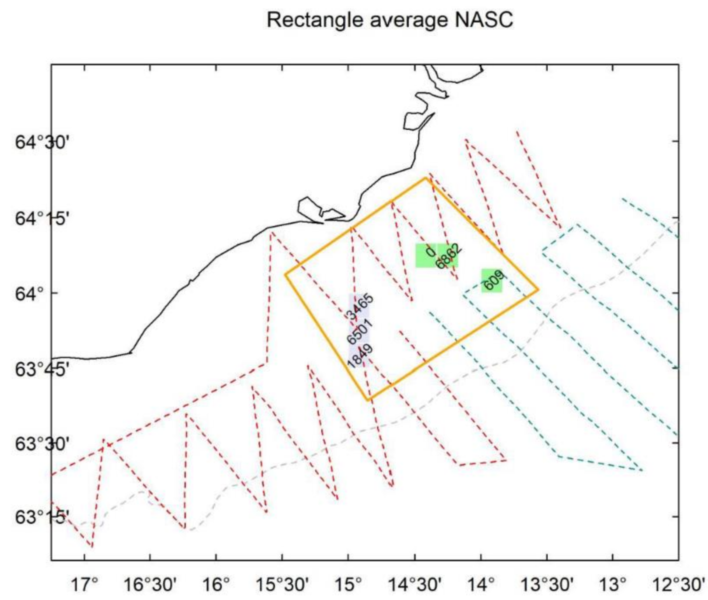
Length (cm)/Age	1	2	3	4	5	Total N	Total B	Mean weight (g)
10	2.7	1.4				4.1	22.9	5.6
11	19.2	4.1				23.3	180.6	7.7
12	49.4	12.3				61.7	626.0	10.1
13	54.8	8.2				63.1	827.7	13.1
14	37.0	6.9				43.9	733.8	16.7
15	90.5	5.5				96.0	2003.0	20.9
16	76.8	26.1				102.8	2645.5	25.7
17	45.2	9.6				54.8	1714.3	31.3
18		31.5				31.5	1187.6	37.7
19		21.9				21.9	989.3	45.1
20		42.5				42.5	2249.6	52.9
21		97.8				97.8	6049.6	61.9
22		131.8				131.8	9617.0	73.0
23		71.2				71.2	5983.6	84.0
24			17.0			17.0	1690.4	99.5
25			41.9			41.9	4745.1	113.3
26			54.8	10.1		64.9	8556.9	131.9
27			64.9	10.1		75.0	11021.3	146.9
28			17.0			17.0	2807.2	165.3
29				62.1		62.1	11273.6	181.4
30				43.3	20.3	63.5	13111.2	206.4
31					2.7	2.7	582.9	212.5
32					1.4	1.4	337.6	246.2
34					1.4	1.4	411.2	299.9
Total N	375.7	470.8	195.5	125.7	25.7	1193.4	89368.0	
Percentage (%)	31.5	39.4	16.4	10.5	2.2			
Total B	7280.6	27550.1	25969.5	23051.3	5516.6			
Mean weight (g)	19.4	58.5	132.8	183.4	214.3	74.9		
Mean length (cm)	14.4	20.2	26.1	28.9	30.4	20.5		



Mynd 7. Leiðarlínur og dreifing síldar samkvæmt bergmálsgildum (stöplarit) fyrir íslenska sumargotssíld í AH3-2024 (rautt) og AMM3-2024 (grænt).

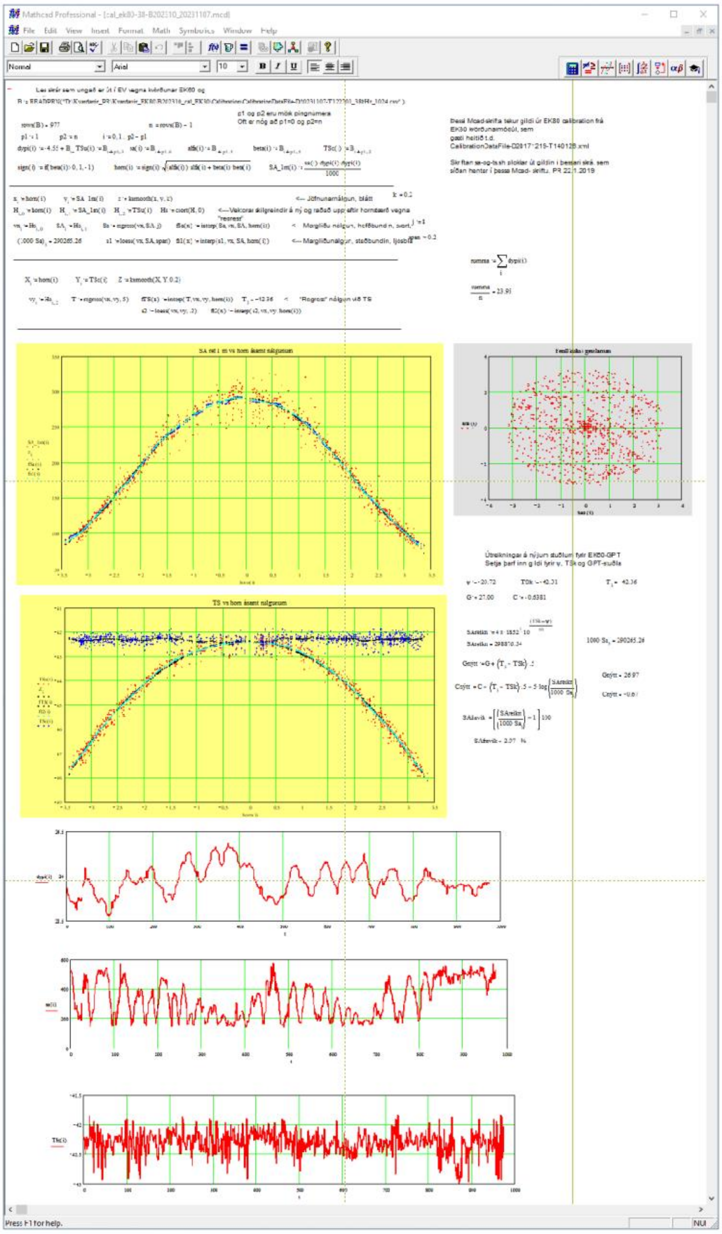


Mynd 8. Leiðangurslínur í í AH3-2024 (rautt) og AMM3-2024 (grænt) ásamt svæðisskiptingu (Vestur - blátt), austur- grænt) og staðsetning sýna úr B2-2024 (st. 71 og 73) og AH3-2024 (st. 1).



Mynd 9. Leiðarlínur og dreifing síldar samkvæmt bergmálsgildum (NASC gildi innan reita) fyrir íslenska sumargotssíld í AH3-2024 (rautt) og AMM3-2024 (grænt).

Viðauki 3 -Kvörðunarupplýsingar



WD02: Greenland halibut in 5, 6, 12 and 14: Re-evaluation of management reference points

Bjarki Þór Elvarsson

Introduction

This document describes the re-estimation of biomass and fishing mortality reference points for Greenland halibut in 5, 6, 12 and 14. This re-estimate was needed after an error was discovered during the update assessment of Greenland halibut and beaked redfish. The routine that collated SSB from the model output incorrectly calculated mean weight at length resulting in a downward bias in total and spawning stock biomass estimates. As the estimate of B_{lim} for GHL was based on B_{loss} it was affected by this error and thus the biomass and mortality reference points needed to be revised. Figure 1 illustrates the difference between last years estimates and the current years estimate. This difference can almost entirely be attributed to this error.

Reference point colculations

The same procedures, as used at WKBNORTH last year, were followed for this update reference point estimation. According ICES technical guidelines, two types of reference points are referred to when giving advice for category 1 stocks: *precautionary approach* (PA) reference points and *maximum sustainable yield* (MSY) reference points. The PA reference points are used when assessing the state of stocks and their exploitation rate relative to the precautionary approach objectives. The MSY reference points are used in the advice rule applied by ICES to give advice consistent with the objective of achieving MSY.

Generally ICES derives these reference points based on the level of the spawning stock biomass and fishing mortality. The following sections describe the derivation of the management reference points in terms of fishing mortality (F) and SSB (B). It further describes the model for stock–recruitment, weight and maturity at age, and assessment error which in combination with the MCMC results is used to project the stock in order to derive the PA and MSY reference points.

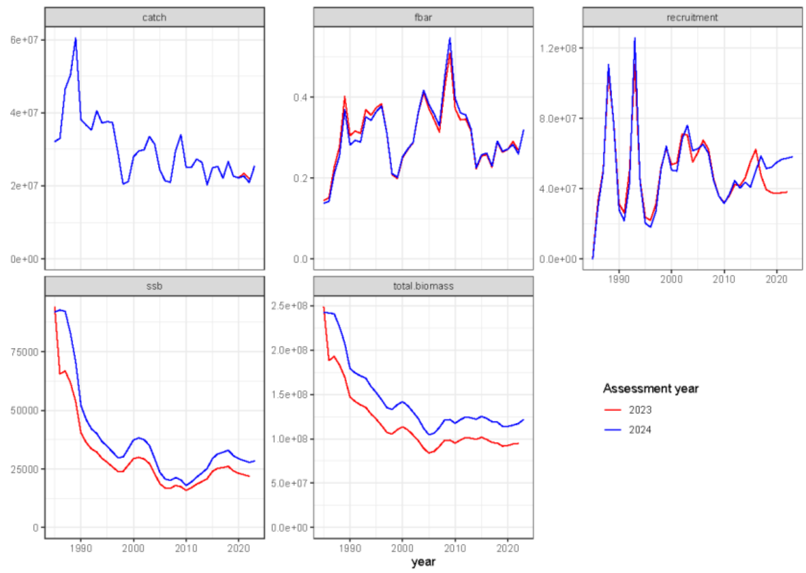


Figure 1: Greenland halibut. Comparisons of populations estimates between assessment years, illustrating the effects of last years error (see text for further details).

Setting B_{lim} and B_{pa}

B_{lim} was considered from examination of the SSB–Recruitment scatterplot based on the estimates from the stock assessment, as illustrated in fig. Figure 2. The plot is shows no evidence of impaired recruitment and no clear relation between stock and recruitment (Type 5). In that scenario B_{lim} is derived from the lowest observed SSB (i.e. $B_{loss} = 1.8213 \times 10^4$ t).

In line with ICES technical guidelines B_{pa} is then calculated based on multiplying B_{lim} with $e^{1.645\sigma_{SSB}}$, where σ is the CV in the assessment year of SSB or 0.19, used for calculating B_{pa} from B_{lim}. This is considered to reflective of the true assessment error of the SSB as the assessment is seen to be stable and input data are internally consistent. Therefore B_{pa} should be set at $B_{lim}e^{1.645*\sigma_{SSB}} = 2.4895464 \times 10^4$ t.

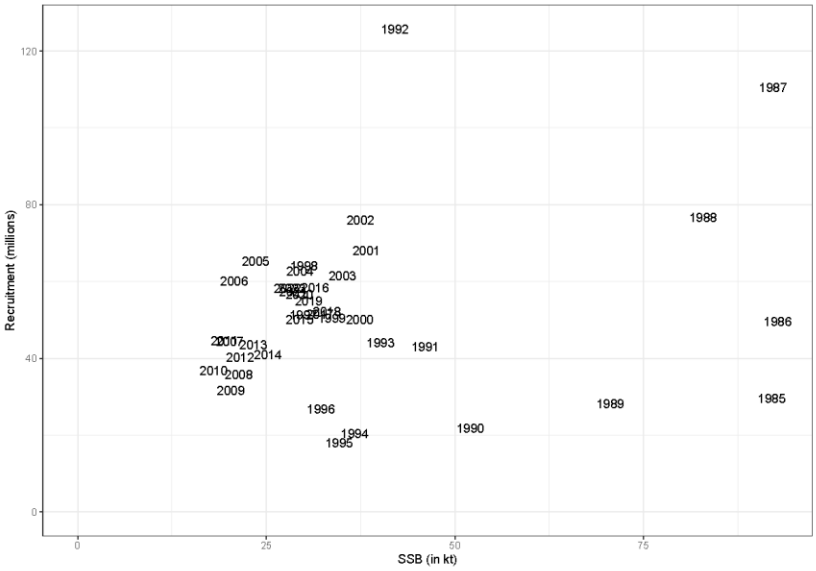


Figure 2: Greenland halibut. Fitted stock recruitment relationship

Stock recruitment relationship

A variety of approaches are common when estimating a stock–recruitment relationship. In the absense of a stock-recruitment signal from the available historical data (Fig. Figure 2), the

ICES guidelines suggest that the "hockey-stick'' recruitment function is used, i.e.

$$R_y = \bar{R}_y \min(1, S_y/B_{break})$$

where R_y is annual recruitment, S_y the spawning stock biomass, B_{break} the break point in hockey stick function and $\bar{R}_y$ is the recruitment when not impaired due to low levels of SSB. Here $\bar{R}_y$ is considered to be drawn from historical estimates after 1995 using a 7 year block-bootstrap from the bootstrap model estimates. This is done to account for possible auto-correlation in the recruitment time–series.

Biological parameters in the forecast

Maturity, growth and length-weight relationship in the forecast are based on the processes estimated within the model and bootstrap replicates. Similarly, fleet selectivities are the same as estimated by the model with catch proportions by fleet fixed to the average of last 5 years. Uncertainty in these estimates is capture by the spatial bootstrap.

Management procedure in forward projections

Illegal landings and discards by the fishing vessels are considered to be negligible (as noted above). Observation error is addressed by the MCMC simulation approach employed in here. The appropriate assessment error is simulated in terms of fishing mortality by assuming F in the projections is a log-normal AR(1) process with the default values for CV as 0.212 and autocorrelation of 0.423.

Setting F_{lim} and F_{pa}

According to the ICES guidelines, the precautionary reference points are set by simulating the stock using the stock-recruitment, growth and maturity relationship described above, based on a wide range of fishing mortalities, ranging from 0 to 1 and setting F_{lim} as the F that, in equilibrium, gives a 50% probability of SSB > B_{lim} without assessment error.

For each MCMC replicate the stock status was projected forward 50 years as simulations, and average of those projected values used to estimate the MSY reference points.The results from the steady state simulations estimate the value of F, F_{lim}, resulting in 50% long–term probability of SSB > B_{lim} to be at 0.41.

MSY reference points

As an additional simulation experiment where, in addition to recruitment and growth variations, assessment error was added. The harvest rate that would lead to the maximum sustainable yield, F_{msy}, was then estimated. Average annual landings and 90% quantiles were used to determine the yield by F. The equilibrium yield curve is shown in Figure 3, where the maximum average yield, under the recruitment assumptions, is 2.5567×10^4 tons.

In line with ICES technical guidelines, the MSY $B_{trigger}$ is set as B_{pa} as this is the first time the reference points are evaluated. Maximum yield is estimated to be obtained at a F of 0.22. F_{p05}, i.e. the maximum F that has less than 5% chance of going below B_{lim} when the advice rule is applied, is 0.29, thus not limiting the estimate of F_{msy}. The equilibrium spawning stock biomass is shown in figure Figure 3.

Table 1

Greenland halibut in 5a. Overview of estimated reference points

Reference point	Updated Value	2023 benchmark	Basis
Blim	18213	15657	Lowest observed stock biomass
Bpa	24895	21402	Blim x exp(1.645 sigma_SSB)
Btrigger	24895	21402	Bpa
Flim	0.41	0.5	F leading to P(SSB < Blim) = 0.5
Fmsy	0.22	0.24	F leading to MSY
Fpa	0.29	0.38	F, when ICES AR is applied, leading to P(SSB > Blim) = 0.05
HRlim	0.56	0.61	HR leading to P(SSB < Blim) = 0.5
HRpa	0.39	0.46	HR, when ICES AR is applied, leading to P(SSB > Blim) = 0.05
MSY	25567	26554	MSY

The updated estimate of B_{lim} has resulted in subsequent revisions of other ref points. F_{msy} was slightly lowered from 0.24 to 0.22. This is not related to precautionarity, as the estimate F_{pa} is higher but only minor pertubations in yield. The difference in expected yield between 0.22 and 0.24 is 21 tonnes (set table 2).

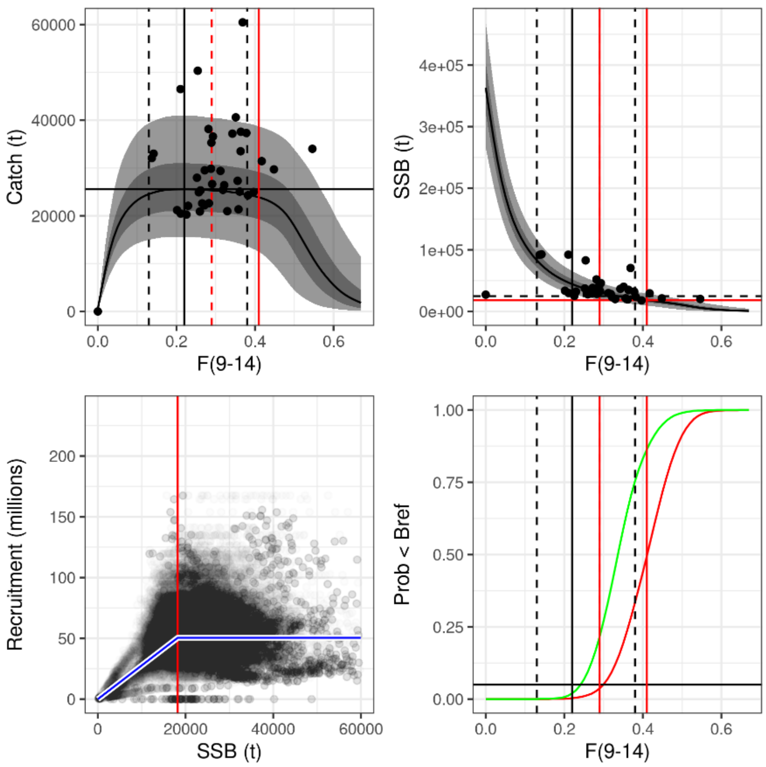


Figure 3: Greenland halibut in 5a. Equilibrium catch, recruitment, SSB and risk from forward projections.

Table 2

Expected range of yield by fishing mortality targets
Columns represent the distribution quartile

F(9-14)	0.05	0.25	0.5	0.75	0.95
0.15	15305	20626	25055	30381	40121
0.16	15437	20782	25250	30627	40416
0.18	15565	20963	25481	30923	40811
0.19	15571	20988	25522	30974	40904
0.20	15573	21000	25541	30987	40937
0.21	15589	21017	25559	30990	40925
0.22	15598	21030	25567	30986	40913
0.24	15572	21007	25547	30971	40944
0.25	15525	20974	25526	30957	40900
0.26	15459	20930	25494	30925	40813
0.27	15387	20878	25449	30863	40701
0.28	15303	20818	25387	30782	40601
0.30	15144	20726	25284	30664	40468

Table 3

Expected range of SSB by fishing mortality targets
Columns represent the distribution quartile

F(9-14)	0.05	0.25	0.5	0.75	0.95
0.15	47665	60762	70703	82077	101280
0.16	43961	56186	65538	76209	94291
0.18	37648	48497	56873	66343	82506
0.19	35004	45319	53268	62252	77615
0.20	32646	42470	50020	58577	73237
0.21	30528	39871	47047	55221	69262
0.22	28633	37510	44335	52158	65620
0.24	25284	33368	39577	46713	59051
0.25	23822	31573	37526	44331	56154
0.26	22482	29908	35615	42105	53441
0.27	21269	28380	33845	40056	50937
0.28	20158	26989	32232	38191	48641
0.30	18147	24517	29383	34888	44565

Table 4

Probability of the SSB being below Blim and Bpa respectively by fishing mortality targets

F(9-14)	P(SSB<Blim)	P(SSB<Bpa)
0.15	0.000	0.001
0.16	0.000	0.001
0.18	0.001	0.003
0.19	0.001	0.004
0.20	0.001	0.007
0.21	0.002	0.012
0.22	0.003	0.020
0.24	0.007	0.047
0.25	0.010	0.068
0.26	0.014	0.095
0.27	0.019	0.129
0.28	0.027	0.169
0.30	0.051	0.270

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Greenland commercial data for Atlantic cod in Greenland waters for 2023

Anja Retzel

Greenland Institute of Natural Resources, Nuuk, Greenland

anre@natur.gl

Abstract
In total, 56,609 tons of Atlantic cod were fished in Greenland in 2023.

Materials and methods

Inshore
The information on landings in weight is compiled by the Greenland Fisheries License Control (GFLK). Sales slips on the factories document inshore catches with information on gear and position of catch.

Each cod is weighted in a "Grader data" system at some factories. Its function is to weigh every single cod processed at the factory. Grader data was used to calculate length. The length-weight relationship was found from the inshore surveys, and with a=0.000007193 and b=3.06163, length was found as:

length = exp((log(weight)-log(a))/b)

Grader data was available from NAFO divisions 1AX (Illulissat) and 1D (Nuuk). The length calculated from NAFO 1D was used on fisheries data from NAFO divisions 1D-1F, whereas the length calculations from NAFO 1AX were used on fisheries data from divisions 1AUM, 1AUP and 1AX. For the regions NAFO 1B and 1C, length measurements taken from the catch landed in May were used.

Weight at age was supplemented with data from the inshore surveys as limited otolith samples were taken from the fishery.

Offshore

The information from the offshore fishery on landings in weight is compiled by the Greenland Fisheries License Control (GFLK) and is available on haul-by-haul scale provided by logbooks.

Sampling of length frequencies and information on length, weight and age were collected by the ship crew, who length-measured 150 randomly selected cod twice a week and took individual measurements (length, weight, gutted weight and otoliths) from 20 randomly selected cod twice a week.

Results

Inshore
The total catch in the inshore area in West Greenland was 22,655 tons, and 440 tons in East Greenland (table 1). In West Greenland, most of the catch was fished in NAFO div 1D and 1C in June and July (table 2), and the dominant gear was Poundnet (table 3). In East Greenland, the majority is fished in September with longlines.

TAC for the inshore fishery in 2023 was 17,000 tons at the start of the year. In fall, the TAC was increased to 24,300 tons. In total, 22,655 tons were fished in West Greenland, an increase of 7,500 tons compared to 2022 (table 1). In particular, Nafo division 1D catches almost doubled, constituting 36% of the total catches, followed by Nafo division 1C, which constituted 32% (Table 2).

The dominating gear is pound nets which constitutes 67% of the total catch (table 3). The gear is especially used in Nafo division 1B-1F, whereas longlines are dominating in the northern areas (1AX, 1AUM and 1AUP) and in East Greenland (ICES 14b).

The total number of fish used in length calculations was 1,394,716 in NAFO 1D and 171,308 in NAFO 1AX (table 4). In NAFO 1C, the number of fish measured was 1,430 in May (table 5).

Mean length in the fishery in NAFO division 1D-1F was 52 cm, in 1B-1C 49 cm and 59 cm in division 1A (1AX, 1AUM and 1AUP) (figure 2).

In East Greenland (ICES 14b), 440 tons were fished inshore in 2023 (table 1). There are no samples from this fishery, and the catch has not been used in any assessment.

Offshore

TAC for the offshore fishery in 2023 in South and East Greenland was 32,945 tons, with 25,000 tons restricted to the Dohrn Bank area (Q1+Q2, figure 4) and 7,945 tons to the remaining area Q3-Q6+1F. A trial fishery of 1,500 tons was set for West Greenland, and 1,000 tons were allocated to NAFO div. 1E and 500 tons to NAFO div. 1D. Total TAC for the offshore area (both East and West) amounted to 34,445 tons.

In total, 33,514 tons were fished, with 239 tons north of Dohrn Bank (NQ1, table 6 and 7), 24,902 tons in the Dohrn Bank area (Q1Q2), and 6,926 tons south of Dohrn Bank (Q3-Q6). Only 228 tons were taken in SouthWest Greenland (NAFO 1F, figure 4), and 1,278 tons were fished in NAFO 1D and 1E.

Greenland fished 26,937 tons, Faeroese Island 3,200 tons, EU 1,915 tons and Norway 1,461 tons.

The fishing fleet is composed of trawlers and longliners, where trawlers dominate, with 80% of the total catch in East Greenland (table 8). Most trawl catches are fished in a small area on the edge of Dohrn Bank near the EEZ to Iceland (table 8, figure 4). Most longline catches are taken in Q3Q4.

In West Greenland, the longliners dominate, fishing 83 % of the total catch (table 8).

Mean length in the fishery follows a geographical gradient with the smallest (60 cm) furthest to the north in West Greenland (NAFO 1D), increasing in length going south and East with the largest on Dohrn Bank (80 cm, figure 5).

Discussion

Length from samples from the inshore fisheries in May in NAFO division 1C was used on fisheries data for NAFO divisions 1B-1C. The reason for not using grader data from NAFO 1D was that length frequencies were very different between NAFO 1C and NAFO 1D in May (figure 3). In 2022, length frequencies from grader data from NAFO 1D were used on fisheries data from NAFO 1B-1C as no sampling had taken place in these areas (Retzel 2023). This can cause uncertainties in the assessment of the northern inshore stock component.

Cod is mainly caught as bycatch in the Greenland halibut fishery in the northern areas from Disko Bay and northwards (NAFO 1AX, 1AUM and 1AUP). The dominating gear is longline, followed by gillnet. From Nafo division 1B and southwards, the dominating gear is poundnet. The difference in gear results in very different size distributions between the two areas.

Catch by Stock

Northern West Greenland Inshore Spawning Cod (N-WISC)

The catch of the N-WISC peaked in 2016 and 2017 with 12,000 tons and then declined to app. 4,000 tons in 2019-2022 (table 11). In 2023, the catches increased to 6,000 tons. Until 2016, the majority is caught in NAFO division 1B, but from 2016 onwards, the majority is caught in NAFO division 1C (app. 60%). In the northern part of the area (NAFO division 1A), app. 10% of the catch is caught. The area for the catch of N-WISC is from Uppernavik (1AUM) in the north of Greenland to the Maniitsoq area (1C) in mid-Greenland (Figure 6).

Southern West Greenland Inshore Spawning Cod (S-WISC)

The catch of S-WISC has steadily increased to 5,000 tons in 2019 (table 12). Hereafter, it declined to 2,600 tons in 2022 and then doubled to 5,000 tons in 2023. Until 2013, 70% of the catches were caught in NAFO division 1D; since then, the proportion has increased to app. 90%. The area for the catch of S-WISC is from South Greenland (1F) to the Nuuk fjord system in Mid-Greenland (Figure 6).

West Greenland Offshore Spawning Cod (WOSC)

The catch of WOSC peaked in 2016 and 2017 with 12,000 tons, then declined to app. 4,000 tons in 2021 and increased to 8,000 tons in 2023 (table 13). On average, 95% of the WOSC is caught inshore, except in the years 2008 and 2015-2019, where between 10-20% were caught offshore. The area for the catch of WOSC is from South Greenland (1F) to North Greenland inshore and offshore (Figure 7) with app. 90% caught in NAFO divisions 1A-1D.

East Greenland Iceland Offshore Spawning Cod (EGIOSC)

The catch of EGIOSC has steadily increased to 37,000 tons in 2023 (table 14), making it the stock that is mostly caught in Greenland (66% in 2023). From 2000-2013 (except 2008), the majority (60%) was fished inshore in West Greenland. In 2008, the majority (62%) was fished offshore in West Greenland. From 2015, the catches in West Greenland declined and increased in East Greenland, especially in the Dohrn Bank region, where 70 % of the total catch has been taken in recent years (Figures 8 and 9).

References

Horsted, S.A. 2000. A review of the cod fisheries at Greenland, 1910-1995. J.Northw.Atl.Fish.Sci. 28: 1-112.

Retzel, A. 2023. Greenland commercial data for Atlantic cod in Greenland waters for 2022. ICES North Western Working Group 2023, WD: 05.

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Tables

Inshore Catches

Table 1: Cod catches (t) divided into NAFO divisions, caught in the inshore fishery (1911-1993: Horsted 2000, 1994-2006: Statistic Greenland, 2007-present: Greenland Fisheries License Control). ICES 14b=inshore East Greenland.

	NAFO divisions								
Year	1A	1B	1C	1D	1E	1F	Unknown NAFO div	Total WestGreenland	ICES 14b
1911				19				19	
1912				5				5	
1913				66				66	
1914				60				60	
1915		47	6	45				98	
1916		66	24	103				193	
1917		67	28	59				154	
1918		106	26	140		169		441	
1919		39	37	140	148	137		501	
1920		117	32	187	23	95		454	
1921		116	92	97	7	196		508	
1922		82	178	144	40	158		602	
1923		120	116	147	0	307		690	
1924		131	223	221	1	267		843	
1925		122	371	318	45	168		1024	
1926		97	785	673	170	499		2224	
1927		282	974	982	305	1027		3570	
1928		426	888	1153	497	1199		4163	
1929		1479	1572	1335	642	2052		7080	
1930	137	2208	2326	1681	994	2312		9658	
1931	315	1905	2026	1520	835	2453		9054	
1932	358	1713	2130	1042	731	3258		9232	
1933	304	1799	1743	1148	948	2296		8238	
1934	451	2080	1473	652	921	3591		9168	
1935	524	1870	1277	769	670	2466		7576	
1936	329	2039	1199	705	717	2185		7174	
1937	135	1982	1433	854	496	2061		6961	
1938	258	1743	1406	703	347	1035		5492	
1939	416	2256	1732	896	431	1430		7161	
1940	482	2478	1600	1061	646	1759		8026	
1941	636	3229	1473	823	593	1868		8622	
1942	879	3831	2249	1332	1003	2733		12027	
1943	1507	5056	2016	1240	1134	2073		13026	
1944	1795	4322	2355	1547	1198	2168		13385	
1945	1585	4987	2844	1207	1474	2192		14289	
1946	1889	5210	2871	1438	1139	2715		15262	
1947	1573	5261	3323	2096	1658	4118		18029	
1948	1130	5660	3756	1657	1652	4820		18675	
1949	1403	4580	3666	2110	2151	3140		17050	
1950	1657	6358	4140	2357	2278	4383		21173	
1951	1277	5322	3324	2571	2101	3605		18200	

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1952	646	4443	2906	2437	2216	4078		16726	
1953	1092	5030	3662	5513	3093	4261		22651	
1954	950	6164	3118	3275	1773	3418		18698	
1955	591	5523	3225	4061	2773	3614		19787	
1956	475	5373	3175	5127	3292	3586		21028	
1957	277	6146	3282	5257	4380	5251		24593	
1958	19	6178	3724	5456	3975	6450		25802	
1959	237	6404	5590	5009	3767	6570		27577	
1960	188	6741	6230	3614	3626	6610		27009	
1961	601	6569	6726	4178	6182	9709		33965	
1962	315	7809	6269	3824	5638	11525		35380	
1963	295	4877	3178	2804	3078	9037		23269	
1964	275	3311	2447	8766	2206	4981		21986	
1965	325	5209	4818	6046	2477	5447		24322	
1966	483	8738	5669	7022	2335	4799		29046	
1967	310	5658	6248	6747	2429	6132		27524	
1968	142	1669	2738	6123	2837	7207		20716	
1969	57	1767	4287	7540	2017	5568		21236	
1970	136	1469	2219	3661	2424	5654		15563	
1971	255	1807	2011	3802	1698	3933		13506	
1972	263	1855	3328	3973	1533	3696		14648	
1973	158	1362	1225	3682	1614	1581		9622	
1974	454	926	1449	2588	1628	1593		8638	
1975	216	1038	1930	1269	964	1140		6557	
1976	204	644	1224	904	1367	831		5174	
1977	216	580	2505	2946	3521	4231		13999	
1978	348	1587	3244	2614	4642	7244		19679	
1979	433	1768	2201	6378	9609	15201		35590	
1980	719	2303	2269	7781	10647	14852		38571	
1981	281	2810	3599	6119	7711	11505	7678	39703	
1982	206	2448	3176	7186	4536	3621	5491	26664	
1983	148	2803	3640	7430	5016	2500	7205	28742	
1984	175	3908	1889	5414	1149	1333	6090	19958	
1985	149	2936	957	1976	1178	1245		8441	
1986	76	1038	255	1209	1456	1268		5302	
1987	77	2366	423	6407	3602	1326	403	14604	
1988	333	6294	1342	2992	3346	4484		18791	
1989	634	8491	5671	8212	10845	4676		38529	
1990	476	9857	1482	9826	1917	5241		28799	
1991	876	8641	917	2782	1089	4007		18312	
1992	695	2710	563	1070	239	450		5727	
1993	333	327	168	970	19	109		1926	
1994	202	336	588	745	151	92		2113	72
1995	65	484	704	329	40	86	1	1709	26
1996	54	199	495	133	17	46		944	5
1997	22	438	199	100	13	130		903	32
1998	15	111	80	78	0	38		323	32
1999	6	140	55	336	7	4		548	24
2000	160	143	0	332	0	12		647	20

2001	252	1046	245	54	0	81	6	1684	20
2002	413	1802	505	214	24	813	120	3891	33
2003	1109	1522	334	274	3	479	236	3957	4
2004	902	1600	385	507	30	257	970	4653	1
2005	638	1827	1173	614	284	420	23	4979	0
2006	641	1783	1183	1282	358	1830	1190	8267	1
2007	738	2119	1304	1843	660	4391		11055	42
2008	870	3067	1538	3171	224	1134		10003	6
2009	325	1288	1189	2009	1142	1718		7671	2
2010	559	2990	1607	1795	1458	859		9268	2
2011	567	2364	2850	2905	1274	1047		11007	0
2012	632	1227	2115	4343	2002	299		10617	0.02
2013	1500	2558	2792	4703	1448	200		13201	35
2014	3083	6143	3756	4582	684	82		18330	38
2015	4088	7912	6426	6613	117	115		25272	50
2016	5929	11466	11270	5279	87	173		34203	39
2017	5797	11111	10060	4066	56	131		31220	82
2018	2213	6422	6189	7043	31	390		22289	51
2019	1988	2925	4212	8673	131	1822		19750	143
2020	1382	2324	4482	7412	222	2104		17926	223
2021	1133	2910	4217	4597	93	629		13580	286
2022	1657	2479	5707	4814	74	349		15079	360
2023	2679	3979	7307	8183	54	454		22655	440

Table 2: West Greenland inshore cod catches (tons) divided into month and NAFO–divisions.

NAFO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	%
1AUM	22	29	22	17	18	22	86	382	59	29	13	7	705	3%
1AUP	0	2	2	1	0	0	0	13	45	24	29	0	116	1%
1AX	81	116	82	46	65	97	171	298	326	436	122	18	1858	8%
1B	45	0	10	18	106	762	1029	733	237	309	398	331	3979	18%
1C	201	88	90	108	1024	1446	1449	820	371	867	466	377	7307	32%
1D	250	199	411	909	1677	1473	1330	561	483	494	246	150	8183	36%
1E		0	0	0	19	4	12	10	7	2	0	0	54	0.2%
1F	9	5	3	0	102	33	46	36	71	107	31	11	454	2%
Total	607	438	620	1100	3011	3838	4124	2853	1598	2268	1304	895	22655	
%	3%	2%	3%	5%	13%	17%	18%	13%	7%	10%	6%	4%		
ICES 14b								82	228	98	32	0.002	440	

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Table 3: West Greenland inshore cod catches (%) divided into month and gear and NAFO divisions and gear. ICES 14b is not included in gear/month.

Gear/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Poundnet	0.2%	0.02%	0.4%	4%	12%	15%	15%	9%	3%	4%	2%	2%	**67%**
Gillnet	1%	0.5%	0.4%	0.2%	0.2%	0.1%	0.04%	0.1%	0.1%	0.3%	0.1%	0.1%	**3%**
Jig	0.1%	0.1%	1%	0.4%	1%	1%	2%	3%	3%	3%	1%	0.2%	**16%**
Longline	2%	1%	1%	1%	0.4%	1%	0.4%	0.5%	1%	2%	2%	1%	**14%**
Total	**3%**	**2%**	**3%**	**5%**	**13%**	**17%**	**18%**	**13%**	**7%**	**10%**	**6%**	**4%**	

Gear/ NAFO	1AUM	1AUP	1AX	1B	1C	1D	1E	1F	**Total**	14b
Poundnet	1%		2%	14%	23%	26%	0.2%	1%	**67%**	
Gillnet	0.1%		1%	0.5%	0.1%	1%	0.001%	0.001%	**3%**	
Jig	0.1%	0.3%	2%	3%	5%	5%	0.03%	1%	**16%**	36%
Longline	1%	0.3%	3%	0.2%	4%	4%	0.01%	1%	**14%**	64%
Total	**3%**	**1%**	**8%**	**18%**	**32%**	**36%**	**0.2%**	**2%**		

Table 4: Number of weight measured cod at factories. Recalculated to length and used in the assessment.

NAFO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1AX	11333	11838	750	4262	9301	10329	1984		35171	34683	45397	6260	**171308**
1D	78958	64562	85639	166759	137727	199911	212653	86816	155126	129450	61827	15288	**1394716**

Table 5: Sampling from West Greenland inshore fisheries. Number (count) of aged cod by NAFO division and number of landings/number of length measured cod by NAFO division and gear.

	Aged cod		**Length measured cod**		
	NAFO div	Count	NAFO div	Gear	Count
	1C	70	1C	Jig	2/506
	1D	100	1C	Poundnet	6/924
	1F	21			
Total		191			8/1430

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Offshore catches

Table 6: Offshore catches (t) divided into NAFO divisions in West Greenland and East Greenland (ICES 14b). 1924-1995: Horsted 2000, 1995-2000: ICES Catch Statistics, 2001-present: Greenland Fisheries License Control. In East Greenland, the catch is solely recognized as the East Greenland Iceland Offshore Spawning Cod (EGIOSC).

Year	NAFO 1A	NAFO 1B	NAFO 1C	NAFO 1D	NAFO 1E	NAFO 1F	Unknown NAFO div.	Total West Greenland	Total East Greenland ICES 14b
1924							200	200	
1925							1871	1871	
1926							4452	4452	
1927							4427	4427	
1928							5871	5871	
1929							22304	22304	
1930							94722	94722	
1931							120858	120858	
1932							87273	87273	
1933							54351	54351	
1934							88422	88422	
1935							65796	65796	
1936							125972	125972	
1937							90296	90296	
1938							90042	90042	
1939							62807	62807	
1940							43122	43122	
1941							35000	35000	
1942							40814	40814	
1943							47400	47400	
1944							51627	51627	
1945							45800	45800	
1946							44395	44395	
1947							63458	63458	
1948							109058	109058	
1949							156015	156015	
1950							179398	179398	
1951							222340	222340	
1952	0	261	2996	18188	707	37905	257488	317545	
1953	4546	46546	10611	38915	932	25242	98225	225017	
1954	2811	97306	18192	91555	727	15350	60179	286120	4321
1955	773	50106	32829	87327	3753	4655	68488	247931	5135
1956	15	56011	38428	128255	8721	4922	66265	302617	12887
1957	0	58575	32594	62106	29093	16317	47357	246042	10453
1958	168	55626	41074	73067	21624	26765	75795	294119	10915
1959	986	74304	10954	30254	12560	11009	67598	207665	19178
1960	35	58648	18493	35939	16396	9885	76431	215827	23914
1961	503	78018	43351	70881	16031	14618	90224	313626	19690
1962	1017	122388	75380	57972	25336	17289	125896	425278	17315
1963	66	70236	73142	76579	46370	16440	122653	405486	23057
1964	96	49049	49102	82936	33287	13844	99438	327752	35577
1965	385	80931	66817	71036	15594	15002	92630	342395	17497
1966	12	99495	43557	62594	19579	18769	95124	339130	12870
1967	361	58612	78270	122518	34096	12187	95911	401955	24732
1968	881	12333	89636	94820	61591	16362	97390	373013	15701
1969	490	7652	31140	65115	41648	11507	35611	193163	17771
1970	278	3719	13244	23496	23215	15519	18420	97891	20907
1971	39	1621	28839	21188	9088	20515	26384	107674	32616
1972	0	3033	42736	18699	7022	4396	20083	95969	26629
1973	0	2341	17735	18587	10581	2908	1168	53320	11752
1974	36	1430	12452	14747	8701	1374	656	39396	6553
1975	0	49	18258	12494	6880	3124	549	41354	5925
1976	0	442	5418	10704	8446	2873	229	28112	13025
1977	127	301	4472	7943	8506	2175	35477 [1]	23524	18000 [2]
1978	0	0	11856	2638	3715	549	34563 [1]	18758	26000 [2]

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1979	0	16	6561	4042	1115	537	51139 [1]	12271	34000 [2]
1980	0	1800	2200	2117	1687	384	7241 [1]	8188	12000 [2]
1981	0	0	4289	4701	4508	255	0	13753	16000 [2]
1982	0	133	6143	10977	11222	692	1174	30341	27000 [2]
1983	0	0	717	6223	16518	4628	293	28379	13378
1984	0	0	0	4921	5453	3083	0	13457	8914
1985	0	0	0	145	1961	1927	2402	6435	2112
1986	0	0	0	2	72	24	1203	1301	4755
1987	0	0	5	815	67	43	3041	3971	6909
1988	0	0	919	17463	10913	6466	8101	43862	9457
1989	0	0	0	11071	48092	14248	2	73413	14669
1990	0	0	2	563	21513	10580	7503	40161	33508
1991	0	0	0	0	104	1942	0	2046	21596
1992	0	0	0	0	0	0	0	0	11349
1993	0	0	0	0	0	0	0	0	1135
1994	0	0	0	0	0	0	0	0	437
1995	0	0	0	0	0	0	0	0	284
1996	0	0	0	0	0	0	0	0	192
1997	0	0	0	0	0	0	0	0	355
1998	0	0	0	0	0	0	0	0	345
1999	0	0	0	0	0	0	0	0	116
2000	0	0	0	0	0	0	0	0	63
2001	0	0	0	0	0	0	0	0	125
2002	0	0	0	0	0	0	0	0	398
2003	0	0	0	0	0	0	0	0	485
2004	0	0	0	5	3	1	0	9	778
2005	0	0	0	0	0	72	0	72	819
2006	0	0	0	0	0.05	414	0	414	2042
2007	0	0	0	31	435	2011	0	2477	3194
2008	0	0	0	23	526	11378	0	11927	3258
2009	0	0	0	0	6	3354	0	3360	1642
2010	0	0	0	0	2	288	0	290	2388
2011	0	0	0	0.1	8	542	0	550	4571
2012	0	0	1	97	243	1473	0	1814	3941
2013	0	0	0	215	270	1412	0	1897	4104
2014	0	0	30	68	18	1833	0	1949	6060
2015	0	0	341	954	3569	3950	0	8814	11805
2016	0	0	67	1924	1764	2320	0	6075	12497
2017	0	0.4	1442	730	852	2561	0	5585	13738
2018	0	0	1994	675	1517	1815	0	6001	13251
2019	0	0	654	57	186	916	0	1813	17158
2020	0	0	101	0	1	675	0	777	15258
2021	0	0	96	0	0	192	0	288	25637
2022	0	0	0	0	0	0	0	0	26981
2023	0	0	0	469	809	228	0	1506	32008

1) Estimates for assessment include estimates of unreported catches. The total estimated value for West Greenland (inshore + offshore) was 73000 t in 1977 and 1978, 1979: 99000 t, 1980: 54000 t. The value given in the table are these values minus the inshore catches minus known offshore NAFO division catches.

2) Estimates for assessment include estimates of unreported catches in East Greenland.

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Table 7: Cod catches (tons) by area and month. East Greenland (14b) divided into 4 areas. NQ1 is located furthest to the north. In East Greenland the catch is solely recognized as the East Greenland Iceland Offshore Spawning Cod (EGIOSC).

	ICES/ NAFO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	%
West GL	1D							125	86	39			219	469	31%
	1E						163	100	138	128			280	809	54%
	1F							45	182					228	15%
	Total						**163**	**270**	**406**	**167**			**499**	**1506**	
	%						11%	18%	27%	11%			33%		
East GL	14b (NQ1)							57	70	17	9	86		239	1%
	14b (Q1Q2)	5824	1204	1086	163	730	3426	2533	196	817	893	1700	6329	24902	78%
	14b (Q3Q4)	58	212	881	2164	1088	737		24	1	91	238	39	5532	17%
	14b (Q5Q6)		387	133	236	544	32	1						1334	4%
	Total	**5881**	**1803**	**2100**	**2563**	**2362**	**4196**	**2591**	**291**	**835**	**993**	**2024**	**6368**	**32008**	
	%	18%	6%	7%	8%	7%	13%	8%	1%	3%	3%	6%	20%		

Table 8: Cod catches (t) by gear, area and month. East Greenland (14b) divided into 4 areas. NQ1 is located furthest to the north. In East Greenland the catch is solely recognized as the East Greenland Iceland Offshore Spawning Cod (EGIOSC).

Gear	ICES/ NAFO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Longline	1D							125	86	39			93	343
West Gl	1E						163	100	138	128			150	679
	1F							45	182					228
	Total						**163**	**270**	**406**	**167**			**243**	**1249**
East GL	14b (NQ1)								1	5	7	86		98
	14b (Q1Q2)	264						24	3	34	120	501	533	1478
	14b (Q3Q4)	38	77	876	2027	982	90		24	1	91	238	39	4483
	14b (Q5Q6)		387	122	2	172	18							702
	Total	**301**	**465**	**998**	**2029**	**1154**	**109**	**24**	**28**	**39**	**217**	**825**	**572**	**6761**
Trawl	1D												126	126
West Gl	1E												130	130
	1F													0
	Total												**256**	**256**
East Gl	14b (NQ1)							57	70	12	3			141
	14b (Q1Q2)	5560	1204	1086	163	730	3426	2509	193	784	773	1199	5796	23423
	14b (Q3Q4)	20	135	5	137	106	647							1049
	14b (Q5Q6)			11	235	371	14	1						632
	Total	**5580**	**1338**	**1102**	**535**	**1208**	**4087**	**2567**	**263**	**796**	**776**	**1199**	**5796**	**25246**

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Table 9: Length measured cod (number of hauls/number of length measured cod) in offshore fisheries by area and month used in assesment.

Gear	ICES/ NAFO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Longline	14b (NQ1)										1/118		
	14b (Q1Q2)										2/300	6/894	
	14b (Q3Q4)	1/288			17/3208	17/2471	2/445				2/201	7/705	
	14b (Q5Q6)												
	1F							2/293					
	1E						10/1556	6/886	10/1465	11/1645			7/1050
	1D							6/878	5/752	3/455			4/602
Trawl	14b (NQ1)												
	14b (Q1Q2)	22/3362	12/1803	11/1673	4/600	6/898	24/3580	20/3580		6/900	2/300	6/900	14/2307
	14b (Q3Q4)	1/150	5/748	2/300	2/300	1/149	1/150						
	14b (Q5Q6)			4/599	1/150	6/896							
	1F												
	1E												5/754
	1D												4/605

Table 10: Numbers of otoliths collected and age read from cod in offshore fisheries by area and month.

ICES/ NAFO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14b (NQ1)												
14b (Q1Q2)	342				19	240			100		128	117
14b (Q3Q4)				207							152	
14b (Q5Q6)					64				20			
1F							40	21				
1E						78	10	38	40			79
1D							97		56			14

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Table 11: Commercial catch of Northern Inshore spawning cod (N-WISC) by NAFO division and in the inshore and offshore area of West Greenland. * Not possible to split data into stock in 2001.

	Inshore				Offshore	In+Offshore
Year/NAFO	1A	1B	1C	**Total**	1C	**Total**
2000	32	66		**98**		**98**
2001						
2002	75	861	247	**1183**		**1183**
2003	250	742	167	**1159**		**1159**
2004	233	948	222	**1403**		**1403**
2005	129	856	534	**1519**		**1519**
2006	194	1017	653	**1863**		**1863**
2007	156	1146	605	**1907**		**1907**
2008	158	1546	729	**2432**		**2432**
2009	54	671	550	**1275**		**1275**
2010	120	1516	740	**2376**		**2376**
2011	94	1288	1323	**2704**		**2704**
2012	136	640	992	**1768**		**1768**
2013	317	1215	1258	**2789**		**2789**
2014	783	2917	1723	**5424**	5	**5428**
2015	928	3750	3198	**7876**	48	**7924**
2016	1391	5402	5935	**12728**	11	**12739**
2017	1502	5060	5312	**11875**	195	**12070**
2018	590	2907	3222	**6719**	296	**7015**
2019	502	1460	2258	**4220**	86	**4306**
2020	305	1233	2493	**4031**	10	**4041**
2021	234	1526	2297	**4057**	12	**4068**
2022	341	1168	2712	**4221**		**4221**
2023	544	1957	3579	**6081**		**6081**

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Table 12: Commercial catch of Southern Inshore spawning cod (S-WISC) by NAFO division and in the inshore and offshore area of West Greenland.* Not possible to split data into stock in 2001.

	Inshore				Offshore				In+Offshore
Year/NAFO	1D	1E	1F	**Total**	1D	1E	1F	**Total**	**Total**
2000	136		2	**138**					**138**
2001*									
2002	90	4	79	**173**					**173**
2003	125	1	95	**220**					**220**
2004	268	7	46	**321**					**321**
2005	245	46	50	**340**			1	**1**	**341**
2006	620	71	203	**894**			8	**8**	**902**
2007	773	135	486	**1394**	1	16	40	**58**	**1452**
2008	1282	44	128	**1455**	1	24	184	**209**	**1664**
2009	791	196	180	**1167**			53	**53**	**1220**
2010	715	244	102	**1061**			6	**6**	**1066**
2011	1205	221	143	**1569**			10	**10**	**1579**
2012	1913	332	50	**2295**	4	7	38	**49**	**2345**
2013	1870	247	42	**2159**	9	11	32	**51**	**2210**
2014	1759	145	18	**1922**	4	1	58	**63**	**1985**
2015	3043	33	28	**3104**	74	230	144	**448**	**3552**
2016	2548	31	42	**2621**	234	173	119	**526**	**3147**
2017	2012	20	34	**2066**	110	97	160	**366**	**2432**
2018	3558	11	134	**3702**	102	185	135	**421**	**4123**
2019	4452	36	408	**4897**	8	24	62	**94**	**4991**
2020	3712	66	436	**4213**			28	**28**	**4241**
2021	2353	32	280	**2665**			20	**20**	**2685**
2022	2439	29	133	**2601**					**2601**
2023	4527	23	195	**4744**	65	108	18	**191**	**4936**

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Table 13: Commercial catch of West Greenland Offshore Spawning Cod (WOSC) by NAFO division and in the inshore and offshore area of West Greenland.* Not possible to split data into stock in 2001.

	Inshore							Offshore					In+Offshore
Year/NAFO	1A	1B	1C	1D	1E	1F	**Total**	1C	1D	1E	1F	**Total**	**Total**
2000	80	48		48			**176**						**176**
2001*													
2002	211	594	106	34	2	13	**959**						**959**
2003	605	570	79	52	0	15	**1321**						**1321**
2004	529	613	96	100	3	8	**1349**						**1349**
2005	300	562	233	84	16	8	**1203**				2	**2**	**1206**
2006	359	693	362	316	33	34	**1797**			0	12	**12**	**1809**
2007	392	601	269	390	63	73	**1788**		5	61	41	**107**	**1895**
2008	463	898	321	508	18	20	**2226**		4	82	162	**248**	**2474**
2009	175	350	253	287	71	28	**1163**			1	56	**57**	**1220**
2010	313	943	382	274	89	17	**2018**				5	**5**	**2023**
2011	342	649	659	478	82	25	**2235**			1	12	**13**	**2248**
2012	367	359	449	548	132	16	**1873**		12	25	43	**79**	**1953**
2013	809	798	668	752	166	13	**3206**		32	35	45	**112**	**3318**
2014	1618	1870	938	899	83	7	**5415**	10	13	3	76	**102**	**5517**
2015	2066	2116	1583	1725	24	15	**7529**	118	227	687	342	**1374**	**8903**
2016	2845	3189	2709	1728	30	48	**10551**	24	684	537	373	**1618**	**12169**
2017	2862	3515	2552	1280	19	34	**10262**	552	275	292	513	**1632**	**11894**
2018	1165	2264	1699	2204	10	97	**7440**	821	283	566	391	**2062**	**9501**
2019	1083	984	1161	2401	18	103	**5750**	298	23	70	151	**542**	**6292**
2020	787	718	1180	1903	27	57	**4672**	39		0	46	**85**	**4757**
2021	677	914	1204	1249	17	33	**4094**	45			33	**77**	**4172**
2022	1021	815	1891	1433	16	22	**5198**						**5198**
2023	1552	1359	2330	2099	10	37	**7387**		176	288	27	**491**	**7878**

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Table 14: Commercial catch of East Greenland Iceland Offshore Spawning Cod (EGIOSC) by NAFO division in the inshore and offshore area of West Greenland and total Greenland. * Not possible to split data into stock in 2001.

Year/ NAFO	Inshore West							Offshore West					In+Offshore West	East+West
	1A	1B	1C	1D	1E	1F	Total	1C	1D	1E	1F	Total	Total	Total
2000	47	29		148		10	234						234	297
2001*														
2002	140	405	169	96	19	748	1576						1576	1975
2003	324	307	110	115	2	400	1258						1258	1742
2004	378	461	168	273	29	271	1580						1580	2358
2005	213	417	411	288	223	363	1916				68	68	1984	2803
2006	197	373	366	561	315	1901	3713				394	394	4107	6149
2007	189	372	431	680	462	3831	5964		24	357	1930	2312	8276	11470
2008	249	623	488	1381	162	986	3890		18	421	11033	11471	15361	18620
2009	97	267	387	931	875	1510	4066			5	3245	3250	7316	8958
2010	126	532	485	806	1125	740	3814			2	277	279	4093	6481
2011	131	427	868	1222	971	879	4498			7	520	527	5026	9597
2012	128	228	674	1881	1537	232	4681		81	211	1391	1684	6365	10306
2013	375	546	867	2081	1034	144	5047		174	224	1336	1734	6780	10884
2014	682	1355	1095	1924	457	56	5570	16	50	14	1699	1779	7349	13409
2015	1094	2046	1646	1845	60	72	6763	176	653	2652	3464	6945	13708	25513
2016	1692	2875	2625	1003	26	82	8303	32	1006	1053	1828	3920	12223	24720
2017	1433	2536	2195	774	17	63	7018	694	345	463	1888	3391	10409	24148
2018	458	1251	1268	1281	10	160	4428	877	290	766	1289	3222	7650	20901
2019	403	480	793	1819	77	1310	4883	271	26	92	702	1091	5975	23133
2020	290	373	808	1797	129	1611	5009	53		1	601	656	5664	20923
2021	222	470	716	995	45	316	2764	39			139	179	2943	28580
2022	295	497	1103	942	28	194	3059						3059	30039
2023	583	662	1397	1557	21	222	4443		228	412	183	823	5266	37274

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Figures

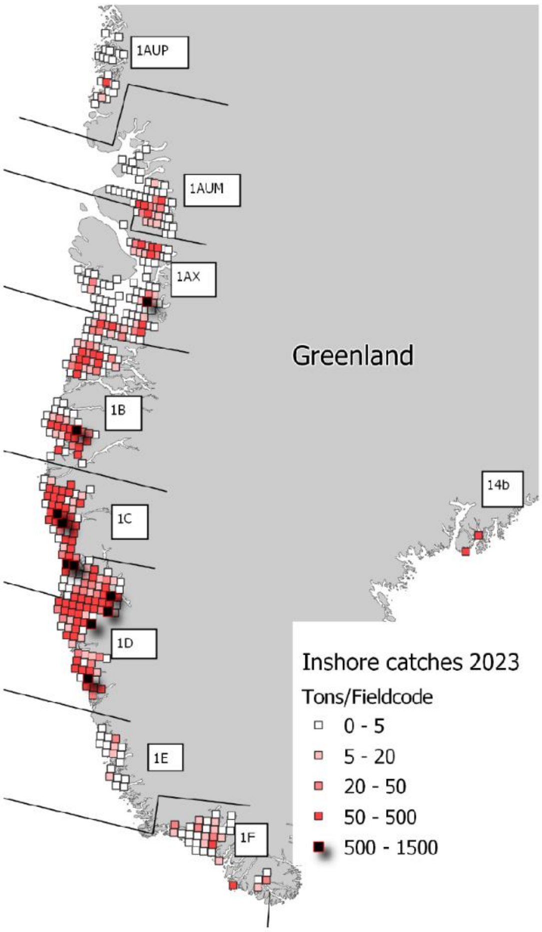

Figure 1: Distribution of commercial inshore fishery along the coastline of Greenland in total tons by field code.

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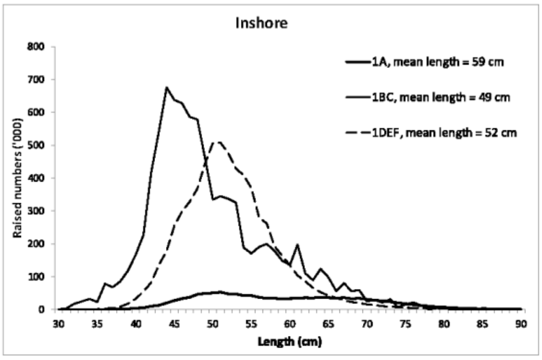

Figure 2: Length distribution in the inshore fishery. NAFO 1A corresponds to the inshore area of Disko Bay (1AX), Uummaannaq (1AUM) and Upernavik (1AUP) furthest to the north.

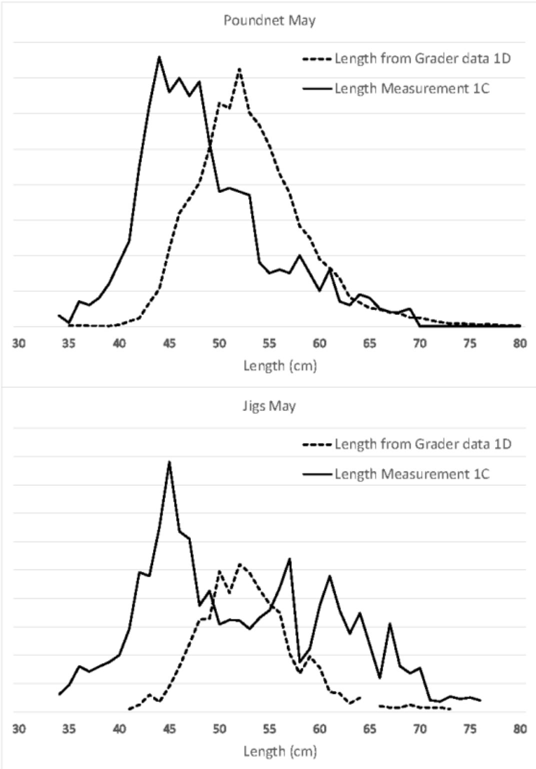

Figure 3: Length distribution in the inshore fishery for Poundnets (top) and jigs (bottom) in NAFO 1D and NAFO 1C. Based on Grader data in NAFO 1D and length measurements in NAFO 1C.

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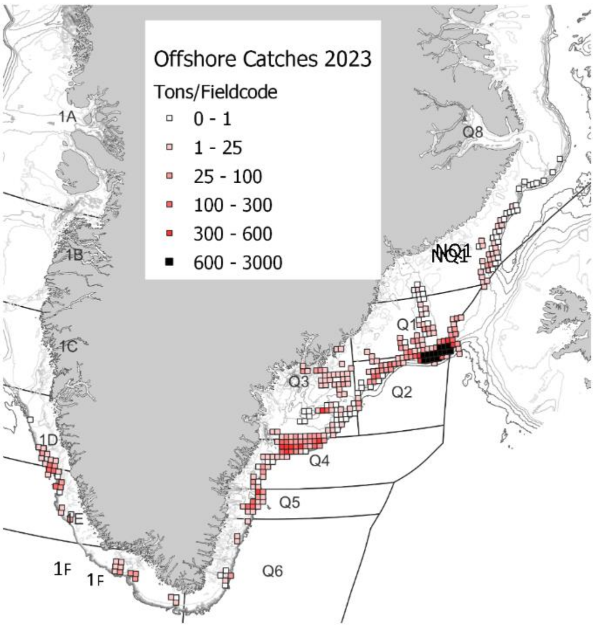

Figure 4: Distribution of commercial offshore fishery along the coastline of Greenland in total tons by field code. Dohrn Bank is in the eastern part of Q2.

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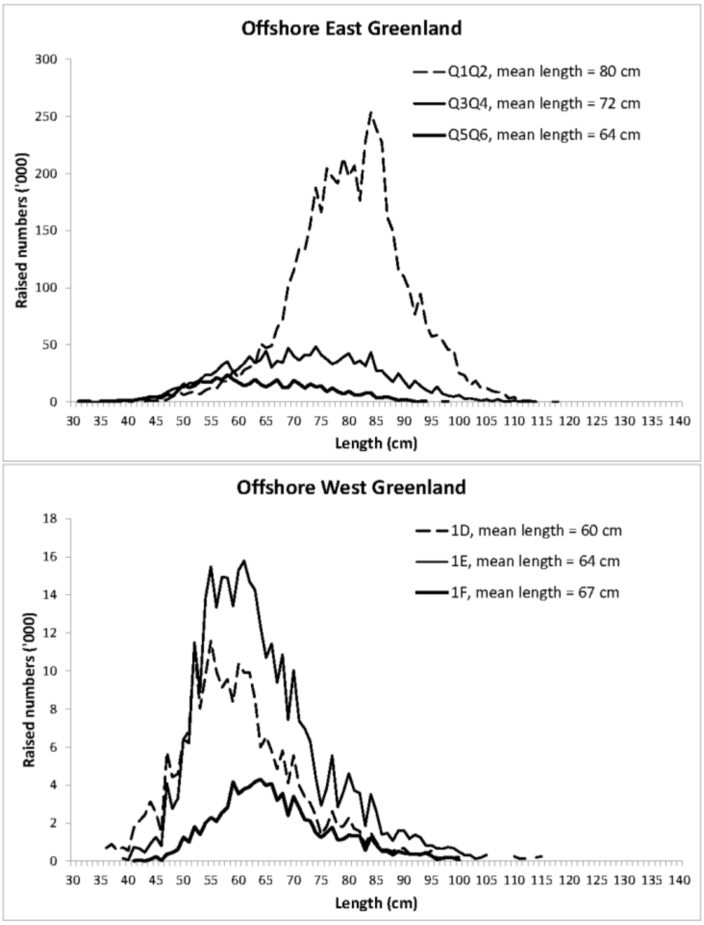

Figure 5: Length distribution in East and West Greenland offshore fishery. Q1Q2 corresponds to the Dohrn Bank area.

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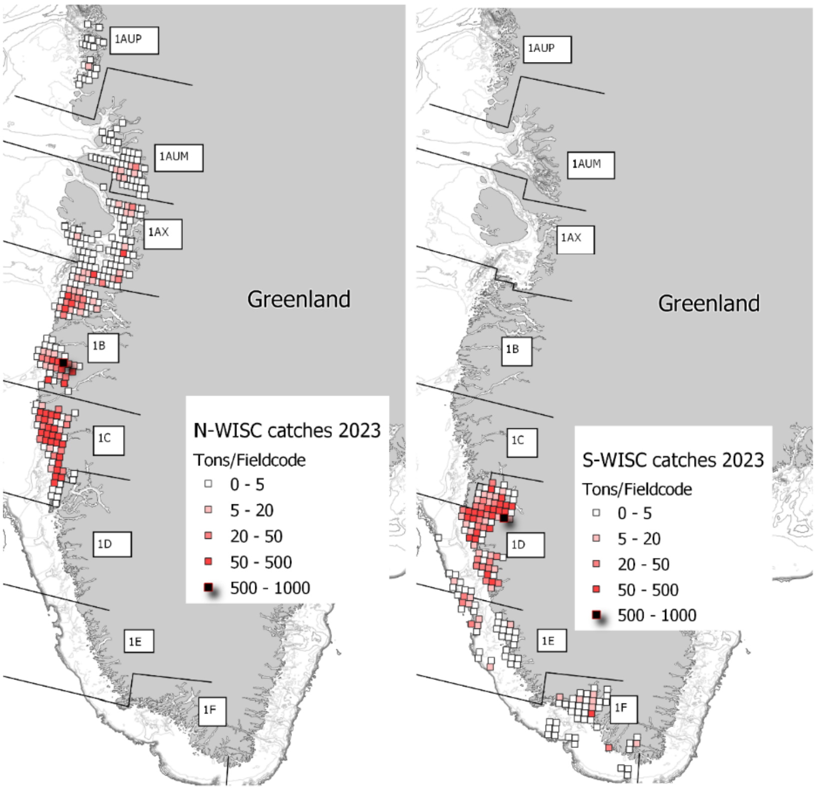

Figure 6: Distribution of Northern (N-WISC) and Southern (S-WISC) West Greenland Inshore Spawning Cod in the commercial fishery in Greenland in total tons by field code.

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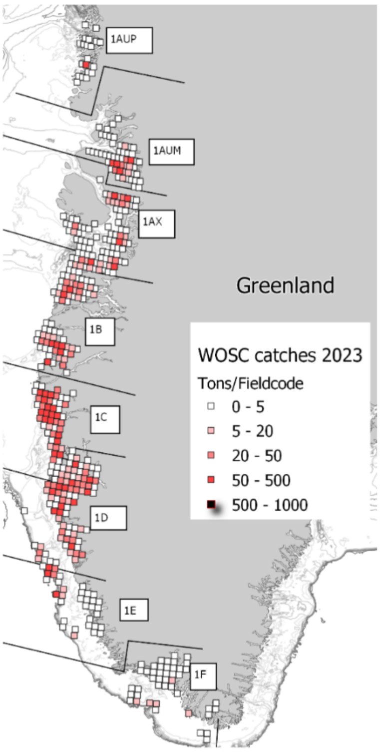

Figure 7: Distribution of West Greenland Offshore Spawning Cod (WOSC) in the commercial fishery in Greenland in total tons by field code.

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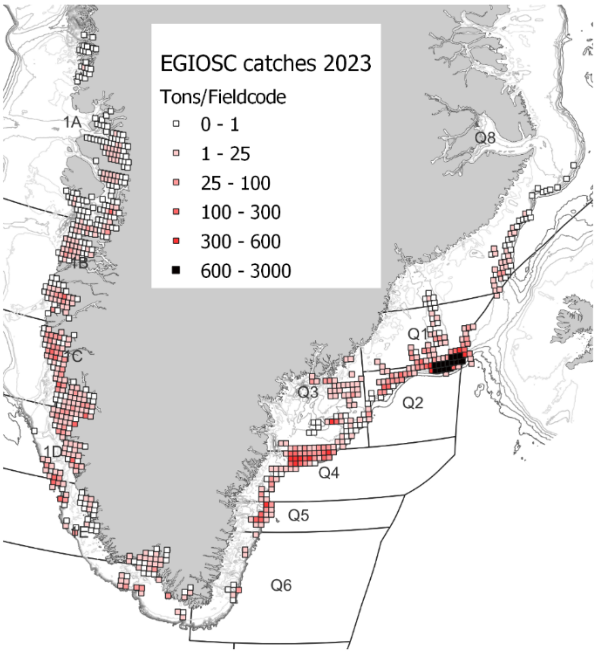

Figure 8: Distribution of East Greenland Iceland Offshore Spawning Cod (EGIOSC) in the commercial fishery in Greenland in total tons by field code. Dohrn Bank is in the eastern part of Q2.

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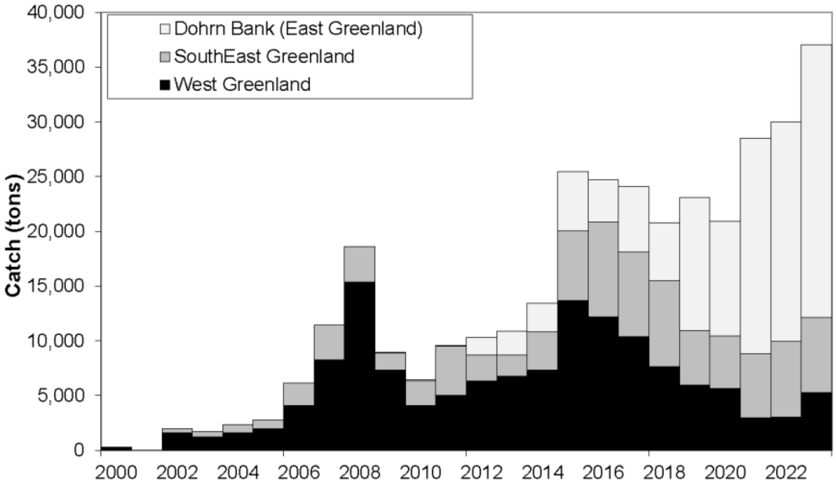

Figure 9: Total catch of East Greenland Iceland Offshore Spawning Cod (EGIOSC) by area. Dohrn Bank = Q1-Q2, SouthEast Greenland = Q3-Q6, West Greenland = NAFO divisions 1A-1F.

ICES North Western Working Group, 22 – 26 April 2024: WD 04

Sensitivity test of changes to the genetic data for Atlantic cod in Greenland waters in the 2023 assessment.

Tanja Buch[1], Anja Retzel[1], Teunis Jansen[1,2], Søren Post[1]

[1]Greenland Institute of Natural Resources, 3900 Nuuk, Greenland,
[2]DTU Aqua, National Institute of Aquatic Resources, 2800 Kgs. Lyngby, Denmark

Introduction

The cod stocks in Greenland are:

- West Greenland Inshore Spawning Cod (WISC), assessed as:
    - Northern West Greenland Inshore Spawning Cod (N-WISC)
    - Southern West Greenland Inshore Spawning Cod (S-WISC)
- West Greenland Offshore Spawning Cod (WOSC)
- East Greenland Iceland Offshore Spawning Cod (EGIOSC)
- Iceland Inshore Spawning Cod (ISI)

Details on the cod stocks, data, and assessment methods can be found in WKGREENCOD WD01, WD02, and WD05-WD11 as well as the stock annex cod.21.1.isc (WISC), cod.21.1.osc (WOSC) and cod.2127.1.14.osc (EGIOSC).

In order to improve sampling coverage for the years 2008 and 2010 archived samples were analysed in 2023. These samples showed higher than previously seen presence of the Icelandic inshore spawning cod stock (ISI) in the inshore areas 1E and 1F (figure 1). Previously it was decided to exclude the ISI stock from the stock splitting (see WKGREENCOD WD 01 and WD 05), the basis for this was that we were seeing only few occurrences and without patterns. The period 2008-2010 had a large fishery in the areas where the new samples showed high prevalence of ISI, this raised concerns that the split of catches for this time period were incorrect.

It was therefore decided that for the splitting model ISI was merged with EGIOSC. This was done in order to account for the presence of this stock historically and any future incoming ISI cohorts. The number of ISI individuals observed in Greenland waters are at such a low level that it is difficult to include it as a separate stock in the split model. Merging the stock with the EGIOSC stock are also in line with previous studies (Christensen et al 2022) and in Iceland the two stocks are combined for the assessment (ICES 2023). Continuous sampling will allow monitoring of this stock, should it become prevalent in large numbers this decision can be re-evaluated.

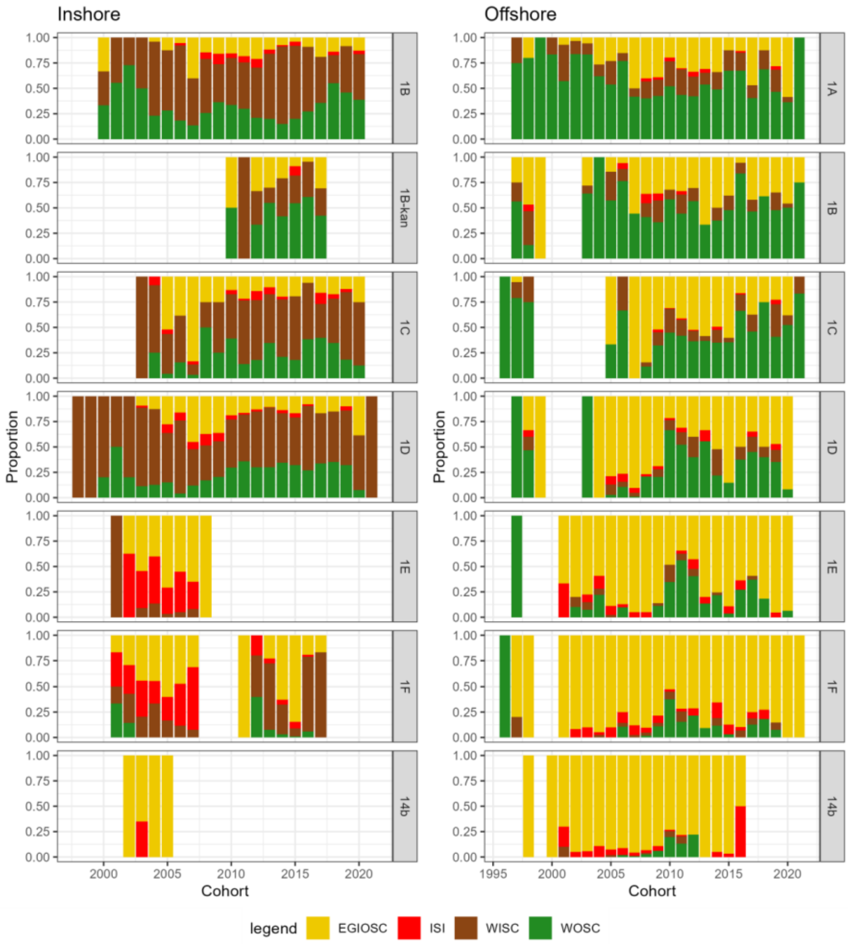

Figure 1: Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2022 by area and cohort.

Methods

In order to test the impact of both adding additional samples historically and merging ISI with EGIOSC 3 separate test were conducted by making changes to the dataset used to fit the split model:

1. Adding the new 2008 and 2010 samples to the existing dataset
2. Using the existing dataset without the new samples but with ISI and EGIOSC merged
3. Adding the new 2008 and 2010 samples to the existing dataset and with ISI and EGIOSC merged.

ICES North Western Working Group, 22 – 26 April 2024: WD 04

The remained data treatment and assessment set up remained the same as described in the stock annexes for cod.21.isc (northern and southern component) and cod.21.osc.

Data added to the dataset was 777 + 437 ISI = 1214 samples (table 1) resulting in a total of 9885 samples (table 2).

Table 1. Overview of added samples used to split data by year, in/offshore and NAFO divisions.

	NEW DATA Added (EGIOSC, WOSC, WISC)						ISI added					
Inshore	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**
2000	0	0	0	0	0	0	0	0	0	0	0	0
2008	39	30	0	16	7	25	0	0	0	2	21	19
2010	28	18	0	33	9	32	0	0	0	1	2	21
2011	0	0	0	0	39	0	0	1	3	5	23	0
2012	0	0	0	0	0	0	0	1	0	1	0	0
2013	0	0	0	0	0	0	2	16	0	11	0	0
2016	0	0	0	0	0	0	2	1	0	2	0	0
2017	0	0	0	0	0	0	0	84	0	25	0	0
2018	0	0	0	0	0	0	0	0	5	2	0	0
2019	0	0	0	0	0	0	2	2	7	7	0	9
2020	0	0	0	0	0	0	0	0	0	0	0	2
2021	0	0	0	0	0	0	3	2	5	1	0	1
2022	0	0	0	0	0	0	2	1	3	2	0	0
Offshore	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**
2000	0	0	0	0	0	0		1		1		
2008	0	0	0	41	107	96				4	9	8
2010	0	0	52	77	62	66		1		4	4	3
2011	0	0	0	0	0	0		4	2	1		6
2012	0	0	0	0	0	0	1	1	1			
2013	0	0	0	0	0	0	1	4		9	3	14
2016	0	0	0	0	0	0	3				2	6
2017	0	0	0	0	0	0						
2018	0	0	0	0	0	0			2	1		
2019	0	0	0	0	0	0			5	1	6	10
2020	0	0	0	0	0	0						
2021	0	0	0	0	0	0						
2022	0	0	0	0	0	0	1		1	4	7	7

Table 2. Number of samples per area for the years 2000-2022: Inshore and Offshore. Area specifies the NAFO subarea. Samples give the number of cod sampled, where age and position are available and genetic assignment is 0.7 or above.

NAFO	**Inshore**	**Offshore**	**Combined**
1A		312	312
1AUM	145		145
1AUP	52		52
1AX	465		465
1B	1985	498	2483
1B-kan	151		151
1C	600	860	1460
1D	2147	709	2856
1E	135	676	811
1F	365	785	1150
Total	**5383**	**4502**	**9885**

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The procedures were the same as for the last assessment. Overview of the naming of the assessment models are given in Table 3 and can be found on www.stockassessment.org.

Table 3. Overview of run number, stock name and assessment name.

Run	Stock	Stockassessment.org name
1	Cod.21.isc (north) (N-WISC)	Sensitivity1_N-WISC_23
1	Cod.21.isc (south) (S-WISC)	Sensitivity1_S-WISC_23
1	Cod.21.osc (WOSC)	Sensitivity1_WOSC_23
2	Cod.21.isc (north) (N-WISC)	Sensitivity2_N-WISC_23
2	Cod.21.isc (south) (S-WISC)	Sensitivity2_S-WISC_23
2	Cod.21.osc (WOSC)	Sensitivity2_WOSC_23
3	Cod.21.isc (north) (N-WISC)	Sensitivity3_N-WISC_23
3	Cod.21.isc (south) (S-WISC)	Sensitivity3_S-WISC_23
3	Cod.21.osc (WOSC)	Sensitivity3_WOSC_23

Results

In the following all the SAM assessments updated with the new input data were compared to the equivalent SAM assessment accepted at the NWWG 2023, this will be referred to as the basemodel.

Run 1: Adding the new 2008 and 2010 samples to the existing dataset.

For run 1 the addition of extra samples overall the internal consistencies for both survey and commercial data for all three stocks were similar to those presented at NWWG 23.

For N-WISC the estimated catches are in line with those estimated by the basemodel. SSB is at the same level as the basemodel, and F is slightly higher in the early part of the timeseries (see Figure A1).

For S-WISC the estimated catch was revised down for the years 2008-2014, but was within the confidence interval of the basemodel estimates. In the same time period SSB was reduced slightly and recruitment in 2007 and 2009 were also lower (see Figure A2). For the retrospective analysis the peels are similar.

For WOSC the estimated catches are in line with those estimated by the basemodel. SSB is at the same level as the basemodel, and F is slightly lower in the early part of the timeseries (see Figure A3).

For all stocks the perception of the stock status remains the same with the update, the impact are mainly for S-WISC catches which is expected.

Run 2: Using the existing dataset without the new samples but with ISI and EGIOSC merged.

For run 2 where of ISI was merged with EGIOSC, the internal consistencies for both survey and commercial data for all three stocks were similar to those presented at NWWG 23. For S-WISC the internal consistency for the inshore survey were improved slightly. For the S-WISC the SSB was a bit lower for most of the timeseries, catches are a bit lower in the middle of the timeseries. For WOSC and N-WISC the estimates SSB, catches and F are in line with baseline estimates.

Run 3: Adding the new 2008 and 2010 samples to the existing dataset and with ISI and EGIOSC merged.

For all three stocks run 3 was similar to run 1, indicating the main impact of the update are related to adding for samples for the years 2008 and 2010.

Although this sensitivity analysis show that the overall perceptions of the stocks do not change with updates of historic data, adding additional samples when available still improves understanding of the stock structure. And in this case indicates some years with larger proportion of ISI than previously seen.

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Conclusion

The updated assessment did not change the perception of stock status and did not have any major effect on the assessment model (SAM) output. The main impact was on S-WISC in the middle of the timeseries, which was expected as the added data updates the perception of the number of EGIOSC fish in the distribution areas of the S-WISC stock.

References

Christensen, H.T., Rigét, F., Retzel, A., Nielsen, E.H., Nielsen, E.E., Hedeholm, R.B. 2022. Year-round genetic monitoring of mixed stocks in an Atlantic cod (*Gadus morhua*) fishery; implications for management. ICES Journal of Marine Science. 79(5), 1515-1529. DOI: 10.1093/icesjms/fsac076.

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ICES. 2023b. Northwestern Working Group (NWWG). ICES Scientific Reports. 5:64. https://doi.org/10.17895/ices.pub.23267153

Appendix

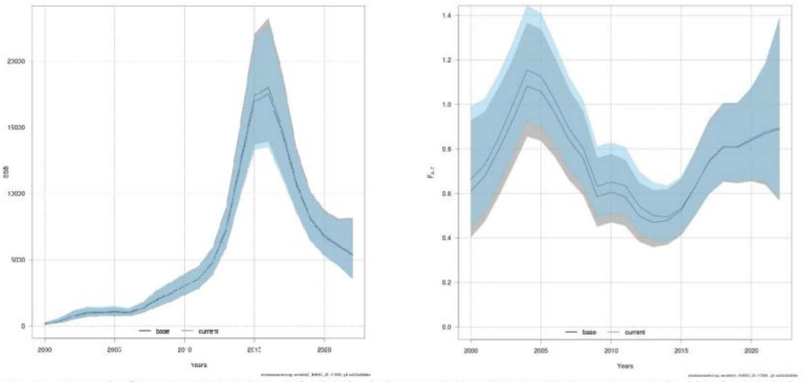

Figure A1. SSB and F for N-WISC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 1 assessment.

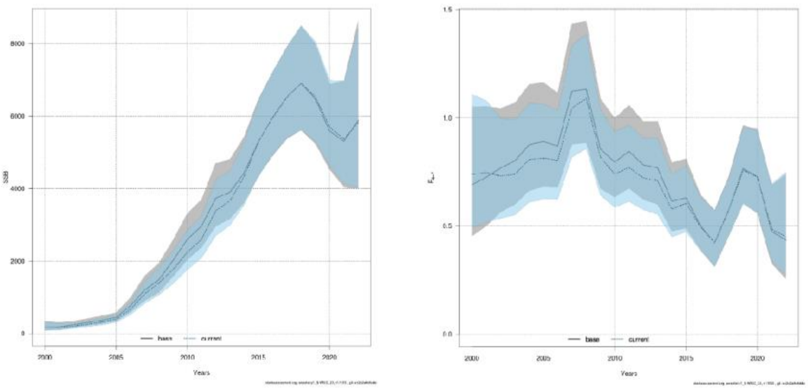

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Figure A2. SSB and F for S-WISC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 1 assessment.

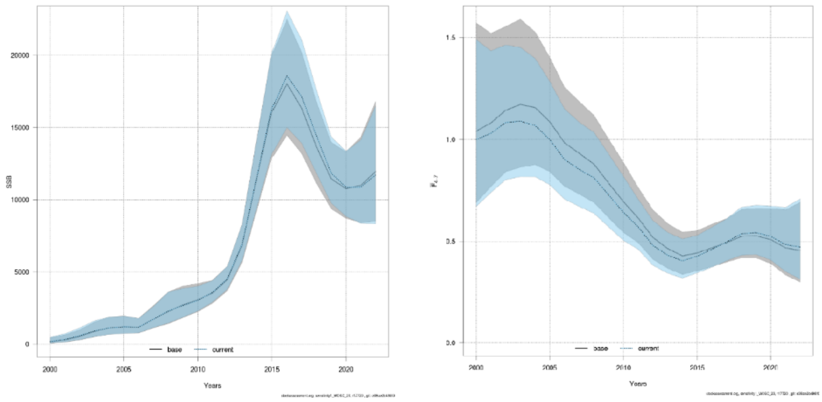

Figure A3. SSB and F for WOSC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 1 assessment.

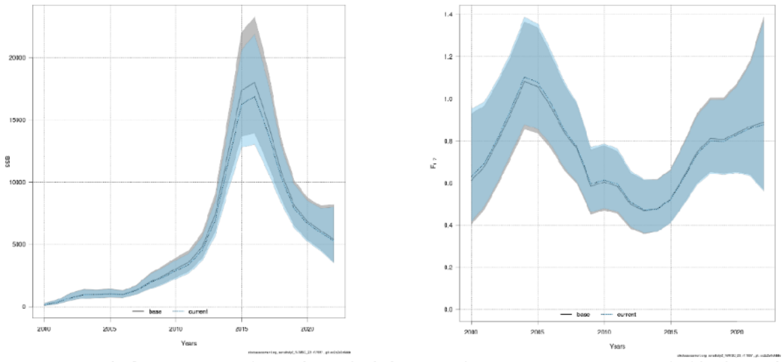

Figure A4. SSB and F for N-WISC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 2 assessment.

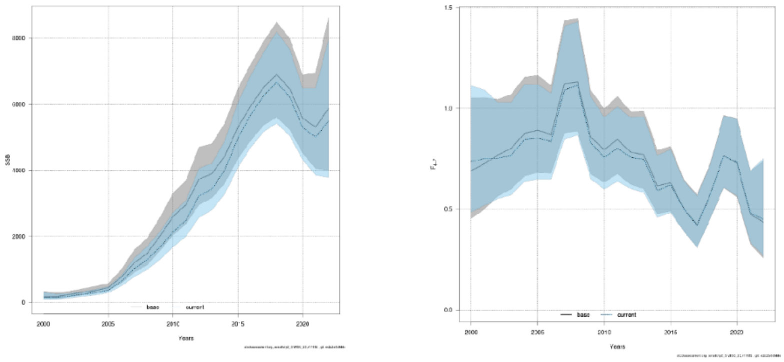

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Figure A5. SSB and F for S-WISC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 2 assessment.

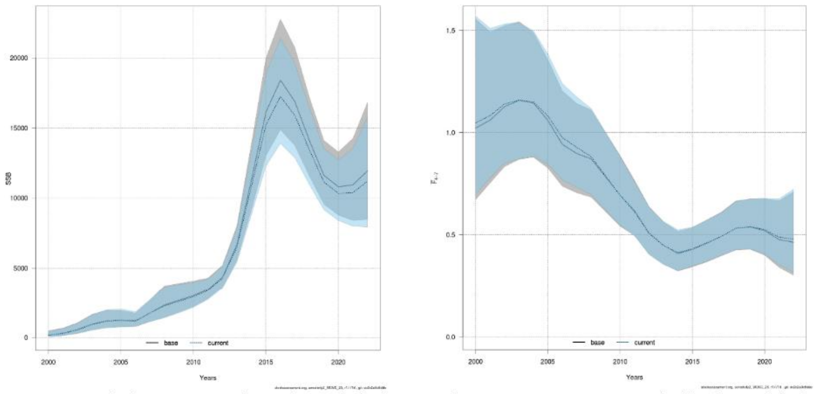

Figure A6. SSB and F for WOSC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 2 assessment.

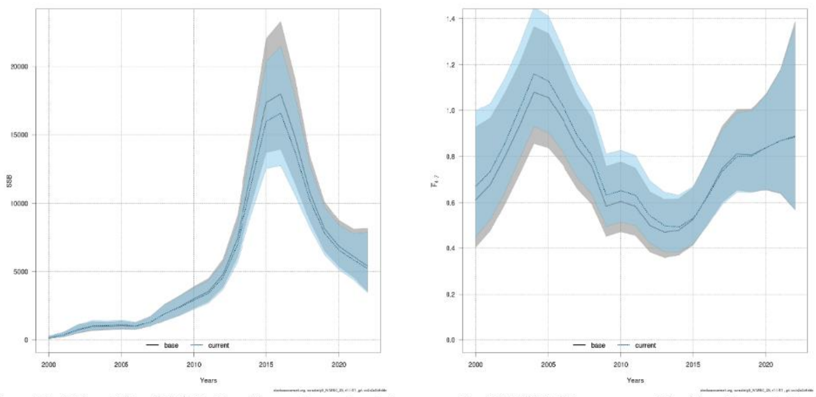

Figure A7. SSB and F for N-WISC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 3 assessment.

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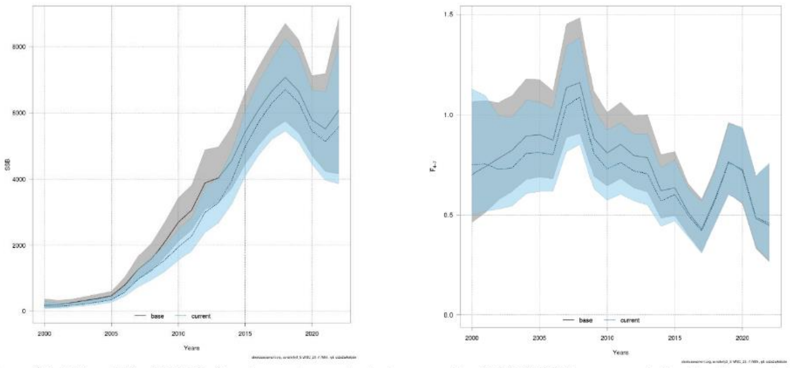

Figure A8. SSB and F for S-WISC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 3 assessment.

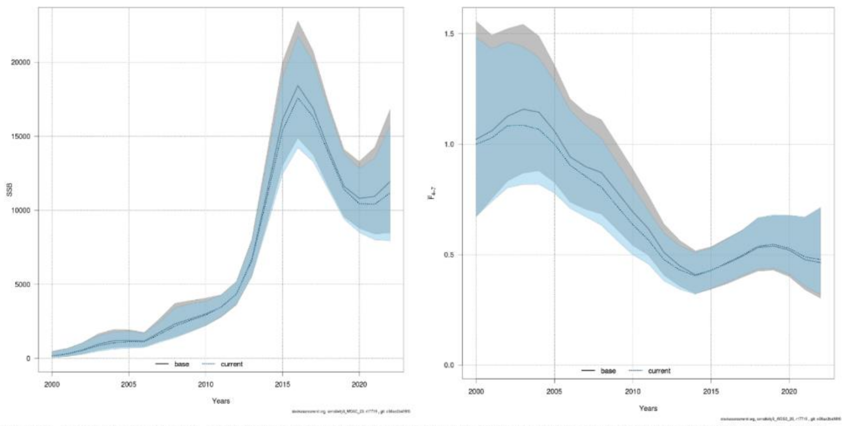

Figure A9. SSB and F for WOSC. Grey line and grey shaded area are the 2023 NWWG assessment the blue lien and shaded area are from the run 3 assessment.

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Greenland Genetic data for Atlantic cod in Greenland waters used in assessment 2024

Anja Retzel, Tanja B. Buch

Greenland Institute of Natural Resources, Nuuk, Greenland

anre@natur.gl

Introduction

This document gives an overview of the available genetic data for cod in Greenland used in the assessment process. The cohort groupings used and the procedure for defining these groups are described. A comparison of the composition of stocks between raw and predicted data are presented. The stocks are:

- West Greenland Inshore Spawning Cod (WISC)
- West Greenland Offshore Spawning Cod (WOSC)
- East Greenland Iceland Offshore Spawning Cod (EGIOSC)
- Iceland Inshore Spawning Cod (ISI)

In addition to the samples available for the NWWG 2023 (Retzel & Buch 2023), 1215 samples from surveys and 85 from the inshore commercial fishery in 2023 have been added to the dataset. In addition, 1214 historical samples have also been added (see WD 04). Only samples for which an age is assigned, position is available, and which have been assignment to one of the four stocks (WOSC, WISC, EGIOSC, ISI) with a probability of 0.7 or higher are included (table 1). ISI is treated as EGIOSC in the model (se WD 04). The total number of samples with all the information needed for the GAM model are 11083 from West Greenland (table 2). Sampling is well spread from north to south comprising the distribution limit of Atlantic cod in Greenland (figure 1).

Results

The new data show the same pattern of distribution with WOSC dominating in the northern region, WISC dominating inshore in the mid region, and EGIOSC dominating in the southern region. The offshore mid region is a mix between WOSC and EGIOSC (figure 2).

Cohort grouping

The strength of cohorts is highly variable, as is the distribution range along the coast (how far north in West Greenland). As the geographical distribution varies between cohorts, we aimed to model the distribution by cohort and age. However, the genetic samples do not have proper coverage for all cohorts throughout the region; therefore, we grouped those showing similar distribution patterns. To identify "similar" strong cohorts, mean CPUE by cohort for all stations in the Greenland offshore bottom trawl survey (SF) for ages 3, 4 and 5 was calculated (Figure 3). Values were normalized (divided by max). Strong cohorts were then defined as those above the 75% quantile. In addition, mean center of distribution by age (Figure 4) was performed on these strong cohorts to identify a difference in the distribution range. Furthermore, the genetic split of the strong cohorts by NAFO region was investigated to find out if there was a difference in the proportions across regions (Figure 5-15).

Finally, cohorts showing similar distribution patterns were grouped and used as categorical factors in the GAM model.

Based on the above, the following grouping was decided (figure 18-20):

- **LowMediumYC_Before09:** Low and medium sized cohorts of mixed origin before 2009 YC where EGIOSC leave West Greenland at age ~5 (1996,1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, 2007,2008)
- **LargeYC_EG_NotFarWest**: Strong cohorts distributed further south, primarily of EGIOSC origin (2003, 2014 and 2015): however, as too low sampling in the age group 2-3, it was decided to include the 1997 YC in this group as it has similar genetic split as the 2003+2014 and 2015 YC at older ages.
- **LargeYC_EG_FarWest_09**: A single strong cohort primarily of EGIOSC origin (2009 YC) reaching far north.
- **LargeMediumYC_10_11_12**: Strong and medium cohorts primarily of WOSC origin (2010,2011,2012 YC). 2010 is a strong cohort, but due to low sampling inshore at ages 4-6, it was decided to group it with 2011 and 2012. These 3 YC were fished at high levels in the inshore fishery at ages 4-6 and had a similar genetic composition.
- **LowMediumYC_After12**: Low and medium sized cohorts of mixed origin after 2009 YC where EGIOSC are staying in West Greenland at older ages +5 (2013, 2016, 2017,2018 and 2021).
- **Cohort_17**: 2017 Cohort by itself as it does not resemble any of the other cohorts groupings.
- **LargeYC_19_20:** 2019+2020 as they are strong cohorts.

New data from 2023 changed the perception of groupings of new cohorts in the group "LowMediumYC_After12" where 2017 cohort was treated by itself and the 2019 and 2020 became a group by itself.

New Cohorts

Each year the 5 most recent cohorts are scrutinized to judge which cohort grouping they fall into (figure 16-17). Several aspects are combined to judge what characterizes a specific cohort.

1. Which stock dominates a specific cohort (focus on offshore data), and particularly if a cohort is dominated by EGIOSC, how far north is this stock the dominating one. Review of inshore composition to judge if there are any patterns.
2. How large is the cohort, roughly grouped into low, medium and large.
3. For large cohorts, how far north do we see the large cohorts.
4. Compare to previously defined groupings and judge if the cohort fits into an already defined cohort group. If not, consider if there are enough samples that a new grouping should be added.
5. Default for incoming cohorts is '**LowMediumYC_After12**'.

Test of split model

I order to judge the impact of the cohort groupings and other assumptions in the split model, the split model was used to predict on the genetic dataset. For all cases where more than 10 samples were available the predicted data showed good agreement with the samples and the definition of cohort groupings. See figures 21-26.

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References

Retzel, A., Buch, T.B., 2023. Greenland Genetic data for Atlantic cod in Greenland waters used in assessment 2023. ICES North Western Working Group 2023, WD 04.

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Tables

Table 1. Overview of samples collected and used to split data (all samples have location and age, and are assigned to one of the three stocks (WOSC, WISC, EGIOSC) with 0.7 or higher. Samples which have not been used for the split model before are marked with 'new' in the year column. Currently data from east Greenland are not used in the split model.

Year	Source	Area	Samples	Method	Reference
2000	Both commercial fisheries and surveys. Focus on years important to the fisheries. Fin clippings and otolith archive	West offshore 1A-1D, 1F	91 + 2 ISI (NEW) = 93	GeneClass/ DAPC	Bonanomi et al 2015
2008	Spawning samples (March to May). fin clippings.	West offshore: 1E West Inshore: 1D-1F	142 + 20 ISI (NEW) = 162	DAPC	Therkildsen et al 2013
2008	Both commercial fisheries and surveys. Focus on years important to the fisheries. Fin clippings and otolith archive	West offshore: 1B,1D-1F	43 + 5 ISI (NEW) = 48	GeneClass/ DAPC	Bonanomi et al 2015
2008 NEW	Survey. Fin clippings (Analysed 2023)	West Offshore: 1D-1F	260	GeneClass	NWWG 2024
2008 NEW	Spawning samples. Fin clippings (Analysed 2023)	West Inshore: 1AX, 1B, 1D-1F	139	GeneClass	NWWG 2024
2010	Spawning samples (March to May). fin clippings.	West offshore: 1A-1C, 1F West: inshore 1B East offshore + inshore	185 + 9 ISI (NEW) = 194	DAPC	Therkildsen et al 2013
2010 (NEW)	Survey. Fin clippings (Analysed 2023)	West Offshore: 1C-1F	268	GeneClass	NWWG 2024
2010 (NEW)	Spawning samples. Fin clippings (Analysed 2023)	West Inshore: 1AUM, 1AX, 1B, 1D-1F	144	GeneClass	NWWG 2024
2011	Survey fin clippings	West inshore: 1C East offshore	59 + 6 ISI (NEW) = 65		WKGREENCOD
2011	Survey finclippings (analysed in 2022)	West offshore: 1A-1F West inshore: 1B-1E East offshore	548 + 46 ISI (NEW) + 39 (NEW) = 633	Geneclass	WKGREENCOD
2012	Both commercial fisheries and surveys. Focus on years important to the fisheries. Fin clippings and otolith archive	West offshore: 1A-1F	134 + 3 ISI (NEW) = 137	GeneClass/ DAPC	Bonanomi et al 2015
2012	Survey finclippings (analysed in 2022)	West offshore: 1B-1C West inshore: 1B, 1D	94 + 2 ISI (NEW) = 96	Geneclass	WKGREENCOD
2013	Commercial samples, fin clippings. Collected in connection with master thesis	West inshore 1B and 1D	173 + 27 ISI (NEW) = 200	GeneClass/ DAPC	Henriksen 2015
2013	Survey, fin clippings (analysed in 2022)	West offshore 1A-1F East offshore	1117 + 53 ISI (NEW) = 1170	GeneClass	WKGREENCOD
2016	survey, fin clippings	West inshore: 1A, 1B, 1D	320 + 4 ISI (NEW) = 324	GeneClass/ DAPC	WKGREENCOD
2016	Survey, fin clippings (analysed 2022)	West offshore: 1A-1F	365 + 12 ISI (NEW) = 377	GeneClass	WKGREENCOD
2017	PIFT project. Commercial west inshore (jan-dec)	West Inshore 1B, 1D	2236 + 109 ISI (NEW) = 2345	GeneClass	PIFT 2017
2018	PIFT project. Commercial west inshore (jan-feb)	West inshore 1D	56 + 2 ISI (NEW) = 28	GeneClass	PIFT 2017
2018	Survey, fin clippings. From tagging of spawning cod.	West inshore: 1C	49	Genclass	WKGREENCOD
2018	Commercial fin clippings	West inshore: 1C	107 + 5 ISI (NEW) = 112	GeneClass	WKGREENCOD
2018	Survey fin clippings, spawning fish	West offshore: 1C (Tovqussaq banke)	93 + 2 ISI (NEW) = 95	GeneClass	WKGREENCOD
2018	Commercial trial fisheries, fin clippings. Apr-May	East offshore	184 + 3 ISI (NEW) = 187	GeneClass	WKGREENCOD
2018	Commercial fishery spawning time. Fin clippings. Apr-May	West offshore: 1C, 1D	164 + 1 ISI (NEW) = 165	GeneClass	WKGREENCOD
2019	Commercial fisheries inshore fin clippings	West inshore: 1B-kangatsiaq	63 + 2 ISI (NEW) = 65	GeneClass	WKGREENCOD
2019	Commercial fisheries inshore fin clippings	West offshore: 1D West inshore: 1B-Sisimiut, 1B-Kangatsiaq, 1C, 1D, 1F	296 + 14 ISI (NEW) = 310	GeneClass	WKGREENCOD

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2019	Survey West Greenland. Apr-July	West offshore: 1A-1F West inshore: 1A-1D	1238 + 26 ISI (NEW) = 1264	GeneClass	WKGREENCOD
2019	Walther Herwig Survey. Oct. Fin clippings	West offshore: 1E+1F East offshore	183 + 12 ISI (NEW) = 195	GeneClass	WKGREENCOD
2019	Survey. Fin clippings (analysed in 2022)	West offshore: 1C, 1D West inshore: 1AUM	21	GeneClass	NWWG 2023
2020	Commercial data. Fin clippings	West inshore: 1F	51 + 2 ISI (NEW) = 53	GeneClass	WKGREENCOD
2021	Survey fin clippings	West inshore: 1A-1D	433 + 11 ISI (NEW) = 444	GeneClass	WKGREENCOD
2021	Commercial. Finclippings	West inshore: 1F	76 + 1 ISI (NEW) = 77	GeneClass	WKGREENCOD
2022	Survey. Fin clippings	West offshore: 1A-1F West inshore: 1A-1D	935 + 28 ISI (NEW) = 963	GeneClass	NWWG 2023
2022	Commercial. Finclippings	West inshore: 1D	53	GeneClass	NWWG 2023
2023 (NEW)	Survey. Fin clippings	West offshore: 1A-1F West inshore: 1A-1D	1215	GeneClass	NWWG 2024
2023 (NEW)	Commercial. Fin clippings	West Inshore: 1C+1D+1F	85	GeneClass	NWWG 2024

Table 2. Number of samples per area for the years 2000-2023: Inshore and Offshore. Area specifies the NAFO subarea. Samples give the number of cod sampled, where age and position are available and genetic assignment is 0.7 or above. Cohorts gives the number of cohorts represented in the samples.

Area	Samples	Cohorts
Inshore		
1A (1AUP,1AUM,1AX)	839	25
1B	2223	22
1C	739	19
1D	2251	24
1E	135	8
1F	386	16
Total inshore West Greenland	**6573**	
14b	25	4
Offshore		
1A	365	20
1B	590	22
1C	951	20
1D	825	22
1E	830	22
1F	949	25
Total Offshore West Greenland	**4510**	
14b	958	23
Total West Greenland	**11083**	

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Figures

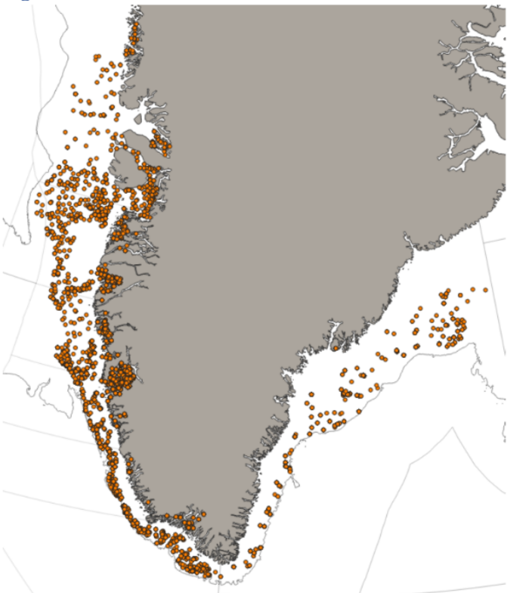

Figure 1. Overview of location of samples collected around Greenland (red marks) I 2000-2023. Assignment >= 0.7.

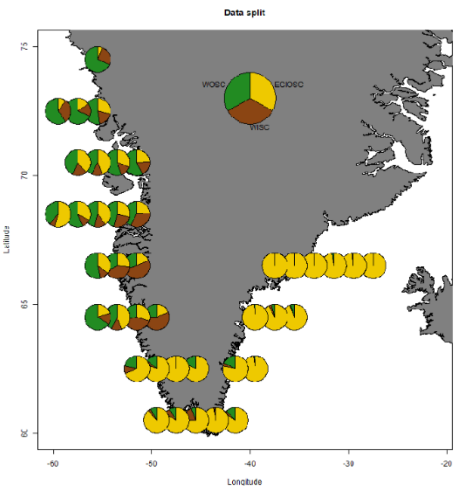

Figure 2. Map of Greenland with piecharts showing the proportion of each of the three cod stocks based on individual cod sampled for genetics from both commercial fisheries ad scientific surveys in the period 2000-2023. Location of piechart correspond to geographic location of split between the stocks.

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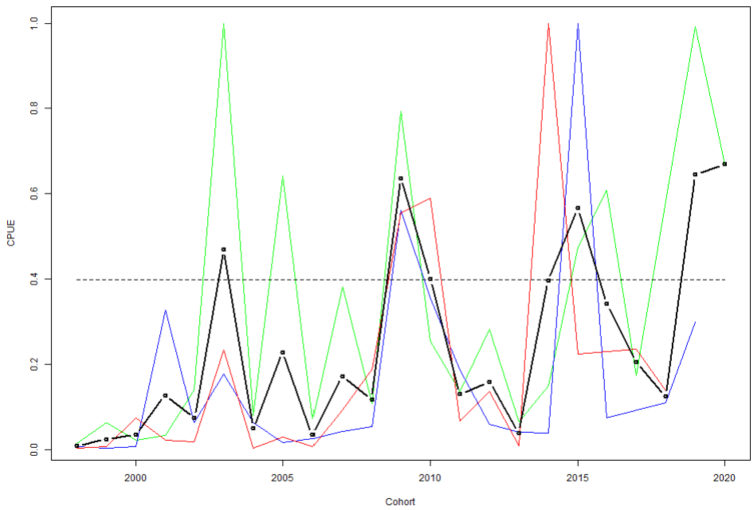

Figure 3: Normalized CPUE (black) with 75% quantile (dashed) of ages 3 (green), 4 (blue) and 5 (red) in the Greenland bottom trawl survey.

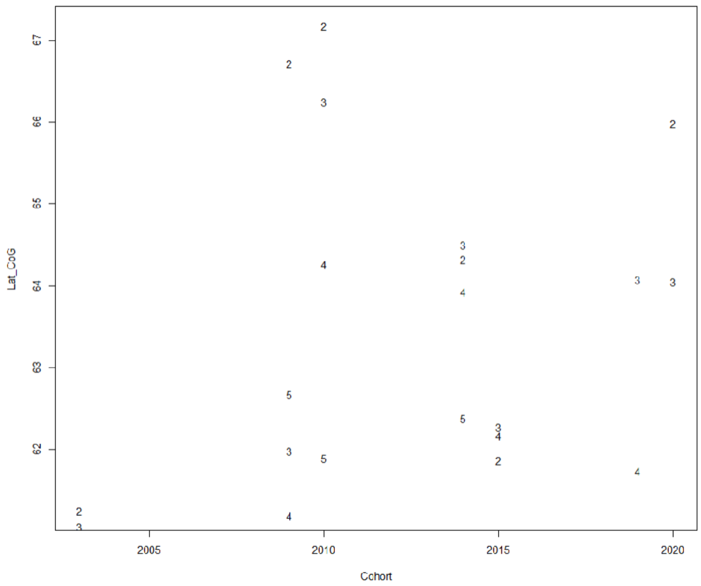

Figure 4: Mean center of distribution by age of cohort 2003, 2009, 2010, 2014, 2015, 2019 and 2020. Y axis is latitude.

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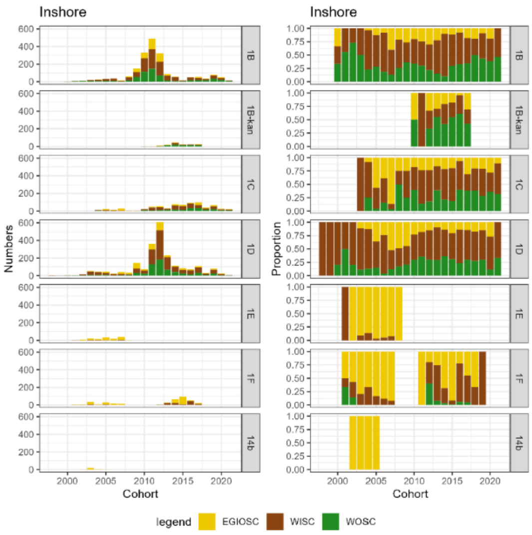

Figure 5. Overview of inshore samples collected in 2000-2023 by area and cohort, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

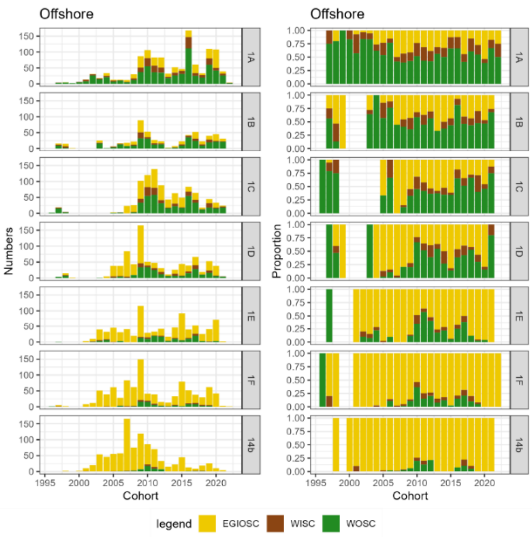

Figure 6. Overview of offshore samples collected in 2000-2023 by area and cohort, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

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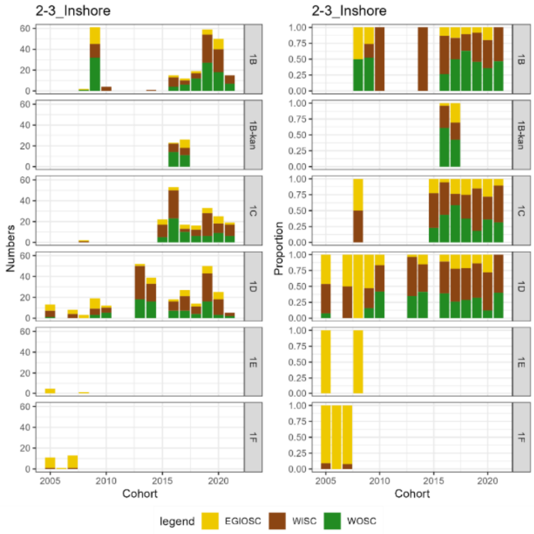

Figure 7. Overview of inshore samples collected in 2000-2023 by area and cohort of ages 2-3, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

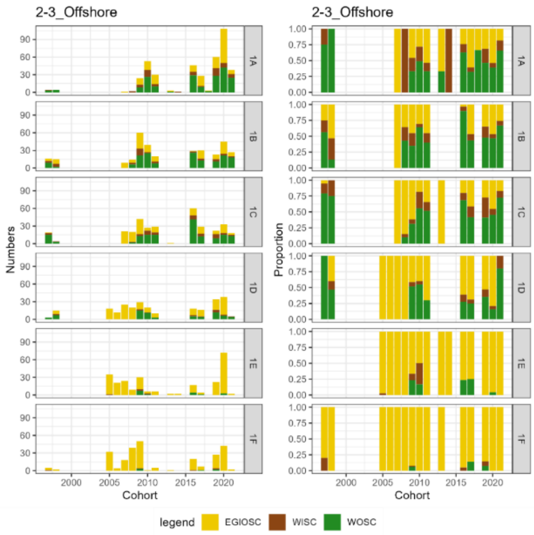

Figure 8. Overview of offshore samples collected in 2000-2023 by area and cohort of ages 2-3, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

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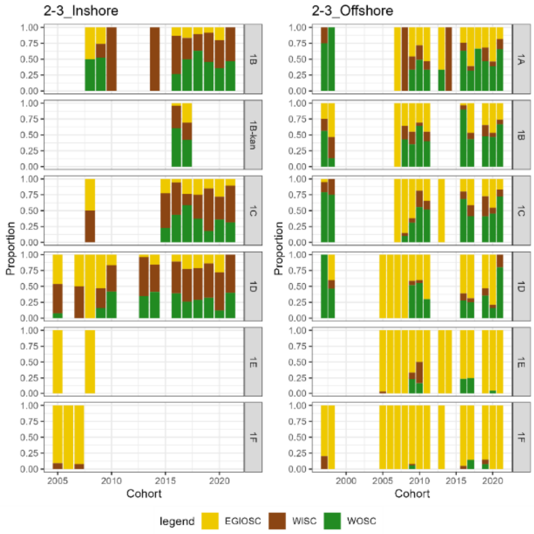

Figure 9. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2023 by area and cohort of ages 2-3, all samples with assignment 0.7 or above.

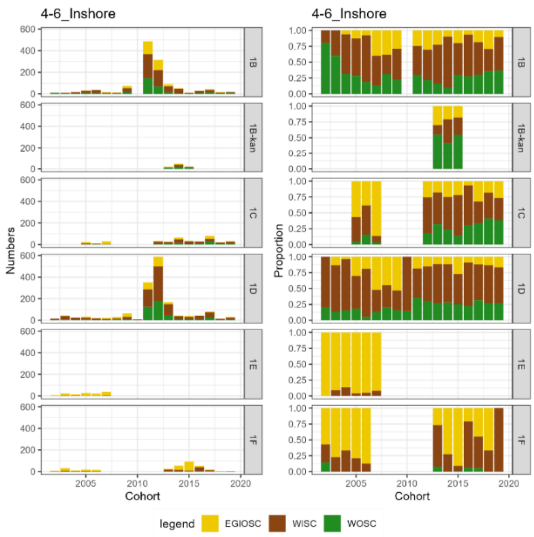

Figure 10. Overview of inshore samples collected in 2000-2023 by area and cohort of ages 4-6, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

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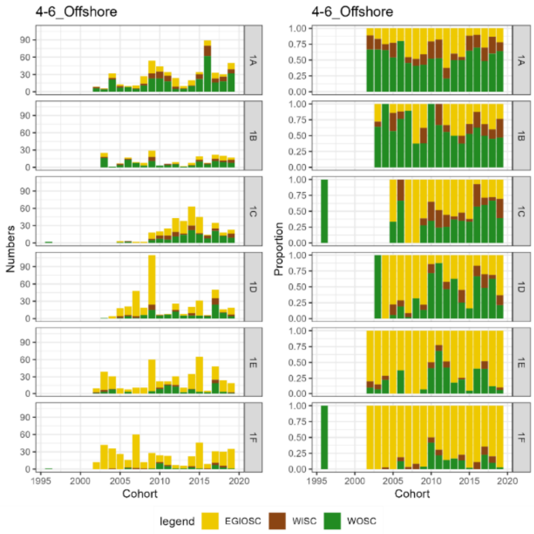

Figure 11. Overview of offshore samples collected in 2000-2023 by area and cohort of ages 4-6, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

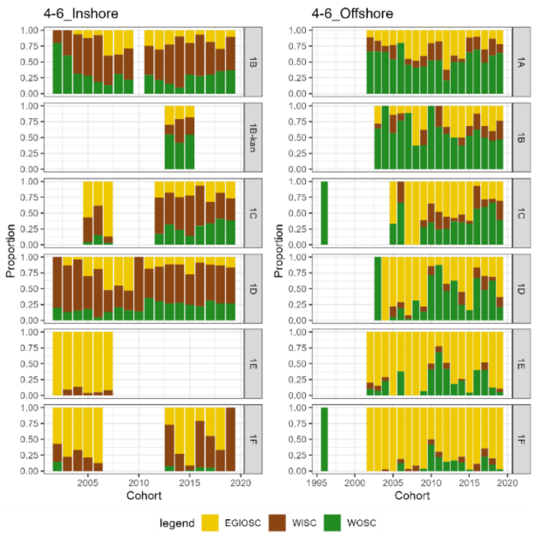

Figure 12. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2023 by area and cohort of ages 4-6, all samples with assignment 0.7 or above.

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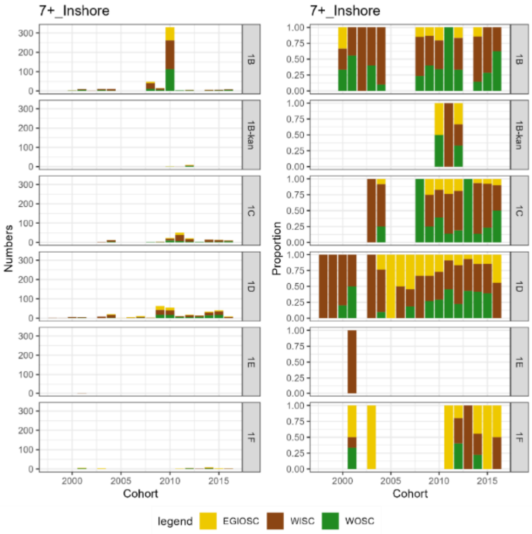

Figure 13. Overview of inshore samples collected in 2000-2023 by area and cohort of ages 7+, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

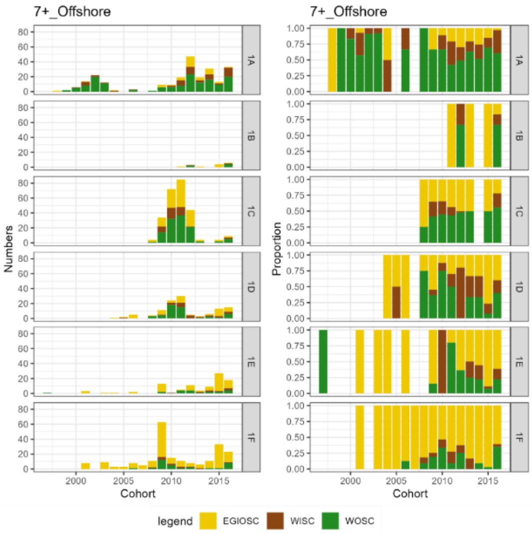

Figure 14. Overview of offshore samples collected in 2000-2023 by area and cohort of ages 7+, all samples with assignment 0.7 or above. Left: number of samples, right: proportion by stock.

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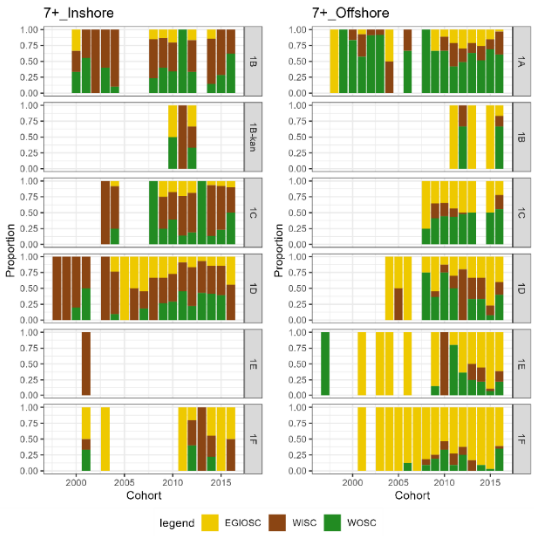

Figure 15. Overview (proportion by stock) of inshore (left) and offshore (right) samples collected in 2000-2023 by area and cohort of ages 7+, all samples with assignment 0.7 or above.

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Figure 16 Comparison stock composition of the 5 most recent cohorts to the cohort grouping based on data for older cohorts. Left-hand plot and middle plots show sample size and composition for older cohorts groupings. Right-hand plot show composition for the most recent cohorts: 2017-2020 (age 2-3), 2021 (age 2). Top inshore, bottom offshore.

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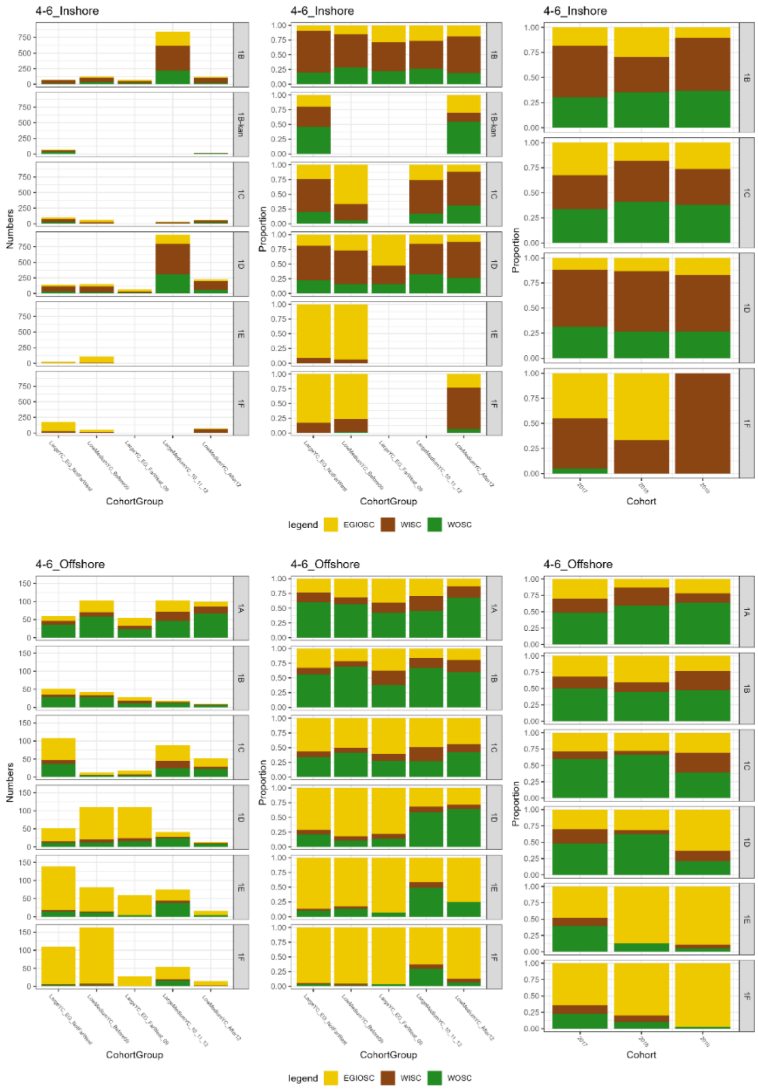

Figure 17 Comparison stock composition of the 3 most recent cohorts to the cohort grouping based on data for older cohorts. Left-hand plot and middle plots show sample size and composition for older cohorts groupings. Right-hand plot show composition for the cohorts: 2017 (ages 4-6), 2018 (age 4-5) and 2019 (age 4). Top inshore, bottom offshore.

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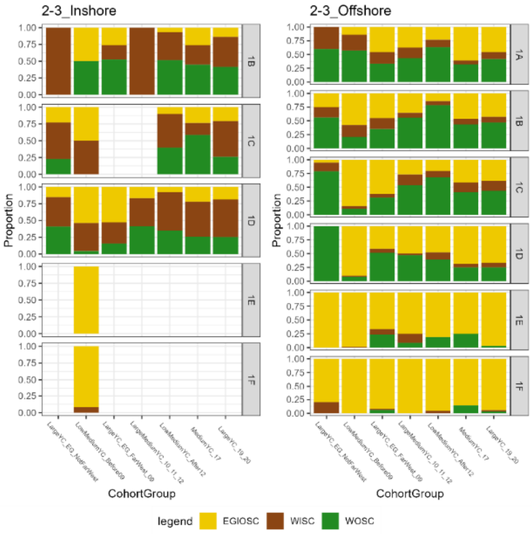

Figure 18: Composition of stocks in new Groupings of cohorts for the ages 2-3 inshore (left) and offshore (right).

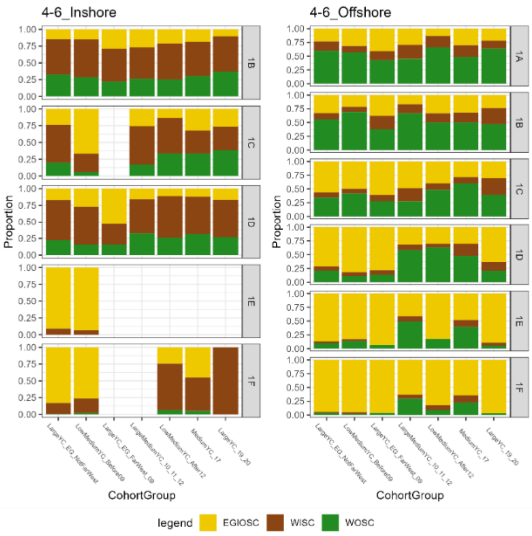

Figure 19: Composition of stocks in new Groupings of cohorts for the ages 4-6 inshore (left) and offshore (right).

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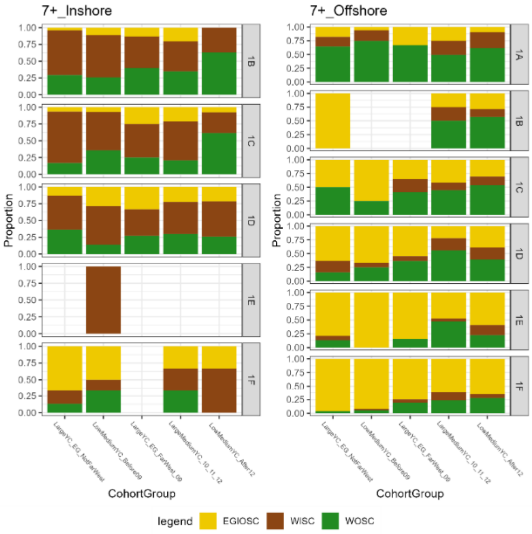

Figure 20: Composition of stocks in new Groupings of cohorts for the ages 7+ inshore (left) and offshore (right).

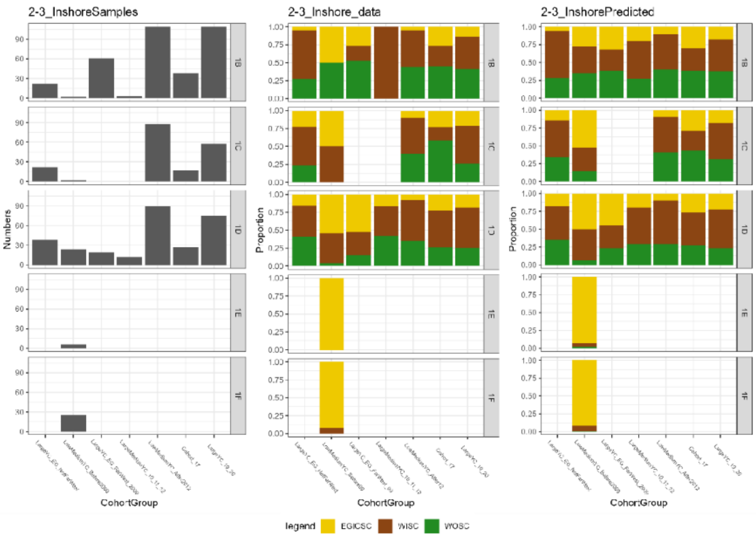

Figure 21 Comparison of cohort groups based on genetic data and predicted data. For ages 2-3 inshore, by NAFO area. Left had plots give the number of samples, middle plot is the raw data, and right-hand plot is the predicted data.

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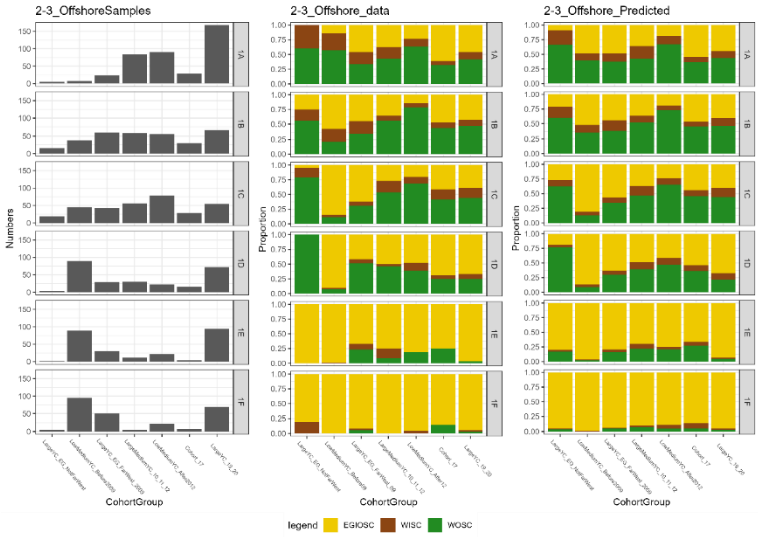

Figure 22 Comparison of cohort groups based on genetic data and predicted data. For ages 2-3 offshore, by NAFO area. Left had plots give the number of samples, middle plot is the raw data, and right-hand plot is the predicted data.

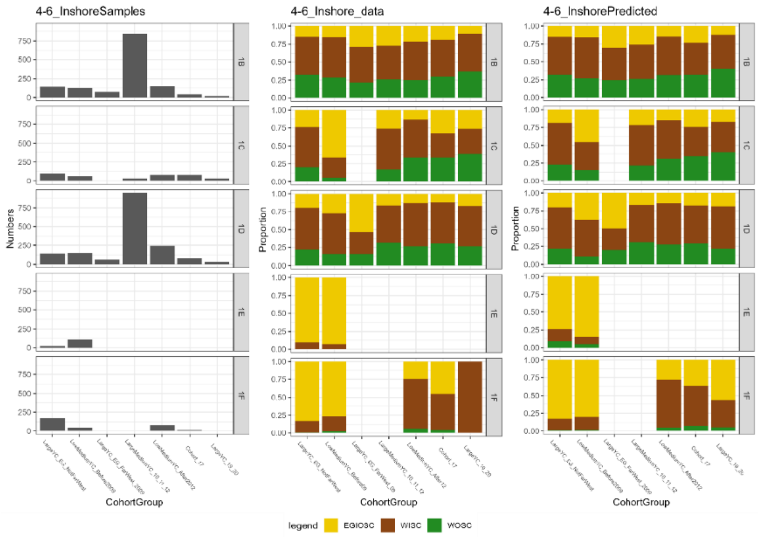

Figure 23 Comparison of cohort groups based on genetic data and predicted data. For ages 4-6 inshore, by NAFO area. Left had plots give the number of samples, middle plot is the raw data, and right-hand plot is the predicted data.

ICES North Western Working Group, 22 – 26 April 2024, WD: 05

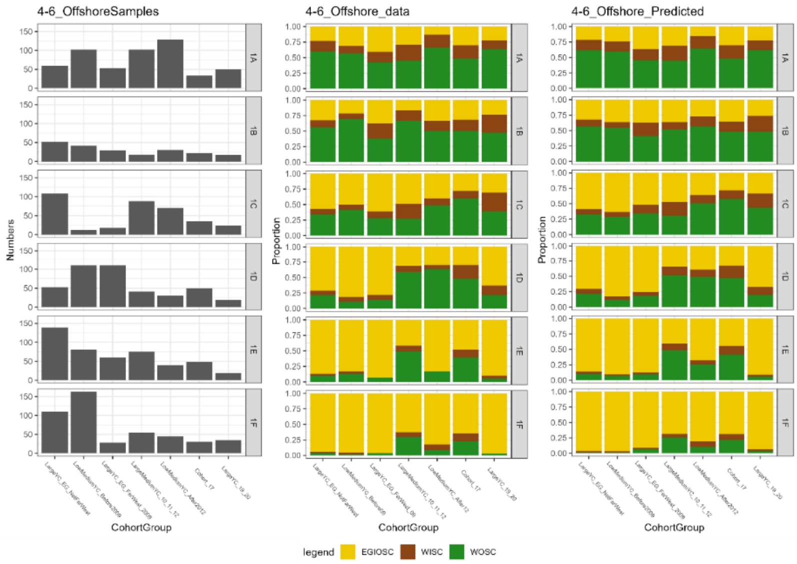

Figure 24 Comparison of cohort groups based on genetic data and predicted data. For ages 4-6 offshore, by NAFO area. Left had plots give the number of samples, middle plot is the raw data, and right-hand plot is the predicted data.

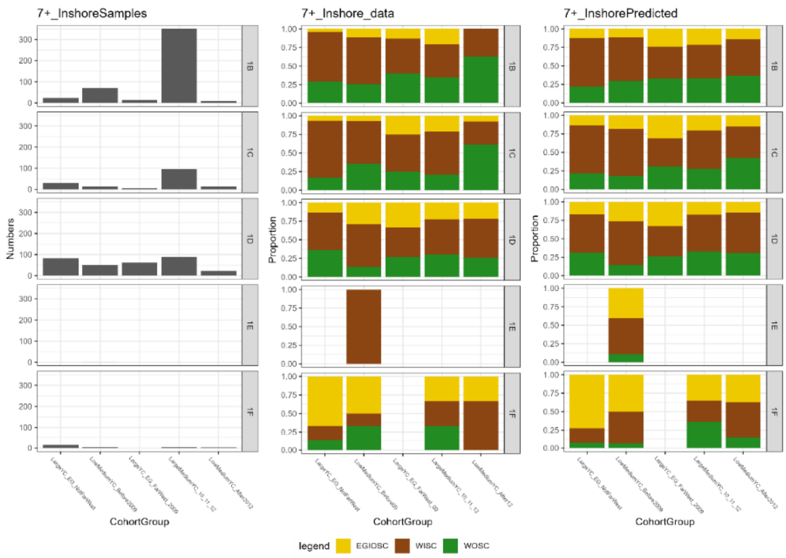

Figure 25 Comparison of cohort groups based on genetic data and predicted data. For ages 7+ inshore, by NAFO area. Left had plots give the number of samples, middle plot is the raw data, and right-hand plot is the predicted data.

ICES North Western Working Group, 22 – 26 April 2024, WD: 05

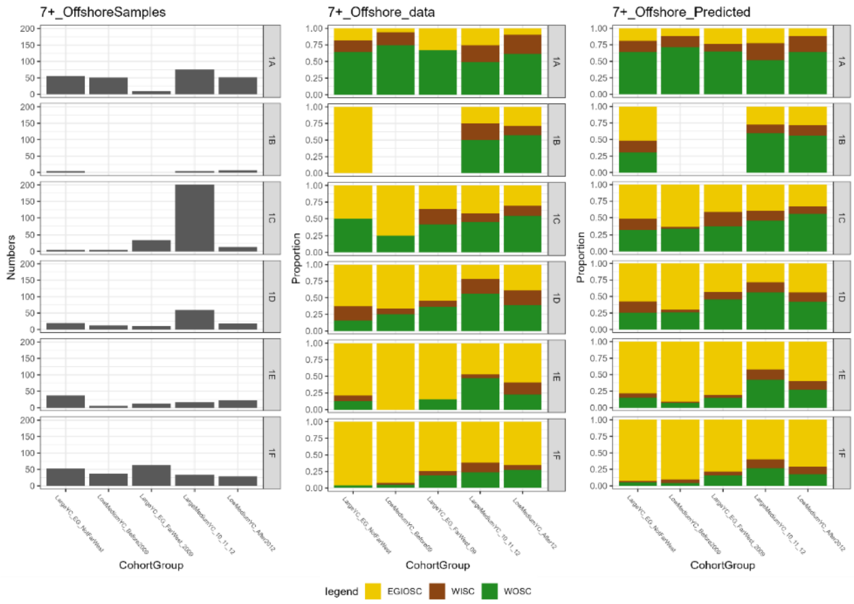

Figure 26 Comparison of cohort groups based on genetic data and predicted data. For ages 7+ offshore, by NAFO area. Left had plots give the number of samples, middle plot is the raw data, and right-hand plot is the predicted data.

WD06. ICES NWWG, 22-26 April 2024

A SAM assessment and reference points for the northern part of West Greenland inshore spawning cod stock (N-WISC)

Stockassessment.org run name: **NWWG24_N-WISC**

Tanja Buch[1], Teunis Jansen[1,2], Anders Nielsen[2], Anja Retzel[1], Søren Post[1]

[1]Greenland Institute of Natural Resources, 3900 Nuuk, Greenland,
[2]DTU Aqua, National Institute of Aquatic Resources, 2800 Kgs. Lyngby, Denmark

Introduction

The Atlantic cod (*Gadus morhua*) in Greenland waters is primarily of three genetically distinct stocks: West Greenland inshore (WISC), West Greenland offshore (WOSC), and East Greenland-Iceland (EGIOSC) (see WKGREENCOD WD01 for details). Previously advice has been provided based on geographical areas. At WKGREENCOD in 2023 data from the commercial fisheries and scientific surveys in Greenland waters are split into the three stock components (see WKGREENCOD WD01, WD02, WD05). For detail on additional genetic data used in the model for splitting data into stocks see WD03 and WD04. The N-WISC stock represents the WISC stock in NAFO aeras 1A, 1B and 1C.

This document presents the results of the state-space model (SAM) (Nielsen and Berg, 2014) for the N-WISC stock and estimated reference points using EqSim. This document was updated for NWWG 2024.

Configuration for the SAM assessment for this stock was updated and differs slightly from the benchmark configurations. These changes was accepted at NWWG 2024.

Input data

The procedures for the input data for the SAM assessment model are described in WKGREENCOD WD05. Details for commercial data for 2023 are in WD03. The Assessment covers the period 2000-2023.

Total catches
Total catches were available for the stock N-WISC from 2000-2023, due to poor sampling in 2001 catch data are not included from that year (see Table 1 for input file). No discarding is believed to take place, landings are assumed to equal catches. The catches are from NAFO areas 1A, 1B and 1C. There are many zero catches for age 2, therefore age 2 was removed from in the input files, configurations for age 2 catches was set to -1 indicating no data (see Table 2).

In 2022 on commercial samples were available for NAFO areas 1A-1C, therefore data from NAFO area 1D (the S-WISC stock component) were used. In 2023 samples were available from NAFO area 1C were most of the catches are from. Analysis showed that in 2023 there were a big difference in length distribution between NAFO areas 1D and 1C, the 2022 data are therefore expected to be attached with some uncertainty.

Catch mean weight at age
Catch mean weight at age were estimated for all years. Some age-year combination without sufficient data were left as NA in the input file (see Table 1 for input file). The given catch mean weights were then treated as observation to inform the catch weight process (GMRF with cohort and within year

correlations) ($catchWeightModel, $keyCatchWeightMean and $keyCatchWeightObsVar in Table 2). See figure 1 for catch weights estimated by the model.

Landings mean weights and discard mean weights are set equal to catch mean weight without any smoothing as these are not used.

Stock mean weight at age
The same process as described to Catch mean weights were used for stock mean weights (see Table 1 for input file) ($stockWeightModel, $keyStockWeightMean and $keyStockWeightObsVar in Table 2), see figure 2 for stock weight estimated by the model.

Surveys
Survey CPUE index by age for ages 2-8 estimated from inshore gillnet survey in area 1D (see Table 1 for input file), for details on survey data see WD05 and for details on index calculations see WD06.

Landings fraction
Set to 1, landings are assumed to equal catches.

Natural mortality
Set to default 0.2 for all years and ages (see Table 1 for input file). See details in WD05.

Maturity
Maturity ogive is based on genetic dataset presented in WD01 (see Table 1 for input file). The ogive is based on the entire GRI stock. Not enough data to produce annual maturity ogives. Details are given in WD05.

F before spawning
The fraction of the fishing mortality rate, which is applied prior to spawning divided into age classes for each year. Set to 0 for all years and ages.

M before spawning
The fraction of the natural mortality rate, which is applied prior to spawning divided into age classes for each year. Set to 0 for all years and ages.

Assessment

<u>Configurations</u>

Recruitment
Recruitment parameters are estimated within the assessment model. The parameter structure is assumed as a plain random walk process ($stockRecruitmentModelCode in Table 2).

Fishing mortality and Fbar
Fishing mortality is estimated individually for ages 3-8, age 9 and 10 are assumed to be the same, age 2 is set to -1 and therefore not used ($keyLogFsta in Table 2). It is assumed that there are no correlations across ages ($corFlag in Table 2), this is supported by changes in the selectivity pattern during the assessment period, meaning that correlations between ages are unlikely to be consistent throughout the period (Figure 3). The Fbar range was set to 4-7 years old at the benchmark in 2023, this was changed at NWWG 2024 as these ages constitutes the main part of the catches in the most recent part of the timeseries ($fbarRange in Table 2).

Survey
The survey catchability parameters are estimated individually for age 2, 3 and 4. Ages 5 and 6 and coupled and ages 7 and 8 are coupled ($keyLogFpar in Table 2).

Variance parameters
For age 2 the coupling of the recruitment and survival process variance parameters for the log(N)-process are different from the other ages ($keyVarLogN in Table 2). In the model.R script the following was added: par$logSdLogN<-c(0,-5), which sets the process variance of N to a very low value. This was needed due to the short assessment time series.

The variance parameters for the catch are separate for age 3 and they are coupled for ages 4-10. Age to is set to -1 and not used. The variance parameters for the survey are separate for age 2 and 3, ages 4-6 are coupled and ages 7 and 8 are coupled ($keyVarObs in Table 2).

The covariance structure for catch is assumed to be independent ($obsCorStruct in Table 2). For the survey the covariance structure is assumed to follow an AR(1) structure. This was done because there was evidence of year effects in the observation residuals for the survey.

For the catches the variation around the mean were allowed to vary additionally, at WKGREENCOD 2023 (see WKGREENCOD WD 10) parameters were separate for age 3 and coupled for ages 4-10 (see $predVarObsLink in Table 2) (see Breivik et al 2021). However, during the update with 2023 data the parameter for age 3 was highly uncertain, scrutiny of the data indicated that for age 3 was highly variable with poor signal (see run NWWG24_N-WISC_OrgConfig on stockassessment.org). This configuration was therefore changed for NWWG 24 such that only one parameter for ages 4-10 are estimated by the model. This update resulted better estimates of parameters.

Model diagnostics

Uncertainty surrounding the SSB and F estimates appears reasonable (Figure 7 and 8), although high on F for the most recent years in the time series. The estimated catches follow the same trend as the observed catches, but do not capture the large catches in 2016 and 2017 (Figure 4). The model does not capture the increase in catches in 2023 well. Compare to the SAM model from NWWG 23 the F in 2022 was lower and recruitment in 2021 (the 2019 cohort) is estimated higher when the 2023 data are added to the model.

Parameter estimation
Parameter estimates are given in Table 3. A first update of the SAM model with 2023 data and benchmark configuration (NWWG24_N-WISC_OrgConfig) gave very high uncertainty on several parameters. Changes where therefore made to the $predVarObsLink (additional variance around estimates), see above for details. This change resulted in better estimation of parameters.

Residuals
Observation residuals for both catches and survey shows some tendency for larger residuals early in the time series (Figure 5). There is a block of negative residuals for the survey residuals early in the timeseries. For the catch residuals there are a block of positive residuals, showing that the model underestimate catches in these years.

Stock summary

Fishing mortality

Fishing mortality peaked in 2004 at 1.1 and then decreased to the lowest level of 0.498 in the assessment time period in 2014, it has since increase a bit with a decrease in the last few years (Figure 6). The estimate of F in 2021 has been revised down compared to the 2023 assessment.

SSB
SSB was at a low level at the beginning of the timeseries and increased from 180 in 2000 to 17200 in 2016. SSB has been stable around 6700-7000 in the past four years (Figure 7).

Recruitment
Recruitment was at a low level at the beginning of the assessment period, it increased and had a peak in 2013 (cohort 2011). Recruitment has been decreasing since. Recruitment in 2021 are high (cohort 2019), although this estimate is associated with very large confidence intervals (Figure 8).

Retrospective analysis
In order to test the robustness of the assessment a 5-year retrospective analysis (Figures 9-11) were conducted. For F all peels are within the confidence intervals. For F there is a tendency to underestimate F (Mohn's rho=0.199), with two peels ending outside of the confidence interval. For SSB there is a tendency to underestimate SSB (Mohn's rho=-0.158), with peels being just inside the confidence interval. For recruitment there is a tendency to underestimate recruitment (Mohn's rho=-0.392).

Alternative SAM configurations

Because of the retrospective patterns of this assessment a number of configurations were tested. Because the survey data for 2022 did not see the 2019 yearclass at the same scale as it was see at age 2 in 2021 and age 4 in 2023, additional uncertainty was added to this year using the $keyXtraSd configuration. This did not have an impact. Further the coupling of ages for the coupling of correlation parameters (in $KeyCorObs) was explore based on data, this did not have an impact on the assessment. The impact of outliers in the data was explored, by excluding specific years and observations, this resulted in an unstable model. All this was done in order to better understand the cause of the retrospective patterns.

Additional exploration of both commercial and survey data was also carried out to check for any uncertainty.

Short term forecast

Short term forecasts were set up using mainly default settings for the SAM run on stockassessment.org. Uncertainty on F were taken from the model. Catch ad stock weights were taken from the model used for these, the model is set up to estimate further ahead in time than the assessment run. For maturity and natural mortality average of the last 5 years were used, currently maturity and natural mortality is constant over time so the time period for this would not have any impact. The default for the recruitment is the last 10 years, it was decided at the meeting that this period is appropriate.

Reference points

The estimation of reference points follows ICES Reference Points guidance, 2021. The estimation was done using the R-programme EqSim developed by D. C. M. Miller, which works directly on a specified SAM fit. The code for the final run is on the ICES sharepoint for the WKGREENCOD benchmark and named 'NWWG24_N-WISC_EqSim_Final.R'. David Miller provided guidance on the ICES procedures and EqSim settings.

Blim was based on the average SSB of the three years with highest recruitment (SSB in 2009-2011, recruitment in 2011-2013). This gave a B_{lim} of 2943 t.

The simulation settings for the stock-recruitment relationship were as follows. The number of simulations were set to 1500. Stock recruitment pairs for recruitment in 2019-2021 was excluded due to large uncertainty surrounding the estimated recruitment. For assessment error sigmaF was set to default of 0.2 and sigmaSSB was 0.216 from the SAM assessment. The default values were used for forecast errors: cvF=0.22, phiF=0.423, cvSSB=0 and phiSSB=0. For weight at age the last 5 years were used, based on figure 16 there has been a reduction in weight-at-age in the assessment period. For selectivity the last 10 years were used, there appear to have been a change in selectivity early in the assessment period (Figure 17). For the simulations segmented regression (with breakpoint fixed at B_{lim}) and Beverton-Holt were used. Run settings are given in table 4. The estimated reference points are given in table 5.

It was decided to follow standard ICES guidelines for the basis of $MSYB_{tigger}$, which were set at B_{pa}.

Conclusion

The model presented here fit the observation reasonably well and seem to capture trends in stock size and fishing mortality well. The retrospective patterns are concerning, but seems largely related to the change in perception of the 2019 cohort.

The assessment model is based on data for the WISC stock in the northern part of the stock area (NAFO area 1A-1C), rather than previous geographical data split. The model in combination with one for S-WISC provides a useful tool for assessing the WISC stock.

References

Breivik, O. N., Nielsen, A., Berg, C. W. 2021. Prediction-variance relation in a state-space fish stock assessment model. ICES Journal of Marine Science. 78 (10): 3650-3657.

Buch, T.B., Retzel, A., Riget, F., Jansen, T., Post, S.L., Boje, J., Berg, C., Bjare, F. 2023. DNA split of Atlantic cod (*Gadus morhua*) stocks in Greenland waters. An overview of data. Report of the Workshop on three Greenland cod stocks (WKGREENCOD) WD 01.

Nielsen, A., Berg, C. W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries research. 158: 96-101.

WD10. ICES WKGREENCOD, 7-10 February 2023

Table 1. Input files to SAM runs.

Catch in Numbers (thousands)

1	2							
2000	2023							
2	10							
1								
1.00E-04	0.660081	28.74842	43.67151	0.943568	0.032347	0.019839	1.00E-04	1.00E-04
-1	-1	-1	-1	-1	-1	-1	-1	-1
0.092159	166.8372	721.9665	225.4463	9.314978	3.051298	0.209061	0.083001	0.024439
0	28.14189	92.37644	403.3955	49.57142	3.952587	0.587695	0.720194	0.325281
0	192.0063	574.2951	233.01	41.08725	13.30647	0	0	0
4.465684	331.7705	615.9472	296.9641	26.13838	2.104704	0	0	0
5.401652	1032.636	758.5262	218.4245	8.491203	0	0	0	0
0	783.6162	961.6964	131.7104	17.11016	8.44759	2.69851	1.739867	0.129894
0	125.8893	1149.581	647.3311	97.19028	11.2154	2.248963	0.826516	0
0	108.3029	325.5269	427.2952	61.08688	1.493129	0.225553	0	0.036137
0.013194	6.121345	140.4698	410.7844	474.5097	64.75253	13.1423	9.528648	12.71052
0	14.72922	420.4648	657.0513	348.8228	67.32452	26.82519	3.056989	1.864806
0.064739	113.0556	269.9534	327.0552	159.963	40.20705	8.096625	4.350547	0.439341
0.226931	57.03224	667.0001	558.5809	200.6629	68.63231	22.24726	20.92507	2.931159
0	11.9052	411.9977	1110.329	672.5535	104.4292	55.21006	36.59247	20.95867
0	8.827832	624.0298	1840.503	888.9417	338.4374	42.93097	3.970562	3.363491
0	3.41406	763.2633	3574.425	2166.935	375.8691	90.34437	21.8455	1.244983
0	15.00716	553.879	2562.238	2068.131	1348.49	148.3242	82.9044	18.3775
0	2.21277	828.7638	1167.758	1156.033	664.4604	266.0471	45.71112	26.16996
0	18.96683	377.5635	1703.971	537.6172	262.1045	132.0166	33.34773	7.690339
0	15.6797	334.8445	953.2473	1053.646	167.5458	83.2107	25.27813	14.36405
0	0.764407	287.499	1257.535	594.1674	437.1848	42.31661	32.02711	5.936254
0	55.20914	479.2586	1442.552	705.3759	72.11195	54.19143	12.1977	12.33493
0	184.2757	2352.819	873.6916	881.7538	303.7649	89.35518	27.77589	3.246398

Table 1 *continued*

Mean Weight in Catch (kilograms)

1	3							
2000	2023							
2	10							
1								
NA	0.641808	1.120983	1.453028	2.378079	2.62124	2.408667	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA
0.36	0.707845	0.998694	1.397425	2.317673	1.884027	2.852515	3.559567	3.355852
NA	1.059815	1.445614	2.099405	2.510019	3.897149	5.351454	4.539769	6.682845
NA	0.996253	1.263823	1.508814	2.370574	2.77441	NA	NA	NA
0.409169	0.762842	1.100555	1.733057	2.535642	2.737143	NA	NA	NA
0.362207	0.756374	0.962649	1.477489	3.14623	NA	NA	NA	NA
NA	0.709103	1.069099	1.666367	2.558686	3.889552	5.706479	6.196443	9.364545
NA	0.675533	0.909758	1.556538	2.369529	3.988109	5.774379	7.232136	NA
NA	0.645872	1.095151	1.614509	2.437821	5.400539	5.85566	NA	8.32
0.5	0.715408	1.184759	1.693137	2.230081	3.196331	4.872378	6.908764	9.007743
NA	0.732399	1.084927	1.574925	2.248544	3.28417	5.603538	8.221623	11.34166
0.501355	0.823038	1.211943	1.986604	2.832137	4.034002	6.050203	6.708571	9.826476
0.244788	0.765683	1.32392	1.694972	2.299141	3.468559	4.265406	4.682311	7.907118
NA	0.683888	1.235704	1.954113	2.545061	3.466849	5.311272	5.725551	7.870319
NA	0.831165	1.194009	1.850065	2.58761	3.461217	5.126374	7.895979	12.77112
NA	0.589039	1.095821	1.519479	2.246029	3.090056	3.788058	3.960525	9.45069
NA	0.460124	0.792366	1.259431	1.861689	2.615337	3.642371	4.121039	7.530076
NA	0.383304	0.93057	1.194506	1.847657	2.361288	3.061088	3.78284	5.958465
NA	0.799411	0.841279	1.13137	1.617944	2.405416	2.87688	3.814675	4.935565
NA	0.516524	0.882284	1.26966	1.61406	2.24665	3.169741	4.15678	5.648709
NA	0.463732	1.075951	1.372087	1.546765	1.842929	3.257976	4.308971	5.460652
NA	0.703224	1.007424	1.390971	1.655185	2.876519	3.495845	4.769961	5.694262
NA	0.478774	0.915423	1.191731	1.866583	2.360623	3.335161	4.206608	6.030852

Table 1 *continued*

Mean Weight in survey (kilograms)

1	3								
2000	2023								
2	10								
1									
NA	NA	NA	NA	NA	NA	NA	NA	NA	
NA	NA	NA	NA	NA	NA	NA	NA	NA	
0.18728	0.314305	0.973178	1.498242	2.135451	NA	NA	NA	NA	
0.220018	0.62776	1.003128	1.931651	2.897211	2.940008	NA	NA	NA	
0.227609	0.645517	1.084576	1.574985	2.453173	NA	NA	NA	NA	
0.211085	0.4457	1.155765	1.842556	2.109256	2.794586	NA	NA	NA	
0.193716	0.609694	0.865742	1.227464	3.317033	NA	NA	NA	NA	
0.143392	0.356067	0.947849	1.825629	NA	NA	NA	NA	NA	
NA	NA	NA	NA	NA	NA	NA	NA	NA	
NA	NA	NA	NA	NA	NA	NA	NA	NA	
0.227981	0.502206	1.021057	1.582688	2.24002	4.048524	NA	NA	NA	
0.188822	0.332779	1.000482	1.516966	2.03541	2.367941	NA	NA	NA	
0.177907	0.516609	1.073968	1.996147	2.478708	NA	NA	NA	NA	
0.144009	0.404478	1.035372	1.524095	2.094862	3.24816	3.450421	NA	NA	
0.14416	0.395049	1.061259	1.75011	2.618765	3.887408	5.460066	4.46	NA	
0.132617	0.433202	1.061711	1.85795	2.676441	4.112047	5.512461	NA		16.1
0.112063	0.297551	0.788946	1.384297	2.169231	3.051051	4.422074	3.53		11.33
0.086046	0.225583	0.548266	1.186337	1.793345	2.631472	3.462187	4.69635		12.5
0.084673	0.251084	0.550739	1.174735	1.79128	2.825771	4.107466	6.535	NA	
0.091721	0.28471	0.691184	1.125309	1.620372	2.804158	3.577171	NA	NA	
0.113858	0.341721	0.702758	1.291006	2.007929	2.569902	3.234162	3.312	NA	
0.132034	0.259843	0.901172	1.356815	1.629331	2.202574	NA	NA	NA	
0.08895	0.307338	0.554877	1.435342	1.845886	2.849738	3.310368	NA	NA	
0.093271	0.30371	0.924982	1.309694	2.200378	2.428642	3.093191	NA	NA	

Table 1 *continued*

Proportion		Mature	at	Year	Start			
1	6							
2000	2023							
2	10							
1								
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000

Table 1 *continued*

Natural Mortality
1 5
2000 2023
2 10
1

0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 1 *continued*

Inshore
Gillnet (1B) CPUE N-WISC
102
GillnetSurveyIndex

2002	2023						
1	1	0.5	0.6				
2	8						
1	103.242	35.38581	12.38879	4.349851	0.277626	0	0
1	34.95418	37.96016	9.427185	1.700541	0.140616	0.009684	0
1	24.29112	15.83036	7.762009	1.900642	0.377068	0	0
1	97.84406	14.57043	2.698056	3.184897	0.245501	0.17254	0
1	77.38449	27.40182	12.90666	4.409656	0.370725	0	0
1	87.37201	41.30892	14.6133	0.358405	0	0	0
1	-1	-1	-1	-1	-1	-1	-1
1	-1	-1	-1	-1	-1	-1	-1
1	76.55566	62.88293	31.96476	6.741043	0.678148	0.224673	0
1	166.1908	77.82724	22.48005	11.83457	2.370518	0.167359	0
1	101.4911	119.1419	16.06453	4.27035	1.658085	0	0
1	87.14452	58.53446	44.92666	15.50549	5.003975	0.803162	0.266209
1	25.24879	25.08514	13.57397	8.493845	2.249171	0.209411	0.2869
1	18.05431	24.31017	32.7058	26.08815	18.43861	1.833824	0.457126
1	18.49211	47.91143	23.57978	19.37026	11.64543	3.042536	0.719726
1	3.872619	42.34408	44.59188	17.85562	11.34778	4.604128	0.350239
1	12.6284	14.73587	15.56222	8.82429	2.869215	0.810325	0.288942
1	25.60733	68.9034	11.21508	21.77347	6.680194	0.719443	0.740236
1	21.76309	36.42029	28.76344	9.628173	3.242745	0.178785	0.166022
1	104.7103	35.16488	10.94467	18.23212	1.528297	1.31941	0
1	22.37766	35.49884	7.899525	2.664316	2.867685	0.913842	0.299639
1	13.8803	27.61086	36.99178	8.781328	6.268349	2.393909	0.745155

Table 2. SAM configurations for NWWG24_N-WISC

```
# Configuration saved: Mon Jan 16 14:23:05 2023
#
# 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
# Negative numbers indicate that the parameter is not included in the model
#
$minAge
# The minimium age class in the assessment
 2

$maxAge
# The maximum age class in the assessment
 10

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

$keyLogFsta
# Coupling of the fishing mortality states processes for each age (normally only
# the first row (= fleet) is used).
# Sequential numbers indicate that the fishing mortality is estimated individually
# for those ages; if the same number is used for two or more ages, F is bound for
# those ages (assumed to be the same). Binding fully selected ages will result in a
# flat selection pattern for those ages.
  -1 0  1  2  3  4  5  6  6
 -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).
# 0: independent means there is no correlation between F across age
# 1: compound symmetry means that all ages are equally correlated;
# 2: AR(1) first order autoregressive - similar ages are more highly correlated than
# ages that are further apart, so similar ages have similar F patterns over time.
# if the estimated correlation is high, then the F pattern over time for each age
# varies in a similar way. E.g if almost one, then they are parallel (like a
# separable model) and if almost zero then they are independent.
# 3: Separable AR - Included for historic reasons . . .  more later
 0

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is
# not used, as that is covered by fishing mortality).
 -1 -1 -1 -1 -1 -1 -1 -1 -1
  0  1  2  3  3  4  4 -1 -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

$keyVarF
# Coupling of process variance parameters for log(F)-process (Fishing mortality
# normally applies to the first (fishing) fleet; therefore only first row is used)
  -1  0  0  0  0  0  0  0  0
 -1 -1 -1 -1 -1 -1 -1 -1 -1

$keyVarLogN
# Coupling of the recruitment and survival process variance parameters for the
# log(N)-process at the different ages. It is advisable to have at least the first age
# class (recruitment) separate, because recruitment is a different process than
# survival.
```

```
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
# First row refers to the coupling of the variance parameters for the catch data
# observations by age
# Second and further rows refers to coupling of the variance parameters for the
# index data observations by age
  -1  0  1  1  1  1  1  1  1
   2  3  4  4  4  5  5 -1 -1

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

$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).
#2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
  NA  NA  NA  NA  NA  NA  NA  NA
  0  0  0  0  0  0 -1 -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, 3 piece-wise constant, 61 for segmented regression/hockey stick, 62 for AR(1), 63 for bent hyperbola / smooth hockey stick, 64 for power function with degree < 1, 65 for power function with degree > 1, 66 for Shepher, 67 for Deriso, 68 for Saila-Lorda, 69 for sigmoidal Beverton-Holt, 90 for CMP spline, 91 for more flexible spline, and 92 for most flexible spline).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


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

$fbarRange
# lowest and higest age included in Fbar
 5 8

$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

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "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 (for each age group)
 0 0 0 0 0 0 0 0 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

$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)

$predVarObsLink
Coupling of parameters used in a prediction-variance link for observations.
-1 -1 0 0 0 0 0 0 0
-1 -1 -1 -1 -1 -1 -1 NA NA

$hockeyStickCurve
#
20

$stockWeightModel
Integer code describing the treatment of stock weights in the model (0 use as known, 1 use as observations to inform stock weight process (GMRF with cohort and within year correlations))
1

$keyStockWeightMean
Coupling of stock-weight process mean parameters (not used if stockWeightModel==0)
0 1 2 3 4 5 6 7 8

$keyStockWeightObsVar
Coupling of stock-weight observation variance parameters (not used if stockWeightModel==0)
0 0 0 0 0 0 0 0 0

$catchWeightModel
Integer code describing the treatment of catch weights in the model (0 use as known, 1 use as observations to inform catch weight process (GMRF with cohort and within year correlations))
1

$keyCatchWeightMean
Coupling of catch-weight process mean parameters (not used if catchWeightModel==0)
0 1 2 3 4 5 6 7 8

$keyCatchWeightObsVar
Coupling of catch-weight observation variance parameters (not used if catchWeightModel==0)
0 0 0 0 0 0 0 0 0

$matureModel
Integer code describing the treatment of proportion mature in the model (0 use as known, 1 use as observations to inform proportion mature process (GMRF with cohort and within year correlations on logit(proportion mature)))
0

$keyMatureMean
Coupling of mature process mean parameters (not used if matureModel==0)
NA NA NA NA NA NA NA NA NA NA

$mortalityModel
Integer code describing the treatment of natural mortality in the model (0 use as known, 1 use as observations to inform natural mortality process (GMRF with cohort and within year correlations))
0

$keyMortalityMean
#
NA NA NA NA NA NA NA NA NA NA

$keyMortalityObsVar
Coupling of natural mortality observation variance parameters (not used if mortalityModel==0)
NA NA NA NA NA NA NA NA NA NA

$keyXtraSd

An integer matrix with 4 columns (fleet year age coupling), which allows additional uncertainty to be estimated for the specified observations

Table 3. Table of SAM model parameters.

Parameter name	par	sd(par)	exp(par)	Low	High
logFpar_0	-4.781	0.252	0.008	0.005	0.014
logFpar_1	-4.533	0.166	0.011	0.008	0.015
logFpar_2	-4.879	0.167	0.008	0.005	0.011
logFpar_3	-4.836	0.162	0.008	0.006	0.011
logFpar_4	-5.243	0.211	0.005	0.003	0.008
logSdLogFsta_0	-1.276	0.171	0.279	0.198	0.393
logSdLogN_0	-0.912	0.207	0.402	0.265	0.607
logSdLogObs_0	0.591	0.184	1.806	1.250	2.610
logSdLogObs_1	1.426	0.461	4.161	1.656	10.456
logSdLogObs_2	0.065	0.149	1.068	0.793	1.437
logSdLogObs_3	-0.366	0.157	0.693	0.507	0.948
logSdLogObs_4	-0.314	0.124	0.730	0.570	0.936
logSdLogObs_5	-0.211	0.179	0.810	0.566	1.158
transfIRARdist_0	-0.484	0.281	0.616	0.351	1.082
predVarObs_0	-0.678	0.189	0.508	0.348	0.741
logPhiSW_0	4.182	1.540	65.503	3.010	1425.453
logPhiSW_1	5.062	1.601	157.958	6.432	3879.404
logSdProcLogSW_0	0.653	0.690	1.920	0.483	7.632
meanLogSW_0	-1.956	0.127	0.141	0.110	0.182
meanLogSW_1	-1.009	0.124	0.365	0.284	0.468
meanLogSW_2	-0.172	0.123	0.842	0.658	1.076
meanLogSW_3	0.360	0.122	1.434	1.122	1.832
meanLogSW_4	0.739	0.123	2.093	1.635	2.678
meanLogSW_5	1.045	0.126	2.845	2.211	3.661
meanLogSW_6	1.315	0.134	3.724	2.849	4.869
meanLogSW_7	1.368	0.151	3.928	2.907	5.308
meanLogSW_8	2.472	0.179	11.851	8.287	16.948
logSdLogSW_0	-2.104	0.162	0.122	0.088	0.169
logPhiCW_0	4.274	1.368	71.820	4.659	1107.029
logPhiCW_1	5.345	1.364	209.603	13.702	3206.466
logSdProcLogCW_0	0.727	0.638	2.068	0.577	7.408
meanLogCW_0	-1.109	0.147	0.330	0.246	0.443
meanLogCW_1	-0.438	0.130	0.645	0.497	0.837
meanLogCW_2	0.009	0.129	1.009	0.779	1.306
meanLogCW_3	0.367	0.129	1.443	1.116	1.867
meanLogCW_4	0.724	0.129	2.063	1.595	2.669
meanLogCW_5	1.032	0.130	2.807	2.166	3.639
meanLogCW_6	1.369	0.132	3.931	3.020	5.115
meanLogCW_7	1.564	0.134	4.780	3.654	6.252
meanLogCW_8	1.919	0.137	6.817	5.180	8.971
logSdLogCW_0	-2.155	0.124	0.116	0.090	0.149

WD10. ICES WKGREENCOD, 7-10 February 2023

Table 4. Run setting for EqSim

From R scripts	description	Value
stockName	Name of the stock	Cod.21.1.isc_1a-c(N-WISC)
SAOAssessment	Name of assessment on stockassessmet.org	NWWG24_N-WISC
sigmaF	From SAM assessment	0.2
sigmaSSB	From SAM assessment	0.216
noSims	Recommended minimum 1000	1500
SRused	Models used in the simulations (usually segmented regression (with breakpoint fixed to Blim), Ricker, beverton-holt).	Segreg_Bevholt
SRyears_min	Same as assessment	2000
SRyears_max	Same as assessment	2022
rhoRec	Autocorrelation in recruitment	0.81
numAvgYrsB	Years used for the average Weight at age	FALSE
numAvgYrsS	Years used for the average selectivity	5
cvF	Forecast error F	10
phiF	Forecast error F	0.212
cvSSB	Forecast error SSB	0.423
phiSSB	Forecast error SSB	0
SSB05	5th percentile of SSB in the final year of the assessment, used in MSY Btrigger calculation. If set at 0, ignored.	0
rmSRRYrs	Which years (SSB years, not recruitment years) to exclude from the SRR fits	2019-2021 SSB

Table 5. Reference points estimated from EqSim. Compare to WKGREENCOD 2023 reference points

Framework	Reference point	New		WKGREENCOD	Technical basis
MSY approach	MSY $B_{trigger}$	4197	Bpa	9941	Scaled from B_{lim} using average of the ratios between MSY $B_{trigger}$ and B_{lim} from cod.21.1.osc (5.4) and cod.21.1.isc in NAFO 1D-F (3.9)
	F_{MSY}	0.27	Stochastic simulations (EqSim) using segmented regression (with breakpoint fixed at Blim) and Beverton–Holt.	0.24	Based on the average of F_{MSY} from the cod.21.1.osc (F_{MSY} = 0.18) and cod.21.1.isc in NAFO 1D-F (F_{MSY} = 0.29).
Precautionary approach	B_{lim}	2943	Average of 3 large recuitment at low SSB, recruitment in 2011-2013 (SSB in 2009-2011)	2147	From segmented regression breakpoint
	B_{pa}	4197	$B_{lim} \times \exp(\sigma \times 1.645)$; σ = 0.216	3015	$B_{lim} \times \exp(\sigma \times 1.645)$; σ = 0.207
	F_{lim}	4.4	Not reported	-	Not defined
	F_{pa}	2.03	Not reported	-	Not defined

WD10. ICES WKGREENCOD, 7-10 February 2023

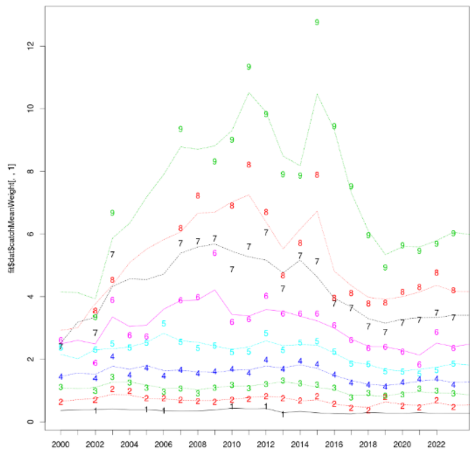

Figure 1. Catch weight at age (in kilograms). Numbers give the input values by age, the line give the estimates from the model

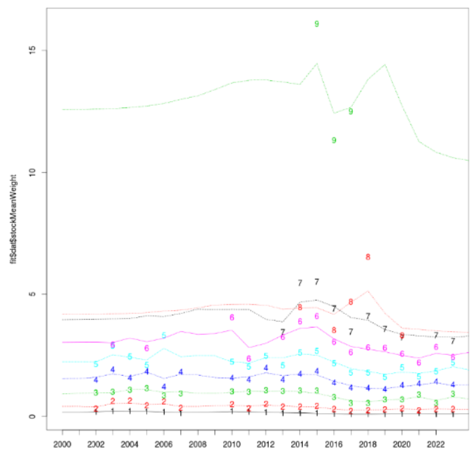

Figure 2. Stock weight at age (in kilograms). Numbers gives the input values by age, the line give the estimates from the model.

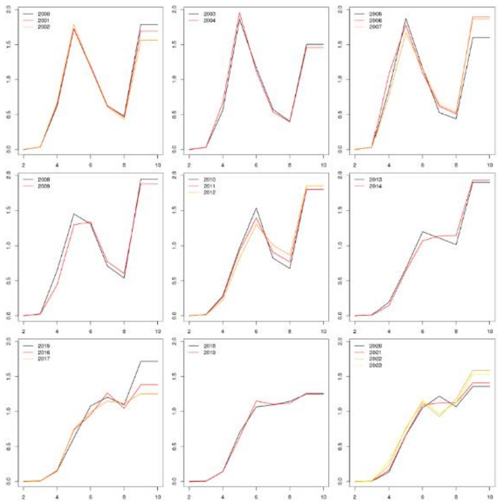

Figure 3. Selection pattern (F_{age}/F_{bar}) from the SAM model.

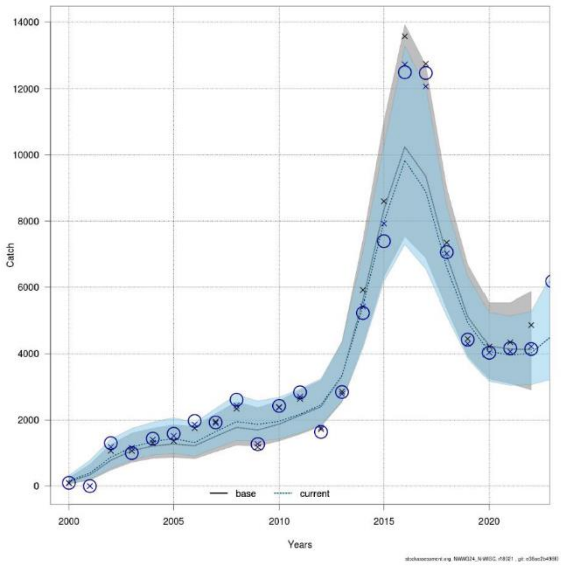

Figure 4. Estimated (line), observed catches (x), and catches based on smoothed catch weights (o). Estimated catch is shown with 95% confidence intervals. Blue lines, shaded area, and symbols are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison.

WD10. ICES WKGREENCOD, 7-10 February 2023

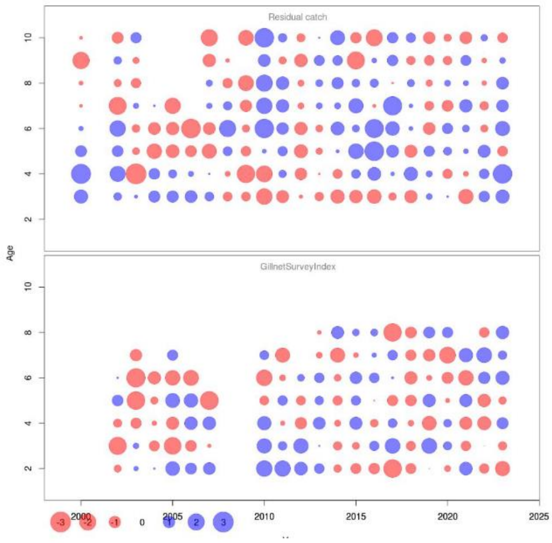

Figure 5. Normalized residuals derived from SAM. Blue indicate positive residuals (observation larger than predicted) and red circles indicated negative residuals.

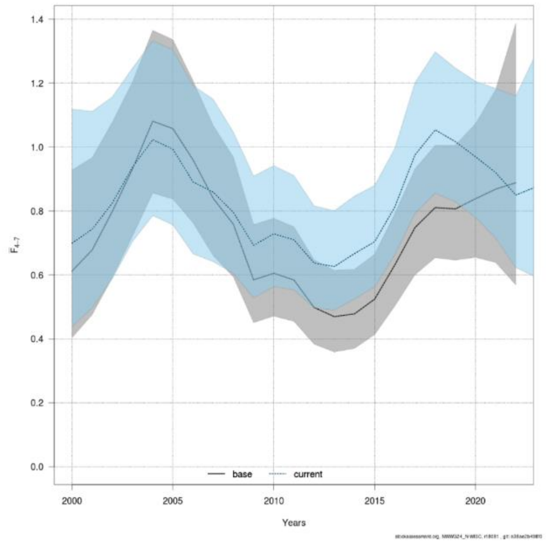

Figure 6. Estimated historical pattern of fishing mortality (Fbar5-8, not that yaxis legend is wrong). The shaded area is 95% confidence intervals. Blue are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison (Fbar was 4-7).

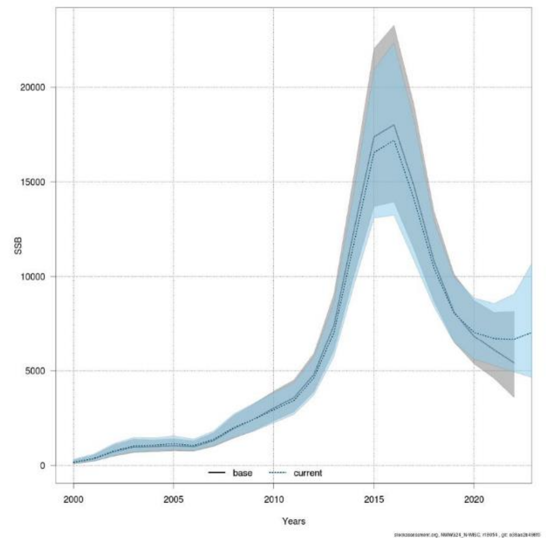

Figure 7. Estimated historical patterns of spawning stock biomass (SSB). The shaded area is 95% confidence intervals. Blue are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison.

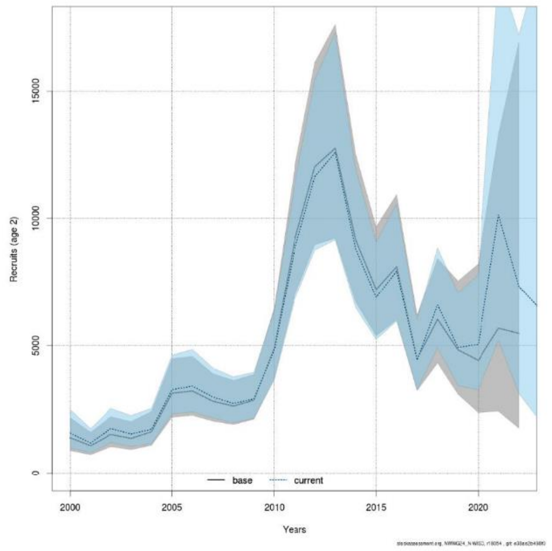

Figure 8. Estimated historical patterns of age 2 recruitment. The shaded area is 95% confidence intervals. Blue are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison.

WD10. ICES WKGREENCOD, 7-10 February 2023

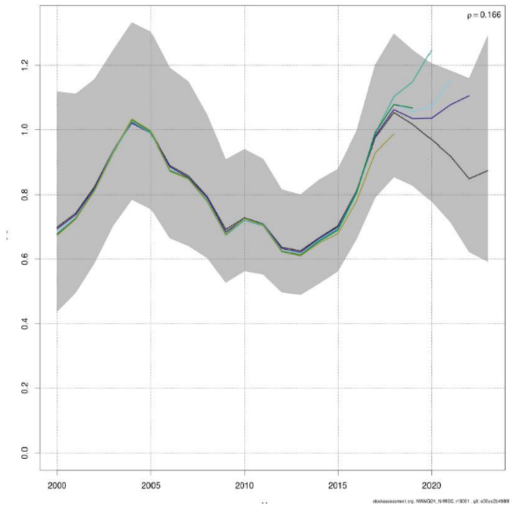

Figure 9. Retrospective plots of Fbar (5-8) (5 years peel). Mohn's rho is given in the upper right corner.

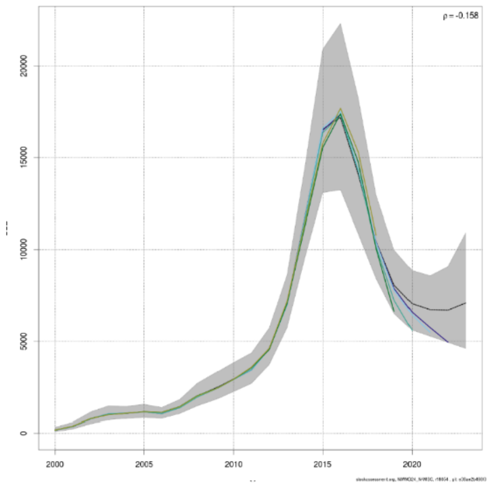

Figure 10. Retrospective plots of SSB (5 years peel). Mohn's rho is given in the upper right corner.

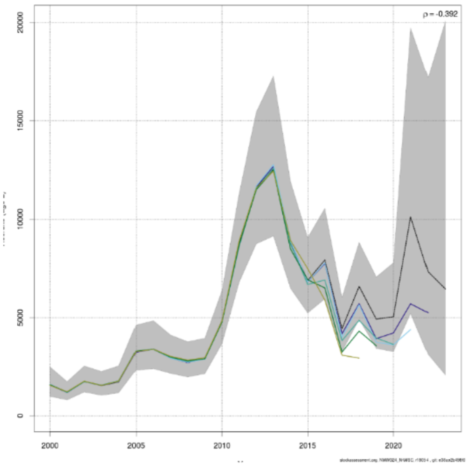

Figure 11. Retrospective plots of age 2 recruitment (5 years peel). Mohn's rho is given in the upper right corner.

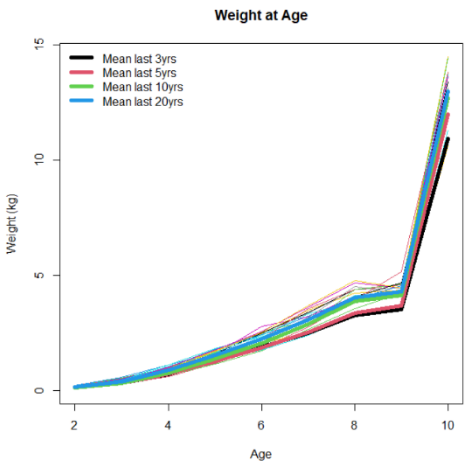

Figure 12. Stock weight at age for all years, bold line show means.

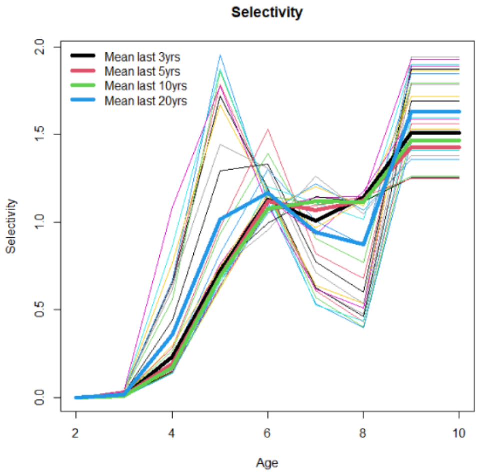

Figure 13. Selectivity at age for all years, bold line show means.

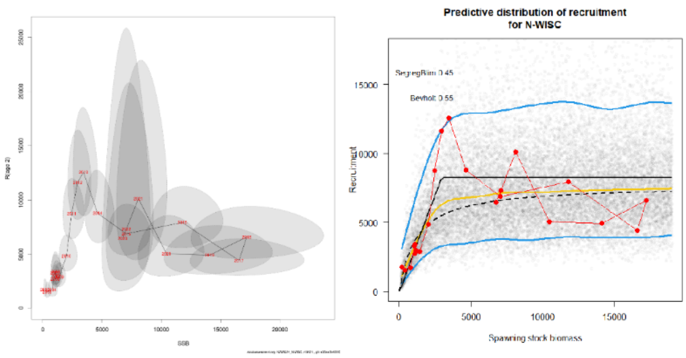

Figure 14. left: SSB-recruitment relationship, labels indicate recruitment year. right: SSB-recruitment relationship estimated by simulation using EqSim with fitted SSB-recruitment relationships. Dashed: Ricker curve. Dotted: Beverton-Holt curve. Solid: Segmented regression. The curve fits are indicated.

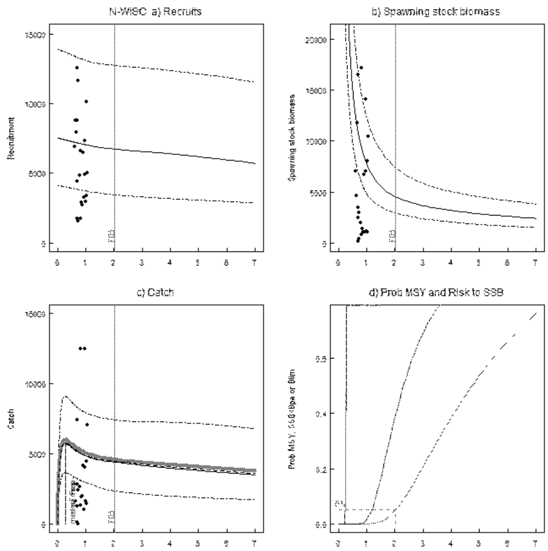

Figure 15. EqSim plots of recruitment, SSB, catch and probability of SSB falling below Bpa and Blim. F is on the x-axis.

WD07. ICES NWWG, 22-26 May 2024

A SAM assessment and reference points for the southern part of West Greenland inshore spawning cod stock (S-WISC)

Stockassessment.org run name: **NWWG24_S-WISC**

Tanja Buch[1], Teunis Jansen[1,2], Anders Nielsen[2], Anja Retzel[1], Søren Post[1]

[1]Greenland Institute of Natural Resources, 3900 Nuuk, Greenland,
[2]DTU Aqua, National Institute of Aquatic Resources, 2800 Kgs. Lyngby, Denmark

Introduction

The Atlantic cod (*Gadus morhua*) in Greenland waters is primarily of three genetically distinct stocks: West Greenland inshore (WISC), West Greenland offshore (WOSC), and East Greenland-Iceland (EGIPSC) (see WKGREENCOD WD01 for details). Previously advice has been provided based on geographical areas. At WKGREENCOD in 2023 data from the commercial fisheries and scientific surveys in Greenland waters are split into the three stock components (see WKGREENCOD WD01, WD02, WD05). For the details on the updated genetic data set used for splitting the data into stocks see WD04 and WD05.

This document presents the updated results of the state-space model (SAM) (Nielsen and Berg, 2014) for the S-WISC stock and the estimated reference points using EqSim. The S-WISC stock represents the WISC stock in NAFO aeras 1D, 1E and 1F.

Input data

The procedures for the input data for the SAM assessment model are described in WKGREENCOD WD05. Details for commercial data for 2023 are in WD03. The Assessment covers the period 2000-2023.

Total catches
Total catches were available for the stock S-WISC from 2000-2023, due to poor sampling in 2001 catch data are not included from that year (see Table 1 for input file). No discarding is believed to take place, landings are assumed to equal catches. The catches are from NAFO areas 1D, 1E and 1F. There are many zero catches for age 2, rather than removing age 2 in the input files, configurations for age 2 catches was set to -1 indicating not data (see Table 2).

Catch mean weight at age
Catch mean weight at age were estimated for all years. Some age-year combination without sufficient data were left as NA in the input file (see Table 1 for input file). The given catch mean weights were then treated as observation to inform the catch weight process (GMRF with cohort and within year correlations) ($catchWeightModel, $keyCatchWeightMean and $keyCatchWeightObsVar in Table 2). See figure 1 for catch weights estimated by the model.

Landings mean weights and discard mean weights are set equal to catch mean weight without any smoothing as these are not used.

Stock mean weight at age
The same process as described to Catch mean weights were used for stock mean weights (see Table 1 for input file) ($stockWeightModel, $keyStockWeightMean and $keyStockWeightObsVar in Table 2), see figure 2 for stock weight estimated by the model.

Surveys
Survey CPUE index by age for ages 2-8 estimated from inshore gillnet survey in area 1D (see Table 1 for input file), for details on index calculations see WKGEENCOD WD06.

Landings fraction
Set to 1, landings are assumed to equal catches.

Natural mortality
Set to default 0.2 for all years and ages (see Table 1 for input file). See details in WKGREENCOD WD05.

Maturity
Maturity ogive is based on genetic dataset presented in WKGREENCOD WD01 (see Table 1 for input file). The ogive is based on the entire GRI stock. Not enough data to produce annual maturity ogives. Details are given in WKGREENCOD WD05.

F before spawning
The fraction of the fishing mortality rate, which is applied prior to spawning divided into age classes for each year. Set to 0 for all years and ages.

M before spawning
The fraction of the natural mortality rate, which is applied prior to spawning divided into age classes for each year. Set to 0 for all years and ages.

Assessment

Configurations

Recruitment
Recruitment parameters are estimated within the assessment model. The parameter structure is assumed as a plain random walk process ($stockRecruitmentModelCode in Table 2).

Fishing mortality and Fbar
Fishing mortality is estimated individually for ages 3-8, age 9 and 10 are assumed to be the same, age 2 is set to -1 and therefore not used ($keyLogFsta in Table 2). It is assumed that there are no correlations across ages ($corFlag in Table 2), this is supported by changes in the selectivity pattern during the assessment period, meaning that correlations between ages are unlikely to be consistent throughout the period (Figure 3). The Fbar range was set to 4-7 years old at the benchmark, at NWWG 2024 the Fbar range was changed to 5-8 as these ages constitutes the main part of the catches in the most recent part of the timeseries ($fbarRange in Table 2).

Survey
The survey catchability parameters are estimated individually for ages, 2, 3 and 4. They are coupled for ages 5 and 6 and for ages 7 and 8 ($keyLogFpar in Table 2).

Variance parameters
For age 2 the coupling of the recruitment and survival process variance parameters for the log(N)-process are different from the other ages ($keyVarLogN in Table 2). In the model.R script the following was added: par$logSdLogN<-c(0,-5), which sets the process variance of N to a very low value. This was needed due to the short assessment time series.

The variance parameters for the catch are separate for age 3 and they are coupled for ages 4-10. Age to is set to -1 and not used. The variance parameters for the survey are separate for age 2 and 3, ages 4-8 are coupled ($keyVarObs in Table 2).

The covariance structure for catch is assumed to be independent ($obsCorStruct in Table 2). For the survey the covariance structure is assumed to follow an AR(1) structure. This was done because there was evidence of year effects in the observation residuals for the survey.

For the catches the variation around the mean were allowed to vary additionally, parameters were coupled for ages 2-3 and for ages 4-10 (see $predVarObsLink in Table 2) (see Breivik et al 2021).

Model diagnostics

Uncertainty surrounding the SSB and F estimates appears reasonable (Figure 7 and 8), although high on F for the first couple of years in the time series. The estimated catches follow the same trend as the observed catches, but fluctuations are smaller (Figure 4). The model is not able to estimate the increase in catches in 2023, but the observed catches are just within the confidence intervals (Figure 4).

Parameter estimation
Parameter estimates are given in Table 3.

Residuals
Observation residuals for both catches and survey shows some tendency for larger residuals early in the time series (Figure 5). There is a block of negative residuals for the survey residuals early in the timeseries and a block of positive residuals in the most recent years. For the catch residuals there are a block of positive residuals, showing that the model underestimate catches in these years. There are some year effects in the residuals.

Alternative SAM configurations

In order to explore the patterns in the residuals and the issues with estimating the high catches in 2024 and couple of configurations was explored in order to improve understanding of the model fit. First a test was done to see the impact if the model were force to fit the observed catches, this did not change the perception of the stock. The configuration for the additional variance around estimates ($PredVarObsLink) were edited to have a separate parameter for age 4 this had no major impact on the model. The Coupling of the variance parameters ($keyVarObs) were explored due to some high parameter estimates, age 4 were set to have its own parameter, this did not improve the model.

Stock summary

Fishing mortality
Fishing mortality peaked in 2007 at 1.243 and then decreased to the lowest level in the assessment period in 2017, it since fluctuated and has increased to 0.618 in 2023 (Figure 6).

SSB
SSB was at a low level at the beginning of the timeseries and increased from 167 in 2000 to 6742 in 2018. Since the SSB has since decreased but remain at a high level relative to the assessment period (Figure 7).

Recruitment
Recruitment was at a low level at the beginning of the assessment period, it increased and had a peak in 2016 (cohort 2014), 2019 (cohort 2017) and in 2021 (cohort 2019). The two most recent years

recruitment have decreased, although these estimates are associated with very large confidence intervals (Figure 8).

Retrospective analysis
In order to test the robustness of the assessment a 5-year retrospective analysis (Figures 9-11) were conducted. For F all peels are within the confidence intervals. Peels for F show good agreement (Mohn'r rho=0.001) (Figure 9). For SSB the oldest and most recent peels underestimate SSB and peels in-between shows a tendency to overestimate SSB. The two most recent peels underestimate SSB, but are within the confidence intervals (Mohn'r rho= -0.05) (Figure 10). For recruitment peels show a tendency to underestimate recruitment (Mohn's rho=-0.373) (Figure 11).

Short term forecast

Short term forecasts were set up using mainly default settings for the SAM run on stockassessment.org. Uncertainty on F were taken from the model. Catch and stock weights were taken from the model used for these, the model is set up to estimate further ahead in time than the assessment run. For maturity and natural mortality average of the last 5 years were used, currently maturity and natural mortality is constant over time so the time period for this would not have any impact. The default for the recruitment is the last 10 years, it was decided at the meeting that this period is appropriate.

Reference points

The estimation of reference points follows ICES Reference Points guidance, 2021. The estimation was done using the R-programme EqSim developed by D. C. M. Miller, which works directly on a specified SAM fit. The code for the final run is on the ICES sharepoint for the NWWG 24 and named 'NWWG24_S-WISC_EqSim_Final.R'. David Miller provided guidance on the ICES procedures and EqSim settings.

Following ICES guidelines the stock-recruitment relationship appears to follow a type 2 stock type, where B_{lim}= segmented regression change point, however this gave a low Blim. It was therefore decided to set Blim as the average of three years where recruitment started to increase (recruitment in 2012-2014, and SSB in 2010-2012). This gave a B_{lim} of 2462. Following initial runs it was decided to exclude recent recruitment estimates due to very high uncertainty (recruitment in 2021-2023, SSB in 2019-2021), this is in line with ICES guidelines.

The simulation settings for the stock-recruitment relationship were as follows. The number of simulations were set to 1500. For assessment error sigmaF and sigmaSSB was set to default of 0.2. The default values were used for forecast errors: cvF=0.212, phiF=0.423, cvSSB=0 and phiSSB=0. For weight at age the last 5 years were used, based on figure 16 there has been a reduction in weight-at-age in the assessment period. For selectivity the last 10 years were used, there appear to have been a change in selectivity early in the assessment period (Figure 17).

For the segmented regression the breakpoint was fixed to Blim, this resulted in that the level part of the segmented regression was above the estimated recruitments. It was therefore decided to also fixe the slope for the segmented regression. The slope was fixed such that the level part of the segmented regression was at the average recruitment of the years 2012 (first year used to estimate Blim) to 2020 (last year in timeseries used in the simulations, 2021-2023 were uncertain estimated). The slope was fixed to 2.1. Fixing both the slope and breakpoint of the segmented regression resulted in the segmented regression getting a low weight (compared to Ricker and Beverton-Holt) in the simulations.

The Ricker model was included in the simulations for this stocks, the indications of density dependence for this stock was discussed at NWWG 2024.This stock is at a high level based both on the assessment, results from an a acoustic survey that are in the upstart phase, and perception of the stock from the industry. The main part of this stock are in the Nuuk fjord, it is therefore expected that there are a physical boundary for stock growth. And in recent years there's been a drop in weight-at-age in the survey data. All of this indicates that under current circumstances it is unlikely that the stock size will be able reach stock level much above the current level.

Due to uncertainty in the estimates of reference points, and a large estimate of Fmsy, relative to othere cod stocks, the lower level of Fmsy is also presented to give a range in the advised catches.

Run settings are given in table 4. The estimated reference points are given in table 5. Due to very high estimate of F_{lim}, it was decided to not report on this value.

It was decided to follow standard ICES guidelines for the basis of $MSYB_{tigger}$, which were set at B_{pa}.

Conclusion

The model presented here fit the observation reasonably well and seems to capture trends in stock size and fishing mortality well.

References

Breivik, O. N., Nielsen, A., Berg, C. W. 2021. Prediction-variance relation in a state-space fish stock assessment model. ICES Journal of Marine Science. 78 (10): 3650-3657.

Nielsen, A., Berg, C. W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries research. 158: 96-101.

Table 1. Input files to SAM runs.

Catch in Numbers (thousands)

1	2							
2000	2023							
2	10							
1								
1.00E-04	0.793964	38.93993	62.07122	1.377184	0.047447	0.028541	1.00E-04	1.00E-04
-1	-1	-1	-1	-1	-1	-1	-1	-1
0.007364	17.18544	98.0071	39.75315	2.211902	0.923647	0.07717	0.0356	0.011644
0	4.470471	28.67744	33.30953	15.16996	7.538604	3.282937	3.394399	2.83093
0	6.161103	48.87058	112.6526	30.74672	2.137195	0.738316	0	0
0.000367	63.75377	122.1168	28.24534	26.58065	7.775146	2.587457	1.253451	0.030993
1.523062	494.8169	383.8878	100.4681	4.446128	0.799555	0.355972	0.033419	0.000477
0.028148	53.45459	974.3216	192.0597	34.95586	9.86052	3.623157	2.369715	1.779151
0	76.03608	905.3465	445.8495	79.12774	21.86891	1.325776	0	0
0.024374	22.00264	507.7184	448.2183	32.20038	6.299966	1.86515	0.268101	2.089
0.0109	23.97422	106.5822	362.063	185.3643	8.149162	1.549293	0.394697	0.79964
0.020067	13.78788	392.8636	357.2238	248.3372	46.59408	18.89541	2.313426	1.296631
0.035218	81.50858	337.4274	674.8034	192.8544	42.06427	2.376189	1.399542	6.947901
0	4.128848	453.645	390.6813	270.7961	102.6546	36.06298	9.628399	0.440796
0	7.665747	231.9663	396.6828	299.0817	43.58328	9.79902	4.736815	2.189293
0.05172	2.237758	416.5244	906.6207	367.8932	254.2307	20.02427	2.32946	1.053755
0	11.57496	311.5487	1220.485	465.8096	88.75709	22.74769	5.490808	2.544607
0.016713	6.694257	175.6164	673.1653	356.4926	164.9001	90.74116	12.13497	7.700152
0.003594	7.613766	287.712	1066.912	899.8266	496.7816	165.0413	41.48498	16.51772
0	2.425293	342.4627	1513.105	1410.158	592.0083	144.0142	30.5367	7.45919
0	32.05712	590.6137	960.0003	1133.585	303.9325	147.8209	31.20862	11.64492
0.000973	0.928871	333.4664	784.3331	435.7753	274.7368	41.60444	11.85081	7.937059
0	9.846102	81.42845	878.7477	502.8658	308.5946	173.9501	28.26062	4.904716
0	6.273255	901.591	727.6625	1116.776	671.9372	203.9275	29.50968	6.876599

Table 1 *continued*

Mean Weight in Catch (kilograms)

1	3							
2000	2023							
2	10							
1								
NA	0.641808	1.120983	1.453028	2.378079	2.62124	2.408667	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA
0.36	0.707845	0.998694	1.397425	2.317673	1.884027	2.852515	3.559567	3.355852
NA	1.0204	1.32872	1.914603	2.64373	3.118567	3.82932	5.178636	6.981696
NA	0.890787	1.090179	1.660006	2.00526	4.324258	6.131665	NA	NA
0.303882	0.912498	1.11705	1.696517	2.342388	2.625469	2.8378	6.942667	7.582453
0.362088	0.734762	0.950086	1.548464	2.875723	3.746741	5.142035	7.832512	8.126823
0.194933	0.722388	0.955078	1.542382	2.624526	4.261527	5.006923	6.889712	10.33394
NA	0.578555	0.867019	1.359872	1.99314	2.993319	3.843217	NA	NA
0.241705	0.636927	0.878977	1.37612	2.324998	4.079164	5.836554	8.546285	14.16653
0.502949	0.669823	0.911832	1.488398	1.962371	3.097669	4.96527	7.207421	18.59193
0.375913	0.6172	0.866937	1.365336	1.865838	3.327549	5.147272	6.763082	8.779587
0.33677	0.728879	1.060237	1.753869	2.580547	3.029427	5.106263	7.484625	13.87103
NA	0.760212	1.242364	1.577629	2.262953	2.67898	3.09964	2.503226	8.003833
NA	0.68838	1.213322	1.845695	2.450439	3.230041	4.977061	5.379195	8.353199
0.126285	0.50159	1.02599	1.508902	2.250287	3.187228	4.536673	7.081664	9.043975
NA	0.465706	0.893828	1.312794	1.938242	2.714969	3.258068	3.794213	8.718415
0.175223	0.633287	0.79767	1.275438	1.793908	2.541663	3.017397	4.239587	5.899611
0.090885	0.386176	0.743217	1.024636	1.37352	1.905132	2.639655	3.099141	4.041773
NA	0.40028	0.74094	1.023818	1.324319	1.526384	1.924299	3.421387	4.598435
NA	0.546396	0.952717	1.202922	1.360348	1.697204	2.166043	2.606857	4.004523
0.283159	0.61419	0.984451	1.322289	1.482853	1.738112	2.422648	3.679712	6.376435
NA	0.624319	0.789764	1.109976	1.323326	1.560345	1.829731	2.454535	4.247756
NA	0.6961	1.010488	1.210447	1.40846	1.532201	1.985023	2.992891	6.398734

Table 1 *continued*

Mean Weight in survey (kilograms)

1	3							
2000	2023							
2	10							
1								
NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA
0.178711	0.372855	1.164987	1.666899	NA	NA	NA	NA	NA
0.200384	0.509219	0.903717	1.313719	2.940008	2.940008	NA	NA	NA
0.244195	0.411248	1.007491	1.555912	1.82487	3.23	5.1	NA	NA
0.21572	0.405074	1.193628	1.35984	NA	NA	NA	NA	NA
0.180079	0.5015	0.904282	1.914018	2.88	4.46	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA
0.106996	0.312471	0.544616	1.27122	2.236465	NA	NA	NA	NA
0.13531	0.373555	0.793965	1.154585	2.343402	NA	4.62	NA	NA
0.187473	0.414688	0.840456	1.526005	1.823862	NA	NA	NA	NA
0.203682	0.448732	0.859835	1.267448	1.684729	2.693545	3.14	NA	NA
0.191192	0.556588	1.098621	1.804766	3.167868	4.731064	6.836147	NA	NA
0.121691	0.312833	1.10983	1.361354	2.09763	2.308694	2.521522	2.246	NA
0.120639	0.352143	0.979343	1.67501	2.13143	1.922605	5.042	NA	NA
0.10434	0.272676	0.713028	1.382702	2.108191	3.130409	NA	NA	NA
0.10979	0.281234	0.784065	1.199983	1.727793	2.222613	3.534	3.216	8.534193
0.14053	0.277927	0.637082	1.144455	1.674742	2.144053	3.483952	NA	3.98
0.105514	0.26423	0.534864	0.880574	1.279475	1.732384	2.006669	2.383061	2.878
0.089153	0.231504	0.48118	0.719475	1.143764	1.407083	2.022413	3.39	2.36
0.123506	0.278703	0.513948	0.908574	1.200449	1.302811	1.853526	1.78	NA
0.119077	0.29454	0.620332	0.985807	1.16801	1.35504	2.184218	2.589228	NA
0.100747	0.26275	0.466657	1.006275	1.291268	1.603316	1.963955	2.317174	4.931661
0.100742	0.241078	0.575256	0.944976	1.190312	1.534726	1.966242	3.106839	NA

Table 1 *continued*

Proportion	Mature	at	Year	Start				
1	6							
2000	2023							
2	10							
1								
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000
0.020	0.085	0.299	0.661	0.899	0.976	0.995	0.999	1.000

Table 1 *continued*

Natural Mortality
1 5
2000 2023
2 10
1

0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 1 *continued*

Inshore							
Gillnet (1D)	CPUE	S-WISC					
102							
GillnetSurveyIndex							
2002	2023						
1	1	0.5	0.6				
2	8						
1	2.030076	1.694993	1.120311	0.220737	0	0	0
1	2.163314	1.42689	1.24443	0.485243	0.056223	0.008049	0
1	15.59074	5.023375	1.194868	0.830836	0.136351	0.024381	0.097228
1	20.48483	3.803144	1.073705	0.297858	0	0	0
1	43.91534	13.30384	5.369011	0.515045	0.133845	0.166821	0
1	-1	-1	-1	-1	-1	-1	-1
1	1.223006	18.87783	29.70469	3.959445	0.029871	0	0
1	17.80642	5.133497	35.04736	14.37024	0.397063	0	0.186944
1	8.774837	52.23121	7.970768	14.25703	1.153039	0	0
1	10.52315	1.547878	7.718505	3.3221	2.568714	1.264628	0.112798
1	28.43018	14.28744	10.7732	16.08469	1.04543	0.239955	0.343681
1	48.77247	34.55479	27.89985	13.46559	5.094573	1.558193	0.868891
1	21.33349	41.53324	26.55715	11.0199	3.751872	0.45993	0.16916
1	23.13662	44.64827	39.27455	16.36684	2.80479	1.228572	0
1	29.75841	56.05443	19.36197	25.04827	4.239948	0.249542	0.399869
1	6.161722	42.34397	35.78032	26.88068	8.051932	0.744861	0.641008
1	7.949663	26.87329	34.5858	26.14594	13.14114	4.593444	0.821411
1	13.15665	24.30492	31.16952	33.25539	15.21119	4.407329	0.259565
1	3.624026	26.43903	17.97405	13.28566	18.72488	7.269911	1.711621
1	20.47404	16.06326	57.36092	38.12176	23.16952	14.13204	0.881085
1	8.129301	54.94482	15.77351	28.55162	10.53598	6.563384	2.944724
1	4.716399	18.14337	26.66762	11.00527	12.49503	3.68749	1.708386

Table 2. SAM configurations for NWWG24_S-WISC

```
# Configuration saved: Mon Jan 16 14:23:05 2023
#
# 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
# Negative numbers indicate that the parameter is not included in the model
#
$minAge
# The minimium age class in the assessment
 2

$maxAge
# The maximum age class in the assessment
 10

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

$keyLogFsta
# Coupling of the fishing mortality states processes for each age (normally only
# the first row (= fleet) is used).
# Sequential numbers indicate that the fishing mortality is estimated individually
# for those ages; if the same number is used for two or more ages, F is bound for
# those ages (assumed to be the same). Binding fully selected ages will result in a
# flat selection pattern for those ages.
  -1 0  1  2  3  4  5  6  6
 -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).
# 0: independent means there is no correlation between F across age
# 1: compound symmetry means that all ages are equally correlated;
# 2: AR(1) first order autoregressive - similar ages are more highly correlated than
# ages that are further apart, so similar ages have similar F patterns over time.
# if the estimated correlation is high, then the F pattern over time for each age
# varies in a similar way. E.g if almost one, then they are parallel (like a
# separable model) and if almost zero then they are independent.
# 3: Separable AR - Included for historic reasons . . .  more later
 0

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is
# not used, as that is covered by fishing mortality).
 -1 -1 -1 -1 -1 -1 -1 -1 -1
  0  1  2  3  3  4  4 -1 -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

$keyVarF
# Coupling of process variance parameters for log(F)-process (Fishing mortality
```

normally applies to the first (fishing) fleet; therefore only first row is used)
-1 0 0 0 0 0 0 0 0
-1 -1 -1 -1 -1 -1 -1 -1 -1

$keyVarLogN
Coupling of the recruitment and survival process variance parameters for the
log(N)-process at the different ages. It is advisable to have at least the first age
class (recruitment) separate, because recruitment is a different process than
survival.
0 1 1 1 1 1 1 1

$keyVarObs
Coupling of the variance parameters for the observations.
First row refers to the coupling of the variance parameters for the catch data
observations by age
Second and further rows refers to coupling of the variance parameters for the
index data observations by age
-1 0 1 1 1 1 1 1 1
2 3 4 4 4 5 5 -1 -1

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

$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).
#2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
NA NA NA NA NA NA NA NA
0 0 0 0 0 0 -1 -1

$stockRecruitmentModelCode
Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, 3 piece-wise constant, 61 for segmented regression/hockey stick, 62 for AR(1), 63 for bent hyperbola / smooth hockey stick, 64 for power function with degree < 1, 65 for power function with degree > 1, 66 for Shepher, 67 for Deriso, 68 for Saila-Lorda, 69 for sigmoidal Beverton-Holt, 90 for CMP spline, 91 for more flexible spline, and 92 for most flexible spline).
0

$noScaledYears
Number of years where catch scaling is applied.
0

$keyScaledYears
A vector of the years where catch scaling is applied.

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

$fbarRange
lowest and higest age included in Fbar
5 8

$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

$obsLikelihoodFlag
Option for observational likelihood | Possible values are: "LN" "ALN"
"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 (for each age group)
0 0 0 0 0 0 0 0 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

$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)

$predVarObsLink
Coupling of parameters used in a prediction-variance link for observations.
0 0 1 1 1 1 1 1 1
-1 -1 -1 -1 -1 -1 -1 NA NA

$hockeyStickCurve
#
20

$stockWeightModel
Integer code describing the treatment of stock weights in the model (0 use as known, 1 use as observations to inform stock weight process (GMRF with cohort and within year correlations))
1

$keyStockWeightMean
Coupling of stock-weight process mean parameters (not used if stockWeightModel==0)
0 1 2 3 4 5 6 7 8

$keyStockWeightObsVar
Coupling of stock-weight observation variance parameters (not used if stockWeightModel==0)
0 0 0 0 0 0 0 0 0

$catchWeightModel
Integer code describing the treatment of catch weights in the model (0 use as known, 1 use as observations to inform catch weight process (GMRF with cohort and within year correlations))
1

$keyCatchWeightMean

Coupling of catch-weight process mean parameters (not used if catchWeightModel==0)
0 1 2 3 4 5 6 7 8

$keyCatchWeightObsVar
Coupling of catch-weight observation variance parameters (not used if catchWeightModel==0)
0 0 0 0 0 0 0 0 0

$matureModel
Integer code describing the treatment of proportion mature in the model (0 use as known, 1 use as observations to inform proportion mature process (GMRF with cohort and within year correlations on logit(proportion mature)))
0

$keyMatureMean
Coupling of mature process mean parameters (not used if matureModel==0)
NA NA NA NA NA NA NA NA NA

$mortalityModel
Integer code describing the treatment of natural mortality in the model (0 use as known, 1 use as observations to inform natural mortality process (GMRF with cohort and within year correlations))
0

$keyMortalityMean
#
NA NA NA NA NA NA NA NA NA

$keyMortalityObsVar
Coupling of natural mortality observation variance parameters (not used if mortalityModel==0)
NA NA NA NA NA NA NA NA NA

$keyXtraSd
An integer matrix with 4 columns (fleet year age coupling), which allows additional uncertainty to be estimated for the specified observations

Table 3. Table of SAM model parameters.

Parameter name	par	sd(par)	exp(par)	Low	High
logFpar_0	-5.548	0.193	0.004	0.003	0.006
logFpar_1	-4.928	0.150	0.007	0.005	0.010
logFpar_2	-4.650	0.102	0.010	0.008	0.012
logFpar_3	-4.414	0.102	0.012	0.010	0.015
logFpar_4	-4.276	0.223	0.014	0.009	0.022
logSdLogFsta_0	-1.090	0.161	0.336	0.244	0.464
logSdLogN_0	-0.639	0.182	0.528	0.366	0.760
logSdLogObs_0	0.029	1.470	1.029	0.054	19.454
logSdLogObs_1	2.109	0.479	8.238	3.158	21.485
logSdLogObs_2	-0.191	0.170	0.826	0.588	1.159
logSdLogObs_3	-0.451	0.161	0.637	0.461	0.879
logSdLogObs_4	-0.900	0.131	0.407	0.313	0.529
logSdLogObs_5	-0.065	0.143	0.937	0.704	1.247
transfIRARdist_0	0.523	0.294	1.687	0.937	3.034
predVarObs_0	0.217	0.480	1.242	0.476	3.242
predVarObs_1	-1.190	0.350	0.304	0.151	0.613

logPhiSW_0	5.439	1.516	230.165	11.106	4769.848
logPhiSW_1	6.061	1.553	428.590	19.195	9569.628
logSdProcLogSW_0	1.385	0.713	3.994	0.960	16.613
meanLogSW_0	-1.949	0.242	0.142	0.088	0.231
meanLogSW_1	-1.085	0.240	0.338	0.209	0.546
meanLogSW_2	-0.298	0.238	0.742	0.461	1.195
meanLogSW_3	0.173	0.238	1.189	0.739	1.912
meanLogSW_4	0.544	0.238	1.723	1.070	2.774
meanLogSW_5	0.772	0.240	2.163	1.338	3.497
meanLogSW_6	1.079	0.243	2.941	1.809	4.780
meanLogSW_7	1.038	0.252	2.825	1.706	4.679
meanLogSW_8	1.418	0.269	4.130	2.410	7.079
logSdLogSW_0	-1.850	0.133	0.157	0.121	0.205
logPhiCW_0	4.203	1.290	66.863	5.065	882.630
logPhiCW_1	4.816	1.266	123.511	9.817	1553.983
logSdProcLogCW_0	0.969	0.604	2.635	0.787	8.819
meanLogCW_0	-1.385	0.180	0.250	0.175	0.359
meanLogCW_1	-0.442	0.169	0.643	0.458	0.902
meanLogCW_2	-0.042	0.166	0.959	0.687	1.338
meanLogCW_3	0.329	0.165	1.390	0.999	1.934
meanLogCW_4	0.642	0.165	1.900	1.366	2.644
meanLogCW_5	0.901	0.167	2.462	1.764	3.437
meanLogCW_6	1.162	0.169	3.198	2.278	4.488
meanLogCW_7	1.459	0.174	4.302	3.038	6.093
meanLogCW_8	1.902	0.180	6.698	4.676	9.593
logSdLogCW_0	-2.093	0.172	0.123	0.087	0.174

Table 4. Run setting for EqSim

From R scripts	description	Value
stockName	Name of the stock	S-WISC
SAOAssessment	Name of assessment on stockassessmet.org	NWWG24_S-WISC
sigmaF	From SAM assessment	0.2
sigmaSSB	From SAM assessment	0.2
noSims	Recommended minimum 1000	1500
SRused	Models used in the simulations (usually segmented regression with breakpoint fixed and blim and slope fixed at 2.1), Ricker, beverton-holt). Weight given to the model in the simulation given in brackets.	Segreg_Ricker_Bevholt
SRyears_min	Same as assessment	2000
SRyears_max	One less than assessment	2022
rhoRec	Autocorrelation in recruitment	FALSE
numAvgYrsB	Years used for the average Weight at age	5
numAvgYrsS	Years used for the average selectivity	10
cvF	Forecast error F	0.212
phiF	Forecast error F	0.423
cvSSB	Forecast error SSB	0
phiSSB	Forecast error SSB	0
rmSRRYrs	Which years (SSB years, not recruitment years) to exclude from the SRR fits	2019 -2021 SSB

Table 5. Reference points estimated from EqSim. Compared with reference points estimated at WKGREENCOD 2023.

Framework	Reference point	Value	Technical basis	WKGREENCOD 2023	Technical basis
MSY approach	MSY $B_{trigger}$	3421	Bpa	4116	0.5 × B_{MSY}
	F_{MSY}	0.54	Stochastic simulations (EqSim) using segmented regression (breakpoint fixed to Blim, slope fixed to 2.1), Ricker and Beverton–Holt.	0.29	Stochastic simulations (EqSim) using segmented regression, Ricker and Beverton–Holt.
	$F_{MSYlower}$	0.27	Consistent with lower range resulting in no more than 5% reduction in long-term yield compared to MSY		
Precautionary approach	B_{lim}	2462	Average of the corrosponding SSB for the 3 years where recruitment starts to increase in 2012-2014 (SSB in 2010-2012)	1067	From segmented regression breakpoint
	B_{pa}	3421	B_{lim} × exp(σ × 1.645), σ = 0.2	1510	B_{lim} × exp(σ × 1.645), σ = 0.211
	F_{lim}	2.15	Not defined	-	Not defined
	F_{pa}	1.38	Not defined	-	Not defined

WD11. ICES WKGREENCOD, 7-10 February 2023

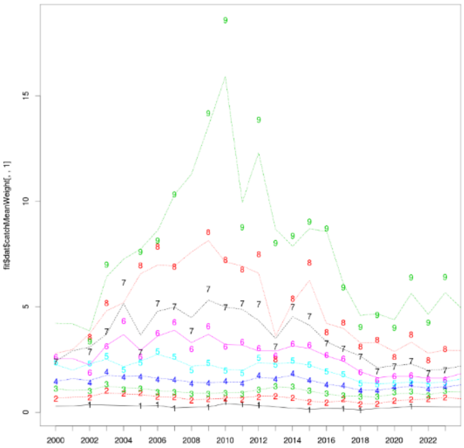

Figure 1. Catch weight at age (in kilograms). Numbers give the input values by age, the line give the estimates from the model

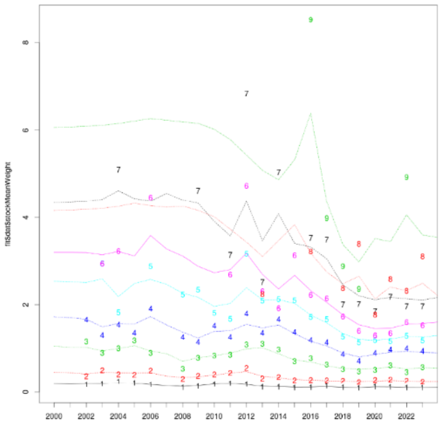

Figure 2. Stock weight at age (in kilograms). Numbers gives the input values by age, the line give the estimates from the model.

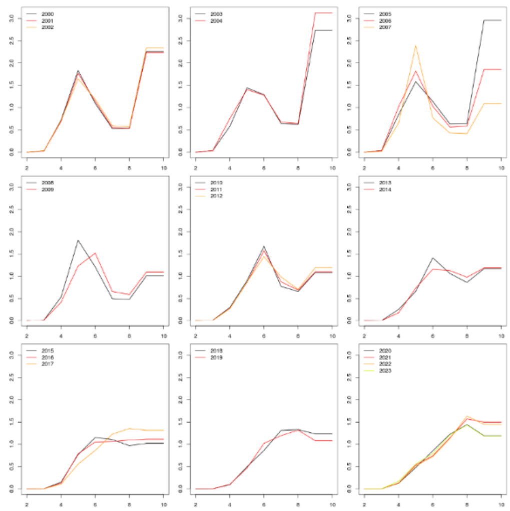

Figure 3. Selection pattern (F_{age}/Fbar) from the SAM model.

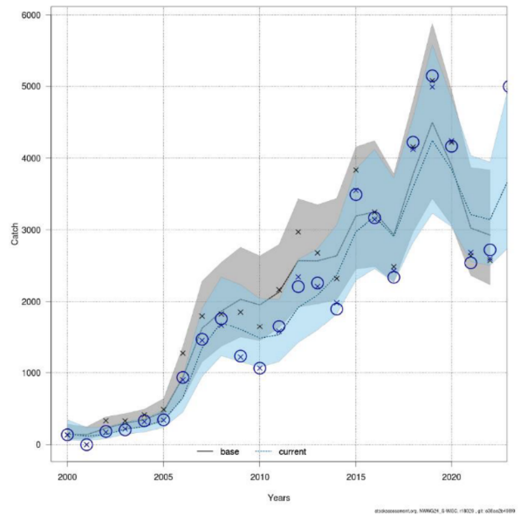

Figure 4. Estimated (blueline), observed catches (blue x), and catches based on smoothed catch weights (blue o). Estimated catch is shown with 95% confidence intervals. Black/grey lines are from the 2023 assessment.

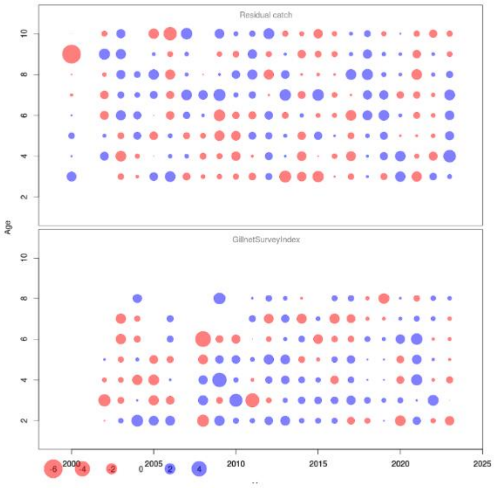

Figure 5. Normalized residuals derived from SAM. Blue indicate positive residuals (observation larger than predicted) and red circles indicated negative residuals.

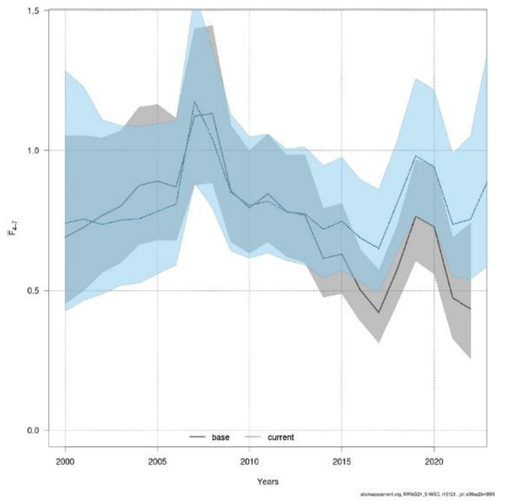

Figure 6. Estimated historical pattern of fishing mortality (Fbar5-8, not that legend for the y axis is wrong). The shaded area is 95% confidence intervals. Blue line and shaded area are the current assessment, the black/grey line are the accepted assessment from 2023.

WD11. ICES WKGREENCOD, 7-10 February 2023

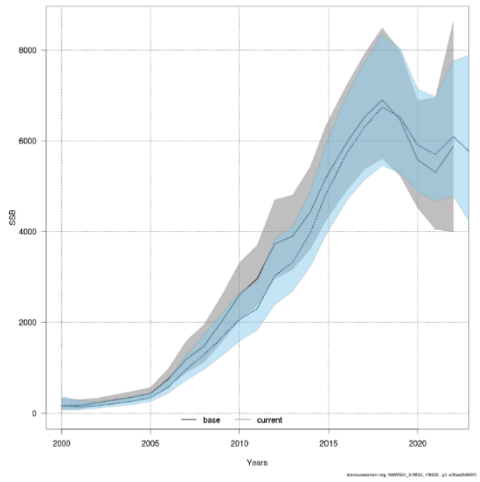

Figure 7. Estimated historical patterns of spawning stock biomass (SSB). The shaded area is 95% confidence intervals. Blue line and shaded area are the current assessment, the black/grey line are the accepted assessment from 2023.

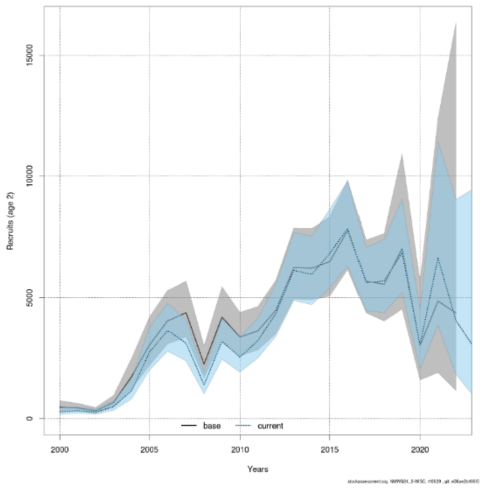

Figure 8. Estimated historical patterns of age 2 recruitment. The shaded area is 95% confidence intervals. Blue line and shaded area are the current assessment, the black/grey line are the accepted assessment from 2023.

WD11. ICES WKGREENCOD, 7-10 February 2023

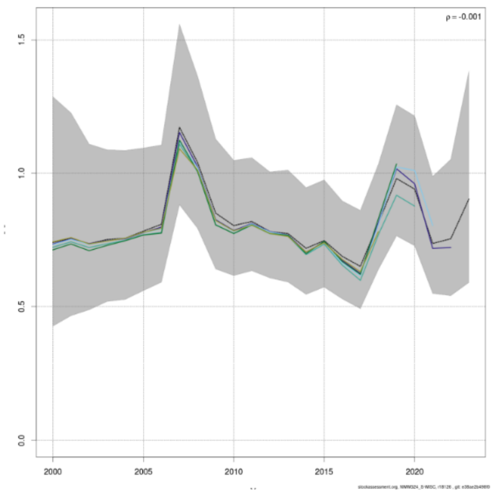

Figure 9. Retrospective plots of Fbar (5-8) (5 years peel). Mohn's rho is given in the upper right corner.

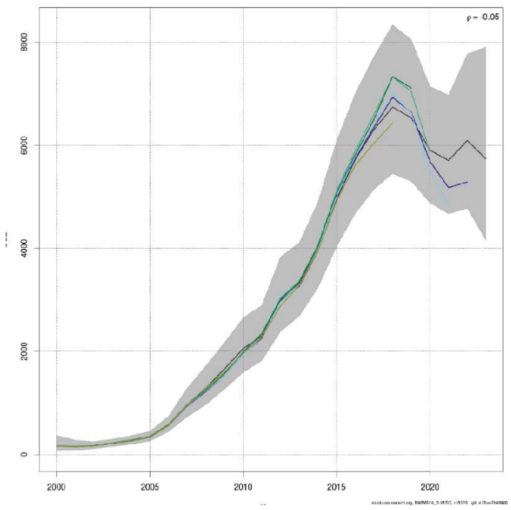

Figure 10. Retrospective plots of SSB (5 years peel). Mohn's rho is given in the upper right corner.

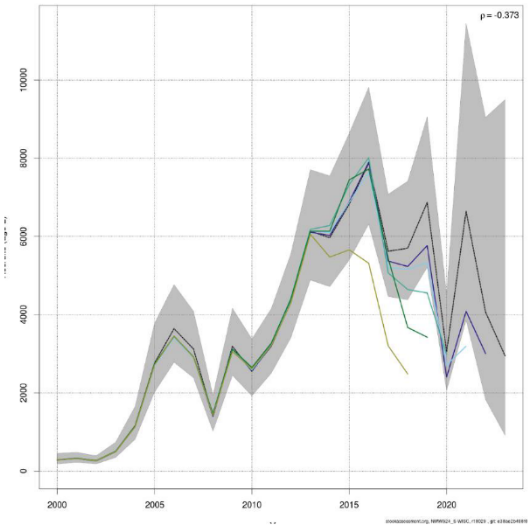

Figure 11. Retrospective plots of age 2 recruitment (5 years peel). Mohn's rho is given in the upper right corner.

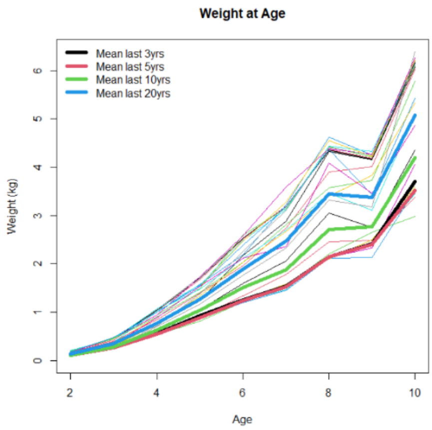

Figure 12. Stock weight at age for all years, bold line show means.

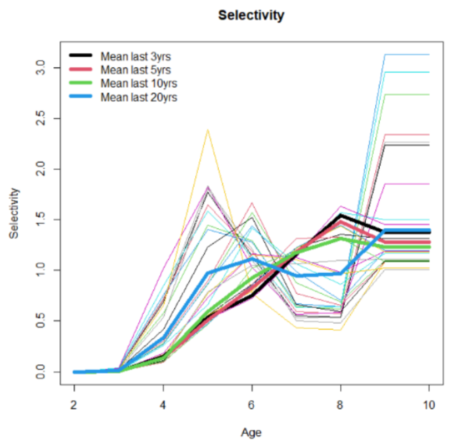

Figure 13. Selectivity at age for all years, bold line show means.

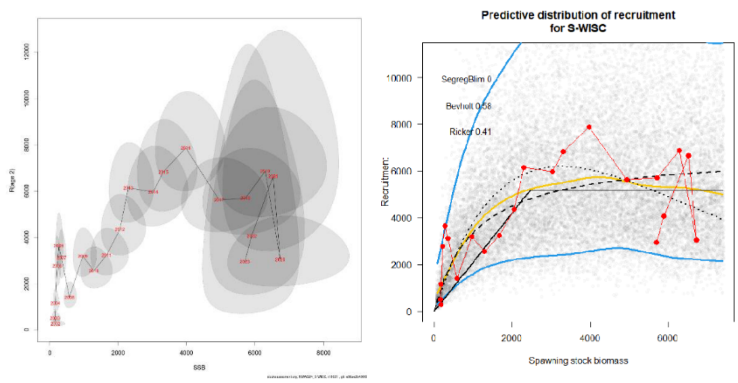

Figure 14. left: SSB-recruitment relationship, labels indicate recruitment year. right: SSB-recruitment relationship estimated by simulation using EqSim with fitted SSB-recruitment relationships. Dashed: Ricker curve. Dotted: Beverton-Holt curve. Solid: Segmented regression (with breakpoint fixed to Blim and slope fixed to 2.1). The curve fits are indicated.

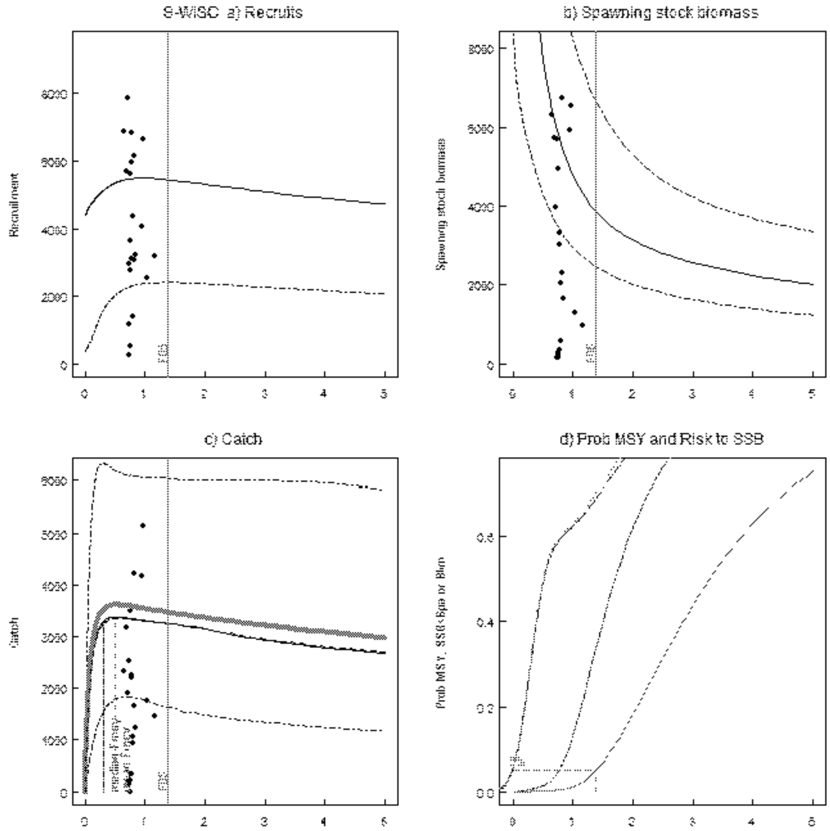

Figure 15. EqSim plots of recruitment, SSB, catch and probability of SSB falling below Bpa and Blim. F is on the x-axis.

WD08. ICES NWWG, 22-26 May 2024

A SAM assessment and reference points for the West Greenland offshore spawning cod stock (WOSC)

Stockassessment.org run name: **NWWG24_WOSC**

Tanja Buch[1], Teunis Jansen[1,2], Anders Nielsen[2], Anja Retzel[1], Søren Post[1]

[1]Greenland Institute of Natural Resources, 3900 Nuuk, Greenland,
[2]DTU Aqua, National Institute of Aquatic Resources, 2800 Kgs. Lyngby, Denmark

Introduction

The Atlantic cod (*Gadus morhua*) in Greenland waters is primarily of three genetically distinct stocks: West Greenland inshore (WISC), West Greenland offshore (WOSC), and East Greenland-Iceland (EGIOSC) (see WKGREENCOD WD01 for details). Previously advice has been provided based on geographical areas. At WKGREENCOD data from the commercial fisheries and scientific surveys in Greenland waters are split into the three stock components (see WKGREENCOD WD01, WD02, WD05). For detail on additional genetic data used in the model for splitting data into stocks see WD04 and WD05.

This document presents the results of the state-space model (SAM) (Nielsen and Berg, 2014) for the WOSC stock and estimation of reference points using EqSim. This document was updated for NWWG 2024, including the reference points accepted at NWWG 2024.

At WKGREENCOD it was recommended that new reference points were estimated at NWWG 24 when two more years on data were available.

Input data

The procedures for the input data for the SAM assessment model are described in WKGREENCOD WD05. Details for commercial data for 2023 are in WD03. The Assessment covers the period 2000-2023.

Total catches
Total catches were available for the stock WOSC from 2000-2023, due to poor sampling in 2001 catch data are not included from that year (see Table 1 for input file). No discarding is believed to take place, landings are assumed to equal catches.

Catch mean weight at age
Catch mean weight at age were estimated for all years. Some age-year combination without sufficient data were left as NA in the input file (see Table 1 for input file). The given catch mean weights were then treated as observation to inform the catch weight process (GMRF with cohort and within-year correlations) ($catchWeightModel, $keyCatchWeightMean and $keyCatchWeightObsVar in Table 2). See figure 1 for catch weights estimated by the model.

Landings mean weights and discard mean weights are set equal to catch mean weight without any smoothing as these are not used.

Stock mean weight at age
The same process as described to Catch mean weights were used for stock mean weights (see Table 1 for input file) ($stockWeightModel, $keyStockWEightMean and $keyStockWeightObsVar in Table 2),

see figure 2 for stock weight estimated by the model. The stock weights are calculated from the Greenlandic offshore survey.

Surveys
Two tuning series are used for this assessment. The first is a survey index by age for ages 2-7 estimated using INLA (see Table 1 for input file), for details on survey data see WKGREENCOD WD05 and for details on INLA see WKGREENCOD WD03. Input data for INLA is two offshore trawl surveys. The second is a CPUE index by age for ages 2-6 for the inshore gillnet survey in NAFO areas 1B and 1D combined into one index (see WKGREENCOD WD05 for information on survey and WKGREENCOD WD06 for index calculations).

Landings fraction
Set to 1, landings are assumed to equal catches.

Natural mortality
Set to default 0.2 for all years and ages (see Table 1 for input file). See details in WKGREENCOD WD05.

Maturity
Maturity ogive is based on genetic dataset presented in WD01 (see Table 1 for input file). There are currently not data to produce annual maturity ogives. Details are given in WKGREENCOD WD05.

F before spawning
The fraction of the fishing mortality rate, which is applied prior to spawning divided into age classes for each year. Set to 0 for all years and ages.

M before spawning
The fraction of the natural mortality rate, which is applied prior to spawning divided into age classes for each year. Set to 0 for all years and ages.

Assessment

Configurations

Recruitment
Recruitment parameters are estimated within the assessment model. The parameter structure is assumed as a plain random walk process ($stockRecruitmentModelCode in Table 2).

Fishing mortality and Fbar
Fishing mortality is estimated individually for ages 2-8, age 9 and 10 are assumed to be the same ($keyLogFsta in Table 2). It is assumed that there are no correlations across ages ($corFlag in Table 2), this is supported by changes in the selectivity pattern during the assessment period, meaning that correlations between ages are unlikely to be consistent throughout the period (Figure 3). The Fbar range was set to 4-7 years old at the benchmark in 2023, this was range to 5-8 at NWWG 2024 as these ages constitutes the main part of the catches in the recent half of the timeseries ($fbarRange in Table 2).

Survey
The survey catchability parameters are estimated individually for each age for the INLA index (fleet 2), this is related to the way the index for each age is estimated separately using INLA. For the CPUE index (fleet 3) survey catchability parameters are coupled for ages 2-3, separate for age 4 and coupled age 5-6, this coupling was based on parameter estimates from a run with separate parameters for each age ($keyLogFpar in Table 2).

Variance parameters
For age 2 the coupling of the recruitment and survival process variance parameters for the log(N)-process are different from the other ages ($keyVarLogN in Table 2). In the model.R script the following was added: par$logSdLogN<-c(0,-5), which sets the process variance of N to a very low value. This was needed due to the short assessment time series.

The variance parameters for the catch are separate for age 2 and 3, and they are coupled for ages 4-10. The variance parameters are separate for the two surveys. For the INLA index the variance parameters are separate for age 2 and 3, ages 4-6 are coupled and ages 7-8 are coupled ($keyVarObs in Table 2). For the CPUE index the variance parameters are separate for age 2 and 3, and ages 4-6 are coupled.

The covariance structure for the catches is assumed to be independent for the catches (fleet 1) ($obsCorStruct in Table 2). For both the tuning series the covariance structures were assumed to be AR(1), with different parameters for fleet 2 and 3. This was done to allow for year effects, it was coupled for all ages within fleet. Meaning that any year effect is assumed for impact all ages. This was done because earlier runs showed indications of year effects in the residuals. This would also account for any effect of vessels change.

Observation variance
Additional uncertainty was added for the early period, 2000-2010 (see $keyXtraSd in Table 2). All years and ages were couple for each fleet, such that there was one parameter for each fleet. The reason for allowing for additional uncertainty in the observations were based on previous SAM runs where the observation residuals showed a tendency for larger residuals early in the period for all fleets. Further look into the background data found that the sampling coverage for the genetic split in this early period were not as good as the most recent period. Additional, for the catches the sampling coverage are better in the most recent period.

<u>Model diagnostics</u>

For both SSB and F the uncertainty surrounding the estimates are reasonable (Figure 7 and 8), although uncertainty for F a bit high early in the period. For the most recent years with high catches the model tends to underestimate catch (Figure 4), the increase in catches in 2023 are not well estimated by the model. Figure 5 shows the relative weight of the different data sources, the model puts high weight on the catches for age 4-10 and then gillnet index for age 3-4. Age 2 from the catches is given very low weighting.

Parameter estimation
Parameter estimates are given in Table 3.

Residuals
There are some patterns in the residuals. For the catch residuals there are a block of positive residuals, showing that the model underestimate catches in these years. There is a block of negative residuals for the INLA survey residuals early in the timeseries. There appears to be some year effects.

<u>Stock summary</u>

Fishing mortality
Fishing mortality was high early in the timeseries , and F dropped to 0.416 in 2014 and has fluctuated around that level since (Figure 7).

SSB

SSB was at a low level at the beginning of the timeseries and increased from 172 in 2000 to 17793 t in 2016. Since the SSB has decreased and shows a small increase since 2021 (Figure 8).

Recruitment
Recruitment has fluctuated during the timeseries with peak in recruitment in the years 2011, 2018 and 2021 (cohorts 2009, 2016 and 2019 respectively) (Figure 9). The 2021 estimated recruitment were much higher than the estimated recruitment for the same year from the NWWG 2023 assessment model.

Retrospective analysis
In order to test the robustness of the assessment a 5-year retrospective analysis (Figures 10-12) were conducted. For F all peels are within the confidence intervals and fluctuate around the current estimate (Mohn'r rho=-0.055) (Figure 10). Similarly, all peels for SSB, except the oldest, are within confidence intervals and show some tendency to overestimate SSB when the stock is decreasing, i.e. (Mohn'r rho= 0.061) (Figure 11). For recruitment there is a tendency to underestimate recruitment (Mohn's rho=-0.304) (Figure 12).

Sensitivity to tuning series (leave one out analysis)
Leave one out plots show the estimates when removing one of the tuning series, the results are in figures 13-15. For Fbar the trends are similar when leaving out one or the other tuning series, in the early years when leaving out the CPUE index the fluctuations are smaller (Figure 13). For SSB there are the same overall trend the main difference is that without the gillnet index the SSB are higher in the final year (Figure 14). For the recruitment leaving out one or the other tuning series has a large impact (Figure 15). For the run without the INLA index the recruitment is smoother and fluctuates less. For the run without the gillnet index the fluctuations are much larger and recruitment is high in the most recent years.

Alternative SAM configurations

Due to the model not being able to estimate the observed catches and due to some of the retrospective patterns some of the configurations where checked. The coupling of the survey catchability parameters (in $KeyLogFpar), parameters for age 2 and 3 were uncoupled, this did not improve the model.

Outliers in both survey indices were checked.

Short term forecast
Short term forecasts were set up using mainly default settings for the SAM run on stockassessment.org. Uncertainty on F were taken from the model. Catch and stock weights were taken from the model used for these, the model is set up to estimate further ahead in time than the assessment run. For maturity and natural mortality average of the last 5 years were used, currently maturity and natural mortality is constant over time so the time period for this would not have any impact. The default for the recruitment is the last 10 years, it was decided at the meeting that this period is appropriate.

Reference points using EqSim
The estimation of reference points follows ICES Reference Points guidance, 2021. The estimation was done using the R-programme EqSim developed by D. C. M. Miller, which works directly on a specified SAM fit. The code for the final run is on the ICES sharepoint for the NWWG 24 and named 'NWWG24_WOSC_EqSim_Final.R'. David Miller provided guidance on the ICES procedures and EqSim settings.

Following ICES guidelines the stock-recruitment relationship appears to follow a type 2 stock type, where B_{lim}= segmented regression change point. This was found to not be appropriate for this stock, instead the average of the 3 years with low SSB giving high recruitment were used (SSB in 2009-2011, recruitment in 2011-2013). Following initial runs it was decided to exclude the most recent recruitment estimates due to very high uncertainty (recruitment in 2021-2023, SSB in 2019-2021), this is in line with ICES guidelines. B_{lim} was set to 3050 t.

The simulation settings for the stock-recruitment relationship were as follows. The number of simulations were set to 1500. For assessment error sigmaF and sigmaSSB were set to the default value of 0.2. The default values were used for forecast errors: cvF=0.212, phiF=0.423, cvSSB=0 and phiSSB=0. For weight at age the last 5 years were used, based on figure 16 there has been a reduction in weight-at-age in the assessment period. For selectivity the last 10 years were used, there appear to have been a change in selectivity early in the assessment period, but selectivity was stable in the last 10 years (Figure 17). For the simulations segmented regressions (with breakpoint fixed at Blim) and Beverton-Holt were used. Run settings are given in table 4. The estimated reference points are given in table 5. Due to very high estimates of of F_{pa} and F_{lim}, it was decided to not report on these values.

Conclusion

The model presented here fit the observation reasonably well, and seem to capture trends in stock size and fishing mortality well.

The assessment model is based on data for the WOSC stock, rather than previous geographical data split. The model provides a useful tool for assessing the WOSC stock.

References

ICES (2021): ICES fisheries management reference points for category 1 and 2 stocks (2021). ICES Technical Guidelines. Report. https://doi.org/10.17895/ices.advice.7891

Nielsen A, Berg CW. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries research. 158: 96-101.

WD08. ICES NWWG, 22-26 May 2024

Table 1. Input files to SAM runs (rounded values, unrounded values can be found on stockassessment.org)

Catch in Numbers (thousands)

1	2							
2000	2023							
2	10							
1								
1.00E-04	1.365711	47.56198	80.96694	1.86709	0.065717	0.039939	1.00E-04	1.00E-04
-1	-1	-1	-1	-1	-1	-1	-1	-1
0.050216	113.0915	578.5356	195.3814	9.124514	3.131678	0.217576	0.084399	0.023263
0	26.56474	102.8377	455.6319	57.42597	6.657891	1.535647	1.57438	0.922602
0	146.3076	514.7957	260.6663	52.31436	11.76542	0.27698	0	0
3.341217	213.6338	468.7797	243.7397	32.00581	4.810201	1.593261	0.476694	0.013985
2.8798	1131.617	635.4463	206.7643	9.977854	1.204576	0.508915	0.080245	0.000595
0.032153	388.2718	983.9132	172.6258	47.83384	20.68084	6.926459	3.857158	1.982289
0	86.86217	1047.732	691.4489	144.483	29.29446	3.363369	0.843826	0
0.017117	71.5341	341.9664	432.7877	55.572	5.337099	1.539407	0.218433	0.464806
0.005647	7.914973	118.873	404.9923	402.7557	39.99828	12.31938	7.54714	9.168758
0.027731	10.22565	332.8217	524.04	315.2375	64.77505	25.05116	3.235328	1.871882
0.137717	164.399	223.6086	373.8075	192.1226	53.52136	10.57786	6.503805	3.028524
0.16637	40.06863	936.1289	527.8731	257.6773	102.4291	34.25008	24.91605	6.146074
0	11.59338	425.5396	1115.309	624.8901	107.9016	77.06153	45.16354	20.45256
0.288102	7.74847	577.9909	1979.858	1198.74	428.6512	85.10115	12.51315	7.033273
0	12.62351	591.2409	2841.113	2366.853	559.5638	94.41937	21.62343	2.917998
0.049717	15.04152	474.3022	1792.671	1851.176	1546.152	289.8127	72.40495	22.45801
0.00205	6.188066	670.0171	1413.496	1539.637	1060.712	590.8164	135.1624	40.25231
0	19.9377	358.4348	1567.101	1117.823	716.8418	295.086	92.91356	28.65129
0	40.4757	452.4557	853.0083	1098.827	351.073	208.5018	62.51272	32.96415
0.00522	1.948503	484.8747	1091.756	479.3763	348.4526	104.0506	67.04696	19.27347
0	34.92356	350.3111	1649.363	836.3686	234.6465	172.9157	64.83232	28.73142
0	105.1771	2080.199	949.6666	1199.977	843.9671	210.4449	57.78351	23.58889

Table 1 *continued*

Mean Weight in Catch (kilograms)

1	3							
2000	2023							
2	10							
1								
NA	0.641808	1.120983	1.453028	2.378079	2.62124	2.408667	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA
0.36	0.707845	0.998694	1.397425	2.317673	1.884027	2.852515	3.559567	3.355852
NA	1.058237	1.436687	2.095418	2.525389	3.642075	4.462442	4.886106	6.888771
NA	0.995138	1.258865	1.531094	2.292444	2.930009	6.131665	NA	NA
0.409151	0.774065	1.101804	1.731614	2.477109	2.690337	2.897396	6.906364	8.793568
0.362231	0.753172	0.961611	1.486182	2.990063	3.744749	4.960456	7.447182	8.126823
0.195466	0.691269	1.03949	1.71337	2.821629	4.240584	5.689469	6.682775	10.19662
NA	0.64586	0.91172	1.476595	2.210017	3.345033	5.349382	7.299839	NA
0.232031	0.639847	1.005632	1.518242	2.361624	4.522207	6.090312	8.58905	13.57155
0.501236	0.691216	1.133106	1.626531	2.218908	3.279206	4.883047	6.922051	9.534507
0.376681	0.715923	1.040343	1.549214	2.174886	3.316753	5.47422	7.788394	10.62401
0.426085	0.785404	1.157089	1.836909	2.773728	3.799076	5.559146	6.754123	12.93406
0.244788	0.766581	1.279398	1.669708	2.288767	3.295335	3.842188	4.399858	6.489927
NA	0.685462	1.210646	1.945656	2.59129	3.498063	5.363997	5.789139	7.430064
0.126285	0.678942	1.096645	1.679575	2.402325	3.438695	4.851411	7.267148	11.5314
NA	0.514791	1.032764	1.462186	2.193457	3.061747	3.942492	4.393514	8.846459
0.161803	0.502496	0.800382	1.300478	1.888924	2.714083	3.463871	4.297866	7.42765
0.090885	0.391747	0.899917	1.137314	1.63069	2.183174	2.981163	3.631154	5.215359
NA	0.717323	0.799898	1.09019	1.44566	1.916438	2.649757	3.819269	5.446105
NA	0.533633	0.899952	1.231384	1.483073	2.0135	2.614391	3.552723	5.288371
0.283159	0.508687	1.011063	1.35202	1.637714	1.89734	3.303035	4.434656	6.070321
NA	0.696428	0.984727	1.308135	1.634646	1.927063	2.514505	4.008627	5.464857
NA	0.480593	0.942346	1.215777	1.733711	2.025147	2.608353	3.930927	6.226063

Table 1 *continued*

Mean Weight in survey (kilograms)

1	3							
2000	2023							
2	10							
1								
0.152118	0.316586	0.755494	1.065945	NA	NA	NA	NA	NA
0.223639	0.465955	0.857223	1.350469	NA	NA	NA	NA	NA
0.226148	0.401448	0.765943	0.949195	1.79	NA	NA	NA	NA
0.187552	0.370069	0.807125	1.630056	2.025764	NA	NA	NA	NA
0.205346	0.433129	0.911216	1.206379	1.952854	3.050581	NA	NA	7.105
0.151202	0.296044	0.684983	1.399215	1.692268	2.755427	3.599298	4.508613	NA
0.129505	0.338031	0.514385	0.782964	1.923317	2.876906	NA	NA	NA
0.147541	0.363127	0.630953	1.314945	3.289768	6.920221	8.349851	NA	NA
0.110764	0.275489	0.528908	0.942663	1.79346	2.888164	NA	NA	NA
0.114861	0.378774	0.712288	1.352292	2.240279	3.815	NA	NA	NA
0.146977	0.312732	0.708955	1.176071	1.988707	3.000861	NA	NA	NA
0.167588	0.411304	0.754749	1.397639	2.127971	3.53944	7.68	NA	NA
0.135682	0.379036	0.727165	1.207572	1.79538	3.354197	4.741	NA	NA
0.110429	0.334233	0.59088	0.795394	1.685778	2.705983	4.129875	5.668816	NA
0.136108	0.298431	0.676046	0.961201	1.751346	2.519183	3.690909	5.212082	8.871032
0.101825	0.345954	0.613875	1.113336	1.630018	2.593044	4.089712	4.89458	9.065
0.092592	0.34587	0.72756	1.119647	1.758158	2.775577	4.144732	6.256932	17.6
0.086856	0.261163	0.648646	1.027525	1.46461	1.936028	3.797242	5.979443	5.21
0.078238	0.265155	0.542641	0.907882	1.509054	2.508788	2.87059	3.612029	10.47859
0.095535	0.289511	0.617739	1.040217	1.349587	2.122235	2.187697	2.264533	5.782379
0.101258	0.278385	0.541703	1.105105	1.605967	3.010339	3.544602	4.666338	5.652323
NA	NA	NA	NA	NA	NA	NA	NA	NA
0.104291	0.357049	0.62503	1.195239	1.62063	3.248129	4.121938	5.588703	6.022674
0.088132	0.281957	0.602471	1.122242	1.841176	2.482601	3.653989	3.952647	5.666868

Table 1 *continued*

Proportion	Mature	at	Year	Start				
1	6							
2000	2023							
2	10							
1								
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1
0.032	0.117	0.349	0.685	0.898	0.973	0.993	0.998	1

Table 1 *continued*

Natural Mortality
1 5
2000 2023
2 10
1

0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 1 *continued*

TrawlSurveyIndex	INLA	COD	WOSC	WG	INLA run version:	Thu Apr 18 10:38:46 2024
102						
TrawlSurveyIndex	WG					
2000	2023					
1	1	0.58	0.65			
2	7					
1	0.145312	0.210034	0.013806	-1	-1	-1
1	0.590653	0.04088	0.0136	0.00276	-1	-1
1	0.186242	0.103293	0.005944	3.87E-06	-1	-1
1	0.059642	0.062837	0.021265	0.002635	0.000932	-1
1	0.400989	0.043746	0.008573	0.008872	0.001182	-1
1	12.89566	0.185122	0.128618	0.02725	0.012443	0.004266
1	0.672956	3.300716	0.125281	0.017371	0.012147	0.009192
1	1.162257	0.217783	0.443905	0.037511	0.00338	0.00135
1	0.36958	0.622877	0.167357	0.243014	0.01683	0.002171
1	0.971886	0.157947	0.101084	0.054917	0.004167	0.000439
1	0.276225	0.399233	0.076658	0.078734	0.009191	0.00567
1	13.72306	0.331412	0.171424	0.058722	0.03813	0.002791
1	8.618235	3.316245	0.13112	0.161109	0.02482	0.009877
1	2.661842	2.740726	1.971456	0.349803	0.204459	0.028971
1	1.616446	0.940613	1.051034	1.25992	0.092913	0.041912
1	2.324339	1.381021	0.921958	2.127299	1.285876	0.119362
1	2.187551	0.593316	0.371815	0.335257	0.250748	0.149763
1	5.404575	1.225332	0.287728	0.553513	0.759116	0.590533
1	5.269477	1.464335	0.425792	0.168685	0.117206	0.110498
1	3.749268	3.110356	1.545369	0.57104	0.230459	0.390254
1	1.3155	1.74346	0.560411	0.156115	0.044452	0.044673
1	-1	-1	-1	-1	-1	-1
1	5.02456	3.549898	0.988555	1.127251	0.422507	0.084458

	1	5.00667	2.372107	1.0531	0.49308	0.502719	0.33339
GillnetSurveyIndex							
	2002	2023					
	1	1	0.5	0.6			
	2	6					
	1	27.35593	11.10073	4.46364	1.610378	0.119475	
	1	9.577287	12.35593	3.359153	0.586371	0.040771	
	1	5.354398	4.57288	2.778323	0.694475	0.12897	
	1	41.26959	4.390277	0.941836	1.360292	0.113872	
	1	17.18717	11.18264	3.865809	1.606573	0.183915	
	1	-1	-1	-1	-1	-1	
	1	-1	-1	-1	-1	-1	
	1	-1	-1	-1	-1	-1	
	1	19.25619	17.94425	11.2552	2.838882	0.275956	
	1	145.942	24.71748	7.177181	4.316804	0.926664	
	1	39.67896	79.19682	5.485752	2.590051	0.705792	
	1	35.24978	21.84959	24.28986	5.253063	1.780924	
	1	11.96796	15.8001	8.969269	5.274191	0.959121	
	1	16.08266	18.82571	16.42783	10.56592	9.596825	
	1	14.99271	34.73206	9.303364	11.64291	5.391645	
	1	3.452225	22.0586	20.51695	12.01169	5.84231	
	1	10.13088	12.44601	11.6723	7.950916	7.439427	
	1	25.87476	44.6848	10.50639	10.99944	5.374781	
	1	17.93814	32.58075	12.90756	4.208279	6.802011	
	1	101.0776	21.37501	34.19977	11.34353	9.198113	
	1	21.54799	19.79865	5.584355	13.24178	3.578589	
	1	11.41689	13.73079	21.26067	3.896702	4.228508	

Table 2. SAM configurations for WOSC

```
# Configuration saved: Mon Jan  9 14:29:49 2023
#
# 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
# Negative numbers indicate that the parameter is not included in the model
#
$minAge
# The minimium age class in the assessment
 2

$maxAge
# The maximum age class in the assessment
 10

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

$keyLogFsta
# Coupling of the fishing mortality states processes for each age (normally only
# the first row (= fleet) is used).
# Sequential numbers indicate that the fishing mortality is estimated individually
# for those ages; if the same number is used for two or more ages, F is bound for
# those ages (assumed to be the same). Binding fully selected ages will result in a
# flat selection pattern for those ages.
  0  1  2  3  4  5  6  7  7
 -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).
# 0: independent means there is no correlation between F across age
# 1: compound symmetry means that all ages are equally correlated;
# 2: AR(1) first order autoregressive - similar ages are more highly correlated than
# ages that are further apart, so similar ages have similar F patterns over time.
# if the estimated correlation is high, then the F pattern over time for each age
# varies in a similar way. E.g if almost one, then they are parallel (like a
# separable model) and if almost zero then they are independent.
# 3: Separable AR - Included for historic reasons . . .  more later
 0

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is
# not used, as that is covered by fishing mortality).
 -1 -1 -1 -1 -1 -1 -1 -1 -1
  0  1  2  3  4  5 -1 -1 -1
  6  6  7  8  8  -1  -1 -1 -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

$keyVarF
# Coupling of process variance parameters for log(F)-process (Fishing mortality
# normally applies to the first (fishing) fleet; therefore only first row is used)
  0  0  0  0  0  0  0  0  0
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1

$keyVarLogN
# Coupling of the recruitment and survival process variance parameters for the
# log(N)-process at the different ages. It is advisable to have at least the first age
# class (recruitment) separate, because recruitment is a different process than
# survival.
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
# First row refers to the coupling of the variance parameters for the catch data
# observations by age
# Second and further rows refers to coupling of the variance parameters for the
# index data observations by age
  0  1  2  2  2  2  2  2  2
  3  4  5  5  6  7 -1 -1 -1
  8  9  10 10  10  -1   -1  -1  -1

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

$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).
#2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
```

```
 NA  NA  NA  NA  NA  NA  NA  NA
  0   0   0   0   0  -1  -1  -1
  1   1   1   1 -1  -1  -1  -1
```

$stockRecruitmentModelCode
Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, 3 piece-wise constant, 61 for segmented regression/hockey stick, 62 for AR(1), 63 for bent hyperbola / smooth hockey stick, 64 for power function with degree < 1, 65 for power function with degree > 1, 66 for Shepher, 67 for Deriso, 68 for Saila-Lorda, 69 for sigmoidal Beverton-Holt, 90 for CMP spline, 91 for more flexible spline, and 92 for most flexible spline).
 0

$noScaledYears
Number of years where catch scaling is applied.
 0

$keyScaledYears
A vector of the years where catch scaling is applied.

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

$fbarRange
lowest and higest age included in Fbar
 5 8

$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

$obsLikelihoodFlag
Option for observational likelihood | Possible values are: "LN" "ALN"
 "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 (for each age group)
 0 0 0 0 0 0 0 0 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

$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)

$predVarObsLink

```
# Coupling of parameters used in a prediction-variance link for observations.
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 NA NA NA
 -1 -1 -1 -1 -1 NA NA NA NA

$hockeyStickCurve
#
 20

$stockWeightModel
# Integer code describing the treatment of stock weights in the model (0 use as known, 1 use as observations to inform stock weight process (GMRF with cohort and within year correlations))
 1

$keyStockWeightMean
# Coupling of stock-weight process mean parameters (not used if stockWeightModel==0)
 0 1 2 3 4 5 6 7 8

$keyStockWeightObsVar
# Coupling of stock-weight observation variance parameters (not used if stockWeightModel==0)
 0 0 0 0 0 0 0 0 0

$catchWeightModel
# Integer code describing the treatment of catch weights in the model (0 use as known, 1 use as observations to inform catch weight process (GMRF with cohort and within year correlations))
 1

$keyCatchWeightMean
# Coupling of catch-weight process mean parameters (not used if catchWeightModel==0)
 0 1 2 3 4 5 6 7 8

$keyCatchWeightObsVar
# Coupling of catch-weight observation variance parameters (not used if catchWeightModel==0)
 0 0 0 0 0 0 0 0 0

$matureModel
# Integer code describing the treatment of proportion mature in the model (0 use as known, 1 use as observations to inform proportion mature process (GMRF with cohort and within year correlations on logit(proportion mature)))
 0

$keyMatureMean
# Coupling of mature process mean parameters (not used if matureModel==0)
 NA NA NA NA NA NA NA NA NA

$mortalityModel
# Integer code describing the treatment of natural mortality in the model (0 use as known, 1 use as observations to inform natural mortality process (GMRF with cohort and within year correlations))
 0

$keyMortalityMean
#
 NA NA NA NA NA NA NA NA NA

$keyMortalityObsVar
# Coupling of natural mortality observation variance parameters (not used if mortalityModel==0)
 NA NA NA NA NA NA NA NA NA

$keyXtraSd
```

An integer matrix with 4 columns (fleet year age coupling), which allows additional uncertainty to be estimated for the specified observations

1	2000	2	0
1	2001	2	0
1	2002	2	0
1	2003	2	0
1	2004	2	0
1	2005	2	0
1	2006	2	0
1	2007	2	0
1	2008	2	0
1	2009	2	0
1	2010	2	0
1	2000	3	0
1	2001	3	0
1	2002	3	0
1	2003	3	0
1	2004	3	0
1	2005	3	0
1	2006	3	0
1	2007	3	0
1	2008	3	0
1	2009	3	0
1	2010	3	0
1	2000	4	0
1	2001	4	0
1	2002	4	0
1	2003	4	0
1	2004	4	0
1	2005	4	0
1	2006	4	0
1	2007	4	0
1	2008	4	0
1	2009	4	0
1	2010	4	0
1	2000	5	0
1	2001	5	0
1	2002	5	0
1	2003	5	0
1	2004	5	0
1	2005	5	0
1	2006	5	0
1	2007	5	0
1	2008	5	0
1	2009	5	0
1	2010	5	0
1	2000	6	0
1	2001	6	0
1	2002	6	0
1	2003	6	0
1	2004	6	0
1	2005	6	0
1	2006	6	0
1	2007	6	0
1	2008	6	0
1	2009	6	0
1	2010	6	0
1	2000	7	0
1	2001	7	0
1	2002	7	0
1	2003	7	0
1	2004	7	0
1	2005	7	0

1	2006	7	0
1	2007	7	0
1	2008	7	0
1	2009	7	0
1	2010	7	0
1	2000	8	0
1	2001	8	0
1	2002	8	0
1	2003	8	0
1	2004	8	0
1	2005	8	0
1	2006	8	0
1	2007	8	0
1	2008	8	0
1	2009	8	0
1	2010	8	0
1	2000	9	0
1	2001	9	0
1	2002	9	0
1	2003	9	0
1	2004	9	0
1	2005	9	0
1	2006	9	0
1	2007	9	0
1	2008	9	0
1	2009	9	0
1	2010	9	0
1	2000	10	0
1	2001	10	0
1	2002	10	0
1	2003	10	0
1	2004	10	0
1	2005	10	0
1	2006	10	0
1	2007	10	0
1	2008	10	0
1	2009	10	0
1	2010	10	0
2	2000	2	1
2	2001	2	1
2	2002	2	1
2	2003	2	1
2	2004	2	1
2	2005	2	1
2	2006	2	1
2	2007	2	1
2	2008	2	1
2	2009	2	1
2	2010	2	1
2	2000	3	1
2	2001	3	1
2	2002	3	1
2	2003	3	1
2	2004	3	1
2	2005	3	1
2	2006	3	1
2	2007	3	1
2	2008	3	1
2	2009	3	1
2	2010	3	1
2	2000	4	1
2	2001	4	1
2	2002	4	1

2	2003	4	1
2	2004	4	1
2	2005	4	1
2	2006	4	1
2	2007	4	1
2	2008	4	1
2	2009	4	1
2	2010	4	1
2	2000	5	1
2	2001	5	1
2	2002	5	1
2	2003	5	1
2	2004	5	1
2	2005	5	1
2	2006	5	1
2	2007	5	1
2	2008	5	1
2	2009	5	1
2	2010	5	1
2	2000	6	1
2	2001	6	1
2	2002	6	1
2	2003	6	1
2	2004	6	1
2	2005	6	1
2	2006	6	1
2	2007	6	1
2	2008	6	1
2	2009	6	1
2	2010	6	1
2	2000	7	1
2	2001	7	1
2	2002	7	1
2	2003	7	1
2	2004	7	1
2	2005	7	1
2	2006	7	1
2	2007	7	1
2	2008	7	1
2	2009	7	1
2	2010	7	1
3	2000	2	2
3	2001	2	2
3	2002	2	2
3	2003	2	2
3	2004	2	2
3	2005	2	2
3	2006	2	2
3	2007	2	2
3	2008	2	2
3	2009	2	2
3	2010	2	2
3	2000	3	2
3	2001	3	2
3	2002	3	2
3	2003	3	2
3	2004	3	2
3	2005	3	2
3	2006	3	2
3	2007	3	2
3	2008	3	2
3	2009	3	2
3	2010	3	2

3	2000	4	2
3	2001	4	2
3	2002	4	2
3	2003	4	2
3	2004	4	2
3	2005	4	2
3	2006	4	2
3	2007	4	2
3	2008	4	2
3	2009	4	2
3	2010	4	2
3	2000	5	2
3	2001	5	2
3	2002	5	2
3	2003	5	2
3	2004	5	2
3	2005	5	2
3	2006	5	2
3	2007	5	2
3	2008	5	2
3	2009	5	2
3	2010	5	2
3	2000	6	2
3	2001	6	2
3	2002	6	2
3	2003	6	2
3	2004	6	2
3	2005	6	2
3	2006	6	2
3	2007	6	2
3	2008	6	2
3	2009	6	2
3	2010	6	2

Table 3. Table of SAM model parameters.

Parameter name	par	sd(par)	exp(par)	Low	High
logFpar_0	-7.799	0.190	0.000	0.000	0.001
logFpar_1	-8.481	0.170	0.000	0.000	0.000
logFpar_2	-9.060	0.209	0.000	0.000	0.000
logFpar_3	-8.906	0.214	0.000	0.000	0.000
logFpar_4	-8.837	0.194	0.000	0.000	0.000
logFpar_5	-8.603	0.215	0.000	0.000	0.000
logFpar_6	-5.543	0.161	0.004	0.003	0.005
logFpar_7	-5.851	0.142	0.003	0.002	0.004
logFpar_8	-5.758	0.133	0.003	0.002	0.004
logSdLogFsta_0	-1.436	0.218	0.238	0.154	0.368
logSdLogN_0	-0.713	0.182	0.490	0.341	0.705
logSdLogObs_0	0.380	0.217	1.462	0.947	2.256
logSdLogObs_1	-0.169	0.192	0.845	0.575	1.240
logSdLogObs_2	-0.839	0.114	0.432	0.344	0.543
logSdLogObs_3	-0.455	0.185	0.635	0.438	0.919
logSdLogObs_4	-0.559	0.192	0.572	0.390	0.838
logSdLogObs_5	-0.310	0.156	0.734	0.537	1.002
logSdLogObs_6	-0.420	0.161	0.657	0.476	0.907
logSdLogObs_7	-0.313	0.167	0.731	0.524	1.021

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logSdLogObs_8	-0.184	0.173	0.832	0.588	1.176
logSdLogObs_9	-0.604	0.187	0.547	0.376	0.795
logSdLogObs_10	-0.666	0.147	0.514	0.383	0.689
transfIRARdist_0	-0.323	0.301	0.724	0.397	1.321
transfIRARdist_1	-0.186	0.339	0.830	0.422	1.634
logPhiSW_0	3.907	1.445	49.737	2.762	895.611
logPhiSW_1	4.205	1.457	67.007	3.637	1234.412
logSdProcLogSW_0	0.344	0.638	1.411	0.394	5.057
meanLogSW_0	-2.073	0.105	0.126	0.102	0.155
meanLogSW_1	-1.123	0.101	0.325	0.266	0.398
meanLogSW_2	-0.438	0.099	0.646	0.530	0.787
meanLogSW_3	0.079	0.098	1.082	0.890	1.316
meanLogSW_4	0.564	0.099	1.758	1.443	2.142
meanLogSW_5	1.043	0.101	2.837	2.317	3.473
meanLogSW_6	1.415	0.107	4.118	3.323	5.102
meanLogSW_7	1.564	0.115	4.779	3.795	6.020
meanLogSW_8	2.034	0.124	7.644	5.970	9.787
logSdLogSW_0	-1.815	0.105	0.163	0.132	0.201
logPhiCW_0	4.068	1.301	58.451	4.333	788.542
logPhiCW_1	4.705	1.288	110.463	8.400	1452.610
logSdProcLogCW_0	0.842	0.612	2.320	0.682	7.897
meanLogCW_0	-1.418	0.160	0.242	0.176	0.333
meanLogCW_1	-0.449	0.150	0.639	0.473	0.863
meanLogCW_2	-0.009	0.148	0.991	0.737	1.331
meanLogCW_3	0.352	0.146	1.422	1.061	1.905
meanLogCW_4	0.700	0.146	2.014	1.503	2.698
meanLogCW_5	0.972	0.148	2.643	1.967	3.551
meanLogCW_6	1.291	0.150	3.637	2.693	4.913
meanLogCW_7	1.568	0.154	4.795	3.521	6.531
meanLogCW_8	1.940	0.160	6.956	5.051	9.580
logSdLogCW_0	-2.391	0.257	0.092	0.055	0.153
logXtraSd_0	1.120	0.134	3.064	2.345	4.004
logXtraSd_1	0.852	0.153	2.344	1.724	3.186
logXtraSd_2	0.272	0.193	1.312	0.892	1.929

Table 4. Run setting for EqSim

From R scripts	description	Value
stockName	Name of the stock	Cod.21.1.osc (WOSC)
SAOAssessment	Name of assessment on stockassessmet.org	NWWG24_WOSC
sigmaF	From SAM assessment	0.2
sigmaSSB	Default value of 0.2	0.2
noSims	Recommended minimum 1000	1500
SRused	Models used in the simulations (segmented regression with breakpoint fixed at Blim and beverton-holt).	Segreg_Bevholt
SRyears_min	Same as assessment	2000
SRyears_max	Same as assessment	2022
rhoRec	Autocorrelation in recruitment	F (default)
numAvgYrsB	Years used for the average Weight at age	5
numAvgYrsS	Years used for the average selectivity	10

cvF	Forecast error F	Default = 0.212
phiF	Forecast error F	Default = 0.423
cvSSB	Forecast error SSB	Default = 0
phiSSB	Forecast error SSB	Default = 0
rmSRRYrs	Which years (SSB years, not recruitment years) to exclude from the SRR fits	2019 -2021 SSB

Table 5. Reference points estimated from EqSim. Flim and Fpa not reported. Compared to current reference points estimated at WKGREENCOD 2023.

Framework	Reference point	New	Technical basis	Current	Technical basis
MSY approach	MSY $B_{trigger}$	15411	0.5 × B_{MSY}.	17 256	0.5 × B_{MSY}.
	F_{MSY}	0.25	Stochastic simulations (EqSim) using Beverton–Holt, segmented regression and ricker.	0.18	Stochastic simulations (EqSim) using Beverton–Holt.
Precautionary approach	B_{lim}	3050	Breakpoint of segmented regression	3219	Average SSB of the three years with low SSB and high recruitment.
	B_{pa}	4238	B_{lim}*exp(sigmaSSB*1.645), sigmaSSB = 0.2.	4473	B_{lim}*exp(sigmaSSB*1.645), sigmaSSB = 0.245.
	F_{lim}	5.33	Equilibrium F, which will maintain the stock above B_{lim} with a 50% probability.	NA	Equilibrium F, which will maintain the stock above B_{lim} with a 50% probability.
	F_{pa}	8.58	The fishing mortality including the advice rule that, if applied as a target in the ICES MSY advice rule (AR) would lead to SSB ≥ Blim with a 95% probability (also known as F_{p05}).	1.33	The fishing mortality including the advice rule that, if applied as a target in the ICES MSY advice rule (AR) would lead to SSB ≥ Blim with a 95% probability (also known as F_{p05}).

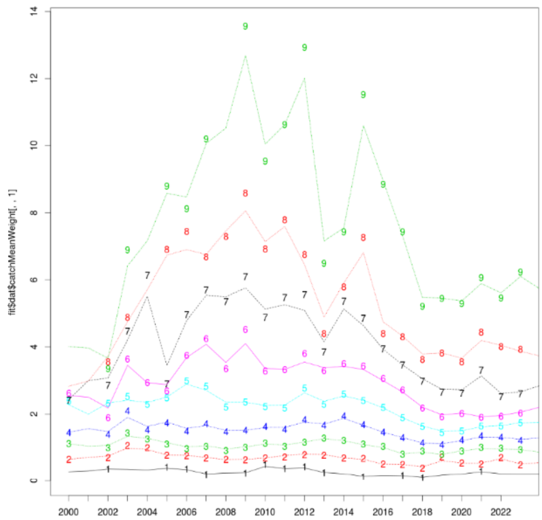

Figure 1. Catch weight at age (in kilograms). Numbers give the input values by age, the line give the estimates from the model

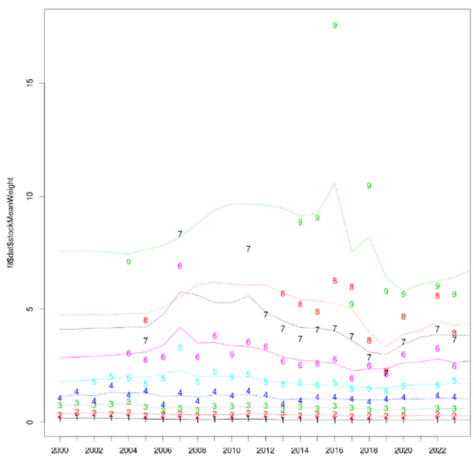

Figure 2. Stock weight at age (in kilograms). Numbers gives the input values by age, the line give the estimates from the model.

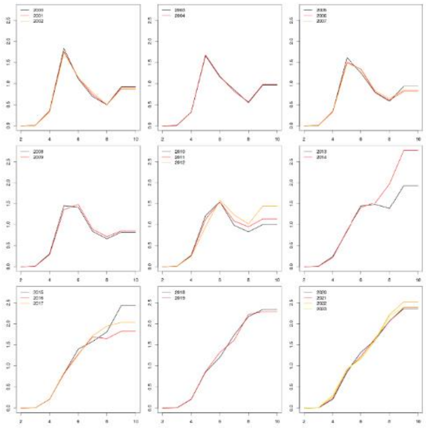

Figure 3. Selection pattern (F_{age}/Fbar) from the SAM model.

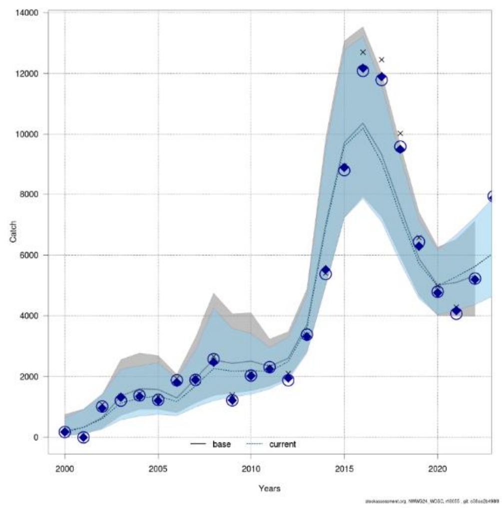

Figure 4. Estimated (line), observed catches (x), and catches based on smoothed catch weights (o). Estimated catch is shown with 95% confidence intervals. Blue lines, shaded area, and symbols are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison.

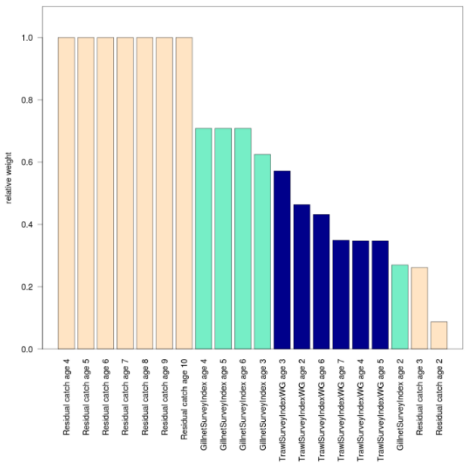

Figure 5. Relative weighting of input data.

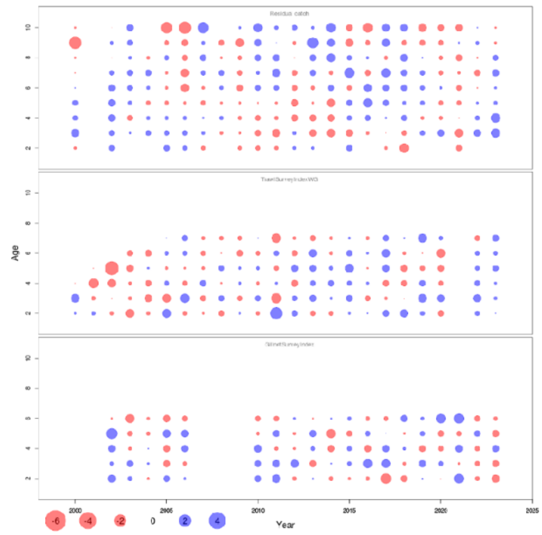

Figure 6. Normalized residuals derived from SAM. Blue indicate positive residuals (observation larger than predicted) and red circles indicated negative residuals.

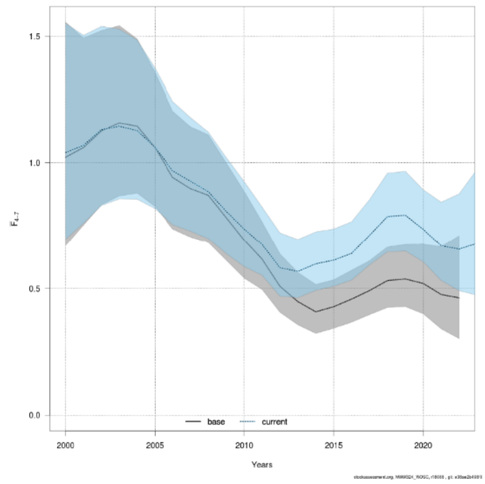

Figure 7. Estimated historical pattern of fishing mortality (Fbar5-8). The shaded area is 95% confidence intervals. Blue are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison, using Fbar4-7.

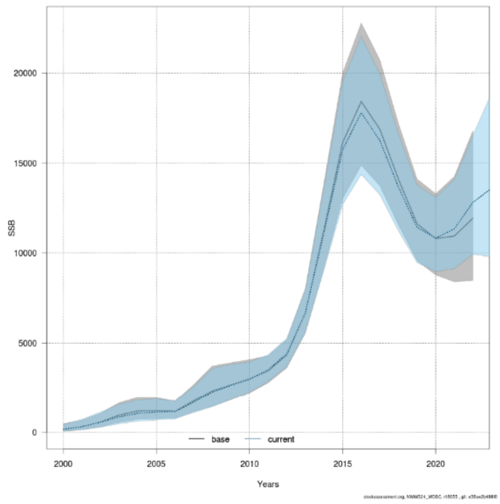

Figure 8. Estimated historical patterns of spawning stock biomass (SSB). The shaded area is 95% confidence intervals. Blue are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison.

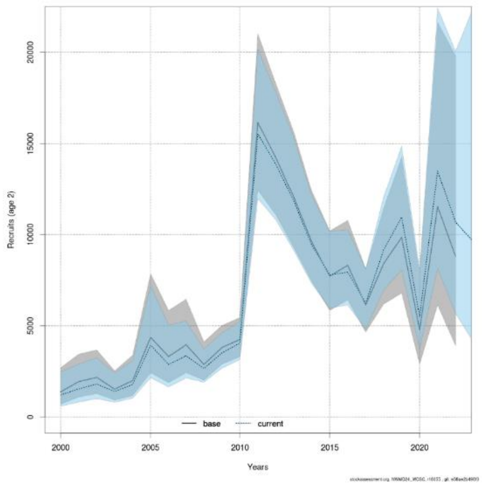

Figure 9. Estimated historical patterns of age 2 recruitment. The shaded area is 95% confidence intervals. Blue are the updated NWWG 2024 assessment, black/grey are the assessment from NWWG 2023 for comparison.

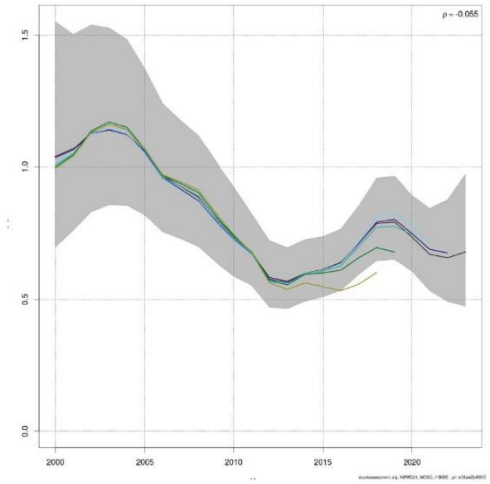

Figure 10. Retrospective plots of Fbar (5 years peel). Mohn's rho is given in the upper right corner.

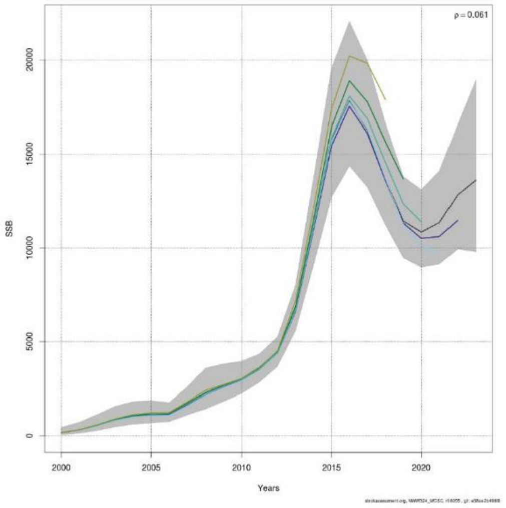

Figure 11. Retrospective plots of SSB (5 years peel). Mohn's rho is given in the upper right corner.

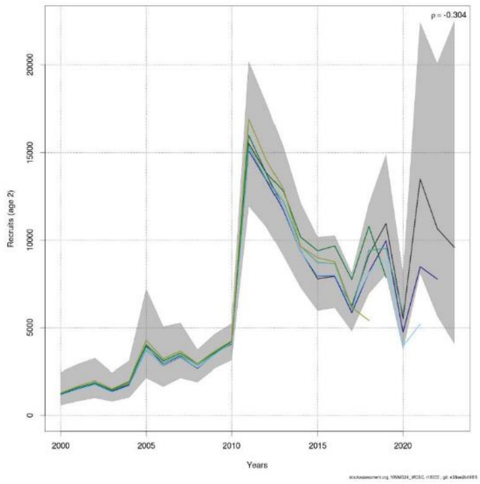

Figure 12. Retrospective plots of age 2 recruitment (5 years peel). Mohn's rho is given in the upper right corner.

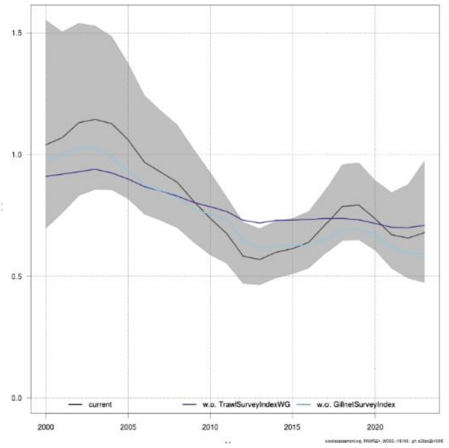

Figure 13. Leave one out plot for Fbar. Black line is with all data. Dark blue line without the INLA survey index. Light blue line without the CPUE index.

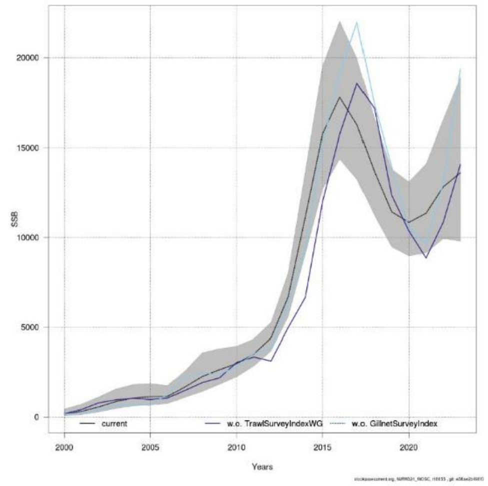

Figure 14. Leave one out for SSB Black line is with all data. Dark blue line without the INLA survey index. Light blue line without the CPUE index.

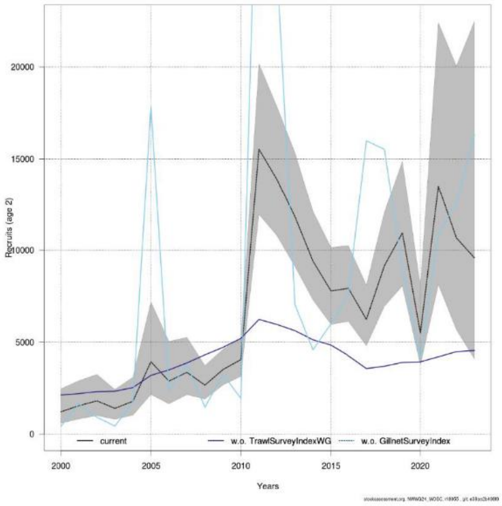

Figure 15. Leave one out for recruitment Black line is with all data. Dark blue line without the INLA survey index. Light blue line without the CPUE index.

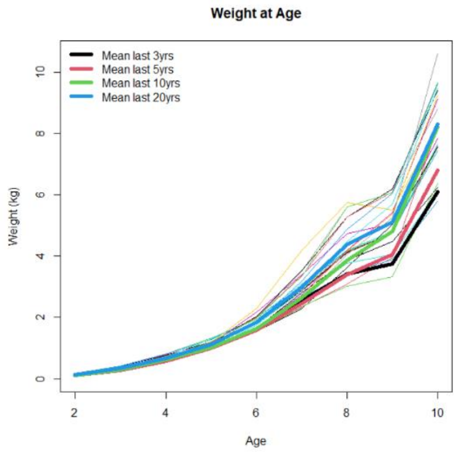

Figure 16. Stock weight at age for all years, bold line show means.

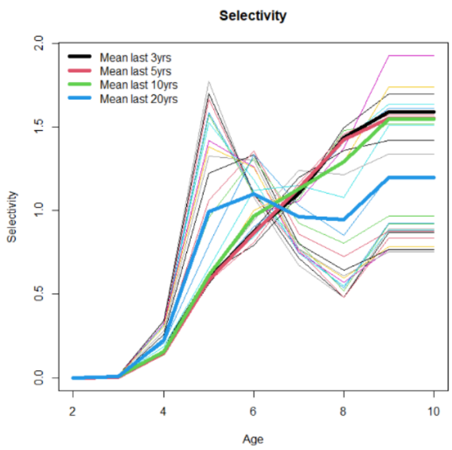

Figure 17. Selectivity at age for all years, bold line show means.

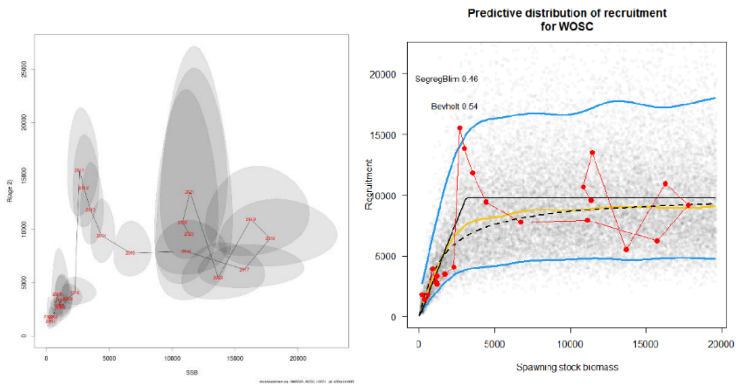

Figure 18. left: SSB-recruitment relationship, labels indicate recruitment year. right: SSB-recruitment relationship estimated by simulation using EqSim with fitted SSB-recruitment relationships. The solid line gives the fitted model and the blue lines indicated the interval in which 95% of the simulations falls.

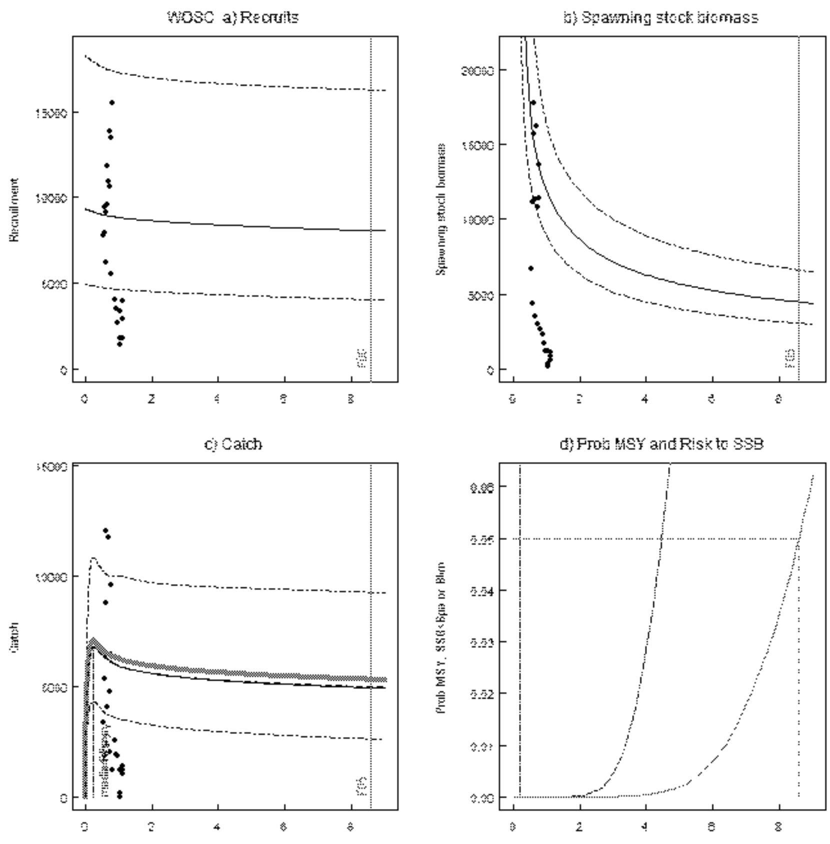

Figure 19. EqSim plots of recruitment, SSB, catch and probability of SSB falling below Bpa and Blim. F is on the x-axis.

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West Greenland Inshore north-south spawning populations of Atlantic cod (*Gadus morhua*)

Anja Retzel, Einar Eg Nielsen

Introduction

Several genetically distinct cod populations exist in Greenland waters (Therkildsen et al. 2013). The inshore area is subject to the highest mixing of the populations as the inshore stocks hardly migrate offshore and between inshore areas, whereas the offshore stocks migrate inshore (Storr-Paulsen et al. 2004, Hedeholm 2018). Different trends are seen in survey and catch development in the different inshore areas, indicating differences in dynamics and recruitment. Here, we argue that an inshore northern spawning stock and an inshore southern spawning stock should be recognized based on evidence from tagging, survey trends, catch data and genetics.

Tagging

In the period 2003-2022, 5,823 cod were tagged in the inshore area of West Greenland (Table 1). After 100 days at liberty, 359 cod were recaptured. Of these, only 2 migrated southwards from the northern region (Nafo 1B) to the southern region (Nafo 1D, table 2, figure 1). In the southern region, 2 migrated southwards from Nafo 1D to Nafo 1F, and 3 migrated from Nafo 1F to Iceland (Ices Va). The genetic composition of the cod is unknown, but the composition of south and westward migrating cod has a high probability of not belonging to the West Greenland inshore spawning stocks (Bonanomi et al. 2016).

Table 1: Numbers of tagged cod (2003-2022) in the inshore area of West Greenland by Nafo divisions.

Nafo area	Numbers tagged
1A	16
1B	1198
1C	433
1D	3368
1E	0
1F	808

Table 2: Numbers of tagged and recaptured cod (>100 days at liberty, 2003-2022) by Nafo divisions. Ices Va = Iceland.

Tagged/Recaptured	Nafo 1A	Nafo 1B	Nafo 1C	Nafo 1D	Nafo 1E	Nafo 1F	Ices Va
Nafo 1A	1						
Nafo 1B		82		2			
Nafo 1C			7				
Nafo 1D				188		2	
Nafo 1E							
Nafo 1F						74	3

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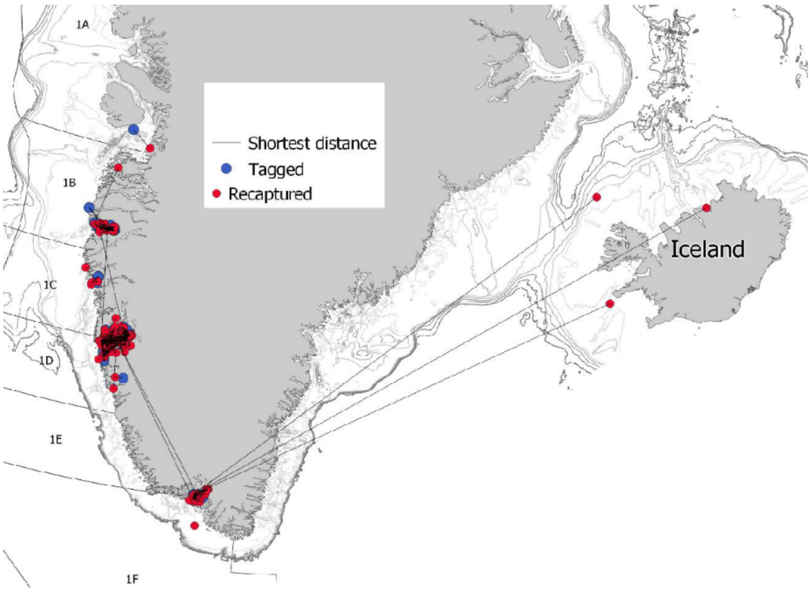

Figure 1: West Greenland inshore positions of tagged (blue) and recaptured (red, >100 days at liberty) in the period 2003-2022. The grey lines indicate the shortest migration distance.

Evidence from tagging, therefore, strongly suggests that cod belonging to the West Greenland inshore spawning stock are highly sedentary.

Surveys

A gill-net survey has since 1982 been performed in the Sisimiut Area (Nafo 1B) and the Nuuk area (Nafo 1D). In 2017, the Maniitsoq area (Nafo 1C) was included in the survey area (figure 2). For more information on survey design, see Stock annex: Cod.21.1 (ICES 2023)

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Figure 2: Position for inshore gill-net survey in the Sisimiut area (Nafo 1B), Maniitsoq area (Nafo 1C) and Nuuk area (Nafo 1D).

The survey indices for the West Greenland Inshore Spawning Stock (WISC) in each area are shown in Figure 3. From age 4-8, the indices for the Maniitsoq and Sisimiut area are very similar at a low level, whereas the indices are increasing and at a higher level in the Nuuk area. Very few cod are caught at older ages (>8 years), and therefore, comparisons are difficult between these.

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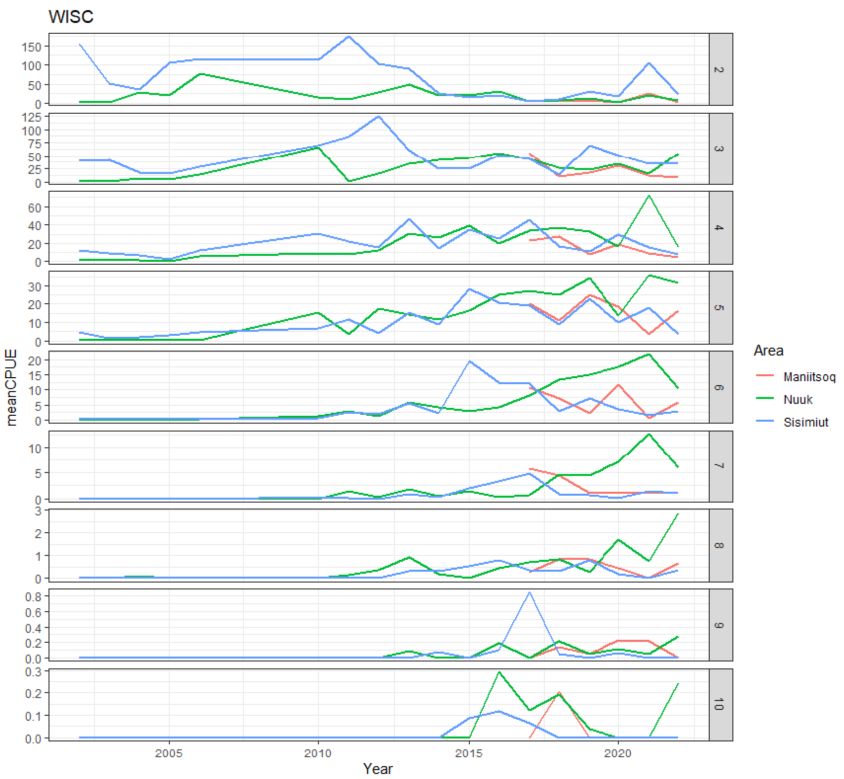

Figure 3: Survey indices by age (catch pr 100 hr.) for the West Greenland inshore spawning cod stock (WISC) in the Maniitsoq area (red, Nafo 1C), Nuuk area (green, Nafo 1D) and Sisimiut area (blue, Nafo 1B).

The biomass index between the surveys is also similar between Sisimiut and Maniitsoq, with a declining trend in recent years, whereas the biomass index in the Nuuk area is increasing (Figure 4).

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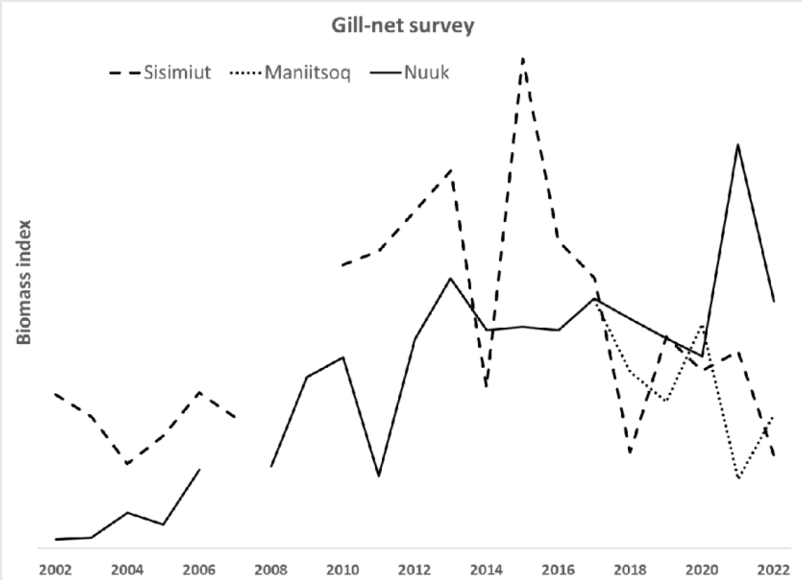

Figure 4: Biomass index for West Greenland inshore spawning cod stock by area (Sisimiut=Nafo 1B, Maniitsoq=Nafo 1C and Nuuk=Nafo 1D) from the gill-net survey.

Commercial fishery

The development in the fishery has been very different between Nafo regions. In general, catches of the West Greenland Inshore spawning cod stock are low in the northern region corresponding to Nafo division 1A and in the southern region corresponding to Nafo divisions 1E and 1F (figure 5). However, catches in the northern region follow the catches in the mid-region corresponding to Nafo divisions 1B and 1E, where catches increased from 2013 and culminated in 2016 and 2017 and then declined to nearly half in 2018 and further down in 2019 and 2020. In contrast, the catches in Nafo division 1D have steadily increased since 2010, and catches in divisions 1E and 1F have remained low throughout all the years.

Catches combined in divisions 1A+1B+1C have been almost 4 times as high in 2016 and 2017 compared to the catches in divisions 1D+1E+1F.

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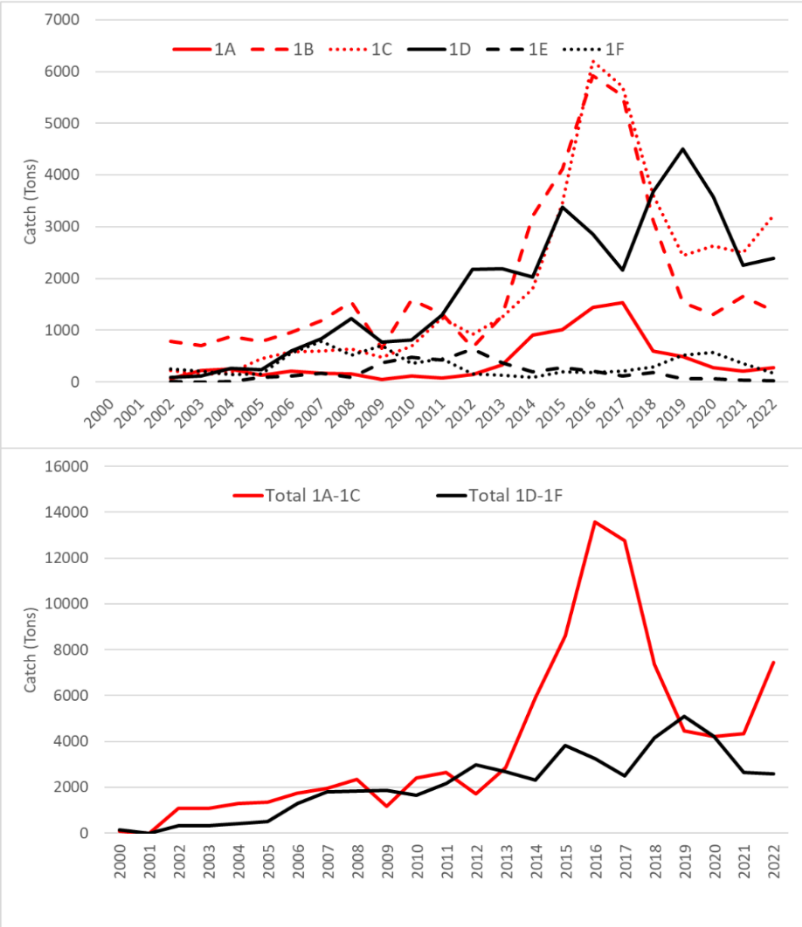

Figure 5: Commercial catches (tons) of the West Greenland Inshore Spawning cod stock (WISC) by Nafo division (top) and summed over Nafo divisions 1A+1B+1C and 1D+1E+1F (below).

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Genetics

Comparison of genetic data from a 96 SNP (Single Nucleotide Polymorphisms) panel for 83 genetically determined inshore cod collected in Nuuk (N=39) and Sisimiut (N=44) in 2013, did not reveal any genetic differentiation between inshore cod from the two areas. Wright´s fixation index, "Fst" was estimated to 0.003 (95% bootstrap values 0 - 0.007 NS). Likewise, there was no clear pattern regarding the genetic similarity among individuals. I.e. inshore cod did not cluster genetically with respect to area sampled (see Figure 6). Although the genetic data does not suggest evolutionary separated inshore cod populations in West Greenland, it does not rule out an ecological separation of the fisheries stocks. It is possible that migration rates among areas are high enough to prevent genetic differentiation (or the separation is too recent), but low enough to be significant on a short-term management scale. Alternatively, more detailed genomic analysis and more samples could reveal more subtle genetic differentiation among the areas, potentially revealing a pattern similar to the genetic population structure observed among Norwegian coastal cod.

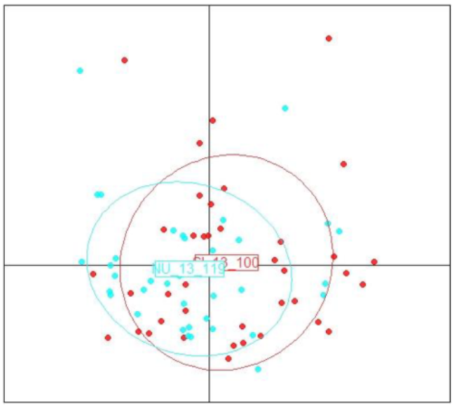

Figure 6: PCA plot illustrating genetic similarities among inshore cod collected in Nuuk (light blue) and Sisimiut (red).

Conclusion

Combining information from tagging, survey indices, and commercial data strongly suggests that the dynamic and stock status between the northern and southern regions in the inshore area in West Greenland are different. Survey indices and catches have declined in the northern region, whereas they have increased in the southern division 1D (corresponding to the Nuuk area). We, therefore, argue that as the survey indices and catch development are different between the northern region of Nafo 1A+1B+1C and the southern region of Nafo 1D+1E+1F the assessment of the West Greenland inshore cod stocks should be split in two with the delineation between Nafo 1C and 1D (with the Godthåbsfjord belonging to Nafo 1D, figure 2).

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Therkildsen, N.O., Hemmer-Hansen, J., Hedeholm, R.B., Wisz, M.S., Pampoulie, C., Meldrup, D., Bonanomi, S., Retzel, A., Olsen, S.M., Nielsen, E.E. 2013. Spatiotemporal SNP analysis reveal pronounced biocomplexity at the northern renge margin of Atlantic cod Gadus morhua. Evoltutionary Applications. DOI 10.1111/eva. 12055

NWWG 2024 WD10: Reference points re-evaluation for beaked redfish (*Sebastes mentella*) in Subarea 14 and Division 5.a

19/04/2024 MFRI, Hafnarfjörður, Iceland

William E. Butler, Bjarki Þ. Elvarsson, and Kristján Kristinsson

Summary

In 2023, an assessment model using the Gadget modelling framework was benchmarked for beaked redfish (*Sebastes mentella*) in Subarea 14 and Division 5a (ICES 2023). A full description of the model is available in the benchmark report (ICES 2023). The purpose of this document is to present re-evaluated reference points based on biomass trajectories that have been corrected. An error in the procedure for calculating biomass from the model output was found, this affected the estimates of total biomass (TB) and spawning stock biomass (SSB), and thus the reference points B_{lim} and B_{pa}, correcting the biomass levels therefore necessitates re-calculation of the stock's reference points. The error did not affect estimated recruitment levels nor exploitation rates.

Figure Figure 1 shows biomass trajectories before and after the correction. There is an upward revision in the estimated SSB and TB. The difference is largest (~12%) when the SSB stabilised from 2000 to 2008. However, throughout the time series the uncorrected estimates of SSB and TB both fall within the uncertainties (yellow shaded area) of the respective revised estimates Figure 1. Furthermore, the corrected terminal estimates of both SSB and TB are very similar to the uncorrected equivalents (3% increase) so the status of the fishery and the advice for the 2023-2024 fishing year remain unchanged Figure 1.

The following sections outline the procedures for calculating reference points. A table showing the original and re-evaluated reference points is found at the bottom of the working document.

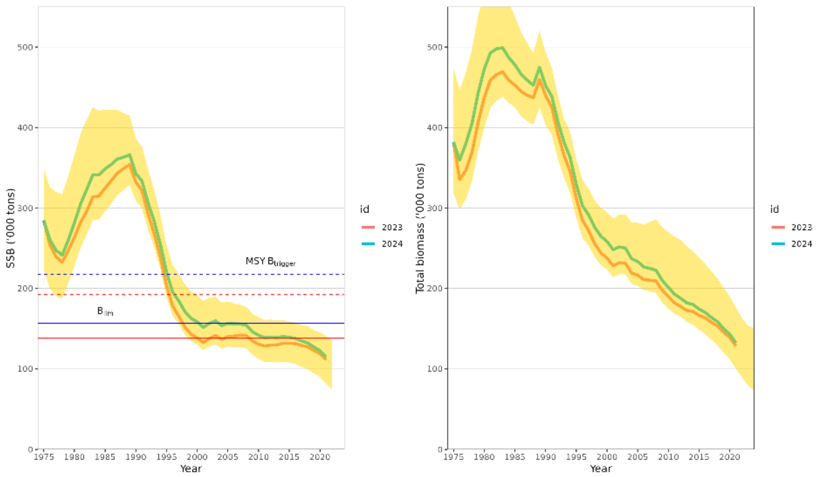

Figure 1: Iceland slope beaked redfish. Estimates of total stock biomass and spawning stock biomass. The blue line shows the re-evaluated model outputs, the red line shows the original model outputs. The original and revised values for B_{lim} and B_{pa}/MSY $B_{trigger}$ reference points are shown in red and blue respectively. The dotted red/blue lines show B_{pa}/MSY $B_{trigger}$, the solid red/blue lines show B_{lim}.

Model output

Reference points

According to ICES technical guidelines, two types of reference points are referred to when giving advice for category 1 stocks: *precautionary approach* (PA) reference points and *maximum sustainable yield* (MSY) reference points. The PA reference points are used when assessing the state of stocks and their exploitation rate relative to the precautionary approach objectives. The MSY reference points are used in the advice rule applied by ICES to give advice consistent with the objective of achieving MSY.

Generally ICES derives these reference points based on the level of the spawning stock biomass and fishing mortality. The following sections describe the derivation of the management reference points in terms of fishing mortality (F) and SSB (B). It further describes the model for stock–recruitment, weight and maturity at age, and assessment error which in combination with the MCMC results is used to project the stock in order to derive the PA and MSY reference points.

Setting B_{lim} and B_{pa}

Initially, B_{lim} was considered from examination of the SSB–Recruitment scatterplot based on the estimates from the stock assessment Figure 2. The plot shows a wide dynamic range of SSB and evidence that recruitment has been imparied, corresponding to ICES stock Type 2. In this scenario, B_{lim} is derived from the segmented regression change point. However, attempts to fit a segmented regression using the FLCore R package did not produce an adequate fit to the data, primarily because the slope does not go through the origin. Therefore, B_{lim} was calculated by taking the median SSB from 2000-2005 Figure 2, $B_{lim} = 156568$ tons. This period was chosen because the SSB was stable but at a low size and prior to the prolonged period of low recruitment. Based on the corrected SSB, B_{lim} has increased by 18311 tons over the original estimate of 138257 tons Figure 1.

In line with ICES technical guidelines B_{pa} is then calculated based on multiplying B_{lim} with $e^{1.645\sigma_{SSB}}$, where σ is the CV in the assessment year of SSB. However, the estimated σ is not considered to reflective of the true assessment error of the SSB due to various uncertainties, thus the CV used here to determine B_{lim} is 0.2, which is the default ICES value for assessment error. Therefore B_{pa} should be set at $B_{lim}e^{1.645*0.2} = 217563$ tons. Based on the corrected SSB, B_{pa} has increased by 25445 tons over the original estimate of 192119 tons Figure 1.

Stock recruitment relationship

A variety of approaches are common when estimating a stock–recruitment relationship. In the absence of a stock-recruitment signal from the available historical data Figure 2, the ICES guidelines suggest that the ''hockey-stick" recruitment function is used, i.e.

$$R_y = \bar{R}_y \min(1, S_y/B_{break})$$

where R_y is annual recruitment, S_y the spawning stock biomass, B_{break} the break point in hockey stick function and $\bar{R}_y$ is the recruitment when not impaired due to low levels of SSB. Here $\bar{R}_y$ is considered to be drawn from historical estimates after 1984 using a 7 year block-bootstrap from the bootstrap model estimates. This is done to account for possible auto-correlation in the recruitment time–series.

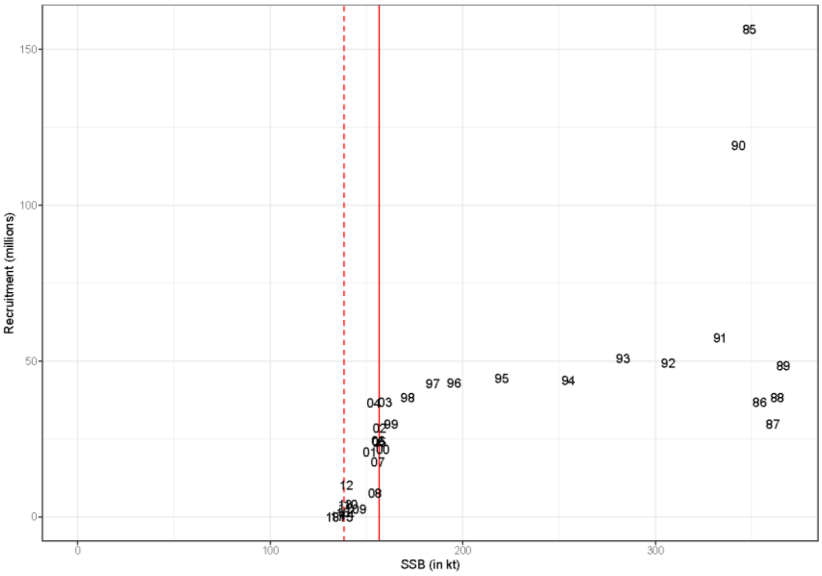

Figure 2: Icelandic slope beaked redfish. Fitted stock recruitment (age 3) relationship using revised SSB estimates. The solid red line shows the re-evaluated B_{lim}, the dashed red line shows the previous B_{lim}.

Biological parameters in the forecast

Maturity, growth and the length-weight relationship in the forecast are based on the processes estimated within the model and bootstrap replicates. Similarly, the commercial fleet selectivity is the same as estimated by the model.

Management procedure in forward projections

Illegal landings and discards by the fishing vessels are considered to be negligible. Observation error is addressed by the MCMC simulation approach employed in here. The appropriate assessment error is simulated in terms of fishing mortality by assuming F in the projections is a log-normal AR(1) process with the default values for CV as 0.212 and autocorrelation of 0.423.

Setting F_{lim} and F_{pa}

According to the ICES guidelines, the precautionary reference points are set by simulating the stock using the stock-recruitment, growth and maturity relationship described above, based on a wide range of fishing mortalities, ranging from 0 to 0.4 and setting F_{lim} as the F that, in equilibrium, gives a 50% probability of SSB $> B_{lim}$ without assessment error.

For each MCMC replicate the stock status was projected forward 200 years as simulations, and the average of the last 50 years of projected values were used to estimate the MSY reference points. F_{lim} is defined as the value of F that results in a 50% long–term probability of SSB $> B_{lim}$. This was calculated from the steady state simulations and the revised estimate the F_{lim} is 0.079, the original value of F_{lim} was 0.11.

MSY reference points

To calculate MSY reference points, an additional simulation experiment was conducted which included assessment error in addition to recruitment and growth variations. The harvest rate that would lead to the maximum sustainable yield, F_{msy}, was estimated. Average annual landings and 90% quantiles were used to determine the yield by F. The equilibrium yield curve is shown in Figure 3, where the maximum average yield, under the recruitment assumptions, is 9527 tons. This is a decrease from the previous MSY of 11639 tons.

In line with ICES technical guidelines, the MSY $B_{trigger}$ is set as B_{pa} because this is the first time the reference points are evaluated. Maximum sustainable yield is estimated to be obtained at an F of 0.062. F_{p05}, i.e., the maximum F that has less than 5% chance of going below B_{lim} when the advice rule is applied, is 0.041. This value is less than the initial F_{msy}, therefore the suggested F_{target} is set to $F_{p05} = 0.041$. The equilibrium spawning stock biomass is shown in figure Figure 3. The re-evaluated estimate for F_{target} is lower than the original F_{target} that equalled 0.061 and was also set to F_{p05}.

Icelandic slope beaked redfish in 5a. Overview of estimated reference points.

Reference point	Corrected value	Previous value	Basis
Blim	156568.000	138257.000	Median SSB from 2000-2005

Bpa	217563.426	192118.866	Blim x exp(1.645 sigma_SSB)
Btrigger	217563.426	192118.866	Bpa
Flim	0.079	0.110	F leading to P(SSB < Blim) = 0.5
Fmsy	0.041	0.061	F leading to MSY
Fpa	0.041	0.061	F, when ICES AR is applied, leading to P(SSB > Blim)
HRlim	0.080	0.110	HR leading to P(SSB < Blim) = 0.5
HRmsy	0.040	0.060	HR leading to MSY
HRpa	0.040	0.060	HR, when ICES AR is applied, leading to P(SSB > Blir
MSY	9526.844	11638.531	MSY

ICES. 2023. "Benchmark workshop on Greenland halibut and redfish stocks (WKBNORTH)," June. https://doi.org/10.17895/ices.pub.22304638.v1.

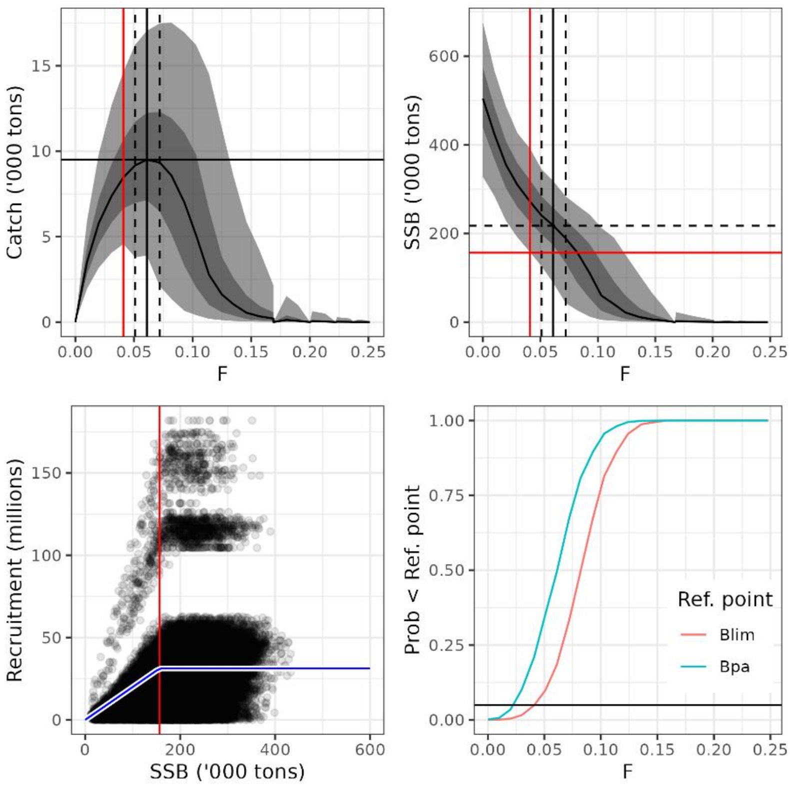

Figure 3: Icelandic slope beaked redfish in 5a. Equilibrium catch, recruitment, SSB and risk from forward projections.

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Greenland shrimp and fish survey results for redfish in East Greenland offshore waters in 2023

Henrik Christiansen

Greenland Institute of Natural Resources
3900 Nuuk, Greenland
e-mail: hech@natur.gl

Abstract

A shallow-water stratified bottom trawl survey in ICES division 14.b off East Greenland is conducted annually by the Greenland Institute of Natural Resources. This shrimp and fish survey covers depths down to 600 m in three depth strata and six subareas and collects data on biomass, abundance, and size of redfish. The survey has been conducted from 2008- 2016, in 2020, 2022, and 2023. Biomass and abundance estimates, distribution of the biomass, and length distributions of *Sebastes mentella*, *Sebastes norvegicus*, and juvenile *Sebastes* sp. (< 18 cm) are reported in this working document. According to these survey results, the biomass of both *S. mentella* and *S. norvegicus* is currently low, with a slight decrease of both *S. norvegicus* and *S. mentella* in 2023 compared to 2022. Recruitment of (undetermined) redfish, however, has increased again in 2023 compared to 2022 in terms of biomass. In terms of abundance, juveniles have decreased from 2023 compared to 2022, indicating that the observed increase is likely mainly reflecting growth. After a long period where juvenile redfish where nearly absent in the survey, the biomass for juveniles is now at the highest level since 2012.

1. Introduction

The Greenland Institute of Natural Resources conducts an annual shrimp and fish survey in East Greenland in ICES division 14.b. Here, results from this survey are presented for beaked redfish *Sebastes mentella*, golden redfish *Sebastes norvegicus*, and juvenile redfish *Sebastes* sp. (<18 cm), which are not identified to species level. Regular survey results are available for the years 2008-2016. In 2017, the Greenland shrimp and fish survey was only partly conducted, due to a breakdown of the research vessel. In 2018, 2019, and 2021 no survey was conducted. In 2020, the survey was conducted with 100 completed stations. In 2022, the survey was conducted with 102 completed stations and in 2023 with 122 completed stations.

Both redfish species are fished commercially in the East Greenland area. Since 1995, *S. mentella* has mainly been caught as by-catch in the fishery targeting Greenland halibut (*Reinhardtius hippoglossoides*), but in 2009 a fishery targeting demersal redfish was initiated followed by an increase in landings (6 613 t in 2010), which are, however, still considerably lower than historical catches (ICES 2013). Recent increases in the fishery for Atlantic cod (*Gadus morhua*) in the area also caused an increase of valuable redfish by-catch in this cod fishery. In 2015, a fishery targeting especially *S. norvegicus* was initiated north of 66° N with a quota of 3 500 t.

There are presently three surveys covering the redfish stocks on the Greenland slope. The German survey (ICES 14.b and NAFO 1F-1C, since 1982), the Greenland deep-water survey (ICES 14.b, since 1998, and NAFO 1CD, since 1997) and the shallower Greenland shrimp and fish survey (ICES 14.b, since 2008, and NAFO 1F-A, since 1990). The latter has better depth coverage for *S. mentella* (0-600 m) compared to the German survey (0-400 m) and the Greenland deep water survey (400-1500 m), which have both been used previously in the assessment. All three surveys target a broad range of demersal fish (with main targets Atlantic cod and Greenland halibut).

Sebastes mentella: From the 1970s to the 1990s the estimated biomass and abundance of *S. mentella* declined (Rätz 1996), but in the following years strong year classes were observed and the stock off Greenland increased. Survey biomass indices decreased again from 1999-2002, but subsequently returned to higher levels and remained high for a decade. However, in 2011, both the German survey and the shallower Greenland fish and shrimp survey observed a large decline for *S. mentella* (ICES 2014). Both surveys also showed that only a few year classes were present in the stock compared to the previous period (ICES 2014). In 2014 the biomass and abundance estimates in the Greenland shrimp and fish survey were the lowest observed during the time series until then, and the decline continued in 2015. In 2016, the biomass estimates of *S. mentella* almost tripled compared to 2015. This increase, however, is mainly due to one enormous haul in stratum Q2 accounting for 70 % of the total biomass estimate. Survey data is lacking for 2017-2019. In 2020 the survey biomass estimate for *S. mentella* was at a new record low (18.4 kt) and subsequently increased to 33.3 kt in 2022.

Sebastes norvegicus: The biomass of golden redfish in East Greenland decreased gradually during the 1980s in the German survey and was at very low levels during the 1990s. After the end of the 1990s biomass indices steadily increased to levels higher than observed in the mid-1980s. The Greenland shrimp and fish survey showed a massive increase in biomass of golden redfish (20-30 cm) in 2011 and the index has fluctuated greatly since then. In 2015 and 2016, the biomass index for *S. norvegicus* increased. No data is available for the years 2017-2019. In 2020 the survey index from the Greenland shrimp and fish survey showed a strong decrease, with the total biomass index being similar to the low indices from 2008 to 2010. In 2022, the biomass index was slightly higher than in 2020, but still much lower than in 2011-2016.

Juvenile redfish: From 2008 to 2012, biomass and abundance indices of small (<18 cm), juvenile redfish estimated from the Greenland shrimp and fish survey were comparatively high. In contrast, juvenile redfish were nearly absent in the period from 2013 to 2020 (with no data in 2017-2019). In 2022 higher juvenile biomass was recorded for the first time again since 2012, albeit still at a lower level.

2. Materials and Methods

In 2007, the Greenland shrimp and fish survey conducted in West Greenland was expanded to include East Greenland waters. The survey has been conducted with the 722 GRT stern trawler M/Tr 'Paamiut' until 2017. In that year the survey had to be aborted due to vessel breakdown. In 2018, 2019, and 2021 no survey was conducted. In 2020 the survey was conducted from the commercial vessel (CV) 'Helga Maria'. In 2022 the survey was for the first time conducted with the new vessel RV 'Tarajoq', owned by the Greenland Institute of Natural Resources. The same cosmos trawl and procedures were used throughout the years on all vessels. The survey area is divided into subareas (Q1-Q5) and depth strata (0-200, 201-400, and 401-600 m; Table 1). Further details on the survey design can be found in the stock annex (ICES 2017).

Catch handling

For each haul the catch was sorted by species, total weight was recorded, and individual length was measured (TL to 1.0 cm below). Redfish were additionally sexed, and individual weight and maturity were recorded and otoliths sampled. Small redfish (<18 cm) were in most cases not determined to species and are recorded as juvenile redfish (*Sebastes* sp.). Species determination has been inconsistent in the period, and especially the earliest years could be associated with some sampling error.

The survey biomass and abundance estimates are based on the swept area method (estimated trawled distance*estimated wing spread excluding bridles and doors) with the parameters estimated from GPS positions and Scanmar recordings at the start and end of each haul. All catches are standardized to 1 km^2 before further calculations and the catchability is set to 1.0 for all species, making all estimates index values.

3. Results and discussion

In 2023, 122 hauls were obtained and all depth strata were covered, except the shallow parts of Q1 (0-200 m). This is roughly the same coverage as in previous years. In general, changes in survey trends are driven by few large hauls leading to somewhat fluctuating indices and relatively large CVs (Table 2). This is especially applicable in 2016, where one haul in Q2 accounted for 70 % of the total biomass of *S. mentella*. The relatively short time series, the fluctuating nature of the indices and the long life span of redfish (Stransky *et al*. 2005), calls for some caution in interpretation of stock trends, particularly when considering year to year estimates. Overall, biomass and abundance estimates for *S. mentella* in 2023 are low compared to the period 2008 – 2016 and even lower in 2023 compared to 2022. For *S. norvegicus* the 2023 estimates are low compared to the period 2011 – 2016, but higher than in the period 2008 – 2010, although a decrease has been observed from 2022 to 2023. For juvenile *Sebastes* sp. the 2023 estimates are relatively high, continuing the increasing trend observed already in 2022. The 2023 index is comparable to the estimate from 2010, but still lower compared to 2009, 2011 and 2012. Overall, the 2023 estimates follow the 2022 estimates with slight decreases in *S. mentella* and *S. norvegicus*, and a continuing increase in juvenile redfish.

Sebastes mentella

The biomass of *S. mentella* is not evenly distributed in the area and highest concentrations are traditionally found in stratum Q3 between 201 – 600 m (Table 2). In 2020 most of the biomass (around 50 %) was concentrated in the 401 – 600 m zone in Q3. Similarly, 71 % of the biomass were concentrated in the 401 – 600 m zone of Q3 in 2022. In 2023, most of the biomass (62 %) was concentrated in two depths zones (201-400 and 401-600 m) in Q3. In 2020, 2022, and 2023 there was, unlike in previous years, very little biomass of *S. mentella* in Q2 and Q5. In all years, only comparatively small amounts of *S. mentella* are found in Q1 and Q6 and in all areas the species is virtually absent in the shallowest depth zone (0 – 200 m) (Table 2). In 2016, the biomass index for *S. mentella* was estimated at 163.7 Kt, which is an increase of 170 % compared to 2015 (Table 2 and Fig. 1). However, if one extremely large haul in Q2 is excluded from calculations, the biomass declined with around 50 % in 2016 compared to 2015. In 2020, the estimated biomass dropped to 18.4 Kt (which is a record low), following the overall trend of declining biomass and abundance indices since 2008 (Fig. 2). In 2022, a slight increase compared to 2020 was observed with a biomass estimate of 33.3 Kt, but the biomass is still at the second lowest value observed in the entire time series. In 2023, the overall estimate decreased again to 25.5 Kt. The patterns observed regarding biomass are largely mirrored in abundance, with e.g. the 2022 estimate of 39.3 mio. Being the second lowest in the time series (Table 3 and Fig. 2). In 2023, however, the abundance index increased markedly to 122.1 mio, which is opposite of the biomass trend and indicates that smaller *S. mentella* are now part of this stock biomass. This can be seen as well in the length distribution (Fig. 7), where for the first time since 2012 larger parts of small *S. mentella* are appearing. The mode of the length distribution has been gradually increasing over time, reaching 42 cm in 2022, but in 2023 it has been down shifted to around 18-19 cm due to these smaller individuals. Therefore, overall the S. mentella stock in ICES 14.b is still at a status of low biomass, but small fish are entering the stock and may lead to increases in the future. The distribution of the species off East Greenland is patchy, but seems to be well covered by the survey (Fig. 4).

Sebastes norvegicus

In 2015 and 2016, the biomass indices for *S. norvegicus* were 227 Kt and 323 Kt, respectively, whereas it dropped to 40.2 Kt in 2020 being the lowest index for more than 10 years (Table 2, Fig. 1). In 2022, the biomass index roughly doubled compared to 2020 to 83.1 Kt, but which is still considerably lower than the 2016 level. In 2023, the index decreased again to 62.0 Kt. Throughout the time series, index values have been highly variable between years, but an increase from the 2008-2010 period to the 2011-2016 period seems to be evident. The increase in 2011 was caused mainly by the appearance of smaller fish (<30 cm) (Fig. 8). This large size class can be followed until 2016 where the fish measure from 25-40 cm with a mode around 30 cm. In 2020 the few *S. norvegicus* measured are around 18 cm and 37 cm (Fig. 8). In 2022 an increase in smaller *S. norvegicus* (<25 cm) seems to be responsible for the increase in biomass and abundance compared to 2020 (Fig. 8). In 2023, approximately three modes can be observed the length distribution (Fig. 8). While from 2020 to 2022 the increase in abundance was stronger than the increase in biomass, this is also apparent from 2022 to 2023 but as a decrease. Therefore, overall, there are some signs for improvement in stock biomass and abundance over the past few years. However, there are also indications that most recently (2023) some of the incoming year classes are being depleted already again due to fishery and/or uncertainty in survey estimates. The survey coverage is similar between all surveyed years and shows that overall *S. norvegicus* appears to be relatively widely distributed in the area (Fig. 5).

Depth overlap between S. mentella and S. norvegicus

The proportional contribution of both redfish species in the survey shifts with depth (Fig. 3). At depths shallower than 350 m, the catches are dominated by *S. norvegicus*. From 300 to about 450 m, the catch is progressively dominated by *S. mentella* and at depths greater than 450 m *S. mentella* constitutes most of the catch. The depth distribution in 2023 shows that relatively many *S. mentella* were caught in shallower (< 350 m) water compared to other years, which may be a reflection of the many smaller (<20 cm) individuals that are now present in the survey. Over the entire time series the strongest change in proportions occurs around 350 m depth.

Sebastes sp.

From 2013-2016, juvenile redfish *Sebastes* sp. (i.e. fish <18 cm) were at a very low level - the estimates of biomass and abundance in 2016 of 0.2 Kt and 4.6 mio., respectively, were the lowest in the entire time series (Table 2 & 3, Fig. 1 & 2). In 2020, biomass and abundance indices increased to 3.6 Kt and 237.2 mio., respectively, and increased again in 2022 to 17.2 Kt and 901.7 mio., respectively. In 2023, biomass increased again to 25.8 Kt, while abundance decreased to 776.9 mio., indicating that not more juvenile redfish are entering the stock, but that the present juveniles are growing. Accordingly, the length distribution has shifted in 2023 compared to 2022 (Fig. 9). In 2023, these juveniles seem to concentrate in the 201-400 m depth of Q3 (80 % of the biomass; Table 2, Fig. 6), while in earlier years with high biomass of juveniles they have been distributed almost across the entire survey area (Fig. 6).

Conclusion

All combined, the biomass and abundance of *S. mentella* and *S. norvegicus* is low in 2023, with a slight decrease compared to 2022. For *S. mentella* the decrease could be related to high uncertainty of the 2022 results (CV 55 %), which is much lower in 2023 (CV 15 %) and could be a result of the inherent uncertainty due to schooling behaviour. Furthermore, abundance of *S. mentella* has increased in 2023 compared to 2022, which is due to more smaller individuals being present in this stock. The juvenile redfish (<18 cm) have overall increased in biomass, but decreased in abundance, which indicates growth of the present individuals. Many of the individuals recorded as juveniles in 2022, seem to have recruited to the *S. mentella* stock and only a smaller part to the *S. norvegicus* stock, contrary to preliminary indications in 2022. It remains unknown to which stock the currently high biomass of juveniles present in the area will recruit in the future.

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Tables and figures

Table 1. Effort (hauls) in the different survey areas and depth strata (m) off East Greenland in the yearly shrimp and fish survey of the Greenland Institute of Natural Resources. *in 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021, no survey was conducted.

Year	Depth strata (m)	Survey area						Total
		Q1	Q2	Q3	Q4	Q5	Q6	
	0-200	0	0	2	0	3	7	
2008	201-400	6	4	5	5	3	3	52
	401-600	2	2	5	2	1	2	
	0-200	0	1	3	3	2	5	
2009	201-400	21	7	17	14	3	6	97
	401-600	1	3	5	3	1	2	
	0-200	0	2	4	1	2	5	
2010	201-400	16	8	12	7	2	4	82
	401-600	5	2	8	1	2	1	
	0-200	0	2	2	2	2	5	
2011	201-400	16	5	13	8	3	7	85
	401-600	5	3	6	2	2	2	
	0-200	0	2	3	3	2	6	
2012	201-400	15	10	15	8	3	8	98
	401-600	6	2	10	2	2	1	
	0-200	0	2	3	2	0	6	
2013	201-400	20	7	9	10	3	7	92
	401-600	5	3	10	2	2	1	
	0-200	0	2	0	2	2	5	
2014	201-400	14	10	6	5	5	8	80
	401-600	0	2	0	2	2	5	
	0-200	0	2	2	2	2	7	
2015	201-400	17	8	10	8	4	6	95
	401-600	9	1	12	2	2	1	
	0-200	0	1	4	1	3	7	
2016	201-400	21	7	13	11	3	7	101
	401-600	8	3	9	1	1	2	
	0-200	1	1	3	2	2	5	
2017*	201-400	1	3	4	4	4	5	36
	401-600	0	0	0	0	0	1	
	0-200	0	0	0	0	0	0	
2018-19*	201-400	0	0	0	0	0	0	0
	401-600	0	0	0	0	0	0	
	0-200	1	2	5	3	1	6	
2020	201-400	18	9	14	8	4	8	100
	401-600	5	2	8	2	2	2	
	0-200	0	0	0	0	0	0	
2021*	201-400	0	0	0	0	0	0	0
	401-600	0	0	0	0	0	0	
	0-200	4	2	10	5	2	4	
2022	201-400	16	8	17	4	4	4	102
	401-600	6	3	8	2	2	1	
	0-200	0	2	4	4	2	3	
2023	201-400	26	9	19	9	3	6	122
	401-600	8	10	9	3	2	3	

Table 2. Biomass (kg*10⁶, Kt) indices of redfish (*S. mentella* and *S. norvegicus*) and juvenile redfish (*Sebastes* sp., <18 cm) for the East Greenland area by year and subarea. Coefficients of variation (CV, %) are given for the total estimate. *in 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021, no survey was conducted.

Sebastes mentella

Year	Q1			Q2			Q3			Q4			Q5			Q6			Total (Kt)	CV (%)
	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m		
2008		2.6	0.3		65.2	0.7	0.0	82.1	21.2		1.2	11.1	0.0	1.8	58.3	0.0	1.5	2.2	248.3	47
2009		3.7	0.1	0.0	10.4	2.0	0.3	42.2	58.6	0.0	79.4	7.3	0.1	21.5	9.3	0.0	0.0	1.9	236.7	35
2010		6.2	1.5	0.0	25.6	2.9	0.0	179.4	39.7	0.0	23.2	7.0	0.0	0.4	3.7	0.0	0.2	0.7	290.5	35
2011		4.2	1.8		4.8	1.1	0.0	61.9	17.7		0.0	7.6	0.0	19.0	5.1		0.1	0.7	123.1	25
2012		0.1	0.5		1.7	2.5	0.0	45.3	41.4			3.3			4.4	0.0		1.4	100.6	29
2013		0.1	1.1	0.0	1.9	0.2	0.0	21.5	43.0	0.0	0.0	4.6		78.7	9.9	0.0	0.6	0.7	162.3	50
2014		0.2	0.0	0.0	0.4	0.2	-	0.0	57.2	0.0	0.0	0.9	0.0	6.0	0.0	0.0	0.0	2.7	67.6	24
2015		0.0	0.2	0.0	0.2	8.1	0.0	6.7	27.0	0.0	0.0	5.2	0.0	6.8	4.4	0.0	0.0	2.0	60.6	28
2016		0.2	0.7	0.0	2.8	127.9	0.0	1.3	15.0	0.0	0.0	10.0	0.0	0.0	2.7	0.0	0.5	2.6	163.7	79
2017*		-	-	-	-	-	-	-	-	-	-	-	-	-	.	-	-	-	-	-
2018-19		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2020		0.2	0.6	0.0	0.0	0.1	0.0	1.0	9.8	0.0	0.0	2.2	0.0	0.1	3.6	0.0	0.0	0.9	18.4	16
2021		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022		0.3	0.3	0.0	0.5	1.9	0.0	1.0	23.9	0.0	0.0	2.3	0.0	0.2	1.8	0.0	0.1	1.1	33.3	55
2023		0.8	0.4	0.0	1.7	0.4	0.2	7.4	8.3	0.0	0.3	0.5	0.0	0.6	2.5	0.0	0.3	2.2	25.5	15

Sebastes norvegicus

Year	Q1			Q2			Q3			Q4			Q5			Q6			Total (Kt)	CV (%)
	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m		
2008		2.3	0.0		12.0	0.2	0.1	7.9	4.6		0.7	1.0	0.0	0.5	0.0	0.3	4.6	0.0	34.1	32
2009		3.0	0.1	0.0	5.3	0.0	0.5	14.1	11.1	0.1	4.5	0.0	0.0	0.5	0.0	0.2	1.0	0.2	40.5	27
2010		4.7	0.4	0.0	5.7	0.3	0.3	16.4	1.7	0.0	0.1	0.1	0.0	0.1	0.3	0.7	0.7	0.2	31.7	30
2011		7.1	0.6	0.0	7.3	0.0	0.0	262.4	6.7	0.1	41.7		0.1	29.1	0.7	1.8	3.0	0.1	360.9	36
2012		8.3	1.5	0.0	8.8		0.4	64.3	5.9	0.1	5.4		0.0	3.2	0.9	1.1	1.3	1.1	102.3	27
2013		4.6	1.2	0.0	51.5	1.5	0.2	47.4	1.4	0.1	12.8	0.2		162.3	0.1	0.9	6.7	0.0	291.0	57
2014		1.1	1.6	0.0	14.6	0.0	-	86.2	0.4	0.4	16.9	1.5	0.3	9.3	3.6	0.7	1.6	0.1	138.4	41
2015		5.3	1.1	0.0	15.3	1.4	0.1	176.6	3.1	0.0	13.2	0.2	0.1	4.9	0.6	1.0	3.7	0.0	226.7	37
2016		4.8	2.6	0.0	5.7	232,4	0.2	49.7	1.6	0.1	18.8	0.6	0.0	2.8	0.0	0.4	2.7	0.5	322.7	79
2017*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2018-19		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2020		1.3	0.5	0.0	2.2	0.6	0.0	16.7	1.1	0.0	1.3	0.3	0.4	9.1	2.3	0.3	4.1	0.0	40.2	41
2021		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022		1.4	0.0	0.0	8.7	0.2	0.1	52.1	0.0	10.3	2.3	0.1	0.1	5.7	0.9	0.9	0.2	0.0	83.1	39
2023		1.0	0.2	0.0	11.0	0.3	0.2	27.0	0.9	0.0	0.9	0.2	0.2	0.9	8.6	1.6	8.7	0.3	62.0	31

***Sebastes* sp.**

Year	Q1			Q2			Q3			Q4			Q5			Q6			Total (Kt)	CV (%)
	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m		
2008		1.8	0.0		0.0	0.0	0.0	5.4	0.0		1.1	0.1	0.0	0.1	0.0	0.3	0.3	0.0	9.0	53
2009		2.8	0.0	0.0	0.3	0.0	0.2	34.0	0.2	0.1	3.1	0.0	0.0	0.0	0.0	0.1	0.3	0.0	41.3	63
2010		4.5	0.0	0.0	0.7	0.0	0.3	13.7	0.2	0.1	0.9	0.0	0.1	0.8	0.0	0.6	1.8	0.0	23.6	31
2011		5.1	0.0	0.0	0.0	0.0	0.2	24.1	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0.	0.0	0.0	30.2	57
2012		0.6	0.3		1.8	0.0	0.0	33.1	0.0	0.0	0.6		0.0	0.0		0.1	0.1		36.8	79
2013		0.3	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.1	0.0		0.0	0.0	0.0	0.0	0.0	1.2	33
2014		0.0	0.0	0.0	0.1	0.0	-	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	26
2015		0.0	0.0	0.0	0.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0.	0.0.	0.8	45
2016		0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	30
2017*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2018-19		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2020		<0.1	0.0	<0.1	0.3	0.0	<0.1	1.7	<0.1	<0.1	1.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	3.6	23
2021		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022		2.4	0.0	0.0	0.8	0.0	0.2	11.9	0.4	0.1	0.7	0.2	0.0	0.1	0.0	0.3	0.1	0.0	17.2	22
2023		1.8	0.2	0.0	0.5	0.0	0.0	20.7	0.8	0.1	1.1	0.1	0.0	0.0	0.0		0.2	0.0	25.8	27

Table 3. Abundance indices (mio.) for redfish (*S. mentella* and *S. norvegicus*) and juvenile redfish (*Sebastes* sp., <18cm.) for the East Greenland area by year and area. Coefficients of variation (CV, %) are given for the total estimate. *in 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021, no survey was conducted.

Sebastes mentella

	Q1			Q2			Q3			Q4			Q5			Q6			Total (mio)	CV (%)
Year	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m		
2008		23.3	2.8		87.3	1.4	0.2	640.5	141.9		5.9	23.6	0.0	10.8	335.8	0.0	7.9	6.7	1286.1	49
2009		22.9	0.8	0.0	32.3	5.0	0.7	221.7	219.8	0.0	240.7	31.9	0.3	95.0	18.0	0.0	0.0	5.6	894.7	29
2010		28.8	9.0	0.0	42.3	4.5	0.1	574.5	171.6	0.1	132.6	32.2	0.0	2.8	7.8	0.1	0.8	1.1	1008.2	33
2011		15.5	7.8		15.8	2.0	0.2	217.9	44.0		0.0	29.5	0.0	47.9	8.7		0.6	1.6	391.5	22
2012		0.3	1.5		3.3	5.0	0.0	144.4	132.1			8.7			7.5	0.1		3.0	306.0	27
2013		0.3	4.4	0.0	3.8	0.3	0.0	65.1	134.2	0.0	0.0	9.8		98.3	18.4	0.0	2.4	0.8	337.8	33
2014		1.1	0.2	0.0	0.9	0.3		0.1	144.4	0.0	0.0	1.6	0.0	18.9	0.0	0.0	0.0	4.0	171.5	25
2015		0.1	0.5	0.0	0.3	10.4	0.0	28.6	61.0	0.0	0.0	8.1	0.0	13.6	5.4	0.0	0.0	2.4	130.4	23
2016		0.6	1.5	0.0	5.0	123.4	0.0	5.1	28.8	0.0	0.0	13.7	0.0	0.0	4.4	0.0	2.2	3.6	188.2	67
2017*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2018-19		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2020		0.3	0.6	0.0	0.0	0.1	0.0	1.5	13.7	0.0	0.0	2.8	0	0.1	4.2	0.0	0.2	0.9	24.4	16
2021		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022		1.4	0.4	0.0	0.6	1.8	0.0	3.0	27.1	0.0	0.0	1.9	0.0	0.3	1.9	0.0	0.1	0.9	39.3	49
2023		9.5	3.7	0.0	4.2	0.4	0.9	76.1	18.4	0.1	1.9	0.6	0.0	1.0	2.3	0.0	0.8	2.1	122.1	25

Sebastes norvegicus

	Q1			Q2			Q3			Q4			Q5			Q6			Total (mio)	CV (%)
Year	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m		
2008		11.4	0.1		40.8	0.1	0.3	26.8	13.9		3.6	0.3	0.0	2.3	0.0	1.6	6.7	0.0	108.0	29
2009		8.2	0.2	0.0	13.5	0.0	1.1	70.3	23.3	0.7	16.0	0.0	0.0	17	0.0	1.2	3.1	0.1	139.7	27
2010		13.7	1.1	0.0	11.7	0.1	0.4	353.0	1.0	0.2	0.2	0.1	0.1	0.4	0.2	2.0	2.8	0.1	70.8	34
2011		32.6	1.8	0.0	18.3	0.0	0.29	1316.6	13.1	1.3	127.1		0.3	48.8	0.3	8.3	21.6	0.0	1590.6	36
2012		25.1	4.3	0.1	31.7		1.0	344.7	6.2	0.5	35.3		0.1	9.0	0.6	2.9	8.2	0.2	470.0	35
2013		21.7	4.3	0.0	206.7	2.2	1.0	219.8	0.4	0.4	40.4	0.0		163.0	0.1	4.8	24.0	0.0	688.9	34
2014		3.8	3.6	0.0	34.3	0.0		248.5	0.3	1.8	44.5	2.4	0.5	11.4	6.7	2.6	6.4	0.0	366.8	40
2015		12.1	2.1	0.0	32.1	0.8	0.2	507.3	4.8	0.1	23.3	0.1	0.3	15.1	0.2	1.9	10.4	0.0	610.7	37
2016		12.1	4.1	0.0	6.7	58.8	0.3	112.4	2.1	0.3	28.0	0.1	0.1	5.7	0.0	1.1	4.2	0.2	236.2	38
2017*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2018-19		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2020		3.4	0.9	<0.1	7.5	0.5	<0.1	29.7	1.0	0.4	8.7	0.1	2.4	9.8	1.6	0.3	4.1	0.0	70.4	29
2021		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022		3.4	0.0	0.0	36.1	0.1	0.3	136.8	0.0	11.1	7.4	0.1	0.6	26.9	0.8	1.0	0.3	0.0	224.8	37
2023		2.1	0.6	0.0	16.0	0.1	0.8	70.7	0.2	0.0	1.3	0.2	0.2	0.5	4.0	3.5	6.7	0.1	107.1	29

***Sebastes* sp.**

	Q1			Q2			Q3			Q4			Q5			Q6			Total (mio)	CV (%)
Year	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m	0-200m	201-400m	401-600m		
2008		56.3	0.0		0.1	0.0	0.3	271.1	0.0		77.4	3.1	0.2	4.2	0.0	23.4	16.2	0.1	452.5	53
2009		76.9	0.0	0.5	8.9	0.0	18.8	591.3	7.5	9.5	207.7	3.5	2.2	0.8	0.9	7.2	17.8	0.6	953.9	28
2010		90.2	0.3	0.1	15.1	0.0	7.0	240.5	2.2	5.8	36.0	0.7	1.9	29.2	0.2	19.2	48.3	0.6	497.1	26
2011		58.2	0.0	0.5	0.0		7.2	455.0	0.0	12.4	0.0		0.4			0.0	0.0	0.0	533.7	64
2012		10.3	1.6		10.9	0.0	1.1	213.0	0.0	0.5	12.8		0.0	0.5		1.6	1.2		253.6	56
2013		6.8	0.0	0.2	0.0	0.0	2.7	30.4	0.1	2.4	3.4	0.0		0.2	0.0	0.5	0.1	0.0	46.8	36
2014		1.5	0.0	0.0	1.5	0.0		15.6	0.2	0.9	0.5	0.1	0.1	0.2	0.0	0.2	0.1	0.0	20.9	33
2015		0.7	0.0	0.0	1.7	0.0	0.4	16.5	0.1	0.0	0.7	0.1	0.0	0.1	0.0	0.2	0.1	0.0	20.6	52
2016		0.6	0.0	0.0	0.1	0.0	01	2.5	0.1	0.0	0.5	0.1	0.0	0.3	0.0	0.1	0.1	0.0	4.6	22
2017*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2018-19		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2020		2.7	0	<0.1	8.2	0.0	0.1	139.0	0.5	1.8	50.4	0.5	1.4	1.5	0.9	29.1	1.1	<0.1	237.2	23
2021		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022		55.1	0.4	0.1	31.1	0.0	12.4	442.9	15.6	26.3	120.5	8.1	12.2	10.1	3.4	113.2	18.5	31.8	901.7	18
2023		42.7	4.5	0.1	10.8	0.0	3.0	617.2	16.5	4.4	49.9	4.0	0.1	0.8	0.6	11.8	10.2	0.2	776.9	23

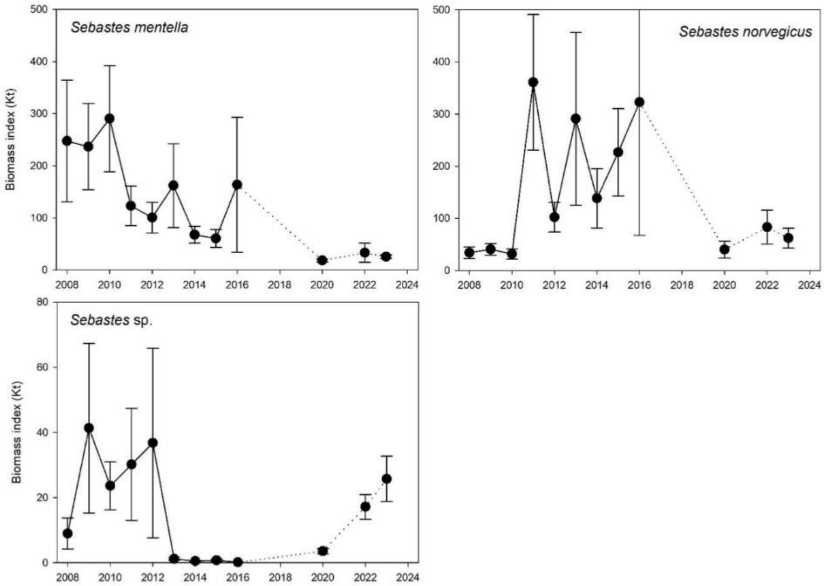

Figure 1: Biomass (kg*10^6, Kt) (±SD) indices for *S. mentella*, *S. norvegicus* and *Sebastes* sp. (<18 cm) off East Greenland in 2008-2016, 2020, 2022, and 2023. All surveyed areas (Q1-Q6) are combined. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted, therefore no data is shown (dotted line).

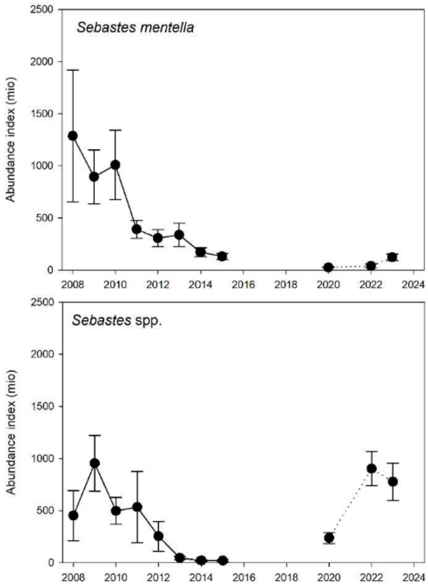

Figure 2: Abundance (millions) indices (±SD) for *S. mentella*, *S. norvegicus* and *Sebastes* sp. (<18 cm) off East Greenland in 2008-2016, 2020, 2022, and 2023. All surveyed areas (Q1-Q6) are combined. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted, therefore no data is shown.

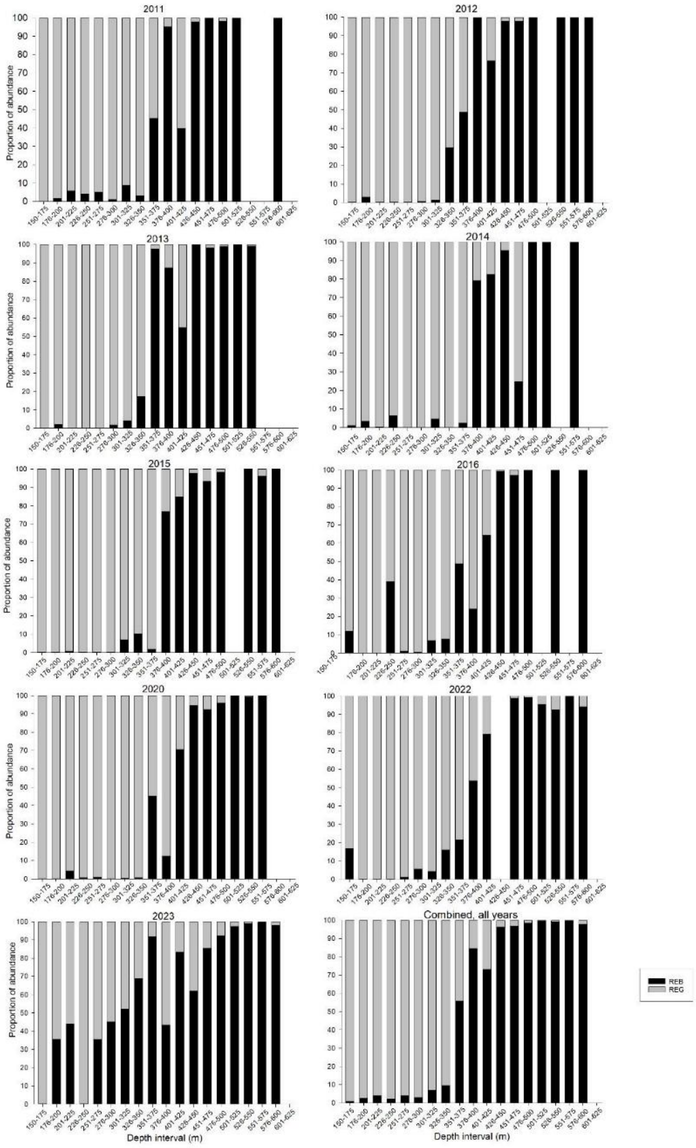

Figure 3: The proportional contribution of *S. mentella* (REB, black) and *S. norvegicus* (REG, grey) to the biomass estimate in the East Greenland survey area at different depths (Q1-Q6 combined) from 2011-2020. No data is available from 2017-2019 and 2021. The proportions are calculated in relation to the combined biomass caught in a given 25 m-depth interval.

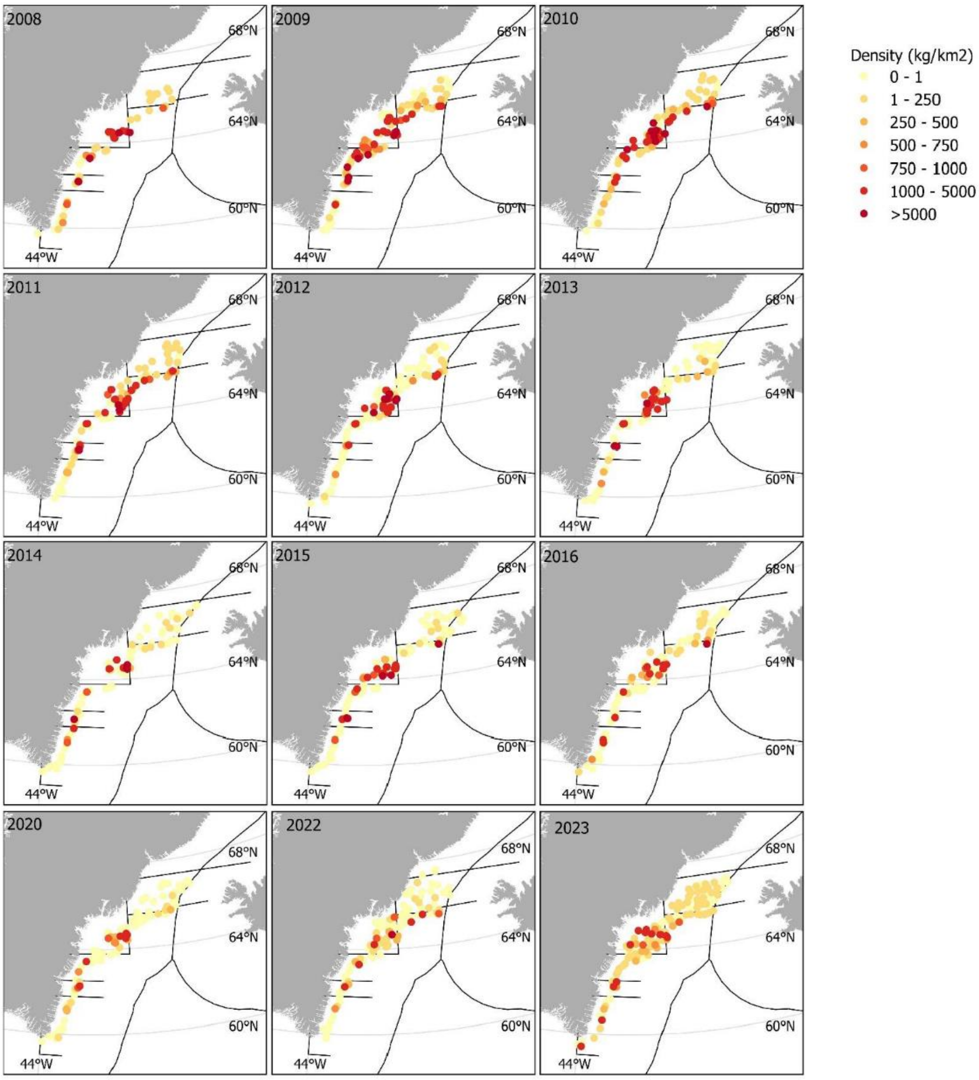

Figure 4: Distribution of the *S. mentella* biomass (kg/km²) off East Greenland in 2008-2023. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted.

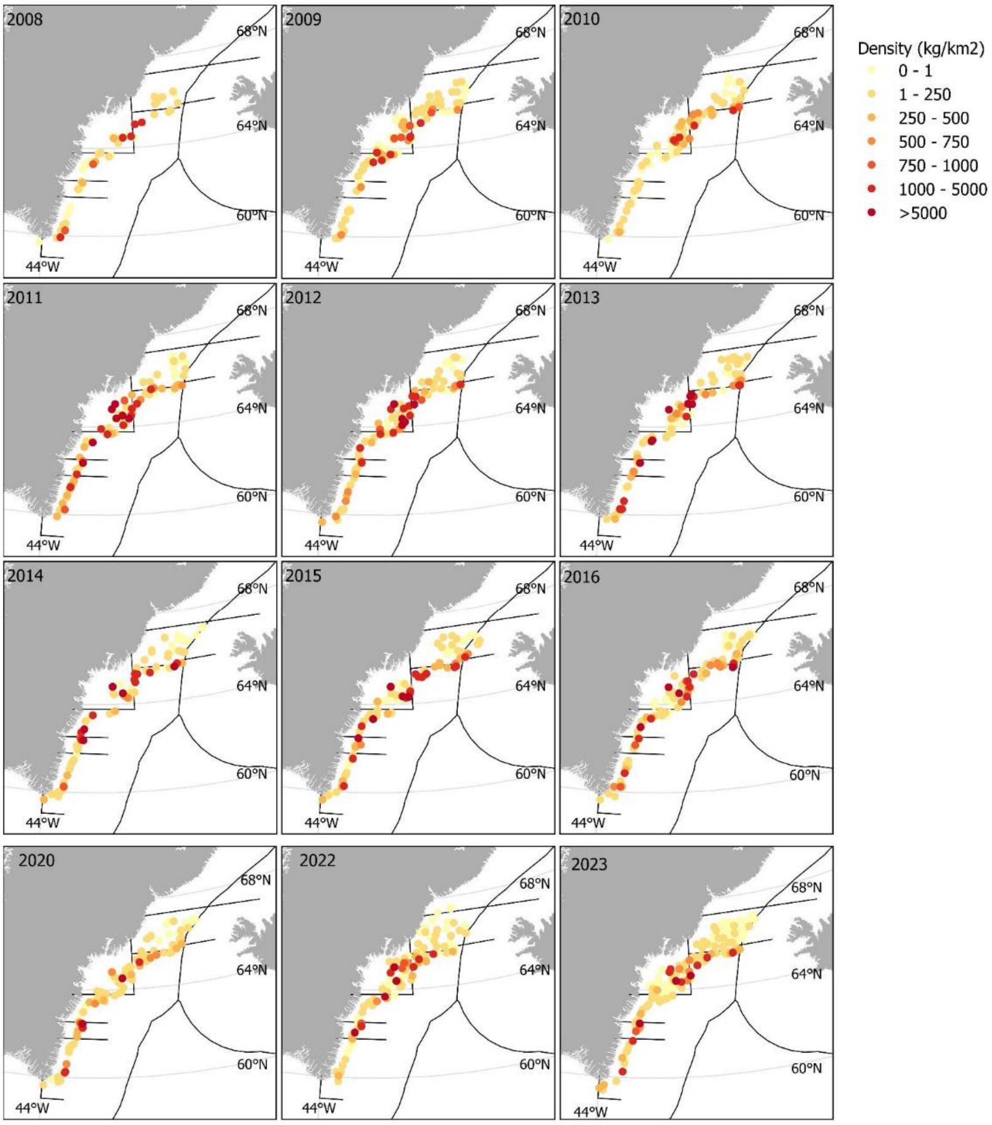

Figure 5: Distribution of the *S. norvegicus* biomass (kg/km²) in 2008-2023 off East Greenland. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted.

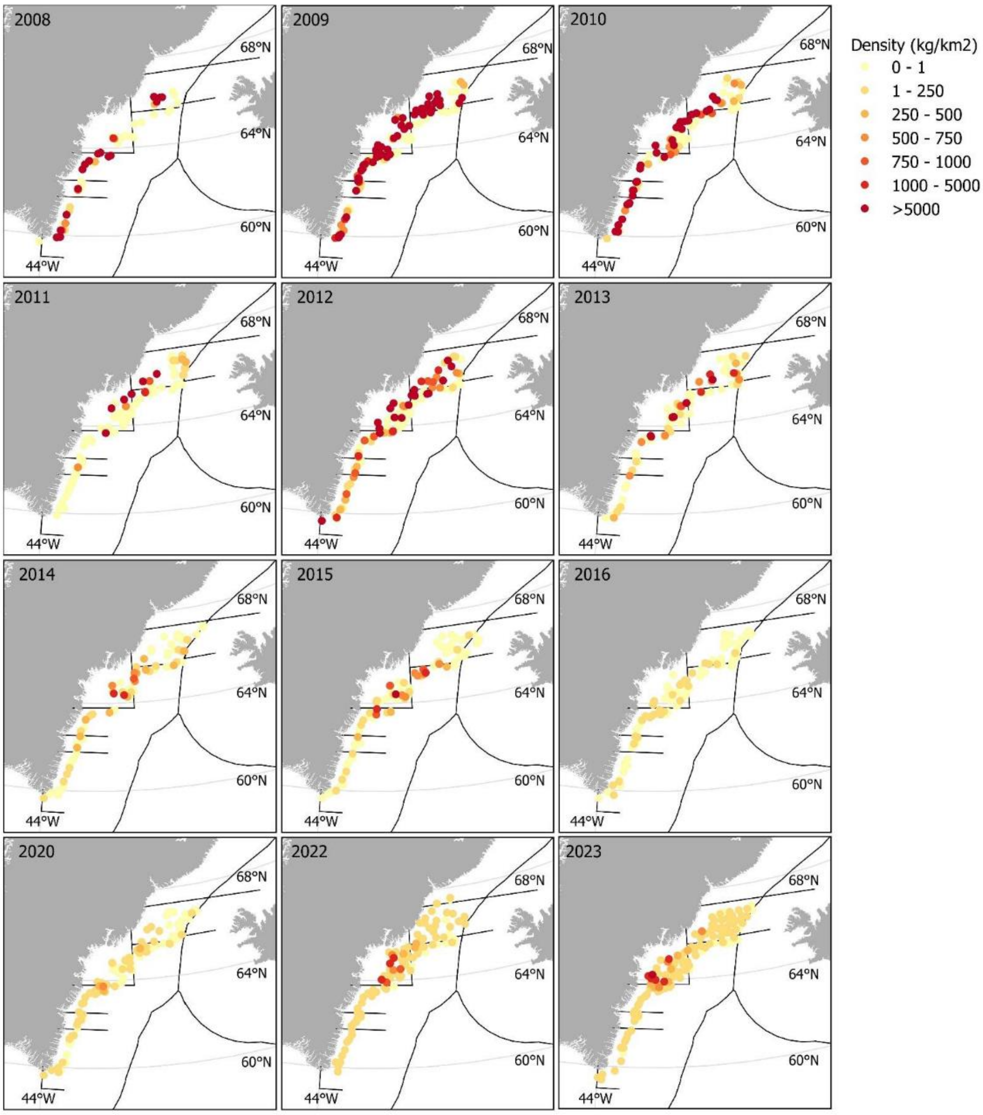

Figure 6: Distribution of the *Sebastes* sp. (<18cm.) biomass (kg/km^2) in 2008-2023 off East Greenland. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted.

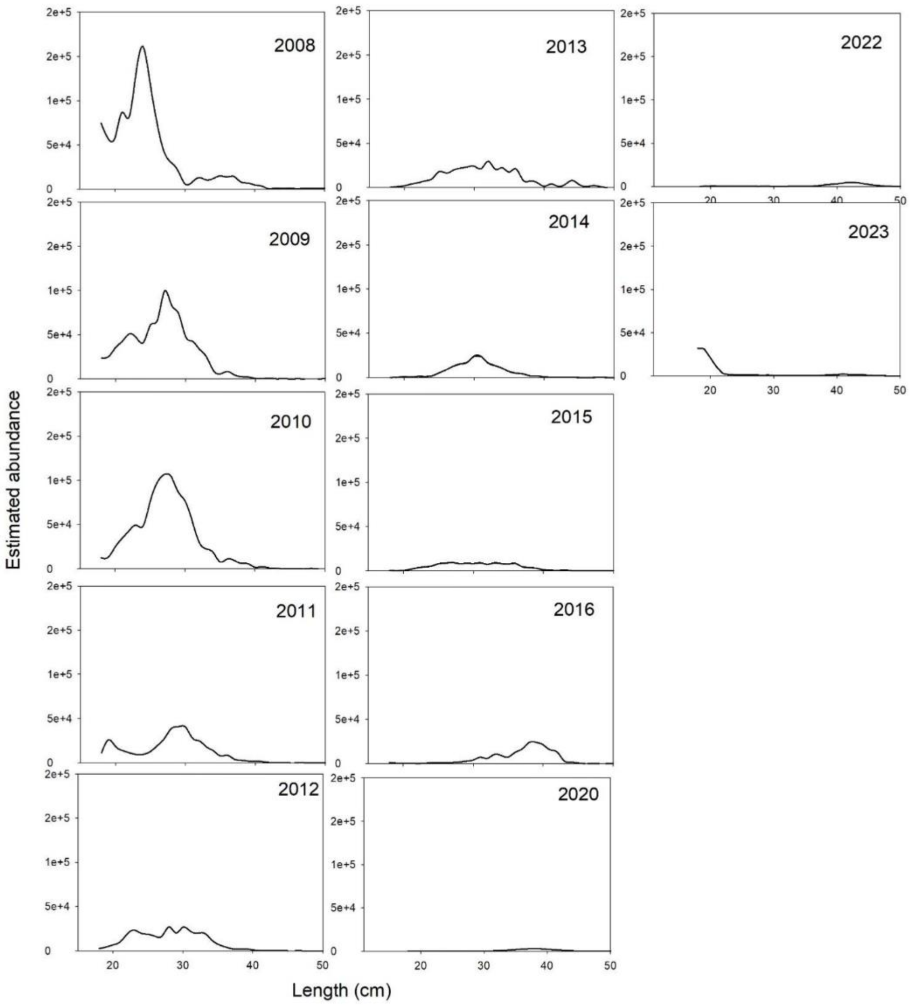

Figure 7: Overall length distributions for *S. mentella* off the Greenlandic East coast in 2008-2023 for all surveyed areas combined (Q1-Q6). In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted.

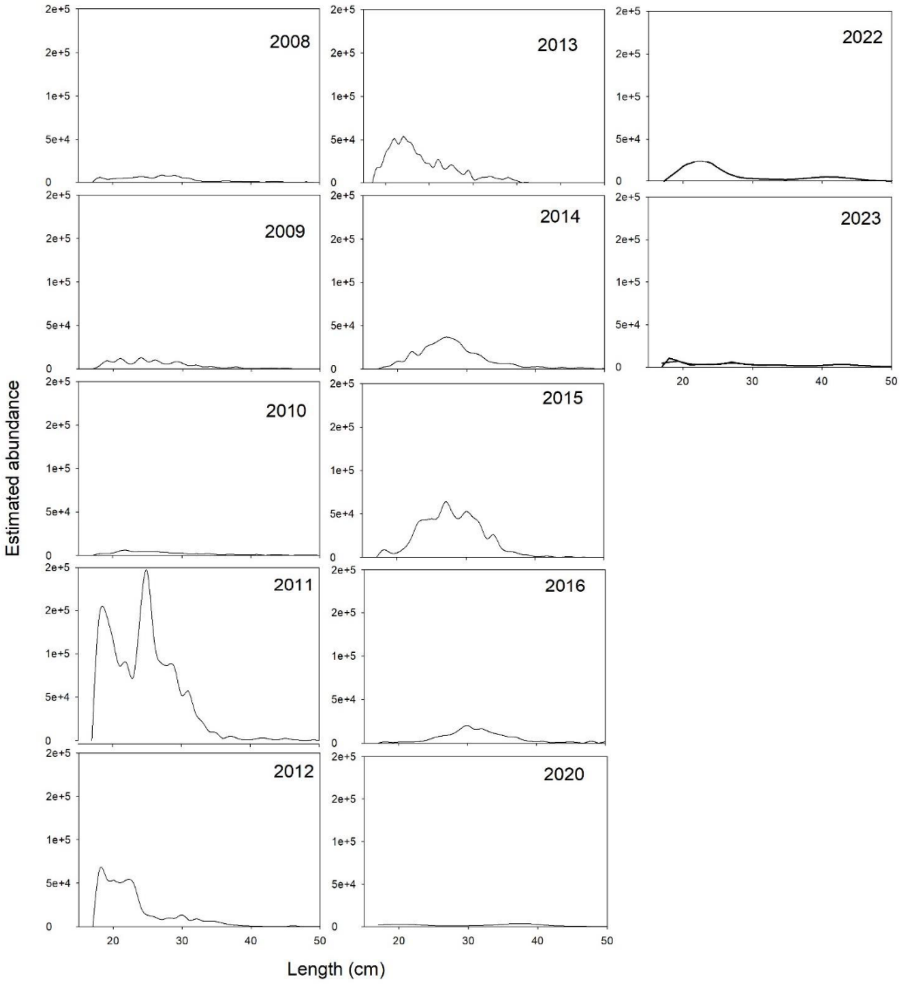

Figure 8: Overall length distributions for *S. norvegicus* off the Greenlandic East coast in 2008-2023 off East Greenland. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted.

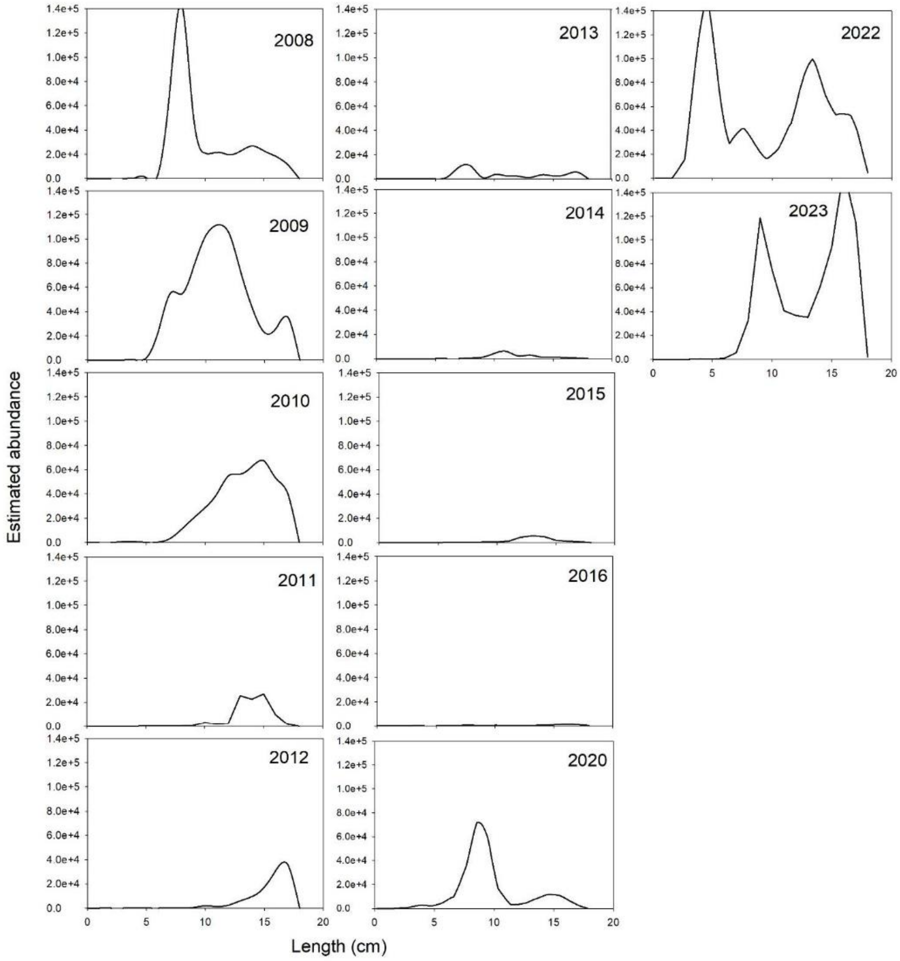

Figure 9: Overall length distributions for *Sebastes* sp. (<18 cm) off the Greenlandic East coast in 2008-2023 off East Greenland. In 2017 the survey was aborted due to vessel breakdown and in 2018, 2019, and 2021 no survey was conducted.

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The fishery for demersal redfish (*Sebastes mentella*) in ICES division 14.b in 2022

Henrik Christiansen

Greenland Institute of Natural Resources
3900 Nuuk, Greenland
e-mail: hech@natur.gl

Abstract

This document reports on catches of demersal redfish *Sebastes mentella* in ICES division 14.b, where the species is caught as by-catch in Greenland halibut, cod, or shrimp fisheries or in some years in a directed fishery. The annual landings include not only *S. mentella*, but also *S. norvegicus*. The proportions of these species in the landings is estimated based on a species split ratio. In 2023, the applied species split of 29:71 (*S. mentella*:*S.norvegicus*) was determined based on survey data, resulting in catches of 1 255 t and 3 073 t for *S. mentella* and *S. norvegicus*, respectively. The catch of *S. mentella* is thus at the second lowest level since 2009, when 895 t were landed, and far lower than at the highest point in the past twenty years, which was in 2011 with 7 376 t being landed. The CPUE index from the directed redfish fishery is correspondingly following an overall decreasing trend since 2010, despite some fluctuations. The by-catch CPUE index is fluctuating with a vague increasing trend in the years 2010 – 2023. The length distribution in the fishery as estimated from commercial samples shows a mode at 38 cm in 2023.

1. Description of the fishery

Demersal redfish in ICES division 14.b is caught either as by-catch in the Greenland halibut, cod, or shrimp fisheries or as the target species when concentrations and sizes are appropriate. This directed fishery is almost exclusively conducted with bottom trawls. An insignificant longline fishery is also present. The amount of redfish caught in the shrimp fishery is limited due to mandatory grid separators, which were introduced in 2002, and a general effort reduction in the shrimp fishery since 2006. No redfish by-catch from the shrimp fishery is landed, because all fish caught on shrimp trawlers must be discarded due to hygienic regulations.

Three surveys are presently covering the redfish stocks on the Greenland slope. The German survey (ICES 14.b, NAFO 1F-1C, since 1982), the Greenland deep-water survey (ICES 14.b, since 1998, NAFO 1CD, since 1997) and the shallower Greenland shrimp and fish survey (ICES 14.b, since 2008, NAFO 1F-A, since 1990). From the surveys we know that demersal redfish found on the shelf consist of a mixture of *Sebastes norvegicus* and *S. mentella*. It is observed that *S. norvegicus* dominates catches at shallow depths (<400 m), but with increasing depth the ratio shifts to catches being increasingly dominated by *S. mentella*.

In division 14.b, a large catch of 59 700 t demersal redfish was taken in 1976 with a subsequent 0 catch in 1977. From 1978 to 1994 annual landings ranged from 5 000 to 20 000 t yr^{-1} with one exception (2 284 t in 1989). After 1994, total catches decreased drastically with annual landings <1 000 t in the three following years (Table 1). In 1998, Germany started a directed fishery for redfish with annual landings around 1 000 t in 1998-2001, increasing to 2 109 t in 2002. Samples taken from the German fleet indicated that substantial quantities of the redfish caught, especially in 2002, were juveniles, i.e. fish less than 30 cm. After the German fleet stopped fishing in 2002 the majority of catches were taken by British, Faroese, Norwegian and Greenlandic vessels. The British fishery took place from 2001 to 2005 and since 2010 only Greenland the EU, Norway, Russia and Germany have had any significant catches. Very little targeted demersal redfish fishery was conducted in division 14.b in 2003-2008 with annual landings gradually decreasing from 446 t in 2003 to 92 t in 2008. In 2009, three Greenlandic vessels started a fishery targeting demersal redfish. Each vessel was given a research quota of 250 t and when including the Faroese and Norwegian catches the final 2009 landings were 1 118 t redfish. In 2010, a quota of 5,000 t was given and 400 t of these were allocated to the Norwegian fleet. After the quota of 5 000 t was fished an extraordinary research quota of 1,000 t was given to a Greenlandic vessel. There was no jurisdiction in 2010 that clearly delimited the pelagic redfish from the demersal redfish found on the shelf. A few vessels benefitted from that by fishing their pelagic quota on the shelf (2 179 t). The total catch of demersal redfish in 2010 was therefore 8 266 t (Table 1). In 2011 and 2012, a quota of 8 500 t was given for combined demersal catches of redfish (*S. mentella* and *S. norvegicus*). The combined catches of *S. mentella* and *S. norvegicus* on the shelf were around 8 000 t in the years 2010-2017. The catch level in the 21st century peaked in 2015 with 8 539 t. In the following years annual landings decreased gradually to 3 112 t in 2022. In 2023 the total catch increased compared to 2022 to 4 328 t, which is nevertheless the second lowest annual catch in the period 2010-2023.

2. Results

Species split

Before 2009, *S. mentella* and *S. norvegicus* were not distinguished in the demersal fishery and the ratio between both species was considered to be 90:10 (*S. mentella:S. norvegicus*) from which catches of *S. mentella* have been estimated. Since 2009, an annual split ratio and estimates for each species are made based on survey data, analyses of samples from the commercial fishery, and/or from landings data. Between 2009 and 2015 the proportion varied between 88:12 (2011) and 70:30 (2015). In 2016, the overall proportion between *S. mentella* and *S. norvegicus* shifted, and the ratio was estimated to be 36:64 (based on commercial samples). The proportional shift was confirmed in scientific surveys. In 2017, the requirements in the fishery license were changed, so that the fishermen themselves register which of the two species are caught. However, due to uncertainty regarding the accuracy of species identification on industry vessels, samples from the commercial fishery have been sent to the Greenland Institute of Natural Resources. These samples are used as one possible indicator to estimate the proportion of each species in the fishery.

In 2017 and 2018, the proportional split was made based on logbooks and still supported the proportional shift with *S. norvegicus* being more abundant than *S. mentella*. In 2019, the split was 61:39 based on samples from a trial fishery resulting in an opposite overall proportion similar to 2015 and earlier. However, in 2020 the split was made from samples of the commercial fishery resulting in a 29:71 ratio, which was also roughly supported by logbook data (40:60). For estimating annual catches in 2020, the split based on commercial samples (29:71) was used. In 2021, no survey data was available and commercial samples were few. Therefore, a split based on logbooks was used with a ratio of 22:78 (*S.mentella*:*S. norvegicus*), which is similar to the ratio applied in 2020 (see Table 1). In 2022, a ratio of 29:71 was estimated from survey data, while 21:79 was estimated from logbooks, and 70:30 from commercial samples. The split estimated from survey data was considered most objective and realistic and used to estimate catch proportions of both species in 2022. In 2023, the split was made based on survey data again, which indicated the same ratio as in 2022, i.e. 29:71 (*S.mentella*:*S.norvegicus*). These proportions were also roughly supported by logbook data (26:74).

Catches

Starting in 2011, a line following the outside of the 1 000 m depth contour was used to separate the Greenland slope area from the Irminger Sea. By definition, all catches taken west of this line are treated as demersal redfish, and all catches taken east of the line are treated as pelagic redfish (Table 2, Fig. 1).

The Greenland authority operates the quota uptake by categorising the catches in three types of redfish: 1) Fish caught by bottom trawl and longlines on the bottom are called *Sebastes norvegicus*, 2) fish caught pelagically in the Irminger Sea are called *Sebastes mentella*, and 3) fish caught as by-catch in the shrimp fishery are called *Sebastes* sp.. Total catches of *S. mentella* and *S. norvegicus* combined were 4 328 t in 2023, which is the second lowest among all years since 2010, but a slight increase compared to 2022 (Table 1). The total catch was split using survey proportions in 2023, resulting in estimated landings of 1 255 t *S. mentella* and 3 073 t *S. norvegicus* (Table 1).

The geographical distribution of the fishery in the period 2000 to 2022 is shown in Fig. 2. In years with no or very little direct redfish fishery (e.g. 2003 -2008), the catches follow the fishery for Greenland halibut near the slope towards greater depths, indicating that most of these catches are by-catch. In years with direct fishery on *S. mentella*, areas with the largest catches are relatively concentrated at 64°N 36°W and just northeast from there at 64° 30' – 65°N 35°W at depths between 350-400 m (Fig. 2). In recent years, the fishery has operated at shallower depth than before. In 2017 - 2023, the catch depth was even further reduced, and >50% of the catch was fished below 370-400 m, which according to the survey is the depth range where an abrupt shift in abundance between *S. mentella* and *S. norvegicus* occurs. In comparison, 50 % of the catch in 2011 and 2012 was caught at around 370 m. This is consistent with an increasing share of *S. norvegicus* in the fishery, as this species prefers shallower depths.

To minimize by-catch in the shrimp fishery the trawls have been equipped with grid separators since 2002 (G.H. 2001). However, the 22 mm spacing between the bars in the separator allows small fish to enter the cod end. A study from 2007 found that the mean length of redfish that entered the cod end of the shrimp fishery was 13-14 cm (Sünksen 2007). The same author documented that by weight redfish accounted for less than 1% of the amount of shrimp that were caught. After the separator grids were introduced in the fishery the by-catch dropped from 100-200 t to a lower level. Since 2006, only a minor shrimp fishery has taken place in ICES 14.b and the level of by-catch is insignificant, although there was an increase in 2023 (Table 4).

In 2023, Greenland had the largest landings of redfish from ICES 14.b followed by the EU and Norway. Overall, since 2000, Greenland is the most important nation in the fishery, followed by Germany, Norway and the EU (Table 3).

In 2023, the catches were taken over the course of the entire year, with the largest landings in December (Table 5). In the years 2020-21 the majority of catches were taken in summer, but the overall catch level was also higher in these years.

CPUE (Redfish directed fishery)

The CPUE derived from the redfish directed fishery can be split into two periods: 1999-2008 and 2009-recent (Table 6 and Fig. 3). The catches from 1999-2008 were almost exclusively by-catch, whereas catches from 2009-recent were from a redfish directed fishery. This is reflected in the CPUE where the onset of the directed fishery is associated with a large increase in CPUE. This means that the useable part of the time series is only the period between 2009-recent.

Additionally, the nature of the fishery (schooling fish behaviour) can result in extremely high catches in spite of declining biomass making the CPUE series a somewhat biased indicator. At the redfish ICES benchmark in 2012 (WKRED), the CPUE based on the directed fishery was evaluated as non-useful in the assessment for two reasons: the fishery targets an aggregating species which may allow a high CPUE at low stock sizes, and the distribution of the directed fishery is probably not representative of stock distribution. Nevertheless, since 2012, there has been a slightly fluctuating yet decreasing trend in the CPUE potentially reflecting the decreasing biomass estimate from scientific surveys.

By-catch CPUE (Greenland halibut fishery)

At the redfish ICES benchmark in 2012 (WKRED), a by-catch CPUE index based on the Greenland halibut directed fishery was introduced as a possible proxy for redfish population size. The rationale for using by-catch CPUE was that a longer time series is available and the fishery covers a wider area on the Greenland slope than the redfish directed fishery and thereby gives a greater coverage of the stock distribution. Furthermore, the Greenland halibut directed fishery has been fairly stable over a long period. It should be mentioned, that redfish by-catch reports do not distinguish between *S. norvegicus* and *S. mentella*, but as the Greenland halibut fishery takes place at depths >400m, the confounding effect of the *S. norvegicus* contribution is assumed to be negligible. Logbooks on a haul-by-haul basis of all redfish catches from all fisheries are available from 2001-2023. Details on the calculation procedure can be found in Hedeholm and Boje (2012). The available data are summarized in Table 7 and Fig. 4.

The by-catch CPUE index is fairly stable throughout the period, albeit with year to year fluctuations. In the available data, these fluctuations reached a low point in 2010. In the years from 2010-2023 a vague increasing trend with some year-to-year variation can be observed (Fig. 5). This trend is opposite to the observed decrease in the CPUE index from the directed redfish fishery (Fig. 4) as well as trends from survey data from the past decade.

Commercial samples

For *S. mentella* in 2010 and 2011, there was a clear mode around 38 cm. In 2012 and again in 2013 the mode was around 34 cm and in 2014 and 2015, the mode was around 35 cm and 36 cm. In 2016, the mode was clearly around 34 cm for *S. mentella*. No commercial samples from the commercial fishery were available in 2017-2019, so no length data was obtained for these years. In 2020, the mode of *S. mentella* was obtained from commercial samples and was around 37 cm. in 2021, the numbers of samples was too small to assess the mode in the length distribution. In 2022 the length distribution of commercial samples (n = 489) had a mode at 36 cm and a second mode at 41 cm. In 2023, the mode of the length distribution from commercial samples (n = 785 *S. mentella*) was at 38 cm.

References

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Tables and Figures

Table 1. Catches (tons) of demersal redfish from ICES 14.b.

Year	*S. Norvegicus*	*S. mentella*	total
1974		0	
1975		4 400	
1976		59 700	
1977		0	
1978		5 403	
1979		5 131	
1980		10 406	
1981		19 391	
1982		12 140	
1983		15 207	
1984		9 126	
1985		9 376	
1986		12 138	
1987		6 407	
1988		6 065	
1989		2 284	
1990		6 097	
1991		7 057	
1992		7 022	
1993		14 828	
1994		19 305	
1995		819	
1996		730	
1997		199	
1998		1 376	
1999		853	
2000		982	
2001		901	
2002		2109	
2003		446	
2004		482	
2005		267	
2006		202	
2007		226	
2008		92	
2009	223	895	1 118
2010	1 653	6 613	8 266

Table 1 *continued*. Catches (tons) of demersal redfish from ICES 14.b.

Year	*S. norvegicus*	*S. mentella*	total
2011	1 005	7 376	8 381
2012	1 973	6 243	8 216
2013	1 485	6 761	8 246
2014	2 706	4 608	7 314
2015	2 562	5 977	8 539
2016	5 442	3 061	8 503
2017	4 541	3 027	7 568
2018	4 004	1 972	5 976
2019	2 665	3 998	6 663
2020	4 105	1 677	5 782
2021	3 523	1 302	4 825
2022	2 210	902	3 112
2023	3 073	1 255	4 328

Table 2. Positions delimiting the pelagic *S. mentella* stocks from the redfish found on the shelf at the east coast of Greenland.

Point	Decimal degrees N	Decimal degrees W	Degrees minutes N	Degrees minutes W
1	59.25	-54.43	59°15'	54°26'
2	59.25	-44.00	59°15'	44°00'
3	59.50	-42.75	59°30'	42°45'
4	60.00	-42.00	60°00'	42°00'
5	62.00	-40.50	62°00'	40°30'
6	62.00	-40.00	62°00'	40°00'
7	62.67	-40.25	62°40'	40°15'
8	63.15	-39.67	63°09'	39°40'
9	63.50	-37.25	63°30'	37°15'
10	64.33	-35.00	64°20'	35°00'
11	65.25	-32.50	65°15'	32°30'
12	65.25	-29.84	65°15'	29°50'

Table 3. Landings (tons) of demersal redfish caught in ICES 14.b by nation. Note that these catches have not been split into *S. mentella* and *S. norvegicus* catches according to the splitting factor applied in Table 1.

Year	DEU	ESP	EU	FRO	GBR	GRL	ISL	NOR	POL	RUS	UNK	Sum
1999											853	853
2000	884		11			19		65			3	982
2001	782				11	9		99				901
2002	1 703			48	16	246	29	32		36		2 109
2003	3	2	2	20	155	232		32				446
2004	5	1	79	12	221	93		68	3			482
2005	2		4	38	96	72		56				267
2006	1					152		48				202
2007	7		15	138		35		30				226
2008	1		8	50	5	5		23				92
2009				203		822		93				1 118
2010	10		12	381		5 672		2 190		1		8 266
2011	1 262		26	2		6 757		334		1		8 381
2012	1 810		5	32		5 964	1	403		1		8 216
2013	1 957			32	30	5 863		356		8		8 246
2014	1 973		0.2	13		4 611	98	613		5		7 314
2015	1 987			74		4 979	208	822		469		8 539
2016			1 759	25	2	5 859		858				8 503
2017	1 060		537	31		4 736		787		418		7 568
2018	418		1 295	48		3 276		489		450		5 976
2019	976		1 021	5		3 410		985		266		6 663
2020			2 050	9		2 399		1 069		256		5 782
2021	808		894	32		2 051		1 002		38		4 825
2022			1 185	6		1 044		823		54		3 112
2023			1 007	32		2 567		722				4 328
Sum	15 649	3	9 909	1 231	536	60 667	336	11 998	3	2 003	856	103 397

Table 4. Discarded by-catch (tons) of *Sebastes* sp. from the shrimp fishery in ICES 14.b.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
1999	6	16	17	5	1	13	2	48	22	30	40	33	234
2000	10	3	31	17	15	4	21	78	28	18	9	6	239
2001	7	9	10	16	9	11	4	5	3	3	28	6	111
2002	3	11	9	6	1	0	0	5	4	8	3	5	55
2003	5	6	8	5	5	8	8	15	2	10	12	4	88
2004	7	10	17	13	4	2	27	20	7	2	9	0	118
2005	7	14	16	8	7	5	6	21	14	4	5	20	126
2006	6	2	4	1	3	5	2	4	4	0	0	4	35
2007	7	3	2	1	0	0	0	0	0	0	0	0	14
2008	0	2	2	0	0	1	0	0	0	0	0	1	7
2009	1	2	11	1	0	0	0	0	0	0	0	0	16
2010	1	2	2	1	1	0	1	0	0	0	0	2	10
2011	0	0	0	0	1	0	0	0	0	0	0	0	3
2012	0	0	1	1	1	0	0	0	0	0	0	0	4
2013	0	1	1	0	0	0	0	0	0	0	0	0	2
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	1	0	0	0	0	0	0	0	0	0	1
2023	0	2	3	1	0	0	0	0	0	0	0	0	6
Sum	60	83	135	76	48	49	71	196	84	75	106	81	1 062

Note: Grid separators were introduced in 2002.

Table 5. Landings (tons) of demersal redfish caught in ICES 14b by month. Note that these catches have not been split into *S. mentella* and *S. norvegicus* catches according to the splitting factor applied in table 1.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
1999		10		108		4	42	10	15	34	481	149	853
2000	18	238	286	260	10	4	79	72	13	0	3		982
2001			1				108	2		184	369	236	901
2002		183	445	354	390	50	472	35	44	59	77		2 109
2003			9	4	26	27	135	195	20	16	12		446
2004				35	41	63	75	48	64	96	25	35	482
2005			1	15	66	24	80	29	13	18	19		267
2006		3	7	50	14	39	20	61	2	1	1	2	202
2007	6	13	8	8	14	42	4	106	16	7	1	1	226
2008	4	3	1	6	12	11	31	12	10	2			92
2009				1	84	346	148	105	128		288	17	1 118
2010	799	786	708	1 058	2 149	2 100	108	134	88	301	36		8 266
2011	419	1 396	1 661	1 017	268	250	236	598	255	583	1223	475	8 381
2012	899	2 197	628	852	577	699	966	143	44	23	474	712	8 215
2013			709	1 290	925	1 423	1 218	1 086	723	227	119	527	8 246
2014	10	421	206	1 210	1 187	1 709	231	401	376	448	632	479	7 314
2015	543	786	1 016	451	507	1 611	1 160	1 024	504	393	74	467	8 539
2016	306	214	1 130	1 185	1 426	1 864	1 298	559	466	38	14	1	8 501
2017	373	1 977	1 368	751	308	513	1 111	249	38	651	102	124	7 568
2018	798	1 273	819	779	367	189	1 049	22	176	234	225	45	5 976
2019	23	211	1 102	653	1 359	1 316	601	520	365	379	36	98	6 663
2020	22	354	510	17	129	2 189	731	705	439	309	310	67	5 782
2021	113	164	369	275	284	1 090	846	1 184	235	10	127	124	4 825
2022	305	257	186	346	246	726	154	317	254	128	69	124	3 112
2023	267	163	109	583	152	239	546	404	237	491	259	876	4 328
Sum	4 905	10 649	11 280	11 308	10 541	16 528	11 450	8 021	4 524	4 632	4 976	4 559	103 394

Table 6. Logbook ln CPUE (kg/hr) for redfish caught in the redfish directed fishery in ICES 14.b. Based on the model: ln CPUE = year + ICES subdivision.

Year	ln CPUE (kg/hr)	± SE	Kg/hr
1999	6.3389	0.0855	566
2001	6.3091	0.0818	550
2002	6.5143	0.0709	675
2003	5.5022	0.0979	245
2004	5.4359	0.0862	229
2005	5.1600	0.1071	174
2006	5.2841	0.1502	197
2007	5.5203	0.1814	250
2008	4.9290	0.1792	138
2009	6.6883	0.1104	803
2010	8.5842	0.0693	5 347
2011	8.2159	0.0703	3 699
2012	7.4629	0.0641	1 742
2013	7.5437	0.0647	1 889
2014	7.3832	0.0576	1 609
2015	6.9906	0.0502	1 086
2016	7.4224	0.0529	1 673
2017	7.2814	0.0521	1 453
2018	6.9830	0.0539	1 078
2019	7.1723	0.0712	1 303
2020	7.0034	0.0593	1 100
2021	6.7635	0.0523	866
2022	6.6249	0.0600	754
2023	6.7574	0.0577	860

Table 7. By-Catch ln CPUE (kg/hr) for redfish caught in the Greenland halibut directed fishery in ICES 14.b. Based on the model: ln CPUE = year + depth+ ICES subdivision. N is the number of hauls made at a starting depth of <1000 m.

Year	N	ln CPUE (kg/hr)	± SE	Kg/hr
2001	1 231	0.3556	0.0653	1.43
2002	1 267	0.8650	0.0644	2.38
2003	1 209	0.3087	0.0657	1.36
2004	1 420	0.2316	0.0631	1.26
2005	1 126	0.3684	0.0653	1.45
2006	589	0.7980	0.0778	2.22
2007	1 013	0.4541	0.0675	1.57
2008	1 036	0.2594	0.0667	1.30
2009	1 417	0.2102	0.0630	1.23
2010	1 392	-0.1135	0.0628	0.89
2011	1 108	0.4270	0.0661	1.53
2012	1 305	0.6015	0.0634	1.82
2013	933	0.4508	0.0679	1.57
2014	688	0.4895	0.0730	1.63
2015	730	0.2105	0.0715	1.23
2016	326	0.7824	0.0933	2.19
2017	748	0.5826	0.0704	1.79
2018	835	0.3826	0.0703	1.47
2019	758	0.7221	0.0715	2.06
2020	496	0.7641	0.0748	2.15
2021	685	0.5854	0.0704	1.80
2022	780	0.7880	0.0683	2.20
2023	1 035	1.1101	0.0644	3.03
Total	22 127			

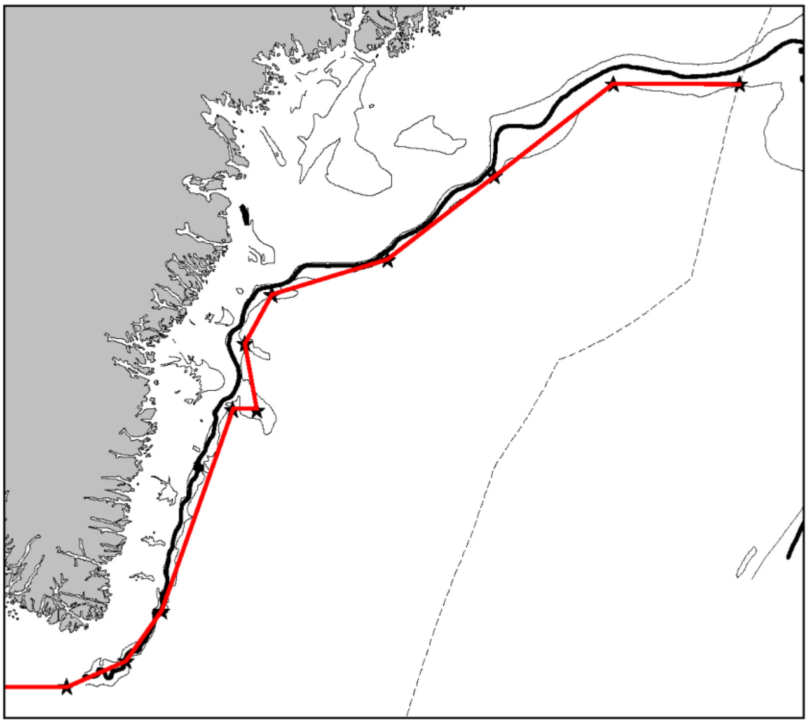

Figure 1: The red line following the outside of the 1000-meter depth contour delimits the shelf area where ICES gives advice separately from the pelagic redfish stocks. The line was introduced in 2011. 500, 1000 and 1500 m depth curves are shown on the map, with the 1000-meter depth curve being bold. The dashed line is the 200 nm fishery zone line.

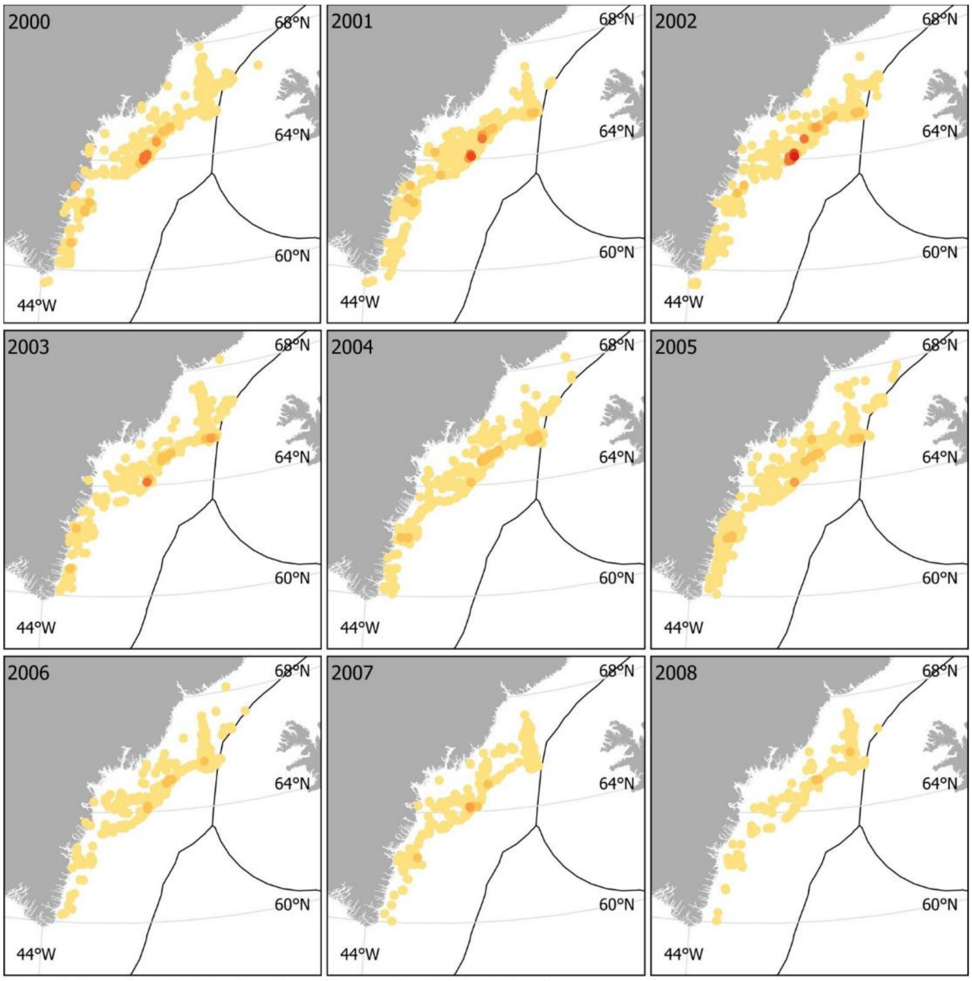

Figure 2: Annual distribution of catches of demersal redfish in ICES 14.b.

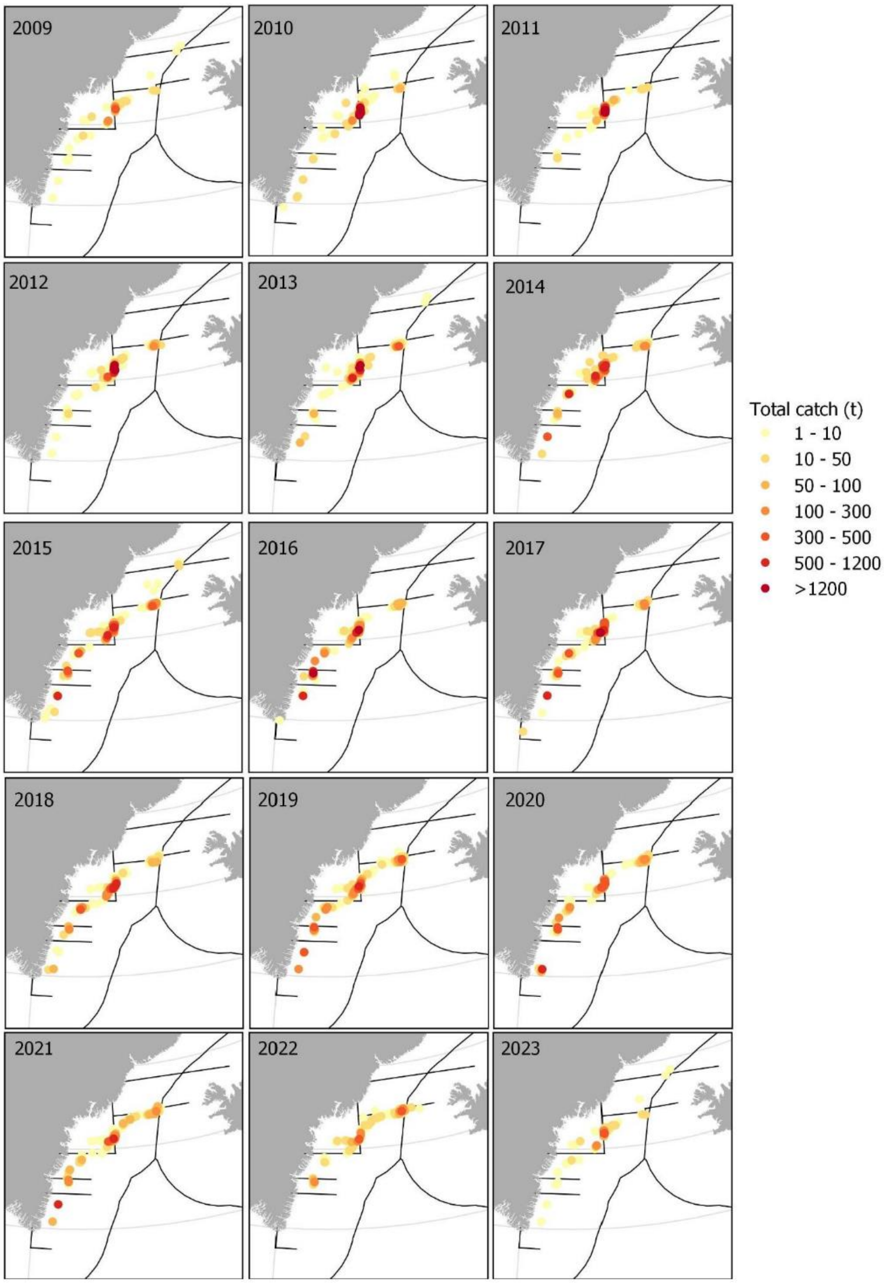

Figure 2 continued: Annual distribution of catches of demersal redfish in ICES **14.b.**

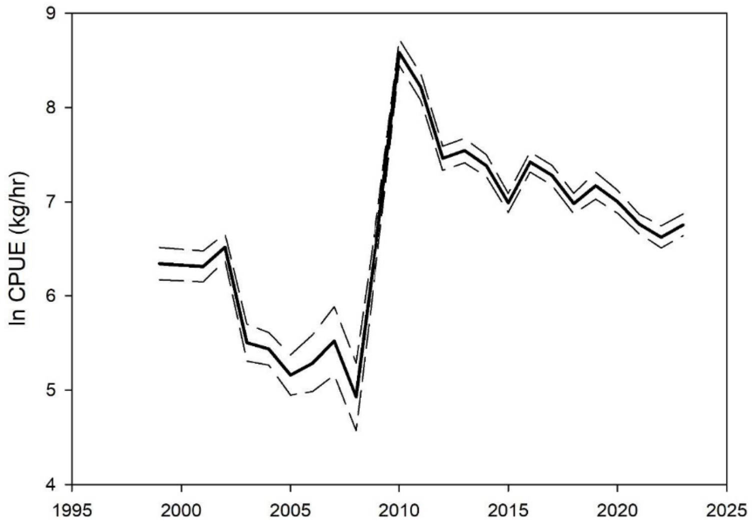

Figure 3: Logbook ln CPUE (kg/hr) for redfish caught in the redfish directed fishery in ICES 14.b Based on the model: ln CPUE = year + ICES subdivision. Dashed lines are 2*SE.

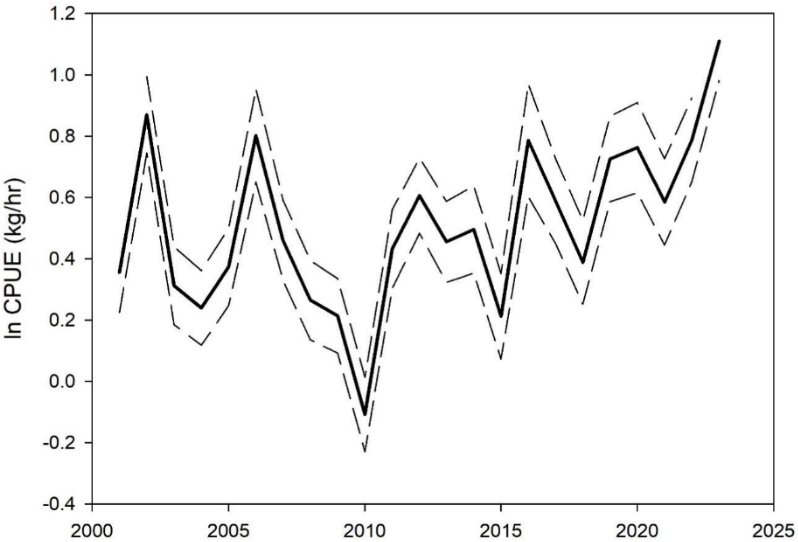

Figure 4: ln CPUE (kg/hr) for redfish caught as by-catch in the Greenland halibut directed fishery in ICES 14.b. Based on the model: ln CPUE = year + depth+ ICES subdivision. Dashed lines are 2*SE.

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Deep-survey for Greenland halibut in ICES Division 14.b, September-October 2023

Henrik Christiansen, Adriana Nogueira, Jesper Boje

Greenland Institute of Natural Resources
3900 Nuuk, Greenland
e-mail: hech@natur.gl

Abstract

A deep-water stratified bottom trawl survey in ICES division 14.b off East Greenland is conducted annually by the Greenland Institute of Natural Resources. The survey covers depth from 400 to 1500 m and collects data on biomass, abundance, and size of Greenland halibut and other species. The survey has been conducted from 1998 to 2016 (no survey was conducted in 2001) using RV Paamiut and an Alfredo II bottom trawl gear. RV Paamiut was retired in 2017. Since 2022 the survey is conducted with RV Tarajoq, a new Vessel owned by the Greenland Institute of Natural Resources, and also using a new trawl gear, a Bacalao 476. This document presents the survey biomass and abundance estimates and length frequency distributions in ICES division 14.b for Greenland halibut (*Reinhardtius hippoglossoides*), beaked redfish (*Sebastes mentella*), golden redfish (*Sebastes norvegicus*), juvenile redfish (*Sebastes* sp.), roughhead grenadier (*Macrourus berglax*), and roundnose grenadier (*Coryphaenoides rupestris*).

1. Introduction

During the period 1987-1989 the Japan Marine Fishery Resources Research Centre and the Greenland Institute of Natural Resources (GINR) jointly conducted three bottom trawl surveys off East Greenland as part of a joint venture agreement on fisheries development and fisheries research in Greenland waters (Jørgensen and Akimoto 1990; Yatsu and Jørgensen 1988abc; Yatsu and Jørgensen 1989). The surveys were primarily aimed at Greenland halibut (*Reinhardtius hippoglossoides*) and redfish (*Sebastes* spp.) and covered various areas between Cape Farewell and 72°N at depths down to 1500 m. During the period 1989-1996 GINR conducted annual shrimp trawl surveys with RV Paamiut off East Greenland (Anon. 1997), but the surveys only covered depths down to 600 m with a poor coverage of depths > 400 m. In 1998, GINR initiated a bottom trawl surveys series with RV Paamiut, which has been rigged for deep sea trawling, using an Alfredo III bottom trawl. No comparative trawling between the RV Shinkai Maru and RV Paamiut was conducted, making comparisons between the surveys difficult, and there is little overlap in depth range between the shrimp trawl survey and the present deep-water survey. There was no survey off East Greenland in 2001. The vessel (RV Paamiut) used for the surveys from 1998-2016 was retired in 2018 before paired trawling experiments with a replacement vessel could be conducted. In 2022, the new vessel owned by GINR, RV Tarajoq began a new survey series using a Bacalao 476 trawl.

2. Materials and methods

Until 2008, the Greenland halibut deep-water survey was conducted in June and suffered in almost all years under the ice coverage found at the east coast of Greenland during early summer. Therefore, from 2008 and onwards, surveys have taken place in August/September and ice-induced problems have largely vanished. Also, in 2008 the survey was combined with the shallower Greenland shrimp and fish survey (which was previously only conducted off West Greenland), that uses a different gear and trawls in shallower waters than the Greenland halibut deep-water survey. The combination of the two surveys led to a change in trawling hours so that most of the stations were taken during night. Prior to the change in timing of the survey, a GLM analysis was performed on commercial catch rates and showed only minor effects of these changes. In 2023 the Greenland halibut survey was conducted between September 18 and October 4.

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Stratification

The survey was planned to cover ICES division 14.b from 61°N to 67°N between the 3-nm line and the 200-nm line or the midline to Iceland at depths from 400 to 1500 m. The survey area was originally stratified in five Subareas Q1-Q5 (Table 1). The stratification has been changed repeatedly in the past.

In 2004 the stratification was changed to reduce variance of the Greenland halibut biomass estimates and to increase strata size. Larger strata corresponds to fewer strata and should thereby reduce the amount of strata without observations due to bad weather, ice, or other complications. The "old" stratum Q1 was divided in two. The northern, shallow part of the stratum was separated from the rest of the stratum, primarily because the fish fauna here is different from the rest of the stratum and because Greenland halibut is generally smaller in this area. This northern shallow area is now stratum Q1 (Table 1, Fig. 1). The remaining part of the old Q1 was combined with Q2 as there was no difference in the catches of Greenland halibut in the two areas. The depth strata 1001-1200 m, 1201-1400 m, and 1401-1500 m was combined to one depth stratum, because the catches of Greenland halibut were generally small in these strata. Stratum Q3 was not changed. In Q5 the two small depth strata 801-1000 and 1001-1200 were combined because the catches of Greenland halibut were at the same level in the two strata throughout the years. The spatial extent of these new strata was measured using "MapInfo" v.4.0 and this stratification scheme is what is currently used for reporting in this working document (Table 1).

In addition, area Q6 off Southeast Greenland has been included in previous years' plans, but it was never possible to trawl in this area due to ice and rough bottom, and Q6 has been excluded from the survey area since 2004. In 2022-2023, plans were made to include new, previously not surveyed areas, because 1) the survey time series was altered through the introduction of a new vessel and new trawl anyway, 2) the new trawl enables deeper trawling/trawling over rougher bottom, and 3) commercial Greenland halibut fishery is taking place in the new areas. Areas Q4 and Q8 are tentatively included in the survey program since 2023, depending on available time during the survey. However, for this year's reporting they are not included here as only few stations were taken in these areas. If a longer time series becomes available for these areas (Q4 and Q8), the reporting will be updated.

Sampling design

From 1998 to 2016, the survey was planned as a stratified random bottom trawl survey with a total of 70 hauls, yielding an overall coverage of 527 km^2 per haul. Each stratum was allocated at least two hauls. The remaining hauls were allocated in order to minimize the variance in the estimation of the biomass of Greenland halibut; *i.e.* strata with great variation in the catches of Greenland halibut in the previous year's survey were assigned relatively more hauls than strata with little variation in the catches.

In 2004 a new method of choosing stations was introduced combining the use of a minimum between-stations-distance rule (buffer zone) with a random allocation scheme (Kingsley et al. 2004). In Q5 depth stratum 801-1200 m only 7 positions were suitable for trawling. The positions of the 3 hauls allocated to this stratum were chosen at random between the 7 trawlable positions. In 2022, the stratified random bottom trawl survey was changed to a fixed station allocation design due to many stations being moved and problems finding suitable fishing grounds because of rough sea bed.

Vessel and gear

From 1998 to 2017, the survey was conducted by the 1084 GT trawler RV Paamiut, using an Alfredo III trawl with a mesh size on 140 mm and a 30-mm mesh-liner in the cod-end. The ground gear was of the rock hopper type. The trawl doors were changed to "Injector" weighing 2700 kg, in 2004, but this has not affected the performance of the trawl. Figures of rigging and bobbins chain together with further information about the gear is given in Jørgensen (1998). A Furuno net sonde mounted on the head rope measured net height. Scanmar sensors measured the distance between the trawl doors. In 2022, RV Tarajoq (2896 GT) began a new survey series using a Bacalao 476 trawl with a mesh size on 136 mm and a 30-mm mesh-liner in the cod-end using the same trawl doors as on RV Paamiut (Table 2).

Swept area calculation

Nominal swept area for each tow was calculated as the straight-line distance between its GPS start and end positions multiplied by the wingspread. Trawl door distance was normally recorded 3-5 times per tow and the average value was used to calculate wingspread, provided at least 3 records are available. With the Alfredo trawl wingspread was calculated as:

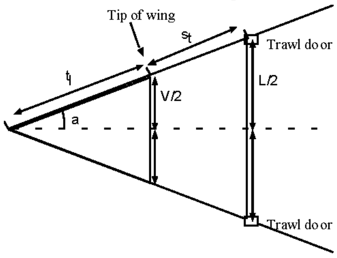
Distance between outer bobbins=10.122 + trawl door distance * 0.142

This relationship was estimated based on flume tank measurements of the trawl and rigging (Jørgensen 1998).

In 2022, the gear was changed to Bacalao 476 gear. For this trawl, wingspread is calculated as follows:

$V = (t_l \cdot L) / (t_l + s_t)$

where V is wingspread; L is trawl door distance ; t are the trawl wings; and s are the bridles. The trawl wings are 26.83 m long and the bridles are 129 m long in this trawl. This calculation assumes that the trawl geometry is a triangle:



However, the actual shape of the Bacalao trawl is likely not a triangle, therefore a constant based on data from the Canadian survey was applied. Scanmar sensors measured wingspread during the Canadian survey in Subarea 0A at the same depths as the deep Greenland halibut survey of GINR. The difference between estimates presented here and the sensor measurements in each depth strata from the Canadian survey was added as a constant to the wingspread calculations presented here.

Trawling procedure

Towing time is usually 30 min, but towing times down to 15 min are accepted. Average towing speed is 3.0 kn. Towing speed is estimated from the start and end positions of the haul. Trawling takes place day and night. Near-bottom temperatures are measured at 0.1°C precision using a Seamon sensor mounted on a trawl door.

Catch handling

For each haul the catch was sorted by species, total weight was recorded, and individual length was measured (TL to 1.0 cm) easured. Subsets of Greenland halibut and redfish were additionally sexed, individual weight and maturity recorded, and otoliths sampled. Small redfish (<18 cm) were not determined to species and were instead recorded as juveniles (*Sebastes* sp.). In case of large catches subsamples of the catch were measured. Subsamples always comprise at least 200 specimens.

Biomass and abundance estimates are based on swept area calculations as outlined above with a catchability coefficient of 1.0. All catches are standardised to 1 km^2 swept area before further calculations. In strata with one haul only SE is estimated as: SE= biomass or abundance. As the survey was previously conducted in early June, when large amounts of ice flow southwards along the East Greenland coast, some areas were poorly sampled due to ice. To compensate for this the Greenland halibut biomass is run through a GLM model where logcpue = year + subdivision + depth. In 2011, age readings from otoliths were stopped as the results obtained seemed unreliable. After international agreement in 2016, the readings for this survey started again in 2023.

3. Results and discussion

In 2023 many stations were not taken due to bad weather. In total, 39 stations were taken, causing bad coverage especially in Q5 (Table 4). Therefore all results have to be interpreted with caution and keeping in mind that less data is available in 2023 to produce reliable biomass and abundance estimates in East Greenland from this survey. Thus, most total biomass estimates represent a decrease compared to 2022, which is likely due to the reduced amount of stations taken.

Greenland halibut (Reinhardtius hippoglossoides)

The total biomass of Greenland halibut at depths between 401-1500 m was estimated at 6,110 tons (SE 2359 t) in 2023 (Table 7, Fig. 3), which a slight reduction compared to 7,787 t (SE 1798 t) in 2022 (Table 5). Most of the biomass was caught in Q1 at 401-600 m and in Q5 at 801-1200 m, while no halibut was caught in Q5 at 401-600 m and the biomass was comparatively low in Q2 and Q3. The by far highest density (5.9 t per km^2) was observed in Q5 at 801-1200 m. Total abundance was estimated at 2,985,000 (SE 1,338,000, Table 8, Fig., 4). The length distribution was similar compared to previous years (Fig. 5).

Beaked redfish (Sebastes mentella)

Beaked redfish biomass was estimated at 19,454 t (SE 3,650 t) in 2023 (Table 9, Fig. 7), which is a decrease compared to 23,739 t (SE 4,390 t) in 2022 (Table 6). The highest density was in Q3 at 601-800 m (3.1 t per km^2). Total abundance was estimated as 27,763,000 (SE 3,634,00, Table 10) with most of the abundance in Q3 and Q5 in 2023. The stratum with the highest abundance was Q3 at 601-800 m, the same as in 2022, but deeper than in 2016. The length distribution shows an increase in small beaked redfish (around 20 cm), a continuation of the very small indication of incoming recruits in 2022. The main mode of the length distribution is around 42 cm (Fig. 9).

Golden redfish (Sebastes norvegicus)

Total biomass of golden redfish in 2023 was estimated at 9,600 t (SE 9,176 t, Table 11, Fig. 11), which is an increase compared to 2022 (8,465 t ± 4,956 t, Table 6). However, both years are characterized by very high standard error, which reflects the high variability and uncertainty that the schooling behavior of this species causes for biomass estimates. In fact, almost the entire 2023 catch of golden redfish was taken in one haul in area Q2 at 401-600 m depth. Main abundance was estimated as 2,769,000 (SE 2,659,000) in the total area but suffers from the same underlaying uncertainty (Table 12). The length frequency distribution in 2023 is similar to 2022, but the relatively small and localized sample size prevents further conclusions from this length distribution (Fig. 13).

Juvenile redfish (Sebastes sp.)

All redfish <18 cm are not identified to species level and instead characterized as *Sebastes* sp.. In 2023, an increase in biomass of juvenile redfish was apparent in the deep survey, from 157 t (SE 39 t) in 2022 (Table 6) to 211 t (SE 101 t) in 2023 (Table 13, Fig. 15). The total abundance, however, increased less steeply to 3,983,000 (SE 1,686,000) in 2023 (Table 6, Table 14, Fig. 16). The mode of the length distribution was at 18 cm, with only very limited smaller redfish recruits being observed (Fig. 17).

Roughhead grenadier (Macrourus berglax)

The 2023 total biomass estimate for roughhead grenadier was 6,321 t (SE4,131 t, Table 15, Fig. 19), which is a strong reduction compared to 2022 where the total biomass estimate was 12,914 t (SE 3,861 t, Table 5). Correspondingly, the abundance decreased to 3,565,000 (Table 16, Fig. 20). The length distribution is bimodal with a mode around 20 cm and 36 cm, respectively (Fig. 21).

Roundnose grenadier (Coryphaenoides rupestris)

In total, only 37 t (SE 0 t) of roundnose grenadier were estimated to be present in the area in 2023, which is a strong decrease compared to 84 t (SE 17 t) in 2022 (Table 5). This species is generally less abundant than roughhead grenadier in the area, but also seems to be in decline in recent years. However, the low estimate for 2023 is also a result of the species being taken in only one of all taken stations and it is important to consider that much fewer hauls were made in 2023 than in previous years. The corresponding abundance estimate for 2023 is also low at 2,839,000 (SE 0, Table 18). The length distribution indicates that only small roundnose grenadiers were sampled with a mode around 3 cm (Fig. 25).

Temperature

The average bottom temperature by stratum ranged from 0.83°C in area Q1 at 401-600 m to 5.13°C in Q5 601-800 m (Table 20).

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Table 1. Stratification of the survey area into subareas and depth strata (m) with corresponding spatial area coverage (km²) and coverage in percentage of the total area. This stratification scheme was introduced in 2004.

Subarea	Depth strata (m)	Area coverage (km^2)	% coverage
Q1	401-600	6975	18.7
Q2	401-600	1246	3.3
Q2	601-800	1475.4	3.9
Q2	801-1000	1988.3	5.3
Q2	1001-1500	6689.4	17.9
Q3	401-600	9830.2	26.3
Q3	601-800	3788.1	10.1
Q3	801-1000	755.4	2
Q3	1001-1200	191.1	0.5
Q3	1201-1400	213.3	0.6
Q3	1401-1500	312.9	0.8
Q4	401-600	2053.6	
Q4	601-800	665.7	
Q4	801-1000	336.2	
Q4	1001-1200	549.9	
Q4	1201-1400	1147	
Q4	1401-1500	940.5	
Q5	401-600	1819.4	4.9
Q5	601-800	257.1	0.7
Q5	801-1200	255.6	0.7
Q5	1201-1400	985.5	2.6
Q5	1401-1500	614.5	1.6
Sum (without Q4)		37397.2	100

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Table 2. General survey information and gear specifications for the surveys 1998-2016 on board RV Paamiut and for the survey in 2022-2023 with RV Tarajoq

Procedure	Specifications	
Vessel	R/V Paamiut	R/V Tarajoq
TRB	1084 GT	2896 GT
Dimensions	LOA 58.61m, Beam 11.21 m	LOA 61.4 m, Beam 16.3 m
Main engine	2000BHP, Diesel 257, 1471KW	3943/4896 BHP, Diesel 475, 2900/3600 KW
Survey Area	14b (401- 1500 m)	14b (401- 1500 m)
Years	1998-2016 (no survey 2001)	2022-2023
Time of year	August/September	September/October
Number of days	15	15
Towing speed (knots)	3	3
Tow duration	30 min	30 min
Gear	Alfredo 3	Bacalao 476
Vertical trawl opening (m)	5.6	4.5*
Distance between doors	120 -145 m	151.8*
Wing spread	10.122 + distance between the doors * 0.142.	$V = (t_l \bullet L) / (t_l + s_t)$ + constant
Mesh size (mm)	140	136
Door	until 2003:Greenland Perfect (370*250 cm) from 2004: Shark injector (353*273)	Shark injector (353*273)
Door type (kg)	2400 kg with extra 20 kg	2850
Mesh size (mm)	44	44
Mesh-line in the cod-end	30 mm	30
Sampling design	Buffered Random Stratified	Fixed stations
Number of Stations	100	74 fixed + 70 extra (min 80)
Number of strata	10	10
Trawling schedule	24 hours	
Criteria for rejecting a haul	Snag of the trawling gear in the bottom Damage in the cod-end or severe damages in large sections of the wings or belly Less than 15 minutes of effective trawling time Gear malfuntion	
Criteria for change haul position	Wrong depth interval Poor bottom conditions	
Sampling species	All fish species and invertebrates	
Target species	Greenland halibut	

Table 3. Number of valid hauls for the period 1998 - 2003. No survey was conducted in 2001.

Subarea	Depth stratum (m)	Area (km2)	1998	1999	2000	2002	2003
Q1	401-600	7444.1	6	4	3	1	4
Q1	601-800	622	3	3	3	3	3
Q1	801-1000	652.3	3	3	3	2	2
Q1	1001-1200	881.8	2	2	2	2	1
Q1	1201-1400	741.4	2	2	2	2	1
Q1	1401-1500	462.3	2	2	2	2	2
Q2	401-600	777	2	2	2	2	3
Q2	601-800	853.4	4	3	3	3	3
Q2	801-1000	1336	5	4	3	4	3
Q2	1001-1200	1699.3	2	2	2	2	2
Q2	1201-1400	1742	2	2	2	0	2
Q2	1401-1500	1162.6	1	2	2	2	1
Q3	401-600	9830.2	6	7	9	3	1
Q3	601-800	3788.1	3	4	4	1	5
Q3	801-1000	755.4	2	0	2	0	2
Q5	401-600	1819.4	2	2	1	0	0
Q5	601-800	257.1	0	2	2	2	1
Q5	801-1000	106.7	0	2	2	2	2
Q5	1001-1200	148.9	2	2	2	2	1
Q5	1201-1400	985.5	2	2	2	3	1
Q5	1401-1500	614.5	3	2	2	2	0
TOTAL			54	54	55	40	40

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Table 4. Number of valid hauls for the period 2004-2016 with RV Paamiut (no survey in 2001) and in 2022-2023 with RV Tarajoq, after a new stratification scheme was introduced.

Subarea	Depth stratum (m)	Area (km2)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2022	2023
Q1	401-600	6975	2	0	0	2	4	4	2	8	7	10	7	11	12	0	5	2
Q2	401-600	1246	4	4	5	3	5	4	4	2	4	5	5	5	5	0	7	2
Q2	601-800	1475.4	5	5	6	5	7	5	5	6	9	5	7	7	7	0	5	1
Q2	601-1000	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Q2	801-1000	1988.3	8	9	12	9	3	9	8	8	9	8	7	8	10	0	8	7
Q2	1001-1500	6689.4	3	3	4	3	4	5	5	4	7	4	7	7	7	0	5	0
Q3	401-600	9830.2	9	1	2	2	2	5	5	6	4	9	7	8	11	0	4	7
Q3	601-800	3788.1	4	8	2	6	6	10	6	7	7	11	12	10	14	0	11	4
Q3	801-1000	755.4	0	2	0	0	2	3	3	5	4	4	5	5	6	0	5	5
Q4	801-1200	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Q5	401-600	1819.4	3	0	1	2	3	2	0	1	2	1	2	3	3	0	4	2
Q5	601-800	257.1	3	1	3	2	3	4	1	3	3	6	6	6	6	0	6	3
Q5	801-1000	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1
Q5	801-1200	255.6	3	4	3	4	0	4	3	3	4	5	6	2	5	0	2	0
Q5	1201-1400	985.5	5	6	3	5	3	6	5	8	5	9	3	7	9	6	9	0
Q5	1401-1500	614.5	3	4	2	3	1	3	3	5	2	3	3	5	5	4	2	0
		TOTAL	52	47	43	46	47	64	50	66	67	80	78	84	100	10	73	36

Table 5. Biomass and abundance (*10^3) of Greenland halibut, roughhead grenadier, and roundnose grenadier, for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

		Greenland halibut				Roughhead grenadier				Roundnose grenadier			
Year	Vessel	Biomass	SE	Abundance	SE	Biomass	SE	Abundance	SE	Biomass	SE	Abundance	SE
1998	PA	20013.11	2826.32	14818.54	1995.48	3480.9	546.2	4027.81	639.14	2877.29	1299.84	6166.28	2654.39
1999	PA	14796.63	2124.47	10245.8	1684.64	4741.67	803.82	5268.51	979.85	4303.63	463.11	9661.55	1012.45
2000	PA	22705.38	3250.94	18898.08	3074.75	3434.36	351.12	3894.76	380.16	2294.69	1237.14	5630.96	2486.13
2001	PA	-	-	-	-	-	-	-	-	-	-	-	-
2002	PA	14694.01	3803.66	9718.42	2688.53	4523.51	2095.86	5409.19	3429.93	1771.06	1224.19	7065.28	4542.48
2003	PA	15189.3	3014.06	14970.1	4378.5	3100.01	609.13	3421.35	741.1	4459.12	2097	13593.18	4742.32
2004	PA	16243.67	2182.76	14026.52	2445.67	3150.55	532.5	2813.58	266.75	1151.83	792	4369.14	1841.27
2005	PA	13551.72	2521.56	9592.74	2618.41	4237.93	872.42	5230.35	1225.6	1174	337.77	5883.41	1813.27
2006	PA	23284.16	4048.47	13198.9	2739.43	3972.49	597.02	4600.06	620.9	689.04	300.31	3781.2	967.65
2007	PA	11950.88	2223.44	6979.95	1180.09	3435.29	637.47	3590.22	445.99	878.79	250.81	8312.51	2493.72
2008	PA	10579.4	1496.19	5333	699.52	6841.49	983.99	6590.11	818.97	772.93	242.56	4296.04	1277.88
2009	PA	7562.53	914.2	4017.21	507.13	7256.96	1425.21	6836.17	1173.32	215.67	52.05	1452.29	368.99
2010	PA	9037.6	1452.35	3831.95	526.3	9201.84	2292.12	7532.03	1162.02	416.21	93.74	2525.65	478.99
2011	PA	8823.58	1151.52	4673.16	649.25	5855.39	1032.07	5678.71	1055.34	3202.25	2821.1	9207.74	6687.45
2012	PA	9514.43	1379.96	4464.94	635.18	7926.09	1330.41	7060.19	1030.43	5379.46	4774.44	15325.86	13521.71
2013	PA	5802.78	800.37	2491.81	343.86	7604.93	1765.46	5756.69	1212.99	294.99	151.77	1469.95	694.61
2014	PA	9711.93	1347.3	3914.3	400.21	6816.97	1043.22	5426.8	713.5	106.1	36.39	826.32	322.61
2015	PA	11284.93	3752.3	5784.61	1851.89	8751.71	2292.95	5647.58	1239.19	999.46	815.95	3065.97	2106.33
2016	PA	9428.23	1119.21	4865.92	579.49	6953.35	1190.37	6004.64	1043.39	170.25	46.08	530.16	127.62
2017	-	-	-	-	-	-	-	-	-	-	-	-	-
2018	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	-	-	-	-	-	-	-	-	-	-	-	-	-
2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-	-	-	-	-
2022	TJ	7828.31	1797.6	3849.34	919.61	12913.87	3860.92	7338.93	1703.29	84.01	17.25	1501.97	640.44
2023	TJ	6109.02	2358.98	2985.92	1338.43	6320.94	4130.93	3575.53	2300.02	37.27	0	2838.93	0

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Table 6. Biomass and abundance (*10^6) of beaked redfish, golden redfish, and juvenile redfish (*Sebastes* sp.), for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

		Beaked redfish				Golden redfish				Juvenile redfish			
Year	**Vessel**	**Biomass**	**SE**	**Abundance**	**SE**	**Biomass**	**SE**	**Abundance**	**SE**	**Biomass**	**SE**	**Abundance**	**SE**
1998	PA	14217.25	2659.84	75636.46	8678.99	721.08	530.71	1541.78	1286.37	0	0	0	0
1999	PA	22161.53	2670.33	135015.12	18642.96	1758.15	926.61	4293.37	2043.8	0	0	0	0
2000	PA	12781.08	2442.46	64594.77	12402.48	2329.22	2149.02	6519.11	6232.3	0	0	0	0
2001	PA	-	-	-	-	-	-	-	-	-	-	-	-
2002	PA	16275.49	6762.36	55183.56	18786.75	23.29	5.51	5.28	1.88	51.12	51.12	43.05	43.05
2003	PA	15951.03	5761.7	57995.01	29666.8	4295.69	2087.05	13610.4	7790.45	0	0	0	0
2004	PA	5384.41	1251.55	26593.49	7619.97	47.96	28.86	417.07	315.07	7033.53	4010.41	39718.77	21814.2
2005	PA	3783.7	918.98	9836.59	3125.25	69.26	27.53	139.47	71.31	5371.11	2348.15	22621.55	9390.89
2006	PA	13968.99	3848.81	57548.18	16495.73	3291.41	1115.76	13713.13	6358.7	1123.42	674.31	3473.54	2147.91
2007	PA	1974.54	790.84	6342.76	3268.7	755.41	571.39	2257.57	1731.87	23644.13	8564.24	104701.57	30576.62
2008	PA	23313.04	6193.8	101903.69	30118.08	1680.46	917.91	4627.67	3021.84	0	0	0	0
2009	PA	22161.64	3699.77	75572.04	24931.1	903.64	362.17	631.36	301.18	151.59	104.92	2377.94	1753.52
2010	PA	37004.71	14739.03	143326.68	78069.41	2540.38	899.51	1822.16	748.46	188.38	146.87	2377.81	1740.07
2011	PA	22450.08	4528.58	63732.82	12903.41	782.7	397.43	565.07	248.43	42.79	29.8	249.88	176.18
2012	PA	41578.39	9443.71	103008.89	28465.33	863.5	462.74	1453.68	1243.43	47.71	36.53	264.66	199.5
2013	PA	34041.88	7383.67	69848.07	11308.06	2571.75	2033.8	864.64	500.15	0.6	0.6	9.19	9.19
2014	PA	26551.11	4204.7	56902.24	9927.24	2250.63	1651.45	1818.96	1608.77	0	0	0	0
2015	PA	34045.82	6521.48	80396.68	15791.03	909.16	511.46	508.68	197.35	0.82	0.76	7.35	5.75
2016	PA	29238.98	3830.31	51290.24	6900.16	5256.5	3037.41	6349.78	4428.18	0.14	0.14	19.84	19.84
2017	-	-	-	-	-	-	-	-	-	-	-	-	-
2018	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	-	-	-	-	-	-	-	-	-	-	-	-	-
2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-	-	-	-	-
2022	TJ	23231.93	4212.9	25870.78	4337.68	8455.73	4946.12	2232.39	1246.73	156.91	39.03	3156.08	700.79
2023	TJ	19454.97	3650.08	27763.59	3633.9	9599.54	9175.58	2769.93	2659.34	210.68	101.26	3983.95	1685.92

Table 7. Mean Catch (kg) and biomass (tons) of Greenland halibut by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Catch	Biomass	SE
Q1	0401-0600	6975	2	412.468	2877	1779
Q2	0401-0600	1246	2	31.742	40	40
Q2	0601-0800	1475	1	0	0	0
Q2	0801-1000	1988	2	55.918	111	19
Q3	0401-0600	9830	7	41.318	406	171
Q3	0601-0800	3788	4	176.27	668	308
Q3	0801-1000	755	5	661.248	500	160
Q5	0401-0600	1819	2	0	0	0
Q5	0601-0800	257	3	19.382	5	5
Q5	0801-1200	256	1	5880.058	1503	1499
TOTAL		28389	29	83.09	6110	2359

Table 8. Mean number and abundance ('000) of Greenland halibut by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Number	Abundance	SE
Q1	0401-0600	6975	2	185	1288	739
Q2	0401-0600	1246	2	8	10	10
Q2	0601-0800	1475	1	0	0	0
Q2	0801-1000	1988	2	30	60	0
Q3	0401-0600	9830	7	19	183	80
Q3	0601-0800	3788	4	50	190	63
Q3	0801-1000	755	5	266	201	77
Q5	0401-0600	1819	2	0	0	0
Q5	0601-0800	257	3	8	2	2
Q5	0801-1200	256	1	4112	1051	1108
TOTAL		28389	29	47.14	2985	1338

Table 9. Mean Catch (kg) and biomass (tons) of beaked redfish by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Catch	Biomass	SE
Q1	0401-0600	6975	2	20.644	144	88
Q2	0401-0600	1246	2	320.135	399	76
Q2	0601-0800	1475	1	42.691	63	97
Q2	0801-1000	1988	2	12.723	25	4
Q3	0401-0600	9830	7	221.377	2176	678
Q3	0601-0800	3788	4	3095.127	11725	3437
Q3	0801-1000	755	5	1970.294	1488	1006
Q5	0401-0600	1819	2	1802.832	3280	103
Q5	0601-0800	257	3	510.298	131	63
Q5	0801-1200	256	1	91.34	23	36
TOTAL		28389	29	128.57	19454	3650

Table 10. Mean number and abundance ('000) of beaked redfish by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Number	Abundance	SE
Q1	0401-0600	6975	2	56	392	236
Q2	0401-0600	1246	2	286	357	45
Q2	0601-0800	1475	1	45	66	117
Q2	0801-1000	1988	2	15	30	0
Q3	0401-0600	9830	7	915	8998	1683
Q3	0601-0800	3788	4	3191	12089	3056
Q3	0801-1000	755	5	1971	1489	974
Q5	0401-0600	1819	2	2289	4165	60
Q5	0601-0800	257	3	570	146	82
Q5	0801-1200	256	1	122	31	56
TOTAL		28389	29	128	27763	3634

Table 11. Mean Catch (kg) and biomass (tons) of golden redfish by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Catch	Biomass	SE
Q1	0401-0600	6975	2	3.058	21	21
Q2	0401-0600	1246	2	7649.646	9531	9175
Q2	0601-0800	1475	1	0	0	0
Q2	0801-1000	1988	2	0	0	0
Q3	0401-0600	9830	7	0	0	0
Q3	0601-0800	3788	4	11.808	45	45
Q3	0801-1000	755	5	0	0	0
Q5	0401-0600	1819	2	0	0	0
Q5	0601-0800	257	3	7.85	2	1
Q5	0801-1200	256	1	0	0	0
TOTAL		28389	29	323.19	9599	9176

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Table 12. Mean number and abundance ('000) of golden redfish by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Number	Abundance	SE
Q1	0401-0600	6975	2	6	39	39
Q2	0401-0600	1246	2	2181	2717	2659
Q2	0601-0800	1475	1	0	0	0
Q2	0801-1000	1988	2	0	0	0
Q3	0401-0600	9830	7	0	0	0
Q3	0601-0800	3788	4	3	11	11
Q3	0801-1000	755	5	0	0	0
Q5	0401-0600	1819	2	0	0	0
Q5	0601-0800	257	3	8	2	1
Q5	0801-1200	256	1	0	0	0
TOTAL		28389	29	93.67	2769	2659

Table 13. Mean Catch (kg) and biomass (tons) of juvenile redfish (*Sebastes* sp.) by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Catch	Biomass	SE
Q1	0401-0600	6975	2	0.652	5	5
Q2	0401-0600	1246	2	0	0	0
Q2	0601-0800	1475	1	0	0	0
Q2	0801-1000	1988	2	0	0	0
Q3	0401-0600	9830	7	20.735	204	101
Q3	0601-0800	3788	4	0.205	1	1
Q3	0801-1000	755	5	0.009	0	0
Q5	0401-0600	1819	2	0.812	1	0
Q5	0601-0800	257	3	0.162	0	0
Q5	0801-1200	256	1	0	0	0
TOTAL		28389	29	3.57	211	101

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Table 14. Mean number and abundance (*000) of juvenile redfish (*Sebastes* sp.) by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Number	Abundance	SE
Q1	0401-0600	6975	2	11	78	78
Q2	0401-0600	1246	2	0	0	0
Q2	0601-0800	1475	1	0	0	0
Q2	0801-1000	1988	2	0	0	0
Q3	0401-0600	9830	7	388	3809	1684
Q3	0601-0800	3788	4	7	27	16
Q3	0801-1000	755	5	7	5	5
Q5	0401-0600	1819	2	33	60	38
Q5	0601-0800	257	3	14	4	2
Q5	0801-1200	256	1	0	0	0
TOTAL		28389	29	59.38	3983	1686

Table 15. Mean Catch (kg) and biomass (tons) of roughhead grenadier by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Catch	Biomass	SE
Q1	0401-0600	6975	2	13.324	93	93
Q2	0401-0600	1246	2	425.35	530	174
Q2	0601-0800	1475	1	3100.53	4575	4117
Q2	0801-1000	1988	2	381.336	758	223
Q3	0401-0600	9830	7	11.117	109	70
Q3	0601-0800	3788	4	20.914	79	46
Q3	0801-1000	755	5	39.398	30	11
Q5	0401-0600	1819	2	72.178	131	131
Q5	0601-0800	257	3	12.041	3	3
Q5	0801-1200	256	1	49.31	13	11
TOTAL		28389	29	145.5	6321	4131

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Table 16. Mean number and abundance ('000) of roughhead grenadier by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Number	Abundance	SE
Q1	0401-0600	6975	2	17	118	118
Q2	0401-0600	1246	2	389	485	193
Q2	0601-0800	1475	1	1429	2108	2275
Q2	0801-1000	1988	2	250	496	192
Q3	0401-0600	9830	7	10	97	53
Q3	0601-0800	3788	4	14	54	32
Q3	0801-1000	755	5	45	34	6
Q5	0401-0600	1819	2	84	152	152
Q5	0601-0800	257	3	16	4	1
Q5	0801-1200	256	1	105	27	29
TOTAL		28389	29	81.01	3575	2300

Table 17. Mean Catch (kg) and biomass (tons) of roundnose grenadier by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Catch	Biomass	SE
Q1	0401-0600	6975	2	0	0	0
Q2	0401-0600	1246	2	0	0	0
Q2	0601-0800	1475	1	0	0	NA
Q2	0801-1000	1988	2	0	0	0
Q3	0401-0600	9830	7	0	0	0
Q3	0601-0800	3788	4	0	0	0
Q3	0801-1000	755	5	0	0	0
Q5	0401-0600	1819	2	0	0	0
Q5	0601-0800	257	3	0	0	0
Q5	0801-1200	256	1	145.812	37	NA
TOTAL		28389	29	0	37	0

Table 18. Mean number and abundance ('000) of roundnose grenadier by subarea and depth stratum in 2023.

Div	Stratum (m)	Area (sq.km)	Tow number	Mean Number	Abundance	SE
Q1	0401-0600	6975	2	0	0	0
Q2	0401-0600	1246	2	0	0	0
Q2	0601-0800	1475	1	0	0	NA
Q2	0801-1000	1988	2	0	0	0
Q3	0401-0600	9830	7	0	0	0
Q3	0601-0800	3788	4	0	0	0
Q3	0801-1000	755	5	0	0	0
Q5	0401-0600	1819	2	0	0	0
Q5	0601-0800	257	3	0	0	0
Q5	0801-1200	256	1	11107	2839	NA
TOTAL		28389	29	0	2839	0

Table 19. Average bottom temperature from 1998 to 2003. This is an un-weighted mean of all stations.

Stratum	1998	1999	2000	2002	2003
Q1_0401-0600	1.47	3.10	2.33	5.60	1.52
Q1_0601-0800	2.37	2.60	2.10	4.40	3.77
Q1_0801-1000	1.73	2.00	3.00	2.55	2.45
Q1_1001-1200	1.50	1.90	1.05	1.45	3.70
Q1_1201-1400	1.20	0.85	0.65	1.60	3.00
Q1_1401-1500	0.55	0.10	0.80	0.95	2.55
Q2_0401-0600	3.90	4.20	4.40	3.95	4.80
Q2_0601-0800	3.57	3.50	3.70	3.77	3.63
Q2_0801-1000	3.16	2.48	2.70	2.93	3.77
Q2_1001-1200	2.35	1.45	2.40	2.35	3.90
Q2_1201-1400	1.05	1.40	2.00	0.00	1.85
Q2_1401-1500	1.80	0.65	1.60	1.45	1.90
Q3_0401-0600	3.87	3.43	3.71	3.57	4.60
Q3_0601-0800	3.80	3.50	3.65	3.50	3.70
Q3_0801-1000	3.75	0.00	3.70	0.00	3.90
Q5_0401-0600	4.90	4.90	4.70	0.00	0.00
Q5_0601-0800	0.00	4.75	4.65	4.65	5.00
Q5_0801-1000	0.00	4.55	4.25	3.85	4.80
Q5_1001-1200	3.65	4.00	4.05	3.55	4.00
Q5_1201-1400	3.15	2.80	3.40	2.67	3.70
Q5_1401-1500	3.00	2.85	3.00	2.05	0.00

Table 20. Average bottom temperature from 2004 to 2023. This is an un-weighted mean of all stations.

Stratum	2004	2023	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015	2016	2022	2023
Q1_0401-0600	1.06	0.83	0.00	0.00	1.38	1.99	1.03	0.94	0.83	0.99	0.80	0.72	0.74	0.81	0.83
Q2_0401-0600	4.03	4.52	3.63	4.25	5.40	5.01	4.27	3.44	3.91	3.82	4.01	3.46	3.49	4.25	4.52
Q2_0601-0800	5.29	1.73	3.54	3.53	5.20	2.38	3.53	3.60	3.39	3.62	4.45	2.75	3.22	3.83	1.73
Q2_0801-1000	3.65	3.01	2.68	2.74	3.82	2.22	3.19	2.61	3.22	2.79	2.80	2.62	3.19	3.35	3.01
Q2_1001-1500	2.01	0.00	1.57	1.93	3.19	2.21	1.08	2.23	1.90	2.91	2.36	2.05	2.44	2.57	0.00
Q3_0401-0600	3.29	4.30	2.88	3.32	3.99	4.16	4.36	3.81	3.65	4.10	4.05	3.53	4.03	3.73	4.30
Q3_0601-0800	3.03	4.16	3.28	3.24	3.85	3.93	4.44	3.66	3.41	4.16	3.90	3.48	3.90	3.62	4.16
Q3_0801-1000	0.00	4.13	3.50	0.00	0.00	4.05	4.46	3.66	3.44	4.16	3.96	3.59	4.03	3.66	4.13
Q5_0401-0600	5.00	4.88	0.00	5.08	5.11	5.32	0.00	5.01	4.54	4.80	4.77	4.51	4.84	4.85	4.88
Q5_0601-0800	4.91	5.13	4.63	4.80	5.09	5.15	5.22	5.03	4.73	5.11	4.86	4.58	4.76	4.94	5.13
Q5_0801-1200	4.35	4.80	4.07	4.30	4.56	4.71	4.34	4.60	4.34	4.23	4.14	4.15	4.30	4.67	4.80
Q5_1201-1400	3.07	0.00	3.28	3.48	3.54	3.67	3.00	3.51	3.14	3.42	3.36	3.32	3.18	3.38	0.00
Q5_1401-1500	2.70	0.00	2.78	2.95	3.19	3.36	2.90	3.24	3.27	3.14	3.13	2.78	3.37	3.09	0.00

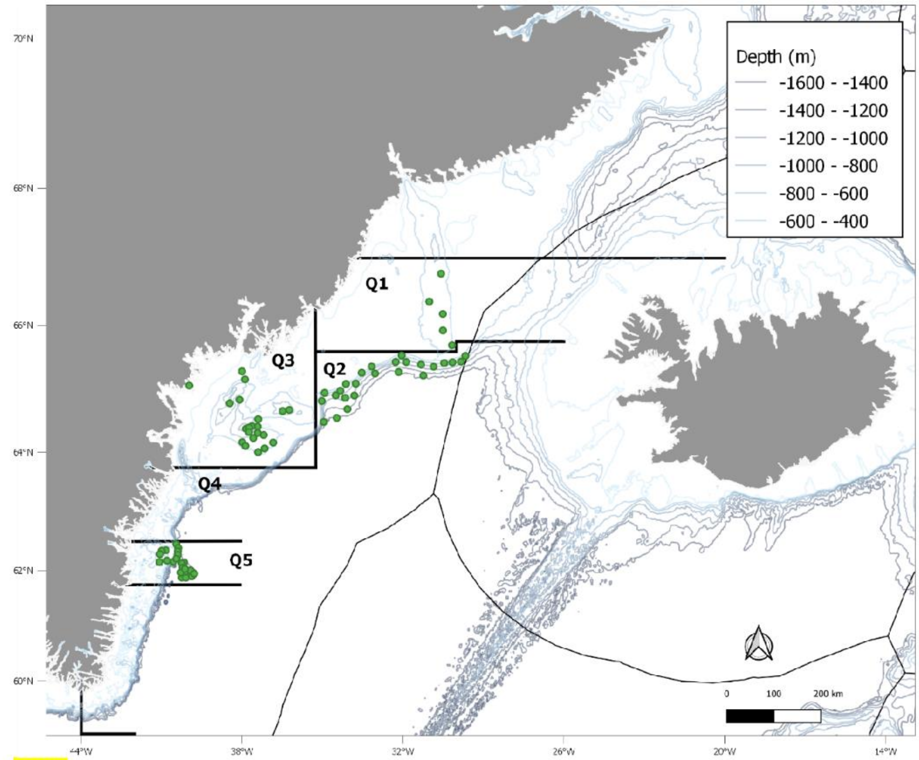

Figure 1. Hauls position for the Greenland halibut deep survey in East Greenland, ICES 14b,in 2022.

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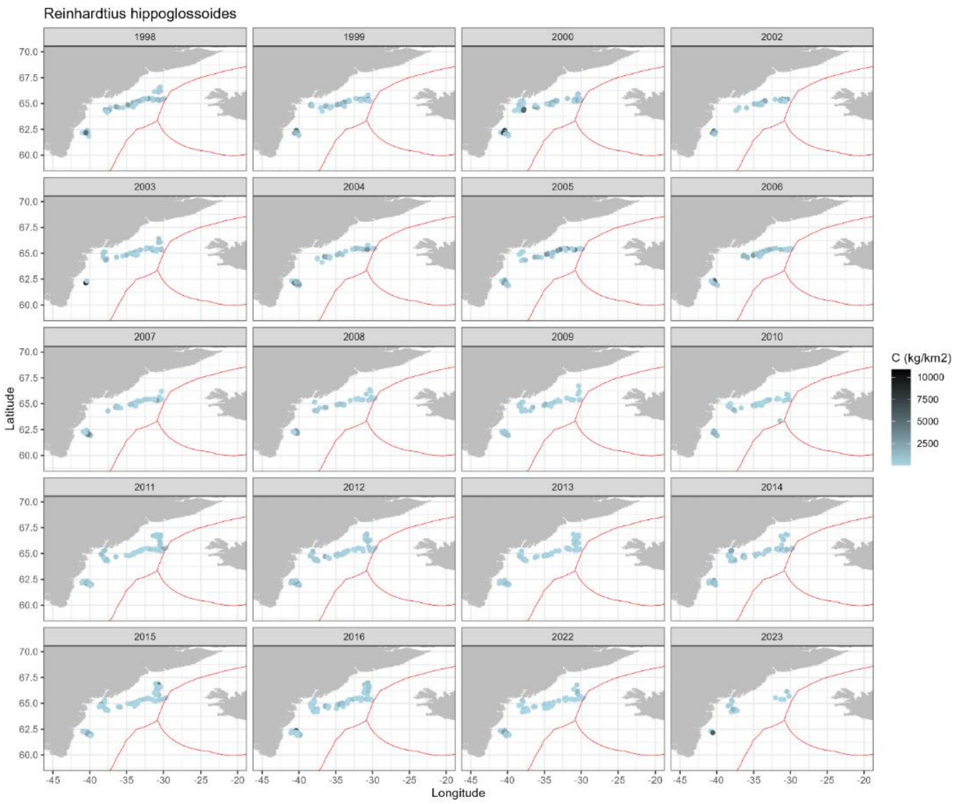

Figure 2. Distribution of survey catches of Greenland halibut off East Greenland for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

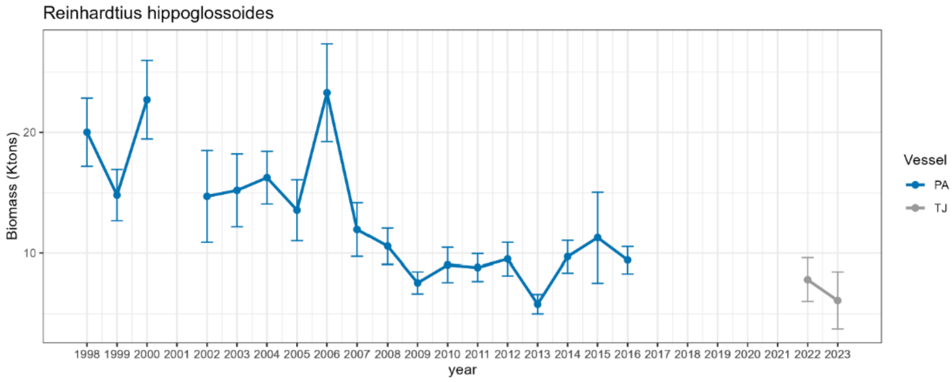

Figure 3. Total biomass and SE of Greenland halibut for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

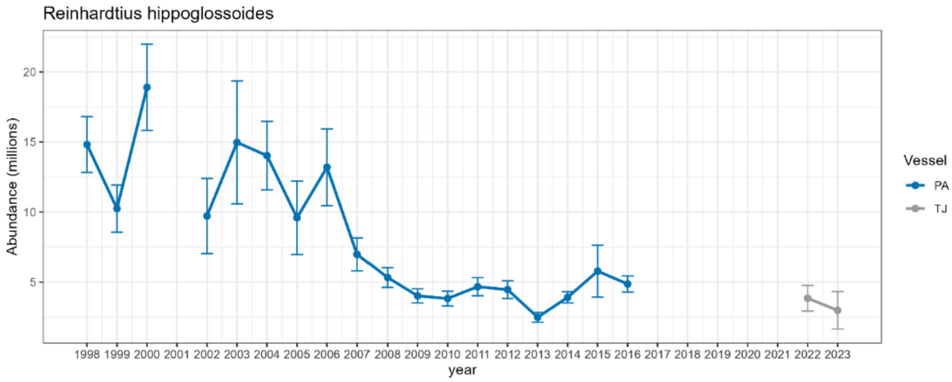

Figure 4. Total abundance and SE of Greenland halibut for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

19

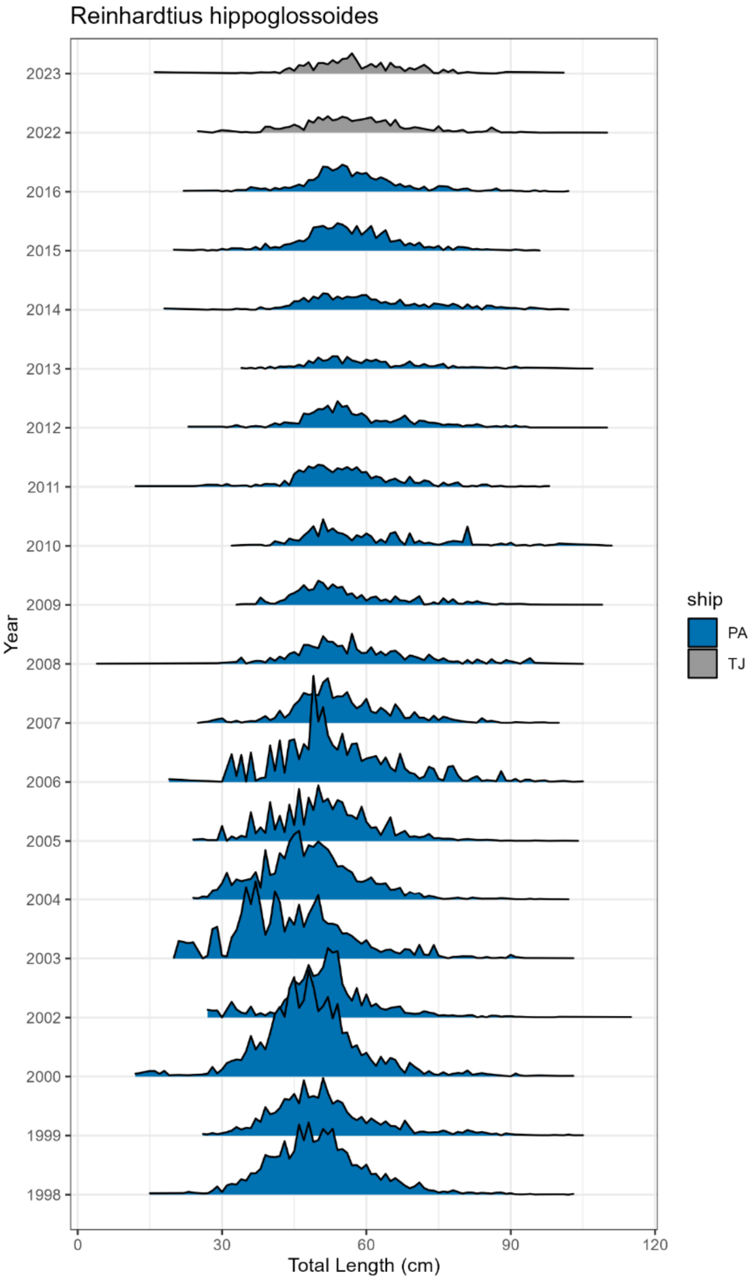

Figure 5. Overall length distribution (per swept area) of Greenland halibut by year for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

20

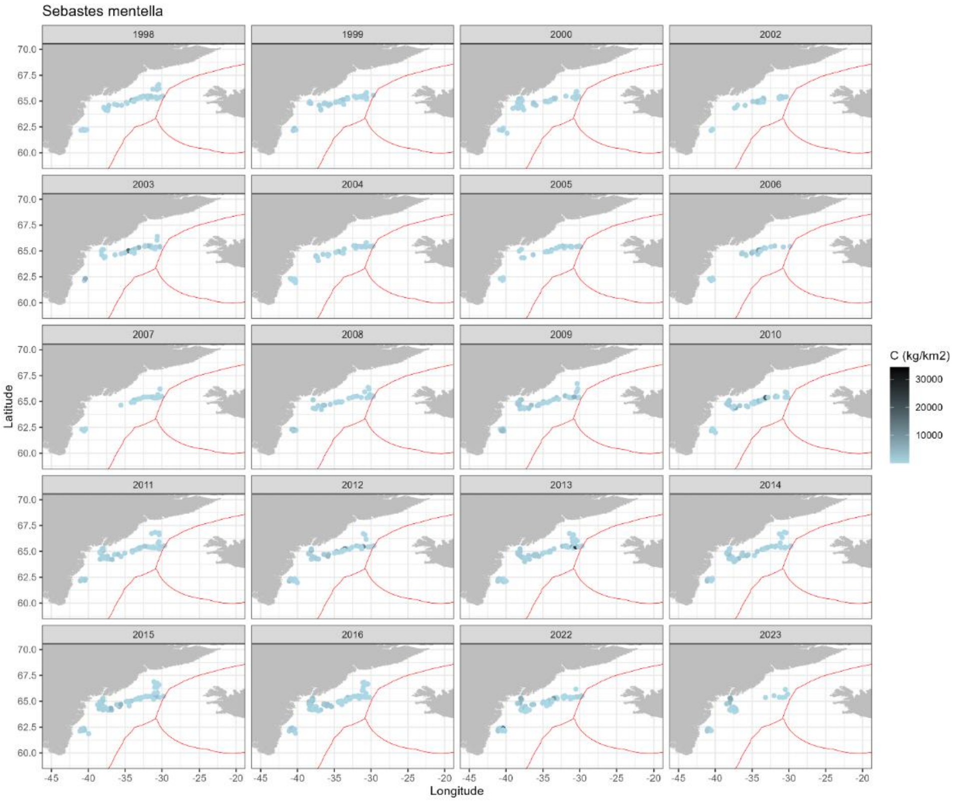

Figure 6. Distribution of survey catches of beaked redfish off East Greenland for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

21

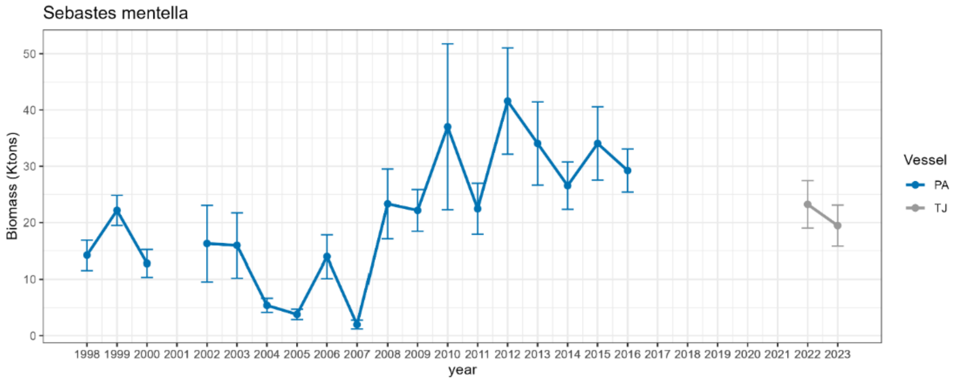

Figure 7. Total biomass and SE of beaked redfish for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

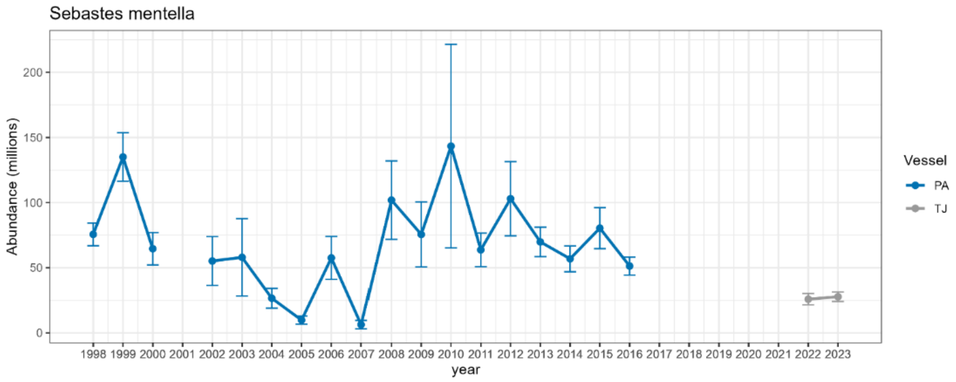

Figure 8. Total abundance and SE of beaked redfish for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

22

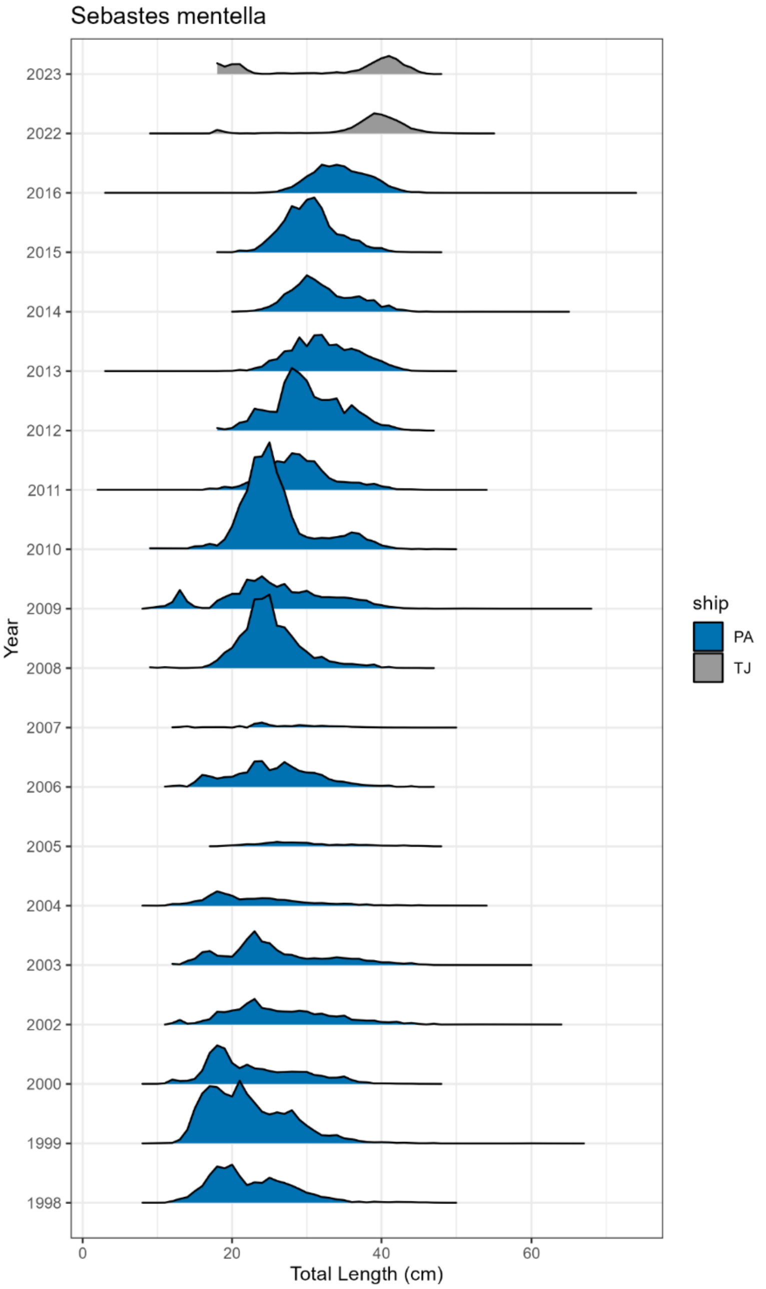

Figure 9. Overall length distribution (per swept area) of beaked redfish by year for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

23

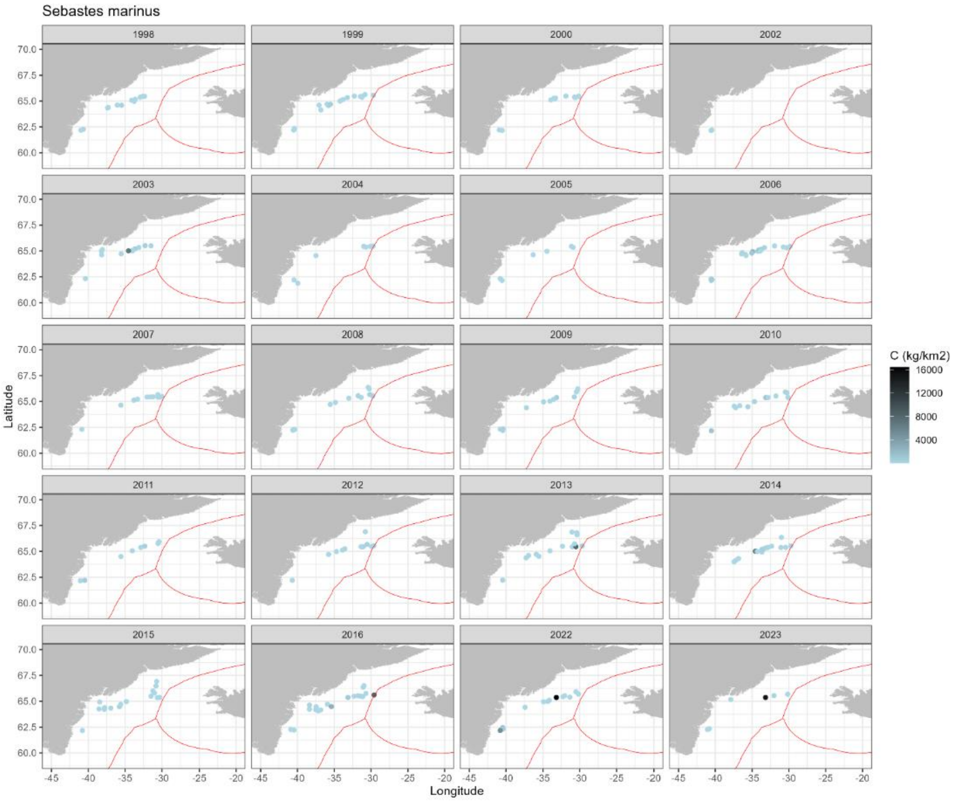

Figure 10. Distribution of survey catches of golden redfish off East Greenland for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

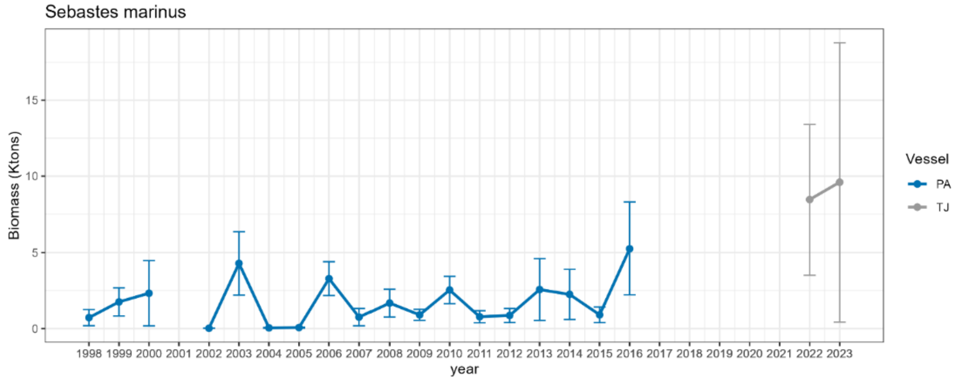

Figure 11. Total biomass and SE of golden redfish for the period 1998-2016 (no survey in 2001) with RV Paamiut and in 2022-2023 with RV Tarajoq.

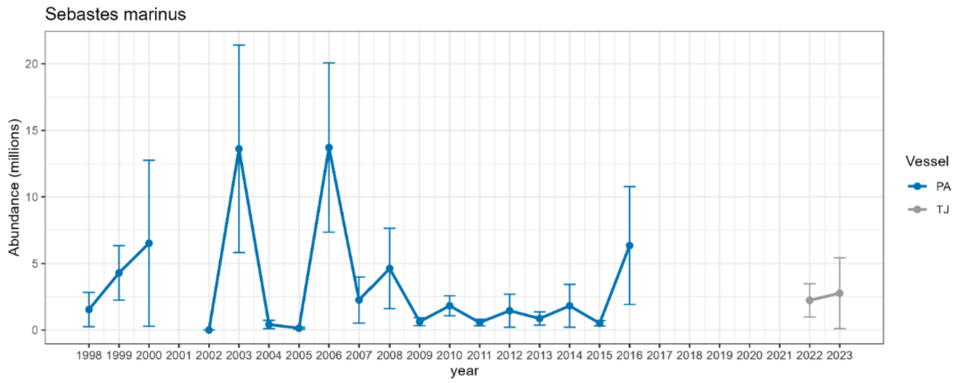

Figure 12. Total abundance and SE of golden redfish for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

25

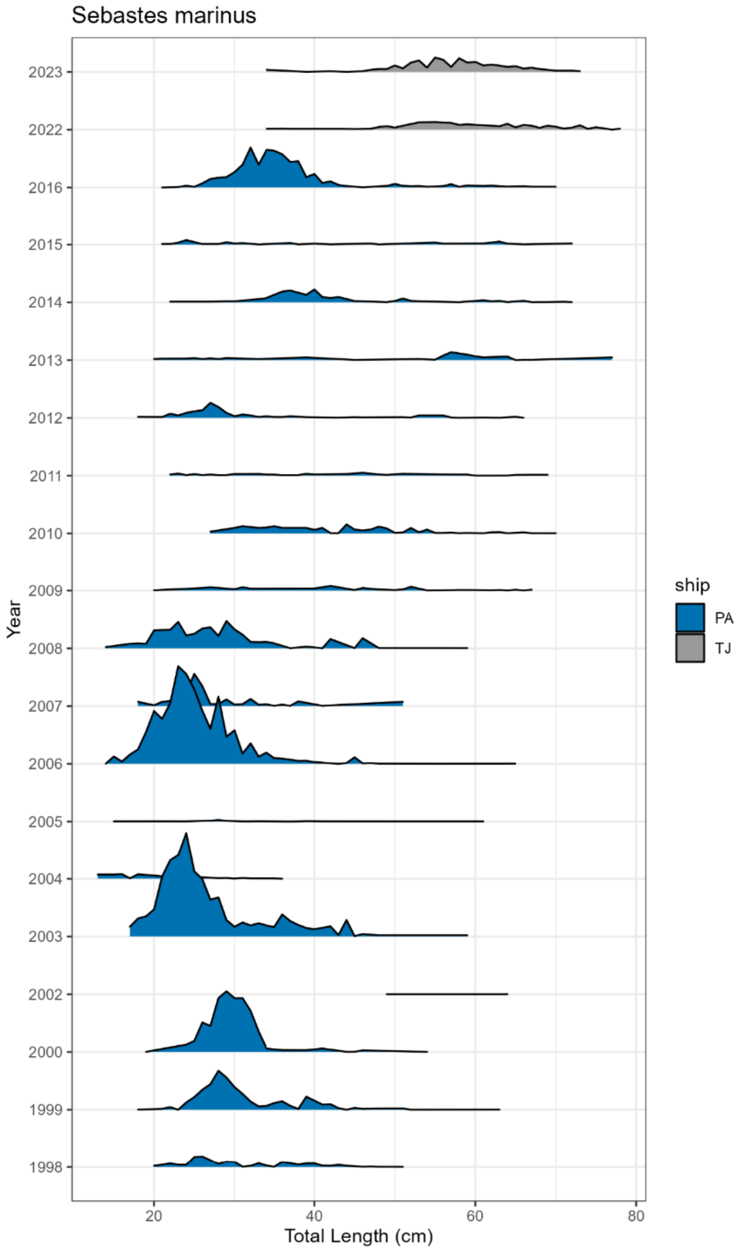

Figure 13. Overall length distribution (per swept area) of golden redfish by year for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

26

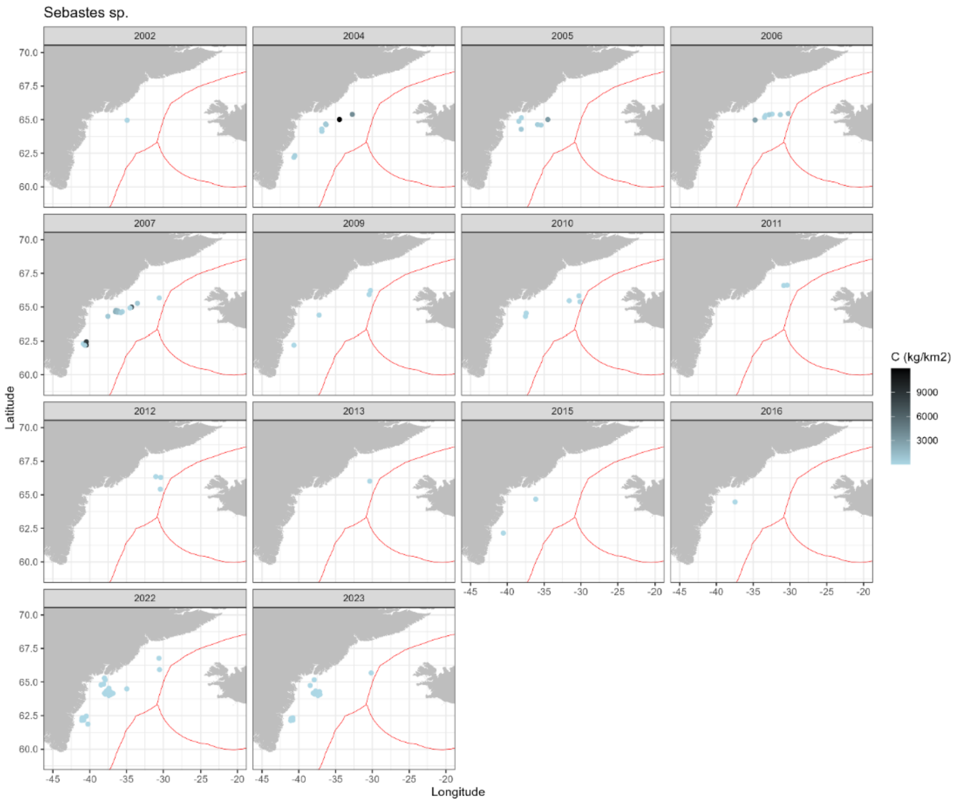

Figure 14. Distribution of survey catches of juvenile redfish (*Sebastes* sp.) off East Greenland for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

27

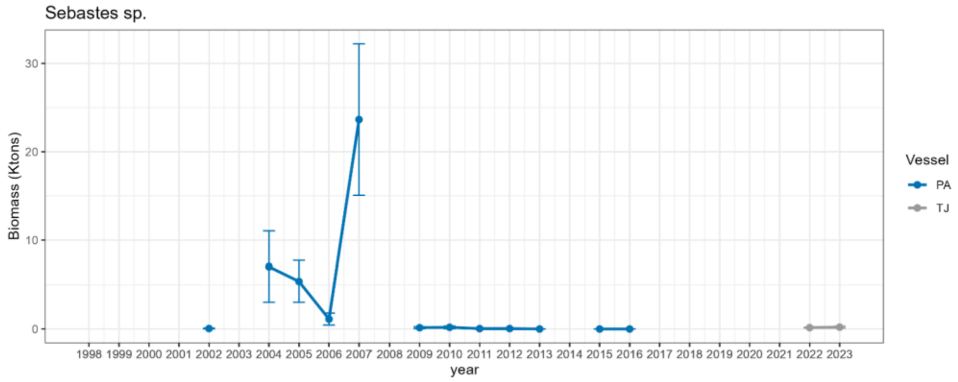

Figure 15. Total biomass and SE of juvenile redfish (*Sebastes* sp.) for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

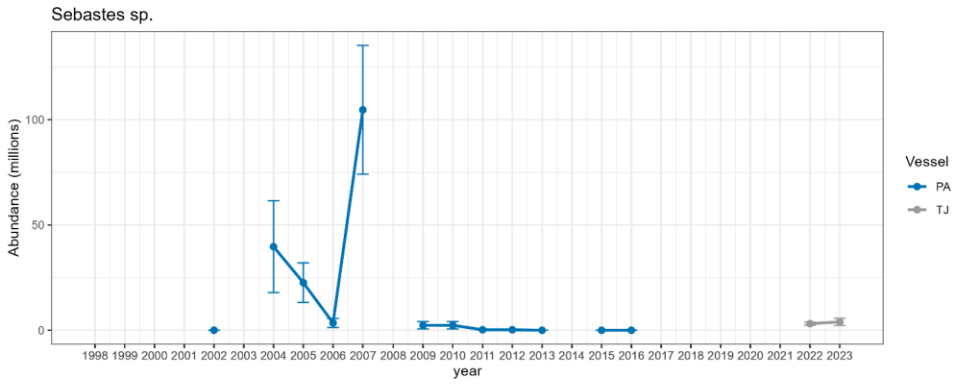

Figure 16. Total abundance and SE of juvenile redfish (*Sebastes* sp.) for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

28

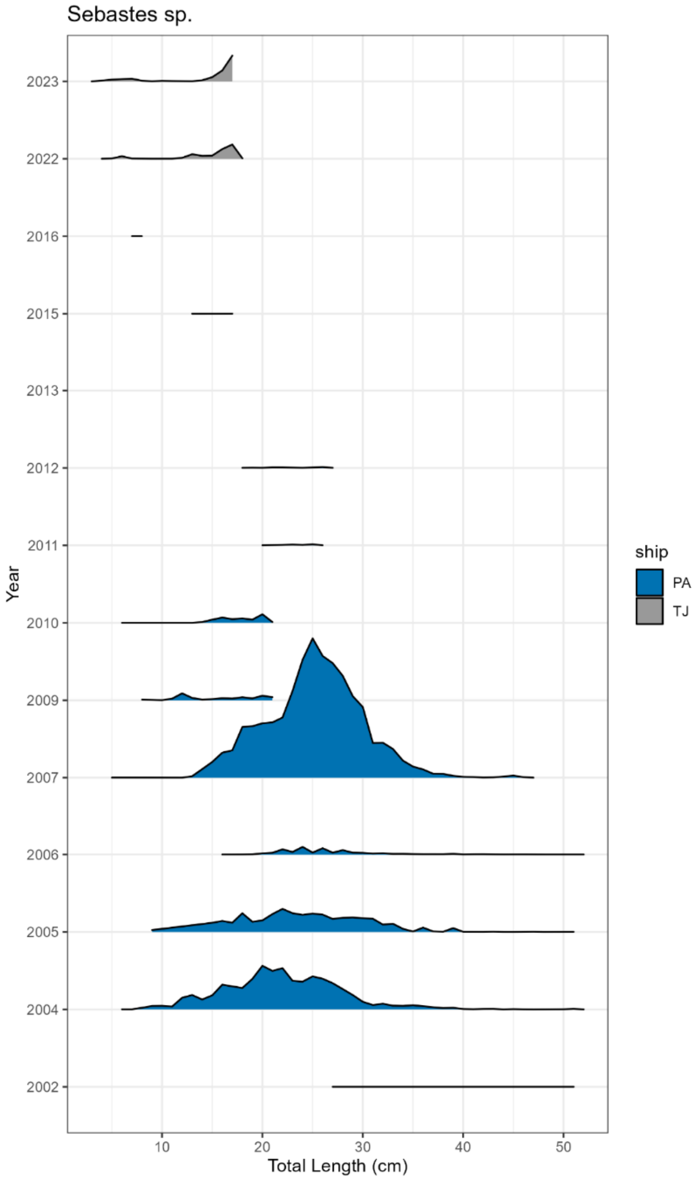

Figure 17. Overall length distribution (per swept area) of juvenile redfish (*Sebastes* sp.) by year for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

29

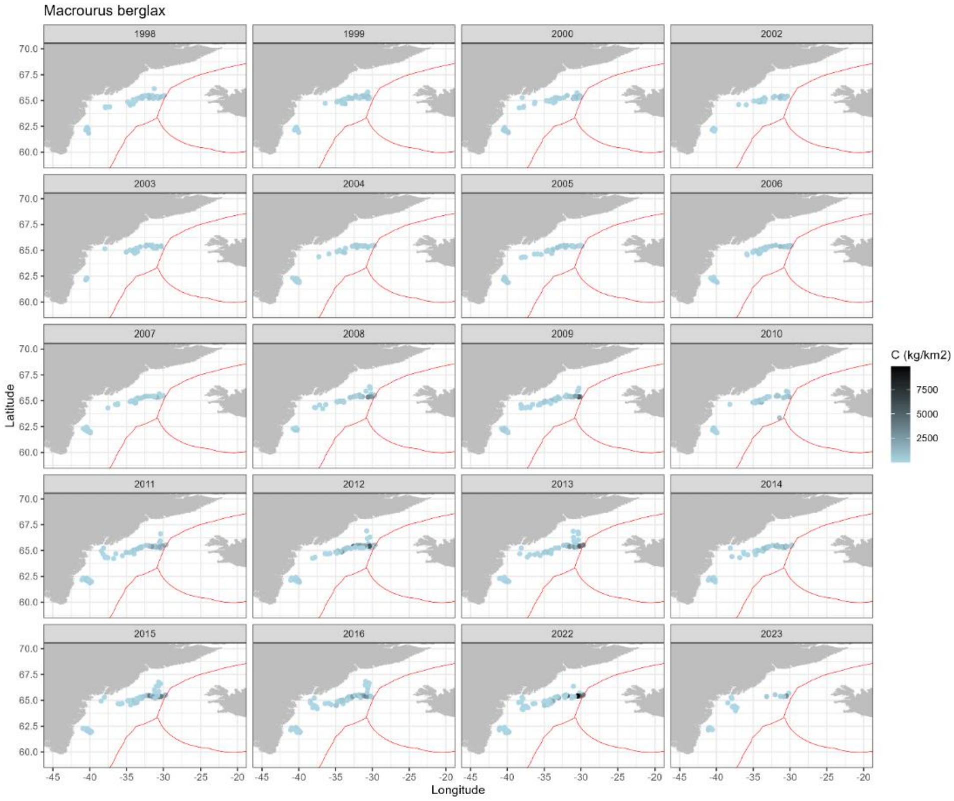

Figure 18. Distribution of survey catches of roughhead grenadier off East Greenland for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

30

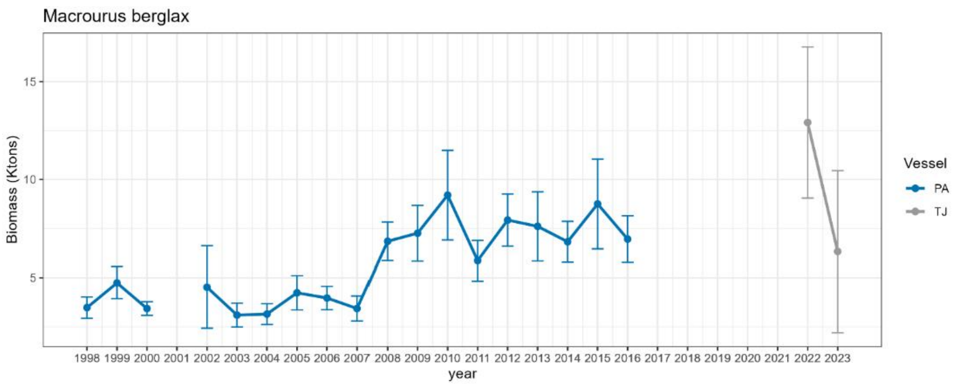

Figure 19. Total biomass and SE of roughhead grenadier for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

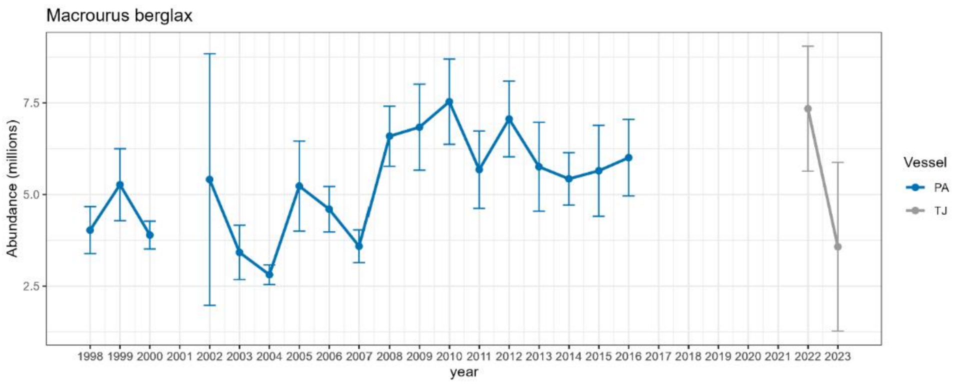

Figure 20. Total abundance and SE of roughhead grenadier for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

31

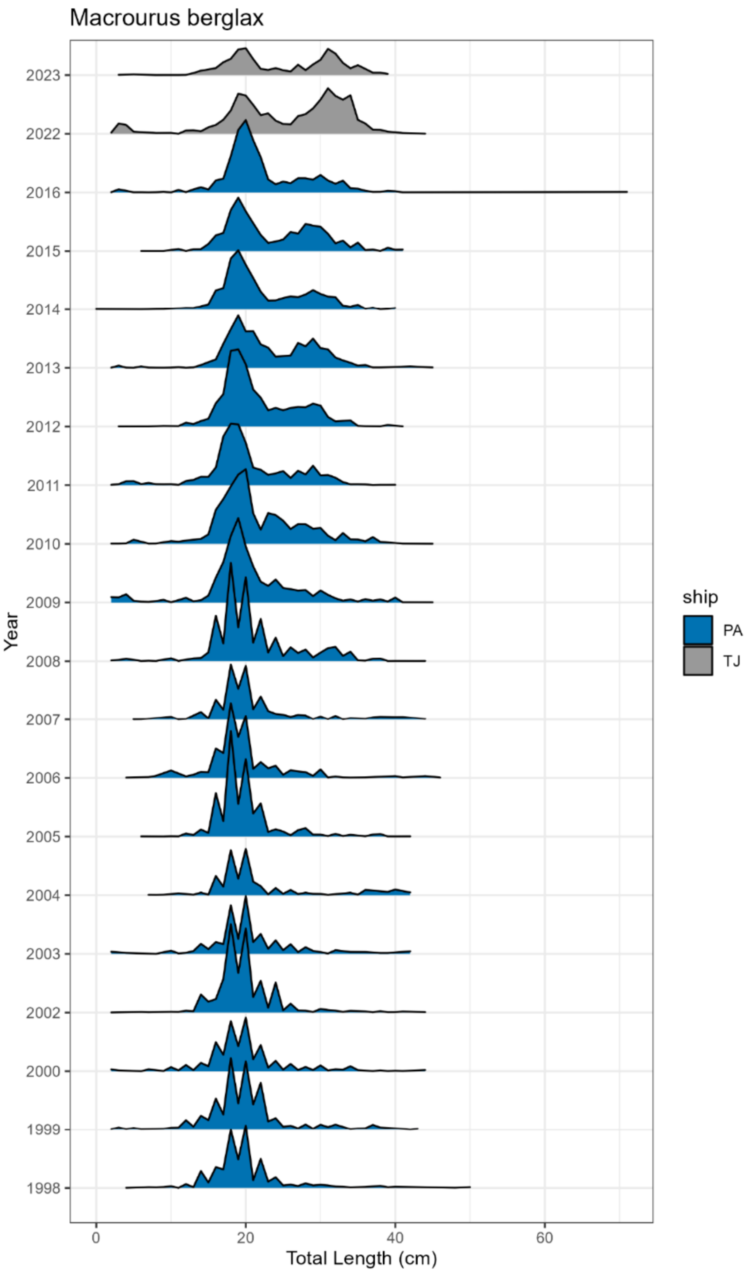

Figure 21. Overall length distribution (per swept area) roughhead grenadier by year for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

32

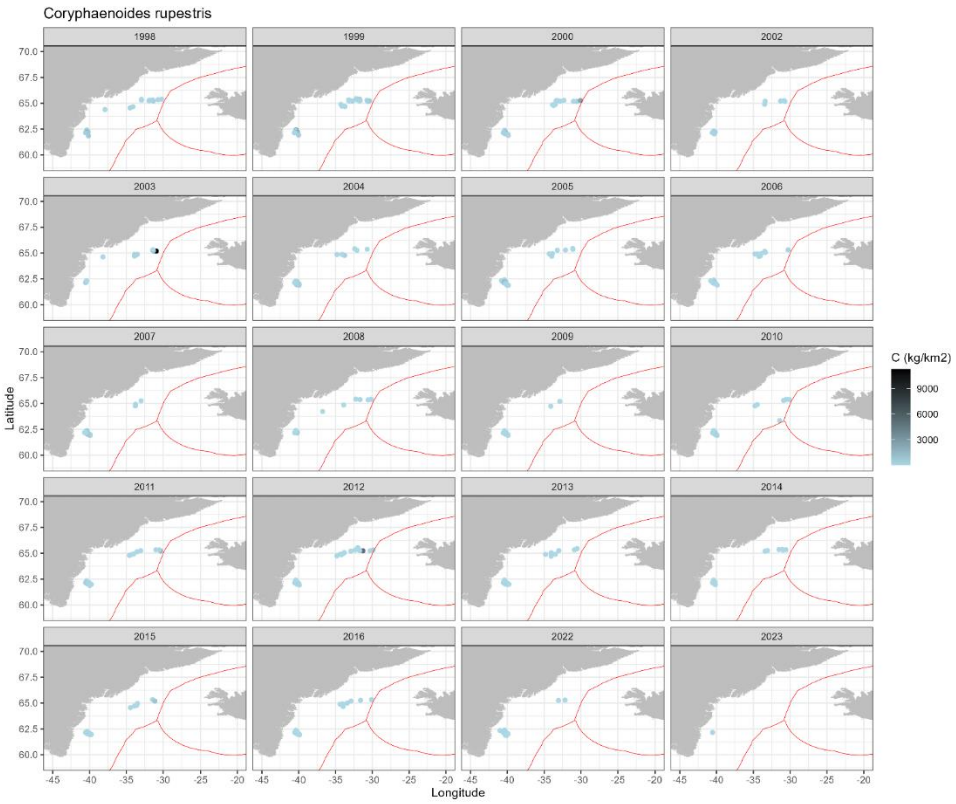

Figure 22. Distribution of survey catches of roundnose grenadier off East Greenland for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

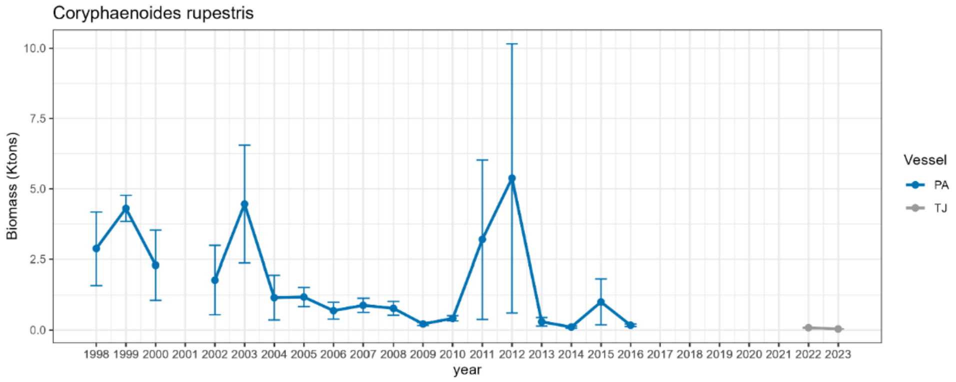

Figure 23. Total biomass and SE of roundnose grenadier for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

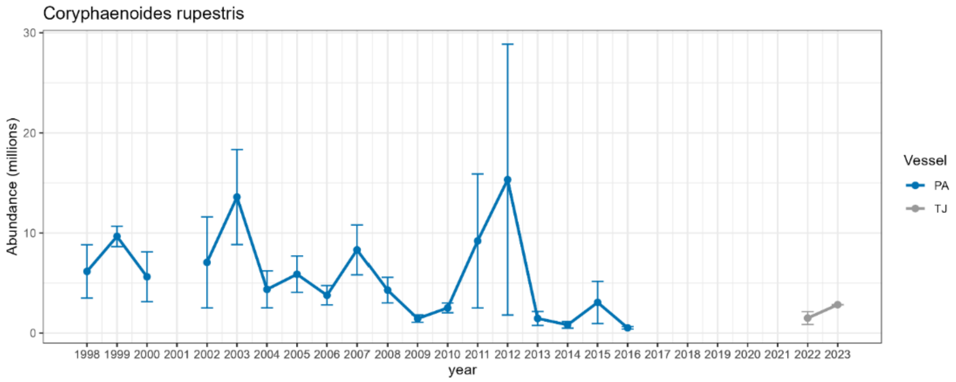

Figure 24. Total abundance and SE of roundnose grenadier for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

34

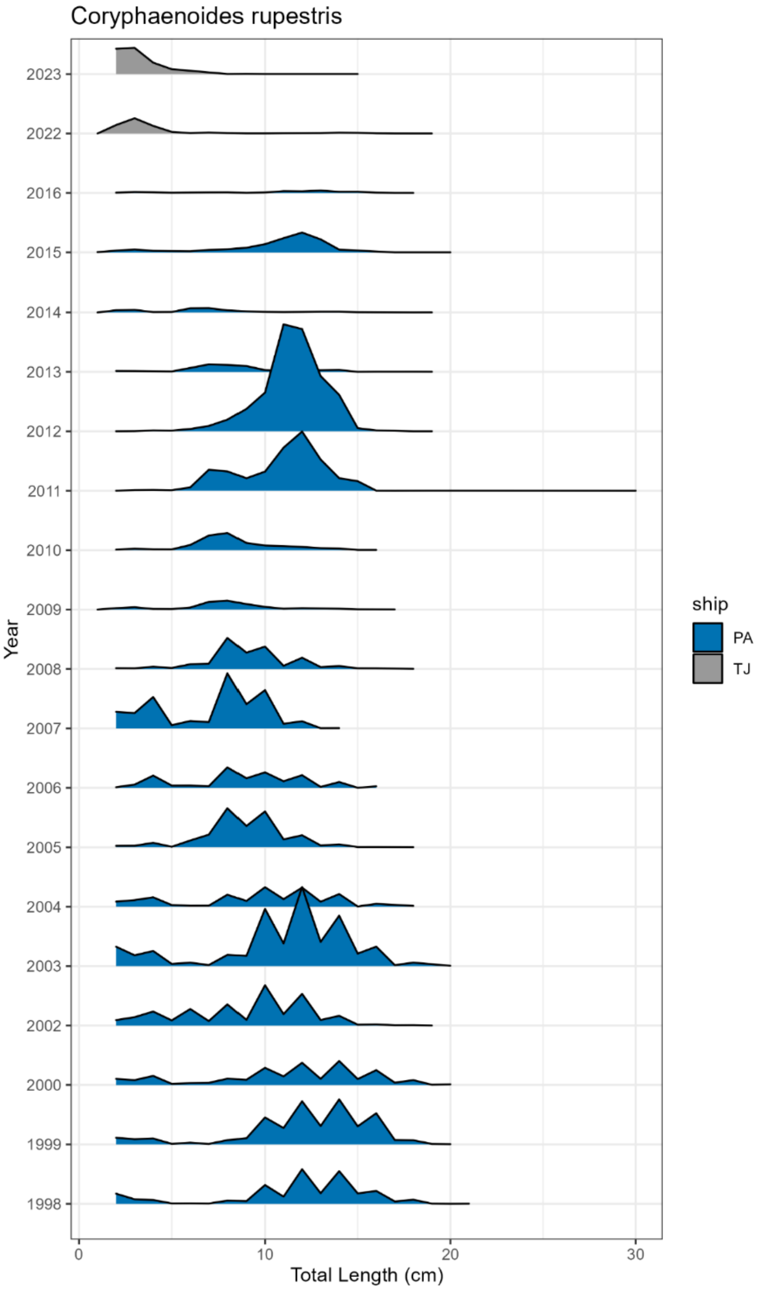

Figure 25. Overall length distribution (per swept area) of roundnose grenadier by year for the period 1998-2016 (no survey in 2001) with RV Paamiut and 2022-2023 with RV Tarajoq.

Annex 4: Audit reports

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Audit of Demersal beaked redfish (Southeast Greenland)

Date: 03.05.2024

Auditor: Katrine Melaa

- *Audience to write for: ADG, ACOM, benchmark groups and EG next year.*
- *Aim is to audit (check if correct):*
    - *the stock assessment– concentrate on the input data, settings and output data from the assessment*
    - *the correct use of the assessment output in the forecast, and check if forecast settings are applied correctly*
- *Any deviations from the stock annex should be described sufficiently.*
- *By the conclusion of the working group, all update assessments should be audited successfully.*
- *Store all audits on SharePoint for future reference.*

General

No analytical assessment, but biomass estimated and recommended to follow the rb catch rule. The stock has not been benchmarked, but planned for a new benchmark in 2026. Recommendation of estimating MSY proxy reference points and recruitment, using the combination of surveys. More studies are needed on connectivity between beaked redfish in East-Greenland and adjacent waters, such as the Icelandic slope stock. There is a lack of input parameters such as Linf, M and k to estimate length-based indicators. Survey results and data from the fishery indicates that the stock is at low levels with low recruitment.

For single stock summary sheet advice:

Short description of the assessment: extremely useful for reference of ACOM.

1) **Assessment type: Not assessed**
2) **Assessment**: trends (biomass indices)
3) **Forecast**: not presented
4) **Assessment model**: *no*
5) **Data issues:**
6) **Consistency**:
7) **Stock status**: *At a low level. Few year classes in fishery.*
8) **Management Plan**: Mixed TAC with golden redfish, but recommended zero catch.

General comments

Technical comments

Conclusions

There is no new assessment on this stock.

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Template for audit of assessments made by EG members
Text in italics is explanatory – to be deleted from final report

Audit of (Stock name)

Date: 03.05.2024
Auditor: Anja Retzel, Tanja Buch

- *Audience to write for: ADG, ACOM, benchmark groups and EG next year.*
- *Aim is to audit (check if correct):*
    - *the stock assessment– concentrate on the input data, settings and output data from the assessment*
    - *the correct use of the assessment output in the forecast, and check if forecast settings are applied correctly*
- *Any deviations from the stock annex should be described sufficiently.*
- *By the conclusion of the working group, all update assessments should be audited successfully.*
- *Store all audits on SharePoint for future reference.*

General

- The stock has been assessed in agreement with the report and stock annex.
- Mean weight at age in the catches for the assessment year needs to be predicted and are based on the spring survey weight measurement using the slope and the intercept from a linear relationship between survey and catch weights of ages 3-9 in preceding years. The result is high mean catch weight for age 3 and 4 because prediction for these age groups are also based on older age groups. At the NWWG a slightly altered method was presented where estimates of the slope and intercept were based on weight at age within each age group 3 to 9. NWWG concluded that this was an improvement, but due to the prospect of setting up an interim benchmark for this minor change the group decided to remain with the original predictions.Next benchmark is likely in 2026 or 2027.

For single stock summary sheet advice:

1) **Assessment type: update**
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: Separable statistical catch at age (MUPPET)
5) **Data issues:** All data is available as described in the Stock Annex
6) **Consistency**: This is a highly consistent assessment.
7) **Stock status**: MGTBtrigger is 220 kt and SSB in 2024 is estimated at 377 477 kt. Reference biomass (B4+) was estimated at 1 075 600 kt in 2024. Harvest rate in 2023 is 0.18. Hence the stock is well above limits and is fished at the management target.
8) **Management Plan**: The advice follows the outline defined in the management plan. Because SSB> $MGTB_{trigger}$, the $TAC_{2024/2025}$ is set as ($TAC_{2023/2024}$ + 0.2*$B_{B4+,2024}$)/2. In accordance with this plan, the proposed TAC for 2022/23 is 213 214 kt.

General comments

This was a well documented, well ordered and considered section. It was easy to follow and interpret.

Technical comments

None

Conclusions

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

The assessment has been performed in accordance with the Stock annex and the results can be used as basis for advice.

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Template for audit of assessments made by EG members
Text in italics is explanatory – to be deleted from final report

Audit of Icelandic slope beaked redfish (East of Greenland, Iceland grounds)

Date: 03.05.2024
Auditor: Katrine Melaa

- *Audience to write for: ADG, ACOM, benchmark groups and EG next year.*
- *Aim is to audit (check if correct):*
  - *the stock assessment– concentrate on the input data, settings and output data from the assessment*
  - *the correct use of the assessment output in the forecast, and check if forecast settings are applied correctly*
- *Any deviations from the stock annex should be described sufficiently.*
- *By the conclusion of the working group, all update assessments should be audited successfully.*
- *Store all audits on SharePoint for future reference.*

General

Stock was benchmarked last year, and is now assessed as category 1 stock, an improvement from previous category 3. New assessment is based on an age- and length based assessment model (GADGET). Overall, everything fine. The retrospective analysis is generally consistent. Low amount of pre-fishery juveniles are found in surveys, and only redfish of 3+ ages included in the model. Minor inaccuracies in the model output related to smaller amount of age data available are discussed in the assessment, and more age data can improve future estimates. This is also expected to cause some variation in the higher peels in the retrospective model. Variability introduced by the survey indices used as input data was also raised, as redfish tend to aggregate, resulting in a few very large hauls. Settings for the forecast applied correctly, but more age data will reduce uncertainty. The SSB is estimated to be at its historically lowest level, recruitment is low and the stock is made up of an increasingly large proportion of older, more mature fish, causing concerns regarding the productivity of the stock. This was the first evaluation of reference points, and they are corrected from last years. Current F-target set to 0.041 (=F_{p05}), which is lower than the original F-target at 0.061 (=F_{p05}). Previous estimates of SSB and TB are within uncertainties of updated estimates, and there is no change in the status of the stock or fishery from previous year.

For single stock summary sheet advice:

Short description of the assessment: extremely useful for reference of ACOM.

1) **Assessment type: update**
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: *GADGET*
5) **Data issues:** *Error in estimating biomass from model output, affecting Blim and Bpa. Not found to affect recruitment level or exploitation rates.*
6) **Consistency**: *Last yr assessment accepted. Benhmarked last year.*
7) **Stock status**: *SSB at historicaly low levels. Low abundance of juveniles (<30cm).*
8) **Management Plan**: *Quotas separated from golden redfish was implemented from the start of fishing year 2010.*

General comments

The stock was benchmarked in 2023, and this is an updated assessment. The stock is now assessed as category 1 stock.

Technical comments

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Conclusions

The assessment has been performed correctly

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Template for audit of assessments made by EG members
Text in italics is explanatory – to be deleted from final report

Audit of (Stock name)

Date: 25.04.24
Auditor: Karl Werner

- *Audience to write for: ADG, ACOM, benchmark groups and EG next year.*
- *Aim is to audit (check if correct):*
    - *the stock assessment– concentrate on the input data, settings and output data from the assessment*
    - *the correct use of the assessment output in the forecast, and check if forecast settings are applied correctly*
- *Any deviations from the stock annex should be described sufficiently.*
- *By the conclusion of the working group, all update assessments should be audited successfully.*
- *Store all audits on SharePoint for future reference.*

General

Stock was benchmarked last year, hence this is an update assessment. Assessment is based on genetics data for one population spatially overlapping with several other cod populations in West Greenland. Everything is fine, only reference point determination causes troubles. Reference points for F partially too high, ICES framework should provide easier and less technocratic solutions for situations, when the framework does not give reasonable results. Further genetic sequencing data were added this year, which changed the perspective of the stock slightly but not dramatic. Internal consistencies and retros are fine.

For single stock summary sheet advice:

Short description of the assessment: extremely useful for reference of ACOM.

1) **Assessment type: update**
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: *SAM*
5) **Data issues:** *No data issues*
6) **Consistency**: *Last yr assessment accepted, benchmarked last year*
7) **Stock status**: *B>Blim after considerably stock increase in the 2000s*
8) **Management Plan**: *NO MP*

General comments

Everything is well documented, further information about stock split and genetics data base can be found in the benchmark report.

Technical comments

Conclusions

The assessment has been performed correctly

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Checklist for audit process

General aspects

- Has the EG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- If a management plan is used as the basis of the advice, has been agreed to by the relevant parties and has the plan been evaluated by ICES to be precautionary?
- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?
- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Audit of cod.21.27.1.14

Date: 13/05/2024

Auditor: Bjarki Þór Elvarsson

General

Last year the ADG downgraded the assessment for this stock due to high uncertainty regarding the origin of a large proportion of the fish caught on the EG fishing grounds, on Dohrn bank in particular. This will require further study before the stock is upgraded to higher assessment category.

For single stock summary sheet advice:

1) **Assessment type: update/SALY**
2) **Assessment**: trends
3) **Forecast**: not presented
4) **Assessment model**: category 5
5) **Data issues:** No data issues that affect the advice were detected
6) **Consistency:** The advice is consistent with last years assessment
7) **Stock status**: Unknown
8) **Management Plan**: No management plan recognised by ICES in place for this stock

General comments

The assessment of this stock is in-line with the agreed methodology. The input data is well documented and justifications of the current assessment is well described.

Technical comments

No comments

Conclusions

The assessment has been performed correctly

<u>Format for audits</u> (to be drawn up by expert groups and not review groups)

Review of ICES Scientific Report, NWWG, 2024, 22-26 April.

Reviewers: Luis Ridao Cruz

Expert group Chair: Helba Bára Mohr Wang &Teunis Jansen

Secretariat representative: Neil Campbell

General

- The stock underwent a benchmark in 2019 and at the same meeting management strategy evaluation were carried out, which resulted in new reference points. Only results from the last three assessments should be compared to the reference points indicated.

For single-stock summary sheet advice

Stock **Haddock in division 5.a (Iceland ground).**

Short description of the assessment as follows:

1) Assessment type: Category 1, Statistical catch-at-age model.
2) Assessment: accepted
3) Forecast: accepted
4) Assessment model: Statistical catch-at-age model. Using catch-at-age and two survey indices (Spring suryve SMB and fall survey SMH) for tuning.
5) Consistency: The assessment is considered to be consistent with previous assessments. Advised catches increased as a result of the predicted increase in reference biomass (B_{45cm+})
6) Stock status: Spawning size is above $B_{trigger}$, and B_{PA}.
7) Management plan: Management plan is consistent with both precautionary approach and the ICES MSY approach. The advice follows the management plan, the advice for 2024/2025 is 76774 tonnes which is a slight increase from the previous year.

General comments

- The fishing year starts at 1. September and advice TAC is for the period 1.9.2024 to 30.8.25.

Technical comments

The catch scenario is provided for the fishery year from 1 September 2024 to 31 August 2025.
Need to include the advice for 2024/2025 fishing year in Table 6 and Figure 34 of the report.

Conclusions
The assessment has been performed correctly . Comments and edits are incorporated on the report.

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Audit of (ghl.27.561215 – Greenland halibut)

Date: 6. May 2024

Auditor: Kistján Kristinsson

General

- Error discovered during the update assessment.
  - The routine that collated SSB from the model output incorrectly calculated the mean weight at length resulting in a downward bias in total and spawning stock biomass estimates.
- For this reason, all reference points were estimated and revised.
  - The revision of reference points followed the same procedure as used at WKBNORTH 2023.
  - Resulted in higher estimates of $B_{trigger}$, B_{lim} and B_{pa} and lowered estimates of F_{MSY}, F_{lim} and F_{pa}
- Due to this update of the reference point last years advice needed also to be corrected based on the updated F_{MSY} and $B_{trigger}$ values.
- These changes led to decreased advice for 2024 (from 21 541 t to 19 xxx t) – the revised advice for 2024 has not been published.
- These changes were accepted during the NWWG meeting and both ICES and the group did not consider it necessary to take the issues through inter-benchmark as no changes were made in the procedure of reference points calculations.

For single stock summary sheet advice:

1) **Assessment type:** update (first used in 2023)
2) **Assessment**: analytical, age-length based assessment.
3) **Forecast**: Short-term forecast presented
4) **Assessment model**: GADGET – tuning by commercial fleets from Iceland, Greenland and the Faroe Islands. Combined survey index from two surveys from East-Greenland and Iceland.
5) **Data issues:** Sampling is adequate and no issues regarding the data. The survey in East-Greenland Waters was conducted in 2022 and 2023, but was not conduceted 2017–2021. The survey index used in the assessment is a combined survey index from the East-Greenland deep-water survey and the Icelandic bottom trawl autumn survey. Age data is available from the Icelandic autumn survey 2015–2023.
6) **Consistency**: Last year assessment accepted.
7) **Stock status**: $B>B_{lim}$ for a while but $B<$MSY $B_{trigger}$ and $B<B_{pa}$ in the terminal year. $F<F_{lim}$ but $F>F_{MSY}$ and $F>F_{pa}$. R (age 5) has increased in the past 3 years.
8) **Management Plan**: MSY approach (F_{MSY}). No agreed management plan between the three nations (Greenland, Iceland, the Faroe Islands).

General comments

This is a well documented and accurate assessment of Greenland halibut, given the large data demands for all the age classes in the stock. The gadget model captures the overall trends in the data and the model is a good tool for assessing the stock and to base advice to managers.

Technical comments

See comments in the beginning of this document regarding the error detection in the year assessment.

Conclusions

The assessment has been performed correctly and in line with the description in the stock annex.

Template for audit of assessments made by EG members

Audit of Iceland summer spawning herring (her.27.5a)

Date: 11th May 2024
Auditor: Henrik Christiansen

General

The stock was recently benchmarked and extensive documentation of the benchmark and a thoroughly updated SA are available. A SAM model that was accepted during the benchmark is used and the HCR has been assessed by ICES and is considered precautionary and to conform to ICES MSY approach. This HCR is implemented in a management plan by the Icelandic Government.

For single stock summary sheet advice:

1) **Assessment type:** update after benchmark
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: statistical catch at age model (SAM), with catch-at-age, 3 survey indices + juvenile index
5) **Data issues:** there was a surprising decrease in biomass east of Iceland which causes the survey index to not cover the whole stock, but this is considered in the assessment following a conservative approach (and cause for lowering the TAC)
6) **Consistency:** consistent with the recent benchmark WIKICEHER (2024) recommendation, the new assessment should be accpeted
7) **Stock status**: Fishing pressure below HR_{MSY}, HR_{pa}, and HR_{lim} and SSB above MSY $B_{trigger}$, B_{pa}, and B_{lim}.
8) **Management Plan**: Management plan follows a HCR that was suggested during the benchmark; adopted by the Icelandic Government. HCR was evaluated by ICES and is considered precautionary and conforms to ICES MSY approach. SSB is above MGT $B_{trigger}$, so the future TAC is HR_{MGT} * B_{Ref}. MGT $B_{trigger}$ is 273 kt and HR_{MGT} is 0.19.

General comments

This stock has been benchmarked in February 2024. There was a significant decrease of herring measured during acoustic surveys in the East of Iceland. It is unclear whether this stock component is "lost", migrated elsewhere or similar. The current assessment and advice considers this stock component as absent and thus results in a decreased advice for 2025, which is consistent with a conservative/precautionary approach. If the estimate increases in the future, the assessment can be updated/adjusted accordingly.

Technical comments

No further comments, the assessment has been conducted thoroughly and according to the stock annex.

Conclusions

The assessment has been performed correctly.

Template for audit of assessments made by EG members

Text in italics is explanatory – to be deleted from final report

Audit of (reg.27.561214)

Date: 6 May 2024

Auditor: Petur Steingrund

General

Compared with some other assessments of redfish this assessment is very advanced being age disaggregated where year classes can be followed up to old age. This assessment is based on extensive length and age data.

From the advice sheet we get the information that the basis for the advice was revised (in a recent benchmark) (WKBNORTH, ICES, 2023a). The new assessment framework allows for changes in selectivity and growth over time, corresponding to observations, leading to an upward revision of stock biomass and a downward revision of fishing mortality.

It is also stated that: " Since 2009, surveys of golden redfish have consistently shown very low abundance of small fish (≤ 30 cm). While current estimates of SSB were revised upwards with the change in assessment model, they are on a decreasing trend since 2017. The assessment also shows historically low levels of incoming cohorts. This raises concerns about the productivity of the stock. Without substantial recruitment, biomass levels are likely to continue to decline for several years leading to decreasing catch advice."

For single stock summary sheet advice:

1) **Assessment type: SAM.** Used for the first time. The stock was benchmarked in February 2023. The model was changed from GADGET to SAM.
2) **Assessment**: Analytical age-disaggregated assessment.
3) **Forecast**: Presented.
4) **Assessment model**: SAM assessment based on catch-at-age data (1966, 1972, 1995-2023) and tuned with the spring survey (in kg per hour, 1995-2023) and the autumn survey (ages, 1996-2023, 2011 missing). In addition the assessment is tuned with catches in tons (1966-1994).
5) **Data issues:** Sampling is adequate although less than previous years. The Greenland (German autumn) survey had not been conducted in recent years and assumed to be constant when combined with both Icelandic surveys, but this issue had little influcne on the overall tuning indicies. Catches from Subarea 6 are not included in the stock assessment because they are only reported as *Sebastes* sp. This is a minor part of the catches (some 50-500 tons out of 30-60000 tons).
6) **Consistency:** It is difficult to find out whether the assessment is performed according to the annex because the settings are not displayed in the report. Therefore, the settings should be shown in the report. The assessment looks good and has small and random observation residuals. The Mohn's Rho is less than 0.2. The issue with variable individual growth has been solved by moving from Gadget to SAM. It is a little bit strange that the recruitment indices (numbers 4-11 cm) are not so well in line with the recruitment at age 6, the explanation being that the annual variability in mortality up to age 6 has been obscuring this pattern – thus the prominent 1985 and 1990 year classes as age 0-2 are not so prominent at age 6 when entering the fishery.
7) **Stock status**: Fishing pressure on the stock is below F_{MSY}, F_{pa} and F_{lim}, and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.
8) **Management Plan**: The MSY approach is used for this stock, i.e. no special management plan as was the case in the past. In the advice it is stated that "Management of *Sebastes mentella* and *S. norvegicus* catches in East Greenland under a combined species TAC prevents effective control of the single-species exploitation rates and is causing overexploitation of *S. mentella* for which there is

Template for audit of assessments made by EG members
Text in italics is explanatory – to be deleted from final report

zero catch advice. ICES advises that management should be implemented at the species level".

General comments

This is a well documented and accurate assessment of a redfish stock, given the large data demands for all the age classes in the stock. The high performance of the assessment, e.g. the following of year classes all the way to old age, indicates that the stock definition is correct and that there is a good use of tuning series in the model.

Technical comments

It would be preferable if the assessment was available on stockassessment.org – because that would make the comparison with the stock annex much easier as well as to get an overview of which data were used in the assessment as well as the results.

Conclusions

The assessment has apparently been performed according to the annex and is suitable as basis for the advice.

Audit of Iceland ground saithe

Date: 14/05/2024

Auditor: Helga Bára Mohr Vang

General

The assessment of Icelandic saithe has its challenges and is relatively uncertain. This is mainly due to fluctuations in survey data, poor recruitment estimates and changes in the fleet selectivity, probably partially caused by biological reasons; saithe´s schooling behaviour and being semi-pelagic.

The unfilled quotas (TAC) in recent years pose a challenge. While the assessment model interprets this as low fishing mortality, the targeting of smaller fish in recent years suggests otherwise. Furthermore, conflicting signal between catch and survey data pose an additional challenge for the assessment quality. Catch data shows a recent sharp decline in last two years, while surveys indicate high abundance. This mismatch creates difficulties in weighting data within the stock assessment model and the recent, substantial difference between catch and total allowable catch (TAC) warrants further investigation.

For single stock summary sheet advice:

Separable statistical catch-at-age model (Muppet), with changes in selectivity for three different time periods, using catches in the model and in the forecast. Input data is Catch-at-age and age-disaggregated abundance indices from the Icelandic bottom-trawl survey (spring). The assessment and harvest control rules were evaluated in 2019.

1) **Assessment type:** Update.
2) **Assessment**: Analytical.
3) **Forecast**: Presented.
4) **Assessment model**: Separable statistical catch-at-age model (Muppet).
5) **Data issues:** None.
6) **Consistency**: Last year´s assessment accepted.
7) **Stock status**: B>Blim and B>MSY $B_{trigger}$ for most of the timeseries,HR < HRmsy, R uncertain, seem to be high recent years but decreasing trend in the last two years.
8) **Management Plan**: The Icelandic ministry has a management plan on saithe in order to provide long-term maximum sustainable yield. The harvest rate according to the management plan is 0.2. Realized harvest rates can range from 0.14 to 0.29. This management plan is evaluated by ICES.

General comments

This is a very well documented and clear assessment and report section.

Technical comments

None.

Conclusions

The assessment has been performed correctly and according to the stock annex.