ARCTIC FISHERIES WORKING GROUP (AFWG)

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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

Daniel Howell

Authors

Jane Aanestad Godiksen • Erik Berg • Matthias Bernreuther • Bjarte Bogstad • José Miguel Casas Thomas de Lange Wenneck • Elena Eriksen • Johanna Fall • Anatoly Filin • Harald Gjøsæter • Elvar Hallfredsson • Hannes Höffle • Daniel Howell • Edda Johannesen • Yuri Kovalev • Kjell Nedreaas • Holly Ann Perryman • Dmitri Prozorkevich • Alexey Russkikh • Silje Elizabeth Seim • Arved Staby • Ross Tallman • Mikko Juhani Vihtakari • Tone Vollen • Kristin Windsland • Natalia Yaragina

ICES
International Council for the Exploration of the Sea
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Contents

i Executive summary

Assessments run at AFWG provide the scientific basis for the management of cod, haddock, saithe, redfish, Greenland halibut, and capelin in subareas 1 and 2. Taking the catch values provided by the Norwegian fisheries ministry for Norwegian catches and raising the total landed value to the total catches gives an approximate nominal first-hand landed value for the combined AFWG stocks of ca. 20 billion NOK or ca. 2 billion EUR (2018 estimates). NEA cod and coastal cod were benchmarked in 2021. For NEA cod this resulted in updates to the existing SAM assessment model. For coastal cod, the stock has been split into two components. North of 67°N the coastal cod is now assessed with a SAM assessment model, while between 62°N and 67°N the coastal cod is assessed using a category 3 approach based on a CPUE time-series. AFWG is currently working towards running a benchmark (and subsequent HCR evaluation) for Greenland halibut, which is planned for 2022–2023.

The key feature driving the stock assessments this year was that several key surveys (the ecosystem survey, winter survey, and the Lofoten survey) all came in with low totals for the main AFWG stocks. This has led to downward revisions of many of the stocks described here. Several data errors were discovered following the AFWG meeting in April 2021. These had very minor impacts on the NEA cod and haddock assessments (which are not updated in this report), but revised the quota for northern coastal cod from an initial estimate of zero catch to 7865 t (version in this report based on the corrected data).

Stock-by-stock summaries

Cod in subareas 1 and 2 (Northeast Arctic) was assessed using the SAM model following the outcome of the benchmark meeting (WKBARFAR 2021). The biomass is declining, but SSB is still well above B_{pa}. The TAC advice for 2022 is 708 480 tonnes, corresponding to F = 0.50. This is 20% down on the TAC and the advice for 2021. F is above F_{pa}, because the harvest control rule adopted in 2016, limits the annual decrease to 20%. Without this constraint, the advice would have been 604 125 tonnes. The decrease from last year's advice is due to changes in SAM settings and input data at the benchmark, as well as low survey indices in 2021.

Cod in subareas 1 and 2 North of 67°N (Norwegian coastal cod North)—cod.27.2.coastN—is a new ICES stock following a benchmark in 2021 and is the northern part of the previous coastal cod stock. The stock was assessed using the new SAM model developed at the benchmark meeting (WKBARFAR 2021). The spawning-stock biomass increased by 10 000 t in 2020 compared to 2019, but spawning-stock biomass is still below B_{lim} and F increased in 2020. However, the data indicates that the stock is capable of rising above B_{lim} within one year. The catch advice is set to be no more than 7865 t (including all commercial and recreational catches), which is estimated to be the largest catch permitting recovery above B_{lim} in one year.

Cod (Gadus morhua) in Subarea 2 between 62°N and 67°N (Norwegian coastal cod South)—cod.27.2.coastS—is a new ICES stock following a benchmark in 2021 and is the southern part of the previous coastal cod stock. The stock is assessed using the 2-over-3 rule based on a CPUE series from the Norwegian coastal reference fleet (9–15 m, fishing with gillnets in the second half of the year), alongside a LBSPR model to evaluate the necessity of a precautionary buffer. In principle, the CPUE could be used to tune a SPiCT model, however, the time-series needs to be extended before this is practicable. A key uncertainty is the lack of good data on the substantial recreational portion of the overall catch. The current assessment shows a decrease in the spawning potential ratio with a decline in both mean length and mean length of largest 5%. These combine to depict a somewhat depleted and worsening stock status. Given the largely stable CPUE trend in recent years and no adopted reference points, the 2-over-3 rule, including a precautionary buffer, suggests a 6% decrease in next year's catches compared to the last three years average.

Haddock in subareas 1 and 2 (Northeast Arctic) was assessed using the SAM model. The spawning-stock biomass has declined since 2013 but is still well above B_{pa}. The TAC advice for 2022 is 180 003 tonnes, corresponding to F = 0.35. This is 23% down on the TAC and the advice for 2021. The decrease from last year's advice is mainly due to low indices from surveys in autumn 2020 and winter 2021. The retrospective trend indicates that the catch advice given in 2020 for 2021 is likely biased high. The catch in 2020 was 15% lower than TAC and the catch is expected to be below the TAC also in 2021, especially since the TAC in 2021 was higher than the 2020 TAC.

Saithe in subareas 1 and 2 (Northeast Arctic) was assessed using the SAM model. The spawning-stock biomass is well above B_{pa} and has been increasing since 2011, although the increase has been lower in the last years. Considering uncertainty fishing mortality has been below $F_{pa} = 0.35$ since 2015. The TAC advice for 2022 is 197 212 tonnes (corresponding to $F_{mp} = 0.32$) and is very similar to the 197 779 tonnes TAC and advice for 2021. Currently, particularly the strong 2013 (8-year old fish) and the 2016 (5-year old fish) year classes are contributing substantially to the SSB. The retrospective trend indicates that SSB was only slightly overestimated in 2017–2019. In 2020 preliminary catches totalled 169 405 tonnes, corresponding to 99% of the quota allocated.

Redfish (Sebastes mentella, Sebastes norvegicus) in subareas 1 and 2 (Northeast Arctic): is assessed on a two-year cycle, with the next advice in 2022. Interim model results for *S. mentella* indicate that at current levels of exploitation SSB by the end of 2020 is estimated to be 874 727 t with fishing mortality of the plus-group corresponding to $F_{19+} = 0.05$, higher than in 2019 but still below the advised quota. Catches of *S. norvegicus* in 2020 amounted to 9033 t, continuing the trend of increased bycatch since the quota for beaked redfish was raised in 2019. The stock was not assessed in 2021.

Greenland halibut is assessed on a two-year cycle, with advice provided this year. Poor recruitment over the last decade combined with fishing c. 1/3 above advice over the last decade has led to a continued decline in the fishable 45 cm+ biomass, which is currently estimated at 601 kt. The previous precautionary basis for advice was rejected by the Advice Drafting Group (ADG), and an HR_{pa} proposal was requested. Following a delay due to COVID-19, this has now been submitted to ICES for consideration by the ADG.

Anglerfish (Lophius budegassa, Lophius piscatorius) in subareas 1 and 2 (Northeast Arctic): AFWG does not currently give advice on this stock. However, following a recent benchmark, we are now in a position to do so if requested by the managers. Management is based on technical measures rather than a quota. Data-limited model results based on length data from the fishery suggest that the exploitation pattern is appropriate, while the rate is close that which would lead to maximum yield.

Barents Sea capelin: following ToR b), the data on Barents Sea capelin were updated. No assessment is conducted during the spring AFWG meeting, the assessment occurs in autumn following the ecosystem survey[1]. A benchmark will be held in 2022 for this stock together with capelin in the Iceland-East Greenland-Jan Mayen area[2].

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[1] As of October 2021, Section 10 of this report has been updated to reflect the outcomes of the autumn survey and the consequent meeting held online 4–5 October 2021.

[2] The two capelin stocks will be included in the benchmark workshop WKREDCAP 2022, together with beaked redfish (*Sebastes mentella*) in Subarea 14 and Division 5.a, Icelandic slope stock (East of Greenland, Iceland grounds).

ii Expert group information

Expert group name	Arctic Fisheries Working Group (AFWG)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chair	Daniel Howell, Norway
Meeting venue and dates	14–20 April 2021, online meeting (26 participants)

1 Introduction and ecosystem considerations

Arctic Fisheries Working Group

1.1 Terms of reference

2020/2/FRSG02 The **Arctic Fisheries Working Group** (AFWG), chaired by Daniel Howell, Norway, will meet online 14–20 April 2021 to:

a) Address generic ToRs for Regional and Species Working Groups, for all stocks except the Barents Sea capelin, which will be addressed at a meeting in autumn;
b) For Barents Sea capelin oversee the process of providing intersessional assessment;
c) Conduct reviews as required of time any series computed using the STOX and ECA open source software for use in assessment in the Barents Sea.

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 2021 ICES data call.

AFWG will report by 7 May 2021 and 8 October 2021 for Barents Sea capelin for the attention of the Advisory Committee.

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 Additional requests

There were no additional requests.

1.3 Responses to terms of reference

Under ToR a (address generic ToRs), the stock assessments and advice were conducted according to generic ToRs c and d, while the generic ToR e benchmark review can be found further down in this introduction and the haddock, NEA cod and coastal cod sections. Work on generic ToRs a and b will be conducted intersessionally as it becomes appropriate.

ToR b is handled in detail by the capelin subgroup of AFWG, held in autumn after the capelin survey. A brief report on the previous capelin assessment is given in this report.

ToR c is to review data changes as required, and this was not required in 2021.

1.4 Benchmarks

A cod benchmark (WKBARFAR 2021) was conducted in early 2021 (ICES, 2021a). This benchmark resulted in a modification of the existing NEA cod SAM assessment model. For coastal cod, the benchmark resulted in the stock being split into two, a category one northern stock (with a SAM stock assessment) and a category three southern stock (2-over-3 rule based on a CPUE series).

Capelin[3] is scheduled to have a benchmark in 2022, with HCR revision conducted at the benchmark. Greenland halibut is scheduled for a benchmark in 2023[4], followed by an HCR evaluation.

1.5 Total catches

In this report, the terms 'landings' and 'catches' are, somewhat incorrectly, used as synonyms, as discards are in no cases used in the assessments. This does not mean, however, that discards have not occurred, but the WG has no information on the possible extent. In contrast, available information indicates low discard rates at present (less than 5% of catch) and it is assumed that discards are negligible in the context of the precision of the advice.

As in previous years, a report from the Norwegian-Russian Analysis group dealing with estimation of total catch of cod and haddock in the Barents Sea in 2018 was available to AFWG. The report presents estimated catches made by Norwegian, Russian and third countries separately. According to that report, the total catches of both cod and haddock reported to AFWG are very close (within 1%) to the estimates made by the analysis group. Thus, it was decided to set the IUU catches for 2017 to zero.

For further information on under- and misreporting, we refer to the 2016 AFWG report.

Discards estimates (1994–2020) of redfish, cod, haddock and Greenland halibut juveniles in the commercial shrimp fishery in the Barents Sea are presented in Figure 0.1. These estimates are obtained with a spatio-temporal model based on a procedure elaborated in Breivik *et al.* (2017). In Breivik *et al.* (2017) an extensive validation study indicates that the new procedure obtains bycatch estimates with approximately correct uncertainty. Previous estimates for the period 1982–2015 are given in earlier reports (e.g. AFWG 2018), and we have not been able to compare these two time-series in detail. Such a comparison should be performed on a relatively fine spatio-temporal resolution. The bycatch estimates illustrated in Figure 0.1 and are available for each quarter in each main statistical area (not shown in report). Note that it is still a work in progress regarding improving the new estimates.

The new time-series in Figure 0.1 are obtained by scaling the estimated bycatch in the Norwegian fishery with the international fishery in each ICES area. The scaling procedure assumes that the Norwegian fishery is representative of the international fishery. This assumption is necessary because the international catch data are available only to a low spatio-temporal resolution. If the international vessels in a relatively high degree trawl at locations not trawled by Norwegian vessels, the bycatch estimates illustrated in figure 0.1 may be biased.

1.5.1 Uncertainty in catch data

For the Norwegian estimates of catch numbers at-age and mean weight-at-age for cod and haddock methods for estimating the precision have been developed, and the work is still in progress (Aanes and Pennington, 2003; Hirst *et al.*, 2004; Hirst *et al.*, 2005; Hirst *et al.*, 2012). The methods are general and can in principle be used for the total catch, including all countries' catches, and provide estimates both at-age and at-length groups. Typical error coefficients of variation for the catch numbers-at-age are in the range of 5–40% depending on age and year. It is evident that the estimates of the oldest fish are the most imprecise due to the small numbers in the catches and resulting small number of samples on these age groups. From 2006 onwards, the Norwegian catch-at-age in the assessment has been calculated using the ECA method described by Hirst *et*

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[3] Currently part of benchmark workshop WKREDCAP 2022.

[4] Proposed for a 2022–2023 benchmark together with NWWG Greenland halibut, ghl.27.561214.

al. (2005). The methodology for using ECA to split cod catches into NEA cod and coastal cod is still under development (WKARCT 2015). ECA has now been implemented for saithe, and with partial success for *S. mentella*. A new version of the program (StoX-ECA) is now being tested.

Aging error is another source of uncertainty, which causes increased uncertainty in addition to bias in the estimates: An estimated age distribution appears smoother than it would have been in absence of ageing error. Some data have been analysed to estimate the precision in ageing (Aanes, 2002). If the ageing error is known, this can currently be taken into account for the estimation of catch-at-age described above.

For capelin, the uncertainty in the catch data is not evaluated. The catch data are used, however, only when parameters in the predation model are updated at infrequent intervals, and the uncertainty in the catch data are considered small compared with other types of uncertainties in the estimation.

We note that the SToX survey methodology reviewed by the group is able to produce uncertainty estimates for the survey time-series.

Additional sources of uncertainty arising from sources beyond sampling or age-reading errors have implications for a number of the stocks assessed here. Coastal cod catches, and to a lesser extent catches of the much larger NEA cod stock, have uncertainty issues due to the difficulty of splitting catches between the two stocks. A similar issue applies to small *S. norvegicus* stock and the larger *S. mentella* stock, where species misidentification can be a significant source of error. Finally, there is no agreement between Norway and Russia on an age-reading methodology for Greenland halibut, and such data are not used for tuning the model. The absence of age data creates an important (but unquantifiable) source of error on the GHL stock estimate.

1.5.2 Sampling effort–commercial fishery

Concerns about commercial sampling: The main Norwegian sampling program for demersal fish in ICES subareas 1 and 2 has been port sampling, carried out onboard a vessel travelling from port to port for approximately 6 weeks each quarter. A detailed description of this sampling program is given in Hirst *et al.* (2004). However, this program was, for economic reasons, terminated 1 July 2009. Sampling by the 'reference fleet' and the Coast Guard has increased in recent years. However, the reduction in port sampling of many different vessels seems to have increased the uncertainty in the catch-at-age estimates from 2009 onwards (WD6, 2010). A Norwegian port sampling program was restarted in 2011, although with a lower effort, this improved the basis for the 2011–2019 catch-at-age estimates. From 2014 this program is run by 4-year contracts of a vessel that sails between fish landing sites along the coast from about 66°N to Varanger (70°N, 30°E) three periods a year during the first, second, and fourth quarters, altogether up to 120 days. This is a reduction compared to about 180 days a year before 2009. The catch sampling is done of landed fish, mainly from the fleet fishing in coastal waters, and usually inside the plant, and the rented vessel acts as a transport, accommodation and working (age reading, data work) platform. AFWG recommends that such sampling is also carried out during the third quarter.

Table 0.1–Table 0.4 show the development of the Norwegian, Russian, Spanish and German sampling of commercial catches in the period 2008–2020. The tables show the total sampling effort, but do not show how well the sampling covers the fishery. Indices of coverage should be developed to indicate this. The main reason for the general strong decrease in numbers of Norwegian samples in the first part of this period is the termination of the port sampling program in northern Norway. This program is now up and running again. It should be considered whether catch sampling carried out by different countries fishing by trawl for the same time and area could be coordinated and data shared on a detailed level to a greater extent than is done today.

Cod, haddock and saithe: Available catch-at-age and length data covered the largest portion of catches by the respective fisheries. However, there was a period in spring 2020 when port sampling was at a lower level than usual due to the COVID-19 situation. However, the aggregation level (time and space) used when splitting these catches into Northeast Arctic cod and Norwegian Coastal Cod is also an important issue. Despite the improvement in sampling coverage in 2016–2020, the number of samples should be increased in the coming years, with the aim of covering all quarters and areas contributing the highest catches.

Due to the adopted amendments of the Russian Federal Law "On fisheries and preservation of aquatic biological resources" coming into force, especially concerning the destruction of biological resources caught under scientific research, sampling activities (age sample numbers and length/weight measurements of fish) on board fishing vessels are also reduced, especially in ICES subareas 2.a and 2.b, which may result in greater uncertainty of the stock assessments due to possible biases in the age–length distributions of the commercial catch.

Length measurements of fish and age sampling by Russia have been especially low in ICES subareas 2.a and 2.b in the first half of 2020 due to administrative difficulties in arrangement (stationing) observers onboard fishing vessels (a prolonged procedure via open contest). Available Norwegian data on cod and haddock length measurements onboard Russian vessels made by the Norwegian Coast Guard in the Norwegian economic zone have been used, where possible, in calculations of catch-at-age data by Russia.

Data issues with *S. mentella*: There is still a concern about the biological sampling from the fishery and scientific surveys that may have become critically low, however, there is also a lag of several years between collection of age samples and the processing of them. This is elaborated in the section for this stock.

Data issues with *S. norvegicus*: Despite a recent increase in age-reading for this species, age data are rather poor, and effort in age sampling from the catches is required. The other main source of uncertainty is species misidentification from *S. mentella*, and consequently, careful monitoring that species composition is being reported correctly is required.

Data issues with NEA Greenland halibut: There is still a concern about the biological sampling from the fishery that may have become critically low. Age information is not available, due to disagreements on age reading method, and may affect precision in the assessment which at the moment is length-based. Norwegian landings are split on Greenland halibut by sex for area, gear groups, and quarters. Annual sample level has decreased in the last years and may affect the precision of the catch distribution.

The samples and data basis behind each stock assessment are discussed more in detail under each stock-specific section of this report (e.g. the coastal cod). The number of aged individuals per 1000 t is now well below the standard set by the EU in their Data Collection regulations. For several stocks sampling is inadequate for area/quarter/gear combinations making up considerable proportions of the total catch.

Discontinuation of the Russian autumn survey decreased considerably the biological sampling (age sample numbers, abundance indices evaluations, maturity status of fish definitions, feeding data collections, etc.).

1.5.3 The percentage of the total catch that has been taken in the NEAFC regulatory areas by year in the last year

Generic ToR c-iii asks for the percentage of the total catch that has been taken in the NEAFC regulatory area by year in the last year. In the area where AFWG stocks are distributed, there are two areas outside national EEZs which are part of the NEAFC regulatory area: The International area in ICES Subarea 1 in the Barents Sea (“loophole”, denoted as 1.a or 27_1_A) and the International area in ICES divisions 2.a and 2.b in the Norwegian Sea (“banana hole”, denoted as 2.a.1 and 2.b.1 or 27_2_A_1 and 27_2_B_1). In the table below the WG presents the most likely landings from these areas based on the official reports and discussions within the WG. The text table below shows the percentages for *S. mentella*, Northeast Arctic cod and haddock and Greenland halibut. For the other AFWG stocks, no catches are taken in those areas. The highest precision in these numbers is probably the *S. mentella* figures since these figures have been tabulated each year since 2004, and have been given regular and special attention, also by NEAFC.

	ICES 1.a	**ICES 2.a.1**	**ICES 2.b.1**	**Total**	**%NEAFC**
2020					
NEA cod	1607	9	0	1616	0.23%
Coastal cod	0	0	0	56653	0.0%
NEA haddock	0	0	0	182468	0.0%
NEA saithe	0	3	0	169405	<0.1%
Sebastes mentella	0	5469	0	54686	10.0%
Sebastes norvegicus	0	0	0	9033	0.0%
Greenland halibut	450	0	0	28713	1.5%
Capelin	0	0	0	0	0.0%
Anglerfish	0	0	0	2280	0.0%
2019					
NEA cod	1094	0	0	692609	0.16%
Coastal cod	0	0	0	52807	0.0%
NEA haddock	394	0	0	175402	0.225%
NEA saithe	250	7	0	163180	0.001%
Sebastes mentella	0	6060	0	45954	13.2%
Sebastes norvegicus	0	0	0	8285	0.0%
Greenland halibut	1108	3	0	28832	3.8%
Capelin	0	0	0	0	0.0%
Anglerfish	0	0	0	2809	0.0%
2018					
NEA cod	1724	2	0	778627	0.22%
Coastal cod	0	0	0	36375	0.0%
NEA haddock	24.1	0	0	191276	0.013%

	ICES 1.a	**ICES 2.a.1**	**ICES 2.b.1**	**Total**	**%NEAFC**
NEA saithe	2.4	0	0	181280	0.001%
Sebastes mentella	3	7823	0	38765	20.2%
Sebastes norvegicus	0	0	0	6647	0.0%
Greenland halibut	798	0	0	28544	2.80%
Capelin	0	0	0	0	0.0%
Anglerfish	0	0	0	1903	0.0%
2017					
NEA cod	1212	12	0	868276	0.14%
Coastal cod	0	0	0	51053	0.0%
NEA haddock	90	0	0	227588	0. 0004%
NEA saithe	70	11	0	145403	0.06%
Sebastes mentella	0	6463	0	31200	20.7%
Sebastes norvegicus	5	0	0	5340	0.1%
Greenland halibut	592	6	0	26380	2.3%
Capelin	0	0	0	0	0.0%
Anglerfish	0	0	0	1478	0.0%
2016					
NEA cod	3619	0	0	849422	0.4%
Coastal cod	0	0	0	54767	0.0%
NEA haddock	7	0	0	233416	0.003%
NEA saithe	81	0	0	140392	0.06%
Sebastes mentella	0	7170	0	35429	20.2%
Sebastes norvegicus	10	0	0	4674	0.2%
Greenland halibut	363	5	0	24972	1.5%
Capelin	0	0	0	0	0.0%
Anglerfish	0	0	0	1435	0.0%
2015					
NEA cod	9	0	0	864384	0.001%
Coastal cod	0	0	0	35843	0.0%

	ICES 1.a	ICES 2.a.1	ICES 2.b.1	Total	%NEAFC
NEA haddock	702	0	0	194756	0.4%
NEA saithe	30	0	0	131765	0.0%
Sebastes mentella	0	4752	0	25856	18.4%
Sebastes norvegicus	13	0	0	3632	0.4%
Greenland halibut	55	0	0	24748	0.2%
Capelin	0	0	0	115044	0.0%
Anglerfish	0	0	0	1043	0.0%
2014					
NEA cod	534	0	0	986449	0.1%
Coastal cod	0	0	0	33660	0.0%
NEA haddock	0	0	0	177522	0.0%
NEA saithe	0	0	0	132005	0.0%
Sebastes mentella	0	4020	0	18780	21.4%
Sebastes norvegicus	0	0	0	4438	0.0%
Greenland halibut	211	0	0	23025	0.9%
Capelin	0	0	0	66000	0.0%
Anglerfish	0	0	0	1657	0.0%

1.6 Uncertainties in survey data

While the area coverage of the winter surveys for demersal fish was incomplete in 1997 and 1998, the coverage was normal for these surveys in 1999–2002. In autumn 2002, 2006 and winter 2003, 2007, 2016 and 2017 however, surveys were again incomplete due to lack of access to both the Norwegian and Russian Economic Zones. This affects the reliability of some of the most important survey time-series for cod and haddock and consequently also the quality of the assessments.

It is very important that the Norwegian and Russian authorities give each other's research vessels full access to the respective economic zones when assessing the joint resources, as was the case for Joint winter surveys (BS-NoRu-Q1 (Btr) and BS-NoRu-Q1 (Aco)) in 2004–2005, 2008–2011 and 2013, for example.

The area coverage in the winter survey was extended from 2014 onwards (Figure 0.2, Table 3.5). With the recent expansion of the cod distribution, it is likely that in years before 2014 the coverage in the February survey (BS-NoRu-Q1 (BTr) and BS-NoRu-Q1 (Aco)) has been incomplete, in particular for the younger ages. This could cause a bias in the assessment, but the magnitude is unknown. The 2014–2021 surveys covered considerably larger areas than earlier winter surveys and showed that cod, haddock and Greenland halibut was distributed far outside the standard survey area. The 2017 and 2018 surveys were restricted by ice Northeast of Hopen Island, and the survey did not extend quite as far as in the years 2014–2016. In 2019 the coverage was almost as extensive as in 2014. Coverage in 2020 and 2021 was less extensive mainly due to increased ice cover in the east. For all stocks except Greenland halibut, mainly younger age groups are found in the northern area. It should however be noted that the survey index from this survey is currently not used in the assessment of Greenland halibut.

The survey estimates within the new, extended area are now used for the tuning data for cod, but with the bottom trawl series split in 2014, as decided at the WKBARFAR 2021 benchmark. For haddock, the new northern area is also included as decided at the WKDEM benchmark in 2020.

There are also other issues with incomplete survey coverage of stocks, e.g. haddock off the Norwegian coast south of Finnmark is not covered in the winter survey and the *S. mentella* survey in the Norwegian Sea does not cover the entire distribution area.

From 2004 onwards, a joint Norwegian-Russian survey has been conducted in August-September. This is a multi-purpose survey termed an "ecosystem survey" because most of the ecosystem is covered; including an acoustic survey for the pelagic species, which is used for capelin assessment, and a bottom trawl survey which includes non-commercial species. The ecosystem survey is now included in both cod and haddock assessments. The survey is also utilized in the assessment of redfish and Greenland halibut.

In 2018, a large area in the eastern Barents Sea was not covered due to technical problems with one vessel, while in 2019, most of the Barents Sea was covered except parts of the International waters and the Northeastern most part. In 2020 the spatial coverage was good, but for COVID-19 related reasons, the survey was less synoptic than usual as the time between the start and end of the survey was 13 weeks while the normal is about 8 weeks (Fig 0.3). Also, one of the vessels used had not previously been used in this type of bottom trawl surveys. The bottom trawl survey indices for cod and haddock from this survey in 2020 were considerably lower than expected, in particular for cod, but it was decided to include them in the assessment. Also, the survey coverage for capelin was not complete at the time assessment and advice had to be provided. Although this did not affect the advice this year, which would have been zero catch even when using the final estimate for the entire area, that may not be the case in future.

It is very important that this survey should be continued with complete spatial coverage and as synoptic as possible. In addition to being the only survey used in capelin assessment and being used in assessment of demersal stocks, it has been shown to be valuable for sampling of synoptic ecosystem information, cover the entire area of fish distribution in the Barents Sea, and provide additional data on geographical distribution of demersal fish, which could prove valuable in future inclusion of more ecosystem information in the fish stock assessments.

The Norwegian coastal survey (NOcoast-Aco-4Q) has in its current design been conducted since 2002. The survey covers the coastal area, including most fjords, and shelf area, including banks, between Kirkenes in northern Norway and Stadt off central Norway. The survey area is divided into seventeen strata, each containing several substrata, and is generally covered by two vessels, which collect acoustic data along defined transects and catch and biological data from both fixed bottom trawl stations and trawl stations identifying acoustic registrations. The coverage of the area has been fairly consistent throughout the time-series. In 2020 bad weather prevented the coverage of three substrata in the southern part of the survey area. Historically the contribution of these areas to the saithe and coastal cod survey index has been low, and it is therefore assumed that the lack of coverage of these areas in the 2020 estimate will not affect the final survey index.

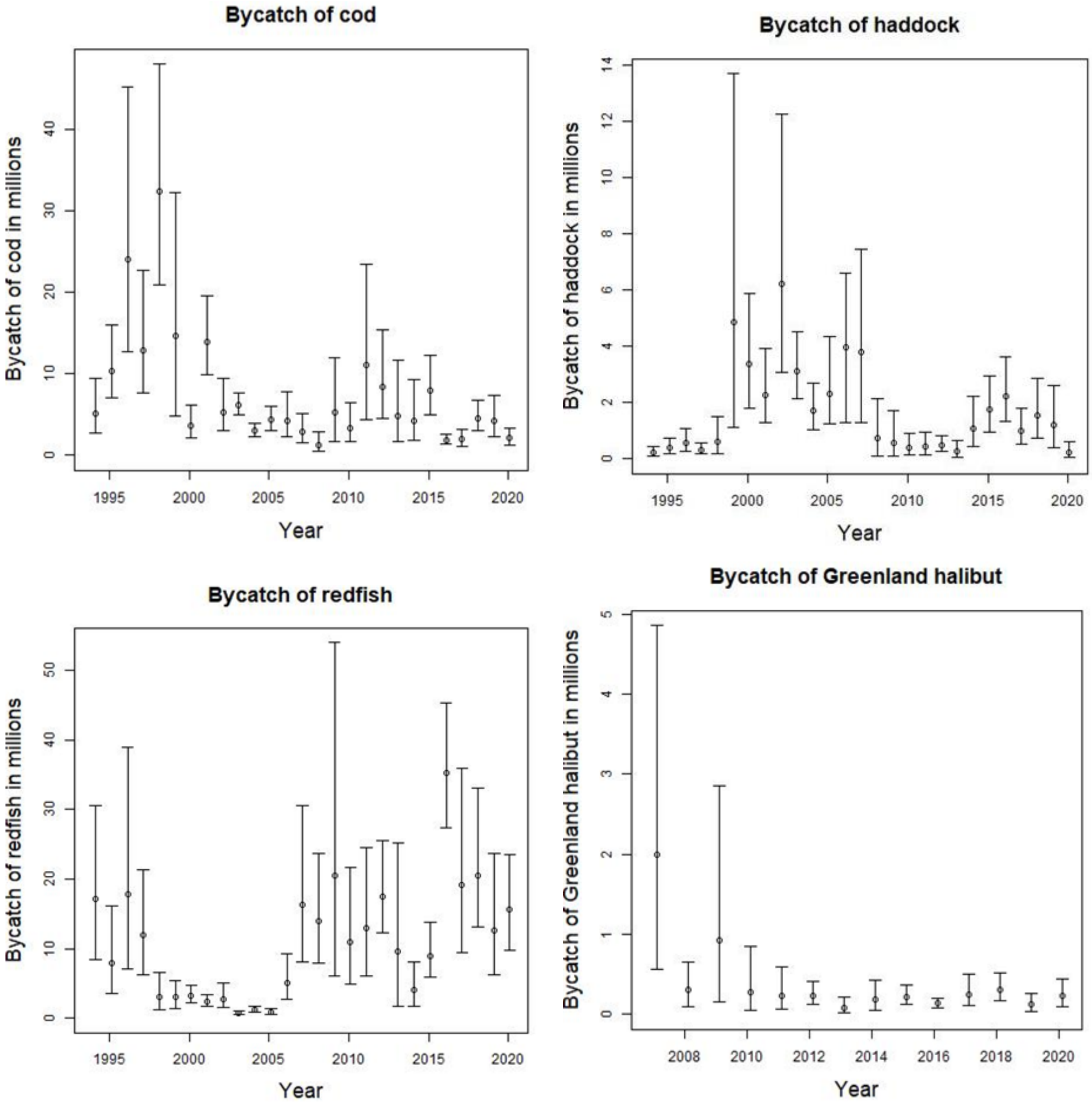

Figure 0.1. Estimated bycatch of cod, haddock, redfish and Greenland halibut in the Barents Sea shrimp fishery. Intervals are 90% confidence intervals.

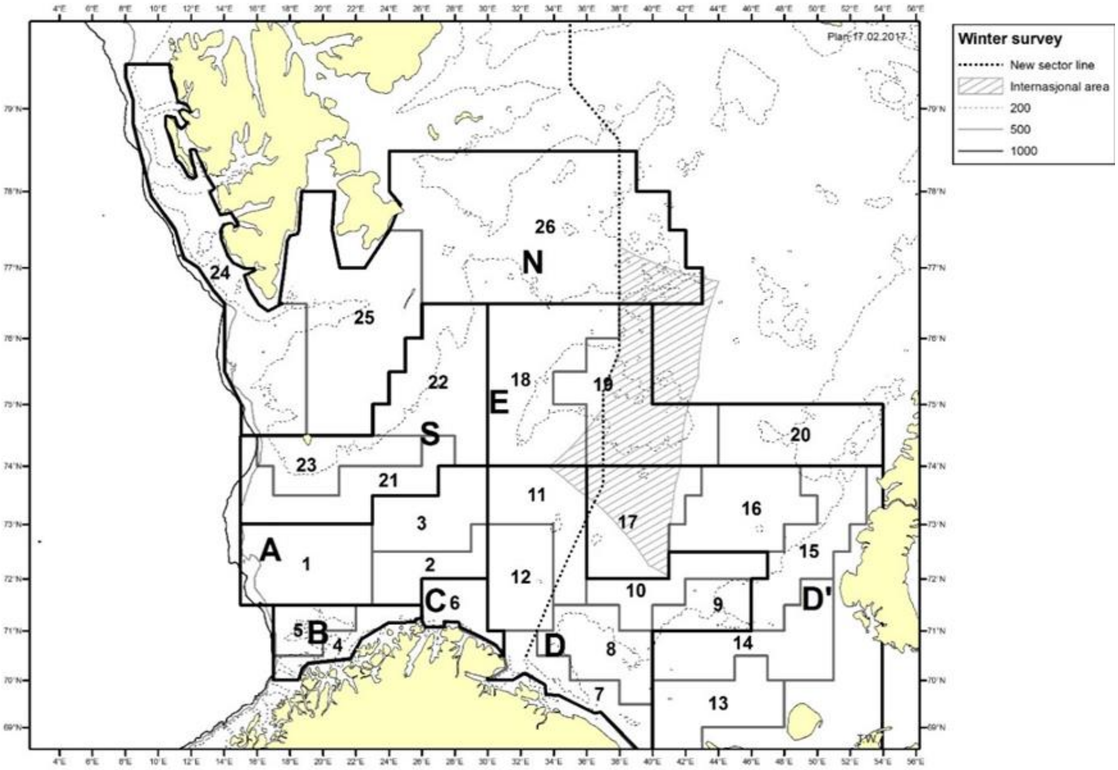

Figure 0.2. Strata (1–26) and main areas (A,B,C,D,D',E and S) used for swept-area estimations and acoustic estimations with StoX. Strata (24–26, main area N) are covered since 2014, and are now included in the standard time-series.

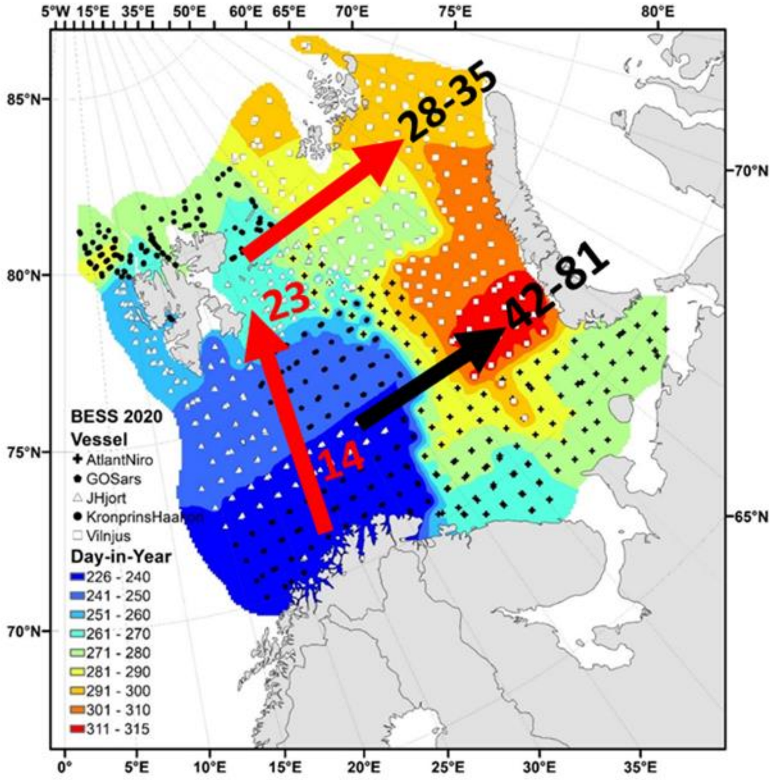

Fig 0.3. Barents Sea Ecosystem Survey (BESS) 2020, area coverage and trawl stations.

After AFWG 2021 minor errors were discovered in the Norwegian SToX dataseries for 2021 for NEA cod and haddock. The advice has been updated and reflects the corrected data. However the values presented in this report are prior to the correction. More detail is given in the relevant stock sections.

1.7 Age reading

In 1992, PINRO, Murmansk and IMR, Bergen began a routine exchange program of cod otoliths in order to validate age readings and ensure consistency in age interpretations (Yaragina *et al.*, 2009b, AFWG 2008, WD20). Later, a similar exchange program has been established for haddock, capelin and *S. mentella* otoliths. Once a year (now every second year, no exchanges of redfish age readers so far) the age readers have come together and evaluated discrepancies, which are seldom more than 1 year, and the results show an improvement over the period, despite still observing discrepancies for cod in the magnitude of 15–30%. An observation that is supported by the results of an NEA cod otolith exchange between Norway, Russia and Germany (Høie *et al.*, 2009; AFWG 2009, WD 6). 100 cod otoliths were read by three Norwegian, two Russian and one German reader, reaching nearly 83% agreement (coefficient of variation 8%). The age reading comparisons of these 100 cod otoliths show that there are no reading biases between readers within each country. However, there is a clear trend of bias between the readers from different countries, Russian age readers assign higher ages than the Norwegian and German age readers. This systematic difference is a source of concern and is also discussed in Yaragina *et al.* (2009b). This seems to be a persistent trend and will be revealed in the following annual otolith and age reader exchanges.

From 2009 onwards, it was decided to have meetings between cod and haddock otolith readers only every second year. The overall percentage agreement for the 2017–2018 exchange was 87.7% for cod (WD 08), which was a little lower than at the previous meeting. The general trend is that the Russian readers assigned slightly higher ages than the Norwegian readers compared to the modal age for age group 7 years and older. The main reason for cod ageing discrepancies between Russian and Norwegian specialists was still a result of different interpretations of the false zones. This can partly be caused by different reading techniques, i.e. IMR reading opaque zones and PINRO reading translucent zones. For haddock, the main reason for discrepancies between PINRO and IMR readers was a different interpretation of the otolith summer structures in the first and second year of fish' life due to false zones. Sometimes discrepancies were caused by a different interpretation of the latest increments that were very thin in some cases.

For both species, the samples collected in autumn appeared to be the hardest to interpret. The main reason for that seems to be difficulties in determining if the marginal increment represents summer (opaque) or winter (translucent) growth.

A positive development is seen for haddock age readings showing that the frequency of a different reading (usually ±1 year) has decreased from above 25% in 1996–1997 to about 10% at present. The discrepancies are always discussed and a final agreement on the exchanged cod and haddock otoliths is achieved for all otoliths at present, except ca. 2–5%. For haddock, the overall percentage agreement for recent data (2017–2018) was 88.1% and the precision CV was 3.0%, the same values for cod totalled 87.7% and 3.7% accordingly and considered to be satisfactory.

The next workshop on cod and haddock otolith reading will be held in May–June of 2021.

As the EU catches only make up a few percent (<10%) of the total, the German and Spanish length and age data do not have a major impact on the assessment of the relevant stocks. But in order to use consistent datasets, regular age-reading comparisons should be made. EU age readers could be invited to the NOR-RUS exchanges and workshops.

To determine the effects of changes in age reading protocols between contemporary and historical practices, randomly chosen cod otolith material from each decade for the period 1940s–1980s has been re-read by experts (Zuykova *et al.,* 2009). Although some year-specific differences in age determination were seen between historical and contemporary readers, there was no significant effect on length-at-age for the historical period. A small systematic bias in the number spawning zones detection was observed, demonstrating that the age at first maturation in the historic material as determined by the contemporary readers is younger than that determined by historical readers. The difference was largest in the first sampled years constituting approximately 0.6 years in 1947 and 1957. Then it decreased with time and was found to be within the range of 0.0–0.28 years in the 1970–1980s. The study also shows that cod otoliths could be used for age and growth studies even after long storage.

For capelin otoliths, there is a very good correspondence between the Norwegian and Russian age readings, with a discrepancy in less than 5% of the otoliths. This was confirmed at the Norwegian-Russian age reading workshop on capelin in October 2011 (WD 13, 2012).

For some of the samples, a very high agreement was reached after the initial reading by the different experts. In other cases, some disagreement was evident after the first reading. After the initial reading, the results were analysed. The otoliths that caused disagreement were read again and discussed among the readers. After discussions about the reasons for disagreement, some readers wanted to change their view on some of the otoliths. When the samples were read once more, the agreement was 95%.

It was concluded that experts from all laboratories normally interpret capelin otoliths equally. Difficult otoliths are sometimes interpreted differently, but these samples are few, and should not cause large problems for common work on capelin biology and stock assessment. All participants noted the great value of conducting joint work on otolith reading, and it was decided to continue the programme of capelin otolith exchange and to involve the labs at Iceland and Newfoundland in the exchange program. Readers from Norway and Russia should continue to meet at Workshops every second year. A capelin age reading Workshop was held in Murmansk in April 2016, and the report from that meeting was presented to the capelin assessment meeting in October 2016. An age reading Workshop for capelin was held in Murmansk in October 2019.

In order to achieve the most accurate age estimates, ICES recommends methods and best practices for age reading of both redfish and Greenland halibut. Still there continue to be differences in opinion between PINRO and IMR regarding age reading methods for these species. It is recommended to start an annual or biannual exchange of otoliths and age reading experts on these species in order to identify the differences in interpretation and to discuss possibilities for a common approach.

The report from the Workshop on Age Reading of Greenland Halibut (WKARGH; ICES CM 2011/ACOM:41) described and evaluated several age reading methods for Greenland Halibut. A second workshop (WKARGH 2) was conducted in August 2016 and worked on further validation on new age reading methods. The workshop recommended that two new methods can be used to provide age estimations for stock assessments. Further, recognizing some bias and low precision in methods, the WKARGH2 recommends that an ageing error matrix or growth curve with error be provided for use in future stock assessments (WKARGH2 report 2016, ICES CM 2016/SSGIEOM:16). WKARGH2 recommends regular inter-lab calibration exercises to improve precision (i.e. exchange of digital images between readers for each method and between methods). The new age readings are not comparable with older data or the Russian age readings, and the new methods show that the species is more slow-growing and vulnerable than the previous age readings suggest. AFWG suggests that Russian and Norwegian scientists and age readers meet to work out issues of disagreements on Greenland halibut aging.

From 2009 onwards, an exchange of *Sebastes mentella* otoliths is conducted annually between the Norwegian and Russian laboratories (see section 6.2.2). In 2011 ICES/PGCCDBS identified differences in the interpretation of age structure by different national laboratories and recommended that international exchanges of otoliths be conducted (ICES C.M. 2011/ACOM:40). The work was conducted during 2011 (Heggebakken, 2011) with participation from Canada, Iceland, Norway, Poland and Spain. Unfortunately, Russia did not respond to the invitation to participate. The agreement in age determination was 79.2% (with allowance for ±1 years) for all ages combined, but 38.6% when only fish older than 20 years were considered. It is recommended that 1) future exchanges be conducted every 3–5 years, 2) that these should primarily focus on 20+-year-old fish and 3) that Russian scientists contribute to future exchanges. A meeting between *S. mentella* age readers from Norway and Russia was held in 2013. Otolith exchanges took place in 2014. It is recommended that such meetings and otolith exchanges be conducted regularly in future.

1.8 Assessment method issues

For coastal cod, the benchmark has resulted in a split into two stocks. For the northern (north of 67 degrees) part there is now a SAM assessment model. However there is no Fmsy (since we have no data above B_{lim}), and there is a need for a rebuilding plan for this stock. In addition, since this is the first assessment model it is likely that there will be a need for a revision once we accumulate some years' experience running the model. The southern (between 62 and 67 degrees north) now gives advice based on a 2-over-3 rule. A surplus production, based on the reference fleet CPUE, was developed. However, the CPUE time-series was too short to adequately tune the model. This should be investigated further as the time-series is extended, with a view to an eventual benchmark and adoption of the production model for assessment purposes.

Work is in progress on revising the capelin assessment methodologies, with a planned benchmark (in conjunction with Iceland) in 2022. Greenland halibut also has a benchmark (again jointly with Iceland) in 2022, planned to be followed by an HCR evaluation. For Greenland halibut the target F is the key issue, with the previous F_{pa} being rejected by the Advice Drafting Group. A revised F_{pa} has therefore been submitted.

1.9 Environmental information included in the advice of NEA cod

For the fourteenth time, environmental information has been applied in the advice from AFWG. In this year's assessment ecosystem information was directly used in the projection of NEA cod. A combination of regression models, which is based on both climate and stock parameters, were used for the prediction of recruitment-at-age 3, see section 1.11.4.

In addition, the temperature is part of the NEA cod consumption calculations that goes into the historical back-calculations of the amount of cod, haddock, and capelin eaten by cod.

1.10 Proposals for status of assessments in 2021–2022

For anglerfish there is currently no advice, however following the benchmark in 2018 we are now in a position to conduct an assessment and provide advice if requested to do so. Greenland halibut is assessed this year and will be benchmarked next year in time for the next advice in 2023, the two redfish stocks will get an update assessment in 2022.

Table 0.1. Age and length sampling by Norway of commercial catches in 2008–2019. Number of samples and average number of fish per sample. Also, number of age samples and aged individuals per 1000 t caught. For comparison, also the EU DCF requirements are shown.

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
NEA-cod + coastal cod												
	2008	336	2526	51263		464	16026	196067	12.9	2.4	81.7	125
	2009	272	2669	53350		417	14170	224816	11.9	1.9	63.0	125
	2010	175	2542	39733		338	7671	263816	9.6	1.3	29.1	125
	2011	273	2305	46227		434	10043	331535	7.0	1.3	30.3	125
	2012	356	3132	57954		618	14710	363207	8.6	1.7	40.5	125
	2013	266	2917	81583	84	1275	13940	464258	6.3	2.7	30.0	125
	2014	556	2063	254627	306	1170	14815	465554	4.4	2.5	31.8	125
	2015	498	1654	130514	89	1392	16500	413741	4.0	3.4	39.9	125
	2016	482	2500	91590	401	1398	17027	403907	6.2	3.5	42.2	125
	2017	413	2615	91366	348	1458	15471	408423	6.4	3.6	37.9	125
	2018	873	3163	122788	346	1545	15535	369897	8.6	4.2	42.0	125
	2019	842	3093	135375	337	1457	12519	322233	9.6	4.5	38.9	125
	2020	389	1869	53587	259	653	12431	334773	5.6	2.0	37.1	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
NEA-haddock												
	2008	285	2177	45038		281	9474	72553	30.0	3.9	130.6	125
	2009	233	2255	41481		206	6010	104882	21.5	2.0	57.3	125
	2010	154	2155	38045		232	5458	123517	17.4	1.9	44.2	125
	2011	227	2028	39663		312	7225	158293	12.8	2.0	45.6	125
	2012	258	2609	47995		386	8191	159008	16.4	2.4	51.5	125
	2013	89	2142	62193	86	965	5718	99127	21.6	9.7	57.7	125
	2014	425	1479	114560	126	825	7297	91333	16.2	9.0	79.9	125
	2015	397	1380	76574	47	967	8394	95086	14.5	10.2	88.3	125
	2016	237	1986	47032	208	391	8202	108718	18.3	3.6	75.4	125
	2017	215	2108	57461	150	1084	8805	113206	18.6	9.6	77.8	125
	2018	536	2435	85303	130	1088	8397	93839	25.9	11.6	89.5	125
	2019	497	2269	83378	123	1003	7652	93860	24.2	10.7	81.5	125
	2020	142	1055	32009	70	342	6589	88108	12.0	3.9	74.8	125
NEA-saithe												
	2008	252	1327	19419		160	5262	165998	8.0	1.0	31.7	125
	2009	182	1337	13354		113	2981	144570	9.2	0.8	20.6	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2010	138	1316	15998		151	3667	174544	7.5	0.9	21.0	125
	2011	152	1210	17412		215	4843	143314	8.4	1.5	33.8	125
	2012	209	1474	19191		204	4113	143104	10.3	1.4	28.7	125
	2013	87	1570	69469	69	788	5507	111981	14.0	7.0	49.2	125
	2014	192	697	54365	94	575	5390	115880	6.0	5.0	46.5	125
	2015	206	839	69375	43	614	6484	114830	7.3	5.3	56.5	125
	2016	226	1448	52376	151	737	7278	121710	11.9	6.1	59.8	125
	2017	195	1416	42812	141	788	6348	128651	11.0	6.1	49.3	125
	2018	388	1665	43938	148	823	6937	162454	10.2	5.1	42.7	125
	2019	380	1629	43503	136	817	6552	144133	11.3	5.7	45.5	125
	2020											
S. Norvegicus												
	2008	104	1093	18305		98	2281	6180	176.9	15.9	369.1	125
	2009	66	1131	17386		96	2302	6215	182.0	15.4	370.4	125
	2010	49	1050	19339		97	2164	6515	161.2	14.9	332.2	125
	2011	75	1064	16347		106	2310	4645	229.1	22.8	497.3	125
	2012	78	993	12994		76	1297	4250	39.1	3.1	56.7	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2013	35	654	627	17	74	1122	4244	154.1	17.4	264.4	125
	2014	24	66	919	24	24	365	3053	21.6	7.9	119.6	125
	2015	28	121	3497	22	405	1281	2492	48.6	162.5	514.0	125
	2016	54	642	2376	36	517	1585	4606	139.4	112.2	344.1	125
	2017	69	695	6177	44	571	1633	3354	207.2	170.2	486.9	125
	2018	64	778	7354	32	629	1252	4287	181.5	146.7	292.0	125
	2019	47	810	9828	17	206	958	5667	142.9	36.4	173.8	125
	2020	47	761	9631	15	172	0	5902	128.9	29.1	0	
*S. mentella ***												
	2008	13	178	1038		0	0	2214	80.4	0.0	0.0	125
	2009	12	319	1841		2	40	2567	124.3	0.8	15.6	125
	2010	11	284	3664		11	320	2245	126.5	4.9	142.5	125
	2011	9	255	3210		11	298	2690	94.8	4.1	110.8	125
	2012	13	166	2187		13	241	2098	79.1	6.2	114.9	125
	2013	14	184	383	5	13	390	1361	135.2	9.6	286.6	125
	2014	11	36	4664	12	49	5	13402	2.7	3.7	0.4	125
	2015	21	166	23794	10	21	184	19700	8.4	1.1	9.3	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2016	23	285	5470	9	22	169	19083	15.0	1.2	8.9	125
	2017	30	256	3196	24	211	24	17280	14.8	12.2	1.4	125
	2018	39	409	8782	20	364	25	19287	21.2	18.9	1.3	125
	2019	21	345	5884	5	24	0	24141	14.3	1.0	0	125
	2020	29	475	10796	8	65	0	33997	14.0	1.9	0	
Greenland halibut												
	2008	53	580	9074		0	0	7394	78.4	0.0	0.0	125
	2009	36	922	12853		0	0	8446	109.2	0.0	0.0	125
	2010	26	519	8395		0	0	7685	67.5	0.0	0.0	125
	2011	29	463	8204		0	0	8273	56.0	0.0	0.0	125
	2012	34	610	7716		0	0	10074	60.6	0.0	0.0	125
	2013	26	597	4930		0	0	12613	47.3	0.0	0.0	125
	2014	33	236	2559	10	0	0	10876	21.7	0.0	0.0	125
	2015	31	273	8769	11	0	0	10704	25.5	0.0	0.0	125
	2016	83	384	2304	60	0	0	12573	30.5	0.0	0.0	125
	2017	67	556	10022	43	317	0	13194	42.1	24.0	0.0	125
	2018	96	582	11720	63	342	0	14876	39.1	23.0	0.0	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2019	61	394	9286	47	80	0	14813	26.6	5.4	0.0	125
	2020	80	429	9110	52	80	0	14532	29.5	5.5	0.0	
*Anglerfish (Monk)******												
	2013	8	55	1551	0	0	0	2988	18	36.5	0.0	125
	2014	8	33	836	0	0	0	1655	19	18.1	24.8	125
	2015	8	74	2054	0	0	0	933	82	35.3	0.0	125
	2016	8	57	1339	0	0	0	1355	41	17.9	0.0	125
	2017	8	88	3604	0	0	0	1473	59	23.8	0.7	125
	2018	8	94	3233	0	0	0	1884	49	24.4	1.1	125
	2019	8	68	3223	0	0	0	2750	24	22.5	0.0	125
	2020	8	89	4129	0	0	0	2258	39	0	0.0	
Capelin												
	2008	4	3	150		0	0	5000	0.6	0.0	0.0	125
	2009	18	97	7039		39	1039	233000	0.4	0.2	4.5	125
	2010	75	230	6191		47	1291	246000	0.9	0.2	5.2	125
	2011	115	315	8346		48	1313	273000	1.2	0.2	4.8	125
	2012	84	308	9337		29	843	181328	1.7	0.2	4.6	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of unique vessels (***)	No of age samples	No of aged individuals	Landing tonnes	Length-samples per 1000 t	Age samples per 1000 t	Aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2013	12	213	12215	47	47	773	156340	1.4	0.3	4.9	125
	2014	27	113	9054	1	8	1086	40021	2.8	0.2	27.1	125
	2015	65	722	83776	65	722	5393	71435	10.1	10.1	75.5	125
	2016	7	27	1863	7	27	649					125
	2017	21	43	2294	14	25	305					125
	2018	68	207	15022	33	76	823	123461	1.7	0.6	6.7	125
	2019	4	26	260	2	13	0	0				125
	2020							0				

***) In addition to age the otoliths are also used for identification of coastal cod.**

****) Age samples from surveys with commercial trawl come in addition.**

*****) From 2013 No of unique vessels are split by length and age samples.**

******) Only from large meshed gillnets as basis for assessment**

Table 0.2. Age and length sampling by Russia of commercial catches and age sampling of surveys in 2008–2020. Also length-measured individuals and aged individuals per 1000 t caught. For comparison also the EU DCF requirements are shown.

Stock	Year	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
NEA-cod*										
	2008	380592	3097	7565	10662	190225	2001	16.3	56.0	125
	2009	178038	1075	7426	8501	229291	776	4.7	37.1	125
	2010	126502	1828	7670	9498	267547	473	6.8	35.5	125
	2011	122623	2376	5783	8159	310326	395	7.7	26.3	125
	2012***	140028	2040	7742	9782	329943	424	6.2	29.6	125
	2013	131455	1999	8103	10102	432314	304	4.6	23.4	125
	2014	114538	3110	7154	10264	433479	264	7.2	23.7	125
	2015***	105721	2486	6095	8581	381188	277	6.5	22.5	125
	2016	158006	5090	2704	7794	394107	401	12.9	19.8	125
	2017	161192	4918	6121	11039	396195	407	12.4	27.9	125
	2018	157048	3129	1982	5111	340364	461	9.2	15.0	125
	2019***	83018	2093	3737	5830	316813	262	6.6	18.4	125
	2020***	112950	3105	3858	6963	312683	361	9.9	22.3	125

Stock	Year	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
NEA-haddock										
	2008	216959	2498	5677	8175	68792	3154	36.3	118.8	125
	2009	43254	489	5421	5910	85514	506	5.7	69.1	125
	2010	85445	834	5060	5894	111372	767	7.5	52.9	125
	2011	61990	1570	3584	5154	139912	443	11.2	36.8	125
	2012***	87880	1545	5034	6579	143886	611	10.7	45.7	125
	2013	42927	1205	4021	5226	85668	501	14.1	61.0	125
	2014	45447	899	3796	4695	78725	577	11.4	59.6	125
	2015***	31009	914	2972	3886	91864	338	9.9	42.3	125
	2016	55598	2691	1884	4575	115710	480	23.3	39.5	125
	2017	74297	3554	2614	6168	106714	696	33.3	57.8	125
	2018	61360	2274	1136	3410	90486	678	25.1	37.7	125
	2019***	44728	1923	1778	3701	76125	588	25.3	48.6	125
	2020***	69301	2356	1575	3931	89030	778	26.5	44.2	125
NEA-saithe										
	2008	8865	479	175	654	11577	766	41.4	56.5	125
	2009	5279	7	68	75	11899	444	0.6	6.3	125

Stock	Year	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2010	422	112	249	361	14664	29	7.6	24.6	125
	2011	88	9	27	36	10007	9	0.9	3.6	125
	2012	4062	145	104	249	13607	299	10.7	18.3	125
	2013	17124	402	76	478	14796	1157	27.2	32.3	125
	2014	2302	278	26	304	12396	186	22.4	24.5	125
	2015	1505	104	131	235	13181	114	7.9	17.8	125
	2016	4233	272	16	288	15203	278	17.9	18.9	125
	2017	1762	228	110	338	14551	121	15.7	23.2	125
	2018	4758	454	9	463	14171	336	32.0	32.7	125
	2019	4528	94	0	94	13990	324	6.7	6.7	125
	2020	83	17	96	113	14082	6	1.2	8.0	125
S. marinus (norvegicus)										
	2008	1196	45	17	62	749	1597	60.1	82.8	125
	2009	241	2	27	29	698	345	2.9	41.5	125
	2010	486	25	199	224	806	603	31.0	277.9	125
	2011	885	77	62	139	919	963	83.8	151.3	125
	2012	1564	58	54	112	681	2297	85.2	164.5	125

Stock	Year	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2013	770	22	142	164	797	966	27.6	205.8	125
	2014	589	25	33	58	806	731	31.0	72.0	125
	2015	120		20	20	664	181	0.0	30.1	125
	2016	1113	147	34	181	776	1434	189.4	233.2	125
	2017	1426	86	101	187	1131	1261	76.0	165.3	125
	2018	1877	30	21	51	1546	1214	19.4	33.0	125
	2019	1015	150	0	150	1804	563	83.2	83.2	125
	2020	2107	47	31	78	2492	846	18.9	31.3	125
S. mentella										
	2008	21446	471	3379	3850	7117	3013	66.2	541.0	125
	2009	29435	761	1447	2208	3843	7659	198.0	574.6	125
	2010	2776	100	2295	2395	6414	433	15.6	373.4	125
	2011	917	7	640	647	5037	182	1.4	128.4	125
	2012	7802	422	1146	1568	4101	1902	102.9	382.3	125
	2013	19092	1253	1625	2878	3677	5192	340.8	782.7	125
	2014	817	25	1297	1322	1704	479	14.7	775.8	125
	2015	771		1818	1818	1142	675	0.0	1591.9	125

Stock	Year	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2016	27765	1076	85	1161	8419	3298	127.8	137.9	125
	2017	958	99	1000	1099	4952	193	20.0	221.9	125
	2018	21004	845	39	884	10497	2001	80.5	84.2	125
	2019	6881	400	469	869	13164	523	30.4	66.0	125
	2020	8718	340	612	952	13997	623	24.3	68.0	125
Greenland halibut										
	2008	106411	1519	3366	4885	5294	20100	286.9	922.7	125
	2009	77554	819	2282	3101	3335	23255	245.6	929.8	125
	2010	32090	416	2784	3200	6888	4659	60.4	464.6	125
	2011	9892	115	1541	1656	7053	1403	16.3	234.8	125
	2012	82943	2140	2506	4646	10041	8260	213.1	462.7	125
	2013	12608	555	2756	3311	10310	1223	53.8	321.1	125
	2014	24346	633	2106	2739	10061	2420	62.9	272.2	125
	2015	22116	575	2489	3064	12953	1707	44.4	236.5	125
	2016	11818	574	221	795	10576	1117	54.3	75.2	125
	2017	24061	1205	1579	2784	10713	2246	112.5	259.9	125
	2018	21893	954	308	1262	12072	1814	79.0	104.5	125

Stock	Year	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2019	861	125	1552	1677	12198	71	10.2	137.5	125
	2020	1387	165	1853	2018	12266	113	13.5	164.5	125
Capelin										
	2008**	82625	1644	2341	3985	5000	16525	328.8	797.0	125
	2009	94541	900	2511	3411	73000	1295	12.3	46.7	125
	2010	67265	1072	4043	5115	77000	874	13.9	66.4	125
	2011	63784	1273	2271	3544	86531	737	14.7	41.0	125
	2012	20023	1130	1783	2913	68182	294	16.6	42.7	125
	2013	54708	1565	1007	2572	60413	906	25.9	42.6	125
	2014	13206	850	1249	2099	25720	513	33.0	81.6	125
	2015	27200	1000	1004	2004	115				125
	2016	8669	3954	1047	5001	0				125
	2017			4115	4115	6				125
	2018	14491	250	1050	1300	65934	220	3.8	19.7	125
	2019			1498	1498	34				125
	2020			1245	1245	19				125

***) In addition also used long-term mean age–length keys.**

****) Age samples from surveys with commercial trawl come in addition.**

*****) In addition used samples from Russian vessels, sampled by the Norwegian Coast Guard in 2012, 2015, 2019 and 2020.**

Table 0.3. Age and length sampling by Spain[5] of commercial catches and length sampling of surveys in 2008–2020. Also length-measured individuals and aged individuals per 1000 t caught. For comparison also the EU DCF requirements are shown.

Stock	Year	No of vessels	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
NEA-cod											
	2008	2	10108	610		610	9658	1047	63	63	125
	2009	2	8733	1834		1834	12013	727	153	153	125
	2010	2	28297	1735		1735	12657	2236	137	137	125
	2011	2	11633	964		964	13291	875	73	73	125
	2012	2	9849	998		998	12814	769	78	78	125
	2013	2	30295	2381		2381	15041	2014	158	158	125
	2014	2	27828	2306		2306	16479	1689	140	140	125

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[5] The onshore and the at-sea sampling programs coordinated by the IEO were suspended in most of 2020, due notably to administrative problems and to a lesser extend to COVID-19. This affected all stocks. Both sampling programmes are hired by IEO through call for tenders addressed to specialized companies. The public tender launched in 2019 (to start in 2020) was declared void, having to be re-launched again. This second launch was delayed as a result of the paralysis of public activity during the state of alarm due to the COVID-19 pandemic, and could only be reopened in June-July. Given that the process of awarding the contract by public tender takes three-four months under normal conditions, it was finally resolved in December 2020 and signed in January 2021. Since then all activities have been resumed. The sampling to obtain the biological variables of the population (mainly reproduction and growth) is normally carried out in the IEO laboratories. This activity has also faced problems in 2020. On the one hand the administrative and financial difficulties of the IEO prevented the purchasing of samples in the market and on the other hand the three months closure of the labs (15 March to 21 June) due to COVID-19 did not allow for a normal activity.

Stock	Year	No of vessels	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2015	2	18568	1445		1445	18772	989	77	77	125
	2016	2	27937	1246		1246	14640	1908	85	85	125
	2017	2	33984	2018		2018	14414	2358	140	140	125
	2018	1	25933	911		911	14415	1799	63	63	125
	2019	1	5781	1117		1117	13939	415	80	80	125
	2020						11403				125
NEA-haddock*											
	2009	1	2561				240				
	2010	1	3243				379				
	2011	1	1796				408				
	2012	2	3198				647				
	2013	1	660				413				
	2014	1	2460				370				
	2015	1	702				418				
	2016	2	701				357				
	2017	1	710				156				
	2018	1	154				169				

Stock	Year	No of vessels	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2019						280				
	2020						45				
NEA-saithe											
	2009	1	123				2				
	2013	1					5				
	2014	1					13				
	2015	1					33				
	2016						25				
	2017						85				
	2018						60				
	2019						199				
	2020						0				
S. mentella											
	2008**	1	2275	28			987	2304	28	0	125
	2011*	1	86				1237				
	2012**	2	11579	476			1612	7183	295	0	125
	2014**	1	6177				1146	5390			

Stock	Year	No of vessels	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2015**	1	6117				2371	2580			
	2016**	1	11806				3133	3768			
	2017**	1	5015				2624	1911			
	2018**	1	11638				2399	4851			
	2019**	1	11952				1908	6265			
	2020**						737				
	2018		21004	845	39	884	10497	2001	80.5	84.2	125
	2019		6881	400	469	869	13164	523	30.4	66.0	125
	2020		8718	340	612	952	13997	623	24.3	68.0	125
Greenland halibut											
	2008	2	11662				112	103826			
	2009	1	3383				210	16143			
	2010	1	5783				182	31800			
	2011	1	8541				169	50600			
	2012	1	4809				186	25907			
	2013	1	11988				190	63019			
	2014	1	12002				206	58262			

Stock	Year	No of vessels	No of length-measured individuals (commercial catches)	No of aged individuals (commercial catches)	No of aged individuals (surveys)	Total no of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Aged individuals per 1000 t (commercial catches)	Total aged individuals per 1000 t	EU DCF for comparison per 1000 t
	2015	1	17552				111	158126			
	2016	1	15031				218	68837			
	2017										
	2018										
	2019	1					49				
	2020						96				

*) Sampling from bycatch in cod fishery.

**) Sampling from pelagic redfish fishery.

***) Sampling from Spanish Greenland halibut survey.

Table 0.4. Age and length sampling by Germany of commercial catches and age sampling of surveys in 2008–2020. Also length-measured individuals and aged individuals per 1000 t caught. For comparison also the EU DCF requirements are shown.

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Age-sampled individuals per 1000 t	EU DCF for comparison
NEA cod									
	2008	5	3	65800	2033	4955	13280	410	125
	2009	5	2	43107	2419	8585	5021	282	125
	2010	5	2	51923	3075	8442	6151	364	125
	2011	4	1	7318	769	4621	1584	166	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Age-sampled individuals per 1000 t	EU DCF for comparison
	2012	4	2	16315	1924	8500	1919	226	125
	2013	4	2	29281	2043	7939	3688	257	125
	2014	4	1	23137	1291	6225	3717	207	125
	2015	4	1	39335	886	6427	6120	138	125
	2016	3	1	22109	1060	6636	3332	160	125
	2017	4	1	19942	785	5969	3341	132	125
	2018	4	2	43371	2283	7774	5579	294	125
	2019	2	1	17954	1444	8535	2104	169	125
	2020	2	1	21716	1021	9786	2219	104	125
NEA haddock									
	2008	5	3	5548	442	535	10370	826	125
	2009	5	2	23348	958	1957	11931	490	125
	2010	5	2	54704	1039	3539	15457	294	125
	2011	4	1	1925	160	1724	1117	93	125
	2012	4	2	4088	502	1111	3680	452	125
	2013	4	1	7040	478	501	14052	954	125
	2014	4	1	3113	261	340	9156	768	125
	2015	4	1	616	325	124	4968	2621	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Age-sampled individuals per 1000 t	EU DCF for comparison
	2016	3	1	4807	544	170	28276	3200	125
	2017	4	1	3464	527	155	22348	3400	125
	2018	4	2	4345	497	391	11113	1271	125
	2019	2	1	5031	393	208	24188	1889	125
	2020	2	1	2979	356	283	10527	1258	125
NEA saithe									
	2008	5	3	10210	605	2263	4512	267	125
	2009	6	2	8667	1091	2021	4288	540	125
	2010	7	2	11424	1001	1592	7176	629	125
	2011	4	1	4863	530	1371	3547	387	125
	2012	7	2	14193	1202	1371	10356	877	125
	2013	4	1	1190	414	1212	982	342	125
	2014	3	1	25	0	259	97	0	125
	2015	4	0	0	0	424	0	0	125
	2016	3	1	13981	909	951	14701	956	125
	2017	4	1	15734	603	1154	13634	523	125
	2018	4	1	19718	473	1651	11943	286	125
	2019	2	1	9465	1521	1387	6824	1097	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Age-sampled individuals per 1000 t	EU DCF for comparison
	2020	2	1	11900	745	1573	7565	474	125
Redfish									
	2008	5	3	330	0	46	7174	0	125
	2009	8	2	0	0	100	0	0	125
	2010	6	2	0	0	52	0	0	125
	2011	6	1	7937	0	844	9404	0	125
	2012	9	2	4036	0	584	6911	0	125
	2013	4	1	1315	0	81	16235	0	125
	2014	4	1	571	0	451	1266	0	125
	2015	4	1	76	0	266	286	0	125
	2016	3	1	6095	0	497	12264	0	125
	2017	4	1	977	0	770	1269	0	125
	2018	4	2	3438	0	2508	1371	0	125
	2019	2	1	8958	0	1741	5145	0	125
	2020	3	1	4248	0	1998	2126	0	125
Greenland halibut									
	2008	5	2	0	0	5	0	0	125
	2009	3	2	0	0	19	0	0	125

Stock	Year	No of unique vessels	No of length samples	No of length-measured individuals	No of aged individuals	Landings tonnes	Length-measured individuals per 1000 t	Age-sampled individuals per 1000 t	EU DCF for comparison
	2010	2	2	0	0	14	0	0	125
	2011	3	1	0	0	81	0	0	125
	2012	4	2	0	0	40	0	0	125
	2013	3	1	1298	0	49	26544	0	125
	2014	4	1	1076	0	34	31647	0	125
	2015	4	1	658	0	32	20563	0	125
	2016	3	1	365	0	9	40556	0	125
	2017	4	1	0	0	21	0	0	125
	2018	4	1	257	0	52	4942	0	125
	2019	2	1	511	0	45	11356	0	125
	2020	2	1	305	0	74	4122	0	125

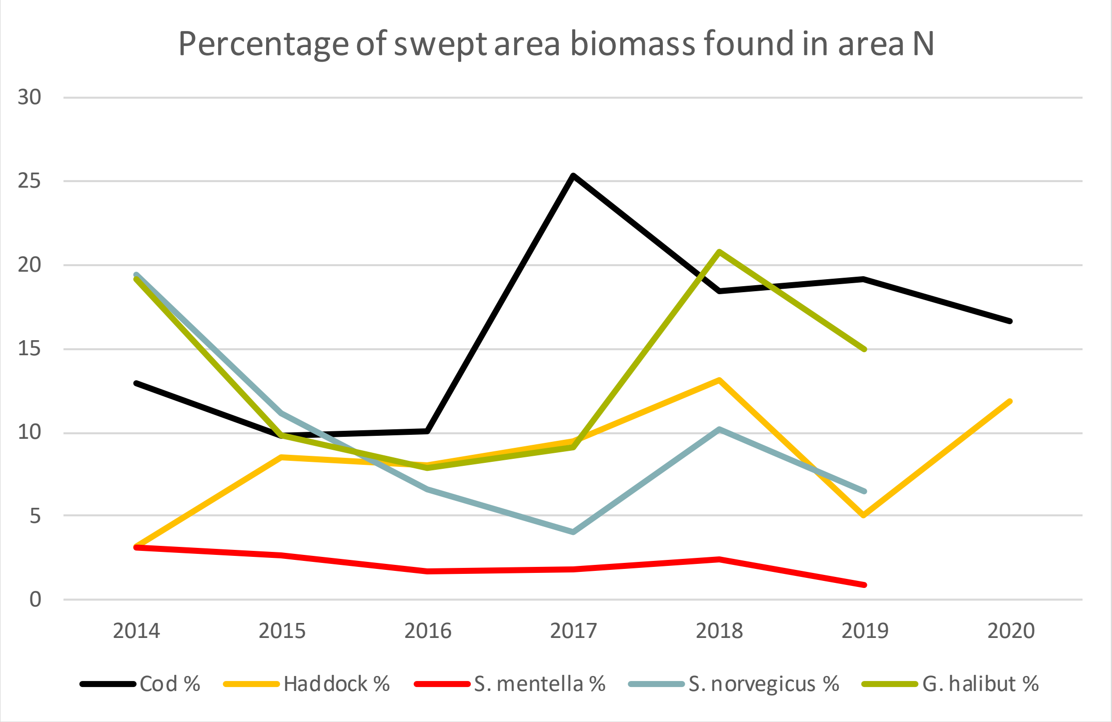


Figure 0.4. Proportion of swept-area biomass in the Joint winter survey found in the new northern area (N), by year and species. For 2020 the indices for redfish and Greenland halibut have not yet been calculated.

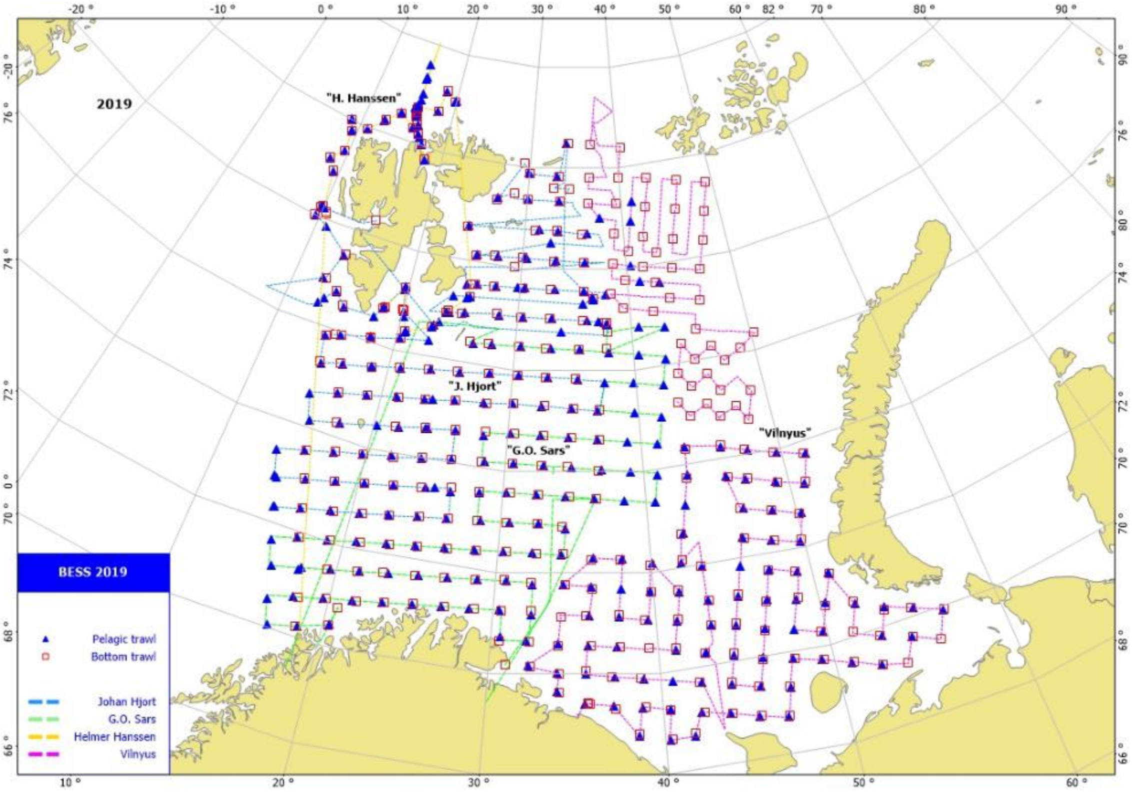


Figure 0.5. Barents Sea Ecosystem survey (BESS) 2019, realized vessel tracks with pelagic and bottom trawl sampling stations.

1.11 Ecosystem information

The aim of this section is to collect important ecosystem information influencing the assessment of fish stocks handled by AFWG. In general, such information is collected and updated by the ICES WGIBAR group, here we only provide information that is directly relevant to the assessment of the AFWG stocks as well as information that is updated after the 2021 WGIBAR report was finished.

1.11.1 0-group abundance

The recruitment of the Barents Sea fish species measured as 0-group has shown a large year-to-year variability. The most important reasons for this variability are variations in the spawning biomass, hydrographic conditions, changes in circulation pattern, food availability and predator abundance, and distribution. In 2018 and 2020, 0-group indices were strongly affected by incomplete area coverage in the Barents Sea, but attempts have been made to correct for this (Prozorkevitch and Van der Meeren, 2021).

1.11.2 Consumption, natural mortality, and growth

Cod is the most important predator among fish species in the Barents Sea. It feeds on a wide range of prey, including larger zooplankton, most available fish species, including own juveniles and shrimp (Tables 1.1–1.2). Cod prefer capelin as a prey, and fluctuations of the capelin stock may have a strong effect on growth, maturation, and fecundity of cod, as well as on cod recruitment because of cannibalism. The role of euphausiids for cod feeding increases in the years when capelin stock is at a low level (Ponomarenko and Yaragina, 1990). Also, according to Ponomarenko (1973; 1984), interannual changes of euphausiid abundance are important for the survival rate of cod during the first year of life.

The food consumption by NEA cod in 1984–2020, based on data from the Joint Russian-Norwegian stomach content database, is presented in Tables 1.1–1.2. The Norwegian (IMR) calculations are based on the method described by Bogstad and Mehl (1997). The main prey items in 2020 were capelin (about 2 million tonnes), followed by krill, amphipods and polar cod of which the consumption was about 500 thousand tonnes of each category. Shrimp, long rough dab, cod, herring, haddock and snow crab were all less important (between 90 and 180 thousand tonnes for each species). The increase in consumption of polar cod from 2019 to 2020 is consistent with the markedly increased abundance of this species. The decrease in consumption of young cod and haddock is consistent with the low abundance of age 0 and 1 of these species in 2020. The consumption calculations made by The consumption per cod by cod age-groups are shown in Tables 1.3–1.4 (IMR and PINRO estimates), while the proportion of cod and haddock in the diet by cod age-group (IMR estimates) is given in Tables 1.5 and Table 1.6. IMR show that the total consumption by age 1 and older cod in 2020 was 5.2 million tonnes. For technical reasons, PINRO estimates (Table 1.2 and 1.4) were not updated this year.

Growth of cod as calculated from weight at age in the winter survey has shown a declining trend in the last years, but this decline has now been halted, and for age 6 and older the trend seems to have been reversed. However, weight at age 3 and 4 was the lowest in this survey series from 1994–present, and for ages 3 and 6–8 it was among the three lowest values in the same period. The trends in consumption per cod by age-group in recent years seem consistent with the trends in size at age.

Weight at age in the Lofoten survey was stable from 2019 to 2021, while weight-at-age in catch of cod decreased slightly for ages 3–9 from 2018–2020.

How is the outlook for cod food abundance in 2021? Total abundance of pelagic fish stocks is at an average level, for the most important pelagic species, capelin, the abundance of immature capelin in 2020 was intermediate due to a very strong 2019 year class (the strongest since 2000). Polar cod abundance in 2020 was close to the highest value observed in the 35-year time-series due to the 2019 year class being the strongest ever observed. However, the herring abundance in the Barents Sea is now low as the strong 2016 year class has left the Barents Sea and the following year classes, which still are found in the Barents Sea, are weak. Also, age 1–2 cod and haddock abundance in 2021 is low. On the positive side, shrimp abundance is high, while the abundance of other prey species is around average. Altogether there seems to be reasonable consistency between growth, consumption and feeding data.

One direct application for the management of results from the trophic investigations in the Barents Sea is the inclusion of predator's consumption into fish stock assessment. Predation on cod and haddock by cod has since 1995 been included in the assessment of these two species. These data, summarized in Tables 1.1, 1.3 and 1.5, are used for estimation of cod and haddock consumed by cod and further for estimation of their natural mortality within the SAM model (see sections 3.3.3 and 4.5.5). The average natural mortality for the last years is used as predicted M for the coming years for cod and haddock.

Cod consumption was used in capelin assessment for the first time in 1990, to account for natural mortality due to cod predation on mature capelin in the period January–March (Bogstad and Gjøsæter, 1994). This methodology has been developed further using the Bifrost and CapTool models (Gjøsæter *et al.*, 2002; Tjelmeland, 2005; ICES CM 2009/ACOM:34). CapTool is a tool (in Excel with @RISK) for implementing results from Bifrost in the short term (half-year) prognosis used for determining the quota.

In recent years the abundance of large cod and haddock has been very high, and it is still at a high level for cod. There are a limited number of predators on such large fish. As predation is likely to be a major source of natural mortality, it could thus be considered whether the natural mortality in older age groups should be reduced in such a situation. The assumption of reduced natural mortality on older cod was explored by IBPCOD 2017, but no evidence of this was found based on available catch and survey data. To investigate this further, analyses on predator consumption and biomass flow at higher trophic levels like those done by Bogstad *et al.* (2000) should be updated, and such work is ongoing for marine mammals. For cod, in particular, the fishing mortality since 2008 has been so much lower than before that the relative impact of the natural mortality on the survival of older fish has increased considerably.

The amount of commercially important prey consumed by other fish predators (haddock, Greenland halibut, long rough dab, and thorny skate), has also been calculated (Dolgov *et al.*, 2007), but these consumption estimates have not been used in assessment for any prey stocks yet. Marine mammals are not included in the current fish stock assessments. However, it has been attempted to extend the stock assessment models of Barents Sea capelin (Bifrost) by including the predatory effects of minke whales, and harp seals (Tjelmeland and Lindstrøm, 2005).

1.11.3 Maturation, condition factor, and fisheries–induced evolution

Data on maturity-at-age are one of the basic components for spawning-stock biomass (SSB) estimates. There have been substantial changes observed in maturity-at-age of NEA cod over a large historical period (since 1946) showing an acceleration in maturity rates, especially in the 1980s. They are thought to be connected both with compensatory density-dependence mechanisms and genetic changes in individuals (Heino *et al.*, 2002; Jørgensen *et al.*, 2008; Kovalev and Yaragina, 2009; Eikeset *et al.*, 2013; Kuparinen *et al.*, 2014) resulted from strong fishing pressure.

Studies on possible evolutionary effects for this stock should be updated with data for recent years to investigate the effects on population dynamics, including growth, maturation and evolutionary effects, of a prolonged period with low fishing mortality and high stock size.

Recent laboratory and fieldwork have shown that skipped spawning does occur in NEA cod stock (Skjæraasen *et al.*, 2009; Yaragina, 2010). Experimental work on captive fish has demonstrated that skipped spawning is strongly influenced by individual energy reserves (Skjæraasen *et al.*, 2009). This is supported by the field data, which suggest that gamete development could be interrupted by a poor liver condition especially. Fish that will skip spawning seem to remain in the Barents Sea and do not migrate to the spawning grounds. These fish need to be identified and excluded when estimating the stock–recruitment potential as currently they are included in the estimate of SSB. However, more work needs to be undertaken to improve our knowledge of skipped spawning in cod (e.g. comparisons and intercalibration of Norwegian and Russian databases on maturity stages should be done) and other species in order to quantify its influence on the stock reproductive potential.

1.11.4 Recruitment prediction for northeast Arctic cod

Prediction of recruitment in fish stocks is essential to harvest prognosis. Traditionally, prediction methods have been based on spawning-stock biomass and survey indices of juvenile fish and have not included effects of ecosystem drivers. Multiple linear regression models can be used to incorporate both environmental and parental fish stock parameters. In order for such models to give predictions, there need to be a time-lag between the predictor and response variables. In this section, a model for Northeast Arctic cod which is in use in assessment is presented. Note that a recruitment model for Barents Sea capelin with similar features also was presented to the group (WD 13).

1.11.5 Historic overview

Several statistical models, which use multiple linear regressions, have been developed for the recruitment of northeast Arctic cod. All models try to predict recruitment-at-age 3 (at 1 January), as calculated from the assessment model, with cannibalism included. This quantity is denoted as R3. A collection of the most relevant models previously presented to AFWG is described below.

Stiansen *et al.* (2005) developed a model (JES1) with 2-year prediction possibility:

JES1: R3~ Temp(-3) + Age1(-2) + MatBio(-2)
JES2: R3~ Temp(-3) + Age2(-1) + MatBio(-2)
JES3: R3~ Temp(-3) + Age3(0) + MatBio(-2)

Temp is the Kola annual temperature (0–200 m, station 3–7), Age1 is the winter survey bottom trawl index for cod age 1, and MatBio the maturing biomass of capelin on 1 October. The number in parentheses is the time-lag in years. Two other similar models (JES2, JES3) can be made by substituting the winter index term Age1(-2) with Age2(-1) and Age3(0), giving 1 and 0-year predictions, respectively.

Svendsen *et al.* (2007) used a model (SV) based only on data from the ROMS numerical hydrodynamical model, with 3-year prognosis possibility:

SV: R3~ Phyto(-3) + Inflow(-3)

Where Phyto is the modelled phytoplankton production in the whole Barents Sea and Inflow is the modelled inflow through the western entrance to the Barents Sea in autumn. The number in parentheses is the time-lag in years. The model has not been updated since 2007.

The recruitment model (TB) suggested by T. Bulgakova (AFWG 2005, WD14) is a modification of Ricker's model for stock–recruitment defined by:

TB: R3~ m(-3) exp[-SSB(-3) + N(-3)]

Where R3 is the number of age 3 recruits for NEA cod, m is an index of population fecundity, SSB is the spawning-stock biomass and N is equal to the number of months with positive temperature anomalies (TA) on the Kola Section in the birth year for the year class. The number in parentheses is the time-lag in years. For the years before 1998 TA was calculated relative to monthly average for the period 1951–2000. For intervals after 1998, the TA was calculated with relatively linear trend in the temperature for the period 1998–present. The model was run using two-time intervals (using cod year classes 1984–2000 and year classes 1984–2004) for estimating the model coefficients. The models have not been updated since 2009.

Titov (Titov, AFWG 2010, WD 22) and Titov *et al.* (AFWG 2005, WD 16) developed models with 1 to 4-year prediction possibility (TITOV0, TITOV1, TITOV2, TITOV3, TITOV4, respectively), based on the oxygen saturation at bottom layers of the Kola section stations 3–7 (OxSat), air temperature at the Murmansk station (Ta), water temperature: 3–7 stations of the Kola section (layer 0–200 m; Tw), ice coverage in the Barents Sea (I), spawning-stock biomass (SSB), annual values of 0-group cod abundance index, corrected for capture efficiency (CodC0) and the bottom trawl swept-area abundance of cod at the age 1 and 2, 3 derived from the joint winter Barents Sea acoustic survey (CodB1, CodB2, CodB3). At the 2010 AFWG assessment it was suggested (Dingsør *et al.*, 2010, WD 19, and related discussions in the working group to try to simplify these models).

Hjermann *et al.*, (2007) developed a model with a one-year prognosis, which has been modified by Dingsør *et al.* (AFWG 2010, WD19) to four models with 2-year projection possibility.

H1: log(R3)~ Temp(-3) + log(Age0)(-3) +$BM_{cod3\text{-}6}$ /$ABM_{capelin}$(-2,-1)
H2: log(R3)~ Temp(-2) +I(surv)+ Age1(-2) + $BM_{cod3\text{-}6}$ /$ABM_{capelin}$ (-2,-1)
H3: log(R3)~ Temp(-1) + Age2(-1) + $BM_{cod3\text{-}6}$ /$ABM_{capelin}$ (-1)
H4: log(R3)~ Temp(-1) + Age3(0)

Temp is the Kola yearly temperature (0–200 m), Age0 is the 0-group index of cod, Age1, Age2 and Age3 are the winter survey bottom trawl index for cod age 1, 2 and 3, respectively, $BM_{cod3\text{-}6}$ is the biomass of cod between age 3 and 6, and ABM is the maturing biomass of capelin. The number in parentheses is the time-lag in years. The models were not updated this year.

At AFWG 2008, Subbey *et al.* presented a comparative study (AFWG 2008, WD27) on the ability of some of the above models in predicting stock–recruitment for NEA cod (Age 3). At the assessment in 2010, a WD by Dingsør *et al.* (AFWG 2010, WD19) was presented, which investigated the performance of some of the mentioned recruitment models. It was strongly recommended by the working group that a Study Group should be appointed to look at criteria for choosing/rejecting recruitment models suitable for use in stock assessment.

The "Study Group on Recruitment Forecasting" (SGRF; ICES CM 2011/ACOM:31, ICES CM 2012/ACOM:24, ICES CM 2013/ACOM:24) have had three meetings (in October 2011 and 2012, and November 2013). Their mandate is to give a "best practice" (Standards and guidelines) for choosing recruitment models after their next meeting, which may be implemented at the next AFWG.

The SGRF 2012 report addressed the problem of combining several model predictions to obtain a recruitment estimate with minimum variance. The method (involving a weighted average of individual model predictions) was proposed as a replacement for the hybrid method of Subbey *et al.* (2008). One major issue not addressed in ICES SGRF (2012) was how to choose the initial ensemble of models, whose weighted average is sought. There are practical constraints (with respect to time and personnel), which stipulates that not all plausible models can be included in the calculation of the hybrid recruitment value. A methodology for choosing models to include in the calculation of a hybrid, representative recruitment forecast was addressed in SGRF 2013. Details can be found in the SGRF 2013 ICES report.

1.11.6 Models used in 2021

The model approach taken in 2021 was the same as in 2018–2020. Some changes were made in 2018, they are described below.

In 2018 at the meeting of the AFWG, the correction and simplification of models were continued. Due to the fact that in 2017–2018 there was a significant correction of the initial biological data, which caused significant changes in the results of the prognostic models, in 2018 a complete audit of both prognostic models and the hybrid model combining the results of their work was carried out. The main purpose of the model revision was to increase the stability of the models, that is, to reduce the possibility of potential correction of the models due to correction of the biological data included in the model. The solution to the problem was found by increasing the retrospective database backwards in time, that is, from the beginning of the 1980s to the beginning of the 1960s. Accordingly, sets of predictor sets have been revised. The number of models was reduced from 5 to 2 and the names of the models were changed from Titov0(1,2,3,4) to TitovES (environment, short prediction) and TitovEL (environment, long prediction).

This has been conducted and has improved the statistical performance (details are shown in Titov, AFWG 2018, WD23):

TitovES: R32 ~ DOxSat2(t-13) + ITw(t-43) + expIce(t-40) + Ice(t-15)
TitovEL: R34 ~OxSat(t-39)+ ITw(t-43)

Where DOxSat(t-13)~ expOxSat(t-13) + OxSat(t-39), ITw(t-43) ~ I(t-43) +Tw(t−46). The number in parentheses is the time-lag in months, relative to April in the year when the prediction is carried out.

At the 2018 AFWG assessment, a hybrid model (i.e. an average combination) of the best functioning statistical recruitment models were repeated. A statistical analysis of the accuracy of the model's work was carried out, which consisted in estimating the errors in the recovery of data on the number of NEA cod recruitment. Accuracy of the model's work was verified by calculation of standard deviations of the NEA cod recruitment predicted values from the SAM values for the period 2005–2015 when the model was adjusted for data from 1983 to 2004, which consisted in estimating the errors in the recovery of data on the number of NEA cod recruitment.

Figure 1.1 shows the standard deviations of the NEA cod recruitment prediction. It can be seen that the addition of biological parameters (CodB1, CodB2, CodB3, CodC0, SSB) to environmental models (TitovES, TitovEL) substantially increases the error.

Based on these calculations, after comparing the results of constructing independent retrospective forecasts using the methodology previously used in ICES SGRF (ICES CM 2013/ACOM:24), it was decided to abandon the use of biological predictors and to use only environmental data in the NEA cod recruitment forecasting models. It was also found that all models (TitovES, TitovEL, RCT3) satisfy the quality conditions with respect to the forecast for the mean values accepted as the criterion for entering into the calculation of the hybrid model adopted earlier (ICES CM 2013/ACOM:24). It was decided that all biological data will be included in calculations based on the RCT3 model, and the remaining two models (TitovES, TitovEL) will be used only to account for the effect of environmental conditions on NEA cod recruitment.

In AFWG 2021 the procedure for estimating weights for various models (TitovES, TitovEL, RCT3) was repeated using the same method as was made on Study Group on Recruitment

Forecasting (SGRF) in 2013. The input data for the models are given below in Tables 1.7 (TitovES, TitovEL) and 1.8 (RCT3).

In summary, the SAM estimate for age 3 from the AFWG 2021 assessment was used as historical R3. The recruitment forecast for 2021–2024 are based on a hybrid model with weighting estimated at AFWG 2021. The weights and forecasts for the 2021 AFWG assessment can be found in Table 1.9.

It was noted that the oceanographic dataset for the Titov ES and EL models cover the year classes from 1959 onwards, while the survey data used in the RCT3 model only cover the year classes from 1991 onwards, although those survey dataseries started in 1981. Further, the area covered in the surveys was extended in 2014, which is accounted for in the cod assessment by splitting the bottom trawl survey series in that year, while no such split was made in the RCT3 model. It should be investigated how this area expansion in the survey best could be accounted for in the recruitment model.

New software in R was presented during AFWG 2021 for predicting cod recruitment using the hybrid model (WD 20) including the automatic procedure for the submodel's weight estimation. A comparison of predicted values with "old" software (WD 21) was done and the results were identical.

Table 1.1. The North-east arctic COD stock's consumption of various prey species in 1984-2020 (1000 tonnes) based on Norwegian consumption calculations

Year	Other	Amphipods	Krill	Shrimp	Capelin	Herring	Polar cod	Cod	Haddock	Redfish	G. halibut	Blue whiting	Long rough c	Snow crab	Total
1984	494	27	119	447	739	82	16	23	52	374	0	0	25	0	2398
1985	1252	188	64	179	1780	214	3	31	54	244	0	2	48	0	4058
1986	679	1426	133	165	961	162	156	74	110	340	0	0	66	0	4273
1987	813	1372	89	233	295	38	225	26	6	340	1	0	11	0	3449
1988	447	1419	337	151	382	8	99	11	2	259	0	5	6	0	3126
1989	679	823	245	123	589	3	37	8	10	222	0	0	67	0	2805
1990	1149	123	80	162	1409	7	5	16	14	188	0	81	86	0	3320
1991	688	63	71	164	2441	7	10	22	16	264	7	8	240	0	4002
1992	826	97	154	354	2266	275	92	46	88	172	23	2	94	0	4487
1993	709	242	669	305	2873	155	269	261	69	92	2	2	27	0	5674
1994	611	552	693	506	1060	146	599	223	48	76	0	1	43	0	4558
1995	827	972	527	358	607	117	245	367	114	194	2	0	36	0	4366
1996	604	620	1166	345	548	46	101	536	67	95	0	10	37	0	4173
1997	466	404	545	350	978	5	115	350	44	33	0	34	15	0	3340
1998	448	411	513	375	836	104	174	163	36	9	0	14	18	0	3100
1999	422	166	306	300	2047	151	258	67	30	18	1	35	9	0	3808
2000	427	188	492	503	1935	61	218	83	58	8	0	41	21	0	4035
2001	721	176	382	291	1836	76	264	68	51	6	1	157	32	0	4060
2002	376	96	260	241	2004	86	280	108	127	1	0	239	16	0	3834
2003	545	285	545	238	2152	216	275	110	166	3	0	74	53	0	4662
2004	626	560	347	246	1253	216	358	126	198	3	11	56	65	1	4065
2005	781	579	527	274	1399	132	388	118	324	2	5	115	53	0	4697
2006	870	225	1078	353	1737	170	108	80	361	12	2	163	130	0	5287
2007	1259	310	1091	428	2140	285	266	88	378	46	0	44	75	0	6411
2008	1578	160	931	385	2865	105	514	187	293	59	13	18	93	0	7201
2009	1495	243	635	265	3978	123	730	196	252	28	3	5	115	2	8072
2010	1616	415	1049	281	3900	52	334	241	267	142	10	14	133	7	8462
2011	1556	254	902	221	4120	84	424	286	279	115	0	26	122	9	8398
2012	1975	316	842	345	3641	51	519	373	220	51	34	8	125	7	8506
2013	1774	261	566	267	3660	51	137	380	200	111	1	21	167	15	7612
2014	1409	326	475	202	3713	72	31	358	88	31	11	18	106	9	6849
2015	1595	619	637	243	3278	126	147	213	178	140	43	59	85	33	7396
2016	1691	530	745	299	2210	95	346	198	222	57	6	87	120	10	6617
2017	1053	126	582	251	2950	193	88	315	272	45	4	24	139	53	6097
2018	1032	267	644	180	2886	203	246	246	276	34	70	47	52	44	6227
2019	779	212	415	308	2600	181	168	188	212	44	0	2	99	50	5258
2020	919	523	535	172	2021	107	467	115	92	30	14	13	150	90	5247

Table 1.2. The North-east arctic COD stock's consumption of various prey species in 1984-2020 (1000 tonnes) based on Russian consumption calculations (Dolgov, WD 07 AFWG 2020)

	NOT UPDATED THIS YEAR														
Year	**Other**	**Amphipods**	**Krill**	**Shrimp**	**Capelin**	**Herring**	**Polar cod**	**Cod**	**Haddock**	**Redfish**	**G. halibut**	**Blue whitin**	**Long rough**	**Snow crab**	**Total**
1984	560	31	94	353	593	34	18	14	50	197	0	5	52		2000
1985	767	441	31	211	1041	26	0	89	36	100	0	18	22		2779
1986	615	949	66	159	855	51	169	26	99	166	1	3	26		3186
1987	541	593	79	233	175	9	118	23	2	119	1	10	5		1908
1988	544	196	239	146	348	21	0	21	76	133	0	0	22		1745
1989	496	324	190	117	767	4	37	35	2	178	0	0	64		2213
1990	278	31	105	266	1264	65	8	24	15	237	0	39	79		2409
1991	289	81	55	277	3204	25	45	52	22	141	5	6	46		4248
1992	788	38	211	258	2021	335	196	82	37	117	1	0	42		4125
1993	563	174	184	220	2743	170	170	144	148	40	5	4	47		4611
1994	447	296	359	458	1276	102	486	383	72	55	0	1	40		3976
1995	502	455	396	533	670	192	191	541	130	110	3	0	52		3775
1996	674	346	957	195	469	74	74	451	57	67	0	9	45		3415
1997	463	134	510	257	511	52	111	383	35	29	2	17	17		2520
1998	311	220	645	286	916	73	134	131	23	15	0	24	20		2797
1999	179	81	458	268	1540	80	177	49	16	14	0	27	9		2898
2000	243	122	437	394	1800	53	167	59	32	4	0	28	21		3360
2001	384	75	411	322	1522	93	148	62	52	4	2	145	31		3250
2002	225	45	286	202	2400	55	302	100	80	4	0	110	17		3825
2003	400	171	547	227	1219	153	221	132	331	2	0	28	51		3481
2004	496	393	478	256	1097	129	369	86	144	7	16	48	62		3583
2005	620	163	688	244	1023	168	320	112	271	7	2	67	47		3731
2006	786	86	1547	274	1341	268	125	95	285	17	1	103	148		5076
2007	831	192	1340	420	1881	275	289	68	329	29	1	32	73		5760
2008	1021	51	1005	345	3278	122	664	156	331	60	13	17	121		7184
2009	1048	189	938	284	3360	229	828	142	347	28	0	8	285		7687
2010	973	330	1843	255	4120	143	512	181	246	163	1	16	136		8918
2011	1251	202	831	226	4473	85	422	259	359	143	2	57	170		8479
2012	1771	164	600	273	2986	97	439	291	415	41	7	33	133		7251
2013	1366	210	648	334	3676	45	146	447	272	178	2	40	216		7581
2014	1391	121	744	208	3340	56	98	390	170	20	7	27	154		6726
2015	1122	301	1160	442	2675	69	159	175	180	87	14	39	117		6539
2016	1542	654	775	216	2221	86	248	239	158	48	3	51	328		6568
2017	1042	85	681	316	2709	99	75	271	315	188	3	26	249		6060
2018	1153	146	1541	178	1624	271	117	352	479	41	41	41	121		6105
2019	751	97	498	189	2103	379	131	415	292	47	0	15	159		5075

Table 1.3		**Consumption per cod by cod age group (kg/year), based on Norwegian consumption calculations.**									
Year/Age	1	2	3	4	5	6	7	8	9	10	11+
1984	0.247	0.815	1.683	2.521	3.951	5.208	8.009	8.524	9.180	9.912	9.954
1985	0.304	0.761	1.833	3.105	4.675	7.360	11.246	11.972	12.497	13.751	13.869
1986	0.161	0.498	1.343	3.152	5.669	6.884	11.018	11.944	12.749	13.513	13.768
1987	0.219	0.602	1.290	2.051	3.532	5.489	7.077	8.107	8.923	9.343	9.301
1988	0.164	0.702	1.150	2.149	3.743	5.877	10.098	11.222	12.575	13.127	13.373
1989	0.223	0.715	1.606	2.714	3.980	5.611	7.678	8.499	9.597	10.198	10.628
1990	0.363	0.906	1.909	3.058	4.218	5.447	6.527	6.877	7.075	7.455	7.955
1991	0.293	0.972	2.178	3.536	5.318	7.073	9.470	10.238	11.292	12.339	12.037
1992	0.215	0.665	2.100	3.135	4.142	5.093	7.868	9.023	9.402	10.124	10.156
1993	0.112	0.529	1.548	3.045	4.823	6.292	9.413	11.272	11.798	12.288	12.880
1994	0.130	0.406	0.924	2.523	3.508	4.544	6.404	8.844	9.716	9.988	10.232
1995	0.103	0.299	0.918	1.824	3.359	5.261	7.726	10.425	12.300	12.770	13.191
1996	0.108	0.359	0.938	1.855	3.055	4.434	7.409	11.124	14.591	15.048	15.432
1997	0.140	0.327	0.952	1.778	2.717	3.537	5.261	8.128	12.659	13.389	13.205
1998	0.117	0.400	0.991	1.953	2.922	4.188	5.751	8.078	11.375	12.071	12.113
1999	0.163	0.505	1.095	2.720	3.719	5.444	6.975	9.193	10.953	12.063	12.181
2000	0.170	0.499	1.239	2.467	4.262	5.650	7.975	9.405	12.679	13.401	13.542
2001	0.171	0.448	1.308	2.435	3.688	5.305	7.550	11.238	13.477	14.400	14.674
2002	0.199	0.553	1.163	2.443	3.382	4.721	6.366	9.069	10.301	11.513	11.098
2003	0.207	0.648	1.316	2.391	4.002	5.958	8.438	10.435	12.903	13.576	14.443
2004	0.222	0.476	1.298	2.285	3.339	5.568	7.444	11.468	17.366	19.237	18.956
2005	0.203	0.659	1.380	2.746	4.247	6.365	7.670	10.284	13.851	14.895	15.610
2006	0.204	0.626	1.584	2.811	4.241	6.316	7.868	11.626	14.023	15.100	15.929
2007	0.256	0.653	1.738	3.092	4.471	6.237	8.277	10.287	12.786	13.554	13.988
2008	0.204	0.724	1.469	2.877	4.082	7.111	8.407	11.463	15.655	16.348	16.617
2009	0.192	0.618	1.494	2.769	4.434	5.759	8.470	11.487	12.793	13.632	13.821
2010	0.203	0.635	1.357	2.504	3.989	5.709	8.447	12.078	15.363	16.040	16.394
2011	0.219	0.663	1.419	2.627	4.033	5.351	7.272	9.663	15.139	16.314	16.304
2012	0.231	0.763	1.503	2.688	4.103	5.077	7.312	10.038	15.400	16.594	16.518
2013	0.182	0.674	1.447	2.531	3.908	4.999	5.954	7.582	11.489	12.510	13.450
2014	0.224	0.648	1.308	2.549	3.763	4.253	5.837	8.010	10.796	11.514	12.026
2015	0.218	0.662	1.426	2.528	4.254	5.695	7.376	8.628	13.081	13.892	15.034
2016	0.252	0.722	1.578	2.769	3.919	5.514	7.201	8.040	12.056	12.652	14.479
2017	0.248	0.791	1.529	2.653	3.977	5.628	7.031	8.143	11.271	14.168	16.982
2018	0.194	0.775	1.566	2.813	4.391	5.208	6.811	10.602	12.879	17.074	15.980
2019	0.191	0.515	1.343	2.288	3.517	4.417	6.219	8.963	12.186	11.715	12.973
2020	0.175	0.465	1.086	2.461	3.503	4.926	6.796	10.080	11.988	13.655	15.837
Average	**0.201**	**0.613**	**1.406**	**2.590**	**3.969**	**5.500**	**7.639**	**9.785**	**12.275**	**13.221**	**13.647**

Table 1.4		Consumption per cod by cod age group (kg/year), based on Russian consumption calculations.											
		NOT UPDATED THIS YEAR											
Year/Age	1	2	3	4	5	6	7	8	9	10	11	12	13+
1984	0.262	0.895	1.611	2.748	3.848	5.486	6.992	8.561	10.572	13.166	13.200	15.547	17.153
1985	0.295	0.753	1.658	2.681	4.264	6.599	8.241	9.745	10.974	14.448	17.327	17.391	19.186
1986	0.179	0.526	1.455	3.455	5.001	5.991	6.458	8.157	9.766	11.457	13.188	14.621	16.134
1987	0.145	0.432	0.852	1.558	3.073	4.380	7.357	9.667	12.705	14.481	15.899	16.616	18.318
1988	0.183	0.704	1.075	1.628	2.391	4.386	8.207	9.978	10.868	16.536	14.639	16.046	17.000
1989	0.282	0.909	1.465	2.207	3.243	4.798	6.578	8.725	11.134	15.798	16.313	18.436	18.041
1990	0.288	1.006	1.694	2.693	3.278	3.833	5.583	6.870	10.715	11.426	13.555	15.964	17.595
1991	0.241	0.936	2.670	4.472	6.037	7.844	9.590	11.543	14.969	19.292	18.590	21.720	23.960
1992	0.178	0.969	2.475	2.866	3.995	5.137	6.723	7.414	8.755	12.303	14.288	15.184	16.745
1993	0.133	0.476	1.512	2.865	3.944	5.108	7.372	8.945	10.343	11.600	14.835	16.536	18.249
1994	0.180	0.512	1.212	2.402	3.517	5.359	7.560	10.001	11.818	12.896	14.499	17.656	19.469
1995	0.194	0.497	0.962	1.801	3.204	4.847	7.332	9.688	13.835	15.247	16.899	19.273	21.254
1996	0.170	0.498	1.028	1.916	3.059	4.189	6.987	10.212	12.185	13.614	14.529	16.275	17.945
1997	0.119	0.341	0.992	1.908	2.668	3.503	4.954	7.980	12.174	16.762	16.710	18.410	20.308
1998	0.232	0.528	1.081	2.016	2.823	4.089	5.469	7.346	9.586	13.012	14.404	15.640	17.243
1999	0.261	0.431	1.128	2.490	3.676	5.222	6.398	8.220	9.194	13.364	15.268	16.990	18.727
2000	0.186	0.545	1.288	2.551	4.387	6.559	8.833	10.483	11.522	15.132	17.090	19.793	21.822
2001	0.150	0.413	1.163	2.110	3.430	5.571	6.835	10.233	12.457	15.130	17.341	19.307	21.345
2002	0.252	0.677	1.303	2.699	3.847	5.591	7.846	10.796	13.238	18.787	17.836	20.278	22.359
2003	0.228	0.618	1.296	2.028	3.547	4.716	6.684	8.905	13.418	14.492	19.480	19.309	21.292
2004	0.250	0.654	1.412	2.567	3.857	5.660	7.730	11.126	15.907	20.770	21.607	24.940	27.503
2005	0.255	0.687	1.514	2.504	3.896	5.264	7.192	9.395	13.163	15.981	20.628	21.448	23.639
2006	0.354	0.925	1.881	2.813	4.019	5.332	7.450	10.328	13.111	17.759	19.488	22.322	24.609
2007	0.234	0.681	1.874	3.128	4.459	5.893	7.563	9.178	12.032	15.919	19.961	21.644	23.863
2008	0.223	0.719	1.697	2.959	4.194	6.073	7.809	10.464	13.627	17.254	21.590	23.373	25.779
2009	0.217	0.624	1.495	2.526	4.304	5.623	7.855	11.490	13.341	15.988	18.770	21.866	24.111
2010	0.235	0.651	1.401	2.577	4.065	5.757	8.312	11.805	16.090	16.844	20.129	23.023	25.387
2011	0.248	0.721	1.497	2.513	3.859	4.963	6.848	9.213	13.799	19.074	20.784	23.791	26.241
2012	0.207	0.588	1.203	2.292	3.266	4.461	5.862	7.629	11.713	16.211	19.345	21.032	23.190
2013	0.190	0.656	1.641	2.552	3.809	4.952	5.791	7.757	10.881	14.989	19.785	22.386	24.691
2014	0.242	0.622	1.321	2.340	3.608	4.387	5.560	7.447	9.017	12.547	16.044	18.854	20.781
2015	0.234	0.745	1.390	2.406	3.915	4.922	5.960	7.505	10.265	12.116	16.245	19.978	22.023
2016	0.307	0.870	1.722	2.813	3.474	4.740	6.754	9.117	10.665	14.810	19.921	24.195	26.683
2017	0.244	0.779	1.582	2.531	3.748	4.943	6.601	9.180	11.302	16.016	20.086	23.464	25.870
2018	0.316	0.867	1.846	2.699	3.736	5.000	6.489	9.170	11.166	14.577	18.672	21.848	24.091
2019	0.269	0.655	1.383	2.204	3.316	4.500	6.415	9.078	13.251	15.509	19.423	22.635	24.958
Average	**0.227**	**0.670**	**1.466**	**2.514**	**3.743**	**5.158**	**7.005**	**9.260**	**11.932**	**15.147**	**17.455**	**19.661**	**21.599**

Table 1.5 Proportion of cod in cod diet, based on Norwegian consumption calculations

Year/age	1	2	3	4	5	6	7	8	9	10	11+
1984	0.0000	0.0000	0.0032	0.0000	0.0432	0.0262	0.0332	0.0361	0.0371	0.0392	0.0394
1985	0.0015	0.0009	0.0014	0.0017	0.0312	0.0074	0.0822	0.0826	0.0833	0.0835	0.0840
1986	0.0000	0.0022	0.0015	0.0004	0.0130	0.1743	0.1760	0.1761	0.1758	0.1749	0.1745
1987	0.0000	0.0000	0.0007	0.0050	0.0103	0.0244	0.0383	0.0395	0.0412	0.0409	0.0443
1988	0.0000	0.0000	0.0000	0.0002	0.0059	0.0014	0.0037	0.0036	0.0031	0.0035	0.0031
1989	0.0000	0.0006	0.0016	0.0019	0.0027	0.0039	0.0036	0.0036	0.0039	0.0038	0.0040
1990	0.0000	0.0000	0.0000	0.0007	0.0010	0.0010	0.0165	0.0172	0.0181	0.0179	0.0178
1991	0.0000	0.0005	0.0000	0.0003	0.0032	0.0020	0.0222	0.0227	0.0230	0.0231	0.0231
1992	0.0000	0.0021	0.0037	0.0129	0.0248	0.0475	0.0119	0.0160	0.0232	0.0232	0.0231
1993	0.0000	0.0410	0.0370	0.0515	0.0541	0.1135	0.0498	0.0795	0.0797	0.0796	0.0802
1994	0.0000	0.0037	0.0927	0.0349	0.0285	0.0785	0.1248	0.1330	0.2659	0.2674	0.2668
1995	0.0069	0.0812	0.0747	0.0803	0.0923	0.1118	0.1387	0.2526	0.2542	0.2539	0.2545
1996	0.0000	0.1500	0.2566	0.2051	0.1321	0.1263	0.1874	0.2091	0.2436	0.2447	0.2437
1997	0.0000	0.0687	0.0762	0.1137	0.1558	0.1555	0.2315	0.2269	0.2919	0.2850	0.2916
1998	0.0000	0.0134	0.0272	0.0418	0.1037	0.0978	0.1090	0.1498	0.2722	0.2741	0.2718
1999	0.0000	0.0000	0.0048	0.0136	0.0147	0.0338	0.0618	0.1114	0.1902	0.1907	0.1843
2000	0.0000	0.0000	0.0287	0.0148	0.0134	0.0266	0.0497	0.0570	0.2682	0.2699	0.2594
2001	0.0000	0.0160	0.0116	0.0082	0.0131	0.0241	0.0498	0.0375	0.3250	0.3233	0.3268
2002	0.0000	0.0385	0.0597	0.0142	0.0187	0.0284	0.0357	0.0623	0.1582	0.1560	0.1555
2003	0.0000	0.0190	0.0198	0.0199	0.0206	0.0188	0.0451	0.1030	0.2194	0.2219	0.2228
2004	0.0081	0.0234	0.0280	0.0269	0.0296	0.0319	0.0380	0.0663	0.1062	0.1062	0.1077
2005	0.0000	0.0266	0.0230	0.0266	0.0145	0.0277	0.0436	0.0779	0.1484	0.1462	0.1437
2006	0.0000	0.0103	0.0007	0.0128	0.0288	0.0158	0.0392	0.0368	0.0810	0.0821	0.0820
2007	0.0000	0.0000	0.0011	0.0117	0.0119	0.0304	0.0282	0.0901	0.1407	0.1413	0.1383
2008	0.0000	0.0559	0.0257	0.0101	0.0157	0.0098	0.0764	0.0873	0.0975	0.0959	0.0981
2009	0.0116	0.0225	0.0262	0.0251	0.0152	0.0139	0.0219	0.0945	0.1078	0.1082	0.1076
2010	0.0000	0.0327	0.0580	0.0270	0.0243	0.0243	0.0203	0.0383	0.1367	0.1369	0.1353
2011	0.0129	0.0152	0.0492	0.0170	0.0361	0.0300	0.0238	0.0575	0.1279	0.1279	0.1278
2012	0.0274	0.0608	0.0640	0.0618	0.0274	0.0432	0.0410	0.0373	0.0685	0.0691	0.0681
2013	0.0214	0.0303	0.0459	0.0389	0.0276	0.0224	0.0478	0.0538	0.1166	0.1171	0.1335
2014	0.0824	0.0363	0.0450	0.0342	0.0213	0.0456	0.0661	0.0787	0.0658	0.0658	0.0752
2015	0.0000	0.0088	0.0308	0.0283	0.0266	0.0192	0.0233	0.0281	0.0555	0.0553	0.0539
2016	0.0157	0.0192	0.0063	0.0393	0.0146	0.0172	0.0266	0.0137	0.0906	0.0914	0.0910
2017	0.0419	0.0354	0.0386	0.0470	0.0436	0.0400	0.0560	0.0913	0.0686	0.1015	0.1409
2018	0.0000	0.0186	0.0680	0.0480	0.0351	0.0378	0.0567	0.0310	0.0243	0.0076	0.0252
2019	0.0000	0.0000	0.0328	0.0296	0.0339	0.0228	0.0366	0.0741	0.0934	0.0252	0.0792
2020	0.0000	0.0227	0.0013	0.0041	0.0110	0.0177	0.0311	0.0504	0.0683	0.0649	0.1118

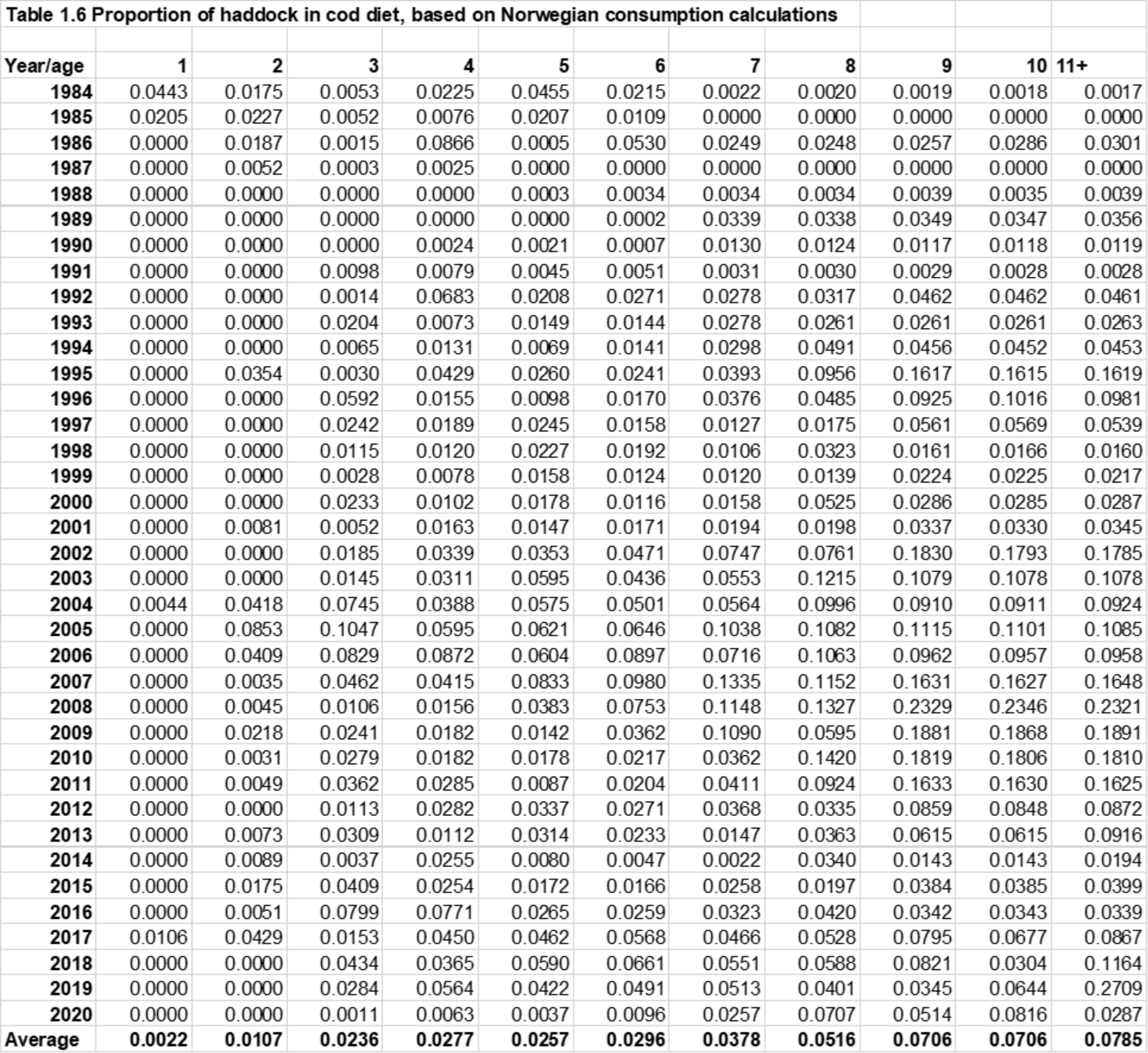


Table 1.6 Proportion of haddock in cod diet, based on Norwegian consumption calculations

Year/age	1	2	3	4	5	6	7	8	9	10	11+
1984	0.0443	0.0175	0.0053	0.0225	0.0455	0.0215	0.0022	0.0020	0.0019	0.0018	0.0017
1985	0.0205	0.0227	0.0052	0.0076	0.0207	0.0109	0.0000	0.0000	0.0000	0.0000	0.0000
1986	0.0000	0.0187	0.0015	0.0866	0.0005	0.0530	0.0249	0.0248	0.0257	0.0286	0.0301
1987	0.0000	0.0052	0.0003	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1988	0.0000	0.0000	0.0000	0.0000	0.0003	0.0034	0.0034	0.0034	0.0039	0.0035	0.0039
1989	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0339	0.0338	0.0349	0.0347	0.0356
1990	0.0000	0.0000	0.0000	0.0024	0.0021	0.0007	0.0130	0.0124	0.0117	0.0118	0.0119
1991	0.0000	0.0000	0.0098	0.0079	0.0045	0.0051	0.0031	0.0030	0.0029	0.0028	0.0028
1992	0.0000	0.0000	0.0014	0.0683	0.0208	0.0271	0.0278	0.0317	0.0462	0.0462	0.0461
1993	0.0000	0.0000	0.0204	0.0073	0.0149	0.0144	0.0278	0.0261	0.0261	0.0261	0.0263
1994	0.0000	0.0000	0.0065	0.0131	0.0069	0.0141	0.0298	0.0491	0.0456	0.0452	0.0453
1995	0.0000	0.0354	0.0030	0.0429	0.0260	0.0241	0.0393	0.0956	0.1617	0.1615	0.1619
1996	0.0000	0.0000	0.0592	0.0155	0.0098	0.0170	0.0376	0.0485	0.0925	0.1016	0.0981
1997	0.0000	0.0000	0.0242	0.0189	0.0245	0.0158	0.0127	0.0175	0.0561	0.0569	0.0539
1998	0.0000	0.0000	0.0115	0.0120	0.0227	0.0192	0.0106	0.0323	0.0161	0.0166	0.0160
1999	0.0000	0.0000	0.0028	0.0078	0.0158	0.0124	0.0120	0.0139	0.0224	0.0225	0.0217
2000	0.0000	0.0000	0.0233	0.0102	0.0178	0.0116	0.0158	0.0525	0.0286	0.0285	0.0287
2001	0.0000	0.0081	0.0052	0.0163	0.0147	0.0171	0.0194	0.0198	0.0337	0.0330	0.0345
2002	0.0000	0.0000	0.0185	0.0339	0.0353	0.0471	0.0747	0.0761	0.1830	0.1793	0.1785
2003	0.0000	0.0000	0.0145	0.0311	0.0595	0.0436	0.0553	0.1215	0.1079	0.1078	0.1078
2004	0.0044	0.0418	0.0745	0.0388	0.0575	0.0501	0.0564	0.0996	0.0910	0.0911	0.0924
2005	0.0000	0.0853	0.1047	0.0595	0.0621	0.0646	0.1038	0.1082	0.1115	0.1101	0.1085
2006	0.0000	0.0409	0.0829	0.0872	0.0604	0.0897	0.0716	0.1063	0.0962	0.0957	0.0958
2007	0.0000	0.0035	0.0462	0.0415	0.0833	0.0980	0.1335	0.1152	0.1631	0.1627	0.1648
2008	0.0000	0.0045	0.0106	0.0156	0.0383	0.0753	0.1148	0.1327	0.2329	0.2346	0.2321
2009	0.0000	0.0218	0.0241	0.0182	0.0142	0.0362	0.1090	0.0595	0.1881	0.1868	0.1891
2010	0.0000	0.0031	0.0279	0.0182	0.0178	0.0217	0.0362	0.1420	0.1819	0.1806	0.1810
2011	0.0000	0.0049	0.0362	0.0285	0.0087	0.0204	0.0411	0.0924	0.1633	0.1630	0.1625
2012	0.0000	0.0000	0.0113	0.0282	0.0337	0.0271	0.0368	0.0335	0.0859	0.0848	0.0872
2013	0.0000	0.0073	0.0309	0.0112	0.0314	0.0233	0.0147	0.0363	0.0615	0.0615	0.0916
2014	0.0000	0.0089	0.0037	0.0255	0.0080	0.0047	0.0022	0.0340	0.0143	0.0143	0.0194
2015	0.0000	0.0175	0.0409	0.0254	0.0172	0.0166	0.0258	0.0197	0.0384	0.0385	0.0399
2016	0.0000	0.0051	0.0799	0.0771	0.0265	0.0259	0.0323	0.0420	0.0342	0.0343	0.0339
2017	0.0106	0.0429	0.0153	0.0450	0.0462	0.0568	0.0466	0.0528	0.0795	0.0677	0.0867
2018	0.0000	0.0000	0.0434	0.0365	0.0590	0.0661	0.0551	0.0588	0.0821	0.0304	0.1164
2019	0.0000	0.0000	0.0284	0.0564	0.0422	0.0491	0.0513	0.0401	0.0345	0.0644	0.2709
2020	0.0000	0.0000	0.0011	0.0063	0.0037	0.0096	0.0257	0.0707	0.0514	0.0816	0.0287
Average	**0.0022**	**0.0107**	**0.0236**	**0.0277**	**0.0257**	**0.0296**	**0.0378**	**0.0516**	**0.0706**	**0.0706**	**0.0785**

Table 1.7. Parameters of TitovES and TitovEL models (subscripts correspond to the time-lag in months before the start of the year to which the value Cod3 is attributed).

Year	Cod3	$OxSatt_{39}$	$DOxSatt_{13}$	$ITwt_{43}$	$Icet_{15}$	$expIcet_{40}$
1962	1252375	−0.19	−6.6	1.86	0.5	0
1963	900621	−0.94	−2.37	1.59	1.5	0
1964	468028	1.63	1.23	2.47	9	0
1965	870506	0.88	−0.2	3.91	15.7	0
1966	1842715	−1.09	−3.98	7.97	5.3	0
1967	1311586	−0.23	−2.84	8.23	5	9.3
1968	183717	1.5	−0.13	3.78	15.5	0
1969	110450	0.85	0.63	1.77	15.9	0
1970	205641	−0.17	−0.23	3.51	19.8	7.9
1971	402577	0.06	−0.12	−0.13	18.8	2.7
1972	1045979	−3.32	−6.59	14.55	−0.6	428.9
1973	1723668	−2.1	−10.37	19.14	1.8	768.6
1974	568211	1.06	−1.73	2.4	2	0
1975	608710	1.9	0.78	−2.64	−1.2	0
1976	607084	1.33	−1.28	−3.07	−1.9	0
1977	372778	−0.07	−1.84	−2.44	2.5	0
1978	622679	1.19	0.1	1.05	−1	0
1979	202675	0.5	−1.48	−0.12	3.5	0
1980	130292	−0.31	−2.72	1.98	12.9	0
1981	143781	0.76	−0.18	1.94	14.7	0
1982	183737	0.8	0.61	−3.15	8	0.1
1983	141514	0.78	0.22	1.87	12.2	8.5
1984	442251	−2.21	−2.35	−3.08	12.9	0
1985	534310	−0.1	−1.17	3.59	−1.2	0.1
1986	1374917	−2.14	−4.39	1.39	−8.5	2.9
1987	360087	−0.33	−1.69	2.12	0.6	0
1988	335536	0.87	−1.4	−2.34	3.8	0
1989	157635	0.32	−3.42	−5.17	10.5	0

Year	**Cod3**	**OxSatt$_{39}$**	**DOxSatt$_{13}$**	**ITwt$_{43}$**	**Icet$_{15}$**	**expIcet$_{40}$**
1990	130130	1.11	−1.32	−4.21	10.5	0
1991	295846	0.88	0.7	2.42	6.5	0
1992	715916	1.34	0.48	1.37	−0.9	0
1993	988150	−1.98	−3.86	6.12	−0.6	0
1994	752473	−0.5	−2.26	8.25	−4.9	0
1995	539384	0.83	−2.42	4.36	1.8	0
1996	407389	0.86	−0.08	0.55	0.7	0
1997	785420	0.88	0.17	3.11	−7.3	0
1998	1063528	0.3	−6.08	−2.32	−2.5	0
1999	632034	−0.72	−2.4	−6.81	2.9	0
2000	749727	1.86	1.55	−2.29	13.6	0
2001	593152	0.62	0.05	−6.04	2.3	0
2002	374202	−0.88	−0.98	3.63	−9.9	0.8
2003	756675	−0.39	−0.64	8.5	−5.8	0
2004	242069	−2.2	−2.53	−4.62	−1.4	0
2005	693264	−1.65	−1.82	−1.45	4.9	0
2006	536630	−1.18	−1.65	−4	−6	0
2007	1243906	−1.39	−4.42	7.42	−12.3	0
2008	1002761	−1.14	−1.59	3.39	−18	0
2009	581758	0.79	−1.83	−1.61	−17.5	0
2010	201832	−0.38	−2.6	−8.94	−9	0
2011	358117	0.83	−0.07	−5	−4.3	0
2012	503017	0.91	−0.13	−5.05	−4.3	0
2013	464921	0.04	−0.09	1.44	−10.5	0
2014	852202	−0.46	−1	1.43	−17.8	0
2015	452019	−1.26	−1.62	−2.22	−10.5	0
2016	286334	−1.31	−1.92	−7.52	−5.8	0
2017	781901	−0.33	−0.64	−1.69	−14.4	0
2018	508296	−1.24	−1.41	0.1	−20.9	0

Year	Cod3	$OxSatt_{39}$	$DOxSatt_{13}$	$ITwt_{43}$	$Icet_{15}$	$expIcet_{40}$
2019	659091	−0.63	−1.08	−1.71	−13.2	0
2020	572413	−2.02	−2.19	−6.35	−13.6	0
2021	NA	−0.8	−1.08	−1.33	−9.2	0
2022	NA	−1.55	−2.1	−2.47	−12.8	0
2023	NA	−1.52	NA	−4.18	NA	0
2024	NA	−0.31	NA	−5.63	NA	0

Table 1.8 Initial data for RCT3 model.

year class	recruitment	BST1	BST2	BST3	BSA1	BSA2	BSA3
1982	534	NA	NA	NA	NA	NA	NA
1983	1375	NA	NA	NA	NA	NA	NA
1984	360	NA	NA	NA	NA	NA	NA
1985	336	NA	NA	NA	NA	NA	NA
1986	158	NA	NA	NA	NA	NA	NA
1987	130	NA	NA	NA	NA	NA	NA
1988	296	NA	NA	NA	NA	NA	NA
1989	716	NA	NA	NA	NA	NA	NA
1990	988	NA	NA	NA	NA	NA	NA
1991	752	NA	NA	294	NA	NA	324
1992	539	NA	557	283	NA	624	138
1993	407	1044	541	163	903	212	99
1994	785	5356	792	318	2175	272	159
1995	1064	5899	1423	355	1826	565	391
1996	632	5044	496	188	1699	475	148
1997	750	2491	350	246	2524	232	295
1998	593	473	242	183	365	263	177
1999	374	129	78	118	153	52	61
2000	757	713	419	377	364	209	307
2001	242	34	66	64	19	53	33
2002	693	3022	243	249	1505	117	125

year class	recruitment	BST1	BST2	BST3	BSA1	BSA2	BSA3
2003	537	323	217	116	161	139	65
2004	1244	853	289	361	500	158	59
2005	1003	674	370	194	411	47	200
2006	582	595	102	126	85	94	108
2007	202	69	36	37	51	26	23
2008	358	389	95	85	205	44	40
2009	503	1028	226	76	620	91	83
2010	465	617	100	69	266	40	61
2011	852	703	143	227	497	89	287
2012	452	436	191	144	313	211	139
2013	286	1246	343	99	1759	211	56
2014	782	1642	306	179	1904	202	112
2015	508	312	129	139	241	73	109
2016	659	645	501	282	439	280	204
2017	572	2714	559	238	2058	362	117
2018	NA	1791	274	115	1437	158	70
2019	NA	165	33	NA	93	17	NA
2020	NA	88	NA	NA	44	NA	NA

Table 1.9. Overview available prognoses of NEA cod recruitment (in million individuals of age 3) from different models.

Model	Parameter	Years of prediction	2021 Prognosis	2022 Prognosis	2023 Prognosis	2024 Prognosis
TitovEL	R at age 3	4	590	614	548	386
	Model weight		0.34	0.47	1	1
TitovES	R at age 3	2	559	627		
	Model weight		0.42	0.53	0	0
RCT3	R at age 3	3	525	301	384	
	Model weight		0.24	0	0	
Hybrid	R at age 3	4	561	621	548	386

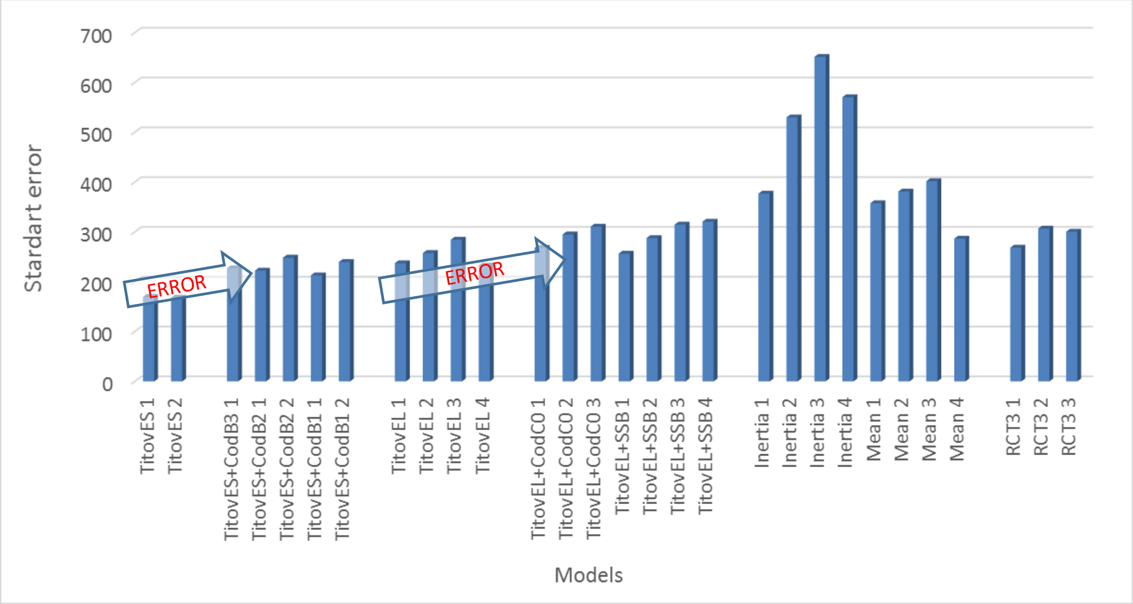


Figure 1.1. Standard errors of the NEA cod recruitment predicted values from the SAM values.

2 Cod in subareas 1 and 2 (Norwegian coastal waters)

Gadus morhua – cod.27.1-2coastN and cod.27.2.coastS

A benchmark assessment (WKBARFAR) was conducted in February 2021 in order to address the failure of the current management plan to reduce fishing mortality on Norwegian coastal cod (ICES 2021a). The main outcome of the benchmark was that from assessment year 2021 onwards, Norwegian coastal cod (NCC; formally cod.27.1-2coast) will be split into two stocks/components by 67 degrees latitude—a data-rich one in the north: cod.27.1-2coastN (northern Norwegian coastal cod); and a data-limited one in the south: cod.27.2coastS (southern Norwegian coastal cod; Figure 2.0.1). The majority (approximately 80–90%) of NCC catches are taken north of 67°N (Table 2.1.1), and this is also where the coastal survey has the best coverage. Genetic studies have revealed a genetic gradient in cod along the Norwegian coast without areas of distinct breaks in population connectivity (Dahle *et al.*, 2018). However, NCC in northern Norway have more genetic material in common with the Northeast Arctic cod (NEAC; cod.27.1-2), compared to Norwegian coastal cod further south (Dahle *et al.*, 2018).

Recent updates of the catch series, a revision of the acoustic survey index and a new swept-area index have improved the data basis for assessment in the northern area. The data for northern Norwegian coastal cod were considered of high enough quality to support an age-based analytical assessment. Southern Norwegian coastal cod (62–67°N) represents the remaining commercial catches of NCC north of 62°N (approximately 10–20%) and is not as consistently covered by the main survey relevant to monitoring cod. Current data availability and quality cannot support a full analytical assessment, and a data-limited approach has therefore been developed to support management of this stock.

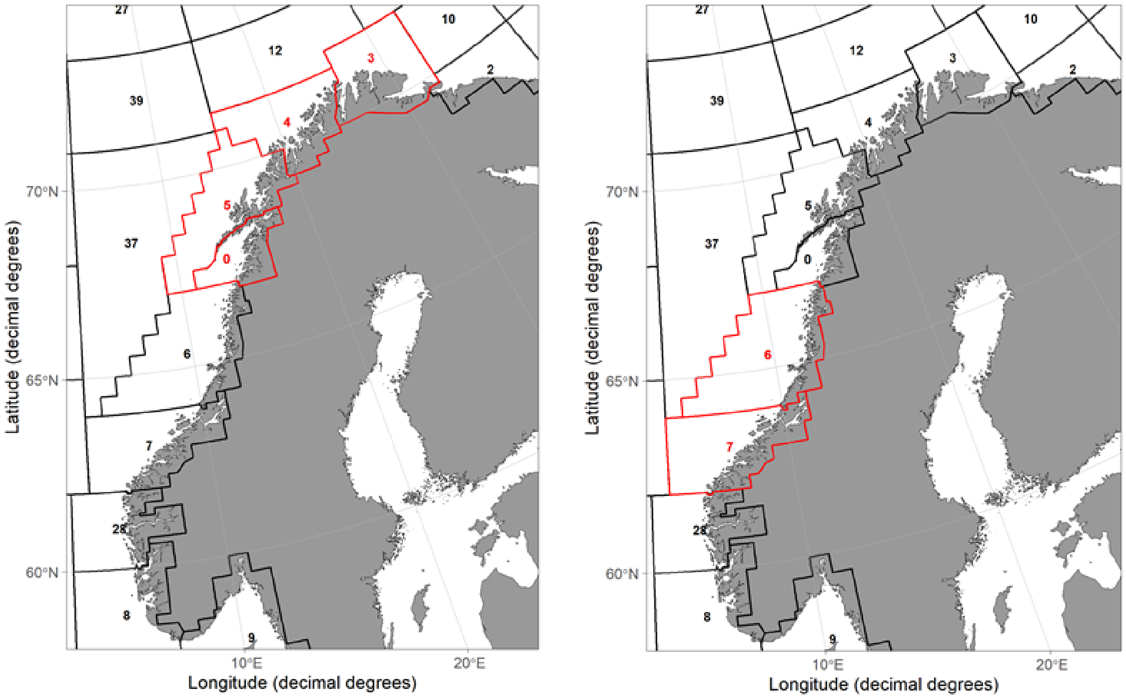


Figure 2.0.1 Norwegian catch reporting areas used to define stock distribution areas for northern Norwegian coastal cod (left) and southern Norwegian coastal cod (right).

2.1 Fisheries (both stocks)

Coastal cod is fished throughout the year and within nearly all the distribution areas in the Norwegian statistical areas 03, 04, 05, 00, 06, 07 (Figure 2.0.1). Most of the coastal cod catches are taken as a bycatch in fisheries aimed at Northeast Arctic cod during its spawning and feeding migrations to coastal waters. The main fishery for coastal cod, therefore, takes place in the first half of the year. The main fishing areas are along the coast from Varangerfjord to Lofoten (areas 03, 04, 05, 00).

Recreational and tourist fisheries take an important fraction of the total catches in some local areas, especially near the coastal cities, and in some fjords where commercial fishing activity is low. However, there are a few reports trying to assess the amount in certain years. In 2010, these reports were used to construct a time-series of recreational catches (ICES 2010). These catch estimates are quite uncertain. No additional information was included during 2010–2018, and the annual recreational catch during this period has been assumed equal to the one estimated for 2009 (12 700 t).

A new project was conducted in the period 2017–2020 by IMR in collaboration with several Norwegian institutions (NINA, Akvaplan-niva, NMBU and Nordland Research), and a number of international partners. Three study areas Troms, Hordaland, and Oslofjord, were chosen because they represent contrasts in recreational fishing. The project is currently being finished and reports will follow, but some preliminary results were presented at the benchmark assessment (WKBARFAR WD13, ICES 2021a), and further used in the present coastal cod assessments.

Historically there has been no reporting system for NCC taken by recreational or tourist fishers in Norway. In 2019, the Norwegian Directorate for Fisheries established a web portal for obligatory catch reporting (both kept and released fish) by all registered fishing businesses. Tourist fishing effort related to tourist fishing businesses has about doubled from 2009 to 2019. The total quantity of cod caught by tourists staying in tourist businesses has also more than doubled from 1586 tonnes in 2009 (Vølstad *et al.*, 2011) to about 3455 tonnes in 2019.

The current (2019) documented estimate of about 9000 tonnes (WKBARFAR WD13, ICES 2021a) is clearly an underestimate as tourists outside registered tourist businesses and residents fishing with fixed gears are not included. In the estimate of 9000 tonnes is also a share of the catch taken by anglers and released again. Based on investigations in other countries, the AFWG anticipates a mortality rate of 100% of fish caught by rod from land, and 20% of released cod caught by rod and handline at sea (e.g. Weltersbach and Strehlow, 2013; Capizzano *et al.*, 2016). Until there is a better quantification of the missing recreational segments, the benchmark WK proposed to keep the quantity of 12 700 tonnes recreational catch of Norwegian coastal cod north of 62°N on top of the commercial reported landings, with 7900 tonnes north of 67°N and 4800 tonnes between 62–67°N (Table 2.1).

The catch reporting (both kept and released fish) by the registered fishing businesses to the Norwegian Directorate of Fisheries in the corona-year 2020 shows a 77% decrease in catches of NCC compared to 2019. In the current assessment, the WG has taken this into account and reduced the rod and line catches from boats accordingly and kept the other recreational catches unchanged compared to 2019. This results in total 10 039 tonnes unreported NCC caught by recreational fishers north of 62°N in 2020, with 6233 tonnes caught north of 67°N and 3806 tonnes between 62–67°N.

The total catch numbers-at-age (Tables 2.2.3c and Table 2.3.3) have been upscaled from the estimated catch-at-age in the commercial landings, according to the added amount in tonnes.

It is necessary to update the recreational catch with a better estimate as soon as this is available.

2.1.1 Revision of catch data

The benchmark assessment (WKBARFAR, ICES 2021a) tested and analysed two major catch data revisions: i) using the ECA model to separate the Norwegian coastal cod and the Northeast Arctic cod in the commercial catches by the structure of the otoliths in commercial samples, and ii) revising the catch in tonnes since 1992 using recommended seasonal product-round fish conversion factors instead of fixed factors for the whole year.

Until 1992, Norway used seasonal conversion factors to convert the weight of "headed-and-gutted" cod to round weight (1.6 during winter and 1.4 during the rest of the year). From 1992 onwards, this factor was set to 1.50 for the same product in all Norwegian cod fisheries all year around. From 2000 onwards, this factor was also agreed upon by the Joint Norwegian-Russian Fisheries Commission (JNRFC). From 2000, it hence became constant for all cod fisheries at all times of the year, although there is a larger difference between "headed-and-gutted" weight and round weight in the winter season when at least the Norwegian coastal fisheries for cod are dominated by mature fish with gonads.

Based on a report published by the Norwegian Directorate of Fisheries in 2015 (Blom, 2015), and summaries of this previously reported to the AFWG as WD 15 in 2017 and as WD 09 in 2020 (Nedreaas, 2017; Fotland and Nedreaas, 2020), ICES advice for NEA cod in 2018 states that "The use of constant conversion factors between round and gutted weight for all seasons and areas introduces a bias to the catch statistics". During the benchmark meeting (WKBARFAR, ICES 2021a) the Norwegian landings of cod by vessels below 28 m in January–April, all gears, were hence corrected by using 1.311 and 1.671 for the products "gutted with head" and "gutted without head", respectively, for each year since 1994.

Catch numbers-at-age are estimated for both stocks of NCC (i.e. northern and southern) by the ECA model. The commercial catches have been calculated back to 1984, but for the current assessment revised catch data were available for the period 1994–2020 for both stocks. The plan is to revise the catch data for both NCC stocks back to 1984.

2.1.2 Catch sampling

The basis for estimating Norwegian coastal cod catches is the total landings of cod from fisheries operating within the Norwegian statistical areas 03, 04, 05, 00, 06, 07 (ref. Figure 2.0.1), combined with the catch samplings of these fisheries. Commercial catches of cod are separated into types of cod by the structure of the otoliths in the commercial catch samples. Figure 2.1.2 illustrates the main difference between the two types: The figure and the following text is from (Berg *et al.*, 2005):

> **Coastal cod has a smaller and more circular first translucent zone than northeast Arctic cod, and the distance between the first and the second translucent zone is larger. The shape of the first translucent zone in northeast Arctic cod is similar to the outer edge of the broken otolith and to the subsequent established translucent zones. This pattern is established at an age of 2 years, and error in differentiating between the two major types does not increase with age since the established growth zones do not change with age.**

The precision and accuracy of the separation method for categorizing cod-type was investigated by comparing the results of different otolith reads to the results of genetic analyses, and the investigation determined that the results from the otolith method are high in accuracy (Berg *et al.*, 2005). Nevertheless, in cases with a low percentage misclassification of large catches of pure NEA cod, the catches of coastal cod could be severely overestimated.

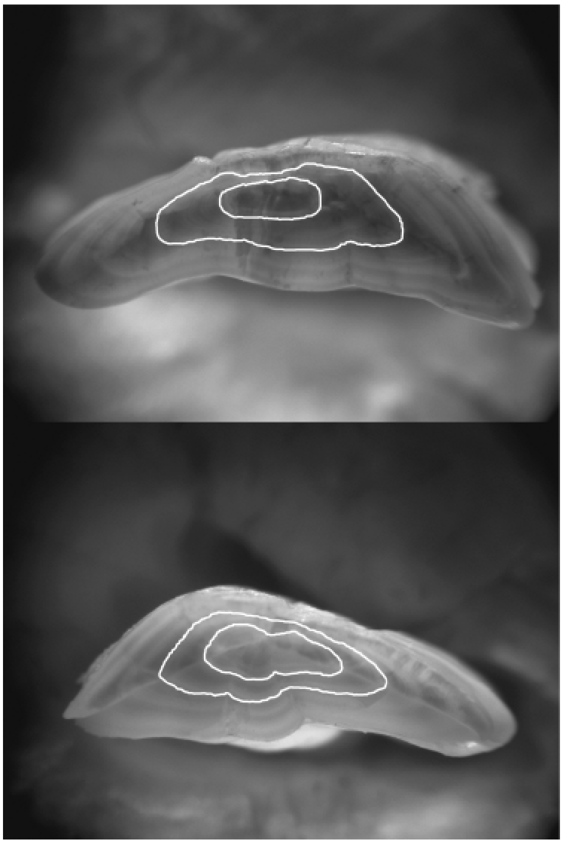


Figure 2.1.2. An image of a Norwegian coastal cod otolith (top) and a Northeast Arctic cod otolith (bottom). The two first translucent zones are highlighted. (from Berg *et al.*, 2005).

Since the catches are separated by type of cod by the structure of the otoliths, the numbers of age samples are critical for the estimated catch of coastal cod. Table 2.1.2 shows the sampling of the cod fisheries by quarters, split by NCC and NEAC. The Norwegian sampling program changed in 2010, which led to poor sampling in that year. The sampling in later years gradually improved, and the number of samples (but not the number of otoliths) is now well above the level prior to 2010.

The number of otoliths sampled in 2020 is lower than in 2018 and 2019 due to reduced access to fish landing sites because of COVID-19, but the proportion of NCC in samples was similar; a total of 9012 fish were aged in 2020, whereof 37% were classified as Norwegian coastal cod.

2.1.3 Regulations

The Norwegian cod TAC is a combined TAC for both the NEAC stock and NCC stocks. Landings of cod are counted against the overall cod TAC for Norway, where the expected catch of NCC (North and South) is in the order of 10%. The NCC part of this combined quota was set 40 000 t in 2003 and earlier years. In 2004, it was set to 20 000 t, and in the following years to 21 000 t. There are no separate quotas given for the coastal cod for the different groups within the fishing fleet. Catches of coastal cod are thereby not effectively restricted by quotas.

Since the coastal cod is fished under a merged Norwegian coastal cod/Northeast Arctic cod quota, the main objective of these regulations is to move the traditional coastal fishery from areas with high fractions of NCC to areas where the proportion of NEAC is higher. Most regulation measures for NEAC also applies to NCC; minimum catch size, minimum mesh size, maximum bycatch of undersized fish, closure of areas having high densities of juveniles, and some seasonal and area restrictions. A number of regulations contribute to some protection of NCC, e.g. a ban on trawl fishing inside 6 nautical miles from the baseline and "fjord-lines" that were drawn along the coast to close the fjords for direct cod fishing with vessels larger than 15 metres. For more details about the technical regulations, see ICES (2020).

Table 2.1.1. Left: estimated commercial catches of Norwegian coastal cod North of 67˚N (NCC North) and between 62–67˚N (NCC South), and Northeast Arctic cod between 62–67˚N (NEAC South). Middle: estimated recreational catches of cod north of 67˚N and between 62–67˚N, all assumed to be coastal cod. Right: Recreational catches of NCC North and South that were sold and included in the commercial catch statistics. Note that an initial unlikely low share of NCC vs. NEAC in the 2001 commercial landings compared to years before/after was replaced by an average of the 2000 and 2002 NCC values.

	Commercial catch (tonnes):			Recreational catch (tonnes):			Sold recreational catch included in commercial catch (tonnes)*:		
	NCC North	NCC South	NEAC South	NCC North	NCC South	Total	NCC North	NCC South	Total
1994	52 579	6 381	23 430	9 144	5 556	14 700			
1995	56 907	8 936	16 981	9 144	5 556	14 700			
1996	41 820	6 207	13 250	9 020	5 480	14 500			
1997	46 605	4 746	12 695	9 020	5 480	14 500			
1998	45 462	6 200	9 389	9 082	5 518	14 600			
1999	38 743	5 522	7 101	8 646	5 254	13 900			
2000	33 081	5 838	4 329	8 460	5 140	13 600			
2001	24 470	5 250	3 499	8 335	5 065	13 400			
2002	32 188	6 937	4 266	8 460	5 140	13 600			
2003	29 253	8 905	3 943	8 646	5 254	13 900			
2004	31 198	6 866	3 941	8 335	5 065	13 400			
2005	30 097	8 005	1 462	8 211	4 989	13 200			
2006	36 884	8 612	1 175	8 087	4 913	13 000			
2007	26 200	7 695	2 250	8 087	4 913	13 000			
2008	27 711	9 889	1 376	7 962	4 838	12 800			
2009	22 988	7 145	2 474	7 900	4 800	12 700			
2010	34 804	7 634	2 685	7 900	4 800	12 700			
2011	27 982	7 128	7 474	7 900	4 800	12 700			
2012	26 778	8 187	4 942	7 900	4 800	12 700	1 425	239	1 665
2013	21 376	5 131	8 395	7 900	4 800	12 700	450	167	617
2014	22 750	6 244	6 682	7 900	4 800	12 700	774	229	1 003
2015	34 483	5 004	5 424	7 900	4 800	12 700	618	226	844

	Commercial catch (tonnes):			Recreational catch (tonnes):			Sold recreational catch included in commercial catch (tonnes)*:		
	NCC North	NCC South	NEAC South	NCC North	NCC South	Total	NCC North	NCC South	Total
2016	49 503	5 962	2 006	7 900	4 800	12 700	810	332	1 142
2017	54 273	4 159	1 242	7 900	4 800	12 700	772	307	1 078
2018	34 532	4 436	1 822	7 900	4 800	12 700	1 206	340	1 546
2019	35 861	2 965	1 677	7 900	4 800	12 700	1 603	339	1 943
2020	43 133	3 481	987	6 233	3 806	10 039	1 785	347	2 132

***Source: Norwegian Directorate of Fisheries. All reported recreational cod assumed to be coastal cod.**

Table 2.1.2. Number of otoliths sampled by quarter from commercial catches. NCC: Norwegian coastal cod. NEAC: Northeast Arctic cod. The table includes all otoliths from the Norwegian catch sampling areas 0 and 3–7 (covering both Norwegian coastal cod stocks).

	Quarter 1		Quarter 2		Quarter 3		Quarter 4		Total		
Year	NCC	NEAC	NCC	NEAC	NCC	NEAC	NCC	NEAC	NCC	NEAC	%NCC
1985	1451	3852	777	1540	1277	1767	1966	730	5471	7889	41
1986	940	1594	1656	2579	0	0	669	966	3265	5139	39
1987	1195	2322	937	3051	638	1108	1122	1137	3892	7618	34
1988	257	546	160	619	87	135	55	44	559	1344	29
1989	556	1387	72	374	65	501	97	663	790	2925	21
1990	731	2974	61	689	252	97	265	674	1309	4434	23
1991	285	1168	92	561	77	96	279	718	733	2543	22
1992	152	619	281	788	79	82	272	672	784	2161	27
1993	314	1098	172	1046	0	0	310	541	796	2685	23
1994	317	1605	179	923	21	31	126	674	643	3233	17
1995	188	1591	232	1682	2095	1057	752	1330	3267	5660	37
1996	861	5486	591	1958	1784	1076	958	2256	4194	10776	28
1997	1106	5429	367	2494	1940	894	1690	1755	5103	10572	33
1998	608	4930	552	1342	489	1094	2999	2217	4648	9583	33
1999	1277	4702	493	2379	202	717	961	1987	2933	9785	23
2000	1283	4918	365	2112	386	1295	472	668	2506	9993	20
2001	1102	5091	352	2295	126	786	432	983	2012	9155	18
2002	823	5818	321	1656	503	831	897	1355	2544	9660	21

	Quarter 1		Quarter 2		Quarter 3		Quarter 4		Total		
Year	NCC	NEAC	NCC	NEAC	NCC	NEAC	NCC	NEAC	NCC	NEAC	%NCC
2003	821	4197	445	2850	790	936	1112	1286	3168	9269	25
2004	1511	7539	758	2565	532	685	531	1317	3332	12106	22
2005	1583	6219	767	4383	473	258	877	1258	3700	12188	23
2006	2244	5087	1329	2819	590	271	119	71	4282	8248	34
2007	1867	5895	944	2496	503	648	637	1163	3951	10202	28
2008	1450	4162	1116	3122	626	515	693	999	3885	8798	31
2009	1114	5109	558	2592	126	253	842	465	2640	8419	24
2010	736	2000	572	992	464	195	325	270	2097	3457	38
2011	643	2271	789	2548	412	296	732	443	2576	5558	32
2012	1294	6283	749	1864	379	85	324	185	2746	8417	25
2013	966	5389	832	3155	216	88	1115	385	3129	9017	26
2014	1019	4470	869	3312	338	29	1060	524	3286	8335	28
2015	746	7770	618	3619	327	354	511	547	2202	12290	15
2016	2465	5581	1073	2445	616	207	1501	727	5655	8960	39
2017	2276	4568	879	2742	810	151	1231	475	5196	7936	40
2018	2007	4927	924	1882	498	104	1143	435	4572	7348	40
2019	1830	4594	759	1969	838	260	1284	445	4711	7268	39
2020	1926	3551	587	1688	424	85	434	317	3371	5641	37
Av85–20	**1110**	**4021**	**617**	**2087**	**527**	**472**	**800**	**852**	**3054**	**7461**	**29**

2.2 Cod in subareas 1 and 2, north of 67°N (northern Norwegian coastal cod)

2.2.1 Stock status summary

An assessment based on the decisions of the 2021 WKBARFAR benchmark (ICES 2021a) is presented for this stock.

The 2021 assessment shows that SSB declined from a level just above B_{lim} at the start of the assessment period (1994) to a low level in 1999. Between 1999–2002, SSB increased, but to a level lower than the one observed at the start of the assessment period. After 2002, SSB stayed at a similar level until 2010, after which it increased to approximately 50 000 t lower than the 1994 level. After 2016, there has been a declining trend back towards the level estimated in 2003–2010, followed by an increase from 2019 to 2020 of approximately 10 000 t. Fishing mortality mainly follows the trend in SSB, with highest F in the period with lowest estimated SSB. However, F was higher at the start of the assessment period compared to 2013–2014, although SSB was higher in the first period. F also increased from 2019 to 2020 despite increasing SSB. Recruitment peaked in 1996 and has not been as high since. Comparatively good recruitment was seen in 2013–2018, after which it declined in 2019. In 2020, recruitment was the lowest observed since 2006, and the third-lowest observed in the time-series. TSB in 2020 is 9500 t lower than in 2019 and the lowest observed since 2013.

No previous advice has been issued for this stock. The 2021 advice for the previous Norwegian coastal cod stock (comprising the two new stocks) was to follow the Norwegian management plan, which implied reducing fishing mortality to 0.1.

Further details on the stock assessment procedure can be found in the Stock Annex.

2.2.2 The fishery (Table 2.2.1–Table 2.2.4)

Commercial landings of northern Norwegian coastal cod in 2020 were 43 133 t. Of the total landings, 28% were taken in ICES Division 1.b and the rest in Division 2.a (Table 2.2.1). The highest landings were made in the Norwegian catch reporting areas 03 and 04, using Danish seine, longline and jig (Table 2.2.2). In total, a third of the landings were taken in gillnet fisheries, while trawl made up approximately 12% of landings.

The level of discarding and misreporting from coastal vessels has been investigated for three periods: 2000 and 2002–2003 (WD 14 at 2002 WG), and 2012–2018 (Berg and Nedreaas 2021). The report from the 2000-investigation concluded that there was both discarding and misreporting by species in 2000. In the gillnet fishery for cod, discarding and misreporting represented approximately 8–10% relative to reported catch, and 1/3 of this was probably coastal cod. Data from 2002–2003 showed that misreporting in the coastal gillnet fisheries had been reduced significantly since 2000. A recent work by Berg and Nedreaas (2021) estimating discards of cod in the coastal gillnet fisheries during 2012–2018 showed that discarding (as percentage of total catch in weight including discards) decreased from less than 1% at the beginning of the period to less than 0.5% during 2016–2018. In weight, this corresponds to a decrease from more than 500 tonnes-per-year to about 180 tonnes-per-year. The reason for discarding seems to be highgrading by size (and price) during the first half of the year, and damaged fish (same size as landed fish) in the second half of the year.

Tourist fishing businesses reporting to the Norwegian Directorate of Fisheries in 2019 showed that about 42% of the reported rod and line catch was released, and with an assumed mortality of 20% of the released cod from the boat (see section 2.1), this corresponds to about 8% discards (dead fish) in the rod and line sector of the recreational fishery.

In the stock assessment, discarding is not included in the commercial landings, i.e. commercial catches are assumed equal to landings, but discarding in the rod and line (from boat) sector of the recreational fishery is included in the recreational catch estimate.

2.2.3 Survey results

A trawl-acoustic survey along the Norwegian coast from the Russian border to 62°N was started in autumn 1995. In 2003, this survey was combined with the former saithe survey at the coastal banks and moved from September to October–November (ICES acronym: A6335). Since then, the survey design included fixed bottom trawl stations in addition to trawl hauls set out on acoustic registrations. The seabed along the Norwegian coast is rugged, with sharp drops and peaks over short distances. This makes it difficult to get reliable survey indices both with acoustics and bottom trawl sampling. Acoustics can reach areas where the seabed is too uneven to perform bottom trawling, but species detection and discrimination can be hindered by dead zones and acoustic shadows. Acoustics and bottom trawl data therefore contain both independent and overlapping information. For the 2021 benchmark, one acoustic and one swept-area index was prepared (WD 06 to AFWG 2021), and it was decided to include them both in the assessment. It should be noted that the uncertainties associated with the indices are rather large and increasing with age.

The survey indices are calculated with the software StoX (Johnsen *et al*., 2019), developed at the Institute of Marine Research in Norway. Instead of conventional age–length keys, StoX uses an imputation algorithm to assign age information to individuals that have been length measured but not aged. Crucial to coastal cod, the software also imputes other biological information, particularly otolith type, which is used to split the index on NEAC and NCC. The underlying assumption is that the proportion of NCC in length samples are representative of the proportion in the environment. StoX also estimates coefficients of variation using a bootstrap routine. The bootstrapping consists of two parts; resampling of primary sampling units (trawl stations or acoustic transects) with replacement, and the imputation of missing ages by random draw from individuals in the same length group. Primarily, age information is drawn from individuals in the same length group sampled in the same trawl haul. Should there be none, the draw extends to all trawl hauls within the same survey strata, and lastly, to the entire survey area. The CV is the variability resulting from both parts of the bootstrap routine.

The results of the 2020 survey (Staby *et al.,* 2021) north of 67°N are presented in Tables 2.2.5–2.2.12.

2.2.3.1 Indices of abundance and survey mortality (Tables 2.2.5–2.2.8, Figures 2.2.2–2.2.4)

Both the acoustic (Table 2.2.5) and swept-area (Table 2.2.7) survey indices are lower in 2020 than in 2019, for nearly all age groups. The 2020 estimates of age 1 and 2 abundance are particularly low. The coefficient of variation (CV) is generally higher for ages 8 and above where there is less data. Both acoustic and swept-area index CVs for age 1, 9, and 10 were higher in 2020 than in 2018 and 2019, reflecting the low abundances of these age groups (Tables 2.2.6 and 2.2.8).

Survey mortality increased in 2020 relative to 2019, for most age groups (Figure 2.2.4). Generally, internal consistencies are low in both survey indices, and consequently, the survey mortality is highly variable between years (Figure 2.2.4).

2.2.3.2 Age reading and stock separation (Table 2.2.9)

About 2500 cod otoliths were sampled north of 67°N during the 2020 survey, which is up from 2100 in 2019 and the largest number of samples since 2003 (Table 2.2.9). The proportions of NCC at age among those otoliths were similar to previous years (Table 2.2.9). An error was discovered in the separation of stocks after AFWG was conducted. This error resulted in too few fish being categorized as coastal cod in 2020, and hence an erroneously low value for the coastal cod survey index in 2020. This error only affects northern coastal cod, and only in 2020. The error has been corrected, and the data and results presented here are based on the corrected data.

2.2.3.3 Length and weights-at-age (Tables 2.2.10–2.2.11, Figure 2.2.5)

Mean lengths-at-age in 2020 were similar to previous years (Table 2.2.10). Mean weight at age 1 was higher than in 2019, while it was similar for the other ages (Table 2.2.11). For age 8 and older the mean lengths and weights show larger variations, probably caused by few fish sampled in some years (Figure 2.2.5).

2.2.3.4 Maturity-at-age (Table 2.2.12, Figure 2.2.6)

The fraction of mature fish in the autumn survey (Table 2.2.12) show rather large variation between years. While some of the variation is likely related to variation in stock size and size at age, it may also be partly caused by the difficulty of distinguishing mature and immature cod in autumn. Coastal cod spawn in February–June and many mature individuals are therefore in a resting state at the time of the survey in October–November. As part of the 2021 benchmark, the maturity ogive was recalculated to include spent/resting individuals to address this discrepancy. This gave an ogive similar to that estimated from a smaller fishery-dependent dataset, collected during the spawning season. In 2020, the proportion mature at age 2–7 increased relative to 2020, while it decreased for age 8 (Figure 2.2.6). The proportion mature at age 2 in 2020 was particularly high, at a level not seen since 2008.

2.2.4 Data used in the Assessment

2.2.4.1 Catch numbers-at-age (Table 2.2.3c)

The estimated total catch-at-age (2–10+) for the period 1994–2020, including both commercial and recreational catches, is used in the assessment (Table 2.2.3c). Tables 2.2.3a and 2.2.3b show the commercial and recreational catches separately. The catch of ages 4–7 were higher in 2020 than in the two previous years, while the catch of age 10+ were about half compared to the two previous years. The total catch in tonnes increased by 5500 t compared to 2019.

2.2.4.2 Catch weight-at-age (Table 2.2.4)

Weight-at-age in catches is derived from the commercial sampling and is shown in Table 2.2.4. The same weight-at-age is assumed for recreational and tourist catches. Mean weights of ages 2–5 in 2020 are the highest observed in the time-series. Weight of the plus group is an average for the ages included in the plus group, weighted by abundance at age.

2.2.4.3 Tuning data (Table 2.2.13)

The acoustic and swept-area survey indices for ages 2–10+ are used in the assessment (Table 2.2.13). The acoustic index is split in two parts; 1995–2002 and 2003- due to a change in catchability when fixed bottom trawl stations were introduced in the survey.

2.2.4.4 Stock weight-at-age (Table 2.2.14)

The weight-at-age for ages 2–7 in the stock (Table 2.2.14) is obtained from the Norwegian coastal survey (Table 2.2.11), while catch weight-at-age (Table 2.2.4) is used for ages 8–10+ due to large uncertainty for these ages in survey data (Figure 2.2.5). The survey weights are assumed to be relevant to the weight-at-age in the stock at survey time (October). These weights will, however, overestimate the stock biomass at the start of the year, and in the assessment model, SSB is therefore calculated after applying 80% of the year’s fishing and natural mortality, corresponding to the survey timing.

2.2.4.5 Maturity-at-age (Table 2.2.12)

Annual maturity-at-age observed in the survey is used in the assessment (Table 2.2.12). Maturity of the plus group is an average for the ages included in the plus group, weighted by abundance-at-age.

2.2.4.6 Natural mortality (Table 2.2.15)

In Northeast Arctic cod, cannibalism has been documented to be a significant source of mortality that varies in relation to alternative food and in relation to the abundance of large cod. This might also be the case for the coastal cod (Pedersen and Pope 2003a and b). In the 2005 coastal cod survey 1125 cod stomachs were analysed (Mortensen 2007). The observed average frequency of occurrence of cod in cod stomachs was around 4%. Other important predators on cod in coastal waters are cormorants, harbour porpoises and otters (Anfinsen 2002; Pedersen *et al.*, 2007; Mortensen 2007). Young saithe (ages 2–4) has also been observed to consume post-larvae and 0-

group cod during summer/autumn (Aas 2007). As detailed data on consumption of coastal cod is lacking, natural mortality in the assessment is assumed dependent on cod size; M is calculated based on stock weight-at-age, following the method by Lorenzen (1996). With this method, M ranges from approximately 0.6 for age 2 to 0.2 for the plus group (Table 2.2.15).

2.2.5 Final assessment run

The 2021 assessment was run with the configuration decided upon at the 2021 benchmark (Table 2.2.16). The main features of the configuration are: 1) Coupling of fishing mortality states for ages 7–9, 2) Coupling of survey catchability parameters for ages 5–6 in the acoustic index part 1 and for ages 5–9 in the other two survey indices, 3) Separate variance parameter for age 2 in the catch, 4) AR(1)-correlation between ages in the acoustic index part 2 and the swept-area index, and 5) Recruitment modelled as random walk.

The log-likelihood, number of parameters and AIC of the final run are presented in the table below. There were no problems with model convergence. In the 2021 assessment, there was no "base" (previous year's assessment) to compare with and the "Current" and "base" model are therefore the same.

Model	**Log(L)**	**#par**	**AIC**
Current	−180.17	37	434.33
base	−180.17	37	434.33

The estimated survey catchabilities at age are presented in Table 2.2.17.

2.2.5.1 Model diagnostics (Figure 2.2.8–Figure 2.2.10)

A 5-year retrospective peel indicated no large problems with the estimates of SSB and Fbar (Figure 2.2.8). The second half of the model period has larger uncertainty as there is an additional survey index (from bottom trawl) that gives generally higher abundance estimates compared to the acoustic index. Mohn's rho (average 5-year retrospective bias) was 0.1 for SSB, −0.1 for Fbar, and 0.29 for recruitment. Thus, the model would have overestimated recruitment, particularly from 2013 and onwards, had it been run in previous years.

The process residuals were improved at the benchmark by splitting the acoustic index in two parts. Some clustering of positive/negative residuals remain in the log(N) residuals, with more negative residuals in the period 1995–2002 compared to the later period (Figure 2.2.9). The one-step-ahead residuals (Figure 2.2.10) were also improved by introducing correlations between ages in the survey indices. Evaluation of this correlation structure should be made at the next benchmark to see if the residuals can be further improved.

2.2.5.2 Model results (Table 2.2.18–2.2.20)

Recruitment in 2020 is the third-lowest estimate in the period covered by the model (Table 2.2.18). While SSB increased with 10 000 t in 2020, Fbar also increased compared to 2019 reflecting an increase in catches of ages 4–7 (Table 2.2.18 and Table 2.2.3c). Fishing mortality for ages 6–9 in 2020 were higher than in 2018 and 2019, while F for age 10+ was lower (Table 2.2.19). Abundances of ages 9 and 10+ in 2020 are the lowest seen since 2005 and 2009, respectively (Table 2.2.20). Abundance of ages 4 and 8 increased compared to 2019.

2.2.6 Reference points

Reference points were evaluated at the 2021 benchmark (ICES 2021a). The estimated stock–recruitment relationship showed increasing recruitment with increasing SSB throughout the model period, and the same pattern results from adding 2020 data in the assessment (Figure 2.2.11). At the benchmark, B_{lim} was therefore set near the highest SSB observed, based on the reasoning that the lack of plateau in the SSB-recruit relationship indicates that the stock is below full reproductive capacity. In the assessment model, recruitment is at age 2. A similar pattern of increasing recruitment with SSB is evident when age 3 abundance is plotted against SSB (Figure 2.2.12).

No reference points for fishing mortality could be determined at the benchmark due to the lack of observations above B_{lim}.

2.2.6.1 Management plan

No management plan is currently implemented for this stock.

2.2.7 Predictions

2.2.7.1 Input data (Tables 2.2.21a-b)

The built-in forecast option in SAM is used for short term prediction. Status quo fishing is assumed for the interim year, i.e. same F as in the final year of assessment (Table 2.2.21a). Process noise is included in the prediction (i.e. processNoiseF=FALSE). Averages from the last 5 years of the assessment are used for stock weights, catch weights, maturity, and natural mortality-at-age (Table 2.2.21b). Recruitment is the median resampled from the last 10 years (Table 2.2.21a).

2.2.7.2 Catch options for 2021 (Table 2.2.22, Figure 2.2.13)

The ICES advice basis for northern Norwegian coastal cod is the precautionary approach. This leads to catch advice of no more than 7865 tonnes in 2022. This catch level is expected to lead to a 25% increase in SSB relative to SSB estimated for 2021, while the same level of fishing in 2022 as in 2020 is expected to give a 0.15% decrease in SSB. Zero catch in 2022 is expected to give a 30% increase in SSB (Table 2.2.21, Figure 2.2.13).

2.2.7.3 Comparison of the present and last year's assessments

No previous assessment is available for this stock.

2.2.8 Comments to the assessment and the forecast

The assessment model performs rather well despite uncertainties in survey data. The main problem for this assessment is the lack of a full set of reference points and the uncertainty in the reference level for SSB. There is a need to perform further simulations to improve the reference points. Since this stock is part of a mixed fishery with Northeast Arctic cod and cannot be visually separated at sea, this year's catch advice is unlikely to be followed in practice. It is therefore advised to develop a management plan for this stock, detailing catch levels and regulations that may lead to the rebuilding of the stock over a longer period.

2.2.9 Tables and figures

Table 2.2.1. Northern Norwegian coastal cod. Total commercial catch (t) by fishing areas in 2020.

Year	03	04	00	05	Total in Division 1.b (NOR area 03)	Total in Division 2.a (NOR areas 04+00+05)	Total
2020	12245	12393	7652	10832	**12245**	**30877**	**43122***

***Differs slightly from Table 2.2.3a due to different spatial units used in estimation.**

Table 2.2.2. Commercial catch of northern Norwegian coastal cod (t) in 2020 by gear and Norwegian statistical fishing area.

Year	2020					
Area	**03**	**04**	**00**	**05**	**Total north of 67°N**	**% by gear**
Gillnet	1259	3931	4018	3813	13021	30.2
L.line/Jig						
Danish seine						
Trawl	1519	2342	0.2	1443	5304	12.3
Others*	9467	6120	3634	5576	24797	57.5
Total	**12245**	**12393**	**7652**	**10832**	**43122****	

***in 2020, longline, jig and Danish seine are all included in the 'others' category.**

****Differs slightly from Table 2.2.3a due to different spatial units used in estimation.**

Table 2.2.3a. Northern Norwegian coastal cod. Estimated commercial landings in numbers ('000) at-age and total tonnes by year.

	Age								Tonnes
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Landed**
1994	11	98	978	4394	3760	2756	1119	304	675	52579
1995	21	228	814	2743	4796	3164	1815	943	612	56907
1996	41	768	1415	2035	3130	3086	1210	542	584	41820
1997	57	1111	2106	1956	2344	2721	1856	565	746	46605
1998	436	1631	6433	4391	2784	835	779	377	393	45462
1999	79	912	3395	4938	2037	783	527	394	425	38743
2000	30	534	2549	3925	2240	826	376	112	273	33081
2001	10	330	1863	2242	1641	961	305	104	493	24470
2002	42	308	1551	2585	2391	1057	630	183	363	32188
2003	120	350	952	1859	2173	1206	582	308	252	29253

	Age								Tonnes
Year	2	3	4	5	6	7	8	9	10+	Landed
2004	23	179	1067	1520	2189	1570	784	328	371	31198
2005	13	241	924	1984	2003	1463	716	255	345	30097
2006	23	222	1276	1977	2619	1735	1017	402	396	36884
2007	36	376	1198	1667	1327	1088	477	277	279	26200
2008	63	387	997	1909	1549	1005	576	278	287	27711
2009	21	456	667	1177	1194	812	419	431	211	22988
2010	29	530	754	2832	1947	1055	528	283	857	34804
2011	65	465	1209	1318	1239	1081	568	343	583	27982
2012	374	1017	1126	1118	1287	760	364	177	596	26778
2013	131	503	1024	1038	909	704	478	219	340	21376
2014	88	505	824	1258	839	676	523	297	397	22750
2015	331	1106	1411	1251	1700	1040	639	437	873	34483
2016	75	937	1988	1582	1723	2119	1174	640	1073	49503
2017	846	1577	2071	2323	2087	1491	1331	700	903	54273
2018	171	563	1465	1634	1525	1416	747	518	497	34532
2019	49	953	1299	1776	1585	1260	985	318	519	35861
2020	40	534	2205	2116	2538	1615	906	354	309	43133

Table 2.2.3b. Northern Norwegian coastal cod. Estimated catch number ('000) at-age in recreational and tourist catches.

	Age									Tonnes
Year	2	3	4	5	6	7	8	9	10+	landed
1994	2	17	170	764	654	479	195	53	117	9144
1995	3	37	131	441	771	508	292	151	98	9144
1996	9	166	305	439	675	666	261	117	126	9020
1997	11	215	408	378	454	527	359	109	144	9020
1998	87	326	1285	877	556	167	156	75	78	9082
1999	18	204	758	1102	455	175	118	88	95	8646
2000	8	136	652	1004	573	211	96	29	70	8460
2001	3	112	635	764	559	327	104	36	168	8335

	Age								Tonnes
Year	2	3	4	5	6	7	8	9	10+	landed
2002	11	81	408	679	628	278	166	48	95	8460
2003	36	104	281	549	642	356	172	91	74	8646
2004	6	48	285	406	585	419	209	88	99	8335
2005	4	66	252	541	546	399	195	69	94	8211
2006	5	49	280	433	574	380	223	88	87	8087
2007	11	116	370	514	410	336	147	85	86	8087
2008	18	111	287	549	445	289	165	80	82	7962
2009	7	157	229	405	410	279	144	148	73	7900
2010	7	120	171	643	442	240	120	64	194	7900
2011	18	131	341	372	350	305	160	97	165	7900
2012	110	300	332	330	380	224	107	52	176	7900
2013	48	186	379	383	336	260	177	81	126	7900
2014	31	175	286	437	291	235	181	103	138	7900
2015	76	253	323	287	389	238	146	100	200	7900
2016	12	150	317	253	275	338	187	102	171	7900
2017	123	230	301	338	304	217	194	102	131	7900
2018	39	129	335	374	349	324	171	119	114	7900
2019	11	210	286	391	349	278	217	70	114	7900
2020	6	77	319	306	367	233	131	51	45	6233

Table 2.2.3c. Northern Norwegian coastal cod. Total estimated catch number ('000) at age, including recreational and tourist catches.

	Age									Tonnes
Year	2	3	4	5	6	7	8	9	10+	landed
1994	13	115	1148	5158	4414	3235	1313	356	793	61723
1995	24	264	945	3183	5567	3672	2106	1094	711	66051
1996	50	934	1720	2473	3805	3752	1471	659	709	50840
1997	68	1326	2514	2334	2797	3248	2215	674	890	55624
1998	523	1957	7718	5268	3341	1002	935	452	471	54544
1999	97	1116	4152	6040	2492	957	644	482	520	47390

	Age									Tonnes
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**landed**
2000	38	670	3201	4929	2812	1037	472	141	342	41541
2001	13	442	2497	3006	2199	1288	409	140	661	32806
2002	53	389	1959	3265	3019	1335	796	231	459	40648
2003	156	454	1234	2408	2815	1562	754	399	326	37900
2004	30	227	1352	1926	2774	1989	993	415	470	39533
2005	17	307	1176	2525	2550	1862	911	324	440	38308
2006	28	271	1556	2410	3193	2115	1240	490	482	44970
2007	47	492	1567	2181	1737	1423	624	362	365	34287
2008	81	498	1284	2458	1994	1294	741	358	369	35674
2009	28	612	896	1582	1605	1091	563	579	284	30888
2010	35	651	925	3474	2388	1295	647	347	1051	42704
2011	83	597	1550	1690	1588	1386	728	440	747	35882
2012	484	1317	1458	1447	1666	984	471	229	772	34678
2013	179	689	1403	1421	1245	965	655	300	466	29276
2014	119	680	1110	1695	1130	911	704	400	534	30650
2015	407	1360	1734	1537	2089	1278	785	537	1072	42383
2016	86	1086	2305	1835	1998	2458	1362	743	1244	57403
2017	969	1806	2373	2661	2391	1707	1525	802	1035	62173
2018	210	691	1800	2007	1873	1740	918	637	611	42432
2019	60	1163	1585	2167	1934	1537	1202	387	633	43761
2020	45	612	2524	2422	2905	1849	1037	405	353	49366

Table 2.2.4. Northern Norwegian coastal cod. Mean catch weight at age (kg).

	Age								
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1994	0.910	1.422	1.987	2.649	3.479	4.343	5.245	6.487	8.825
1995	0.784	1.272	1.708	2.236	3.073	4.203	5.228	6.121	9.469
1996	0.874	1.269	1.722	2.385	2.968	3.660	4.544	5.462	7.814
1997	1.115	1.490	1.902	2.497	3.219	3.930	4.738	5.616	7.768

	Age								
Year	2	3	4	5	6	7	8	9	10+
1998	0.719	1.212	1.654	2.343	3.346	3.969	4.786	5.389	9.584
1999	0.989	1.512	1.975	2.501	3.331	4.032	4.923	5.415	8.339
2000	1.019	1.452	2.057	2.598	3.447	4.449	5.553	5.834	9.781
2001	1.014	1.448	1.905	2.593	3.266	3.756	4.498	4.794	7.711
2002	0.929	1.470	2.059	2.760	3.590	4.467	5.268	6.236	9.943
2003	1.082	1.687	2.180	2.944	3.754	4.672	5.417	5.713	9.070
2004	1.145	1.604	2.186	2.848	3.640	4.555	5.367	5.930	7.991
2005	1.112	1.622	2.249	3.017	3.539	4.371	5.233	5.981	8.320
2006	1.522	2.020	2.491	3.284	4.075	4.887	5.806	6.638	9.710
2007	1.072	1.546	2.168	2.968	3.987	4.925	5.781	6.871	9.771
2008	1.153	1.663	2.355	3.043	3.970	4.902	5.844	6.279	9.239
2009	1.331	1.761	2.502	3.328	4.196	5.218	6.178	6.516	9.248
2010	1.252	1.770	2.375	3.103	3.834	4.483	5.437	6.185	7.599
2011	1.080	1.689	2.310	3.031	3.906	4.681	5.941	6.422	8.346
2012	1.010	1.653	2.328	3.232	4.246	5.111	6.448	6.914	9.446
2013	1.107	1.674	2.295	3.122	3.997	4.873	5.892	6.800	10.104
2014	1.187	1.788	2.410	3.222	4.118	5.165	5.791	6.461	9.643
2015	1.055	1.545	2.192	3.030	3.745	4.724	5.601	6.482	9.044
2016	1.279	1.774	2.363	3.171	3.972	4.868	5.893	6.850	8.928
2017	1.316	1.785	2.468	3.225	4.077	5.014	5.977	6.933	9.356
2018	1.141	1.700	2.307	3.090	3.878	4.770	5.711	6.581	9.333
2019	1.431	1.904	2.615	3.254	4.116	4.868	5.748	6.562	8.561
2020	1.487	2.147	2.823	3.514	4.218	4.932	5.655	6.387	9.024

Table 2.2.5. Northern Norwegian coastal cod. Acoustic abundance indices by age (in thousands) and total biomass (t) from the Coastal survey (A6335). The split between coastal cod and Northeast Arctic cod is uncertain for age 1.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Sum	Biomass
1995	26495	8774	4974	6382	6440	4373	1309	532	319	132	59729	55126
1996	17580	9025	8592	4576	5306	2723	1022	213	32	24	49093	39263

	Age										
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Sum**	**Biomass**
1997	16567	15358	16930	7710	4484	2316	716	328	59	33	64502	45756
1998	8360	6757	8524	8261	3717	1530	700	102	122	45	38118	39474
1999	2494	3486	3387	2788	2498	751	172	30	22	20	15648	16167
2000	5028	7439	5831	3939	3853	2825	622	258	71	32	29899	35602
2001	2711	4551	4246	3776	2184	1499	974	149	29	93	20211	27250
2002	1188	2071	2532	2926	2075	970	596	293	106	124	12882	21203
2003	3276	2168	3026	3303	1838	1519	651	364	190	69	16403	23978
2004	3046	2643	2819	2589	1686	1094	371	213	104	72	14639	18237
2005	904	1201	2228	1816	1490	843	234	233	127	79	9156	14690
2006	4981	1836	2587	2210	1453	1612	1046	130	89	27	15970	22116
2007	2458	3037	2778	3794	2437	1632	1215	441	120	41	17952	33314
2008	2344	1739	1684	1511	985	761	399	225	97	74	9821	15491
2009	3907	1502	2084	2596	1373	605	386	378	140	64	13035	18716
2010	5509	2503	2853	2240	1679	583	309	432	229	195	16531	21966
2011	2104	2542	1869	2372	1469	1215	394	278	137	150	12529	23115
2012	3561	2170	3546	1832	1154	791	503	254	107	224	14142	20913
2013	4694	3084	1597	1770	1287	838	657	430	216	252	14825	21105
2014	6030	4171	3066	2137	2904	1609	1151	429	462	326	22286	37127
2015	3421	3122	2465	1802	1017	1128	477	363	303	265	14362	23144
2016	2921	3341	3667	2349	2308	841	669	452	222	308	17078	30763
2017	1018	3289	3202	2335	1764	1122	450	256	181	183	13800	25998
2018	4977	2847	1837	2376	1246	946	494	246	136	169	15274	22602
2019	2607	2992	3724	2221	2149	1272	656	212	262	266	16360	29992
2020	477	1619	3365	3564	1821	853	491	299	85	126	12702	25425

Table 2.2.6. Northern Norwegian coastal cod. Acoustic abundance index coefficient of variation (CV, in %) by age.

	Age									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1995	17	13	9	12	14	21	19	40	51	41

	Age									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1996	20	11	15	17	14	26	54	39	52	156
1997	24	25	16	16	14	25	26	47	90	81
1998	26	19	12	16	16	31	69	40	87	104
1999	24	10	11	20	17	23	19	47	40	92
2000	14	16	12	10	9	10	15	29	49	89
2001	18	31	18	16	19	18	21	41	72	69
2002	25	17	21	16	14	15	23	36	72	67
2003	27	26	14	14	14	16	18	22	26	35
2004	17	15	14	12	13	17	17	25	69	33
2005	18	23	18	10	14	20	23	30	40	61
2006	108	68	15	14	15	27	22	23	31	
2007	21	20	19	15	16	16	21	31	45	97
2008	24	19	14	13	12	14	20	24	39	37
2009	22	20	15	12	17	14	18	19	31	25
2010	41	18	16	13	12	22	22	22	21	21
2011	22	17	16	15	15	15	27	21	19	35
2012	20	20	13	14	15	11	19	16	24	18
2013	14	16	14	15	14	13	17	20	31	37
2014	16	19	12	15	15	13	15	14	23	43
2015	21	16	11	10	12	12	16	16	16	27
2016	29	15	10	8	11	16	17	21	39	31
2017	34	16	12	16	14	18	23	28	43	25
2018	18	17	17	16	18	9	18	60	20	35
2019	18	20	15	13	12	15	18	28	33	35
2020	30	16	17	11	12	14	19	26	40	57

Table 2.2.7. Northern Norwegian coastal cod. Swept-area abundance indices by age (in thousands) and total biomass (t) from the Coastal survey (A6335). The split between coastal cod and Northeast Arctic cod is uncertain for age 1.

	Age											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Sum**	**Biomass**
2003	5254	3268	3763	4521	2700	2319	863	489	220	69	23467	33861
2004	2837	2201	2396	2602	1463	722	359	181	46	63	12868	15980
2005	665	1042	1988	1478	1268	746	157	107	68	54	7574	11379
2006	1802	2156	2623	2946	1554	1026	941	171	107	23	13349	22526
2007	446	911	853	1071	789	465	394	114	75	29	5146	11943
2008	2463	1822	2795	1883	1419	1145	580	348	161	94	12710	23090
2009	6642	2251	3570	3716	1584	868	712	466	204	160	20172	24986
2010	7412	2353	3268	3385	2397	784	383	733	317	328	21360	29875
2011	2322	3471	2498	2866	2095	1445	292	315	213	310	15827	27845
2012	4299	3218	4485	2784	1537	1042	930	411	200	346	19251	28587
2013	6382	4101	1706	2666	1887	1575	890	578	297	419	20502	32875
2014	5696	5448	4026	3034	3521	2016	1388	465	364	337	26296	43823
2015	4298	4733	4154	3727	2068	1818	902	506	397	222	22827	40385
2016	3944	4433	4522	2610	1995	746	735	413	203	210	19810	31320
2017	768	2891	2407	1563	1151	715	308	200	147	157	10308	18682
2018	4070	3197	1916	1879	1049	748	323	183	128	168	13661	18815
2019	2234	2114	2470	1508	1460	839	490	148	129	211	11601	19974
2020	560	1670	2599	2416	1188	611	291	177	49	72	9632	14211

Table 2.2.8. Northern Norwegian coastal cod. Swept-area abundance index coefficient of variation (CV, in %).

	Age									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2003	23	23	16	14	12	12	24	32	25	69
2004	27	16	16	16	21	21	23	34	40	37
2005	21	28	30	22	16	25	24	25	45	58
2006	20	34	24	26	17	13	24	30	34	
2007	23	28	30	18	17	15	24	31	44	87
2008	15	26	21	13	11	17	15	20	37	36

	Age									
Year	1	2	3	4	5	6	7	8	9	10
2009	16	16	18	14	14	18	15	21	24	27
2010	9	16	19	21	16	18	26	27	21	16
2011	20	24	27	19	23	17	25	23	23	35
2012	9	37	24	13	12	13	16	17	23	20
2013	14	17	15	23	20	21	16	17	31	38
2014	17	30	17	16	17	26	14	15	22	39
2015	19	17	18	27	29	22	30	19	19	23
2016	20	13	13	10	9	13	16	24	20	20
2017	30	20	17	15	9	17	18	39	30	27
2018	15	19	16	15	12	11	15	27	19	19
2019	15	16	16	13	10	9	12	17	25	30
2020	21	14	16	13	13	16	15	19	31	41

Table 2.2.9. Proportion Norwegian coastal cod by age among all aged cod in the Norwegian coastal survey north of 67°N. The split between coastal cod and Northeast Arctic cod is uncertain for age 1.

	Age									
Year	1	2	3	4	5	6	7	8	9	10	Total number of aged cod otoliths
1995	0.92	0.98	0.94	0.86	0.60	0.54	0.60	0.56	0.90	1.00	2236
1996	0.87	0.96	0.89	0.81	0.68	0.60	0.41	0.42	0.27	0.25	2289
1997	0.88	0.91	0.86	0.79	0.71	0.64	0.43	0.26	0.14	0.75	1774
1998	0.89	0.85	0.80	0.74	0.80	0.69	0.50	0.34	0.32	0.60	2639
1999	0.88	0.90	0.81	0.64	0.58	0.62	0.52	0.20	0.22	0.13	2911
2000	0.97	0.91	0.85	0.76	0.65	0.57	0.42	0.46	0.18	0.08	4325
2001	0.88	0.84	0.74	0.71	0.65	0.55	0.45	0.41	0.21	0.31	3282
2002	0.84	0.86	0.78	0.68	0.54	0.34	0.32	0.29	0.10	0.18	2265
2003	0.90	0.94	0.87	0.88	0.85	0.75	0.65	0.59	0.52	0.57	2953
2004	0.86	0.76	0.77	0.59	0.67	0.57	0.60	0.49	0.41	0.63	2287
2005	0.65	0.81	0.76	0.76	0.65	0.59	0.48	0.56	0.50	0.44	1209
2006	0.98	0.93	0.94	0.83	0.75	0.71	0.68	0.68	0.57	0.00	1419

	Age										Total number of aged cod otoliths
Year	1	2	3	4	5	6	7	8	9	10	
2007	0.73	0.81	0.76	0.82	0.73	0.61	0.69	0.43	0.83	0.50	1021
2008	0.99	0.99	0.99	0.83	0.89	0.84	0.78	0.67	0.94	0.75	1448
2009	0.94	0.94	0.83	0.69	0.55	0.58	0.75	0.76	0.73	0.72	1944
2010	0.94	0.94	0.89	0.75	0.66	0.49	0.60	0.86	0.90	0.97	2093
2011	0.90	0.93	0.91	0.89	0.77	0.66	0.52	0.73	0.80	0.83	1577
2012	0.94	0.89	0.90	0.82	0.83	0.73	0.71	0.61	0.88	0.84	1831
2013	0.93	0.94	0.88	0.77	0.79	0.83	0.74	0.79	0.73	1.00	1920
2014	0.99	0.99	0.99	0.96	0.93	0.90	0.93	0.87	0.87	0.88	2361
2015	0.89	0.93	0.89	0.86	0.75	0.73	0.65	0.73	0.82	0.96	1859
2016	0.99	0.98	0.99	0.90	0.84	0.69	0.75	0.80	0.71	0.83	2041
2017	1.00	0.98	0.95	0.93	0.86	0.74	0.78	0.68	0.84	1.00	1732
2018	0.99	0.97	0.91	0.86	0.88	0.82	0.72	0.68	0.87	0.90	2395
2019	0.95	0.99	0.97	0.88	0.84	0.83	0.84	0.76	0.82	0.91	2107
2020	1.00	0.84	0.85	0.81	0.71	0.70	0.75	0.83	0.78	0.64	2504

Table 2.2.10. Northern Norwegian coastal cod. Mean length (cm) at-age from Coastal survey data (A6335). Mean lengths of ages > 7 have higher uncertainty due to few samples. The split between coastal cod and Northeast Arctic cod is uncertain for age 1. For the plus group, mean length is the average mean length for ages 10+, weighted by abundance-at-age.

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
1995	18.9	31.4	42.1	51.8	58.8	64.3	77.5	82.4	87.1	105.7
1996	16.7	28.3	41.3	51.9	58.1	65.2	74.8	86.7	99.6	115.0
1997	16.6	29.6	40.7	52.0	58.1	66.9	66.8	68.6	102.0	92.0
1998	17.8	30.3	44.0	52.0	60.3	67.8	74.9	82.2	83.8	107.8
1999	19.4	31.2	44.1	54.1	58.7	65.4	74.0	89.0	88.2	72.7
2000	20.0	32.5	44.0	54.0	61.4	64.5	73.8	81.9	80.3	90.3
2001	20.0	33.7	45.7	55.4	61.1	65.2	67.6	76.1	87.2	109.7
2002	21.6	32.6	45.0	54.5	62.0	68.8	72.4	70.5	66.7	91.8
2003	19.3	33.3	43.8	52.6	60.9	67.7	73.7	78.8	81.9	107.9

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
2004	21.1	32.7	44.0	54.5	59.2	67.7	70.5	75.5	74.2	79.5
2005	21.6	35.7	44.7	55.4	60.5	62.6	71.4	71.7	80.3	105.9
2006	20.6	34.1	46.2	55.0	60.0	68.8	71.4	74.6	89.0	117.6
2007	21.2	35.9	47.2	56.8	62.7	67.3	73.7	83.4	100.5	99.3
2008	22.1	35.4	48.3	57.9	68.5	69.1	75.8	75.8	71.7	82.3
2009	19.8	32.9	46.7	57.1	64.7	71.4	76.6	76.9	81.2	76.7
2010	18.9	36.9	47.8	56.9	64.1	71.2	76.4	75.5	82.1	83.1
2011	19.1	34.6	48.7	61.0	67.6	71.2	78.1	80.8	80.5	81.6
2012	20.3	32.9	48.3	59.3	65.5	71.4	76.4	80.7	82.2	83.5
2013	21.2	34.3	45.6	56.9	67.7	70.9	73.3	77.3	82.4	88.4
2014	21.1	33.7	48.8	58.0	66.9	72.8	77.5	81.7	80.8	91.4
2015	19.9	34.6	48.3	60.3	67.8	72.6	77.9	79.9	82.2	84.8
2016	20.3	33.1	48.2	58.0	69.5	73.5	76.9	82.5	87.5	87.7
2017	20.3	37.0	47.6	58.7	66.7	74.0	79.5	86.0	84.0	92.8
2018	17.0	37.6	48.0	60.1	68.7	71.5	81.1	84.7	92.1	84.1
2019	19.6	33.7	49.0	59.0	68.2	73.5	80.4	84.4	84.1	95.4
2020	20.6	33.0	46.7	58.3	66.6	72.5	77.8	82.4	93.3	85.3

Table 2.2.11. Northern Norwegian coastal cod. Mean weight (g) at-age from Coastal survey data (A6335). Mean weights of ages > 7 have higher uncertainty due to few samples. The split between coastal cod and Northeast Arctic cod is uncertain for age 1. For the plus group, mean weight is the average mean weight for ages 10+, weighted by abundance-at-age.

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
1995	58	282	719	1395	2091	2767	4693	5905	7211	13022
1996	41	216	672	1349	1939	2779	4223	6638	11146	20000
1997	41	244	655	1393	1914	2921	2988	3768	9600	7779
1998	49	259	840	1406	2261	3173	4320	5275	5896	15476
1999	63	272	793	1508	1964	2759	4257	7262	6561	5934
2000	69	322	826	1561	2363	2811	4260	5977	6061	7553
2001	74	377	933	1660	2320	2998	3338	4478	7193	13677

	Age									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
2002	88	357	918	1595	2377	3468	4415	3868	3588	10135
2003	68	361	820	1427	2269	3127	4114	5493	6350	13767
2004	88	338	877	1646	2153	3197	3810	4656	4184	5457
2005	99	436	878	1727	2205	2542	3666	3520	5562	14216
2006	83	400	989	1649	2231	3502	3992	4445	8004	21921
2007	97	486	1066	1865	2579	3168	4520	6363	11111	13111
2008	97	427	1109	1971	3327	3393	4543	4921	4270	6451
2009	74	357	1032	1878	2695	3803	4599	5146	5349	5205
2010	63	502	1088	1872	2745	3586	4684	5096	6263	6698
2011	59	401	1165	2279	3109	3702	5163	5593	6174	5963
2012	73	355	1141	2026	2907	3690	4688	5549	6118	6504
2013	85	384	918	1817	3041	3438	3963	4926	5662	8265
2014	80	359	1122	1894	2929	3690	4646	5562	5550	8639
2015	73	406	1115	2145	2987	3774	4839	5299	5869	6708
2016	73	347	1101	1904	3327	3928	4689	5885	7273	8108
2017	83	504	1058	1969	2943	3997	4676	6985	6306	8472
2018	52	522	1109	2094	3206	3763	5391	5818	8438	6378
2019	62	372	1131	1984	2983	3815	5141	5908	6420	9215
2020	96	379	1010	1928	2972	3767	4995	5825	9305	7132

Table 2.2.12. Northern Norwegian coastal cod. Maturity-at-age as determined from maturity stages observed in the coastal survey (A6335). Maturity for age 10+ is the average proportion mature for ages 10 and above, weighted by abundance-at-age. The split between coastal cod and Northeast Arctic cod is uncertain for age 1.

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
1995	0.00	0.00	0.13	0.51	0.60	0.78	0.86	0.99	1.00	1.00
1996	0.00	0.02	0.14	0.38	0.74	0.84	0.92	1.00	1.00	1.00
1997	0.03	0.06	0.25	0.36	0.64	0.93	0.92	0.86	1.00	1.00
1998	0.01	0.03	0.13	0.24	0.56	0.70	0.98	0.93	0.88	1.00
1999	0.00	0.02	0.06	0.27	0.52	0.69	0.74	1.00	0.57	1.00
2000	0.00	0.00	0.06	0.20	0.51	0.68	0.80	0.92	1.00	1.00
2001	0.00	0.00	0.04	0.27	0.76	0.96	0.97	0.97	1.00	1.00
2002	0.00	0.01	0.11	0.30	0.78	0.89	0.98	0.94	1.00	1.00
2003	0.00	0.00	0.03	0.28	0.55	0.88	0.95	0.93	1.00	1.00
2004	0.00	0.01	0.11	0.30	0.78	0.92	0.94	1.00	1.00	1.00
2005	0.00	0.00	0.11	0.37	0.56	0.83	0.94	0.97	1.00	1.00
2006	0.00	0.01	0.19	0.53	0.72	0.93	0.90	0.96	1.00	1.00
2007	0.00	0.00	0.16	0.54	0.72	0.93	0.96	1.00	1.00	1.00
2008	0.00	0.02	0.10	0.30	0.73	0.88	0.97	1.00	1.00	1.00
2009	0.00	0.00	0.05	0.21	0.39	0.64	0.77	0.90	0.97	0.94
2010	0.00	0.00	0.03	0.27	0.57	0.78	0.92	0.99	0.98	1.00
2011	0.02	0.00	0.05	0.31	0.63	0.74	0.89	0.90	0.88	1.00
2012	0.00	0.01	0.04	0.28	0.57	0.86	0.89	1.00	0.96	1.00
2013	0.00	0.00	0.02	0.22	0.57	0.86	0.99	0.94	0.96	1.00
2014	0.00	0.00	0.03	0.15	0.56	0.78	0.90	0.98	1.00	1.00
2015	0.00	0.01	0.04	0.19	0.48	0.74	0.78	0.93	0.95	1.00
2016	0.00	0.00	0.06	0.28	0.61	0.85	0.91	0.98	1.00	1.00
2017	0.00	0.00	0.05	0.29	0.60	0.83	0.95	1.00	0.91	1.00
2018	0.00	0.00	0.07	0.24	0.60	0.79	0.94	1.00	1.00	1.00
2019	0.00	0.00	0.05	0.23	0.50	0.73	0.89	1.00	0.97	1.00
2020	0.00	0.02	0.07	0.33	0.61	0.88	0.97	0.98	1.00	1.00

Table 2.2.13. Northern Norwegian coastal cod. Tuning data used in the final SAM run.

```
Norwegian Coastal cod
101
A6335-acoustic-1995
1995    2002
1       1       0.75    0.85
2       10
1       8.774   4.974   6.382   6.440   4.373   1.309   0.532   0.319   0.132
1       9.025   8.592   4.576   5.306   2.723   1.022   0.213   0.032   0.024
1       15.358  16.930  7.710   4.484   2.316   0.716   0.328   0.059   0.033
1       6.757   8.524   8.261   3.717   1.530   0.700   0.102   0.122   0.045
1       3.486   3.387   2.788   2.498   0.751   0.172   0.030   0.022   0.020
1       7.439   5.831   3.939   3.853   2.825   0.622   0.258   0.071   0.032
1       4.551   4.246   3.776   2.184   1.499   0.974   0.149   0.029   0.093
1       2.071   2.532   2.926   2.075   0.970   0.596   0.293   0.106   0.124

A6335-acoustic-2003
2003    2020
1       1       0.75    0.85
2       10
1       2.168   3.026   3.303   1.838   1.519   0.651   0.364   0.190   0.069
1       2.643   2.819   2.589   1.686   1.094   0.371   0.213   0.104   0.072
1       1.201   2.228   1.816   1.490   0.843   0.234   0.233   0.127   0.079
1       1.836   2.587   2.210   1.453   1.612   1.046   0.130   0.089   0.027
1       3.037   2.778   3.794   2.437   1.632   1.215   0.441   0.120   0.041
1       1.739   1.684   1.511   0.985   0.761   0.399   0.225   0.097   0.074
1       1.502   2.084   2.596   1.373   0.605   0.386   0.378   0.140   0.064
1       2.503   2.853   2.240   1.679   0.583   0.309   0.432   0.229   0.195
1       2.542   1.869   2.372   1.469   1.215   0.394   0.278   0.137   0.150
1       2.170   3.546   1.832   1.154   0.791   0.503   0.254   0.107   0.224
1       3.084   1.597   1.770   1.287   0.838   0.657   0.430   0.216   0.252
1       4.171   3.066   2.137   2.904   1.609   1.151   0.429   0.462   0.326
1       3.122   2.465   1.802   1.017   1.128   0.477   0.363   0.303   0.265
1       3.341   3.667   2.349   2.308   0.841   0.669   0.452   0.222   0.308
1       3.289   3.202   2.335   1.764   1.122   0.450   0.256   0.181   0.183
1       2.847   1.837   2.376   1.246   0.946   0.494   0.246   0.136   0.169
1       2.992   3.724   2.221   2.149   1.272   0.656   0.212   0.262   0.266
1       1.619   3.365   3.564   1.821   0.853   0.491   0.299   0.085   0.126

A6335-trawl-2003
2003    2020
1       1       0.75    0.85
2       10
1       3.268   3.763   4.521   2.700   2.319   0.863   0.489   0.220   0.069
1       2.201   2.396   2.602   1.463   0.722   0.359   0.181   0.046   0.063
1       1.042   1.988   1.478   1.268   0.746   0.157   0.107   0.068   0.054
1       2.156   2.623   2.946   1.554   1.026   0.941   0.171   0.107   0.023
1       0.911   0.853   1.071   0.789   0.465   0.394   0.114   0.075   0.029
1       1.822   2.795   1.883   1.419   1.145   0.580   0.348   0.161   0.094
1       2.251   3.570   3.716   1.584   0.868   0.712   0.466   0.204   0.160
1       2.353   3.268   3.385   2.397   0.784   0.383   0.733   0.317   0.328
1       3.471   2.498   2.866   2.095   1.445   0.292   0.315   0.213   0.310
1       3.218   4.485   2.784   1.537   1.042   0.930   0.411   0.200   0.346
1       4.101   1.706   2.666   1.887   1.575   0.890   0.578   0.297   0.419
1       5.448   4.026   3.034   3.521   2.016   1.388   0.465   0.364   0.337
1       4.733   4.154   3.727   2.068   1.818   0.902   0.506   0.397   0.222
1       4.433   4.522   2.610   1.995   0.746   0.735   0.413   0.203   0.210
1       2.891   2.407   1.563   1.151   0.715   0.308   0.200   0.147   0.157
1       3.197   1.916   1.879   1.049   0.748   0.323   0.183   0.128   0.168
1       2.114   2.470   1.508   1.460   0.839   0.490   0.148   0.129   0.211
1       1.670   2.599   2.416   1.188   0.611   0.291   0.177   0.049   0.072
```

Table 2.2.14. Northern Norwegian coastal cod. Stock mean weight-at-age (kg) was used in the assessment model. Mean weights at age in the catch are used in place of stock weights for ages 8–10+. Mean weights in 1994, when the survey had not yet started, are means of stock weights in the years 1995–1997 for ages 2–7 and set to weight in catch for ages 8–10+.

	Age								
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1994	0.247	0.682	1.379	1.981	2.822	3.968	5.245	6.487	8.825
1995	0.282	0.719	1.395	2.091	2.767	4.693	5.228	6.121	9.469
1996	0.216	0.672	1.349	1.939	2.779	4.223	4.544	5.462	7.814
1997	0.244	0.655	1.393	1.914	2.921	2.988	4.738	5.616	7.768
1998	0.259	0.840	1.406	2.261	3.173	4.320	4.786	5.389	9.584
1999	0.272	0.793	1.508	1.964	2.759	4.257	4.923	5.415	8.339
2000	0.322	0.826	1.561	2.363	2.811	4.260	5.553	5.834	9.781
2001	0.377	0.933	1.660	2.320	2.998	3.338	4.498	4.794	7.711
2002	0.357	0.918	1.595	2.377	3.468	4.415	5.268	6.236	9.943
2003	0.361	0.820	1.427	2.269	3.127	4.114	5.417	5.713	9.07
2004	0.338	0.877	1.646	2.153	3.197	3.810	5.367	5.93	7.991
2005	0.436	0.878	1.727	2.205	2.542	3.666	5.233	5.981	8.32
2006	0.400	0.989	1.649	2.231	3.502	3.992	5.806	6.638	9.71
2007	0.486	1.066	1.865	2.579	3.168	4.520	5.781	6.871	9.771
2008	0.427	1.109	1.971	3.327	3.393	4.543	5.844	6.279	9.239
2009	0.357	1.032	1.878	2.695	3.803	4.599	6.178	6.516	9.248
2010	0.502	1.088	1.872	2.745	3.586	4.684	5.437	6.185	7.599
2011	0.401	1.165	2.279	3.109	3.702	5.163	5.941	6.422	8.346
2012	0.355	1.141	2.026	2.907	3.690	4.688	6.448	6.914	9.446
2013	0.384	0.918	1.817	3.041	3.438	3.963	5.892	6.800	10.104
2014	0.359	1.122	1.894	2.929	3.690	4.646	5.791	6.461	9.643
2015	0.406	1.115	2.145	2.987	3.774	4.839	5.601	6.482	9.044
2016	0.347	1.101	1.904	3.327	3.928	4.689	5.893	6.850	8.928
2017	0.504	1.058	1.969	2.943	3.997	4.676	5.977	6.933	9.356
2018	0.522	1.109	2.094	3.206	3.763	5.391	5.711	6.581	9.333
2019	0.372	1.131	1.984	2.983	3.815	5.141	5.748	6.562	8.561

	Age								
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
2020	0.379	1.010	1.928	2.972	3.767	4.995	5.655	6.387	9.024

Table 2.2.15. Northern Norwegian coastal cod. Natural mortality at age is used in the assessment model. Estimated from mean weights at age (Table 2.2.14) by the Lorenzen (1996) method.

	Age								
Year	2	3	4	5	6	7	8	9	10+
1994	0.687	0.504	0.407	0.364	0.327	0.295	0.271	0.254	0.231
1995	0.661	0.496	0.405	0.358	0.329	0.280	0.271	0.258	0.226
1996	0.716	0.507	0.410	0.367	0.329	0.289	0.283	0.267	0.240
1997	0.690	0.511	0.406	0.368	0.324	0.321	0.279	0.265	0.240
1998	0.677	0.473	0.404	0.350	0.316	0.287	0.278	0.268	0.225
1999	0.668	0.482	0.396	0.365	0.329	0.288	0.276	0.268	0.235
2000	0.634	0.476	0.392	0.345	0.327	0.288	0.266	0.262	0.224
2001	0.604	0.458	0.384	0.347	0.321	0.311	0.284	0.278	0.241
2002	0.615	0.461	0.389	0.345	0.307	0.285	0.270	0.257	0.223
2003	0.612	0.477	0.403	0.350	0.317	0.292	0.268	0.264	0.229
2004	0.625	0.467	0.386	0.355	0.315	0.298	0.269	0.261	0.238
2005	0.578	0.467	0.380	0.353	0.338	0.302	0.271	0.260	0.235
2006	0.594	0.450	0.385	0.351	0.306	0.294	0.262	0.252	0.224
2007	0.559	0.440	0.371	0.336	0.316	0.283	0.263	0.249	0.224
2008	0.582	0.435	0.365	0.311	0.309	0.283	0.262	0.256	0.228
2009	0.614	0.444	0.370	0.332	0.299	0.282	0.258	0.253	0.228
2010	0.554	0.437	0.371	0.330	0.304	0.280	0.268	0.257	0.242
2011	0.593	0.428	0.349	0.318	0.301	0.272	0.261	0.255	0.235
2012	0.615	0.431	0.362	0.324	0.301	0.280	0.254	0.249	0.226
2013	0.601	0.461	0.374	0.320	0.308	0.295	0.261	0.250	0.222
2014	0.613	0.433	0.369	0.323	0.301	0.281	0.263	0.254	0.225
2015	0.591	0.434	0.356	0.321	0.299	0.277	0.265	0.254	0.229
2016	0.620	0.436	0.369	0.311	0.296	0.280	0.261	0.250	0.230
2017	0.553	0.441	0.365	0.323	0.294	0.280	0.260	0.249	0.227

	Age								
Year	2	3	4	5	6	7	8	9	10+
2018	0.547	0.435	0.358	0.315	0.300	0.268	0.264	0.253	0.227
2019	0.607	0.432	0.364	0.322	0.298	0.272	0.263	0.253	0.233
2020	0.603	0.447	0.367	0.322	0.299	0.275	0.265	0.255	0.229

Table 2.2.16. SAM configuration.

Model used: SAM (State–space assessment model; https://www.stockassessment.org; Nielsen and Berg 2014).

Software used: Template Model Builder (TMB) and R.

Age range of assessment: 2–10, where 10 is a plus group.

Start year of assessment: 1994

Last change of configuration: WKBarFar 2021

The assessment is available at www.stockassessment.org under the name NCCN67_AFWG2021_Corr

```
# Configuration saved: Wed Jan 27 12:03:27 2021
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 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 1 1 1
$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
  0  1  2  3  4  5  5  5  6
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, 2 AR(1), 3 separable AR(1).
 2
```

```
$keyLogFpar
# Coupling of the survey catchability parameters (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  5  6  7
 8  9  10 11 11 11 11 11 12
 13 14 15 16 16 16 16 16 17
$keyQpow
```

Table 2.2.16. SAM configuration continued.

```
# Density dependent catchability power parameters (if any).
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally 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
 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1
$keyVarObs
# Coupling of the variance parameters for the observations.
 0  1  1  1  1  1  1  1  1
 2  2  2  2  2  2  2  2  2
 3  3  3  3  3  3  3  3  3
 4  4  4  4  4  4  4  4  4
$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible values are: "ID" "AR" "US"
 "ID" "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
 NA  NA  NA  NA  NA  NA  NA  NA
 0  1  2  3  3  4  4  5
 6  7  7  7  8  9  9  9
```

```
$stockRecruitmentModelCode

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

 0


$noScaledYears

# Number of years where catch scaling is applied.

 0
```

Table 2.2.16. SAM configuration continued.

```
$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

 4 7

$keyBiomassTreat

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

 -1 -1 -1 -1

$obsLikelihoodFlag

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

 "LN" "LN" "LN" "LN"

$fixVarToWeight

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

 0

$fracMixF

# The fraction of t(3) distribution used in logF increment distribution

 0

$fracMixN

# The fraction of t(3) distribution used in logN increment distribution

 0

$fracMixObs

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

 0 0 0 0

$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 -1 -1 -1

-1 -1 -1 -1 -1 -1 -1 -1 -1

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

Table 2.2.17. SAM output. Estimated catchability at age for each fleet. In the SAM configuration, catchabilities are coupled (set equal) for ages 5-6 in the acoustic index part 1, and for ages 5–9 in the other two indices.

Fleet	2	3	4	5	6	7	8	9	10+
Acoustic index pt. 1	0.103	0.163	0.228	0.308	0.308	0.233	0.128	0.097	0.126
Acoustic index pt. 2	0.058	0.098	0.138	0.157	0.157	0.157	0.157	0.157	0.164
Swept-area index	0.060	0.100	0.140	0.153	0.153	0.153	0.153	0.153	0.173

Table 2.2.18. SAM output. Estimated recruitment (1000’s), Spawning-stock biomass (SSB, t), average fishing mortalities for ages 4–7 (Fbar(4–7)), and Total-stock biomass (TSB, t).

Year/Age	R (age 2)	Low	High	SSB	Low	High	Fbar (4-7)	Low	High	TSB	Low	High
1994	93167	64940	133663	121460	102525	143892	0.236	0.194	0.287	309739	270300	354933
1995	118218	86771	161062	102158	87017	119934	0.303	0.255	0.361	298854	264867	337203
1996	141681	103458	194025	80532	68850	94195	0.328	0.277	0.388	253383	224115	286474
1997	131307	96508	178652	65430	56184	76196	0.395	0.335	0.466	238844	208897	273083
1998	111445	82418	150695	56474	47967	66489	0.417	0.351	0.496	259744	225417	299299
1999	94384	69919	127409	46915	39424	55829	0.383	0.321	0.459	227431	197574	261800
2000	81853	60737	110309	53922	45426	64006	0.281	0.233	0.339	233031	202456	268225
2001	74792	55615	100582	69821	59298	82211	0.237	0.196	0.285	229830	199481	264797
2002	71973	54133	95692	83623	71350	98007	0.254	0.212	0.305	241969	211543	276771
2003	64546	50342	82760	70424	60137	82471	0.239	0.199	0.286	225252	197282	257187
2004	67260	53234	84980	74887	63786	87921	0.266	0.223	0.317	223234	194831	255779
2005	47688	36702	61962	66755	56611	78718	0.254	0.213	0.303	217546	189027	250368
2006	48613	37441	63119	83734	70408	99582	0.294	0.244	0.354	224622	195225	258446
2007	58323	45554	74671	88964	74190	106678	0.226	0.184	0.276	229070	197157	266148
2008	63129	49325	80798	86631	71479	104996	0.222	0.181	0.271	243754	208729	284657
2009	57062	44428	73289	67221	54983	82183	0.185	0.151	0.227	243099	207717	284509
2010	58091	45440	74264	81219	66377	99379	0.218	0.178	0.266	263740	225207	308866
2011	79004	62060	100573	92614	75146	114142	0.193	0.157	0.236	282675	240281	332550

Year/Age	R (age 2)	Low	High	SSB	Low	High	Fbar (4-7)	Low	High	TSB	Low	High
2012	63136	49052	81263	98152	78499	122725	0.157	0.128	0.193	284079	239940	336337
2013	87542	68422	112006	104302	83762	129878	0.131	0.107	0.161	273810	231600	323712
2014	91802	72232	116674	110631	89811	136277	0.127	0.104	0.155	299085	254989	350806
2015	93654	73379	119530	100512	81617	123781	0.176	0.145	0.213	324205	278494	377419
2016	85893	67073	109994	108961	89125	133212	0.243	0.202	0.291	322536	277653	374675
2017	81129	62195	105829	92856	75042	114900	0.293	0.242	0.354	308476	262874	361989
2018	88742	66250	118869	87692	70095	109707	0.248	0.203	0.304	295124	245933	354154
2019	70293	50909	97057	77424	60225	99535	0.256	0.204	0.322	273093	221567	336601
2020	47259	31667	70530	80046	58135	110214	0.297	0.221	0.399	247612	191054	320911

Table 2.2.19. SAM output. Estimated fishing mortalities at age. F for ages 7-9 are coupled (set equal) in the SAM configuration.

Year/Age	2	3	4	5	6	7	8	9	10+
1994	0.000	0.005	0.041	0.154	0.313	0.435	0.435	0.435	0.763
1995	0.000	0.008	0.056	0.183	0.382	0.593	0.593	0.593	1.003
1996	0.001	0.016	0.086	0.224	0.413	0.587	0.587	0.587	1.073
1997	0.001	0.021	0.112	0.27	0.509	0.689	0.689	0.689	1.296
1998	0.001	0.033	0.186	0.395	0.558	0.529	0.529	0.529	1.02
1999	0.001	0.026	0.158	0.363	0.499	0.513	0.513	0.513	0.982
2000	0.001	0.018	0.123	0.289	0.364	0.347	0.347	0.347	0.681
2001	0.001	0.014	0.094	0.225	0.313	0.314	0.314	0.314	0.723
2002	0.001	0.013	0.085	0.219	0.344	0.368	0.368	0.368	0.783
2003	0.001	0.012	0.066	0.185	0.311	0.393	0.393	0.393	0.759
2004	0.001	0.009	0.057	0.167	0.326	0.517	0.517	0.517	0.876
2005	0.001	0.009	0.059	0.169	0.295	0.496	0.496	0.496	0.949
2006	0.001	0.012	0.073	0.213	0.351	0.542	0.542	0.542	1.296
2007	0.001	0.017	0.078	0.2	0.271	0.351	0.351	0.351	0.845
2008	0.001	0.018	0.072	0.213	0.28	0.321	0.321	0.321	0.598
2009	0.001	0.017	0.051	0.163	0.254	0.27	0.27	0.27	0.457
2010	0.001	0.02	0.058	0.188	0.305	0.317	0.317	0.317	0.558
2011	0.002	0.024	0.067	0.154	0.232	0.317	0.317	0.317	0.49
2012	0.002	0.03	0.074	0.137	0.189	0.228	0.228	0.228	0.375
2013	0.002	0.029	0.07	0.113	0.15	0.189	0.189	0.189	0.311
2014	0.002	0.026	0.069	0.106	0.143	0.185	0.185	0.185	0.322
2015	0.003	0.034	0.091	0.137	0.202	0.269	0.269	0.269	0.465
2016	0.003	0.033	0.105	0.156	0.276	0.425	0.425	0.425	0.598
2017	0.003	0.04	0.126	0.196	0.317	0.512	0.512	0.512	0.638
2018	0.002	0.026	0.089	0.16	0.261	0.452	0.452	0.452	0.496
2019	0.002	0.023	0.089	0.161	0.275	0.448	0.448	0.448	0.467
2020	0.002	0.019	0.087	0.18	0.345	0.479	0.479	0.479	0.395

Table 2.2.20. SAM output. Estimated stock numbers at age (1000's).

Year/Age	2	3	4	5	6	7	8	9	10+
1994	93255	32066	35997	38592	18199	10235	4682	1160	1682
1995	117847	43217	21285	23442	21638	9340	4867	2455	1239
1996	140946	62223	25078	14316	13935	10251	3764	1861	1291

Year/Age	2	3	4	5	6	7	8	9	10+
1997	130577	76812	33057	14449	8006	6968	4316	1535	1192
1998	111048	65408	46677	18559	7873	3358	2558	1496	835
1999	94243	53821	36124	24080	8125	3094	1542	1186	895
2000	81710	49201	31714	20474	11365	3591	1485	719	846
2001	74734	41855	31452	18267	10013	5635	1776	727	977
2002	72109	41589	25923	20052	10495	5119	2982	922	844
2003	66126	41601	28887	15395	12422	5415	2649	1549	736
2004	68658	37563	28319	17277	10227	5545	2664	1165	1044
2005	49178	43471	23381	18921	12501	4680	2573	1072	879
2006	50300	33063	24940	14636	11542	7402	2377	1267	679
2007	59807	28800	23273	15042	8997	6496	2676	1270	662
2008	63708	37949	19540	12887	9941	5312	3303	1297	980
2009	58336	39771	27528	12939	7403	5364	3147	2060	1072
2010	59296	37656	25472	19318	7767	4240	3415	1869	2063
2011	80455	32046	24763	15335	11639	4222	2578	1853	2191
2012	65191	50675	23464	14011	9968	6579	2607	1268	2478
2013	89485	27603	26457	15573	10630	6712	4150	1750	2129
2014	94428	37965	18091	19356	10407	7029	4131	2816	2261
2015	96804	43735	25607	12890	12932	6520	3976	2866	2879
2016	90624	49582	23692	18356	8179	7701	4240	2250	3128
2017	86788	48234	24428	16422	10856	5190	3687	2207	2376
2018	97956	37373	28342	14221	10350	5537	2711	1695	1945
2019	83054	53667	21894	17808	10098	6042	2531	1470	1699
2020	54381	49334	34278	16180	9809	5644	3134	1117	1364

Table 2.2.21a. Northern Norwegian coastal cod. Assumptions for the interim year and in the forecast: Fbar, recruitment, SSB and catch.

Variable	Value	Notes
$F_{\text{ages 4–7}}$ (2021)	0.275	F_{sq} = median fishing mortality in 2020.
SSB (2021)	92 885	Short-term forecast fishing at *status quo* (F_{sq}); Tonnes.
$R_{\text{age 2}}$ (2021, 2022, and 2023)	88 137	Median resampled recruitment (2011-2020) as estimated by a stochastic projection; Thousands.
Total catch (2021)	47 809	Short-term forecast fishing at F_{sq}; Tonnes.

Table 2.2.21b. Northern Norwegian coastal cod. Assumptions for the interim year and in the forecast: mean weights in catch and stock, maturity at age, and natural mortality at age (5-year averages).

Age	Weight in catch (kg)	Weight in stock (kg)	Proportion mature	Natural mortality
2	1.331	0.425	0.006	0.586
3	1.862	1.082	0.059	0.438
4	2.515	1.976	0.273	0.365
5	3.251	3.086	0.582	0.318
6	4.052	3.854	0.815	0.297
7	4.890	4.978	0.933	0.275
8	5.797	5.797	0.991	0.263
9	6.663	6.663	0.976	0.252
10+	9.040	9.040	1.000	0.229

Table 2.2.22. Northern Norwegian coastal cod. Catch scenarios.

Basis	Total catch (2022)	Ftotal (2022)	SSB (2023)*	% SSB change **	% Advice change ***
ICES advice basis					
Precautionary approach	7865	0.039	115 782	25	-
Other scenarios					
F = 0	0	0	120 404	30	-
F = F_{2020}	48 497	0.275	92 748	−0.15	-
F = 0.1^	19 435	0.10	109 084	17	

*** For this stock, SSB is calculated at the time of survey (October) as maturity ogives and stock weights are from the survey. Thus, SSB is influenced by fisheries between 1 January and 1 October. The actual spawning time is March–June.**

**** SSB in October 2022 relative to SSB in October 2021.**

***** Advice value for 2022 relative to advice value for 2021. Not presented this year as it is the first advice for this stock.**

^ Corresponding to the target F in 2021 according to the previous management plan for the combined northern and southern coastal cod.

Figure 2.2.1. Northern Norwegian coastal cod. Standard figures. SAM estimates of a) SSB, b) Fbar(4-7), c) recruitment (age 2,), and d) catch input data.

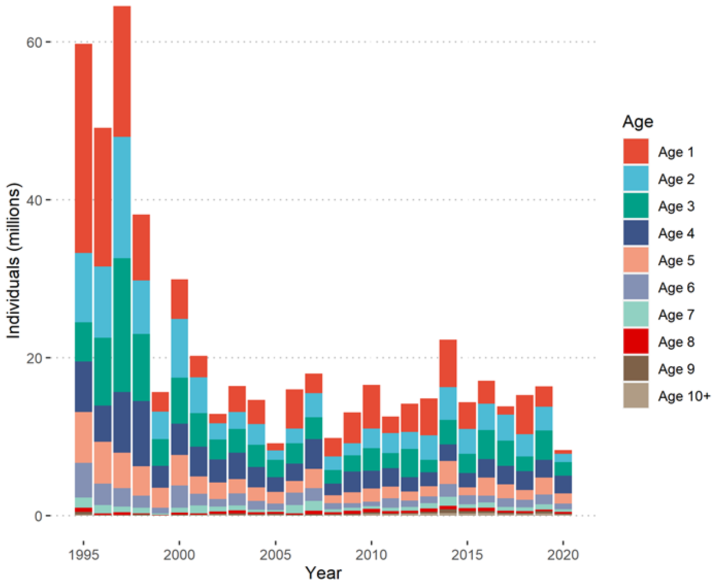


Figure 2.2.2. Acoustic abundance index by age (colours) from the Coastal survey in October–November (survey code A6335).

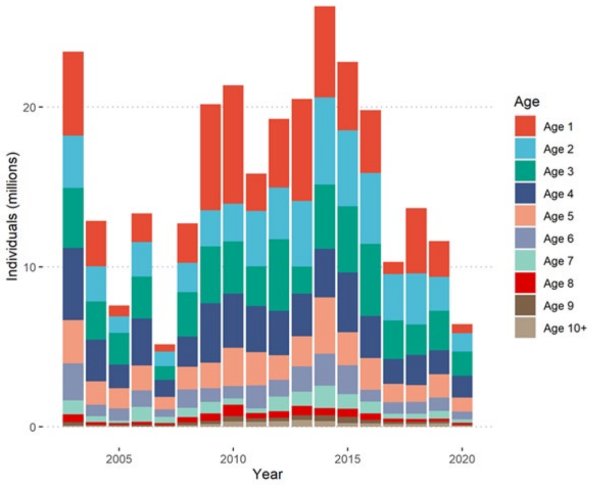
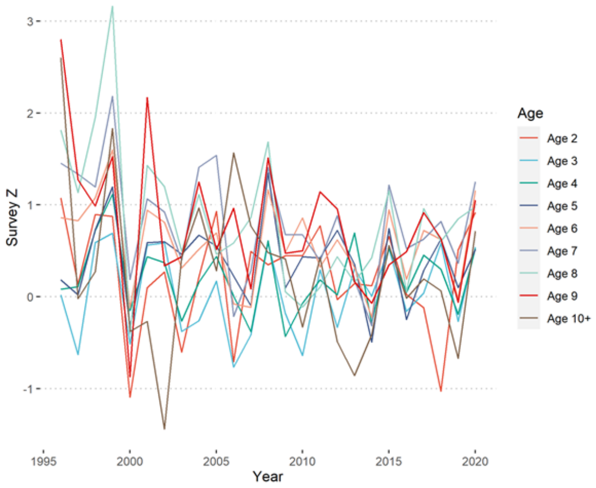


Figure 2.2.3. Swept area abundance index by age (colours) from the coastal survey in October–November (survey code A6335).



2.2.4. Survey mortality (Z) at age (colours) in the acoustic index (top) and swept area index (bottom). Z was estimated as -log($A_{a+1,y+a}$/$A_{a,y}$), where $A_{a,y}$ is abundance of age *a* in year *y*.

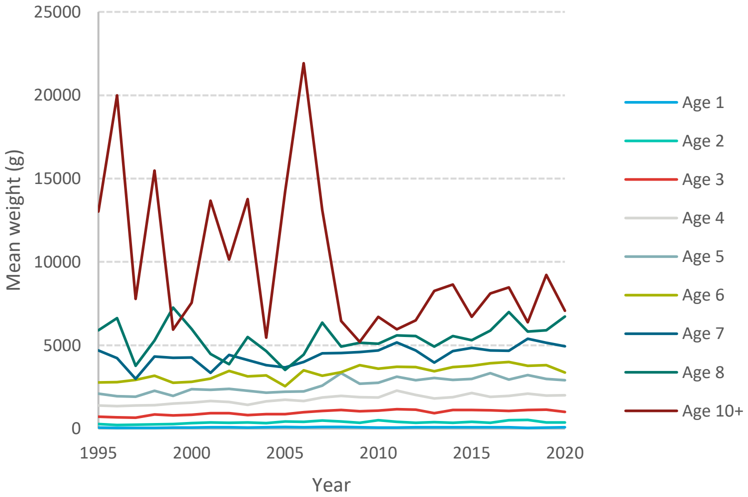
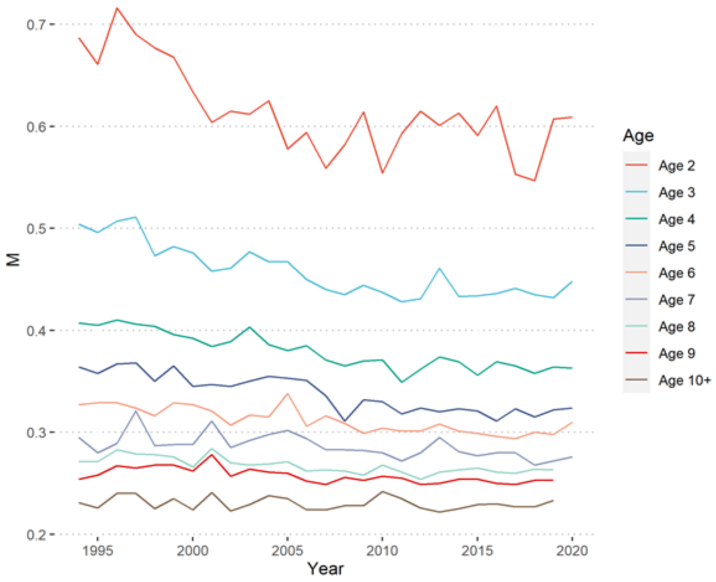


Figure 2.2.5. Mean weight-at-age in the coastal survey. Few individuals of ages 10+ were sampled in the beginning of the time series, leading to extremely large variation in mean weights.

Figure 2.2.6. Proportions mature-at-age as observed in the Coastal survey.



2.2.7. Natural mortality-at-age estimated from stock weights-at-age by the Lorenzen (1996) method.

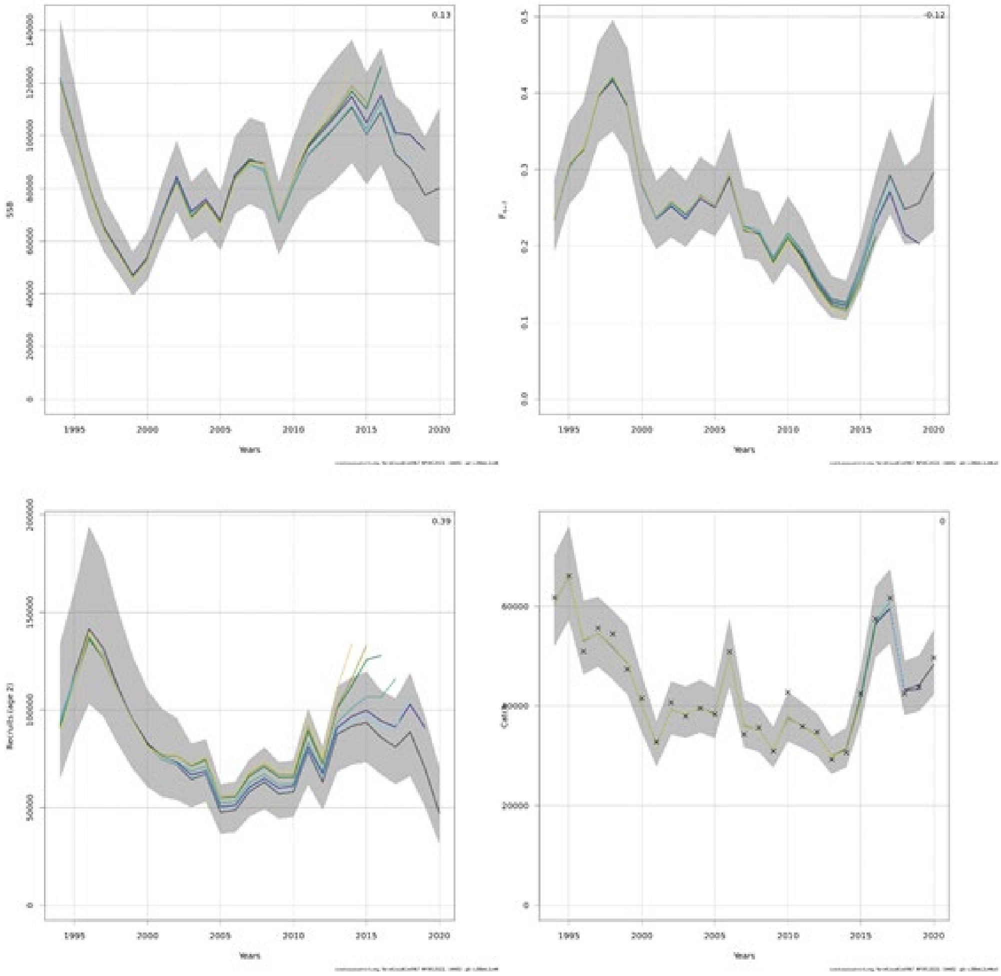


Figure 2.2.8. Northern Norwegian coastal cod. 5-year retrospective peel: a) SSB, b) Fbar, c) recruitment, and d) catch. The Mohn's rho value (average retrospective bias) is indicated in the upper right corner of each panel.

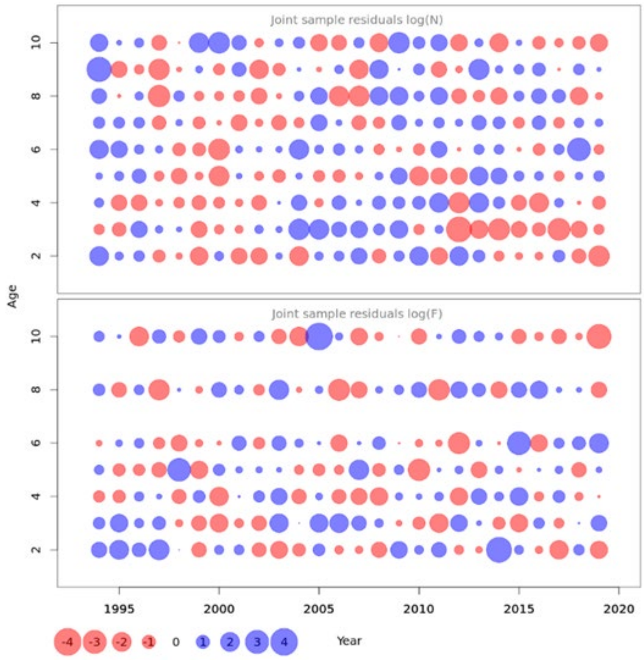


Figure 2.2.9. Residuals for the log(N) (top) and log(F) (bottom) process from the final SAM run.

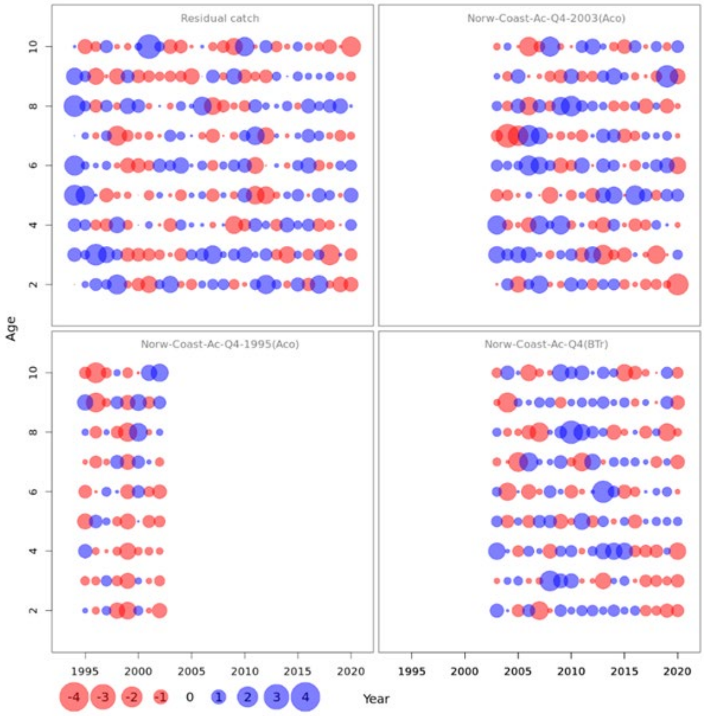


Figure 2.2.10. One-step-ahead residuals by fleet from the final SAM run. Blue circles indicate positive residuals and red circles indicate negative residuals. Top left: catch, top right: acoustic index pt. 1, bottom left: acoustic index pt. 2, bottom right: swept-area index.

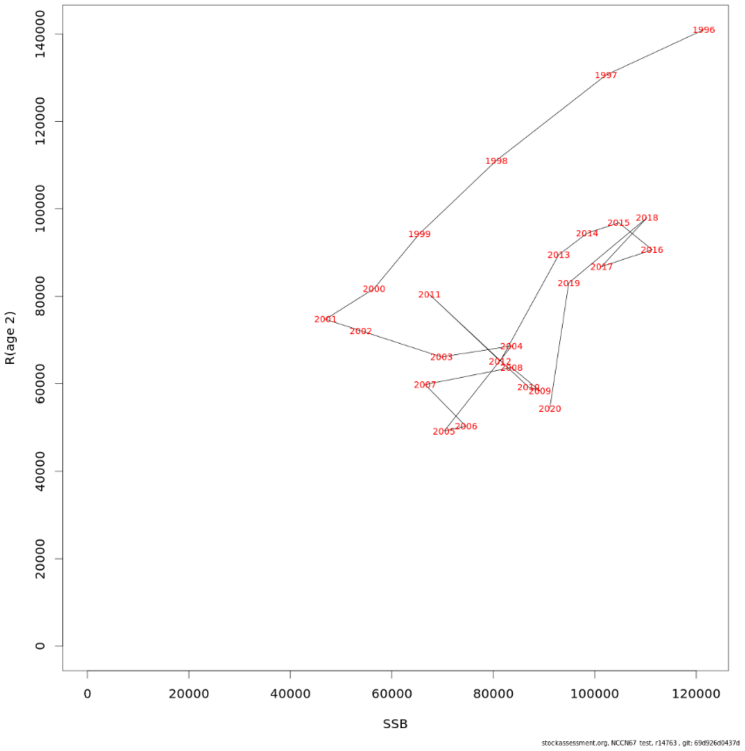


Figure 2.2.11. Stock–recruitment relationship from SAM. Estimated recruitment-at-age 2 (1000's) is plotted against estimated SSB (t) in the year of spawning (two years previously). The year labels in the figure indicate year of recruitment.

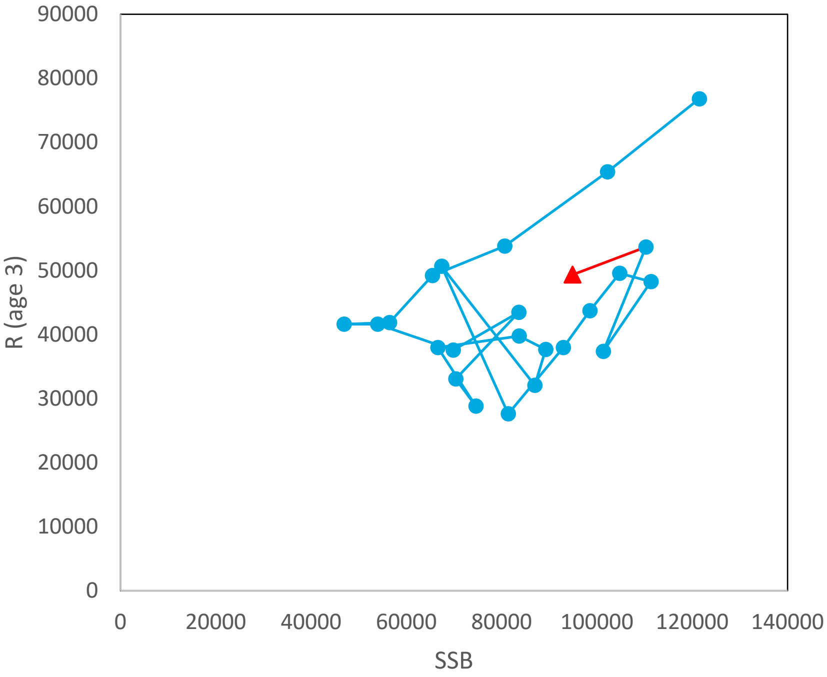


Figure 2.2.12. Comparative stock–recruitment relationship: estimated abundance-at-age 3 (1000's) plotted against estimated SSB (t) in the year of spawning (three years previously). Recruitment in 2020 is marked with a red triangle.

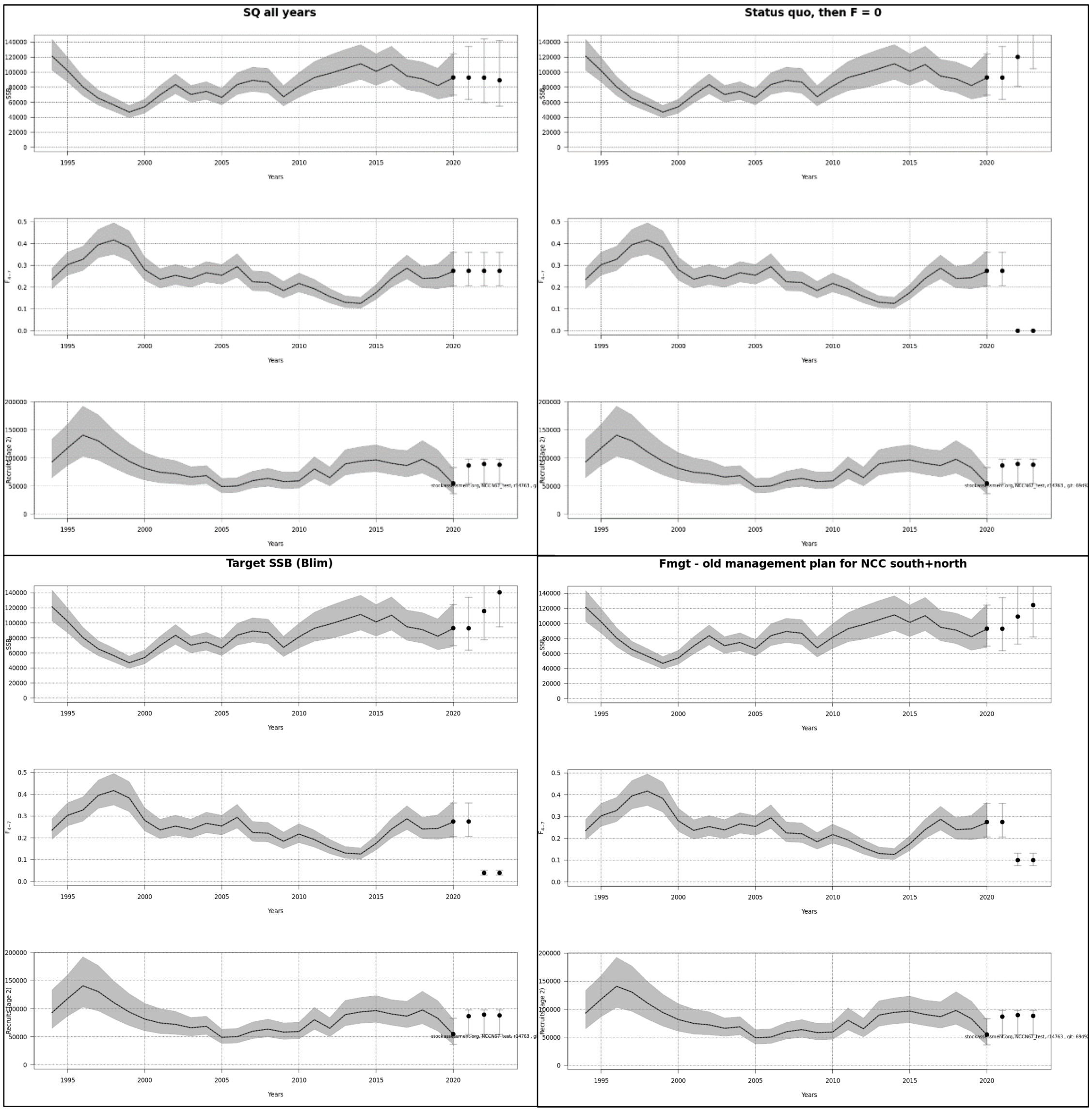


Figure 2.2.13. Short-term prediction. Predicted SSB (top panels), Fbar (middle panels) and recruitment (bottom panels) at status quo fishing (top left), status quo then zero fishing (top right), fishing at the level that will put the stock above B_{lim} at the end of the advice year (bottom left), and F=0.1, current F target in the old management plan for all coastal cod north of 62°N (northern and southern Norwegian coastal cod). In the forecast, recruitment is the same for all scenarios (resampled from the period 2003-2020).

2.3 Coastal cod south between 62–67˚N (Norwegian coastal cod South)

2.3.1 Stock status summary

An assessment based on the decisions of the 2021 WKBARFAR benchmark (ICES 2021a) is presented for this stock.

The catches have decreased since 2010–2012, to a large extent explained by a decreased commercial fishing effort until 2017 but have continued to decrease even after 2017 when the effort has been slightly increasing. The recreational fishery by tourists and Norwegian residents is assumed to catch similar amounts as the commercial fishery, and a prerequisite for more accurate future assessments is a better estimation of the recreational catches.

Until we have several years in the CPUE series and can use the recommended SPiCT or JABBA surplus production models, the assessment of coastal cod 62–67°°N is trend-based (the "2 over 3" rule) using the Reference fleet CPUE (which is more controlled than a full fleet CPUE). LBSPR and other length-based indicators have been used as additional information to assess the need for a 20% precautionary buffer in the "2 over 3" rule. ICES lacks for time being a framework for using LBSPR directly as a basis for quota advice.

Between 2007–2019, the mean "Spawning potential ratio", i.e. the ratio between the recruitment potential of the current stock and the theoretical recruitment potential without fishing, fluctuated between 20 and 30%, with an overall downward trend. This places the stock below the target values (30–40%) and – at the end of the series – even below 20%, generally accepted as a limit reference point in the absence of further information on the stock dynamics. The decrease in the spawning potential ratio is concomitant with a decline of both mean length and mean length of the largest 5% of the caught fish. These all together depict a somewhat depleted and worsening stock status.

The ratio between the two last year's CPUE (2019–2020) and the three previous years (2016–2018) gives a factor of 1.17. Including a precautionary 20% results in a final factor of 0.94, or a recommended 6% decrease in catch advice compared to the three last years' catches.

No previous advice has been issued for this stock. The 2021 advice for the previous Norwegian coastal cod stock (comprising the two new stocks) was to follow the Norwegian management plan, which implied reducing fishing mortality to 0.05.

The new formal name of the stock is "Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N (Norwegian coastal cod South)" and its stock code "cod.27.2.coastS".

2.3.2 Fisheries (Table 2.3.2–Table 2.3.4)

Coastal cod is fished throughout the year but the main (about 70%) commercial fishery for coastal cod in the area between 62°N and 67°N takes place during February-April. The main fishing areas are along the coast of Helgeland including Træna and Lovund, Vikna, Halten bank, and further along the coast of Trøndelag and Møre and Romsdal counties. Except for the Borgundfjord at Møre, the quantities fished inside fjords are quite low.

In the 1990ies the average percentage share between gear types in the estimated coastal cod commercial landings was around 65% for gillnet, 26% for longline/handline, 8% for Danish seine, and 1% for bottom trawl. In 2020 this share was 67% for gillnet, 30% for longline/handline/Danish seine, and 3% for bottom trawl (Table 2.3.4).

Recreational and tourist fisheries take an important fraction of the total catches in some local areas, especially near the coastal cities, and in some fjords where commercial fishing activity is low. However, there are a few reports trying to assess the amount in certain years (see section 2.1). The current split of the recreational catches between the area north of 67˚N and between 62–67°˚N in 2019–2020 is done based on the tourist fishing businesses' reporting to the Norwegian Directorate of Fisheries by county. Since the 67˚N latitude goes through the Nordland county, the splitting north and south of 67˚N for this county is done proportional to the number of tourist fishing businesses north and south of this latitude. The same area proportion (37.8% south and 62.2% north) of the recreational fishery is used for the whole time-series back to 1994, and this is a very rough assumption that should be further investigated and better documented. In recent years the recreational cod catches between 62°N and 67°N are estimated to about 55% of total cod catches in this region (Tables 2.1.1 and 2.3.3).

Discarding is known to take place. There have previously been conducted two investigations trying to estimate the level of discarding and misreporting from coastal fishing vessels in two periods (2000 and 2002–2003, WD 14 at 2002 WG). The amount of discards was calculated, and the report from the 2000-investigation concluded there was both discard and misreporting by species in 2000, in the gillnet fishery approximately 8–10% relative to reported catch. 1/3 of this was probably coastal cod. The last report concluded that misreporting in the Norwegian coastal gillnet fisheries have been reduced significantly since 2000.

According to a recent report by Berg and Nedreaas (2021) up to 5% was discarded in the commercial gillnet fishery between 62–67°N during 2012–2018, and about 7% in the rod and line sector of the recreational fishery. The latter estimate is based on reporting to the Directorate of Fisheries in 2019 showing that about 35% of the reported rod and line catch was released with an assumed mortality of 20% of the released cod (see chapter 2.1). Discarding is not included in the commercial catch in this report but discarding in the rod and line (from boat) sector of the recreational fishery is included in the recreational catch estimate.

2.3.2.1 Estimated catches and Catch-at-age (Table 2.3.2–Table 2.3.4, and Figure 2.1.1 and Figure 2.3.1–Figure 2.3.2)

The current coastal cod assessments include all coastal cod caught within the coastal statistical areas 600, 601, 700 and 701 which extend beyond the 12 nautical mile zone (see Figure 2.1.1). Estimated commercial and recreational catches of Coastal cod and Northeast Arctic cod in these statistical areas between 62–67°˚N are shown in Table 2.1 and in Figures 2.3.1–Figure 2.3.2.

The estimated commercial catch-at-age (2–10+) for the period 1994–2020 is given in Table 2.3.2. Table 2.3.3 shows the total catch numbers-at-age when recreational and tourist fishing is included. The commercial catch in 2020 by gear and Norwegian statistical fishing areas is presented in Table 2.3.4.

2.3.2.2 Catch weights-at-age (Table 2.3.5)

Weight-at-age in catches is derived from the commercial sampling and is shown in Table 2.3.5. The same weight-at-age is assumed for the recreational and tourist catches.

2.3.2.3 Catches in 2021

No catch prediction for 2021 have been made, but it is reasonable to assume the same catch level as in 2020, i.e. a somewhat reduced recreational fishery due to the Covid19 pandemic and travel restrictions for foreign tourists.

2.3.3 Reference fleet

The Norwegian Reference Fleet is a group of active fishing vessels paid and tasked with providing information about catches (self-sampling) and general fishing activity to the Institute of Marine Research. The fleet consists of both high seas and coastal vessels that cover most of the Norwegian waters. The Highseas Reference Fleet began in 2000 and was expanded to include coastal vessels in 2005 (Clegg and Williams, 2020). The Coastal reference fleet has reported catch-per-gillnet soaking time (CPUE) from their daily catch operations (WD 07).

These fleets catch cod from both coastal and NEA populations, which can be discriminated based on their otolith shape. Size distribution of individuals is sampled from a subset of fishing events and, within the size samples, individuals are sampled for otolith in a presumably random way.

To determine the origin of the cod, we use all data from north of 62°N (i.e. ICES Subarea 2.a.2; Norwegian statistical areas 3, 4, 5, 0, 6, 7) with information on otolith type. The probability of a fish caught to be coastal cod (as opposed to NEA cod) is modelled using a Binomial GLM. The covariates area (Norwegian statistical area), year, quarter and gear, all coded as factors, were examined and a model selection was performed based on an information theory approach. The modelled proportions of coastal cod per area and quarter, from 2007 to 2020, are presented in the Stock Annex. Further use for the elaboration of the CPUE index specifically focuses on areas 6 and 7 (between 62–67°N) and quarters 3 and 4 because it is believed that this is the best data to inform about coastal cod status in this area.

2.3.4 CPUE standardization of reference fleet data (Table 2.3.6 and Figure 2.3.3–Figure 2.3.7.

Raw CPUE data are seldom proportional to population abundance as many factors (e.g. changes in fish distribution, catch efficiency, effort, etc) potentially affect its value. Therefore, CPUE standardization is an important step that attempts to derive an index that tracks relative population dynamics.

There are two cod stocks (two ecotypes) that are mixed in the Norwegian waters: the coastal cod (NCC) and the Northeast Arctic cod (NEAC). In this working document, our interest lies in deriving the abundance index of coastal cod, therefore, a few steps need to be taken to derive the corresponding coastal cod abundance index:

1. Fit a model to determine whether an individual fish is categorized as coastal or NEAC. This step allows determining the probability of catching coastal cod vs. NEAC during the time frame of interest.
2. Perform a CPUE standardization using the data from the reference fleet (on total cod catch; the division to ecotypes happens in the next step).
3. Use the output from the above two steps and create an index of abundance for coastal cod.

Below, we defined some important terms we used for the CPUE standardization.

Standardized effort (gillnet day) = gear count x soaking time (hours) / 24 hours

CPUE (per gillnet day) = catch weight/standardized effort

Step 1: Coastal cod vs. NEAC?

In order to determine the origin of cod, we used all data from above 62^{0}N (i.e. areas 3, 4, 5, 0, 6, 7) with information on otolith type. The latter is the source of identification that helps separate coastal vs. NEAC. Otolith types 1 and 2 were categorized as "coastal" and type 3, 4, 5, as NEAC. A total of 27897 samples were used for the analysis between 2007–2020.

From the above samples, we removed any covariates that had less than three observations to ensure estimability (the covariate in question was mostly the gear type; the final sample size was N = 27892). We then fitted a binomial model with logit link using four different explanatory variables: year, area, quarter, and gear, using the following formula:

> Glm1 <- glm(is_coastal ~ factor(area)*factor(startyear) + factor(quarter) + factor(gear), family=binomial, data=Data_proportion)

(eq 1)

Using the above model (Figure 2.3.3), we then predicted the proportion of coastal cod that would be expected in areas 6 and 7, during quarters 3 and 4, between 2007–2020 (see Figure 2.3.4).

Step 2: CPUE standardization

Many different R packages (e.g. mgcv::gam, glmmTMB::glmmTMB, sdmTMB::sdmTMB, and own model in TMB to allow implementing a mixture model), as well as many different combinations of likelihood functions (e.g. normal, lognormal, gamma, negative binomial, student t, tweedie), zero inflation, and parameter, were tested to find a model which showed an acceptable residual pattern. However, model exploration was not conclusive when using the entire CPUE data from the area north of 62°N (N = 11805, with only 59 zeros). All the models struggled to fit the extremely skewed CPUE data (many extremely small values below 1 and large values above 1000, while the bulk of the values are in the scale of dozens).

The final model for the CPUE standardization was fitted on all cod data (no distinction between coastal and NEAC yet) but limited to areas 6 and 7 and quarters 3 and 4, between 2007–2020. Further data filtering was performed to remove erroneous data points (e.g. gearcount = 1) and any gear code with less than 3 observations or only used in one year. This reduced the final data set to N = 686 (with only 3 zeros):

> glmmTMB_pos <- glmmTMB(log(cpue_all) ~ factor(startyear) + factor(area) + factor(gear) + factor(quarter) + (1|area_year) + (1|quarter_year), family = gaussian, data=subset(nord_use, cpue_all>0))

(eq 2)

The expression (1|area_year) indicates that the area and year variable was concatenated into a single variable and considered as a random effect acting on the intercept. In essence, this treatment models the interaction effect between year and area on the intercept, but the approach only considers existing interaction (as opposed to all possible combinations of year and area which would be un-estimable)—which is an advantage in a data-limited situation such as ours.

Joining steps 1 and 2 to create a standardized coastal cod CPUE

The final cod CPUE model showed a reasonable residual behaviour (Figure 2.3.5) and therefore, we proceeded with the derivation of the standardized coastal cod CPUE index for areas 6 and 7 and quarters 3 and 4.

The standardized coastal cod index (CPUE_stdcoastal) was calculated as:

> CPUE_stdcoastal = Pcoastal * CPUEcod

(eq 3)

Where Pcoastal is the predicted proportion of coastal cod in the catch based on the output from step1, and CPUEcod is the predicted cod (of both ecotypes) CPUE based on step 2.

And the variance of (CPUE_stdcoastal) was calculated as:

$$V(CPUE\_std_{coastal}) = \left(\widehat{P_{coastal}}\right)^2 V(CPUE_{cod}) + \left(\widehat{CPUE_{cod}}\right)^2 V(P_{coastal}) \qquad \text{(eq 4)}$$

Some combinations of area_year and quarter_year random interaction effect were not present in the datasets for the CPUE standardization model. However, glmmTMB can handle any missing new levels of random effect variables when making a prediction (it assumes it is equal to zero and inflates the prediction error by its associated random effect variance). For diagnostic plots, see WD 07.

The standardized CPUE index for coastal cod in areas 6 and 7, i.e. between 62–67°N, during quarters 3 and 4, between 2007–2020, is shown in Figure 2.3.6. The composite standardized CPUE index for coastal cod in the entire area between 62–67°N during quarters 3 and 4, is shown in Figure 2.3.7 and Table 2.3.6.

2.3.5 Stochastic LBSPR (Table 2.3.1)

Given the uncertainty in parameters and the demonstrated sensitivity of the model to input parameters (Hordyk *et al.*, 2015b, 2015a), the AFWG has implemented a stochastic Length-based spawning potential ratio (LBSPR) approach similar on the principle to the one developed for anglerfish within the Arctic fisheries working group (see section 9). Differences with this former approach include variations in the parameterization of random inputs, and the inclusion, in the present model, of bootstrapped size distributions to account for uncertainty in the observation of length compositions.

Size distributions are estimated based on reference fleet data using, unlike for the CPUE index (see above), only catches sampled for size.

Most of the parameters estimated during WKBARFAR (ICES 2021) do not need to be re-evaluated on an annual basis and can be randomly generated using the mean and standard deviation from Table 2.3.1 below. Only in case of shift in the growth and/or condition of the fish should the growth parameters and/or the two natural mortality parameters (M and Mpow, sensitive to the conditions) be respectively re-estimated. Because they are more variable and have typically asymmetric distributions, it is recommended to regenerate sets of random maturity ogive each time with updated data.

Table 2.3.1. Parameters used to set up the stochastic LBSPR approach and their value (including uncertainty). Parameters in bold are the inputs of the LBSPR model. Other parameters not detailed here were left to their default values.

Parameter	Mean value (sd)	Description, comment
M	0.228 (0.0012)	Natural mortality (year^{-1}) at asymptotic length (L_{inf}). Fitted from size varying M estimates based on resampled reference fleet commercial sampling data following Lorenzen (1996).
M_{pow}	0.939 (0.0042)	aka exponent c, equ. 17 in Hordyk *et al.* (2016): parameterization of the size varying mortality in LBSPR. Fitted from size varying M estimates, following Lorenzen (1996), based on resampled reference fleet commercial sampling data.
k	0.248 (0.0033) *	growth coefficient from a von Bertalanffy growth function.
M/k	0.919 (0.0078)	M/k at L_∞, derived from the above estimates.
L_{inf}	95.45 (0.528) *	Asymptotic length L_∞ (cm), as defined in a von Bertalanffy growth function.

Parameter	Mean value (sd)	Description, comment
t_0	-0.0388	Theoretical time (year) when length = 0 in a von Bertalanffy growth function. Not a LBSPR parameter *per se*, but used for the estimation of k and Linf above parameters. Estimate borrowed from the coastal cod North of 67°N (EP method).
CVL_{inf}	0.155 (0.0006)	Coefficient of variation of asymptotic length. Encompass all inter-individual growth variability of LBSPR. The values used are the CV of size at age, and its uncertainty, estimated for the coastal cod North of 67°N (EP method). Estimated and randomly generated on the log scale (mean = -1.862; s.d. = 0.0039).
LM50	63.36 (1.688) †	Length (cm) at 50% maturity. Estimated from resampled coastal survey data (2010–2019) using a binomial glm.
LM95	79.92 (3.924) †	Length (cm) at 95% maturity. Estimated from resampled coastal survey data (2010–2019) using a binomial glm.

*randomly generated preserving the correlation structure between k and Linf using a multinormal distribution.

†pairs (LM50, LM95) estimated from a same bootstrapped dataset and year drawn together to preserve the correlation between the two parameters and avoid using a parameterization based on the distribution of ΔLm = LM95 – LM50.

Growth parameters

In a von Bertalanffy growth model, the asymptotic length (L∞) and the growth coefficient (k) have strongly correlated estimates. This correlation should therefore be maintained when generating random parameters. This can be achieved using a multinormal distribution random generator with the means in Table 2.3.1 and the variance-covariance matrix in Stock Annex.

Natural mortality

One of the most critical parameters for the performance of LBSPR is M/k. Here we had first-hand growth parameter estimates but no a priori information on M/k in coastal cod. Estimating M based on life history was therefore favoured and four methods tested: one giving a constant M (Then *et al.*, 2015, 2018) and three size varying M estimates (Lorenzen, 1996; Gislason *et al.*, 2010; Charnov *et al.*, 2013). SPR estimates based on these four different M were shown to have different absolute values but fairly similar trends. Among the four options examined for the parameterization of natural mortality, the size varying M following Lorenzen (1996) was retained based on its consistency with cannibalism-driven mortality in the partially sympatric NEA cod. It also provides the SPR and F/M estimates the closest to a M=0.2 scenario, while there is consensus that it represents a more realistic alternative than the later.

The Lorenzen M estimate is based on individual weights but is here re-parameterized as length varying using individuals sampled for weight and length in the reference fleet data. It may therefore need to be re-estimated in case of sustained substantial shift in the condition of fish.

Maturity ogive

Maturity is estimated for the whole autumn coastal survey data north of 62°N, on account of scarcity of biological cod samples for the area between 62°N and 67°N alone. For consistency with the choices made for the northern stock, resting individuals (stage 4) are included in the mature fraction. The maturity parameters (length at 50% and 95% maturity) are estimated by fitting a binomial GLM on yearly bootstrapped maturity data with covariate length (500 resampled datasets). For more details, see Stock Annex.

Size distribution resampling

The LBSPR model is fitted on 1000 bootstrapped size composition data and parameter sets. While input parameters were randomly generated/drawn as per Table 2.3.1, the generation of the randomized datasets is twofold:

1. random attribution of unclassified individuals between coastal and NEA cod, based on the size-based stock segregation model (section B.1) and using a binomial random generator: the number of coastal cod is drawn for each stratum defined by a combination size class, area, year, quarter and gear, based on the number of unclassified cod in the stratum and the probability P(coastal|size, area, year, quarter, gear) from the model described in section C.1.

2. bootstrap of the length composition within years: drawing the same number of individuals within each year of data from step 1, with replacement.

For each of the 1000 randomized data and parameter set, SPR, F/M and the selectivity parameter SL50% and SL95% are estimated and their resulting distributions evaluated.

2.3.6 Results of the Assessment (Figure 2.3.6–Figure 2.3.13)

2.3.6.1 Standardized CPUE index

The final standardized CPUE index for coastal cod indicates a general declining trend in all areas and quarter since 2007 with some interannual variability with a possible increase (large uncertainty) in 2020 (Figures 2.3.6 and 2.3.7).

The final standardized CPUE index for coastal cod indicates general stability since 2007 with some interannual variability and a possible increase (large uncertainty) in 2020. A declining trend is, however, seen in the southernmost part of the area, i.e. Møre-Trøndelag (statistical area 07).

A slightly new CPUE index of abundance was made as an extra check of the large uncertainty in 2020. Here we included the boat effect as a fixed effect since the model fit was much better than having the boat as a random effect, and then using one of the boats that was fishing for several years. This was made to possibly account for the unbalanced boat/gear use in the time-series. Even if it reduced the variance in 2020, we believe that the extra variance created by adding new boats and new fishing grounds to the time-series should not be disregarded. This issue will be further investigated until next year’s assessment.

2.3.6.2 Effort and CPUE from official landings statistics

It has also been investigated whether official reported landings and measures of fishing effort in the sales note statistics can provide a CPUE index that can be used in assessment and practical management. If so, this will give a much larger material than just a few boats in the Coastal Reference Fleet that primarily sample biological data from the fisheries. On the other hand, a reference fleet CPUE is more controlled (e.g. with regards to technology creep and fishing behaviour) than a full fleet CPUE.

The number of sales notes has been shown to give an overestimation of the fishing effort since a trip can give several sales notes by splitting the entire trip catch into several sales, each with its own sales note. We have therefore come to the conclusion that a trip best can be described by combining the vessel’s "Registration mark" in the sales note statistics with "Last catch date", and this we define as a trip and estimate effort according to.

Vessel size/Year	2018		2019		2020	
	Number of trips	Landed round weight (t)	Number of trips	Landed round weight (t)	Number of trips	Landed round weight (t)
(blank)	680	29	605	30	603	33
< 11 m	4203	229	3814	191	4311	298

Vessel size/Year	2018		2019		2020	
	Number of trips	Landed round weight (t)	Number of trips	Landed round weight (t)	Number of trips	Landed round weight (t)
11–14.99 m	1107	129	1221	145	1125	114
15–20.99 m	89	24	99	20	71	19
21–27.99 m	3	2	1	1	32	15
>= 28 m	1	3	1	0	8	1

The text table above shows the number of trips and landings (round weight) per vessel length group for cod caught inside 12 nautical miles during the second half-year during 2018–2020, all gears. This shows that the vessel length groups <11–14.99 m represented by the coastal reference fleet (ch. 2.2.6) are responsible for most of the effort and cod landings. The 9–15 m vessels in the reference fleet represent the gear and vessel size category responsible for about 60% of the total annual cod commercial catches in the area, and 88% of the effort (fishing trips) and 86% of cod catches in the second half of the year.

Figures 2.3.8 and 2.3.9 show the effort and CPUE from official landings statistics from 2007–2020. These data show a similar development of the CPUE as the more controlled and standardized reference fleet data do. These time-series can also be used by managers to adjust the number of trips as a measure of effort adjustment.

2.3.6.3 Stochastic LBSPR outputs and interpretation

SPR and F/M distributions per year are compared to their reference points. Between 2007–2019 for instance, the mean SPR fluctuates between 20 and 30%, with an overall downward trend (Figure 2.3.10), which places it below the target values (30–40%) and – at the end of the series – just below the limit reference point 20%, generally accepted in the absence of further information on the stock dynamics (ICES 2018; Prince *et al.*, 2020; Mace and Sissenwine, 1993). The relative fishing mortality F/M is estimated above the value which achieve long-term SPR=40%, or the more usual proxy F/M=1 and follows an upward trend (Figure 2.3.11). The decrease in the spawning potential ratio is concomitant with a decline of the size-based indicators $L_{max5\%}$ (the mean length of the largest 5% of individuals in the catch) and mean length in catch (Figure 2.3.12). These all together depict a somewhat depleted and worsening stock status.

In the absence of clear information on the stock-recruitment relationship, a more legitimate reference point cannot be estimated and even a SPR of 30% should be considered as a potentially non-precautionary level, and SPR=40% preferred as B_{MSY} proxy (Clark, 2002; Hordyk *et al.*, 2015a). In conformity with ICES guidelines (ICES, 2018) and commonly used SPR-based proxies (Prince *et al.*, 2020; Mace and Sissenwine, 1993), the corresponding limit reference point (proxy for B_{lim} = BMSY/2) should be SPR=20%.

A simulation function in the LBSPR package allows to estimate a F/M which, at equilibrium and given the parameters, lead to a chosen SPR. The estimated F/M can therefore be compared to FSPR40%/M (Figure 2.3.11) or other usual proxies.

2.3.6.4 Total mortality (Z) from catch curves

Since catch in numbers-at-age data is available for this stock (Tables 2.3.2 and 2.3.3) for a longer period (1994–2020) it is possible to estimate the total mortality from catch-curve analyses. The assumptions usually made for catch-curve analysis are that (1) there are no errors in the estimation of age composition, (2) recruitment is constant or at least varies without trend over time, (3) Z is constant over time and across ages, and (4) above some determined age, all animals are equally available and vulnerable to the fishery and the sampling process. The catch-curve estimates a single total mortality rate for all years/ages that compose its synthetic cohort, and this total mortality estimate is generally similar to the average of the true total mortality rate.

With the available catch-at-age data it was possible to estimate the average total mortality of ages 5–14 for the years 1994–2020. Note that Tables 2.3.2 and 2.3.3 only present data up to age group 10+, but catch-at-age data were available to the AFWG up to age group 15+. Figure 2.3.13 shows a very stable level of the total mortality during the entire time-series, varying without trend around the long-term average of Z=0.75. With natural mortality of 0.23 (at L-infinity) this implies fishing mortality around 0.5.

2.3.7 Comments to the Assessment

The assessment is rather uncertain. The reasons for this include highly uncertain data for the recreational catch and uncertainty in the catch split between Northeast Arctic cod and coastal cod, although the CPUE series is calculated for the second half of the year to minimize the mixing of the two stocks in the dataseries. The assessment is also dependent on the representativeness of the coastal reference fleet’s gillnet CPUE series. Gillnet is responsible for most of the catches, and the 9–15 m vessels in the reference fleet represent the gear and vessel size category responsible for about 60% of the total annual cod commercial catches in the area, and 88% of the effort (fishing trips) and 86% of cod catches in the second half of the year.

Since ICES lacks a framework for using LBSPR directly as a basis for quota advice, LBSPR and length-based analyses have been used as additional information to assess the need for a 20% buffer in the “2 over 3” rule, as recommended by the benchmark reviewers.

2.3.8 Reference points

No biological reference points are established except the SPR and F/M reference levels often referred to in literature. See section 2.3.6.1 above.

2.3.9 Catch scenarios for 2022

The ICES Guidance for completing single-stock advice for category 3 stocks was applied (ICES, 2012, 2021). A composite standardized CPUE index from the coastal reference fleet (9–15 m vessel length) in coastal waters between 62°N and 67°N during quarters 3 and 4, between 2007–2020, is used as index for the stock development. The advice is based on the ratio of the two latest index values (index A) with the three preceding values (index B), multiplied by the average catches for years 2018–2020 (Table 2.3.7–Table 2.3.8). The index is estimated to have increased by less than 20% and thus the uncertainty cap was not applied. Fishing pressure is thought to be above, and stock size is thought to be below, possible MSY reference points; therefore, the precautionary buffer was applied in the advice. Discarding (dead fish) is known to take place (less than 5% in the commercial fishery (Berg and Nedreaas 2021), and about 7% in the rod and line sector of the recreational fishery), but ICES cannot quantify the corresponding catch.

The corresponding catch advice for 2022 is estimated to 7613 tonnes. Assuming recreational catches at 4202 tonnes, this implies a commercial catch of no more than 3411 tonnes. The catch advice is a decrease relative to the average catches 2018–2020 because of the application of the precautionary buffer, but an increase relative to the catch in 2020.

Alternative 1 - Index values weighted with the inverse variance

Since the CPUE index for the stock development is calculated with variance, the AFWG did an alternative “2 over 3” estimation using indices A and B weighted by the inverse variance, especially since the last CPUE year (2020) had a relatively large variance. This gives an index ratio A/B=1.029 (Table 2.3.7) and corresponding catch advice for 2022 of 6666 tonnes when also using the 20% precautionary buffer.

Alternative 2 – Using the rfb-rule (WKLIFE X)

ACOM intends to implement WKLIFE X methods (ICES 2020, Annex 3) in 2022. The AFWG was informed that a workplan will be developed for training, technical guidelines, special implementation workshops, and a big review group will be initiated later in 2021.

In this year’s advice “season”, ICES will hence provide advice using the “old” methods UNLESS a stock was benchmarked with the new WKLIFE X methods.

WKLIFE has developed a harvest control rule to provide MSY advice for category 3 stocks based on the “2 over 3 rule”. The recommended harvest rule, i.e. the rfb-rule, improves on the “2 over 3” rule with the addition of multipliers based on the stock’s life-history characteristics, the status of the stock in terms of relative biomass, and the status of the stock relative to a target reference length. The necessary parameters for using the rfb-rule were estimated during the benchmark assessment for this stock in February 2021 (WKBARFAR), and are presented in Tables 2.3.1 and 2.3.7. The corresponding catch advice will be higher than using the “old” “2 over 3 rule”.

2.3.10 Management considerations

Norwegian coastal cod is taken as part of a mixed fishery with Northeast Arctic cod (cod.27.1-2), from which it cannot be visually distinguished. Without the option of setting a direct TAC, the coastal cod stocks are managed by technical regulatory measures. Despite management actions, the previous management plan has not led to significantly reduced fishing mortality. A new plan is therefore required, with regulations better targeted to areas and seasons where catches of coastal cod are high. The split of the coastal cod stock in two units – one data rich in the north and one data poor in the south – combined with improved genetic stock identification techniques improves the spatial resolution of the assessment and allows development of more targeted management measures. The stock split follows the Norwegian catch reporting areas, with areas 0,3,4, and 5 encompassing the northern stock, and areas 6 and 7 encompassing the southern (Figure 2.1).

The zero-catch advice for cod.27.1-2coastN (Northern Norwegian coastal cod) and non-zero catch advice for cod.27.2coastS (Southern Norwegian coastal cod) are not necessarily indicative of a better state for the southern stock. The difference is primarily due to the default ICES advice arising from the use of an analytic category 1 assessment in the north and a data-limited category 3 assessment in the south. Furthermore, the use of a longer time-series for the northern stock permits comparison with reference points from a higher stock state. Developing and adopting rebuilding plans for these two stocks should resolve this discrepancy.

ICES finds it difficult to give precise catch advice when the recreational catches, likely contributing more than 50% of total catches, are poorly estimated. A prerequisite for more accurate future assessments is a better estimation of the recreational catches.

2.3.11 Rebuilding plan for coastal cod

The Norwegian Ministry of Fisheries is working on a new rebuilding plan. Fisheries scientists need to discuss with managers, how to facilitate rebuilding of the stock, evaluate rebuilding targets and measures to avoid high fishing pressure in areas with high fractions of coastal cod. Stronger restrictions are required in all areas where coastal cod is distributed. Until a longer perspective rebuilding plan is established, the necessary management action for next year will be to reduce the fishery so that the combined commercial and recreational catches will become at least 6% lower than the three last years' average.

2.3.12 Recent ICES advice

For the years 2004–2011, the advice was; No catch should be taken from this stock and a recovery plan should be developed and implemented.

For 2012, and later the advice has been to follow the rebuilding plan. The latest ICES advice strongly recommends a new rebuilding plan.

2.3.13 Figures and tables

Table 2.3.2. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Estimated commercial landings in numbers ('000) at-age, and total tonnes by year.

	Age									**Tonnes**
	2	3	4	5	6	7	8	9	10+	Landed
1994	1	7	111	288	361	279	158	71	112	6381
1995	3	32	210	399	491	467	267	114	96	8936
1996	2	64	242	384	304	253	130	36	44	6207
1997	2	117	171	212	189	185	131	44	33	4746
1998	20	177	446	496	332	109	82	22	23	6200
1999	3	116	313	308	255	123	53	66	26	5522
2000	2	242	697	411	159	57	51	17	37	5838
2001	2	94	423	457	304	149	52	17	86	5250
2002	9	88	360	409	441	138	52	12	16	6937
2003	23	204	237	571	398	380	112	22	53	8905
2004	5	112	334	260	400	232	139	35	26	6866
2005	2	65	381	522	445	262	122	37	19	8005
2006	10	48	308	617	565	179	99	54	50	8612
2007	11	154	364	497	379	113	51	23	29	7695
2008	31	103	893	665	195	265	69	38	47	9889

	Age									Tonnes
	2	3	4	5	6	7	8	9	10+	Landed
2009	1	224	663	259	311	107	74	42	20	7145
2010	5	115	400	434	245	260	50	36	45	7634
2011	3	59	310	484	267	194	65	36	35	7128
2012	28	113	268	501	317	279	73	36	36	8187
2013	5	54	239	214	248	169	80	27	16	5131
2014	1	56	166	390	265	226	79	43	38	6244
2015	21	149	257	229	263	120	69	37	41	5004
2016	1	83	248	313	206	200	121	66	83	5962
2017	13	73	275	279	157	97	70	24	34	4159
2018	9	57	131	298	255	141	90	36	32	4436
2019	4	34	85	101	128	121	77	21	24	2965
2020	1	46	164	140	144	79	84	37	16	3481

Table 2.3.3. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Total estimated catch number ('000) at age, including recreational and tourist catches.

	Age									Tonnes	Hereof
	2	3	4	5	6	7	8	9	10+	landed	rec. (t)
1994	2	14	207	538	676	523	296	132	210	11937	5556
1995	4	51	341	647	797	757	433	184	155	14492	5556
1996	3	120	455	723	572	476	245	68	82	11687	5480
1997	5	253	369	456	407	399	283	95	72	10226	5480
1998	38	334	842	937	628	207	155	42	43	11718	5518
1999	5	226	610	600	497	240	103	128	51	10776	5254
2000	3	456	1311	773	299	107	96	32	69	10979	5140
2001	3	184	832	897	598	293	101	34	169	10315	5065
2002	15	153	627	711	768	240	91	22	28	12077	5140
2003	36	325	377	907	633	605	178	35	85	14159	5254
2004	9	194	581	451	695	403	242	60	45	11931	5065
2005	3	105	619	848	722	426	197	61	31	12994	4989
2006	16	76	484	968	888	282	156	84	79	13525	4913

	Age								Tonnes	Hereof
	2	3	4	5	6	7	8	9	10+	landed	rec. (t)
2007	18	252	597	814	620	185	83	38	47	12609	4913
2008	46	153	1330	990	290	395	103	56	71	14727	4838
2009	1	375	1109	433	519	178	124	70	34	11945	4800
2010	7	187	651	706	398	423	81	58	74	12434	4800
2011	5	98	518	811	447	325	109	59	58	11928	4800
2012	45	179	425	795	502	442	115	57	58	12987	4800
2013	9	105	463	414	480	327	154	52	31	9931	4800
2014	1	100	293	690	469	400	140	76	68	11044	4800
2015	41	293	503	449	515	234	135	72	80	9804	4800
2016	2	151	448	566	371	360	218	120	150	10762	4800
2017	28	158	592	600	337	208	152	51	73	8959	4800
2018	19	118	272	620	532	293	187	75	66	9236	4800
2019	12	88	223	265	336	316	201	54	63	7765	4800
2020	1	97	342	293	301	166	177	78	34	7287	3806

Table 2.3.4. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Commercial catch in 2020 by gear and Norwegian statistical fishing area. Both fishing areas lie within ICES Division 2.a.

Year	**2020**			
Area	06	07	Total between 62 and 67°N	% by gear
Gillnet	1355	988	2343	67.3
Longline/Handline				
Danish seine				
Trawl	14	93	107	3.1
Others*	366	665	1031	29.6
Total	1735	1746	3481	

***in 2020, longline, handline and Danish seine are all included in the 'others' category.**

Table 2.3.5. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Mean weight at age in the catch.

CWT	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1994	1.028	1.537	2.206	2.985	3.822	4.908	5.954	7.468	9.571

CWT	2	3	4	5	6	7	8	9	10+
1995	0.845	1.392	1.950	2.603	3.649	4.811	6.076	7.404	10.566
1996	1.177	1.975	2.554	3.392	4.186	5.242	6.429	7.283	11.591
1997	1.348	2.004	2.611	3.439	4.282	5.387	6.563	7.467	10.828
1998	1.007	1.737	2.454	3.373	4.483	5.484	6.914	7.825	14.092
1999	1.459	2.231	2.927	3.800	4.854	6.032	7.009	8.257	12.088
2000	1.344	1.971	2.811	3.568	4.610	5.588	6.860	7.815	11.806
2001	0.565	0.981	1.533	2.250	3.129	4.160	5.375	6.722	16.118
2002	1.372	2.330	3.302	4.199	5.225	6.290	7.226	9.768	13.031
2003	1.312	2.143	2.962	3.899	4.702	5.648	6.616	7.425	11.376
2004	1.368	2.124	2.758	3.684	4.705	5.858	6.874	7.901	11.117
2005	1.488	2.332	2.990	3.701	4.562	5.637	6.699	7.703	10.364
2006	1.526	2.158	2.866	3.790	4.703	5.769	6.725	7.876	10.103
2007	1.613	2.295	3.285	4.337	5.744	7.105	8.397	9.991	12.359
2008	1.455	2.221	3.179	3.932	5.443	6.533	7.990	8.341	11.107
2009	1.667	2.135	3.234	4.207	5.279	6.527	7.568	7.606	11.305
2010	1.480	2.262	3.325	4.431	5.534	6.335	7.598	9.048	9.543
2011	1.381	2.127	3.172	4.263	5.511	6.510	8.012	9.032	11.065
2012	1.214	2.012	3.011	4.302	5.520	6.686	8.188	9.569	11.635
2013	1.269	2.027	3.092	4.024	5.268	6.370	7.524	8.918	12.241
2014	1.304	2.194	3.047	3.998	4.959	6.115	7.181	8.234	11.537
2015	1.219	1.832	2.726	3.797	4.627	5.845	7.009	8.195	10.981
2016	1.339	1.930	2.617	3.578	4.471	5.421	6.429	7.445	9.132
2017	1.529	2.022	2.750	3.663	4.543	5.612	6.542	7.489	9.678
2018	1.190	1.848	2.547	3.434	4.265	5.301	6.375	7.333	9.393
2019	1.662	2.283	3.120	3.895	4.840	5.796	6.743	7.737	9.548
2020	1.660	2.395	3.150	3.922	4.707	5.505	6.313	7.130	8.993

Table 2.3.6. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Composite standardized CPUE index from the coastal reference fleet during quarters 3 and 4, between 2007–2020. 95% confidence interval (calculated using the approximation: mean +/- SD).

Year	CPUE index	SD +/-
2007	0.24	0.66
2008	0.38	0.89
2009	0.23	0.50
2010	0.14	0.32
2011	0.21	0.54
2012	0.18	0.49
2013	0.05	0.11
2014	0.12	0.27
2015	0.22	0.51
2016	0.24	0.54
2017	0.27	0.72
2018	0.11	0.28
2019	0.13	0.33
2020	0.35	0.96

Table 2.3.7. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Parameters used for calculating "2 over 3" and the "rfb" (ICES WKLIFE X 2021).

Parameter	Value	Value multiplied with precautionary buffer = 0.8
Average CPUE 2019–2020	0.243	
Average CPUE 2016–2018	0.207	
Average CPUE 2019–2020 (weighted)	0.154	
Average CPUE 2016–2018 (weighted)	0.150	
r (plain)	1.174	0.94
r (weighted)	1.029	0.82
Mean length in observed catch, $L_{y\text{-}1\ (2020)}$	73.7 cm	
Length at modal abundance	74 cm	
Lc is defined as length at 50% of modal abundance	61 cm	
L_{inf}	95.45 cm	

Parameter	**Value**	**Value multiplied with precautionary buffer = 0.8**
$L_{F=M}=0.75L_c + 0.25L_{inf}$	69.63 cm	
$f = L_{y-1}/L_{F=M}$	1.06	
I_{y-1}	0.36	
$I_{trigger} = 1.4I_{loss}$	0.07	
b	1.0	
m when k=0.248	0.8	
Total factor rfbm (with plain r)	**1.00**	
Total factor rfbm (with “weighted” r)	**0.87**	

Table 2.3.8. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. The basis for the catch scenarios ^.

Index A (2019–2020)		0.243
Index B (2016–2018)		0.207
Index ratio (A/B)		1.174
Uncertainty cap	Not applied	
Average catches for 2018–2020		8096
Discard rate		Not quantified
Precautionary buffer	Applied	0.8
Catch advice *		7613
% Advice change **		−6%

^ The figures in the table are rounded. Calculations were done with unrounded inputs and computed values may not match exactly when calculated using the rounded figures in the table.

*** [average catches for 2018–2020] × [index ratio] × [precautionary buffer].**

**** Advice value for 2022 relative to average catches for 2018–2020.**

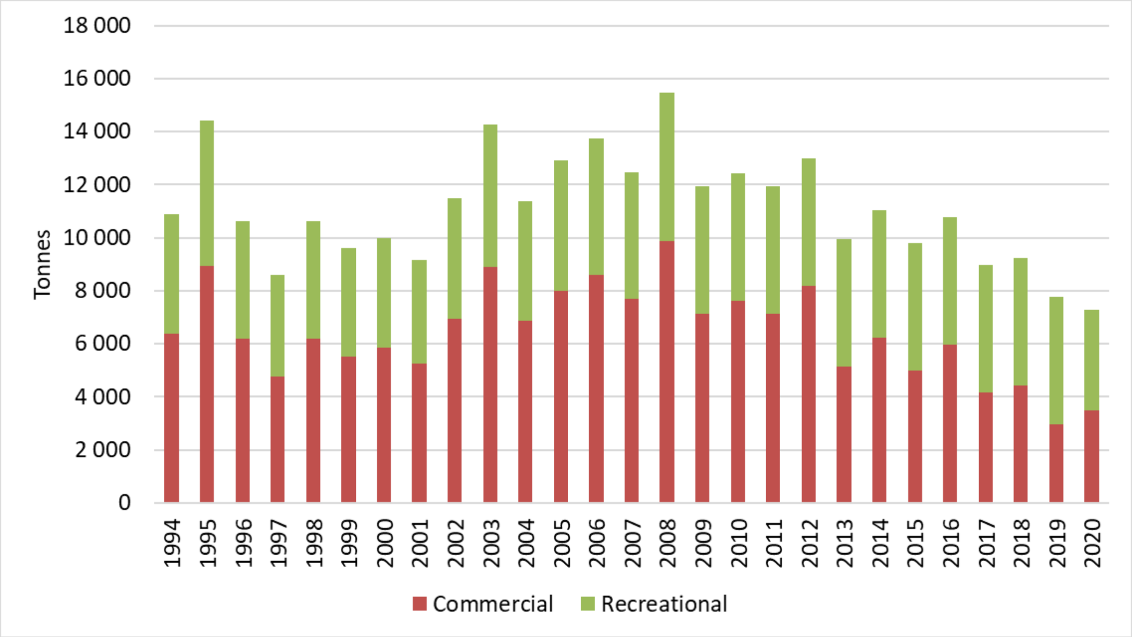


Figure 2.3.1. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Commercial and recreational catches. Recreational catches are fixed from 2009–2019 at 4800 tonnes.

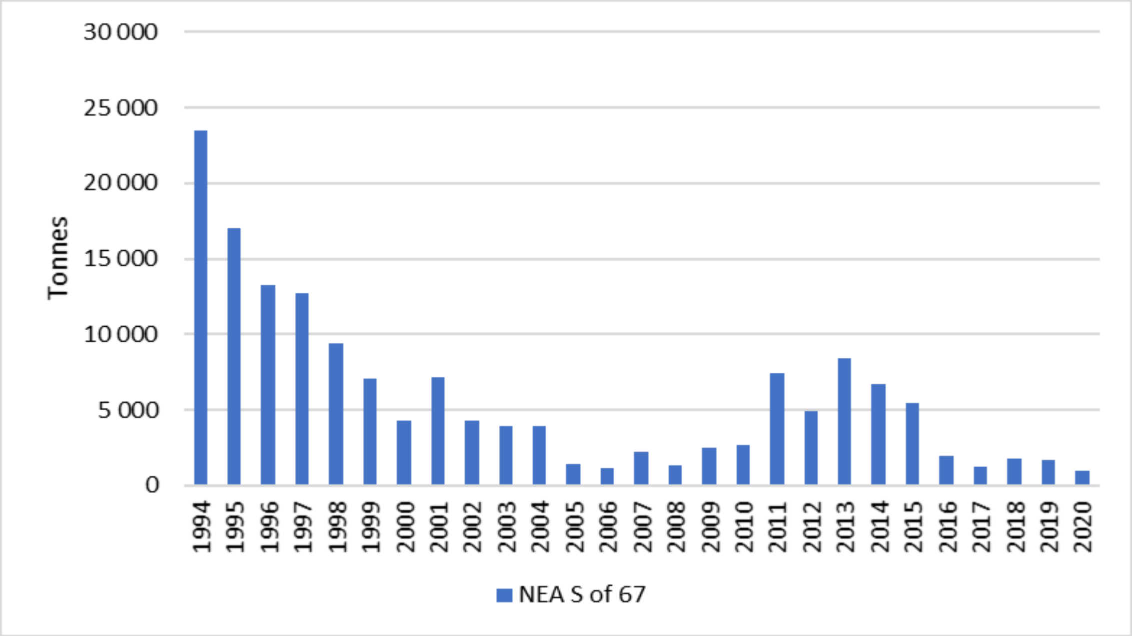


Figure 2.3.2. Estimated landings of Northeast Arctic cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N.

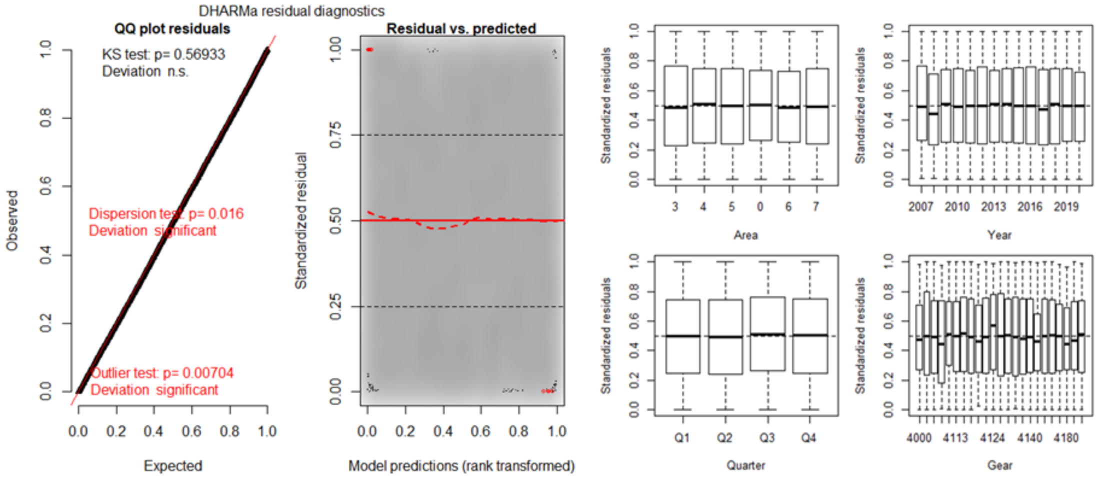


Figure 2.3.3. Residual diagnostic plots for the final binomial model to differentiate coastal cod vs. NEAC. The panel on the left is a standard output from the residual diagnostics using the R package DHARMa. The panel on the right plots the model standardized residuals against available covariates. Both panels indicate no significant issues with the final model.

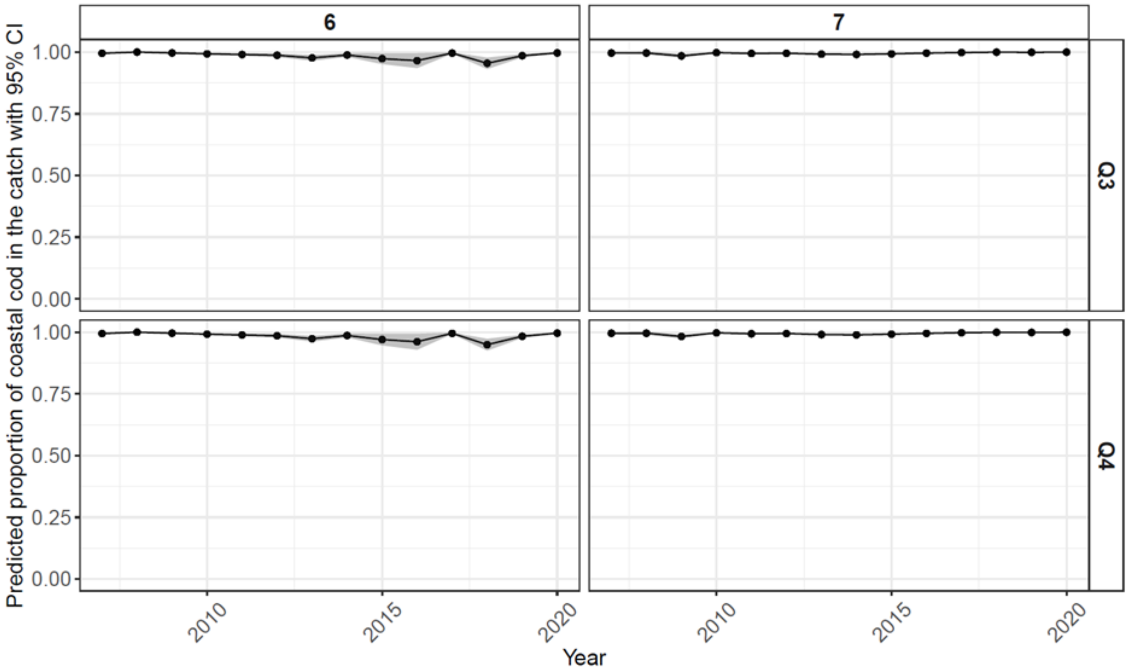


Figure 2.3.4. Predicted probability of catching coastal cod based on the quarter (vertical panels), areas (horizontal panels), and years (x-axis within each panel). The grey shaded polygon represents the 95% confidence interval.

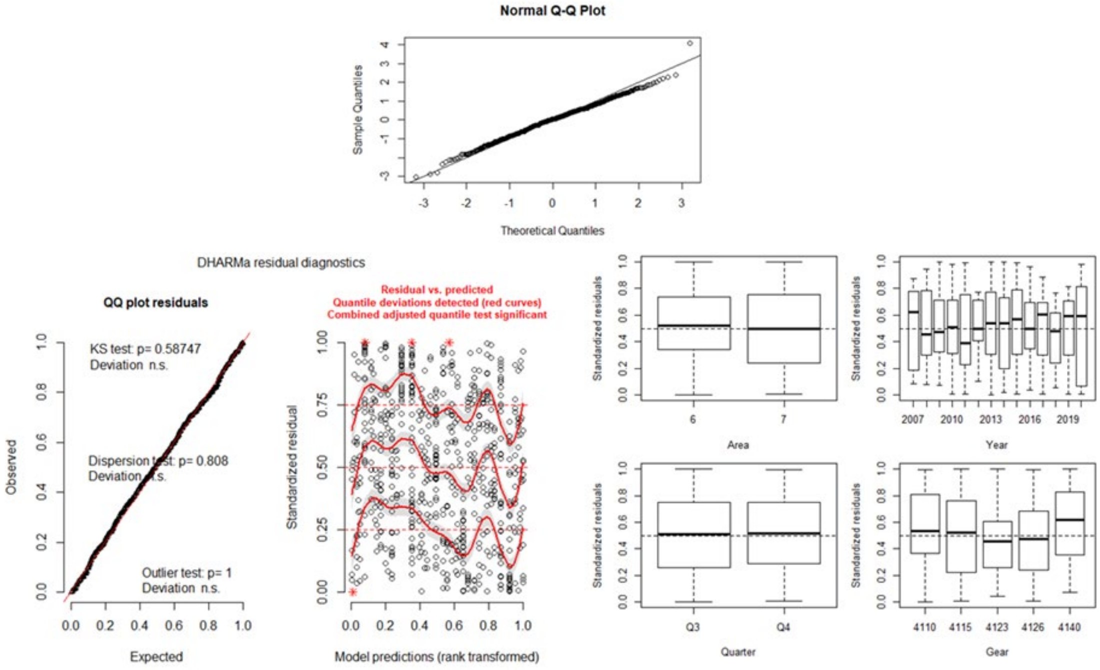


Figure 2.3.5. Residual diagnostic plots for the final CPUE model fitted to cod data in area 6 and 7, and quarters 3 and 4. The top panel is the normal QQ-plot. The panel on the left is a standard output from the residual diagnostics using the R package DHARMa. The panel on the right plots the model standardized residuals against available covariates. All panels indicate no significant (though some) issues with the final model.

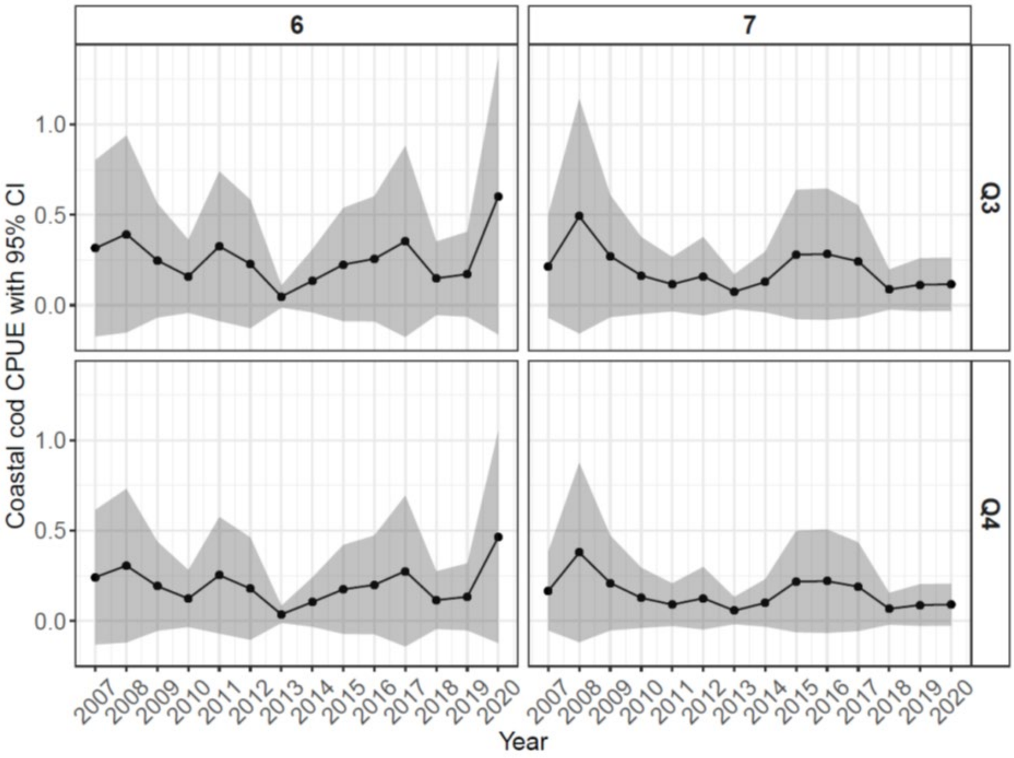


Figure 2.3.6. Standardized CPUE index for coastal cod in area 6 and 7 during quarters 3 and 4, between 2007–2020. The grey shaded polygon represents the 95% confidence interval (calculated using the approximation mean +/- 1.96 std which is why some values goes below 0).

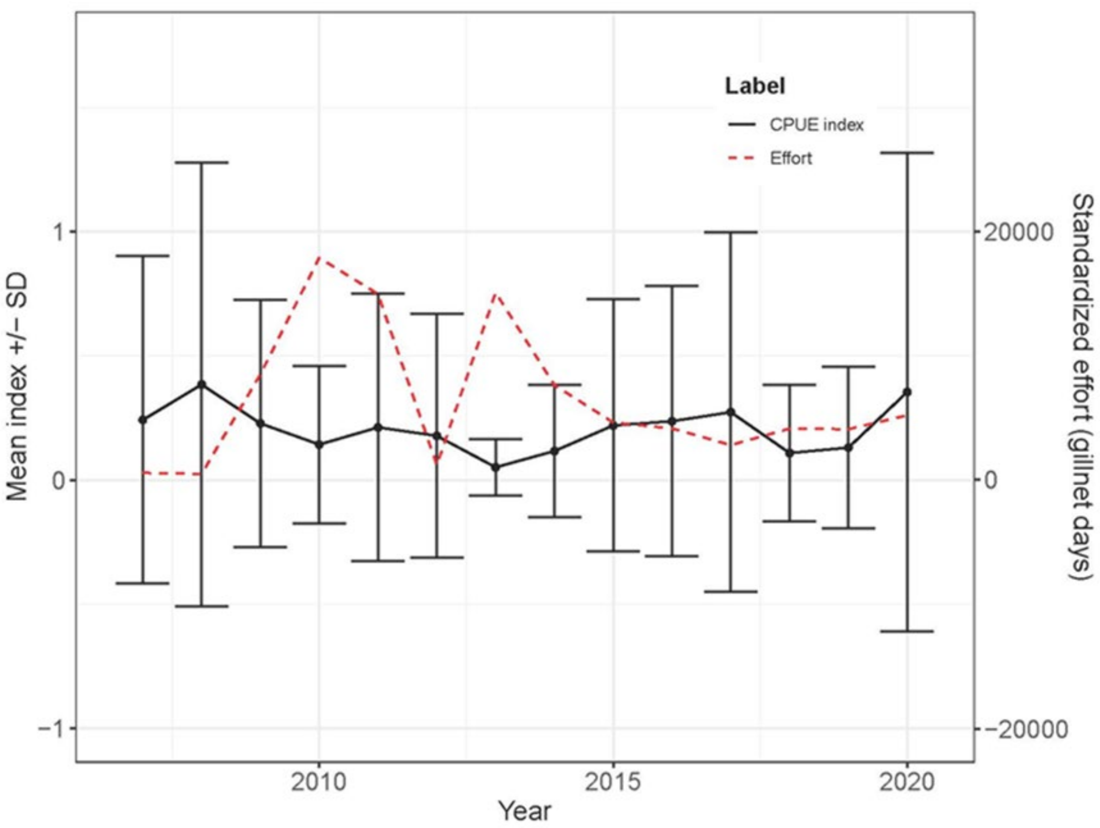


Figure 2.3.7. Composite standardized CPUE index for coastal cod in area 6 and 7 during quarters 3 and 4, between 2007–2020. 95% confidence interval (calculated using the approximation: mean +/- 1.96 std.; negative values are therefore introduced in the plot as an artifact of this procedure) are given by error bars.

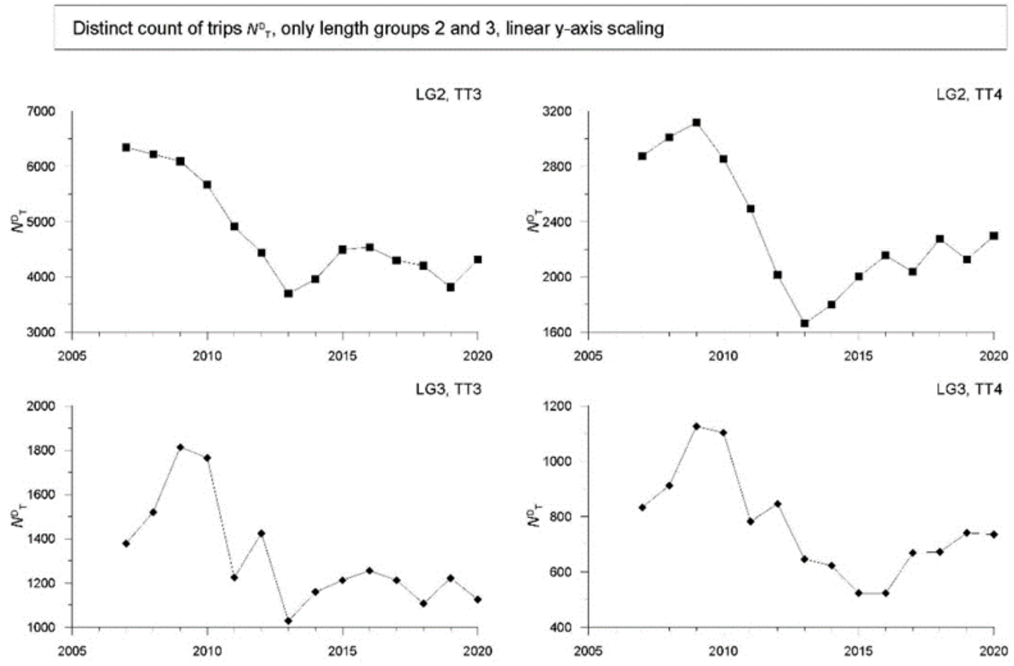


Figure 2.3.8. Fishing effort presented as the number of sales note trips for two boat sizes, LG2 = <11 m and LG3 = 11–14.99 m, for areas 62–67°˚N in the second half of the year. Left panel: all gears; right panel: gillnet only. Note different y-axes.

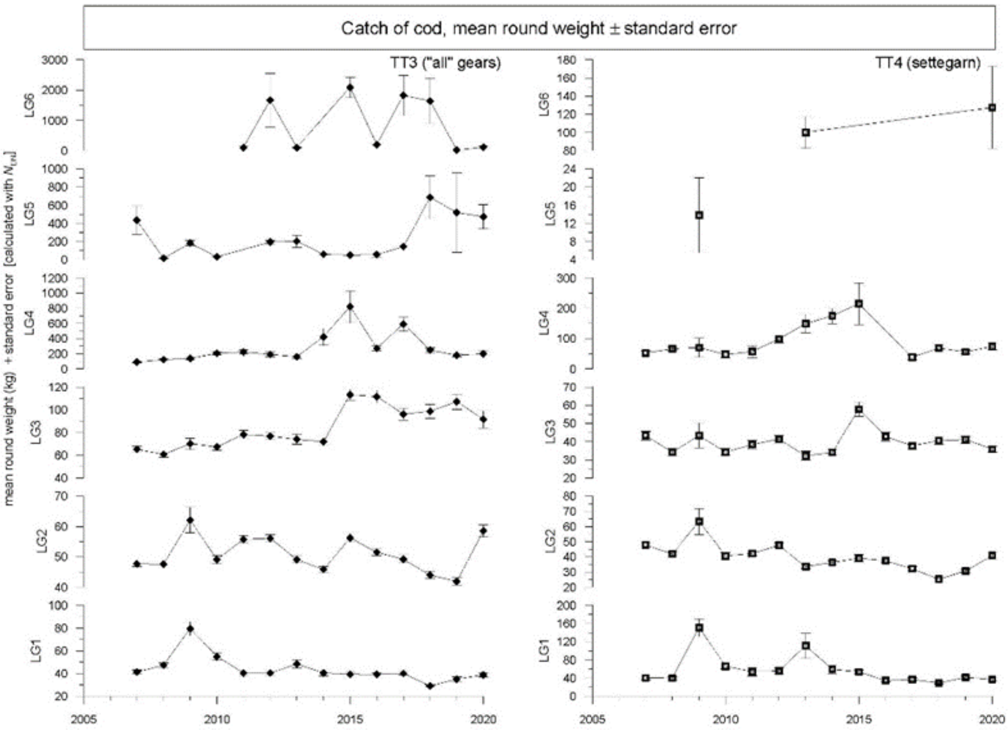


Figure 2.3.9. CPUE (kg cod per sales note trip) per boat size (LG1-LG6) for area 62–67°N in the 2nd half of the year. Left panel: all gears; right panel: gillnet only.

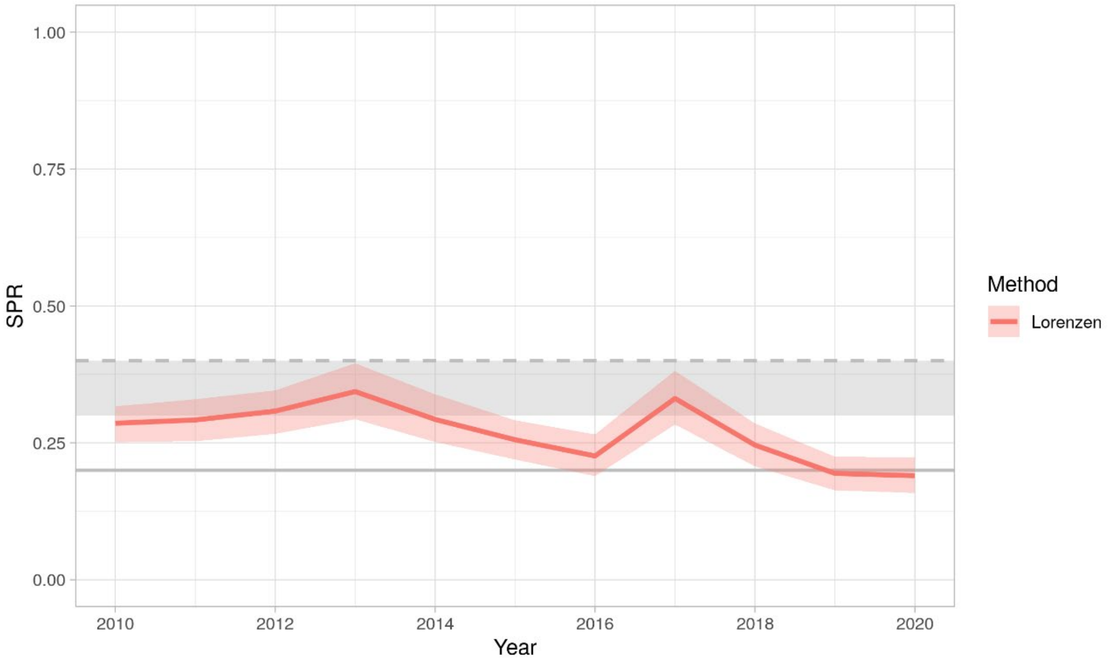


Figure 2.3.10. Estimated spawning potential ratio (SPR) per year for coastal cod south of 67°N. Mean (solid line) and confidence intervals (shaded red area, 95% IQR), based on the stochastic LBSPR. The grey shaded area delimits the SPR30%-40% zone (common targets) and the dotted horizontal line the SPR20% limit reference point (Prince *et al.*, 2020).

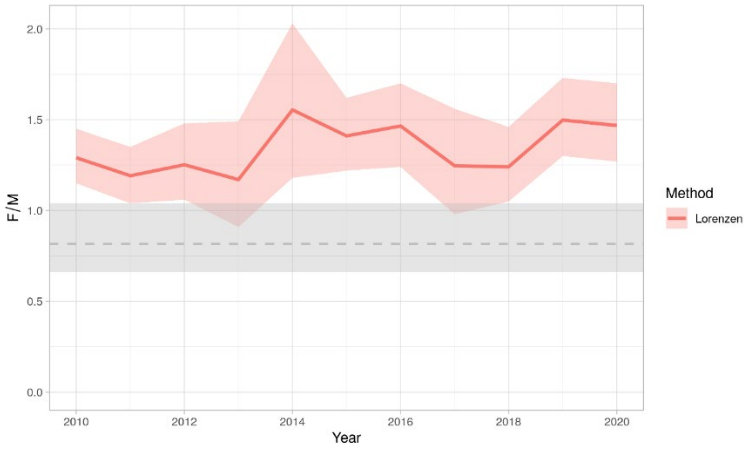


Figure 2.3.11. Estimated fishing mortality, relative to natural mortality (F/M) per year for coastal cod south of 67°N. Mean (solid line) and confidence intervals (shaded red area, 95% IQR), based on the stochastic LBSPR.

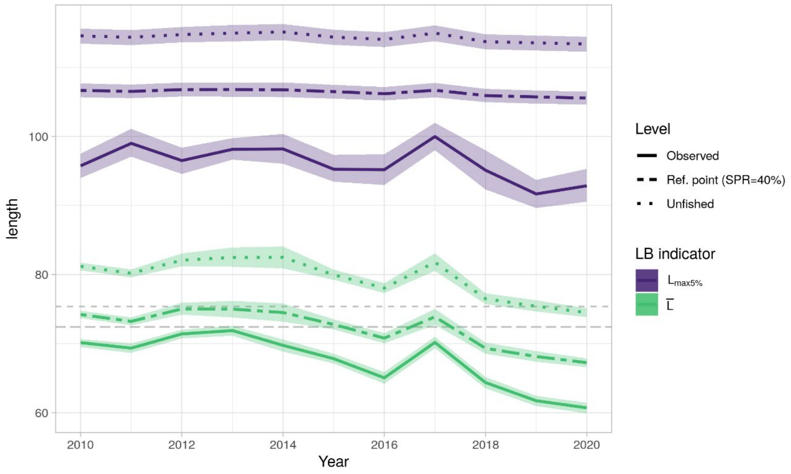


Figure 2.3.12. Variations in time of the size-based indicators Lmax5% and mean length in catch ($\bar{L}$), and their reference points (mean and 95%CI). The reference points were estimated using the LBSPR simulation model together with the stochastic parameters detailed in Table 2.3.1 (mortality scenario following Lorenzen, 1996) and SPRs of 40% and 100% (unfished).

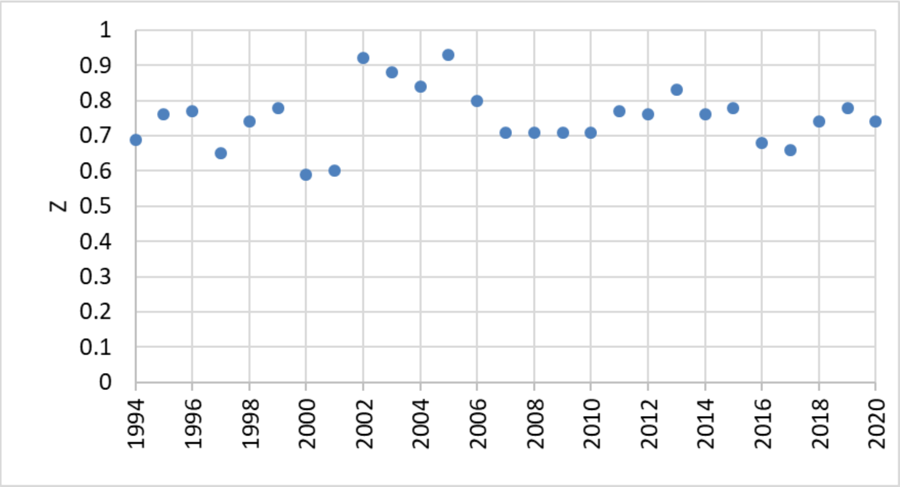


Figure 2.3.13. Total mortality (Z) estimated from catch curves (average over ages 5–14 in commercial and recreational catches) 1994–2020.

3 Cod in subareas 1 and 2 (Northeast Arctic)

Gadus morhua – cod.27.1-2

3.1 Status of the fisheries

3.1.1 Historical development of the fisheries (Table 3.1)

From a level of about 900 000 t in the mid-1970s, total catch declined steadily to around 300 000 t in 1983–1985 (Table 3.1). Catches increased to above 500 000 t in 1987 before dropping to 212 000 t in 1990, the lowest level recorded in the post-war period. The catches increased rapidly from 1991 onwards, stabilized around 750 000 t in 1994–1997 but decreased to about 414 000 t in 2000. From 2000–2009, the reported catches were between 400 000 and 520 000 t, in addition there were unreported catches (see below). Catches have been above the long-term average since 2011 and have decreased from a peak of 986 449 tonnes in 2014 to 692 000 tonnes in 2019–2020. The fishery is conducted both with an international trawler fleet and with coastal vessels using traditional fishing gears. Quotas were introduced in 1978 for the trawler fleets and in 1989 for the coastal fleets. In addition to quotas, the fishery is regulated by a minimum catch size, a minimum mesh size in trawls and Danish seines, a maximum bycatch of undersized fish, closure of areas having high densities of juveniles and by seasonal and area restrictions.

3.1.2 Reported catches prior to 2021 (Table 3.1–Table 3.4, Figure 3.1)

The provisional catch of cod in Subarea 1 and divisions 2.a and 2.b for 2020 reported to the working group is 738 204 t (including both NEA cod and NCC catches).

Reported catch figures used for the assessment of Northeast Arctic cod:

The historical practice (considering catches between 62°N and 67°N for the whole year and catches between 67°N and 69°N for the second half of the year to be Norwegian coastal cod) has been used for estimating the Norwegian landings of Northeast Arctic cod up to and including 2011 (Table 3.2). The catches of coastal cod subtracted from total cod catches in Subarea 1 and divisions 2.a and 2.b for the period 1960–2020 are given in Table 3.2. For 2012–2020 the Norwegian catches have been analysed by an ECA-version designed for simultaneously providing estimates of catch numbers-at-age for each of the two stocks. Coastal cod catches in 2020 for the southern and northern area combined were 45 301 tonnes using the current conversion factors between round and gutted weight, and this amount was as in previous years subtracted from the total cod catch north of 62°N to get the figure for NEA cod used in that assessment (Table 3.1 and 3.2). The figure for total coastal cod catch in 2020 using the revised conversion factors, as decided at WKBARFAR 2021 and used in the coastal cod assessment was 46 614 tonnes (Table 2.1a), which is 2.9% above the value using the current conversion factors.

These values for coastal cod are now inconsistent with the coastal cod catches presented in section 2, as the coastal cod catch time-series were revised at WKBARFAR, but not the NEA cod time-series. At WKBARFAR, the proposal for revision of NEA cod catch dataseries was rejected, as Norwegian data for many years and age groups (especially ages 12+ in years prior to 2013) were changed considerably and the reason for this was not sufficiently explained. WKBARFAR recommended that when the revision of the historical Norwegian catch data are ready it should be submitted to ICES for review, ideally by a review attached to the AFWG. The catch by area is shown in Table 3.1, and further split into trawl and other gears in Table 3.3. The distribution of catches by areas and gears in 2020 was similar to 2019. The nominal landings by country are given in Table 3.4.

There is information on cod discards (see section 1) but it was not included in the assessment because these data are fragmented and different estimates are in contradiction with each other. Moreover the level of discards is relatively small in the recent period and inclusion of these estimates in the assessment should not change our perception on NEA cod stock size.

In summer/autumn 2018, a Norwegian vessel caught 441 t of cod in the Jan Mayen EEZ, which is a part of ICES area 2a, mostly by longline. Cod is known to occasionally occur in this area, but rarely in densities which are suitable for commercial fisheries. The cod caught in this area in 2018 was large (65–110 cm), and otolith readings and genetics both showed this cod to be a mix of Northeast Arctic and Icelandic cod. Norway did in 2019–2020 carry out an experimental longline fishery during four different periods in each year in order to investigate further the occurrence of cod in this area in space and time as well as stock identity. The size distribution and genetic composition of the cod caught in this area in 2019–2020 was similar to that in 2018, although there was somewhat more smaller cod (< 65 cm) in 2020 than in 2019. Most of the cod caught in April–May 2019 was spawning or spent, while most cod caught in March 2020 had not started spawning. Cod spawning in this area has not been observed prior to 2019. Total catches in 2019 amounted to 628 t and in 2020 to 522 t. The 2018 catches in this area were partly counted against the Norwegian TAC for cod north of 62°N , while the 2019 and 2020 TAC for this area comes in addition to the Norwegian TAC for cod as agreed by JNRFC. There has been varying practice considering including those catches in the assessment, they were included in 2020 but the plan is to exclude them for all years in future assessments. Regulations for the fishery in this area for 2021 have not yet been decided upon.

3.1.3 Unreported catches of Northeast Arctic cod (Table 3.1)

In the years 2002–2008 certain quantities of unreported catches (IUU catches) have been added to the reported landings. More details on this issue are given in the Working group reports for that period.

There are no reliable data on level of IUU catches outside the periods 1990–1994 and 2002–2008, but it is believed that their level was not substantial enough to influence on historical stock assessment.

According to reports from the Norwegian-Russian analysis group on estimation of total catches the total catches of cod since 2009 were very close to officially reported landings.

3.1.4 TACs and advised catches for 2020 and 2021

The Joint Norwegian-Russian Fisheries Commission (JNRFC) agreed on a cod TAC of 738 000 t for 2020, and in addition 21 000 t Norwegian coastal cod. The total reported catch of 738 204 t in 2020 was 20 796 t below the agreed TAC. Since 2015 JNRFC has decided that Norway and Russia can transfer to next year or borrow from last year 10% of the cod country’s quota. That may lead to some deviation between agreed TAC and reported catch. Ignoring quota transfers, Norwegian catches in 2020 were about 10 000 t below the TAC, as were Russian catches, while third country catches were close to the TAC. The difference for Norway was mainly due to quota transfers between 2019 and 2020.

The advice for 2021 given by ACOM in 2020 was 885 600 t based on the agreed harvest control rule. The quota established by JNRFC for 2021 was set equal to the advice. In addition, the TAC for Norwegian Coastal Cod was set to the same value for 2021 as for 2020: 21 000 t.

3.2 Status of research

3.2.1 Fishing effort and CPUE (Table A1, Figure 3.6a–c.)

CPUE series of the Norwegian and Russian trawl fisheries are given in Table A1. The data reflect the total trawl effort (Figure 3.6a), both for Norway and Russia. The Norwegian series is given as a total for all areas. Norwegian data for 2011–2020 are not necessarily compatible with data for 2007 and previous years. Norwegian CPUE has been relatively stable since 2016 (Figure 3.6b), while in 2020 Russian CPUE decreased in areas 1 and 2b but increased in 2a compared to 2019. The trawl CPUE for Norway and Russia in the first part of 2020 were at the same level as in 2019 while in the second half of 2020 they were considerably lower than during the same period in 2019, particular for the Russian fleet, as seen from the monthly values in Figure 3.6c.

3.2.2 Survey results - abundance and size at age (Tables 3.5, A2-A14)

Joint Barents Sea winter survey (bottom trawl and acoustics) Acronyms: BS-NoRu-Q1 (BTr) and BS-NoRu-Q1 (Aco)

The preliminary swept-area estimates and acoustic estimates from the Joint winter survey on demersal fish in the Barents Sea in winter 2021 are given in Tables A2 and A3. More details on this survey are given in WD 02. The total area covered was larger than in 2020 but about the same as in 2019. The coverage was limited by ice particularly in the east and southeast. However, the fish density at the edge of the survey area was generally quite low, so overall the coverage was considered to be good. Note that since the AFWG was conducted, minor errors were discovered in the winter survey for 2021 (both acoustic and bottom trawl). These had minimal (<2%) impact on the assessment of SSB and no impact on the advised catch for NEA cod. This report is not updated to account for correcting these errors.

Before 2000 this survey was made without participation from Russian vessels, while in 2001–2005, 2008–2016 and 2018–2021 Russian vessels have covered important parts of the Russian zone. In 2006–2007 the survey was carried out only by Norwegian vessels. In 2007, 2016 and 2021 the Norwegian vessels were not allowed to cover the Russian EEZ. The method for adjustment for incomplete area coverage in 2007 is described in the 2007 report. The same method was used to adjust the 1997–1998 survey indices in the 2016 revision (Mehl *et al.,* 2016). Table 3.5 shows areas covered in the time-series and the additional areas implied in the method used to adjust for missing coverage in the Russian Economic Zone. In 5 of the 8 adjusted years (including 2021) the adjustments were not based on area ratios, but the "index ratio by age" was used. This means that the index by age for the covered area was scaled by the observed ratio between total index and the index for the same area observed in the years prior to the survey. The adjustments for 2017 were based on average index rations by age for 2014–2016. Adjustments were also made in 2020–2021 using the average index ratios by age for 2018–2019 and 2019–2020, respectively.

Regarding the older part of this time-series it should be noted that the survey prior to 1993 covered a smaller area (Jakobsen *et al.,* 1997), and the number of young cod (particularly 1 and 2 year-old fish) was probably underestimated. Other changes in the survey methodology through time are described by Jakobsen *et al.*(1997), while the surveys for the years 2007–2012 and 2013–2018 are reported in Mehl *et al.* (2013, 2014, 2015, 2016, 2017a). Note that the change from 35 to 22 mm mesh size in the codend in 1994 is not corrected for in the time-series. This mainly affects the age 1 indices.

Updated survey series for bottom trawl and acoustic indices are given in Fall *et al.* (2020 winter survey report).

With the recent expansion of the cod distribution it is likely that in recent years the coverage in the February survey (BS-NoRu-Q1 (BTr) and BS-NoRu-Q1 (Aco)) has been incomplete, in particular for the younger ages. This could cause a bias in the assessment, but the magnitude is unknown. The 2014–2021 surveys covered considerably larger areas than earlier winter surveys, and showed that most age groups of cod (particularly ages 1 and 2) were distributed far outside the standard survey area. The bottom trawl survey estimates including the extended area for 2014–2021 were used in the tuning data separately from the same index before 2014, as decided at WKBARFAR 2021.

Lofoten acoustic survey on spawners Acronym: Lof-Aco-Q1

The estimated abundance indices from the Norwegian acoustic survey off Lofoten and Vesterålen (the main spawning area for this stock) in March/April are given in Table A4. A description of the survey, sampling effort and details of the estimation procedure can be found in Korsbrekke (1997). The survey series for 2010–2020 was revised for the benchmark. The 2021 survey results in biomass terms was 237 thousand tonnes, this is 57% below the 2020 level and the lowest since 2008. The survey was carried out in the usual direction from north to south, while the 2020 survey was carried out in the opposite direction. It was noted that on the inner side of the Lofoten Islands the cod abundance was very low compared to previous years, this is in line with catch reports from fishers this winter.

Russian autumn survey Acronym: RU-BTr-Q4

Abundance estimates from the Russian autumn survey (November-December) are given in Table A9 (acoustic estimates) and Table A10 (bottom trawl estimates). The entire bottom trawl time-series was in 2007 revised backwards to 1982 (Golovanov *et al.*, 2007, WD3), using the same method as in the revision presented in 2006, which went back to 1994. The new swept-area indices reflect Northeast Arctic cod stock dynamics more precisely compared to the previous one - catch per hour trawling. The Russian autumn survey in 2006 was carried out with reduced area coverage. Divisions 2a and 2b were adequately investigated in the survey in contrast to Subarea 1, where the survey covered approximately 40% of the long-term average area coverage. The Subarea 1 survey indices were calculated based on actual covered area (40 541 sq. miles). The 2007 AFWG decided to use the “final" year class indices without any correction because of satisfactory internal correspondence between year class abundances at age 2–9 years according to the 2006 survey and ones due to the previous surveys.

This survey was not conducted in 2016, but was carried out in 2017, when 79% of the standard survey area was covered (Sokolov *et al.*, 2018, WD 11). The index shows a reliable internal consistence and it was decided to use it in the assessment. This survey was not carried out in 2018–2020 and will likely be discontinued.

Joint Ecosystem survey Acronym: Eco-NoRu-Q3 (Btr)

Swept-area bottom trawl estimates from the joint Norwegian-Russian ecosystem survey in August-September for the period 2004–2020 are given in Table A14. This survey normally covers the entire distribution area of cod at that time of the year.

In 2014 this survey had an essential problem with area coverage in the northwest region because of difficult ice conditions. In the area covered by ice in 2014 a substantial part of population was distributed during 2013 survey. So, based on those observations AFWG decided in 2015 to exclude 2014 year from that tuning series in current assessment. In 2016 there was incomplete coverage in the international waters and close to the Murmansk coast. An adjustment for this incomplete coverage was made based on interpolation from adjacent areas (Kovalev *et al.*, 2017, WD 12). At this time of the year, usually a relatively small part of the cod stock is found in the area which was not covered in 2016. In 2017 and 2019 the coverage was close to complete, although the far north-eastern part of the survey area (west of the north island of Novaya Zemlya) was not covered due to military restrictions. In 2018, a large area in the eastern part of the Barents Sea was not covered Thus it was decided not to include 2018 data from this survey in the assessment. The coverage in 2020 was less synoptic than usual, as explained in Section 0.6. As the survey indices from the BESS 2020 showed an unexplainable large decline compared to the 2019 indices, it was considered to exclude 2020 indices from this survey, but it was decided to keep them in and re-evaluate next year whether they should still be included in the assessment.

The survey indices are calculated both the BioFox and StoX calculation methods, and as in earlier years, the Biofox series was used in the tuning. A research recommendation from WKBARFAR was to unify these two methods for estimating indices from ecosystem survey. However, the benchmark decided to use weight at age from the StoX in calculations of weight at age used in the assessment.

Survey results: length and weight-at-age (Tables A5-A8, A11-A12, A15)
Length-at-age is shown in Table A5 for the Norwegian survey in the Barents Sea in winter, in Table A7 for the Lofoten survey and in Table A11 for the Russian survey in October-December. Weight-at-age is shown in Table A6 for the Norwegian survey in the Barents Sea in winter, in Table A8 for the Lofoten survey, Table A12 for the Russian survey in October-December and Table A15 for the BESS survey (calculated using StoX).

The joint winter survey in 2021 showed low values for most age groups, and for ages 4 and 5 the observed values were the lowest observed in the revised time-series going back to 1994. Length and weight at age in the Lofoten survey is stable. The size at age in the BESS survey shows similar trends, but the 2020 values are not as low compared to the time-series average as in the 2021 winter survey. One reason for this could be that the BESS survey in 2020 ended later in autumn than usual. The development of size at age and growth is discussed in an ecological context in section 1.2.

3.2.3 Age reading

The joint Norwegian-Russian work on cod otolith reading has continued, with regular exchanges of otoliths and age readers (see section 1.7). The results of fifteen years of annual comparative age readings are described in Yaragina *et al.* (2009). Zuykova *et al.* (2009) re-read old otoliths and found no significant difference in contemporary and historical age determination and subsequent length-at-age. However, age at first maturation in the historical material as determined by contemporary readers is younger than that determined by historical readers. Taking this difference into account would thus have effect on the spawning stock–recruitment relationship and thus on the biological reference points. The overall percentage agreement for the 2017–2018 exchange was 87.7% (WD 8, AFWG 2020). The main reason for cod ageing discrepancies between Russian and Norwegian specialists remains the same, representing the latest summer growth zone, and different interpretations of the false zones. The general trend is that the Russian readers assign slightly lower ages than the Norwegian readers compared to the modal age for all age groups. This is opposite of what we have seen in previous readings, where the Russian readers has tended to be slightly overestimating the age compared to the Norwegian readers. More details can be found in section 0.7.

The trend with bias in NEA cod age determination registered for some years of the period 1992–2018 between experts of both countries is a solid argument to continue comparative cod age reading between PINRO and IMR to monitor the situation. The German participant has expressed an intention to join the age reading cooperation in future.

3.3 Data used in the assessment

Data for the period 1946–1983 are taken from the AFWG 2001 report (ICES CM 2001/ACFM:19) and were not revised at the WKBARFAR benchmark in 2021.

3.3.1 Catch-at-age (Table 3.6)

For 2020, age compositions from all areas were available from Russia, Norway and Germany (divisions 1 and 2a). Unsampled catches were distributed on age by using data from Russian trawl in Subarea 1 and Division 2a, and by using data from Norwegian trawl in Division 2b. The catch-at-age data were calculated using InterCatch (Table 3.6).

There is still a concern about the biological sampling from parts of the Norwegian fishery that may be too low. Also the split between NEA cod and coastal cod may be affected by the sampling coverage.

Length distributions from the Russian fishery were made by observers on board fishing vessels in reasonably sufficient quantity in all areas. Also, length samples of cod taken by Norwegian Coast Guard on board Russian fishing vessels in Norwegian economic zone (NEZ) in the first and second quarter and in Division 2.b in the fourth quarter of 2020 were used in calculations of length/age distributions. These data were combined with Russian observers' data. An advantage of adding the Norwegian Coast Guard data are that they were taken regularly over the whole NEZ area and Division 2.b. However, biological sampling from the trawl fishery has been relatively low, especially in Division 2a.

Some minor error corrections in historical catch-at-age data (1984–2019) were made since WKBARFAR benchmark in 2021.

3.3.2 Survey indices used in assessment (Table 3.13, A13)

The following survey dataseries were used:

Fleet code	**Name**	**Place**	**Season**	**Age**	**Years**
Fleet 15*	Joint bottom trawl survey	Barents Sea	Feb-Mar	3–12+	1981–2013, 2014–2021
Fleet 16	Joint acoustic survey	Barents Sea+Lofoten	Feb-Mar	3–12+	1985–2021
Fleet 18	Russian bottom trawl surv.	Total area	Oct-Dec	3–12+	1982–2017
Fleet 007	Ecosystem surv.	Total area	Aug-Sep	3–12+	2004–2020

***Survey indices for Fleet 15 were divided by two series (before and after 2014) in model tuning as decided at WKBARFAR 2021.**

The tuning fleet file is shown in Table 3.13. Note that the joint acoustic survey (sum of Barents Sea and Lofoten acoustic survey indices) is given in Table A13.

Survey indices for Fleet 15 have been multiplied by a factor 100, while survey indices for Fleets 007, 16 and 18 have been multiplied by a factor 10. This is done to keep the dynamics of the surveys even for very low indices, because some models (e.g. XSA) adds 1.0 to the indices before the logarithm is taken.

3.3.3 Weight-at-age (Table 3.7–Table 3.9, A2, A4, A6, A8, A12)

Catch weights

For 2020, the mean weight-at-age in the catch (Table 3.8) was obtained from InterCatch as a weighted average of the weight-at-age in the catch for Norway, Russia, and Germany (Table 3.7). The weight-at-age in the catch for all countries is given in Table 3.7. For ages up to and including 11, observations are used. Following the WKBARFAR 2021 decision, weight at age in catch for the years 1983-present for ages 12–15+ are calculated by a cohort-based von Bertalanffy approach used to replace previous fixed values.

Stock weights

For ages 1–11 stock weights-at-age at the start of year y ($W_{a,y}$) for 1983–2021 are calculated combining, when available, weight at age from the wWinter, Lofoten, Russian autumn and ecosystem surveys. Ecosystem survey data were added following the WKBARFAR 2021. The details are given in the stock annex. For ages 12–-15+ a similar approach as for weight at age in the catch was used.

3.3.4 Natural mortality including cannibalism (Table 3.12, Table 3.17)

A natural mortality (M) of 0.2+ cannibalism was used. Cannibalism is assumed to only affect natural mortality of ages 3–6.

The method used for calculation of the prey consumption by cod described by Bogstad and Mehl (1997) is used to calculate the consumption of cod by cod (Table 3.12) for use in cod stock assessment. The consumption is calculated based on cod stomach content data taken from the joint PINRO-IMR stomach content database (methods described in Mehl and Yaragina 1992). On average about 9000 cod stomachs from the Barents Sea have been analysed annually in the period 1984–2020.

These data are used to calculate the per capita consumption of cod by cod for each half-year (by prey age groups 0–6 and predator age groups 1–11+). It was assumed that the mature part of the cod stock is found outside the Barents Sea for three months during the first half of the year. Thus, consumption by cod in the spawning period was omitted from the calculations.

An iterative procedure was applied to include the per capita consumption data in the SAM run. It is described in detail in Stock Annex.

For the cod assessment data from annual sampling of cod stomachs has been used for estimating cannibalism, since the 1995 assessment. The argument has been raised that the uncertainty in such calculations are so large that they introduce too much noise in the assessment. A rather comprehensive analysis of the usefulness of this was presented in Appendix 1 in the 2004 AFWG report. The conclusion was that it improves the assessment.

The data on cod cannibalism for the historical period (1946–1983) was included in assessment during the benchmark to make the time-series consistent (ICES 2015, WKARCT 2015). These estimates (Table 3.17) were based on hindcasted values of NEA cod natural mortality-at-ages 3–5 using PINRO database on food composition from cod stomach for the historical period (Yaragina *et al.,*. 2018).

At this year's meeting the consumption data for period 1994–2020 were slightly changed compare to last year's assessments because of changes in cod weights- and maturities-at-age in stock done during the WKBARFAR in 2021.

3.3.5 Maturity-at-age (Table 3.10–Table 3.11, Table 3.10– Table 3.11)

Historical (pre–1982) Norwegian and Russian time-series on maturity ogives were reconstructed by the 2001 AFWG meeting (ICES CM 2001/ACFM:19). The Norwegian maturity ogives were constructed using the Gulland method for individual cohorts, based on information on age at first spawning from otoliths. For the period 1946–1958 only the Norwegian data were available. The Russian proportions mature-at-age, based on visual examinations of gonads, were available from 1959.

Since 1982 Russian and Norwegian survey data have been used (Table 3.10). For the years 1985–2020, Norwegian maturity-at-age ogives have been obtained by combining the Barents Sea winter survey and the Lofoten survey. Russian maturity ogives from the autumn survey as well as from commercial fishery for November-February are available from 1984 until present. The Norwegian maturity ogives tend to give a higher percent mature-at-age compared to the Russian ogives, which is consistent with the generally higher growth rates observed in cod sampled by the Norwegian surveys. The percent mature-at-age for the Russian and Norwegian surveys have been arithmetically averaged for all years, except 1982–1983 when only Norwegian observations were used and 1984 when only Russian observations were used.

Russian data for the autumn survey for 2018 and later years were not available as the survey was not conducted. In WD 15, 2019, updated correction factors to allow for this when calculating the combined maturity-at-age in 2019 were calculated, based on historical differences between Norwegian and Russian data. These correction factors were then applied to the Norwegian data for 2020–2021.

The approach used for calculating maturity-at-age is the same as previously used and consistent with the approach used to estimate the weight-at-age in the stock, except that no data from the BESS survey are used. However, since survey data, both abundance indices and proportion mature, have been revised, the entire time-series of ogives back to 1994 was revised at the benchmark. The proportions of mature cod for age 13–15 are set to 1 for the period 1984–present.

Maturity-at-age for cod has been variable the last five years, particularly for ages 6–9. According to the combined data, maturity-at-age decreased in 2015–2016, then increased, but decreased again from 2019 to 2021 (Table 3.11).

3.4 Changes of data and assessment model settings at the latest benchmark

As mentioned in Sections 3.2 and 3.3, the survey-based dataseries (indices, weight at age in stock, maturity-at-age) were revised at the WKBARFAR benchmark. Further, age 12+ are now used in the tuning instead of age 12 for all series and age 3 indices are now also included in the assessment also for the bottom trawl and acoustic series form the winter survey (Fleet 15 and 16).

In addition weight at age in catch and in stock for ages 12–15+ were revised.

SAM settings were considerably revised at WKBARFAR.

3.5 Assessment using SAM

3.5.1 SAM settings (Table 3.14)

The SAM model settings optimized by WKBARFAR are shown in Table 3.14.

3.5.2 SAM diagnostics (Figure 3.1 and Figure 3.2 a–c)

Residuals for the SAM run are shown in Figure 3.2a, while retrospective plots of F, SSB and recruitment are shown in Figure 3.2b. Figure 3.2c shows the catchability by survey and age group.

Some high negative residuals in terminal year are observed for Ecosystem survey (Fleet007) for older ages and for some ages in Fleet15 (second part) in SAM.

The retrospective pattern is generally good (Figure 3.2b), but the largest discrepancies are observed for SSB (Mohn's rho 8%), while rho's for R and F are much smaller (2%). One of the possible sources of the observed retro pattern in SSB could be influence of ecosystem survey in 2020. The SAM run without that year included for the ecosystem survey shows a much better retro pattern.

The simulations done for testing model sensitivity to initial values of parameters (Jit analysis) showed the model result to be independent of them.

3.5.3 Results of assessment (Table 3.15– Table 3.18, Table 3.20, Figure 3.1)

Summaries of landings, fishing mortality, stock biomass, spawning-stock biomass and recruitment since 1946 are given in Table 3.18 and Figure 3.1.

The fishing mortalities and population numbers are given in Tables 3.15 and 3.16.

The estimated $F_{5\text{–}10}$ in 2020 is 0.43, which is above F_{pa} (Table 3.18), but equal to what the harvest control rule would have given based on this year's calculation of SSB in 2020. Fishing mortality has been increasing slowly in recent years. The spawning-stock biomass in 2021 is estimated to be 885 kt (Table 3.20), which is high but much lower than the peak in 2013 (2257 kt). One should bear in mind that in the early part of the time-series (before the 1980s) the fraction at age of mature fish was considerably lower.

Total stock biomass in 2021 is estimated to 2092 kt which is close to the long-term mean and well below the highest level observed after 1955 (3740 kt in 2013).

It is noted that the exploitation pattern is still dome-shaped with a marked decrease in selectivity above age 12, although the dome-shape is not as strong than in previous assessments.

M values (M = 0.2+cannibalism mortality) are given in Table 3.17. For ages 3–5 the M matrix in 1946–1983 also includes M2 since the benchmark meeting in 2015 (WKARCT 2015).

3.6 Reference points and harvest control rules

The current reference points for Northeast Arctic cod were estimated by SGBRP (ICES CM 2003/ACFM:11) and adopted by ACFM at the May 2003 meeting.

At the 46th session of JRNFC a new version of the management rule was adopted (see section 3.7.3). The TAC advice for 2022 is based on the agreed harvest control rule.

3.6.1 Biomass reference points

The values adopted by ACFM in 2003 are B_{lim} = 220 000 t, B_{pa} = 460 000 t. (ICES CM 2003/ACFM:11).

3.6.2 Fishing mortality reference points

The values adopted by ACFM in 2003 are $F_{lim} = 0.74$ and $F_{pa} = 0.40$. (ICES CM 2003/ACFM:11). The F_{MSY} for NEA cod was estimated by WKBARFAR 2021 to be in the range 0.40 - 0.60.

3.6.3 Harvest control rule

The history of how the harvest control rule has developed is given in the 2017 AFWG report. JNRFC in 2015 asked ICES to explore the consequences of 10 different harvest control rules. This was done by WKNEAMP (ICES 2015, 2016). JNRFC in 2016 adopted one of the rules explored by WKNEAMP (Rule 6 in that report).

The current rule reads as follows:

> **The TAC is calculated as the average catch predicted for the coming 3 years using the target level of exploitation (F_{tr}).**
>
> **The target level of exploitation is calculated according to the spawning-stock biomass (SSB) in the first year of the forecast as follows:**
>
> **if $SSB < B_{pa}$, then $F_{tr} = SSB / B_{pa} \times F_{MSY}$;**
>
> **if $B_{pa} \leq SSB \leq 2 \times B_{pa}$, then $F_{tr} = F_{MSY}$;**
>
> **if $2 \times B_{pa} < SSB < 3 \times B_{pa}$, then $F_{tr} = F_{MSY} \times (1 + 0.5 \times (SSB - 2 \times B_{pa}) / B_{pa})$;**
>
> **if $SSB \geq 3 \times B_{pa}$, then $F_{tr} = 1.5 \times F_{MSY}$;**
>
> **where $F_{MSY}=0.40$ and $B_{pa}=460\ 000$ tonnes.**
>
> **If the spawning-stock biomass in the present year, the previous year and each of the three years of prediction is above B_{pa}, the TAC should not be changed by more than +/- 20% compared with the previous year's TAC. In this case, F_{tr} should however not be below 0.30.**

3.7 Prediction

3.7.1 Prediction input (Table 3.16, Table 3.19, Figure 3.3–Figure 3.5)

The input data to the short-term prediction with management option table (2021–2024) are given in Table 3.19. For 2021 stock weights and maturity were calculated from surveys as described in Sections 3.3.2 and 3.3.4.

Catch weights in 2021 onwards and stock weights in 2022 and onwards for age 3–11 are predicted by the method described by Brander (2002), where the latest observation of weights by cohort are used together with average annual increments to predict the weight of the cohort the following year. The method is given by the equation:

$$W(a+1,y+1)=W(a,y) + Incr(a), \text{ where } Incr(a) \text{ is a ``medium term'' average of } Incr(a,y)= W(a+1,y+1)-W(a,y) \qquad \text{(eq 1)}$$

This method was introduced in the cod prediction in the 2003 working group. Since 2005 working group an average of the 3 most recent values of annual increments have been used for predicting stock weights. For catch weights the last 5-year period for averaging the increments is used (changed from 10-year period at the benchmark). Figures 3.3 and 3.4 show how these predictions perform back in history.

The maturity ogive for the years 2022–2024 was predicted by using the 2019–2021 average. The exploitation pattern in 2021 and later years was set equal to the previous 5 years according to the benchmark decision and as described at Stock Annex.

The stock number-at-age in 2021 was taken from the final SAM run (Table 3.16) for ages 4 and older. The recruitment-at-age 3 in the years 2021–2024 was estimated as described in section 3.7.2. Figure 3.5 shows the development in natural mortality due to cannibalism for cod (prey) age groups 1–3 together with the abundance of capelin in the period 1984–2020. There was no clear trend in natural mortality, and the average M values for the last 3 years are used to predict natural mortality of age groups 3–6 for years 2021–2024 (based on benchmark decision, WKARCT 2015 and unchanged at WKBARFAR 2021).

The assessment shows a slightly increasing F from 2015 to 2020. In accordance with the benchmark decision (WKARCT 2015, not reviewed at WKBARFAR 2021) and with support from AFWG 2019 WD 11 (Kovalev and Chetyrkin, 2019), the last year's assessment F in terminal year 2020 (*status quo*) is used for F in the intermediate year (2021). Table 3.19 shows input data to the predictions. The results of prediction show that the catch in 2021 predicted using F_{sq} is about 230 kt less than the agreed TAC. As the coastal cod catch in recent years has been about 20 kt higher than the TAC of 21 kt, this means that if the total TAC for Northeast arctic cod and Coastal cod will be taken, the predicted catch using F_{sq} will be about 210 kt or 24% below the TAC. Reported catches so far in 2021 indicate that the TAC is not likely to be taken.

3.7.2 Recruitment prediction (Table 1.9)

At the 2008 AFWG meeting it was decided to use a hybrid model, which is a weighted arithmetic mean of different recruitment models (see section 1). It was agreed to use the same approach this year. The input data for those models are the following time-series; ice coverage, intensity of interaction between the arctic and boreal oceanic systems on the shelf of the Barents Sea, temperature and oxygen saturation at the Kola section. Prognosis from all the models, including the hybrid is presented in Table 1.9. Since 2014 the hybrid model is based on objective weighting of different submodels and includes the RCT3 model (see section 1 for details). The numbers-at-age 3 calculated by the hybrid method were: 561 million for the 2018 year class, 621 million for the 2019 year class, 548 million for the 2020 year class and 386 million for the 2021 year class (Table 1.9).

Although age 3 indices from the winter bottom trawl and acoustic surveys are now also included in the SAM tuning, it was decided at the benchmark to continue using in the predictions recruitment estimates at age 3 in the assessment year (intermediate year in prediction) from the hybrid model. The difference between the SAM estimate and the hybrid model estimate of age 3 in 2021 was small (483 vs. 561 million individuals).

The values used for the 2019 and 2020 year classes in the prediction are higher than the very low survey indices for those year classes at age 1 and 2 indicate. The reason for this should be investigated. It was noted that the age 1–3 survey series used in the hybrid model are not split in 2014 when the survey area was extended, as was done for the bottom trawl indices for age 3 and older used in the SAM assessment.

3.7.3 Prediction results (Table 3.20–Table 3.21)

The catch corresponding to F_{sq} in 2021 is 653.5 kt (Table 3.20). The resulting SSB in 2022 is 852 kt, which is slightly below SSB in 2021. Table 3.20 shows the short-term consequences over a range of F-values in 2022. The detailed outputs corresponding to F_{sq} in 2021 and the F corresponding to the HCR and F_{pa} in 2022 is given in Table 3.21. Summarized results are shown in the text table below.

Since SSB in 2022 is between B_{pa} = 460 000 t and 2 × B_{pa} = 920 000 t, F = 0.40 is used in the 3-year prediction, giving catches of 596 273, 596 141 and 606 946 tonnes in 2022, 2023, and 2024, respectively. The average of this is 599 787 tonnes. According to the HCR the maximum year-to-year decrease in TAC is limited by 20% which corresponds to a TAC of 708 480 tonnes for 2022.

Basis	**Total catch (2022)**	**Ftotal (2022)**	**SSB(2023)**	**% SSB change ***	**% TAC change ****	**% Advice change *****
ICES advice basis						
Management plan^	708 480	0.50	758 177	−11	−20	−20
Other options						
MSY approach: F_{MSY}	596 273	0.40	839 903	−1	−33	−33
F = 0	0	0	1 306 235	53	−100	−100
F = F2020	637 009	0.4340	809 979	−5	−28	−28
F_{pa}	596 273	0.40	839 903	−1	−33	−33
F_{lim}	951 449	0.74	589 364	−31	7	7

Weights in tonnes.

^ 20% decrease from TAC 2021

*** SSB 2023 relative to SSB 2022.**

**** Catch 2022 relative to TAC 2021**

***** Advice for 2022 relative to advice for 2021**

This catch forecast covers all catches. It is then implied that all types of catches are to be counted against this TAC. It also means that if any overfishing is expected to take place, the above calculated TAC should be reduced by the expected amount of overfishing.

3.8 Comparison with last year's assessment and prediction

3.8.1 Comparison to 2020 assessment and 2021 benchmark assessment (Figure 3.8b)

The text tables below compare this year's estimates with the 2020 AFWG estimates and the WKBARFAR 2021 with the AFWG 2020 estimates, for numbers-at-age (millions), total biomass, spawning biomass (thousand tonnes) in 2020, as well as reference F for the year 2019.

							N 2020								TSB	SSB	F
	F(2019)	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+	2020	2020	2020
Assessment																	
AFWG 2020	0.338	583*	460.18	290.83	284.66	111.15	64.75	66.94	29.4	11.276	4.364	2.529	3.595	9.803	2640	1368	0.338**
AFWG 2021	0.408	561	388.17	326.36	188.43	145.28	56.17	30.32	27.55	8.734	2.939	1.133	0.671	2.805	2248	1004	0.434
Ratio	1.21	0.96	0.84	1.12	0.66	1.31	0.87	0.45	0.94	0.77	0.67	0.45	0.19	0.29	0.85	0.73	1.28
AFWG2021/AFWG 2020																	

							N 2020								TSB	SSB	F
	F(2019)	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+	2020	2020	2020
Assessment																	
AFWG 2020	0.338	583*	460.18	290.83	284.66	111.15	64.75	66.94	29.4	11.276	4.364	2.529	3.595	9.803	2640	1368	0.338**
WKBarFar 2021	0.386	692.1	525.88	329.7	286.56	106.5	57.75	57.32	24.38	9.19	4.087	1.867	2.207	5.271	2498	1091	0.385
Ratio	1.14	1.19	1.14	1.13	1.01	0.96	0.89	0.86	0.83	0.82	0.94	0.74	0.61	0.54	0.95	0.80	1.14
WKBARFAR 2021/AFWG 2020																	

***estimated by recruitment models **assuming F_{sq}**

At the WKBARFAR benchmark, the number in 2020 at age 3–5 was adjusted upwards compared to AFWG 2020 for ages 3–5 and downwards for ages 7 and older. Thus SSB was adjusted considerably downwards while immature fish abundance increased slightly. At AFWG 2021, number-at-ages 10 and older was adjusted further downwards. For younger ages, the changes went in both directions, but mostly there was a decrease from the benchmark, with age 7 being the main exception. On the other hand, age 9 in 2020 was adjusted considerably downwards.

3.8.2 Comparison to prediction

The changes in the advice are large compared to last year. The advice for 2022 is 708 480 t, while the advice for 2021 given by ICES was 885 600 tonnes. However, the advice for 2022 is not very different from the advice for 2019 and 2020.

There has been a downwards revision of the assessed stock in 2021 compared with the assessment in 2020. This revision is mainly due to revision in data and model settings made at WKBARFAR 2021, and partly due to an additional year of data. Overall, TSB in 2020 decreased by 392 kt from the AFWG 2020 to the AFWG 2021 assessment, with most of the reduction (364 kt) being in SSB. As this reduction in SSB occurs in the interval between $2*B_{pa}$ and $3*B_{pa}$ (920 and 1380 kt), where the second slope of the two-step HCR is, the reduction in SSB will lead to a larger reduction in TAC advice than the reduction in TSB alone would indicate. The downwards revision in SSB together with the decreasing trend in the stock results in a decrease in the target F to 0.40 compared with last year's 0.597. The average catch predicted for the coming 3 years, using the mentioned target level of exploitation (Ftr) in the HCR resulted in TAC advice equal to 708 480 t. This value corresponds to the −20% limit on year-to-year TAC change stated in the HCR, and is higher than the value without applying such a constraint (604 125 t).

3.9 Concerns with the assessment

The WG realizes that imprecise input data, in particular the catch-at-age matrix, and discontinuation of some surveys as well as incomplete spatial coverage and reduced synopticity in surveys could be a main obstacle to producing precise stock assessments, regardless of which model is used.

All surveys indicate a decreasing stock but this trend is stronger in the BESS than in the other surveys. This increases the uncertainty of assessment.

3.10 Additional assessment methods

All models use the same tuning data. The XSA model, which for many years was the main assessment model and since 2016 has been used as an auxiliary model, is no longer run for Northeast Arctic cod.

3.10.1 TISVPA (Table 3.22–Table 3.24, Figure 3.7a–c)

This year the TISVPA model was applied to NEA cod with the same settings as last year and using the same data as SAM except that natural mortality values from cannibalism were taken from the SAM runs. During AFWG 2021 the results of exploratory runs using the TISVPA model were discussed (WD 18). The residuals of the model approximation of catch-at-age and "fleets" data are presented in Figure 3.7a. Likelihood profiles for different data source are presented in Figure 3.7b. Retrospective run results are shown in Figure 3.7c. The results (Table 3.22–Table 3.24) generally support the results of the SAM model, with a similar SSB estimate but a lower TSB estimate in 2021.

3.10.2 Model comparisons (Figure 3.2a, Figure 3.7a, Figure 3.8a)

Figure 3.8a compares the results of SAM and TISVPA, showing F, SSB, TSB and recruitment. F, TSB and SSB in 2021 is very similar for all models, while recruitment in recent years is lower in TISVPA than in SAM. The residual pattern for the ecosystem survey in TISVPA model have some similarity to SAM model residuals for year 2020 (Figures 3.2a, 3.7a).

3.11 New and revised data sources

This section describes some data sources, which could be revised or included in the assessment in future.

3.11.1 Consistency between NEA cod and coastal cod catch data (Table 3.2)

Consistency between the catch data used for NEA cod and coastal cod should be ensured. The revised catch figures used in the coastal cod assessment do not correspond to the difference between the total cod catch and the catch used in the NEA cod assessment (Table 3.2). These discrepancies will be adjusted when the NEA cod catch series are revised (section 3.2.2).

3.11.2 Discard and bycatch data (Table 3.25–Table 3.26)

Work on updating discard and bycatch dataseries (Table 3.25 and Table 3.26) is ongoing, new data on age groups were not available in time for AFWG 2019. Revised bycatch estimates for the period 2005–2020 are described in section 1.6. At WKARCT in 2015 it was, however, decided not to include those data in the catch-at-age matrix.

Table 3.26 (taken from Ajiad *et al.*, WD2, 2008) presents bycatch in the Norwegian shrimp fishery by cod age (previously this has been given by cod length). The bycatch mainly consists of age 1 and 2 fish, but the bycatch is generally small compared to other reported sources of mortality: catches, discards and the number of cod eaten by cod. From 1992 onwards, bycatches of age 3 and older fish are negligible, because use of sorting grids was made mandatory. However, in 1985, bycatches of age 5 and 6 cod were about one third of the reported catches for those age groups. The year class for which the bycatches were highest, was the 1983 year class (total bycatch of age 2 and older fish of about 60 million, compared to a stock estimate of about 1300 million at age 3.

Table 3.1. Northeast Arctic cod. Total catch (t) by fishing areas and unreported catch.

Year	Subarea 1	Division 2.a	Division 2.b	Unreported catches	Total catch
1961	409 694	153 019	220 508		783 221
1962	548 621	139 848	220 797		909 266
1963	547 469	117 100	111 768		776 337
1964	206 883	104 698	126 114		437 695
1965	241 489	100 011	103 430		444 983
1966	292 253	134 805	56 653		483 711
1967	322 798	128 747	121 060		572 605
1968	642 452	162 472	269 254		1 074 084
1969	679 373	255 599	262 254		1 197 226
1970	603 855	243 835	85 556		933 246
1971	312 505	319 623	56 920		689 048
1972	197 015	335 257	32 982		565 254
1973	492 716	211 762	88 207		792 685
1974	723 489	124 214	254 730		1 102 433
1975	561 701	120 276	147 400		829 377
1976	526 685	237 245	103 533		867 463
1977	538 231	257 073	109 997		905 301
1978	418 265	263 157	17 293		698 715
1979	195 166	235 449	9 923		440 538
1980	168 671	199 313	12 450		380 434
1981	137 033	245 167	16 837		399 037
1982	96 576	236 125	31 029		363 730
1983	64 803	200 279	24 910		289 992
1984	54 317	197 573	25 761		277 651
1985	112 605	173 559	21 756		307 920
1986	157 631	202 688	69 794		430 113
1987	146 106	245 387	131 578		523 071
1988	166 649	209 930	58 360		434 939
1989	164 512	149 360	18 609		332 481

Year	Subarea 1	Division 2.a	Division 2.b	Unreported catches	Total catch
1990	62 272	99 465	25 263	25 000	212 000
1991	70 970	156 966	41 222	50 000	319 158
1992	124 219	172 532	86 483	130 000	513 234
1993	195 771	269 383	66 457	50 000	581 611
1994	353 425	306 417	86 244	25 000	771 086
1995	251 448	317 585	170 966		739 999
1996	278 364	297 237	156 627		732 228
1997	273 376	326 689	162 338		762 403
1998	250 815	257 398	84 411		592 624
1999	159 021	216 898	108 991		484 910
2000	137 197	204 167	73 506		414 870
2001	142 628	185 890	97 953		426 471
2002	184 789	189 013	71 242	90 000	535 045
2003	163 109	222 052	51 829	115 000	551 990
2004	177 888	219 261	92 296	117 000	606 445
2005	159 573	194 644	121 059	166 000	641 276
2006	159 851	204 603	104 743	67 100	537 642
2007	152 522	195 383	97 891	41 087	486 883
2008	144 905	203 244	101 022	15 000	464 171
2009	161 602	207 205	154 623		523 431
2010	183 988	271 337	154 657		609 983
2011	198 333	328 598	192 898		719 829
2012	247 938	331087	148 638		727 663
2013	360 673	421678	183 858		966 209
2014	320 347	468 934	197 168		986 449
2015	272 405	375 328	216 651		864 384
2016	321 347	351 468	176 607		849 422
2017	309 902	360 477	197 898		868 276
2018	249 397	321 548	207 681		778 627

Year	Subarea 1	Division 2.a	Division 2.b	Unreported catches	Total catch
2019	234 985	318 539	139 084		692 609
2020[1]	234 029	298 707	160 166		692 903

Data provided by Working Group members.

1 - Provisional figure

Table 3.2. Catches of Norwegian Coastal Cod in subareas 1 and 2, 10^3 tonnes, which are removed from the NEA cod assessment.

Year	Norwegian catches of cod removed from the NEACcod-assessment
v1960–70	38.6
1971–79	no data
1980	40
1981	49
1982	42
1983	38
1984	33
1985	28
1986	26
1987	31
1988	22
1989	17
1990	24
1991	25
1992	35
1993	44
1994	48
1995	39
1996	32
1997	36
1998	29
1999	23
2000	19

Year	Norwegian catches of cod removed from the NEACcod-assessment
2001	14
2002	20
2003	19
2004	14
2005	13
2006	15
2007	13
2008	13
2009	15
2010	13.5
2011	18.8
2012	35.5
2013	30.1
2014	33.6
2015	35.8
2016	54.9
2017	51.0
2018	36.3
2019	40.1
2020	45.3

Table 3.3. Northeast Arctic COD. Total nominal catch ('000 t) by trawl and other gear for each.

	Subarea 1		**Division 2.a**		**Division 2.b**	
Year	Trawl	Others	Trawl	Others	Trawl	Others
1967	238	84.8	38.7	90	121.1	-
1968	588.1	54.4	44.2	118.3	269.2	-
1969	633.5	45.9	119.7	135.9	262.3	-
1970	524.5	79.4	90.5	153.3	85.6	-
1971	253.1	59.4	74.5	245.1	56.9	-
1972	158.1	38.9	49.9	285.4	33	-

	Subarea 1		Division 2.a		Division 2.b	
Year	Trawl	Others	Trawl	Others	Trawl	Others
1973	459	33.7	39.4	172.4	88.2	-
1974	677	46.5	41	83.2	254.7	-
1975	526.3	35.4	33.7	86.6	147.4	-
1976	466.5	60.2	112.3	124.9	103.5	-
1977	471.5	66.7	100.9	156.2	110	-
1978	360.4	57.9	117	146.2	17.3	-
1979	161.5	33.7	114.9	120.5	8.1	-
1980	133.3	35.4	83.7	115.6	12.5	-
1981	91.5	45.1	77.2	167.9	17.2	-
1982	44.8	51.8	65.1	171	21	-
1983	36.6	28.2	56.6	143.7	24.9	-
1984	24.5	29.8	46.9	150.7	25.6	-
1985	72.4	40.2	60.7	112.8	21.5	-
1986	109.5	48.1	116.3	86.4	69.8	-
1987	126.3	19.8	167.9	77.5	129.9	1.7
1988	149.1	17.6	122	88	58.2	0.2
1989	144.4	19.5	68.9	81.2	19.1	0.1
1990	51.4	10.9	47.4	52.1	24.5	0.8
1991	58.9	12.1	73	84	40	1.2
1992	103.7	20.5	79.7	92.8	85.6	0.9
1993	165.1	30.7	155.5	113.9	66.3	0.2
1994	312.1	41.3	165.8	140.6	84.3	1.9
1995	218.1	33.3	174.3	143.3	160.3	10.7
1996	248.9	32.7	137.1	159	147.7	6.8
1997	235.6	37.7	150.5	176.2	154.7	7.6
1998	219.8	31	127	130.4	82.7	1.7
1999	133.3	25.7	101.9	115	107.2	1.8
2000	111.7	25.5	105.4	98.8	72.2	1.3

	Subarea 1		**Division 2.a**		**Division 2.b**	
Year	Trawl	Others	Trawl	Others	Trawl	Others
2001	119.1	23.5	83.1	102.8	95.4	2.5
2002	147.4	37.4	83.4	105.6	69.9	1.3
2003	146	17.1	107.8	114.2	50.1	1.8
2004	154.4	23.5	100.3	118.9	88.8	3.5
2005	132.4	27.2	87	107.7	115.4	5.6
2006	141.8	18.1	91.2	113.4	100.1	4.6
2007	129.6	22.9	84.8	110.6	91.6	6.3
2008	123.8	21.1	94.8	108.4	95.3	5.7
2009	130.1	31.5	102	105.2	142.1	11.4
2010	151.1	32.9	130	141.4	149.2	5.4
2011	158.1	38.4	163.5	167	181	11.9
2012	212.1	35.9	172.7	158.4	133.8	14.9
2013	308.5	52.2	216.9	204.7	159.7	24.1
2014	268.8	51.5	246.8	222.1	177.9	19.3
2015	224.3	48.1	192.2	183.2	197.7	19.0
2016	285.5	35.8	181.7	169.8	156.3	20.3
2017	265.4	44.5	189.5	171.0	180.0	17.9
2018	204.7	44.7	156.7	164.9	192.0	15.6
2019	199.4	35.6	177.8	140.7	128.9	10.1
2020 [1]	199.4	34.6	157.2	141.5	153.5	6.7

Data provided by Working Group members

1 Provisional figures

Table 3.4. Northeast Arctic COD. Nominal catch(t) by countries. (Subarea 1 and divisions 2a and 2b combined, data provided by Working group members.

Year	Faroe Islands	France	German Dem.Rep.	Fed.Rep. Germany	Norway	Poland	United Kingdom	Russia[2]		Others	Total all countries
1961	3 934	13 755	3 921	8 129	268 377	-	158 113	325 780		1 212	783 221
1962	3 109	20 482	1 532	6 503	225 615	-	175 020	476 760		245	909 266
1963	-	18 318	129	4 223	205 056	108	129 779	417 964		-	775 577
1964	-	8 634	297	3 202	149 878	-	94 549	180 550		585	437 695
1965	-	526	91	3 670	197 085	-	89 962	152 780		816	444 930
1966	-	2 967	228	4 284	203 792	-	103 012	169 300		121	483 704
1967	-	664	45	3 632	218 910	-	87 008	262 340		6	572 605
1968	-	-	225	1 073	255 611	-	140 387	676 758		-	1 074 084
1969	29 374	-	5 907	5 543	305 241	7 856	231 066	612 215		133	1 197 226
1970	26 265	44 245	12 413	9 451	377 606	5 153	181 481	276 632		-	933 246
1971	5 877	34 772	4 998	9 726	407 044	1 512	80 102	144 802		215	689 048
1972	1 393	8 915	1 300	3 405	394 181	892	58 382	96 653		166	565 287
1973	1 916	17 028	4 684	16 751	285 184	843	78 808	387 196		276	792 686
1974	5 717	46 028	4 860	78 507	287 276	9 898	90 894	540 801		38 453	1 102 434
1975	11 309	28 734	9 981	30 037	277 099	7 435	101 843	343 580		19 368	829 377
1976	11 511	20 941	8 946	24 369	344 502	6 986	89 061	343 057		18 090	867 463
1977	9 167	15 414	3 463	12 763	388 982	1 084	86 781	369 876		17 771	905 301
1978	9 092	9 394	3 029	5 434	363 088	566	35 449	267 138		5 525	698 715
1979	6 320	3 046	547	2 513	294 821	15	17 991	105 846		9 439	440 538
1980	9 981	1 705	233	1 921	232 242	3	10 366	115 194		8 789	380 434
						Spain					
1981	12 825	3 106	298	2 228	277 818	14 500	5 262	83 000		-	399 037
1982	11 998	761	302	1 717	287 525	14 515	6 601	40 311		-	363 730
1983	11 106	126	473	1 243	234 000	14 229	5 840	22 975		-	289 992
1984	10 674	11	686	1 010	230 743	8 608	3 663	22 256		-	277 651
1985	13 418	23	1 019	4 395	211 065	7 846	3 335	62 489		4 330	307 920
1986	18 667	591	1 543	10 092	232 096	5 497	7 581	150 541		3 505	430 113
1987	15 036	1	986	7 035	268 004	16 223	10 957	202 314		2 515	523 071
1988	15 329	2 551	605	2 803	223 412	10 905	8 107	169 365		1 862	434 939
1989	15 625	3 231	326	3 291	158 684	7 802	7 056	134 593		1 273	332 481
1990	9 584	592	169	1 437	88 737	7 950	3 412	74 609		510	187 000
1991	8 981	975	**Greenland**	2 613	126 226	3 677	3 981	119 427 [3]		3 278	269 158
1992	11 663	2	3 337	3 911	168 460	6 217	6 120	182 315	**Iceland**	1 209	383 234
1993	17 435	3 572	5 389	5 887	221 051	8 800	11 336	244 860	9 374	3 907	531 611
1994	22 826	1 962	6 882	8 283	318 395	14 929	15 579	291 925	36 737	28 568	746 086
1995	22 262	4 912	7 462	7 428	319 987	15 505	16 329	296 158	34 214	15 742	739 999
1996	17 758	5 352	6 529	8 326	319 158	15 871	16 061	305 317	23 005	14 851	732 228
1997	20 076	5 353	6 426	6 680	357 825	17 130	18 066	313 344	4 200	13 303	762 403
1998	14 290	1 197	6 388	3 841	284 647	14 212	14 294	244 115	1 423	8 217	592 624
1999	13 700	2 137	4 093	3 019	223 390	8 994	11 315	210 379	1 985	5 898	484 910
2000	13 350	2 621	5 787	3 513	192 860	8 695	9 165	166 202	7 562	5 115	414 870
2001	12 500	2 681	5 727	4 524	188 431	9 196	8 698	183 572	5 917	5 225	426 471
2002	15 693	2 934	6 419	4 517	202 559	8 414	8 977	184 072	5 975	5 484	445 045
2003	19 427	2 921	7 026	4 732	191 977	7 924	8 711	182 160	5 963	6 149	436 990
2004	19 226	3 621	8 196	6 187	212 117	11 285	14 004	201 525	7 201	6 082	489 445
2005	16 273	3 491	8 135	5 848	207 825	9 349	10 744	200 077	5 874	7 660	475 276
2006	16 327	4 376	8 164	3 837	201 987	9 219	10 594	203 782	5 972	6 271	470 527
2007	14 788	3 190	5951	4619	199 809	9 496	9298	186 229	7316	5 101	445 796
2008	15 812	3 149	5 617	4 955	196 598	9 658	8 287	190 225	7 535	7 336	449 171
2009	16 905	3 908	4 977	8 585	224 298	12 013	8 632	229 291	7 380	7 442	523 431
2010	15 977	4 499	6 584	8 442	264 701	12 657	9 091	267 547	11 299	9 185	609 983
2011	13 429	1 173	7 155	4 621	331 535	13 291	8 210	310 326	12 734	17 354 [4]	719 829
2012 [5]	17523	2841	8520	8 500	315 739	12814	11166	329 943	9536	11 081	727 663
2013	13833	7858	7885	8 010	438 734	15042	12536	432 314	14734	15 263	966 209
2014	33298	8149	10864	6 225	431 846	16378	14762	433 479	18205	13 243	986 449
2015	26568	7480	7055	6 427	377 983	19905	11778	381 188	16120	9 880	864 384
2016	24084	7946	8607	6 336	348 949	14640	13583	394 107	16031	15 139	849 422
2017	28637	9554	13638	5 977	357 419	14414	16731	396 180	11925	13 802	868 276
2018	26152	6605	12743	9 768	333 539	13143	11533	340 364	10708	14 071	778 627
2019	22270	6371	7553	8 470	282 120	13939	11214	316 813	12294	11 565	692 609
2020 [1]	21679	5796	7391	9 725	289 472	11403	12113	312 683	9734	12 908	692 903

[1] Provisional figures.

[2] USSR prior to 1991.

[3] Includes Baltic countries.

[4] Includes unspecified EU catches.

[5] Revised figures.

Table 3.5. Barents Sea winter survey. Area covered ('000 square nautical miles) and areas implied in the method used to adjust for missing coverage in Russian Economic Zone. In 4 of the 5 adjusted years the adjustments were not based on area ratios, but the "index ratio by age" was used. This means that the index by age (for the area outside REZ) was scaled by the observed ratio between total index and the index outside REZ observed in the years prior to the survey.

Year	Area covered	Additional area implied in adjustment	Adjustment method
1981–1992	88.1		
1993	137.6		
1994	161.1		
1995	191.9		
1996	166.1		
1997	88.4	56.2	Index ratio by age
1998	100.4	51.1	Index ratio by age
1999	118.5		
2000	163.2		
2001	164.7		
2002	157.4		
2003	147.4		
2004	164.4		
2005	179.9		
2006	170.1	18.1	Partly covered strata raised to full strata area
2007	123.9	56.7	Index ratio by age
2008	165.2		
2009	171.8		
2010	160.5		
2011	174.3		
2012	151.3	16.7	Index ratio by age
2013	203.6		
2014	266.8		
2015	243.3		
2016	228.0		
2017	184.4	37.5	Index ratio by age
2018	236.3		

Year	Area covered	Additional area implied in adjustment	Adjustment method
2019	241.2		
2020	203.2	25.1	Index ratio by age
2021	242.9	10.9	Index ratio by age

Table 3.6. Northeast Arctic cod. Catch numbers-at-age (Thous)

`SAM Sat Apr 17 21:10:24 2021`

Year age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTALNUM
1946	4008	10387	18906	16596	13843	15370	59845	22618	10093	9573	5460	1927	750	189376
1947	710	13192	43890	52017	45501	13075	19718	47678	31392	9348	9330	4622	4103	294576
1948	140	3872	31054	55983	77375	21482	15237	9815	30041	7945	4491	3899	4205	265539
1949	991	6808	35214	100497	83283	29727	13207	5606	8617	13154	3657	1895	2167	304823
1950	1281	10954	29045	45233	62579	30037	19481	9172	6019	4133	6750	1662	1450	227796
1951	24687	77924	64013	46867	37535	33673	23510	10589	4221	1288	1002	3322	611	329242
1952	24099	120704	113203	73827	49389	20562	24367	15651	8327	3565	647	467	1044	455852
1953	47413	107659	112040	55500	22742	16863	10559	10553	5637	1752	468	173	156	391515
1954	11473	155171	146395	100751	40635	10713	11791	8557	6751	2370	896	268	123	495894
1955	3902	37652	201834	161336	84031	30451	13713	9481	4140	2406	867	355	128	550296
1956	10614	24172	129803	250472	86784	51091	14987	7465	3952	1655	1292	448	166	582901
1957	17321	33931	27182	70702	87033	39213	17747	6219	3232	1220	347	299	173	304619
1958	31219	133576	71051	40737	38380	35786	13338	10475	3289	1070	252	40	141	379354
1959	32308	77942	148285	53480	18498	17735	23118	9483	3748	997	254	161	98	386107
1960	37882	97865	64222	67425	23117	8429	7240	11675	4504	1843	354	102	226	324884
1961	45478	132655	123458	51167	38740	17376	5791	6778	5560	1682	910	280	108	429983
1962	42416	170566	167241	89460	28297	21996	7956	2728	2603	1647	392	280	103	535685

Year age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTALNUM
1963	13196	106984	205549	95498	35518	16221	11894	3884	1021	1025	498	129	157	491574
1964	5298	45912	97950	58575	19642	9162	6196	3553	783	172	387	264	131	248025
1965	15725	25999	78299	68511	25444	8438	3569	1467	1161	131	61	79	197	229081
1966	55937	55644	34676	42539	37169	18500	5077	1495	380	403	77	9	70	251976
1967	34467	160048	69235	22061	26295	25139	11323	2329	687	316	225	40	14	352179
1968	3709	174585	267961	107051	26701	16399	11597	3657	657	122	124	70	46	612679
1969	2307	24545	238511	181239	79363	26989	13463	5092	1913	414	121	23	46	574026
1970	7164	10792	25813	137829	96420	31920	8933	3249	1232	260	106	39	35	323792
1971	7754	13739	11831	9527	59290	52003	12093	2434	762	418	149	42	25	170067
1972	35536	45431	26832	12089	7918	34885	22315	4572	1215	353	315	121	40	191622
1973	294262	131493	61000	20569	7248	8328	19130	4499	677	195	81	59	55	547596
1974	91855	437377	203772	47006	12630	4370	2523	5607	2127	322	151	83	62	807885
1975	45282	59798	226646	118567	29522	9353	2617	1555	1928	575	231	15	37	496126
1976	85337	114341	79993	118236	47872	13962	4051	936	558	442	139	26	53	465946
1977	39594	168609	136335	52925	61821	23338	5659	1521	610	271	122	92	54	490951
1978	78822	45400	88495	56823	25407	31821	9408	1227	913	446	748	48	51	339609
1979	8600	77484	43677	31943	16815	8274	10974	1785	427	103	59	38	45	200224
1980	3911	17086	81986	40061	17664	7442	3508	3196	678	79	24	26	8	175669

Year age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTALNUM
1981	3407	9466	20803	63433	21788	9933	4267	1311	882	109	37	3	NA	135439
1982	8948	20933	19345	28084	42496	8395	2878	708	271	260	27	5	5	132355
1983	3108	19594	20473	17656	17004	18329	2545	646	229	74	58	20	5	99741
1984	6942	14240	18807	20086	15145	8287	5988	783	232	153	49	12	8	90732
1985	24634	45769	27806	19418	11369	3747	1557	768	137	36	31	32	8	135312
1986	28968	70993	78672	25215	11711	4063	976	726	557	136	28	34	14	222093
1987	13648	137106	98210	61407	13707	3866	910	455	187	227	21	59	20	329823
1988	9828	22774	135347	54379	21015	3304	1236	519	106	69	43	14	5	248639
1989	5085	17313	32165	81756	27854	5501	827	290	41	13	NA	11	16	170872
1990	1911	7551	12999	17827	30007	6810	828	179	59	15	6	5	2	78199
1991	4963	10933	16467	20342	19479	25193	3888	428	48	12	NA	NA	2	101755
1992	21835	36015	27494	23392	18351	13541	18321	2529	264	82	3	9	NA	161836
1993	10094	46182	63578	33623	14866	9449	6571	12593	1749	377	63	22	NA	199167
1994	6531	59444	102548	59766	32504	10019	6163	3671	7528	995	121	19	4	289313
1995	4879	42587	115329	98485	32036	7334	3014	1725	1174	1920	222	41	NA	308746
1996	7655	28782	80711	100509	54590	10545	2023	930	462	230	809	84	NA	287330
1997	12827	36491	69633	83017	65768	28392	4651	1151	373	213	144	238	NA	302898
1998	31887	88874	48972	40493	34513	26354	6583	965	197	69	42	22	53	279024

Year age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**+gp**	**TOTALNUM**
1999	7501	77714	92816	31139	15778	15851	8828	1837	195	40	34	8	30	251771
2000	4701	33094	93044	47210	12671	6677	4787	1647	321	71	11	NA	14	204248
2001	5044	35019	62139	62456	22794	5266	1773	1163	343	85	6	7	22	196117
2002	2348	31033	76175	67656	42122	11527	1801	529	223	120	21	9	6	233570
2003	7263	20885	64447	71109	36706	14002	2887	492	142	97	21	43	NA	218094
2004	2090	38226	50826	68350	50838	18118	6239	1746	295	127	39	16	8	236918
2005	5815	19768	113144	61665	44777	20553	6285	2348	562	100	21	24	7	275069
2006	8548	47207	33625	78150	31770	15667	7245	1788	737	210	26	45	155	225173
2007	25473	43817	62877	26303	34392	11240	4080	1381	505	285	44	13	35	210445
2008	8459	51704	40656	35072	14037	20676	5503	1794	715	229	42	26	13	178926
2009	4866	38711	83998	46639	20789	8417	8920	1957	872	987	76	21	20	216273
2010	1778	16193	53855	75853	36797	17062	4784	4325	3034	913	189	49	35	214867
2011	1418	8033	32472	70938	73875	21116	11708	5058	3237	600	434	12	0	228901
2012	2695	10462	16646	40372	70014	48315	12326	5214	1926	1124	317	70	24	209505
2013	2903	13659	22752	21020	54231	74451	47124	9143	2963	694	449	89	145	249623
2014	5234	19226	38407	36633	29901	56109	47540	22738	3717	1169	313	210	157	261354
2015	4315	31383	41181	51209	33745	22530	23609	24553	16071	2510	468	134	254	251962
2016	2076	11291	50231	43609	35265	23417	14592	20105	15862	4781	871	249	308	222657

Year age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTALNUM
2017	6535	13128	28365	66504	46136	28507	15307	10073	12169	6465	1927	399	285	235800
2018	6120	28569	27128	33816	54328	28323	16208	9722	7132	3740	2295	840	271	218492
2019	4389	21405	48422	29849	26548	39759	17395	8883	4606	2109	715	564	322	204966
2020	3992	22446	37649	52454	31009	20904	23618	11768	6130	1572	591	310	278	212721

Table 3.7. Northeast Arctic cod. Weights-at-age (kg) in landings from various countries.

Norway														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1983	0.41	0.82	1.32	2.05	2.82	3.94	5.53	7.70	9.17	11.46	16.59	16.42	16.96	24.46
1984	1.16	1.47	1.97	2.53	3.13	3.82	4.81	5.95	7.19	7.86	8.46	7.99	9.78	10.64
1985	0.34	0.99	1.43	2.14	3.27	4.68	6.05	7.73	9.86	11.87	14.16	14.17	13.52	15.33
1986	0.30	0.67	1.34	2.04	3.14	4.60	5.78	6.70	7.52	9.74	10.68	12.86	9.59	16.31
1987	0.24	0.48	0.88	1.66	2.72	4.35	6.21	8.78	9.78	12.50	13.75	15.12	10.43	19.95
1988	0.36	0.56	0.83	1.31	2.34	3.84	6.50	8.76	9.97	11.06	14.43	19.02	12.89	10.16
1989	0.53	0.75	0.90	1.17	1.95	3.20	4.88	7.82	9.40	11.52	11.47		19.47	14.68
1990	0.40	0.81	1.22	1.59	2.14	3.29	4.99	7.83	10.54	14.21	17.63	7.97	14.64	
1991	0.63	1.37	1.77	2.31	3.01	3.68	4.63	6.06	8.98	12.89	17.00		14.17	16.63
1992	0.41	1.10	1.79	2.45	3.22	4.33	5.27	6.21	8.10	10.51	11.59		15.81	6.52
1993	0.30	0.83	1.70	2.41	3.35	4.27	5.45	6.28	7.10	7.82	10.10	16.03	19.51	17.68
1994	0.30	0.82	1.37	2.23	3.35	4.27	5.56	6.86	7.45	7.98	9.53	12.16	11.45	19.79
1995	0.44	0.78	1.26	1.87	2.80	4.12	5.15	5.96	7.90	8.67	9.20	11.53	17.77	21.11
1996	0.29	0.90	1.15	1.67	2.58	4.08	6.04	6.62	7.96	9.36	10.55	11.41	9.51	24.24
1997	0.35	0.78	1.14	1.56	2.25	3.48	5.35	7.38	7.55	8.30	11.15	8.64	12.80	
1998	0.38	0.68	1.03	1.64	2.23	3.24	4.85	6.88	9.18	9.84	15.78	14.37	13.77	15.58
1999	0.46	0.88	1.16	1.65	2.40	3.12	4.26	6.00	6.52	10.64	14.05	12.67	9.20	17.22
2000	0.31	0.65	1.23	1.80	2.54	3.58	4.49	5.71	7.54	7.86	12.71	14.71	15.40	20.26
2001	0.30	0.77	1.18	1.83	2.75	3.64	4.88	5.93	7.43	8.90	10.22	11.11	13.03	18.85
2002	0.31	0.90	1.40	1.90	2.60	3.55	4.60	5.80	7.40	9.56	8.71	12.92	8.42	17.61
2003	0.55	0.88	1.39	2.01	2.63	3.59	4.83	5.57	7.26	9.36	9.52	9.52	10.68	21.66
2004	0.54	1.08	1.41	1.95	2.69	3.46	4.77	6.72	7.90	8.66	12.21	14.02	16.50	11.37
2005	0.58	0.92	1.38	1.86	2.61	3.54	4.57	6.41	8.24	9.89	11.04	14.08	11.81	20.08
2006	0.51	0.97	1.45	2.06	2.71	3.56	4.57	5.53	6.61	7.53	8.55	8.44	9.82	12.31
2007	0.53	1.07	1.70	2.37	3.26	4.36	5.45	6.71	8.08	8.56	9.75	11.72	12.72	15.58
2008	0.65	1.12	1.70	2.44	3.32	4.41	5.61	6.84	8.25	9.31	10.54	12.45	13.59	21.15

Norway														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
2009	0.56	0.98	1.47	2.10	2.83	3.90	5.06	5.76	7.31	7.79	7.81	10.68	11.83	14.76
2010	0.55	0.95	1.46	2.06	2.93	4.02	5.40	6.44	7.19	8.43	9.11	10.46	11.39	15.55
2011	0.53	1.09	1.50	2.06	2.85	3.70	5.01	6.26	7.33	8.34	9.87	13.23		
2012		0.83	1.32	1.92	2.65	3.52	4.71	6.34	8.11	9.92	11.31	13.45	15.75	
2013	0.43	0.95	1.40	2.00	2.64	3.44	4.51	5.67	7.29	8.80	10.33	11.38	12.56	
2014	0.59	1.07	1.55	2.15	2.80	3.70	4.57	5.78	6.97	8.35	9.46	10.99	12.28	15.49
2015	0.64	0.96	1.42	1.96	2.57	3.30	4.13	5.49	6.46	7.18	8.63	10.37	12.24	14.60
2016	0.59	0.96	1.46	1.99	2.71	3.57	4.56	5.78	6.82	8.08	9.33	10.01	11.68	14.79
2017	0.55	0.99	1.53	2.06	2.69	3.64	4.72	5.91	6.91	7.88	9.41	10.93	11.78	15.07
2018	0.62	1.05	1.51	2.11	2.80	3.48	4.54	5.80	6.97	7.64	9.11	10.29	11.35	14.05
2019	0.51	0.96	1.43	2.02	2.72	3.60	4.51	5.80	6.91	7.94	8.89	10.94	11.55	14.49
2020	0.58	0.94	1.42	2.01	2.66	3.50	4.59	5.77	7.03	8.46	9.78	10.97	12.74	16.08

Russia (trawl only)														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1983	0.65	1.05	1.58	2.31	3.39	4.87	6.86	8.72	10.40	12.07	14.43			
1984	0.53	0.88	1.45	2.22	3.21	4.73	6.05	8.43	10.34	12.61	14.95			
1985	0.33	0.77	1.31	1.84	2.96	4.17	5.94	6.38	8.58	10.28				
1986	0.29	0.61	1.14	1.75	2.45	4.17	6.18	8.04	9.48	11.33	12.35	14.13		
1987	0.24	0.52	0.88	1.42	2.07	2.96	5.07	7.56	8.93	10.80	13.05	18.16		
1988	0.27	0.49	0.88	1.32	2.06	3.02	4.40	6.91	9.15	11.65	12.53	14.68		
1989	0.50	0.73	1.00	1.39	1.88	2.67	4.06	6.09	7.76	9.88				
1990	0.45	0.83	1.21	1.70	2.27	3.16	4.35	6.25	8.73	10.85	13.52			
1991	0.36	0.64	1.05	2.03	2.85	3.77	4.92	6.13	8.36	10.44	15.84	19.33		
1992	0.55	1.20	1.44	2.07	3.04	4.24	5.14	5.97	7.25	9.28	11.36			
1993	0.48	0.78	1.39	2.06	2.62	4.07	5.72	6.79	7.59	11.26	14.79	17.71		
1994	0.41	0.81	1.24	1.80	2.55	2.88	4.96	6.91	8.12	10.28	12.42	16.93		

Russia (trawl only)														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1995	0.37	0.77	1.21	1.74	2.37	3.40	4.71	6.73	8.47	9.58	12.03	16.99		
1996	0.30	0.64	1.09	1.60	2.37	3.42	5.30	7.86	8.86	10.87	11.80			
1997	0.30	0.57	1.00	1.52	2.18	3.30	4.94	7.15	10.08	11.87	13.54			
1998	0.33	0.68	1.06	1.60	2.34	3.39	5.03	6.89	10.76	12.39	13.61	14.72		
1999	0.24	0.58	0.98	1.41	2.17	3.26	4.42	5.70	7.27	10.24	14.12			
2000	0.18	0.48	0.85	1.44	2.16	3.12	4.44	5.79	7.49	9.66	10.36			
2001	0.12	0.31	0.62	1.00	1.53	2.30	3.31	4.57	6.55	8.11	9.52	11.99		
2002	0.20	0.60	1.05	1.46	2.14	3.27	4.47	6.23	8.37	10.06	12.37			
2003	0.23	0.63	1.06	1.78	2.40	3.41	4.86	6.28	7.55	11.10	13.41	12.12	14.51	
2004	0.30	0.57	1.09	1.55	2.37	3.20	4.73	6.92	8.41	9.77	11.08			
2005	0.33	0.65	0.98	1.50	2.10	3.08	4.31	5.81	8.42	10.37	13.56	14.13		
2006	0.27	0.68	1.05	1.49	2.25	3.16	4.54	5.90	8.59	10.31	12.31			
2007	0.23	0.67	1.12	1.66	2.25	3.31	4.57	6.27	8.20	10.02	12.36	12.42		
2008	0.28	0.64	1.16	1.74	2.65	3.58	4.74	5.73	7.32	8.07	9.52	12.52		
2009	0.31	0.64	1.09	1.58	2.11	3.19	4.80	6.58	7.97	9.84	11.51			
2010	0.25	0.57	1.00	1.64	2.28	3.14	4.53	5.98	8.03	9.71	10.70	13.53		
2011	0.25	0.62	1.05	1.56	2.18	2.95	4.33	6.21	8.04	10.13	12.25	15.18		
2012	0.29	0.60	1.07	1.66	2.25	2.95	4.17	6.23	8.58	11.08	12.24	14.07	15.22	16.39
2013	0.33	0.63	1.05	1.54	2.26	3.09	4.08	5.47	7.37	9.59	12.57	15.54	17.05	
2014	0.32	0.61	1.05	1.61	2.26	3.15	4.00	5.24	7.13	9.46	11.18	14.47		
2015	0.30	0.60	0.97	1.49	2.11	3.13	4.64	5.78	7.13	9.53	12.12	16.71	17.37	
2016	0.26	0.55	0.97	1.53	2.20	3.19	4.50	6.12	7.97	9.55	10.95	14.35	14.74	17.25
2017	0.33	0.63	1.03	1.56	2.24	3.24	4.67	6.34	7.74	9.40	11.12	14.43	16.67	11.91
2018	0.33	0.68	1.06	1.62	2.40	3.22	4.66	6.23	7.79	8.91	10.26	11.26	13.41	10.14
2019	0.29	0.62	1.10	1.60	2.33	3.22	4.44	6.45	8.10	9.60	11.02	13.83	10.65	10.65
2020	0.27	0.47	0.93	1.44	2.05	2.95	4.28	5.73	7.59	8.45	10.66	12.3	12.2	12.23

Germany (Division IIa and IIb)														
Year	Age													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1994		0.68	1.04	2.24	3.49	4.51	5.79	6.93	8.16	8.46	8.74	9.48	15.25	
1995		0.44	0.84	1.5	2.72	3.81	4.46	4.81	7.37	7.69	8.25	9.47		
1996		0.84	1.15	1.64	2.53	3.58	4.13	3.9	4.68	6.98	6.43	11.32		
1997		0.43	0.92	1.42	2.01	3.15	4.04	5.16	4.82	3.96	7.04	8.8		
1998	0.23	0.73	1.17	1.89	2.72	3.25	4.13	5.63	6.5	8.57	8.42	11.45	8.79	
1999[1]		0.853	1.448	1.998	2.65	3.473	4.156	5.447	6.82	5.902		8.01		
2000[2]	0.26	0.73	1.36	2.04	2.87	3.67	4.88	5.78	7.05	8.45	8.67	9.33	6.88	
2001	0.38	0.80	1.21	1.90	2.74	3.90	4.99	5.69	7.15	7.32	11.72	9.11	6.60	
2002	0.35	1.00	1.31	1.80	2.53	3.64	4.38	5.07	6.82	9.21	7.59	13.18	19.17	19.20
2003	0.22	0.44	1.04	1.71	2.31	3.27	4.93	6.17	7.77	9.61	9.99	12.29	13.59	
2004[2]	0.22	0.73	1.01	1.75	2.58	3.33	4.73	6.32	7.20	8.45	9.20	11.99	10.14	13.11
2005[3]	0.57	0.77	1.13	1.66	2.33	3.36	4.38	5.92	6.65	7.26	10.01	11.14		
2006[2]	0.71	0.91	1.39	1.88	2.56	3.77	5.33	6.68	9.14	10.89	11.51	16.83	18.77	
2007[3]	0.59	1.35	1.79	2.51	3.53	4.00	4.95	6.55	7.54	9.71	11.40	11.57	23.34	15.61
2008[3]	0.23	0.51	1.14	1.76	2.57	3.15	4.40	5.43	7.18	8.39	10.15	10.03	10.99	14.26
2009[3]	0.35	0.60	1.19	1.83	2.96	4.08	5.61	6.97	8.55	9.13	10.54	13.34	10.30	17.06
2010[3]	0.36	0.67	0.93	1.71	2.46	3.21	4.93	6.75	7.80	8.70	8.53	10.17	12.36	14.11
2011[1]			1.75	3.09	3.30	3.28	4.13	4.99	6.61	7.91	9.38	10.79	14.67	14.91
2013[3]			1.03	1.37	1.87	2.65	3.45	4.49	7.26	11.42	12.86	13.07		
2014[4]		0.68	0.96	1.39	1.69	3.06	4.07	5.65	8.15	10.36	13.07	13.52		
2015[4]	0.82	1.05	1.67	2.33	3.56	4.50	5.41	6.20	6.39					
2016[1]		1.38	2.60	3.55	4.81	6.33	7.61	8.90	9.26	10.83	13.41	16.84	17.03	17.76
2017[1]		1.58	2.79	3.93	3.93	4.77	6.35	8.16	9.09	10.39	11.24	12.48	14.39	13.04
2018[3]	0.58	1.16	1.76	2.45	3.34	4.13	5.81	7.16	8.99	9.96	10.85	11.73	14.01	17.79
2019[1]		0.82	1.37	1.80	2.26	3.49	4.45	5.44	7.08	9.25	9.39	13.30	12.24	15.25
2020[5]			1.6	1.63	2.48	3.13	5.01	5.93	8.36	9.31	12.16	12.96	12.77	14.08

1-Division IIa only

2-IIa and IIb combined

3-I,IIa and IIb combined

4-Division IIb only

5-I and IIa combined

Spain (Division IIb)														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1994	0.43	1.08	1.38	2.32	2.47	2.68	3.46	5.20	7.04	6.79	7.20	8.04	10.46	15.35
1995	0.42	0.51	0.98	1.99	3.41	4.95	5.52	8.62	9.21	11.42	9.78	8.08		
1996		0.66	1.12	1.57	2.43	3.17	3.59	4.44	5.48	6.79	8.10			
1997[1]	0.51	0.65	1.22	1.68	2.60	3.39	4.27	6.67	7.88	11.34	13.33	10.03	8.69	
1998	0.47	0.74	1.15	1.82	2.44	3.32	3.71	5.00	7.26					
1999[1]	0.21	0.69	1.06	1.69	2.50	3.32	4.72	5.76	6.77	7.24	7.63			
2000[1]	0.23	0.61	1.24	1.75	2.47	3.12	4.65	6.06	7.66	10.94	11.40	7.20		
2001	0.23	0.64	1.25	1.95	2.86	3.55	4.95	6.46	8.50	11.07	13.09			
2002	0.16	0.55	1.00	1.48	2.17	3.29	4.47	5.35	8.29	12.23	9.01	12.16	15.2	
2003		0.58	1.05	1.70	2.33	3.33	4.92	6.24	9.98	13.07	14.74	14.17		
2004[1]	0.31	0.56	0.80	1.28	1.96	2.59	3.72	5.36	5.28	7.41		11.43		
2005[1]		0.63	1.14	1.85	2.48	3.43	4.25	5.38	8.41	11.19	15.04	16.93		
2006	0.30	0.61	0.99	1.46	2.04	2.55	3.39	3.50	4.70	6.36				
2007	0.42	0.60	1.20	1.76	2.40	3.18	3.96	5.19	6.61	9.48	7.65	12.65	15.74	19.66
2009[1]	0.12	0.45	0.95	1.60	2.18	3.36	4.52	6.04	7.30	9.42	10.35	11.47	12.54	
2010[2]	0.18	0.56	1.11	1.73	2.36	3.36	5.14	6.88	8.64	9.65	6.83			
2011[1]		0.45	0.90	1.26	1.84	2.55	4.08	5.61	8.17	8.14	7.31	8.91		
2012[2]		0.40	0.84	1.29	1.96	2.78	3.71	4.99	7.42		7.19	9.32		
2013	0.17	0.72	1.06	1.63	2.36	3.14	3.90	4.36	6.55					
2014	0.24	0.43	0.74	1.27	1.85	2.60	3.56	4.51	5.52	7.18	9.42	9.26	13.16	15.05
2015[2]		0.40	0.80	1.19	1.79	2.45	3.38	4.41	5.85	6.64	7.48	6.77		
2016[3]	0.11	0.38	0.76	1.20	1.72	2.50	3.39	4.96	7.11	8.56				
2017[2]	0.12	0.42	0.75	1.17	1.69	2.50	3.39	4.47	5.69	5.93	6.00	10.91	13.57	10.52
2018[2]	0.19	0.45	0.83	1.30	1.86	2.57	3.55	4.92	5.51	7.84	7.08	7.28		
2019[2]	0.19	0.39	0.90	1.30	1.85	2.65	3.48	4.83	5.96	5.67	7.04	8.36		

1-IIa and IIb combined

2-I,IIa and IIb combined

3-I and IIb combined

Iceland (Sub-area I)														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1994	0.42	0.85	1.44	2.77	3.54	4.08	5.84	6.37	7.02	7.48	7.37			
1995		1.17	0.91	1.60	2.28	3.61	4.73	6.27			6.26			
1996		0.36	0.99	1.55	2.83	3.79	4.81	5.34	7.25	7.68	9.08	8.98	10.52	
1997	0.42	0.43	0.76	1.60	2.40	3.45	4.40	5.74	6.15		8.28	10.52	9.89	

UK (England and Wales)														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1995[1]			1.47	2.11	3.47	5.57	6.43	7.17	8.12	8.05	10.2	10.1		
1996[2]			1.55	1.81	2.42	3.61	6.3	6.47	7.83	7.91	8.93	9.38	10.9	
1997[2]			1.93	2.17	3.07	4.17	4.89	6.46		12.3	8.44			

1-Division IIa and IIb

2-Division IIa

Poland (Division IIb)														
Year	**Age**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
2006	0.18	0.51	0.89	1.55	2.23	3.6	5.28	6.95	8.478	11	10.8	15.6	18.9	
2008		0.49	0.90	1.45	2.24	2.79	3.82	4.68	5.015	6.45	7.02	7.22	5.99	6.91
2009			1.02	1.72	2.65	3.81	5.23	6.91	8.862	11.1	13.6	16.5		
2010			1.39	1.66	2.29	2.98	3.92	5.18	6.313	6.66	8.72	9.05		
2011			0.99	1.50	2.17	3.15	4.43	7.45	7.28					
2016[1]		0.84	1.59	2.29	2.81	3.91	4.78	5.61	6.709	7.89	8.54	11.6	13.7	16.09
2017[2]		0.71	1.23	1.52	2.47	3.52	4.78	6.97	9.193	9.95	10.9	14.1		
2018[3]		0.74	1.15	1.66	2.45	3.55	4.48	6.06	6.31	7.59	7.91	8.28	8.52	9.40
2019[1]				1.57	2.00	2.69	4.04	5.61	7.23	9.13	11.62	12.41	13.46	11.47

1-Division IIa

2-Division IIa and IIb

3-I and IIb combined

Table 3.8. Northeast Arctic cod. Catch weights at age (kg)

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Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1946	0.35	0.59	1.11	1.69	2.37	3.17	3.98	5.05	5.92	7.2	8.15	8.13	9.25
1947	0.32	0.56	0.95	1.5	2.14	2.92	3.65	4.56	5.84	7.42	8.85	8.79	10
1948	0.34	0.53	1.26	1.93	2.46	3.36	4.22	5.31	5.92	7.09	8.43	8.18	9.43
1949	0.37	0.67	1.11	1.66	2.5	3.23	4.07	5.27	5.99	7.08	8.22	8.26	8.7
1950	0.39	0.64	1.29	1.7	2.36	3.48	4.52	5.62	6.4	7.96	8.89	9.07	10.27
1951	0.4	0.83	1.39	1.88	2.54	3.46	4.88	5.2	7.14	8.22	9.39	9.5	9.52
1952	0.44	0.8	1.33	1.92	2.64	3.71	5.06	6.05	7.42	8.43	10.19	10.13	10.56
1953	0.4	0.76	1.28	1.93	2.81	3.72	5.06	6.34	7.4	8.67	10.24	11.41	11.93
1954	0.44	0.77	1.26	1.97	3.03	4.33	5.4	6.75	7.79	10.67	9.68	9.56	11.11
1955	0.32	0.57	1.13	1.73	2.75	3.94	4.9	7.04	7.2	8.78	10.08	11.02	12.11
1956	0.33	0.58	1.07	1.83	2.89	4.25	5.55	7.28	8	8.35	9.94	10.25	11.56
1957	0.33	0.59	1.02	1.82	2.89	4.28	5.49	7.51	8.24	9.25	10.61	10.82	12.07
1958	0.34	0.52	0.95	1.92	2.94	4.21	5.61	7.35	8.67	9.58	11.63	11	13.83
1959	0.35	0.72	1.47	2.68	3.59	4.32	5.45	6.44	7.17	8.63	11.62	11.95	13
1960	0.34	0.51	1.09	2.13	3.38	4.87	6.12	8.49	7.79	8.3	11.42	11.72	13.42
1961	0.31	0.55	1.05	2.2	3.23	5.11	6.15	8.15	8.68	9.6	11.95	13.18	13.42
1962	0.32	0.55	0.93	1.7	3.03	5.03	6.55	7.7	9.27	10.56	12.72	13.48	14.44
1963	0.32	0.61	0.96	1.73	3.04	4.96	6.44	7.91	9.62	11.31	12.74	13.19	14.29
1964	0.33	0.55	0.95	1.86	3.25	4.97	6.41	8.07	9.34	10.16	12.89	13.25	14
1965	0.38	0.68	1.03	1.49	2.41	3.52	5.73	7.54	8.47	11.17	13.72	13.46	14.12
1966	0.44	0.74	1.18	1.78	2.46	3.82	5.36	7.27	8.63	10.66	14.15	14	15
1967	0.29	0.81	1.35	2.04	2.81	3.48	4.89	7.11	9.03	10.59	13.83	14.15	16.76
1968	0.33	0.7	1.48	2.12	3.14	4.21	5.27	6.65	9.01	9.66	14.85	16.3	17
1969	0.44	0.79	1.23	2.03	2.9	3.81	5.02	6.43	8.33	10.71	14.21	15	17
1970	0.37	0.91	1.34	2	3	4.15	5.59	7.6	8.97	10.99	14.07	14.61	16

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1971	0.45	0.88	1.38	2.16	3.07	4.22	5.81	7.13	8.62	10.83	12.95	14.25	15.97
1972	0.38	0.77	1.43	2.12	3.23	4.38	5.83	7.62	9.52	12.09	13.67	13.85	16
1973	0.38	0.91	1.54	2.26	3.29	4.61	6.57	8.37	10.54	11.62	13.9	14	15.84
1974	0.32	0.66	1.17	2.22	3.21	4.39	5.52	7.86	9.82	11.41	13.24	13.7	14.29
1975	0.41	0.64	1.11	1.9	2.95	4.37	5.74	8.77	9.92	11.81	13.11	14	14.29
1976	0.35	0.73	1.19	2.01	2.76	4.22	5.88	9.3	10.28	11.86	13.54	14.31	14.28
1977	0.49	0.9	1.43	2.05	3.3	4.56	6.46	8.63	9.93	10.9	13.67	14.26	14.91
1978	0.49	0.81	1.45	2.15	3.04	4.46	6.54	7.98	10.15	10.85	13.18	14	15
1979	0.35	0.7	1.24	2.14	3.15	4.29	6.58	8.61	9.22	10.89	14.34	14.5	15.31
1980	0.27	0.56	1.02	1.72	3.02	4.2	5.84	7.26	8.84	9.28	14.45	15	15.5
1981	0.49	0.98	1.44	2.09	2.98	4.85	6.57	9.16	10.82	10.77	13.93	15	16
1982	0.37	0.66	1.35	1.99	2.93	4.24	6.46	8.51	12.24	10.78	14.04	15	16
1983	0.84	1.37	2.09	2.86	3.99	5.58	7.77	9.29	11.55	11.42	12.8	14.18	15.55
1984	1.42	1.93	2.49	3.14	3.91	4.91	6.02	7.4	8.13	11.42	12.8	14.18	15.55
1985	0.94	1.37	2.02	3.22	4.63	6.04	7.66	9.81	11.8	11.42	12.8	14.18	15.55
1986	0.64	1.27	1.88	2.79	4.49	5.84	6.83	7.69	9.81	11.42	12.8	14.18	15.55
1987	0.49	0.88	1.55	2.33	3.44	5.92	8.6	9.6	12.17	11.42	12.8	14.18	15.55
1988	0.54	0.85	1.32	2.24	3.52	5.35	8.06	9.51	11.36	11.42	12.8	14.18	15.55
1989	0.74	0.96	1.31	1.92	2.93	4.64	7.52	9.12	11.08	11.42	12.8	14.18	15.55
1990	0.81	1.22	1.64	2.22	3.24	4.68	7.3	9.84	13.25	11.42	12.8	14.18	15.55
1991	1.05	1.45	2.15	2.89	3.75	4.71	6.08	8.82	11.8	11.42	12.8	14.18	15.55
1992	1.16	1.57	2.21	3.1	4.27	5.19	6.14	7.77	10.12	11.42	12.8	14.18	15.55
1993	0.81	1.52	2.16	2.79	4.07	5.53	6.47	7.19	7.98	11.46	12.8	14.18	15.55
1994	0.82	1.3	2.06	2.89	3.21	5.2	6.8	7.57	8.01	9.96	13.01	14.18	15.55
1995	0.77	1.2	1.78	2.59	3.81	4.99	6.23	8.05	8.74	9.77	11.39	14.55	15.55
1996	0.79	1.11	1.61	2.46	3.82	5.72	6.74	8.04	9.28	10.45	11.19	12.82	16.05
1997	0.67	1.04	1.53	2.22	3.42	5.2	7.19	7.73	8.61	11.14	11.93	12.61	14.23
1998	0.68	1.05	1.62	2.3	3.3	4.86	6.87	9.3	10.3	10.75	12.68	13.39	14.01
1999	0.63	1.01	1.54	2.34	3.21	4.29	6	6.73	10.08	11.15	12.26	14.19	14.84

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
2000	0.57	1.04	1.61	2.34	3.34	4.48	5.72	7.52	8.02	11.93	12.68	13.74	15.68
2001	0.66	1.05	1.62	2.51	3.51	4.78	6.04	7.54	9	10.23	13.52	14.2	15.21
2002	0.72	1.13	1.56	2.31	3.52	4.78	6.2	7.66	9.14	10.38	11.69	15.08	15.68
2003	0.67	1.12	1.83	2.5	3.58	5.04	6.36	8.2	10.71	10.17	11.85	13.14	16.6
2004	0.72	1.13	1.61	2.43	3.27	4.72	6.71	7.98	9.19	10.84	11.62	13.31	14.57
2005	0.69	1.08	1.57	2.21	3.26	4.44	6.23	8.19	9.72	10.63	12.35	13.07	14.75
2006	0.72	1.16	1.6	2.39	3.32	4.54	5.47	6.78	7.7	10.8	12.12	13.84	14.49
2007	0.74	1.21	1.83	2.51	3.82	5.04	6.58	8.08	8.94	10.35	12.3	13.6	15.31
2008	0.77	1.27	1.87	2.82	3.79	5.12	6.22	7.75	8.4	10.14	11.82	13.8	15.05
2009	0.75	1.17	1.74	2.42	3.86	5.35	6.43	8.01	8.67	10.05	11.59	13.28	15.26
2010	0.78	1.2	1.74	2.44	3.4	5.04	6.25	7.32	8.53	10.38	11.5	13.03	14.71
2011	0.78	1.31	1.72	2.37	3.2	4.62	6.18	7.47	8.57	10.39	11.85	12.94	14.46
2012	0.67	1.14	1.73	2.34	3.12	4.4	6.28	8.24	10.35	10.37	11.86	13.31	14.36
2013	0.71	1.17	1.67	2.36	3.19	4.22	5.58	7.31	9.08	11.03	11.84	13.32	14.75
2014	0.79	1.2	1.73	2.34	3.28	4.21	5.49	6.98	8.67	10.82	12.55	13.3	14.76
2015	0.78	1.09	1.55	2.18	3.14	4.46	5.61	6.62	7.34	10.21	12.33	14.06	14.74
2016	0.78	1.14	1.66	2.26	3.25	4.5	5.98	7.31	8.54	9.37	11.67	13.82	15.54
2017	0.71	1.15	1.66	2.32	3.32	4.67	6.13	7.15	8.14	9.6	10.75	13.12	15.29
2018	0.86	1.17	1.71	2.5	3.31	4.61	6.03	7.32	8.06	9.71	11	12.14	14.55
2019	0.68	1.15	1.66	2.39	3.33	4.45	6.11	7.29	8.41	9.81	11.12	12.4	13.51
2020	0.71	1.08	1.6	2.19	3.09	4.39	5.73	7.22	8.41	9.99	11.23	12.53	13.79

Table 3.9. Northeast Arctic cod. Stock weights at age (kg).

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Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1946	0.35	0.59	1.11	1.69	2.37	3.17	3.98	5.05	5.92	7.2	8.146	8.133	9.253
1947	0.32	0.56	0.95	1.5	2.14	2.92	3.65	4.56	5.84	7.42	8.848	8.789	9.998
1948	0.34	0.53	1.26	1.93	2.46	3.36	4.22	5.31	5.92	7.09	8.43	8.181	9.433
1949	0.37	0.67	1.11	1.66	2.5	3.23	4.07	5.27	5.99	7.08	8.218	8.259	8.701
1950	0.39	0.64	1.29	1.7	2.36	3.48	4.52	5.62	6.4	7.96	8.891	9.07	10.271
1951	0.4	0.83	1.39	1.88	2.54	3.46	4.88	5.2	7.14	8.22	9.389	9.502	9.517
1952	0.44	0.8	1.33	1.92	2.64	3.71	5.06	6.05	7.42	8.43	10.185	10.134	10.563
1953	0.4	0.76	1.28	1.93	2.81	3.72	5.06	6.34	7.4	8.67	10.238	11.409	11.926
1954	0.44	0.77	1.26	1.97	3.03	4.33	5.4	6.75	7.79	10.67	9.68	9.557	11.106
1955	0.32	0.57	1.13	1.73	2.75	3.94	4.9	7.04	7.2	8.78	10.077	11.023	12.105
1956	0.33	0.58	1.07	1.83	2.89	4.25	5.55	7.28	8	8.35	9.944	10.248	11.564
1957	0.33	0.59	1.02	1.82	2.89	4.28	5.49	7.51	8.24	9.25	10.605	10.825	12.075
1958	0.34	0.52	0.95	1.92	2.94	4.21	5.61	7.35	8.67	9.58	11.631	11	13.832
1959	0.35	0.72	1.47	2.68	3.59	4.32	5.45	6.44	7.17	8.63	11.621	11.95	13
1960	0.34	0.51	1.09	2.13	3.38	4.87	6.12	8.49	7.79	8.3	11.422	11.719	13.424
1961	0.31	0.55	1.05	2.2	3.23	5.11	6.15	8.15	8.68	9.6	11.952	13.181	13.422
1962	0.32	0.55	0.93	1.7	3.03	5.03	6.55	7.7	9.27	10.56	12.717	13.482	14.44

Year_age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**+gp**
1963	0.32	0.61	0.96	1.73	3.04	4.96	6.44	7.91	9.62	11.31	12.737	13.193	14.287
1964	0.33	0.55	0.95	1.86	3.25	4.97	6.41	8.07	9.34	10.16	12.886	13.251	14
1965	0.38	0.68	1.03	1.49	2.41	3.52	5.73	7.54	8.47	11.17	13.722	13.465	14.118
1966	0.44	0.74	1.18	1.78	2.46	3.82	5.36	7.27	8.63	10.66	14.148	14	15
1967	0.29	0.81	1.35	2.04	2.81	3.48	4.89	7.11	9.03	10.59	13.829	14.146	16.756
1968	0.33	0.7	1.48	2.12	3.14	4.21	5.27	6.65	9.01	9.66	14.848	16.3	17
1969	0.44	0.79	1.23	2.03	2.9	3.81	5.02	6.43	8.33	10.71	14.211	15	17
1970	0.37	0.91	1.34	2	3	4.15	5.59	7.6	8.97	10.99	14.074	14.611	16
1971	0.45	0.88	1.38	2.16	3.07	4.22	5.81	7.13	8.62	10.83	12.945	14.25	15.973
1972	0.38	0.77	1.43	2.12	3.23	4.38	5.83	7.62	9.52	12.09	13.673	13.852	16
1973	0.38	0.91	1.54	2.26	3.29	4.61	6.57	8.37	10.54	11.62	13.904	14	15.841
1974	0.32	0.66	1.17	2.22	3.21	4.39	5.52	7.86	9.82	11.41	13.242	13.704	14.291
1975	0.41	0.64	1.11	1.9	2.95	4.37	5.74	8.77	9.92	11.81	13.107	14	14.293
1976	0.35	0.73	1.19	2.01	2.76	4.22	5.88	9.3	10.28	11.86	13.544	14.311	14.284
1977	0.49	0.9	1.43	2.05	3.3	4.56	6.46	8.63	9.93	10.9	13.668	14.255	14.906
1978	0.49	0.81	1.45	2.15	3.04	4.46	6.54	7.98	10.15	10.85	13.177	14	15
1979	0.35	0.7	1.24	2.14	3.15	4.29	6.58	8.61	9.22	10.89	14.344	14.5	15.315
1980	0.27	0.56	1.02	1.72	3.02	4.2	5.84	7.26	8.84	9.28	14.448	15	15.5

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1981	0.49	0.98	1.44	2.09	2.98	4.85	6.57	9.16	10.82	10.77	13.932	15	16
1982	0.37	0.66	1.35	1.99	2.93	4.24	6.46	8.51	12.24	10.78	14.041	15	16
1983	0.37	0.92	1.6	2.44	3.82	4.76	6.17	7.7	9.25	12.621	14.544	16.466	18.388
1984	0.42	1.16	1.81	2.79	3.78	4.57	6.17	7.7	9.25	12.621	14.544	16.466	18.388
1985	0.413	0.875	1.603	2.81	4.059	5.833	7.685	10.117	14.29	12.621	14.544	16.466	18.388
1986	0.311	0.88	1.47	2.467	3.915	5.81	6.58	6.833	11.004	12.621	14.544	16.466	18.388
1987	0.211	0.498	1.254	2.047	3.431	5.137	6.523	9.3	13.15	12.621	14.544	16.466	18.388
1988	0.212	0.404	0.79	1.903	2.977	4.392	7.812	12.112	13.107	12.621	14.544	16.466	18.388
1989	0.299	0.52	0.868	1.477	2.686	4.628	7.048	9.98	9.25	12.621	14.544	16.466	18.388
1990	0.398	0.705	1.182	1.719	2.458	3.565	4.71	7.801	8.956	12.621	14.544	16.466	18.388
1991	0.518	1.136	1.743	2.428	3.214	4.538	6.88	10.719	9.445	12.621	14.544	16.466	18.388
1992	0.44	0.931	1.812	2.716	3.895	5.176	6.774	9.598	12.427	12.621	14.544	16.466	18.388
1993	0.344	1.172	1.82	2.823	4.031	5.497	6.765	8.571	10.847	12.621	14.544	16.466	18.388
1994	0.237	0.757	1.419	2.458	3.845	5.374	6.648	7.653	8.136	12.916	16.114	16.466	18.388
1995	0.197	0.487	1.141	2.118	3.504	4.915	6.949	9.051	9.775	11.409	15.248	18.62	18.388
1996	0.206	0.482	0.98	2.041	3.52	5.507	7.74	9.922	10.63	12.093	13.533	17.659	21.171
1997	0.211	0.537	1.11	1.876	3.381	5.258	8.546	10.653	10.776	13.232	14.313	15.745	20.122
1998	0.242	0.561	1.179	1.936	2.944	4.583	7.092	10.7	12.042	13.771	15.607	16.617	18.021

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1999	0.209	0.514	1.183	2.007	3.037	4.479	6.512	10.028	11.117	14.698	16.215	18.057	18.981
2000	0.194	0.465	1.218	1.963	3.064	4.12	5.746	7.157	9.961	14.589	17.26	18.733	20.557
2001	0.284	0.513	1.21	2.25	3.299	5.066	6.373	9.29	11.456	13.317	17.138	19.887	21.294
2002	0.23	0.603	1.184	2.138	3.336	4.81	6.912	8.809	10.475	12.534	15.703	19.752	22.549
2003	0.233	0.551	1.317	2.022	3.239	4.984	6.727	8.422	14.226	12.524	14.815	18.164	22.403
2004	0.24	0.55	1.074	2.038	2.911	4.402	6.263	8.535	10.197	12.371	14.803	17.176	20.674
2005	0.225	0.61	1.083	1.87	3.002	3.971	5.789	8.127	12.759	12.611	14.63	17.163	19.594
2006	0.252	0.591	1.219	2.014	3.028	4.434	5.999	7.774	9.954	13.679	14.902	16.97	19.58
2007	0.249	0.663	1.329	2.127	3.183	4.59	6.477	8.88	12.124	12.261	16.111	17.274	19.368
2008	0.286	0.726	1.418	2.41	3.331	4.914	6.747	8.851	10.393	12.776	14.504	18.617	19.701
2009	0.274	0.652	1.353	2.312	3.803	5.103	6.75	9.252	10.119	12.323	15.09	16.83	21.168
2010	0.258	0.608	1.208	2.01	3.088	4.903	6.498	7.992	9.689	12.467	14.574	17.483	19.214
2011	0.225	0.6	1.097	1.926	2.861	4.403	6.531	8.648	9.885	12.508	14.738	16.909	19.929
2012	0.227	0.555	1.182	1.834	2.831	4.124	6.056	8.584	11.498	12.249	14.785	17.092	19.3
2013	0.247	0.577	1.134	1.998	2.841	4.015	5.523	8.077	10.304	13.207	14.491	17.144	19.501
2014	0.216	0.577	1.137	1.791	2.781	3.85	5.245	6.992	9.378	12.746	15.578	16.816	19.558
2015	0.229	0.54	1.134	1.934	2.753	4.081	5.315	7.135	8.947	11.778	15.056	18.025	19.198
2016	0.21	0.536	1.001	1.812	2.72	3.958	5.64	7.064	8.569	10.885	13.954	17.445	20.522

Year_age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**+gp**
2017	0.255	0.675	1.107	1.896	2.826	4.158	5.7	7.628	9.071	10.634	12.934	16.216	19.888
2018	0.286	0.62	1.188	1.949	2.768	4.059	5.749	7.38	9.097	10.8	12.646	15.073	18.54
2019	0.24	0.603	1.085	1.82	3.025	4.296	5.891	7.293	9.667	11.186	12.837	14.749	17.28
2020	0.148	0.503	1.055	1.692	2.59	4.064	5.617	7.673	9.313	11.306	13.278	14.964	16.922
2021	0.175	0.44	0.972	1.755	2.71	3.865	5.703	7.448	9.084	11.187	13.415	15.459	17.159

Table 3.10. Northeast Arctic cod. Basis for maturity ogives (percent) used in the assessment. Norwegian and Russian data.

Norway								
	Percentage mature							
	Age							
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1982	0	5	10	34	65	82	92	100
1983	5	8	10	30	73	88	97	100

Russia								
	Percentage mature							
	Age							
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1984	0	5	18	31	56	90	99	100
1985	0	1	10	33	59	85	92	100
1986	0	2	9	19	56	76	89	100
1987	0	1	9	23	27	61	81	80
1988	0	1	3	25	53	79	100	100
1989	0	0	2	15	39	59	83	100
1990	0	2	6	20	47	62	81	95
1991	0	3	1	23	66	82	96	100
1992	0	1	8	31	73	92	95	100
1993	0	3	7	21	56	89	95	99
1994	0	1	8	30	55	84	95	98
1995	0	0	4	23	61	75	94	97
1996	0	0	1	22	56	82	95	100
1997	0	0	1	10	48	73	90	100
1998	0	0	2	15	47	87	97	96
1999	0	0.2	1.3	9.9	38.4	74.9	94	100
2000	0	0	6	19.2	51.4	84	95.5	100
2001	0.1	0.1	3.9	27.9	62.3	89.4	96.3	100

Russia								
	Percentage mature							
	Age							
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2002	0.1	1.9	10.9	34.4	68.1	82.8	97.6	100
2003	0.2	0	11	29.2	65.9	89.6	95.1	100
2004	0	0.7	8	33.8	63.3	83.4	96.4	96.4
2005	0	0.6	4.6	24.2	61.5	84.9	95.3	98.1
2006	0	0	6.1	29.6	59.6	89.5	96.4	100
2007	0	0.4	5.7	20.8	60.4	83.5	96	100
2008	0	0.5	4	24.6	48.3	84.4	94.7	98.7
2009	0	0	6	28	66	85	97	100
2010	0	0.2	1.5	22.8	47	77.4	90.2	95.5
2011	0	0	2.2	20.7	50.4	73.7	90.6	95.6
2012	0.2	0	1.5	10.8	43.9	76.1	90.8	96.4
2013	0	0	0.6	10.6	41.8	70.6	89.8	96.9
2014	0	0	1.9	14.1	45.9	76	92	97.5
2015	0	0.2	0.2	7.9	27	60.8	83.4	93.7
2016	0	0	0.2	5.2	22.4	44.1	74.8	92.5
2017*	0	0	0.8	6.3	20.8	51.6	80.4	98.6
2018	0	0.5	2.5	23.6	53.9	79.4	92.5	96.0
2019**	0	0	4.5	11.9	56.4	91.8	95.1	100
2020**	0	0.4	1.7	15.8	43.8	71.2	74.9	84.9
2021**	0	0	2.7	16.1	44.1	72.2	87.1	88.1

Norway								
	Percentage mature							
	Age							
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1985	0.31	1.36	8.94	38.33	51.27	85.13	100	79.2
1986	2.92	7	7.85	18.85	49.72	66.52	35.59	80.09

Norway								
	Percentage mature							
	Age							
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1987	0	0.07	4.49	12.42	16.28	31.23	19.32	
1988	0	2.35	6.16	40.54	53.63	45.36	100	100
1989	1.52	0.67	3.88	30.65	70.36	82.02	100	100
1990	1.52	0.67	4.18	22	57.45	80.95	100	100
1991	0.1	3.4	13.93	38.03	75.52	90.12	95.39	100
1992	0.22	1.85	21.04	52.83	86.95	96.52	99.83	100
1993	0	2.6	10.37	52.6	84.8	97.25	99.3	99.73
1994	0.51	0.33	15.78	36.92	62.84	88.44	97.56	100
1995	0	0.62	8.19	51.48	63.75	81.11	98.01	99.34
1996	0.03	0	2.82	29.56	70.22	82.06	100	100
1997	0	0	1.48	17.91	73.31	93.01	99.12	100
1998	0.12	0.68	3.17	15.42	47.31	75.73	94.3	100
1999	0.42	0.16	1.6	27.46	70.48	94.57	98.99	100
2000	0	0.11	8.15	30.23	77.3	81.95	100	100
2001	0.49	0.51	9.03	43.81	62.52	74.36	94.13	100
2002	0.27	0.73	5.94	43.22	68.4	85.31	92.52	100
2003	0.02	0.18	6.5	35.97	68.56	87.97	96.3	100
2004	0.24	1.36	10.23	54.56	81.84	90.94	98.76	98.91
2005	0	0.27	9	55.16	81.77	93.51	98.03	100
2006	0	0.22	5.92	44.25	69.85	89.89	96.65	100
2007	0.12	0.33	8.7	47.88	84.29	91.68	99.11	100
2008	0	0.27	9.27	34.13	61.39	88.04	91.17	100
2009	0	0	9	46	85	86	98	99
2010	0	0.36	7.5	41.75	67.7	90.1	95.29	98.55
2011	0	0.2	5.2	48	77.7	89.7	97.3	97.2
2012	0	0	7.7	32.2	67.5	81	90.9	96.3

Norway								
	Percentage mature							
	Age							
Year	3	4	5	6	7	8	9	10
2013	0	0.3	1	20.2	55.3	80	91.8	99.3
2014	0	0.4	2	13.3	56.7	85	93.8	98.7
2015	0	0	1.9	10.9	29.2	79.1	93.1	99.6
2016	0.07	0.2	1.0	6.4	28.5	71.3	86.1	98.6
2017	0	0.2	0.5	18	54.8	81.4	95.9	100
2018	0	0.1	3.0	16.2	38.3	61.0	93.7	98.9
2019	0	0.4	4.0	24.0	68.6	93.2	96.7	99.8
2020	0	0.44	3.18	13.68	42.51	80.06	91.18	94.03
2021	0.28	0.25	0.79	17.11	43.21	68.80	90.75	98.63

***Not used in inputs (instead ratios presented in WD 10, 2017 used for further calculations)**

****Not used in inputs (instead ratios presented in WD 15, 2019 used for further calculations)**

Table 3.11. Northeast Arctic cod. Proportion mature-at-age.

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Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1946	0	0	0.01	0.03	0.06	0.11	0.18	0.44	0.65	0.86	0.96	0.96	1
1947	0	0	0.01	0.03	0.06	0.13	0.16	0.42	0.75	0.91	0.95	1	1
1948	0	0	0.01	0.03	0.07	0.13	0.25	0.47	0.73	0.91	0.97	1	1
1949	0	0	0.01	0.03	0.09	0.17	0.29	0.54	0.79	0.88	0.97	1	1
1950	0	0	0.01	0.03	0.09	0.23	0.35	0.52	0.79	0.95	0.97	1	1
1951	0	0	0.01	0.03	0.1	0.24	0.4	0.58	0.72	0.85	0.96	1	1
1952	0	0	0.01	0.03	0.08	0.22	0.41	0.63	0.82	0.92	0.97	1	1
1953	0	0	0.01	0.03	0.07	0.19	0.4	0.64	0.84	0.94	0.97	1	1
1954	0	0	0.01	0.03	0.08	0.16	0.37	0.68	0.87	0.93	0.96	1	1
1955	0	0	0.01	0.03	0.07	0.13	0.26	0.53	0.83	0.92	0.97	1	1
1956	0	0	0.01	0.03	0.06	0.12	0.14	0.41	0.67	0.91	0.96	1	1
1957	0	0	0.01	0.03	0.06	0.09	0.12	0.22	0.6	0.82	0.97	1	1
1958	0	0	0.01	0.03	0.06	0.1	0.1	0.3	0.5	0.82	0.97	1	1

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1959	0	0	0.01	0.04	0.12	0.34	0.49	0.67	0.84	0.87	1	1	1
1960	0	0.01	0.03	0.06	0.1	0.19	0.45	0.69	0.77	0.85	0.99	1	1
1961	0	0	0.01	0.06	0.12	0.31	0.65	0.91	0.98	0.98	1	0.96	1
1962	0	0	0.01	0.05	0.15	0.34	0.61	0.81	0.92	0.97	1	0.932	1
1963	0	0.01	0.01	0.03	0.07	0.28	0.42	0.81	0.98	0.98	1	0.966	1
1964	0	0	0	0.03	0.13	0.37	0.66	0.89	0.95	0.99	1	1	1
1965	0	0	0	0.01	0.06	0.2	0.55	0.73	0.99	0.98	1	1	1
1966	0	0	0.01	0.02	0.06	0.22	0.35	0.74	0.94	0.94	1	1	1
1967	0	0	0	0.03	0.07	0.14	0.38	0.64	0.89	0.9	1	1	1
1968	0	0	0.03	0.05	0.09	0.19	0.39	0.58	0.82	1	1	1	1
1969	0	0	0	0.02	0.04	0.12	0.34	0.55	0.74	0.95	1	1	1
1970	0	0.01	0	0.01	0.07	0.23	0.58	0.81	0.89	0.91	1	1	1
1971	0	0	0.01	0.05	0.11	0.3	0.59	0.79	0.86	0.88	1	1	1
1972	0.01	0.02	0.02	0.01	0.1	0.34	0.64	0.81	0.94	1	1	1	1
1973	0	0	0	0.02	0.16	0.53	0.81	0.92	0.95	0.98	1	1	1
1974	0	0	0	0.01	0.03	0.21	0.5	0.96	1	0.96	1	1	1
1975	0	0	0.01	0.02	0.09	0.21	0.56	0.78	0.79	0.95	1	1	1
1976	0	0	0	0.05	0.12	0.29	0.45	0.84	0.83	1	0.9	1	1
1977	0	0	0.02	0.08	0.26	0.54	0.76	0.87	0.93	0.94	0.9	1	1
1978	0	0	0	0.02	0.13	0.44	0.71	0.77	0.81	0.89	0.8	1	1
1979	0	0	0	0.03	0.13	0.39	0.77	0.89	0.83	0.78	0.9	1	1
1980	0	0	0	0.02	0.13	0.35	0.65	0.82	1	0.9	0.9	1	1
1981	0	0	0.02	0.07	0.2	0.54	0.8	0.97	1	1	1	1	1
1982	0	0.05	0.1	0.34	0.65	0.82	0.92	1	1	1	1	1	1
1983	0.01	0.08	0.1	0.3	0.73	0.88	0.97	1	1	1	1	1	1
1984	0	0.05	0.18	0.31	0.56	0.9	0.99	1	1	1	1	1	1
1985	0	0.01	0.09	0.36	0.55	0.85	0.96	0.9	1	1	1	1	1
1986	0	0.05	0.08	0.19	0.53	0.71	0.62	0.9	1	1	1	1	1
1987	0	0.01	0.07	0.18	0.22	0.46	0.5	0.75	1	1	1	1	1

Year_age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**+gp**
1988	0	0.02	0.05	0.33	0.53	0.62	1	1	1	1	1	1	1
1989	0.008	0.003	0.029	0.228	0.547	0.705	0.915	1	1	1	1	1	1
1990	0.008	0.013	0.051	0.21	0.522	0.715	0.905	0.975	1	1	1	1	1
1991	0.001	0.032	0.075	0.305	0.708	0.861	0.957	1	1	1	1	1	1
1992	0.001	0.014	0.145	0.419	0.8	0.943	0.974	1	1	1	1	1	1
1993	0	0.028	0.087	0.368	0.704	0.931	0.972	0.994	1	1	1	1	1
1994	0	0.005	0.119	0.336	0.583	0.876	0.965	0.99	1	1	1	1	1
1995	0	0.005	0.06	0.373	0.614	0.748	0.955	0.98	1	1	1	1	1
1996	0	0	0.016	0.252	0.619	0.817	0.975	1	1	1	1	1	1
1997	0	0	0.014	0.14	0.597	0.842	0.95	0.967	1	1	1	1	1
1998	0	0.005	0.031	0.168	0.468	0.828	0.956	0.98	1	1	1	1	1
1999	0	0.001	0.014	0.17	0.506	0.841	0.961	1	1	1	1	1	1
2000	0	0	0.066	0.261	0.699	0.872	0.978	1	1	1	1	1	1
2001	0.001	0.006	0.069	0.378	0.646	0.851	0.955	1	1	1	1	1	1
2002	0.001	0.015	0.085	0.412	0.695	0.846	0.97	1	1	1	1	1	1
2003	0.001	0	0.089	0.331	0.662	0.882	0.96	1	1	1	1	1	1
2004	0	0.009	0.092	0.438	0.728	0.883	0.973	0.974	1	1	1	1	1
2005	0	0.003	0.066	0.366	0.72	0.897	0.971	0.991	1	1	1	1	1
2006	0	0.015	0.061	0.367	0.633	0.907	0.961	1	1	1	1	1	1
2007	0	0.007	0.076	0.37	0.719	0.884	0.977	1	1	1	1	1	1
2008	0.005	0.008	0.082	0.309	0.539	0.869	0.928	0.994	1	1	1	1	1
2009	0	0	0.081	0.362	0.745	0.859	0.978	0.997	0.994	1	1	1	1
2010	0.005	0.006	0.06	0.335	0.552	0.838	0.931	0.971	0.983	1	1	1	1
2011	0	0	0.04	0.339	0.644	0.798	0.932	0.963	0.991	1	1	1	1
2012	0.001	0	0.058	0.209	0.544	0.799	0.93	0.967	0.99	1	1	1	1
2013	0	0	0.01	0.156	0.482	0.763	0.913	0.982	0.985	1	1	1	1
2014	0	0	0.025	0.137	0.516	0.806	0.935	0.984	0.996	1	1	1	1
2015	0	0.001	0.004	0.074	0.282	0.681	0.891	0.963	0.984	1	1	1	1
2016	0	0	0.002	0.057	0.256	0.569	0.832	0.955	0.984	1	1	1	1

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
2017	0	0.018	0.003	0.148	0.463	0.749	0.931	0.99	1	1	1	1	1
2018	0	0.003	0.028	0.207	0.478	0.731	0.916	0.971	1	1	1	1	1
2019	0	0	0.01	0.126	0.466	0.842	0.942	0.968	0.996	1	1	1	1
2020	0	0	0.014	0.116	0.361	0.775	0.904	0.955	1	1	1	1	1
2021	0.002	0.002	0.006	0.142	0.393	0.66	0.889	0.976	0.957	1	1	1	1

Table 3.12. The Northeast Arctic cod stock's consumption of cod in million individuals

Year/age	0	1	2	3	4	5	6
1984	0.000	444.793	22.421	0.216	0.000	0.000	0.000
1985	1646.300	356.452	71.610	0.197	0.000	0.000	0.000
1986	69.788	1140.065	344.772	87.575	0.000	0.000	0.000
1987	655.229	195.917	328.064	14.440	0.000	0.000	0.000
1988	32.232	486.338	26.522	1.792	0.000	0.000	0.000
1989	947.615	142.107	0.000	0.000	0.000	0.000	0.000
1990	0.000	108.740	23.196	0.000	0.000	0.000	0.000
1991	118.655	137.811	180.868	1.609	0.000	0.000	0.000
1992	3136.027	893.837	143.253	4.174	0.000	0.000	0.000
1993	3882.321	18273.196	479.941	46.584	1.309	0.421	0.000
1994	7994.069	7030.331	650.414	130.088	49.798	7.935	0.413
1995	8215.712	14883.942	759.195	211.397	67.146	3.744	0.224
1996	10359.897	22194.437	1478.602	136.428	52.697	18.476	1.071
1997	3087.255	18165.901	1907.141	165.772	15.725	1.222	0.221
1998	93.616	5782.534	583.122	205.385	23.515	1.463	0.468
1999	638.847	2124.668	305.355	50.820	4.202	0.004	0.000
2000	1921.393	2561.048	188.889	38.444	14.001	3.845	0.042
2001	94.522	2397.127	114.550	23.796	11.630	1.792	0.916
2002	7579.447	456.386	404.318	41.309	5.324	0.808	0.017
2003	5392.632	4114.100	107.429	24.114	0.000	0.000	0.000
2004	6492.720	2413.993	566.424	20.453	10.459	1.325	0.226
2005	2471.254	3030.736	133.376	80.275	4.557	5.527	0.514

Year/age	0	1	2	3	4	5	6
2006	3295.083	2131.960	150.936	6.290	2.030	0.075	0.000
2007	2286.367	1149.305	189.571	74.677	3.445	0.128	0.000
2008	14254.749	695.971	85.770	96.946	32.044	4.240	0.000
2009	9501.679	7295.908	142.051	66.490	20.599	5.123	0.219
2010	4125.979	7084.630	299.399	53.694	27.910	16.915	2.242
2011	12413.114	4396.901	450.706	172.425	40.771	10.781	5.150
2012	21166.208	11742.803	1014.087	101.931	30.845	4.365	0.000
2013	26858.477	4925.670	1572.174	174.858	16.890	7.507	1.132
2014	36285.134	6154.893	732.616	195.070	53.208	5.174	0.064
2015	1541.100	10561.520	307.344	68.247	39.793	16.841	1.659
2016	11871.321	2539.152	501.568	11.974	18.726	27.386	6.464
2017	22048.064	1596.572	388.184	116.690	8.031	4.421	3.029
2018	7446.421	14075.658	279.208	35.827	2.239	0.269	0.000
2019	858.743	8725.376	853.377	55.002	5.824	0.019	0.000
2020	4375.080	3074.313	356.638	150.881	45.899	11.701	0.605

Table 3.13. Northeast Arctic cod. Tuning data.

North-East Arctic cod (Sub-areas I and II) (run name: XSAASA01)										
104										
FLT15_I: NorBarTrSur_I										
1981	2021									
1	1	0.085	0.189							
3	12									
1	1640	2330	4000	3840	480	100	30	NA	NA	NA
1	2830	2770	2360	1550	1600	140	20	NA	NA	NA
1	2495	5234	4333	1696	582	321	97	NA	NA	NA
1	9749	2828	2144	1174	407	40	8	NA	NA	NA
1	16679	12598	1992	767	334	21	7	NA	NA	NA
1	80500	14393	6414	830	191	34	4	NA	NA	NA
1	24038	39115	5435	1570	200	45	3	NA	NA	NA
1	14803	8049	17331	2048	358	53	3	NA	NA	NA
1	4636	7586	3779	9019	982	94	10	NA	NA	NA
1	2835	3487	3459	2056	2723	161	38	NA	NA	NA
1	4585	3367	2565	2149	1215	1267	61	NA	NA	NA
1	15826	5771	1782	1283	767	429	272	NA	NA	NA
1	27389	14013	7248	1583	624	389	223	NA	NA	NA
1	29392	30704	15333	4572	795	261	148	55	55	13
1	28284	24236	25101	7642	1798	242	107	50	61	19
1	16308	11743	13859	10888	2443	264	37	17	12	16
1	31799	6844	7426	5999	2667	485	64	91	8	NA
1	35510	16694	3167	2615	1752	816	79	52	4	4
1	18848	18075	6139	1271	681	514	101	26	2	6
1	24581	13003	11173	2675	456	184	121	33	10	5
1	18279	19511	8290	3796	945	117	44	19	4	1
1	11836	13756	10895	4579	1440	220	32	18	5	2
1	37670	12631	9393	6688	1750	467	102	17	4	4
1	6388	18462	5346	4324	3059	685	165	28	7	2
1	24888	5506	10297	2238	1636	381	92	30	4	10
1	11649	11538	2832	4342	1372	524	136	24	18	18
1	36113	12773	6851	1365	2360	682	230	41	11	10
1	19437	30059	11190	4024	1734	811	179	36	3	3
1	12628	19670	22023	6069	1790	902	524	51	17	7
1	3681	11425	15480	14450	3956	1124	367	160	58	12
1	8540	5037	12970	13866	10351	1637	436	120	82	39
1	7572	6459	3371	9069	13258	4861	902	226	88	111
1	6884	11409	6318	4043	6454	7638	3352	222	287	84
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FLT15_II: NorBarTrSur_II										
2014	2021									
1	1	0.085	0.189							
3	12									
1	22685	9379	8859	5639	3274	5305	3619	981	101	120
1	14407	22825	14729	11353	7443	2922	5351	1808	338	98
1	9937	13548	18831	11347	7233	2856	1317	1606	677	180
1	17925	6215	8454	9016	3782	2633	818	326	261	451
1	13941	18478	6181	6417	7388	2588	928	587	129	419
1	28157	17915	22190	7965	3296	3831	815	262	54	70
1	23773	16024	13156	11488	4983	2426	2044	453	166	243
1	11474	12073	11355	5471	4034	1424	816	406	143	45

FLT16: NorBarLofAcSur										
1985		2021								
1	1	0.085	0.26							
3	12									
1	1530	1416	204	151	157	33	13	10	5	NA
1	4996	1343	684	116	77	31	3	NA	4	NA
1	628	2049	502	174	14	30	7	NA	NA	NA
1	504	355	578	109	40	3	0	1	NA	NA
1	170	344	214	670	166	32	5	2	NA	NA
1	148	206	262	269	668	73	6	3	NA	NA
1	502	346	293	339	367	500	37	2	2	NA
1	1765	658	215	184	284	254	824	43	17	NA
1	3572	1911	1131	354	255	252	277	442	49	NA
1	3239	3745	2293	961	234	118	103	42	187	29
1	1377	1395	2036	1016	281	47	45	29	26	81
1	994	896	1128	974	462	59	11	4	9	15
1	1586	442	503	459	510	215	23	7	1	8
1	3912	1898	449	415	349	271	51	10	2	1
1	1476	1303	523	139	118	187	99	10	2	1
1	2948	1673	1492	546	146	69	50	13	6	2
1	1774	1606	851	621	191	27	8	6	3	1
1	614	1062	1011	713	366	94	12	8	6	0
1	3067	1168	1271	1461	677	235	38	4	1	2
1	334	852	349	456	480	217	88	24	2	7
1	1250	333	693	341	438	180	75	18	1	3
1	648	538	186	420	176	159	87	23	3	10
1	585	304	308	129	466	151	80	33	9	4
1	1999	2887	1166	789	248	352	55	28	17	7
1	1078	1825	1415	560	415	128	266	36	17	4
1	228	880	1614	1750	618	314	108	125	40	29
1	404	283	674	1595	2727	645	233	68	75	9
1	828	494	344	895	2266	1335	257	104	38	28
1	606	845	724	541	1336	2338	1617	215	111	88
1	2869	1242	1115	777	553	1490	1739	980	146	105
1	1387	2356	1300	1442	964	498	969	686	325	127
1	563	769	1199	664	594	409	356	565	344	286
1	1115	424	444	742	486	484	268	167	146	230
1	1090	1499	540	584	775	456	193	141	61	137
1	2036	1254	1446	639	493	739	273	218	65	111
1	1173	1173	819	943	506	509	495	195	84	80
1	700	648	528	389	370	155	119	146	82	34

FLT18: RusSweptArea										
1982	2020									
1	1	0.9	1							
3	12									
1	1413	1525	721	198	551	174	37	19	15.1	1.5
1	520	642	506	358	179	252	94	NA	NA	NA
1	1189	700	489	357	154	69	61	17	14.6	7.4
1	1188	1592	1068	365	165	37	8	16	1.5	20.9
1	1622	1532	1493	481	189	42	2	6	NA	NA
1	557	3076	900	701	184	60	25	4	0.7	3.3
1	993	938	2879	583	260	47	24	NA	NA	NA
1	490	978	1062	1454	1167	299	112	47	18.5	11.7
1	167	487	627	972	1538	673	153	49	9.1	1.7
1	1077	484	532	583	685	747	98	14	2.6	NA
1	675	308	239	273	218	175	25	25	4	0.1
1	1604	1135	681	416	354	87	3	7	0.6	0.7
1	1363	1309	1019	354	128	49	21	11	5.7	2.2
1	589	1065	1395	849	251	83	19	18	9.5	5.8
1	733	784	1035	773	348	132	19	5	12	1.6
1	1342	835	613	602	348	116	32	30	NA	NA
1	2028	1363	788	470	259	130	48	5	NA	0.9
1	1587	2072	980	301	123	94	42	4	NA	NA
1	1839	1286	1786	773	114	52	23	9	3.9	0.4
1	1224	1557	1290	1061	304	50	14	5	25.4	13.1
1	980	1473	1473	896	600	182	29	8	0.8	0.5
1	1246	1057	1166	1203	535	241	40	9	3.1	1.1
1	329	1576	880	1111	776	279	93	23	3.6	2.5
1	1408	631	1832	744	605	244	88	28	6.4	1.1
1	927	1613	777	1801	662	342	161	43	17.5	7.4
1	2579	1617	1903	846	1525	553	226	86	49	18.5
1	2203	3088	1635	1472	830	863	291	115	33	19
1	974	2317	3687	2016	1175	620	413	205	65	41
1	334	1070	2505	3715	1817	789	395	299	155.9	75.2
1	882	508	1432	3065	3300	917	439	176	175.5	105.4
1	815	1114	839	2122	3358	1878	432	195	45.7	76.3
1	747	1174	1177	884	2349	3132	1367	306	92.4	98.5
1	1399	1368	1725	1483	1111	1929	1297	383	93.4	55.1
1	657	1583	1742	1932	1610	925	1158	761	241.6	113.6
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	1456	884	1063	1952	1231	567	266	120	119.8	103.8
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FLT007: Ecosystem_2018corr										
2004	2020									
1	1	0.65	0.75							
3	12									
1	1477	4215	1502	798	402	101	22	5	1.3	2
1	2166	558	1009	280	156	57	12	5	1.2	0.5
1	1861	2056	599	698	176	81	26	6	2.5	0.4
1	5862	1592	791	246	269	60	22	9	1.5	2.4
1	6526	4834	1323	511	128	175	33	9	2.3	3.9
1	2023	2806	2896	1017	319	127	73	26	8.1	5.1
1	568	1770	3972	4249	1427	385	105	68	15.9	6.2
1	1236	1015	2402	3004	1784	323	77	18	13.4	8.7
1	2291	1464	700	1508	1652	845	127	44	15.5	20.8
1	2491	1836	1257	632	1182	1302	538	91	33.2	24.6
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	1744	2252	1413	726	486	262	353	266	78.7	27
1	772	937	1216	701	444	272	138	132	54.2	30.2
1	3750	1415	1049	1209	626	280	112	64	44.5	71.7
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	4166	2323	2151	766	422	444	161	49	21.9	29.5
1	1337	1343	986	796	316	157	114	29	11.1	11.2

Table 3.14. Parameters settings used in SAM run.

```
$minAge
# The minimium age class in the assessment
 3
$maxAge
# The maximum age class in the assessment
 15
$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
 1 1 1 1 1 1
$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
  0  1  2  3  4  5  6  7  8  9 10 11 11
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, or 2 AR(1)
 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 -1 -1 -1 -1
  0  1  2  3  4  5  6  7  8  8 -1 -1 -1
  9 10 11 12 13 14 15 16  17 17 -1 -1 -1
 18 19 20 21 22 23 24 25 26 26 -1 -1 -1
 27 28 29 30 31 32 33 34 35 35 -1 -1 -1
 36 37 38 39 40 41 42 43 44 44 -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 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only first row is used)
  0  1  1  1  1  1  1  1  1  1  1  1  1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1 1 1 1 1
$keyVarObs
# Coupling of the variance parameters for the observations.
  0  1  2  2  2  2  2  2  3  3  4  4  4
  5  6  6  6  6  7  7  7  7  7 -1 -1 -1
```

```
  5  6  6  6  6  7  7  7  7  7 -1  -1  -1
  8  8  8  8  8  8  9  9  9  9 -1  -1  -1
 10  10  10  10  10  10  11  11  11  11  -1  -1  -1
 12  12  12  12  12  12  12  12  12  12  -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" "AR" "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).
#3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 13-14 14-15
NA NA NA NA NA NA NA NA NA NA NA NA
0 0 0 0 1 1 2 2 3 -1 -1 -1
0 0 0 0 1 1 2 2 3 -1 -1 -1
4 4 4 5 6 6 6 7 8 -1 -1 -1
9 9 9 9 9 10 10 10 11 -1 -1 -1
12 12 12 13 13 13 14 14 15 -1 -1 -1
$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for Beverton–Holt).
 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 10
$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, and 2 FSB index).
 -1 -1 -1 -1 -1 -1
$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN" "LN" "LN"
$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight, 1 fix variance to weight).
 0
```

Table 3.15. Northeast Arctic cod. Fishing mortality

`SAM, Apr 17 21:10:25 2021`

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	FBAR5–10
1946	0.003	0.020	0.070	0.138	0.273	0.250	0.381	0.397	0.575	0.563	0.627	0.647	0.647	0.251
1947	0.002	0.021	0.091	0.188	0.388	0.295	0.451	0.447	0.692	0.635	0.689	0.782	0.782	0.310
1948	0.001	0.022	0.096	0.220	0.463	0.346	0.511	0.451	0.713	0.694	0.742	0.923	0.923	0.348
1949	0.002	0.030	0.139	0.301	0.472	0.366	0.460	0.477	0.771	0.751	0.788	1.029	1.029	0.369
1950	0.002	0.043	0.165	0.315	0.437	0.363	0.480	0.538	0.837	0.854	0.816	1.150	1.150	0.383
1951	0.009	0.078	0.231	0.344	0.446	0.392	0.496	0.567	0.781	0.866	0.841	1.198	1.198	0.413
1952	0.014	0.103	0.276	0.429	0.476	0.408	0.522	0.638	0.842	0.919	0.844	1.199	1.199	0.458
1953	0.020	0.112	0.251	0.360	0.404	0.374	0.474	0.613	0.813	0.824	0.799	1.020	1.020	0.413
1954	0.017	0.116	0.267	0.384	0.424	0.359	0.490	0.707	0.832	0.823	0.790	0.929	0.929	0.438
1955	0.015	0.108	0.294	0.492	0.496	0.508	0.565	0.750	0.895	0.866	0.791	0.862	0.862	0.518
1956	0.018	0.122	0.348	0.578	0.557	0.596	0.588	0.739	0.892	0.985	0.825	0.804	0.804	0.568
1957	0.021	0.137	0.293	0.529	0.547	0.586	0.536	0.675	0.880	0.914	0.822	0.719	0.719	0.528
1958	0.035	0.181	0.360	0.544	0.540	0.512	0.509	0.693	0.829	0.880	0.721	0.631	0.631	0.526
1959	0.035	0.202	0.425	0.525	0.527	0.529	0.552	0.722	0.788	0.802	0.708	0.644	0.644	0.547
1960	0.036	0.211	0.407	0.511	0.496	0.548	0.526	0.756	0.854	0.803	0.698	0.712	0.712	0.541
1961	0.038	0.225	0.489	0.577	0.547	0.644	0.696	0.850	0.897	0.863	0.742	0.749	0.749	0.634
1962	0.036	0.224	0.580	0.745	0.631	0.683	0.795	1.007	0.935	0.845	0.775	0.738	0.738	0.740

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	FBAR5–10
1963	0.024	0.194	0.580	0.793	0.752	0.770	0.891	1.078	1.077	0.850	0.802	0.735	0.735	0.811
1964	0.019	0.160	0.413	0.554	0.584	0.697	0.932	0.883	0.976	0.802	0.881	0.756	0.756	0.677
1965	0.023	0.144	0.366	0.461	0.474	0.590	0.786	0.799	0.806	0.671	0.891	0.759	0.759	0.579
1966	0.031	0.141	0.290	0.390	0.470	0.601	0.754	0.791	0.715	0.655	0.799	0.675	0.675	0.549
1967	0.029	0.155	0.267	0.332	0.466	0.640	0.829	0.812	0.771	0.665	0.793	0.610	0.610	0.558
1968	0.025	0.176	0.355	0.433	0.497	0.635	0.848	0.833	0.749	0.601	0.800	0.631	0.631	0.600
1969	0.026	0.182	0.402	0.480	0.627	0.811	1.005	0.922	0.834	0.631	0.757	0.621	0.621	0.708
1970	0.034	0.165	0.376	0.466	0.587	0.822	0.996	0.933	0.796	0.578	0.713	0.631	0.631	0.697
1971	0.031	0.156	0.308	0.357	0.504	0.807	0.981	0.920	0.802	0.605	0.691	0.617	0.617	0.646
1972	0.051	0.184	0.335	0.404	0.430	0.719	1.054	1.010	0.894	0.652	0.746	0.636	0.636	0.659
1973	0.132	0.226	0.387	0.441	0.462	0.701	0.919	0.861	0.846	0.674	0.757	0.621	0.621	0.628
1974	0.158	0.296	0.480	0.520	0.511	0.627	0.672	0.868	0.910	0.715	0.893	0.629	0.629	0.613
1975	0.115	0.276	0.506	0.620	0.640	0.731	0.726	0.731	0.936	0.778	0.953	0.598	0.598	0.659
1976	0.142	0.306	0.529	0.615	0.685	0.851	0.876	0.677	0.799	0.821	0.942	0.675	0.675	0.705
1977	0.128	0.333	0.629	0.677	0.707	0.899	1.125	0.858	0.897	0.810	1.052	0.810	0.810	0.816
1978	0.110	0.253	0.567	0.733	0.765	0.892	1.215	0.945	1.297	1.005	1.201	0.916	0.916	0.853
1979	0.056	0.202	0.410	0.622	0.711	0.805	1.093	0.991	1.290	1.093	1.126	1.008	1.008	0.772
1980	0.038	0.158	0.346	0.628	0.724	0.811	1.000	1.055	1.226	0.996	1.162	0.906	0.906	0.761

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	FBAR5–10
1981	0.032	0.142	0.284	0.583	0.785	0.969	1.159	0.974	1.069	0.937	1.045	0.835	0.835	0.792
1982	0.040	0.158	0.287	0.644	0.841	0.917	1.131	0.829	0.823	0.924	0.866	0.823	0.823	0.775
1983	0.027	0.163	0.300	0.551	0.905	1.077	1.068	0.847	0.715	0.727	0.802	0.867	0.867	0.791
1984	0.024	0.155	0.330	0.583	1.057	1.167	1.166	0.898	0.747	0.703	0.671	0.893	0.893	0.867
1985	0.037	0.160	0.388	0.667	0.944	1.146	0.936	0.783	0.760	0.656	0.594	0.951	0.951	0.810
1986	0.031	0.169	0.452	0.762	0.910	1.137	0.931	1.041	0.887	0.850	0.587	1.074	1.074	0.872
1987	0.038	0.153	0.466	0.820	1.010	1.110	0.896	1.244	0.975	0.997	0.636	1.257	1.257	0.924
1988	0.034	0.126	0.334	0.637	0.928	1.015	1.023	1.344	0.955	0.912	0.729	1.213	1.213	0.880
1989	0.030	0.106	0.253	0.460	0.642	0.827	0.818	0.996	0.752	0.709	0.696	1.428	1.428	0.666
1990	0.020	0.093	0.180	0.312	0.420	0.500	0.552	0.593	0.652	0.612	0.625	1.308	1.308	0.426
1991	0.020	0.102	0.214	0.346	0.437	0.473	0.506	0.485	0.497	0.594	0.571	1.261	1.261	0.410
1992	0.024	0.114	0.281	0.430	0.529	0.556	0.566	0.560	0.518	0.700	0.540	1.251	1.251	0.487
1993	0.014	0.110	0.316	0.523	0.617	0.659	0.692	0.709	0.688	0.824	0.678	1.224	1.224	0.586
1994	0.012	0.109	0.322	0.597	0.920	0.915	0.869	0.849	0.907	0.931	0.778	1.210	1.210	0.745
1995	0.014	0.116	0.323	0.607	0.929	0.896	0.946	0.921	1.004	0.961	0.858	1.122	1.122	0.770
1996	0.021	0.133	0.352	0.619	0.887	0.938	0.857	1.096	0.959	0.961	0.928	1.029	1.029	0.791
1997	0.022	0.167	0.444	0.682	0.899	1.200	1.125	1.262	1.027	1.017	0.924	0.936	0.936	0.935
1998	0.026	0.179	0.470	0.708	0.857	1.162	1.133	1.306	1.049	0.895	0.829	0.785	0.785	0.939

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	FBAR5–10
1999	0.015	0.148	0.459	0.679	0.870	1.102	1.217	1.291	0.951	0.879	0.688	0.692	0.692	0.937
2000	0.009	0.114	0.362	0.585	0.832	1.019	1.105	1.180	0.841	0.894	0.547	0.672	0.672	0.847
2001	0.009	0.096	0.294	0.531	0.754	0.924	0.887	1.045	0.727	0.762	0.436	0.702	0.702	0.739
2002	0.008	0.091	0.277	0.520	0.772	0.882	0.833	0.784	0.619	0.721	0.382	0.660	0.660	0.678
2003	0.010	0.089	0.285	0.474	0.726	0.808	0.770	0.728	0.559	0.621	0.353	0.624	0.624	0.632
2004	0.010	0.090	0.294	0.500	0.761	0.851	0.886	0.920	0.617	0.657	0.332	0.519	0.519	0.702
2005	0.011	0.102	0.319	0.516	0.731	0.859	0.939	0.860	0.649	0.719	0.330	0.463	0.463	0.704
2006	0.016	0.102	0.282	0.441	0.613	0.731	0.788	0.763	0.654	0.740	0.352	0.538	0.538	0.603
2007	0.017	0.091	0.241	0.348	0.446	0.538	0.553	0.515	0.626	0.718	0.359	0.456	0.456	0.440
2008	0.011	0.070	0.163	0.276	0.367	0.444	0.477	0.429	0.573	0.669	0.369	0.369	0.369	0.359
2009	0.010	0.058	0.133	0.222	0.316	0.353	0.453	0.361	0.519	0.716	0.404	0.312	0.312	0.306
2010	0.009	0.050	0.108	0.179	0.279	0.375	0.389	0.411	0.582	0.586	0.456	0.284	0.284	0.290
2011	0.006	0.049	0.107	0.162	0.254	0.350	0.439	0.521	0.544	0.491	0.442	0.230	0.230	0.305
2012	0.007	0.047	0.120	0.162	0.241	0.324	0.413	0.472	0.526	0.453	0.414	0.220	0.220	0.289
2013	0.007	0.048	0.123	0.191	0.269	0.360	0.439	0.502	0.539	0.457	0.392	0.239	0.239	0.314
2014	0.008	0.054	0.143	0.230	0.313	0.391	0.413	0.499	0.580	0.496	0.398	0.251	0.251	0.331
2015	0.010	0.056	0.151	0.270	0.324	0.394	0.360	0.487	0.722	0.563	0.415	0.264	0.264	0.331
2016	0.009	0.052	0.149	0.259	0.340	0.417	0.403	0.534	0.815	0.622	0.449	0.283	0.283	0.350

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	FBAR5–10
2017	0.010	0.057	0.152	0.272	0.355	0.475	0.471	0.577	0.890	0.701	0.485	0.290	0.290	0.384
2018	0.011	0.059	0.158	0.265	0.362	0.457	0.514	0.637	0.891	0.779	0.514	0.282	0.282	0.399
2019	0.009	0.061	0.155	0.251	0.361	0.482	0.510	0.691	0.856	0.819	0.508	0.259	0.259	0.409
2020	0.009	0.060	0.157	0.266	0.377	0.480	0.539	0.785	0.877	0.845	0.526	0.241	0.241	0.434
FBAR	0.010	0.060	0.157	0.261	0.367	0.473	0.521	0.705	0.874	0.814	0.516	0.260		

Table 3.16. Northeast Arctic COD Stock number-at-age (Thous)

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Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTAL
1946	1135788	673447	368922	170374	77540	84044	226764	80614	36008	30581	18809	8088	1995	2912974
1947	581941	678173	497718	297877	133287	53334	56210	132717	45802	17371	14681	8420	4520	2522053
1948	438495	333453	461332	345543	207140	75302	34966	29882	69604	18393	7666	6094	4977	2032846
1949	625699	286421	262850	354740	228994	104145	42883	16916	15958	28246	7428	3005	3612	1980897
1950	1026289	394679	228003	186847	208567	114717	57072	22790	8661	6120	11093	2733	1943	2269514
1951	2445052	784058	311246	176855	114626	111071	65970	28196	10895	2982	2093	4041	1193	4058279
1952	2343271	1142862	464111	190263	115912	61757	61091	33261	13115	4216	1025	729	1281	4432893
1953	2420871	1121669	640545	245343	90633	60007	33121	28491	13939	4520	1346	356	477	4661318
1954	831333	1392086	712164	387865	137794	48657	34604	17296	12911	5053	1646	496	245	3582150
1955	383557	550030	925137	436299	224114	75104	30519	18117	6934	4698	1836	617	240	2657200

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTAL
1956	746609	245807	396250	552943	212676	113018	35671	14606	7032	2276	1660	691	298	2329537
1957	1428442	404735	150540	208923	238721	95088	49172	15386	5685	2358	663	596	362	2600672
1958	937440	718081	249267	95707	100297	109295	40956	23285	6418	1910	780	227	381	2284045
1959	1314694	488736	429677	141032	47114	47559	54793	20164	9515	2297	638	320	267	2556806
1960	1483389	627007	253277	207775	69312	23040	22893	25307	8034	3645	862	256	262	2725059
1961	1554485	709902	348968	134231	102448	36312	11334	12013	9795	2782	1376	361	209	2924217
1962	1252375	815845	393065	169388	64401	49190	15644	4561	4402	3275	939	542	221	2773848
1963	900621	703227	457805	166536	63099	28906	20764	5767	1329	1471	1160	350	301	2351334
1964	468028	409336	369099	179312	54937	21672	10588	6928	1522	350	516	433	257	1522980
1965	870506	247989	258463	199920	82930	23755	8202	3221	2390	451	122	172	266	1698388
1966	1842715	561254	165004	144335	106213	44039	10938	3045	1178	896	192	39	163	2880008
1967	1311586	1272325	393425	105077	80211	55301	20428	4374	1136	491	389	73	81	3244897
1968	183717	1018021	892662	279468	72002	42107	23711	7293	1616	422	206	146	70	2521442
1969	110450	138283	707101	496680	154885	41113	19617	8553	2640	651	194	74	95	1680337
1970	205641	85642	88050	370860	238713	64528	15127	5826	2766	914	280	75	75	1078498
1971	402577	144737	57585	45157	174681	103435	22571	4586	1860	1030	428	113	65	958827
1972	1045979	311616	104639	37160	27113	81739	36156	6982	1532	695	466	181	80	1654337
1973	1723668	750447	211782	63601	21142	15821	32389	9738	1983	500	296	179	114	2831661

Year_age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**+gp**	**TOTAL**
1974	568211	1214867	516750	122967	35281	11274	6597	10173	3410	702	207	118	131	2490686
1975	608710	366545	672580	258926	61634	18442	5346	3066	3305	1119	284	68	109	2000136
1976	607084	445875	227168	312094	108601	26058	7495	2258	1301	999	417	88	82	1739520
1977	372778	419035	274357	112989	137148	43331	8842	2624	1045	526	345	136	73	1373231
1978	622679	247732	219663	112822	47653	55821	14045	2251	894	385	210	98	77	1324331
1979	202675	447989	155327	90932	40844	17647	18418	3270	697	186	116	51	57	978210
1980	130292	155113	301715	87258	39247	16093	6536	5042	981	155	48	32	31	742541
1981	143781	102417	112595	174252	38040	15670	6029	2074	1396	231	47	12	21	596563
1982	183737	126101	83645	63342	81754	15284	4648	1517	643	379	74	13	11	561149
1983	141514	137439	92475	51860	28732	28260	4910	1238	567	230	118	26	9	487379
1984	442251	115561	83599	54108	24608	10641	7719	1353	440	242	95	41	12	740671
1985	534310	388889	82590	44867	24228	6361	2799	1912	437	166	101	41	18	1086720
1986	1374917	406832	245743	46587	19122	7407	1598	1009	750	176	73	47	19	2104281
1987	360087	1009632	257001	109705	16499	6823	1787	574	287	255	62	35	19	1762766
1988	335536	239626	593614	118643	32964	5027	1739	625	135	90	73	27	12	1328112
1989	157635	228475	147532	302747	55094	9930	1484	487	126	41	29	27	10	903617
1990	130130	128201	128716	94933	140107	22887	2904	533	138	48	16	11	7	648632
1991	295846	126093	97490	85560	61507	81244	11439	1372	247	54	22	7	4	760886

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTAL
1992	715916	270862	100817	69005	48560	33859	46245	6076	805	133	25	10	3	1292314
1993	988150	502301	241460	72845	36842	23486	15481	23997	3045	435	58	13	3	1908114
1994	752473	732759	400196	146966	39199	15936	10658	6384	9849	1329	161	24	4	2115938
1995	539384	492484	525039	231641	63093	12523	5319	3437	2212	3253	425	61	7	1878879
1996	407389	304466	337308	282239	103864	19865	4296	1585	1117	619	1025	147	18	1463938
1997	785420	210434	206036	183000	119806	37428	6317	1650	440	337	193	333	48	1551443
1998	1063528	478552	127601	98021	70895	41547	9524	1628	357	132	95	61	120	1892061
1999	632034	604809	264985	62522	32893	26006	11636	2528	347	98	46	33	68	1638006
2000	749727	409959	377210	122447	24444	11220	7403	2651	586	109	33	19	41	1705849
2001	593152	533789	291155	184584	51933	8998	3404	1928	666	201	35	15	26	1669888
2002	374202	430656	367941	186135	82158	20377	3116	1183	564	251	79	19	17	1466696
2003	756675	287667	287454	235160	84302	30316	6773	1146	445	265	97	46	15	1690360
2004	242069	575263	214309	182400	116317	33942	10973	2652	493	228	128	55	26	1378854
2005	693264	185631	405774	136165	94377	39206	11221	4008	856	215	100	81	40	1570938
2006	536630	467590	141119	231818	68923	34127	13728	3396	1376	381	85	62	70	1499304
2007	1243906	436976	304344	89000	120464	30519	12712	4646	1209	583	152	48	65	2244624
2008	1002761	966398	334693	167959	53182	63401	15804	5785	2011	553	226	88	58	2612919
2009	581758	786082	737615	248496	89681	33914	29121	8114	3156	975	239	126	83	2519359

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp	TOTAL
2010	201832	453844	646771	548012	169178	54809	19264	15054	4798	1687	374	134	126	2115883
2011	358117	181500	377832	534262	390226	86933	32026	10888	8445	2131	810	181	159	1983510
2012	503017	275696	146709	315471	407162	221596	45594	16568	5538	4053	1073	437	218	1943135
2013	464921	369325	226090	129011	243287	267395	138031	24018	8977	2638	2122	582	449	1876846
2014	852202	357736	297268	182017	102626	172079	150135	67574	11880	4149	1345	1174	673	2200859
2015	452019	573369	300103	213797	133367	68981	99660	77937	32181	5620	2027	734	1180	1960976
2016	286334	316470	418548	215227	136866	77503	45139	55725	36725	12607	2621	1086	1200	1606049
2017	781901	241199	228531	287358	147649	79492	41832	25192	24806	13661	5536	1368	1381	1879906
2018	508296	547174	190157	161562	188440	87140	40741	22286	11459	8106	5456	2743	1620	1775181
2019	659091	378054	394365	152320	94700	110096	46911	20048	9548	3862	2946	2581	2523	1877045
2020	572413	443253	285668	249747	104606	58411	58219	22301	8816	3250	1394	1444	3015	1812537
2021		388172	326358	188432	145279	56170	30322	27549	8734	2939	1133	671	2805	1661419

Table 3.17. Northeast Arctic cod. Natural mortality used in final run

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Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1946	0.490	0.304	0.226	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1947	0.544	0.325	0.231	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1948	0.493	0.305	0.226	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1949	0.434	0.282	0.221	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1950	0.316	0.236	0.210	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1951	0.724	0.394	0.247	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1952	0.715	0.391	0.246	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1953	0.537	0.322	0.230	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1954	0.388	0.264	0.217	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1955	0.406	0.271	0.218	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1956	0.590	0.342	0.235	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1957	0.725	0.395	0.247	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1958	0.562	0.332	0.232	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1959	0.713	0.390	0.246	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1960	0.704	0.387	0.245	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1961	0.609	0.350	0.237	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1962	0.520	0.315	0.229	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1963	0.788	0.419	0.253	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1964	0.603	0.348	0.236	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1965	0.416	0.275	0.219	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1966	0.353	0.250	0.214	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1967	0.271	0.219	0.206	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1968	0.224	0.201	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1969	0.206	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1970	0.293	0.227	0.208	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1971	0.256	0.213	0.205	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1972	0.323	0.239	0.211	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1973	0.217	0.200	0.201	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
1974	0.217	0.200	0.201	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1975	0.232	0.204	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1976	0.224	0.200	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1977	0.249	0.210	0.204	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1978	0.234	0.204	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1979	0.208	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1980	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1981	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1982	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1983	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1984	0.201	0.200	0.219	0.210	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1985	0.205	0.225	0.201	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1986	0.270	0.217	0.255	0.233	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1987	0.256	0.238	0.220	0.274	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1988	0.223	0.212	0.244	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1989	0.200	0.230	0.200	0.233	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1990	0.200	0.200	0.206	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1991	0.200	0.200	0.200	0.206	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1992	0.207	0.200	0.200	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1993	0.240	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1994	0.348	0.261	0.215	0.220	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1995	0.530	0.314	0.228	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1996	0.524	0.327	0.244	0.217	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1997	0.421	0.269	0.243	0.227	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1998	0.429	0.274	0.221	0.270	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1999	0.264	0.234	0.239	0.225	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2000	0.248	0.212	0.244	0.227	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2001	0.236	0.220	0.200	0.231	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2002	0.278	0.212	0.200	0.224	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Year_age	3	4	5	6	7	8	9	10	11	12	13	14	+gp
2003	0.239	0.200	0.200	0.211	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2004	0.250	0.215	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2005	0.298	0.212	0.214	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2006	0.203	0.228	0.200	0.206	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2007	0.247	0.200	0.247	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2008	0.258	0.213	0.200	0.232	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2009	0.274	0.208	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2010	0.296	0.234	0.206	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2011	0.422	0.312	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2012	0.380	0.300	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2013	0.394	0.235	0.204	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2014	0.370	0.294	0.212	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2015	0.356	0.262	0.235	0.204	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2016	0.216	0.256	0.265	0.215	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2017	0.399	0.218	0.213	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2018	0.276	0.215	0.200	0.215	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2019	0.303	0.222	0.220	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2020	0.415	0.231	0.213	0.216	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Table 3.18. Northeast Arctic cod. Summary table.

`SAM, Apr 17 21:10:26 2021`

Year	RECRUITS	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 5–10
1946	1135788	3922916	951257	706000	0.7422	0.2514
1947	581941	3382444	903002	882017	0.9768	0.3097
1948	438495	3346692	784808	774295	0.9866	0.348
1949	625699	2889457	595004	800122	1.3447	0.3691
1950	1026289	2789609	535963	731982	1.3657	0.3828
1951	2445052	3709628	494928	827180	1.6713	0.4128
1952	2343271	4137579	489062	876795	1.7928	0.458
1953	2420871	4106232	411896	695546	1.6886	0.4126

Year	RECRUITS	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 5–10
1954	831333	4208804	407928	826021	2.0249	0.4384
1955	383557	3545134	328216	1147841	3.4972	0.5175
1956	746609	3326386	281791	1343068	4.7662	0.5677
1957	1428442	2812873	212420	792557	3.7311	0.5276
1958	937440	2359384	205292	769313	3.7474	0.5262
1959	1314694	2727446	434170	744607	1.715	0.5466
1960	1483389	2353397	384244	622042	1.6189	0.5405
1961	1554485	2353878	386337	783221	2.0273	0.6338
1962	1252375	2180958	315428	909266	2.8826	0.7402
1963	900621	2012402	216372	776337	3.588	0.8105
1964	468028	1507547	200639	437695	2.1815	0.6771
1965	870506	1451326	108010	444930	4.1194	0.5792
1966	1842715	2213432	120906	483711	4.0007	0.5494
1967	1311586	2728486	128596	572605	4.4527	0.5576
1968	183717	3288929	222794	1074084	4.821	0.6001
1969	110450	2829574	149048	1197226	8.0325	0.7077
1970	205641	2167602	242300	933246	3.8516	0.6965
1971	402577	1657516	330605	689048	2.0842	0.6463
1972	1045979	1608552	353303	565254	1.5999	0.6589
1973	1723668	2279737	334009	792685	2.3732	0.6283
1974	568211	2188062	158889	1102433	6.9384	0.613
1975	608710	2094916	133446	829377	6.2151	0.6587
1976	607084	1943691	167169	867463	5.1891	0.7053
1977	372778	1937560	336183	905301	2.6929	0.8156
1978	622679	1589042	228078	698715	3.0635	0.8529
1979	202675	1137172	180492	440538	2.4408	0.7719
1980	130292	852518	108433	380434	3.5085	0.7605
1981	143781	963860	161314	399038	2.4737	0.7923
1982	183737	750840	321065	363730	1.1329	0.7748

Year	RECRUITS	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 5–10
1983	141514	747868	311275	289992	0.9316	0.7913
1984	442251	831178	243575	277651	1.1399	0.8671
1985	534310	1006525	195200	307920	1.5775	0.8104
1986	1374917	1409753	164255	430113	2.6186	0.872
1987	360087	1243086	115231	523071	4.5393	0.9244
1988	335536	1008678	191380	434939	2.2726	0.8801
1989	157635	953135	236896	332481	1.4035	0.6659
1990	130130	903703	300543	212000	0.7054	0.4261
1991	295846	1337457	631789	319158	0.5052	0.4101
1992	715916	1685490	801116	513234	0.6406	0.4867
1993	988150	2201357	700998	581611	0.8297	0.5859
1994	752473	2118586	571721	771086	1.3487	0.7453
1995	539384	1852971	534198	739999	1.3853	0.7702
1996	407389	1697469	550491	732228	1.3301	0.7914
1997	785420	1542345	545261	762403	1.3982	0.9353
1998	1063528	1360918	385646	592624	1.5367	0.9393
1999	632034	1207368	280650	484910	1.7278	0.9365
2000	749727	1227729	255508	414868	1.6237	0.8472
2001	593152	1478197	382986	426471	1.1135	0.7393
2002	374202	1594432	520717	535045	1.0275	0.678
2003	756675	1680492	570925	551990	0.9668	0.6318
2004	242069	1566989	665416	606445	0.9114	0.7019
2005	693264	1517099	578794	641276	1.108	0.7041
2006	536630	1541849	583476	537642	0.9214	0.6028
2007	1243906	1866680	650377	486883	0.7486	0.44
2008	1002761	2548331	721138	464171	0.6437	0.3593
2009	581758	3081618	1009877	523430	0.5183	0.3062
2010	201832	3325191	1241679	609983	0.4913	0.2901
2011	358117	3563773	1803005	719830	0.3992	0.3054

Year	RECRUITS	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 5–10
2012	503017	3644935	2022883	727663	0.3597	0.2886
2013	464921	3740027	2257041	966209	0.4281	0.3139
2014	852202	3480488	2153272	986449	0.4581	0.3312
2015	452019	3321906	1750900	864384	0.4937	0.3308
2016	286334	2898026	1407673	849422	0.6034	0.3504
2017	781901	2829945	1428859	868276	0.6077	0.3838
2018	508296	2631587	1286834	778627	0.6051	0.3989
2019	659091	2528242	1227414	692609	0.5643	0.4085
2020	572413	2248053	1004037	692903	0.6901	0.4342
Arith. Mean	740346	2223721	568086	672476	2.0335	0.5937

Table 3.19. Northeast Arctic cod. Input for the short-term prediction.

2021								
Age	**N**	**M**	**Mat**	**PF**	**PM**	**SWT**	**Sel**	**CWT**
3	561000	0.3313	0.002	0	0	0.175	0.011	0.755
4	388172	0.2227	0.002	0	0	0.440	0.064	1.086
5	326358	0.2110	0.006	0	0	0.972	0.170	1.603
6	188432	0.2103	0.142	0	0	1.755	0.290	2.289
7	145279	0.2	0.393	0	0	2.710	0.396	3.125
8	56170	0.2	0.660	0	0	3.865	0.509	4.346
9	30322	0.2	0.889	0	0	5.703	0.535	5.848
10	27549	0.2	0.976	0	0	7.448	0.705	7.017
11	8734	0.2	0.957	0	0	9.084	0.955	8.391
12	2939	0.2	1	0	0	11.187	0.825	10.002
13	1133	0.2	1	0	0	13.415	0.546	11.402
14	671	0.2	1	0	0	15.459	0.300	12.654
15	2805	0.2	1	0	0	17.159	0.300	13.958

2022								
Age	**N**	**M**	**Mat**	**PF**	**PM**	**SWT**	**Sel**	**CWT**
3	621000	0.3313	0.001	0	0	0.178	0.011	0.726
4		0.2227	0.001	0	0	0.466	0.064	1.132
5		0.2110	0.010	0	0	0.902	0.170	1.604
6		0.2103	0.128	0	0	1.618	0.290	2.288
7		0.2	0.407	0	0	2.709	0.396	3.219
8		0.2	0.759	0	0	3.991	0.509	4.379
9		0.2	0.912	0	0	5.463	0.535	5.804
10		0.2	0.966	0	0	7.422	0.705	7.134
11		0.2	0.984	0	0	9.354	0.955	8.190
12		0.2	1	0	0	10.951	0.825	9.988
13		0.2	1	0	0	13.266	0.546	11.415
14		0.2	1	0	0	15.552	0.300	12.831
15		0.2	1	0	0	17.651	0.300	14.083

2023								
Age	**N**	**M**	**Mat**	**PF**	**PM**	**SWT**	**Sel**	**CWT**
3	548000	0.3313	0.001	0	0	0.177	0.011	0.726
4		0.2227	0.001	0	0	0.469	0.064	1.132
5		0.2110	0.010	0	0	0.928	0.170	1.604
6		0.2103	0.128	0	0	1.548	0.290	2.288
7		0.2	0.407	0	0	2.573	0.396	3.219
8		0.2	0.759	0	0	3.990	0.509	4.379
9		0.2	0.912	0	0	5.589	0.535	5.804
10		0.2	0.966	0	0	7.182	0.705	7.134
11		0.2	0.984	0	0	9.328	0.955	8.190
12		0.2	1	0	0	11.221	0.825	9.988
13		0.2	1	0	0	13.030	0.546	11.415
14		0.2	1	0	0	15.403	0.300	12.831
15		0.2	1	0	0	17.744	0.300	14.083

Table 3.20. Northeast Arctic cod. Management option table.

2021					
Biomass (t)	SSB (t)	FMult	FBar	Landings (t)	
2091633	884509	1	0.434	653500	
2022				2023	
Biomass	SSB	FBar	Landings	Biomass	SSB
2002020	851783	0.00	0	2629316	1306235
		0.05	88431	2533231	1234101
		0.10	172371	2442432	1166506
		0.15	252105	2356569	1103128
		0.20	327897	2275319	1043672
		0.25	399991	2198384	987863
		0.30	468613	2125487	935451
		0.35	533976	2056371	886203
		0.40	596273	1990799	839903
		0.45	655688	1928550	796353
		0.50	712389	1869420	755370
		0.55	766535	1813219	716783
		0.60	818271	1759770	680434
		0.65	867736	1708908	646178
		0.70	915056	1660481	613879
		0.75	960352	1614345	583411
		0.80	1003734	1570369	554658
		0.85	1045308	1528427	527512
FLR					

Table 3.21. Northeast Arctic cod. Detailed prediction output assuming Fsq in 2021 and HCR in 2022.

Fbar	age						
range:	5-10						
Year:	2021						
F	multiplier:	1					
Fbar:	0.4340						
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)
3	0.011	5037	4	561000	98	1386	0
4	0.064	21467	23	388172	171	924	0
5	0.170	46152	74	326358	317	2113	2
6	0.290	42993	98	188432	331	26758	47
7	0.396	43298	135	145279	394	57122	155
8	0.509	20473	89	56170	217	37099	143
9	0.535	11481	67	30322	173	26967	154
10	0.705	12782	90	27549	205	26901	200
11	0.955	4945	41	8734	79	8363	76
12	0.825	1517	15	2939	33	2939	33
13	0.546	436	5	1133	15	1133	15
14	0.300	159	2	671	10	671	10
15+	0.300	663	9	2805	48	2805	48
Total	NA	211404	654	1739564	2092	195179	885
		Thous	Thou. tonnes	Thous	Thou. tonnes	Thous	Thou. tonnes
Fbar	age						
range:	5-10						
Year:	2022						
F	multiplier:	1.14					
Fbar:	0.4965						
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)
3	0.012	6373	5	621000	110	414	0
4	0.073	25102	28	398532	186	266	0
5	0.195	46625	75	291542	263	2915	3
6	0.332	57089	131	222945	361	28537	46
7	0.452	37970	122	114254	310	46463	126
8	0.582	32335	142	80087	320	60786	243
9	0.611	11580	67	27649	151	25207	138
10	0.807	7397	53	14546	108	14056	104
11	1.092	6830	56	11142	104	10968	103
12	0.944	1548	15	2753	30	2753	30
13	0.625	448	5	1054	14	1054	14
14	0.344	142	2	537	8	537	8
15+	0.344	559	8	2107	37	2107	37
Total	NA	234000	708	1788149	2002	196064	852
		Thous	Thou. tonnes	Thous	Thou. tonnes	Thous	Thou. tonnes

Table 3.22. Northeast Arctic cod. Assessments results by means of TISVPA.

Year	B(3+)	SSB	R(3)	F(5-10)
1984	807954	250746	410523	0.797
1985	980750	198920	572528	0.636
1986	1373006	181043	1093298	0.777
1987	1235908	134626	287903	1.008
1988	1014506	224385	216977	0.981
1989	916885	239238	176343	0.468
1990	990201	334926	208876	0.311
1991	1552666	722740	394071	0.227
1992	1941853	963126	677277	0.407
1993	2420887	851159	985577	0.613
1994	2220662	642878	733691	0.809
1995	1899651	565667	451863	0.739
1996	1831162	635149	398175	0.702
1997	1707205	701702	615599	1.022
1998	1310400	440043	786884	1.039
1999	1086240	278844	446021	0.956
2000	1057202	237512	551676	0.671
2001	1282493	363769	454131	0.533
2002	1402591	484448	403270	0.517
2003	1513047	529317	651690	0.510
2004	1466859	619630	270922	0.613
2005	1440571	562183	521538	0.619
2006	1497323	593686	532430	0.650
2007	1801766	625622	1305559	0.513
2008	2545295	664342	1258479	0.367
2009	3212962	962458	853957	0.353
2010	3480838	1156171	499582	0.389
2011	3610421	1621078	609473	0.335
2012	3692618	1843690	718214	0.302
2013	3787101	2014197	838254	0.313
2014	3553222	1927922	1035664	0.343
2015	3399199	1536347	476073	0.366
2016	3035769	1255420	349877	0.331
2017	3058797	1484139	630535	0.382
2018	2753200	1424145	405472	0.410
2019	2481220	1367254	447065	0.355
2020	2116031	1128535	390173	0.447
2021	1739852	911290		

Table 3.23. NEA cod TISVPA estimates of abundance-at-age (thousands)

	3	4	5	6	7	8	9	10	11	12	13	14	15
1984	410523	135361	73038	41968	24276	12026	8938	1468	676	461	204	35	24
1985	572528	328885	97230	42154	18143	7015	3360	2497	476	386	175	111	28
1986	1093298	450718	227239	56521	19969	6784	2322	1323	1071	220	267	105	43
1987	287903	813483	306460	114066	23174	7127	2188	724	435	368	76	161	55
1988	216977	214133	536192	153748	36097	6227	2073	709	148	142	110	39	14
1989	176343	167180	149847	286245	59642	9164	1507	604	182	33	50	53	77
1990	208876	141119	119573	95102	155696	26282	3530	627	280	102	16	35	14
1991	394071	169454	108844	84293	60687	96088	14766	2047	357	174	67	9	19
1992	677277	319370	131230	77094	53911	35799	58652	8865	1282	238	123	51	6
1993	985577	538231	237036	87118	44197	28095	17282	30658	4521	714	126	89	4
1994	733691	765179	402113	144673	44957	20161	11587	6812	12530	1801	278	63	13
1995	451863	510878	531121	239795	65665	14500	6205	3351	1856	3852	551	138	3
1996	398175	261986	335690	315000	116737	25336	5210	1983	990	512	1385	282	3
1997	615599	230456	167601	193804	154458	48851	9337	2044	630	320	175	617	3
1998	786884	393527	146146	81861	76453	47171	12992	2173	483	115	60	57	138
1999	446021	492048	237442	71578	30352	24034	10507	3707	515	140	25	22	82
2000	551676	335073	321484	111407	25292	10341	5853	2062	1137	156	52	4	51
2001	454131	424077	240836	170235	48105	9087	3647	1697	590	542	64	31	98
2002	403270	353825	307475	147349	79869	20291	3317	1636	627	240	316	43	29
2003	651690	302383	260499	188743	70234	31599	7770	1309	843	315	109	216	5
2004	270922	506524	228784	164312	95987	30781	12864	3571	600	497	170	70	35
2005	521538	208554	372200	144592	81918	37204	11225	4558	1373	239	270	104	30
2006	532430	381711	152345	216484	72092	33374	12883	4166	1540	571	103	180	621
2007	1305559	427361	267972	94678	106475	31217	12822	4136	1598	516	242	61	165
2008	1258479	1002021	316032	160193	53322	52304	14713	6114	1796	763	198	154	77
2009	853957	964086	761058	219428	94827	30261	25732	7558	3264	866	415	128	122
2010	499582	644435	743877	537212	136711	55224	16599	13253	4217	1813	205	275	196
2011	609473	369409	488219	534378	345967	76109	28437	8804	6674	1631	846	73	0
2012	718214	397644	261153	358720	357297	206007	41841	14106	3890	3147	871	447	153
2013	838254	488540	283846	195322	246505	222263	119010	23097	7289	1878	1679	516	840
2014	1035664	562226	372114	207725	136189	150095	120387	60051	11501	3605	982	1048	784
2015	476073	710234	400851	265783	135767	83673	77213	59825	28889	5780	1825	580	1100
2016	349877	330004	516712	277166	170497	78757	46893	39623	27636	11604	2587	1095	1354
2017	630535	279667	242691	345652	180680	104598	43119	25723	17644	11568	5392	1476	1054
2018	405472	417114	211326	165467	214530	103813	57111	21430	12571	6367	4647	2921	942
2019	447065	301865	306286	144999	97871	118343	55958	30358	9624	5342	2504	2244	1281
2020	390173	325871	218726	196445	90708	54824	62333	30750	16717	4549	2761	1448	1299
2021	0	254403	238659	142919	111198	46207	25971	29664	14528	8140	2302	1726	905

Table 3.24. NEA cod TISVPA estimates of fishing mortality coefficients.

F	3	4	5	6	7	8	9	10	11	12	13	14	15
1984	0.023	0.137	0.325	0.561	0.998	0.967	0.990	0.941	0.279	0.926	0.469	0.469	0.469
1985	0.020	0.123	0.314	0.455	0.622	0.911	0.740	0.774	0.685	0.217	0.382	0.382	0.382
1986	0.021	0.148	0.392	0.640	0.743	0.874	1.109	0.905	0.873	0.749	0.443	0.443	0.443
1987	0.025	0.152	0.487	0.842	1.132	1.079	1.061	1.446	1.034	0.967	0.518	0.518	0.518
1988	0.024	0.162	0.417	0.874	1.216	1.330	1.017	1.030	1.248	0.894	0.500	0.500	0.500
1989	0.013	0.089	0.242	0.368	0.564	0.611	0.554	0.471	0.444	0.496	0.260	0.260	0.260
1990	0.008	0.059	0.157	0.263	0.315	0.404	0.377	0.352	0.286	0.266	0.172	0.172	0.172
1991	0.006	0.038	0.112	0.186	0.250	0.258	0.286	0.273	0.241	0.194	0.127	0.127	0.127
1992	0.009	0.066	0.166	0.316	0.439	0.521	0.465	0.533	0.473	0.404	0.219	0.219	0.219
1993	0.015	0.084	0.251	0.403	0.654	0.803	0.825	0.741	0.803	0.682	0.320	0.320	0.320
1994	0.017	0.114	0.278	0.543	0.717	1.051	1.098	1.169	0.939	0.999	0.404	0.404	0.404
1995	0.016	0.109	0.306	0.465	0.742	0.826	1.011	1.087	1.051	0.832	0.397	0.397	0.397
1996	0.020	0.103	0.297	0.530	0.643	0.884	0.824	1.037	1.016	0.956	0.399	0.399	0.399
1997	0.027	0.175	0.377	0.728	1.131	1.157	1.411	1.327	1.618	1.511	0.556	0.556	0.556
1998	0.030	0.177	0.508	0.669	1.068	1.407	1.142	1.440	1.215	1.406	0.555	0.555	0.555
1999	0.025	0.188	0.481	0.884	0.886	1.186	1.244	1.056	1.183	0.991	0.518	0.518	0.518
2000	0.020	0.120	0.389	0.596	0.831	0.686	0.740	0.786	0.641	0.683	0.365	0.365	0.365
2001	0.015	0.106	0.258	0.523	0.624	0.718	0.513	0.561	0.552	0.451	0.286	0.286	0.286
2002	0.013	0.087	0.264	0.401	0.659	0.659	0.644	0.475	0.484	0.467	0.264	0.264	0.264
2003	0.013	0.078	0.216	0.417	0.505	0.712	0.605	0.605	0.420	0.419	0.248	0.248	0.248
2004	0.014	0.098	0.241	0.425	0.687	0.708	0.868	0.746	0.690	0.463	0.290	0.290	0.290
2005	0.015	0.094	0.267	0.412	0.591	0.826	0.716	0.903	0.716	0.647	0.295	0.295	0.295
2006	0.016	0.105	0.273	0.499	0.621	0.768	0.922	0.814	0.952	0.732	0.323	0.323	0.323
2007	0.013	0.085	0.236	0.379	0.553	0.578	0.604	0.730	0.605	0.679	0.267	0.267	0.267
2008	0.009	0.065	0.175	0.300	0.382	0.471	0.424	0.451	0.500	0.414	0.206	0.206	0.206
2009	0.008	0.057	0.164	0.277	0.386	0.423	0.451	0.415	0.413	0.447	0.200	0.200	0.200
2010	0.008	0.058	0.161	0.296	0.408	0.493	0.467	0.510	0.438	0.427	0.220	0.220	0.220
2011	0.007	0.044	0.137	0.239	0.355	0.420	0.438	0.425	0.433	0.367	0.200	0.200	0.000
2012	0.006	0.043	0.106	0.211	0.298	0.383	0.394	0.420	0.381	0.381	0.190	0.190	0.190
2013	0.007	0.042	0.122	0.190	0.309	0.381	0.429	0.450	0.449	0.399	0.212	0.212	0.212
2014	0.008	0.048	0.127	0.232	0.294	0.422	0.455	0.526	0.517	0.504	0.250	0.250	0.250
2015	0.010	0.060	0.144	0.240	0.361	0.397	0.502	0.554	0.601	0.577	0.295	0.295	0.295
2016	0.009	0.062	0.154	0.229	0.310	0.405	0.387	0.499	0.514	0.543	0.290	0.290	0.290
2017	0.016	0.070	0.196	0.306	0.370	0.437	0.500	0.486	0.592	0.597	0.355	0.355	0.355
2018	0.021	0.107	0.197	0.348	0.440	0.457	0.468	0.549	0.498	0.594	0.382	0.382	0.382
2019	0.015	0.116	0.248	0.277	0.395	0.426	0.384	0.401	0.437	0.390	0.325	0.325	0.325
2020	0.013	0.080	0.213	0.353	0.475	0.547	0.543	0.550	0.520	0.481	0.270	0.270	0.270

Table 3.25. North East arctic cod. Stock numbers-at-age (in thousands) estimated by VPA including discard estimates, and % increase in stock numbers relative to a VPA without discards. From Dingsør (2001). The discard numbers applied correspond to method II (1946–1982) and IIIb (1983–1998) mentioned in Dingsør (2001).

	Estimated stock numbers (thousands)			Percent increase		
Year	Age 3	Age 4	Age 5	Age 3	Age 4	Age 5
1946	875 346	602 579	407 163	20 %	4 %	1 %
1947	531 993	676 806	465 099	27 %	14 %	0 %
1948	570 356	392 309	497 476	29 %	14 %	5 %
1949	589 367	416 668	285 459	26 %	16 %	3 %
1950	799 732	414 016	291 200	13 %	9 %	1 %
1951	1 235 322	586 054	302 346	14 %	2 %	0 %
1952	1 388 731	889 509	401 768	17 %	3 %	0 %
1953	1 801 114	975 004	600 908	13 %	2 %	0 %
1954	830 653	1 321 053	684 303	29 %	5 %	0 %
1955	381 489	615 696	907 875	40 %	19 %	2 %
1956	567 555	274 235	399 344	29 %	25 %	3 %
1957	914 850	387 496	161 710	14 %	10 %	2 %
1958	552 600	672 221	262 135	11 %	4 %	2 %
1959	757 567	391 906	406 694	11 %	3 %	0 %
1960	855 470	534 350	240 047	8 %	1 %	0 %
1961	1 041 570	620 707	347 043	13 %	1 %	0 %
1962	894 728	739 196	382 556	23 %	4 %	0 %
1963	551 938	614 025	429 068	17 %	10 %	0 %
1964	389 151	396 165	361 790	15 %	5 %	0 %
1965	845 469	293 844	266 134	9 %	8 %	0 %
1966	1 618 188	647 435	203 168	2 %	4 %	2 %
1967	1 404 569	1 249 506	465 035	9 %	0 %	1 %
1968	210 875	1 088 071	876 095	24 %	6 %	0 %
1969	143 791	155 947	699 033	28 %	15 %	2 %
1970	222 635	104 415	92 541	13 %	17 %	4 %
1971	462 474	164 397	65 112	14 %	6 %	2 %
1972	1 221 559	358 357	115 892	20 %	10 %	1 %
1973	1 858 123	947 409	249 400	2 %	19 %	11 %
1974	598 555	1 246 499	583 612	14 %	2 %	9 %
1975	654 442	382 692	627 793	5 %	10 %	3 %
1976	622 230	477 390	233 608	1 %	2 %	1 %
1977	397 826	426 386	280 645	14 %	0 %	0 %
1978	653 256	277 410	198 204	2 %	11 %	0 %
1979	225 935	460 104	164 243	14 %	2 %	1 %
1980	152 937	171 954	300 312	11 %	11 %	0 %
1981	161 752	116 964	116 337	7 %	7 %	4 %
1982	151 642	125 307	81 780	0 %	4 %	1 %
1983	166 310	115 423	82 423	0 %	-1 %	3 %
1984	408 525	133 333	77 728	3 %	0 %	0 %
1985	543 828	324 072	96 327	4 %	2 %	0 %
1986	1 114 252	412 683	219 993	7 %	2 %	0 %
1987	307 425	767 656	268 642	7 %	4 %	0 %
1988	222 819	215 720	490 161	9 %	3 %	2 %
1989	180 066	166 955	151 576	4 %	6 %	0 %
1990	249 968	139 922	114 006	3 %	2 %	1 %
1991	418 955	200 700	105 559	2 %	2 %	0 %
1992	748 962	333 517	151 973	4 %	1 %	0 %
1993	1 002 933	576 112	238 980	10 %	2 %	0 %
1994	896 184	744 062	420 039	9 %	8 %	0 %
1995	733 664	584 808	476 048	10 %	6 %	3 %
1996	467 093	341 918	344 124	3 %	7 %	3 %
1997	765 234	238 202	193 102	3 %	0 %	4 %
1998	836 301	429 147	144 629	2 %	1 %	-1 %

Table 3.26. Northeast Arctic cod. Number (thousands) of cod by age groups taken as bycatch in the Norwegian shrimp fishery (1984–2006) .

Age\Year	1984	1985	1986	1987	1988	1989	1990	1991
0	322	4537	28	1408	259	717	2971	11651
1	4913	19437	2339	3259	1719	668	13731	34450
2	1624	49334	6952	1961	1534	418	1518	2759
3	1073	2720	5245	499	1380	694	1019	87
4	2200	1891	716	2210	1882	2096	403	64
5	161	9306	737	1715	1124	2281	909	33
6	89	6374	520	411	269	1135	2913	293
7	144	266	92	79	186	184	1434	1138
8	38	1	93	28	178	13	185	316
9	1	2	165	6	1	0	3	29
10	0	3	88	1	0	0	9	0
11	0	0	0	0	0	0	0	0
Total('000)	10564	93872	16976	11576	8532	8206	25095	50819

Age\Year	1992	1993	1994	1995	1996	1997	1998	1999
0	6486	604	1042	1138	519	896	506	651
1	5236	6702	1628	1896	9084	17157	40314	7155
2	2922	4032	410	99	359	1805	5248	245
3	242	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
Total('000)	14886	11339	3080	3133	9962	19858	46068	8052

Age\Year	2000	2001	2002	2003	2004	2005	2006
0	66	1188	478	4253	713	945	1355
1	1572	7187	293	8805	1014	3411	2597
2	3152	1348	893	96	323	1628	218
3	218	0	190	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
Total('000)	5007	9723	1854	13154	2051	5984	4170

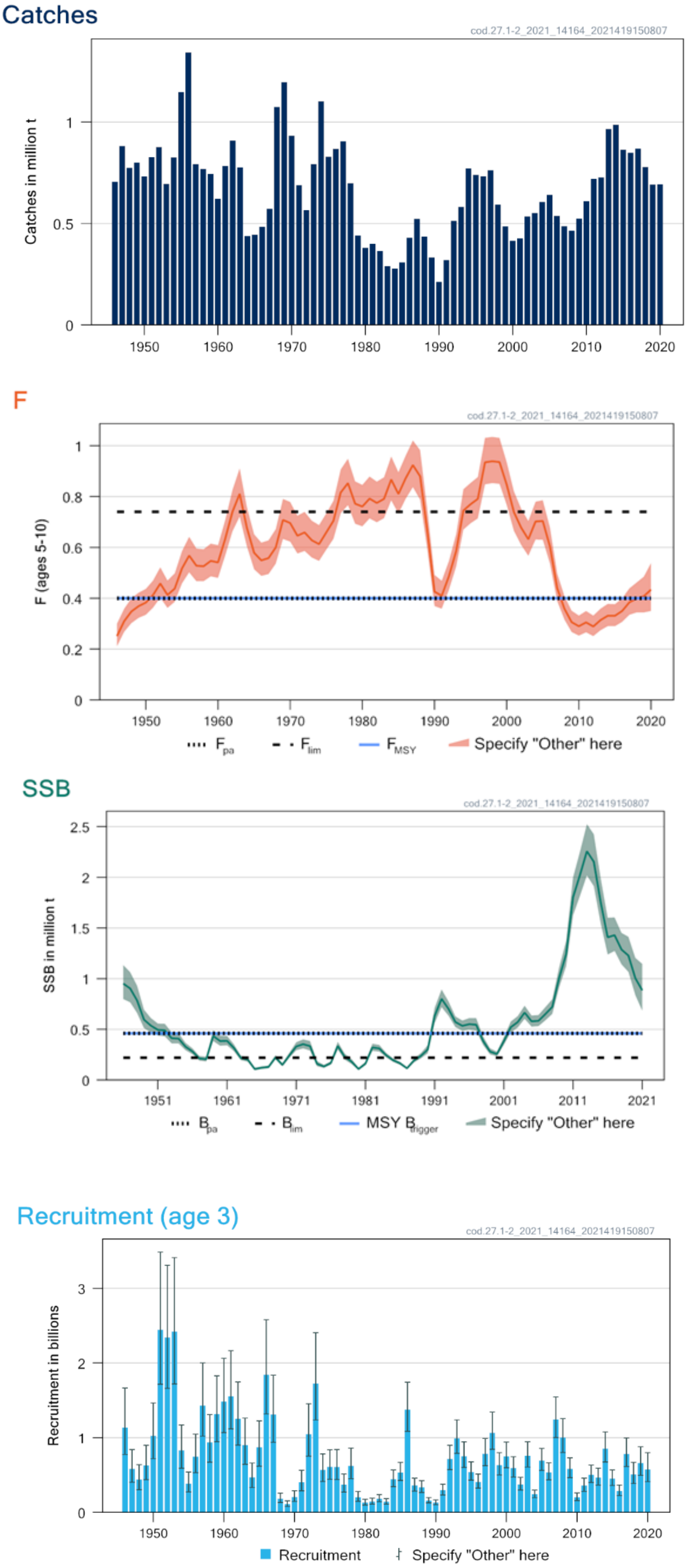


Figure 3.1. ICES Standard plots for Northeast Arctic cod (subareas 1 and 2).

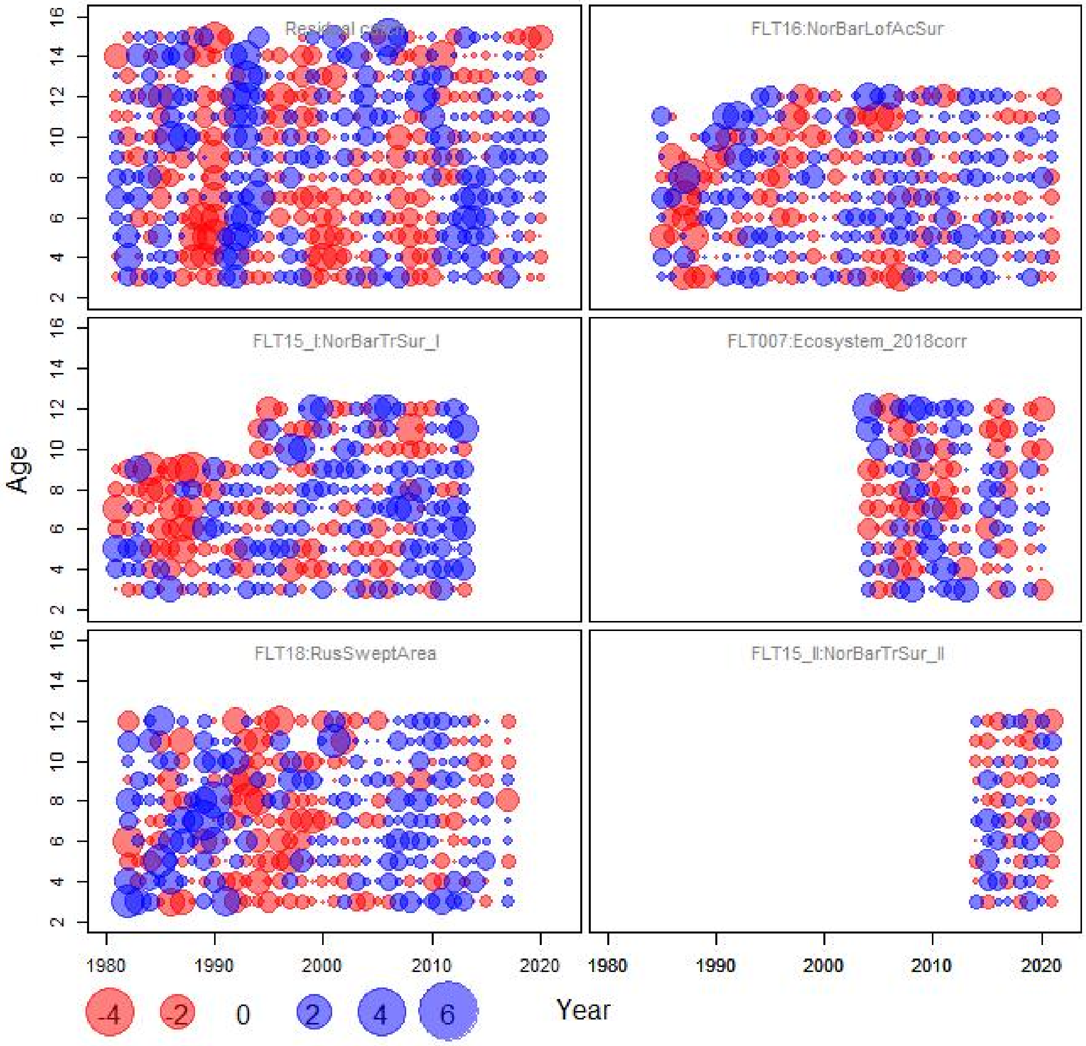


Figure 3.2a. Standardized one-observation-ahead residuals for log-catches and log-indices (Thygesen *et al.*,. 2017) in the final SAM run.

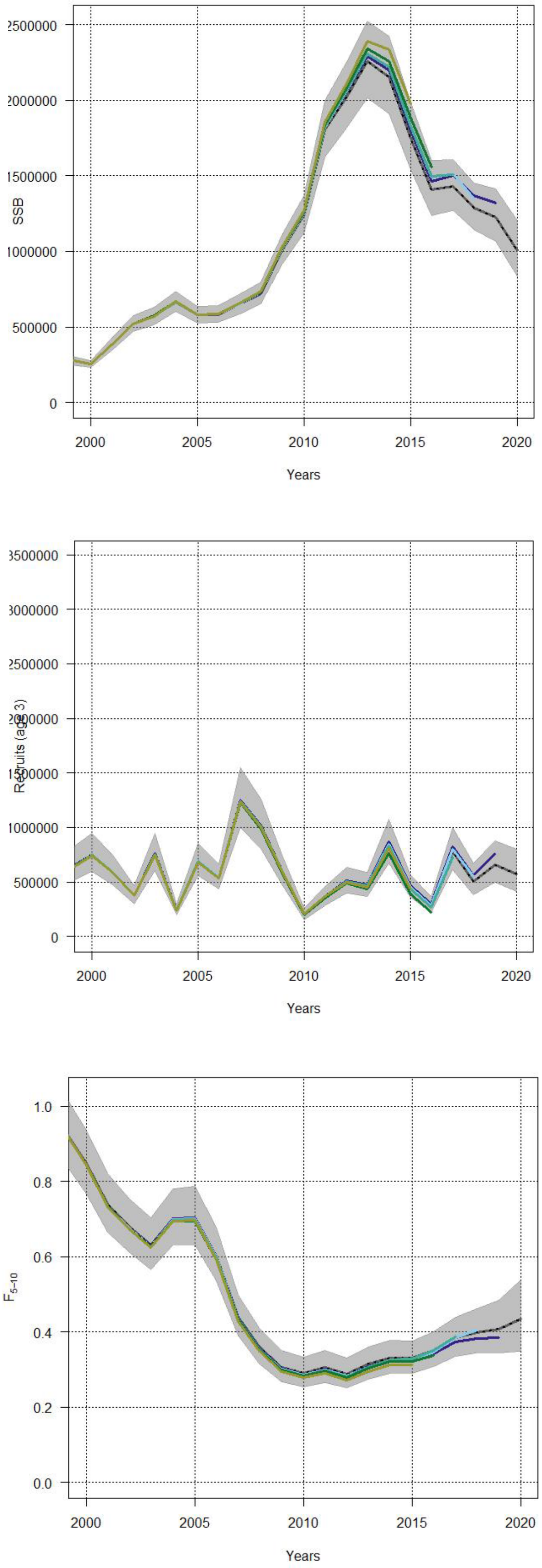


Figure 3.2b. NEA cod SSB, R and F_{bar} retrospective pattern for final SAM run.

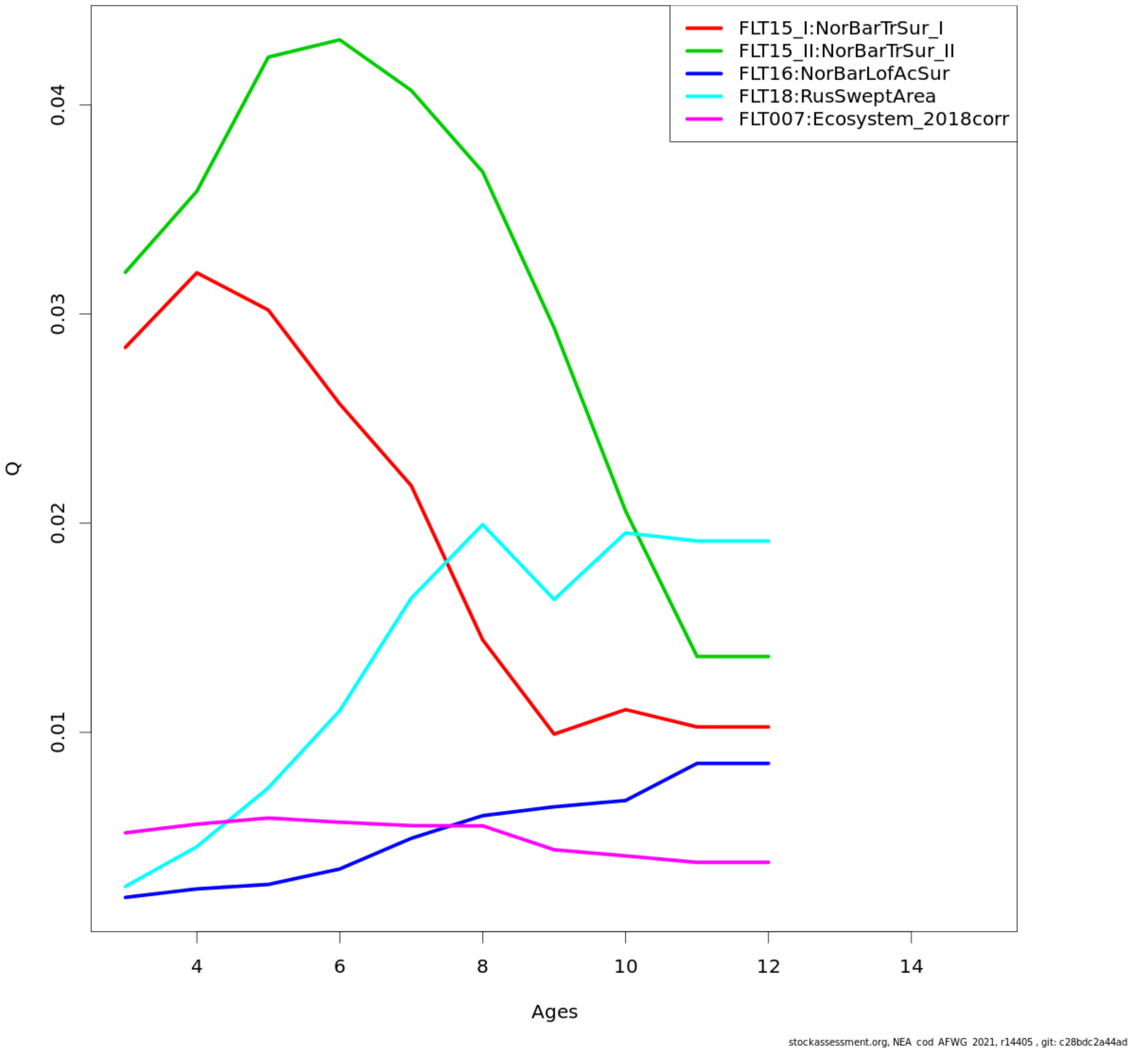


Figure 3.2c. NEA cod. Catchability of different fleets used for final SAM run fit.

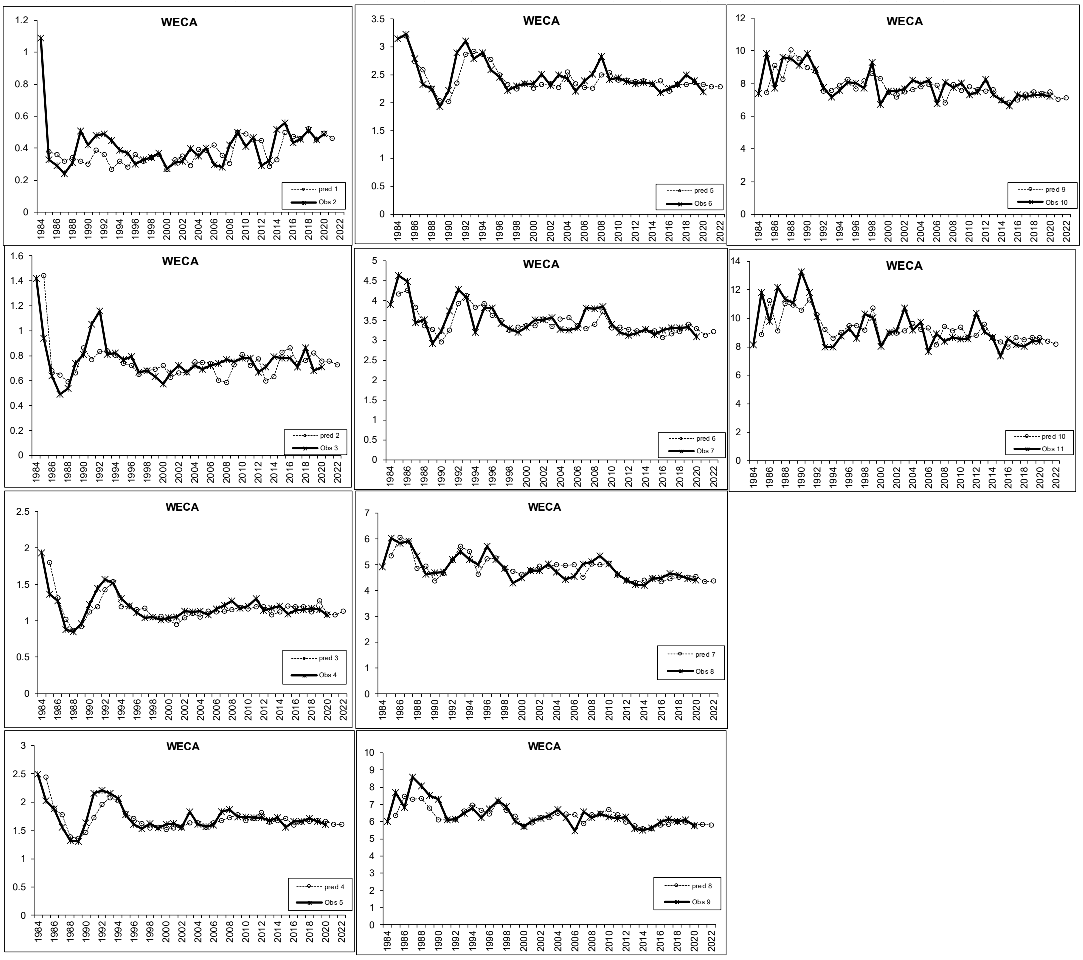


Figure 3.3. Northeast Arctic cod. Weight in catch predictions.

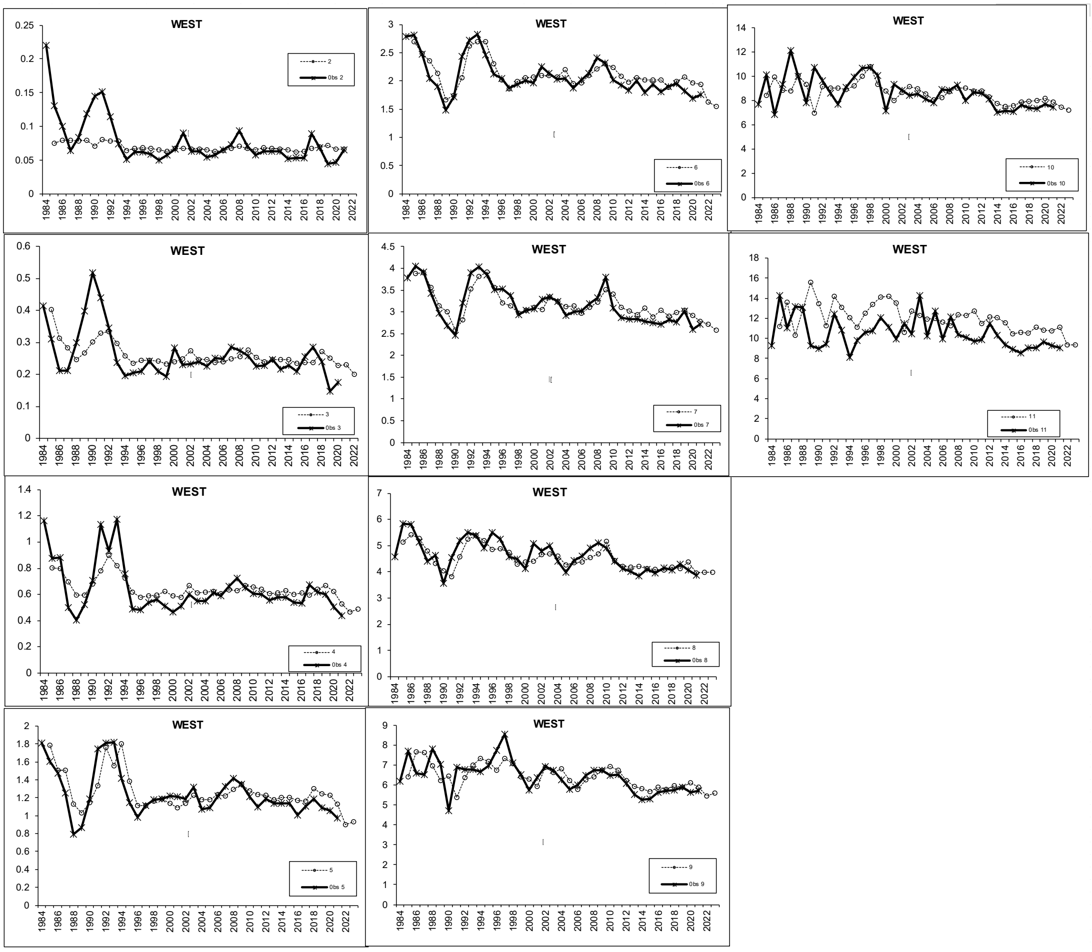


Figure 3.4. Northeast Arctic cod. Weight in stock projections.

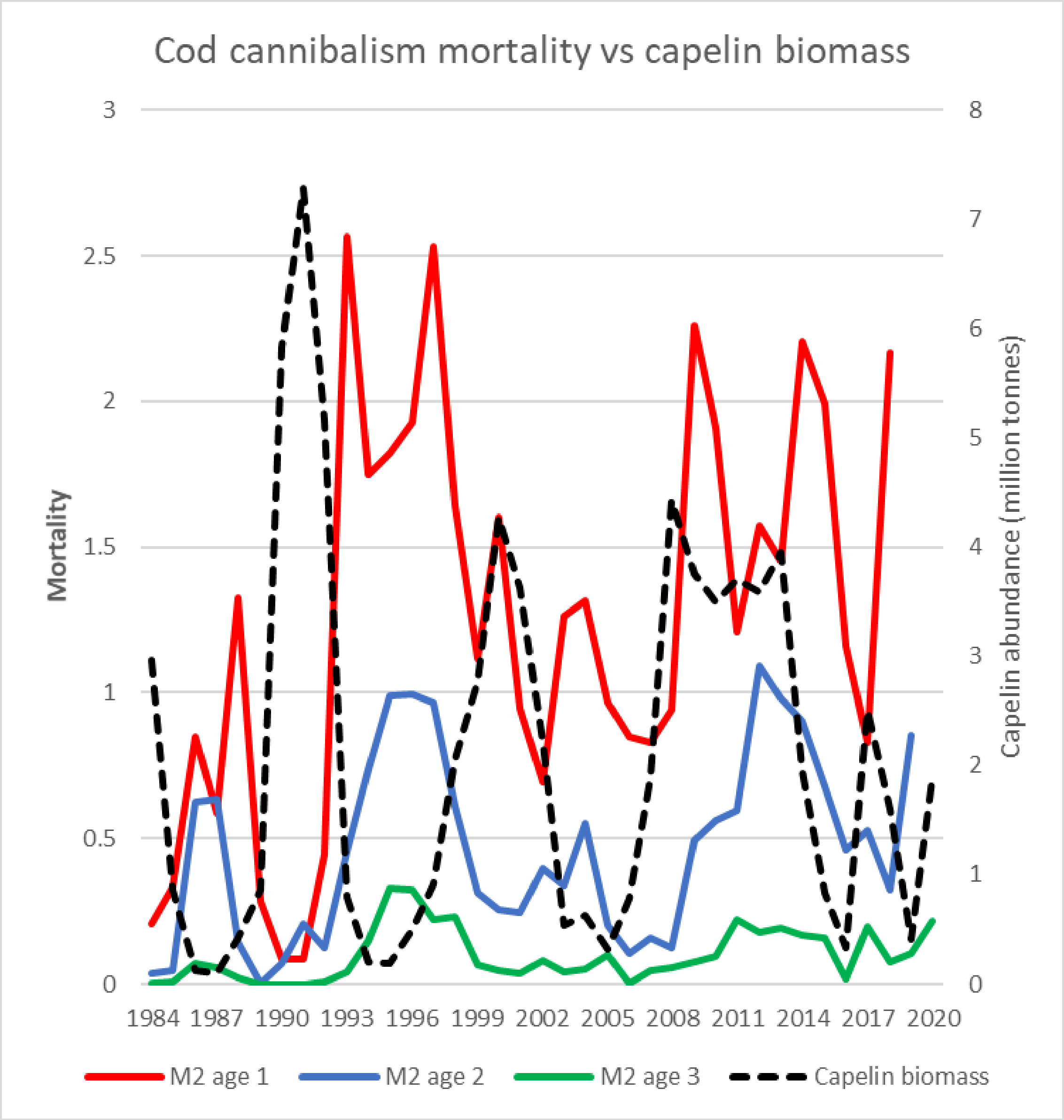
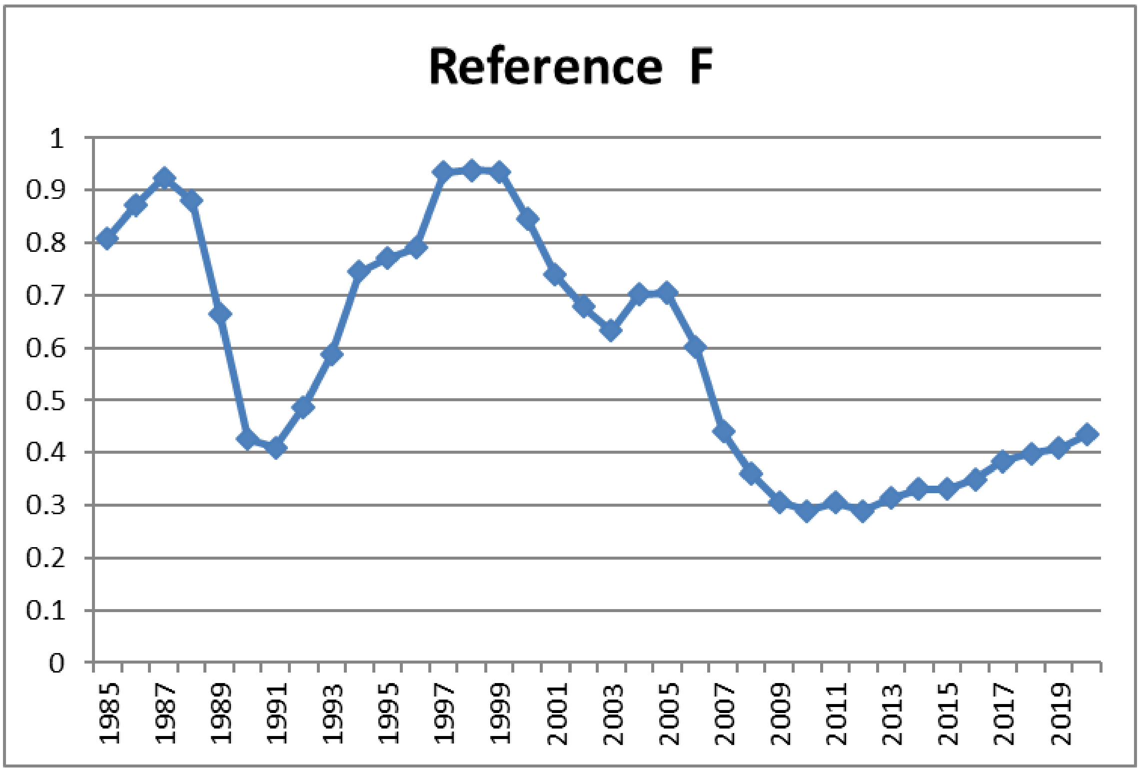


Figure 3.5. NEA cod cannibalism mortality vs. capelin abundance.



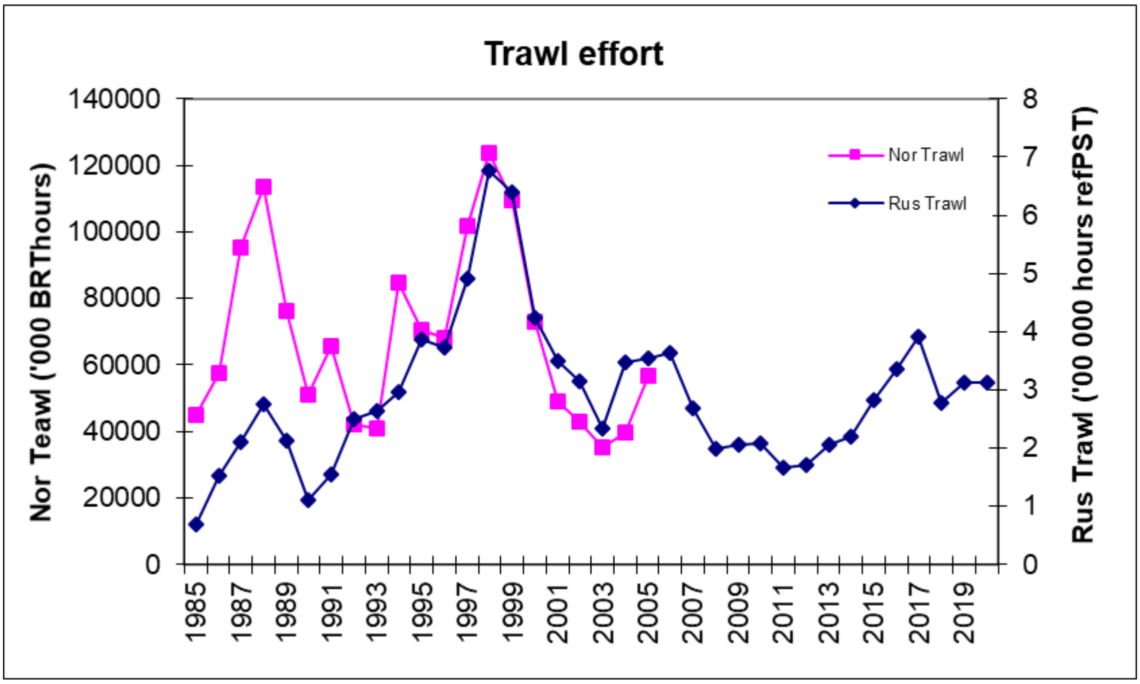


Figure 3.6a. Northeast Arctic cod. Fishing mortality (F5–10; top panel) and trawl efforts in 1985–2020 (bottom panel).

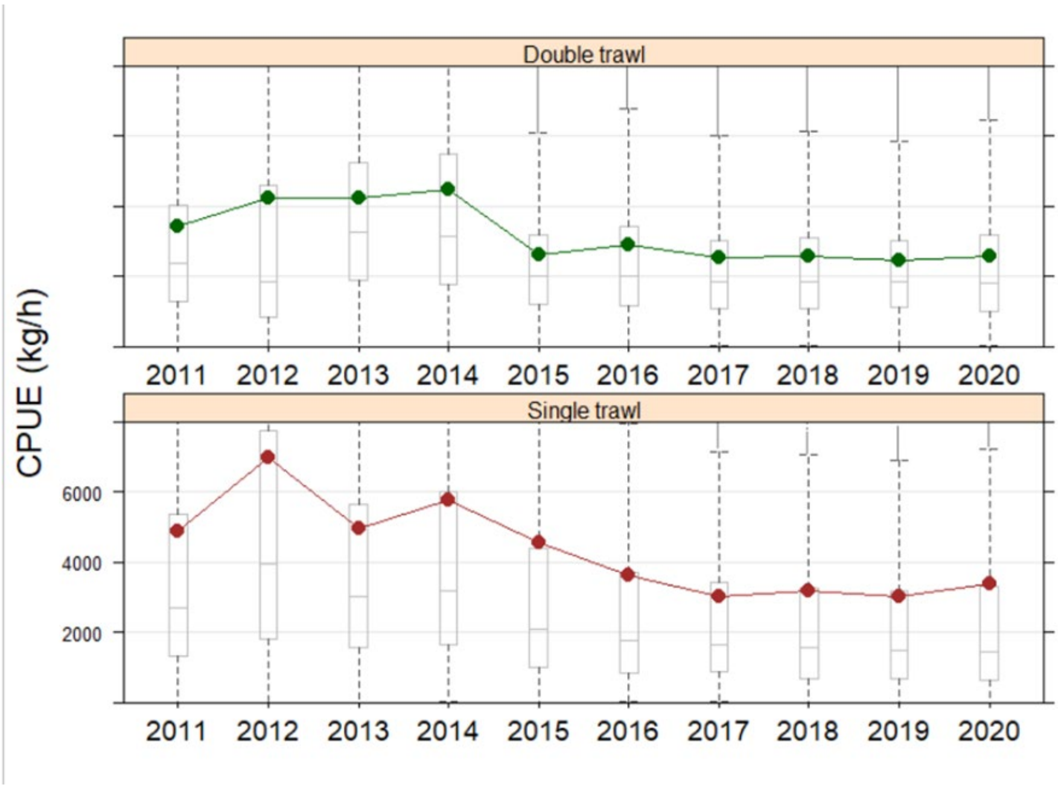


Figure 3. 6b. Cod CPUE in Norwegian trawl catches where cod is the main species (double and single trawl). Connected line shows mean, line inside the box shows the median, and the box shows 25 and 75 percentiles.

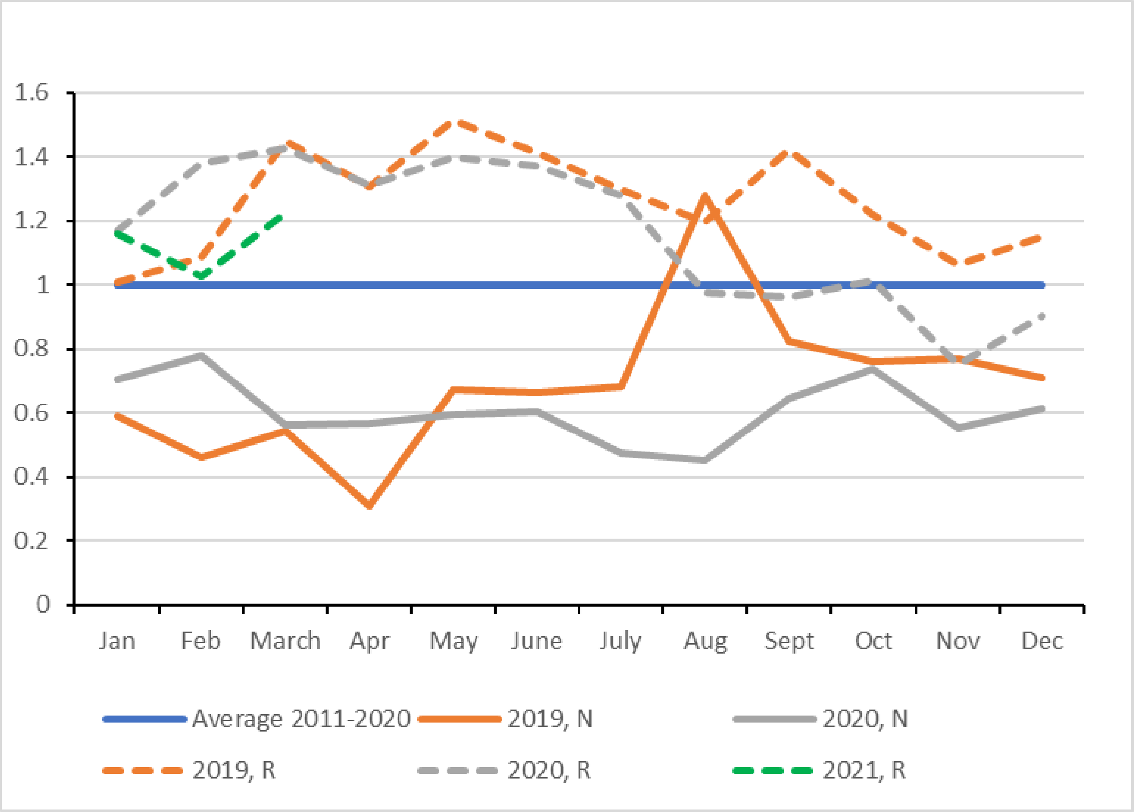
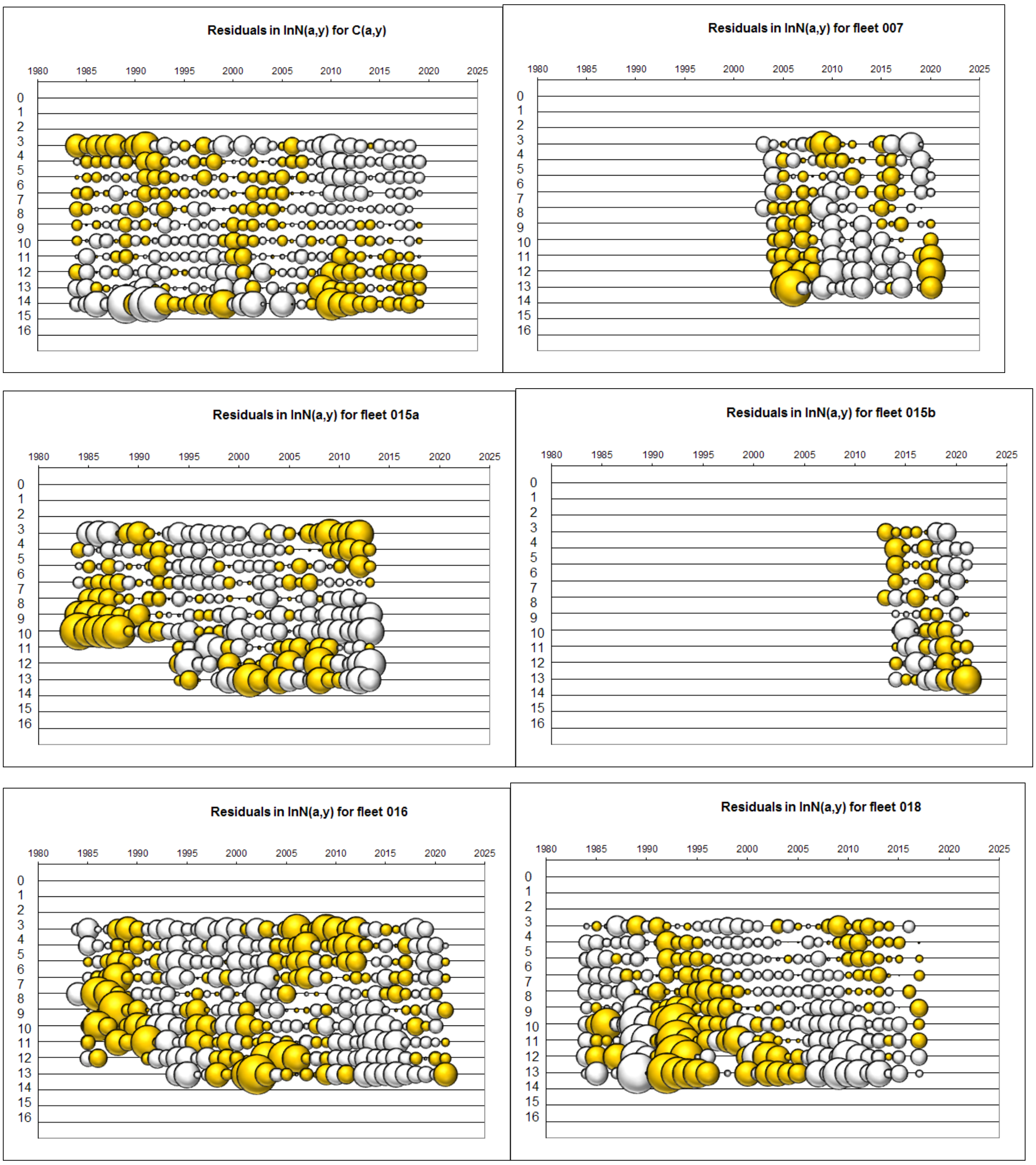


Figure 3.6c. Northeast Arctic cod. Monthly trawl CPUE of Russian (R) and Norwegian (N) vessels in 2019, 2020 and 2021 vs. the long-term average values (2011–2020).


Residuals in lnN(a,y) for C(a,y)

Residuals in lnN(a,y) for fleet 007

Residuals in lnN(a,y) for fleet 015a

Residuals in lnN(a,y) for fleet 015b

Residuals in lnN(a,y) for fleet 016

Residuals in lnN(a,y) for fleet 018

Figure 3.7a. Residuals of the TISVPA data approximation (yellow circles are positive residuals, white – negative, maximum bubble size corresponds to residual = 2.4).

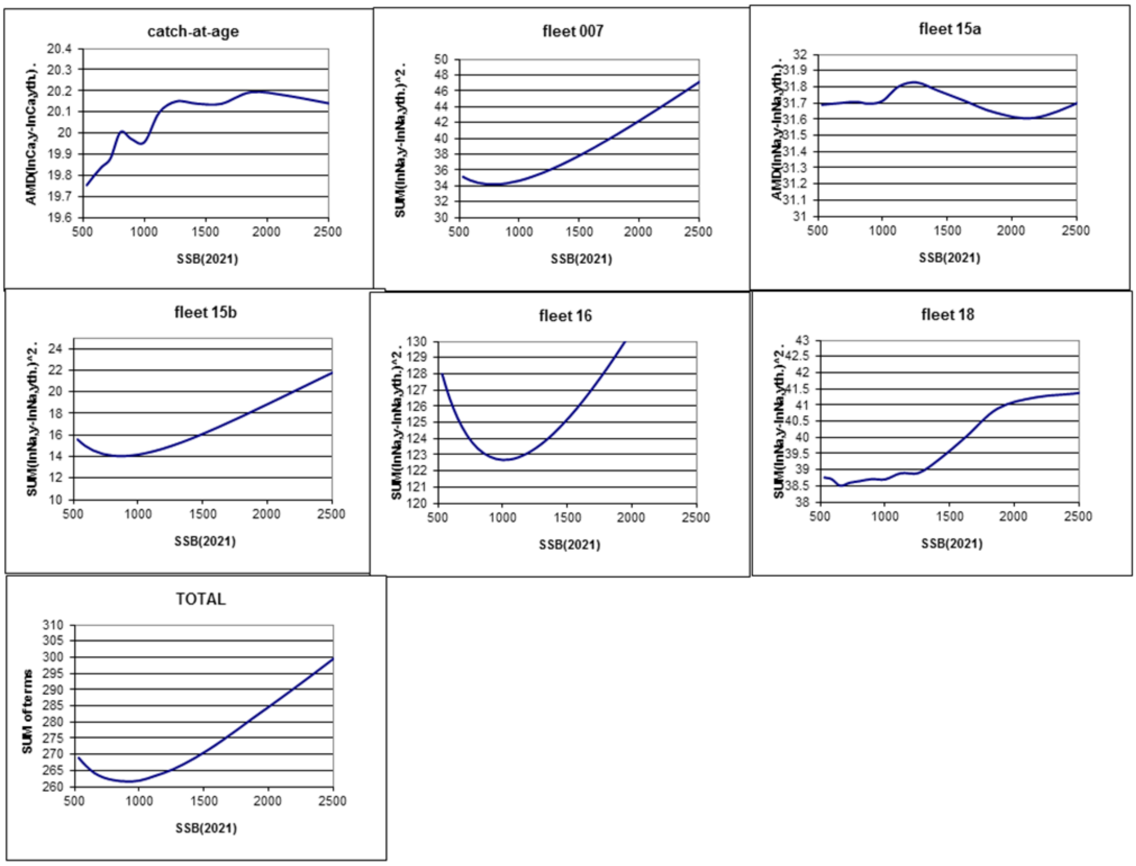


Figure 3.7b. Profiles of the components of the TISVPA objective function.

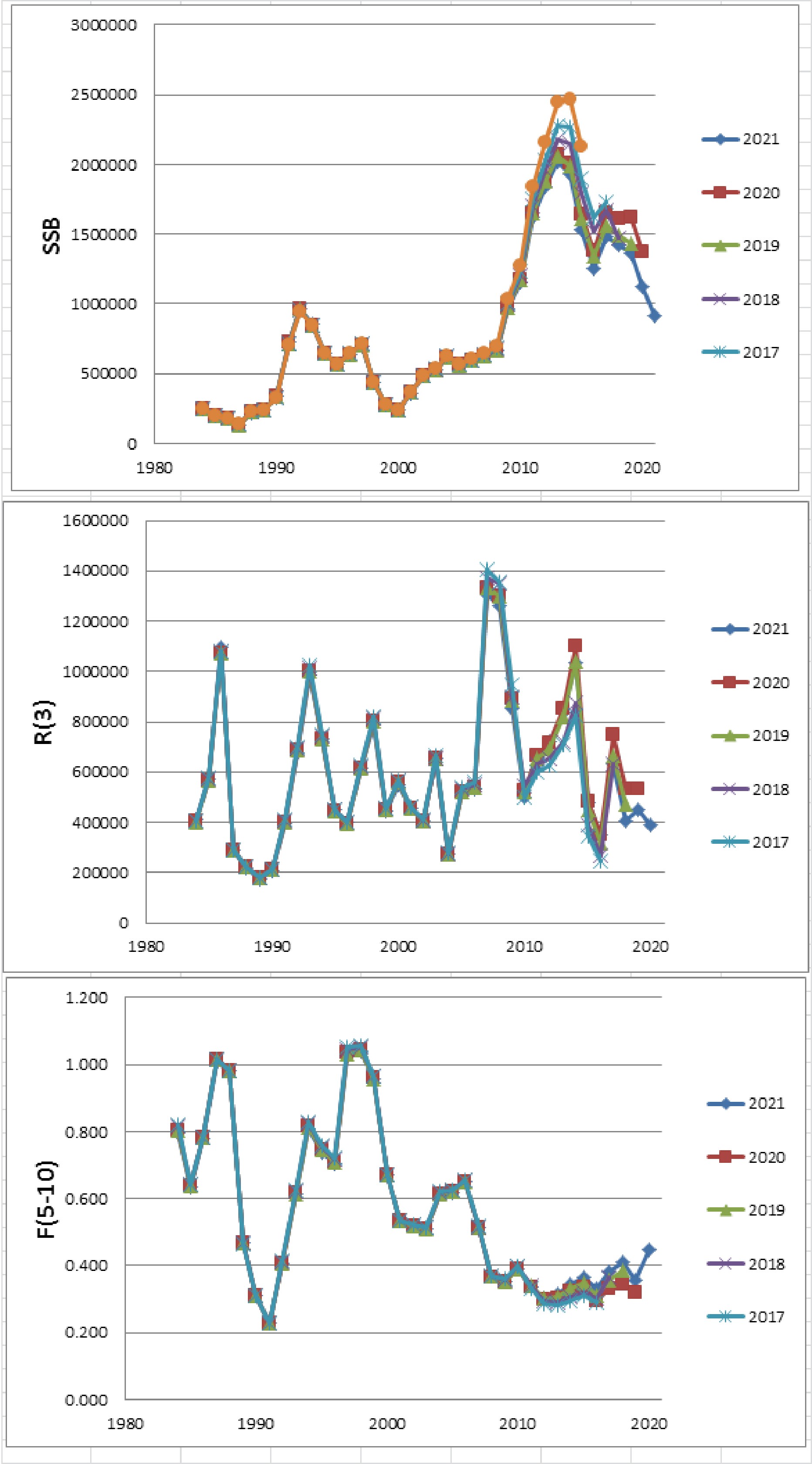


Figure 3.7c. TISVPA retrospective runs.

4 Haddock in subareas 1 and 2 (Northeast Arctic)

Melanogrammus aeglefinus – had.27.1-2

4.1 Introductory note

The haddock input data, SAM model configuration and short-term forecast data input were revised during a benchmark in 2020 (WKDEM 2020).

4.2 Status of the fisheries

4.2.1 Historical development of the fisheries

Haddock is mainly fished by trawl as bycatch in the fishery for cod. Also, a directed trawl fishery for haddock is conducted. The proportion of the total catches taken by direct fishery varies between years. On average approximately 30% of the catch is with conventional gears, mostly longline, which in the past was used almost exclusively by Norway. Some of the longline catch are from a directed fishery, which is restricted by national quotas. In the Norwegian management, the quotas are set separately for trawl and other gears. The fishery is also regulated by a minimum landing size, a minimum mesh size in trawls and Danish seine, a maximum bycatch of undersized fish, closure of areas with high density/catches of juveniles and other seasonal and area restrictions.

The exploitation rate of haddock has been variable. The highest fishing mortalities for haddock have occurred at low to intermediate stock levels and historically show little relationship with the exploitation rate of cod, despite haddock being primarily caught as bycatch in the cod fishery. However, the more restrictive quota regulations introduced around 1990 have resulted in a more stable pattern in the exploitation rate.

The exceptionally strong year classes 2005–2006 contributed to the strong increase to all-time high stock levels and high levels in the last decade. Their importance in the catches is currently minimal.

4.2.2 Catches prior to 2021 (Table 4.1–Table 4.3, Figure 4.1)

The highest landings of haddock historically were 322 kt in 1973. Since 1973 the highest catches observed were about 316 kt in 2012. In 2013–2015 the stock biomass started to decline and the landings in 2018, 2019 and 2020 were below 200 kt (Figure 4.1).

In 2006 it was decided to include reported Norwegian landings of haddock from the Norwegian statistical areas 06 and 07 (i.e. between 62°N and Lofoten Islands). These areas were not previously included in the total landings of NEA haddock as input for this stock assessment (ICES CM 2006/ACFM:19; ICES CM 2006/ACFM:25).

Provisional official landings for 2020 are about 183 kt, which is 15% below agreed TAC (215 kt).

Estimates of unreported catches (IUU catches) of haddock have been added to reported landings for the years from 2002 to 2008. Two estimates of IUU catches were available, one Norwegian and one Russian. At the benchmark in 2011 it was decided to base the final assessment on the Norwegian IUU estimates (ICES CM 2011/ACOM:38; Table 4.1).

We continue to include the estimates of IUU catches 2002–2008, but the IUU are assumed to be negligible for 2009–2020 and therefore set to zero.

4.2.3 Catch advice and TAC for 2021

The catch advice for 2021 was 233 kt and the Joint Norwegian-Russian Fisheries Commission set the TAC in accordance with the HCR. Furthermore, Russia and Norway can transfer 10% of unused part of own quotas from 2020 to 2021 and 10% of unused part own quotas from 2021 to the quota in 2022.

4.3 Status of research

4.3.1 Survey results

Russia provided indices for 1982–2015 and 2017 for the Barents Sea trawl and acoustic survey (TAS) which was carried out in October–December (FLT01, RU-BTr-Q4). The survey was discontinued in 2018.

The Joint Barents Sea winter survey provides two index series used for tuning and recruitment forecast (bottom trawl: FLT02, NoRu-BTr-Q1 and acoustics: FLT04, NoRu-Aco-Q1). The survey area has been extended from 2014 with additional northern areas (N) covered. The extended area is now included in total and standard survey index calculations for haddock (WKDEM 2020). Overall, this survey tracks both strong and poor year classes well. The indices from the Joint winter survey of cod and haddock in the Barents Sea 1994–2021 are given in WD 2. The spatial survey coverage in 2021 was relatively good. Note that since the AFWG was conducted, minor errors were discovered in the winter survey index for 2021 (both acoustic and bottom trawl). These had minimal (< 1%) impact on the assessment of SSB for NEA haddock. This report is not updated to account for correcting these errors.

Both the acoustic and swept indices of all ages were lower in 2021 compared to 2020.

The Joint Barents Sea ecosystem survey provides indices by age from bottom trawl data (FLT007, Eco-NoRu-Q3 Btr) used for tuning and recruitment forecast. At the benchmark in 2011 it was decided to include this survey as tuning series. Tuning indices by age from the joint ecosystem survey are presented in WD 1 (2004–2020 except 2018). The survey coverage in 2020 was good, but the survey covered the eastern Barents Sea much later than the western Barents Sea (almost three months), which might have influenced the results in an unknown way. The distribution of haddock was reduced in 2020 compared 2019, especially on the Novaya Zemlya bank, where haddock was almost absent. The indices were much lower for the youngest and oldest haddock in 2020 compared to 2019.

4.4 Data used in the assessment

4.4.1 Catch-at-age (Table 4.4)

Age and length composition of the landings in 2020 were available from Norway and Russia in Subarea 1 and Division 2.b, and from Norway, Russia, and Germany in Division 2.a. The biological sampling of NEA haddock catches is considered good for the most important ages in the fisheries (see section 1).

Relevant data of estimated catch-at-age obtained from InterCatch for the period 2008–2020 and historical values from 1950–2007 is listed in Table 4.4.

4.4.2 Catch-weight-at-age (Table 4.5)

The mean weight-at-age in the catch was obtained from InterCatch as a weighted average of the weight-at-age in the catch for Norway, Russia and Germany.

4.4.3 Stock-weight-at-age (Table 4.6)

Since 1983 the stock weights-at-age (Table 4.6) are calculated using the average of the weight-at-age estimate from the Joint Barents Sea winter survey and the Russian bottom trawl survey. These averages are assumed to give representative values for the beginning of the year (see stock annex for details). However, the Russian bottom trawl survey has been discontinued and therefor stock weights-at-age were calculated using a correction factor (WKDEM 2020). Since the benchmark in 2006 stock weight at age has been smoothed (ICES 2006, see stock annex for details).

4.4.4 Maturity-at-age (Table 4.7)

Since the benchmark 2006, smoothed estimates were produced separately for the Russian autumn survey and the joint winter survey and then combined using arithmetic average. These averages are assumed to give representative values for the beginning of the year. However, the Russian bottom trawl survey has been discontinued and therefore stock weights-at-age were calculated using a correction factor (see WKDEM 2020 and stock annex).

4.4.5 Natural mortality (Table 4.8)

Natural mortality used in the assessment was 0.2. For ages 3–6 mortality predation by cod are added (see stock annex). For the period from 1984 and onwards actual estimates of predation by cod was used. For the years 1950–1983 the average natural mortality for 1984–2020 was used (age groups 3–6). Estimated mortality from predation by cod in this year's assessment is based on the 'final run' cod assessment. The proportion of F and M before spawning was set to zero.

4.4.6 Data for tuning (Table 4.9)

The following survey series are included in the data for tuning both for SAM, the last age for all surveys is the plus group. Data are lacking (no survey) for FLT01 in 2016, and for FLT007 in 2018 (not included due to poor coverage).

Name	ICES Acronym	Place	Season	Age	Year	prior weight
FLT01: Russian bottom trawl	RU-BTr-Q4	Barents Sea	October–December	3–8	1991–2017	1
FLT02: Joint Barents Sea survey–acoustic	BS-NoRU-Q1(Aco)	Barents Sea	February–March	3–9	1993–2021	1
FLT04: Joint Barents Sea survey–bottom trawl	BS-NoRu-Q1 (BTr)	Barents Sea	February–March	3–10	1994–2021	1
FLT007: Joint Russian-Norwegian ecosystem autumn survey in the Barents Sea–bottom trawl	Eco-NoRu-Q3 (Btr)	Barents Sea	August–September	3–9	2004–2020	1

4.4.7 Changes in data from last year (Table 4.6–Table 4.7, Table 4.9)

At the benchmark (WKDEM 2020) it was decided that historic values (1950–1993) of stock weight and maturity should not be updated in the following years. Due to the smoothing procedure (see stock annex) the stock weight and maturity ate at age back to 1994 are updated every year.

Natural mortality includes cod predation for the ages 3–6. The data from 1984 and onwards are updated every year after the update of the cod assessment. This year, the change in consumption estimates back to 1984 were larger than usual due to the revision of the cod stock undertaken at the cod benchmark held in early 2021. The averages used for the historic period (1950–1983) were updated and used in the assessment.

4.5 Assessment models and settings (Table 4.10)

At the benchmark in 2020 it was decided to continue using the SAM model as the main model and XSA, with revised settings, will be used as additional model for comparison. This year the TISVPA model is also used as an additional model for comparison.

The SAM configuration was revised during the benchmark in 2020. The main changes were 1) to include age group 3 in the winter survey indices (Fleet 02 and 04), 2) include a plus group in all survey series (new option in SAM), 3) include a prediction variance link for the observation variances (new option in SAM, Breivik *et al.*, in prep) 4) correlation structure in observation variance for the surveys (Berg and Nielsen, 2016).

The configuration, settings and tuning of SAM that were decided on during the benchmark (WKDEM 2020) were used in the current assessment. The configuration file is given in Table 4.10 and in the stock annex.

4.6 Results of the assessment (Table 4.11–Table 4.14 and Figure 4.1–Figure 4.3)

The dominating feature of the assessment is that the stock reached an all-time high level around 2011 due to the strong 2004–2006 year classes, and since declined (Table 4.11; Figure 4.1)

Fishing mortality has increased since 2013 (Table 4.12). The estimate of fishing mortality of main ages (4–7) in 2020 was 0.43 and above F_{MSY} = 0.35.

The SSB has decreased since the peak in 2013, and the estimate for 2021 201 kt and is still well above MSY $B_{trigger}$ = 80 kt (Figure 4.1).

Most of last year residuals are negative while catch observation close to predicted values, which means survey tends to underestimate stock. Retrospective estimates confirms that stock going down only based on last year surveys data (Figure 4.2 and Figure 4.3)

4.7 Comparison with last year’s assessment (Figure 4.4)

The text table below compares this year’s estimates with last year’s estimates. Compared to last year’s assessment the current estimates by SAM model of the total stock (TSB) and spawning stock (SSB) are lower for 2020. The F in 2019 is estimated a higher. Estimates for all ages except ages 4 and 5 (2015 and 2016 year classes) were reduced.

Year of assessment , model	F (2019)	Numbers 2020 (ages)											SSB (2020)	TSB (2020)
		3	4	5	6	7	8	9	10	11	12	13+		
2020 SAM	0.38	497	532	171	60	29	11	10	4	4	2	5	243	798
2021 SAM	0.43	442	530	164	48	24	9	8	3	3	2	3	205	723
Ratio 2021/2020	1.1	0.9	1.0	1.0	0.8	0.8	0.8	0.8	0.9	0.7	1.0	0.7	0.8	0.9

4.8 Additional assessment methods (Table 4.15, Figure 4.5–Figure 4.6)

4.8.1 XSA (Figure 4.5)

The Extended Survivors Analysis (XSA) was used to tune the VPA by available index series. As last years, FLR was used for the assessment of haddock (see stock annex), and thus all results concerning XSA are obtained using FLR. The settings used were the same as set in the benchmark in 2015 (WKARCT 2015). The biomass estimates of XSA with these settings significantly deviated from estimates of main model SAM. During the WKDEM 2020 it was found that changing S.E. of the mean survivor estimates shrinkage F from 1.5 to 0.5 gives estimates of biomass dynamics close to SAM estimates. Furthermore, this change improved XSA retrospective pattern. At AFWG 2021 this comparison also done and confirmed that usage of survivor estimates shrinkage 0.5 gave the similar result with SAM estimates.

The estimated consumption of NEA haddock by NEA cod is incorporated into the XSA analysis by first constructing a catch number-at-age matrix, adding the numbers of haddock eaten by cod to the catches for the years where such data are available (1984–2020). The summary of XSA stock estimates with shrinkage value 0.5 are presented in Table 4.15. A retrospective estimate for XSA gave same signals as for main model SAM (Figure 4.5).

4.8.2 TISVPA (Figure 4.6)

The TISVPA (Triple Instantaneous Separable VPA) model (Vasilyev, 2005; 2006) represents fishing mortality coefficients (more precisely – exploitation rates) as a product of three parameters: f(year)*s(age)*g(cohort). The generation-dependent parameters, which are estimated within the model, are intended to adapt traditional separable representation of fishing mortality to situations when several year classes may have peculiarities in their interaction with fishing fleets caused by different spatial distribution, higher attractiveness of more abundant schools to fishers, or by some other reasons. To NEA haddock stock the TISVPA model was at benchmark group for arctic stocks (WKARCT) in 2015 and this year it was decided to apply to NEA haddock using the same data as SAM except that natural mortality values from cannibalism were taken from the SAM runs. All the input data, including catch-at-age, weight-at-age in stock and in catches, maturity-at-age were taken the same as for stock assessment by means of SAM. During AFWG 2021 the results of runs using the TISVPA model were presented in WD#22. Generally biomass estimates of this model were higher than SAM estimates, which can be explained by different assumptions about indices catchability. A retrospective assessment for TISVPA shows same trends as for both another models (Figure 4.6).

4.8.3 Model comparisons (Figure 4.7)

Results from SAM, XSA and TISVPA are compared in Figure 4.7. Comparison of results of SAM, TISVPA and XSA with previous year settings shows that the models estimate similar trends. The TSVPA model is more flexible for settings than the others and taking in account a possible decreasing in survey data consistency, it was attempted to do tuning of surveys not at abundance but to age proportions because the probable change in effective survey catchability.

4.9 Predictions, reference points and harvest control rules (Table 4.16–Table 4.21)

4.9.1 Recruitment (Table 4.16–Table 4.17)

SAM was used to estimate the recruitment at age 3 of the 2018 year class in 2021. The RCT3 program translation in R was used to estimate the recruiting year classes 2019–2020 in 2022 and 2023 with survey data from the ecosystem survey and winter survey. Input data and results are shown in Tables 4.16 and 4.17, respectively.

The text table below shows the recruitment estimates for the year classes 2000–2018 from assessments and RCT3 (shaded cells). Overall, there is a good agreement with the year-class strength estimate from RCT3 and the assessments, for the year classes 2014–2018, the correlation between the initial estimate from RCT3 and the estimate in SAM is 98%. For the 2004–2017 year classes the estimate from SAM was on average 80% of the initial estimate, whereas the SAM estimate of the recruitment at age 3 of the 2018 year class was less than 50% from the initial estimate from RCT3 calculated in 2019.

Year	Year of assessment, base model (XSA 2005-2014)									XSA	SAM	SAM	SAM	SAM	SAM	SAM	SAM
Class	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2015	2016	2017	2018	2019	2020	2021
2000	197	237	236	249	246	222	232	232	232	229	237	179	231	247	244	247	352	340
2001	176	219	224	257	245	237	241	239	239	236	247	184	239	222	218	220	268	260
2002	295	313	339	367	365	371	352	359	359	352	368	275	352	351	349	353	377	366
2003	156	183	135	161	171	185	189	183	186	181	197	169	208	165	161	164	161	158
2004	462	755	672	665	668	610	765	743	725	698	768	687	930	898	869	879	557	543
2005		521	731	943	975	1029	1193	1301	1317	1303	1415	996	1456	1330	1241	1251	1149	1113
2006			463	832	1036	811	1057	1187	1264	1267	1366	827	1254	1083	1027	1030	1063	1025
2007				202	208	212	284	330	370	384	411	211	355	307	305	308	249	241
2008					149	101	120	151	155	169	178	89	157	107	109	110	122	117
2009						303	315	320	345	357	363	230	351	294	291	293	356	340
2010							188	146	137	146	150	100	133	105	105	106	124	119
2011								483	513	482	398	298	397	340	329	332	425	411
2012									124	145	104	78	73	79	70	68	75	72
2013										394	290	197	235	184	174	177	219	213
2014											279	198	247	189	145.96	148	202	194
2015													422	398	333	336	384	368
2016														1067	933	930	875	822
2017															577	629	497	442
2018																344	294	154
2019																	39	31
2020																		95

4.9.2 Prediction data (Table 4.18, Figure 4.8)

The input data for the prediction are presented in Table 4.18.

Stock numbers for 2021–2022 at age 3 are taken from RCT3, and abundance-at-ages 3–13+ in 2020 from the SAM assessment. The average fishing pattern observed in 2018–2020 scaled to F in 2020 was used for distribution of fishing mortality-at-age for 2021–2023 (Figure 4.8). The proportion of M and F before spawning was set to 0.

Input data to projection of weight at age in the stock, weight at age in the catch, maturity and mortality followed the stock annex.

4.9.3 Biomass reference points (Figure 4.1)

Biological and fisheries reference points for NEA haddock were last set following a thorough analysis as part of the WKNEAMP-2 (ICES, 2016) Harvest Control Rule evaluation in 2016. The revised model developed during the 2020 benchmark produced better fits to the data but only a small change in the reconstructed stock (WKDEM 2020). A brief analysis at WKDEM 2020 indicated that the reference points from the current model are very similar to the previously estimated values. Given the more thorough analysis at WKNEAMP-2 (ICES, 2016), this is taken as indicating that there was no evidence to deviate from the reference points set in 2016.

At the last benchmark (WKDEM 2020) it was proposed to keep B_{lim} = 50 000 t and B_{pa} = 80 000 t with the rationale that B_{lim} is equal to B_{loss}, and $B_{pa} = B_{lim}*\exp(1.645*\sigma)$, where $\sigma = 0.3$. This gives a 95% probability of maintaining SSB above B_{lim} taking into account the uncertainty in the assessments and stock dynamics. B_{MSY} trigger was proposed equal B_{pa}, $B_{trigger}$ was then selected as a biomass that is encountered with low probability if F_{MSY} is implemented, as recommended by WKFRAME2 (ICES CM 2011/ACOM:33). Values of reference points compared with current stock values are reflected in Figure 4.1.

4.9.4 Fishing mortality reference points (Figure 4.1)

Biological and fisheries reference points for NEA haddock were last set following a thorough analysis as part of the WKNEAMP-2 (ICES, 2016) Harvest Control Rule evaluation in 2016. The revised model developed during the 2020 benchmark produced better fits to the data but only a small change in the reconstructed stock (WKDEM 2020). A brief analysis at WKDEM 2020 indicated that the reference points from the current model are very similar to the previously estimated values. Given the more thorough analysis at WKNEAMP-2 (ICES, 2016), this is taken as indicating that there was no evidence to deviate from the reference points set in 2016.

There is no standard method of estimating F_{lim} nor F_{pa}, and ACOM accepted to use geometric mean recruitment (146 million) and B_{lim} as basis for the F_{lim} estimate. F_{lim} is then based on the slope of line from origin at SSB = 0 to the geometric mean recruitment (146 million) and SSB = B_{lim}. The SPR value of this slope give F_{lim} value on SPR curve; $F_{lim} = 0.77$ (found using Pasoft). Using the same approach as for B_{pa}; $F_{pa} = F_{lim}*\exp(-1.645*\sigma) = 0.47$.

$F_{MSY} = 0.35$ has been estimated by long-term stochastic simulations. Values of reference points compared with current stock values are reflected in Figure 4.1.

The estimates of cod's consumption of haddock were revised following the cod benchmark in early 2021. At the AFWG 2021 meeting, the haddock F_{MSY} was checked with the new updated mortality estimates and found to still be valid and precautionary.

4.9.5 Harvest control rule

The harvest control rule (HCR) was evaluated by ICES in 2007 (ICES CM 2007/ACFM:16) and found to be in agreement with the precautionary approach. The agreed HCR for haddock with last modifications is as follows (Protocol of the 40th Session of The Joint Norwegian Russian Fisheries Commission (JNRFC), 14 October 2011):

- TAC for the next year will be set at level corresponding to F_{MSY}.

- The TAC should not be changed by more than +/- 25% compared with the previous year TAC.
- If the spawning stock falls below B_{pa}, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from F_{MSY} at B_{pa} to F = 0 at SSB equal to zero. At SSB-levels below B_{pa} in any of the operational years (current year and a year ahead) there should be no limitations on the year-to-year variations in TAC.

As mentioned above F_{lim} and F_{pa} were revised in 2011. The new values of F_{lim} = 0.77 and F_{pa} = 0.47 are higher than the previous values (0.49 and 0.35, respectively). In the 2012 meeting of the JNRFC the proposals of ICES were accepted, and the current HCR management is based on F_{MSY} instead of $F_{pa.}$ This corresponds to the goal of the management strategy for this stock and should provide maximum sustainable yield.

In 2014, JNRFC decided that from 2015 onwards, Norway and Russia can transfer to next year or borrow from last year 10% of the country's quota. At its 45th session in October 2015, the Joint Norwegian-Russian Fisheries Commission (JNRFC) decided that a number of alternative harvest control rules (HCRs) for Northeast Arctic haddock should be evaluated by ICES. This was done by WKNEAMP (ICES 2015/ACOM:60, ICES C. M. 2016/ACOM:47). Six HCRs for NEA haddock including the existing one were tested. At its 46th session in October 2016, the JNRFC decided not to change the HCR.

4.9.6 Prediction results and catch options for 2021 (Table 4.19–Table 4.21)

The projection shows a slight increase in SSB from 203 kt in 2021 to 205 kt in 2022 (Table 4.19). TAC constraint F is used for 2021. The TAC for 2022 is established using the current one-year HCR, in accordance of the management plan. F_{MSY} = 0.35 would give a quota for 2022 of 180 kt, this is a 23% decrease from the TAC and advice for 2021. Yield-per-recruit is given in Table 4.21.

Catch options for 2021 are shown in the text table below (weights in tonnes).

Basis	Total catch (2022)	F ages 4–7 (2022)	SSB (2023)	% SSB change *	% TAC change **	% Advice change ***
ICES advice basis						
Management plan	180003	0.35	201485	−1.6	−22.6	−22.6
Other scenarios						
MSY approach: F_{MSY}	180003	0.35	201485	−1.6	−22.6	−22.6
F = 0	0	0	309362	51.1	−100.0	−100.0
F = F2021	214185	0.44	181739	−11.2	−7.9	−7.9
F_{pa}	227071	0.47	174372	−14.8	−2.4	−2.4
F_{lim}	320921	0.77	122248	−40.3	38.0	38.0

*** SSB 2023 relative to SSB 2022.**

**** Catch in 2022 relative to TAC in 2021**

***** Catch value for 2022 relative to advice value for 2021**

Detailed information about expected catches by following HCR in 2022 and 2023 is given in Table 4.20. This catch forecast covers all catches. It is then implied that all types of catches are to be counted against this TAC. It also means that if any overfishing is expected to take place, the above calculated TAC should be reduced by the expected amount of overfishing.

4.9.7 Comments to the assessment and predictions (Figure 4.2–Figure 4.4 and Figure 4.9)

Haddock was benchmarked prior to last year's assessment (WKDEM 2020). The motivation for the benchmark was the poor retrospective (text table below).

Retrospective bias (Mohn's Rho), 5-year peel	R	SSB	F	TSB
AFWG 2018	−3%	24%	−7%	14%
AFWG 2019	−5%	18%	−7%	7%
WKDEM 2020	−2%	3%	−3%	1%
AFWG 2020	−4%	−3%	0%	−5%
AFWG 2021	1%	6%	−7%	3%

The one step ahead residuals showed no clear pattern (Figure 4.2). This year, we also used model simulations and jitter analysis, as diagnostics of SAM model performance. No problems were detected.

By adding a new year of data, the analytical retrospective bias increased for SSB and F and decreased for R and TSB (Figure 4.3). The increased bias was mainly due to the low survey indices from the ecosystem survey 2020 and winter survey 2021, pulling the stock estimate down. Compared to last year's assessment, except for the ages 4 and 5, estimates of all ages in 2020 was estimated lower at this year's assessment. This is mainly due to the low survey indices from the ecosystem survey of 2020 and winter survey 2021, but also due to update of the data, especially of the predation from cod, following the benchmark of the cod stock in 2021.

According to this year's assessment, the 2016 year class is the sixth strongest year class in the time-series back to 1950 and the 2017 year class is also above average, whereas the 2018 year class is weak. The 2019–2020 year classes are predicted to be well below average, the 2019 year class as the weakest since 1990.

As for the last two assessments F was above F_{MSY} in 2020 (Figure 4.4). This appears to be due to a too optimistic estimate of the stock in the assessment in 2019, and consequently too high TAC set for 2020. There was less fishing on youngest fish than initially assumed. Also, the weight in the catch in 2020 was considerably lower than was assumed in the forecast, especially for the 4-year olds (Figure 4.9).

The retrospective trend indicates that the catch advice given in 2020 for 2021 is likely biased high. The catch in 2020 was 15% lower than TAC and the catch is expected to be below the TAC also in 2021, especially since the TAC in 2021 was higher than the 2020 TAC.

Table 4.1. Northeast Arctic haddock. Total nominal catch (t) by fishing areas

Year	Subarea 1	Division 2.a	Division 2.b	un-reported (2	Total (3	Norw. stat.areas 06 and 07 (4
1960	125026	27781	1844	-	154651	6000
1961	165156	25641	2427	-	193224	4000
1962	160561	25125	1723	-	187409	3000
1963	124332	20956	936	-	146224	4000
1964	79262	18784	1112	-	99158	6000
1965	98921	18719	943	-	118583	6000
1966	125009	35143	1626	-	161778	5000
1967	107996	27962	440	-	136398	3000
1968	140970	40031	725	-	181726	3000
1969	89948	40306	566	-	130820	2000
1970	60631	27120	507	-	88258	-
1971	56989	21453	463	-	78905	-
1972	221880	42111	2162	-	266153	-
1973	285644	23506	13077	-	322227	-
1974	159051	47037	15069	-	221157	10000
1975	121692	44337	9729	-	175758	6000
1976	94054	37562	5648	-	137264	2000
1977	72159	28452	9547	-	110158	2000
1978	63965	30478	979	-	95422	2000
1979	63841	39167	615	-	103623	6000
1980	54205	33616	68	-	87889	5098
1981	36834	39864	455	-	77153	4767
1982	17948	29005	2	-	46955	3335
1983	5837	16859	1904	-	24600	3112
1984	2934	16683	1328	-	20945	3803
1985	27982	14340	2730	-	45052	3583
1986	61729	29771	9063	-	100563	4021
1987	97091	41084	16741	-	154916	3194
1988	45060	49564	631	-	95255	3756

Year	Subarea 1	Division 2.a	Division 2.b	un-reported (2	Total (3	Norw. stat.areas 06 and 07 (4
1989	29723	28478	317	-	58518	4701
1990	13306	13275	601	-	27182	2912
1991	17985	17801	430	-	36216	3045
1992	30884	28064	974	-	59922	5634
1993	46918	32433	3028	-	82379	5559
1994	76748	50388	8050	-	135186	6311
1995	75860	53460	13128	-	142448	5444
1996	112749	61722	3657	-	178128	5126
1997	78128	73475	2756	-	154359	5987
1998	45640	53936	1054	-	100630	6338
1999	38291	40819	4085	-	83195	5743
2000	25931	39169	3844	-	68944	4536
2001	35072	47245	7323	-	89640	4542
2002	40721	42774	12567	18736/5310	114798/101372	6898
2003	53653	43564	8483	33226/9417	138926/115117	4279
2004	64873	47483	12146	33777/8661	158279/133163	3743
2005	53518	48081	16416	40283/9949	158298/127964	5538
2006	51124	47291	33291	21451/8949	153157/140655	5410
2007	62904	58141	25927	14553/3102	161525/150074	7110
2008	58379	60178	31219	5828/-	155604/149776	6629
2009	57723	66045	76293	0	200061	4498
2010	62604	86279	100318	0	249200	3661
2011	86931	99307	123546	0	309785	4169
2012	90141	96807	128679	0	315627	3869
2013	68416	64810	60520	0	193744	4000
2014	61537	58320	57665	0	177522	3433
2015	75195	61567	57993	0	194756	3902
2016	78714	95140	59561	0	233416	3233
2017	94772	75455	57362	0	227589	2987

Year	Subarea 1	Division 2.a	Division 2.b	un-reported (2	Total (3	Norw. stat.areas 06 and 07 (4
2018	80902	58522	51853	0	191276	4437
2019	87446	50967	36989	0	175402	2812
2020[1)]	98341	57397	26730	0	182468	3196

1) Provisional figures

2) Figures based on Norwegian/Russian IUU estimates. From 2009, IUU estimates are made by a Joint Russian-Norwegian analysis group under the Russian-Norwegian Fisheries Commission.

3) In 2002–2008, the Norwegian IUU estimates were used in final assessment.

4) Included in total landings and in landings in region 2.a.

Table 4.2. Northeast Arctic haddock. Total nominal catch ('000 t) by trawl and other gear for each area

	Subarea 1		Division 2.a		Division 2.b		Unreported[2]
Year	Trawl	Others	Trawl	Others	Trawl	Others	
1967	73.7	34.3	20.5	7.5	0.4	-	-
1968	98.1	42.9	31.4	8.6	0.7	-	-
1969	41.4	47.8	33.2	7.1	1.3	-	-
1970	37.4	23.2	20.6	6.5	0.5	-	-
1971	27.5	29.2	15.1	6.7	0.4	-	-
1972	193.9	27.9	34.5	7.6	2.2	-	-
1973	242.9	42.8	14	9.5	13.1	-	-
1974	133.1	25.9	39.9	7.1	15.1	-	-
1975	103.5	18.2	34.6	9.7	9.7	-	-
1976	77.7	16.4	28.1	9.5	5.6	-	-
1977	57.6	14.6	19.9	8.6	9.5	-	-
1978	53.9	10.1	15.7	14.8	1	-	-
1979	47.8	16	20.3	18.9	0.6	-	-
1980	30.5	23.7	14.8	18.9	0.1	-	-
1981	18.8	17.7	21.6	18.5	0.5	-	-
1982	11.6	11.5	23.9	13.5	-	-	-
1983	3.6	2.2	8.7	8.2	0.2	1.7	-
1984	1.6	1.3	7.6	9.1	0.1	1.2	-
1985	24.4	3.5	6.2	8.1	0.1	2.6	-

	Subarea 1		**Division 2.a**		**Division 2.b**		**Unreported**[2]
1986	51.7	10.1	14	15.8	0.8	8.3	-
1987	79	18.1	23	18.1	3	13.8	-
1988	28.7	16.4	34.3	15.3	0.6	0	-
1989	20	9.7	13.5	15	0.3	0	-
1990	4.4	8.9	5.1	8.2	0.6	0	-
1991	9	8.9	8.9	8.9	0.2	0.2	-
1992	21.3	9.6	11.9	16.1	1	0	-
1993	35.3	11.6	14.5	17.9	3	0	-
1994	58.6	18.2	26.1	24.3	7.9	0.2	-
1995	63.9	12	29.6	23.8	12.1	1	-
1996	98.3	14.4	36.5	25.2	3.4	0.3	-
1997	57.4	20.7	44.9	28.6	2.5	0.3	-
1998	26	19.6	27.1	26.9	0.7	0.3	-
1999	29.4	8.9	19.1	21.8	4	0.1	-
2000	20.1	5.9	18.8	20.4	3.7	0.1	-
2001	28.4	6.7	23.4	23.8	7	0.3	-
2002	30.5	10.2	19.5	23.3	12.5	0.1	18.7/5.3
2003	42.7	10.9	21.9	21.7	8.1	0.4	33.2/9.4
2004	52.4	12.5	27	20.5	11.5	0.6	33.8/8.7
2005	38.5	15	24.9	20.9	13	1.6	40.3/9.9
2006	40.1	11	22	25.3	30.1	3.2	21.5/8.9
2007	51.8	11.1	30.5	27.7	20.4	5.5	14.6/3.1
2008	46.8	11.6	30.9	29.3	24.9	6.3	5.8/-
2009	49	8.8	40.1	25.3	67.1	7.8	0
2010	43.6	19	50	35.7	87	10.4	0
2011	55.8	31.1	61.1	38.9	107.7	14.3	0
2012	58.8	31.3	57.5	39.2	103.2	24.8	0
2013	40.1	28.3	37.7	26.9	52.1	8.1	0
2014	35.2	26.3	32.5	25.8	49	8.6	0

	Subarea 1		Division 2.a		Division 2.b		Unreported[2]
2015	49.1	26.1	34.6	27	48.5	9.4	0
2016	56.4	22.3	62.5	32.5	45.4	14.1	0
2017	65	29.8	50.7	24.7	47.1	10.3	0
2018	51.7	29.2	36.9	21.6	43.2	8.6	0
2019	53.9	33.5	30.4	20.4	31.0	5.9	0
2020(1)	66.7	31.6	35.1	22.3	23.2	3.5	0

1) Provisional

2) Figures based on Norwegian/Russian IUU estimates.

Table 4.3 Northeast Arctic haddock. Nominal catch (t) by countries. Subarea 1 and divisions 2.a and 2.b combined. (Data provided by Working Group members).

Year	Faroe Islands	France	GDR (–1990) & Greenland (1992–)	Germany	Norway[4]	Poland	UK	Russia[2]	Others	Total[3]
1960	172	-	-	5597	46263	-	45469	57025	125	154651
1961	285	220	-	6304	60862	-	39650	85345	558	193224
1962	83	409	-	2895	54567	-	37486	91910	58	187408
1963	17	363	-	2554	59955	-	19809	63526	-	146224
1964	-	208	-	1482	38695	-	14653	43870	250	99158
1965	-	226	-	1568	60447	-	14345	41750	242	118578
1966	-	1072	11	2098	82090	-	27723	48710	74	161778
1967	-	1208	3	1705	51954	-	24158	57346	23	136397
1968	-	-	-	1867	64076	-	40129	75654	-	181726
1969	2	-	309	1490	67549	-	37234	24211	25	130820
1970	541	-	656	2119	37716	-	20423	26802	-	88257
1971	81	-	16	896	45715	43	16373	15778	3	78905
1972	137	-	829	1433	46700	1433	17166	196224	2231	266153
1973	1212	3214	22	9534	86767	34	32408	186534	2501	322226
1974	925	3601	454	23409	66164	3045	37663	78548	7348	221157
1975	299	5191	437	15930	55966	1080	28677	65015	3163	175758
1976	536	4459	348	16660	49492	986	16940	42485	5358	137264

Year	Faroe Islands	France	GDR (–1990) & Greenland (1992–)	Germany	Norway[4]	Poland	UK	Russia[2]	Others	Total[3]
1977	213	1510	144	4798	40118	-	10878	52210	287	110158
1978	466	1411	369	1521	39955	1	5766	45895	38	95422
1979	343	1198	10	1948	66849	2	6454	26365	454	103623
1980	497	226	15	1365	66501	-	2948	20706	246	92504
1981	381	414	22	2402	63435	Spain	1682	13400	-	81736
1982	496	53	-	1258	43702	-	827	2900	-	49236
1983	428	-	1	729	22364	139	259	680	-	24600
1984	297	15	4	400	18813	37	276	1103	-	20945
1985	424	21	20	395	21272	77	153	22690	-	45052
1986	893	12	75	1079	52313	22	431	45738	-	100563
1987	464	7	83	3105	72419	59	563	78211	5	154916
1988	1113	116	78	1323	60823	72	435	31293	2	95255
1989	1217	-	26	171	36451	1	590	20062	-	58518
1990	705	-	5	167	20621	-	494	5190	-	27182
1991	1117	-	**Greenland**	213	22178	-	514	12177	17	36216
1992	1093	151	1719	387	36238	38	596	19699	1	59922
1993	546	1215	880	1165	40978	76	1802	35071	646	82379
1994	2761	678	770	2412	71171	22	4673	51822	877	135186
1995	2833	598	1097	2675	76886	14	3111	54516	718	142448
1996	3743	6	1510	942	94527	669	2275	74239	217	178128
1997	3327	540	1877	972	103407	364	2340	41228	304	154359
1998	1903	241	854	385	75108	257	1229	20559	94	100630
1999	1913	64	437	641	48182	652	694	30520	92	83195
2000	631	178	432	880	42009	502	747	22738	827	68944
2001	1210	324	553	554	49067	1497	1068	34307	1060	89640
2002	1564	297	858	627	52247	1505	1125	37157	682	114798
2003	1959	382	1363	918	56485	1330	1018	41142	1103	138926

Year	Faroe Islands	France	GDR (–1990) & Greenland (1992–)	Germany	Norway[4]	Poland	UK	Russia[2]	Others	Total[3]
2004	2484	103	1680	823	62192	54	1250	54347	1569	158279
2005	2138	333	15	996	60850	963	1899	50012	1262	158298
2006	2390	883	1830	989	69272	703	1164	53313	1162	153157
2007	2307	277	1464	1123	71244	125	1351	66569	2511	161525
2008	2687	311	1659	535	72779	283	971	68792	1759	155604
2009	2820	529	1410	1957	104354	317	1315	85514	1845	200061
2010	3173	764	1970	3539	123384	379	1758	111372	2862	249201
2011	1759	268	2110	1724	158202	502	1379	139912	4763	310619
2012	2055	322	3984	1111	159602	441	833	143886	3393	315627
2013	1886	342	1795	500	99215	439	639	85668	3260	193744
2014	1470	198	1150	340	91306	187	355	78725	3791	177522
2015	2459	145	1047	124	95094	246	450	91864	3327	194756
2016	2460	340	1401	170	108718	200	575	115710	3838	233412
2017	2776	108	1810	170	113132	228	372	106714	2279	227588
2018	2333	183	1317	385	93839	169	453	90486	2111	191276
2019	1515	143	1208	204	93860	280	456	76125	1611	175402
2020[1)]	1392	96	910	282	88108	45	320	89030	2286	182468

1) Provisional figures.

2) USSR prior to 1991.

3) Figures based on Norwegian IUU estimates in 2002–2008 (see table 4.1)

4) Included landings in Norwegian statistical areas 06 and 07 (from 1983)

Table 4.4. Northeast Arctic haddock. Catch numbers-at-age (numbers, ´000).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
1950	0	4446	3189	37949	35344	18849	28868	9199	1979	1093	853	867	1257
1951	4069	222	65643	9178	18014	13551	6808	6850	3322	1182	734	178	436
1952	0	13674	6012	151996	13634	9850	4693	3237	2434	606	534	185	161
1953	392	8031	64528	13013	70781	5431	2867	1080	424	315	393	202	410
1954	1726	493	6563	154696	5885	27590	3233	1302	712	319	126	68	349

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
1955	0	989	1154	10689	176678	4993	28273	1445	271	100	50	30	20
1956	97	3012	16437	5922	14713	127879	3182	8003	450	200	80	60	45
1957	828	243	2074	24704	7942	12535	46619	1087	1971	356	17	40	119
1958	153	2312	1727	5914	31438	5820	12748	17565	822	1072	226	79	296
1959	169	2425	20318	7826	7243	14040	3154	2237	5918	285	316	71	113
1960	2319	3613	39910	70912	13647	7101	6236	1579	2340	2005	497	70	42
1961	362	5531	15429	56855	63351	8706	3578	4407	788	527	1287	67	80
1962	0	4524	39503	30868	48903	33836	3201	1341	1773	242	247	483	28
1963	3	2143	28466	72736	18969	13579	9257	1239	559	409	80	84	212
1964	149	834	22363	49290	30672	5815	3527	2716	833	104	206	235	190
1965	0	3498	5936	46356	40201	12631	1679	974	897	123	204	123	471
1966	0	2577	26345	22631	63176	29048	5752	582	438	189	186	25	30
1967	0	53	15907	41346	13496	25719	8872	1616	218	175	155	75	41
1968	0	33	657	67632	41267	7748	15599	5292	655	182	101	115	70
1969	0	1061	1524	1968	44634	19002	3620	4937	1628	316	43	43	23
1970	480	281	23444	2454	1906	22417	8100	2012	2016	740	166	26	96
1971	15	3535	1978	24358	1257	918	9279	3056	826	1043	369	130	35
1972	133	9399	230942	22315	42981	3206	1611	6758	2638	900	989	538	120
1973	0	5956	70679	260520	24180	6919	422	426	1692	529	147	339	95
1974	281	3713	9685	41706	88120	5829	4138	382	618	2043	935	276	659
1975	1321	4355	10037	14088	33871	49711	2135	1236	92	131	500	147	287
1976	3475	7499	13994	13454	6810	20796	40057	1247	1350	193	280	652	671
1977	184	18456	55967	22043	7368	2586	7781	11043	311	388	96	101	182
1978	46	2033	47311	18812	4076	1389	1626	2596	6215	162	258	3	139
1979	0	48	17540	35290	10645	1429	812	546	1466	2310	181	87	55
1980	0	0	627	22878	21794	2971	250	504	230	842	1299	111	50
1981	1	68	486	2561	22124	10685	1034	162	162	72	330	564	69
1982	2	29	883	900	3372	12203	2625	344	75	80	91	321	238
1983	3	351	1173	2636	1360	2394	2506	1799	267	37	60	100	132

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
1984	7	754	1271	1019	1899	657	950	2619	352	87	2	22	53
1985	4	2952	29624	1695	564	1009	943	886	1763	588	124	64	93
1986	506	650	23113	68429	1565	783	896	393	702	1144	443	130	414
1987	9	83	5031	87170	64556	960	597	376	212	230	419	245	73
1988	7	139	1439	12478	47890	20429	397	178	74	88	168	198	80
1989	611	221	2157	4986	16071	25313	3198	147	1	28	28	53	96
1990	2	446	1015	2580	2142	4046	6221	840	134	42	14	13	44
1991	23	533	4421	3564	2416	3299	4633	3953	461	83	9	18	27
1992	49	2793	11571	11567	4099	2642	2894	3327	3498	486	35	32	18
1993	498	272	13487	19457	13704	4103	1747	1886	2105	1965	201	96	25
1994	95	187	3374	47821	36333	13264	2057	903	1453	2769	1802	259	49
1995	2	85	2003	16109	72644	19145	6417	746	361	770	655	804	116
1996	35	478	1662	6818	36473	73579	13426	2944	573	365	533	598	767
1997	70	94	2280	5633	12603	32832	49478	5636	778	245	126	158	463
1998	547	1476	1701	11304	9258	8633	13801	19469	2113	330	59	54	377
1999	104	568	16839	8039	15365	6073	4466	6355	6204	647	117	109	220
2000	46	692	1520	29986	6496	5149	2406	1657	1570	1744	183	70	184
2001	374	1758	12971	5230	32049	5279	2941	1137	1161	1169	747	169	288
2002	59	603	7132	46335	11084	21985	2602	1602	482	448	581	349	98
2003	123	611	6803	31448	56480	11736	14541	1637	2178	858	411	413	395
2004	58	1295	7993	21116	41310	41226	4939	4914	598	1252	296	139	465
2005	102	865	11452	19369	22887	37067	24461	2393	2997	990	201	263	1059
2006	271	2496	4539	35040	27571	15033	16023	8567	1259	1298	222	175	321
2007	575	3914	30707	15213	45992	18516	10642	7889	2570	678	605	197	185
2008	440	2089	14536	44192	15926	31173	9145	4520	2846	1181	274	214	166
2009	483	1364	15379	55013	52498	13679	15382	3800	1669	887	285	353	321
2010	457	620	6545	52006	80622	50306	9273	5324	1954	1114	533	242	621
2011	909	806	1277	8501	90394	100522	39496	4397	2340	668	437	269	708
2012	268	611	7814	4206	18007	93055	82721	14445	1325	448	217	216	568

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
2013	402	904	1778	12780	3805	12297	58024	29930	4976	957	331	212	535
2014	528	649	6948	4503	14563	6833	16304	39620	16439	2431	619	440	545
2015	303	1334	1645	27317	8526	16624	7950	20538	25534	6677	1556	295	312
2016	294	655	5774	3482	33177	9563	18045	12030	21875	13492	4757	876	248
2017	724	1898	30744	46463	16895	48927	10518	14992	9 485	8447	6640	1872	317
2018	679	1438	9424	16291	34060	8466	18882	5123	8902	4125	3564	4504	1040
2019	797	968	13908	28572	24171	32555	6278	6803	2601	3618	1225	1715	1400
2020	122	1298	10797	62206	46715	18137	10773	3051	2839	1445	996	915	1092

Table 4.5. Northeast Arctic haddock. Catch weights-at-age (kg).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
1950	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1951	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1952	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1953	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1954	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1955	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1956	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1957	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1958	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1959	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1960	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1961	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1962	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1963	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1964	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1965	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1966	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1967	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1968	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13+**
1969	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1970	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1971	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1972	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1973	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1974	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1975	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1976	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1977	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1978	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1979	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1980	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1981	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1982	0.299	0.519	0.75	1.038	1.321	1.617	1.873	2.147	2.418	2.698	2.931	3.094	3.461
1983	0.188	0.689	1.033	1.408	1.71	2.149	2.469	2.748	3.069	3.687	4.516	3.094	3.461
1984	0.408	0.805	1.218	1.632	2.038	2.852	2.845	3.218	3.605	4.065	4.407	4.734	5.099
1985	0.319	0.383	0.835	1.29	1.816	2.174	2.301	2.835	3.253	3.721	4.084	4.137	4.926
1986	0.218	0.325	0.612	1.064	1.539	1.944	2.362	2.794	3.25	3.643	4.14	4.559	5.927
1987	0.143	0.221	0.497	0.765	1.179	1.724	2.135	2.551	3.009	3.414	3.84	4.415	5.195
1988	0.279	0.551	0.55	0.908	1.097	1.357	1.537	1.704	2.403	2.403	2.486	2.531	2.834
1989	0.258	0.55	0.684	0.84	0.998	1.176	1.546	1.713	1.949	2.14	2.389	2.522	2.797
1990	0.319	0.601	0.793	1.172	1.397	1.624	1.885	2.112	2.653	3.102	3.18	3.438	3.319
1991	0.216	0.616	0.941	1.281	1.556	1.797	2.044	2.079	2.311	2.788	3.408	2.896	3.274
1992	0.055	0.458	0.906	1.263	1.535	1.747	2.043	2.2	2.298	2.494	2.49	2.673	2.923
1993	0.381	0.64	0.94	1.204	1.487	1.748	1.994	2.237	2.417	2.654	2.906	3.184	3.363
1994	0.278	0.521	0.614	0.906	1.287	1.602	1.968	2.059	2.39	2.545	2.881	2.918	3.222
1995	0.258	0.446	0.739	0.808	1.107	1.556	1.838	2.234	2.416	2.602	2.965	3.163	3.786
1996	0.287	0.427	0.683	0.868	1.045	1.363	1.71	1.886	2.214	2.37	2.438	2.707	2.896
1997	0.408	0.575	0.682	1.028	1.151	1.369	1.637	1.856	2.073	2.5	2.279	2.532	2.609

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
1998	0.409	0.593	0.748	0.974	1.262	1.433	1.641	1.863	2.069	2.335	2.511	2.8	2.849
1999	0.435	0.695	0.826	1.079	1.261	1.485	1.634	1.798	2.032	2.237	2.339	2.611	2.865
2000	0.378	0.577	0.853	1.186	1.395	1.588	1.808	1.989	2.264	2.415	2.587	2.647	3.098
2001	0.391	0.647	0.751	1.104	1.459	1.709	1.921	2.182	2.331	2.609	2.757	3.376	3.338
2002	0.159	0.407	0.687	1.001	1.363	1.643	1.975	2.086	2.294	2.487	2.612	2.847	3.501
2003	0.198	0.384	0.594	0.875	1.113	1.364	1.361	1.972	1.636	1.877	2.088	2.351	2.842
2004	0.328	0.429	0.636	0.886	1.183	1.508	1.821	2.075	2.339	2.58	2.527	3.153	3.197
2005	0.285	0.492	0.722	0.906	1.121	1.343	1.619	2.036	2.177	2.382	2.527	2.496	2.81
2006	0.311	0.567	0.745	1.041	1.287	1.504	1.72	2.082	2.377	2.738	3.082	3.02	3.43
2007	0.329	0.431	0.652	0.899	1.197	1.435	1.722	1.99	2.309	2.715	2.987	2.947	3.591
2008	0.383	0.484	0.658	0.901	1.242	1.515	1.781	2.18	2.33	2.664	3.019	3.326	3.829
2009	0.378	0.508	0.707	1.024	1.28	1.538	1.806	2.107	2.398	2.531	2.606	3.089	3.541
2010	0.317	0.499	0.642	0.887	1.137	1.396	1.702	1.907	2.095	2.404	2.534	3.064	3.249
2011	0.423	0.513	0.811	0.953	1.093	1.254	1.462	1.715	1.978	2.328	2.305	2.55	2.76
2012	0.271	0.506	0.756	1.004	1.174	1.371	1.514	1.715	2.051	2.444	2.414	2.615	2.932
2013	0.469	0.542	0.821	1.014	1.217	1.401	1.571	1.714	1.914	2.168	2.24	2.516	2.807
2014	0.469	0.645	0.792	1.033	1.253	1.417	1.625	1.793	1.941	2.081	2.479	2.703	3.011
2015	0.473	0.647	0.876	1.054	1.327	1.571	1.777	1.934	2.025	2.216	2.481	2.99	3.455
2016	0.497	0.743	0.882	1.115	1.369	1.662	1.917	2.089	2.301	2.567	3.076	3.286	3.331
2017	0.449	0.608	0.874	1.088	1.378	1.666	1.879	2.146	2.258	2.476	2.72	2.98	3.713
2018	0.443	0.663	0.820	1.051	1.339	1.629	1.927	2.156	2.372	2.588	2.728	2.773	3.175
2019	0.341	0.508	0.729	0.955	1.275	1.581	1.834	2.151	2.378	2.607	2.868	2.934	3.382
2020	0.364	0.523	0.629	0.788	1.131	1.489	1.821	2.126	2.426	2.651	2.771	3.147	3.359

Table 4.6. Northeast Arctic haddock. Stock weights-at-age (kg). The data from 1950–1993 is unchanged AFWG 2019, the data from 1994 and onward have been updated this year. The ages 3–13 are adjusted to account for the lack of the Russian survey as described in the stock annex, age 1–2 are unadjusted smoothed estimates based on winter survey data.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1950	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1951	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1952	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1953	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1954	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1955	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1956	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1957	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1958	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1959	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1960	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1961	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1962	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1963	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1964	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1965	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1966	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1967	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1968	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1969	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1970	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1971	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1972	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1973	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1974	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1975	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1976	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1977	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1978	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1979	0.031	0.145	0.354	0.653	1.016	1.427	1.867	2.327	2.771	3.195	3.597	3.597	3.597
1980	0.063	0.262	0.454	0.878	1.159	1.675	2.292	3.134	3.31	3.553	3.792	3.792	3.792
1981	0.051	0.274	0.603	0.805	1.315	1.582	2.118	2.728	3.51	3.679	3.904	3.904	3.904
1982	0.036	0.224	0.631	1.049	1.217	1.782	2.017	2.553	3.14	3.853	4.016	4.016	4.016
1983	0.035	0.164	0.524	1.098	1.558	1.663	2.255	2.448	2.97	3.524	4.165	4.165	4.165
1984	0.028	0.158	0.391	0.926	1.632	2.093	2.121	2.718	2.865	3.363	3.878	3.878	3.878
1985	0.03	0.127	0.379	0.700	1.394	2.195	2.626	2.572	3.158	3.261	3.728	3.728	3.728
1986	0.035	0.136	0.311	0.682	1.069	1.898	2.761	3.138	3.005	3.568	3.632	3.632	3.632
1987	0.042	0.161	0.331	0.569	1.047	1.473	2.411	3.307	3.616	3.412	3.946	3.946	3.946
1988	0.039	0.189	0.383	0.603	0.887	1.452	1.895	2.915	3.822	4.054	3.787	3.787	3.787
1989	0.037	0.175	0.445	0.689	0.936	1.248	1.878	2.317	3.395	4.297	4.449	4.449	4.449
1990	0.031	0.169	0.413	0.789	1.054	1.312	1.635	2.308	2.728	3.844	4.73	4.73	4.73
1991	0.025	0.141	0.402	0.737	1.193	1.458	1.714	2.035	2.732	3.122	4.256	4.256	4.256
1992	0.023	0.114	0.34	0.721	1.119	1.63	1.881	2.127	2.437	3.142	3.491	3.491	3.491
1993	0.025	0.107	0.279	0.616	1.100	1.537	2.08	2.308	2.54	2.831	3.531	3.531	3.531
1994	13.8	22.1	0.25	0.502	0.936	1.646	2.17	2.713	2.866	2.817	2.978	3.64	4.181
1995	14.9	22.6	0.261	0.465	0.795	1.311	2.113	2.633	3.166	3.295	3.228	3.163	3.955
1996	14.9	24.3	0.278	0.485	0.744	1.132	1.714	2.568	3.092	3.61	3.719	3.419	3.481
1997	15.2	24.3	0.343	0.512	0.766	1.06	1.49	2.122	3.021	3.546	4.044	3.887	3.738
1998	14	24.8	0.343	0.622	0.813	1.096	1.412	1.873	2.546	3.466	3.957	4.181	4.199
1999	14.2	23	0.363	0.627	0.97	1.154	1.447	1.772	2.263	2.956	3.888	4.111	4.49
2000	13.7	23.3	0.293	0.657	0.976	1.36	1.517	1.822	2.147	2.655	3.365	4.059	4.416
2001	13.2	22.5	0.301	0.538	1.023	1.36	1.774	1.905	2.205	2.539	3.05	3.56	4.361
2002	13.9	21.8	0.273	0.556	0.848	1.428	1.774	2.191	2.299	2.603	2.921	3.252	3.871
2003	13.9	22.8	0.248	0.502	0.873	1.2	1.844	2.191	2.61	2.695	2.993	3.119	3.56
2004	14.1	22.8	0.283	0.461	0.795	1.238	1.572	2.284	2.623	3.043	3.093	3.178	3.434
2005	12.7	23.1	0.283	0.528	0.732	1.132	1.618	1.968	2.702	3.043	3.444	3.282	3.497
2006	12.6	20.9	0.293	0.524	0.831	1.053	1.49	2.023	2.371	3.145	3.46	3.624	3.608

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
2007	13.2	20.9	0.219	0.542	0.831	1.177	1.395	1.873	2.432	2.776	3.555	3.64	3.938
2008	14	21.7	0.219	0.415	0.855	1.177	1.553	1.761	2.263	2.845	3.168	3.738	3.955
2009	14.1	22.9	0.248	0.411	0.664	1.207	1.544	1.936	2.135	2.669	3.242	3.373	4.041
2010	15.3	23.1	0.286	0.461	0.664	0.957	1.581	1.936	2.335	2.526	3.05	3.434	3.689
2011	14.8	24.9	0.295	0.528	0.732	0.951	1.279	1.979	2.335	2.749	2.908	3.252	3.754
2012	15.7	24.3	0.366	0.546	0.836	1.053	1.271	1.626	2.383	2.735	3.137	3.105	3.56
2013	15.1	25.5	0.339	0.667	0.861	1.184	1.395	1.617	1.981	2.79	3.137	3.327	3.419
2014	15.2	24.6	0.391	0.617	1.03	1.215	1.563	1.761	1.97	2.352	3.183	3.327	3.64
2015	14.9	24.8	0.353	0.704	0.962	1.437	1.59	1.946	2.135	2.34	2.728	3.373	3.64
2016	14.2	24.3	0.363	0.642	1.087	1.351	1.865	1.99	2.346	2.513	2.715	2.921	3.689
2017	13.8	23.2	0.343	0.662	0.996	1.516	1.763	2.296	2.395	2.749	2.908	2.907	3.237
2018	13.6	22.7	0.298	0.622	1.023	1.394	1.948	2.179	2.729	2.803	3.153	3.105	3.222
2019	13.4	22.3	0.278	0.55	0.97	1.428	1.804	2.393	2.597	3.159	3.197	3.342	3.419
2020	NA	22.1	0.266	0.516	0.866	1.36	1.854	2.238	2.838	3.028	3.572	3.388	3.656
2021	NA	NA	0.259	0.494	0.813	1.222	1.774	2.284	2.663	3.279	3.444	3.754	3.705

Table 4.7. Northeast Arctic haddock. Proportion mature-at-age. The data from 1950–1993 is unchanged since AFWG 2019, the data from 1994 and onward have been updated this year, ages 11–13+ is set to 1 (not shown)

Year	1	2	3	4	5	6	7	8	9	10
1950	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1951	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1952	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1953	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1954	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1955	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1956	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1957	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1958	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1959	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1960	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1961	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1962	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1963	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1964	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1965	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1966	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1967	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1968	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1969	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1970	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1971	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1972	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1973	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1974	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1975	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1976	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1977	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1978	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1979	0	0	0.027	0.101	0.311	0.622	0.845	0.944	0.982	0.994
1980	0	0	0.026	0.076	0.243	0.649	0.86	0.95	0.984	0.995
1981	0	0	0.056	0.104	0.303	0.549	0.857	0.948	0.984	0.995
1982	0	0	0.053	0.161	0.332	0.577	0.77	0.947	0.983	0.995
1983	0	0	0.057	0.183	0.472	0.665	0.8	0.906	0.983	0.995
1984	0	0	0.044	0.196	0.51	0.801	0.862	0.921	0.967	0.995
1985	0	0	0.027	0.149	0.522	0.796	0.928	0.953	0.973	0.989
1986	0	0	0.021	0.103	0.454	0.758	0.928	0.977	0.984	0.991
1987	0	0	0.021	0.076	0.294	0.713	0.918	0.976	0.993	0.994
1988	0	0	0.025	0.074	0.24	0.576	0.898	0.975	0.993	0.998
1989	0	0	0.032	0.09	0.25	0.534	0.822	0.966	0.993	0.998
1990	0	0	0.046	0.127	0.305	0.578	0.798	0.937	0.99	0.997

Year	1	2	3	4	5	6	7	8	9	10
1991	0	0	0.041	0.164	0.358	0.623	0.82	0.925	0.98	0.997
1992	0	0	0.03	0.147	0.449	0.704	0.855	0.936	0.976	0.994
1993	0	0	0.018	0.113	0.396	0.741	0.878	0.95	0.979	0.992
1994	0	0	0.028	0.083	0.263	0.627	0.838	0.941	0.958	0.957
1995	0	0	0.029	0.074	0.204	0.49	0.825	0.932	0.975	0.98
1996	0	0	0.031	0.079	0.184	0.408	0.716	0.925	0.972	0.99
1997	0	0	0.042	0.086	0.192	0.373	0.634	0.858	0.968	0.988
1998	0	0	0.042	0.117	0.211	0.391	0.602	0.803	0.931	0.986
1999	0	0	0.046	0.119	0.277	0.418	0.616	0.776	0.898	0.964
2000	0	0	0.033	0.128	0.279	0.512	0.645	0.789	0.88	0.946
2001	0	0	0.035	0.092	0.3	0.512	0.735	0.81	0.889	0.937
2002	0	0	0.03	0.097	0.225	0.542	0.735	0.871	0.902	0.942
2003	0	0	0.027	0.083	0.235	0.44	0.757	0.871	0.937	0.949
2004	0	0	0.032	0.073	0.204	0.457	0.666	0.886	0.938	0.969
2005	0	0	0.032	0.09	0.179	0.408	0.683	0.826	0.945	0.969
2006	0	0	0.033	0.089	0.218	0.37	0.634	0.837	0.911	0.973
2007	0	0	0.023	0.094	0.218	0.429	0.594	0.803	0.919	0.954
2008	0	0	0.023	0.063	0.228	0.429	0.659	0.772	0.898	0.958
2009	0	0	0.027	0.062	0.154	0.443	0.655	0.818	0.878	0.947
2010	0	0	0.032	0.073	0.154	0.325	0.67	0.818	0.907	0.936
2011	0	0	0.035	0.09	0.179	0.322	0.543	0.828	0.907	0.952
2012	0	0	0.046	0.095	0.22	0.37	0.54	0.731	0.913	0.951
2013	0	0	0.041	0.131	0.23	0.433	0.594	0.728	0.851	0.955
2014	0	0	0.051	0.116	0.303	0.447	0.662	0.772	0.848	0.918
2015	0	0	0.043	0.142	0.274	0.545	0.673	0.82	0.878	0.917
2016	0	0	0.046	0.123	0.327	0.509	0.762	0.831	0.908	0.935
2017	0	0	0.042	0.129	0.288	0.578	0.732	0.888	0.914	0.952
2018	0	0	0.035	0.117	0.3	0.527	0.785	0.868	0.947	0.956
2019	0	0	0.031	0.096	0.277	0.542	0.744	0.903	0.936	0.974

Year	1	2	3	4	5	6	7	8	9	10
2020	0	0	0.03	0.087	0.233	0.512	0.76	0.879	0.956	0.968
2021			0.029	0.081	0.211	0.45	0.735	0.886	0.942	0.979

Table 4.8. Northeast Arctic haddock. Consumption of Haddock by NEA Cod (mln. spec) age 0–6, and total biomass ages 0–6 consumed.

Age	0	1	2	3	4	5	6	Biomass
1984	1975.1	990.1	15.3	0.1	0.0	0.0	0.0	51.7
1985	2027.1	1378.0	5.1	0.0	0.0	0.0	0.0	53.5
1986	92.8	624.2	224.5	168.5	0.0	0.0	0.0	109.8
1987	0.0	1058.2	0.0	0.0	0.0	0.0	0.0	5.8
1988	0.0	16.8	0.5	8.7	0.0	0.2	0.0	2.5
1989	21.3	221.3	0.0	0.0	0.0	0.0	0.0	9.9
1990	47.9	135.9	33.9	3.3	0.0	0.0	0.0	13.9
1991	0.0	352.4	12.9	0.0	0.0	0.0	0.0	15.5
1992	132.1	1737.1	123.0	0.9	0.0	0.0	0.0	87.7
1993	824.9	1441.6	143.6	32.2	3.1	2.6	0.0	69.3
1994	1348.5	1483.4	73.6	23.9	6.9	0.8	0.0	48.4
1995	181.8	2868.8	167.3	12.4	28.2	27.8	0.3	113.6
1996	359.6	1549.9	154.2	38.2	5.2	2.5	3.2	66.6
1997	0.0	947.0	38.9	26.4	1.7	0.8	0.5	44.0
1998	0.0	1739.4	27.5	1.7	2.6	0.4	0.0	36.0
1999	0.0	1041.9	25.3	0.4	0.0	0.0	0.0	29.6
2000	813.4	1412.0	71.6	2.2	1.1	0.2	0.1	58.3
2001	1047.9	593.6	53.3	4.7	0.1	0.0	0.0	51.2
2002	456.0	2437.4	240.6	39.5	2.3	0.4	0.2	127.0
2003	1140.2	3568.0	214.3	39.3	12.7	1.2	0.0	165.8
2004	5395.1	2862.8	303.7	39.8	9.9	2.5	0.0	198.1
2005	7703.0	6674.7	276.3	55.4	9.3	2.3	0.9	324.5
2006	12706.3	8410.2	375.2	5.5	4.4	1.2	0.5	360.5
2007	1204.2	10143.7	660.2	71.9	3.9	2.2	0.2	377.6
2008	1354.5	964.7	894.3	227.7	44.3	5.7	3.3	293.3

Age	0	1	2	3	4	5	6	Biomass
2009	5607.2	1854.7	274.1	262.0	69.0	22.3	1.5	252.4
2010	1968.7	5687.7	180.0	66.9	68.5	62.2	11.6	266.8
2011	2316.3	2622.4	451.4	56.1	75.1	86.7	19.4	279.0
2012	231.9	7132.1	134.3	107.3	15.0	6.7	4.3	219.5
2013	2172.4	1581.6	376.4	31.6	22.4	5.5	4.2	200.4
2014	1195.0	1991.3	140.6	27.5	1.8	0.6	0.0	87.6
2015	4931.7	2579.5	131.3	13.6	44.5	1.5	0.2	177.8
2016	8067.8	2654.8	276.8	22.6	2.5	7.7	1.8	222.0
2017	4421.9	7602.9	229.3	22.9	12.7	6.2	13.7	271.8
2018	2348.7	7041.1	583.6	65.0	6.9	0.6	0.0	276.1
2019	542.7	4542.6	411.3	119.2	8.1	0.3	0.0	211.8
2020	2008.8	450.9	72.5	63.7	80.4	4.2	0.1	91.7
Av.1984–2020	**2017.4**	**2713.4**	**199.9**	**44.9**	**14.7**	**6.9**	**1.8**	**142.5**

Table 4.9. Northeast Arctic haddock. Survey indices for SAM tuning (see section 4.4.6). The last age is a plus group.

```
Northeast Arctic haddock

      104
    RU-BTr-Q4                  #Russian trawl and acoustic survey bottom trawl index
 1991 2020
    1 1 0.9 1.00
   3 8
   1           62     9     3     6    18    17
   1          346    50     4     6     9     9
   1         1985   356    48     8     4     4
   1          442  1014   116    15     1     6
   1           31   123   370    40     5     4
   1           28    49   362   334    29     6
   1           32    32    10    27    10     8
   1           38    46     8     5    15     5
   1          196    39    37     8     3    14
   1           60   109    26    11     2     5
   1          334    40    65    11     4     4
   1          399   450    47    24     4     3
   1          221   299   231    34    16     3
   1          113    94   107    87     5     6
   1          240    86    48    57    24     3
   1          113   119    57    26    24    13
   1          838    73   137    38    14    15
```

```
1        2557     1051     124      111      17       11
1        1647     1704     631      57       32       9
1        299      1697     1589     466      34       17
1        47       268      1087     783      165      13
1        209      49       160      720      480      70
1        61       175      50       104      374      272
1        250      46       175      56       142      416
1        22       199      40       74       28       171
1        -1       -1       -1       -1       -1       -1
1        71       99       9        38       6        27
1        -1       -1       -1       -1       -1       -1
1        -1       -1       -1       -1       -1       -1
1        -1       -1       -1       -1       -1       -1

 BS-NoRU-Q1(Aco)          # Joint Barents Sea winter survey acoustic index
1994 2021
 1 1 0.077 0.189
 3 9
1        348.7    626.6    121.4    8.55     0.7      0.33     2.71
1        41.5     121.5    395.4    47.6     2.8      0.05     0.83
1        30       22.1     68.7     143.7    5.67     0.94     0.07
1        57.3     22.2     15.5     56.1     62.8     4.68     0.19
1        33.8     58.8     24.2     7.7      14.1     20.7     1.62
1        83.7     21.6     22.1     6.17     1.55     3.88     2.77
1        36.4     75.5     14       12.6     1.57     0.53     3.02
1        233.5    40.2     41.4     2.2      1.61     0.16     0.71
1        255.2    201.8    18.5     11.7     1.59     0.29     0.56
1        203.7    184.6    136      12.3     6.01     0.26     0.9
1        151      101.8    107.8    57.7     7.62     1.15     0.55
1        221.3    115.7    57.4     56.7     12.7     0.38     0.33
1        56.3     123.8    47.4     19.3     13.6     3.23     0.35
1        209.3    46.1     80.6     28.9     10       5.05     2.79
1        812.4    303      90       74.1     7.41     12.8     2.11
1        883.7    630      266.6    38.9     14.6     1.26     1.71
1        128.1    631      604      167      12.1     2.94     2.11
1        54.2     84.2     313      292.2    54.9     1.72     1.47
1        191.6    48.8     88.1     310.6    172.5    30.1     1.01
1        67.3     146.8    35.4     53       223.8    102.7    14.35
1        334.8    39.12    108.71   23.2     34.76    86.34    38.8
1        24.31    189.4    26.6     46.17    9.22     22.41    31.97
1        71.82    12.06    59.67    12.5     17.31    7.48     33.27
1        81.13    65.08    4.8      34.8     6.24     7.93     17.73
1        170.4    62.87    64.18    6.88     15.77    2.75     14.52
1        507.61   146.22   31.73    21.88    4.9      3.27     4.11
1        290.483  302.908  81.912   23.057   11.49    1.804    6.219
1        43.1     114.3    173.8    17.1     6.28     0.48     1.12
```

```
BS-NoRu-Q1 (BTr)          # Joint Barents Sea winter survey bottom trawl index
1994 2021
 1 1 0.077 0.189
 3 10
 1    314.533   436.251   46.176    3.54      0.163     0.13      0.2       0.651
 1    54.857    167.104   343.38    29.623    1.441     0.025     0.043     0.404
 1    55.843    31.334    150.768   238.108   16.131    1.15      0         0.069
 1    79.632    39.855    18.255    61.566    88.411    3.277     0.082     0.043
 1    21.681    36.749    11.844    1.294     9.203     7.212     0.648     0.092
 1    56.92     15.874    9.418     2.831     0.807     1.282     0.771     0.034
 1    24.08     35.241    6.789     4.134     0.684     0.083     0.802     0.288
 1    293.996   26.252    22.997    1.634     0.752     0.058     0.06      0.329
 1    312.87    185.453   12.417    8.04      0.846     0.218     0.009     0.325
 1    352.236   174.452   72.708    5.104     1.682     0.119     0.104     0.217
 1    173.132   100.516   77.021    51.281    7.409     0.912     0.133     0.228
 1    317.889   141.058   50.664    61.191    10.082    0.249     0.08      0.009
 1    78.798    130.76    46.048    20.874    16.208    3.184     0.094     0.265
 1    443.266   81.784    84.667    26.279    5.411     2.197     1.376     0.896
 1    1591.031  583.606   53.079    54.732    6.794     10.248    0.23      0.167
 1    1230.426  751.012   368.33    25.414    12.437    0.851     0.09      0.363
 1    102.451   510.449   443.759   139.316   7.988     1.016     0.386     0.574
 1    52.883    123.634   469.482   290.036   65.236    1.416     1.121     0.184
 1    316.077   28.785    74.714    267.945   154.601   24.766    3.115     0.391
 1    57.444    143.984   22.019    33.624    191.145   69.385    6.114     0.076
 1    381.173   32.729    104.397   23.257    50.035    97.536    38.692    2.425
 1    30.615    187.035   43.601    39.44     14.668    18.735    30.744    10.2
 1    163.385   34.342    115.597   22.406    41.948    12.437    32.396    33.161
 1    134.9     105.5     7.553     55.338    9.692     15.6      2.527     23.861
 1    336.307   86.656    65.764    7.771     15.59     3.621     2.564     11.931
 1    1075.552  187.224   49.399    16.996    4.038     2.948     0.736     1.91
 1    424.225   586.985   99.123    22.08     6.057     2.605     1.042     2.827
 1    118.428   194.033   302.978   20.677    4.628     0.848     0.204     0.93
```

```
FLT007: Eco-NoRu-Q3 (Btr)          # Joint Barents Sea ecosystem survey bottom
                                   trawl index
2004 2020
 1 1 0.65 0.75
 3 9
 1    123.368   70.303    69.118    31.482    2.989     1.721     0.22
 1    324.56    89.531    30.44     32.246    15.035    0.472     1.116
 1    107.467   124.64    41.597    18.98     17.482    7.289     1.384
 1    1282.94   88.498    90.369    19.227    5.881     7.102     3.209
 1    1154.869  405.999   43.133    35.517    4.94      2.514     2.539
 1    650.742   619.088   305.883   21.045    6.549     0.87      0.576
 1    184.001   865.318   666.439   147.72    15.84     2.73      0.589
 1    40.446    73.802    392.93    301.368   37.357    2.972     0.514
 1    92.468    20.348    67.607    214.052   152.03    12.739    2.003
```

1	25.779	65.228	19.575	50.846	150.131	76.427	7.561
1	261.631	40.768	70.161	25.781	60.452	85.771	19.646
1	42.148	213.636	25.132	37.111	20.577	47.868	42.903
1	209.303	34.43	184.09	47.965	56.787	40.367	125.907
1	70.313	70.306	11.47	20.537	3.963	4.025	15.265
1	-1	-1	-1	-1	-1	-1	-1
1	896.982	160.736	38.067	15.133	5.303	5.037	11.56
1	204.059	341.372	58.813	4.918	1.959	0.802	1.483

Table 4.10 Northeast Arctic haddock. SAM model configuration used. Updated at WKDEM 2020

```
#Configuration saved: Wed Feb 12 12:57:09 2020
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
$minAge
# The minimum age class in the assessment
 3
$maxAge
# The maximum age class in the assessment
 13
$maxAgePlusGroup
# Is last age group considered a plus group for each fleet (1 yes, or 0 no).
 1 1 1 1 1
$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
   0  1  2  3  4  5  5  5  5  5  5
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, 2 AR(1), 3
separable AR(1).
 2
$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is not used, as that is covered
by fishing mortality).
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
   0  1  1  1  1  1 -1 -1 -1 -1 -1
   2  3  3  3  3  4  4 -1 -1 -1 -1
   5  6  6  6  6  7  7  7 -1 -1 -1
   8  9  9  9  9  9  9 -1 -1 -1 -1
$keyQpow
# Density dependent catchability power parameters (if any).
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
   0  0  0  0  0  0 -1 -1 -1 -1 -1
   1  1  1  1  1  2  2 -1 -1 -1 -1
   3  3  3  3  3  4  4  4 -1 -1 -1
   5  5  5  5  5  5  5 -1 -1 -1 -1
```

```
$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only first row is used)
  0  1  1  1  1  1  1  1  1  1  1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1 1 1
$keyVarObs
# Coupling of the variance parameters for the observations.
  0  1  2  2  2  2  2  2  2  2  2
  3  3  3  3  3  3 -1 -1 -1 -1 -1
  4  4  4  4  4  4  4 -1 -1 -1 -1
  5  5  5  5  5  5  5  5 -1 -1 -1
  6  6  6  6  6  6  6 -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" "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).
#V1 V2 V3 V4 V5 V6 V7 V8 V9 V10
  NA  NA  NA  NA  NA  NA  NA  NA  NA  NA
  0  1  1  1  2 -1 -1 -1 -1 -1
  3  3  3  3  3  4 -1 -1 -1 -1
  5  5  5  5  5  6  6 -1 -1 -1
  7  7  7  7  7  7 -1 -1 -1 -1
$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton–Holt, and 3 piece-
wise constant).
 0
$noScaledYears
# Number of years where catch scaling is applied.
 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
 4 7
$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, 2 FSB index, 3 total
catch, 4 total landings and 5 TSB index).
 -1 -1 -1 -1 -1
$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN" "LN"
```

```
$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight,
1 fix variance to weight).
 0
$fracMixF
# The fraction of t(3) distribution used in logF increment distribution
 0
$fracMixN
# The fraction of t(3) distribution used in logN increment distribution
 0
$fracMixObs
# A vector with same length as number of fleets, where each element is the fraction of t(3) distri-
bution used in the distribution of that fleet
 0 0 0 0 0
$constRecBreaks
# This option is only used in combination with stock-recruitment code 3)
  $predVarObsLink
# Coupling of parameters used in a mean-variance link for observations.
  0  1  2  2  2  2  2  2  2  2  2
  3  3  3  3  3  3 -1 -1 -1 -1 -1
  4  4  4  4  4  4  4 -1 -1 -1 -1
  5  5  5  5  5  5  5  5 -1 -1 -1
  6  6  6  6  6  6  6 -1 -1 -1 -1
```

Table 4.11. Northeast Arctic haddock. SAM model. Estimated recruitment, spawning-stock biomass (SSB), and average fishing mortality.

Year	R(age 3)	Low	High	SSB	Low	High	Fbar(4–7)	Low	High	TSB	Low	High
1950	72387	46062	113757	214451	191896	239657	0.755	0.637	0.894	387984	347732	432897
1951	657549	421933	1024740	126198	111962	142244	0.683	0.574	0.812	433412	338704	554603
1952	88651	56447	139228	101722	88677	116687	0.712	0.595	0.851	425163	337716	535254
1953	1235085	805743	1893203	120624	103993	139915	0.536	0.443	0.650	733145	558302	962743
1954	133361	85029	209168	174452	147488	206344	0.430	0.353	0.524	826557	650141	1050844
1955	58610	36972	92912	313927	267217	368803	0.445	0.368	0.537	849059	713766	1009997
1956	229244	145866	360280	368382	313148	433358	0.470	0.390	0.567	690111	591624	804993
1957	60266	38168	95158	253706	217108	296473	0.425	0.353	0.512	435085	377199	501855
1958	72860	46450	114287	182036	157918	209837	0.517	0.428	0.623	315294	277030	358844
1959	389171	254295	595585	125360	108680	144599	0.445	0.366	0.540	333166	273423	405963
1960	320748	208438	493573	112847	99388	128128	0.540	0.450	0.648	418829	348061	503987
1961	145185	94620	222773	124852	111078	140333	0.663	0.560	0.786	402474	349320	463715
1962	294861	192640	451325	125250	111167	141117	0.791	0.670	0.933	376991	323928	438745
1963	315359	207593	479068	94365	82948	107352	0.757	0.634	0.905	353624	295169	423655
1964	353500	231399	540029	84511	74143	96329	0.632	0.523	0.763	386037	318642	467687
1965	126853	81897	196486	103153	89857	118418	0.524	0.432	0.635	386407	325823	458256
1966	313477	203773	482241	145776	126683	167746	0.557	0.463	0.671	451214	384496	529509

Year	R(age 3)	Low	High	SSB	Low	High	Fbar(4–7)	Low	High	TSB	Low	High
1967	341190	221107	526492	151263	130129	175829	0.441	0.363	0.535	464389	389441	553759
1968	18013	11107	29212	168174	145329	194610	0.482	0.397	0.586	426984	361320	504581
1969	20599	12799	33151	167949	143974	195917	0.411	0.335	0.504	316968	270836	370956
1970	209787	134801	326485	155435	131552	183655	0.383	0.309	0.474	286902	241277	341154
1971	109545	69787	171952	127588	107314	151692	0.327	0.261	0.409	263556	223617	310629
1972	1052876	667948	1659631	128490	111420	148176	0.653	0.533	0.799	601810	452127	801049
1973	310449	202458	476042	125203	107368	146001	0.534	0.435	0.655	637223	507838	799570
1974	66135	42760	102289	153690	133714	176650	0.504	0.415	0.612	462911	398743	537405
1975	59421	38424	91892	194817	166555	227875	0.497	0.414	0.597	378920	328264	437393
1976	61869	39371	97225	196331	168410	228881	0.721	0.606	0.857	296386	259233	338863
1977	120514	75884	191393	118795	99987	141140	0.735	0.606	0.893	201315	172466	234989
1978	214589	140083	328722	81208	67119	98254	0.623	0.505	0.768	199556	164222	242492
1979	161504	105201	247938	62610	52588	74542	0.580	0.466	0.722	206831	171527	249400
1980	22094	13599	35894	62985	53381	74317	0.471	0.377	0.589	213487	177892	256205
1981	10280	6095	17337	73069	61627	86634	0.432	0.345	0.540	168620	141915	200351
1982	16749	10277	27298	68801	56759	83398	0.379	0.301	0.479	122917	102645	147193
1983	8656	5087	14729	58364	47816	71239	0.351	0.275	0.449	87932	73504	105192
1984	13271	8149	21611	53199	43258	65423	0.315	0.244	0.406	71822	59820	86232

Year	R(age 3)	Low	High	SSB	Low	High	Fbar(4–7)	Low	High	TSB	Low	High
1985	358813	233153	552199	49169	40822	59223	0.395	0.309	0.504	191524	140182	261671
1986	478572	311663	734868	54924	46468	64919	0.535	0.425	0.675	374796	293890	477975
1987	90214	57751	140923	77959	66517	91369	0.628	0.504	0.783	356744	297363	427982
1988	38984	24377	62344	80099	67250	95402	0.509	0.407	0.637	253948	214793	300241
1989	28853	17865	46599	84610	69520	102976	0.372	0.294	0.470	193201	161348	231341
1990	37125	23767	57992	85901	69709	105854	0.211	0.165	0.270	153622	127998	184377
1991	111048	77956	158188	100647	84303	120159	0.239	0.190	0.300	186699	159043	219165
1992	328727	233077	463631	111090	95809	128808	0.294	0.237	0.365	291322	243904	347959
1993	848769	613008	1175203	125741	110626	142922	0.316	0.257	0.389	526073	433781	638001
1994	396614	318970	493159	153834	137161	172532	0.371	0.306	0.451	650312	566914	745978
1995	100060	77811	128671	186134	165514	209324	0.298	0.250	0.356	643113	566516	730065
1996	99507	77719	127404	215730	192019	242370	0.366	0.310	0.431	557155	495314	626717
1997	119084	93193	152169	186891	166282	210055	0.445	0.376	0.527	400459	358952	446765
1998	63240	48775	81995	130850	115668	148025	0.452	0.378	0.541	266478	238448	297802
1999	151245	120741	189455	94816	83809	107270	0.462	0.383	0.557	233978	208477	262597
2000	83258	65021	106611	78075	68910	88460	0.341	0.279	0.417	214801	189585	243371
2001	367666	300041	450533	91259	81229	102526	0.366	0.303	0.442	318048	280668	360407
2002	395448	321892	485812	108683	96817	122003	0.351	0.292	0.423	436563	384807	495280

Year	R(age 3)	Low	High	SSB	Low	High	Fbar(4–7)	Low	High	TSB	Low	High
2003	340113	272564	424403	136879	122623	152791	0.424	0.358	0.503	506909	450642	570201
2004	260359	212216	319424	155689	139461	173805	0.387	0.328	0.456	493539	441891	551224
2005	366492	300172	447466	166962	149621	186313	0.404	0.344	0.476	510380	457657	569177
2006	157564	127155	195244	151329	135466	169050	0.369	0.312	0.437	439168	393891	489649
2007	543223	441281	668715	153562	137718	171230	0.384	0.323	0.455	504466	450324	565117
2008	1112513	913961	1354200	163092	145133	183272	0.314	0.262	0.377	738154	647137	841971
2009	1025284	845638	1243094	183533	163348	206213	0.260	0.216	0.311	996702	871947	1139306
2010	240955	195431	297083	248053	220499	279050	0.244	0.206	0.291	1130768	991062	1290169
2011	117224	92480	148588	355613	315855	400375	0.255	0.217	0.301	1178847	1040816	1335183
2012	340386	276667	418780	475908	419566	539815	0.220	0.186	0.260	1175999	1040560	1329067
2013	119057	94420	150121	523943	460492	596137	0.148	0.124	0.177	1005601	890548	1135517
2014	411335	336043	503497	523619	463357	591718	0.154	0.128	0.185	983944	880258	1099843
2015	72464	56494	92950	497402	444871	556135	0.190	0.159	0.227	874947	787488	972120
2016	212760	170769	265075	489847	438583	547104	0.261	0.219	0.310	803199	722937	892372
2017	194179	156196	241399	410620	369903	455820	0.351	0.296	0.416	702033	634303	776994
2018	367841	295751	457503	303265	271126	339214	0.404	0.339	0.481	617524	553251	689263
2019	821773	668831	1009689	234446	206986	265549	0.433	0.355	0.527	695945	612581	790655
2020	441844	354723	550361	204484	175372	238429	0.438	0.347	0.554	722596	623367	837621

Year	R(age 3)	Low	High	SSB	Low	High	Fbar(4–7)	Low	High	TSB	Low	High
2021	153680	110687	213373	200849	162390	248417				648860	532298	790945

Table 4.12. Northeast Arctic haddock. SAM model estimated fishing mortality-at-age. SAM model.

Year age	3	4	5	6	7	8	9	10	11	12	13
1950	0.096	0.412	0.706	0.849	1.052	0.886	0.886	0.886	0.886	0.886	0.886
1951	0.086	0.359	0.617	0.773	0.981	0.884	0.884	0.884	0.884	0.884	0.884
1952	0.092	0.380	0.641	0.797	1.029	0.933	0.933	0.933	0.933	0.933	0.933
1953	0.067	0.282	0.473	0.588	0.802	0.737	0.737	0.737	0.737	0.737	0.737
1954	0.048	0.207	0.357	0.468	0.689	0.648	0.648	0.648	0.648	0.648	0.648
1955	0.046	0.199	0.368	0.502	0.710	0.600	0.600	0.600	0.600	0.600	0.600
1956	0.050	0.210	0.389	0.549	0.733	0.621	0.621	0.621	0.621	0.621	0.621
1957	0.047	0.198	0.367	0.492	0.643	0.547	0.547	0.547	0.547	0.547	0.547
1958	0.058	0.235	0.450	0.601	0.781	0.690	0.690	0.690	0.690	0.690	0.690
1959	0.059	0.228	0.409	0.521	0.620	0.566	0.566	0.566	0.566	0.566	0.566
1960	0.089	0.317	0.537	0.633	0.672	0.616	0.616	0.616	0.616	0.616	0.616
1961	0.117	0.406	0.682	0.782	0.783	0.694	0.694	0.694	0.694	0.694	0.694
1962	0.147	0.502	0.853	0.941	0.867	0.722	0.722	0.722	0.722	0.722	0.722
1963	0.133	0.471	0.805	0.909	0.845	0.681	0.681	0.681	0.681	0.681	0.681
1964	0.097	0.360	0.634	0.769	0.765	0.647	0.647	0.647	0.647	0.647	0.647
1965	0.077	0.292	0.513	0.635	0.656	0.566	0.566	0.566	0.566	0.566	0.566
1966	0.090	0.328	0.563	0.667	0.670	0.555	0.555	0.555	0.555	0.555	0.555
1967	0.072	0.268	0.446	0.515	0.535	0.465	0.465	0.465	0.465	0.465	0.465
1968	0.084	0.297	0.490	0.554	0.588	0.513	0.513	0.513	0.513	0.513	0.513
1969	0.079	0.267	0.428	0.469	0.481	0.416	0.416	0.416	0.416	0.416	0.416
1970	0.082	0.262	0.402	0.428	0.439	0.381	0.381	0.381	0.381	0.381	0.381
1971	0.073	0.233	0.351	0.355	0.366	0.324	0.324	0.324	0.324	0.324	0.324
1972	0.193	0.503	0.759	0.696	0.654	0.545	0.545	0.545	0.545	0.545	0.545
1973	0.199	0.486	0.641	0.530	0.477	0.381	0.381	0.381	0.381	0.381	0.381
1974	0.179	0.431	0.547	0.515	0.522	0.460	0.460	0.460	0.460	0.460	0.460
1975	0.195	0.459	0.548	0.494	0.487	0.417	0.417	0.417	0.417	0.417	0.417
1976	0.289	0.647	0.785	0.723	0.728	0.640	0.640	0.640	0.640	0.640	0.640
1977	0.322	0.713	0.852	0.719	0.658	0.559	0.559	0.559	0.559	0.559	0.559

Year age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1978	0.223	0.546	0.726	0.644	0.576	0.505	0.505	0.505	0.505	0.505	0.505
1979	0.160	0.443	0.670	0.652	0.557	0.502	0.502	0.502	0.502	0.502	0.502
1980	0.101	0.316	0.525	0.563	0.481	0.459	0.459	0.459	0.459	0.459	0.459
1981	0.085	0.273	0.472	0.538	0.444	0.428	0.428	0.428	0.428	0.428	0.428
1982	0.075	0.244	0.411	0.477	0.385	0.380	0.380	0.380	0.380	0.380	0.380
1983	0.077	0.247	0.388	0.428	0.342	0.341	0.341	0.341	0.341	0.341	0.341
1984	0.069	0.226	0.347	0.376	0.308	0.293	0.293	0.293	0.293	0.293	0.293
1985	0.075	0.257	0.412	0.481	0.429	0.412	0.412	0.412	0.412	0.412	0.412
1986	0.088	0.315	0.541	0.666	0.619	0.588	0.588	0.588	0.588	0.588	0.588
1987	0.097	0.359	0.644	0.786	0.724	0.658	0.658	0.658	0.658	0.658	0.658
1988	0.071	0.278	0.511	0.655	0.592	0.537	0.537	0.537	0.537	0.537	0.537
1989	0.055	0.219	0.388	0.466	0.414	0.362	0.362	0.362	0.362	0.362	0.362
1990	0.029	0.126	0.214	0.255	0.248	0.231	0.231	0.231	0.231	0.231	0.231
1991	0.031	0.136	0.243	0.291	0.285	0.262	0.262	0.262	0.262	0.262	0.262
1992	0.032	0.146	0.291	0.367	0.372	0.341	0.341	0.341	0.341	0.341	0.341
1993	0.026	0.128	0.291	0.407	0.439	0.398	0.398	0.398	0.398	0.398	0.398
1994	0.024	0.124	0.305	0.476	0.579	0.544	0.544	0.544	0.544	0.544	0.544
1995	0.019	0.099	0.231	0.366	0.497	0.489	0.489	0.489	0.489	0.489	0.489
1996	0.024	0.123	0.286	0.439	0.614	0.620	0.620	0.620	0.620	0.620	0.620
1997	0.032	0.158	0.374	0.534	0.716	0.683	0.683	0.683	0.683	0.683	0.683
1998	0.038	0.178	0.402	0.552	0.677	0.676	0.676	0.676	0.676	0.676	0.676
1999	0.045	0.203	0.432	0.560	0.652	0.624	0.624	0.624	0.624	0.624	0.624
2000	0.033	0.159	0.325	0.412	0.468	0.438	0.438	0.438	0.438	0.438	0.438
2001	0.034	0.162	0.355	0.455	0.491	0.449	0.449	0.449	0.449	0.449	0.449
2002	0.031	0.151	0.321	0.453	0.481	0.423	0.423	0.423	0.423	0.423	0.423
2003	0.036	0.169	0.366	0.531	0.629	0.570	0.570	0.570	0.570	0.570	0.570
2004	0.034	0.158	0.329	0.483	0.578	0.547	0.547	0.547	0.547	0.547	0.547
2005	0.037	0.163	0.336	0.494	0.624	0.603	0.603	0.603	0.603	0.603	0.603
2006	0.036	0.159	0.316	0.443	0.558	0.549	0.549	0.549	0.549	0.549	0.549

Year age	3	4	5	6	7	8	9	10	11	12	13
2007	0.037	0.158	0.319	0.465	0.592	0.572	0.572	0.572	0.572	0.572	0.572
2008	0.025	0.112	0.230	0.383	0.532	0.524	0.524	0.524	0.524	0.524	0.524
2009	0.020	0.088	0.178	0.307	0.465	0.479	0.479	0.479	0.479	0.479	0.479
2010	0.020	0.084	0.168	0.287	0.438	0.489	0.489	0.489	0.489	0.489	0.489
2011	0.021	0.088	0.184	0.303	0.446	0.489	0.489	0.489	0.489	0.489	0.489
2012	0.020	0.082	0.159	0.264	0.373	0.400	0.400	0.400	0.400	0.400	0.400
2013	0.015	0.061	0.108	0.171	0.252	0.311	0.311	0.311	0.311	0.311	0.311
2014	0.017	0.069	0.121	0.178	0.249	0.345	0.345	0.345	0.345	0.345	0.345
2015	0.022	0.089	0.160	0.223	0.288	0.396	0.396	0.396	0.396	0.396	0.396
2016	0.029	0.115	0.224	0.312	0.392	0.509	0.509	0.509	0.509	0.509	0.509
2017	0.037	0.150	0.305	0.439	0.511	0.590	0.590	0.590	0.590	0.590	0.590
2018	0.037	0.155	0.348	0.523	0.590	0.640	0.640	0.640	0.640	0.640	0.640
2019	0.035	0.155	0.374	0.596	0.604	0.600	0.600	0.600	0.600	0.600	0.600
2020	0.035	0.156	0.385	0.598	0.615	0.579	0.579	0.579	0.579	0.579	0.579
2021											

Table 4.13. Northeast Arctic haddock. SAM model. Estimated stock numbers-at-age.

Year age	3	4	5	6	7	8	9	10	11	12	13
1950	72387	101009	76017	37150	46935	16676	4880	2688	1381	1458	2057
1951	657549	47705	46081	27475	12803	12509	5437	1943	1014	446	1091
1952	88651	438929	30695	19192	9000	4349	3848	1638	740	358	506
1953	1235085	52138	209525	14008	6354	2642	1334	1051	533	255	309
1954	133361	913544	26058	91355	6875	2330	1091	550	387	198	228
1955	58610	84501	631189	14601	52376	3092	919	454	237	160	168
1956	229244	40701	55883	324913	7240	17802	1441	402	215	114	153
1957	60266	151466	27728	36033	111034	3106	6150	704	168	100	131
1958	72860	39770	92930	15488	20893	40149	1644	2509	354	84	120
1959	389171	51295	26037	40026	7337	7294	14884	731	899	148	88
1960	320748	266359	35741	15664	16981	3484	3678	6151	365	369	109

Year age	3	4	5	6	7	8	9	10	11	12	13
1961	145185	192859	145259	17681	6976	8042	1598	1508	2792	158	204
1962	294861	86481	92421	59752	6747	2709	3285	659	610	1159	139
1963	315359	177692	37947	26417	17576	2650	1088	1226	273	244	536
1964	353500	199644	75558	12273	7678	5842	1227	440	508	123	346
1965	126853	240169	115011	30342	4168	2789	2265	536	199	218	212
1966	313477	82668	159195	62307	12375	1706	1278	942	273	92	187
1967	341190	201060	43604	72639	24821	4868	791	602	450	133	132
1968	18013	248132	118431	21878	36202	12529	2349	410	314	233	138
1969	20599	11699	142453	55382	10694	15788	5755	1164	197	157	175
1970	209787	12601	7442	70596	25187	5928	8046	3010	645	106	186
1971	109545	135078	7121	4480	33447	12303	3367	4542	1695	372	163
1972	1052876	80012	82395	4549	3103	17570	6739	2020	2777	1031	316
1973	310449	611103	46689	23226	1698	1550	7634	2898	926	1381	612
1974	66135	168872	250030	16572	10670	885	1018	4471	1685	549	1231
1975	59421	37507	90353	140384	6794	4948	449	564	2145	815	939
1976	61869	33814	16493	44274	79181	3147	2774	247	336	1149	973
1977	120514	31955	13774	6432	17629	30320	1281	1184	103	150	807
1978	214589	55473	9805	4432	2903	7738	15125	627	564	45	431
1979	161504	118148	23372	3261	2038	1408	4103	7088	338	273	226
1980	22094	103045	58844	8328	1152	1050	718	2169	3494	175	240
1981	10280	15556	63778	26434	3456	551	560	381	1144	1721	215
1982	16749	6731	11059	31900	10551	1721	278	308	219	627	960
1983	8656	11414	4623	6826	13527	5614	984	146	178	128	805
1984	13271	5143	6723	2738	3892	8834	2874	577	80	105	519
1985	358813	8928	2896	3609	1787	2574	5370	1840	369	51	399
1986	478572	277557	5190	1600	1853	994	1477	2795	1027	206	263
1987	90214	251326	157099	2536	656	793	470	680	1205	471	209
1988	38984	69536	135665	46741	1070	233	319	205	302	507	280
1989	28853	25825	49166	71076	12181	553	95	152	99	146	365

Year age	3	4	5	6	7	8	9	10	11	12	13
1990	37125	21055	17098	26048	32816	5474	358	59	87	57	277
1991	111048	25165	13652	14116	20258	20295	3130	252	40	57	205
1992	328727	84057	16045	10130	10434	12634	12657	1883	167	26	158
1993	848769	223913	57735	10760	5933	6253	7669	7276	1047	103	107
1994	396614	587436	154930	31942	4717	3143	3765	4809	4340	594	117
1995	100060	226590	435698	78166	14754	2118	1430	1880	2211	2156	341
1996	99507	61789	169995	248671	32136	7295	1100	713	945	1113	1277
1997	119084	55471	38253	96439	103120	13962	2515	500	315	419	1105
1998	63240	80491	34945	18197	36788	39134	5215	991	213	133	718
1999	151245	48598	47807	17437	8943	15880	13968	1913	411	95	395
2000	83258	120846	31027	21381	6915	4355	6581	5478	813	189	237
2001	367666	68635	94932	16897	10167	3556	2621	3527	2687	439	242
2002	395448	300091	52067	48539	9168	5544	1920	1468	1939	1411	359
2003	340113	261408	196328	34543	25078	4620	3530	1249	843	1100	1007
2004	260359	172273	166036	112867	16305	11103	2162	1680	629	400	1083
2005	366492	171572	94829	110334	51502	6674	5666	1165	744	318	809
2006	157564	219442	109811	52161	45104	21091	3242	2875	569	352	551
2007	543223	121375	168189	61734	26885	19538	8239	1776	1508	293	455
2008	1112513	468268	98184	105061	22152	14209	7305	3341	914	737	371
2009	1025284	728429	383448	62880	40729	10451	5495	3239	1485	513	620
2010	240955	691017	611521	237174	32624	15444	4886	2807	1654	800	679
2011	117224	194409	563046	432721	124025	14466	6299	2164	1383	855	862
2012	340386	73679	139426	404212	273255	55692	6248	2614	1060	724	988
2013	119057	202072	58279	96150	278419	130583	24094	3248	1443	609	1036
2014	411335	74058	147167	50176	89044	149208	62995	11011	1919	910	1046
2015	72464	289943	66054	93229	40823	70958	75588	26121	5433	1045	1069
2016	212760	49328	170881	46203	62182	33887	50649	38657	13022	2602	1031
2017	194179	178302	34064	111000	28140	36803	19145	22167	18206	5675	1498
2018	367841	136644	126603	24863	44110	14515	18040	9062	9354	8647	3170

Year age	3	4	5	6	7	8	9	10	11	12	13
2019	821773	245167	89266	64306	16672	17748	6762	7639	3760	3946	4324
2020	441844	529584	163506	48047	23575	8750	7624	3230	3185	1816	3452
2021	153680	259641	362981	65434	24257	9282	3972	3483	1479	1459	2410

Table 4.14. Northeast Arctic haddock. SAM model. Natural mortality estimated.

Year	3	4	5	6	7	8	9	10	11	12	13
1950	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1951	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1952	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1953	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1954	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1955	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1956	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1957	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1958	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1959	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1960	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1961	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1962	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1963	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1964	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1965	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1966	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1967	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1968	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1969	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1970	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1971	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1972	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1973	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1974	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1975	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1976	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1977	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1978	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1979	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1980	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1981	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1982	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1983	0.347	0.258	0.245	0.242	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1984	0.216	0.224	0.214	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1985	0.209	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1986	0.640	0.262	0.200	0.210	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1987	0.200	0.207	0.421	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1988	0.379	0.200	0.200	0.393	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1989	0.200	0.200	0.200	0.232	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1990	0.328	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1991	0.202	0.216	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1992	0.216	0.205	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1993	0.253	0.248	0.274	0.260	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1994	0.289	0.216	0.295	0.227	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1995	0.379	0.341	0.319	0.291	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1996	0.724	0.319	0.253	0.283	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1997	0.503	0.267	0.255	0.284	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1998	0.230	0.291	0.265	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1999	0.200	0.207	0.278	0.260	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2000	0.214	0.200	0.215	0.245	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2001	0.210	0.200	0.226	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2002	0.323	0.213	0.200	0.204	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Year	3	4	5	6	7	8	9	10	11	12	13
2003	0.417	0.250	0.208	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2004	0.414	0.301	0.201	0.228	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2005	0.396	0.302	0.231	0.270	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2006	0.223	0.214	0.275	0.211	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2007	0.297	0.200	0.239	0.320	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2008	0.371	0.279	0.266	0.338	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2009	0.402	0.248	0.284	0.256	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2010	0.358	0.249	0.273	0.285	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2011	0.529	0.468	0.310	0.227	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2012	0.593	0.313	0.204	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2013	0.460	0.340	0.248	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2014	0.283	0.206	0.219	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2015	0.344	0.402	0.211	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2016	0.305	0.200	0.248	0.229	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2017	0.330	0.296	0.233	0.412	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2018	0.442	0.250	0.265	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2019	0.361	0.269	0.200	0.276	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2020	0.412	0.360	0.323	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
2021	0.412	0.360	0.323	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Table 4.15. Northeast Arctic haddock. Summary XSA (p-shrinkage not applied, F shrinkage= 0.5). Thu Apr 23 16:16:08 2020.

YEAR	RECR_a3	TOTBIO	TOTSPB	LANDINGS	YIELDSSB	SOPCOFAC	FBAR 4–7
1950	82517	242696	134602	132125	0.9816	1.5897	0.8305
1951	669592	356206	101130	120077	1.1874	1.2272	0.6238
1952	76993	235716	57527	127660	2.2191	1.7404	0.7243
1953	1276811	512541	82624	123920	1.4998	1.4279	0.5157
1954	152912	538732	117456	156788	1.3349	1.474	0.3802
1955	68791	486182	178951	202286	1.1304	1.536	0.5112
1956	208993	475286	243778	213924	0.8775	1.2623	0.4328
1957	66305	326559	186324	123583	0.6633	1.2455	0.4322

YEAR	RECR_a3	TOTBIO	TOTSPB	LANDINGS	YIELDSSB	SOPCOFAC	FBAR 4–7
1958	87212	277194	157018	112672	0.7176	1.1252	0.5185
1959	398937	365304	133348	88211	0.6615	0.9405	0.3672
1960	289884	401516	114703	154651	1.3483	1.0411	0.484
1961	130882	391762	130068	193224	1.4856	0.9942	0.6362
1962	291125	346736	118945	187408	1.5756	1.0518	0.8
1963	341475	311066	82694	146224	1.7683	1.1458	0.8645
1964	398845	302301	63902	99158	1.5517	1.3572	0.6522
1965	124503	358459	95547	118578	1.241	1.1507	0.4935
1966	294241	388088	127654	161778	1.2673	1.1621	0.583
1967	362769	468419	154643	136397	0.882	0.9984	0.4147
1968	23990	421753	169593	181726	1.0715	0.9976	0.503
1969	21471	342797	184231	130820	0.7101	0.882	0.3972
1970	202641	286838	156150	88257	0.5652	0.9762	0.3575
1971	122645	345853	168613	78905	0.468	0.7638	0.2465
1972	1252757	619817	123068	266153	2.1626	1.0883	0.6918
1973	342252	604302	114785	322226	2.8072	1.1656	0.5362
1974	69287	604427	200945	221157	1.1006	0.8946	0.4315
1975	60222	493447	256440	175758	0.6854	0.8957	0.4268
1976	66905	307480	206755	137264	0.6639	1.12	0.5705
1977	134417	229040	141828	110158	0.7767	1.09	0.6832
1978	213614	256138	130603	95422	0.7306	0.9219	0.5112
1979	176286	318567	129566	103623	0.7998	0.7684	0.5515
1980	34826	343544	133268	87889	0.6595	0.7568	0.3978
1981	13441	293155	148313	77153	0.5202	0.7174	0.4012
1982	17394	212027	127285	46955	0.3689	0.7224	0.3093
1983	9563	104393	71491	24600	0.3441	1.0373	0.2715
1984	13434	83502	64118	20945	0.3267	1.0547	0.2498
1985	288300	182799	62012	45052	0.7265	0.9761	0.32
1986	529936	343817	62309	100563	1.6139	1.0484	0.4388

YEAR	RECR_a3	TOTBIO	TOTSPB	LANDINGS	YIELDSSB	SOPCOFAC	FBAR 4–7
1987	109761	333920	75055	154916	2.064	0.992	0.5958
1988	54817	260029	78423	95255	1.2146	0.9955	0.499
1989	26591	212726	91989	58518	0.6361	0.9774	0.3892
1990	36885	170781	95306	27182	0.2852	1.0159	0.1562
1991	104289	195374	110525	36216	0.3277	1.0374	0.2082
1992	207573	269180	125749	59922	0.4765	0.9797	0.2838
1993	661827	442193	130412	82379	0.6317	1.0031	0.359
1994	292252	542649	144884	135186	0.9331	1.0056	0.425
1995	97799	538481	158892	142448	0.8965	1.0247	0.3825
1996	102077	472118	184556	178128	0.9652	1.0175	0.4235
1997	115566	349254	162754	154359	0.9484	1.0519	0.4862
1998	58271	249707	124288	100630	0.8097	1.0113	0.4235
1999	230876	252735	93038	83195	0.8942	1.021	0.4212
2000	89446	250625	85299	68944	0.8083	1.026	0.2802
2001	366245	356725	110567	89640	0.8107	0.9903	0.2795
2002	342709	443325	128727	114798	0.8918	1.011	0.3173
2003	224429	474128	150713	138926	0.9218	1.019	0.4292
2004	225230	455037	157794	158279	1.0031	1.0192	0.3795
2005	347443	471039	168020	158298	0.9421	1.0029	0.49
2006	157072	415213	142651	153157	1.0736	0.9938	0.405
2007	668942	496479	140120	161525	1.1528	0.9916	0.4228
2008	1339631	738745	146275	155604	1.0638	0.9928	0.3902
2009	1454218	1075831	168600	200061	1.1866	1.0019	0.3525
2010	526318	1253906	233140	249200	1.0689	0.9994	0.293
2011	245890	1275393	336181	309785	0.9215	0.9978	0.3175
2012	381957	1158133	419440	315627	0.7525	0.9994	0.266
2013	156234	988402	465852	193744	0.4159	0.9967	0.134
2014	389701	993569	511632	177522	0.347	0.9968	0.111
2015	103379	934929	524799	194756	0.3711	0.9953	0.1558

YEAR	RECR_a3	TOTBIO	TOTSPB	LANDINGS	YIELDSSB	SOPCOFAC	FBAR 4–7
2016	260916	846474	496913	233183	0.4693	1.0006	0.2208
2017	200597	729410	417225	227588	0.5455	0.994	0.3318
2018	368406	618897	307333	191276	0.6224	0.9943	0.3915
2019	871151	709103	236928	175402	0.7403	0.9963	0.4545
2020	415726	760305	214036	182468	0.8525	0.9962	0.4345

Table 4.16. Northeast Arctic haddock. Input data for recruitment prediction (RCT3)- recruits as 3 year-olds. Recr: recruitment estimate from SAM 2020 NT1: Norwegian Russian winter bottom trawl survey age 1 NT2: Norwegian Russian winter bottom trawl survey age 2 NT3: Norwegian Russian winter bottom trawl survey age 3 NAK1: Norwegian Russian winter acoustic survey age 1 NAK2: Norwegian Russian winter acoustic survey age 2 NAK3: Norwegian Russian winter acoustic survey age 3 ECO1: Ecosystem survey age 1. ECO2: Ecosystem survey age 2. The Russian survey (RT) was discontinued in 2017 and has not been used for recruitment.

Year class	Recr.	NT1	NT2	NT3	NAK1	NAK2	NAK3	EC01	ECO2
1990	848769	NA	NA	NA	NA	NA	NA	NA	NA
1991	396614	NA	NA	315	NA	NA	349	NA	NA
1992	100060	NA	225	55	NA	188	42	NA	NA
1993	99507	604	200	56	888	89	30	NA	NA
1994	119084	1429	265	80	1198	95	57	NA	NA
1995	63240	301	91	22	133	27	34	NA	NA
1996	151245	1118	197	57	509	151	84	NA	NA
1997	83258	248	83	24	211	30	36	NA	NA
1998	367666	1208	437	294	653	405	234	NA	NA
1999	395448	832	447	313	1063	266	255	NA	NA
2000	340113	1231	475	352	753	268	204	NA	NA
2001	260359	1700	472	173	1315	362	151	NA	NA
2002	366492	3327	707	318	2744	467	221	NA	268
2003	157564	701	386	79	529	144	56	189	114
2004	543223	4473	1310	443	2277	625	209	604	929
2005	1112513	4945	1685	1591	2091	954	812	2270	1819
2006	1025284	3731	2042	1230	2016	1754	884	988	1292
2007	240955	853	317	103	778	209	128	322	144
2008	117224	563	80	53	444	86	54	135	65
2009	340386	1635	354	316	1559	288	192	274	114

Year class	Recr.	NT1	NT2	NT3	NAK1	NAK2	NAK3	EC01	ECO2
2010	119057	676	137	57	429	95	67	105	42
2011	411335	1867	490	381	1583	407	335	591	223
2012	72464	345	124	31	293	110	24	156	75
2013	212760	1281	342	163	1839	247	72	265	145
2014	194179	1134	562	135	1593	107	81	320	145
2015	367841	2299	770	336	1276	331	170	794	189
2016	821773	5065	1676	1076	3344	806	508	936	NA
2017	441844	3823	1125	424	2931	688	286	NA	585
2018	153680	1898	268	118	1545	261	43	379	58
2019	NA	111	31	NA	273	32	NA	27	NA
2020	NA	462	NA	NA	435	NA	NA	NA	NA

Table 4.17. Northeast Arctic haddock Analysis by RCT3 ver3.1 - R translation

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Analysis by RCT3 ver3.1 - R translation

Data for 8 surveys over 31 year classes : 1990 - 2020
Regression type = C
Tapered time weighting applied
power = 3 over 20 years
Survey weighting not applied
Final estimates shrunk towards mean
Estimates with S.E.'S greater than that of mean included
Minimum S.E. for any survey taken as    0.2
Minimum of   3 points used for regression

Forecast/Hindcast variance correction used.

yearclass:2018
   index  slope intercept     se rsquare  n indices prediction se.pred
     NT1 0.9691     5.441 0.2604  0.9137 20   7.549      12.76  0.2972
     NT2 0.8716     7.198 0.3445  0.8606 20   5.594      12.07  0.3981
     NT3 0.6869     8.867 0.1120  0.9830 20   4.783      12.15  0.1292
    NAK1 1.1972     4.034 0.5124  0.7322 20   7.343      12.83  0.5854
    NAK2 0.9353     7.276 0.3050  0.8873 20   5.568      12.48  0.3476
    NAK3 0.8015     8.550 0.1825  0.9560 20   3.786      11.59  0.2206
    EC01 1.0586     6.267 0.3663  0.8532 14   5.941      12.56  0.4250
    ECO2 0.8087     8.248 0.3967  0.8071 15   4.074      11.54  0.4843
 VPA Mean     NA        NA     NA      NA 28      NA      12.58  0.8028
 WAP.weights
    0.13206
    0.07360
    0.29163
    0.03404
    0.09653
    0.23972
    0.06460
    0.04973
    0.01810

yearclass:2019
   index  slope intercept     se rsquare  n indices prediction se.pred
     NT1 1.0341     4.886 0.3606  0.8393 20   4.715      9.762  0.5627
     NT2 0.8802     7.128 0.3358  0.8594 20   3.455     10.170  0.4915
     NT3     NA        NA     NA      NA NA      NA         NA      NA
    NAK1 1.2736     3.396 0.5859  0.6643 20   5.612     10.543  0.7771
    NAK2 0.9857     6.947 0.3531  0.8468 20   3.490     10.388  0.4971
    NAK3     NA        NA     NA      NA NA      NA         NA      NA
    EC01 1.1232     5.823 0.4206  0.8056 15   3.326      9.558  0.6831
    ECO2     NA        NA     NA      NA NA      NA         NA      NA
 VPA Mean     NA        NA     NA      NA 29      NA     12.518  0.7822
 WAP.weights
    0.18821
    0.24677
```

```
        NA
   0.09871
   0.24116
        NA
   0.12772
        NA
   0.09743

yearclass:2020
   index slope intercept     se rsquare  n indices prediction se.pred
     NT1 1.031     4.895 0.3624  0.8374 19   6.137      11.22  0.4597
     NT2    NA        NA     NA      NA NA      NA         NA      NA
     NT3    NA        NA     NA      NA NA      NA         NA      NA
    NAK1 1.257     3.489 0.5814  0.6667 19   6.078      11.13  0.7321
    NAK2    NA        NA     NA      NA NA      NA         NA      NA
    NAK3    NA        NA     NA      NA NA      NA         NA      NA
    EC01    NA        NA     NA      NA NA      NA         NA      NA
    ECO2    NA        NA     NA      NA NA      NA         NA      NA
 VPA Mean    NA        NA     NA      NA 29      NA      12.51  0.7770
 WAP.weights
    0.5733
        NA
        NA
    0.2260
        NA
        NA
        NA
        NA
    0.2006

                  WAP logWAP  int.se
yearclass:2018 188877  12.15 0.09103
yearclass:2019  30736  10.33 0.24414
yearclass:2020  94702  11.46 0.34806
```

Table 4.18. Northeast Arctic haddock. Prediction with management option table: Input data (based on SAM estimates

"MFDP version 1a"

"Run: 2021"

"Time and date: 22:28 19.04.2021"

"Fbar age range: 4-7"

""

2021

Age	N	M	Mat	PF	PM	SWt	Sel	CWt
3	153680	0.405	0.029	0	0	0.259	0.0368	0.693
4	259641	0.293	0.081	0	0	0.494	0.1603	0.919
5	362981	0.263	0.211	0	0	0.813	0.3808	1.180
6	65434	0.225	0.45	0	0	1.222	0.5906	1.475
7	24257	0.2	0.735	0	0	1.774	0.6223	1.843
8	9282	0.2	0.886	0	0	2.284	0.6257	1.920
9	3972	0.2	0.942	0	0	2.663	0.6257	2.150
10	3483	0.2	0.979	0	0	3.279	0.6257	2.413
11	1479	0.2	1	0	0	3.444	0.6257	2.489
12	1459	0.2	1	0	0	3.754	0.6257	2.863
13	2410	0.2	1	0	0	3.705	0.6257	3.453

2022

Age	N	M	Mat	PF	PM	SWt	Sel	CWt
3	30736	0.405	0.03	0	0	0.273	0.0368	0.708
4	.	0.293	0.078	0	0	0.481	0.160	0.905
5	.	0.263	0.199	0	0	0.784	0.3808	1.154
6	.	0.225	0.418	0	0	1.154	0.5906	1.414
7	.	0.2	0.679	0	0	1.609	0.6223	1.745
8	.	0.2	0.871	0	0	2.191	0.6257	1.931
9	.	0.2	0.946	0	0	2.716	0.6257	2.066
10	.	0.2	0.971	0	0	3.085	0.6257	2.314
11	.	0.2	1	0	0	3.686	0.6257	2.379
12	.	0.2	1	0	0	3.624	0.6257	2.799
13	.	0.2	1	0	0	4.059	0.6257	3.468

2023

Age	N	M	Mat	PF	PM	SWt	Sel	CWt
3	94702	0.405	0.03	0	0	0.315	0.0368	0.753
4	.	0.293	0.082	0	0	0.497	0.160	0.922
5	.	0.263	0.192	0	0	0.766	0.3808	1.138
6	.	0.225	0.401	0	0	1.117	0.5906	1.380
7	.	0.2	0.649	0	0	1.526	0.6223	1.696
8	.	0.2	0.833	0	0	2.000	0.6257	1.884
9	.	0.2	0.937	0	0	2.610	0.6257	2.070
10	.	0.2	0.973	0	0	3.145	0.6257	2.283
11	.	0.2	1	0	0	3.507	0.6257	2.334

12	.	0.2	1	0	0	3.854	0.6257	2.775
13	.	0.2	1	0	0	3.938	0.6257	3.471

Table 4.19. Northeast Arctic haddock. Prediction with management option table for 2021–2023 (TAC constraint applied for intermediate year

MFDP version 1a

Run: 2021

2021MFDP Index file 19.04.2021

Time and date: 22:28 19.04.2021

Fbar age range: 4-7

202
1

Biomass	SSB	FMult	FBar	Landings
648860	200849	0.9932	0.4355	232537

2022					2023	
Biomass	SSB	FMult	FBar	Landings	Biomass	SSB
507632	204751	0	0	0	569679	309362
.	204751	0.1	0.0439	26690	544131	293022
.	204751	0.2	0.0877	52064	519923	277586
.	204751	0.3	0.1316	76192	496979	263004
.	204751	0.4	0.1754	99141	475232	249226
.	204751	0.5	0.2193	120972	454615	236208
.	204751	0.6	0.2631	141745	435068	223906
.	204751	0.7	0.307	161515	416531	212280
.	204751	0.8	0.3508	180334	398951	201292
.	204751	0.9	0.3947	198253	382274	190906
.	204751	1	0.4385	215319	366452	181089
.	204751	1.1	0.4824	231576	351439	171807
.	204751	1.2	0.5262	247065	337192	163032
.	204751	1.3	0.5701	261828	323667	154734
.	204751	1.4	0.6139	275901	310828	146888
.	204751	1.5	0.6578	289320	298636	139467
.	204751	1.6	0.7016	302119	287058	132448
.	204751	1.7	0.7455	314329	276060	125808
.	204751	1.8	0.7893	325981	265612	119527
.	204751	1.9	0.8332	337103	255683	113583
.	204751	2	0.877	347723	246247	107960

Table 4.20. Northeast Arctic haddock. Prediction single option table for 2020–2022 based on HCR

MFDP version 1a

Run: Fhcr

Time and date: 22:38 19.04.2021

Fbar age range: 4-7

Year:	2021	F multiplier:	0.9932	Fbar:	0.4355				
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)	SSNos(ST)	SSB(ST)
3	0.0366	4541	3147	153680	39803	4457	1154	4457	1154
4	0.1592	33255	30561	259641	128263	21031	10389	21031	10389
5	0.3782	101347	119589	362981	295104	76589	62267	76589	62267
6	0.5866	26289	38776	65434	79960	29445	35982	29445	35982
7	0.6181	10240	18872	24257	43032	17829	31628	17829	31628
8	0.6215	3934	7553	9282	21200	8224	18783	8224	18783
9	0.6215	1683	3619	3972	10577	3742	9964	3742	9964
10	0.6215	1476	3562	3483	11421	3410	11181	3410	11181
11	0.6215	627	1560	1479	5094	1479	5094	1479	5094
12	0.6215	618	1770	1459	5477	1459	5477	1459	5477
13	0.6215	1021	3527	2410	8929	2410	8929	2410	8929
Total		185031	232537	888078	648860	170074	200849	170074	200849

Year:	2022	F multiplier:	0.7982	Fbar:	0.35				
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)	SSNos(ST)	SSB(ST)
3	0.0294	732	518	30736	8391	922	252	922	252
4	0.128	10320	9340	98822	47533	7708	3708	7708	3708
5	0.304	38324	44226	165188	129507	32872	25772	32872	25772
6	0.4714	64912	91785	191163	220602	79906	92212	79906	92212
7	0.4967	10397	18142	29062	46761	19733	31751	19733	31751

8	0.4994	3846	7426	10704	23452	9323	20427	9323	20427
9	0.4994	1467	3030	4082	11087	3862	10488	3862	10488
10	0.4994	628	1452	1747	5389	1696	5233	1696	5233
11	0.4994	550	1309	1532	5646	1532	5646	1532	5646
12	0.4994	234	654	650	2357	650	2357	650	2357
13	0.4994	611	2120	1702	6906	1702	6906	1702	6906
Total		132021	180003	535387	507632	159906	204751	159906	204751

Year: 2023 F multiplier: 0.7982 Fbar: 0.35

Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)	SSNos(ST)	SSB(ST)
3	0.0294	2256	1699	94702	29831	2841	895	2841	895
4	0.128	2079	1917	19907	9894	1632	811	1632	811
5	0.304	15050	17127	64869	49690	12455	9540	12455	9540
6	0.4714	31818	43909	93703	104666	37575	41971	37575	41971
7	0.4967	34082	57803	95269	145381	61830	94352	61830	94352
8	0.4994	5202	9800	14479	28958	12061	24122	12061	24122
9	0.4994	1911	3955	5318	13881	4983	13007	4983	13007
10	0.4994	729	1664	2028	6379	1973	6207	1973	6207
11	0.4994	312	728	868	3044	868	3044	868	3044
12	0.4994	273	759	761	2933	761	2933	761	2933
13	0.4994	420	1457	1169	4602	1169	4602	1169	4602
Total		94131	140817	393074	399259	138149	201485	138149	201485

Table 4.21. Northeast Arctic haddock. Yield-per-recruit. Input data and results.

MFYPR version 2a

Run: 2021YPR

Time and date: 22:25 19.04.2021

Yield per results

FMult	Fbar	CatchNos	Yield	StockNos	Biomass	SpwnNosJan	SSBJan	SpwnNosSpwn	SSBSpwn
0	0	0	0	4.2321	6.4432	1.9203	5.0608	1.9203	5.0608
0.1	0.0495	0.1087	0.2095	3.7039	4.7588	1.4293	3.4316	1.4293	3.4316
0.2	0.099	0.1778	0.3169	3.3732	3.7718	1.1326	2.4938	1.1326	2.4938
0.3	0.1485	0.2264	0.3785	3.1444	3.1343	0.9353	1.9004	0.9353	1.9004
0.4	0.198	0.2629	0.417	2.9753	2.6943	0.7954	1.5002	0.7954	1.5002
0.5	0.2475	0.2917	0.4427	2.8442	2.3754	0.6914	1.2172	0.6914	1.2172
0.6	0.297	0.3153	0.4607	2.7389	2.1352	0.6114	1.0098	0.6114	1.0098
0.7	0.3465	0.3351	0.4739	2.6519	1.9487	0.5482	0.8532	0.5482	0.8532
0.8	0.396	0.3521	0.4839	2.5784	1.8001	0.497	0.7322	0.497	0.7322
0.9	0.4455	0.367	0.4917	2.5152	1.6793	0.4549	0.6367	0.4549	0.6367
1	0.495	0.3802	0.4979	2.4601	1.5791	0.4196	0.56	0.4196	0.56
1.1	0.5445	0.392	0.5029	2.4114	1.4948	0.3897	0.4974	0.3897	0.4974
1.2	0.594	0.4028	0.5071	2.3679	1.4229	0.3641	0.4458	0.3641	0.4458
1.3	0.6435	0.4126	0.5105	2.3287	1.3608	0.3419	0.4026	0.3419	0.4026
1.4	0.693	0.4216	0.5135	2.2931	1.3066	0.3226	0.3661	0.3226	0.3661
1.5	0.7425	0.4299	0.516	2.2605	1.2588	0.3055	0.3349	0.3055	0.3349
1.6	0.792	0.4377	0.5182	2.2306	1.2164	0.2903	0.3081	0.2903	0.3081
1.7	0.8415	0.445	0.5201	2.2029	1.1784	0.2768	0.2849	0.2768	0.2849
1.8	0.891	0.4519	0.5218	2.1771	1.1442	0.2647	0.2646	0.2647	0.2646
1.9	0.9405	0.4583	0.5234	2.1531	1.1131	0.2538	0.2468	0.2538	0.2468
2	0.99	0.4644	0.5247	2.1306	1.0848	0.2439	0.2311	0.2439	0.2311

	F multiplier	Absolute F

Reference point

Fbar(3-13)	1	0.495
FMax	>=1000000	
F0.1	0.4082	0.2021
F35%SPR	0.3284	0.1626

Weights in kilograms

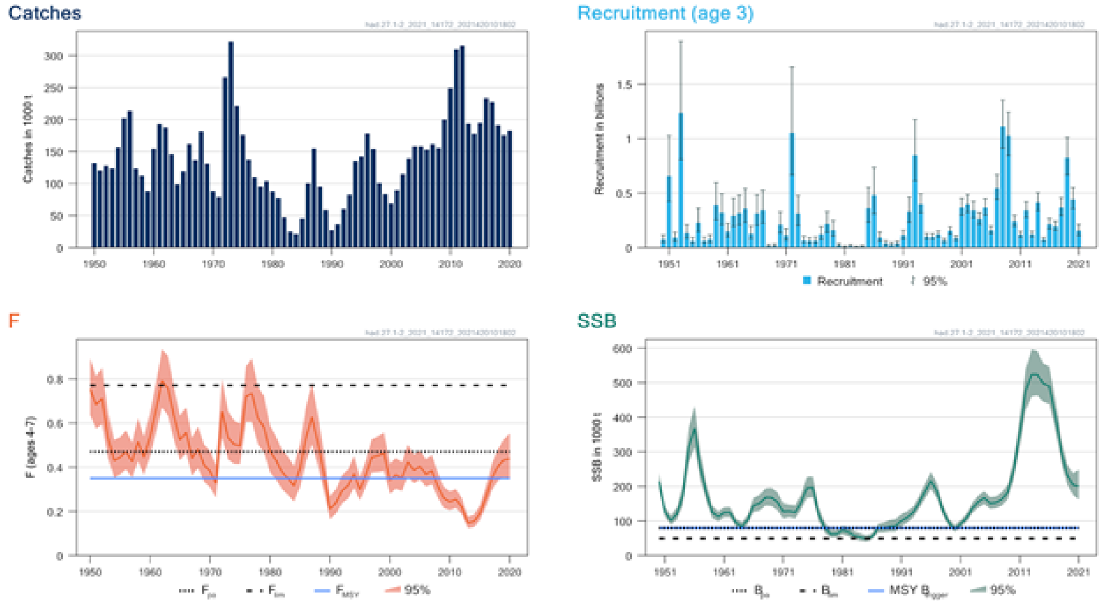

Figure 4.1 Landings, fishing mortality, recruitment, and spawning-stock biomass of Northeast Arctic haddock 1950–2021. Fishing mortality and spawning-stock biomass are given with point wise 95% confidence intervals (shaded areas).

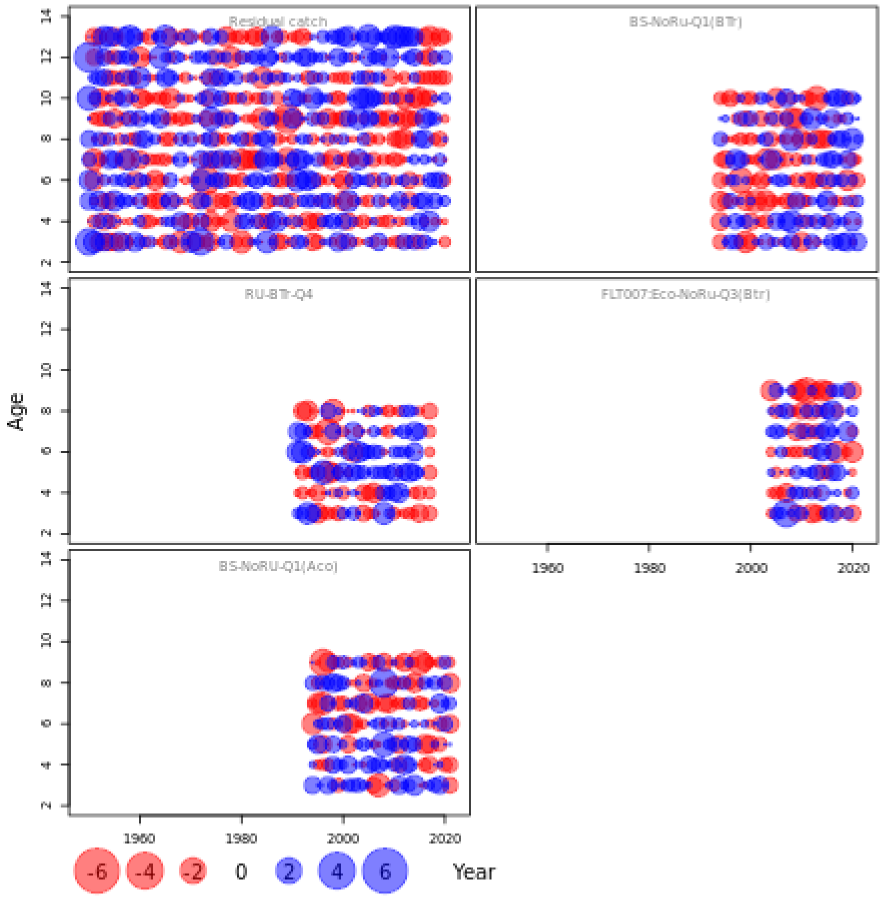

Figure 4.2. Northeast Arctic haddock; on step ahead residuals for the final SAM run. Blue circles indicate positive residuals (observations larger than predicted) and red circles indicate negative residuals.

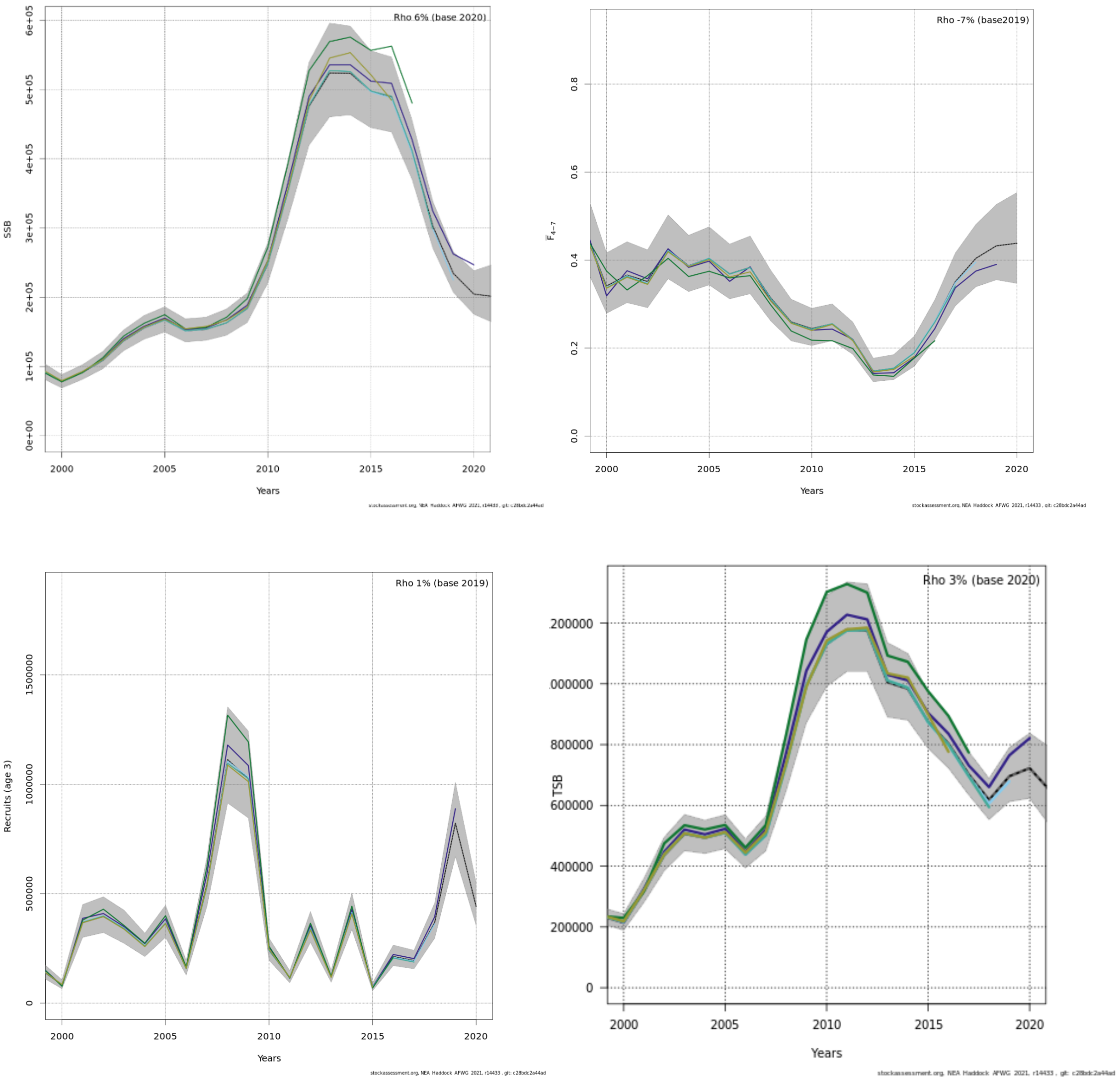

Figure 4.3. Northeast Arctic haddock. 5 year retrospective plots of SSB (top right), fishing mortality (top left), TSB (bottom left), and recruitment (bottom right) for years 2000–2021 (SAM with 95% confidence intervals).

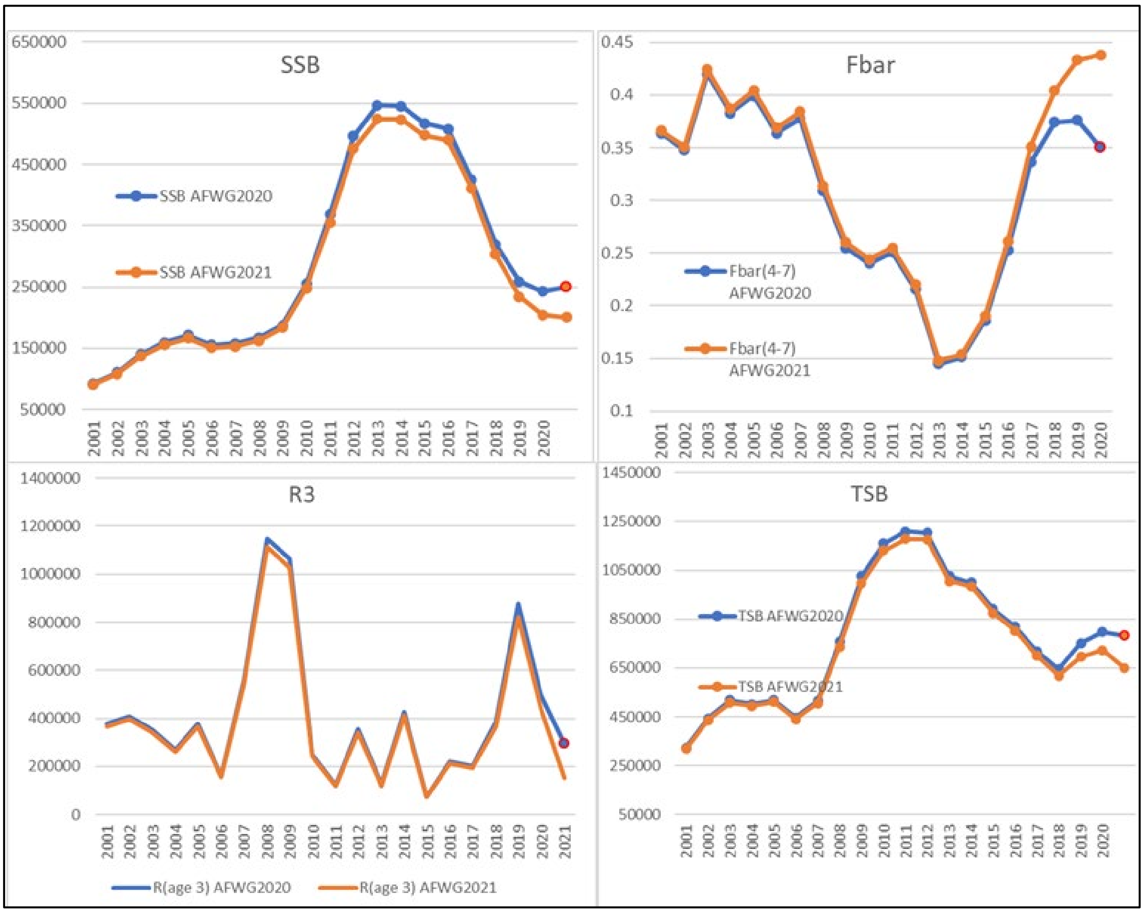

Figure 4.4. Results of assessment of NEA haddock. Fbar, TSB, recruits and SSB from AFWG 2020 (last year) and AFWG 2021 from 2001 and onwards. The last red points on the blue lines are forecasts from last year.

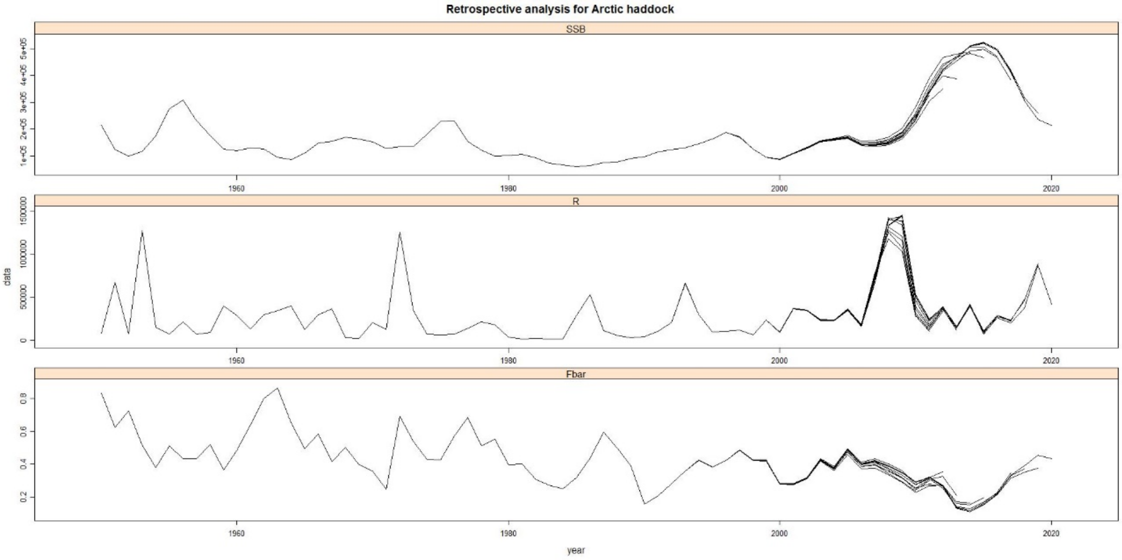

Figure 4.5. Northeast Arctic haddock. Retrospective plots of SSB, fishing mortality and recruitment for assessment years 1950–2020 (XSA without P shrinkage, F shrinkage= 0.5)

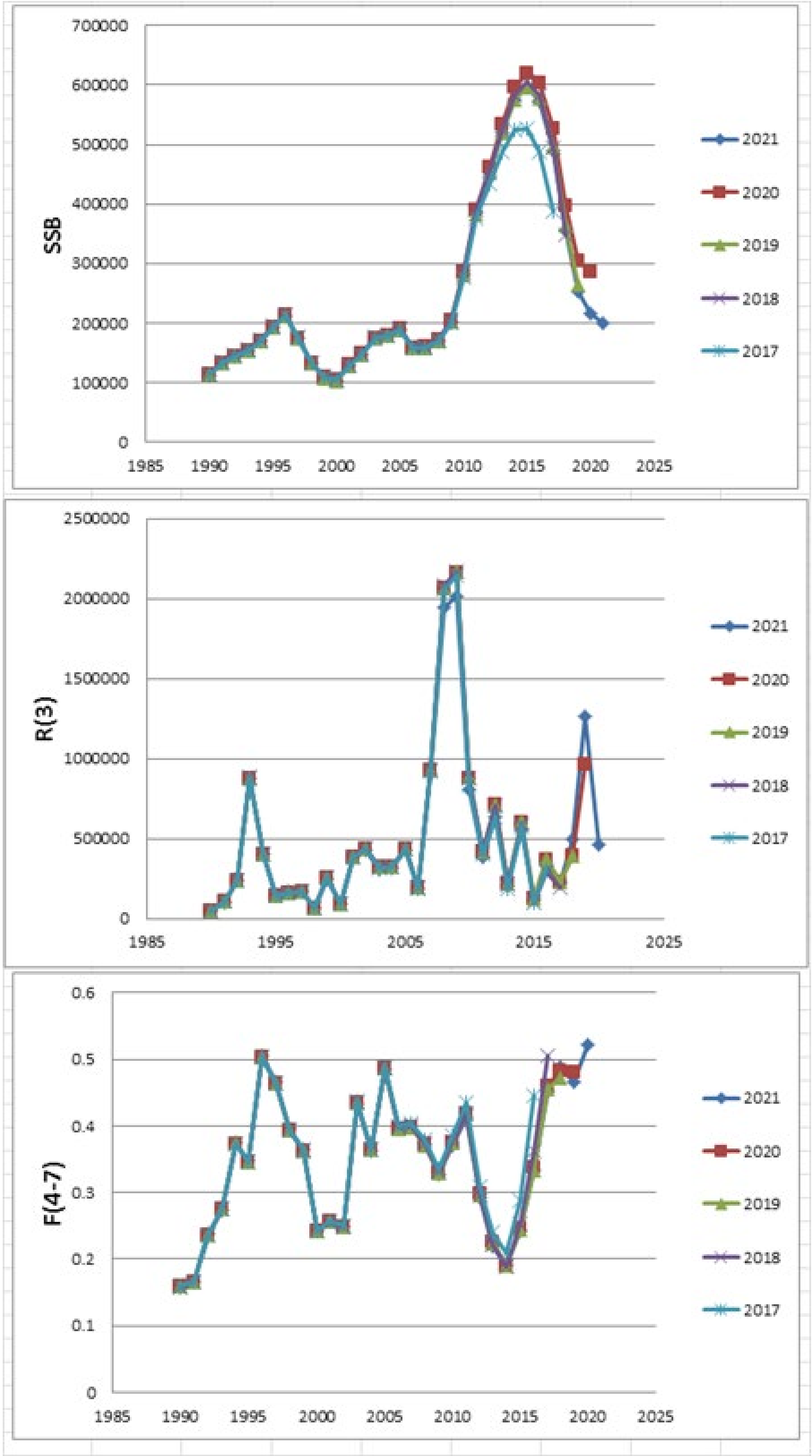

Figure 4.6. Northeast Arctic haddock. Retrospective plots of SSB, fishing mortality and recruitment for assessment years 1990–2020 from TSVPA model (see WD 22).

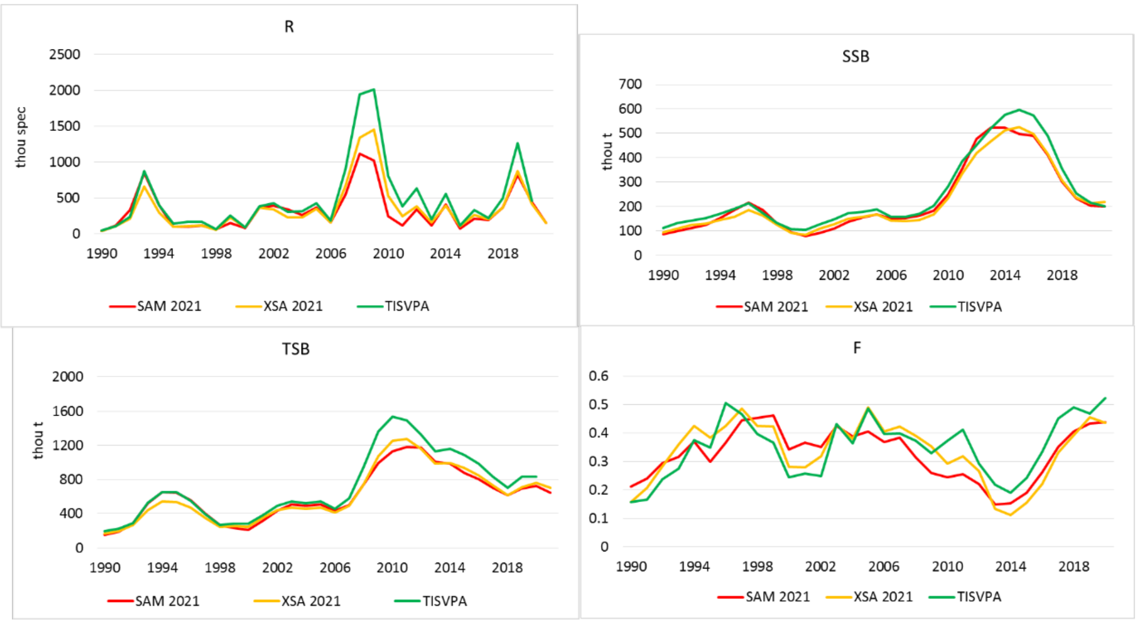

Figure 4.7. Comparison of results of assessment of NEA haddock. Recruits, biomass, spawning biomass and F in 1990–2020 by different models: medium SAM estimates, XSA with setting mentioned at section 4.9 and TISVPA with settings as mentioned at WDXX.

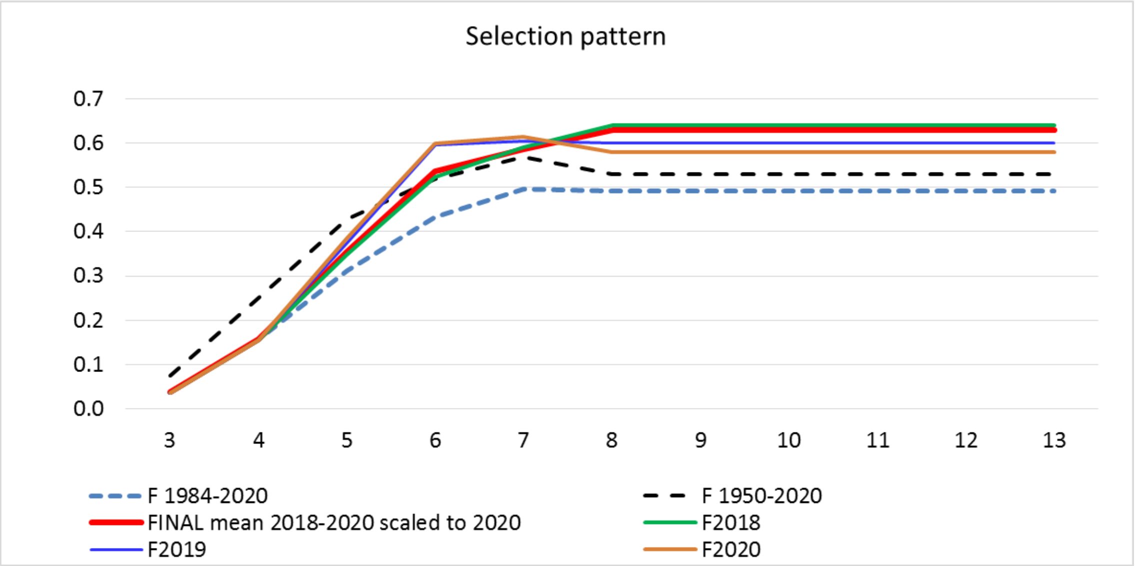

Figure 4. 8 Standard selection pattern model (red) used for short-term forecasts at AFWG 2021.

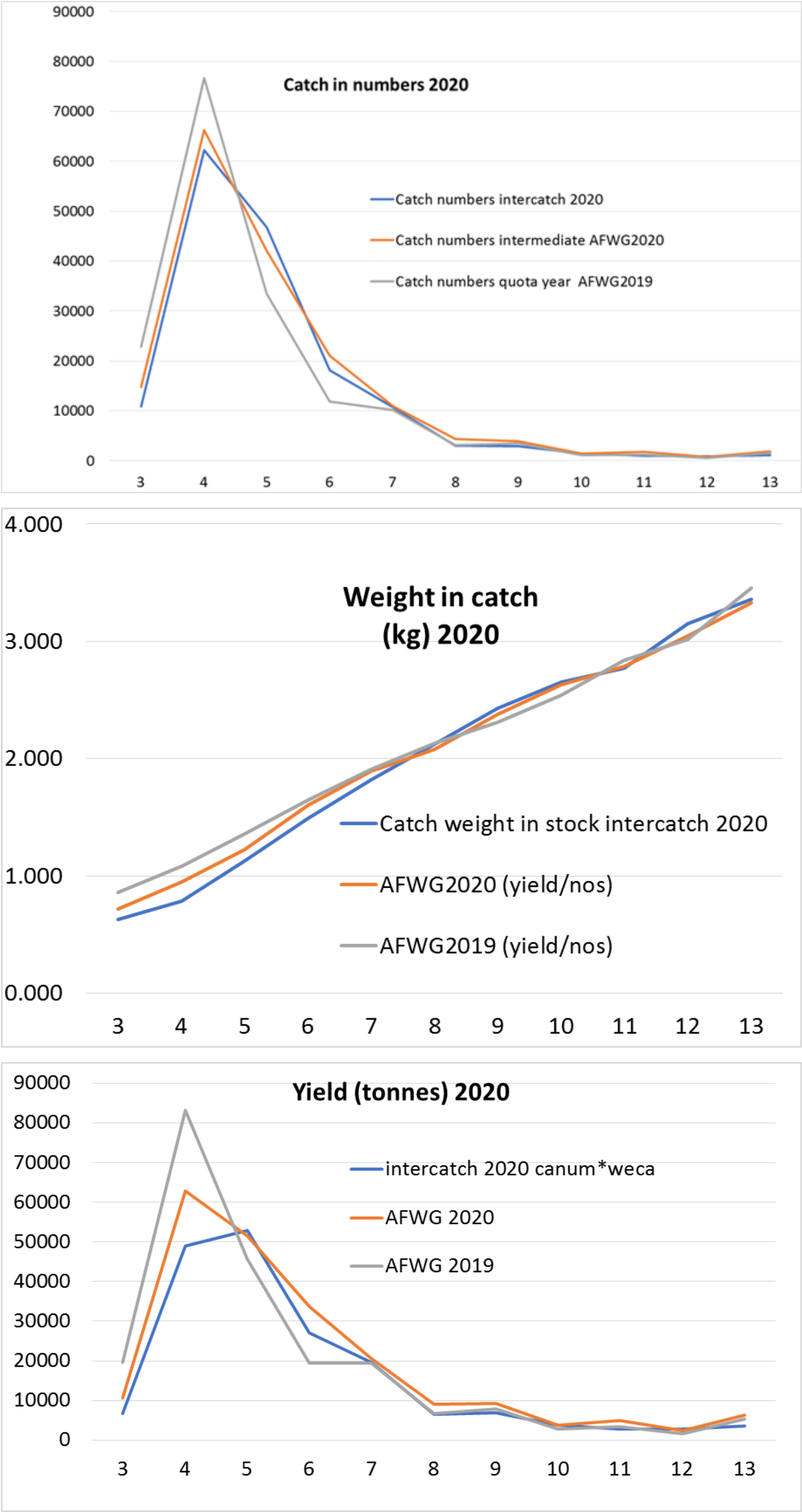

Figure 4.9 Comparisons of catch data by age 2020 from InterCatch with forecasts from AFWG 2019 and 2020. Top: catch number of individuals, middle: catch weights, bottom: yield.

5 Saithe in subareas 1 and 2 (Northeast Arctic)

Pollachius virens – pok.27.1-2

5.1 The fishery (Table 5.1 and Table 5.2, Figure 5.1)

Currently, the main fleets targeting saithe include trawl, purse-seine, gillnet, handline, and Danish seine. Landings of saithe were highest in 1970–1976 with an average of 239 000 t and a maximum of 265 000 t in 1970. This period was followed by a sharp decline to a level of about 160 000 t in the years 1978–1984, while in 1985 to 1991 the landings ranged from 67 000-123 000 t. After 1991 landings increased, ranging between 136 000 t (in 2000) and 212 000 t (in 2006), followed by a decline to 132 000 t in 2015. In 2019 landings were 163 180 t and 169 405 t in 2020.

Discarding, although illegal, occurs in the saithe fishery, but is not considered a major problem in the assessment. Due to its nearshore distribution saithe is virtually inaccessible for commercial gears during the first couple of years of life and there are no reports indicating overall high discard rates in the Norwegian fisheries. There are reported incidents of slipping in the purse-seine fishery, mainly related to minimum landing size. Observations from non-Norwegian commercial trawlers indicate that discarding may occur when vessels targeting other species catch saithe, for which they may not have a quota or have filled it. However, there are no quantitative estimates of the level of discarding available.

5.1.1 ICES advice applicable to 2020 and 2021

The advice from ICES for 2020 was as follows:

ICES advised that catches in 2020 should be no more than 171 982 t.

The advice from ICES for 2021 was as follows:

ICES advised that catches in 2021 should be no more than 197 779 t.

5.1.2 Management applicable in 2020 and 2021

Management of Saithe in subareas 1 and 2 is by TAC and technical measures. For 2020, The Norwegian Ministry of Trade, Industry and Fisheries set the TAC according to the advice from ICES, i.e. 171 982 t.

For 2021, The Norwegian Ministry of Trade, Industry and Fisheries set the TAC according to the advice from ICES, i.e. 197 779 t.

5.1.3 The fishery in 2020 and expected landings in 2021

Provisional figures show that the landings in 2020 were approximately 169 892 t, approximately 2 090 t lower than the TAC of 171 982t.

Since the WG does not have any prognosis of total landings in 2021 available, the TAC of 197 779 t is used in the projections. Here it should be mentioned that the Norwegian quota for 2021 was adjusted, based on quota flexibility, down from 182 404 t to 172 438 t, which means that the total quota of 197 779 t may not be caught in 2021.

5.2 Commercial catch-effort data and research vessel surveys

5.2.1 Catch-per-unit-effort

The NEA saithe IBP (ICES CM 2014/ACOM: 53) recommended leaving out the cpue time-series in the model tuning (see section 5.3.5). A detailed description of the Norwegian trawl cpue and its previous use is given in the stock annex.

5.2.2 Survey results (Figure 5.2-5.3)

An *ad hoc* subgroup of the AFWG was held to review proposed changes to several survey series using the new “StoX” survey computation methodology on 16 and 17 April 2017 at the JRC, Italy. The survey series reviewed included the coastal survey for saithe for the period 2003 to 2017. StoX is a new program developed at IMR Norway, to produce a more robust, transparent, and automated method of computing survey series. The method is currently used in ICES assessments (for example for NSS herring). For the saithe survey series, a WD was presented to the group (Mehl *et al.*, 2018a), examining the differences between the previous survey series and those resulting from StoX in survey indices by age, as well as mean weight and mean length. During the meeting consistency plots were produced for each survey and showed to have a better fit with the StoX series compared to the old series. The meeting concluded that the new StoX survey series should be used to replace the previous survey series in AFWG stock assessment, but that once the assessment model is run the residuals and fits to the data should be examined to check for unexpected detrimental affects on model performance. The resulting SAM model fits using the old and the StoX survey series (using data for both survey series up to 2016, but excluding the 2003 StoX estimate, as this was considered abnormally high) were practically the same, without any detrimental affects on model performance.

The echo abundance observed in 2020 (Staby *et al.*, 2021) increased by < 1% compared to 2019 and was about 92.5% of the average for 2003–2019. The abundance estimated using StoX increased by 1% compared to 2019. This slight increase is the result of higher estimates of 4-, 5-, and 7-year old saithe (2016, 2015 and 2013 year classes respectively), which were 80%, 19% and 84% higher than in 2019, while estimates for 3-, 6-, 8- and 9-year old saithe were below 2019 estimates. The proportion of saithe in the southern part of the survey area (south of the Lofoten islands between 62^0 -67^0N) increased from about 20% in 1997 to above 60% in 2008, decreased in later years and was similar to 2019 at 21% in 2020.

5.2.3 Recruitment indices

Owing to the nearshore distribution of juvenile saithe, obtaining early estimates of recruitment for ages 0–2 has not been possible so far. The survey recruitment indices are strongly dependent on the extent to which 2–4 year old saithe have migrated from the coastal areas and become available to the acoustic saithe survey on the banks, and this varies between years. Also, observations from an observer programme, established in 2000 to start a 0-group index series (Borge and Mehl, WD 21 2002) did not seem to reflect the dynamics in year-class strength very well. (Mehl, WD 6 2007; Mehl, WD 7 to WKROUND 2010). The programme was consequently terminated in 2010.

5.3 Data used in the assessment

5.3.1 Catch numbers-at-age (Table 5.3)

Total Norwegian landings by gear and landings data for all other countries from 2020 were updated based on the official total catch (preliminary) reported to ICES or to Norwegian authorities.

Age composition data for 2020 were available for Norwegian and German landings. An age–length key estimated for Norwegian trawl catches for area 1 and 2.b combined, and 2.a was applied to Russian length data from those subareas respectively. The age length key was based on 500 iterations done in ECA. Landings from other countries were assumed to have the same age composition as the combined Norwegian trawl catches. The biological sampling of all gear groups, areas, and quarters was sufficient to produce a reliable catch-at-age matrix for 2020. As in previous years age data from the Danish seine and bottom-trawl fishery were combined to increase the number of samples by area and quarter, thereby improving the estimate of catch-at-age numbers.

Catch-at-age estimates (numbers and mean weight and length-at-age) were produced with StoX-Reca for the 2020 assessment[1]. Comparative runs with ECA showed that estimates for 2020 and previous years were very similar. This is the first year that catch-at-age estimates are produced with StoX-Reca for input in the SAM assessment. In previous years catch-at-age was estimated manually, and until 2020 with ECA.

5.3.2 Weight-at-age (Table 5.4)

Constant weights-at-age values for age groups 3–11 are used for the period 1960–1979, whereas estimated values for the 12+ group vary during this period. For subsequent years, annual estimates of weight-at-age in the catches are used. Weight-at-age in the stock is assumed to be the same as weight-at-age in the catch. Compared to 2019, estimated weight-at-age for age groups 3–12+ differed only slightly in 2020, with the most notable difference the estimated weight for age group 12+, which showed a visible increase in mean weight.

5.3.3 Natural mortality

A fixed natural mortality of 0.2 for all age groups was used both in the assessment and the forecast.

5.3.4 Maturity-at-age (Table 5.5)

A 3-year running average is used for the period from 1985 and onwards (2-year average for the first and last year). Inconsistencies between proportion mature fish and trends in SSB and recruitment since 2008 resulted in the NEA saithe IBP to recommend the use of a constant maturity ogive for the years from 2007 and onwards based on the average 2005–2007 (ICES CM 2014/ACOM: 53). Analysis are currently being done to investigate which method, i.e. macroscopic determination, otolith spawning rings or histological analysis, is the most reliable to determine the maturity stage.

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[1] https://github.com/StoXProject/RstoxFDA/

5.3.5 Tuning data (Table 5.6)

Until the 2005 WG, the XSA tuning was based on three dataseries: cpue from Norwegian purse-seine and Norwegian trawl and indices from a Norwegian acoustic survey. The 2005 WG found rather large and variable log q residuals and large S.E. log q for the purse-seine fleet, as well as strong year effects, and in the combined tuning the fleet got low scaled weights. The WG decided not to include the purse-seine tuning fleet in the analysis. This was confirmed by new analyses at the 2010 benchmark assessment (ICES CM 2010/ACOM:36). The trawl cpue series on the other hand did not show the trends in stock size abundance of NEA saithe in later years. In the more recent years there were signs of changes in fishing strategy, with fewer and shorter fishing periods and a smaller proportion of directed saithe fishery (Mehl and Fotland, WD 20 2013).

Analyses of the two remaining tuning series done at the 2010 benchmark assessment indicated that there had been a shift in catchability around year 2002. The survey was redesigned in 2003, and the fishery to a larger degree targeted older ages. Permanent breaks were made in both tuning series in 2002. The acoustic survey, compared with the trawl cpue time-series, seemed to track the stock changes better, both in abundance and distribution.

The sensitivity runs presented to the IBP (Fotland WD 30 2014 IBP NEA saithe) clearly showed that the residual pattern got worse (strong year effects) when using both tuning series in SAM. It became obvious that SAM tries to fit something in between both contradicting data sources. Therefore, it had to be decided whether one data source was more reliable or whether both data sources should be considered leading to a fit in between both extremes. Given that cpue series should not be used when larger changes in fishing patterns occur (selectivity, spatial distribution of the fleet, change between targeted and bycatch fishery) it was recommended to leave out the cpue time-series in its current form for now (ICES CM 2014/ACOM: 53). Another reason was that the proportion of catches covered by the index had decreased steadily between 2002 and 2011, further questioning the representativeness of the cpue index. However, it may be worth trying alternative cpue indices (e.g. one index for the targeted fishery only and one index for the fishery with saithe bycatches) until the next benchmark.
The following two tuning fleets are thus used in the present assessment (by the time this report was written the new ICES name for this survey was not available)

- NOcoast-Aco-4Q: Indices from the Norwegian acoustic survey 1994–2001, age groups 3 to 7.
- NOcoast-Aco-4Q: Indices from the Norwegian acoustic survey 2002–2020, age groups 3 to 7.

5.4 SAM runs and settings (Table 5.7)

In connection with the NEA saithe IBP a number of exploratory SAM runs were performed. Model settings and results are presented in working documents included in the IBP report (ICES CM 2014/ACOM: 53).

SAM model settings and configuration in 2021 were the same as in previous simulations.

- Tuning data: Acoustic survey series (age 3–7) only, time-series split (1994–2001 and 2002–present);
- Maturity data: Ogives for the years 2007 and later based on the average of the 2005–2007 data;
- Flat exploitation pattern for age groups 8+;
- Correlated Fs between age groups and time;
- Beverton–Holt stock–recruitment relationship used to estimate recent recruitment.

5.5 Final assessment run (Table 5.8 to Table 5.11, Figure 5.4 to Figure 5.7)

The state–space assessment model (SAM) was used for the final run. SAM catchabilities and negative log likelihood values are given in Table 5.8. The predictive power (AIC) of the model was estimated to 1154. 81, compared to 1128.45 for the 2018 run.

Figure 5.4 presents normalized residuals for the total catches and the two parts of the acoustic tuning series. There are both year- and age effects and the second part of the series seems to perform better than the first part. Figure 5.5 shows plots of the stock numbers from the SAM vs. tuning indices, a circle indicates last year's result.

5.5.1 SAM F, N, and SSB results (Tables 5.9-5.11, Figures 5.6-5.7)

The estimated fishing mortality ($F_{4–7}$) in 2019 was 0.225 (AFWG 2020), which is similar to 0.226 from this year's assessment and below the F_{pa} of 0.35. The fishing mortality ($F_{4–7}$) in 2020 was estimated at 0.219. From 1997 to 2009 fishing mortality was below F_{pa}, but started to increase in 2005 and was above F_{pa} in 2010–2012.

Fishing mortality and stock size have in the last decade generally been considerably over- and underestimated respectively. Due to the changes made to the assessment following the benchmark assessment workshop in 2010 (ICES CM 2010/ACOM: 36) and later the NEA saithe IBP in 2014 (ICES CM 2014/ACOM: 53), the retrospective patterns have improved considerably, as is illustrated in Figure 5.7. Based on the 2020 assessment the SSB has in recent years been slightly overestimated and F_{4-7} underestimated.

The SAM-estimate of the 2014 year class was considered to be reliable enough to be used in the projections. In previous assessments the value of the 3-year olds in the last data year has been set to the long-term geometrical mean, and the value of the year class at age 4 were obtained by applying Pope's approximation. Since 2007 the 2007, 2010, 2013, and 2016 have been above the longterm geometric mean, while in the other years, year-class strength has been considered average or below.

The total biomass (ages 3+) was above the long-term (1960–2019) average from 1996 to 2010, reached a maximum in 2005, declined below the average level between 2011 and 2015, and has been above the long-term average since 2016. The SSB was above the long-term mean from 2000 to 2009, decreased below the average between 2010 to 2013, and has been above since 2014. SSB has been above B_{pa} (220 000 t) since 1996 (Figure 5.1).

5.5.2 Recruitment (Table 5.10, Figure 5.1)

Catches of age group 3 have varied considerably during the period 2004–2017 (Table 5.10). Until the 2005 WG, RCT3-runs were conducted to estimate the corresponding year classes, with 2 and 3 year olds from the acoustic survey as input together with XSA numbers. However, it was stated several times in the ACOM Technical Minutes that it would be more transparent to use the long-term geometric mean (GM) recruitment. GM values were therefore used in the 2005–2014 since the issue was not discussed at the IBP when SAM was adopted as assessment model. During the 2015 AFWG assessment, analyses were performed to investigate if the last year recruitment value from SAM could be used instead of the long-term GM (for method description refer to Stock Annex). Results from this analysis showed that the retrospective runs of SAM gave better estimates of recruitment than the geometric mean and consequently estimates of the recruiting year class (3 year olds in the last data year) from the SAM were accepted for the last year.

5.6 Reference points (Figure 5.1)

In 2010 the age span was expanded from 11+ to 15+ and important XSA parameter settings were changed (ICES CM 2010/ACOM: 36). LIM reference points were re-estimated at the 2010 WG according to the methodology outlined in ICES CM 2003/ACFM: 15, while the PA reference point estimation was based on the old procedure (ICES CM 1998/ACFM: 10). The results were not very much different from the previous analyses performed in 2005 (ICES CM 2005/ACFM: 20), and it was decided not to change the existing LIM and PA reference points. The shift from XSA to SAM resulted in only minor changes in estimated fishing mortality, spawning-stock-biomass and recruitment and no new reference points were estimated.

5.6.1 Harvest control rule

In 2007 ICES evaluated the harvest control rule for setting the annual fishing quota (TAC) for Northeast Arctic saithe. ICES concluded that the HCR was consistent with the precautionary approach for all simulated data and settings, including a rebuilding situation under the condition that the assessment uncertainty and error are not greater than those calculated from historic data. This also held true when an implementation error (difference between TAC and catch) equal to the historic level was included. The HCR was implemented the same year. It contains the following elements:

- Estimate the average TAC level for the coming 3 years based on F_{mp}. TAC for the next year will be set to this level as a starting value for the 3-year period.
- The year after, the TAC calculation for the next 3 years is repeated based on the updated information about the stock development. However, the TAC should not be changed by more than 15% compared with the previous year's TAC.
- If the spawning-stock-biomass (SSB) at the beginning of the year for which the quota is set (first year of prediction), is below B_{pa}, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from F_{mp} at SSB = B_{pa} to 0 at SSB equal to zero. At SSB levels below B_{pa} in any of the operational years (current year and 3 years of prediction) there should be no limitations on the year-to-year variations in TAC.

In 2011 the evaluation was repeated taking into account the changes made to the assessment after the 2010 benchmark assessment (ICES CM 2010/ACOM: 36). The analyses indicate that the HCR still is in agreement with the precautionary approach (Mehl and Fotland, WD 11 2011).

The fishing mortality used in the harvest control rule (F_{mp}) was in 2007 set to $F_{pa} = 0.35$. In June 2013, after the ICES advice for 2014 for this stock had been given, F_{mp} was reduced to 0.32.

5.7 Predictions

5.7.1 Input data (Table 5.12)

The input data to the predictions based on results from the final model run are given in Table 5.12. The estimates for stock number-at-age in 2021 were taken from the final SAM run for ages 4+. The geometric mean (GM) for recruitment (age 3) of 160 million was used in 2021 and subsequent year classes. The natural mortality of 0.2 is the same as used in the assessment. For exploitation pattern the average of the 2018–2020 fishing mortalities for ages 3 to 12 was used, with mortalities for 8+ being constant. For weight-at-age in stock and catch the average of the last three years (2018–2020) from the final SAM run was used. For maturity-at-age the average of the 2005–2007 annual ogives was applied.

5.7.2 Catch options for 2021 (short-term predictions; Tables 5.13-14)

The management option table (Table 5.13) shows that the expected landings of 197 779 t in 2021 will result in a fishing mortality F_{bar} of 0.23 (which adjusted with the F_{Mult} will be 0.265), slightly higher compared to 2020 of 0.26, but well below the F_{pa} of 0.35. A catch in 2022 corresponding to the $F_{status\ quo}$ level (3-year average 2018–2020) of 0.23 will be 169 313 t, while a catch in 2022 corresponding to the evaluated and implemented HCR of 197 212 t will result in F of 0.28 (Table 5.13).

For a catch in 2021 corresponding to the TAC of 197 779 t, the SSB is expected to decrease from about 568 972 t at the beginning of 2021 to 541 708 t at the beginning of 2022. At $F_{status\ quo}$ in 2022 SSB is estimated to decrease to 531 508t at the beginning of 2023 and for a catch corresponding to the HCR it will decrease to about 482 900 in 2023 t.

5.7.3 Comparison of the present and last year's assessment

The current assessment estimated the total stock in 2021 to be 1% higher and the SSB at the same level, compared to the previous assessment. The F in 2019 from the current assessment is virtually the same as from the previous assessment, and the realized F in 2020 is lower compared to the predicted one in 2020 based on the TAC.

	Total stock (3+) by 1 January 2020 (tonnes)	**SSB by 1 January 2020 (tonnes)**	**F_{4-7} in 2020**	**F_{4-7} in 2019**
WG 2020	944 239	552 168	0.236	0.225
WG 2021	949 910	557 582	0.219	0.226

5.8 Comments to the assessment and the forecast (Fig 5.7)

A statistical model is less sensitive to +group setting than XSA. In addition, the results from XSA were more dependent on the input data (use or no use of cpue, split of the tuning survey time-series), the shrinkage parameter and whether the number of iterations is capped or not. XSA only converged at a large number of iterations. In contrast, results from SAM are much more robust and depend to a lesser degree on subjective choice of model settings (such as shrinkage). In addition, SAM as a stochastic model is not treating catches as known without error. The fishing mortality rates could be considered correlated in time, and to reflect that neighbouring age groups have more similar fishing mortalities.

The retrospective pattern has been a major concern in the assessment, but due to the changes done at the benchmark assessment in 2010 (ICES CM 2010/ACOM: 36) and later at the NEA saithe IBP in 2014 (ICES CM 2014/ACOM: 53), the assessment has become stable (Figure 5.7)

The biological sampling from the fishery got critically low after the termination of the original Norwegian port-sampling program in 2009. In 2015 this was in particular the case for samples from trawl in quarter two and three in ICES area 1 and age samples from purse-seine fishery south of Lofoten (ICES area 2.a). In 2020 biological sampling from the saithe purse-seine fishery catches in Norwegian waters was adequate.

Lack of reliable recruitment estimates is a major problem. Prediction of catches will still, to a large extent, be dependent on assumptions of average recruitment in the intermediate year and the forecast period, since fish from age four to seven constitute major parts of the catches. Since the saithe HCR is a three-year-rule, the estimation of average F_{mp} catch in the HCR will affect stock numbers up to age five, and thereby affect the total prognosis of the fishable stock and the quotas derived from it. The recruitment-at-age 3 estimated by the SAM has on average been at about the long-term geometric mean level since 2005.

5.9 Tables and figures

Table 5.1. Saithe in subareas 1 and 2 (Northeast Arctic). Nominal catch (t) by countries as officially reported to ICES.

Year	Faroe Islands	France	Germany (Dem Rep)	Germany (Fed Rep)	Iceland	Norway	Poland	Portugal	Russia[3]	Spain	UK	Others[5]	Total all countries
1960	23	1700		25 948		96 050					9780	14	**133 515**
1961	61	3625		19 757		77 875					4615	18	**105 951**
1962	2	544		12 651		101 895			912		4699	4	**120 707**
1963		1110		8108		135 297					4112		**148 627**
1964		1525		4420		184 700			84		6511	186	**197 426**
1965		1618		11 387		165 531			137		6746	181	**185 600**
1966		2987	813	11 269		175 037			563		13 078	41	**203 788**
1967		9472	304	11 822		150 860			441		8379	48	**181 326**
1968			1248	4753		96 641					8782		**111 424**
1969	20	193	6744	4355		115 140					13 585	23	**140 060**
1970	1097		29 200	23 466		151 759			43 550		15 690		**264 924**
1971	215	14 536	16 840	12 204		128 499	6017		39 397	13 097	10 467		**241 272**
1972	109	14 519	7474	24 595		143 775	1111		1278	9247	8348		**210 456**
1973	7	11320	12 015	30 338		148 789	23		2411	2115	6841		**213 859**
1974	46	7119	29 466	33 155		152 699	2521		28 931	7075	3104	5	**264 121**

Year	Faroe Islands	France	Germany (Dem Rep)	Germany (Fed Rep)	Iceland	Norway	Poland	Portugal	Russia[3]	Spain	UK	Others[5]	Total all countries
1975	28	3156	28 517	41 260		122 598	3860	6430	13 389	11 397	2763	55	**233 453**
1976	20	5609	10 266	49 056		131 675	3164	7233	9013	21 661	4724	65	**242 486**
1977	270	5658	7164	19 985		139 705	1	783	989	1327	6935		**182 817**
1978	809	4345	6484	19 190		121 069	35	203	381	121	2827		**155 464**
1979	1117	2601	2435	15 323		141 346			3	685	1170		**164 680**
1980	532	1016		12 511		128 878			43	780	794		**144 554**
1981	236	218		8431		166 139			121		395		**175 540**
1982	339	82		7224		159 643			14		732		**168 034**
1983	539	418		4933		149 556			206	33	1251		**156 936**
1984	503	431	6	4532		152 818			161		335		**158 786**
1985	490	657	11	1873		103 899			51		202		**107 183**
1986	426	308		3470		63 090			27		75		**67 396**
1987	712	576		4909		85 710			426		57	1	**92 391**
1988	441	411		4574		108 244			130		442		**114 242**
1989	388	460[2]		606		119 625			506	506	726		**122 817**
1990	1207	340[2]		1143		92 397			52		709		**95 848**
1991	963	77[2]	Greenland	2003		103 283			504 [4]		492	5	**107 327**
1992	165	1980	734	3451		119 763			964	6	541		**127 604**

Year	Faroe Islands	France	Germany (Dem Rep)	Germany (Fed Rep)	Iceland	Norway	Poland	Portugal	Russia[3]	Spain	UK	Others[5]	Total all countries
1993	31	566	78	3687	3	140 604		1	9509	4[2]	415	5	**154 903**
1994	67[2]	557	15	1863	4[2]	141 589		1[2]	1640[2]	655[2]	557	2	**146 950**
1995	172[2]	358	53	935		165 001		5	1148		688	18	**168 378**
1996	248[2]	346	165	2615		166 045		24	1159	6	707	33	**171 348**
1997	193[2]	560	363[2]	2915		136 927		12	1774	41	799	45	**143 629**
1998	366	932	437[2]	2936		144 103		47	3836	275	355	40	**153 327**
1999	181	638[2]	655[2]	2473	146	141 941		17	3929	24	339	32	**150 375**
2000	224[2]	1438	651[2]	2573	33	125 932		46	4452	117	454	8[2]	**135 928**
2001	537	1279	701[2]	2690	57	124 928		75	4951	119	514	2	**135 853**
2002	788	1048	1393	2642	78	142 941		118	5402	37	420	3	**154 870**
2003	2056	1022	929[2]	2763	80[2]	150 400		147	3894	18	265	18[2]	**161 592**
2004	3071	255	891[2]	2161	319	147 975		127	9192	87	544	14	**164 636**
2005	3152	447	817[2]	2048	395	162 338		354	8362	25	630		**178 568**
2006	1795	899.7	779[2]	2780	255	195 462	88.9	101	9823	0	532	42	**212 557**
2007	2048	965.6	801[2]	3019	219	178 644	99.3	412	12 168	22	557	11.8	**198 967**
2008	2405	1008.6	513[2]	2264	113	165 998	65.8	348	11 577	33	506	9.7	**184 840**
2009	1611	378.6	697	2021	69	144 570	30.6	184.01	11 899	2	379	24	**161 865**
2010	1632	677.2	954	1592	124	175 246	278.9	93	14 664	8	283	2.5	**195 554**

Year	Faroe Islands	France	Germany (Dem Rep)	Germany (Fed Rep)	Iceland	Norway	Poland	Portugal	Russia[3]	Spain	UK	Others[5]	Total all countries
2011	306	504.2	445	1371	66	143 314	0	45.34	10 007	2	972	15.14	**157 048**
2012	146	780.55	658	1371	126	143 174	0	7.65	13 607	4	1087	0	**160 960**
2013	80	1900.92	972	1212	245	111 961	2.21	17.24	14 796	5	415	21.93	**131 629**
2014	273	1674	407	259	659	115 864	0.86	8.25	12 396	12	518	0	**132 070**
2015	766	515	393	424	248	115 157	1143	10.42	13 181	34	403	0	**132 275**
2016	1148	526	613	952	702	121 705	530	52	15 203	26	301	10	**141 768**
2017 [1]	639	680	407	865	589	126 947	504	86	14 551	88	439	24	**145 819**
2018	626	937	448	1642		162 460	404	51	14 171	60	464	17	**181 280**
2019	618	1472	424	1371		144 076	46	131	13 990	199	419	434	**163 180**
2020		530	410	1544		151697	1.2	132	14082	0	517	118	**169 405**

[1] Provisional figures.

[2] As reported to Norwegian authorities.

[3] USSR prior to 1991.

[4] Includes Estonia.

[5] Includes Denmark. Netherlands. Ireland. and Sweden.

[6] As reported by Working Group member

Table 5.2 Saithe in subareas 1 and 2 (Northeast Arctic). Catch (´000) by fishing gear.

Year	Purse-seine	Trawl	Gillnet	Others	Total
1977	75.2	69.5	19.3	12.7	176.7
1978	62.9	57.6	21.1	13.9	155.5
1979	74.7	52.5	21.6	15.9	164.7
1980	61.3	46.8	21.1	15.4	144.6
1981	64.3	72.4	24.0	14.8	175.5
1982	76.4	59.4	16.7	15.5	168.0
1983	54.1	68.2	19.6	15.0	156.9
1984	36.4	85.6	23.7	13.1	158.8
1985	31.1	49.9	14.6	11.6	107.2
1986	7.9	36.2	12.3	8.2	64.6
1987	34.9	27.7	19.0	10.8	92.4
1988	43.5	45.4	15.3	10.0	114.2
1989	49.5	45.0	16.9	11.4	122.8
1990	24.6	44.0	19.3	7.9	95.8
1991	38.9	40.1	18.9	9.4	107.3
1992	27.1	67.0	22.3	11.2	127.6
1993	33.1	84.9	21.2	15.7	154.9
1994	30.2	82.2	21.1	13.5	147.0
1995	21.8	103.5	26.9	16.1	168.4
1996	46.9	72.5	31.6	20.3	171.3
1997	44.4	55.9	24.4	19.0	143.6
1998	44.4	57.7	27.6	23.6	153.3
1999	39.2	57.9	29.7	23.6	150.4
2000	28.3	54.5	29.6	23.5	135.9
2001	28.1	58.1	28.2	21.5	135.9
2002	27.4	75.5	30.4	21.5	154.8
2003	43.3	73.8	25.2	19.3	161.6
2004	41.8	74.6	26.9	21.3	164.6

Year	Purse-seine	Trawl	Gillnet	Others	Total
2005	42.1	91.8	25.6	19.1	178.6
2006	73.5	87.1	29.7	22.5	212.8
2007	41.8	100.7	33.3	23.2	199.0
2008	39.4	91.2	37.0	17.1	184.7
2009	35.5	81.1	33.2	12.1	161.9
2010	54.9	89.8	36.9	13.2	194.8
2011	45.3	67.1	32.1	12.2	156.7
2012	44.2	73.9	28.3	14.5	160.9
2013	34.7	65.2	19.2	12.7	131.8
2014	29.3	54.8	26.7	21.2	132.0
2015	30.4	55.4	23.5	22.5	131.8
2016	28.9	64.1	21.4	26.9	141.3
2017[1]	32.4	65.0	21.4	27.3	146.1
2018	36.0	83.6	28.8	33.2	181.5
2019	28.7	68.6	29.4	36.6	163.1
2020	26.8	74	30.3	38.3	169.4

[1] **Provisional figures.**

[2] **Unresolved discrepancies between Norwegian catch by gear figures and the total reported to ICES for these years.**

[3] **Includes 4300 tonnes not categorized by gear. proportionally adjusted.**

[4] **Reduced by 1200 tonnes not categorized by gear. proportionally adjusted.**

Table 5.3 Catch numbers-at-age ('000) of northeast Arctic saithe.

	Age groups									
Year	3	4	5	6	7	8	9	10	11	12+
1960	13517	16828	17422	6514	6281	3088	1691	956	481	1481
1961	25237	12929	17707	5379	1886	1371	736	573	538	1202
1962	45932	13720	5449	10218	2991	1262	1156	556	611	1518
1963	51171	35199	7165	5659	4699	1337	1308	848	550	1612
1964	10925	72344	15966	3299	4214	3223	1518	1482	1282	3038
1965	42578	5737	30171	11635	3282	2421	3135	802	1136	2986
1966	25127	61199	14727	14475	5220	1542	1047	1083	530	2724

	Age groups								
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1967	28457	23826	34493	3957	5388	2797	1356	1340	814	2536
1968	29955	21856	6065	9846	936	2274	1070	686	465	922
1969	76011	11745	16650	4666	4716	1107	1682	663	199	303
1970	43834	63270	14081	16298	5157	8004	2521	3722	1103	1714
1971	61743	47522	21614	7661	7690	2326	3489	1760	2514	1888
1972	55351	44490	24752	8650	4769	3012	1584	1817	1044	1631
1973	62938	20793	22199	13224	5868	3246	2368	2153	1291	1947
1974	36884	44149	15714	20476	12182	4815	3267	2512	1440	2392
1975	70255	13502	18901	5123	9018	7841	3365	2714	2237	2544
1976	135592	33159	8618	9448	3725	3483	2905	1870	1183	1940
1977	105935	36703	10845	2205	4633	1557	1718	1030	495	718
1978	56505	31946	14396	5232	1694	2132	1082	1126	756	1726
1979	75819	28545	17280	5384	3550	1178	1659	536	373	1086
1980	40303	36202	9100	6302	3161	1322	145	721	406	1204
1981	85966	22345	22044	3706	2611	2056	378	286	258	385
1982	35853	67150	13481	8477	1088	1291	476	271	124	338
1983	18216	25108	34543	3408	3178	1243	803	261	215	587
1984	43579	34927	12679	11775	1193	1862	589	585	407	537
1985	48989	11992	7200	5287	3746	776	879	134	274	427
1986	21322	12433	5845	4363	2704	1349	338	438	123	152
1987	18555	51742	4506	3238	3624	784	644	267	263	565
1988	8144	35928	32901	4570	2333	1222	968	321	73	30
1989	12607	19400	33343	18578	1762	352	177	189	1	205
1990	23792	16930	9054	10238	7341	1076	160	112	150	118
1991	68682	13630	5752	4883	3877	2381	383	61	90	89
1992	44627	33294	5987	5412	4751	3176	1462	286	93	350
1993	22812	61931	31102	3747	1759	1378	1027	797	76	71
1994	7063	32671	49410	19058	2058	724	421	278	528	129

	Age groups									
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1995	17178	52109	40145	30451	4177	483	125	259	31	263
1996	10510	54886	18499	18357	17834	2849	485	214	148	325
1997	11789	11698	35011	13567	13452	7058	812	55	48	98
1998	3091	16215	11946	31818	8376	5539	2873	727	111	282
1999	9655	12236	22872	10347	18930	3374	3343	2290	419	170
2000	9175	22768	7747	10676	6123	8303	2530	2652	1022	197
2001	3816	7946	26960	8769	7120	3146	4687	1935	1406	528
2002	6582	17492	11573	25671	5312	4276	2382	3431	965	1420
2003	2345	50653	13600	7123	9594	5494	3545	2519	2327	1813
2004	1002	6129	33840	10613	7494	8307	2792	3088	2377	3072
2005	26093	12543	9841	23141	10799	5659	7852	2674	713	1588
2006	1590	68137	12328	10098	16757	8080	5671	5127	1815	2529
2007	3144	4115	39889	15301	7963	11302	7749	4138	2157	849
2008	25259	18953	5969	24363	9712	5624	7697	4705	1606	1572
2009	9050	34311	9954	6628	15930	4766	3021	4224	2471	1426
2010	26382	43436	28514	7988	3129	12444	2749	1314	1212	1431
2011	6239	45213	13307	15157	6622	2901	5934	1730	647	1115
2012	30742	17841	33911	10496	7058	3522	1570	2586	557	890
2013	17151	15491	15946	21980	5512	3298	1149	729	885	653
2014	7650	24769	13822	9343	12331	3284	2130	904	378	763
2015	13185	15459	30159	9271	7324	7133	1697	723	433	620
2016	8278	20955	13044	15532	6621	4774	4363	1053	718	1382
2017	5421	34736	12901	7324	9032	3885	2562	1924	376	1999
2018	5260	19260	41425	12618	5903	5667	2843	1956	1112	1567
2019	12421	15078	15388	25177	8327	3243	2848	1357	619	1171
2020	6216	27602	13466	14054	17767	5031	2034	1469	564	1236

Table 5.4 Catch weight-at-age (kg) northeast Arctic saithe.

	Age groups								
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1960	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.55
1961	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.75
1962	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.52
1963	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.33
1964	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.35
1965	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.54
1966	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.43
1967	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.49
1968	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.36
1969	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.16
1970	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.03
1971	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	7.87
1972	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.14
1973	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.01
1974	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	7.69
1975	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	7.73
1976	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	7.86
1977	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.05
1978	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.00
1979	0.71	1.11	1.63	2.33	3.16	4.03	4.87	5.63	6.44	8.28
1980	0.79	1.27	2.03	2.55	3.29	4.34	5.15	5.75	6.11	7.22
1981	0.73	1.40	2.05	2.76	3.30	4.38	5.95	6.39	6.61	7.00
1982	0.77	1.12	2.02	2.61	3.27	3.91	4.69	5.63	7.18	7.69
1983	1.05	1.33	1.86	2.80	4.00	4.18	5.33	5.68	7.31	9.16
1984	0.71	1.26	2.02	2.70	3.88	4.47	5.36	6.06	6.28	7.88
1985	0.75	1.33	2.07	2.63	3.28	3.96	4.54	5.55	6.88	8.74
1986	0.59	1.22	1.97	2.30	2.87	3.72	4.30	4.69	5.84	7.21
1987	0.53	0.84	1.66	2.32	2.97	4.00	4.72	5.44	5.79	7.42

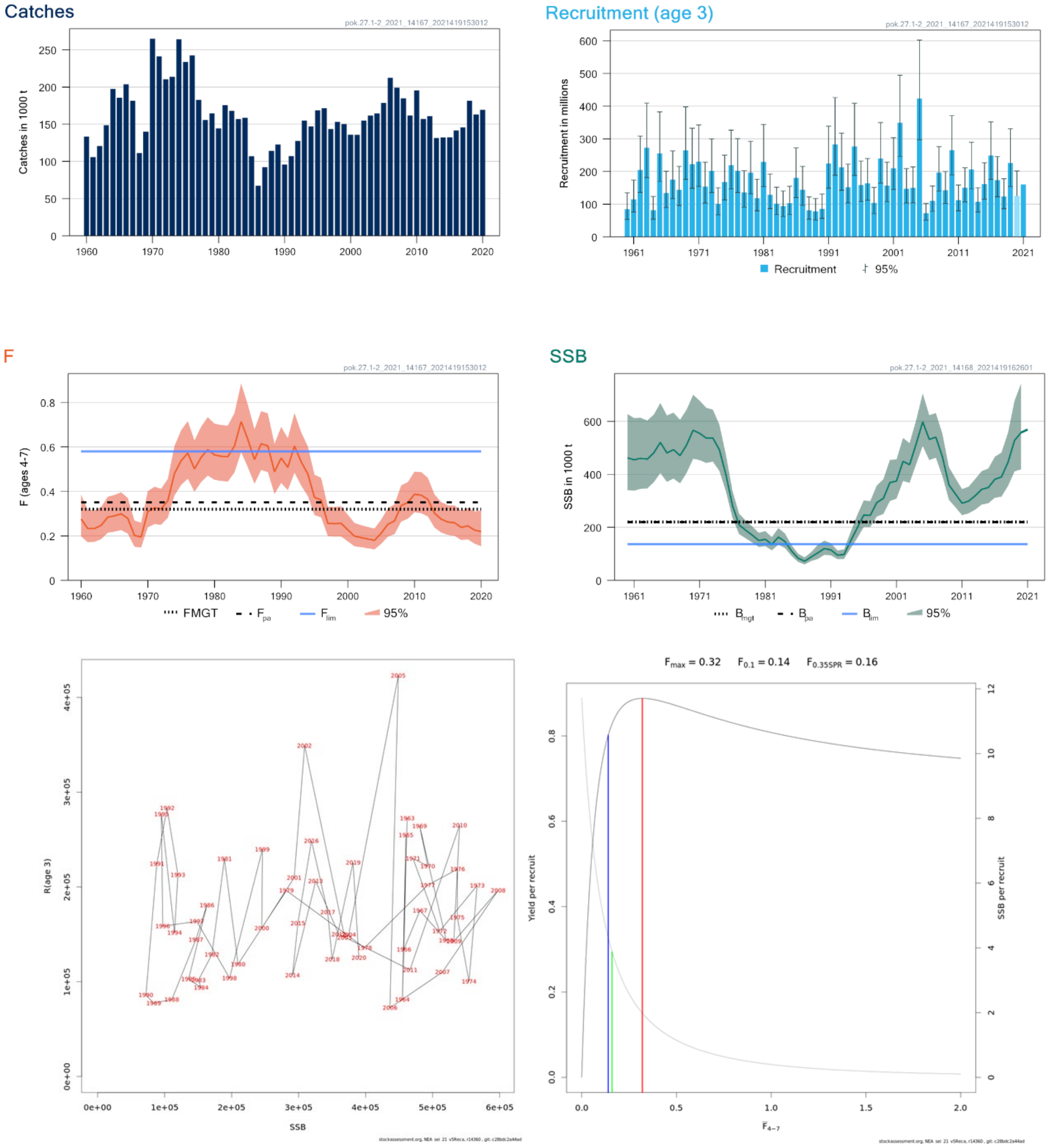
	Age groups									
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1988	0.62	0.87	1.31	2.43	3.87	5.38	5.83	5.36	6.92	8.82
1989	0.74	0.95	1.40	1.78	2.96	3.73	4.62	4.66	8.34	7.69
1990	0.71	1.00	1.45	2.09	2.49	3.75	3.90	6.74	4.94	7.34
1991	0.68	1.05	1.85	2.39	3.08	3.35	4.48	4.66	5.62	7.31
1992	0.67	1.01	1.92	2.28	2.77	3.20	3.73	6.35	6.90	7.83
1993	0.61	0.99	1.65	2.46	2.85	3.03	3.71	4.49	5.56	7.13
1994	0.52	0.76	1.24	2.12	3.22	3.83	4.69	5.31	5.66	7.29
1995	0.56	0.79	1.19	1.71	2.87	3.78	4.06	5.30	6.86	7.65
1996	0.59	0.82	1.33	1.84	2.48	3.73	4.32	5.34	5.98	7.58
1997	0.62	0.95	1.24	1.72	2.35	3.10	4.19	5.79	6.77	7.75
1998	0.68	1.00	1.48	1.87	2.58	3.07	4.13	5.44	6.70	8.59
1999	0.67	1.05	1.45	1.93	2.27	2.97	3.61	4.10	4.93	6.97
2000	0.60	1.03	1.63	2.10	2.67	3.14	3.81	4.41	5.76	8.07
2001	0.75	1.12	1.54	2.04	2.60	3.14	3.63	4.54	5.05	6.17
2002	0.69	1.01	1.50	1.97	2.54	3.25	3.77	4.31	4.91	6.11
2003	0.66	0.91	1.42	1.89	2.54	2.58	3.49	3.75	4.12	5.90
2004	0.70	1.03	1.37	1.90	2.41	2.98	3.44	3.73	4.14	5.47
2005	0.59	0.89	1.49	2.09	2.16	2.99	3.24	3.82	3.92	6.19
2006	0.63	0.83	1.43	1.78	2.27	2.73	3.02	3.90	4.06	5.82
2007	0.73	1.08	1.41	1.86	2.43	2.94	3.35	3.66	4.17	5.54
2008	0.63	0.98	1.38	1.92	2.31	2.83	3.16	3.43	3.82	4.75
2009	0.73	1.03	1.65	2.00	2.37	2.69	3.23	3.38	3.46	4.67
2010	0.70	0.99	1.45	2.14	2.50	3.13	3.34	3.81	3.99	5.17
2011	0.70	0.82	1.42	2.07	2.68	3.25	3.62	3.97	4.52	5.84
2012	0.59	1.07	1.35	2.15	2.82	3.20	3.67	4.16	4.60	5.70
2013	0.57	1.01	1.50	1.83	2.74	3.33	3.91	4.61	4.50	6.13
2014	0.66	0.92	1.58	2.12	2.54	3.49	4.01	4.22	4.71	5.80
2015	0.61	0.85	1.24	1.91	2.45	3.02	3.97	4.74	4.51	6.05

	Age groups								
Year	3	4	5	6	7	8	9	10	11	12+
2016	0.84	1.04	1.46	2.02	2.36	3.12	3.53	4.14	4.65	6.03
2017	0.89	1.12	1.68	2.18	2.63	3.13	3.63	4.16	4.5	5.9
2018	0.91	1.21	1.56	2.02	2.51	3.04	3.44	3.89	4.50	5.60
2019	0.83	1.17	1.64	2.06	2.62	3.18	3.71	4.13	4.88	6.14
2020	0.74	1.06	1.57	2.01	2.53	3.13	3.75	4.36	5.05	6.80

Table 5.5. 3-year running average maturity ogive 1985–2006. Values for 2007–2020 average of 2005–2007.

Year	3	4	5	6	7	8	9	10	11	12+
1985	0	0.02	0.5	0.92	0.99	1	1	1	1	1
1986	0	0.02	0.51	0.94	0.99	1	1	1	1	1
1987	0	0	0.35	0.98	1	1	1	1	1	1
1988	0	0	0.25	0.96	1	1	1	1	1	1
1989	0	0	0.15	0.92	1	1	1	1	1	1
1990	0	0	0.2	0.85	0.99	1	1	1	1	1
1991	0	0.02	0.25	0.84	0.98	1	1	1	1	1
1992	0	0.02	0.3	0.83	0.93	0.92	0.9	0.95	1	1
1993	0	0.02	0.26	0.88	0.92	0.89	0.87	0.89	1	0.99
1994	0	0.02	0.26	0.84	0.9	0.82	0.87	0.89	1	0.99
1995	0	0.02	0.22	0.8	0.92	0.9	0.97	0.94	1	0.99
1996	0	0.03	0.21	0.65	0.91	0.93	1	1	1	1.00
1997	0	0.03	0.14	0.45	0.83	0.94	0.93	0.97	1	1.00
1998	0	0.04	0.07	0.33	0.74	0.93	0.92	0.96	1	1.00
1999	0	0	0.08	0.32	0.74	0.92	0.92	0.96	0.99	0.98
2000	0	0	0.08	0.46	0.82	0.96	0.98	0.99	0.97	0.95
2001	0	0	0.11	0.64	0.93	0.97	0.98	0.99	0.97	0.94
2002	0	0	0.13	0.78	0.95	0.98	0.98	0.99	0.98	0.97
2003	0	0	0.14	0.82	0.96	0.98	0.98	0.99	1	0.99
2004	0	0	0.21	0.8	0.97	0.99	0.99	1	1	0.98
2005	0	0.03	0.3	0.82	0.97	0.99	0.99	1	1	1.00

Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
2006	0	0.04	0.4	0.86	0.98	0.99	1	1	1	1.00
2007	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	0.99
2008	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	0.99
2009	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	0.99
2010	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	0.99
2011	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2012	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2013	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2014	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2015	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2016	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2017	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2018	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2019	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00
2020	0	0.05	0.42	0.87	0.97	0.98	0.98	0.97	0.97	1.00



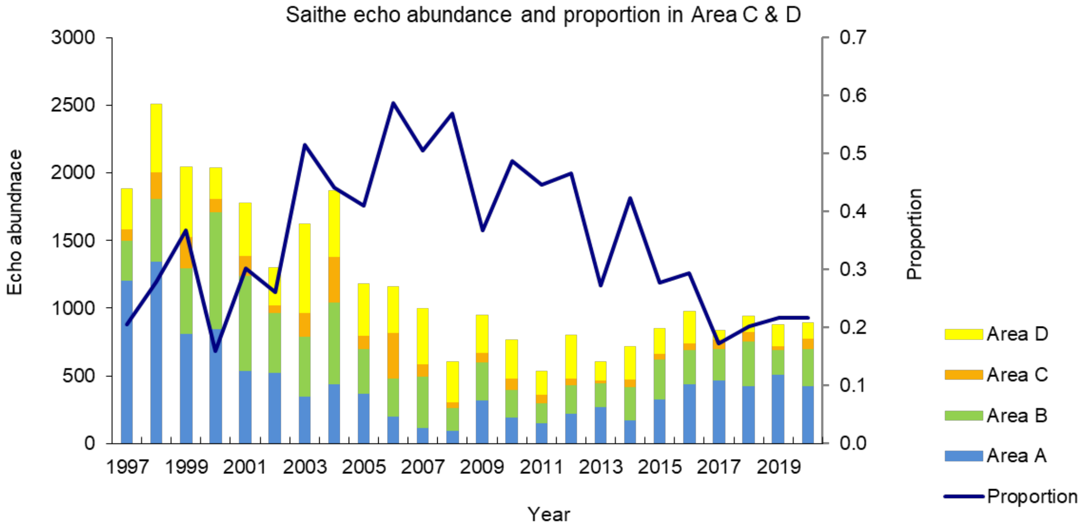


Figure 5.1. Northeast Arctic saithe. Echo abundance and proportion of saithe in the southern half of the survey area (subarea C+D).

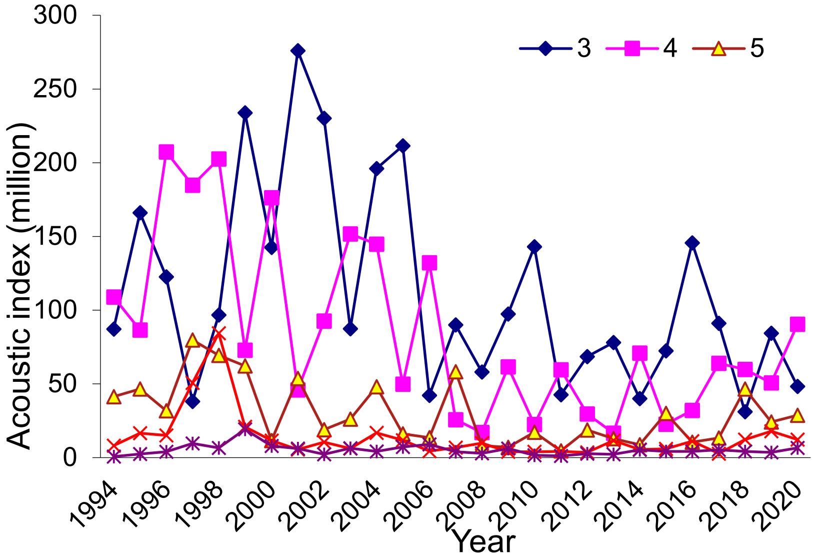


Figure 5.3. Northeast Arctic saithe. acoustic survey tuning indices by age class (3–7). break in 2002 black line.

Figure 5.4. Northeast Arctic saithe. Final run normalized residuals. Blue circles indicate positive residuals (larger than predicted) and filled red circles indicate negative residuals. The top figure shows residuals for the total catch series. the figure in the middle the residuals for the first survey series and the bottom figure the residuals for the survey series from 2002.

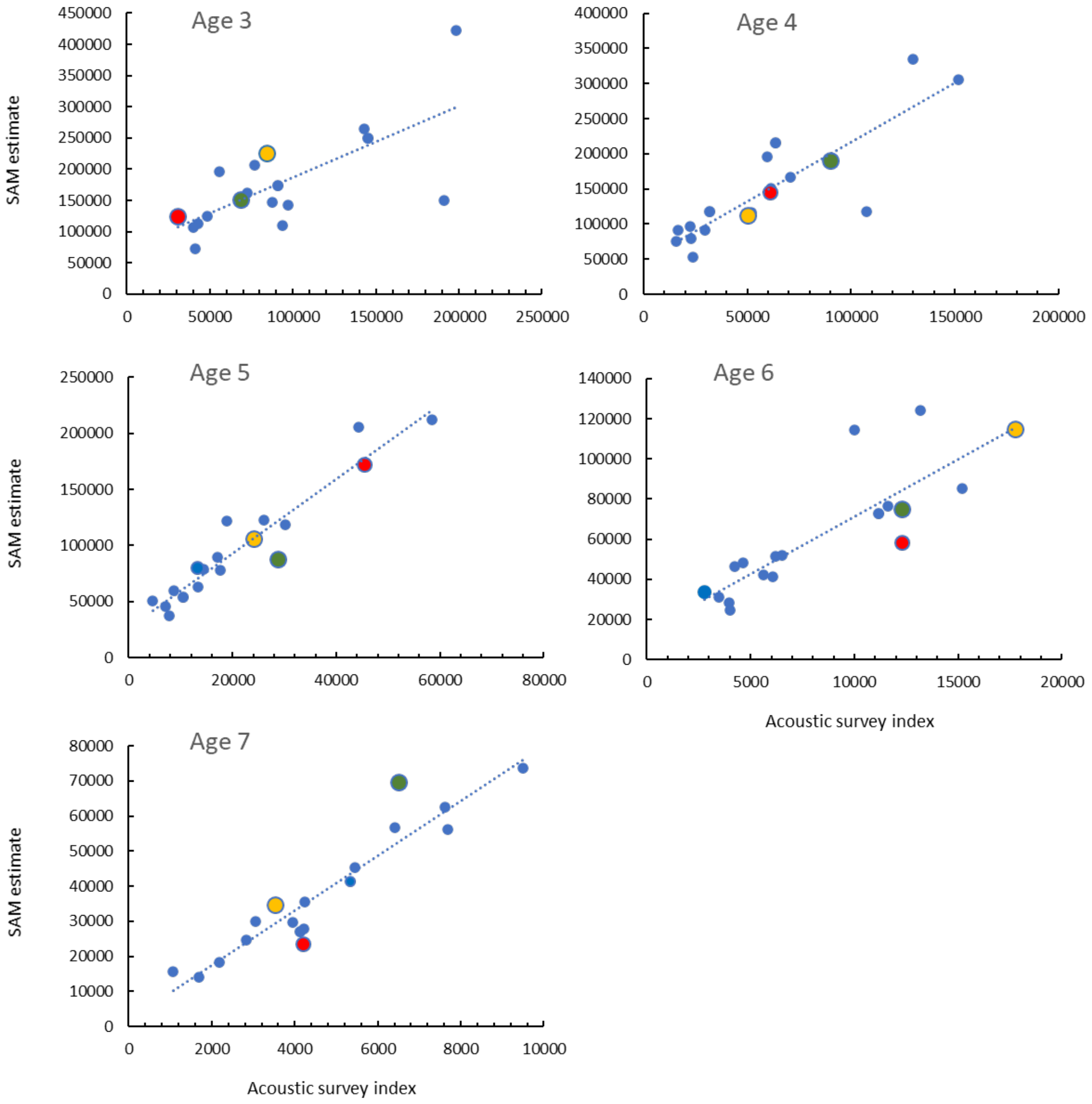


Figure 5.5. NEA saithe - Acoustic survey vs. SAM. red circles show 2018 data. orange circles 2019 data. and green circles 2020 data

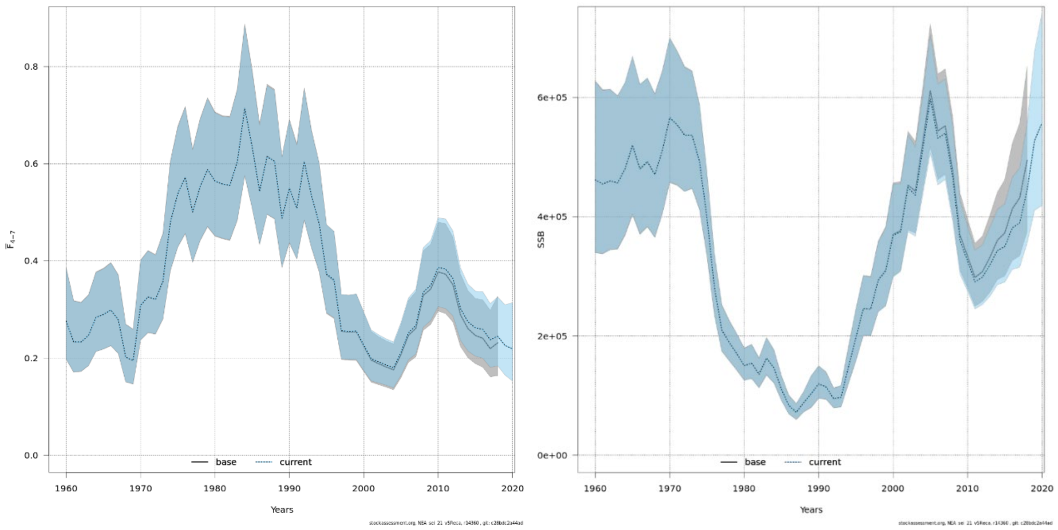


Figure 5.6. F_{4-7} and SSB. Estimates from the current run and point wise 95% confidence intervals are shown by black line and shaded area.

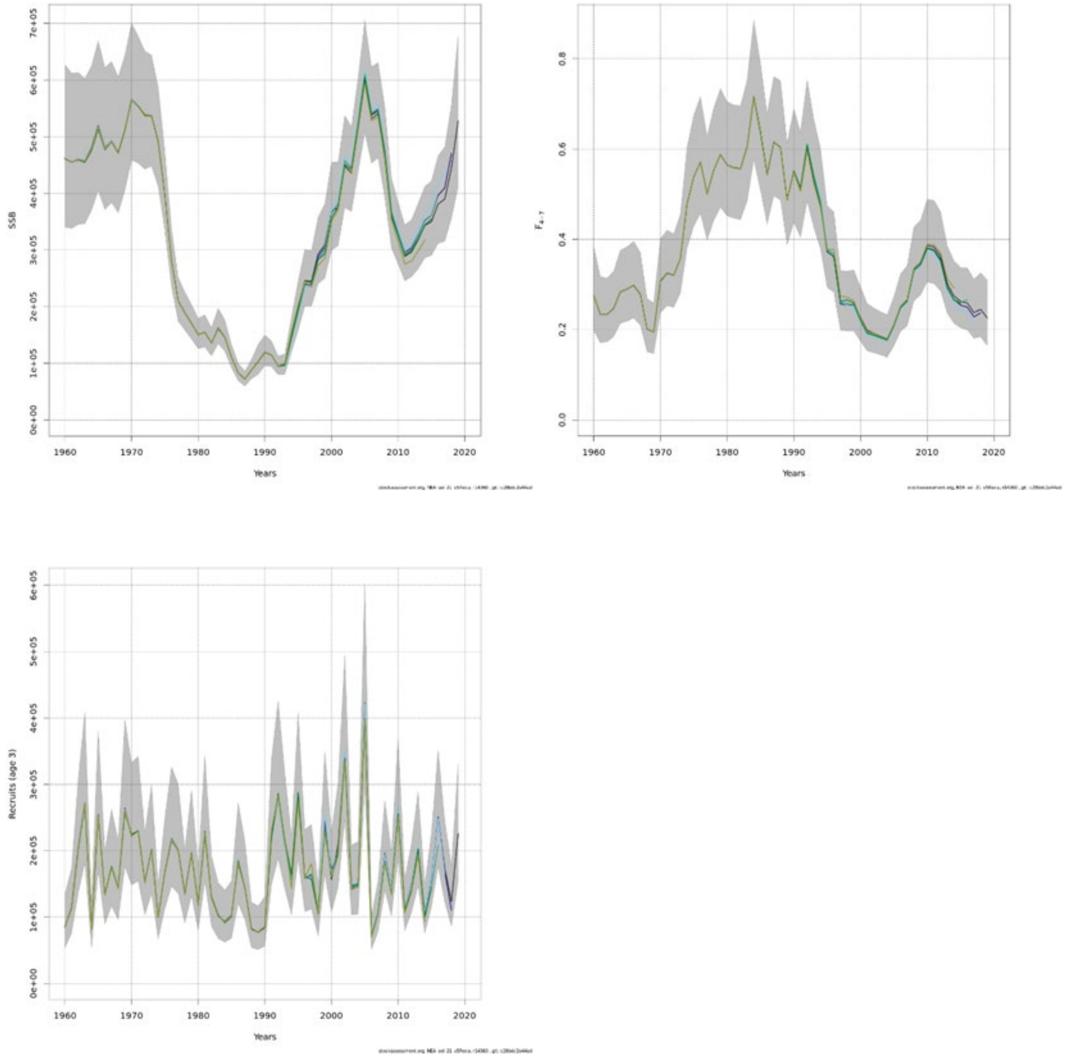


Figure 5.7. Saithe in subareas 1 and 2 (Northeast Arctic) RETROSPECTIVE SAM SSB. F4-7. and recruits.

6 Beaked redfish in subareas 1 and 2 (Northeast Arctic)

Sebastes mentella – reb.27.1–2

6.1 Status of the fisheries

6.1.1 Development of the fishery

A description of the historical development of the fishery in subareas 1 and 2 is found in the stock annex for this stock.

An international pelagic fishery for *S. mentella* in the Norwegian Sea outside EEZs has developed since 2004 (Figure 6.1). This pelagic fishery, which is further described in the stock annex for this stock, is managed by the Northeast Atlantic Fisheries Commission (NEAFC). Since 2014 the directed demersal and pelagic fisheries are reopened in the Norwegian Economic Zone, the Fisheries Protection Zone around Svalbard and, for pelagic fisheries only, in the Fishing Zone around Jan Mayen. The spatial regulation for this fishery is illustrated in Figures 6.2 and 6.3. In 2020, most of the catches of *S. mentella* from the Russian and Norwegian fisheries were taken in the Norwegian Exclusive Economic Zone or as bycatch in the Fisheries Protection Zone around Svalbard. Catches in international waters were mainly taken by EU nations.

Figure 6.2 shows the distribution of catch among national fishing fleets for 2017 to 2020 and the location of Norwegian *S. mentella* catches in the Norwegian EEZ in 2020 as well as bycatch in other areas. The 44th Session of the Joint Norwegian-Russian Fisheries Commission decided to split the total TAC among countries as follows: Norway: 72%, Russia: 18%, Third countries: 10% (as bycatch in the fishery protection zone at Svalbard (Spitsbergen): 4.1%, and international waters of the Norwegian Sea (NEAFC-area): 5.9%). This split was reconducted at the 49th session of the commission in 2019.

6.1.2 Bycatch in other fisheries

During 2003–2013, all catches of *S. mentella*, except the pelagic fishery in the Norwegian Sea outside EEZ, were taken as bycatches in other fisheries. Some of the pelagic catches are taken as bycatches in the blue whiting and herring fisheries. From 2014 onwards most of the catch is taken as targeted catch and no longer as bycatch, following the opening of a targeted fishery in the Norwegian EEZ, Svalbard Fisheries Protection Zone and around Jan Mayen. When fishing for other species it has since 2013 been allowed to have up to 20% redfish (both species together) in round weight as bycatch outside 12 nautical miles and only 10% bycatch inside 12 nautical miles to better protect *S. norvegicus*.

6.1.3 Landings prior to 2021 (Tables 6.1–6.7, Figure 6.1)

Nominal catches of *S. mentella* by country for subareas 1 and 2 combined are presented in Table 6.1, while they are presented for Subarea 1 and divisions 2.a and 2.b in Tables 6.2–6.4. The pelagic catch of *S. mentella* in the Norwegian Sea outside EEZs reported to NEAFC and/or ICES amounted to 6852 t in 2017, 7 739 t in 2018, 6060 t in 2019 and 5469 t in 2020, and is shown by country in Table 6.5. Nominal catches for both redfish species combined (i.e. *S. mentella* and *S.*

norvegicus) by country are presented in Table 6.6. The sources of information used are catches reported to ICES, NEAFC, Norwegian and Russian authorities (foreign vessels fishing in the Norwegian and Russian economic zones) or direct reporting to the AFWG. Where catches are reported as *Sebastes sp*., they are split into *S. norvegicus* and *S. mentella* by AFWG experts based on available correlation between official catches of these two species in the considered areas. All tables have been updated for 2019 and new figures presented for 2020. Total international landings in 1952–2020 are also shown in Figure 6.1.

In 2014, ICES advised that the annual catch in 2015, 2016, and 2017 should be set at no more than 30 000 t and in 2017, ICES advised that the annual catch in 2018 should not exceed 32 658 t. Following the benchmark (WKREDFISH, ICES 2018a) and the subsequent evaluation of a management plan for the stock (WKREBMSE, ICES 2018b) ICES advised an annual catch of no more than 53 757 t for 2019 and 55 860 t in 2020, corresponding to a fishing mortality of F = 0.06. This was continued in 2020, when ICES advised an annual catch of no more than 66 158 t in 2021 and 67 210 t in 2022, still corresponding to F = 0.06.

Because of the novelty of the situation, related with reopening fisheries after 10 years of its ban, the total landings of *S. mentella* in subareas 1 and 2 in 2014, demersal and pelagic catches, amounted to only 18 780 t. The total landings of the demersal and pelagic fishery increased to 35 646 t in 2016, 30 934 t in 2017, 38 739 t in 2018, 45 954 t in 2019 and 54 686 t in 2020. Of this, 5469 t were reported from the pelagic fishery in international waters of the Norwegian Sea. The total landings in 2017 and 2018 were respectively 1201 t and 6107 t above the TAC advised by ICES, but were 7 803 t and 1 174 t below TAC in 2019 and 2020, respectively. Norway caught the major share of the demersal catches, but Russian demersal catches increased substantially after 2017, particularly in ICES Division 2.b.

The redfish population in Subarea 4 (North Sea) is believed to belong to the Northeast Arctic stock. Since this area is outside the traditional areas handled by this Working Group, the catches are not included in the assessment. The total redfish landings (golden and beaked redfish combined) from Subarea 4 have up to 2003 been 1000–3000 t per year. Since 2005 the annual landings from this area have varied between 90 and 333 t (Table 6.7).

6.1.4 Expected landings in 2021

ICES has advised on the basis of precautionary considerations that the annual catch should be set at no more than 66 158 t in 2021. The 49th sessions of the Joint Norwegian-Russian Fisheries Commission decided to follow this advice.

In 2021 Norwegian fishing vessels, can catch and land up to 43 534 t of redfish in the Norwegian economic zone (NEZ) in a limited area north of 65°20′N (see map in Figure 6.3), in international waters and the fisheries zone around Jan Mayen. Of this quantity, 100 t are allocated to cover bycatch in other fisheries and 55 t for research/surveillance and education purposes, while the remaining 43 379 t can be taken in a directed fishery. Only vessels with cod and saithe trawl permits can participate in the directed fishery for redfish. Each vessel which has the right to participate is assigned a maximum quota, which can be adjusted during the year, per how much of the national quota is exploited. The fishery may be stopped if the total quota is reached. This quota must also cover catches of redfish (both species) in other fisheries. It is prohibited to fish for redfish with bottom trawls in the period from 1 March until 10 May. Investigations were conducted in 2015–2016 to see if the protection of females during the main time of larvae release should be improved by extending the period of prohibited fishing until later in May and to see if the area south of Bear Island (Area 20 in Figure 6.3) can be opened for directed fishing, either with or without sorting grid and permissions were granted to a small number of vessels of the Norwegian reference fleet for an earlier onset of fishing to gain further data. The hitherto conclusion is that males dominated the catches (more than 70%) in the main fishing areas south and southwest of Bear Island during the investigations from late April until the directed fishery started on 10 May, and that the area south of Bear Island should stay closed during January-February due to smaller *S. mentella* inhabiting this area at the beginning of the year.

Since 2015, Russia has had access to the NEZ when fishing their quota share. In 2020 Russia may fish 10 055 t (18%) plus 2000 t transferred from Norway to Russia. Apart from this an additional 2000 t were transferred from Norway to Russia to cover bycatch of redfish (both species) in Russian fisheries targeting other species. The remaining 5586 t are divided between third countries in the NEZ and Svalbard Zone (2290 t) and the NEAFC areas (3296 t). Catch in the NEAFC areas in 2020 amounted to 5469 t while the catch in the national economic zones of Norway and Russia as well as the fisheries protection zone around Svalbard was 49 217 t. The total catch in 2020 was 1174 t lower than the advised TAC. It is assumed that the total catch in 2021 should not exceed the TAC of 66 158 t set by ICES.

6.2 Data used in the assessment

Analytical assessment was conducted for this stock following recommendation from the benchmark assessment working group (WKREDFISH, ICES 2018a). Input datasets were updated with the most recently available data. The analytical assessment, based on a statistical catch-at-age model (SCAA), covers the period 1992–2020. The input data consists of the following tables:

- Total catch in tonnes (Table 6.1)
- Catch in tonnes in the pelagic fishery Norwegian Sea outside EEZs (Table 6.5)
- Total catch numbers-at-age 6–19+ (Table 6.8)
- Catch numbers-at-age 7–19+ in the pelagic fishery (Table 6.9)
- Weight-at-age 2–19+ in the population (Table 6.12)
- Maturity-at-age 2–19+ in the population (Table 6.14)
- Russian autumn survey numbers-at-age 0–11 (Table 6.15)
- Ecosystem survey numbers-at-age 2–15 (Table 6.17)
- Winter survey numbers-at-age 2–15 (Table 6.18b)
- Deep pelagic ecosystem survey proportions-at-age (Table 6.19)

There was no direct observation of catch numbers-at-age for the pelagic fishery in the Norwegian Sea outside EEZs in 2012–2020. Instead, numbers-at-age were estimated based on catch-at-age from previous or following year, and weight-at-age and fleet selectivities (section 6.2.2 in AFWG report 2013). In 2013, 2016 and 2019, observations from the scientific survey in the Norwegian Sea were used to derive numbers-at-age in the pelagic fishery. This was considered appropriate given that the survey operates in the area of the fishery, with a commercial pelagic trawl and at the time of the start of the fishery.

6.2.1 Length- composition from the fishery (Figure 6.4)

Comparison of length distributions of the Norwegian and Russian catches of *S. mentella* in 2019–2020 are shown in Figure 6.4. In 2020, the Russian and Norwegian fleets fished smaller fish than in 2019, reflecting good year classes due to enter the fishable stock. In 2020 length of beaked redfish in Norwegian catches was larger than in Russian catches. This is probably due to differences in the fishing areas. The Russian fleet largely operated in area 2b, and the Norwegian fleet in area 2a.

6.2.2 Catch-at-age (Tables 6.8–6.11, Figure 6.5)

Catch-at-age in the Norwegian fishery was estimated using ECA for 2014. For 2015, 2016 and 2018, it was not possible to run ECA and the catch-at-age for the Norwegian Fishery was estimated using the older Biomass program in SAS (Table 6.8). Not enough age readings were available to estimate catch-at-age in 2017, 2019 and 2020. For the demersal fisheries 2017, 2019 and 2020 as well as the pelagic fisheries 2017, 2018 and 2020 (Table 6.9) proportions-at-age in the catch were derived from proportions at-age in earlier years, weight-at-age and fleet selectivity (section 6.2.2 in AFWG report 2013).

The procedure for estimating catch-at-age for recent years in which age data are not available is somewhat problematic. This is because the last year of observation has a large affect on the estimated catch-at-age for several years. At the assessment working group in 2017 and at the benchmark assessment in January 2018, the last year of observations for the catch-at-age was 2014 and the values for the years 2015 and 2016 were extrapolated. Once available, the data for 2015 (demersal) and 2016 (pelagic) were substantially different from these earlier extrapolations.

Age composition of the Russian and Norwegian catches in 2020 was calculated using the age–length key, based on Russian age readings. The joint age–length key for the last three years (2018–2020) was applied. In general the age distribution in the Norwegian fishery was shifted towards older fish compared to the Russian fishery. In the Russian catches fish at age 15–16 dominated, while in the Norwegian catches 16–17 years old. (Figure 6.5). The proportion (by numbers) of individuals at age 18 and older in the Norwegian catches was almost twice as large as in the Russian ones.

Age–length-keys for *S. mentella* are uncertain because of the slow growth rate of individuals and therefore these data should be used with caution. They were not used in the current assessment but may be considered in future assessments. Given that age is difficult to derive from length it is important that age readings are available for the most recent years, at the time of the working group.

6.2.3 Weight-at-age (Tables 6.12, 6.13, Figures 6.6, 6.7)

In earlier assessment, weight-at-age in the stock was set equal to the weight-at-age in the catch. This turned out to be problematic because of important fluctuations in reported weight-at-age in the catch that cannot be explained biologically (i.e. these are noisy data). In 2015, it was advised to either use a fixed weight-at-age for the 19+ group, or use a modelled weight-at-age based on catch and survey records (Planque, 2015). The second option was chosen. Weight-at-age in the population was modelled for each year using mixed-effect models of a von Bertalanffy growth function (in weight). In 2018 an attempt was made to model weight-at-age for each cohort (rather than each year of observation). This showed that the growth function is nearly invariant between cohorts. Therefore, it was decided to use a fixed (i.e. common to all years) weight-at-age as input to the Statistical Catch-at-age model. The observed and modelled weight-at-age are presented in Table 6.12 as well as Figures 6.6 and 6.7.

6.2.4 Maturity-at-age (Table 6.14, Figure 6.8)

The proportion maturity-at-age was estimated for individual years using a mixed-effect statistical model (Table 6.14, Figure 6.8). The modelled values of maturity-at-age for individual years are used in the analytical assessment models, except in 2008, 2011 and 2016–2020 when the fixed effects only were considered, at least in the two latest years due to a lack of age data.

6.2.5 Natural mortality

In previous years, natural mortality for *S. mentella* was set to 0.05 for all ages and all years. This was based on life-history correlates presented in Hoenig (1983). Thirty-nine alternative mortality estimates were explored during the benchmark workshop, based on the review work by Kenchington (2014) and several additional recent papers (Then *et al.*, 2014; Hamel, 2014; Charnov *et al.*, 2013). Overall, the mode of these natural mortality estimates is 0.058 which departs only slightly from the original estimate of 0.050 (Figure 6.9). WKREDFISH 2018 decided to continue using 0.050 as the value of M in the assessment model.

Figure 6.10 shows cod's predation on juvenile (5–14 cm) redfish during 1984–2020. This time-series confirms the presence of redfish juveniles and may be used as an indicator of redfish abundance. A clear difference is seen between the abundance/consumption ratio in the 1980s and at present. A change in survey trawl catchability (smaller meshes) from 1993 onwards (Jakobsen *et al.*, 1997) and/or a change in the cod's prey preference may cause this difference. As long as the trawl survey time-series has not been corrected for the change in catchability, the abundance index of juvenile redfish less than 15 cm during the 1980s might have been considerably higher, if this change in catchability had been corrected for. The decrease in the abundance of young redfish in the surveys during the 1990s is consistent with the decline in the consumption of redfish by cod. It is important that the estimation of the consumption of redfish by cod is being continued.

6.2.6 Scientific surveys

Following a dedicated review, AFWG approves the use of the new SToX versions of winter and ecosystem surveys for use in the *Sebastes mentella* assessment (WD 17 and WD 18 in AFWG 2020). The group recommended that the data be monitored annually to identify if a significant portion of the mentella stock moves east of the strata system. The group further recommended that work continues to investigate redfish-specific strata systems for winter survey.

The results from the following research vessel survey series were evaluated by the Working Group:

6.2.6.1 Surveys in the Barents Sea and Svalbard area (Tables 1.1, 1.2, 6.15–6.18, Figures 6.11, 6.12)

Russian bottom-trawl survey in the Svalbard and Barents Sea areas in October-December for 1978–2015 in fishing depths of 100–900 m (Table 6.15, Figure 6.11). ICES acronym: RU-BTr-Q4.

Russian-Norwegian Barents Sea 'Ecosystem survey' (bottom-trawl survey, August-September) from 1986–2016 in fishing depths of 100–500 m (Figures 6.11–6.12). Data disaggregated by age for the period 1992–2019 (Tables 6.16b-6.17). ICES acronym: Since 2003 part of Eco-NoRu-Q3 (BTr), survey code: A5216.

Winter Barents Seabed-trawl survey (February) from 1986–2014 (jointly with Russia since 2000, except 2006 and 2007) in fishing depths of 100–500 m (Figures 6.11–6.12). Data disaggregated by age for the period 1992–2011 and 2013 (Table 6.18b). ICES acronym: BS-NoRu-Q1 (BTr), survey code: A6996.

The Norwegian survey initially designed for redfish and Greenland halibut is now part of the ecosystem survey and covers the Norwegian Economic Zone (NEZ) and Svalbard Fisheries Protection Zone incl. north and east of Spitsbergen during August 1996–2012 from less than 100 m to 800 m depth. This survey includes survey no. 2 above, and has been a joint survey with Russia since 2003, and since then called the Ecosystem survey. ICES acronym: Eco-NoRu-Q3 (Btr), survey code: A5216.

6.2.6.2 Pelagic survey in the Norwegian Sea (Table 6.19, Figures 6.13, 6.14)

The international deep pelagic ecosystem survey in the Norwegian Sea (WGIDEEPS, ICES 2016, survey code: A3357) monitors deep pelagic ecosystems, focusing on beaked redfish (*Sebastes mentella*). The latest survey was conducted in the open Norwegian Sea from 11 August until 28 August 2019, following similar surveys in 2008, 2009, 2013 and 2016. The spatial coverage of the survey and the catch rates of beaked redfish in the trawl are presented in Figure 6.13. The survey is scheduled every third year. Estimated numbers-at-age from this survey were presented at the benchmark assessment in 2018 and used in the SCAA model. Data for 2016 was updated in 2019, using additional age readings and numbers-at-age for the 2019 survey were presented during AFWG 2020, used in the assessment and updated for AFWG 2021. The details of the data preparation, using StoX, are available from WD7 of AFWG 2018 (Planque *et al.*, 2018). The data used as input to the analytical assessment consists of proportions-at-age from age 2 to 75 years (Figure 6.14).

6.2.6.3 Additional surveys (Figures 6.15–6.17)

The international 0-group survey in the Svalbard and Barents Sea areas in August-September 1980–2019, now part of the Ecosystem survey (Figures 6.15 and 6.16). ICES acronym: Eco-NoRu-Q3 (Btr), survey code: A5216.

A slope survey "Egga-sør survey" was carried out by IMR from 07 March to 07 April 2020, following similar surveys in 2009, 2012, 2014, 2016 and 2018. The spatial coverage of the 2020 survey and the distribution of beaked redfish registered by acoustic is presented in Figure 6.17. Egga-Sør and Egga-Nord surveys operate on a biennial basis. The length and age distributions of beaked redfish from these surveys show consistent ageing in the population and gradual incoming of new cohorts after the recruitment failure period. These surveys are considered as candidates for data input to the analytical assessment of *S. mentella* (see also Planque, 2016).

6.3 Assessment

The group performed the analytical assessment using the statistical catch-at-age (SCAA) model reviewed at the benchmark in January 2018 (WKREDFISH, ICES 2018a). The model was configured as the benchmark baseline model which includes 53 parameters to be estimated and the model converged correctly.

6.3.1 Results of the assessment (Tables 6.20, 6.21, Figures 6.18–6.24)

6.3.1.1 Stock trends

The temporal patterns in recruitment-at-age 2 (Figures 6.18, 6.21) confirm the previously reported recruitment failure for the year classes 1996 to 2003 and indicate a return to high levels of recruitment. The estimates of year-class strength for recent years are uncertain due to limited age data from winter and ecosystem surveys. Modelled spawning-stock biomass (SSB) has increased from 1992 to 2007 (Table 6.21). In the late 2000s the total-stock biomass (TSB) consisted of a larger proportion of mature fish than in the 1990s. This is reversing as individuals from new successful year classes, but still immature, are growing. TSB has increased from about 1.0 to above 1.4 million tonnes in the last 10 years (Table 6.21 and Figures 6.21–6.22). The concurrent decline in SSB from 2007 to 2014 can be attributed to the weak year classes (1996–2003) entering the mature stock. This trend has levelled off and SSB increases again. SSB at the start of 2021 is estimated at 900 221 t.

6.3.1.2 Fishing mortality (Tables 6.20a,b–6.21, Figure 6.19)

The patterns of fleet selectivity-at-age indicate that most of the fish captured by the demersal fleet in 2020 are of age 8 years and older, while the pelagic fleet mostly captures fish of age 14 and older (Tables 6.20a,b and Figure 6.19). While model results at the benchmark workshop showed a gradual shift in the demersal selectivity towards older ages in recent years, this is no longer observed after the 2015 catch-at-age data were incorporated in the model. The demersal fleet selectivity appears shifted towards later ages only in 2014. In 2020 F_{19+} is estimated at 0.05 (Table 6.21), with 0.04 for the demersal and 0.008 for the pelagic fleets (Table 6.20a), respectively.

6.3.1.3 Survey selectivity patterns (Figure 6.20)

Winter and ecosystem surveys selectivity at age are very similar and show reduced selectivity for age 8 years and older, which is consistent with the known geographical distribution of different life stages of *S. mentella* (Figure 6.20). Conversely, the Russian survey shows a reduced selectivity for age 7 years and younger. This is believed to result from gear selectivity.

6.3.1.4 Residual patterns (Figure 6.23)

Residual patterns in catch and survey indices are presented in Figure 6.23a-e. There is generally no visible trend in the residuals for the Russian groundfish survey neither by age nor by year. Trends in residuals are visible in recent years for winter and ecosystem surveys and will need to be investigated further. Alternative methods for the estimation of the survey selectivity patterns will be investigated in the benchmark assessment planned for 2023 and could resolve the issue. Residual patterns for the demersal fleet indicate a similar fit of the model compared to AFWG 2018, when a time varying selectivity-at-age for this fleet was introduced.

6.3.1.5 Retrospective patterns (Figure 6.24)

The historical retrospective patterns for the years 2007 to 2016 are presented in Figure 6.24. All model parameters were estimated in each individual run. The most recent model run (last year of data 2020) is consistent with previous runs. As in 2018 the SSB time-series is smoother than before, due to fixed weight-at-age for every year. The new estimates for winter and Ecosystem surveys in 2020 led to an increase in estimated SSB, up to 19% in the early years and around 7% to 9% in later years. Contrarily, the 2021 update revised SSB moderately down, by about 5% to 6%. Retrospective bias (Mohn's rho) over the last 5 assessments was -48% for recruitment, -2% for F(19+) and +7% for SSB. The benchmark run stands out and this is due to the unavailability of recent catch-at-age data during the benchmark assessment (see section 6.2.2).

6.3.1.6 Projections

F_{MSY} at age 19+ is approximated using $F_{0.1}$ and estimated at 0.084 (section 1.4 of the WKREBMSE report 2018b).

The estimated fishing mortality in 2020 is: $F_{19+} = 0.05$.

If the fishing mortality is maintained, this is expected to lead to a catch of 57 743 t in 2021, well below the advised TAC of 66 158 t. This would lead to an SSB of 925 932 t in early 2022, catches of 59 466 t in 2022 and SSB of 955 688 t in 2023.

Raising F_{19+} to the precautionary approach ($F_{19+} = 0.06$), recommended in the latest advice, in 2022–2024 would lead to average catches of 72 263 t during that period and a SSB of 999 340 t by 2025 (SSB at the start of 2020 is estimated at 874 727 t).

These projections assume that the selectivity patterns of the demersal and pelagic fleets are identical with those estimated for 2019. It is also assumed that the ratio of fishing mortality between these two fleets remains unchanged.

6.3.1.7 Additional considerations

Historical fluctuations in the recruitment-at-age 2 (Figures 6.18 and 6.21) are consistent with the 0-group survey index (Figure 6.16), although the 0-group survey index is not used as an input to the SCAA.

The population age structure derived from the model outputs for the old individuals (beyond 19+, Figure 6.22) is consistent with the age structure reported from the slopes surveys although these are not yet used as input to the model.

Recent recruitment levels estimated with SCAA are highly uncertain since they rely on only few years of observations and since the age readings from winter survey were not available for years 2014–2021. The use of the autoregressive model for recruitment (random effects in the SCAA) which was introduced in this assessment allows for a projection of the recruitment in recent years, despite the current lack of age data.

6.3.1.8 Assessment summary (Table 6.21, Figure 6.21)

The history of the stock as described by the SCAA model for the period 1992–2019 is summarized in Table 6.21 and Figure 6.21. The key elements are as follows:

- upward trend in Total-stock biomass from 1992 to 2006 followed by stabilization until 2011 and a new upward trend until the present,
- upward trend in spawning-stock biomass from 1992 to 2007 followed by stabilization (or slight decline) until 2014 and subsequent increase,
- recruitment failure for year classes 1996–2003 (2y old fish in 1998–2005),
- good (although uncertain) recruitment for year classes born after 2005. Age data for recruits (at age 2y) after 2014 is limited.
- Annual fishing mortality for the 19+ group throughout the assessment period varied between 0.003 and 0.05.

6.4 Comments to the assessment

Currently, the survey series used in the SCAA do not appropriately cover the geographical distribution of the adult population. Data from the pelagic survey in the Norwegian Sea has been reviewed in the last benchmark and is now included in the assessment model. Priority should be given to including additional data from the slope surveys that include older age groups, in the analytical assessment in future (WD 5 in 2016).

The SCAA model relies on the availability of reliable age data in surveys and in the catch. Although additional age reading since the last assessment has improved reliability, it requires a continuous effort to keep these data at an appropriate level.

6.5 Biological reference points

The proposed reference points estimated during the workshop on the management plan for *S. mentella* in (ICES 2018b) were:

Reference point	Value
B_{lim}	227 000 t
B_{pa}	315 000 t
$F_{MSY19+} = F_{0.1}$	0.084

Which are revised from those set during the benchmark in the same year (ICES 2018a) which were B_{pa} = 450 kt, B_{lim} = 324 kt and F_{MSY19+} = $F_{0.1}$ = 0.08.

6.6 Management advice

The present report updates the assessment but does not give advice.

6.7 Possible future development of the assessment

Many developments suggested in earlier years were presented and evaluated at the benchmark in January 2018. These include integrating a stochastic process model i) for recruitment-at-age 2, ii) for the annual component of fishing mortalities, and iii) to account for annual changes in fleet selectivities-at-age. In addition, iv) a right trapezoid population matrix, v) coding of older ages into flexible predefined age-blocks, and vi) integrating of data from pelagic surveys in the Norwegian Sea were implemented. The purpose of these new features was to reduce the number of parameters to estimate (i, ii), include new data on the older age fraction of the population (iv, v, vi) and account for possible temporal changes in selectivity linked to changes in the national and international fisheries and their regulations (iii).

Recommendations that have been followed since comprise:

- An increase in the number of age readings from surveys and from the fishery, particularly for recent years.
- Use of a standardized method (StoX) for the determination of numbers-at-age in the surveys. The use of StoX for survey indices was evaluated at the beginning of AFWG 2020.

Future developments for the assessment of *S. mentella* may possibly include:

- Use of a standardized method (ECA) for the determination of numbers-at-age in the catch.
- A genetic-based method for rapidly identifying Sebastes species (*S. norvegicus*, *S. mentella*, *S. viviparus*);
- Direct use of length information (as in GADGET);
- Development of a joint age–length key for calculation of age composition of all *S. mentella* catches.
- Development of a joint model for *S. mentella* and *S. norvegicus* which can include uncertainty in species identification and reporting of catch of *Sebastes sp*.

Implementing the current model in a more generic framework (SAM or XSAM) would provide a set of diagnostic tools and the wider expertise shared by the groups developing these models. The new version of GADGET, running the currently used TMB-package in the background, may provide an opportunity to put both species on the same platform.

Further studies of redfish mortality at young age, including a scientific publication, should be carried out. These studies should also take account of historic estimates of bycatch. Variable M by age and possibly time period could then be incorporated in the assessment.

6.8 Tables and figures

Table 6.1. *Sebastes mentella* in subareas 1 and 2. Nominal catch (t) by countries in Subarea 1, divisions 2.a and 2.b combined.

Year		Estonia	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Latvia	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	UK	Total
1998		-	20	73	100	14	-	9	-	-	-	9733	13	125	3646	177	134	**14 045**
1999		-	73	26	202	50	-	3	-	-	-	7884	6	65	2731	29	140	**11 209**
2000		-	50	12	62	29	48	1	-	-	-	6020	2	115	3519	87	130	**10 075**
2001		-	74	16	198	17	3	4	-	-	-	13 937	5	179	3775	90	120	**18 418**
2002		15	75	58	99	18	41	4	-	-	-	2152	8	242	3904	190	188	**6993**
2003		-	64	22	32	8	5	5	-	-	-	1210	7	44	952	47	124	**2520**
2004	**Sweden** - 1	-	588	13	10	4	10	3	-	-	-	1375	42	235	2879	257	76	**5493**
2005		5	1147	46	33	39	4	4	-	-	7	1760	-	140	5023	163	95	**8465**
2006	**Canada** - 433	396	3808	215	2483	63	2513	4	341	845	-	4710	2496	1804	11 413	710	1027	**33 261**
2007		684	2197	234	520	29	1587	17	349	785	-	3209	1081	1483	5660	2181	202	**20 219**
2008		-	1849	187	16	25	9	9	267	117	13	2220	8	713	7117	463	83	**13 096**
2009	**EU** - 889	-	1343	15	42	-	33	-	-	-	3	2677	338	806	3843	177	80	**10 246**
2010		-	979	175	21	12	2	-	243	457	-	2065	-	293	6414	1184	79	**11 924**
2011		-	984	175	835	-	2	-	536	565	-	2471	11	613	5037	1678	55	**12 962**

Year	Estonia	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Latvia	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	UK	Total
2012	-	259	-	517	-	36	-	447	449	-	2114	318	1038	4101	1780	-	**11 059**
2013	-	697	-	80	21	1	-	280	262	-	1835	84	1078	3677	1459	-	**9474**
2014	-	743	215	446	15	-	-	215	167	3	13 503	103	505	1704	1162	-	**18 780**
2015	-	657	49	242	48	3	-	537	192	3	19 720	5	678	1142	2529	52	**25 857**
2016	-	502	134	493	74	24	0	1243	1065	-	19 083	208	1066	8419	3213	122	**35 646**
2017	4	443	45	763	66	3	-	562	790	-	17 228	102	1060	6593	2838	436	**30 934**
2018	-	425	67	2473	82	10	-	1020	1010	374	19 287	275	699	10 497	2457	63	**38 739**
2019	-	148	371	1599	615	10	-	-	653	243	24 160	470	1426	13 444	2226	590	**45 955**
2020[1]	-	149	163	1807	62	5	-	2	1081	1483	33 997	4	876	13 874	744	439	**54 686**

1 - Provisional figures.

Table 6.2. *Sebastes mentella* in subareas 1 and 2. Nominal catch (t) by countries in Subarea 1.

Year	Faroe Islands	France	Germany	Greenland	Iceland	Lithuania	Norway	Poland	Portugal	Russia	Spain	UK	Total
1998	20	-	-	-	-	-	26	-	-	378	-	-	**424**
1999	69	-	-	-	-	-	69	-	-	489	-	-	**627**
2000	-	-	-	-	48	-	47	-	-	406	-	-	**501**
2001	-	-	-	-	3	-	8	-	-	296	-	-	**307**

Year	Faroe Islands	France	Germany	Greenland	Iceland	Lithuania	Norway	Poland	Portugal	Russia	Spain	UK	Total
2002	-	-	-	-	-	-	4	-	-	587	-	-	**591**
2003	-	-	-	-	-	-	6	-	-	292	-	-	**298**
2004	-	-	-	-	-	-	2	-	-	355	-	-	**357**
2005	-	-	-	-	-	-	3	-	-	327	-	-	**330**
2006	2	-	-	-	-	-	12	-	-	460	-	2	**476**
2007	-	-	-	-	8	-	11	-	-	210	-	20	**249**
2008	-	-	-	-	-	-	5	-	-	155	-	2	**162**
2009	-	-	-	-	8	-	3	-	-	80	-	-	**91**
2010	-	-	-	-	-	-	20	-	-	10	-	-	**30**
2011	-	-	-	-	-	-	48	-	-	13	-	-	**61**
2012	-	-	-	-	-	-	34	-	-	17	-	-	**51**
2013	-	-	-	-	-	-	61	-	-	27	-	-	**88**
2014	-	-	-	-	-	-	36	-	-	63	-	**-**	**99**
2015	-	-	-	18	-	-	76	1	-	125	-	-	**220**
2016	-	-	-	-	-	-	176	1	-	229	342	-	**748**
2017	-	-	-	12	-	-	165	3	-	196	-	-	**376**
2018	-	-	19	26	3	-	195	-	-	376	-	-	**619**

Year	Faroe Islands	France	Germany	Greenland	Iceland	Lithuania	Norway	Poland	Portugal	Russia	Spain	UK	Total
2019	75	3	-	13	-	1	278	15	-	206	19	3	**613**
2020[1]	33	12	6	18	1	-	263	3	2	118	1	-	**457**

1 - Provisional figures.

Table 6.3. *Sebastes mentella* in subareas 1 and 2. Nominal catch (t) by countries in Division 2.a (including landings from the pelagic trawl fishery in the international waters).

Year		Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Latvia	Norway	Portugal	Poland	Russia	Spain	UK	Total
1998		-	73	58	14	-	6	-	-	9186	118	-	2626	55	106	**12 242**
1999		-	16	160	50	-	3	-	-	7358	56	-	1340	14	120	**9117**
2000		50	11	35	29	-	-	-	-	5892	98	-	2167	18	103	**8403**
2001		63	12	161	17	-	4	-	-	13 636	105	-	2716	18	95	**16 827**
2002		37	54	59	18	41	4	-	-	1937	124	-	2615	8	157	**5054**
2003		58	18	17	8	5	5	-	-	1014	17	-	448	8	102	**1700**
2004	**Sweden** - 1	555	8	4	4	10	3	-	-	987	86	-	2081	7	18	**3764**
2005		1101	36	17	38	2	4	-	-	1083	71	-	3307	20	15	**5694**
2006	**Estonia** - 396 **Canada** – 433	3793	199	2475	52	2513	3	845	-	4010	1731	2467	10 110	589	958	**30 574**
2007	**Estonia** - 684	2157	226	519	29	1579	16	785	349	3043	1395	1079	5061	2159	120	**19 201**

Year		Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Latvia	Norway	Portugal	Poland	Russia	Spain	UK	Total
2008	**Netherlands** - 13	1821	179	9	24	9	9	117	267	1952	666	1	6442	430	62	**12 001**
2009	**EU** – 889	1316	7	23	-	25	-	-	-	2208	764	338	3305	137	62	**9074**
2010		961	175	13	12	2	-	457	243	1705	246	-	5903	1183	55	**10 955**
2011		932	175	697	-	2	-	561	536	1682	599	-	4326	1656	19	**11 185**
2012		259	-	469	-	32	-	449	447	1500	1038	311	3478	1770	-	**9753**
2013	**NL**	675	-	24	21	1	-	262	280	921	1055	68	3293	1435	-	**8035**
2014	2	728	209	411	15	-	-	167	215	4367	505	100	1334	1159	-	**9212**
2015	3	657	49	236	25	3	-	192	537	11 214	678	3	480	2508	47	**16 632**
2016		495	107	493	61	-	24	1065	1243	9546	1052	183	3949	2862	71	**21 151**
2017		425	38	763	44	3	-	790	562	7405	1059	94	3922	2813	429	**18 347**
2018	374	400	47	2440	51	7	-	1010	876	14 643	699	272	4721	2435	62	**28 037**
2019	243	74	363	1599	59	10	-	652	-	18 354	1425	455	7366	2188	570	**33 358**
2020[1]	1483	114	146	1797	41	4	-	1081	-	24 346	874	-	6085	737	404	**37 114**

1 - Provisional figures.

Table 6.4. ***Sebastes mentella*** **in subareas 1 and 2. Nominal catch (t) by countries in Division 2.b.**

Year		Netherlands	Faroe Islands	France	Germany	Greenland	Ireland	Norway	Poland	Portugal	Russia	Spain	Denmark	UK	Total
1998		-	-	-	42	-	3	521	13	7	642	122	-	29	1379
1999		-	4	10	42	-	-	457	6	9	902	15	-	20	1465
2000		-	-	1	27	-	1	82	2	17	946	69	-	27	1172
2001		-	11	4	37	-	-	293	5	74	763	72	**Estonia**	25	1284
2002		-	38	4	40	-	-	210	8	118	702	182	15	31	**1348**
2003		-	6	4	15	-	-	190	7	27	212	39	-	22	**522**
2004		-	33	5	6	-	-	386	42	149	443	250	-	58	**1372**
2005	**Iceland** - 2	7	46	10	17	1	-	673	-	69	1389	143	5	80	**2442**
2006		-	13	16	8	11	1	688	29	73	843	121	-	67	**1870**
2007		-	40	8	1	-	1	155	2	88	389	22	-	62	**768**
2008		-	28	8	7	1	-	263	6	47	520	33	-	19	**932**
2009	**Canada** - 3	3	27	8	19	-	-	466	1	42	458	41	-	17	**1082**
2010		-	18	-	8	-	-	339	-	47	501	1	-	24	**938**
2011	**LT -** 4	-	52	-	139	-	-	741	11	14	698	23	-	36	**1717**
2012	**Iceland** - 4	-	-	-	48	-	-	581	7	-	606	10	-	-	**1256**
2013		-	22	-	56	-	-	854	16	23	357	23	-	-	**1351**

Year		Netherlands	Faroe Islands	France	Germany	Greenland	Ireland	Norway	Poland	Portugal	Russia	Spain	Denmark	UK	Total
2014		1	15	6	34	-	-	9099	3	-	307	3	-	-	**9468**
2015		-	-	-	6	5	-	8429	1	-	536	21	-	5	**9003**
2016		-	7	27	-	14	-	9361	24	14	4241	9	-	50	**13 747**
2017		-	18	7	1	10	-	9658	5	1	2476	25	4	7	**12 211**
2018	**LT** - 144	-	25	20	14	6	-	4449	3	-	5400	22	-	1	**10 083**
2019		-	-	4	-	543	-	5528	-	-	5873	19	-	17	**11 984**
2020[1]	**LV** - 2	-	2	5	4	2	-	9387	-	-	7671	6	-	34	**17 113**

1 - Provisional figures.

Table 6.5. *Sebastes mentella* in subareas 1 and 2. Nominal catch (t) by countries of the pelagic fishery in international waters of the Norwegian Sea (see text for further details).

Year		Estonia	Faroe Islands	France	Germany	Iceland	Latvia	Lithuania	Norway	Poland	Portugal	Russia	Spain	UK	Total
2002		-	-	-	9	-	-	-	-	-	-	-	-	-	**9**
2003		-	-	-	40	-	-	-	-	-	-	-	-	-	**40**
2004		-	500	-	2	-	-	-	-	-	-	1510	-	-	**2012**
2005		-	1083	-	20	-	-	-	-	-	-	3299	-	-	**4402**
2006	**CAN -** 433	396	3766	192	2475	2510	341	845	2862	2447	1697	9390	575	841	**28 770**
2007		684	1968	226	497	1579	349	785	1813	1079	1377	3645	2155	-	**16 157**

Year		Estonia	Faroe Islands	France	Germany	Iceland	Latvia	Lithuania	Norway	Poland	Portugal	Russia	Spain	UK	Total
2008		-	1797	-	-	-	267	117	330	-	641	4901	390	-	**8443**
2009	**EU** - 889	-	1253	-	-	-	-	-	-	337	701	1975	135	-	**5290**
2010		-	912	-	-	-	243	457	450	-	244	5103	820	-	**8229**
2011		-	740	175	693	-	536	561	342	-	595	3621	1648	-	**8911**
2012		-	259	-	469	31	447	449	-	311	1038	2714	1768	-	**7486**
2013		8	675	-	-	-	280	262	1	68	1078	2720	1435	-	**6527**
2014		-	697	-	409	-	215	167	-	100	505	795	1146	-	**4034**
2015		-	606	-	231	-	537	192	-	-	678	-	2508	-	**4752**
2016		-	393	-	493	-	1243	1065	9	-	821	512	2862	-	**7398**
2017	**NL**	-	296	-	761	-	562	790	-	14	791	1014	2624	-	**6852**
2018	374	-	400	-	2192	-	876	1010	-	116	372	-	2399	-	**7739**
2019	244	**Greenland**	-	298	1157	-	-	652	1	364	1096	117	1908	223	**6060**
2020[1]	1366	3	-	73	1380	-	-	1081	-	-	480	25	737	324	**5469**

1 - Provisional figures.

Table 6.6. REDFISH in subareas 1 and 2. Nominal catch (t) by countries in Subarea 1, divisions 2.a and 2.b combined for both *Sebastes mentella* and *S. norvegicus*.

Year	Latvia	Lithuania	Estonia	Faroe Islands	France	Germany[4]	Greenland	Iceland	Ireland	Netherlands	Norway	Poland	Portugal	Russia[5]	Spain	UK (E&W)	UK (Scot.)	Total
1984	-	-	-	-	2970	7457	-	-	-	-	18 650	-	1806	69689	25	716	-	**101 313**
1985	-	-	-	-	3326	6566	-	-	-	-	20 456	-	2056	59943	38	167	-	**92 552**
1986	-	**DK**	-	29	2719	4884	-	-	-	-	23 255	-	1591	20694	-	129	14	**53 315**
1987	-	+	-	450[3]	1611	5829	-	-	-	-	18 051	-	1175	7215	25	230	9	**34 595**
1988	-	-	-	973	3349	2355	-	-	-	-	24 662	-	500	9139	26	468	2	**41 494**
1989	-	-	-	338	1849	4245	-	-	-	-	25 295	-	340	14344	5[2]	271	1	**46 688**
1990	-	37[3]	-	386	1821	6741	-	-	-	-	34 090	-	830	18918	-	333	-	**63 156**
1991	-	23	-	639	791	981	-	-	-	-	49 463	-	166	15354	1	336	13	**67 768**
1992	**CAN**	9	-	58	1301	530	614	-	-	-	23 451	-	977	4335	16	479	3	**31 773**
1993	8[3]	4	-	152	921	685	15	-	-	-	18 319	-	1040	7573	13	734	1	**29 465**
1994	-	28	-	26	771	1026	6	4	3	-	21 466	-	985	6220	34	259	13	**30 841**
1995	-	-	-	30	748	693	7	1	5	1	16 162	-	936	6985	67	252	13	**25 900**
1996	-	-	-	42[3]	746	618	37	-	2	-	21 675	-	522	1641	409	305	121	**26 118**
1997	-	-	-	7	1011	538	39[2]	-	11	-	18 839	1	535	4556	308	235	29	**26 109**
1998	-	-	-	98	567	231	47[3]	-	28	-	26 273	13	131	5278	228	211	94	**33 200**
1999	-	-	-	108	61[3]	430	97	14	10	-	24 634	6	68	4422	36	247	62	**30 195**

Year	Latvia	Lithuania	Estonia	Faroe Islands	France	Germany[4]	Greenland	Iceland	Ireland	Netherlands	Norway	Poland	Portugal	Russia[5]	Spain	UK (E&W)	UK (Scot.)	Total
2000	-	-	-	67[3]	25	222	51	65	1	-	19 052	2	131	4631	87	-	203[6]	**24 536**
2001	-	-	-	111[3]	46	436	34	3	5	-	23 071	5	186	4738	91	-	239[6]	**28 965**
2002	-	-	15	135[3]	89	141	49	44	4	-	10 713	8[3]	276	4736	193[2]	-	234[6]	**16 636**
2003	**S**	-	-	173[3]	30	154	44[3]	9	5[3]	89	8063	7	50	1431	47[2]	-	258[6]	**10 360**
2004	1	-	-	607	17[3]	78	24[3]	40	3	33	7608[12]	42	240	3601[2]	260[2]	-	145[6]	**12 699**
2005	**CAN**	**LT**	5	1194	56	105	75[3]	12[2]	4[3]	55[2]	7845[12]	-	196	5637	171[3]	-	147[6]	**15 502**
2006	433	845	396	3919	223	2518	107[3]	2544[3]	12[3]	21	11 015	2496[2]	1873	12126	719[2]	-	1066[6]	**40 649**
2007	**LV**	785	684	2343	249	587	84[3]	1655[2]	7[3]	20	8993[2]	1081[2]	1708	6550	2186[2]	-	257[6]	**27 591**
2008	267	117	-	2123[3]	250	46	96[3]	36[3]	15[3]	15	7436[1]	8	785	7866	467[2]	**EU[7]**	168[6]	**19 695**
2009	-	-	-	1413	16	100	81	99	-	4	8128	338	836	4541	177	889	111[6]	**16 733**
2010	243[3]	457[3]	-	1150	226	52	84[3]	24[3]	-	-	8059	1[3]	321	6979	1187	-	123[6]	**18 906**
2011	536	565	-	1008[2]	228	844	51	24	-	1	7152	59	638	5956	1684[2]	-	68[6]	**18 814**
2012	447	449	-	346	182	588	58	59	12	5	6361	352	1055	4782	1780[2]	**DK**	100[6]	**16 576**
2013	280	262	-	780	353	81	66	9	1	-	5606	103	1114	4474	1459	1	493[6]	**15 082**
2014	215	167	-	810	434	452	35	29	-	4	16 556	124	510	2510	1162	-	211[6]	**23 219**
2015	537	192	-	733	102	266	259	38	-	3	22 208	22	678	1806	2531	1	109[6]	**29 485**
2016	1243	1065	-	685	164	497	161	79	-	-	22 322	234	1066	9283	32013	7	198[6]	**40 217**

Year	Latvia	Lithuania	Estonia	Faroe Islands	France	Germany[4]	Greenland	Iceland	Ireland	Netherlands	Norway	Poland	Portugal	Russia[5]	Spain	UK (E&W)	UK (Scot.)	Total
2017	562	790	4	566	62	782	127	68	-	2	20 581	129	1150	7890	2882	-	596[6]	**36 192**
2018	1020	1010	-	571	104	2539	159	77	-	374	23 563	311	766	12 331	2469	1	100[6]	**45 395**
2019	-	656	-	392	395	1692	671	93	-	244	29 835	491	1495	15 373	2287	-	615[6]	**54 239**
2020[1]	2	1081	-	315	164	1892	161	57	-	1483	39 899	13	956	16 489	750		456[6]	**63 718**

1 - Provisional figures.

2 - Working Group figure.

3 - As reported to Norwegian authorities or NEAFC.

4 - Includes former GDR prior to 1991.

5 - USSR prior to 1991.

6 - UK(E&W) + UK(Scot.)

7 - EU not split on countries.

Table 6.7. REDFISH in Subarea 4 (North Sea). Nominal catch (t) by countries as officially reported to ICES. Not included in the assessment.

Year	Belgium	Denmark	Faroe Islands	France	Germany	Ireland	Netherlands	Norway	Poland	Portugal	Sweden	UK (Scot.)	Total
1998	2	27	12	570	370	4	21	1113		-	-	749	**2868**
1999	3	52	1	-	58	39	16	862		-	-	532	**1563**
2000	5	41	-	224	19	28	19	443		-	-	618	**1397**

Year	Belgium	Denmark	Faroe Islands	France	Germany	Ireland	Netherlands	Norway	Poland	Portugal	Sweden	UK (Scot.)	Total
2001	4	96	-	272	13	19	+	421		-	-	538	**1363**
2002	2	40	2	98	11	7	+	241		-	-	524	**925**
2003	1	71	2	26	2	-	-	474		**-**	-	463	**1039**
2004	+	42	3	26	1	-	-	287		-	-	214	**578**
2005	2	34	-	10	1	-	-	84		-	-	28	**159**
2006	1	49	1	12	3	-	-	163	-	33	-	79	**341**
2007	+	27	-	8	1	-	-	116	1	-	-	77	**230**
2008	+	3	-	8	1	-	-	77	-	-	1	54	**144**
2009	+	4	1	38	+	-	-	119	-	-	+	86	**248**
2010	-	5	-	3	-	-	-	62	-	-	+	150	**220**
2011	-	9	-	90	1	-	-	66	-	-	+	71	**237**
2012	-	10	-	19	+	-	-	71	-	-	+	87	**187**
2013	-	7	-	40	+	-	-	54	-	-	-	176	**277**
2014	-	-	-	32	1	-	-	146	-	-	+	93	**272**
2015	+	1	-	14	1	-	-	157	-	-	+	61	**234**
2016	-	3	-	11	+	-	-	180	-	-	+	22	**216**
2017	-	3	-	10	+	-	-	168	-	-	+	38	**21**

Year	Belgium	Denmark	Faroe Islands	France	Germany	Ireland	Netherlands	Norway	Poland	Portugal	Sweden	UK (Scot.)	Total
2018	-	10	-	4	-	-	-	71	-	-	+	29	**114**
2019[1]	-	7	+	10	+	-	+	62	-	-	+	10	**89**
2020[1]	-	10	-	4	+	-	+	54	-	-	+	27	**95**

1 - Provisional figures.

+ denotes less than 0.5 tonnes.

Table 6.8. *S. mentella* in subareas 1 and 2. Catch numbers-at-age 6 to 18 and 19+ (in thousands) and total landings (in tonnes). For the period 2012–2016 age data are missing from the pelagic fishery. For the period 2015–2018, age data are missing from all fisheries. The numbers-at-age have been estimated following the method outlined in section 6.2.2.

Year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	+gp	Total No.	Tonnes Land.
1992	1873	2498	1898	1622	1780	1531	2108	2288	2258	2506	2137	1512	677	9258	33 946	15 590
1993	159	159	174	512	2094	3139	2631	2308	2987	1875	1514	1053	527	6022	25 154	12 814
1994	738	730	722	992	2561	2734	3060	1535	2253	2182	3336	1284	734	3257	26 118	12 721
1995	662	941	1279	719	740	1230	2013	4297	3300	2162	1454	757	794	2404	22 752	10 284
1996	223	634	1699	1554	1236	1078	1146	1413	1865	880	621	498	700	2247	15 794	8075
1997	125	533	1287	1247	1297	1244	876	1416	1784	1217	537	1177	342	3568	16 650	8598
1998	37	882	2904	4236	3995	2741	1877	1373	1277	1595	1117	784	786	6241	29 845	14 045
1999	9	83	441	1511	2250	3262	1867	1454	1447	1557	1418	1317	658	3919	21 193	11 209
2000	1	24	390	1235	2460	2149	1816	1205	1001	993	932	505	596	5705	19 012	10 075

Year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	+gp	Total No.	Tonnes Land.
2001	117	372	542	976	925	1712	2651	2660	1911	1773	1220	714	814	16 234	32 621	18 418
2002	2	40	252	572	709	532	1382	1893	1617	855	629	163	237	4082	12 965	6993
2003	6	37	103	93	132	220	384	391	434	466	513	199	231	1193	4402	2520
2004	7	16	70	96	278	429	611	433	1063	813	830	841	607	3076	9170	5493
2005	2	20	57	155	244	262	295	754	783	1896	817	1087	1023	6065	13 460	8465
2006	0	4	3	38	64	121	423	1461	1356	2835	4271	3487	3969	32 084	50 116	33 261
2007	0	1	3	22	33	86	235	631	2194	2825	3657	4359	3540	15 824	33 410	20 219
2008	0	0	1	10	46	100	197	469	612	1502	1384	894	1886	11 906	19 007	13 095
2009	0	1	16	22	42	39	254	258	577	364	823	692	1856	11 706	16 650	10 246
2010	10	4	6	19	34	55	61	241	267	390	566	655	667	13 879	16 854	11 924
2011	4	4	4	25	55	114	11	103	286	394	408	479	567	15 223	17 677	12 962
2012	4	24	29	24	26	66	69	78	80	279	387	365	409	13 332	15 172	11 056
2013	0	3	19	92	88	41	42	42	10	167	144	174	299	11 726	12 847	9474
2014	14	28	346	97	124	96	152	55	111	69	252	293	197	23 744	25 578	18 780
2015	43	41	135	569	849	1362	1254	721	388	952	291	599	877	29612	37 693	25 856
2016	42	0	1015	687	3469	2670	3089	2067	2037	1314	1385	1288	1143	37744	57 950	35 646
2017	0	84	0	4479	2823	11454	5380	4385	2451	2235	1396	1437	1290	20897	58 311	30 934
2018	1173	4126	4511	4873	7166	4872	2339	2925	3570	6944	1973	2330	2677	30661	80 140	38 739

Year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	+gp	Total No.	Tonnes Land.
2019	0	4106	14968	14423	12882	15533	8137	2059	3499	4599	10818	2992	3576	11058	108 650	45 954
2020	0	0	8772	23581	18571	15195	17516	9091	2319	3883	5056	11870	3273	9248	128 375	54 686

Table 6.9. Pelagic *Sebastes mentella* in the Norwegian Sea (outside the EEZ). Catch numbers-at-age.

	Numbers 10^3							Age					
YEAR	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19+**
2006	0	0	0	0	23	93	1083	323	1563	3628	2514	3756	29704
2007	0	0	9	18	25	154	444	1642	2302	3021	3394	3156	12684
2008	0	0	0	0	28	146	115	143	214	594	752	753	13258
2009	0	0	0	0	9	1314	294	471	889	999	869	1150	2981
2010	0	0	0	0	0	0	130	336	254	466	467	508	11510
2011	0	0	0	0	0	223	83	83	168	136	166	136	13182
2012[1]	0	0	0	22	29	19	294	146	132	217	288	126	8939
2013[2]	11	137	98	465	123	158	96	169	246	196	238	598	7968
2014[3]	0	10	125	88	406	103	125	70	113	151	112	130	4398
2015[3]	0	0	0	0	169	54	51	0	0	0	85	22	6345
2016[3]	0	0	154	307	271	276	134	90	107	239	445	229	10499
2017[3]	0	0	0	237	461	389	370	165	100	109	226	402	8351

	Numbers 10^3						Age					
YEAR	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19+**
2018[3]	0	0	0	0	687	1274	1004	873	352	195	199	393	12673
2019	25	5	200	400	220	242	197	279	183	155	135	161	6696
2020[4]	0	44	8	344	670	352	361	270	345	207	163	136	5500

1 - No age data in 2012, catch numbers-at-age are estimated from proportions at age in 2011 and in 2013.

2 - No age data from the catches in 2013. Age readings from the research survey conducted in September 2013 are used to derive catch numbers-at-age.

3 - No age data in 2014 – 2018, catch numbers-at-age are estimated from previous year according to protocol described in section 6.2.2.

4 - No age data in 2020, catch numbers-at-age are estimated from previous year according to protocol described in section 6.2.2.

Table 6.10. *S. mentella* in subareas 1 and 2. Total catch numbers-at-length, in thousands, for 2011–2020.

Year	**Length group**																
	18–20	**20–22**	**22–24**	**24–26**	**26–28**	**28–30**	**30–32**	**32–34**	**34–36**	**36–38**	**38–40**	**40–42**	**42–44**	**44–46**	**46–48**	**48–50**	**50–52**
2011	0	12	0	0	1	8	249	2544	6481	6528	3620	829	95	18	1	0	0
2012	0	0	23	19	26	28	41	287	1898	5030	5385	1911	451	197	43	23	0
2013	0	0	4	32	154	137	90	69	1382	4214	4480	1633	497	197	0	0	0
2014	0	5	0	25	29	235	660	697	3358	7667	8544	3808	787	34	0	0	0
2015	*Data not available at the time of the working group*																
2016	*Data not available at the time of the working group*																
2017	*Data not available at the time of the working group*																

Year	Length group																
	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52
2018	*Data not available at the time of the working group*																
2019	*Data not available at the time of the working group*																
2020	*Data not available at the time of the working group*																

Table 6.11. *S. mentella* in subareas 1 and 2. Catch numbers-at-length, in thousands, in the pelagic fishery for 2011–2020.

Year	Length group																
	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52
2011	0	0	0	0	1	8	244	2562	5887	4425	1537	287	13	0	1	0	0
2012	0	0	0	0	0	0	106	2014	5092	3681	952	48	0	0	0	0	0
2013	0	0	0	0	0	0	75	1352	4791	2967	730	87	6	0	0	0	0
2014	0	0	0	0	0	3	14	349	2408	2454	827	80	6	1	0	0	0
2015	*Data not available at the time of the working group*																
2016	*Data not available at the time of the working group*																
2017	*Data not available at the time of the working group*																
2018	*Data not available at the time of the working group*																
2019	*Data not available at the time of the working group*																

Year	Length group																
	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52
2020	*Data not available at the time of the working group*																

Table 6.12. *S. mentella* in subareas 1 and 2. Observed mean weights-at-age (kg) from the Norwegian data (Catches and surveys combined). Weights-at-age used in the statistical catch-at-age model are identical for every year and given at the bottom line of the table.

Year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
1992	0.167	0.164	0.211	0.241	0.309	0.324	0.378	0.366	0.428	0.454	0.487	0.529	0.571	0.805
1993	0.141	0.181	0.217	0.254	0.306	0.357	0.349	0.400	0.450	0.436	0.460	0.499	0.462	0.846
1994	0.174	0.188	0.235	0.298	0.361	0.396	0.415	0.480	0.492	0.562	0.642	0.636	0.720	0.846
1995	0.158	0.185	0.226	0.261	0.324	0.360	0.432	0.468	0.496	0.519	0.566	0.573	0.621	0.758
1996	0.175	0.189	0.224	0.272	0.323	0.337	0.377	0.518	0.536	0.603	0.690	0.800	0.683	0.958
1997	0.152	0.191	0.228	0.280	0.324	0.367	0.435	0.492	0.521	0.615	0.601	0.611	0.671	0.911
1998	0.120	0.148	0.192	0.261	0.326	0.373	0.427	0.496	0.537	0.566	0.587	0.625	0.658	0.809
1999	0.133	0.170	0.226	0.286	0.343	0.382	0.441	0.483	0.537	0.565	0.620	0.644	0.672	0.757
2000	0.109	0.144	0.199	0.276	0.332	0.392	0.437	0.490	0.540	0.585	0.631	0.650	0.671	0.872
2001	0.115	0.137	0.183	0.262	0.310	0.356	0.400	0.434	0.484	0.534	0.581	0.615	0.624	0.819
2002	0.114	0.139	0.182	0.253	0.329	0.372	0.392	0.434	0.476	0.520	0.545	0.587	0.601	0.833
2003	0.109	0.124	0.196	0.245	0.312	0.371	0.422	0.434	0.477	0.516	0.551	0.591	0.623	0.817

Year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
2004	0.104	0.129	0.180	0.264	0.308	0.376	0.413	0.444	0.478	0.521	0.579	0.614	0.688	0.835
2005	0.104	0.136	0.196	0.263	0.322	0.370	0.408	0.451	0.478	0.523	0.550	0.551	0.640	0.797
2006	0.107	0.143	0.200	0.266	0.314	0.374	0.419	0.462	0.489	0.527	0.570	0.602	0.590	0.796
2007	0.115	0.131	0.180	0.252	0.305	0.364	0.409	0.449	0.485	0.513	0.523	0.554	0.569	0.737
2008	-	0.158	0.177	0.242	0.304	0.402	0.465	0.486	0.511	0.546	0.600	0.596	0.635	0.803
2009	0.129	0.179	0.206	0.249	0.326	0.394	0.510	0.550	0.542	0.583	0.609	0.594	0.595	0.809
2010	0.129	0.128	0.175	0.263	0.375	0.447	0.501	0.541	0.582	0.602	0.593	0.608	0.592	0.706
2011	0.136	0.156	0.183	0.261	0.316	0.435	0.512	0.604	0.655	0.609	0.671	0.647	0.677	0.795
2012	0.135	0.178	0.225	0.246	0.249	0.356	0.474	0.582	0.530	0.626	0.654	0.730	0.699	0.833
2013	0.129	0.145	0.189	0.230	0.270	0.282	0.345	0.384	0.534	0.559	0.634	0.627	0.661	0.720
2014	0.193	0.172	0.221	0.167	0.192	0.239	0.333	0.277	0.364	0.516	0.713	0.780	0.797	0.882
2015	0.167	0.168	0.232	0.294	0.346	0.383	0.457	0.436	0.474	0.538	0.665	0.690	0.724	0.824
2016[1]	0.110	-	0.331	0.356	0.401	0.392	0.434	0.486	0.543	0.579	0.740	0.591	0.598	0.776
2017	0.154	0.196	0.254	0.270	0.306	0.413	0.425	0.458	0.533	0.472	0.562	0.650	0.692	0.796
2018[1]	-	0.233	0.135	0.371	0.323	0.280	0.379	0.452	0.524	0.633	0.483	0.589	0.457	0.821
2019[1]	0.118	0.380	0.341	0.470	0.538	0.523	0.539	0.565	0.572	0.620	0.656	0.601	0.633	0.744
Modelled	0.141	0.188	0.237	0.286	0.334	0.381	0.424	0.465	0.503	0.537	0.569	0.597	0.623	0.755

1 - Provisional figures.

Table 6.13. Pelagic *Sebastes mentella* in the Norwegian Sea (outside the EEZ). Catch weights-at-age (kg).

Year/ Age	11	12	13	14	15	16	17	18	19+
2006	0.44	0.44	0.52	0.44	0.49	0.55	0.53	0.56	0.61
2007	0.39	0.43	0.41	0.48	0.50	0.52	0.55	0.57	0.64
2008	0.36	0.47	0.56	0.50	0.56	0.54	0.56	0.55	0.64
2009	0.38	0.44	0.45	0.48	0.54	0.59	0.64	0.58	0.69
2010	-	-	0.62	0.56	0.54	0.59	0.59	0.56	0.61
2011	-	0.48	0.54	0.54	0.64	0.59	0.54	0.59	0.59
2012	*No data*	-	-	-	-	-	-	-	-
2013[2]	0.31	-	-	-	0.56	0.62	0.60	0.62	0.68
2014	*No data*	-	-	-	-	-	-	-	-
2015	*No data*	-	-	-	-	-	-	-	-
2016	*No data*	-	-	-	-	-	-	-	-
2017	*No data*	-	-	-	-	-	-	-	-
2018	*No data*	-	-	-	-	-	-	-	-
2019	*No data*	-	-	-	-	-	-	-	-
2020[1]	*No data*	-	-	-	-	-	-	-	-

1 - Provisional figures.

2 - As observed in the research survey in the Norwegian Sea in September 2013.

Table 6.14. Proportion of maturity-at-age 6–19+ in *Sebastes mentella* in subareas 1 and 2 derived from Norwegian commercial and survey data. The proportions were derived from samples with at least 5 individuals. a50 w1 and w2 are the annual coefficients for modelled maturity ogives using a double half sigmoid of the form 0.5 ((1+tanh(age- a50)/w1)) for age < a50 and 0.5 (1+tanh((age- a50)/w2) for age > a50. a50 equals the age at 50% maturity.

year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
1992	0.00	0.01	0.02	0.04	0.07	0.14	0.26	0.42	0.53	0.59	0.65	0.70	0.75	1.00
1993	0.01	0.02	0.04	0.08	0.15	0.28	0.44	0.55	0.61	0.67	0.72	0.77	0.82	1.00
1994	0.02	0.04	0.08	0.15	0.28	0.44	0.59	0.72	0.81	0.88	0.93	0.96	0.98	1.00
1995	0.03	0.07	0.13	0.24	0.39	0.57	0.71	0.83	0.90	0.95	0.97	0.98	0.99	1.00
1996	0.01	0.01	0.02	0.05	0.10	0.19	0.33	0.50	0.59	0.66	0.73	0.79	0.84	1.00
1997	0.02	0.04	0.08	0.16	0.29	0.46	0.55	0.61	0.66	0.71	0.76	0.80	0.84	1.00
1998	0.02	0.04	0.08	0.15	0.26	0.43	0.56	0.65	0.73	0.80	0.85	0.90	0.93	1.00
1999	0.03	0.05	0.10	0.20	0.34	0.51	0.57	0.64	0.70	0.75	0.80	0.84	0.87	1.00
2000	0.03	0.06	0.11	0.21	0.36	0.52	0.63	0.73	0.81	0.87	0.91	0.94	0.96	1.00
2001	0.01	0.02	0.04	0.09	0.17	0.30	0.47	0.56	0.62	0.68	0.74	0.79	0.83	1.00
2002	0.02	0.05	0.10	0.19	0.33	0.50	0.54	0.59	0.63	0.67	0.70	0.74	0.77	1.00
2003	0.03	0.06	0.12	0.21	0.36	0.51	0.57	0.63	0.69	0.73	0.78	0.82	0.85	1.00
2004	0.03	0.06	0.12	0.22	0.37	0.51	0.55	0.59	0.63	0.67	0.70	0.73	0.76	1.00
2005	0.02	0.05	0.09	0.18	0.31	0.49	0.55	0.61	0.66	0.71	0.75	0.79	0.83	1.00
2006	0.01	0.02	0.03	0.07	0.13	0.24	0.39	0.53	0.59	0.64	0.70	0.75	0.79	1.00
2007	0.02	0.04	0.09	0.17	0.30	0.47	0.64	0.77	0.87	0.93	0.96	0.98	0.99	1.00
2008[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00

year/Age	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
2009	0.02	0.04	0.09	0.17	0.30	0.47	0.60	0.71	0.80	0.87	0.92	0.95	0.97	1.00
2010	0.02	0.04	0.08	0.16	0.28	0.45	0.54	0.60	0.66	0.71	0.76	0.80	0.83	1.00
2011[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00
2012	0.02	0.05	0.10	0.19	0.32	0.50	0.59	0.68	0.75	0.81	0.86	0.90	0.93	1.00
2013	0.00	0.01	0.02	0.04	0.08	0.15	0.28	0.45	0.62	0.77	0.87	0.93	0.97	1.00
2014	0.00	0.00	0.01	0.02	0.03	0.06	0.12	0.23	0.38	0.53	0.61	0.68	0.74	1.00
2015	0.01	0.02	0.05	0.09	0.17	0.31	0.48	0.54	0.58	0.63	0.67	0.71	0.74	1.00
2016[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00
2017[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00
2018[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00
2019[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00
2020[1]	0.02	0.04	0.08	0.15	0.27	0.43	0.55	0.62	0.68	0.74	0.79	0.83	0.87	1.00

1 - Model parameter estimates were unrealistic and replaced by average parameter values.

Table 6.15. *Sebastes mentella*. Average catch (numbers of specimens) per hour trawling of different ages of *Sebastes mentella* in the Russian groundfish survey in the Barents Sea and Svalbard areas (1976–1983 published in *Annales Biologiques*). The survey was not conducted in 2016 took place in 2017 with insufficient coverage and was terminated after that year.

Year class	0	1	2	3	4	5	6	7	8	9	10	11
1974	-	-	4.8	-	4.9	22.8	4.8	4.8	-	-	-	3
1975	-	7.4	-	1.7	6.4	2.4	3.5	5	-	-	4	-
1976	7	-	8.1	1.2	2.5	6.8	4.9	5	1	13	-	-

Year class	0	1	2	3	4	5	6	7	8	9	10	11
1977	-	0.2	0.2	0.2	0.9	5.1	3.7	1	19	2	-	-
1978	0.8	0.02	0.9	1	5	3.8	2	20	6	-	-	-
1979	-	1.9	1.4	3.6	2.3	9	11	16	1	-	-	0.1
1980	0.3	0.4	2	2.5	16	6	11	25	2	-	1.5	2
1981	-	2.2	3.9	20	6	12	47	18	6.3	1.6	0.5	1
1982	19.8	13.2	13	15	34	44	39	32.6	4.3	3.1	4.9	+
1983	12.5	3	5	6	31	34	32.3	13.3	4	4.2	0.6	1.1
1984	-	10	2	-	5	18.3	19	2.2	2.4	0.2	1.7	2.4
1985	107	7	-	1	5.2	16.2	1.7	1.7	0.6	2.8	3.8	0.3
1986	2	-	1	1.8	8.4	3.6	2.1	1.2	5.6	8.2	0.9	0.7
1987	-	3	37.9	1.3	8	4.1	2	10.6	9.6	1.4	2	1.3
1988	4	58.1	4.3	13.3	25.8	3.9	8.6	11.2	2.8	4.2	3	4.7
1989	8.7	9	17	23.4	4.6	5.4	4	6.6	6.6	4.1	7.7	5.3
1990	2.5	6.3	6.1	1	4.3	1.7	11.5	6.5	5.5	6.7	7.4	3.6
1991	0.3	1	0.5	1.5	1.2	11.3	3.9	3.3	4.6	5.8	2.7	1.9
1992	0.6	+	0.2	0.1	4.3	1.3	2	2.3	4.9	2.3	1	4.1
1993[1]	-	+	1.5	1.8	1	1.2	3	4.2	2.6	2	3.2	2.1
1994	0.3	3.5	1.7	1.7	0.9	3.6	5.2	4.3	3.1	3.3	1.8	1.2

Year class	0	1	2	3	4	5	6	7	8	9	10	11
1995	2.8	1	1.1	0.4	2.2	2.6	3.5	3.4	2.9	1.2	1	8.5
1996[2]	+	0.1	0.1	0.4	0.7	1.1	1	1.4	1	0.8	3.7	0.6
1997	-	-	+	0.4	0.5	0.3	0.9	0.6	1	1.1	0.5	0.4
1998	-	0.1	0.2	0.3	0.2	1.1	0.5	0.7	1	0.4	0.4	0.7
1999	0.1	-	0.1	+	0.1	0.3	0.5	0.8	0.5	0.2	0.4	0.6
2000	-	0.6	0.1	0.5	0.3	0.3	0.6	0.4	0.1	0.1	0.7	0.3
2001	-	0.1	0.4	-	0.1	0.2	0.2	0.3	0.2	0.8	0.1	1
2002[3]	0.1	0.5	0.1	-	-	0.1	0.5	0.4	1.5	0.5	1	1.1
2003	-	-	0.1	-	0.3	1.0	0.5	4.8	2.1	3.7	1.3	1.9
2004	-	0.2	0.3	0.5	1.5	0.9	4.4	3.7	7.5	4.1	3.1	3.3
2005	-	-	1.4	1.9	1.4	2.3	3.9	7.2	6.1	6.8	3.1	
2006[4]	0.1	1.8	1.2	1.1	0.8	2.1	4.1	3.0	6.1	5.9		
2007	2.5	0.4	0.1	1.2	1.7	2.4	3.6	4.3	7.4			
2008	0.1	0.1	1.6	1.8	4.1	2.9	5.8	5.5				
2009	1.6	1.9	1.1	4.4	4.8	2.9	4.8					
2010	7.5	0.7	1.2	1.5	1.9	1.6						
2011	0.1	0.3	0.6	1.6	1.6							
2012	0.2	0.7	0.5	0.3								

Year class	0	1	2	3	4	5	6	7	8	9	10	11
2013	0.1	0.1	0.4									
2014	3.6	1.0										
2015	6.6											

1 - Not complete area coverage of Division 2.b.

2 - Area surveyed restricted to Subarea 1 and Division 2.a only.

3 - Area surveyed restricted to Subarea 1 and Division 2.b only.

4 - Area surveyed restricted to divisions 2.a and 2.b only.

Table 6.16a. *Sebastes mentella*[1] in Division 2.b. Abundance indices (on length) from the bottom-trawl survey in the Svalbard area (Division 2.b) in summer/fall 1986–2020 (numbers in millions).

Year	Length group (cm)									
	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	**Total**
1986[2]	6	101	192	17	10	5	2	4	0	**337**
1987[2]	20	14	140	19	6	2	1	2	0	**204**
1988[2]	33	23	82	77	7	3	2	2	0	**229**
1989	556	225	24	72	17	2	2	8	4	**910**
1990	184	820	59	65	111	23	15	7	3	**1287**
1991	1533	1426	563	55	138	38	30	7	1	**3791**
1992	149	446	268	43	22	15	4	7	4	**958**
1993	9	320	272	89	16	13	3	1	0	**723**
1994	4	284	613	242	10	9	2	2	1	**1167**

Year	**Length group (cm)**									
	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	**Total**
1995	33	33	417	349	77	18	5	1	0	**933**
1996	56	69	139	310	97	8	4	1	1	**685**
1997	3	44	13	65	57	9	5	0	0	**195**
1998	0	37	35	28	132	73	45	2	0	**352**
1999	3	3	124	62	260	169	42	1	0	**664**
2000	0	10	30	59	126	143	21	1	0	**391**
2001	1	5	3	32	57	227	50	3	0	**378**
2002	1	4	6	21	62	266	47	4	0	**410**
2003	1	5	7	11	51	244	45	1	0	**364**
2004	0	2	8	6	14	78	49	2	0	**160**
2005	22	1	4	4	10	70	47	1	0	**158**
2006	85	6	5	7	43	200	108	3	0	**457**
2007	101	55	1	5	10	98	109	3	0	**381**
2008	124	47	22	3	8	22	70	3	0	**299**
2009	9	122	88	14	3	27	219	5	0	**486**
2010	96	18	44	37	2	20	91	7	0	**315**
2011	126	91	81	48	10	7	67	5	1	**436**

Year	Length group (cm)									
	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	Total
2012	29	71	65	77	47	8	94	10	0	**400**
2013	33	43	127	106	67	19	89	13	0	**497**
2014[3]	3	10	59	49	38	24	66	20	0	**268**
2015	85	7	28	157	115	65	69	25	0	**552**
2016	244	33	44	205	138	139	142	48	0	**993**
2017	41	39	8	20	59	76	57	17	0	**317**
2018	66	62	55	35	100	65	80	26	0	**489**
2019	3	25	84	31	59	82	72	25	1	**381**
2020	97	8	57	39	40	115	97	16	0	**469**

1 - Includes some unidentified Sebastes specimens mostly less than 15 cm.

2 - Old trawl equipment (bobbins gear and 80 m sweep length).

3 - Poor survey coverage in 2014.

Table 6.16b. *Sebastes mentella*[1] in Division 2.b. Norwegian bottom-trawl survey indices (on age) in the Svalbard area (Division 2.b) in summer/fall 1992–2019 (numbers in millions).

Year/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1992	283	419	484	131	58	45	14	8	5	2	7	2	1	3	**1462**
1993	2	527	117	202	142	8	23	6	13	1	7	1	1	0	**1050**
1994	7	280	290	202	235	42	94	1	1	3	4	1	1	0	**1161**
1995	4	50	365	237	132	61	19	17	11	0	1	3	0	0	**900**

Year/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1996	13	32	10	36	103	135	78	16	50	28	32	8	21	2	**565**
1997	8	43	6	7	38	18	29	19	6	2	0	2	1	1	**181**
1998	0	25	27	13	10	12	61	52	41	15	0	5	13	0	**276**
1999	3	16	108	25	28	39	106	59	54	26	35	14	18	12	**543**
2000	4	6	5	13	30	21	28	44	66	48	21	19	9	6	**321**
2001	1	4	2	0	12	15	18	36	28	46	45	80	53	14	**354**
2002	3	2	4	1	5	22	34	23	90	35	54	65	17	22	**377**
2003	0	4	3	3	5	3	29	25	25	25	11	164	55	23	**376**
2004	1	1	4	4	1	4	2	9	4	15	14	17	15	15	**108**
2005	15	1	1	3	1	2	2	8	4	5	14	7	30	21	**115**
2006	35	1	3	3	2	6	5	37	3	20	46	69	8	22	**258**
2007	22	30	0	0	3	1	5	4	6	4	3	7	27	17	**131**
2008	6	24	19	11	2	2	2	4	3	3	3	3	6	8	**96**
2009	9	69	50	29	26	25	7	1	1	1	4	20	11	8	**260**
2010	*No age readings available*														
2011	125	42	61	42	12	49	31	4	1	0	2	0	0	1	**369**
2012	27	54	32	27	34	43	26	34	18	9	0	1	0	0	**305**
2013	30	4	29	36	7	93	72	43	40	7	8	3	3	3	**377**

Year/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
2014[2]	0	3	2	7	21	40	13	27	5	30	13	11	3	2	**176**
2015	63	1	10	56	36	54	33	95	28	21	12	4	5	3	**421**
2016	*No age readings available*														
2017	39	26	10	13	14	20	39	16	29	8	6	19	1	28	**269**
2018	*No age readings available*														
2019[3]	0	32	53	0	24	21	21	46	52	76	0	0	0	0	**325**

1 - Includes some unidentified *Sebastes* specimens mostly less than 15 cm.

2 - Old trawl equipment (bobbins gear and 80 m sweep length).

3 - Poor survey coverage in 2014.

Table 6.17. *Sebastes mentella* in subareas 1 and 2. Abundance indices (on age) from the Ecosystem survey in August-September 1996–2020 covering the Norwegian Economic Zone (NEZ) and Svalbard incl. the area north and east of Spitsbergen (numbers in thousands and total biomass in thousand tonnes) and the continental slope down to 1000 m.

Year/ age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total N	Total B
1996	146 198	112 742	22 353	53 507	165 531	181 980	108 738	43 328	65 310	40 546	38 254	19 843	29 446	10 931	17 414	**1 056 120**	**171**
1997	62 682	130 816	12 492	23 452	74 342	55 880	76 607	82 503	17 640	14 274	675	2238	1723	633	8765	**564 723**	**73**
1998	313	78 767	85 715	39 849	25 805	23 413	84 825	100 332	54 287	24 329	11 334	7457	15 250	576	25 212	**577 464**	**105**
1999	5359	23 240	117 170	47 851	41 608	76 797	128 677	73 306	58 018	64 781	49 890	13 565	18 458	12 171	24 672	**755 562**	**155**
2000	5964	23 169	14 336	19 960	52 666	68 081	83 857	77 513	100 442	72 294	71 148	36 599	17 183	20 590	26 501	**690 304**	**178**
2001	5026	6541	10 957	1093	19 766	25 591	36 594	51 644	44 407	61 704	50 083	86 122	53 952	15 699	31 877	**501 057**	**162**
2002	9112	6646	7379	3821	8635	28 215	47 456	63 903	103 368	49 964	76 133	71 970	25 241	36 765	34 957	**573 565**	**181**

Year/ age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total N	Total B
2003	4036	8613	7002	3135	7911	7980	43 544	62 831	51 793	34 642	61 698	168 687	107 721	39 232	27 193	**636 017**	**257**[2]
2004	8554	15 793	11 443	7399	3554	7560	6164	11 686	8566	22 973	25 920	23 199	20 392	19 472	50 960	**243 635**	**91**[2]
2005	32 526	6856	5546	5616	3772	5980	6985	13 151	5803	5700	16 554	34 393	34 987	34 336	53 165	**265 370**	**101**[2]
2006	125 437	4833	6844	6602	4255	8486	7424	38 309	3983	24 756	48 733	71 491	13 957	37 991	159 909	**563 010**	**199**[2]
2007	335 297	199 057	15 305	4867	10 970	2862	8387	9973	14 017	6320	4686	8295	52 422	18 971	223 524	**914 953**	**188**[2]
2008	56 276	210 594	140 764	29 365	7581	3775	2810	6479	6160	3681	3668	5473	7405	10 175	105 726	**599 932**	**90**[2]
2009	122 459	176 405	231 265	82 701	109 509	45 607	15 812	2775	5807	2950	3929	22 097	12 431	9299	331 974	**1 175 019**	**260**[2]
2010	*No age reading*																
2011	423 987	378 581	236 404	62 437	55 643	77 076	48 239	12 383	3128	2012	2878	831	100	2938	103 438	**1 410 075**	**120**[2]
2012	354 863	261 115	352 468	171 535	132 263	74 859	58 937	41 526	21 794	12 670	3552	1051	1559	3376	140 270	**1 631 839**	**185**[2]
2013	299 841	203 094	189 851	194 068	164 206	178 236	112 427	103 262	92 160	13 848	13 956	8579	2784	2857	144 033	**1 723 202**	**271**[2]
2014[1]	2247	20 884	33 295	82 052	52 428	94 324	93 771	68 765	35 193	56 728	40 647	19 047	16 518	3335	163 869	**783 104**	**239**[2]
2015	404 973	86 648	53 046	95 737	53 022	109 686	46 714	126 156	73 141	25 441	19 583	6569	5284	3335	119 261	**1 228 596**	**207**[2]
2016	*No age reading*																
2017	534 647	244 469	213 984	215 852	33 595	45 809	61 428	62 449	37 597	33 901	39 670	37 492	10 364	40 052	85 250	**1 696 557**	**213**[2]
2018	*No age reading*																
2019[3]	93 518	77 195	125 457	81 499	62 447	38 668	61 615	91 672	178 887	124 876	0	0	0	0	60 931	**996 765**	**211**[2]
2020	*No age reading*																

1 - Poor survey coverage in 2014.

2 – Calculated using modelled weight-at-age.

3 – Provisional figures.

Table 6.18a. *Sebastes mentella*[1]. Abundance indices (on length) from the bottom-trawl survey in the Barents Sea in winter 1986–2021 (numbers in millions). The area coverage was extended from 1993 onwards. Numbers from 1994 onwards were recalculated while numbers for 1986–1993 are as in previous reports.

Year	Length group (cm)									
	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	Total
1986	81	152	205	88	169	130	88	24	14	**950**
1987	72	25	227	56	35	11	5	1	0	**433**
1988	587	25	133	182	40	50	48	4	0	**1068**
1989	623	55	28	177	58	9	8	2	0	**961**
1990	324	305	36	56	80	13	13	2	0	**828**
1991	395	449	86	39	96	35	24	3	0	**1127**
1992	139	367	227	35	55	34	8	2	1	**867**
1993	31	593	320	116	24	25	6	1	0	**1117**
1994	8	296	479	488	74	74	17	3	0	**1440**
1995	310	84	571	390	83	58	24	3	0	**1522**
1996	215	102	198	343	136	42	17	1	0	**1054**
1997[2]	63	121	26	281	272	71	40	5	0	**879**
1998[2]	1	87	63	101	204	41	13	2	0	**511**
1999	2	7	69	37	173	74	22	3	0	**388**
2000	9	13	40	78	143	97	27	7	2	**415**
2001	10	23	7	57	78	75	10	1	0	**260**
2002	17	7	19	36	96	116	24	1	0	**317**
2003	4	4	10	13	70	198	46	6	0	**351**
2004	2	3	7	19	33	86	32	2	0	**183**
2005	0	6	7	11	28	154	86	4	0	**296**
2006	100	2	10	15	23	104	83	3	1	**339**
2007	382	121	3	7	12	121	121	7	0	**773**
2008	858	359	27	5	12	104	165	5	0	**1533**
2009	95	325	136	5	9	67	163	6	0	**806**
2010	652	276	215	64	7	74	191	6	0	**1485**
2011	501	230	212	149	14	47	157	5	0	**1315**

Year	**Length group (cm)**								
	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	Total
2012	129	280	86	125	47	14	154	18	0	**855**
2013	249	226	245	159	143	35	193	27	0	**1278**
2014	91	174	250	114	125	51	115	14	0	**933**
2015	174	110	216	302	290	215	171	18	0	**1496**
2016	615	105	149	332	213	163	124	14	1	**1714**
2017	568	185	68	197	286	310	231	11	0	**1855**
2018	190	252	83	109	191	270	217	23	1	**1336**
2019	42	294	270	92	158	255	211	20	0	**1343**
2020	196	123	207	92	118	231	209	25	1	**1202**
2021	889	132	142	124	81	186	172	23	1	**1752**

1 - Includes some unidentified *Sebastes* specimens mostly less than 15 cm.

2 - Adjusted indices to account for not covering the Russian EEZ in Subarea 1.

Table 6.18b. *Sebastes mentella*[1] in subareas 1 and 2. Preliminary Norwegian bottom-trawl indices (on age) from the annual Barents Sea survey in February 1992–2020 (numbers in millions). The area coverage was extended from 1993 onwards.

Year/Age	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
1992															
1993															
1994	4	100	320	168	337	263	92	56	5	31	13	12	24	6	**1432**
1995	316	49	158	230	319	227	80	24	10	17	19	9	9	9	**1477**
1996	193	105	78	108	140	144	134	65	22	24	13	7	9	4	**1047**
1997[2]	60	120	21	51	105	100	135	104	44	48	29	26	8	7	**858**
1998[2]	2	70	47	24	11	51	112	115	35	17	6	7	4	3	**505**
1999	0	1	36	39	29	26	54	64	57	38	17	6	6	2	**376**
2000	19	1	4	31	36	23	28	70	73	47	24	15	10	3	**384**
2001	1	18	8	2	7	26	36	30	42	18	21	27	5	3	**244**
2002	18	4	12	8	2	10	42	56	25	13	36	20	37	13	**296**
2003	0	3	2	4	6	6	14	36	24	17	48	30	61	32	**283**
2004	2	1	4	2	4	10	11	16	14	12	15	25	26	14	**155**

Year/Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
2005	0	4	2	3	6	6	8	14	17	9	17	26	42	56	**209**
2006	75	22	5	4	6	7	10	11	7	14	15	9	43	29	**255**
2007	242	66	5	1	2	2	5	8	9	5	8	22	33	68	**478**
2008	703	180	105	13	0	2	4	6	4	6	4	21	20	29	**1097**
2009	106	108	96	87	68	32	21	14	5	5	20	2	24	7	**594**
2010	160	250	178	167	91	68	25	22	2	10	4	8	12	18	**1014**
2011	362	226	131	129	103	65	41	23	2	6	1	2	2	28	**1119**
2012	*No age readings*														
2013	0	178	249	145	142	124	120	14	32	11	4	25	37	13	**1093**
2014	*No age readings*														
2015	*No age readings*														
2016	*No age readings*														
2017	*No age readings*														
2018	*No age readings*														
2019	*No age readings*														
2020	*No age readings*														
2021	*No age reading*														

1 - Includes some unidentified *Sebastes* specimens mostly less than 15 cm.

2 - Adjusted indices to account for not covering the Russian EEZ in Subarea 1.

Table 6.19. Comparison of results on *Sebastes mentella* from the Norwegian Sea pelagic surveys in 2008, 2009, 2013, 2016, and 2019. Acoustic results for the 2019 survey were not available at the time of AFWG 2021.

	2008	2009	2013	2016	2019
mean length (cm) All/M/F[1]	37.0/36.4/37.5	36.6/36.0/37.1	37.5/37.0/38.1	37.7/37.0/38.3	37.6/37.2/38.0
mean length (cm) S/DSL/D[2]	37.2/36.8/39.1	37.2/36.5/38.3	37.1/37.4/38.9	38.1/37.6/38.4	37.4/37.6/37.7
mean weight (g) All/M/F	619/585/648	625/609/666	659/625/706	656/619/694	683/644/724
Mean age (y) All/M/F	25 / 25 / 25	25 / 25 / 24	28 / 29 / 28	27 / 27 / 26	- / - / -
Sex ratio (M/F)	45% / 55%	45% / 55%	59% / 41%	50% / 50%	51% / 49%
Occurrence	96%	100%	95%	80%	99%
Catch rates	3.80 t/NM2	3.94 t/NM2	3.47 t/NM2	1.01 t/NM2	3.40 t/NM2

	2008	2009	2013	2016	2019
mean s_A	33 m^2/NM2	34 m^2/NM2	19 m^2/NM2	5.2 m^2/NM2	-
Total Area	53 720 NM2	69 520 NM2	69 520 NM2	67 150 NM2	73 364 NM2
Abundance (Acoustics)[3]	395 000 t	532 000 t	297 000 t	136 000 t	-
Abundance (Trawl)[4]	406 000 t	548 000 t	482 000 t	116 000 t	499 000 t

1 - M = males only, F = females only.

2 - S = shallower than DSL, DSL = deep scattering layer, D = deeper than DSL.

3 - The abundance derived from hydroacoustics is calculated assuming a Length-dependent target strength equation of TS=20log(L)-68.0. In 2016 the TS equation used was TS=20log(L)-69.6 following recommendation from ICES-WKTAR (2010).

4 - Trawls: Gloria 2048 in 2008 and 2009 Gloria 2560 HO helix in 2013 and Gloria 1024 in 2016. Trawl catchability for redfish set to 0.5 for all trawls based on results from Bethke *et al.* (2010).

Table 6.20a. *S. mentella* in subareas 1 and 2. Population matrix with numbers-at-age (in thousands) for each year and separable fishing mortality coefficients for the demersal and pelagic fleet by year (Fy) and selectivity at age for the pelagic fleet (Sa). Numbers are estimated from the statistical catch-at-age model.

sa (demersal)	Varies over time																	
sa (pelagic)	0.000	0.000	0.000	0.000	0.000	0.011	0.021	0.040	0.072	0.128	0.218	0.345	0.500	0.654	0.781	0.871	0.927	1.00

Fy (demseral)	Fy (pelagic)	Year/ Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.047	0	1992	400 482	389 741	353 230	226 347	135 488	92 234	89 791	93 917	117 663	81 823	93 165	68 973	70 343	61 008	44 144	28 865	19 263	189 594
0.033	0	1993	269 635	381 031	370 812	336 074	212 616	127 026	86 296	83 827	87 482	109 349	75 866	86 189	63 671	64 803	56 096	40 520	26 454	189 790
0.029	0	1994	186 684	256 540	362 525	352 802	319 693	202 185	120 684	81 795	79 052	81 844	101 509	70 092	79 457	58 648	59 674	51 651	37 307	199 095
0.022	0	1995	176 880	177 618	244 080	344 918	335 435	303 663	191 638	113 922	76 744	73 703	75 960	93 978	64 817	73 442	54 197	55 140	47 725	218 431
0.015	0	1996	141 619	168 289	168 991	232 226	327 949	318 662	287 967	181 152	107 206	71 896	68 826	70 808	87 530	60 347	68 366	50 448	51 324	247 731
0.015	0	1997	100 331	134 741	160 116	160 783	220 890	311 790	302 573	272 671	170 835	100 747	67 437	64 508	66 347	82 008	56 538	64 050	47 263	280 175
0.021	0	1998	51 116	95 458	128 197	152 339	152 942	210 033	296 148	286 703	257 391	160 684	94 563	63 242	60 476	62 193	76 869	52 995	60 036	306 917
0.016	0	1999	44 153	48 634	90 822	121 971	144 924	145 441	199 419	279 828	268 898	240 322	149 816	88 137	58 940	56 361	57 961	71 639	49 389	341 983
0.013	0	2000	34 755	42 009	46 272	86 411	116 045	137 872	138 314	189 354	264 491	252 692	225 223	140 303	82 528	55 187	52 772	54 269	67 077	366 448

Fy (demseral)	**Fy (pelagic)**	**Year/Age**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19+**
0.022	0	2001	37 339	33 067	39 968	44 024	82 214	110 407	131 155	131 410	178 898	248 725	237 429	211 600	131 815	77 535	51 848	49 579	50 986	407 298
0.008	0	2002	38 941	35 525	31 461	38 027	41 864	78 123	104 749	124 064	123 750	167 666	232 279	221 283	197 021	122 681	72 149	48 243	46 130	426 398
0.003	0	2003	43 637	37 050	33 800	29 933	36 180	39 827	74 299	99 503	117 532	116 952	158 314	219 274	208 884	185 979	115 805	68 106	45 540	446 046
0.006	0	2004	57 553	41 518	35 251	32 158	28 476	34 415	37 875	70 629	94 536	111 603	111 009	150 233	208 056	198 187	176 450	109 871	64 615	466 389
0.009	0	2005	132 682	54 758	39 501	33 539	30 594	27 087	32 725	35 992	67 041	89 612	105 673	105 043	142 115	196 789	187 444	166 882	103 912	502 203
0.005	0.037	2006	232 450	126 238	52 099	37 583	31 908	29 103	25 760	31 100	34 148	63 456	84 646	99 708	99 070	134 014	185 561	176 746	157 357	571 518
0.005	0.02	2007	334 514	221 160	120 107	49 568	35 757	30 357	27 676	24 483	29 525	32 351	59 910	79 557	93 210	92 061	123 811	170 622	161 976	665 175
0.005	0.014	2008	329 290	318 267	210 419	114 274	47 161	34 020	28 875	26 317	23 268	28 028	30 647	56 583	74 873	87 407	86 043	115 411	158 754	767 828
0.003	0.01	2009	347 731	313 297	302 809	200 199	108 723	44 870	32 362	27 463	25 018	22 092	26 541	28 937	53 298	70 366	81 967	80 545	107 903	864 910
0.004	0.011	2010	499 621	330 843	298 081	288 103	190 475	103 441	42 683	30 778	26 103	23 751	20 941	25 123	27 351	50 295	66 297	77 127	75 720	913 426
0.006	0.01	2011	564 854	475 356	314 774	283 604	274 107	181 219	98 398	40 592	29 255	24 786	22 518	19 820	23 735	25 792	47 347	62 323	72 432	927 686
0.005	0.01	2012	430 519	537 420	452 269	299 486	269 829	260 792	172 392	93 587	38 590	27 780	23 486	21 284	18 693	22 343	24 238	44 435	58 434	936 507

Fy (demseral)	Fy (pelagic)	Year/ Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.004	0.009	2013	266 964	409 610	511 319	430 303	284 938	256 719	248 087	163 968	88 987	36 672	26 371	22 258	20 126	17 635	21 037	22 787	41 732	933 205
0.016	0.01	2014	258 560	253 998	389 716	486 485	409 404	271 099	244 224	235 990	155 943	84 602	34 842	25 026	21 082	19 016	16 625	19 798	21 423	915 423
0.027	0.009	2015	365 166	246 002	241 662	370 788	462 844	389 498	257 876	232 267	224 355	148 158	80 286	33 001	23 636	19 836	17 820	15 521	18 433	868 602
0.038	0.009	2016	451 107	347 430	234 054	229 925	352 769	440 331	370 468	245 175	220 605	212 602	139 754	75 203	30 686	21 858	18 283	16 392	14 262	813 967
0.029	0.009	2017	511 012	429 198	330 556	222 687	218 746	335 582	418 701	351 919	232 291	207 772	198 260	128 990	68 930	28 016	19 909	16 628	14 894	751 597
0.031	0.009	2018	450 559	486 193	408 353	314 502	211 868	208 105	319 130	397 615	332 524	217 203	192 586	183 085	118 896	63 437	25 746	18 275	15 250	702 184
0.035	0.008	2019	430 622	428 676	462 580	388 520	298 434	200 557	196 202	299 251	370 679	308 459	200 755	177 539	168 427	109 172	58 153	23 572	16 717	655 482
0.042	0.008	2020	430 544	409 708	407 856	440 113	368 806	282 178	188 135	182 261	276 059	340 792	283 133	184 067	162 594	154 051	99 729	53 069	21 495	612 355

Table 6.20b. *S. mentella* in subareas 1 and 2. Fisheries selectivity at age for the demersal fleet by age (Sa). Numbers are estimated from the statistical catch-at-age model.

Year/ Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1992	0.000	0.000	0.000	0.274	0.315	0.359	0.406	0.454	0.503	0.553	0.601	0.647	0.691	0.731	0.768	0.802	0.831	1.000
1993	0.000	0.000	0.000	0.006	0.016	0.044	0.115	0.270	0.512	0.749	0.895	0.960	0.986	0.995	0.998	0.999	1.000	1.000
1994	0.000	0.000	0.000	0.024	0.057	0.129	0.269	0.477	0.693	0.848	0.933	0.972	0.988	0.995	0.998	0.999	1.000	1.000
1995	0.000	0.000	0.000	0.030	0.069	0.150	0.296	0.500	0.704	0.850	0.931	0.970	0.987	0.995	0.998	0.999	1.000	1.000

Year/ Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1996	0.000	0.000	0.000	0.017	0.048	0.131	0.311	0.574	0.801	0.923	0.973	0.991	0.997	0.999	1.000	1.000	1.000	1.000
1997	0.000	0.000	0.000	0.014	0.041	0.113	0.274	0.528	0.768	0.908	0.967	0.989	0.996	0.999	1.000	1.000	1.000	1.000
1998	0.000	0.000	0.000	0.005	0.024	0.100	0.334	0.693	0.910	0.979	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.000	0.000	0.000	0.001	0.006	0.029	0.125	0.411	0.773	0.943	0.988	0.997	0.999	1.000	1.000	1.000	1.000	1.000
2000	0.000	0.000	0.000	0.000	0.001	0.013	0.112	0.556	0.925	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.000	0.000	0.000	0.024	0.056	0.126	0.260	0.460	0.674	0.834	0.924	0.967	0.986	0.994	0.998	0.999	1.000	1.000
2002	0.000	0.000	0.000	0.002	0.011	0.050	0.201	0.545	0.851	0.964	0.992	0.998	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.000	0.000	0.000	0.037	0.081	0.165	0.309	0.503	0.696	0.838	0.921	0.964	0.984	0.993	0.997	0.999	0.999	1.000
2004	0.000	0.000	0.000	0.016	0.038	0.092	0.203	0.392	0.620	0.805	0.912	0.963	0.985	0.994	0.998	0.999	1.000	1.000
2005	0.000	0.000	0.000	0.005	0.016	0.047	0.130	0.310	0.576	0.804	0.925	0.974	0.991	0.997	0.999	1.000	1.000	1.000
2006	0.000	0.000	0.000	0.002	0.007	0.018	0.051	0.134	0.306	0.558	0.783	0.912	0.967	0.988	0.996	0.999	0.999	1.000
2007	0.000	0.000	0.000	0.001	0.003	0.008	0.024	0.065	0.166	0.363	0.620	0.824	0.930	0.975	0.991	0.997	0.999	1.000
2008	0.000	0.000	0.000	0.000	0.001	0.003	0.012	0.053	0.204	0.540	0.844	0.961	0.991	0.998	1.000	1.000	1.000	1.000
2009	0.000	0.000	0.000	0.001	0.005	0.017	0.060	0.190	0.461	0.757	0.919	0.976	0.993	0.998	1.000	1.000	1.000	1.000
2010	0.000	0.000	0.000	0.003	0.008	0.022	0.060	0.154	0.343	0.600	0.812	0.925	0.973	0.990	0.997	0.999	1.000	1.000
2011	0.000	0.000	0.000	0.000	0.002	0.006	0.020	0.069	0.210	0.487	0.773	0.924	0.978	0.994	0.998	0.999	1.000	1.000
2012	0.000	0.000	0.000	0.002	0.004	0.010	0.022	0.050	0.108	0.217	0.389	0.594	0.771	0.885	0.947	0.976	0.989	1.000
2013	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.007	0.020	0.056	0.144	0.326	0.581	0.799	0.919	0.970	0.989	1.000

Year/ Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2014	0.000	0.000	0.000	0.002	0.003	0.007	0.013	0.024	0.045	0.083	0.147	0.248	0.387	0.548	0.699	0.816	0.895	1.000
2015	0.000	0.000	0.000	0.001	0.003	0.007	0.020	0.050	0.124	0.273	0.500	0.727	0.876	0.950	0.980	0.993	0.997	1.000
2016	0.000	0.000	0.000	0.001	0.004	0.013	0.036	0.100	0.249	0.496	0.745	0.896	0.962	0.987	0.996	0.999	0.999	1.000
2017	0.000	0.000	0.000	0.001	0.003	0.013	0.059	0.228	0.581	0.867	0.969	0.993	0.999	1.000	1.000	1.000	1.000	1.000
2018	0.000	0.000	0.000	0.084	0.161	0.287	0.456	0.636	0.785	0.884	0.941	0.971	0.986	0.993	0.997	0.998	0.999	1.000
2019	0.000	0.000	0.000	0.064	0.176	0.397	0.670	0.863	0.951	0.984	0.995	0.998	0.999	1.000	1.000	1.000	1.000	1.000
2020	0.000	0.000	0.000	0.061	0.185	0.441	0.733	0.905	0.971	0.991	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000

Table 6.21. Stock summary for *S. mentella* in subareas 1 and 2 as estimated by the statistical catch-at-age model. Stock biomass is for age 2 y+.

Year	Rec (age 2) in millions	Rec (age 6) in millions	Stock Biomass (tonnes)	SSB (tonnes)	F (12–18)	F(19+)
1992	400	135	529902	251287	0.034	0.047
1993	270	213	572073	296819	0.032	0.033
1994	187	320	625480	372504	0.029	0.029
1995	177	335	685167	427268	0.022	0.022
1996	142	328	745628	353633	0.015	0.015
1997	100	221	804167	434166	0.015	0.015
1998	51	153	857764	490259	0.021	0.021
1999	44	145	900559	552753	0.016	0.016
2000	35	116	936871	640611	0.013	0.013
2001	37	82	966732	593973	0.022	0.022
2002	39	42	978051	669920	0.008	0.008
2003	44	36	992518	739317	0.003	0.003
2004	58	28	1004779	744162	0.006	0.006
2005	133	31	1010390	794940	0.009	0.009
2006	232	32	1012716	782416	0.028	0.042
2007	335	36	992659	911254	0.017	0.025
2008	329	47	987952	853677	0.014	0.019
2009	348	109	992652	886130	0.009	0.013
2010	500	190	1006686	844048	0.01	0.014
2011	565	274	1025073	833040	0.012	0.016
2012	431	270	1052231	827546	0.01	0.014
2013	267	285	1095856	782106	0.008	0.013
2014	259	409	1152683	733907	0.015	0.026
2015	365	463	1202973	757372	0.029	0.036
2016	451	353	1244958	787325	0.041	0.047
2017	511	219	1280146	790415	0.034	0.038
2018	451	212	1327151	811748	0.037	0.041

Year	Rec (age 2) in millions	Rec (age 6) in millions	Stock Biomass (tonnes)	SSB (tonnes)	F (12–18)	F(19+)
2019	431	298	1373398	842086	0.04	0.043
2020	431	369	1418249	874727	0.047	0.05

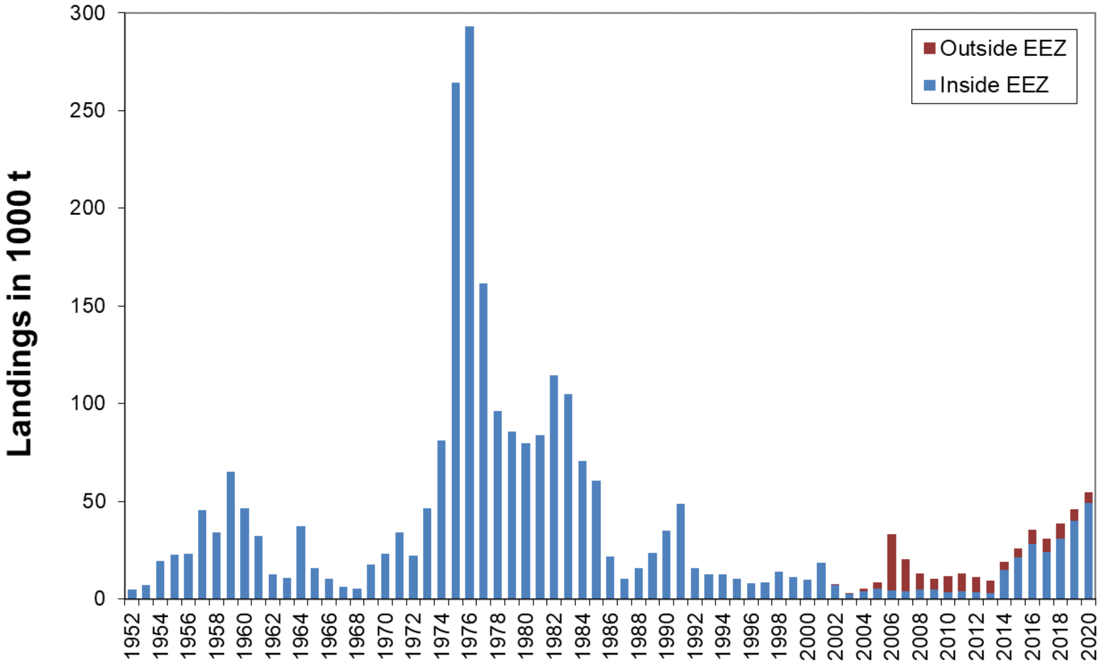


Figure 6.1. *Sebastes mentella* in subareas 1 and 2. Total international landings 1952–2020 (thousand tonnes).

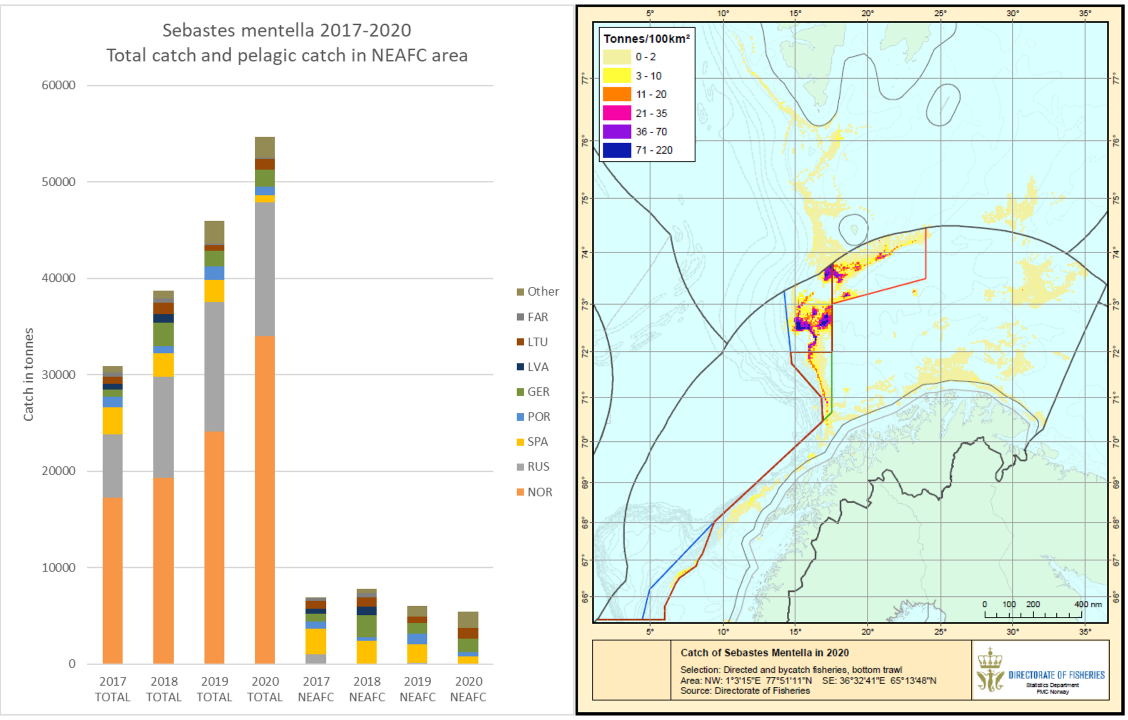


Figure 6.2. *Sebastes mentella* in subareas 1 and 2. Left panel: Catch in tonnes reported by national fleets for the subareas 27.1 and 27.2 and in the NEACF regulatory area. Right panel: Geographical location of the directed Norwegian fishery in 2020 within the Norwegian Exclusive Economic Zone and bycatches by Norwegian vessels in all areas. Directed fishing with bottom trawl is not permitted to the east of the red line. Directed fishing with pelagic trawl is not permitted to the east of the blue line. Directed fishing is not permitted in the Fishery Protection Zone around Svalbard.

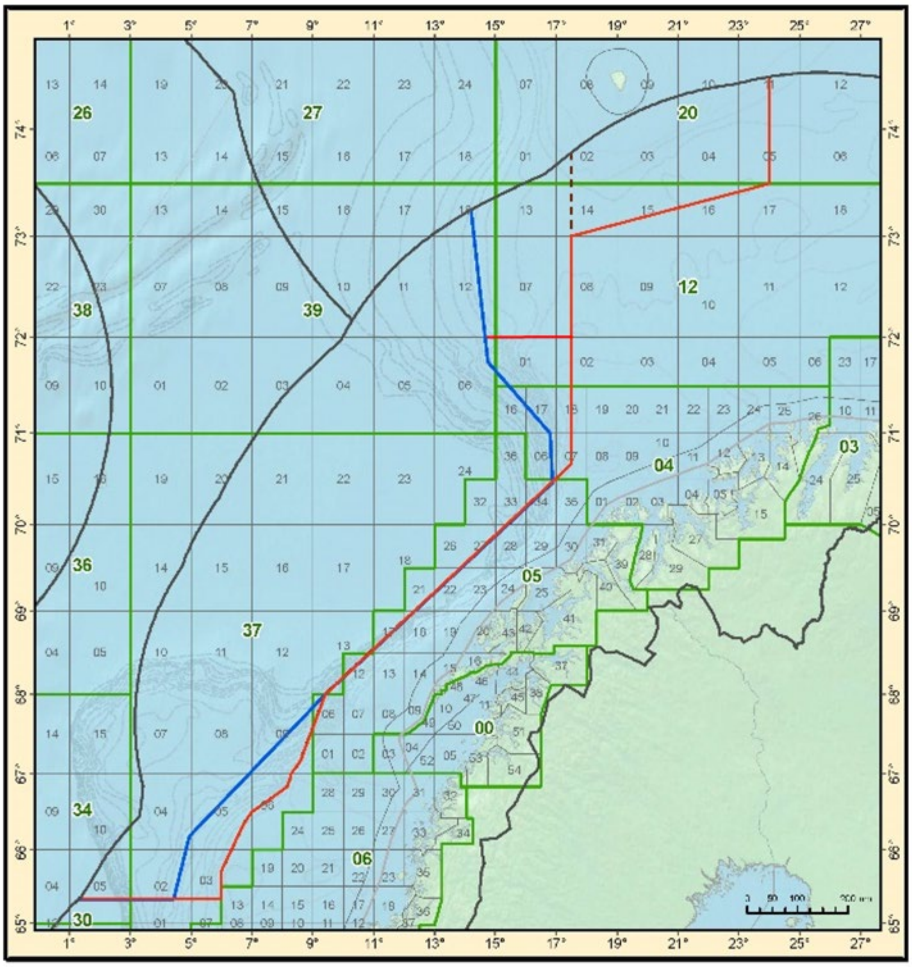


Figure 6.3. Delineation of the geographical limits for directed fishing in the Norwegian Economic Zone in 2014–2020. Directed pelagic trawling is only allowed west of the blue line. Directed demersal trawling is only allowed between the blue and the red line. The area east of the stippled line inside NEZ south of Bear Island is only open for directed demersal trawling after 10 May. The other areas for directed fishing are also open during 1 January to last February. Due to high bycatch ratios of golden redfish 72°N was suggested as southern limit for directed demersal fishing marked by the red line along that latitude to the Norwegian directorate of fisheries in November 2018.

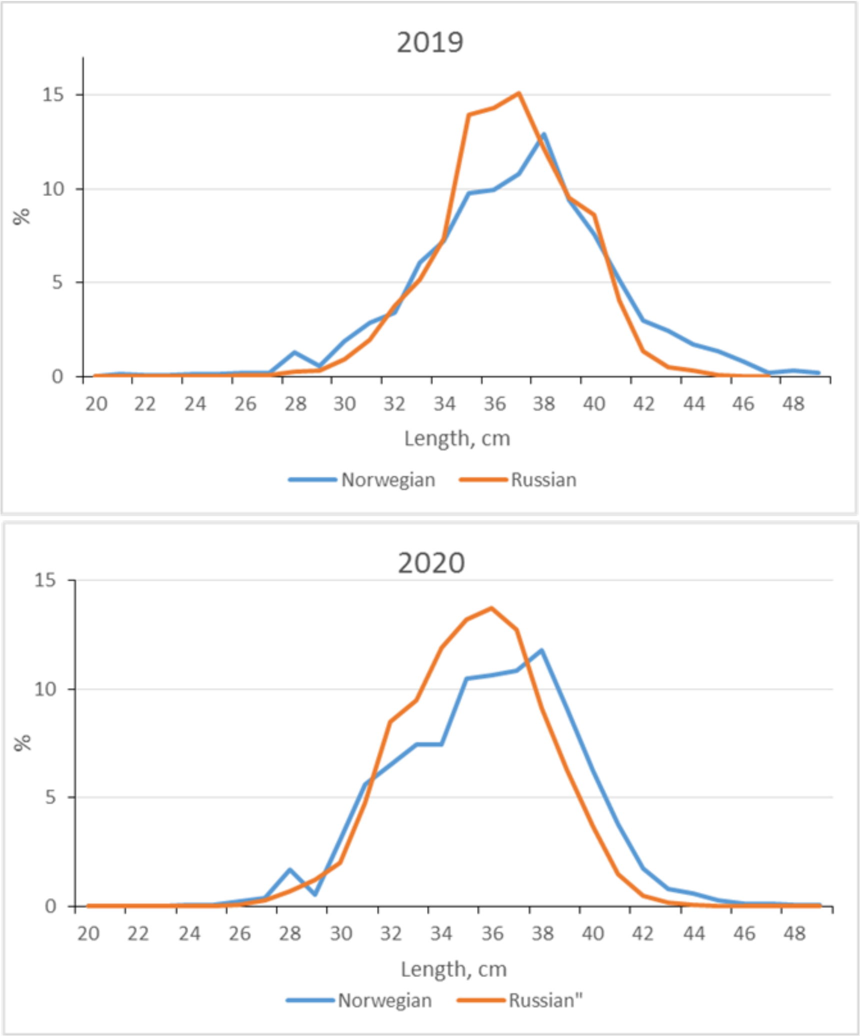


Figure 6.4. *Sebastes mentella* in subareas 1 and 2. Length-distributions of the commercial demersal catches by Norway and Russia in 2019–2020.

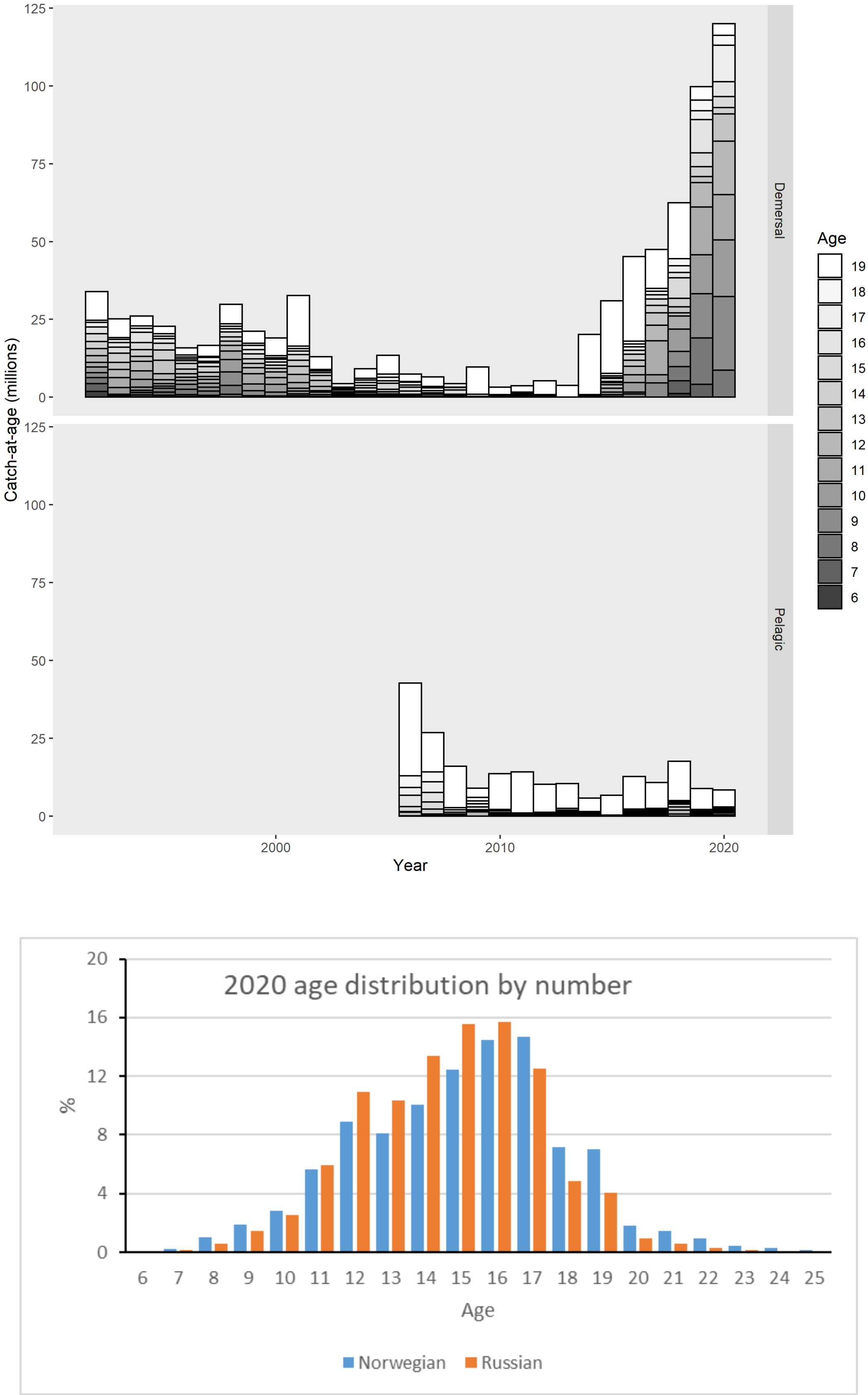


Figure 6.5. ***Sebastes mentella*** **in subareas 1 and 2. Upper panels: Catch numbers-at-age for the demersal and pelagic fleets 1992–2020. Lower panel: Age composition of the commercial demersal catches by Norway and Russia in 2020 (calculated using ALK).**

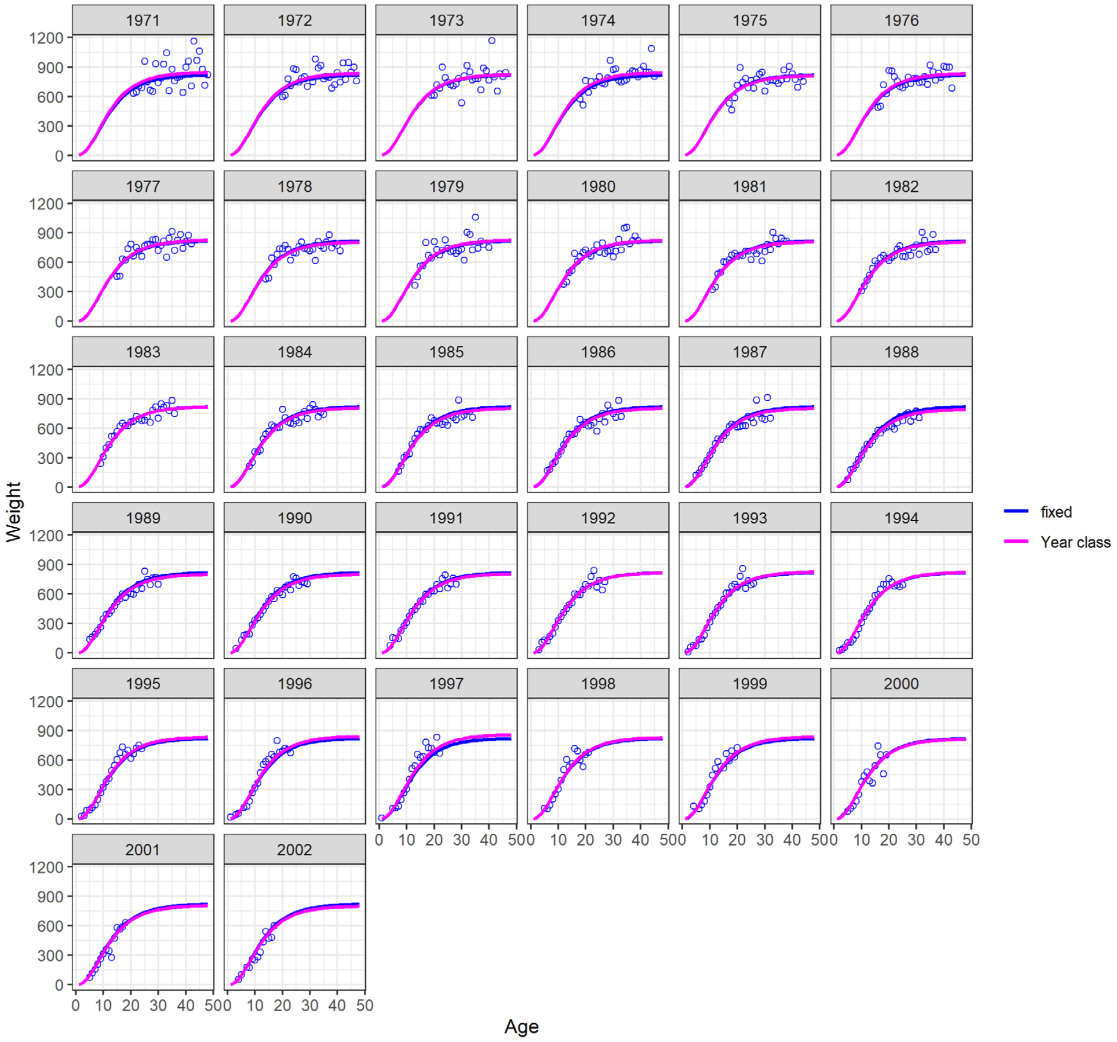
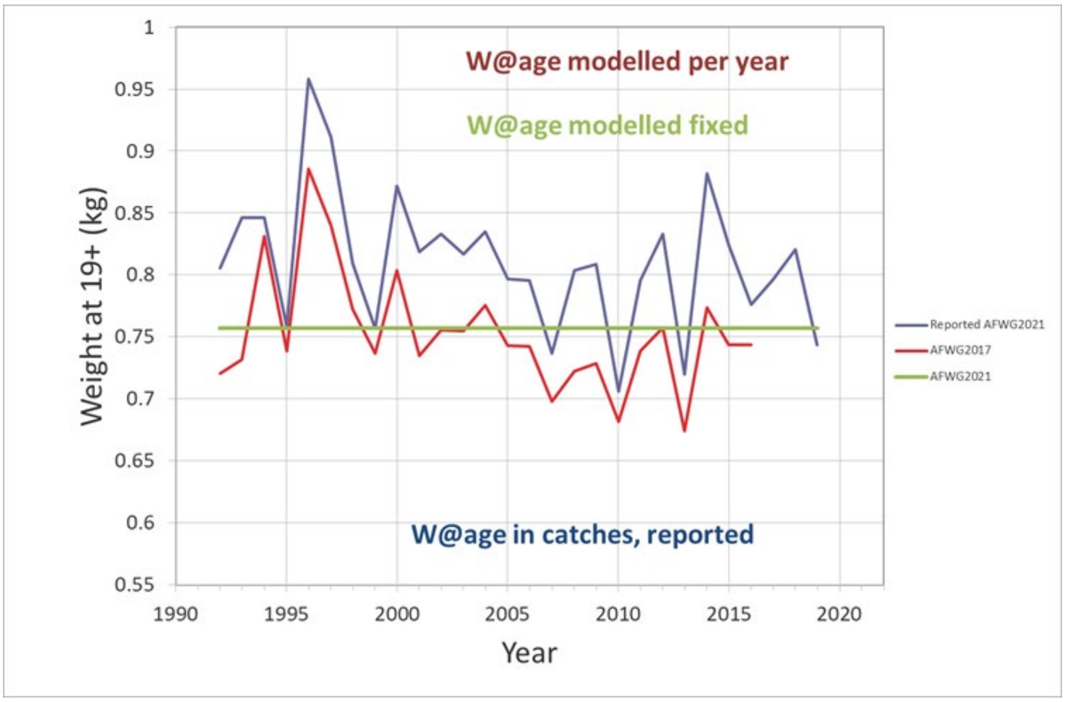


Figure 6.6. Weight-at-age of *S. mentella* per year class in subareas 1 and 2 derived from Norwegian commercial and survey data (Table 6.7). The weights were derived from samples with at least five individuals and are expressed in grammes. The blue and purple lines show the fitted mixed-effect models.



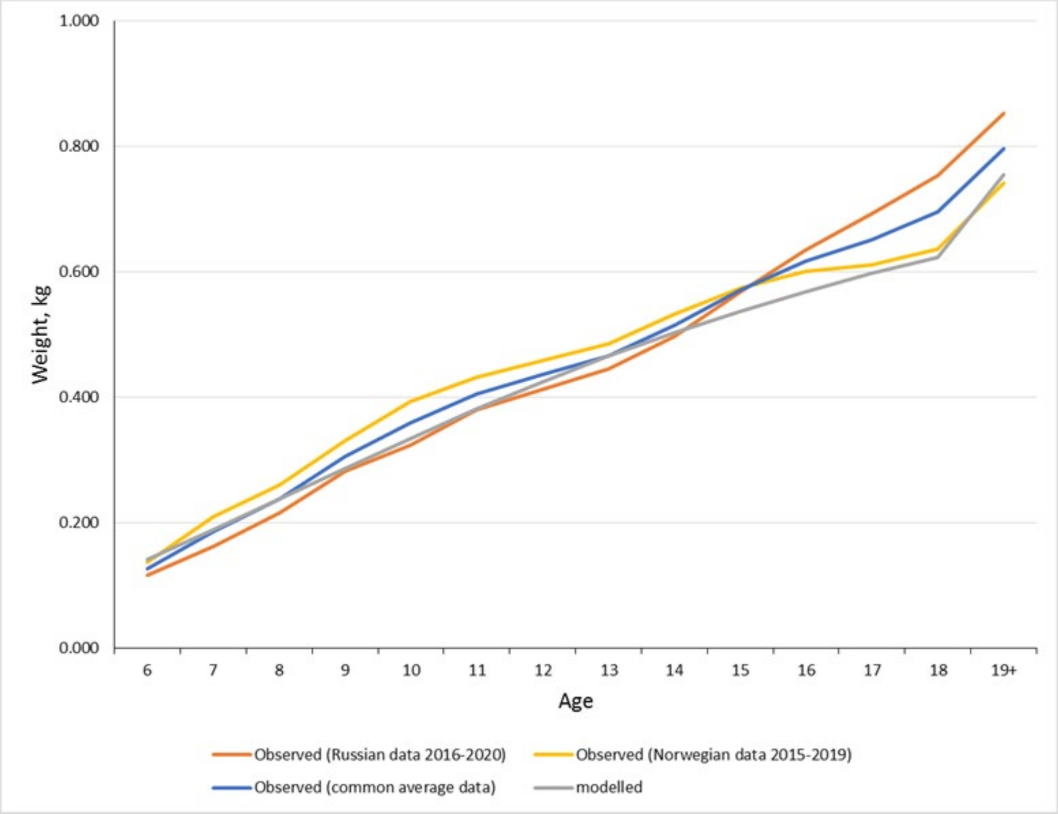


Figure 6.7. *S. mentella* in subareas 1 and 2. The upper panel shows weight-at-age 19+ as reported from catches (blue) or modelled from catches and survey observations (red) using a mixed effect model (Figure 6.5). AFWG 2017 was the last working group using the annual mixed effect model. The weights-at-age used in the assessment were based on the fixed effects model and are therefore the same for every year. These weights were updated in 2021 and differ only slight from those estimated in 2018, 2019 and 2020. The bottom panel shows comparison of the observed Norwegian and Russian weight by age with the modelled one.

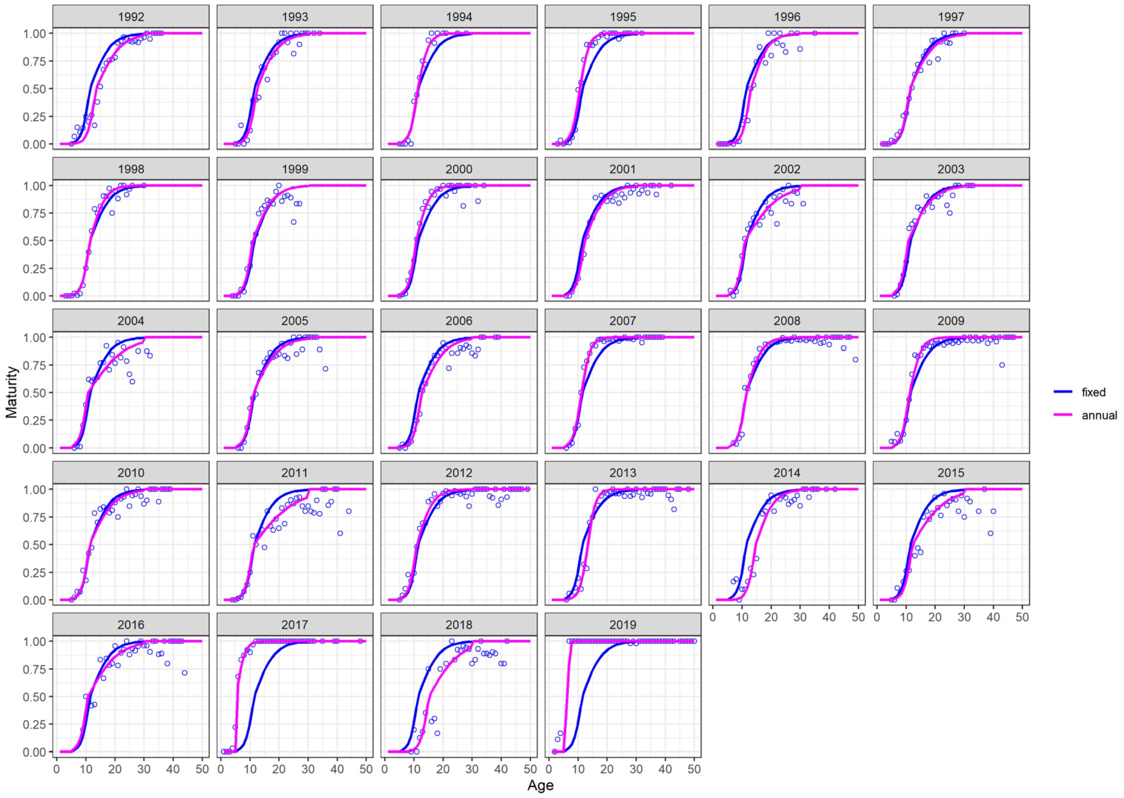


Figure 6.8. Proportion maturity-at-age of *S. mentella* in subareas 1 and 2 derived from Norwegian commercial and survey data (Table D7). The proportions were derived from samples with at least five individuals. The blue and purple lines show the fitted mixed-effect models. For 2008, 2011 and 2016–2019 the common model (fixed effects blue) was used for other years the annual models (random effects purple) were used. Available data for 2019 was insufficient at the time of the meeting and the fixed effect model was used and there was no age data available for 2020.

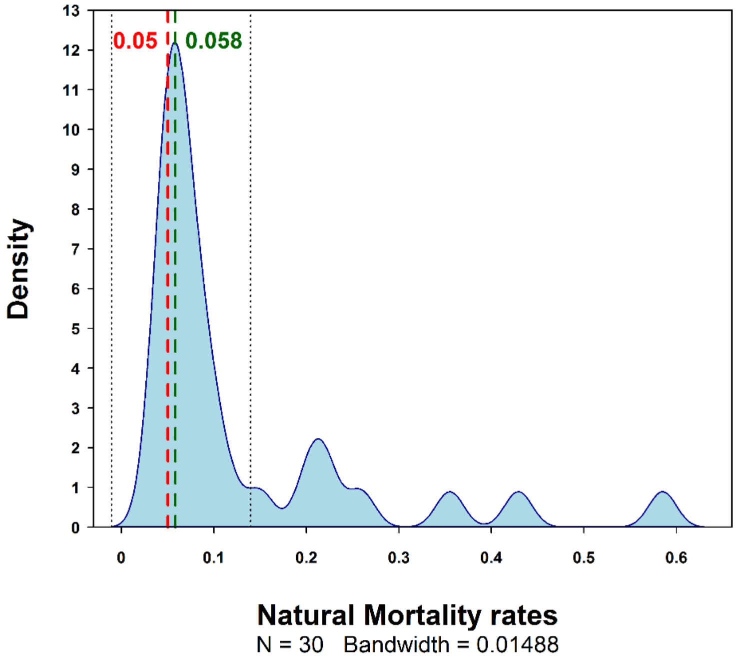


Figure 6.9. Density distribution of natural mortality rates calculated with 30 of the 39 compared methods. The excluded methods are those based on certain taxa or areas. The broken red line indicates the currently used value; the broken green line the most frequent one and the black dotted lines indicate the beginning and end of the distribution’s peak.

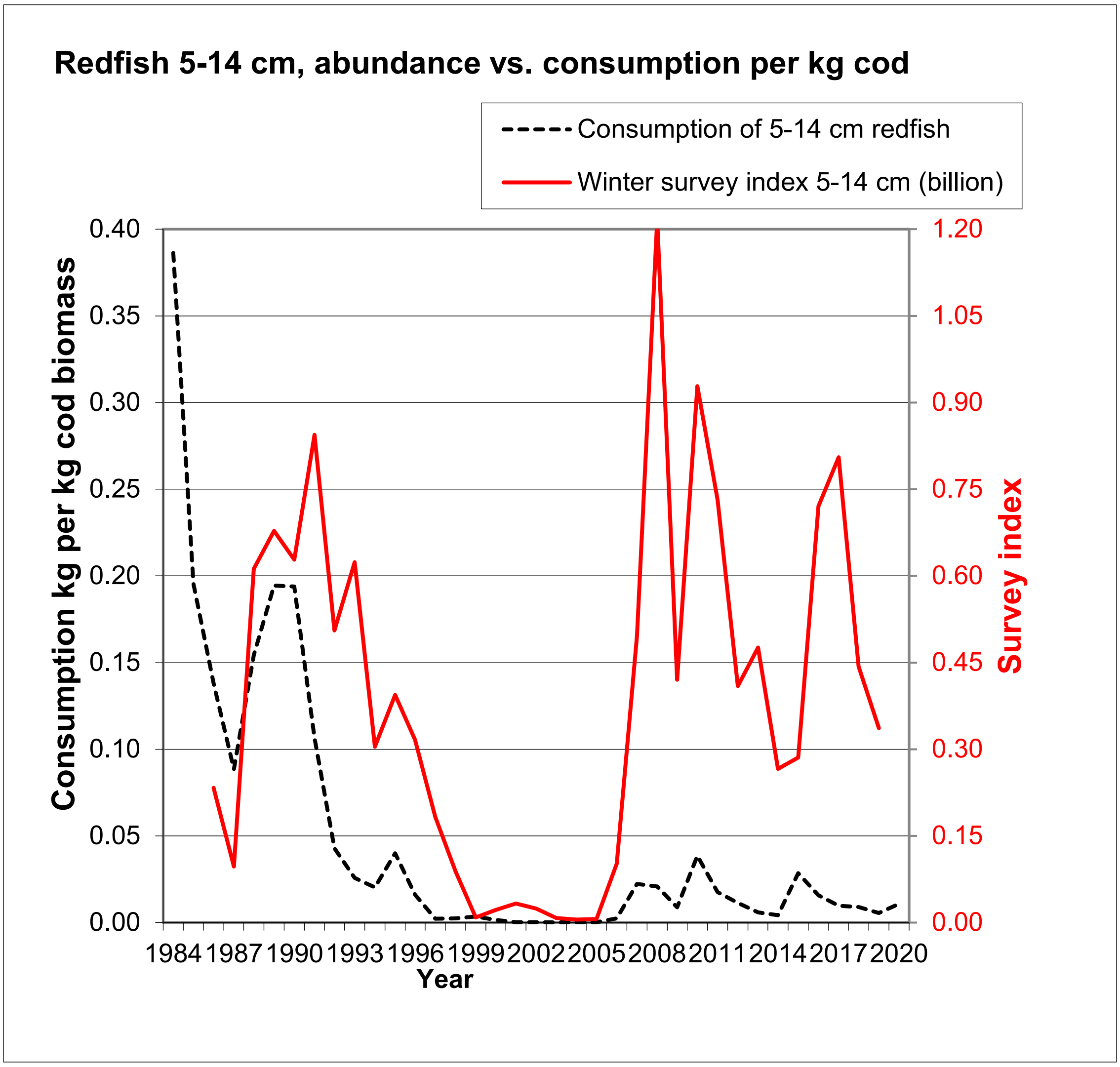


Figure 6.10. Abundance of *S. mentella* (5–14 cm) during the winter survey (February) in the Barents Sea compared with the consumption of redfish (mainly *S. mentella*) by cod (See Section 1 Table 1.1).

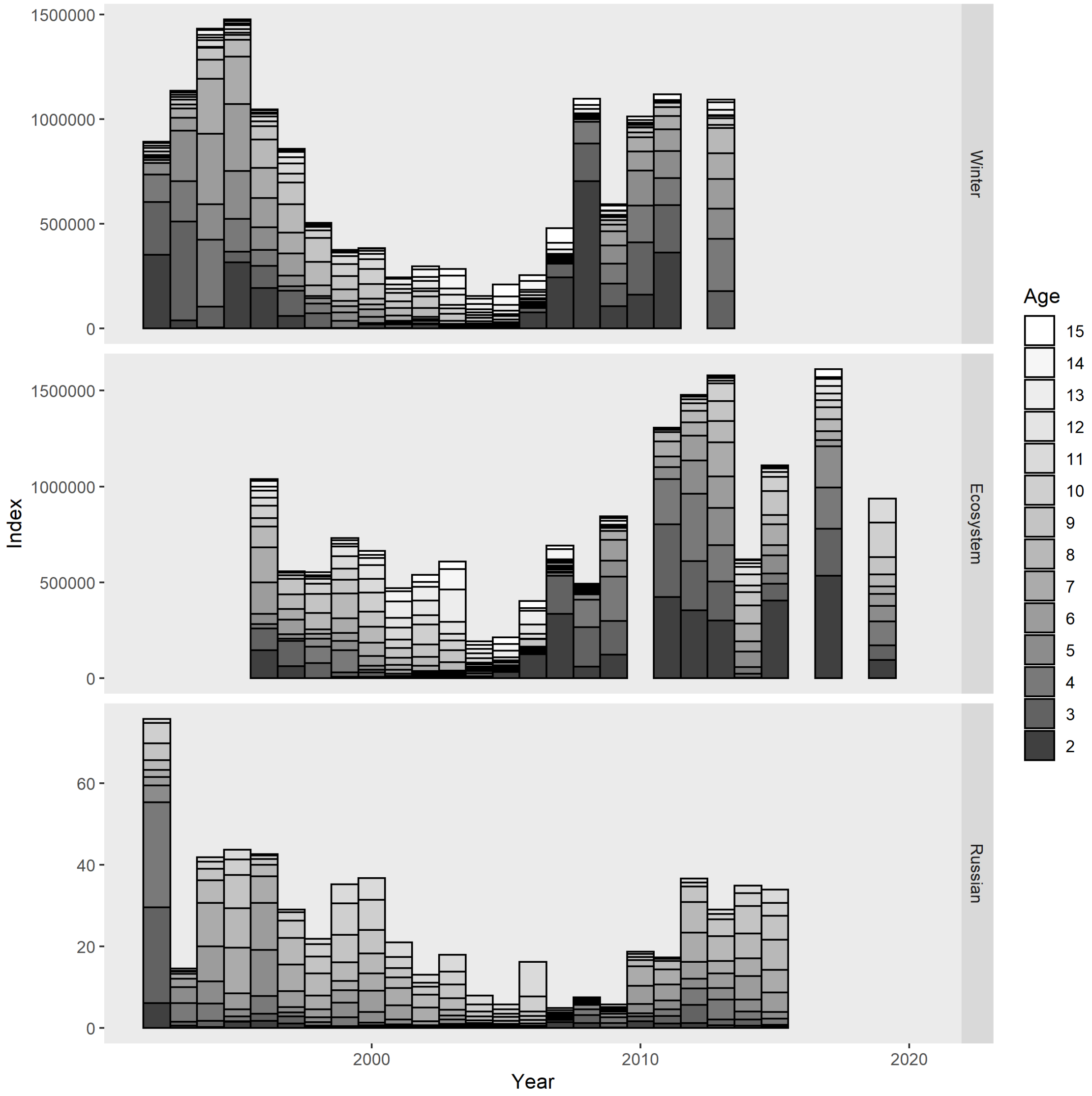


Figure 6.11. ***Sebastes mentella*** **in subareas 1 and 2. Age disaggregated abundance indices for bottom-trawl surveys 1992–2020 in the Barents Sea in winter (winter survey top) in summer (Ecosystem survey middle) and in autumn (Russian groundfish survey bottom).**

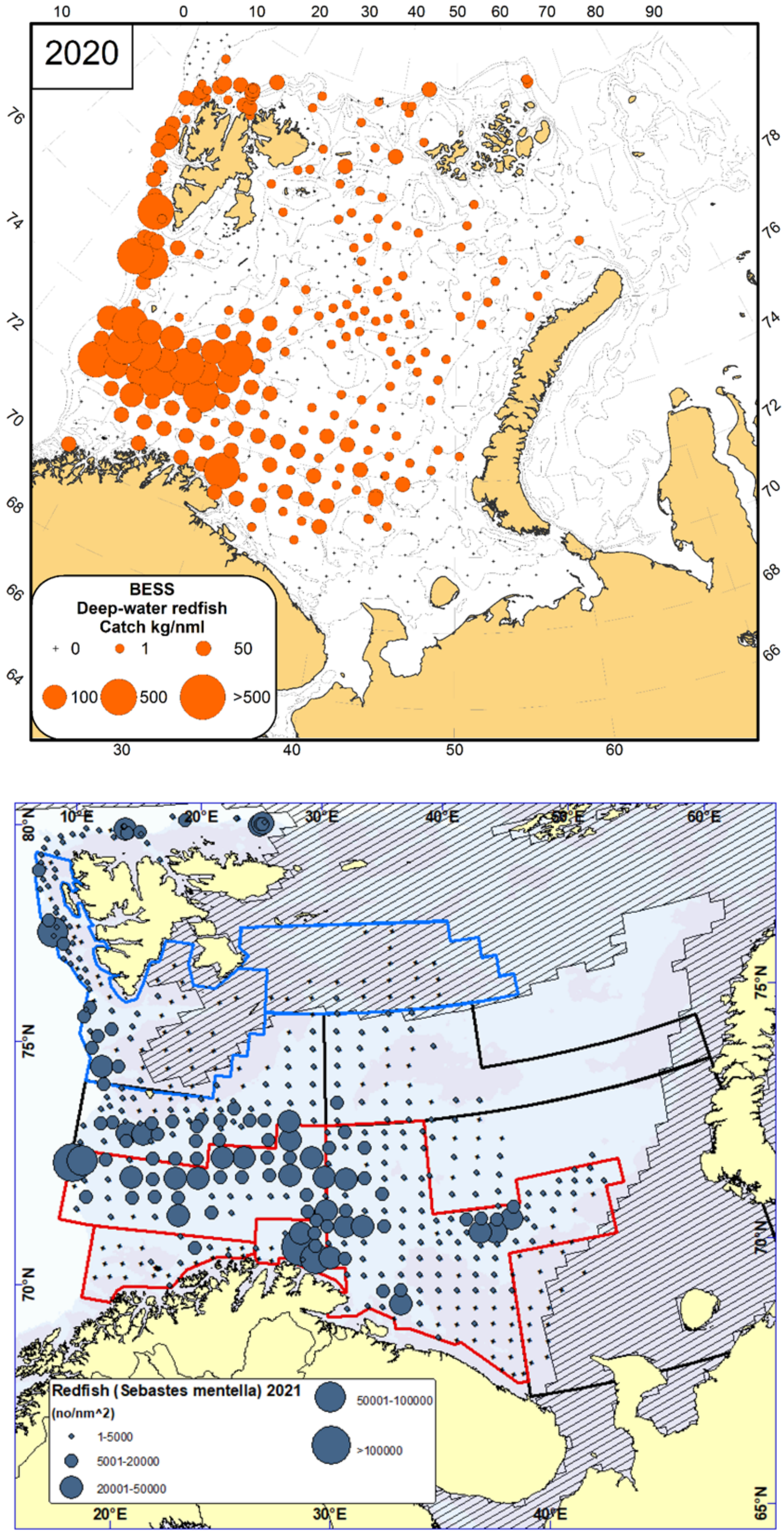


Figure 6.12. ***Sebastes mentella*** **in subareas 1 and 2. Abundance indices for individual trawl stations during the ecosystem survey in autumn 2020 (top) and winter survey 2021 (bottom).**

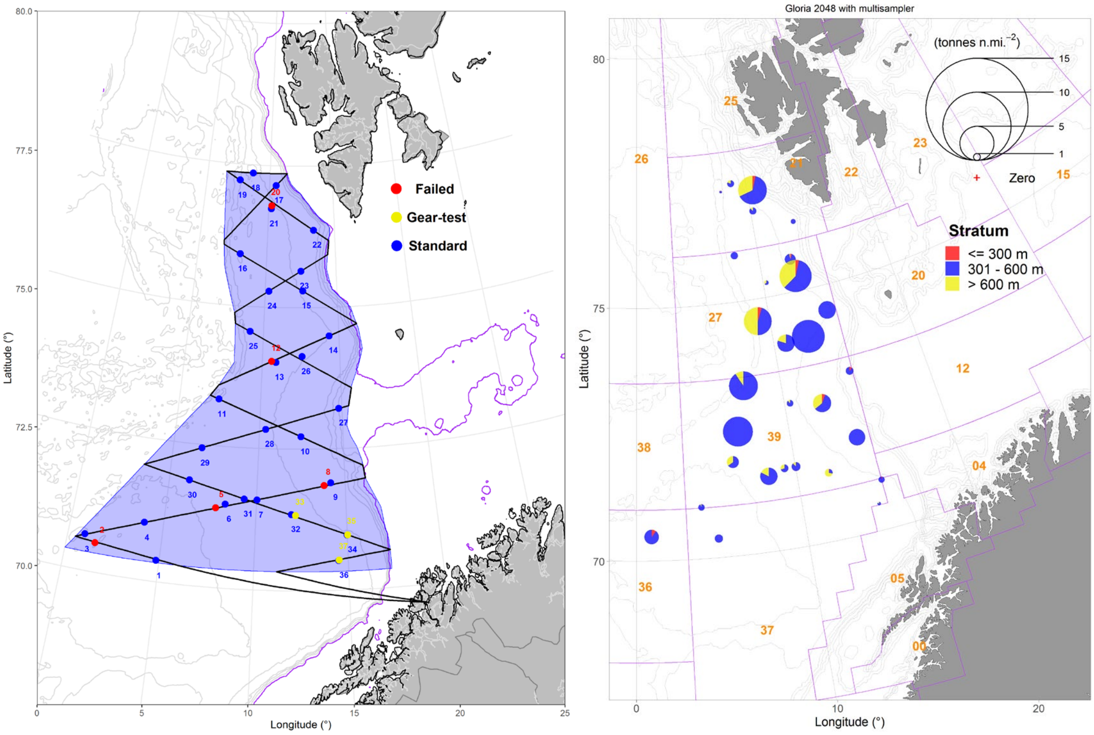


Figure 6.13. ***Sebastes mentella*** **in subareas 1 and 2. Left panel: Survey track of the Deep Pelagic Ecosystem Survey in 2019 and categorized trawls. Only trawls in the category "Standard" served as input for the survey index. Right panel: Catch rates in tonnes per square nautical mile for the surveyed depth layers (< = 300 m, 301–600 m and > 600 m).**

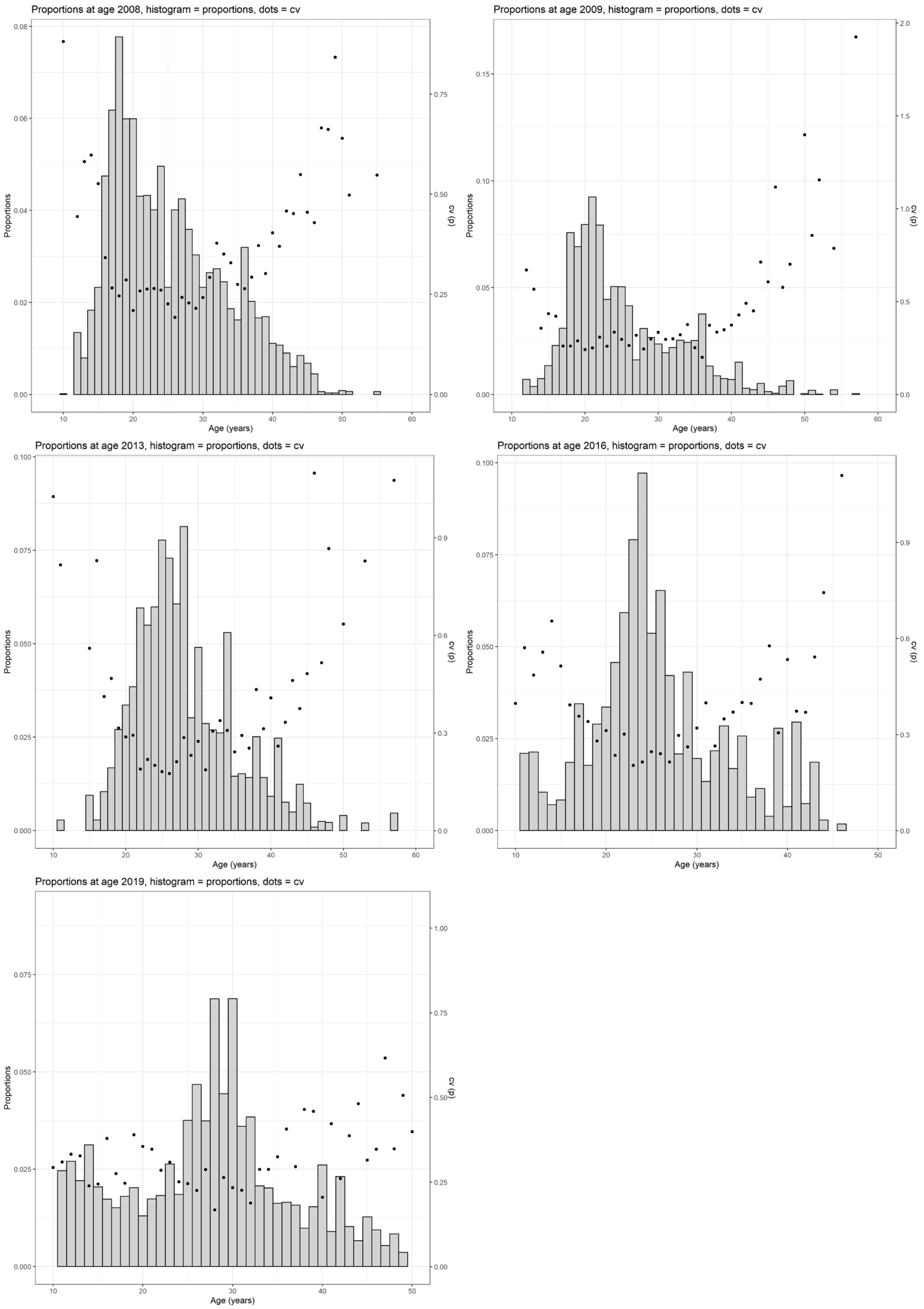


Figure 6.14. ***Sebastes mentella*** **in subareas 1 and 2. Proportions at age during the International Deep Pelagic Ecosystem Survey (WGIDEEPS) in the Norwegian Sea. Bars show proportions at age and dots shows the coefficient of variation for each age. Estimated with RStoX.**

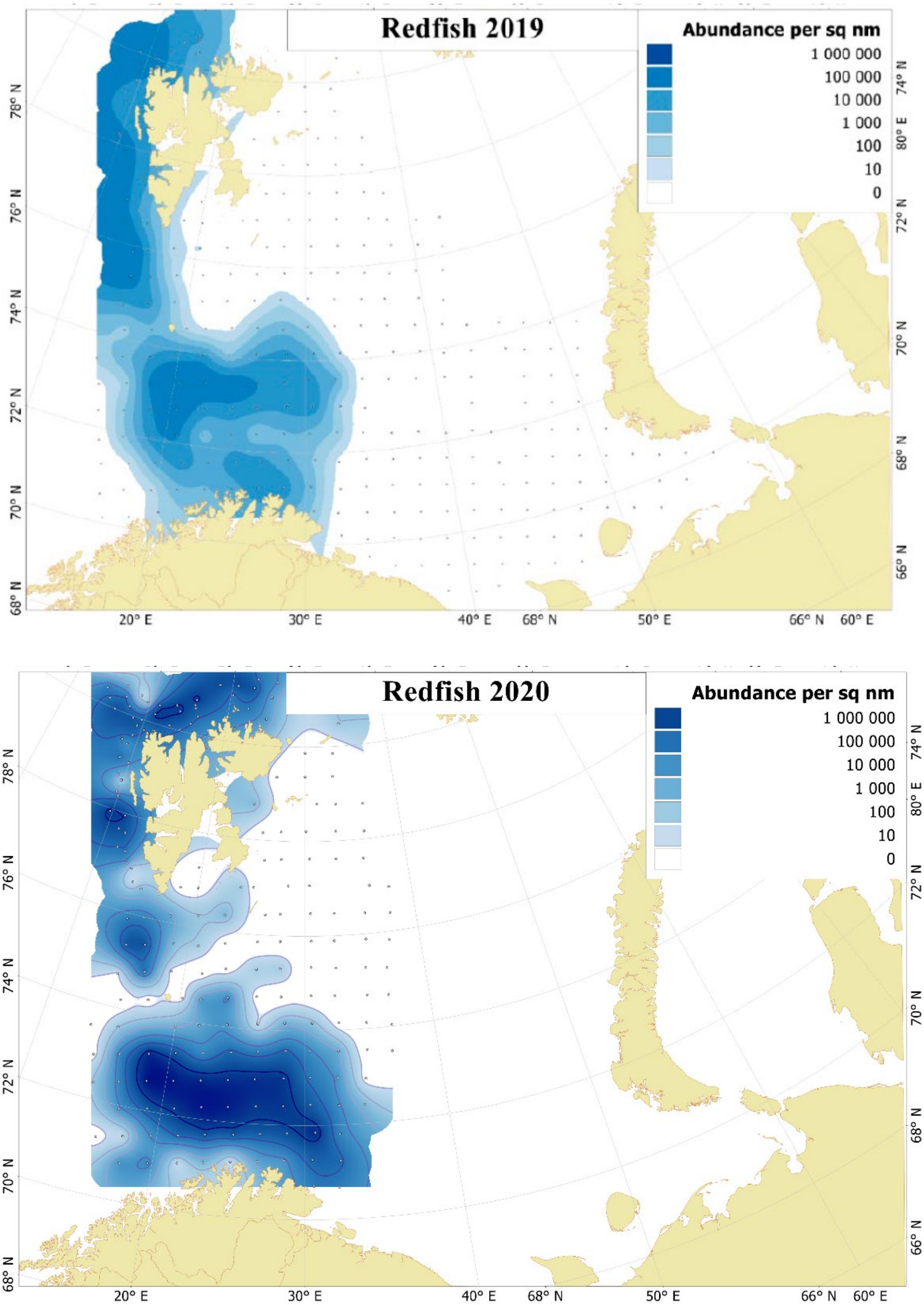


Figure 6.15. Map showing the specific pelagic 0-group trawl stations and the abundance of 0-group Sebastes mentella during the joint Norwegian-Russian Ecosystem survey in the Barents Sea and Svalbard in 2019 (upper panel) and 2020 (lower panel).

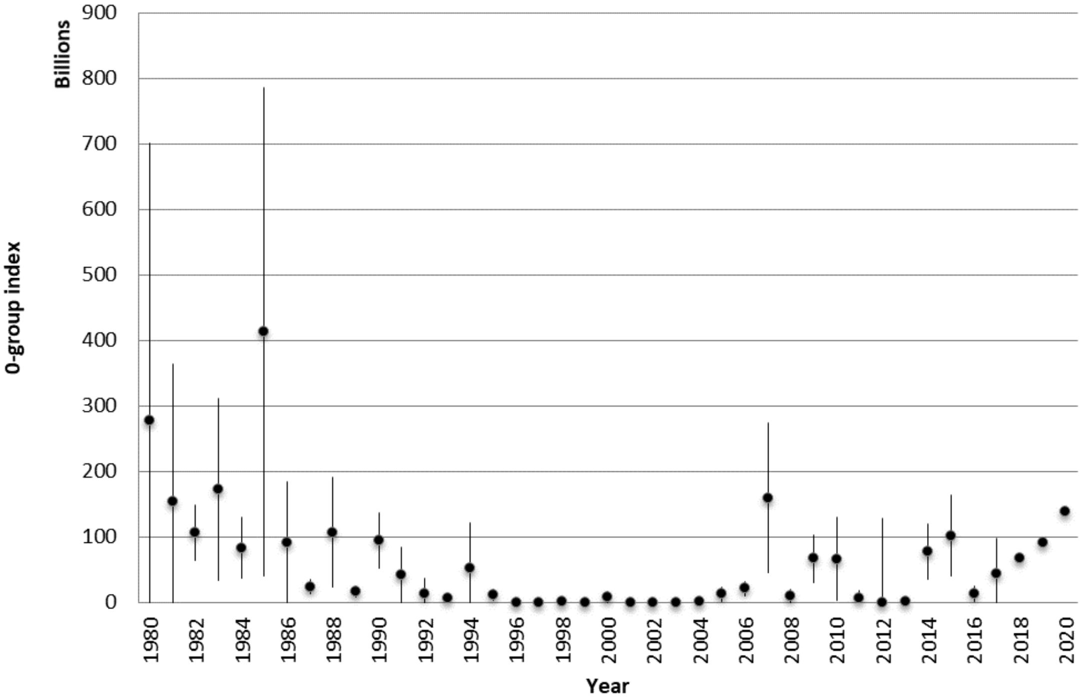


Figure 6.16. *Sebastes mentella* in subareas 1 and 2. Abundance indices (in billions) with 95% confidence limits of 0-group redfish (believed to be mostly *S. mentella*) in the international 0-group survey in the Barents Sea and Svalbard areas in August-September 1980–2020. Since 2018 the method of estimation has changed and does not provide confidence limits.

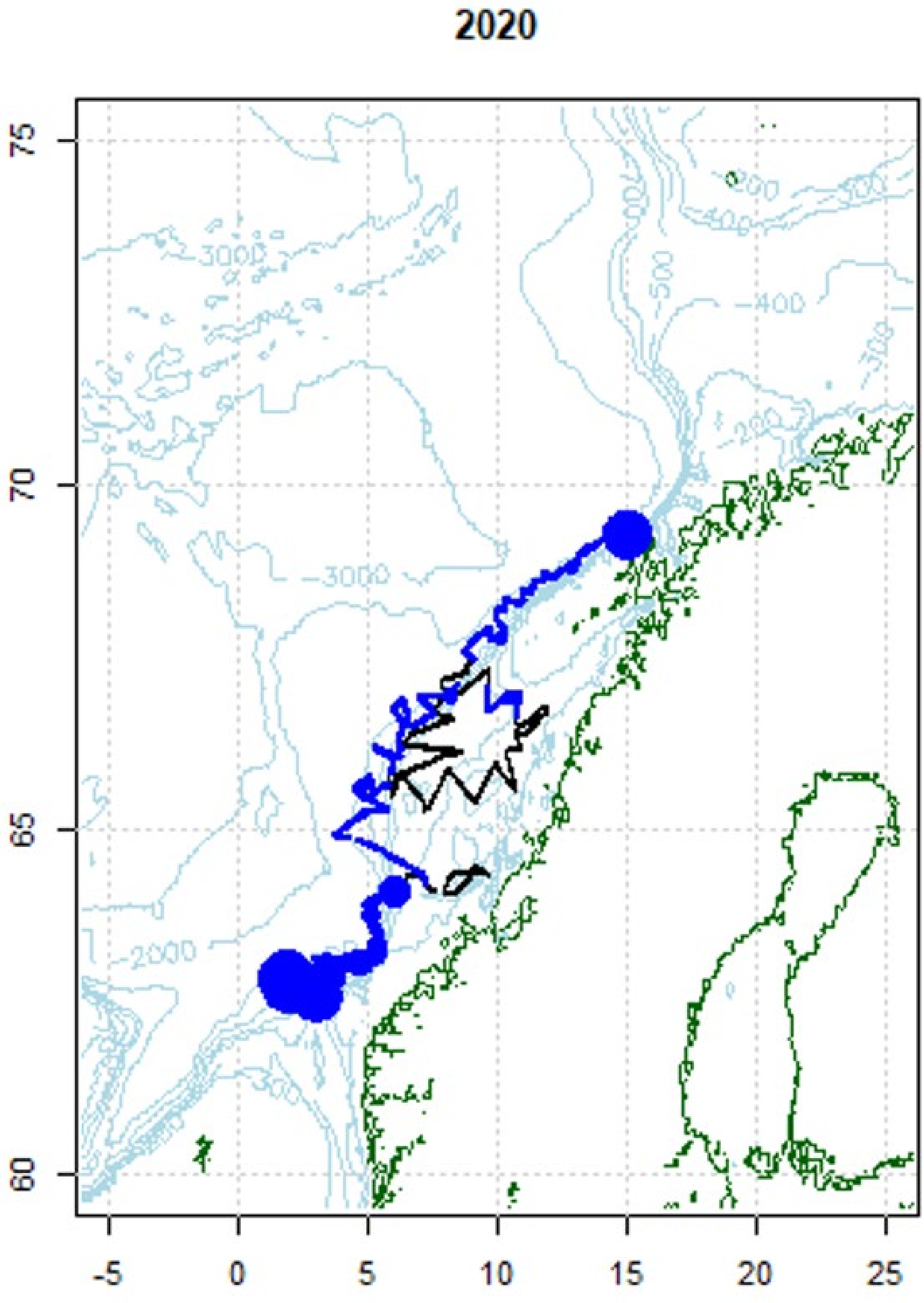
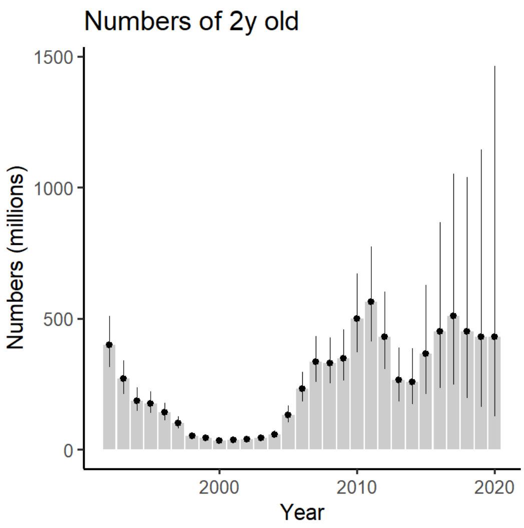
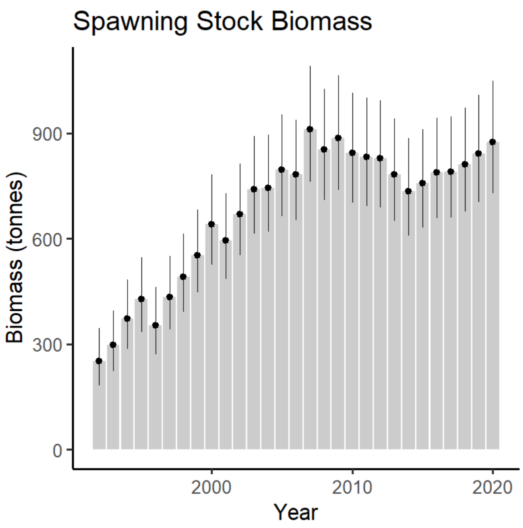


Figure 6.17. ***Sebastes mentella*** **in subareas 1 and 2. Horizontal distribution of** ***S. mentella*** **hydroacoustic backscattering (sA) during the Norwegian slope survey in spring 2020. The circles are proportional to the sA assigned to redfish along the vessel track.**

Recruitment-at-age 2



Spawning-stock biomass



Fishing mortality – year component

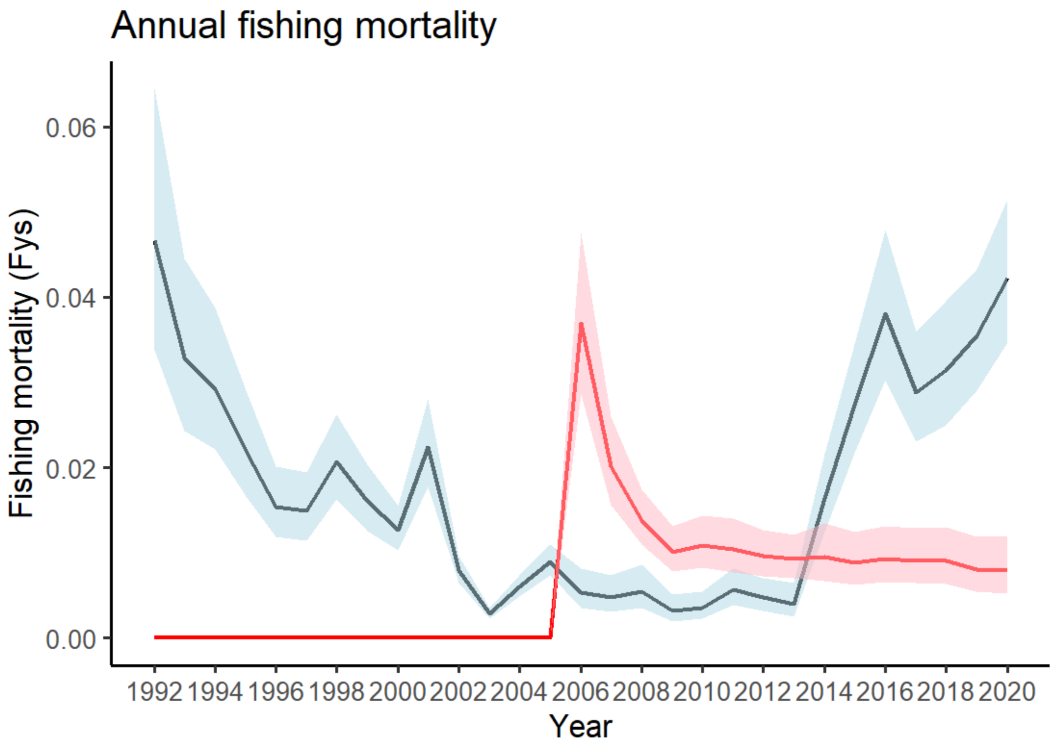


Figure 6.18. *Sebastes mentella* in subareas 1 and 2. Results from the statistical catch-at-age assessment run showing the estimated recruitment-at-age 2 spawning-stock biomass from 1992 to 2020 and annual fishing mortality coefficients by year (Fy) from the demersal (blue) and pelagic (red) fleets. Error bars (top) and the colored envelope (bottom) indicate 95% confidence limits.

Fleet selectivity – age component

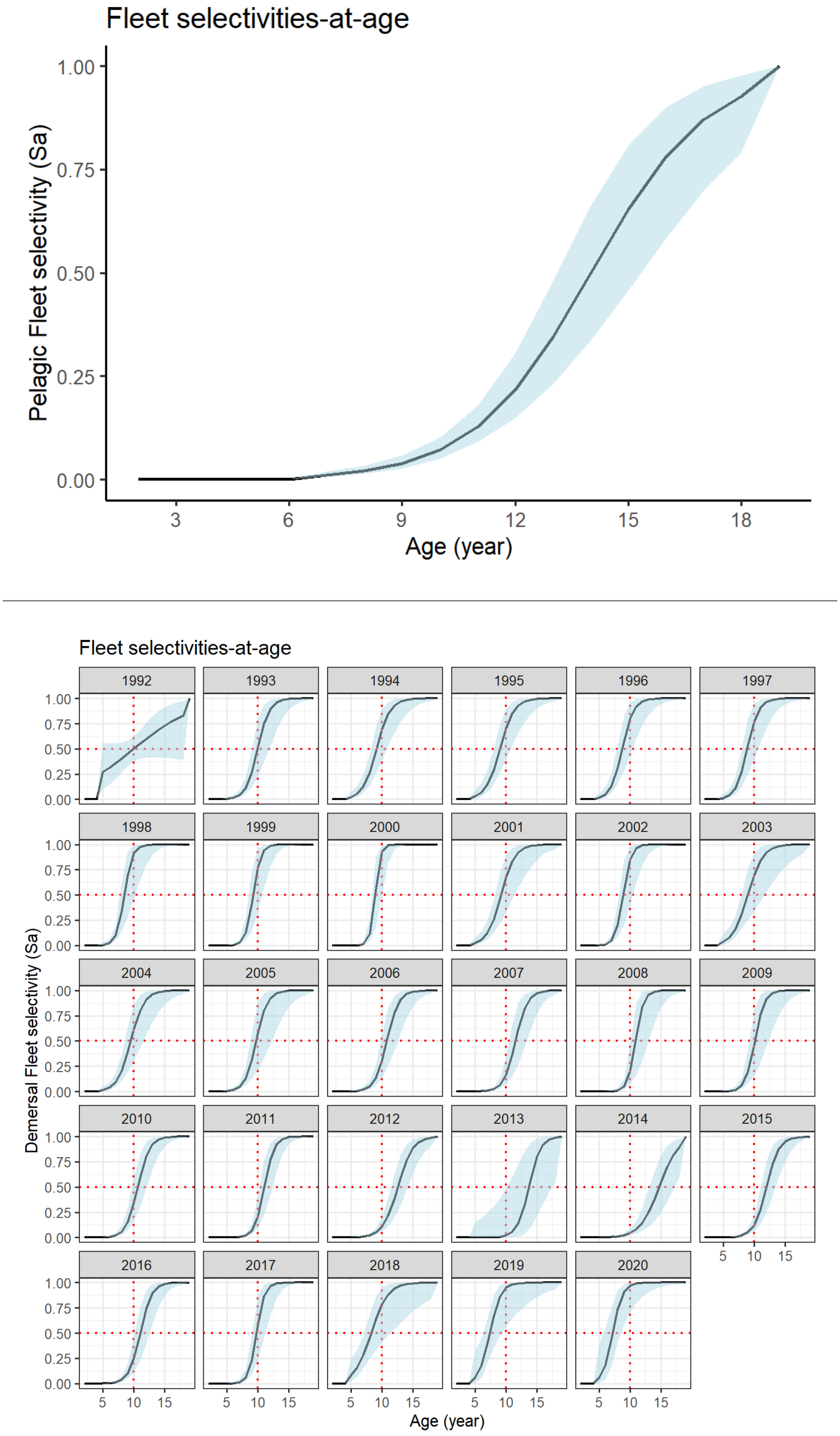


Figure 6.19. *Sebastes mentella* in subareas 1 and 2. Results from the statistical catch-at-age assessment run showing the estimated annual fleet selectivity by age (Fa) from the pelagic (top panel) and demersal (lower panels) fleets. Colored envelopes indicate 95% confidence limits.

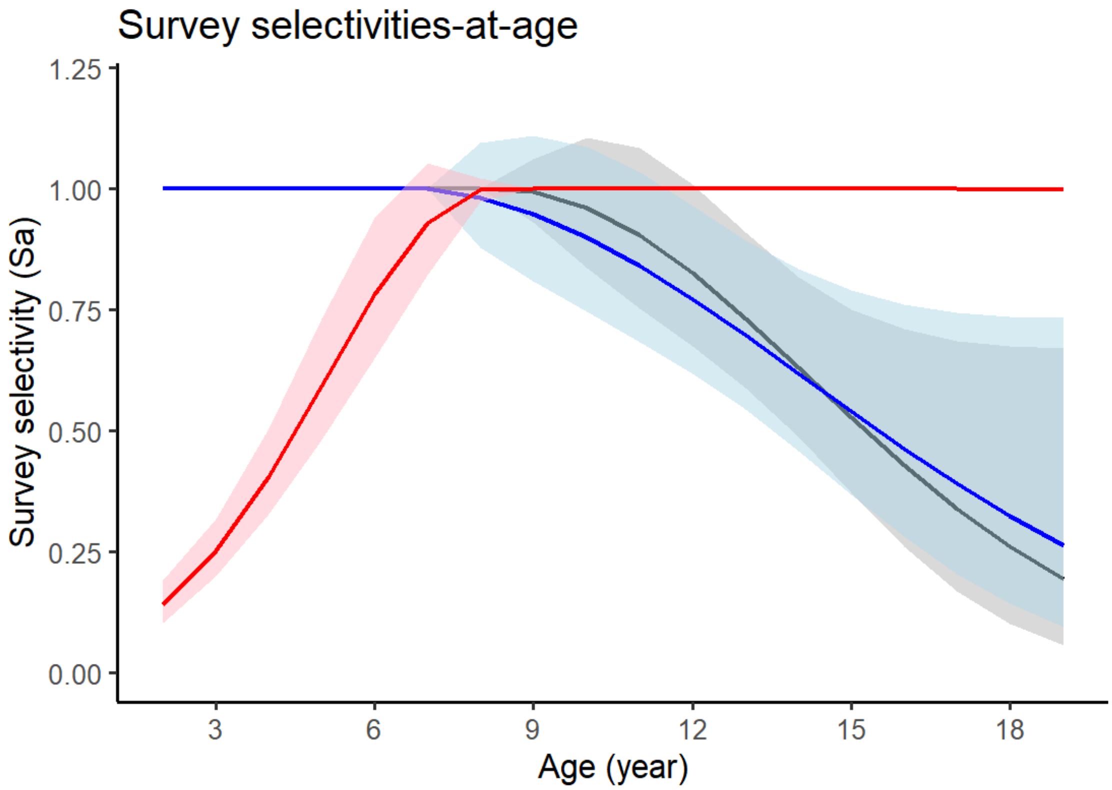


Figure 6.20. ***Sebastes mentella*** **in subareas 1 and 2. Results from the statistical catch-at-age assessment run showing the selectivity-at-age for winter (blue) ecosystem (grey) and Russian groundfish (red) surveys.**

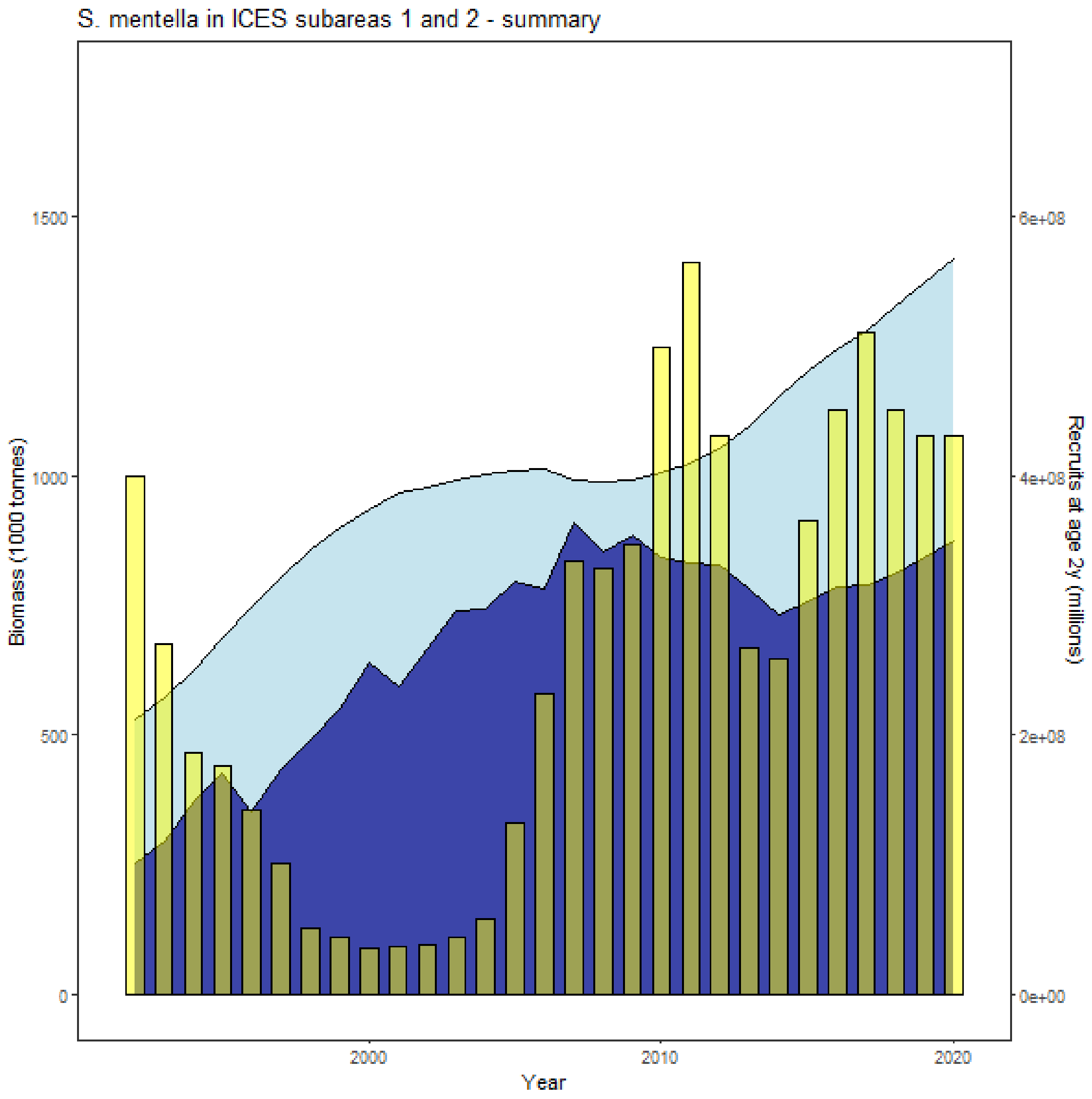


Figure 6.21. ***Sebastes mentella*** **in subareas 1 and 2. Results from the statistical catch-at-age model showing the evolution of total biomass (in tonnes light blue left axis) spawning-stock-biomass (in tonnes dark blue, left axis) and recruitment-at-age 2 (in numbers yellow, right axis) for the period 1992–2020 for** ***S. mentella*** **in subareas 1 and 2.**

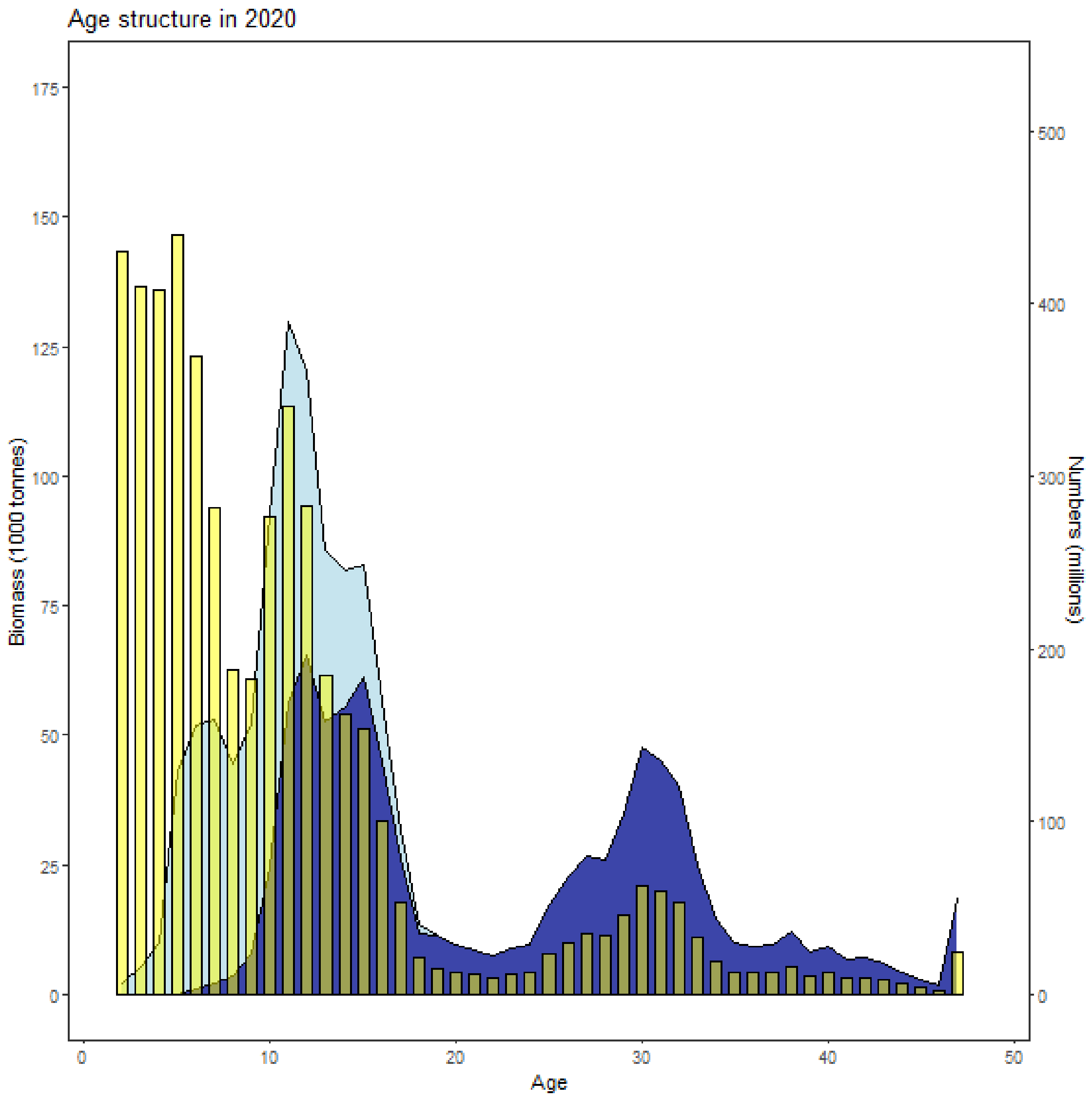


Figure 6.22. ***Sebastes mentella*** **in subareas 1 and 2. Modelled distribution of numbers (yellow bars right *y*-axis) biomass (light blue left *y*-axis) and spawning-stock-biomass (dark blue left *y*-axis) at age 2–45+ in 2020.**

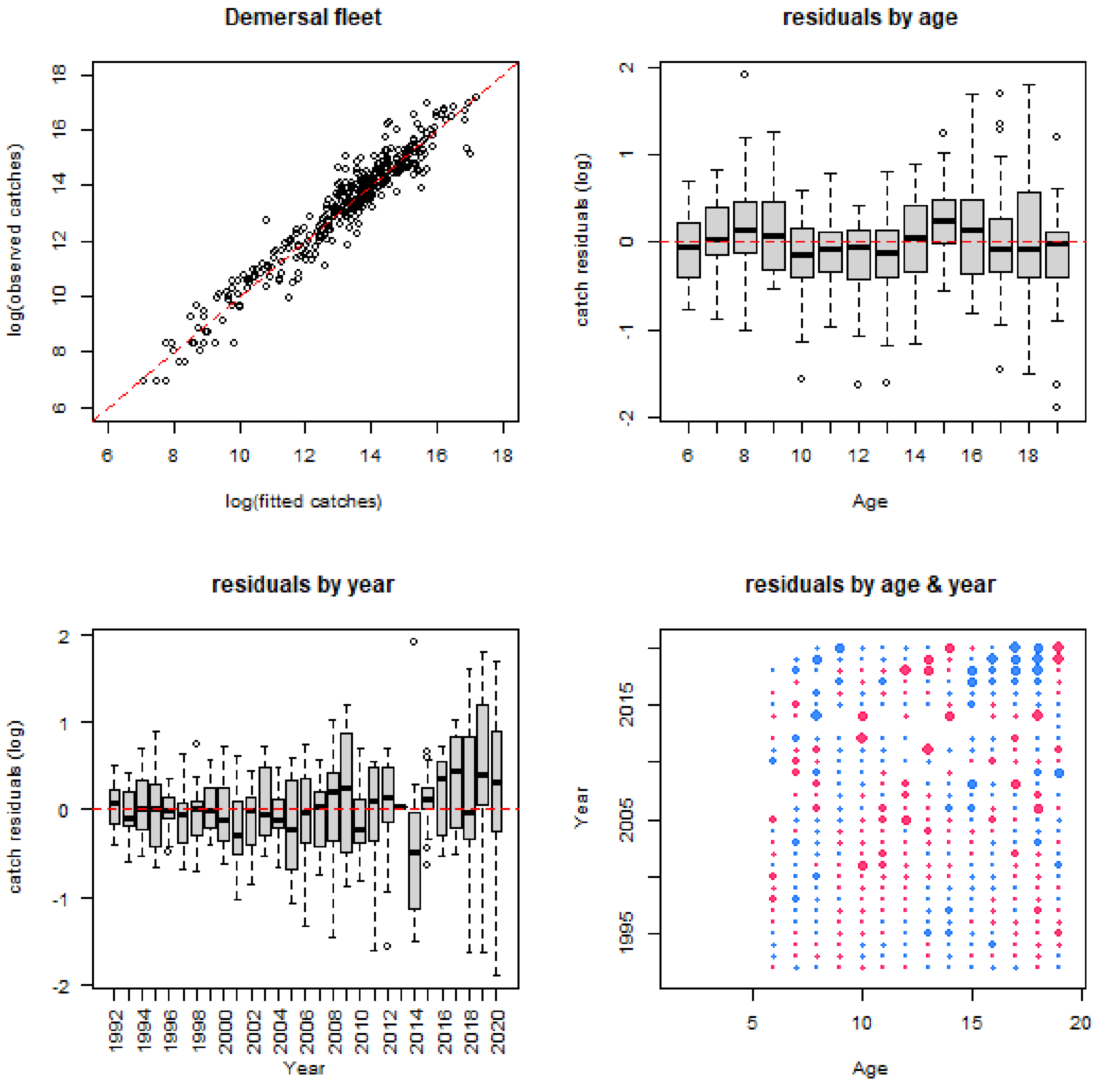


Figure 6.23a. Diagnostic plots for the demersal fleet catch-at-age data. Top-left: scatterplot of observed vs. fitted indices the dotted red line indicates 1:1 relationship. Top right: boxplot of residuals (observed-fitted) for each age. Bottom left: boxplot of residuals for each year. Bottom right: bubble plot of residuals for each age/year combination bubble size is proportional to mean residuals blue are positive and red are negative residuals.

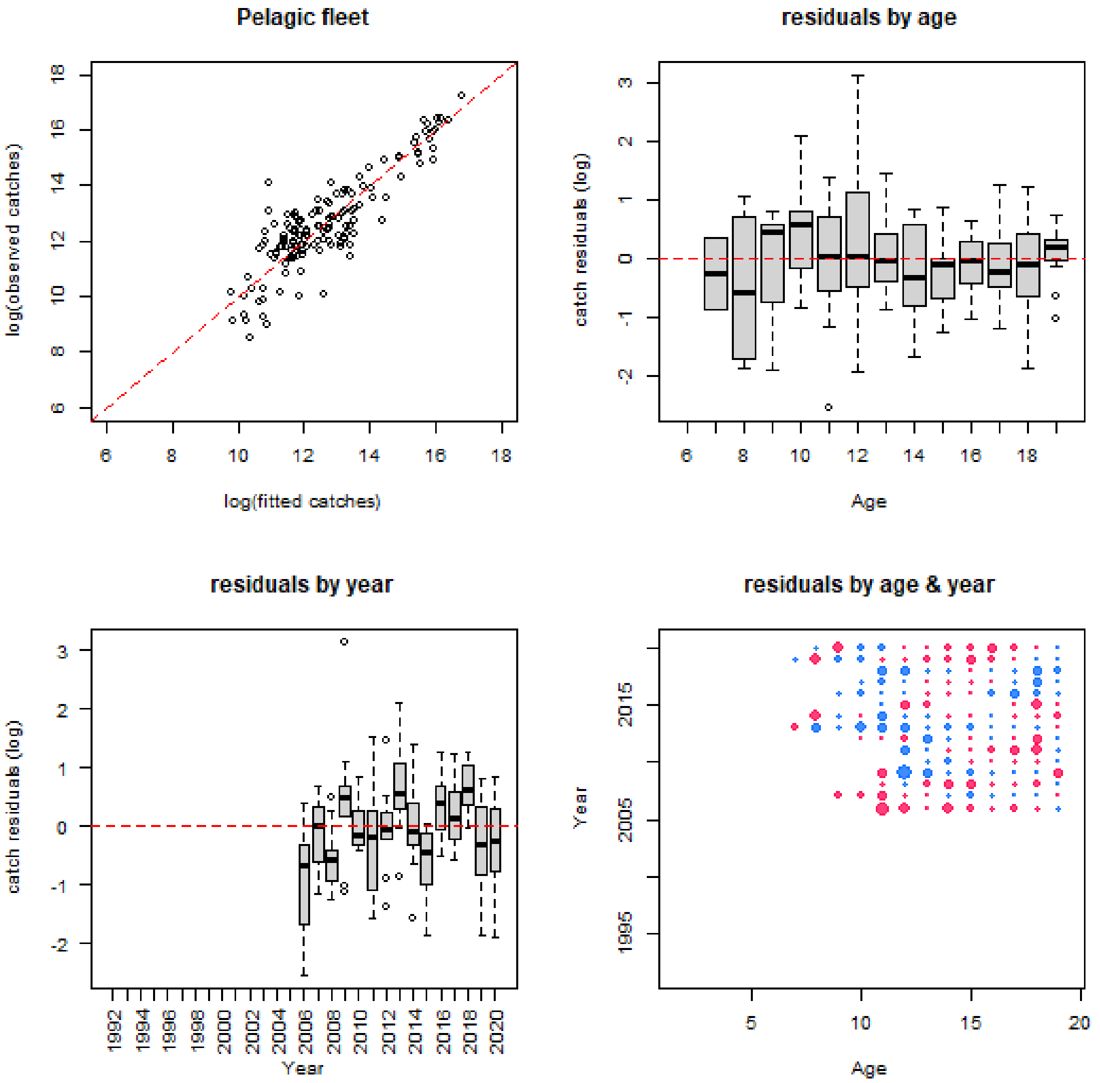


Figure 6.23b. Diagnostic plots for the pelagic fleet catch-at-age data. See legend from Figure 6.23a.

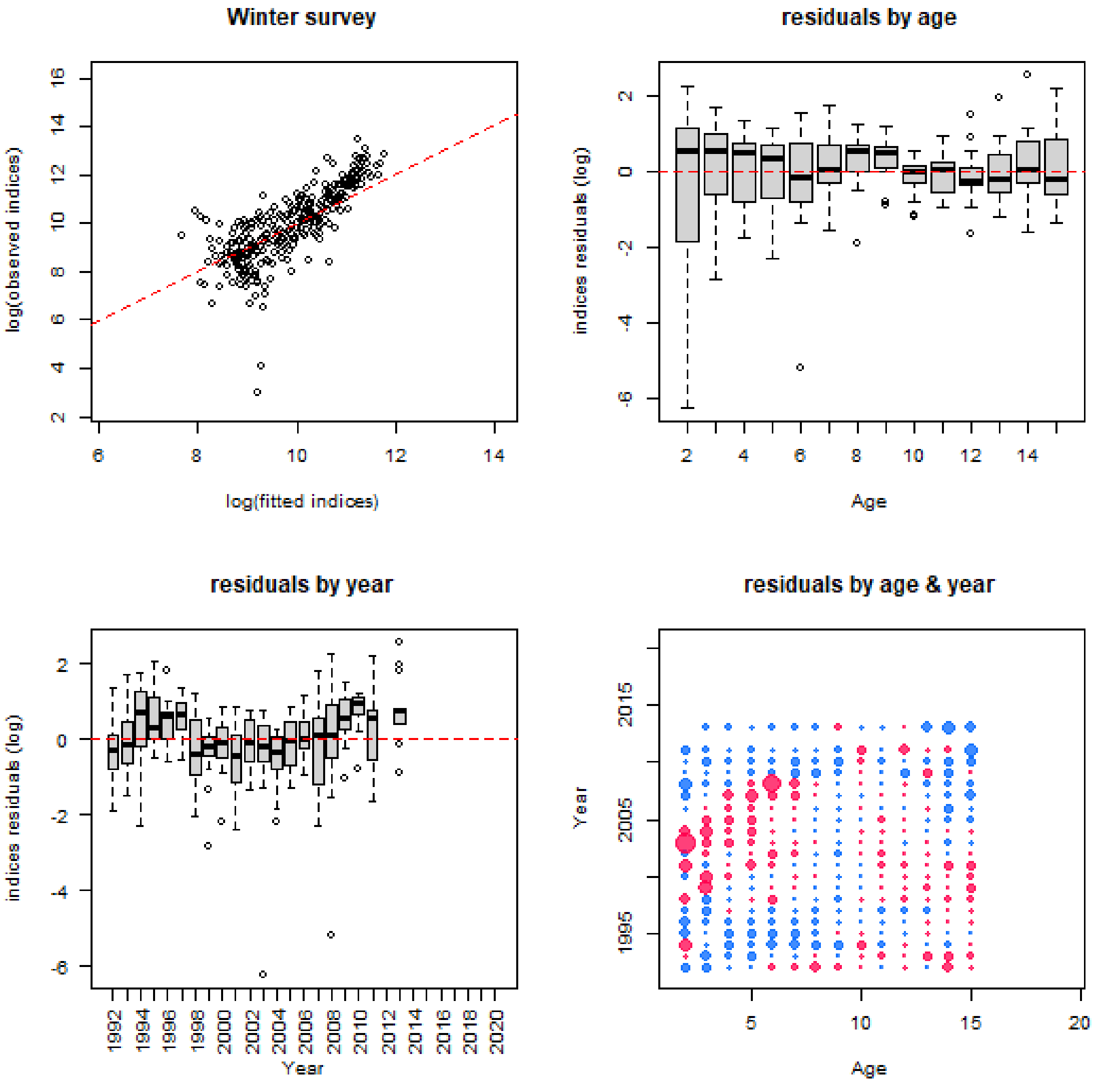


Figure 6.23c. Diagnostic plots for winter survey data. See legend from Figure 6.23a.

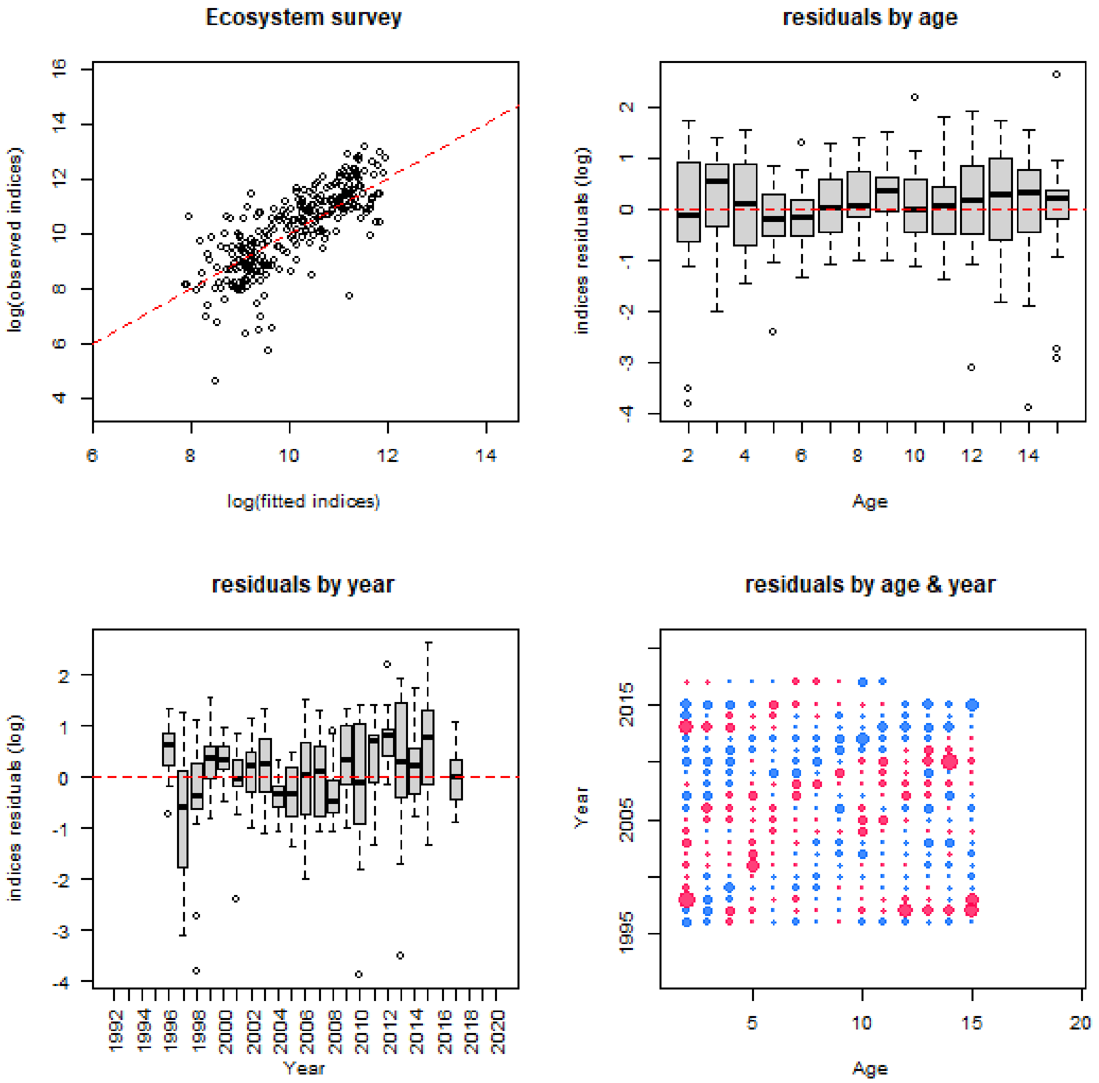


Figure 6.23d. Diagnostic plots for Ecosystem survey data. See legend from Figure 6.23a.

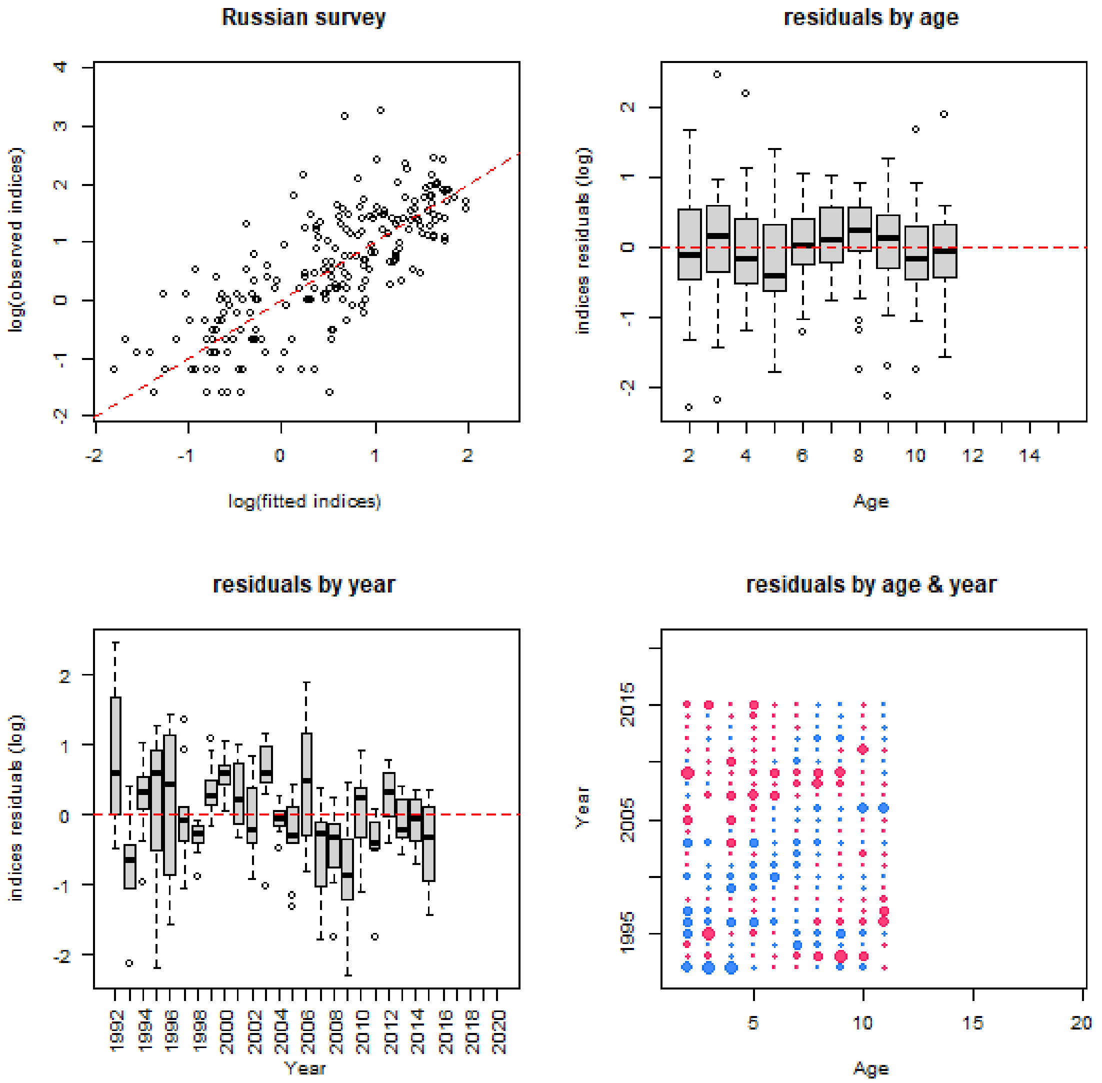


Figure 6.23e. Diagnostic plots for the Russian groundfish survey data. See legend from Figure 6.23a.

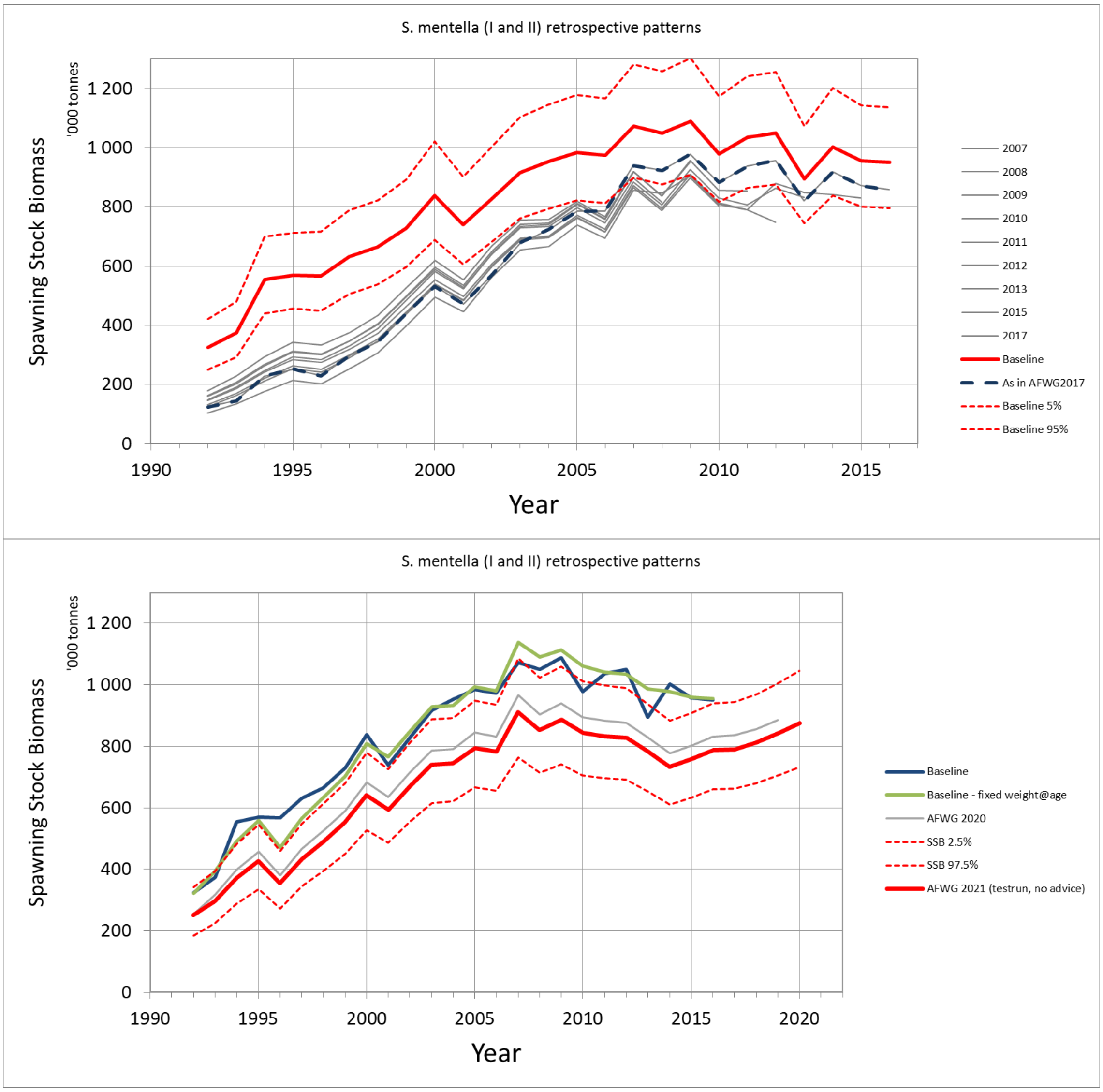


Figure 6.24. The upper panel shows the retrospective patterns of the spawning-stock biomass of *S. mentella* estimated by the SCAA model for runs up to years 2007–2017 and the baseline model of the 2018 benchmark. The lower panel presents the baseline model with fixed weights-at-age and the assessment models for 2020 and 2021. Confidence Intervals are shown for the latest assessment.

7 Golden redfish in subareas 1 and 2 (Northeast Arctic)

Sebastes norvegicus – reg.27.1–2

7.1.1 Recent regulations of the fishery

A description of the historical development of the fishery and regulations is found in the Stock Annex for this stock. The Stock Annex was last updated in February 2018.

Prior to 1 January 2003 there were no regulations particularly for the *S. norvegicus* fishery, and the regulations aimed at *S. mentella* had only marginal effects on the *S. norvegicus* stock. After this date, all directed trawl fishery for redfish (both *S. norvegicus* and *S. mentella*) outside the permanently closed areas were forbidden in the Norwegian Economic Zone north of 62°N and in the Svalbard area. When fishing for other species it was legal to have up to 15% redfish (both species together) in round weight as bycatch per haul and onboard at any time. Until 14 April 2004, there were no regulations of the other gears/fleets fishing for *S. norvegicus*. After this date, a minimum legal catch size of 32 cm has been set for all fisheries, with the allowance to have up to 10% undersized (i.e. less than 32 cm) specimens of *S. norvegicus* (s) per haul. In addition, a time-limited moratorium (up to 8 months) was enforced in the conventional fisheries (gillnet, longline, handline, Danish seine) except for handline vessels less than 11 metres. From 2016, when trawling outside 12 nm, vessels can have up to 20% by weight of redfish in each catch and upon landing. When trawling inside 12 nm, it is permitted to have up to 10% bycatch. Since 2015 it has been prohibited to fish for redfish with conventional gears north of 62°N. The ban does not, however, apply to vessels less than 15 metres fishing with handline from 1 June to 31 August. When fishing with conventional gears for other species, it is permitted to have up to 10% by weight of redfish. Vessels less than 21 metres can still have up to 30% by weight of redfish in the period 1 August to 31 December. Bycatch of redfish is calculated in live weight per week.

7.1.2 Landings prior to 2021 (Tables 7.1–7.4 and Figures 7.1–7.2)

Nominal catches of *S. norvegicus* for the years 1998–2020 by country for subareas 1 and 2 combined, and for each subarea and division are presented in Tables 7.1–7.4. The total landings for both *S. norvegicus* and *S. mentella* are presented in section 6 (Tables 6.6 and 6.7). The sources of information used are catches reported to ICES, NEAFC, Norwegian and Russian authorities (foreign vessels fishing in these countries' economic zone) or direct reporting to the AFWG. Where catches are reported as *Sebastes sp*., they are split into *S. norvegicus* and *S. mentella* by AFWG experts based on available correlation between official catches of these two species in the considered areas. Landings of *S. norvegicus* showed a decrease from a level of 23 000–30 000 t in 1984–1990 to a stable level of about 16 000–19 000 t in the years 1991–1999. Then the landings decreased further, and the total landings figures for *S. norvegicus* in 2003–2013 were low but remarkably stable, between 5500–8000 t. In 2014 the landings decreased to 4436 t, followed by a further decrease in 2015 with landings of 3629 t, mainly due to stronger regulations. This has since reversed with 6656 tonnes in 2018, 8274 tonnes in 2019 and 9033 tonnes in 2020 (provisional). This increase is likely due to the increased quota for beaked redfish and thereby increased bycatch of golden redfish. The time–series of *S. norvegicus* landings is given in Figure 7.1. A map of *Sebastes norvegicus* catches from Norwegian vessels' logbooks in 2020 is shown in Figure 7.2. Note that species identification from landings and logbooks is not always trusted when the Norwegian final landings data are prepared (see Stock Annex).

The Norwegian landings are presented by gear and month/year in figures 7.3a,b. Reported landings were at the lowest level since World War II in 2015. Since 2015 only bycatches of *S. norvegicus* are allowed except for a limited amount caught by vessels less than 15 metres fishing with handline from 1 June to 31 August. The increase in landings since 2015 is due to increased bycatch in trawl.

The reported Russian catches of *S. norvegicus* have been around 600–900 t since 2001, but increased to 1834 tonnes in 2018, 1929 tonnes in 2019 and 2615 tonnes in 2020. Twelve other countries together usually report catches in the 300–600 t range or less (Table 7.1).

The bycatch of redfish (*Sebastes* spp.) in the Norwegian Barents Sea shrimp fisheries during the period 1983–2017 were dominated by *S. mentella*, and hence influenced the *S. norvegicus* to a much lesser extent. However, these bycatches probably inflicted extra mortality on *S. norvegicus* in the coastal areas before the sorting grid was enforced in 1990. From 1 January 2006, the maximum legal bycatch of redfish juveniles in the international shrimp fisheries in the northeast Arctic has been reduced from ten to three redfish per 10 kg shrimp.

Information describing the splitting of the redfish landings by species and area is given in the Stock Annex.

7.1.3 Expected landings in 2021

New regulations were designed and implemented in the Norwegian coastal fisheries with conventional gears in 2016. No directed fishery is allowed, but the bycatch–regulations are currently rather liberal with vessels less than 21 metres being allowed to have up to 30% by weight of redfish in the period 1 August–31 December. The bycatch is calculated in live weight per week.

As expected, total landings in 2020 increased due to the raised quota for *S.mentella*, and thus an increase in bycatch of *S. norvegicus*. The quota for *S. mentella* in 2020 was not reached but catches increased considerably. With an even higher *S. mentella* quota for 2021, the increase in bycatch of *S. norvegicus* is expected to continue in 2021.

7.2 Data used in the assessment (Table 0.1 and Figure E1)

An example of the sampling levels (by season, area and gear) of the data used in the assessment is presented in Figure E1 for 2013. Although Table 0.1 (see Section 0) shows a reasonably good total sampling level for this stock, the number of different boats sampled, and the gear and area coverage should be improved.

7.2.1 Catch–at–length and age (Table 7.5 and Figure 7.4)

The current method used for calculating catch–at–length and age of Norwegian catches is outdated, and there seemed to be issues with the results. Therefore, catch-at-length and catch-at-age were not updated this year. New methods will be implemented and reviewed by the group before AFWG 2022.

Age composition data were only provided by Norway in the latest years. Other countries were assumed to have the same relative age distribution and mean weight as Norway. The catch numbers-at-age matrix is shown in Table 7.5. Catch at length data were also only available from Norway (Figure 7.4).

7.2.2 Catch weight–at–age (Table 7.6)

Weight–at–age data for ages 7–24+ were not available from the Norwegian landings in 2018–2020 during the working group (Table 7.6). Variations in the weight–at–age of young individuals (< 10 years) must be considered with caution as these numbers are derived from only a small number of aged individuals.

7.2.3 Maturity–at–age (Table E4, Figure 7.5a–b)

A maturity ogive has previously not been available for *S. norvegicus*, and knife-edge maturity–at–age 15 (age 15 as 100% mature) had hence been assumed. Maturity–at–age and length is available from Norwegian surveys and landings up to 2019, as reported in Table E4 and presented in Figure 7.5a. Only the data up to 2016 was considered in the model, due to insufficient age readings in the later years. The maturity ogive modelled by Gadget is presented (Figure 7.5b). This analysis shows that 50% of the fish at age 12 are mature.

7.2.4 Survey results (Tables E1a,b–E2a,b–E3, Figures 7.6a,b–7.8)

Results from the following research vessel survey series are available for *S. norvegicus*:

Joint Norwegian–Russian Barents Sea winter bottom–trawl survey (A6996 BS–NoRu–Q1 BTr) from 1986 to 2021 in fishing depths of 100–500 m. Length compositions for the years 1986–2021 are shown in Table E1a and Figure 7.6a. Age compositions for the years 1992–2016 and 2018 are shown in Table E1b and Figure 7.6b. This survey covers important nursery areas for the stock. As described in the stock annex, this survey is used in model tuning.

Norwegian Svalbard (Division 2.b) bottom–trawl survey (August–September) from 1985 to 2020 in fishing depths of 100–500 m (depths down to 800 m incl. in the swept–area). Since 2005 this is part of the Joint Norwegian–Russian Barents Sea Ecosystem survey (A6996 Eco–NoRu–Q3 BTr). Length compositions for the years 1985–2020 and age compositions for the years 1992–2008, 2012, 2013, 2016 and 2018 are shown in Table E2a and E2b, respectively. This survey covers the northernmost part of the species' distribution. Missing age compositions are due to insufficient number of age readings or too few age samples. This survey is not currently included in the model tuning.

Data on length and age from winter and ecosystem surveys have been combined and are shown in Figures 7.7a–b.

Norwegian Coastal and Fjord survey in 1998–2020 from Finnmark to Møre (NOcoast–Aco–Q4). Length composition from catch rates (numbers/nm^2 averaged for all stations within subareas and finally averaged, weighted by subarea, for the total surveyed area) are shown in Figure 7.8 and Table E3. The survey is an acoustic survey designed to obtain indices of abundance and estimates of length and weight–at–age of saithe and cod north of 62°N. The index for golden redfish was previously used in the assessment, but was considered unreliable and stopped in 2010. A new index series was recalculated for the benchmark in 2018 (WKREDFISH 2018a). The aggregated survey index varied too much year–to–year to be driven by the population dynamics, but the length distribution was included in the assessment.

SToX versions of winter and ecosystem surveys are used since AFWG 2020. The group recommended that work continues to investigate redfish–specific strata systems for the survey. The coastal survey for *S. norvegicus* should be converted to SToX in a similar manner, with special attention to the strata system to see if a coherent index of abundance and/or biomass can be obtained for this survey (which is currently only used for annual length distributions).

The bottom–trawl surveys covering the Barents Sea and the Svalbard areas show that the abundance indices over the commercial size range (> 25 cm) were relatively stable up to 1998 but declined to lower levels afterwards. Abundance of pre–recruits (< 25 cm) has steadily decreased since 1991 and has dropped to very low levels after 2000 (Figure 7.6a). An increase in the number of pre–recruits is visible from 2008 onwards. Although this could originally partly result from taxonomic misidentification, the confirmation of increased numbers for individuals of size 15 cm and greater gives some confidence that at least some of the increasing numbers are S. norvegicus.

7.3 Assessment with the Gadget model

7.3.1 Description of the model

Since AFWG2005, the GADGET model has been used for this stock, first with experimental runs, and then as analytical assessments following its adoption by WKRED (2012) benchmark (ICES CM 2012/ACOM:48). The model was then approved again at WKREDFISH (2018a), where it was also recommended to switch to a two–year advice cycle. A number of changes have been made to the model at the benchmark WKREDFISH (2018a); the model is moved to a one–year time–step; the fleet structure has been revised to better reflect recent fishing patterns; age–length data are used for tuning in 5 cm (rather than the previous 1 cm) bins to reduce the extensive noise in this series; proportions (but not absolute abundance) by length in the coastal survey is used for tuning; the model weights have been recalculated; a number of minor errors in the model and data were fixed. Full details are in the WKREDFISH benchmark report (ICES 2018a).

The GADGET model used for the assessment of *S. norvegicus* in subareas 1 and 2 is closely related to the GADGET model that currently is used by the ICES Northwestern WG on *S. norvegicus* (Björnsson and Sigurdsson, 2003). The functioning of a Gadget model, including parameter estimation and data used for tuning, is described in Bogstad *et al.* (2004) and in the stock annex for *S. norvegicus*. In brief, the model is a single species forward simulation age–length structured model, split into mature and immature components. There are three commercial fleets (a gillnet, a trawl and a combined longline and handline fleet). Prior to 2009 the trawl and longline fleets are combined into one, due to difficulties in obtaining data on a finer resolution. The gillfleet has different selectivity from 2009 compared to 2008 and earlier. There are two surveys used in the model, winter survey and coastal survey. Winter survey tunes to total survey index, the coastal survey to length distributions only. Growth and fishing selectivity within each fleet and survey are assumed constant over time (except for the gilfleet), and recruitment is estimated on annual basis (no SSB–recruit relationship).

The weighting scheme for combining the different datasets into a single likelihood score is a method where weights are selected so that the catch and survey data have approximately equal contribution to the overall likelihood score in the optimized model, and that each dataset within each group gives approximately equal contributions to each other. This ensures that both noise and bias (actually divergence from the consensus) are taken into account in the weighting of datasets. The parameters in the model are estimated using a combination of Simulated Annealing (wide-area search) and Hooke and Jeeves (local search) repeated in sequence until a converged solution is found.

7.3.2 Data used for tuning

- Annual catch in tonnes from the commercial fishing fleets, i.e. Norwegian gillnet, and trawl fleet, longline since 2009 and “combined trawl and longline” prior to 2009.

- Annual length distribution of total international commercial landings from the commercial fishing fleets to 2019. Due to late data submissions, there is one–year time–lag in the inclusion of length distributions from other countries than Norway.
- Annual age–length data (1 year by 5 cm resolution) from the same fishing fleets, up to 2018.
- Length disaggregated frequencies from the Barents Sea (Division 2.a) bottom–trawl survey (February) from 1990–2019 (Table E1a).
- Age–length data and aggregated survey indices from the same survey up to 2018, excluding 2017 (Table E1b).
- Length disaggregated frequencies from the Barents Sea (Division 2.a) coastal survey (February) from 1998–2019 (Table E3, Figure 7.8).

7.3.3 Assessment results using the Gadget model (Figures 7.9–7.13)

The general patterns in the stock dynamics of *S. norvegicus* are similar to those modelled for the past several years, but the recruitment event in 2003 is now beginning to have a noticeable positive effect on the overall stock. The overall stock numbers and biomass have shown a decline over a number of years, but the recent recruitment means that immature numbers and biomass are now starting to improve. Some of the 2003 year class are now starting to mature, and the mature stock numbers are therefore stabilizing. The mature biomass is not responding yet, since the maturing fish are still relatively small.

As in previous years, we note that there has been a tendency for some recruitment signal to be reduced in subsequent years, possibly due to misidentification of small *S. mentella* (which is a larger stock and has had good recent recruitment) as *S. norvegicus*, and the model has repeatedly revised down the estimates of this recruitment, although not to zero. The largest fish from the 2003 year class are now entering the mature stock and the fishery, and this is providing multiple sources of information that this was a genuinely good recruitment. The WG stresses that the subsequent recruitment signals (for example the high estimated 2009 year class) should be treated with extreme caution until they enter the fishery (c. 12–15 years after recruiting).

The most important conclusions to be drawn from the current assessment using the Gadget model are:

- The recruitment to the stock has been very poor for a long period, and especially prior to 2005 (Figure 7.10).
- There has been somewhat better-estimated recruitment in recent years, with a reasonably good recruitment in 2003 (Figure 7.13). Indications of a second pulse of good recruitment in 2009 have strengthened in the current assessment, but are still highly uncertain, and will need to be tracked for some years to come, to reduce this uncertainty.
- The estimated fishing mortality (F_{15+}) declined between 1990 and 2005 but remained relatively stable until around 2015, (Figure 7.11, Table 7.7). The current mortality is estimated to F = 0.46 (Figure 7.11), well above a sustainable level for a redfish species, and above the F_{MSY} = 0.05 estimated at WKREDFISH (ICES 2018a). Note that the F estimate is based on the 2003 year class being a good one, and the estimate would be higher if this is not the case.

According to the model the total–stock biomass (3+) of *S. norvegicus* has decreased from about 119 000 tonnes in the early 1990s to just under 40 000 tonnes in 2019 (Figure 7.12, Table 7.8). Due to the improved recruitment from the 2003 year class, the total biomass is beginning to stabilize, although the SSB is continuing to decline. This reduction is primarily the result of prolonged low recruitment, combined with excessively high fishing pressure.

The average assessment bias (Mohn's Rho) over the last 5 assessments was 1% for recruitment, 56% for F(15+) and –29% for SSB. The retrospective plots (Figure 7.13) exhibit a sharp rise in the estimate of mature biomass compared to earlier assessments and a corresponding decline in F(15+), the reason for which is unclear. Whether these changes persist or are eliminated by updated input data in future assessments will have to be monitored.

7.3.4 State of the stock

Survey observations and the Gadget assessment update confirm previous diagnostics that this stock is currently in a very poor situation. This is confirmed by the production model run as a check at WKRED (ICES 2012) and for the 2020 red list evaluation, which produced similar trends. Indications are that the SSB is continuing to fall. This has led to an upwards trend in F to a level that may place an increasing burden on an already poorly performing stock. Furthermore, in the absence of a substantial population of fish in the 10 to 18 age range, the fishery has become increasingly concentrated on the oldest (18 years and older) individuals, reducing the reproductive capacity of the stock.

There are indications that new recruits from the 2003 year class may have entered the population in recent years as noted in previous AFWG reports. The estimated immature biomass is now beginning to increase, but SSB still declines. However, the total level of this recruitment is still uncertain, and although the 2003 year class is estimated to have been the best since the late 1990s, it is not the largest year class seen in the time–series. Consequently, any rebuilding from this year class is likely to be slow. Rebuilding of this stock is therefore dependent on protecting both the existing SSB and any fish recruiting to it. Note that there are significant uncertainties from misidentification between the redfish species in the Barents Sea, and thus the exact values of both stock and F are uncertain, although the trends are clearly defined.

Sebastes norvegicus is currently on the Norwegian Redlist as a threatened (EN) species according to the criteria given by the International Union for Conservation of Nature (IUCN).

Red–listing is understood to mean that a species (or stock) is at risk of extinction. ICES convened two workshops in 2009. The first Workshop WKPOOR1 (ICES CM 2009/ACOM:29) addressed methods for evaluating extinction risk and outlined approaches that could support advice on how to avoid potential extinction. The second Workshop WKPOOR2 (ICES CM 2009/ACOM:49) applied the results of the first workshop to four stocks selected as being of interest to Norway and ICES.

There are three general methods for evaluating extinction risk: (1) screening methods, such as the IUCN redlisting criteria; (2) simple population viability analysis (PVA) based on time–trends; and (3) age-structured population viability analysis. None of the methods are considered reliable for accurately estimating the absolute probability of extinction, but they may be useful to evaluate the relative probability of extinction between species or between management options.

The fishery is largely concentrated on mature individuals. With a currently estimated SSB of around 24 000 tonnes and a F_{MSY} of 0.05, one would expect a sustainable catch to be in the order of 1000 to 1500 tonnes. The current catches are well above this level.

7.3.5 Biological reference points

Reference point calculations were conducted at WKREDFISH benchmark (2018a), based on a B_{Loss} with reasonable recruitment, and a forecast with constant recruitment to produce an F_{MSY} candidate. Note that the benchmark used preliminary data and that the results presented here are slightly changed from those at WKREDFISH (2018). We, therefore, follow the methodology presented at WKREDFISH (2018a) but adjust the B_{lim} based on the revised SSB estimate for 2002.

This has the effect of raising the proposed B_{lim} from 44 000 tonnes to 49 000 tonnes. The F_{MSY} calculations are unaffected, as these are based on steady-state forecasts.

No stock-recruitment relationship is presented for this stock. Within the model, recruitment is modelled as an annual recruitment value with no relationship with the SSB.

- B_{lim}: B_{lim} is based on the Lowest Observed Stock Size at which reasonable recruitment was observed. This is assumed to be the 2003 year class, at which time the SSB is estimated to be 49 000 tonnes (or 44 000 tonnes using the benchmark values)
- B_{pa}: Using the ICES default multiplier of 1.4 for B_{pa} gives a B_{pa} value of 68 600 tonnes (61 000 tonnes using the benchmark values)

The stock is currently well below the biomass limit reference point, and thus F_{MSY} is not recommended as the current fishing level. However, it was considered useful to try to estimate a candidate F_{MSY} reference point, which can be used to compare against management performance. Using yield–per–recruit analysis WKREDFISH (2018a) proposes $F_{0.1}$(15+), estimated to be 0.0525, as a candidate F_{MSY} (Figure E2).

Given the poor state of this stock, management should be based on the need to protect and recover the stock, not on F_{MSY}.

7.3.6 Management advice

AFWG considers that the stock is severely depleted. There are signs that recruitment in 2003 is now beginning to stabilize and, for the immature fish, improve the stock status. However, the stock remains in a poor state, and as of now, there are only weak indications that the mature stock is improving. AFWG, therefore, recommends that current area closures and low bycatch limits should be maintained. No directed fishery should be conducted on this stock at the moment, and the percent legal bycatch should be set as low as possible for other fisheries to continue. There will be no directed fishery for *S. norvegicus* in 2021. It is critical that the bycatch regulations do not allow the catch to increase, as this would impair prospects for recovery.

7.3.7 Implementing the ICES F_{MSY} framework

As a long-lived species, *S. norvegicus* has many year classes contributing to the population, and consequently a relatively stable stock level from year–to year. This makes it relatively simple to manage to some proxy of MSY (e.g. F0.1) once the biomass has reached close to B_{MSY}, provided adequate measures can be implemented to reduce fishing pressure to an appropriate level. It should be noted that the current fishery is well above the preliminary F_{MSY} for the stock. The main focus should therefore be on reducing total F. The current priority is to stabilize the stock and prevent further decline and allow the recruiting 2003 year class to grow and reproduce. Only then could a recovery strategy and eventually an MSY fishery be implemented. The recent upturn in immature biomass gives some hope that such recovery may be possible, given low fishing pressure.

7.4 Tables and figures

Table 7.1. *Sebastes norvegicus* in subareas 1 and 2. Nominal catch (t) by countries in Subarea 1 and divisions 2.a and 2.b combined.

Year	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	UK	Total
1998	–	78	494	131	33	–	19	–	–	16 540	–	6	1632	51	171	**19 155**
1999	–	35	35	228	47	14	7	–	–	16 750	–	3	1691	7	169	**18 986**
2000	–	17	13	160	22	16	–	–	–	13 032	–	16	1112	–	73	**14 461**
2001	–	37	30	238	17	–	1	–	–	9134	–	7	963	1	119	**10 547**
2002	–	60	31	42	31	3	–	–	–	8561	–	34	832	3	46	**9643**
2003	–	109	8	122	36	4	–	–	89	6853	–	6	479	–	134	**7840**
2004	–	19	4	68	20	30	–	–	33	6233	–	5	722	3	69	**7206**
2005	–	47	10	72	36	8	–	–	48	6085	–	56	614	8	52	**7036**
2006	–	111	8	35	44	31	3	–	21	6305	–	69	713	9	39	**7388**
2007	–	146	15	67	84	68	13	–	20	5784	–	225	890	5	55	**7372**
2008	–	274	63	30	71	27	6	–	2	5216	–	72	749	4	85	**6599**
2009	–	70	1	58	81	66	–	–	1	5451	–	30	698	–	31	**6487**
2010	–	171	51	31	72	22	–	–	–	5994	1	28	565	3	44	**6981**
2011	–	24	53	9	51	22	–	–	1	4681	48	25	919	6	13	**5852**

Year	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	UK	Total
2012	–	87	182	71	58	23	12	–	5	4247	34	17	681	–	100	**5517**
2013	–	83	353	1	45	8	1	–	–	3771	19	36	797	–	493	**5609**
2014	–	67	219	6	20	29	–	–	1	3053	21	5	806	–	211	**4436**
2015	1	76	53	24	211	35	–	–	–	2488	17	–	664	2	57	**3629**
2016	7	183	30	4	87	55	–	–	–	3239	26	–	864	–	76	**4572**
2017	–	123	17	19	61	65	–	–	2	3353	27	90	1297	44	160	**5258**
2018	1	146	37	66	77	67	–	–	–	4276	36	67	1834	12	37	**6656**
2019	–	244	24	93	56	83	–	3	–	5667	20	69	1929	61	25	**8274**
2020[1]	–	166	1	85	99	52	–	–	–	5902	9	80	2615	6	18	**9033**

Table 7.2. *Sebastes norvegicus* in subareas 1 and 2. Nominal catch (t) by countries in Subarea 1.

Year	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Norway	Poland	Portugal	Russia	Spain	UK	Total
1998	78	–	5	–	–	–	–	2109	–	–	308	–	30	**2530**
1999	35	–	18	9	14	–	–	2114	–	–	360	–	11	**2561**
2000	–	–	1	–	16	–	–	1983	–	–	146	–	12	**2158**
2001	4	–	11	–	–	–	–	1053	–	–	128	–	16	**1212**
2002	15	1	5	–	–	–	–	693	–	–	220	–	9	**943**
2003	15	–	–	1	–	–	–	815	–	–	140	–	4	**975**
2004	7	–	–	–	–	–	–	1237	–	–	213	–	12	**1469**
2005	10	1	–	–	–	–	–	1002	–	–	61	–	4	**1078**
2006	46	–	–	–	–	–	–	690	–	–	136	–	–	**872**
2007	15	–	12	15	–	–	–	1034	–	–	49	2	20	**1147**
2008	45	7	2	–		–	–	634	–	3	49	–	15	**755**
2009	–	–	3	2	6	–	–	701	–	30	19	–	24	**768**
2010	58	–	–	–	–	–	–	497	–	–	21	1	6	**583**
2011	24	–	–	2	1	–	–	674	–	–	7	–	–	**708**
2012	17	–	3	1	9	2	–	546	–	–	27	–	18	**623**
2013	28	2	1	–	+	–	–	574	–	–	41	–	4	**651**
2014	59	10	6	17	4	–	–	403	2	–	27	–	17	**542**
2015	57	4	9	211	13	–	–	514	2	–	51	2	10	**871**
2016	161	7	4	74	–	51	–	782	4	–	136	–	60	**1275**
2017	81	5	–	8	4	–	–	8 44	2	2	211	2	23	**1182**
2018	146	28	35	29	–	–	–	926	5	3	302	5	25	**1504**
2019	228	11	32	22	30	–	2	1052	4	2	422	3	11	**1819**
2020[1]	145	–	14	18	33	–	–	1158	2	8	708	6	1	**2093**

1 – Provisional figures.

Table 7.3 *Sebastes norvegicus* in subareas 1 and 2. Nominal catch (t) by countries in Division 2.a.

Year	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Netherland	Norway	Poland	Portugal	Russia	Spain	UK	Total
1998	–	494	116	33		19	–	14 326	–	6	1 078	51	137	16 260
1999	–	35	210	38		7	–	14 598	–	3	976	7	156	16 030
2000	17	13	159	22		–	–	11 038	–	16	658	–	61	11 984
2001	33	30	227	17		1	–	8 002	–	6	612	1	103	9 032
2002	45	30	37	31	3	–	–	7 761	–	18	192	2	32	8 151
2003	94	9	122	35	4	–	89	5 970	–	6	264		130	6 723
2004	12	4	68	20	30	–	33	4 872	–	5	396	3	58	5 501
2005	37	9	60	36	8	–	48	4 855	–	56	265	8	48	5 430
2006	60	8	35	44	31	3	21	4 404	–	59	293	9	39	5 006
2007	119	15	55	69	68	13	20	4 101	–	70	599	3	35	5 167
2008	229	56	28	71	27	6	2	4 456	–	68	450	4	70	5 467
2009	70	1	55	79	60	–	1	4 543	–	17	500	–	7	5 333
2010	113	51	31	72	22	–	–	5 414	1	26	287	2	38	6 057
2011	–	51	9	49	20	–	1	3 942	–	–	695	2	13	4 782
2012	49	182	33	57	13	2	2	3 599	–	1	427	–	33	4 398

Year	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Netherland	Norway	Poland	Portugal	Russia	Spain	UK		Total
2013	55	343	–	45	8	–	–	3 076	–	9	475	–	466	**Denmark** – 1	4 478
2014	8	209	–	3	25	–	1	2 465	–	2	559	–	178		3 449
2015	18	49	15	–	22	–	–	1 946	12	–	439	–	47		2 548
2016	22	23	–	13	4	–	–	2 417	8	–	545	–	15		3 047
2017	41	12	19	36	61	–	2	2 455	22	88	680	38	137		3 591
2018	–	9	17	43	67	–	–	3 275	12	64	489	7	12	**–**	3 995
2019	15	14	61	34	53	–	–	4 493	16	68	794	57	13	**Lithuania – 1**	5 619
2020[1]	21	1	58	81	19	–	–	4520	–	72	946	–	15	**–**	5733

1 – Provisional figures.

Table 7.4 *Sebastes norvegicus* in subareas 1 and 2. Nominal catch (t) by countries in Division 2.b.

Year	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Netherlands	Norway	Poland	Portugal	Russia	Spain	UK	Total
1998	–	–	–	10	–				105	–	–	246	–	3	364
1999	–	–	–	–	–				38	–	–	355	–	2	395
2000	–	–	–	–	–				10	–	–	308	–	–	318
2001	–	–	–	–	–				79	–	1	223	–	–	303
2002	–	–	–	–	–				107	–	16	420	1	5	549
2003	–	–	–	–	–				68	–	–	75	–	–	143
2004	–	–	–	–	–				124	–	–	113	–	–	237
2005	–	–	–	13	–				228	–	–	288	–	–	529
2006	–	5	–	–	–				1211	–	10	284	–	–	1510
2007	–	12	–	–	–				649	–	155	242	–	–	1058
2008	–	–	–	–	–				126	–	1	250	–	–	377
2009	–	–	–	–	–				207	–	–	179	–	–	386
2010	–	–	–	–	–				83	–	2	257	–	–	342
2011	–	–	2	–	–	1	–	–	65	48	25	217	4	–	362
2012	–	21	–	35	–	1	8	3	102	34	16	227	–	49	496
2013	–	–	9	–	–	–	1	–	120	19	27	281	–	23	480
2014	–	–	–	–	–	–	–	–	185	19	3	221	–	16	444
2015	1	–	–	–	–	–	–	–	28	3	–	175	–	–	207
2016	7	–	–	–	–	–	–	–	40	14	–	183	–	–	244
2017	–	–	–	–	18	–	–	–	54	2	–	405	4	–	483
2018	1	–	–	14	6	–	–	–	75	19	–	1043	–	–	1158
2019	–	–	–	–	–	–	–	–	122	–	–	712	1	1	836
2020[1]	–	–	–	13	–	–	–	–	224	7	–	961	–	2	1207

[1] Provisional figures.

Table 7.5. *Sebastes norvegicus* in subareas 1 and 2. Catch numbers-at-age (in thousands).

Year/Age	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	+gp	Total Num.	Tonnes Land.
1992	5	22	78	114	394	549	783	1718	3102	2495	2104	1837	998	858	688	547	268	3110	19670	16185
1993	0	24	193	359	406	1036	1022	1523	2353	1410	1655	1678	745	716	534	528	576	3482	18240	16651
1994	46	7	292	640	816	1930	2096	2030	1601	2725	2668	1409	617	733	514	256	177	1508	20065	18120
1995	60	85	230	672	908	1610	2038	2295	1783	1406	785	563	670	593	419	368	250	3232	17967	15616
1996	9	119	313	361	879	1234	1638	2134	1675	1614	1390	952	679	439	560	334	490	3135	17955	18043
1997	9	98	156	321	686	1065	1781	2276	2172	1848	1421	851	804	608	511	205	334	2131	17277	17511
1998	28	51	206	470	721	968	1512	1736	1582	1045	1277	970	1018	846	443	764	486	3389	17512	19155
1999	78	593	855	572	1006	1230	1618	1480	1612	1239	1407	1558	1019	394	197	459	174	2131	17622	18986
2000	4	13	70	245	902	958	1782	1409	2121	2203	1715	753	483	458	132	230	224	895	14597	14460
2001	23	23	44	199	347	482	1120	1342	1674	1653	1243	568	119	183	154	112	135	254	9675	10547
2002	14	36	71	143	414	686	1199	1943	1377	1274	1196	388	313	99	104	117	113	253	9740	9643
2003	22	25	30	44	204	359	705	1687	1338	1071	937	481	367	146	84	51	18	69	7637	7841
2004	19	47	46	65	198	277	504	590	677	963	1059	787	436	169	183	108	79	186	6390	7320
2005	40	55	94	80	165	173	393	779	741	916	926	743	376	210	189	129	111	220	6338	7037
2006	45	32	56	70	245	204	201	809	549	779	794	747	496	332	310	188	165	397	6419	7348
2007	15	21	31	68	138	306	448	495	523	637	892	616	510	396	225	322	170	630	6443	7306
2008	1	4	14	12	49	139	265	366	361	443	442	538	547	479	281	223	144	1032	5342	6557

Year/Age	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	+gp	Total Num.	Tonnes Land.
2009	0	11	2	4	9	23	144	277	315	248	406	374	509	404	331	323	253	911	4544	6487
2010	1	0	10	7	4	20	75	261	291	529	359	311	531	502	385	295	247	776	4605	6982
2011	2	1	3	0	2	5	64	304	466	266	312	223	378	289	247	229	253	985	4028	5852
2012	15	10	5	12	0	2	228	226	322	295	191	169	184	283	266	268	262	1152	3891	5517
2013	31	88	138	57	10	44	58	202	241	437	321	205	213	270	258	196	322	1216	4309	5608
2014	5	4	8	8	8	15	26	49	67	204	197	148	167	184	165	156	213	1197	2821	4438
2015	15	16	14	17	26	43	29	96	113	128	170	147	159	115	99	96	220	1156	2661	3628
2016	53	59	60	88	88	147	293	217	266	81	178	176	110	162	110	182	191	1103	3563	4674
2017[1]	106	82	132	69	132	165	311	455	225	132	105	83	85	102	88	138	182	1169	3760	5257
2018	Data not available during AFWG 2021.																			
2019	Data not available during AFWG 2021.																			
2020	Data not available during AFWG 2021.																			

[1] – Provisional figures. Weight–at–age in the catches was not available for 2018–2020.

Table 7.6. *Sebastes norvegicus* in subareas 1 and 2. Catch weights at age (kg).

Year/Age	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	+gp
1992	0.18	0.29	0.48	0.42	0.50	0.59	0.58	0.65	0.65	0.71	0.82	0.84	0.94	1.02	1.03	1.15	1.27	1.27
1993	0.2	0.33	0.36	0.43	0.51	0.51	0.64	0.64	0.76	0.86	0.89	0.98	1	1.03	1.21	1.03	1.2	1.14
1994	0.25	0.37	0.38	0.49	0.51	0.64	0.74	0.76	0.86	0.95	1.03	1.07	1.11	1.16	1.15	1.13	1.02	1.36
1995	0.33	0.43	0.64	0.61	0.59	0.65	0.74	0.79	0.84	0.92	1.12	1.01	1.01	1.21	1.14	1.09	1.3	1.01
1996	0.22	0.49	0.56	0.65	0.71	0.81	0.84	0.88	0.96	1	1.02	1.01	1	1.03	1.04	1.14	1.09	1.16
1997	0.23	0.51	0.53	0.74	0.72	0.78	0.8	0.86	0.91	0.99	1.16	1.18	1.21	1.34	1.28	1.54	1.19	1.29
1998	0.37	0.21	0.47	0.62	0.67	0.77	0.77	0.85	1.05	0.96	1.25	1.28	1.3	1.23	1.87	1.46	1.73	1.29
1999	0.14	0.26	0.44	0.57	0.69	0.78	0.86	1.04	1.07	1.12	1.18	1.71	1.09	1.18	1.04	1.34	1.18	1.34
2000	0.19	0.24	0.32	0.44	0.53	0.64	0.73	0.84	0.96	1.11	1.25	1.32	1.53	1.06	1.29	1.32	1.12	1.2
2001	0.15	0.26	0.45	0.55	0.58	0.67	0.8	0.89	1.01	1.14	1.33	1.43	1.62	1.6	1.47	2	2.7	2.31
2002	0.17	0.25	0.33	0.42	0.54	0.67	0.72	0.84	0.98	1.09	1.2	1.3	1.44	1.78	1.68	1.88	2.12	1.84
2003	0.19	0.22	0.31	0.39	0.49	0.58	0.69	0.84	0.96	1.05	1.29	1.36	1.65	1.74	2.09	1.85	2.3	2.38
2004	0.21	0.26	0.36	0.45	0.51	0.59	0.68	0.8	0.96	1.07	1.22	1.34	1.57	1.67	1.75	2.09	1.9	2.04
2005	0.16	0.21	0.36	0.45	0.52	0.58	0.68	0.82	0.94	1.03	1.16	1.36	1.46	1.51	1.67	1.91	2.23	2.27
2006	0.13	0.15	0.28	0.41	0.51	0.58	0.66	0.74	0.83	1	1.14	1.27	1.39	1.46	1.37	1.47	1.64	2.03
2007	0.15	0.21	0.33	0.39	0.5	0.59	0.65	0.77	0.9	1	1.09	1.27	1.42	1.32	1.53	1.47	1.69	1.81
2008	0.41	0.55	0.55	0.57	0.52	0.58	0.65	0.81	0.9	1.07	1.14	1.36	1.51	1.81	1.99	2.01	2.26	1.93
2009	0.00	1.01	0.34	0.59	0.61	0.66	0.82	0.92	0.94	1.09	1.22	1.35	1.40	1.57	1.68	1.74	1.73	2.25

Year/Age	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	+gp
2010	0.15	0.00	0.10	0.32	0.52	0.73	0.77	0.89	0.98	1.09	1.25	1.40	1.48	1.64	1.77	1.99	1.82	1.86
2011	0.16	0.20	0.21	0.00	0.54	0.52	0.72	0.91	1.08	1.14	1.20	1.45	1.40	1.43	1.54	1.60	1.74	1.93
2012	0.19	0.25	0.33	0.72	0.61	0.88	0.70	0.86	0.95	1.02	1.13	1.18	1.33	1.48	1.31	1.55	1.50	2.59
2013	0.20	0.27	0.32	0.44	0.47	0.55	0.63	0.88	0.96	1.08	1.08	1.19	1.21	1.39	1.38	1.62	1.41	1.81
2014	0.20	0.26	0.39	0.41	0.56	0.61	0.71	0.87	0.95	1.07	1.14	1.28	1.46	1.35	1.51	1.62	1.69	1.84
2015	0.16	0.22	0.30	0.50	0.51	0.60	0.66	0.88	0.93	1.04	1.15	1.18	1.23	1.34	1.51	1.50	1.48	1.62
2016	0.17	0.21	0.34	0.62	0.53	0.66	0.68	0.86	0.94	1.03	1.11	1.32	1.43	1.29	1.42	1.43	1.48	2.67
2017[1]	0.18	0.23	0.29	0.38	0.55	0.59	0.70	0.80	0.92	1.06	1.15	1.35	1.40	1.56	1.37	1.74	1.83	2.92
2018	Data not available during AFWG 2021.																	
2019	Data not available during AFWG 2021.																	
2020	Data not available during AFWG 2021.																	

[1] – **Provisional figures.**

Table 7.7. *Sebastes norvegicus* in subareas 1 and 2. Fishing mortalities as estimated by Gadget.

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.08	0.07	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01
11	0.11	0.09	0.08	0.08	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.03	0.03	0.02	0.02
12	0.15	0.12	0.11	0.11	0.11	0.06	0.07	0.07	0.08	0.08	0.06	0.05	0.05	0.04	0.04
13	0.20	0.15	0.13	0.13	0.14	0.12	0.10	0.10	0.11	0.11	0.09	0.07	0.07	0.06	0.06
14	0.25	0.19	0.16	0.16	0.17	0.14	0.16	0.13	0.15	0.15	0.13	0.10	0.09	0.08	0.07
15	0.31	0.23	0.19	0.19	0.19	0.16	0.19	0.18	0.18	0.19	0.16	0.12	0.12	0.10	0.09
16	0.38	0.27	0.22	0.21	0.22	0.18	0.21	0.21	0.24	0.23	0.19	0.15	0.14	0.12	0.11
17	0.44	0.32	0.26	0.24	0.25	0.20	0.23	0.22	0.26	0.28	0.22	0.17	0.16	0.13	0.12
18	0.48	0.36	0.29	0.27	0.27	0.22	0.25	0.24	0.27	0.30	0.25	0.19	0.17	0.15	0.13
19	0.51	0.38	0.32	0.29	0.30	0.24	0.26	0.25	0.29	0.32	0.26	0.20	0.18	0.15	0.14
20	0.54	0.40	0.33	0.31	0.31	0.25	0.28	0.27	0.30	0.33	0.27	0.21	0.19	0.16	0.15
21	0.56	0.42	0.34	0.32	0.33	0.26	0.29	0.28	0.31	0.34	0.28	0.21	0.19	0.16	0.15

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
22	0.58	0.43	0.34	0.32	0.33	0.26	0.29	0.28	0.32	0.34	0.28	0.21	0.19	0.15	0.14
23	0.59	0.43	0.34	0.32	0.33	0.26	0.29	0.28	0.32	0.34	0.28	0.20	0.18	0.15	0.14
24	0.58	0.42	0.33	0.31	0.32	0.25	0.28	0.27	0.31	0.33	0.27	0.20	0.18	0.14	0.13
25	0.57	0.41	0.32	0.30	0.30	0.24	0.27	0.26	0.29	0.31	0.25	0.19	0.17	0.13	0.12
26	0.55	0.38	0.30	0.28	0.28	0.23	0.26	0.25	0.28	0.29	0.23	0.17	0.16	0.12	0.12
27	0.52	0.36	0.27	0.26	0.26	0.21	0.24	0.23	0.26	0.27	0.20	0.16	0.15	0.11	0.11
28	0.50	0.34	0.25	0.24	0.24	0.19	0.22	0.21	0.24	0.24	0.19	0.14	0.13	0.10	0.10
29	0.47	0.31	0.23	0.22	0.22	0.17	0.20	0.19	0.22	0.22	0.17	0.12	0.11	0.09	0.09
30	0.43	0.27	0.19	0.17	0.17	0.13	0.14	0.13	0.14	0.14	0.10	0.10	0.09	0.06	0.06
15+	0.500	0.358	0.283	0.266	0.270	0.217	0.242	0.235	0.264	0.280	0.225	0.171	0.156	0.126	0.118

Age	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
9	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.03	0.05

Age	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
11	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.04	0.06	0.09
12	0.04	0.04	0.04	0.04	0.03	0.05	0.04	0.04	0.05	0.04	0.04	0.06	0.07	0.10	0.14
13	0.05	0.06	0.06	0.06	0.05	0.07	0.06	0.06	0.07	0.06	0.05	0.08	0.10	0.14	0.20
14	0.07	0.08	0.08	0.08	0.07	0.09	0.08	0.09	0.10	0.09	0.07	0.11	0.13	0.19	0.27
15	0.09	0.09	0.10	0.10	0.09	0.12	0.10	0.11	0.12	0.11	0.09	0.13	0.16	0.24	0.35
16	0.11	0.11	0.12	0.11	0.11	0.14	0.12	0.13	0.15	0.13	0.11	0.15	0.19	0.28	0.42
17	0.12	0.13	0.13	0.13	0.12	0.16	0.14	0.15	0.17	0.15	0.12	0.17	0.22	0.32	0.49
18	0.13	0.14	0.14	0.14	0.13	0.18	0.15	0.16	0.18	0.16	0.14	0.19	0.24	0.36	0.55
19	0.14	0.14	0.15	0.15	0.14	0.19	0.16	0.17	0.19	0.17	0.14	0.20	0.25	0.38	0.59
20	0.14	0.15	0.15	0.15	0.15	0.19	0.17	0.17	0.20	0.18	0.15	0.20	0.26	0.39	0.62
21	0.14	0.15	0.15	0.15	0.15	0.20	0.17	0.18	0.20	0.18	0.15	0.21	0.26	0.39	0.62
22	0.14	0.15	0.15	0.15	0.15	0.19	0.16	0.17	0.20	0.17	0.15	0.20	0.25	0.38	0.60
23	0.13	0.14	0.15	0.14	0.14	0.19	0.16	0.17	0.19	0.17	0.14	0.19	0.24	0.36	0.56
24	0.12	0.13	0.14	0.13	0.14	0.18	0.15	0.16	0.18	0.16	0.13	0.18	0.23	0.33	0.52
25	0.12	0.13	0.13	0.12	0.13	0.17	0.15	0.15	0.17	0.15	0.13	0.17	0.21	0.31	0.47
26	0.11	0.12	0.12	0.11	0.12	0.16	0.14	0.14	0.16	0.14	0.12	0.16	0.19	0.28	0.42
27	0.11	0.11	0.12	0.10	0.11	0.15	0.13	0.13	0.15	0.13	0.11	0.15	0.18	0.25	0.37
28	0.10	0.11	0.11	0.09	0.10	0.13	0.12	0.12	0.14	0.12	0.10	0.14	0.16	0.23	0.33

Age	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
29	0.09	0.10	0.10	0.09	0.10	0.12	0.10	0.11	0.13	0.11	0.09	0.13	0.15	0.21	0.30
30	0.06	0.07	0.07	0.06	0.07	0.09	0.08	0.09	0.10	0.08	0.07	0.09	0.10	0.13	0.18
15+	0.115	0.123	0.127	0.120	0.122	0.160	0.137	0.144	0.163	0.142	0.122	0.167	0.207	0.302	0.462

Table 7.8. *Sebastes norvegicus* in subareas 1 and 2. Stock numbers, biomass, mean weight and maturity ogives as estimated by GADGET.

		total stock			mature			immature			recruit
year	Number	mean wt	biomass	number	mean wt	biomass	number	mean wt	biomass	F(15+)	age 3
	(millions)	(kg)	(1000t)	(millions)	(kg)		(millions)	(kg)	(1000t)		(millions)
1986	384	0.37	141.98	112	0.67	75.09	271	0.25	66.88		3.79
1987	372	0.37	138.88	111	0.66	73.16	261	0.25	65.72		2.97
1988	347	0.38	133.09	108	0.63	68.34	239	0.27	64.75		1.67
1989	324	0.40	129.33	105	0.62	64.98	219	0.29	64.34		1.57
1990	299	0.40	119.60	100	0.58	57.94	199	0.31	61.65	0.50	1.66
1991	281	0.42	118.20	100	0.59	58.40	182	0.33	59.80	0.36	1.58
1992	266	0.45	119.00	101	0.61	61.70	165	0.35	57.30	0.28	1.46
1993	250	0.47	118.50	101	0.64	65.03	149	0.36	53.47	0.27	1.39
1994	237	0.49	115.64	99	0.68	66.98	138	0.35	48.65	0.27	1.69
1995	221	0.52	114.30	97	0.72	69.98	124	0.36	44.31	0.22	1.09
1996	201	0.54	109.31	93	0.75	70.05	108	0.36	39.26	0.24	0.75
1997	182	0.57	103.72	88	0.79	69.03	95	0.37	34.69	0.24	0.76
1998	160	0.59	95.12	80	0.81	65.00	80	0.37	30.12	0.26	0.40
1999	140	0.61	85.40	71	0.83	59.33	69	0.38	26.07	0.28	0.41
2000	124	0.64	79.18	65	0.86	56.08	58	0.40	23.10	0.23	0.31

		total stock			mature			immature			recruit
year	Number	mean wt	biomass	number	mean wt	biomass	number	mean wt	biomass	F(15+)	age 3
	(millions)	(kg)	(1000t)	(millions)	(kg)		(millions)	(kg)	(1000t)		(millions)
2001	112	0.68	76.15	61	0.90	55.28	51	0.41	20.87	0.17	0.40
2002	102	0.72	73.44	57	0.95	54.70	45	0.42	18.74	0.16	0.32
2003	93	0.78	71.76	55	1.01	54.99	38	0.44	16.77	0.13	0.19
2004	86	0.81	70.10	52	1.07	55.18	35	0.43	14.92	0.12	0.44
2005	80	0.85	68.16	49	1.13	55.01	31	0.42	13.15	0.11	0.31
2006	82	0.80	65.69	45	1.19	53.90	37	0.32	11.79	0.12	1.16
2007	75	0.83	62.67	42	1.24	52.16	33	0.32	10.51	0.13	0.24
2008	70	0.85	60.06	39	1.30	50.48	32	0.30	9.57	0.12	0.38
2009	65	0.88	57.39	36	1.34	48.48	29	0.31	8.91	0.12	0.27
2010	59	0.90	53.11	33	1.37	44.81	27	0.31	8.30	0.16	0.21
2011	65	0.78	50.65	30	1.40	42.32	35	0.24	8.33	0.14	1.27
2012	81	0.60	48.88	28	1.40	39.83	53	0.17	9.05	0.14	2.27
2013	75	0.62	46.64	27	1.35	37.15	47	0.20	9.49	0.16	0.10
2014	69	0.66	45.51	27	1.31	35.54	42	0.24	9.97	0.14	0.03
2015	63	0.71	45.14	27	1.28	34.75	36	0.29	10.39	0.12	0.04
2016	84	0.53	44.56	27	1.25	33.13	58	0.20	11.43	0.17	2.68

		total stock			mature			immature			recruit
year	**Number (millions)**	**mean wt (kg)**	**biomass (1000t)**	**number (millions)**	**mean wt (kg)**	**biomass**	**number (millions)**	**mean wt (kg)**	**biomass (1000t)**	**F(15+)**	**age 3 (millions)**
2017	103	0.43	43.91	26	1.18	31.13	76	0.17	12.78	0.21	2.64
2018	99	0.42	41.73	26	1.06	28.11	73	0.19	13.62	0.30	0.61
2019	136	0.29	39.49	26	0.94	23.89	110	0.14	15.60	0.46	4.73

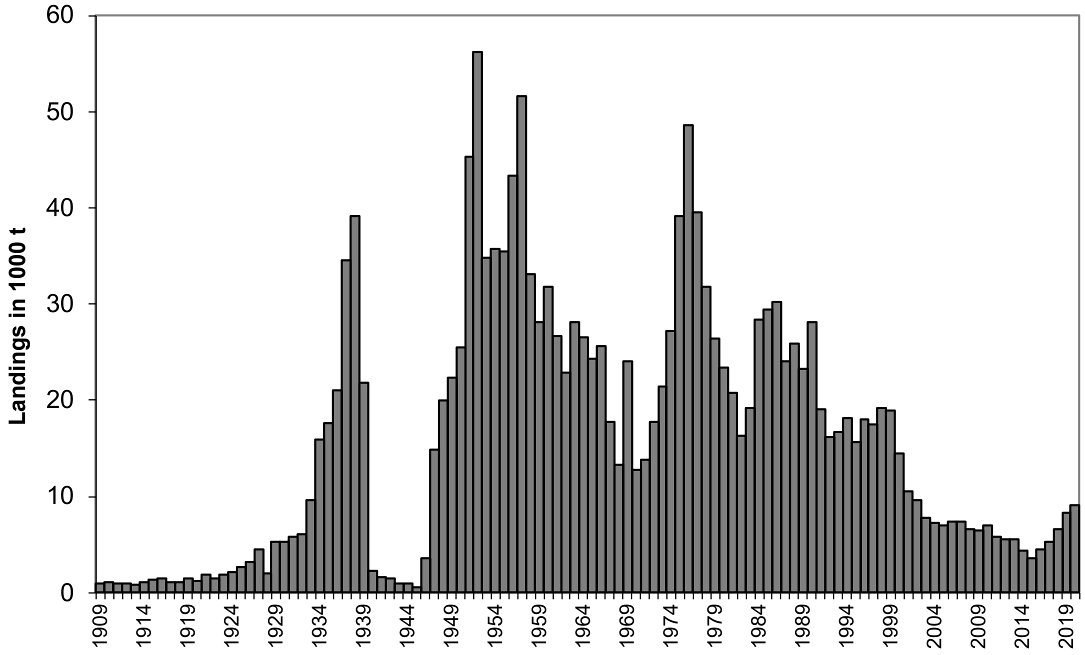


Figure 7.1. Sebastes norvegicus in subareas 1 and 2. Total international landings 1908–2020 (in thousand tonnes).

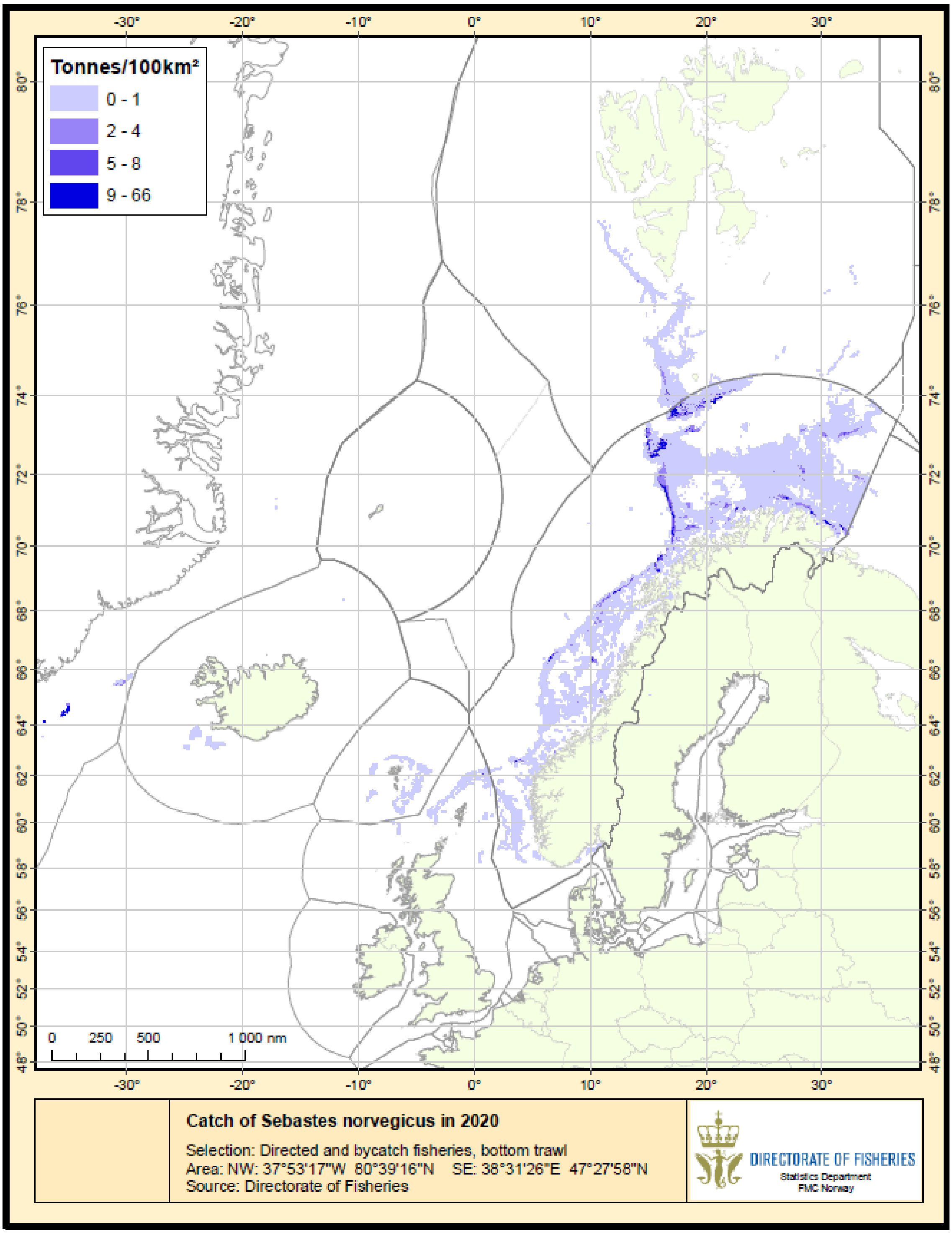
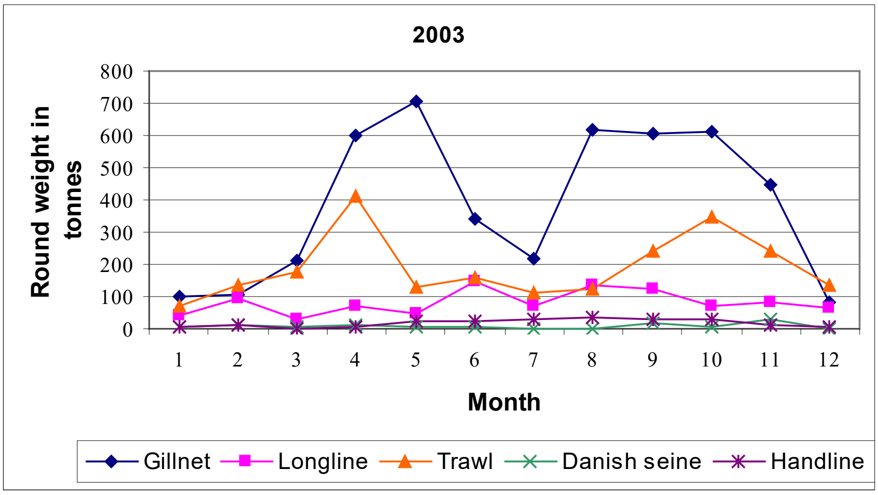
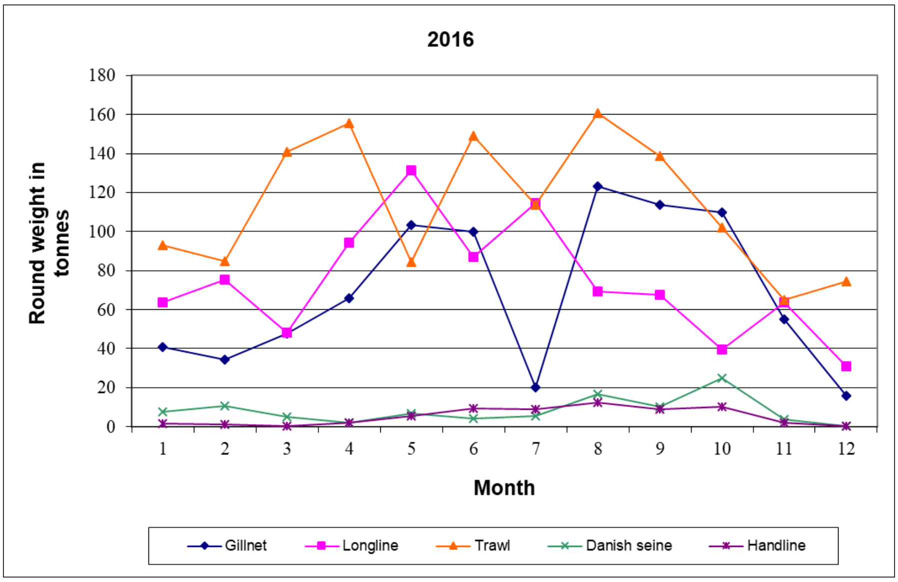


Figure 7.2. Sebastes norvegicus in subareas 1 and 2. Catches (including bycatch) of *Sebastes norvegiucs* in 2020 from Norwegian logbooks. Due to reporting on the genus level these catches may contain a considerable amount of Sebastes mentella.





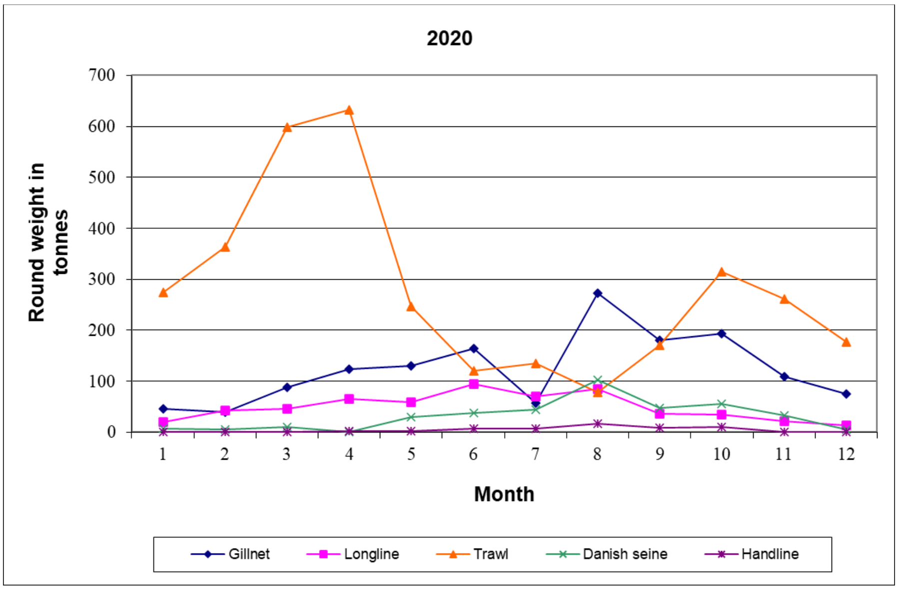


Figure 7.3a. Illustration of the seasonality in the different Norwegian S. norvegicus fisheries in 2003, 2016 and 2020, also illustrating how the current regulations are working.

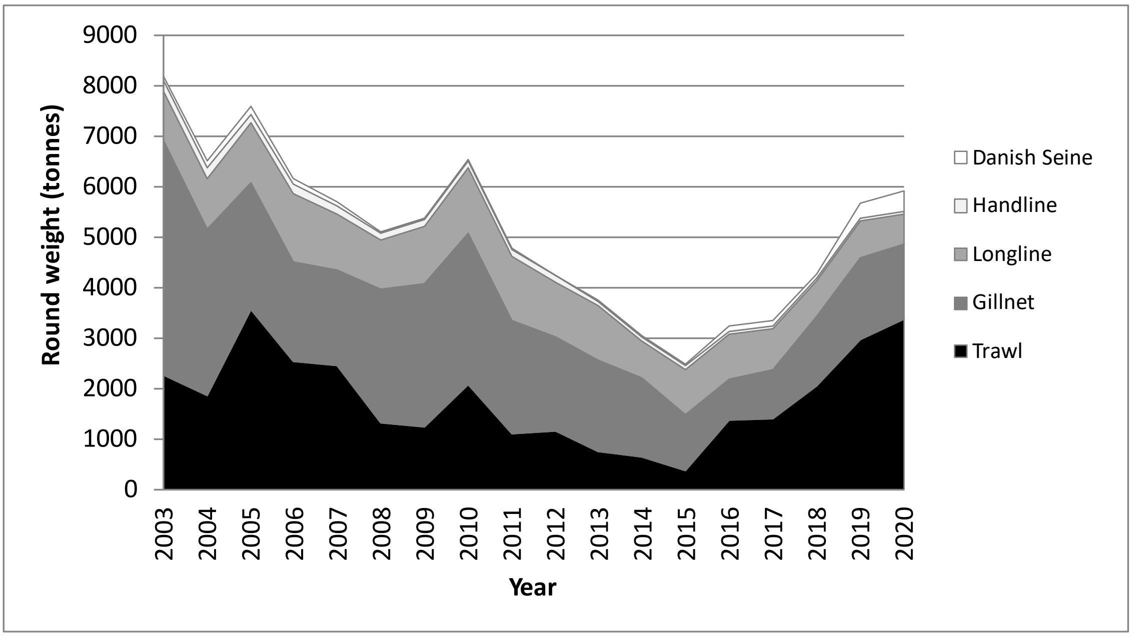


Figure 7.3b. Interannual changes in the Norwegian catches by fleet of *S. norvegicus* fisheries (2003–2020).

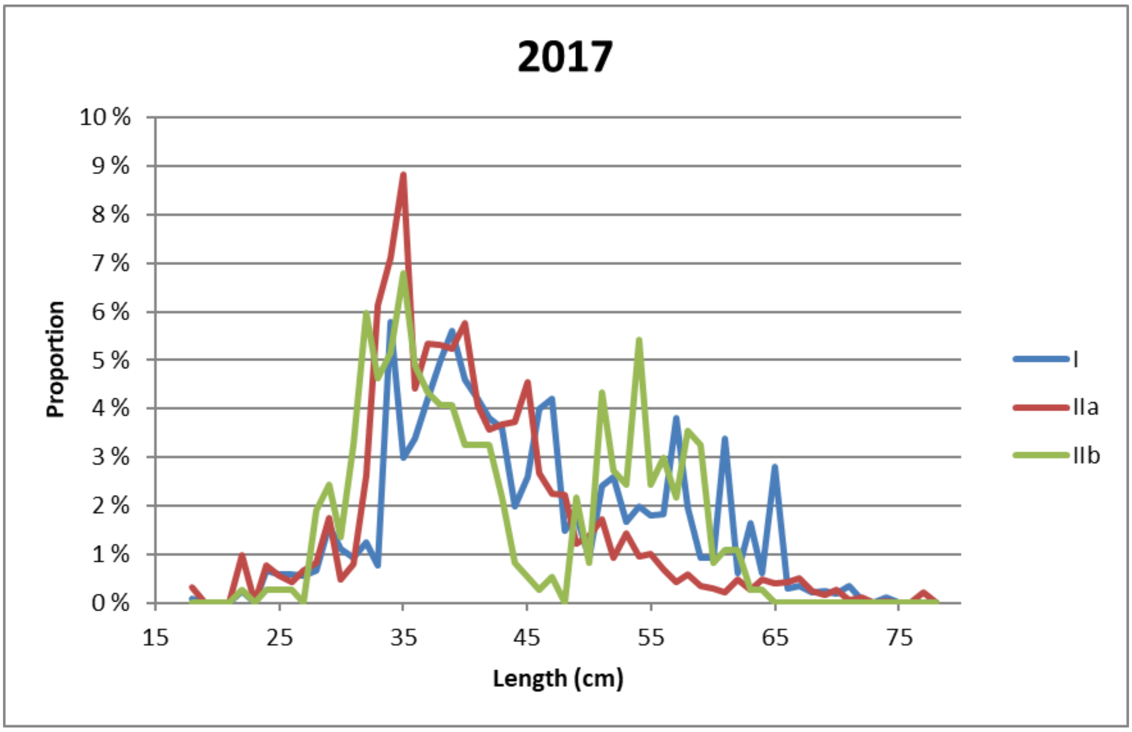


Figure 7.4. *Sebastes norvegicus*. Length frequency of *S. norvegicus* reported from Norwegian catches in Subarea 1, 2.a and 2.b in 2017, all gears combined. Data separated by gears and areas was not available for 2018–2020 during AFWG 2021.

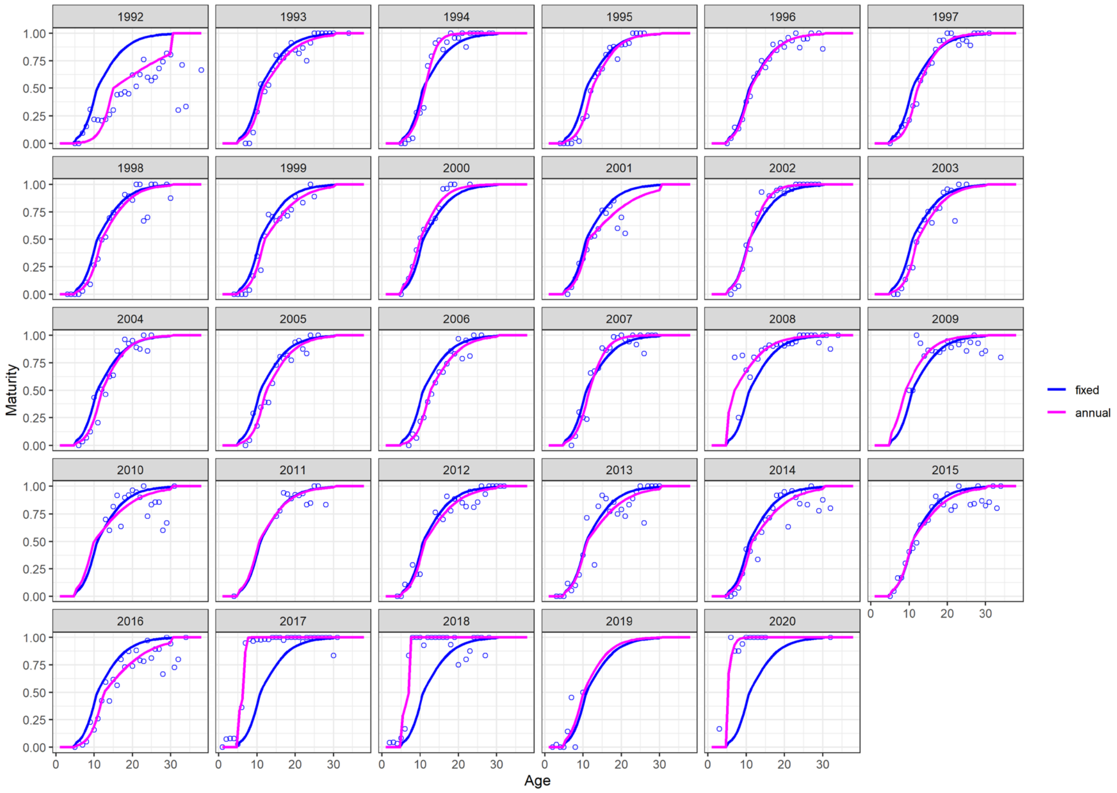
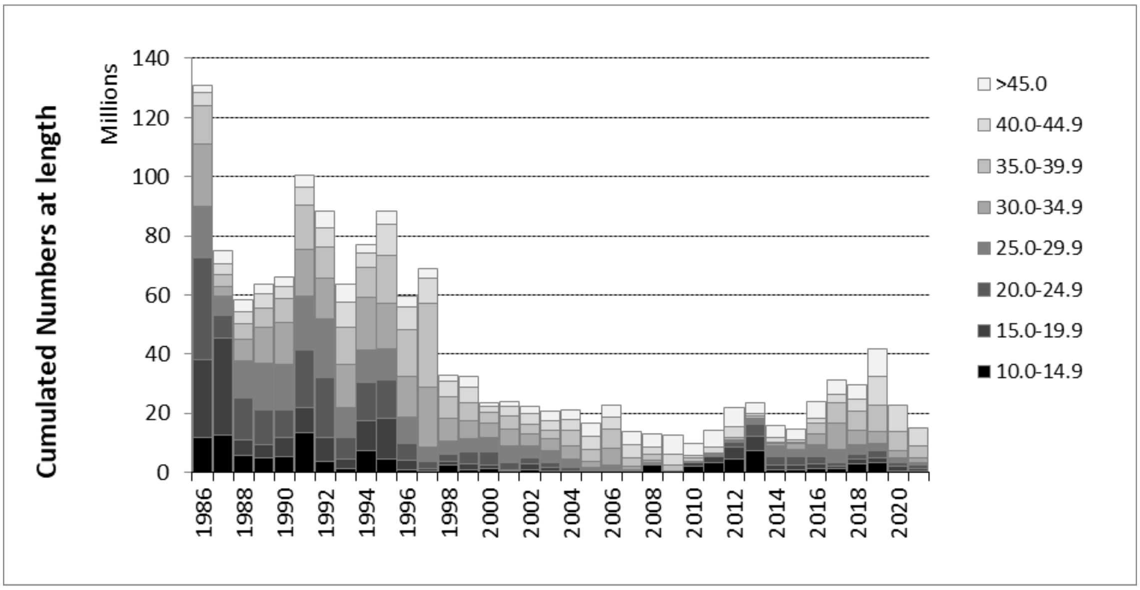


Figure 7.5a. Proportion maturity–at–age of *S. norvegicus* in subareas 1 and 2 derived from Norwegian commercial and survey data (Table E4). The proportions were derived from samples with at least five individuals. Updated for the 2020 assessment, but due to a lack of data in later years only the data up to 2016 was used in the model.

Figure 7.5b. ***Sebastes norvegicus*** **in subareas 1 and 2. Estimates of maturity–at–age by Gadget. Input data have been proportions of** ***S. norvegicus*** **mature both at age and length as collected and classified from Norwegian commercial landings and surveys.**



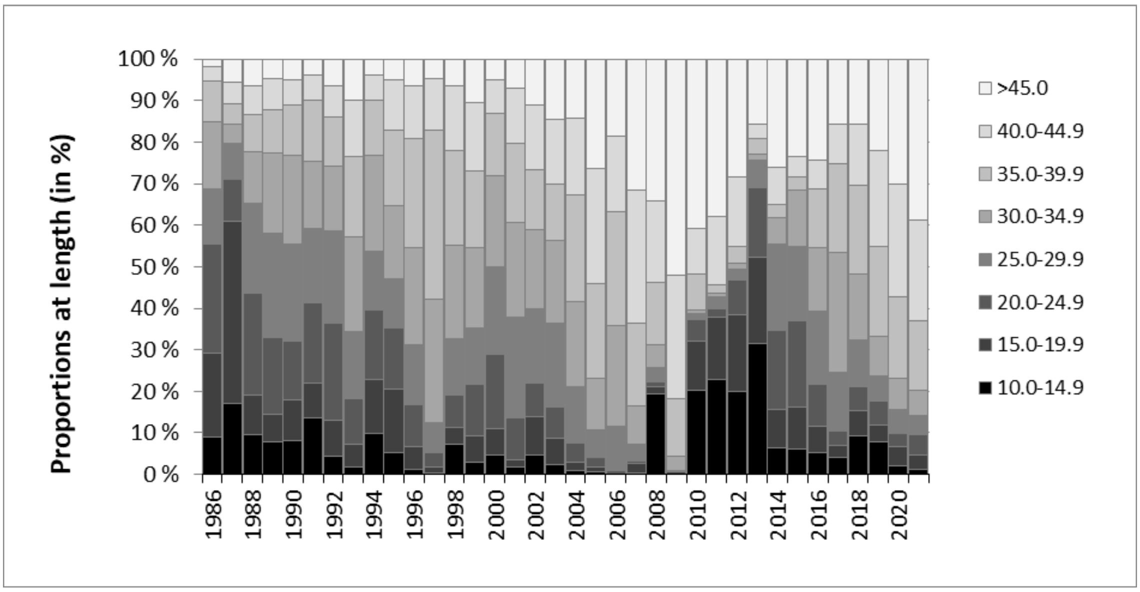


Figure 7.6a. *Sebastes norvegicus*. Abundance indices disaggregated by length for the winter Norwegian Barents Sea (Division 2.a) bottom–trawl survey (BS–NoRu–Q1 (BTr); joint with Russia some of the years since 2000), for 1986–2021 (ref. Table E1a). Top: absolute index values, bottom: relative frequencies.

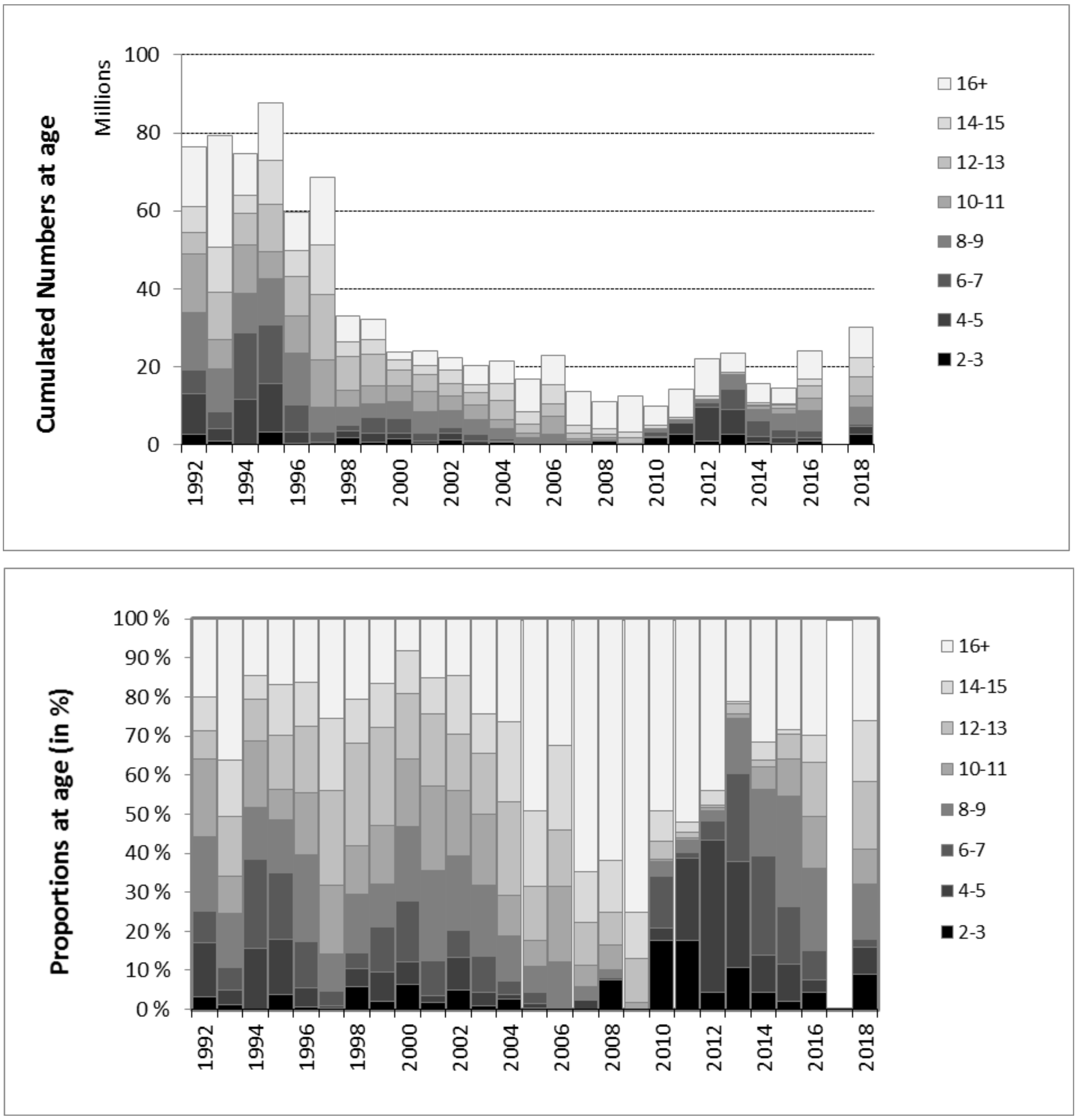


Figure 7.6b. ***Sebastes norvegicus.*** **Abundance indices by age from the winter Norwegian Barents Sea (Division 2.a) bottom–trawl survey (BS–NoRu–Q1 (BTr); joint with Russia some of the years since 2000), for 1992–2018 (ref. Table E1b). Age readings for 2017, 2019 and 2020 not available during AFWG 2021. Top: absolute index, bottom: relative frequencies.**

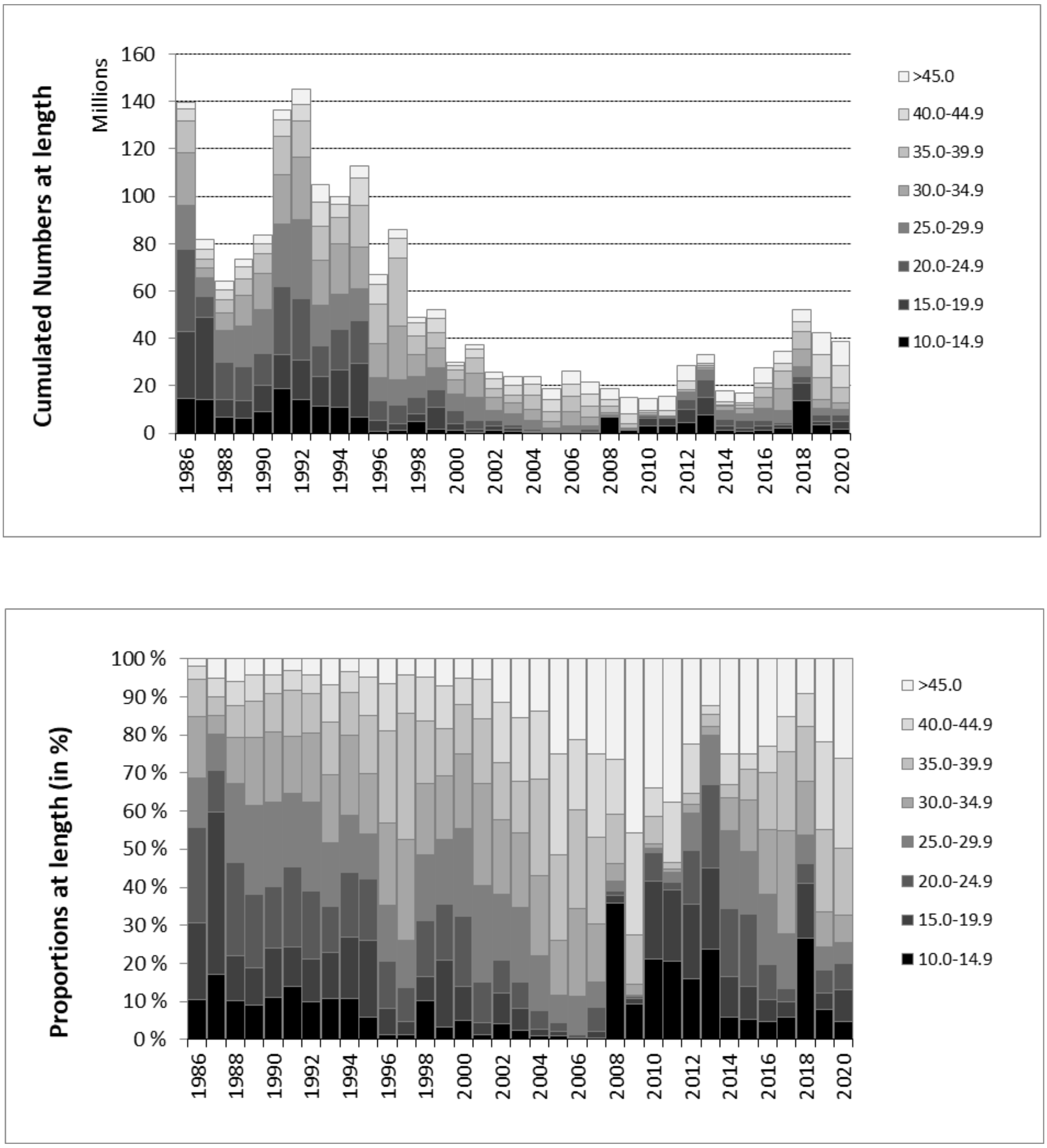


Figure 7.7a. *Sebastes norvegicus.* Abundance indices disaggregated by length when combining the Norwegian bottom–trawl surveys 1986–2020 in the Barents Sea (winter) and at Svalbard (summer/fall). Top: absolute index values. Bottom: relative frequencies. Horizontal line indicates the median length in the surveyed population.

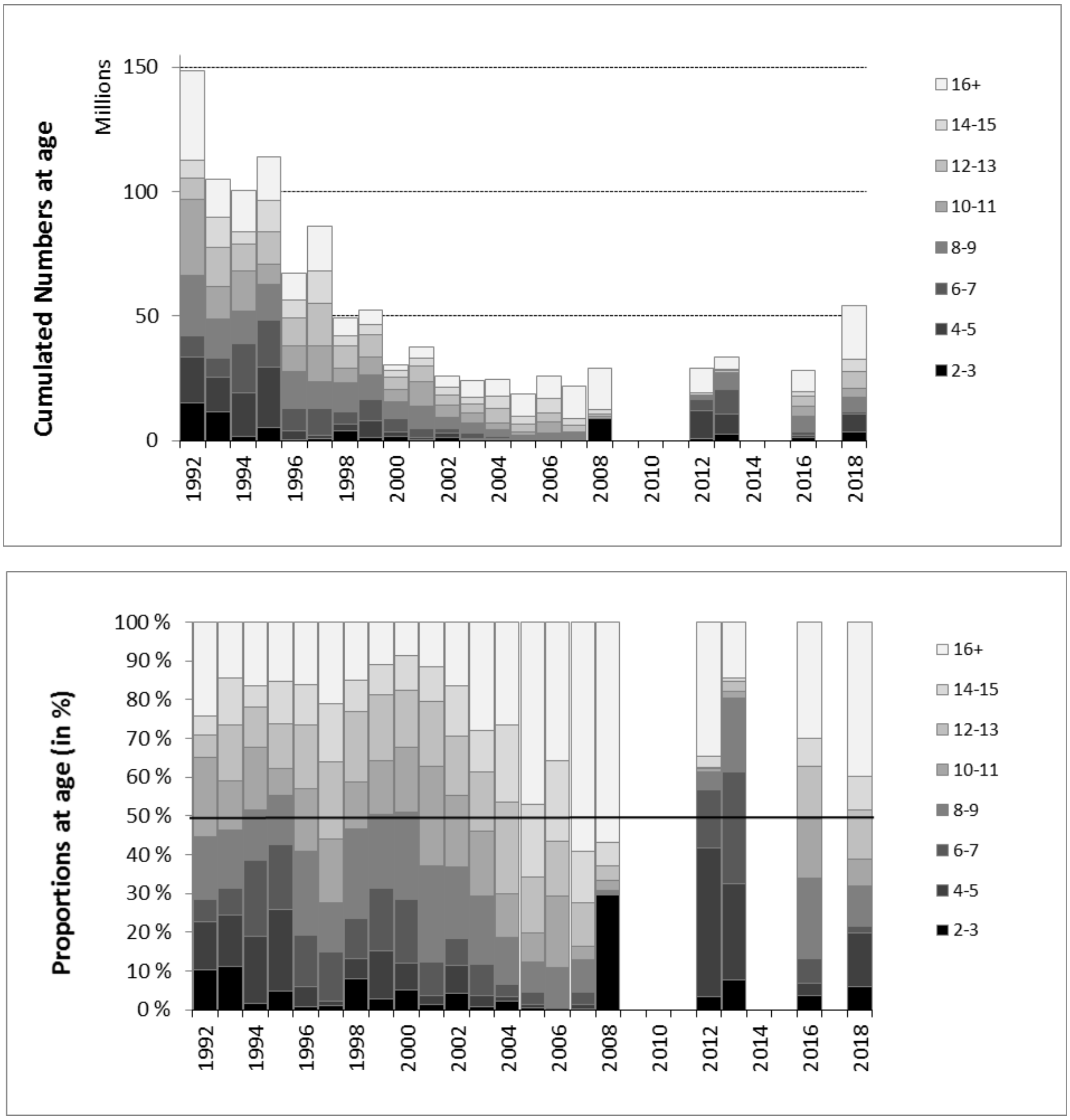


Figure 7.7b. *Sebastes norvegicus*. Abundance indices disaggregated by age. Combined Norwegian bottom–trawl surveys 1992–2018 in the Barents Sea (winter) and Svalbard survey (summer/fall). Top: absolute index values, bottom: relative frequencies. Horizontal line indicates median age of the surveyed population. In 2009–2011, 2014–2015, 2017, 2019 and 2021 there was insufficient number of age readings to derive numbers-at-age.

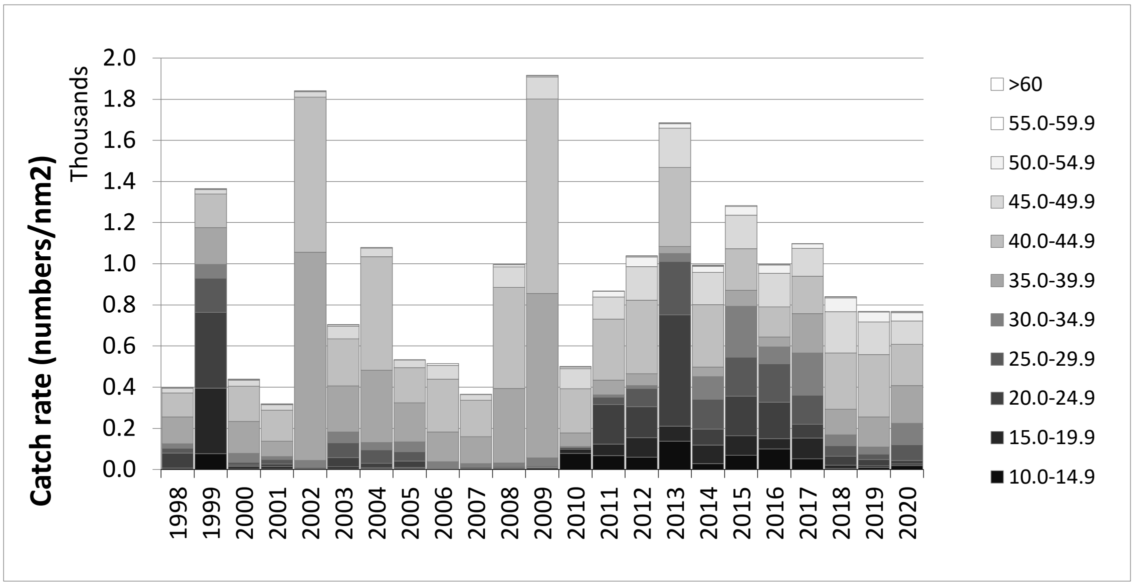


Figure 7.8. ***Sebastes norvegicus.*** **Catch rates (numbers/nm) disaggregated by length for the Barents Sea coastal survey 1998–2020. Top: absolute catch rates. Bottom: relative values.**

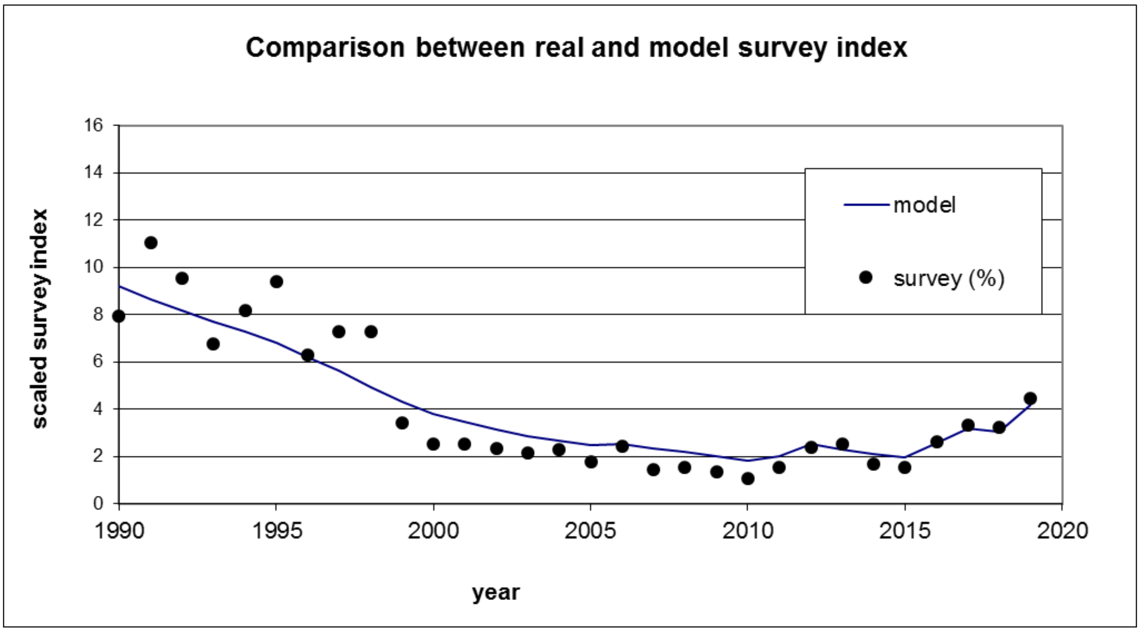


Figure 7.9. ***Sebastes norvegicus*** **in subareas 1 and 2. Comparison of observed and modelled survey indices (total number scaled to sum=100 during the period) for the Barents Sea winter survey in February. Dots: survey indices. Plain lines: survey indices estimated by the model.**

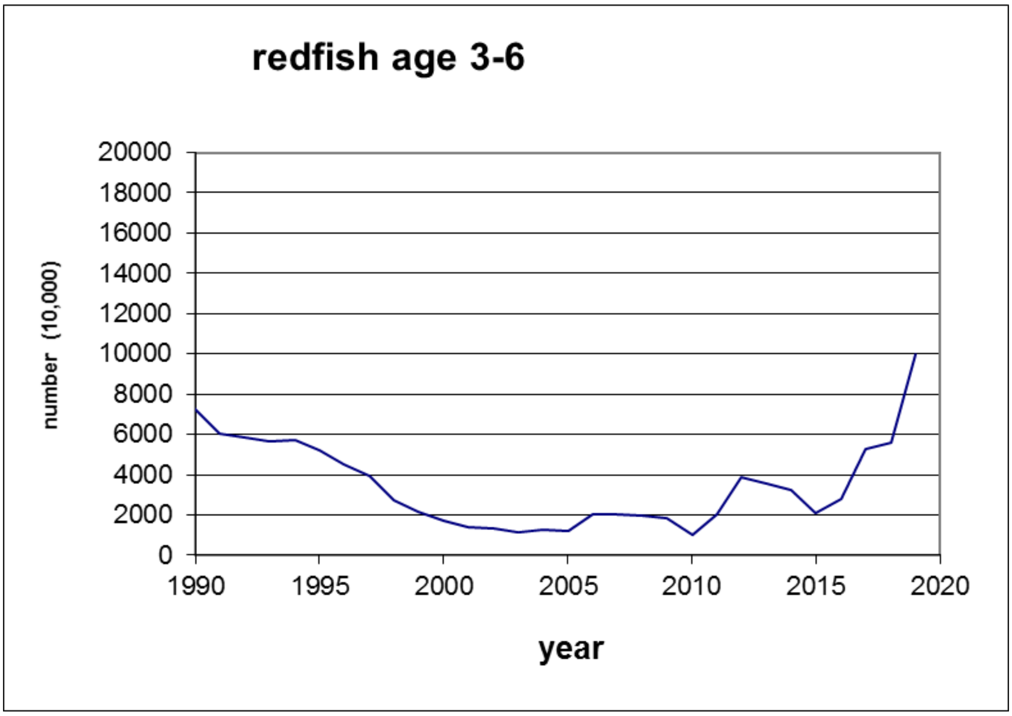


Figure 7.10. ***Sebastes norvegicus*** **in subareas 1 and 2. Estimates of abundance–at–age 3–6 by Gadget. Note that recent year (since 2015) have very little tuning data behind them.**

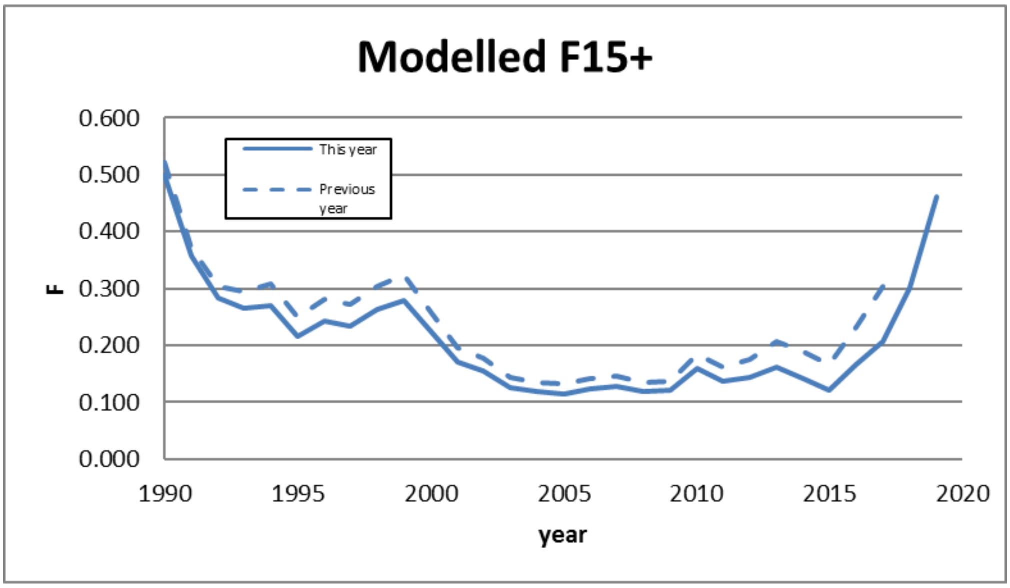


Figure 7.11. ***Sebastes norvegicus*** **in subareas 1 and 2. Unweighted average fishing mortality of ages 15+. Solid line shows this years assessment and the dashed line shows last assessment.**

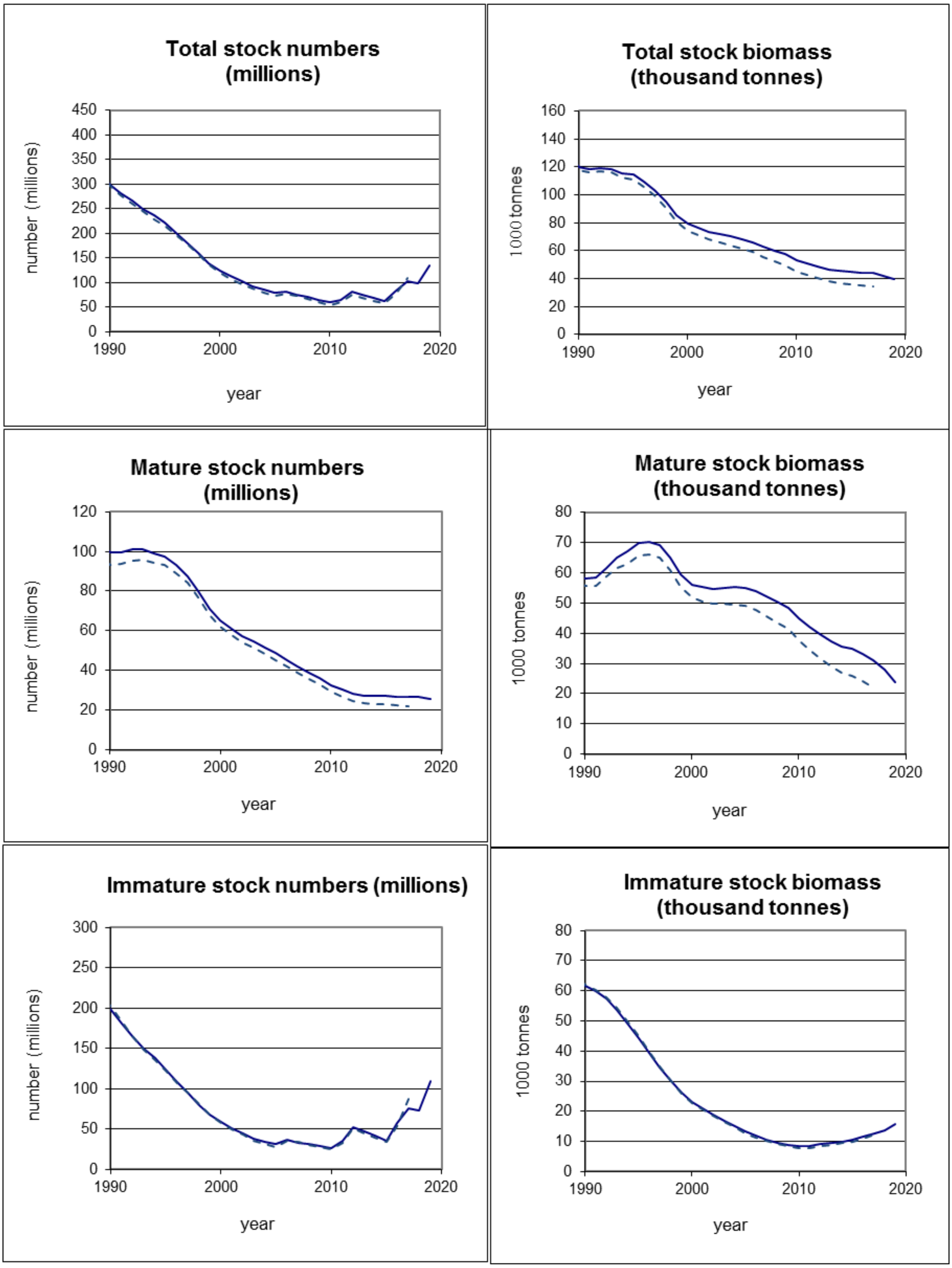


Figure 7.12. ***Sebastes norvegicus*** **in subareas 1 and 2. Stock numbers (in thousands) and biomass (in tonnes) for the total stock (3+; upper panel), and the fishable and mature stock (middle panel), and the immature stock (lower panel), as estimated by Gadget using two surveys as input. Solid line shows this years assessment and the dashed line shows last assessment.**

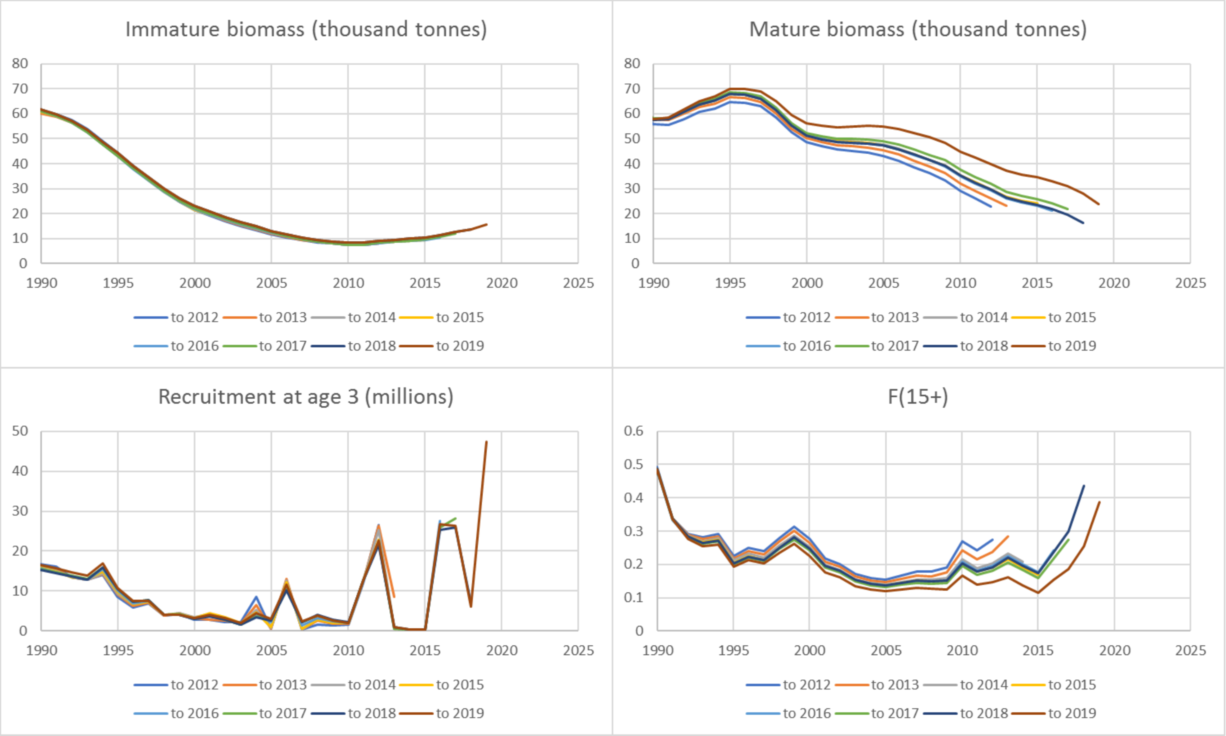


Figure 7.13. Gadget retrospective trends 2012 to 2019, immature biomass, mature biomass, recruitment–at–age 3, and F(15+).

Table E1a. Sebastes norvegicus in subareas 1 and 2. Abundance indices (numbers in millions) – on length – from the wnter Norwegian Barents Sea (Division 2.a) bottom–trawl survey (BS–NoRu–Q1 (BTr)) from 1986 to 2021. The area coverage was extended from 1993.

Length group (cm)										
Year	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	Total
1986	3.0	11.7	26.4	34.3	17.7	21.0	12.8	4.4	2.6	133.9
1987	7.7	12.7	32.8	7.7	6.4	3.4	3.8	3.8	4.2	82.5
1988	1.0	5.6	5.5	14.2	12.6	7.3	5.2	4.1	3.7	59.2
1989	48.7	4.9	4.3	11.8	15.9	12.2	6.6	4.8	3.0	112.2
1990	9.2	5.3	6.5	9.4	15.5	14.0	8.0	4.0	3.4	75.3
1991	4.2	13.6	8.4	19.4	18.0	16.1	14.8	6.0	4.0	104.5
1992	1.8	3.9	7.7	20.6	19.7	13.7	10.5	6.6	5.8	90.3
1993	0.1	1.2	3.5	6.9	10.3	14.5	12.5	8.6	6.3	63.9
1994	0.7	7.5	10.1	12.8	10.9	17.8	10.1	4.8	2.9	77.6
1995	0.4	4.7	13.5	13.1	10.4	15.4	16.2	10.6	4.6	88.9
1996	0.0	0.7	3.3	5.9	8.7	14.0	15.7	7.5	3.9	59.8
1997	0.0	0.5	1.3	2.7	6.9	21.4	28.2	8.5	3.3	72.7
1998	0.1	3.9	2.0	7.4	5.8	25.3	13.2	7.0	2.3	67.0
1999	0.2	0.9	2.1	4.0	4.3	6.2	6.0	5.3	3.4	32.4
2000	0.5	1.1	1.5	4.2	4.9	5.1	3.6	1.9	1.2	23.9
2001	0.1	0.4	0.4	2.5	5.8	5.5	4.5	3.2	1.7	24.0
2002	0.1	1.0	2.0	1.8	3.9	4.2	3.2	3.5	2.4	22.3
2003	0.0	0.5	1.3	1.5	4.2	4.1	2.8	3.2	3.0	20.5
2004	0.7	0.2	0.4	1.0	2.8	4.4	5.4	3.9	3.0	21.8
2005	0.0	0.1	0.2	0.4	1.1	2.1	3.8	4.7	4.4	16.8
2006	0.0	0.0	0.0	0.2	2.5	5.5	6.3	4.2	4.3	22.9
2007	0.0	0.1	0.3	0.1	0.5	1.3	2.7	4.4	4.3	13.7
2008	1.7	2.5	0.2	0.2	0.4	0.7	2.0	2.5	4.5	14.7
2009	0.0	0.0	0.1	0.0	0.0	0.4	1.7	3.8	6.6	12.7
2010	0.4	2.0	1.1	0.5	0.1	0.1	0.9	1.1	4.0	10.2
2011	0.3	3.2	2.1	0.3	0.4	0.1	0.3	2.3	5.3	14.4

Length group (cm)										
Year	**5.0–9.9**	**10.0–14.9**	**15.0–19.9**	**20.0–24.9**	**25.0–29.9**	**30.0–34.9**	**35.0–39.9**	**40.0–44.9**	**> 45.0**	**Total**
2012	0.8	4.4	4.0	1.8	0.5	0.3	0.9	3.6	6.2	22.6
2013	0.1	7.4	4.9	4.0	1.6	0.4	0.9	0.8	3.7	23.8
2014	0.1	1.0	1.5	3.0	3.3	1.0	0.5	1.4	4.1	16.0
2015	0.1	0.9	1.5	3.0	2.6	2.0	0.5	0.7	3.4	14.6
2016	0.7	1.3	1.5	2.4	4.3	3.7	3.4	1.7	5.8	24.7
2017	0.3	1.3	0.9	1.1	4.5	9.1	6.7	3.0	5.0	31.7
2018	1.1	2.7	1.8	1.7	3.3	4.7	6.3	4.3	4.7	30.6
2019	0.7	3.2	1.7	2.4	2.5	3.9	9.0	9.7	9.1	42.3
2020	1.0	0.7	1.5	1.0	1.9	2.4	6.5	8.8	9.9	33.6
2021[1]	0.0	0.3	0.9	1.2	1.1	1.5	4.1	5.9	9.5	24.5

1 – Provisional figures.

Table E1b. ***Sebastes norvegicus*** **in subareas 1 and 2. Norwegian bottom-trawl indices (numbers in thousands) – on age – from the annual Winter Norwegian Barents Sea (Division 2.a) bottom-trawl survey (BS–NoRu–Q1 (BTr)) from 1986 to 2018. Age readings not available for 2019–2021 at the time of AFWG 2021. The area coverage was extended from 1993 onwards.**

Year/AGE	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1992	2 509	4 070	6 395	2 375	3 757	10 392	4 299	3 567	11 526	2 276	3 239	3 070	3 666	15 183	76 324
1993	996	1 308	1 661	3 005	1 559	7 689	3 346	4 801	2 712	5 480	6 568	2 735	8 801	28 737	79 398
1994	0	9 311	2 441	5 722	11 251	6 422	3 609	7 824	4 775	2 032	6 095	1 825	2 651	10 838	74 796
1995	3 222	4 925	7 594	9 150	5 735	8 496	3 529	2 029	4 800	8 077	3 967	5 353	6 072	14 877	87 826
1996	336	689	2 157	2 902	4 158	7 448	5 816	3 082	6 290	4 122	6 158	3 136	3 518	9 656	59 468
1997	154	37	512	832	1 670	2 893	3 614	3 063	9 084	5 669	10 848	10 393	2 351	17 500	68 620
1998	1 658	859	664	392	1 032	2 323	2 567	2 256	1 897	3 595	5 099	999	2 703	6 804	32 848
1999	552	1 036	1 300	2 557	1 241	1 577	1 938	2 966	1 848	3 407	4 704	1 786	1 884	5 306	32 102
2000	376	545	814	1 567	2 129	2 621	1 902	2 228	1 907	1 506	2 448	2 096	484	1 957	22 580
2001	350	117	241	611	1 589	2 634	2 885	2 686	2 514	2 529	1 853	1 214	1 000	3 630	23 853
2002	904	1 182	685	972	592	1 706	2 549	2 032	1 742	2 286	919	1 053	2 308	3 235	22 165
2003	165	157	539	1 340	533	1 204	2 469	1 610	2 071	1 350	1 796	825	1 204	4 935	20 198
2004	0	181	91	219	536	1 039	1 426	1 093	1 145	2 060	3 066	1 780	2 606	5 668	20 910
2005	57	96	74	114	394	483	636	435	689	1 131	1 166	1 592	1 661	8 287	16 815
2006	0	0	0	0	48	955	1 766	2 516	1 918	1 343	1 984	3 163	1 822	7 403	22 918
2007	19	39	256	39	0	297	154	411	324	823	709	866	909	8 881	13 727
2008	826	0	0	0	76	69	144	217	476	340	575	881	606	6 800	11 010

Year/AGE	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
2009	0	0	0	0	0	0	12	53	156	220	1 189	469	1 013	9 429	12 541
2010	0	0	290	1 051	250	0	364	62	0	140	325	278	467	4 793	8 020
2011	1 873	1 635	1 391	134	64	0	439	0	103	0	213	119	249	7 421	13 641
2012	939	3 726	4 933	620	442	267	291	113	102	86	0	465	382	9 715	22 081
2013	1 806	1 633	4 722	2 784	2 570	2 139	1 208	275	0	483	99	166	0	4 970	22 855
2014	676	887	604	1 255	2 735	1 774	943	446	455	53	228	94	621	4 970	15 741
2015	125	441	946	898	1 267	1 585	2 515	349	1 062	442	471	104	53	4 136	14 394
2016	511	487	302	533	1 213	2 366	2 722	2 018	1 178	883	2 425	1 101	555	7 169	23 463
2017	Age data not available during AFWG 2020														
2018	1 624	1 044	998	259	318	1 759	2 501	1 042	1 707	2 467	2 690	3 495	1 202	7 892	28 998

16+ group is considered in the calculation since 2005. Values prior to this date were derived by subtracting the sum of abundance in groups 1–15 to the total abundance, available in Table E1a.

Table E2a. Sebastes norvegicus in subareas 1 and 2. Abundance indices (numbers in thousands) – on length – from the Norwegian Svalbard (Division 2.b) bottom–trawl survey (August–September) from 1985 to 2020. Since 2005 this is part of the Ecosystem survey (Eco–NoRu–Q3 (BTr)).

	Length group (cm)								
Year	5.0–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–44.9	> 45.0	Total
1985[1]	–	1 307	795	1 728	2 273	1 417	311	142	194	8 167
1986[1]	200	2 961	1 768	547	643	1 520	639	467	196	8 941
1987[1]	100	1 343	1 964	1 185	1 367	652	352	29	44	7 036
1988[1]	500	1 001	1 953	1 609	684	358	158	68	95	6 426

	Length group (cm)									
Year	**5.0–9.9**	**10.0–14.9**	**15.0–19.9**	**20.0–24.9**	**25.0–29.9**	**30.0–34.9**	**35.0–39.9**	**40.0–44.9**	**> 45.0**	**Total**
1989	200	1 629	2 963	2 374	1 320	846	337	323	104	10 096
1990	1 700	3 886	4 478	4 047	2 972	1 509	365	140	122	19 219
1991	100	5 371	5 821	9 171	8 523	4 499	1 531	982	395	36 393
1992	1 700	10 228	8 858	5 330	13 960	12 720	4 547	494	346	58 183
1993	200	10 160	9 078	5 855	7 071	4 327	2 088	1 552	948	41 279
1994	100	3 340	5 883	4 185	3 922	3 315	1 021	845	423	23 034
1995	470	2 000	9 100	5 070	3 060	2 400	1 040	920	780	24 840
1996	80	130	1 260	2 480	1 030	480	550	990	400	7 400
1997	0	810	1 980	5 470	5 560	2 340	590	190	450	17 390
1998	180	2 698	1 741	4 620	4 053	1 761	535	545	241	16 374
1999	0	794	7 057	3 698	4 563	2 449	467	619	369	20 016
2000	40	360	1 240	1 390	2 010	760	400	160	390	6 750
2001	10	110	790	1 470	3 710	4 600	1 880	680	370	13 620
2002	0	0	65	415	459	880	621	565	521	3 526
2003	87	87	104	84	534	635	459	759	738	3 487
2004	0	8	9	192	581	667	607	395	213	2 672
2005	0	52	0	84	267	608	411	274	283	1 979

	Length group (cm)									
Year	**5.0–9.9**	**10.0–14.9**	**15.0–19.9**	**20.0–24.9**	**25.0–29.9**	**30.0–34.9**	**35.0–39.9**	**40.0–44.9**	**> 45.0**	**Total**
2006	0	0	75	74	138	437	470	668	1 264	3 126
2007	0	47	83	1 251	938	2 012	2 254	373	1 135	8 093
2008	8 603	4 255	211	25	50	169	525	180	536	14 554
2009	216	1 403	108	108	0	0	197	214	220	2 466
2010	868	1 117	1 845	607	0	123	189	0	996	5 745
2011	0	0	850	50	0	0	0	159	578	1 637
2012	0	111	1 565	2 242	2 217	285	0	0	154	6 574
2013	56	489	2 155	3 307	2 738	433	136	34	349	9 697
2014	64	0	425	167	296	531	74	0	312	1 869
2015	0	0	0	216	198	303	877	18	810	2 422
2016	0	0	121	119	813	1 007	754	300	498	3 612
2017	838	675	577	93	585	291	476	288	262	4 085
2018	826	11 129	5 619	1 000	677	2 741	1 134	127	110	23 363
2019	78	90	104	219	68	0	115	131	182	987
2020	527	1 193	1 728	1 597	290	368	318	365	264	6 644

1 – Old trawl equipment (bobbins gear and 80 m sweep length).

Table E2b. Sebastes norvegicus in subareas 1 and 2. Norwegian bottom-trawl survey indices—on age—from the Norwegian Svalbard (Division 2.b) bottom-trawl survey (August–September) from 1985 to 2016. Since 2005 this is part of the Ecosystem survey (Eco–NoRu–Q3 (BTr)). In 2009–2011, 2014–2015,2019 and 2020, there was insufficient number of age readings to derive numbers-at-age, or age readings were not available at the time of the AFWG 2021.

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1992	284	12 378	5 576	2 279	371	2 064	3 687	5 704	9 215	6 413	1 454	1 387	696	22	51 530
1993	32	10 704	5 710	5 142	1 855	1 052	1 314	3 520	2 847	2 757	2 074	1 245	844	119	39 215
1994	429	1 150	3 418	2 393	1 723	1 106	1 714	1 256	1 938	1 596	2 039	484	550	319	20 115
1995	600	1 600	6 400	5 100	1 800	2 200	1 800	700	700	400	700	500	400	500	23 400
1996	40	110	–	560	1 050	940	930	400	1 050	280	320	590	160	70	6 500
1997	320	490	–	480	1 500	6 950	2 720	1 680	800	1 310	550	30	–	120	16 950
1998	210	1 817	881	202	1 555	2 187	4 551	1 913	1 010	797	49	264	73	187	15 696
1999	0	760	2 893	1 339	3 534	1 037	3 905	2 603	762	1 663	481	361	258	152	19 748
2000	40	20	400	350	840	480	730	1 670	620	340	510	100	80	70	6 250
2001	0	40	50	450	330	790	1 760	1 970	3 300	1 200	1 810	150	660	430	12 940
2002	0	0	–	–	65	160	204	326	364	614	442	328	15	0	2 518
2003	0	0	0	0	95	0	283	227	93	296	285	189	228	341	2 035
2004	0	0	0	0	0	0	359	144	362	152	343	315	316	220	2 209
2005	0	50	0	0	0	73	25	286	106	191	271	167	125	152	1 447
2006	0	0	0	0	0	71	0	0	233	106	174	194	305	179	1 261
2007	0	0	0	0	0	617	1 006	398	0	0	155	799	799	303	4 078

	Age														
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
2008	7 844	0	0	0	0	0	0	37	98	16	18	148	86	164	8 412
2009	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2010	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2011	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2012	0	40	123	2445	2105	1205	642	92	35	0	0	0	0	0	6 687
2013	0	56	383	1532	3963	377	1910	1029	214	121	250	0	0	166	10 000
2014	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2015	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2016	0	0	124	0	0	0	0	813	455	739	0	483	136	263	3 015
2017	356	187	322	97	145	130	193	205	79	292	205	176	278	0	2 667
2018	543	0	1 363	4 066	0	367	885	422	0	970	1 625	0	0	0	10 239

Table E4. Observed proportion of maturity–at–age 5 through 30 in S. norvegicus in subareas 1 and 2 derived from Norwegian commercial and survey data. The proportions were derived from samples with at least five individuals. Data for years after 2016 was considered insufficient until further age reading and is not presented.

Year/Age	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1992	0.00	0.00	0.09	0.15	0.31	0.22	0.21	0.20	0.22	0.26	0.30	0.44	0.45	0.47
1993	–	–	0.00	0.00	0.10	0.29	0.54	0.47	0.53	0.67	0.80	0.75	0.78	0.82
1994	0.00	0.00	0.03	0.05	0.28	0.28	0.32	0.70	0.79	0.91	0.94	0.85	0.92	1.00
1995	0.00	0.00	0.00	0.05	0.02	0.22	0.25	0.48	0.61	0.64	0.68	0.80	0.87	0.88
1996	0.00	0.05	0.14	0.13	0.22	0.38	0.43	0.60	0.64	0.75	0.69	0.77	0.90	0.85
1997	0.00	0.05	0.08	0.15	0.17	0.21	0.34	0.35	0.57	0.64	0.72	0.73	0.85	0.93
1998	0.00	0.00	0.03	0.11	0.09	0.26	0.32	0.49	0.52	0.69	0.74	0.77	0.81	0.91
1999	0.00	0.00	0.00	0.04	0.17	0.35	0.22	0.53	0.73	0.71	0.67	0.69	0.74	0.71
2000	0.00	0.08	0.14	0.25	0.40	0.51	0.59	0.62	0.65	0.69	0.78	0.96	0.96	1.00
2001	–	0.00	0.06	0.14	0.28	0.32	0.40	0.52	0.53	0.60	0.76	0.74	0.81	0.85
2002	–	0.00	0.05	0.07	0.23	0.44	0.41	0.63	0.74	0.93	0.77	0.89	0.90	0.94
2003	–	0.00	0.00	0.05	0.13	0.24	0.24	0.47	0.58	0.68	0.75	0.65	0.77	0.78
2004	–	0.00	0.03	0.07	0.13	0.43	0.21	0.51	0.46	0.63	0.64	0.86	0.82	0.96
2005	–	–	0.00	0.05	0.29	0.18	0.34	0.39	0.39	0.56	0.73	0.81	0.79	0.82
2006	–	–	0.00	0.10	0.06	0.22	0.25	0.39	0.47	0.57	0.67	0.67	0.74	0.86
2007	–	–	0.00	0.08	0.30	0.25	0.24	0.66	0.68	0.70	0.88	0.86	0.89	0.99
2008	–	–	0.80	0.25	0.82	0.68	0.62	0.80	0.79	0.86	0.88	0.91	0.90	0.92
2009	–	–	–	–	–	0.50	0.50	1.00	0.93	0.81	0.86	0.86	0.85	0.85
2010	–	–	–	–	–	–	–	–	0.70	0.60	0.81	0.92	0.64	0.90
2011	–	–	–	–	–	–	–	–	–	–	0.73	0.78	0.94	0.93
2012	0.00	0.11	0.10	0.29	0.20	0.20	–	–	–	0.76	0.72	0.70	0.91	0.78
2013	0.00	0.12	0.05	0.10	0.19	0.38	0.71	–	0.29	0.82	0.92	0.89	0.77	0.86
2014	0.00	0.00	0.02	0.08	0.21	0.43	0.41	0.53	0.33	0.58	0.69	0.71	0.80	0.92
2015	0.00	0.05	0.17	0.17	0.30	0.41	0.44	0.49	0.65	0.67	0.69	0.81	0.91	0.86
2016	0.00	0.04	0.02	0.05	0.23	0.16	0.26	0.43	0.59	0.42	0.62	0.57	0.80	0.73

Year/Age	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1992	0.45	0.62	0.51	0.63	0.76	0.60	0.57	0.60	0.68	0.74	0.82	0.80
1993	0.91	0.85	0.82	0.87	0.75	0.91	1.00	1.00	1.00	1.00	1.00	1.00
1994	0.96	0.96	1.00	0.88	1.00	1.00	1.00	1.00	–	1.00	1.00	–
1995	0.76	0.89	0.90	0.91	1.00	1.00	1.00	1.00	–	–	–	–
1996	0.91	0.88	0.96	0.93	1.00	0.87	0.95	0.95	1.00	–	1.00	0.86
1997	0.94	1.00	1.00	0.95	0.89	0.94	0.93	0.89	1.00	1.00	1.00	–
1998	0.89	0.86	1.00	1.00	0.67	0.70	1.00	1.00	–	–	1.00	0.88
1999	0.77	0.89	–	0.83	–	1.00	0.89	–	–	–	–	–
2000	1.00	–	–	–	1.00	–	–	–	–	–	–	–
2001	0.60	0.70	0.56	–	–	–	–	–	–	–	–	–
2002	0.96	0.92	0.95	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	–
2003	0.93	0.96	0.94	0.67	1.00	–	1.00	–	–	–	–	–
2004	0.92	0.95	0.89	0.88	1.00	0.86	1.00	–	–	–	–	–
2005	0.77	0.94	0.95	0.88	0.83	1.00	–	1.00	–	–	–	–
2006	0.83	0.97	0.79	0.95	0.81	1.00	–	1.00	–	–	–	–
2007	0.98	1.00	0.96	0.94	1.00	0.92	1.00	0.83	1.00	1.00	1.00	–
2008	0.92	0.90	0.93	0.93	0.94	1.00	1.00	1.00	1.00	1.00	0.93	1.00
2009	0.88	0.95	0.89	0.95	0.92	0.95	0.86	0.94	1.00	0.93	0.83	0.86
2010	0.92	0.96	0.95	0.90	1.00	0.73	0.83	0.86	0.86	0.60	0.67	–
2011	0.89	0.92	0.92	0.93	0.83	0.85	1.00	1.00	–	0.83	–	–
2012	0.88	0.89	0.85	0.81	0.95	0.81	0.86	1.00	0.93	1.00	1.00	1.00
2013	0.75	0.79	0.73	0.83	0.89	0.95	1.00	0.67	1.00	1.00	1.00	1.00
2014	0.92	0.95	0.63	0.96	0.90	0.84	0.95	0.83	1.00	–	0.78	0.88
2015	0.83	0.93	0.78	0.82	1.00	0.95	0.96	0.83	0.84	1.00	0.87	0.82
2016	0.87	0.74	0.88	0.79	0.78	0.97	0.81	0.89	0.89	0.67	1.00	0.94

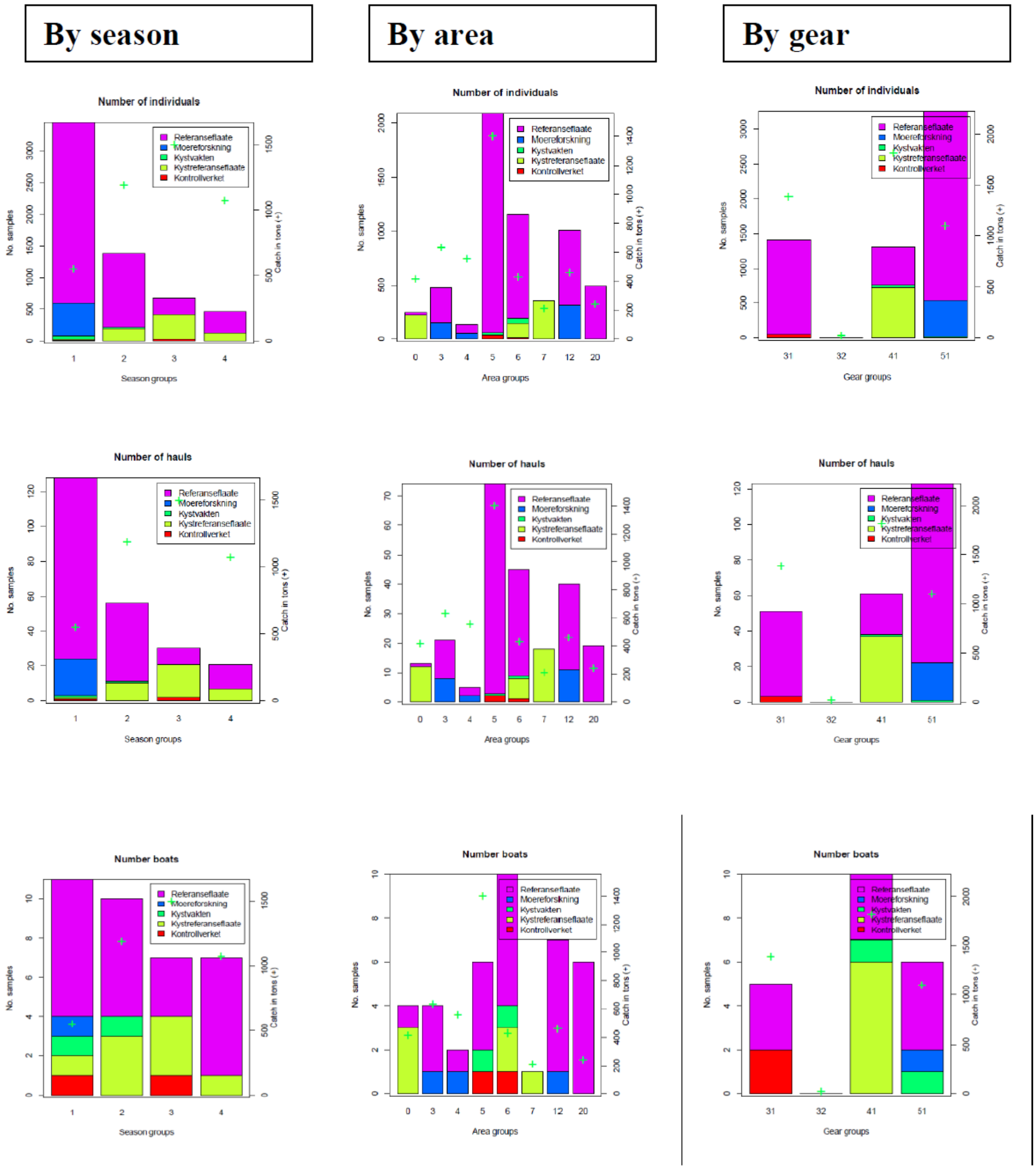


Figure E1. Overview of the Norwegian biological age samples (number individuals, number hauls/sets, number of boats) from the commercial fisheries for *S. norvegicus* in 2013 representing more than 80% of the catches and which the input data to the Gadget model are based upon. The colours denote which sampling platform has been used: High Seas Reference fleet, port sampling, Coast guard, Coastal Reference Fleet, or inspectors/observers at sea. The green crosses show the catch in tonnes for the different seasons, areas and gears.

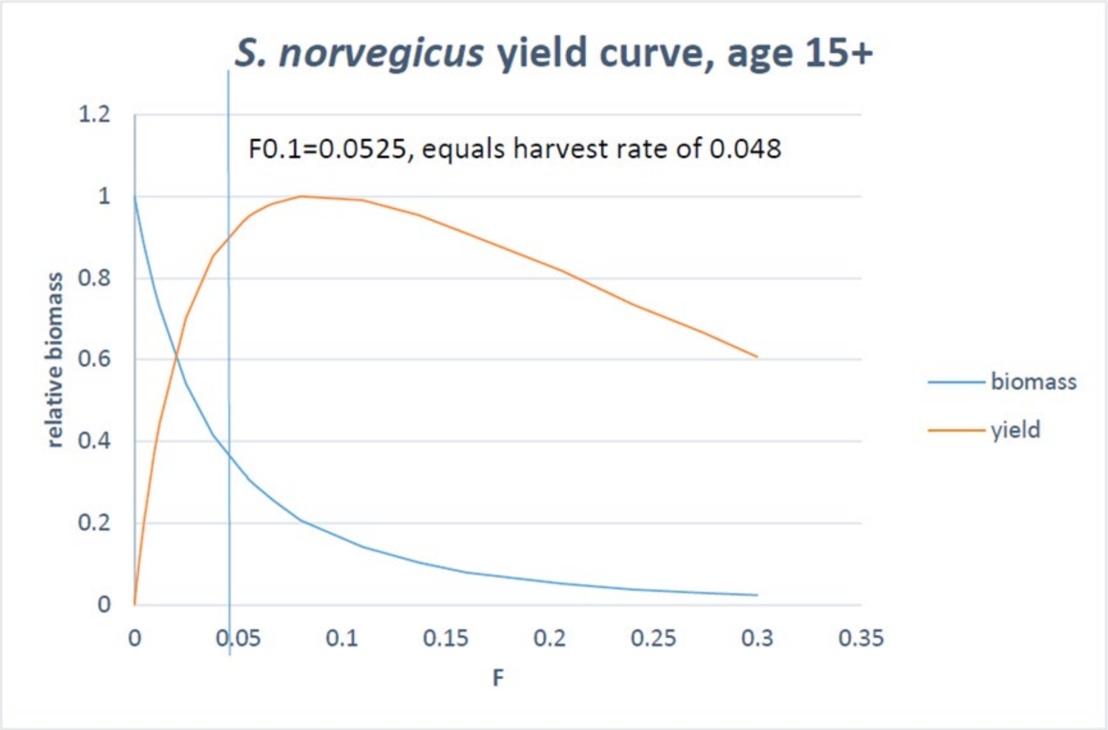


Figure E2. ***Sebastes norvegicus*** **in subareas 1 and 2. Yield-per-recruit for** ***S. norvegicus*****, computed from the GADGET assessment model presented at the benchmark assessment in January 2018 (WKREDFISH, ICES 2018a).**

8 Greenland halibut in subareas 1 and 2 (Northeast Arctic)

Reinhardtius hippoglossoides – ghl.27.1–2

8.1 Status of the fisheries

8.1.1 Landings prior to 2021 (Tables 8.1–8.8, Figures 8.1–8.3)

Nominal landings by country for subareas 1 and 2 combined are presented in Table 8.1. Tables 8.2 to 8.4 give the landings for Subarea 1 and divisions 2a and 2b separately, and landings separated by gear type are presented in Table 8.5. For most countries, the landings listed in the tables are similar to those officially reported to ICES. Some of the values in the tables vary slightly from the official statistics and represent those presented to the Working Group by the members. Catch per unit effort is presented in Table 8.6 and total catch from 1935 to now in Table 8.7 and Figure 8.1.

The preliminary estimate of the total landings for 2020 is 28 713 t. This is 118 t less than the landings in 2019 and about 5713 t more than the ICES advised maximum catch for 2020 (23 000 t). The catches from most countries remained fairly stable, compared to 2019. Combined landings exceeded the quotas set by the Joint Russian-Norwegian Fisheries Commission for 2019 by 1713 t (total TAC 27 000 t). One explanation is the difficulties in bycatch regulation. Also, catches in the report include all landings in ICES 1 and 2, and thus include catches in EU waters in the southern part of ICES 2.

Some fishing for Greenland halibut has taken place in the northern part of Division 4a during the past 20–30 years, varying between a few tonnes and up to 1670 t in 1995 and 2 577 in 1999. From 2005 to 2011 this catch was mostly below 200 t, taken mostly by Norway, France, and the UK. Preliminary numbers show 719 t in 2020, mainly due to the Norwegian trawl fleets (Table 8.8, Figures 8.2 and 8.3). Although there is a continuous distribution of this species from the southern part of Division 2a along the continental slope towards the Shetland area, the stock structure is unclear in this area and these landings have therefore not been added to the total from subareas 1 and 2. Recent mark-recapture and genetic investigations indicate that the stock might have a more south and westward distribution than the current ICES definition of the stock boundaries (Albert and Vollen, 2015, Westgaard *et al.*, 2016).

8.1.2 ICES advice applicable to 2021

The roll over advice from ICES for 2021 was as follows:

ICES advises that when the precautionary approach is applied, catches in 2020 should be no more than 23 000 tonnes. This corresponds to a harvest rate of ≈0.036. All catches are assumed to be landed.

8.1.2.1 Additional considerations

A benchmark and data workshop process led to an agreed analytic assessment in 2015.

A benchmark meeting (WKBUT; ICES 2013/ACOM:44) was held for the Northeast Arctic (NEA) Greenland halibut in 2013, but the benchmark process was prolonged due to problems with data. A data workshop was conducted in November 2014 (DCWKNGHD ICES CM 2014/ACOM:65), followed by a benchmark by correspondence that ended in 2015. The assessment is reported in the benchmark by correspondence (IBPHALI; ICES CM 2015/ACOM:54) and in the stock annex.

8.1.3 Management

The 38th JRNFC's session in 2009 decided to cancel the ban against targeted Greenland halibut fishery and established the TAC at 15 000 t for the next three years (2010–2012). The 40th JRNFC Session in 2011 decided to increase the TAC for 2012 up to 18 000 t, and at the 42nd JRNFC Session in 2012, the TAC for 2013 was increased to 19 000 t. The 43rd and 44th sessions kept the same TAC for 2014 and 2015. For 2016 and 2017 TAC was set to 22 and 24 thousand tonnes, respectively. The TAC for 2018 was 27 thousand tonnes and the same for 2019, 2020 and 2021.

The TAC for Greenland halibut set by JNRFC applies to catches in ICES areas 1, 2a and 2b, except the Jan Mayen EEZ and the part of the EU EEZ which is north of 62°N.

In 2020 catches of 48 tonnes were taken in the Jan Mayen area (within ICES Subarea 2), where Greenland halibut fisheries are not regulated by TAC.

Norway has a quota for Greenland halibut in the EU EEZ which in 2019 and 2020 was set to 1250 t each year and can be fished in ICES areas 2a and 6. Thus this TAC is given partly within and partly outside the stock boundary. In 2019 total of 844 t of this TAC was caught, assumingly mainly in ICES area 2a, but information was not available for catches in 2020. There is no ICES separate advice for the fishery in this area.

The TAC sat by EU for 2020 applied to "Union waters of 2a and 4; Union and international waters of 5b and 6" with a total quota of 2500 t, of which 1250 t were allocated to Norway with the footnote "To be taken in Union waters of 2a and 6. In 6, this quantity may only be fished with longlines (GHL/*2A6-C)." Additionally EU has sat another TAC of 1800 t in "International waters of 1 and 2(GHL/1/2INT)" (this possibly includes the Svalbard zone in EU lingo) and 50 t in "Norwegian waters of 1 and 2(GHL/1N2AB.)", both with the footnote "Exclusively for by-catches[1].

EU has set a TAC of 629 t for 2021 to be taken in Union waters of 2a and 6. In 6, this quantity may only be fished with longlines. EU has sat 1800 t TAC in international waters of ICES 1 and 2, exclusively for bycatches. No directed fisheries are permitted under this[2].

As the UK has left the EU and unilateral agreements between Norway, the UK and the EU are not reached yet the final TAC in this area is not available.

Further information on regulations is found in the Stock Annex.

8.1.4 Expected landings in 2021

Catches in 2020 exceeded the TAC sat by JRNFC and were 28 713 t. The total Greenland halibut landings in the Barents Sea and adjacent waters (ICES Subarea 1 and divisions 2a and 2b) in 2021 may thus be higher than the TAC of 27 000 t. Discards at present are not regarded as a problem.

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[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0123&from=EN

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32021R0092&from=EN

8.2 Status of research

8.2.1 Survey results (Tables 8.9–8.13, Figures 8.4–8.14)

Survey indices from the Russian autumn survey (Figures 8.4–8.6), the Norwegian slope survey (Figures 8.4–8.5 and 8.7–8.8), the Joint Norwegian-Russian Ecosystem survey (A5216), Eco-juv and Eco-south indices; Figures 8.9–8.10) and the Joint Norwegian-Russian Winter Survey (Figure 8.11) are given. Length distributions from these surveys are presented in Tables 8.9–8.12 and Figure 8.12. Results from Spanish surveys are presented in Table 8.13 and Figure 8.13. Results from a Polish spring survey is presented in Figure 8.14.

The Russian bottom-trawl surveys in October-December (ICES acronym: *RU-BTr-Q4*) are important since they usually cover large parts of the total known distribution area of the Greenland halibut within 100–900 m depth. However, it has been considered imprudent to use 2002, 2003 and 2013 data from this survey series. During the 2002 survey, no observations were available from the Exclusive Economic Zone of Norway (NEEZ). In 2003, observations on the main spawning grounds were conducted three weeks later than usual because access to NEEZ was obtained too late. The number of trawl stations was also insufficient due to the same reason. Due to technical problems indices in 2013 were not obtained. Technical and practical changes were made in 2003. In 2017 and 2019 the coverage was insufficient. The assessment was run without 2019 in the index and the effect on biomass estimates were minor. It was decided to keep the 2019 estimate in the current assessment. The 2020 estimate was not considered appropriate to use due to gear-related problems during the survey. A working document with a revision of the Russian index was provided to the 2021 meeting (Russkikh WD12). Revised and recalculated length distributions were not implemented in the 2021 assessment but will be subject to the upcoming benchmark. Length distributions by year for this survey are given in Table 8.9. The biomass indices for this survey increased steeply from 2005 to 2011, but have mainly showed a downward trend since then (Figures 8.4 and 8.5).

Total biomass indices from the Norwegian autumn slope survey (*NO-GH-Btr-Q3*) showed an upward trend in biomass estimates between 1994 and 2003, then a downward trend until 2008 until it increased again in 2009 but levelled out again in 2011, 2013, and 2015 (Figures 8.4–8.5, and 8.7–8.8). Since then there is a downward trend and the index for 2020 is the lowest since the start of the survey. The length distributions from this survey (Figure 8.12, Tables 8.10 and 8.11) show modes that can be followed through the years and indicate new recruitment to the adult stock in 2007. Since then no such large recruit events are apparent in the length distributions, and since 2009 abundance of fish in adult lengths has been declining s as well. This survey was conducted every year during 1994–2009 but is now run biennially.

The Joint Ecosystem Survey in autumn (A5216; *Eco-NoRu-Q3 (Btr)*) covers a large part of the Barents Sea down to 500 m and concerning Greenland halibut it can be regarded to be in the areas where mainly juveniles and immature fish are found. Two indices for Greenland halibut are based on the Joint Ecosystem Survey in the Barents Sea and previous juvenile survey, one for juvenile areas (Figure 8.9) denoted Eco-juv index in the northernmost survey area, and another denoted Eco-south index defined by the survey area south from 76.5°N and west of Spitsbergen (Figure 8.10). The juvenile index, covering the juvenile area (see section 8.3), indicates a highly variable recruitment success with years between good year classes. The trend has mainly been downward since around 2007 and the 2015 estimates are the lowest registered so far, followed by a minor peak in 2017. The Eco-south index for both females and males showed an increasing trend until 2012, followed by a decrease since then. The 2018 estimate in the Eco-south index was excluded from this year’s assessment. The abundance estimate in 2018 peaked to extend that can be considered unrealistic for a slow-growing species. Additionally, there are concerns about the quality of the estimate due to the lack of survey coverage in 2018, especially in the area south of 76.5°N as defined for the Eco-south index (Figure 8.19). The male index shows a similar trend except the increase started a year later, in 2016 - 2018, but is also down in 2019. Length distributions by year for this survey are given in Table 8.11.

The joint winter survey in the Barents Sea (*Eco-NoRu-Q3 (Btr)*) has been run from 1986 to the present (jointly with Russia since 2000, except 2006 and 2007). The survey mainly covers depths of 100–500 m and does not cover the deeper slope areas. Spatially, the survey focuses on the central Barents Sea, and west of Svalbard for some years. The northward coverage is limited by sea ice in some years. It is conducted in February and can thus give information on the stock at a different time of the year, as the other surveys are run in autumn. The biomass index has shown an increasing trend since 2004 with large variations in recent years. This survey is not currently used in the assessment.

The Spanish bottom-trawl survey, (Table 8.13, Figure 8.13) was carried out on a new hired commercial vessel and some changes have been done in the initial standard protocol. The indices for Greenland halibut from earlier Spanish surveys (1997–2005) cannot be standardized with more recent ones (2008 to present, Basterretxea *et al.*, WD13 2013). This means that biomass estimates from the survey are only available for years 2008 and onwards. The Spanish survey has since 2015 only been run in autumn. This survey is not conducted every year. The biomass index from the Spanish survey shows a downward trend since around 2012. This survey is not currently used in the assessment.

Polish bottom-trawl surveys on Greenland halibut were carried out in the Svalbard-Bear Island area (ICES 2b) in October 2006, April 2007, April 2008, June 2009, and March 2011. The main objectives of the survey were to determine the biological structure, distribution, density and standing biomass of Greenland halibut in the survey area (Trella and Janusz, WD6 ICES AFWG 2012). The survey has not been conducted since then. Polish survey index is shown in Figure 8.14, no new data were presented to the meeting. This survey is not currently used in the assessment.

8.2.2 Commercial catch-per-unit-effort (Table 8.6, Figure 8.15)

The CPUE series for the stock was subject to the last benchmark and following data workshops (see reports from WKBUT 2013, DCWKNGHD 2014 and IBPHALI 2015, and working documents by Bakanev (WD14 WKBUT 2013) and Nedreaas (WD 2 DCWKNGHD 2014); Figure 8.15). An alternative CPUE series for the Russian fisheries for the years 2004–2015 was presented at the 2016 meeting (Mikhaylov, WD14 ICES AFWG 2016). It shows some discrepancies compared to the previous CPUE series used for the Russian fisheries for the same years. See the Stock Annex for further comments. The CPUE series are not currently used in the assessment.

8.2.3 Age readings

Based on the scientific understanding that the species is slower growing and vulnerable than the previous age readings suggest, the Norwegian age reading methods were changed in 2006. The new Norwegian age readings are not comparable with older data or the Russian age readings.

The report from Workshop on Age Reading of Greenland Halibut (WKARGH) 14–17 February 2011 (ICES CM 2011/ACOM:41) described and evaluated several age reading methods for Greenland halibut.

The different methods can be classified into two groups: A) Those that produce age–length relationships that broadly compare with the traditional methods described by the joint NAFO-ICES workshop in 1996 (ICES CM 1997/G:1); and B) Several recently developed techniques that show much higher longevity and approximately half the growth rate from 40–50 cm onwards compared to the traditional method.

A second workshop on age reading of Greenland halibut (WKARGH 2) was conducted in August 2016 and worked on further validation on new age reading methods. The workshop recommended that two of the new methods can be used to provide age estimations for stock assessments. Further, recognizing some bias and low precision in methods, the WKARGH2 suggested that an aging error matrix or growth curve with error be provided for use in future stock assessments (WKARGH2 report 2016, ICES CM 2016/SSGIEOM:16).

WKARGH2 recommends regular inter-lab calibration exercises to improve precision (i.e. exchange of digital images between readers for each method and between methods).

AFWG suggests that Russian and Norwegian scientists and age readers meet to work out issues of disagreements on Greenland halibut aging.

8.3 Data used in the assessment

In the assessment, the catch data are split into four aggregated fleets by gear and countries. Longline/gillnet fleets include landings from gillnet, longline, and handline. Trawl fleets include landings from bottom trawl, purse-seine (very minor catches, can be bycatch or misreporting) and Danish seine. Catch in tonnes and length distributions per quarter per fleet per sex from 1992–2020 are used in the assessment. Fleets are split between Norwegian (including 3rd countries) and Russian catches, and selectivities are allowed to vary by sex (logistic for gill fleets, asymmetric dome-shaped for trawl fleets), to account for sexual dimorphism influencing vulnerability to fishing. For each fleet listed below, length distributions and reported catch in tonnes are split by quarter and sex (although length distributions are not available for all quarters for some fleets).

- Russian, trawl and minor gears (split by sex)
- Russian, gillnet and longline (split by sex)
- Norwegian and 3rd countries, trawl and minor gears (split by sex)
- Norwegian and 3rd countries, gillnet and longline (split by sex)

In addition, the model has four surveys, all modelled with asymmetric dome-shaped selectivities (note that in a model context “selectivity” encompasses all aspects of vulnerability to the fishery, including gear effects, vessel effects, area effects etc.). In each case, data are used as length distribution and biomass index. The biomass index was not available to split by sex for all years, so a combined sex index is used. The four survey indices that go into the current assessment are:

- Norway slope (*NO-GH-Btr-Q3*)– based on the Norwegian Greenland halibut slope survey (yearly 1996–2009, biennially since then). Split by sex.
- EcoJuv - a juvenile index based on data from the northern/northeastern areas of the Joint Ecosystem survey (A5216; *Eco-NoRu-Q3 (Btr)*; 2003–present) and the precursory Norwegian juvenile Greenland halibut survey north and east of Svalbard (1996–2002; Hallfredsson and Vollen, WD 1 ICES IBPhali 2015). Split by sex.
- EcoSouth - an index for the Barents Sea south of 76.5°N, based on data from the Joint Ecosystem survey (A5216; *Eco-NoRu-Q3 (Btr)*; 2003–present; Hallfredsson and Vollen, ICES AFWG, WD 20, April 2015). Split by sex.
- Russian - Russian bottom-trawl survey in the Barents Sea (1992–2015 and 2017; *RU-BTr-Q4*). Sex aggregated (can be split by sex in future work).

No age data or CPUE indices are used in the tuning.

8.4 Methods used in the assessment

A new assessment method with a length-based GADGET model was benchmarked in 2015 (IPHALI 2015) and accepted by ACOM the same year. The model is further described in the IPHALI report and the Stock Annex.

8.4.1 Model settings

Model used: Gadget (see ICES, 2015).

Period: 1992–2020, monthly time-steps

Model structure:

- 1 cm length classes (1–114+ cm) and 1-year age classes (1–30+)
- Two sexes, split into mature and immature
- Logistic maturity estimated for each sex
- Von Bertanlanffy growth estimated separately for males and females
- L-W relationship fixed based on data from the Norwegian slope (Females: a = 1.4E-6 and b = 3.47. Males: a = 5.7E-6 and b = 3.12)
- Natural mortality set to 0.1 for all fish
- Initial size of recruits fixed at 8.5 cm (necessary to fix this in the absence of age data)
- Recruitment modelled as annual numbers, no relationship with SSB
- Four aggregated fleets (as described above), each with sex-specific selectivity (logistic for gillnet and longline fleets, asymmetric dome-shaped for trawl)
- Four surveys (as described above), all with asymmetric dome-shaped selectivity

Note that to avoid the problem of modelled fish not covered by any fleet (and therefore not tuned to any data) the gillnet and longline fleets have been assumed to have logistic (flat-topped) selectivity.

8.4.1.1 Estimated parameters:

Estimated parameters are L_{50} and slope for the maturation (male and female separately), two growth parameters per sex, two maturation parameters per sex, one annual recruitment parameter per year, two parameters for s.d. of the length of recruits, parameters governing commercial selectivity (two per sex per gillfleet and three per sex per trawlfleet), one effort parameter per year for each fleet, three parameters per survey per sex governing selectivity, initial population numbers for male and female fish by age, initial population s.d. of lengths by sex and age.

Data used for tuning are:

- Quarterly length distribution of the landings from commercial fishing fleets (by sex)
- Quarterly catch in tonnes for each fleet (by sex)
- Length disaggregated survey indices from the four surveys (by sex except for the Russian survey)
- Overall survey index (by biomass) for the four surveys (by sex except for the Russian survey)
- Estimated maturity ogives (maturity at length in the population) for 1992–2020 (by sex)

Note that no age data are used in tuning the model. Although age readings are available for some years there is not a full agreement on which age-reading methodology should be used, and these data are thus not suitable for inclusion in an assessment model yet.

Concerning the recruitment, it should be noted that age 1 is the age for recruitment to the stock, NOT the age for recruitment to the fishery, which is the quantity normally used to describe recruitment. But since age 1 recruitment is the quantity estimated by the model and the age of recruitment to the fishery can't be defined due to lack of age data, we use age 1 as the recruitment age for this stock. Even if adequate age data were available, the strong sexual dimorphism in growth would make it very difficult to define an appropriate recruitment age to the fishery.

8.5 Results of the assessment

The assessment is conducted every two years and advice was given in 2019 for catches in 2020 and 2021. Model results are shown in Figures 8.16 and 8.17, and Table 8.14. The stock abundance and biomass are presented for fish larger than 45 cm, this corresponds to the minimum legal size and is slightly larger than L_{50} maturity for males. Both 45 cm+ abundance and biomass peaks around 2013–2014 and show a clear downward trend since then. The harvest rate has been steadily increasing since 2009 and has reached levels higher than the HR_{pa} that is recommended by the meeting. There is a retrospective trend to reduce the stock estimate over time (Figure 8.18). AFWG 2021 decided to exclude the ecosystem survey data from 2018 (in line with their exclusion for cod and haddock). This removal has resulted in a downwards revision of the stock biomass since the AFWG 2019 assessment. However, the last 5 years of the retrospective for the 45cm+ biomass are very consistent (Figure 8.18). The modelled recruitment is spiky (Figure 8.17), and this is likely exaggerated due to the lack of age data. However, although the real recruitment is likely more spread out, the modelled peaks show reasonably good agreement to the data from the juvenile survey. This stock is dominated by sporadic recruitment events, and the model does a reasonable job of capturing this. The model estimates a large recruitment event of one-year-old in 2002, which corresponds to recruitment to the adult stock in 2007 as can be seen in length distributions in surveys at the continental slope (Figure 8.12). Since then no such large recruitments events have been estimated by the model, but the model has been consistently estimating reasonably good recruitment in 2009–2010 and 2014, which should be entering the fishery in the coming years.

8.5.1 Biological reference points

The last benchmark (ICES 2015), given the sporadic nature of recruitment and the relatively short period of the model, concluded that constructing a SSB-recruitment relationship had not been possible. It was therefore decided to take the "B_{loss}" route to arriving at a reference point. In the assessment at the benchmark, there was evidence of good recruitment in 1995, when the biomass was around 500 000 tonnes. This could be taken as a reference point, "B_{loss} with good recruitment". It was noted that this is likely to be precautionary, and a "real" B_{lim} is likely to be rather lower. It was therefore recommended to use the 1995 biomass (c. 500 000 tonnes 45+ cm biomass) as a precautionary reference point. It should be noted that because of lack of age data the exact year for modelled good recruitment can vary slightly between assessments. In the current assessment there is relatively good recruitment of 1-year-olds in 1994 (Figure 8.17) and the 45+ biomass in 1993, the year before, is around 500 000 tonnes (figure 8.16).

There is evidence (in the estimated initial population for the assessment model) that an earlier good recruitment event occurred in the 1980s from lower biomass, but the exact biomass level is unknown as this is before the model period. Using 45+ cm biomass (rather than total or female SSB) avoids uncertainty around maturation sizes and the different distributions of males and females, and relates directly to the fishable stock, but does not directly relate to the most vulnerable or critical female SSB. The biomass reference point was used until the last assessment accepted by ACOM in 2019. This year a new approach is implemented for the draft advice. Two options are given for ADG/ACOM to decide on with $HR_{pa} = 0.035$ and $HR_{pa} = 0.025$ as a reference value (see 8.6 Comments to the assessment).

8.5.2 NEA Greenland halibut surplus production models

Results of the assessment of the Barents Sea Greenland halibut stock based on a Bayesian surplus production model was provided by Bakanev in 2013, (WKBUT WD 14). Different sets of abundance indices were used for tuning the model. The analysis of model run results has shown that K is estimated within the range of 810 to 1139 kilotonnes, B_{MSY} of 405 to 570 kilotonnes and MSY of 23 to 47 kilotonnes. However, the model was sensitive to the choice of prior on K. Taking into consideration a high probability of the stock size being at the level which was quite a bit above B_{MSY}, the risk of the biomass being below this optimal one was very small in 2002–2012 (<1%). The risk analysis of the stock size in the prediction years (2013–2020) under the catch of 0 to 30 kilotonnes indicated that the probability of the stock size being under the threshold levels (B_{MSY}, B_{lim}) was also minor (less than 1%). It was concluded that further work was needed on the historical CPUE series. Based on scrutiny of the CPUE series it was recommended to examine runs with the surplus production model for the period 1964 –1991 and 1964 –2005, in addition to runs for the whole 1964–2013 period. Fisheries CPUE series were considered less reliable to reflect stock dynamics than survey indices in the period after regulations of the fishery were introduced in 1992. The Bayesian surplus model was not updated for presentation at the current meeting.

A production model was presented at the 2016 meeting (Mikhaylov, 2016, WD 14), although this model has not been reviewed at a benchmark, nor were biomass trends presented at this meeting. The model has been proposed as a possible method for the estimation of long-term reference points. An update was presented at the 2019 meeting (Mikhaylov 2019, AFWG 2019 WD21). In the current version, the MSY would be around 34 ktonnes, the B_{MSY} around 500 ktonnes and F_{MSY} on the level 0.069. It should be noted that these values are not directly transferable to a different model with different biomass levels and in any case a long-term average. The WD concluded that, in general, the stock can withstand the fishing load in 2016 and the fishing regime was approaching optimum, indicating that the results of the exploratory surplus production model were in general alignment with the assessment.

F_{MSY} is not appropriate to this stock given the recent extended run of poor recruitment, and such values have not been evaluated for precautionarity. In a plenary, it was concluded that it would be useful for further development of the production model to conduct separate exploratory runs for CPUE split into before and after 1992 and run with CPUE only before 1992 and survey data after 1992. This production model was not updated for presentation at the current meeting.

At the 2018 meeting, AFWG results from SPiCT production model were presented (AFWG report 2018). In the run that is presented in this report, all available data up to 2016 were used. For run with default, priors applied K = 995 421 t and deterministic reference points were B_{MSY} = 419 955 t, F = 0.07 and MSY = 29 742 t. Stochastic reference points for this run were in a similar range. Run with default priors deactivated gives similar MSY estimates but otherwise, rather different estimates; K = 2 504 006 t, B_{MSY} = 609 410 t, F = 0.05 and MSY = 28 097 t. Further utilization of this approach demands closer scrutiny of model settings in relation to diagnostics. The SPiCT model can be a flexible tool to examine the production model approach to Greenland halibut, however, concerns highlighted below still apply.

In principle, a production model could be used in conjunction with the GADGET assessment model in order to extend the simulations back in time and provide better estimates for B_{lim}. However, the inability of production models to follow variable recruitment, and especially runs of above or below average recruitment, limits their ability to advise on this stock.

In the benchmark report (IBPHALI 2015) Table 3.3 gives CPUE series and survey estimates that can be helpful for this task (Figure 8.15).

8.6 Comments to the assessment

The draft advice sheet in 2019 was rejected by ADGANW and roll-over advice was used for advice in 2020. ADGANW issued a request to repeat the advice process in 2020 with HR_{pa} reference points for use in the 2021 advice (ICES 2017). Due to the need for a simplified approach related to the 2020 corona virus outbreak, ACOM decided, in agreement with Advice Requestors, that roll-over advice should be used in 2020 to provide advice on fishing opportunities in 2021.

ADGANW 2019 requested that a simple F_{MSY} proxy is developed as well as $B_{trigger}$, or failing that a Fpa to provide precautionary advice. The approach implemented for the current draft advice is documented by Howell (2020, WD 15 and 2021, WD 08) that proposed an interim HR_{pa} (harvest rate pa) until such time as the stock next undergoes a full benchmark followed by an HCR evaluation to come with a full management plan for this stock. Such a benchmark is planned for 2022.

The HR_{pa} is based on the method proposed in the 2017 ICES fisheries management reference points for category 1 and 2 stocks (ICES 2017). This method involved projecting the stock forward under average recruitment to identify the fishing level Flim that drives the stock to B_{lim} under equilibrium. This method was chosen because the lack of age tuning data makes the variability of recruitment unreliable, and using averages is a more robust approach. There is a modification to allow for the fact that in light of the lack of contrast in the data this stock has Bpa set equal to Bl_{im}, and hence the method gives HR_{pa} directly, and there may be no need to first compute an HR_{lim} and then adjust this for an HR_{pa}. In using this approach it is necessary to select the recruitment average to use, and the method chosen was to use the full time-series of recruitment, but excluding the extra-high peak in 2003, with the justification that this recruitment peak is already recruited to the fishery and that such a recruitment peak has not been repeated since and therefore this level of recruitment cannot be expected to enter the fishery in the coming years.

Two alternatives are proposed as HR_{pa} for Greenland halibut in areas 1 and 2 for ADG/ACOM to decide, 0.035 or 0.025, both with the provision that if a large recruitment event is observed in the surveys then the HR_{pa} should be revised before the incoming good recruitment entering the fishery.

This solution for HR_{pa}, if accepted by ACOM, would apply until the planned benchmark, i.e. for one two-year advice cycle.

HR_{pa} is set at 0.035 (following ICES reviews that were arranged afterwards, in conjunction with the AFWG meeting.

The ongoing reduction in sex-split length samples in two survey indices, EcoJuv and EcoSouth required a change in methodology for computing the tuning indices used in the assessment. The change was implemented in the 2019 assessment.

We stress once again that the absolute biomass levels for this model are rather uncertain. Without age data in the model tuning there is little information on total mortality (Z) at age (number-at-age x in year y minus number-at-age x-1 in year y-1 gives information on Z). Without this, there is little information for the model to translate catch information into F and hence inform biomass levels. Furthermore, the conflicting survey signals translate into an uncertainty range of several hundred thousand tonnes (IBPHALI 2015). All the exploratory work suggests that the overall trends are robust, but that care should be taken in interpreting the absolute abundance estimates (and hence absolute estimates of harvest rate).

Although there are few retrospective pattern differences over the last four years, the model exhibits a retrospective pattern in earlier years associated with the biomass peak around 2014 (Figure 8.18). The two coastal shelf surveys (the ecosystem survey (A5216) and the Russian survey) showed a more rapid rise than the other surveys, and then a more rapid reduction. The Russian survey had a very rapid rise and then a rapid decline. The model, therefore, had a series of downward revisions as the peak was passed, where the model now estimates that it had previously been over-optimistic about the size of the peak. It should be noted (ICES IBPHALI REPORT 2015; ICES CM 2015\ACOM:54) that there is an issue with this stock where different surveys give different signals and choosing one survey over the others could affect the biomass level by several hundred thousand tonnes. Given this, a retrospective pattern is probably to be expected as the different surveys evolve. Note also that one of the surveys is run every two years (in odd-numbered years), this accounts for the grouping of lines in the retrospective pattern into pairs.

8.6.1 Future work

Further development of the assessment is needed and, in consistency with conclusions of the IBPHALI benchmark and report of the external benchmark reviewer.

A new benchmark on the stock is planned for 2022, and intersessional work will commence on a issues list. Such a benchmark, especially if it can extend the model back in time to a period of lower stock biomass and includes age data, would allow a more accurate determination of precautionary biomass reference points. It would, therefore, be a precursor to a potential MSE to generate an HCR for this stock and move away from precautionary advice.

8.7 Tables and figures

Table 8.1. Greenland halibut in subareas 1 and 2. Nominal Catch (t) by countries (Subarea 1, divisions 2a, and 2b combined) as officially reported to ICES.

Year	Denmark	Estonia	Faroe Islands	France	Fed. Rep. Germany	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[3]	Spain	GB	UK (Engl. & Wales)	UK (Scot land)	Total
1984	0	0	0	138	2 165	0	0	0	0	0	4 376	0	0	15 181	0	0	23	0	21 883
1985	0	0	0	239	4 000	0	0	0	0	0	5 464	0	0	10 237	0	0	5	0	19 945
1986	0	0	42	13	2 718	0	0	0	0	0	7 890	0	0	12 200	0	0	10	2	22 875
1987	0	0	0	13	2 024	0	0	0	0	0	7 261	0	0	9 733	0	0	61	20	19 112
1988	0	0	186	67	744	0	0	0	0	0	9 076	0	0	9 430	0	0	82	2	19 587
1989	0	0	67	31	600	0	0	0	0	0	10 622	0	0	8 812	0	0	6	0	20 138
1990	0	0	163	49	954	0	0	0	0	0	17 243	0	0	4 764	0	0	10	0	23 183
1991	11	2 564	314	119	101	0	0	0	0	0	27 587	0	0	2 490	132	0	0	2	33 320
1992	0	0	16	111	13	13	0	0	0	0	7 667	0	31	718	23	0	10	0	8 602
1993	2	0	61	80	22	8	56	0	0	30	10 380	0	43	1 235	0	0	16	0	11 933
1994	4	0	18	55	296	3	15	5	0	4	8 428	0	36	283	1	0	76	2	9 226
1995	0	0	12	174	35	12	25	2	0	0	9 368	0	84	794	1106	0	115	7	11 734
1996	0	0	2	219	81	123	70	0	0	0	11 623	0	79	1 576	200	0	317	57	14 347

Year	Denmark	Estonia	Faroe Islands	France	Fed. Rep. Germany	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[3]	Spain	GB	UK (Engl. & Wales)	UK (Scot land)	Total
1997	0	0	27	253	56	0	62	2	0	0	7 661	12	50	1 038	157	0	67	25	9 410
1998	0	0	57	67	34	0	23	2	0	0	8 435	31	99	2 659	259	0	182	45	11 893
1999	0	0	94	0	34	38	7	2	0	0	15 004	8	49	3 823	319	0	94	45	19 517
2000	0	0	0	45	15	0	16	1	0	0	9 083	3	37	4 568	375	0	111	43	14 297
2001	0	0	0	122	58	0	9	1	0	0	10 896	2	35	4 694	418	0	100	30	16 365
2002	0	219	0	7	42	22	4	6	0	0	7 143	5	14	5 584	178	0	41	28	13 293
2003	0	0	459	2	18	14	0	1	0	0	8 216	5	19	4 384	230	0	41	58	13 447
2004	0	0	0	0	9	0	9	0	0	0	13 939	1	50	4 662	186	0	43	0	18 899
2005	0	170	0	32	8	0	0	0	0	0	13 011	0	23	4 883	660	0	29	18	18 834
2006	0	0	204	46	8	0	8	0	0	196	11 119	201	26	6055	29	0	10	2	17 904
2007	0	0	203	41	8	198	15	0	0	0	8230	200	47	6484	8	0	11	8	15 453
2008	0	0	663	42	5	0	28	0	0	0	7393	201	46	5294	94	0	16	10	13 792
2009	0	0	422	16	19	16	15	2	0	0	8 446	204	237	3 335	210	0	9	60	12 990
2010	0	0	272	102	14	15	16	0	0	0	7 700	3	11	6 888	182	0	4	22	15 229
2011	0	0	538	46	80	4	7	0	0	234	8 270	169	21	7 053	144	0	36	4	16 606
2012	0	0	564	40	40	12	13	0	0	0	9 331	22	1	10 041	190	0	21	14	20 288

Year	Denmark	Estonia	Faroe Islands	France	Fed. Rep. Germany	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[3]	Spain	GB	UK (Engl. & Wales)	UK (Scot land)	Total
2013	0	0	783	168	49	22	106	1	0	0	10 403	30	7	10 310	196	0	17	75	22 167
2014	0	0	887	269	33	20	86	0	0	0	11 232	19	0	10 061	206	0	28	184	23 025
2015	0	0	312	227	33	14	53	0	0	5	10 874	13	1	12 953	159	0	25	79	24 748
2016	0	359	483	229	9	17	79	0	0	0	12 932	8	19	10 576	198	0	20	19	24 948
2017	0	523	917	177	21	26	10	0	1	72	13 741	27	13	10 714	56	0	83	0	26 380
2018	2	574	401	150	50	20	24	0	0	206	14 712	27	6	12 072	60	134	0	0	28 438
2019*	0	588	350	105	44	23	9	0	32	377	14 813	122	8	12 198	87	75	0	0	28 832
2020*	1	578	514	49	72	41	19	0	149	226	14 532	97	28	12 266	96	45	0	0	28 713

* **Provisional figures.**

Table 8.2. Greenland halibut in subareas 1 and 2. Nominal catch (t) by countries in Subarea 1 as officially reported to ICES.

Year	Estonia	Faroe Islands	Fed. Rep. Germany	France	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[3]	Spain	GB	UK (England & Wales)	UK (Scot land)	Total
1984	0	0	0	0	0	0	0	0	0	593	0	0	81	0	0	17	0	691
1985	0	0	0	0	0	0	0	0	0	602	0	0	122	0	0	1	0	725

Year	Estonia	Faroe Islands	Fed. Rep. Germany	France	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia^3	Spain	GB	UK (England & Wales)	UK (Scot land)	Total
1986	0	0	1	0	0	0	0	0	0	557	0	0	615	0	0	5	1	1 179
1987	0	0	2	0	0	0	0	0	0	984	0	0	259	0	0	10	0	1 255
1988	0	9	4	0	0	0	0	0	0	978	0	0	420	0	0	7	0	1 418
1989	0	0	0	0	0	0	0	0	0	2 039	0	0	482	0	0	0	0	2 521
1990	0	7	0	0	0	0	0	0	0	1 304	0	0	321	0	0	0	0	1 632
1991	164	0	0	0	0	0	0	0	0	2 029	0	0	522	0	0	0	0	2 715
1992	0	0	0	0	0	0	0	0	0	2 349	0	0	467	0	0	0	0	2 816
1993	0	32	0	0	0	56	0	0	0	1 754	0	0	867	0	0	0	0	2 709
1994	0	17	217	0	0	15	0	0	0	1 165	0	0	175	0	0	0	0	1 589
1995	0	12	0	0	0	25	0	0	0	1 352	0	0	270	84	0	0	0	1 743
1996	0	2	0	0	0	70	0	0	0	911	0	0	198	0	0	0	0	1 181
1997	0	15	0	0	0	62	0	0	0	610	0	0	170	0	0	0	0	857
1998	0	47	0	0	0	23	0	0	0	859	0	0	491	0	0	2	0	1 422
1999	0	91	0	0	13	7	0	0	0	1 101	0	0	1 203	0	0	0	0	2 415
2000	0	0	0	0	0	16	0	0	0	1 021	0	0	1 169	0	0	0	0	2 206
2001	0	0	0	0	0	9	0	0	0	925	0	0	951	0	0	2	0	1 887

Year	Estonia	Faroe Islands	Fed. Rep. Germany	France	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[3]	Spain	GB	UK (England & Wales)	UK (Scot land)	Total
2002	0	0	3	0	0	0	0	0	0	834	0	0	1 167	0	0	0	0	2 004
2003	0	48	0	0	2	0	1	0	0	962	1	0	735	0	0	0.3	0	1 749
2004	0	0	0	0	0	0.3	0	0	0	866	0	0	633	0	0	3	0	1 503
2005	0	0	0	1	0	0	0	0	0	572	0	0	595	0	0	3	0	1 171
2006	0	17	1	0	0	1	0	0	0	575	0	0	626	2	0	2	0	1 224
2007	0	18	0	1	198	3	0	0	0	514	0	3	438	0	0	4	0	1 179
2008	0	13	0	1	0	5	0	0	0	599	0	0	390	0	0	0	0	1 008
2009	0	33	0	0	16	5	0	0	0	734	0	0	483	0	0	1	0	1 272
2010	0	15	0	0	0	16	0	0	0	659	0	0	708	2	0	0	0	1 399
2011	0	63	0	0	0	6	0	0	0	867	0	0	782	0	0	0	0	1 718
2012	0	8	5	0	0	7	0	0	0	921	0	0	1 368	1	0	7	0	2 318
2013	0	39	1	8	0	100	0	0	0	1 055	4	0	1 442	4	0	8	0	2 661
2014	0	143	8	11	19	38	0	0	0	1 271	7	0	1 261	10	0	14	0	2 782
2015	0	96	14	3	12	47	0	0	5	1 424	5	0	1 681	8	0	4	0	3 299
2016	353	84	2	3	3	38	0	0	0	1 265	7	0	1 172	7	0	20	0	2 954
2017	519	125	4	4	2	8	0	1	72	1 389	9	1	1 124	13	0	21	0	3 293

Year	Estonia	Faroe Islands	Fed. Rep. Germany	France	Greenland	Iceland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[3]	Spain	GB	UK (England & Wales)	UK (Scot land)	Total
2018	574	104	9	16	2	20	0	0	199	1 008	4	1	894	2	97	0	0	2 930
2019*	588	116	27	9	6	6	0	32	377	939	119	0	932	16	49	0	0	3 216
2020*	578	123	37	7	11	18	0	142	223	1388	96	17	787	36	1	0	0	3 464

* **Provisional figures.**

Table 8.3. Greenland halibut in subareas 1 and 2. Nominal catch (t) by countries in Division 2a as officially reported to ICES.

Year	Estonia	Faroe Islands	Fed. Rep. Germ.	France	Greenland	Ireland	Iceland	Lithuania	Norway	Poland	Portugal	Russia[5]	Spain	GB	UK (Engl. & Wales)	UK (Scot-land)	Total
1984	0	0	265	138	0	0	0	0	3 703	0	0	5 459	0	0	1	0	9 566
1985	0	0	254	239	0	0	0	0	4 791	0	0	6 894	0	0	2	0	12 180
1986	0	6	97	13	0	0	0	0	6 389	0	0	5 553	0	0	5	1	12 064
1987	0	0	75	13	0	0	0	0	5 705	0	0	4 739	0	0	44	10	10 586
1988	0	177	150	67	0	0	0	0	7 859	0	0	4 002	0	0	56	2	12 313
1989	0	67	104	31	0	0	0	0	8 050	0	0	4 964	0	0	6	0	13 222
1990	0	133	12	49	0	0	0	0	8 233	0	0	1 246	0	0	1	0	9 674
1991	1 400	314	21	119	0	0	0	0	11 189	0	0	305	0	0	0	1	13 349

Year	Estonia	Faroe Islands	Fed. Rep. Germ.	France	Greenland	Ireland	Iceland	Lithuania	Norway	Poland	Portugal	Russia[5]	Spain	GB	UK (Engl. & Wales)	UK (Scot-land)	Total
1992	0	16	1	108	13	0	0	0	3 586	0	15	58	0	0	1	0	3 798
1993	0	29	14	78	8	0	0	0	7 977	0	17	210	0	0	2	0	8 335
1994	0	0	33	47	3	4	0	0	6 382	0	26	67	0	0	14	0	6 576
1995	0	0	30	174	12	2	0	0	6 354	0	60	227	0	0	83	2	6 944
1996	0	0	34	219	123	0	0	0	9 508	0	55	466	4	0	278	57	10 744
1997	0	0	23	253	0	0	0	0	5 702	0	41	334	1	0	21	25	6 400
1998	0	0	16	67	0	1	0	0	6 661	0	80	530	5	0	74	41	7 475
1999	0	0	20	0	25	2	0	0	13 064	0	33	734	1	0	63	45	13 987
2000	0	0	10	43	0	0	0	0	7 536	0	18	690	1	0	65	43	8 406
2001	0	0	49	122	0	1	9	0	8 740	0	13	726	5	0	56	30	9 751
2002	0	0	9	7	22	0	4	0	5 877	0	3	849	0	0	12	28	6 811
2003	0	390	5	2	12	0	0	0	6 713	0	10	1 762	14	0	5	58	8 971
2004	0	0	4	0	0	0	9	0	11 704	0	24	810	4	0	1	0	12 556
2005	0	0	3	31	0	0	0	0	11 216	0	11	1 406	0	0	5	18	12 690
2006	0	175	0	38	0	0	7	0	8 897	0	6	950	0	0	6	2	10 081
2007	0	162	2	37	0	0	12	0	6 761	0	2	489	1	0	2	8	7 475
2008	0	646	4	38	0	0	23	0	5 566	1	1	1 170	0	0	6	10	7 465

Year	Estonia	Faroe Islands	Fed. Rep. Germ.	France	Greenland	Ireland	Iceland	Lithuania	Norway	Poland	Portugal	Russia[5]	Spain	GB	UK (Engl. & Wales)	UK (Scot-land)	Total
2009	0	379	0	13	0	0	10	0	6 456	0	9	1 531	0	0	0	60	8 459
2010	0	255	0	102	15	0	0	0	6 426	0	0	4 757	0	0	0	22	11 577
2011	0	467	0	45	4	0	1	0	6 637	0	0	3 643	2	0	0	4	10 803
2012	0	553	0	37	12	0	6	0	7 934	0	0	3 878	0	0	0	14	12 434
2013	0	739	0	150	22	0	6	0	8 215	0	2	4 143	0	0	0	75	13 352
2014	0	741	0	255	1	0	48	0	8 640	0	0	4 800	0	0	0	184	14 669
2015	0	215	2	221	2	0	6	0	8 166	0	1	3 691	0	0	0	79	12 383
2016	6	380	6	216	14	0	41	0	10 073	0	6	1 797	7	0	0	19	12 566
2017	0	773	0	161	20	0	2	0	10 122	0	7	1 852	1	0	16	0	12 955
2018	0	297	1	104	9	0	4	1	11 226	2	5	695	0	6	0	0	12 350
2019*	0	232	15	95	16	0	4	0	12 121	3	7	2 755	3	12	0	0	15 263
2020*	0	385	21	34	28	0	1	0	11 437	0	8	2 691	0	3	0	0	14 608

* **Provisional figures.**

Table 8.4. Greenland halibut in subareas 1 and 2. Nominal catch (t) by countries in Division 2b as officially reported to ICES.

Year	Denmark	Estonia	Faroe Islands	Fed. rep. Germ.	France	Greenland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[4]	Spain	GB	UK (Engl. & Wales)	UK (Scot land)	Total
1984	0	0	0	1 900	0	0	0	0	0	80	0	0	9 641	0	0	5	0	11 626
1985	0	0	0	3 746	0	0	0	0	0	71	0	0	3 221	0	0	2	0	7 040
1986	0	0	36	2 620	0	0	0	0	0	944	0	0	6 032	0	0	0	0	9 632
1987	0	0	0	1 947	0	0	0	0	0	572	0	0	4 735	0	0	7	10	7 271
1988	0	0	0	590	0	0	0	0	0	239	0	0	5 008	0	0	19	0	5 856
1989	0	0	0	496	0	0	0	0	0	533	0	0	3 366	0	0	0	0	4 395
1990	0	0	23	942	0	0	0	0	0	7 706	0	0	3 197	0	0	9	0	11 877
1991	11	1 000	0	80	0	0	0	0	0	14 369	0	0	1 663	132	0	0	1	17 256
1992	0	0	0	12	3	0	0	0	0	1 732	0	16	193	23	0	9	0	1 988
1993	2	0	0	8	2	0	0	0	30	649	0	26	158	0	0	14	0	889
1994	4	0	1	46	8	0	1	0	4	881	0	10	41	1	0	62	2	1 061
1995	0	0	0	5	0	0	0	0	0	1 662	0	24	297	1022	0	32	5	3 047
1996	0	0	0	47	0	0	0	0	0	1 204	0	24	912	196	0	39	0	2 422
1997	0	0	12	33	0	0	2	0	0	1 349	12	9	534	156	0	46	0	2 153
1998	0	0	10	18	0	0	1	0	0	915	31	19	1 638	254	0	106	4	2 996
1999	0	0	3	14	0	0	0	0	0	839	8	16	1 886	318	0	31	0	3 115

Year	Denmark	Estonia	Faroe Islands	Fed. rep. Germ.	France	Greenland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[4]	Spain	GB	UK (Engl. & Wales)	UK (Scot land)	Total
2000	0	0	0	5	2	0	1	0	0	526	3	19	2 709	374	0	46	0	3 685
2001	0	0	0	9	0	0	0	0	0	1 231	2	22	3 017	413	0	42	0	4 736
2002	0	219	0	30	0	0	6	0	0	432	5	11	3 568	178	0	29	0	4 478
2003	0	0	21	13	0	0	0	0	0	541	4	9	1 887	216	0	35	0	2 726
2004	0	0	0	5	0	0	0	0	0	1 369	1	26	3 219	182	0	39	0	4 840
2005	0	170	0	5	0	0	0	0	0	1 223	0	12	2 882	660	0	21	0	4 973
2006	0	0	12	7	8	0	0	0	196	1 647	201	20	4 479	27	0	2	0	6 600
2007	0	0	23	6	3	0	0	0	0	955	200	45	5 557	7	0	5	0	6 801
2008	0	0	4	1	3	0	0	0	0	1 228	200	45	3 734	94	0	10	0	5 319
2009	0	0	10	19	3	0	2	0	0	1 256	204	228	1 321	210	0	8	0	3 260
2010	0	0	2	14	0	0	0	0	0	615	3	11	1 423	180	0	4	0	2 252
2011	0	0	8	80	1	0	0	0	234	766	169	21	2 628	142	0	36	0	4 085
2012	0	0	2	35	3	0	0	0	0	476	22	1	4 795	189	0	14	0	5 537
2013	0	0	5	48	10	0	1	0	0	1 133	26	5	4 725	192	0	9	0	6 154
2014	0	0	3	25	3	0	0	0	0	1 321	12	0	4 000	196	0	14	0	5 574
2015	0	0	1	17	3	0	0	0	0	1 284	8	0	7 581	151	0	21	0	9 066
2016	2	0	19	1	10	0	0	0	0	1 594	1	13	7 608	183	0	0	0	9 431

Year	Denmark	Estonia	Faroe Islands	Fed. rep. Germ.	France	Greenland	Ireland	Latvia	Lithuania	Norway	Poland	Portugal	Russia[4]	Spain	GB	UK (Engl. & Wales)	UK (Scot land)	Total
2017	0	4	19	17	12	3	0	0	0	2 230	17	5	7 737	42	0	46	0	10 132
2018	2	0	1	40	30	9	0	6	0	2 477	21	0	10 483	58	31	0	0	13 159
2019*	0	0	2	2	1	1	0	0	0	1 753	0	1	8 511	68	14	0	0	10 353
2020*	1	0	6	15	8	2	0	6	3	1 708	1	3	8 788	60	40	0	0	10 641

*** Provisional figures.**

Table 8.5. Greenland halibut in subareas 1 and 2. Landings by gear (tonnes). Approximate figures, the total may differ slightly from Table 8.1.

Year	Gillnet	Longline	Trawl	Danish seine	Other
1980	1 189	336	11 759	-	-
1981	730	459	13 829	-	-
1982	748	679	15 362	-	-
1983	1 648	1 388	19 111	-	-
1984	1 200	1 453	19 230	-	-
1985	1 668	750	17 527	-	-
1986	1 677	497	20 701	-	-
1987	2 239	588	16 285	-	-
1988	2 815	838	15 934	-	-
1989	1 342	197	18 599	-	-

Year	Gillnet	Longline	Trawl	Danish seine	Other
1990	1 372	1 491	20 325	-	-
1991	1 904	4 552	26 864	-	-
1992	1 679	1 787	5 787	-	-
1993	1 497	2 493	7 889	-	-
1994	1 403	2 392	5 353	-	-
1995	1 500	4 034	5 494	-	-
1996	1 480	4 616	7 977	-	-
1997	998	3 378	5 198	-	-
1998	1 327	7 395	6 664	-	-
1999	2 565	6 804	10 177	-	-
2000	1 707	5 029	7 700	-	-
2001	2 041	6 303	7 968	-	-
2002	1 737	5 309	6 115	-	-
2003	2 046	5 483	6 049	-	-
2004	2 290	7 135	8 778	599	-
2005	1 842	7 539	9 420	447	-
2006	1 503	6 146	10 042	205	-
2007	997	4 503	9 618	119	-

Year	Gillnet	Longline	Trawl	Danish seine	Other
2008	901	3 575	9 285	9	8
2009	1 409	4 952	6 583	34	18
2010	1 449	5 427	8 165	170	10
2011	1 583	5 039	9 351	239	15
2012	1 929	5 602	12 130	413	5
2013	2 398	5 805	13 791	176	0
2014	2 647	6 166	13 673	183	0
2015	2 508	6 287	15 445	489	18
2016	2 646	7 290	14 333	650	304
2017	2 677	7 221	15 774	679	29
2018	3 021	6 542	17 367	842	20
2019	3 323	7 028	17 046	1 119	0
2020*	2 976	6 989	17 675	1 044	28

* Provisional figures.

Table 8.6. Greenland halibut in subareas 1 and 2. Catch per unit effort and total effort.

Year	USSR catch/hour trawling (t)		Norway[10] catch/hour trawling (t)		Average CPUE		Total effort (in '000 hrs trawling)[5]	CPUE 7+[6]	GDR[7] (catch/day tonnage (kg)
	RT[1]	PST[2]	A[8]	B[9]	A[3]	B[4]			
1965	0.80	-	-	-	0.80	-	-	-	-

Year	USSR catch/hour trawling (t)		Norway[10] catch/hour trawling (t)		Average CPUE		Total effort (in '000 hrs trawling)[5]	CPUE 7+[6]	GDR[7] (catch/day tonnage (kg))
	RT[1]	PST[2]	A[8]	B[9]	A[3]	B[4]			
1966	0.77	-	-	-	0.77	-	-	-	-
1967	0.70	-	-	-	0.70	-	-	-	-
1968	0.65	-	-	-	0.65	-	-	-	-
1969	0.53	-	-	-	0.53	-	-	-	-
1970	0.53	-	-	-	0.53	-	169	0.50	-
1971	0.46	-	-	-	0.46	-	172	0.43	-
1972	0.37	-	-	-	0.37	-	116	0.33	-
1973	0.37	-	0.34	-	0.36	-	83	0.36	-
1974	0.40	-	0.36	-	0.38	-	100	0.36	-
1975	0.39	0.51	0.38	-	0.39	0.45	99	0.37	-
1976	0.40	0.56	0.33	-	0.37	0.45	100	0.34	-
1977	0.27	0.41	0.33	-	0.30	0.37	96	0.26	-
1978	0.21	0.32	0.21	-	0.21	0.27	123	0.17	-
1979	0.23	0.35	0.28	-	0.26	0.32	67	0.19	-
1980	0.24	0.33	0.32	-	0.28	0.33	47	0.25	-
1981	0.30	0.36	0.36	-	0.33	0.36	42	0.28	-
1982	0.26	0.45	0.41	-	0.34	0.43	39	0.37	-

Year	USSR catch/hour trawling (t)		Norway[10] catch/hour trawling (t)		Average CPUE		Total effort (in '000 hrs trawling)[5]	CPUE 7+[6]	GDR[7] (catch/day tonnage (kg)
	RT[1]	PST[2]	A[8]	B[9]	A[3]	B[4]			
1983	0.26	0.40	0.35	-	0.31	0.38	58	0.32	-
1984	0.27	0.41	0.32	-	0.30	0.37	59	0.30	-
1985	0.28	0.52	0.37	-	0.33	0.45	44	0.37	-
1986	0.23	0.42	0.37	-	0.30	0.40	57	0.32	-
1987	0.25	0.50	0.35	-	0.30	0.43	44	0.35	-
1988	0.20	0.30	0.31	-	0.26	0.31	63	0.26	4.26
1989	0.20	0.30	0.26	-	0.23	0.28	73	0.19	2.95
1990	-	0.20	0.27	-	-	0.24	95	0.16	1.66
1991	-	-	0.24	-	-	-	134	0.18	-
1992	-	-	0.46	0.72	-	-	20	0.29	-
1993	-	-	0.79	1.22	-	-	15	0.65	-
1994	-	-	0.77	1.27	-	-	11	0.70	-
1995	-	-	1.03	1.48	-	-	-	-	-
1996	-	-	1.45	1.82	-	-	-	-	-
1997	0.71	-	1.23	1.60	-	-	-	-	-
1998	0.71	-	0.98	1.35	-	-	-	-	-
1999	0.84	-	0.82	1.77	-	-	-	-	-

Year	USSR catch/hour trawling (t)		Norway[10] catch/hour trawling (t)		Average CPUE		Total effort (in '000 hrs trawling)[5]	CPUE 7+[6]	GDR[7] (catch/day tonnage (kg))
	RT[1]	PST[2]	A[8]	B[9]	A[3]	B[4]			
2000	0.94	-	1.38	1.92	-	-	-	-	-
2001	0.82[11]	-	1.18	1.57	-	-	-	-	-
2002	0.85	-	1.07	1.82	-	-	-	-	-
2003	0.97[12]	-	0.86	2.45	-	-	-	-	-
2004	0.63[13]	-	1.16	1.79	-	-	-	-	-
2005	0.61[12]	-	1.30	2.29	-	-	-	-	-
2006	0.57[12]	-	0.96	2.09	-	-	-	-	-
2007	0.64[12]	-	-	-	-	-	-	-	-
2008	0.48[12]	-	-	-	-	-	-	-	-
2009	0.77[13]	-	-	-	-	-	-	-	-
2010		1.57[12]	-	-	-	-	-	-	-
2011		2.32[12]							
2012		2.06[12]							
2013		2.25[12]							
2014		2.52[12]							

[1] **Side trawlers, 800–1000 hp. From 1983 onwards, stern trawlers (SRTM), 1000 hp. From 1997 based on research fishing.**

[2] **Stern trawlers, up to 2000 HP.**

[3] Arithmetic average of CPUE from USSR RT (or SRTM trawlers) and Norwegian trawlers.

[4] Arithmetic average of CPUE from USSR PST and Norwegian trawlers.

[5] For the years 1981–1990, based on average CPUE type B. For 1991–1993, based on the Norwegian CPUE, type A.

[6] Total catch (t) of seven years and older fish divided by total effort.

[7] For the years 1988–1989, frost-trawlers 995 BRT (FAO Code 095). For 1990, factory trawlers S IV, 1943 BRT (FAO Code 090).

[8] Norwegian trawlers, ISSC-code 07, 250–499.9 GRT.

[9] Norwegian factory trawlers, ISSCFV-code 09, 1000-1999.9 GRT

[10] From 1992 based on research fishing. 1992–1993: two weeks in May/June and October; 1994–1995: 10 days in May/June

[11] Based on fishery from April-October only, a period with relatively low CPUE. In previous years fishery was carried out throughout the whole year.

[12] Based on fishery from October-December only, a period with relatively high CPUE.

[13] Based on fishery from October-November only.

Table 8.7. Greenland halibut in subareas 1 and 2. Catch history back to 1935. Note two year columns.

Year	Norway	Russia	Others	Total	Year	Norway	Russia	Others	Total
1935	1 534	n/a	-	1 534	1979	2 843	10 311	4 088	17 312
1936	830	n/a	-	830	1980	3 157	7 670	2 457	13 284
1937	616	n/a	-	616	1981	4 201	9 276	1 541	15 018
1938	329	n/a	-	329	1982	3 206	12 394	1 189	16 789
1939	459	n/a	-	459	1983	4 883	15 152	2 112	22 147
1940	846	n/a	-	846	1984	4 376	15 181	2 326	21 883
1941	1 663	n/a	-	1 663	1985	5 464	10 237	4 244	19 945
1942	955	n/a	-	955	1986	7 890	12 200	2 785	22 875

Year	Norway	Russia	Others	Total	Year	Norway	Russia	Others	Total
1943	824	n/a	-	824	1987	7 261	9 733	2 118	19 112
1944	678	n/a	-	678	1988	9 076	9 430	1 081	19 587
1945	1 148	n/a	-	1 148	1989	10 622	8 812	704	20 138
1946	1 337	25	-	1 362	1990	17 243	4 764	1 176	23 183
1947	1 409	28	-	1 437	1991	27 587	2 490	3 243	33 320
1948	1 877	110	-	1 987	1992	7 667	718	217	8 602
1949	198	177	-	375	1993	10 380	1235	318	11 933
1950	1 853	221	-	2 074	1994	8 428	283	515	9 226
1951	2 438	423	-	2 861	1995	9 368	794	1 572	11 734
1952	2 576	377	-	2 953	1996	11 623	1 576	1 148	14 347
1953	2 208	393	-	2 601	1997	7 661	1 038	711	9 410
1954	3 674	416	-	4 090	1998	8 435	2 659	799	11 893
1955	3 010	290	-	3 300	1999	15 004	3 823	690	19 517
1956	3 493	446	-	3 939	2000	9 083	4 568	646	14 297
1957	4 130	505	-	4 635	2001	10 896	4 694	775	16 365
1958	2 931	1 261	-	4 192	2002	7 143	5 584	566	13 293
1959	4 307	3 632	-	7 939	2003	8 216	4 384	847	13 447
1960	6 662	4 299	-	10 961	2004	13 939	4 662	298	18 899

Year	Norway	Russia	Others	Total	Year	Norway	Russia	Others	Total
1961	7 977	3 836	-	11 813	2005	13 011	4 883	940	18 834
1962	11 600	1 760	-	13 360	2006	11 119	6 055	730	17 904
1963	11 300	3 240	-	14 540	2007	8 230	6 484	739	15 453
1964	14 200	26 191	-	40 391	2008	7 393	5 294	1 105	13 792
1965	18 000	16 682	-	34 751	2009	8 446	3 335	1 210	12 990
1966	16 434	9 768	119	26 321	2010	7 700	6 888	641	15 229
1967	17 528	5 737	1 002	24 267	2011	8 270	7 053	1 283	16 606
1968	22 514	3 397	257	26 168	2012	9 331	10 041	916	20 288
1969	14 856	19 760	9 173	43 789	2013	10 403	10 310	1 454	22 167
1970	15 871	35 578	38 035	89 484	2014	11 232	10 061	1 732	23 025
1971	9 466	54 339	15 229	79 034	2015	10 874	12 953	921	24 748
1972	15 983	16 193	10 872	43 055	2016	12 932	10 576	1 440	24 948
1973	13 989	8 561	7 349	29 938	2017	13 741	10 714	1 925	26 380
1974	8 791	16 958	11 972	37 763	2018	14 874	12 072	1 598	28 544
1975	4 858	20 372	12 914	38 172	2019	14 813	12 198	1 471	28 482
1976	6 005	16 580	13 469	36 074	2020*	14 532	12 266	1 915	28 713
1977	4 217	15 045	9 613	28 827					
1978	4082	14 651	5884	24 617					

* **Provisional figures.**

Table 8.8. Greenland halibut in ICES Division 4a (North Sea). Nominal catch (t) by countries as officially reported to ICES. Not included in the assessment.

Year	Denmark	Faroe Islands	France	Germany	Greenland	Ireland	Norway	Russia	GB	UK England & Wales	UK Scotland	Netherlands	Total
1973	0	0	0	4	0	0	9	8	0	28	0	0	49
1974	0	0	0	2	0	0	2	0	0	30	0	0	34
1975	0	0	0	1	0	0	4	0	0	12	0	0	17
1976	0	0	0	1	0	0	2	0	0	18	0	0	21
1977	0	0	0	2	0	0	2	0	0	8	0	0	12
1978	0	0	2	30	0	0	0	0	0	1	0	0	33
1979	0	0	2	16	0	0	2	0	0	1	0	0	21
1980	0	177	0	34	0	0	5	0	0	0	0	0	216
1981	0	0	0	0	0	0	7	0	0	0	0	0	7
1982	0	0	2	26	0	0	17	0	0	0	0	0	45
1983	0	0	1	64	0	0	89	0	0	0	0	0	154
1984	0	0	3	50	0	0	32	0	0	0	0	0	85
1985	0	1	2	49	0	0	12	0	0	0	0	0	64
1986	0	0	30	2	0	0	34	0	0	0	0	0	66
1987	0	28	16	1	0	0	35	0	0	0	0	0	80
1988	0	71	62	3	0	0	19	0	0	1	0	0	156

Year	Denmark	Faroe Islands	France	Germany	Greenland	Ireland	Norway	Russia	GB	UK England & Wales	UK Scotland	Netherlands	Total
1989	0	21	14	1	0	0	197	0	0	5	0	0	238
1990	0	10	30	3	0	0	29	0	0	4	0	0	76
1991	0	48	291	1	0	0	216	0	0	2	0	0	558
1992	1	15	416	3	0	0	626	0	0	+	1	0	1 062
1993	1	0	78	1	0	0	858	0	0	10	+	0	948
1994	+	103	84	4	0	0	724	0	0	6	0	0	921
1995	+	706	165	2	0	0	460	0	0	52	283	0	1 668
1996	+	0	249	1	0	0	1 496	0	0	105	159	0	514
1997	+	0	316	3	0	0	873	0	0	1	162	0	1 355
1998	+	0	71	10	0	10	804	0	0	35	435	0	1 365
1999	+	0		1	0	18	2 157	0	0	43	358	0	2 577
2000	+		41	10	0	19	498	0	0	67	192	0	827
2001	+		43	0	0	10	470	0	0	122	202	0	847
2002	+		8	+	0	2	200	0	0	10	246	0	466
2003	0	0	1	+	+	+	453	0	0	+	122	0	576
2004	0	0	0	0	0	0	413	0	0	90	0	0	503
2005	0	0	2	0	0	0	58	0	0	4	0	0	64

Year	Denmark	Faroe Islands	France	Germany	Greenland	Ireland	Norway	Russia	GB	UK England & Wales	UK Scotland	Netherlands	Total
2006	0	0	3	0	0	0	90	0	0	0	7	0	100
2007	0	1	0	0	0	0	133	0	0	1	6	0	141
2008	0	0	0	0	0	0	14	0	0	0	22	0	36
2009	0	9	22	0	0	0	5	0	0	0	129	0	165
2010	+	1	38	0	0	0	10	0	0	0	49	0	98
2011	0	1	39	0	0	0	94	0	0	0	44	0	178
2012	0	0	14	0	0	0	788	0	0	0	43	0	845
2013	0	0	25	0	0	0	122	0	0	0	174	0	321
2014	0	2	27	0	0	0	723	0	0		104	0	856
2015	0	0	34	1	0	0	1 151	0	0	0	127	0	1 313
2016	0	0	31	0	0	0	983	0	0	0	120	0	1 134
2017	0	0	20	0	0	0	753	0	0	0	73	0	846
2018	0	0	15	0	0	0	472	0	42	0	0	0	532
2019	0	0	21	0	0	0	241	0	14	0	0	1	277
2020*	0	0	10	0	0	0	663	0	45	0	0	1	719

Table 8.9. Abundance indices of different length groups in 1984–2020 (in thousands), Russian autumn survey.

Year/Length (cm)	≤30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80	>80	Total
1984	4 837	5 078	11 690	21 171	15 167	10 886	7 370	6 549	3 751	1 786	1 128	483	89 896
1985	4 003	6 748	16 858	24 897	23 244	15 702	8 376	5 704	3 776	2 054	1 028	698	113 088
1986	3 482	6 062	13 765	18 945	15 997	10 369	4 839	3 022	2 534	1 325	440	205	80 985
1987	2 010	4 828	7 228	10 490	8 831	5 513	2 123	1 784	1 437	645	481	421	45 791
1988	3 374	5 111	9 022	10 147	10 128	5 828	2 265	1 862	1 218	511	361	341	50 168
1989	2 030	7 055	13 962	17 252	16 790	10 028	3 789	1 916	1 279	415	200	388	75 104
1990	2 762	6 056	12 802	13 061	9 527	9 829	4 967	2 094	589	312	115	119	62 233
1991	1 036	5 012	16 237	20 998	17 418	11 728	8 012	4 562	814	181	122	174	86 294
1992	184	2 153	17 185	32 399	22 481	12 977	6 229	3 473	1 869	502	182	106	99 740
1993	-	290	3 593	14 782	21 080	16 013	6 743	3 341	2 031	859	269	164	69 165
1994	49	17	1 651	12 582	16 203	12 566	5 391	3 320	2 019	819	188	106	54 911
1995	-	38	1 245	13 193	20 571	12 445	5 432	2 717	1 587	579	187	82	58 076
1996*	-	11	786	13 012	30 573	18 294	5 730	1 795	773	534	169	12	71 689
1997	140	152	1 318	7 744	18 504	17 221	6 932	3 079	1 952	465	195	142	57 844
1998	2 449	2 238	2 949	10 847	24 266	19 640	11 112	5 946	2 158	440	172	90	82 307
1999	1 070	2 815	4 632	7 886	17 734	18 489	10 158	4 827	2 043	529	196	74	70 453
2000	1 274	1 698	5 184	14 996	24 170	20 721	12 805	5 675	3 100	1 228	240	143	91 234
2001	1 399	2 887	7 496	18 136	34 752	29 886	13 463	6 759	3 772	1 511	593	369	121 024

Year/Length (cm)	≤30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80	>80	Total
2002**	662	2 033	6 395	13 329	19 810	13 135	7 180	3 406	1 311	381	129	58	67 828
2003***	955	2 396	7 420	13 006	17 160	11 630	7 978	5 332	3 541	985	485	238	71 126
2004	1 431	2 705	11 945	16 937	20 155	18 274	12 594	6 948	4 783	2 087	813	536	99 209
2005	830	3 970	10 726	17 850	17 547	15 164	9 726	5 859	3 343	1 150	453	545	87 163
2006****	293	1 981	18 471	35 224	36 563	26 335	14 138	7 248	4 943	1 669	668	488	148 021
2007	376	1 431	6 937	24 330	26 780	26 086	22 157	15 586	7 480	3 786	932	628	136 510
2008	463	4 626	19 991	28 799	30 062	32 159	23 175	11 326	8 368	4 198	1 872	1 089	166 129
2009	152	4 919	29 389	48 321	45 833	33 915	24 484	10 227	6 568	3 032	881	616	208 338
2010	146	5 097	37 901	66 086	57 863	46 321	25 428	10 058	8 612	3 983	1 587	1 610	264 692
2011	456	1 285	22 470	61 115	78 247	64 186	49 620	19 412	11 607	7 226	3 529	874	320 025
2012	213	798	12 051	49 062	56 704	52 393	36 362	13 622	7 533	4 213	1 944	1 611	236 506
2013*****													
2014	17	1697	10 296	34 074	45 287	35 861	22 621	8613	5505	2227	929	427	167 553
2015	318	2 099	13 542	35 864	43 551	36 082	21 114	10 924	4 472	1 342	850	339	170 497
2016*****													
2017	158	2 198	10 687	32 464	61 577	71 590	40 700	16 830	7 449	3 483	1 206	1 245	249 585
2018*****													
2019	144	2 186	13 500	27 129	28 572	22 536	13 943	5 825	3 080	1 654	707	406	119 742

Year/Length (cm)	≤30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80	>80	Total
2020*****													

*** Only half of the standard area was investigated**

**** No observations in NEEZ**

***** Observations in the NEEZ on the main spawning grounds were conducted considerably later than usual**

****** Survey was conducted by one vessel with a reduced number of trawls at depths less than 500 m**

*******No indices for 2013, 2016, 2018 and 2020**

Table 8.10. Abundance indices of different length groups in 1994–2019 (in thousands), Norwegian autumn slope survey.

Year	<30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1994	0	0	0	0	1	15	23	80	197	335	645	1 225	1 611	2 432	3 431	3 511	3 830	3 519	3 940	3 724	2 896	3 020
1995	0	0	1	3	6	15	29	86	141	242	472	931	1 210	2 294	3 092	3 840	4 475	4 540	4 633	4 321	3 836	3 856
1996	0	2	1	6	6	2	18	49	54	166	321	772	957	1 787	2 912	3 769	4 728	5 199	5 944	5 644	5 224	5 132
1997	7	5	11	4	33	27	49	186	250	297	443	862	1 009	1 814	2 888	3 578	5 451	5 402	6 132	5 206	4 125	5 455
1998	7	2	6	15	17	22	51	103	174	219	372	504	727	1 061	1 491	2 103	2 941	3 092	3 609	3 735	3 851	4 850
1999	10	4	18	15	20	40	61	75	110	174	202	377	476	862	1 175	1 655	2 397	2 543	3 485	4 214	3 694	5 274
2000	2	7	11	30	34	46	128	122	163	264	383	677	739	932	1 183	1 439	2 038	2 030	2 268	2 644	2 846	3 888
2001	21	20	35	37	77	147	274	270	440	462	724	986	1 176	1 373	1 630	1 720	2 724	2 655	3 349	3 128	3 973	3 999
2002	97	75	107	122	180	267	399	404	723	669	869	1 026	1 097	1 360	1 883	1 870	2 560	2 185	3 322	3 450	3 597	4 032
2003	38	27	65	97	172	270	383	692	783	894	1 214	1 100	1 481	1 561	2 082	1 792	2 468	2 104	3 193	3 360	3 506	3 117
2004	27	15	47	125	191	402	636	639	951	1 042	1 092	1 206	1 337	1 319	1 398	1 546	2 013	1 967	2 638	2 646	3 337	3 373

Year	<30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
2005	66	104	285	317	517	765	861	1 220	1 492	1 540	2 053	2 295	2 293	2 588	2 262	2 677	3 041	2 446	2 854	2 095	3 056	2 336
2006	12	50	80	158	258	456	849	1 022	1 429	1 579	1 603	1 900	1 823	1 824	2 015	1 974	2 529	2 359	2 350	2 137	2 338	2 175
2007	157	96	161	359	766	1 423	2 508	3 142	4 411	5 679	5 346	5 639	5 502	5 038	4 600	3 632	3 667	3 628	3 278	2 571	2 882	2 597
2008	378	384	723	1 323	1 763	1 793	2 441	2 911	3 249	3 685	4 229	4 300	4 257	3 568	3 911	3 534	3 020	3 066	2 769	2 582	2 639	2 284
2009	31	36	93	349	505	934	1 663	2 660	3 050	3 680	4 138	4 885	5 567	4 148	5 327	4 639	3 688	3 752	3 682	3 410	3 553	3 215
2011	0	0	20	36	57	124	288	563	646	1 414	1 454	2 228	2 680	3 174	3 649	3 750	3 532	3 031	3 299	3 991	3 251	2 454
2013	17	5	3	1	13	64	103	122	324	582	1 022	1 266	2 138	2 207	3 553	3 748	3 476	4 124	3 717	3 045	3 718	3 052
2015	3	24	24	36	131	318	439	721	757	1 043	1 253	1 473	2 602	2 444	3 776	4 459	4 602	4 598	4 371	3 962	4 156	3 694
2017	6	20	45	54	63	144	184	328	593	365	928	955	1 267	1 457	1 764	1 983	2 367	2 465	2 651	2 569	2 816	3 011
2019	0	0	28	43	128	362	372	569	874	1 322	1 290	1 424	1 667	2 285	2 210	2 168	2 208	2 229	2 434	2 119	2 305	2 405

Year	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
1994	2 545	2 729	2 398	2 092	1 975	1 547	1 488	1 103	920	788	565	702	576	523	577	370	367	386
1995	3 165	3 152	2 963	2 647	2 272	1 756	1 586	1 153	970	880	764	690	680	592	525	461	387	334
1996	4 106	3 638	3 571	2 752	2 177	1 568	1 443	1 017	867	782	512	449	538	404	391	356	281	248
1997	3 644	3 427	3 018	2 302	2 111	1 502	1 131	1 042	617	849	585	576	537	403	446	481	294	230
1998	4 211	3 824	3 166	2 988	2 857	1 974	1 714	1 515	981	1 172	783	613	598	668	641	569	479	364
1999	4 092	5 196	4 136	3 909	4 122	2 631	2 299	1 787	1 374	1 388	895	1 037	865	886	923	791	807	594
2000	3 692	3 681	3 512	3 016	3 197	2 388	2 007	1 545	1 227	1 327	915	1 028	734	630	732	517	509	505

Year	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
2001	3 649	4 512	4 106	3 005	3 358	2 552	2 589	2 147	1 293	1 350	1 099	939	1 187	684	787	612	751	603
2002	4 241	3 516	3 966	3 602	3 855	2 837	2 511	2 248	1 672	1 787	1 239	1 237	1 139	808	882	604	679	474
2003	4 400	3 465	3 808	3 512	3 907	3 368	3 035	2 319	1 896	1 705	1 612	1 384	1 542	1 130	1 350	972	994	675
2004	3 535	4 405	3 614	3 801	3 249	2 751	2 252	1 911	1 493	1 455	1 372	1 360	1 284	1 162	962	763	891	590
2005	2 400	2 734	2 413	2 084	2 295	1 882	1 681	1 492	1 458	1 168	1 241	1 057	1 065	984	903	782	865	479
2006	2 493	2 125	2 290	2 025	2 189	1 790	1 668	1 542	1 337	1 159	1 188	1 009	925	1 036	807	798	647	678
2007	2 109	2 249	2 123	2 142	1 758	1 609	1 581	1 070	1 008	1 044	625	938	672	558	537	526	394	469
2008	2 288	2 248	2 229	1 815	1 751	1 514	1 150	1 019	861	668	652	657	508	582	629	523	484	361
2009	2 668	2 944	2 850	2 441	2 372	2 233	1 837	1 698	1 503	1 135	845	962	647	858	715	607	653	609
2011	2 905	2 746	2 602	2 713	2 387	1 709	1 704	1 529	978	1 179	577	649	554	440	466	315	440	550
2013	2 498	2 035	1 905	1 631	1 710	1 573	1 424	1 009	790	671	503	506	400	456	234	266	227	176
2015	3 469	2 384	2 546	2 084	2 142	1 734	1 336	1 108	1 020	899	713	621	605	495	274	289	341	291
2017	2 890	2 547	2 501	2 091	1 792	1 786	1 532	1 274	1 269	1 029	765	579	481	446	294	299	247	245
2019	1 653	1 799	1 617	1 490	1 057	1 185	846	840	670	568	461	313	304	312	231	242	179	130

Year	69	70	71	72	73	74	75	76	77	78	79	>80	SUM
1994	256	253	151	136	122	74	113	47	39	40	30	97	57 444
1995	339	244	181	179	97	100	137	56	53	53	34	101	64 574
1996	232	168	118	123	93	97	61	28	40	39	21	74	68 887

Year	69	70	71	72	73	74	75	76	77	78	79	>80	SUM
1997	171	207	216	119	109	111	104	61	32	35	40	185	67 819
1998	308	320	235	222	229	144	102	64	65	61	43	192	59 786
1999	478	406	385	319	182	205	223	125	109	145	51	328	67 569
2000	341	376	232	210	168	153	141	77	96	77	47	233	55 187
2001	490	375	279	170	207	178	157	85	133	69	49	306	66 941
2002	469	383	297	251	183	163	134	104	130	48	65	251	70 069
2003	563	632	464	249	244	170	242	201	128	125	114	356	74 961
2004	654	420	373	325	521	248	181	135	121	100	109	431	68 415
2005	523	508	400	262	196	159	156	162	109	82	61	426	67 190
2006	474	508	397	285	185	276	185	140	136	81	96	497	59 886
2007	289	254	261	101	140	130	75	52	80	59	47	278	90 260
2008	313	258	226	201	138	107	59	62	89	66	76	508	80 851
2009	574	541	271	386	219	171	191	112	121	89	100	407	93 764
2011	415	409	200	285	235	193	225	204	175	51	87	503	67 066
2013	162	173	124	114	109	112	66	72	79	34	43	260	55 662
2015	252	265	176	195	186	205	89	78	73	141	53	286	69 236
2017	178	185	88	98	77	51	61	50	35	40	46	184	49 195
2019	144	117	71	81	50	44	32	31	9	13	12	113	43 056

***Biennial surveys since 2009**

Table 8.11. Abundance indices of females of different length groups in 1994–2019 (in thousands), Norwegian autumn slope survey.

Year	<30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1994	0	0	0	0	1	15	23	80	196	335	643	1 223	1 611	2 429	3 426	3 503	3 824	3 510	3 934	3 716	2 886	3 018
1995	0	0	1	3	6	15	29	86	141	242	472	930	1 210	2 291	3 088	3 837	4 470	4 537	4 629	4 317	3 835	3 855
1996	0	0	0	4	0	1	10	26	28	64	123	228	233	424	415	773	937	1020	1 185	1 151	1 037	1 374
1997	6	5	7	4	17	14	36	134	139	146	187	337	331	419	569	685	899	852	1 169	1 058	828	1 226
1998	5	0	0	11	4	7	26	41	78	77	156	170	190	274	290	364	413	526	605	665	743	970
1999	2	0	1	0	7	14	19	12	41	68	93	137	117	227	285	300	336	313	496	574	533	1 049
2000	1	5	6	14	16	16	44	44	65	121	155	201	229	245	268	278	374	311	303	411	410	517
2001	13	6	14	15	38	61	118	123	177	167	293	411	462	355	425	376	544	477	493	379	558	673
2002	51	48	58	60	77	109	178	182	290	275	326	319	306	407	500	378	515	331	483	461	501	575
2003	25	25	27	43	100	124	182	276	413	429	532	504	512	545	610	450	552	394	539	487	523	406
2004	15	3	13	61	83	160	305	278	436	358	434	404	440	384	381	454	413	362	382	309	427	472
2005	30	24	110	99	182	258	322	464	565	537	723	758	619	630	452	633	723	467	593	293	500	329
2006	4	19	48	81	148	187	327	442	595	674	713	686	648	568	649	482	619	501	503	512	468	452
2007	85	67	104	178	371	731	1 321	1 539	2 259	2 654	2 515	2 403	2 454	2 145	1 580	1 242	1 132	988	851	727	640	554
2008	216	210	432	698	829	958	1 190	1 372	1 529	1 597	1 720	1 516	1 625	1 069	1 180	9 28	889	948	834	677	773	615
2009	13	19	33	146	210	343	662	1 001	1 263	1 470	1 491	1 814	1 979	1 441	1 752	1 533	1 044	1 195	1 037	988	922	878
2011	0	0	8	22	24	31	103	175	195	469	311	538	642	722	623	645	686	664	528	665	751	298

Year	<30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
2013	0	0	0	0	3	11	49	30	50	186	261	246	521	286	650	509	621	693	626	664	745	576
2015	0	7	7	19	67	149	183	304	380	358	391	377	491	387	549	490	682	904	632	689	761	766
2017	4	17	16	43	44	79	83	120	267	117	395	312	365	373	288	411	524	444	6 277	453	439	579
2019	0	0	16	25	92	119	183	300	360	500	527	498	604	609	512	517	426	558	489	503	541	479

***Biennial surveys since 2009.**

Year	51	52	53	54	55	56	57	58	69	60	61	62	63	64	65	66	67	68	69	70	71	72	73
1994	####	####	2 384	2 088	1 969	1 545	1 482	1 098	917	785	560	700	571	522	573	368	364	385	254	253	151	136	122
1995	####	####	2 958	2 646	2 271	1 752	1 586	1 152	968	875	761	689	680	592	525	461	387	333	339	244	181	179	97
1996	####	886	895	771	527	547	639	548	508	602	410	401	481	383	387	344	281	230	232	167	118	123	93
1997	911	985	824	650	669	590	523	562	346	633	484	501	506	364	433	437	289	225	171	207	216	119	109
1998	995	####	999	1 056	903	758	754	831	667	907	615	543	569	639	638	567	453	362	308	307	235	222	225
1999	830	####	928	1 042	1 287	1 019	1 002	955	845	1 106	754	927	816	814	890	780	798	582	478	403	384	317	182
2000	590	591	593	663	756	816	704	649	670	839	699	829	620	588	665	487	491	495	328	376	230	210	167
2001	479	632	761	643	680	698	962	877	743	936	928	714	1 062	594	772	577	746	598	488	370	279	170	207
2002	610	438	638	694	823	672	824	779	780	989	780	1 024	813	705	827	598	656	443	458	383	295	251	183
2003	604	582	662	611	968	854	1 111	964	1 057	1 126	1 260	1 165	1 314	1 085	1 278	938	962	670	555	625	462	249	242
2004	461	638	570	693	760	937	876	839	966	998	1 202	1 186	1 227	1 116	932	749	885	585	639	420	373	325	461
2005	378	411	427	451	597	638	775	718	800	871	935	938	965	904	860	740	860	449	523	465	390	262	192
2006	490	458	461	392	537	523	545	678	805	796	893	865	820	927	775	768	637	633	468	499	376	285	178

Year	51	52	53	54	55	56	57	58	69	60	61	62	63	64	65	66	67	68	69	70	71	72	73
2007	476	499	471	491	469	533	607	549	566	776	494	790	587	534	517	515	394	469	278	254	261	101	133
2008	509	481	515	495	443	547	441	543	466	490	530	572	482	539	610	514	483	361	309	252	226	201	138
2009	640	665	738	639	733	724	698	783	814	605	653	765	534	776	701	525	616	587	561	526	263	378	219
2011	557	468	480	472	466	369	329	469	324	378	341	523	477	348	450	300	415	550	393	409	192	285	235
2013	518	381	477	308	375	529	526	304	296	334	324	377	329	390	218	260	227	174	159	173	120	114	109
2015	826	770	744	579	811	649	471	494	553	537	470	462	420	450	270	283	339	283	251	265	176	195	186
2017	530	438	516	448	392	555	578	498	563	530	473	330	378	371	271	286	243	245	178	185	88	98	77
2019	401	481	431	494	351	391	324	458	402	367	277	254	260	257	210	218	174	123	143	114	71	81	50

***Biennial surveys since 2009**

Year	74	75	76	77	78	79	>80	SUM
1994	74	113	47	39	40	30	95	51 911
1995	100	137	56	53	53	34	99	58 202
1996	92	61	28	40	39	21	74	18 961
1997	111	104	61	29	35	40	185	20 387
1998	144	102	64	65	61	43	192	19 839
1999	205	223	125	109	140	47	328	22 940
2000	153	141	77	96	77	47	233	17 914
2001	178	157	85	131	69	49	306	22 069
2002	163	131	104	130	48	65	251	21 985

Year	74	75	76	77	78	79	>80	SUM
2003	170	242	201	128	125	114	356	28 378
2004	241	181	135	119	100	109	431	25 728
2005	149	156	152	109	82	61	426	24 995
2006	259	185	138	136	81	96	491	24 521
2007	124	75	52	80	59	47	275	38 016
2008	107	59	62	89	66	76	506	32 917
2009	171	191	104	121	80	100	385	36 529
2011	193	225	204	175	51	87	503	18 768
2013	112	66	72	79	34	43	260	14 415
2015	205	89	78	73	141	53	286	20 002
2017	51	61	50	35	40	46	184	20 388
2019	44	32	31	9	13	12	113	14 444

***Biennial surveys since 2009**

Table 8.12. Abundance indices (numbers in thousands) from bottom-trawl surveys in the Barents Sea standard area winter 1994–2021 (Mehl *et al.*, WD4 AFWG 2019).

	Length group (cm)															Biomass (tonnes)
Year	≤14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	≥80	Total	
1994	0	0	21	76	148	1 117	3 139	4 740	3 615	1 941	889	541	21	0	0	16 248	19 228
1995	298	0	0	0	90	129	2 877	7 182	5 739	2 027	1 622	839	489	86	0	21 378	27 459
1996	4 121	0	0	0	62	124	1 214	4 086	4 634	1 871	1 112	638	337	74	12	18 285	20 256

	Length group (cm)																Biomass (tonnes)
Year	≤14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	≥80	Total	
1997[1]	0	68	0	0	55	163	949	4 313	5 629	2 912	1 609	643	300	65	21	16 728	24 214
1998[1]	68	220	945	578	481	487	1 088	4 016	6 591	3 076	1 798	707	326	93	44	20 518	27 248
1999	43	84	241	436	566	269	784	1 701	3 097	1 669	1 094	491	89	75	0	10 640	14 681
2000	140	184	344	836	1 722	3 857	2 253	1 560	2 144	1 714	1 191	615	249	76	0	16 883	17 246
2001	68	49	147	179	737	1 525	3 716	3 271	2 302	2 010	1 088	529	160	50	39	15 871	18 224
2002	271	0	70	34	382	1 015	1 916	3 803	3 250	2 279	1 138	976	242	159	114	15 648	21 198
2003	51	0	74	19	304	715	1 842	3 008	4 765	2 235	714	561	245	146	0	14 678	19 635
2004	106	104	15	0	319	1 253	1 229	1 717	2 277	1 227	798	298	148	94	26	9615	11 872
2005	263	70	159	1 139	2 235	2 621	4 206	3 782	3 847	2 037	917	585	336	118	0	22 314	22 293
2006[2]	0	72	94	414	1 968	5 149	4 613	5 743	4 283	2 132	891	449	258	34	18	26 118	25 579
2007[1]	0	18	146	1 869	1 418	3 114	5 710	5 947	4 287	2 205	963	658	391	80	89	26 896	28 006
2008	0	0	0	243	1 708	5 974	4 654	6 136	5 198	3 403	827	638	174	82	50	29 088	30 153
2009	55	0	0	26	1 044	4 327	8 133	4 551	4 084	2 266	996	627	442	253	154	26 960	28 919
2010	0	0	0	99	678	3 648	5 729	6 560	4 897	2 467	1 064	552	229	128	41	26 092	25 979
2011	51	0	0	0	216	4 396	5 864	5 498	5 237	3 698	699	936	327	252	97	27 271	31 552
2012[3]	77	0	0	0	51	1 145	4 524	5 366	4 517	2 774	1 147	195	73	0	48	19 917	22 656
2013	0	0	0	0	0	511	5 368	4 868	5 374	3 687	1 944	939	348	131	154	23 504	31 748

	Length group (cm)															Biomass (tonnes)
Year	**≤14**	**15–19**	**20–24**	**25–29**	**30–34**	**35–39**	**40–44**	**45–49**	**50–54**	**55–59**	**60–64**	**65–69**	**70–74**	**75–79**	**≥80**	**Total**	
2014	0	0	46	92	156	368	2 271	5 587	5 903	3 555	2 251	1 369	154	260	79	22 090	31 112
2015	367	0	61	0	284	1 612	3 187	6 452	7 249	6 752	3 350	1 936	587	334	0	32 172	46 828
2016	205	0	124	511	950	1 953	3 486	4 539	5 479	5 613	1 999	1 973	646	98	80	27 657	35 831
2017[4]	52	0	0	78	592	1 328	1 885	3 850	4 852	4 550	1 721	1 455	317	190	23	20 827	29 756
2018	0	0	62	0	383	1 333	2 049	3 445	4 258	3 573	1 904	1 366	736	196	20	19 325	28 688
2019	0	0	0	375	272	1 6 71	3 285	4 034	5 177	4 265	3 570	2 526	1 328	535	137	27 176	45 912
2020[3]	80	91	2464	442	790	2272	4391	5136	4929	4613	3278	1803	894	384	250	29 599	43 631
2021[3]	0	154	927	927	2370	2976	3869	4265	3516	2991	2378	1649	670	682	238	27 613	37090

[1] **Indices raised to also represent the Russian EEZ**

[2] **Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005**

[3] **Indices not raised to also represent uncovered parts of the Russian EEZ.**

[4] **Indices raised to also represent uncovered parts of the Russian EEZ**

Table 8.13. Greenland halibut catch in weight, numbers, and biomass (in tonnes) and abundance (in thousands) estimated from Spanish autumn and spring surveys 1997–2019. NB. Absolute biomass and abundance values must not be compared between spring and autumn surveys due to different gears. The trawl used during spring surveys is considered less efficient on benthic species as Greenland halibut and skates, and better to catch species less associated with bottom.

Autumn survey

Year	Catch (Kg)	Catch (numbers)	Biomass™	Abundance (‘000)
1997	195 056	211 533	344 014	379 444
1998	180 974	187 259	351 466	373 149
1999	198 781	172 687	436 956	377 792
2000	169 389	140 355	340 619	291 265
2001	152 681	129 289	283 511	249 219
2002	144 335	115 213	256 460	207 466
2003	151 952	132 117	283 644	256 327
2004	153 859	135 631	320 485	283 965
2005	144 573	134 566	317 320	313 459
2008	91 573	101 578	129 221*	144 561*
2010	167 862	182 464	191 510*	216 731*
2012	178 607	174 670	336 543*	339 697*
2013	172 762	168 619	264 101*	267 548*
2014	175 553	160 557	321 485*	307 679*
2016	176 015	142 413	247 644*	214 778*
2019	50 880	45 631	209 439*	187 830*

No survey in 2006, 2007, 2009, 2011, 2015, 2017, 2018, and 2020.

***New swept-area estimation method**

Spring survey

Year	Catch (Kg)	Catch (numbers)	Biomass™	Abundance (‘000)
2008	96 797	109 515	38 406	38 951
2009	200 299	222 018	58 273	65 464
2011	136 610	160 566	98 142	117 666
2015**	111 425	105 385	150 385	155 333

No survey in 2010, 2012, 2013 and 2014.

****Different from the one used during the 2014 Spanish “autumn” survey.**

Table 8.14. Greenland halibut in subareas 1 and 2. The catch scenarios. Weights in tonnes. Assessment 2021 as basis for advice for 2022 and 2023. NB. according to working group forecast, this may diverge slightly from final advice by ACOMTAC for 2021 from EU/UK was not sat at the time of the working group and TAC change is thus relative only to the TAC sat by JRNFC.

Table a **Greenland halibut in subareas 1 and 2. Annual catch scenarios for 2022. All weights are in tonnes.**

Basis	**Total catch (2022)**	**HR_{total} (2022)**	**Biomass 45 cm+ (2023)**	**% Biomass 45 cm+ change ***	**% TAC change ****	**% Advice change *****
ICES advice basis						
HR = 0.035	19094	0.035	535	−5%	−29%	−17%
Other scenarios						
HR = 0	0	0	554	−1%	−100%	−100%
HR = 0.025	13873	0.025	540	−4%	−49%	−40%
Catch_SQ (HR=0.052/0.055)	28713	0.052/0.055	526	−6%	6%	25%

*** Biomass 45 cm+ 2023 relative to 2022 (561 tonnes).**

**** Advice in 2022 relative to TAC in 2021. Only TAC sat by JRNFC in 2021 (27 000 tonnes) was available.**

***** Advice value for 2022 relative to the advice value for 2021.**

Table b Greenland halibut in subareas 1 and 2. Annual catch scenarios for 2023. All weights are in tonnes.

Basis	**Total catch (2023)**	**HR_{total} (2023)**	**Biomass 45 cm+ (2024)**	**% Biomass 45 cm+ change ***	**% Advice change ****
ICES advice basis					
HR = 0.035	18494	0.035	523	−2%	−3%
Other scenarios					
HR = 0	0	0	558	1%	0%
HR = 0.025	13590	0.025	533	−1%	−2%
Catch_SQ (HR=0.052/0.055)	28713	0.052/0.055	505	−4%	0%

*** Biomass 45cm+ 2024 relative to 2023 (biomass 2023 depends on scenario).**

**** Advice value for 2023 relative to the advice value for same scenario in 2022.**

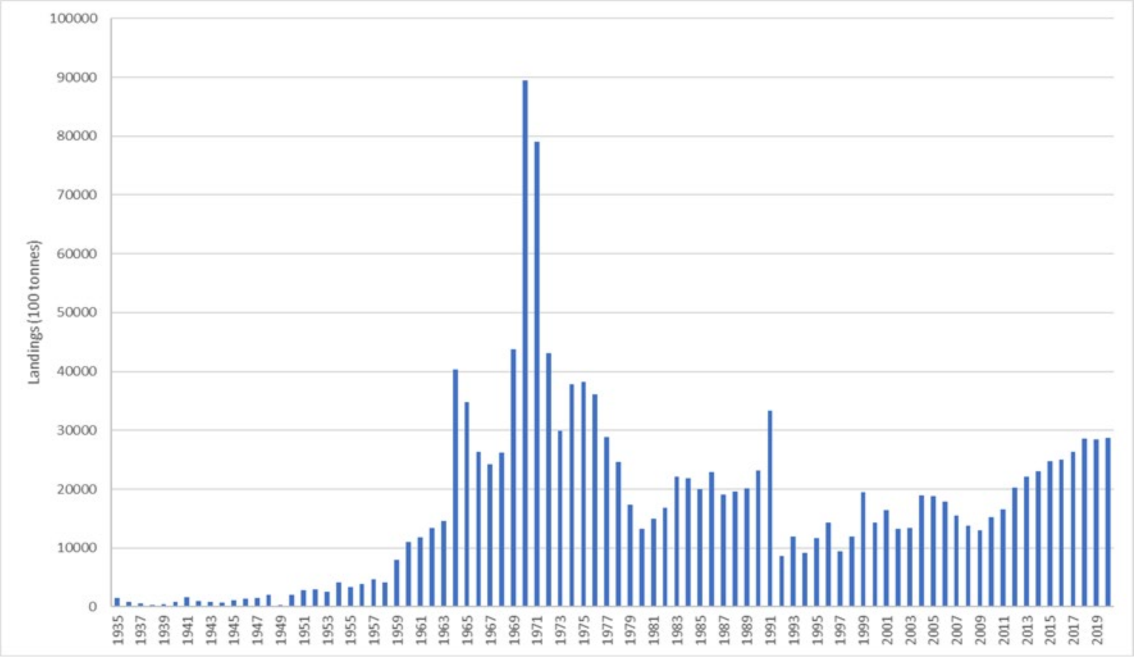


Figure 8.1. NEA Greenland halibut landings. Historical landings (Nedreaas and Smirnov 2003 and AFWG).

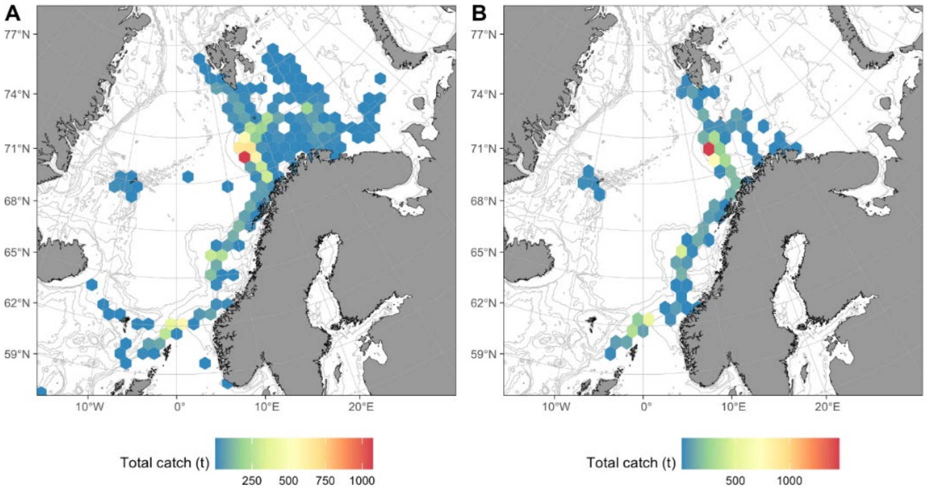


Figure 8.2. Spatial distribution of Greenland halibut catches in 2020 according to Norwegian electronic logbooks, in all registered fisheries including bycatch (A), and catches where G. halibut make more than 50% of the total catches (B).

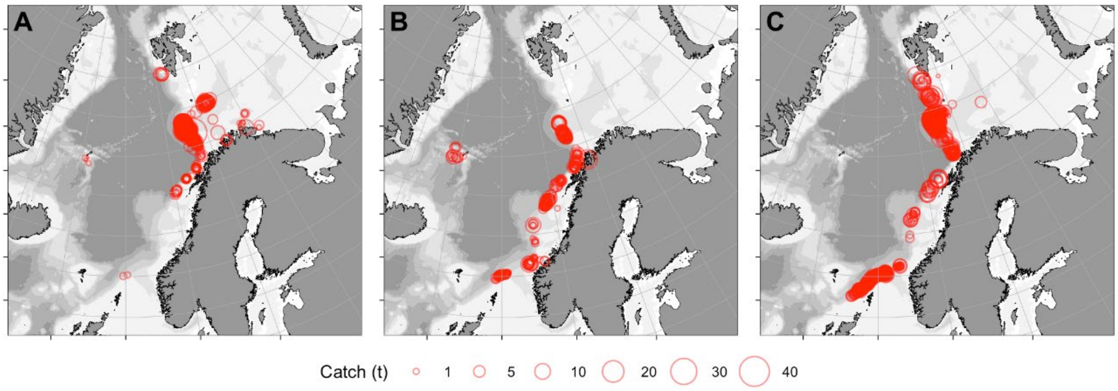


Figure 8.3. Spatial distribution of catches where Greenland halibut make more than 50% of the total catches, according to Norwegian electronic logbooks from 2020. Bubble area is proportional to the size of single catches expressed in metric tonnes. The panels show longline (A), gillnet (B) and trawl (C) catches.

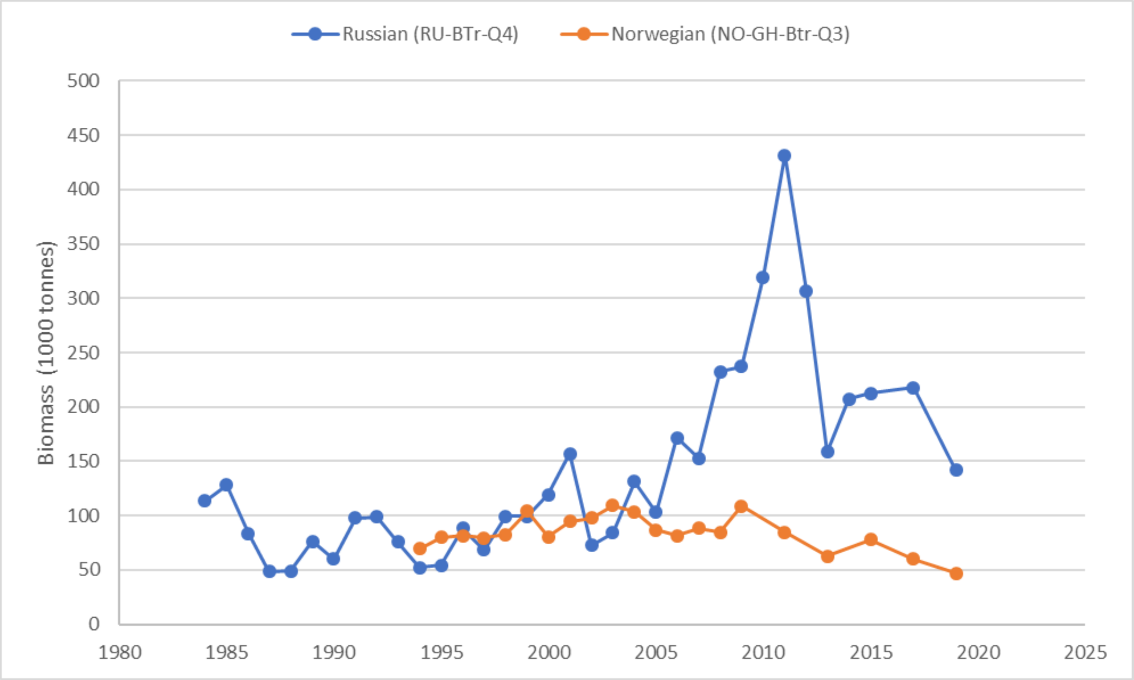


Figure 8.4. NEA Greenland halibut. Total biomass estimates from Russian autumn survey and the Norwegian slope survey. Note that the Norwegian survey is run every other year since 2009. Uncertain estimate for 2013 from the Russian survey. Russian data from 1992 and onwards are revised in 2021 (Russkikh WD12). No Russian data for 2016, 2018 and 2020.

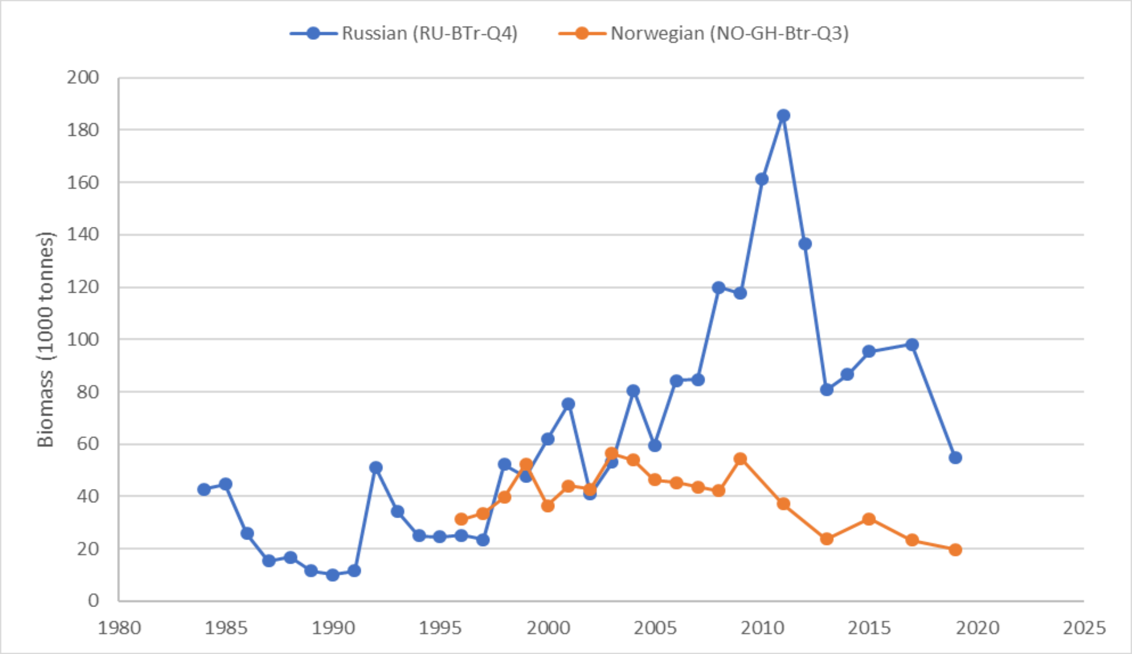


Figure 8.5. NEA Greenland halibut. Swept–area estimate of the female biomass based on the data from the Norwegian slope survey in August (every other year since 2009) and the Russian trawl survey in October–December (compared to previous reports, . Russian data from 1992 and onwards are revised in 2021 (Russkikh WD12)). Uncertain estimate for 2013 from the Russian survey.

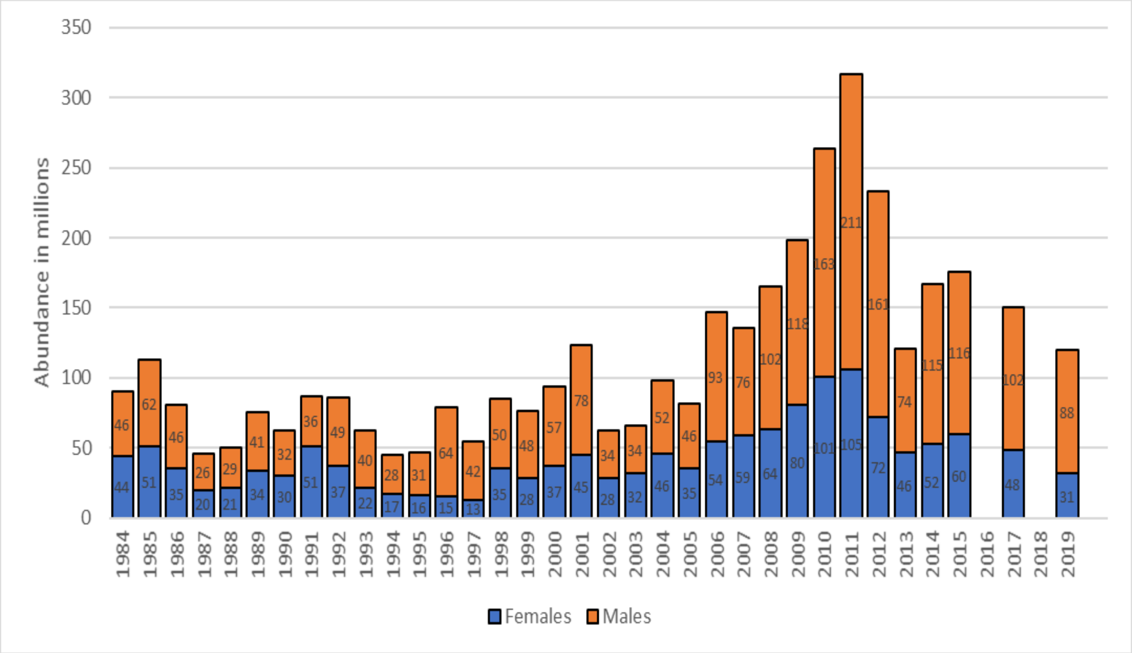


Figure 8.6. Russian autumn survey; Greenland halibut abundance by sex (Russkikh and Smirnov, WD16 AFWG 2016). Russian data from 1992 and onwards are revised in 2021 (Russkikh WD12). In this figure the 1992, 1996, 2002, 2017 and 2019 indices were not raised to also represent uncovered parts of the standard survey area.

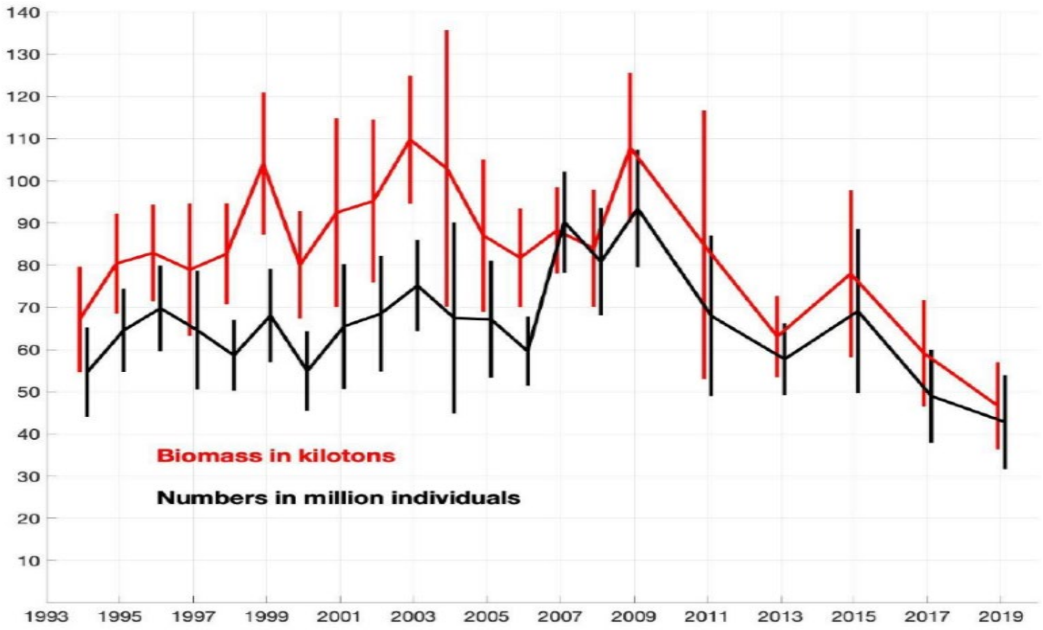


Figure 8.7. Estimated Greenland halibut total abundance in biomass and by number of individuals from the Norwegian slope surveys 1994–2019. The vertical bars show 95% confidence intervals.

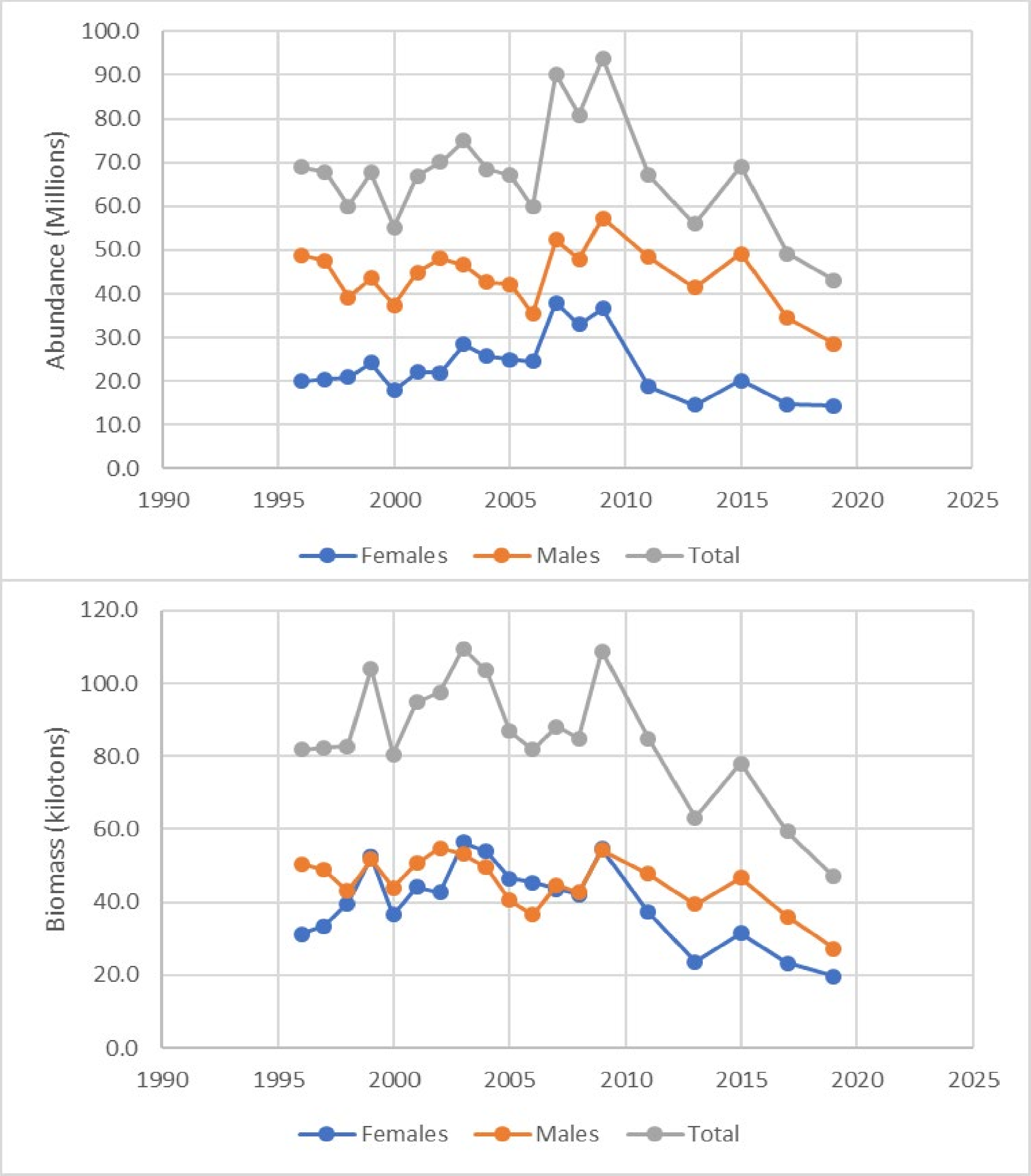


Figure 8.8. Estimated Greenland halibut abundance (upper panel) and biomass (lower panel), by sex, from the Norwegian autumn slope survey.

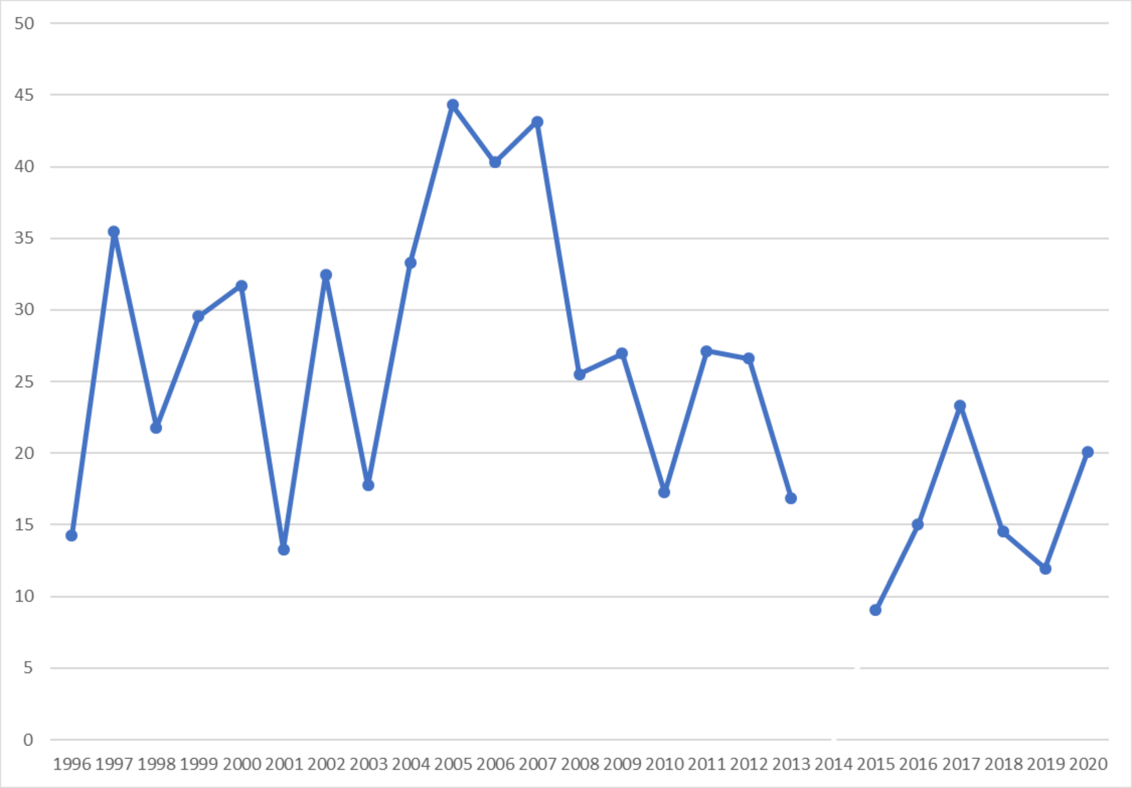


Figure 8.9. Total juvenile biomass index (EcoJuv) (female biomass = male biomass) for Greenland halibut based on the Barents Sea Ecosystem Survey (A5216) 2003 – 2020 (2014 not included due to poor survey coverage in the juvenile area) and the juvenile survey 1996–2002 (for area see Hallfredsson and Vollen, WD20 AFWG 2015).

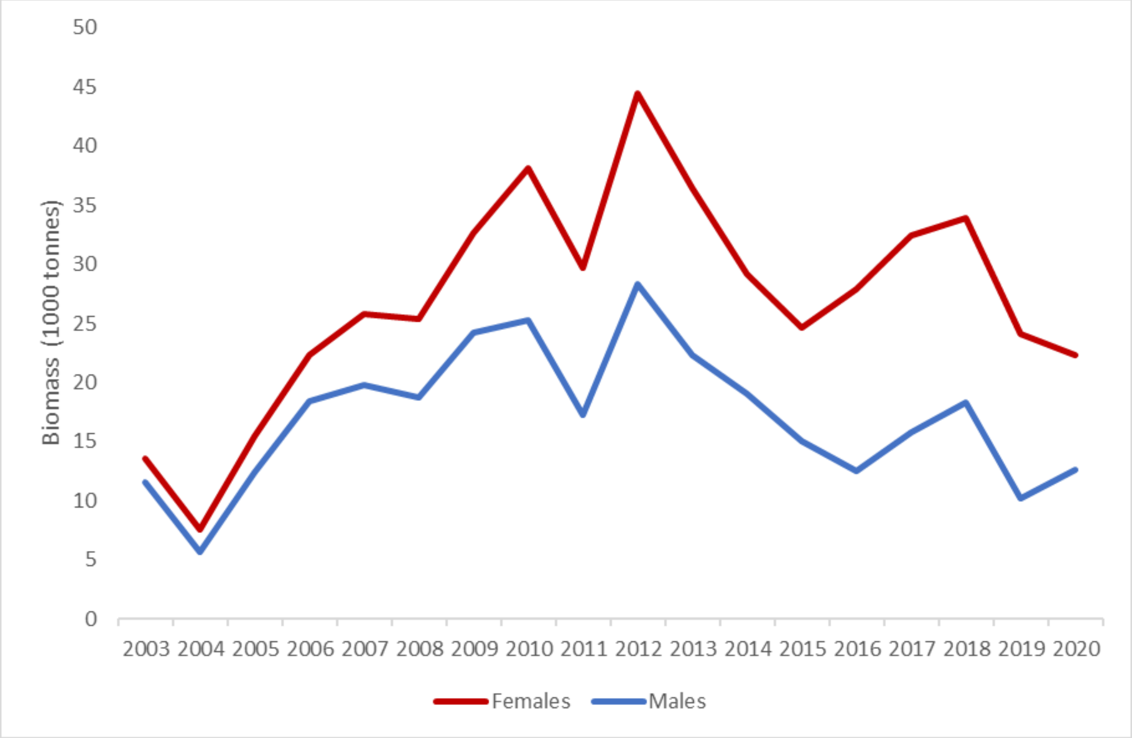


Figure 8.10. Eco–south biomass index by sex for Greenland halibut in the Barents Sea Ecosystem Survey (A5216) 2003 – 2020, outside the juvenile area (for area see Hallfredsson and Vollen, WD20 AFWG 2015). The 2018 estimate is not considered reliable mainly due to lack in survey coverage, and was excluded from the 2021 assessment.

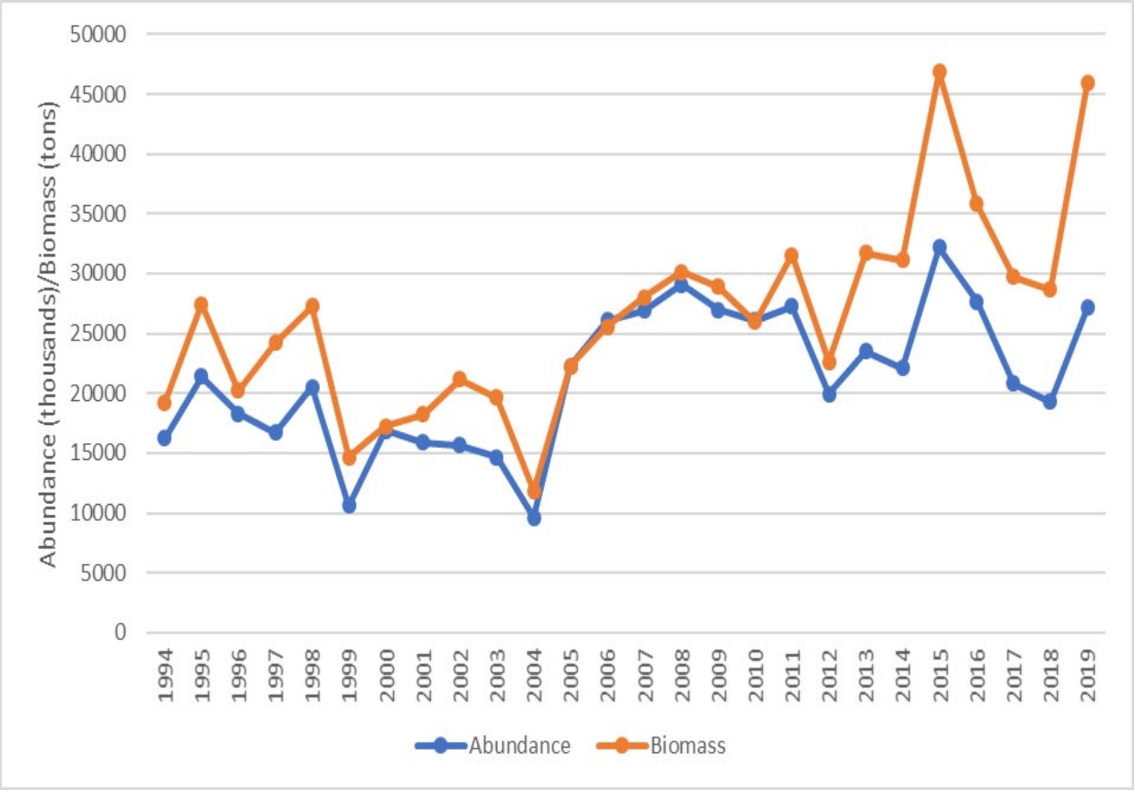


Figure 8.11. Joint Norwegian−Russian winter survey in the Barents Sea 1994–2020; Greenland halibut abundance and biomass estimates.

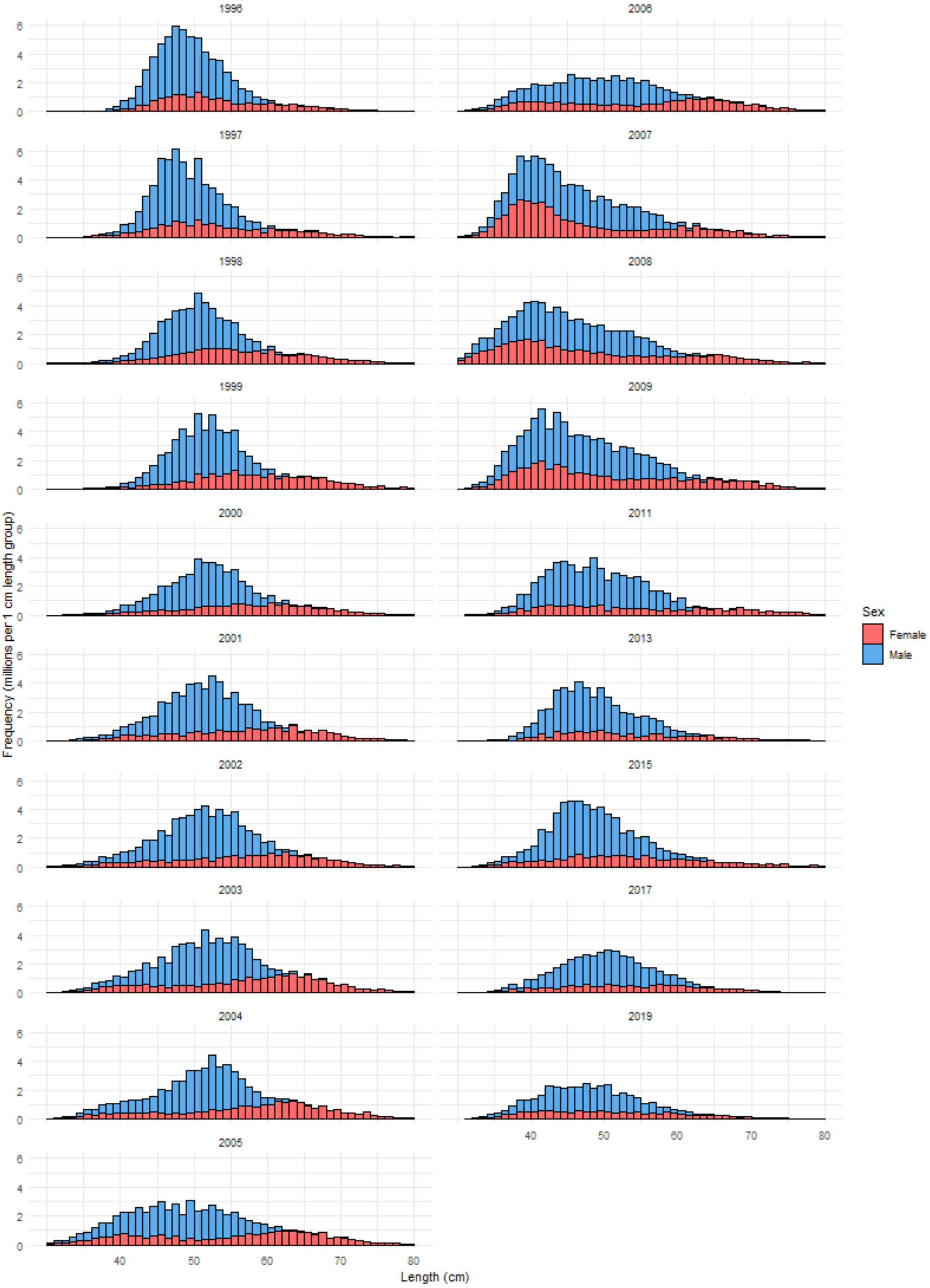


Figure 8.12. Length frequency distribution estimates for the entire area covered by the Norwegian Slope survey during autumns 1996–2019. Note biennial surveys after 2009.

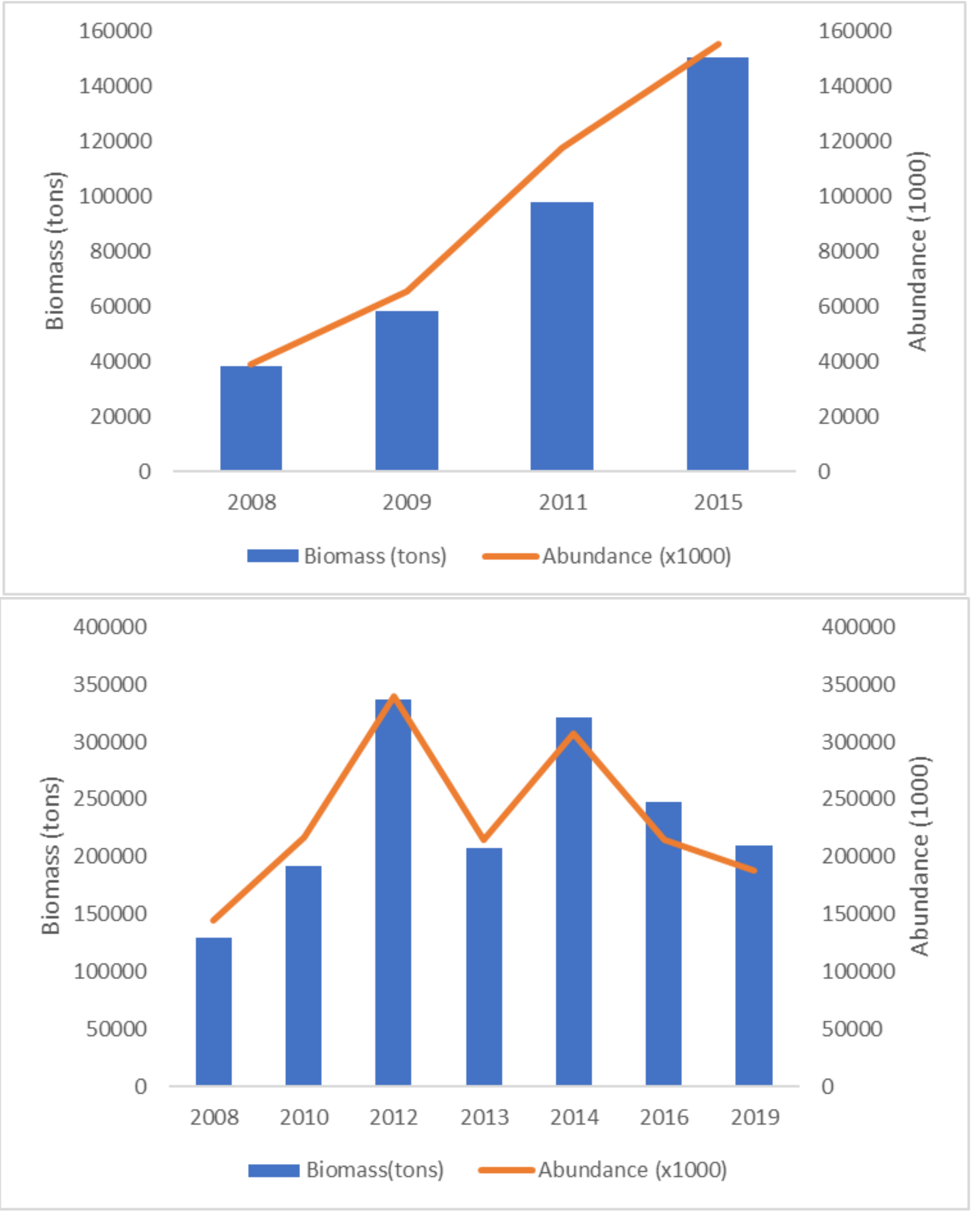


Figure 8.13. Abundance and biomass estimates from Spanish autumn surveys (lower panel) (Muñoz *et al.*, WD7 AFWG 2017), and abundance and biomass estimates from Spanish spring surveys (upper panel) (Muñoz *et al.*, WD10 AFWG 2016). Note that X–axis is not continuous.

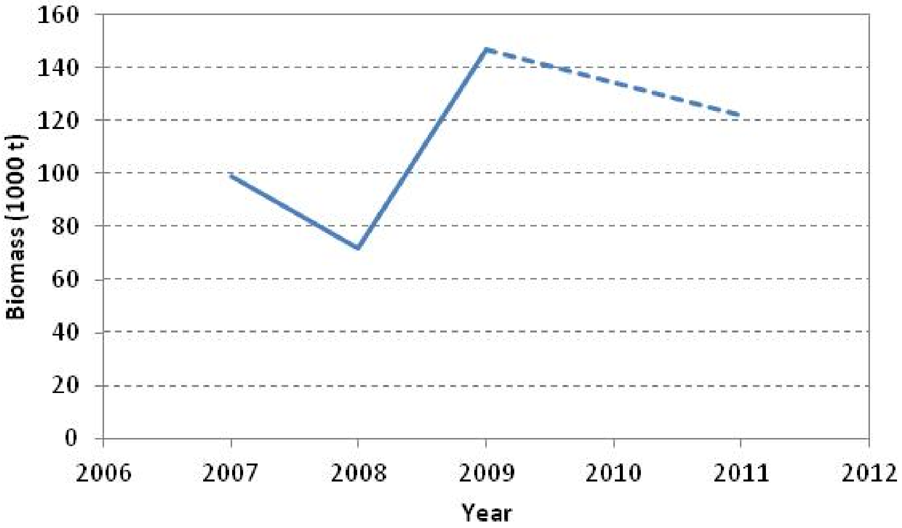


Figure 8.14. Biomass estimates from Polish spring survey (based on: Janusz *et al.*, WD8 AFWG 2008; Janusz and Trella, WD10 AFWG 2009; Trella and Janusz, WD6 AFWG 2012). No update presented to the 2020 AFWG.

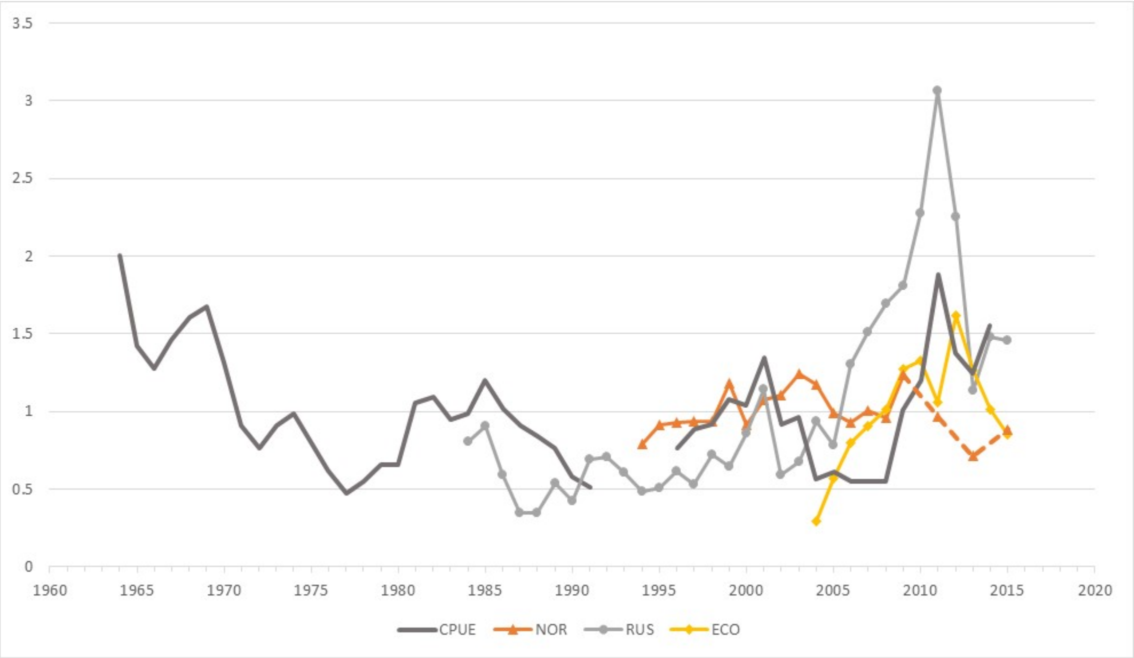
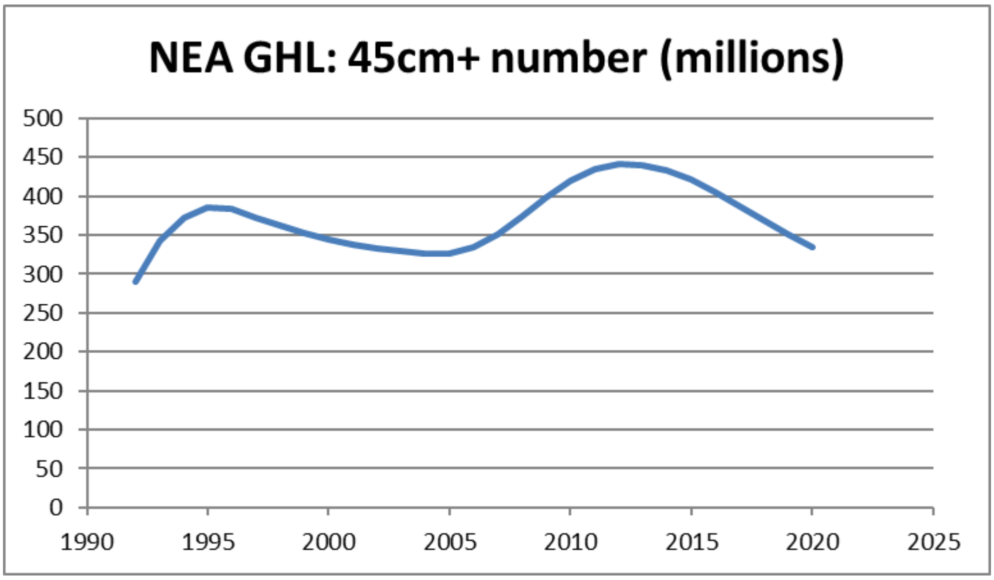
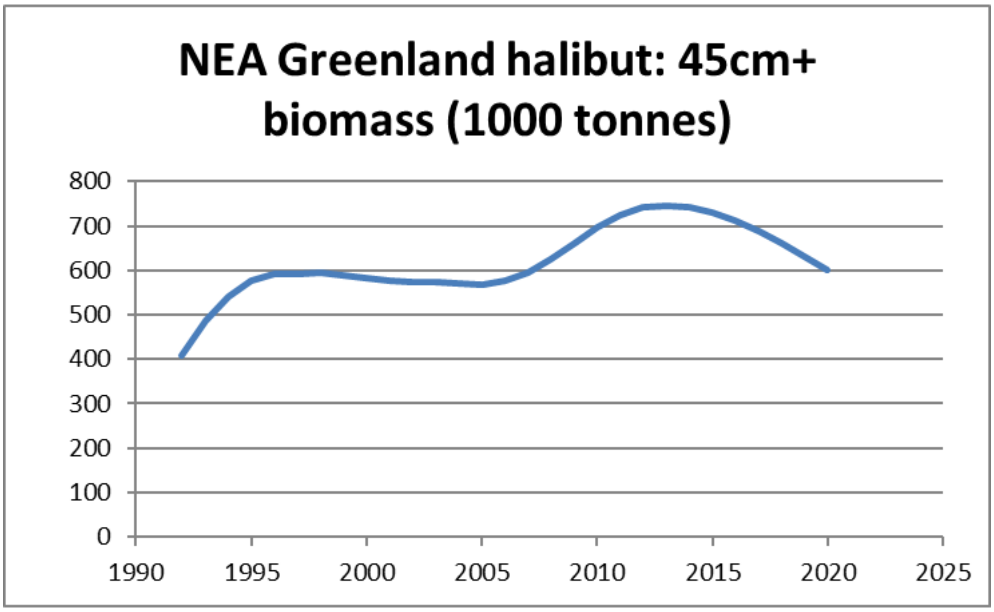


Figure 8.15. Dynamics of indices of the Barents Sea Greenland halibut stock in 1964–2015. Indices are divided by corresponding mean to put them in comparable scale. CPUE series divided in two, 1964–1991 and after 1996. In addition to the standardized CPUE three survey indices are shown; the Russian autumn survey (RUS), the Norwegian autumn survey (NOR) and the EcoSouth index (ECO).


NEA GHL: 45cm+ number (millions)
500
450
400
350
300
250
200
150
100
50
0
1990
1995
2000
2005
2010
2015
2020
2025


NEA Greenland halibut: 45cm+ biomass (1000 tonnes)
800
700
600
500
400
300
200
100
0
1990
1995
2000
2005
2010
2015
2020
2025

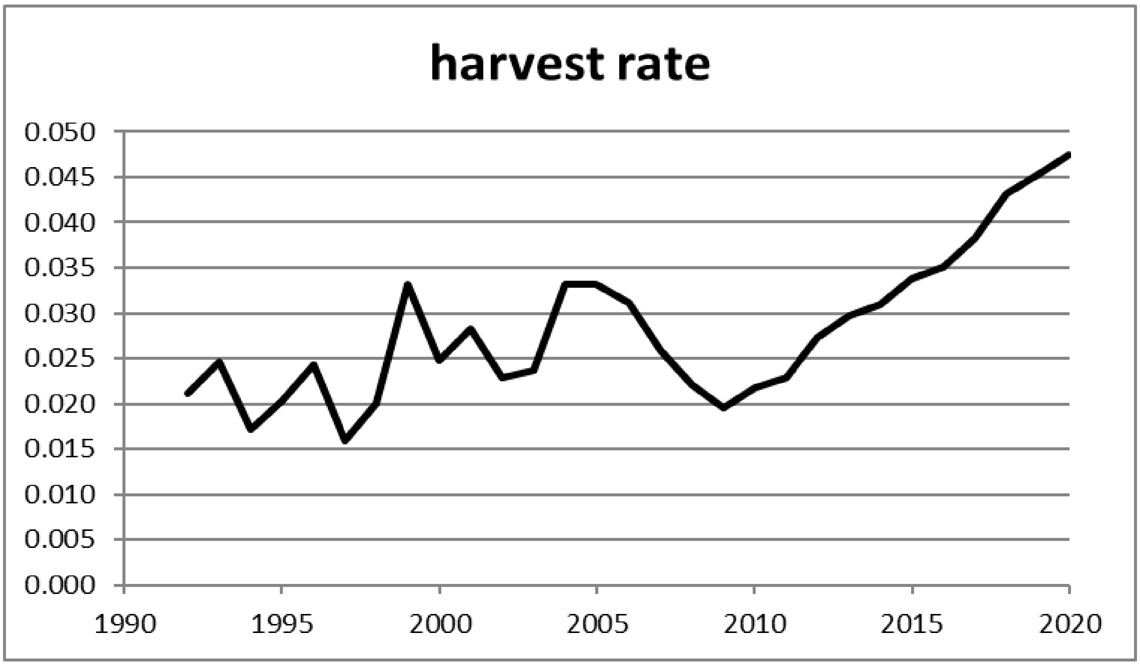


Figure 8.16. Numbers (upper) and biomass (middle)(previous page) for 45+ cm Greenland halibut as estimated by the GADGET model, and estimated exploitation rates (below).

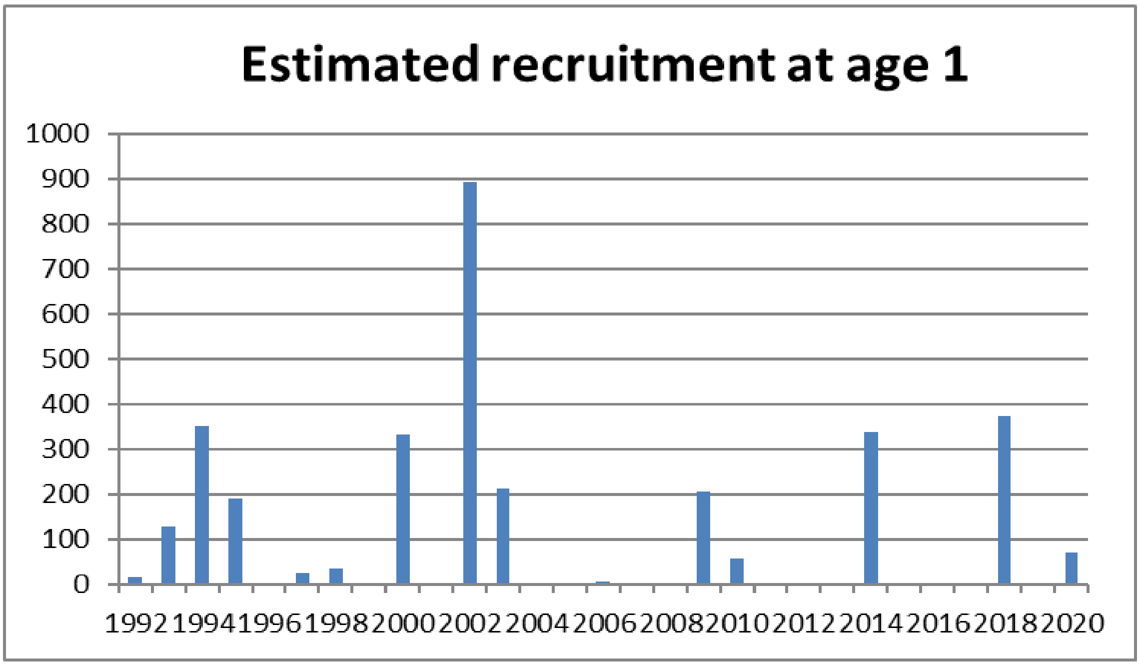


Figure 8.17. Gadget recruitment estimate (in millions) for 1 year olds in the Greenland Halibut stock at 1st January. Note that the most recent year(s) of recruitment are tuned by very few data and should be considered tentative.

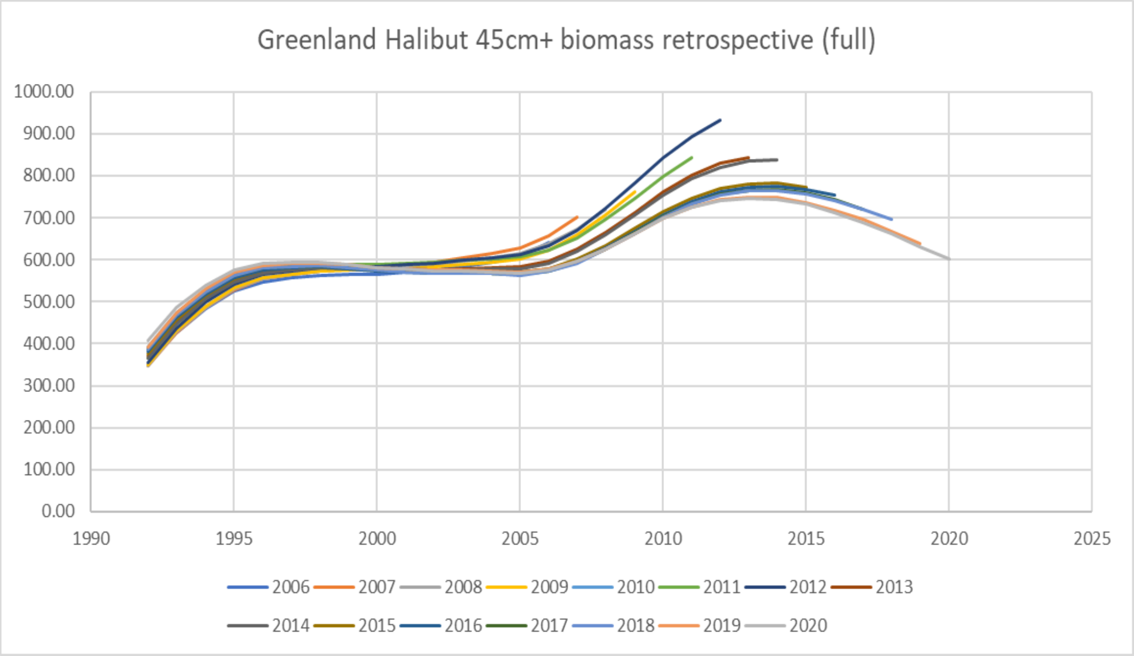
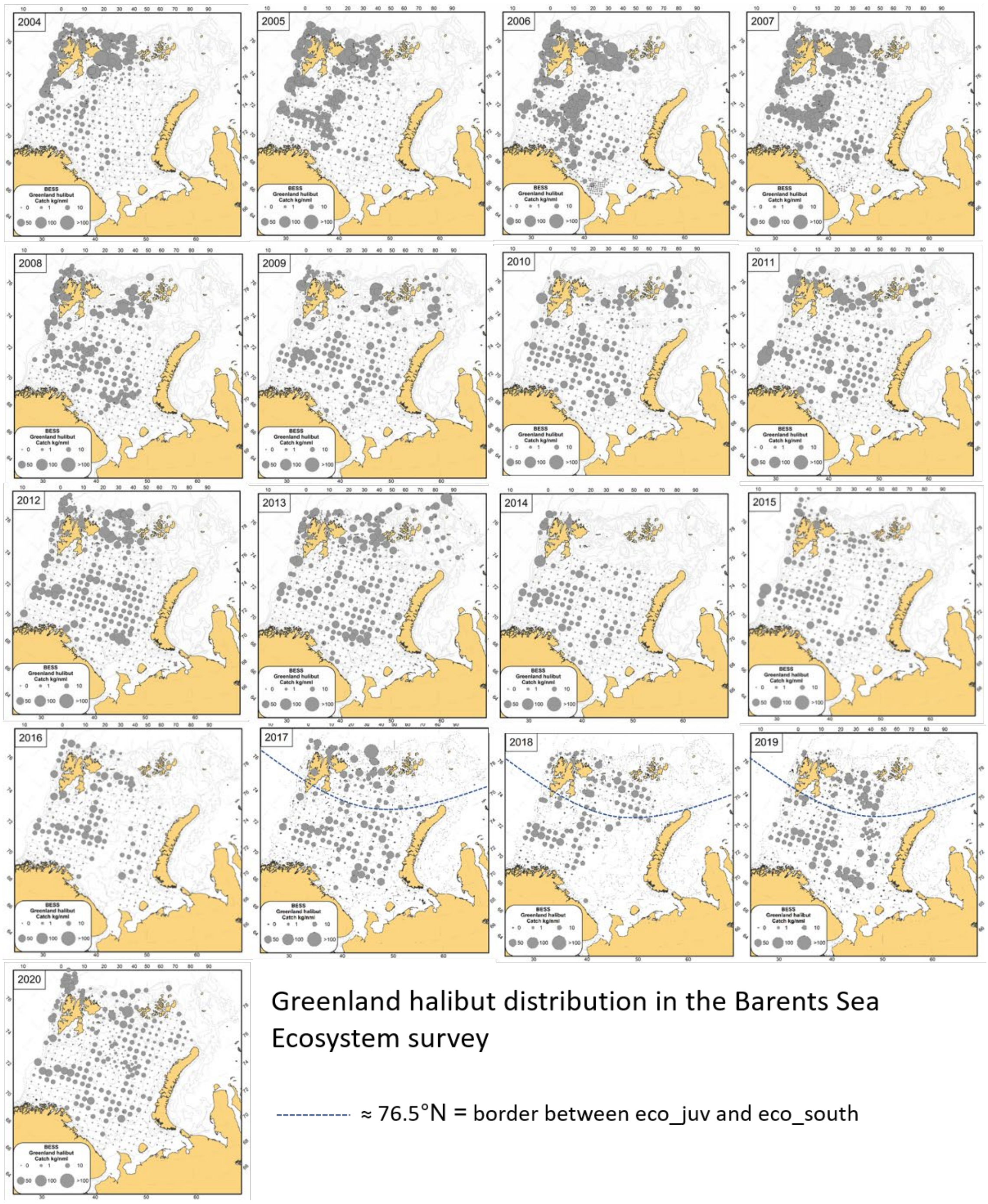


Figure 8.18. Retrospective patterns from the GADGET model run.



Greenland halibut distribution in the Barents Sea Ecosystem survey

≈ 76.5°N = border between eco_juv and eco_south

Figure 8.19. Biomass of G. halibut per station in the Barents Sea ecosystem survey (A5216).

9 Anglerfish in subareas 1 and 2 (Northeast Arctic)

Lophius budegassa and Lophius piscatorius – anf.27.1–2

9.1 General

Our present knowledge of anglerfish (*Lophius* spp.) in ICES subareas 1 and 2 is based on two masters theses (Staalesen, 1995; Dyb ,2003), a report from a Nordic project (Thangstad *et al.*, 2006), working documents to the ICES ASC, WGNSDS, and WGCSE, and more recent catch data collected by the Norwegian Reference Fleet since 2006 (Anon., 2013, Clegg and Williams, 2020). In February 2018, anglerfish in ICES subareas 1 and 2 was subject to a benchmark assessment (WKANGLER 2018). After this benchmark assessment, it was determined that this stock (or rather a stock component and a management unit) is considered a category 3 stock, for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass.

9.1.1 Species composition

Two European anglerfish species of the genus *Lophius* are distributed in the Northeast Atlantic: white (or white-bellied) anglerfish (*L. piscatorius*) and black (or black-bellied) anglerfish (*L. budegassa). Lophius budegassa* are rarely caught in Nordic waters. In Norwegian waters, 1 out of about 2600 anglerfish landed from the Møre coast north of 62°N (2.a) and 1 out of about 1000 from the North Sea were *L. budegassa* back in 2003 (Dyb, 2003; K. Nedreaas, pers. comm.). In recent years (2014–2020) this ratio has some years been up to 1 out of 200 anglerfish being *L. budegassa* in Norwegian waters, but usually about 1 out of 1000.

9.1.2 Stock description and management units

The WGNSDS (Northern Shelf Demersal Stocks) considered the stock structure on a wider European scale in 2004, and found no conclusive evidence to indicate an extension of the stock area northwards to include Division 2.a. Anglerfish in 2.a has therefore been treated and described separately by the ICES Celtic Sea Ecoregion Working Group (WGCSE) who is now assessing the anglerfish in the neighbouring areas. Currently, anglerfish on the Northern Shelf are split into Subarea 6 (including 5.b (EC), 12 and 14) and the North Sea (and 2.a (EC)) for management purposes. However, genetic studies have found no evidence of separate stocks over these two regions (including Rockall) and particle-tracking studies have indicated interchange of larvae between the two areas and further towards ICES divisions 2.a, 5.a and 5.b (Hislop *et al.*, 2001). So, at previous working groups assessments have been made for the whole Northern Shelf area combined, but exclusive ICES divisions 2.a, 5.a and 5.b. In fact, both microsatellite DNA analysis (O'Sullivan *et al.*, 2006) and particle tracking studies carried out as part of EC 98/096 also suggested that anglerfish from further south (Subarea 7) could also be part of the same stock. Hislop *et al.* (2001) simulated the dispersal of *Lophius* eggs and larvae using a particle tracking model. Their results also show the likelihood for *Lophius* at both Iceland (Solmundsson *et al.*, 2007), Faroe Islands (Ofstad, 2013) and Norwegian waters north of 62°N (i.e. subareas 1 and 2) to be recruited from the area west of Scotland including Rockall. This is also supported by research survey data as a migration east-/north-eastwards with size is seen in the International Bottom Trawl Survey (IBTS) and other survey data (e.g. Dyb, 2003).

Results from the use of otolith shape analysis in stock identification of anglerfish (*L. piscatorius*) in the Northeast Atlantic (Cañás *et al.*, 2012) and previous references on *L. piscatorius* stock identification find no biological evidence to support the current separation of *Lophius* stocks in the Northeast Atlantic, but find substructures within the area.

Anglerfish were tagged during two IBTS surveys in the North Sea and five one-day trips using a small (15 m) Danish seiner off the Norwegian coast at around 62°40'N (Møre; Thangstad *et al.*, 2006; Otte Bjelland, IMR-Norway, pers. comm.). A total of 872 individuals were tagged with conventional Floy dart type tags, 123 in the North Sea (25–78 cm) and 749 at Møre (30–102 cm). Some of this is further described in Thangstad *et al*. (2006). The 2019 AFWG report shows the tagging locations and the hitherto recaptures. There are migrations in all directions, i.e. recaptures from the southern North Sea, at the Shetland/Faroes and northwards to Lofoten. Most of the recaptures were done at Møre where most of the fish were tagged.

In 2000–2001 a total of 1768 trawl caught *L. piscatorius* was tagged using conventional dart tags and released on inshore fishing grounds at Shetland (Laurenson *et al*., 2005). Anglerfish of between 25 and 83 cm total length were tagged. The overall recapture rate was 4.5% and times at liberty ranged from 5 to 1078 days. After this publication, Dr Laurenson reported to www.fishupdate.com about a 104 cm anglerfish caught off the Norwegian coast near Ålesund in 2006. The fish had been tagged and released in the Scalloway Deeps on 13 September 2000 when it was 45 cm long and had hence been at liberty for five years and nine months. This is of particular importance as it may indicate a wider mixing of stocks and validate the growth rate of anglerfish.

WKANGLER (2018) considered that most recruitment in subareas 1 and 2 is from the more southerly stock unit, and this would require further R&D work in collaboration with ICES 3.a, 4, and 6 looking at egg and larval dispersion and transportation as well as tagging and genetic studies. To address, stock structure, mixing rates, and growth estimates, WKANGLER (2018) recommended a tagging program coordinated between all countries harvesting *Lophius* and to align tagging methods, measurement protocols and outreach to industry. The WK further recommended a shared site for *Lophius* tagging data and other applicable research projects concerning *Lophius*. Until the true biological stock structure is better understood, WKANGLER (2018) recommends keeping the anglerfish in subareas 1 and 2 as a separate management unit for time being.

9.1.3 Biology

Sex ratios in Subarea 2 show that females outnumber males above approximately 75 cm, and above 100 cm all fish were females (Thangstad *et al.*, 2006). This is very similar to sex ratios reported from distant Portuguese and Spanish waters (Duarte *et al.*, 1997) and hence supports a sex growth difference independent of latitude.

Spawning has been documented to occur in ICES Division 2.a in spring, but the present abundance of anglerfish in subareas 1 and 2 seems to be dependent on influx or migration of juveniles from ICES subareas 4 and 6. Estimation of GSI (gonad-somatic index) for females in Division 2.a, indicates developing ovaries from January to June. The highest values of GSI were found in June when some of the ovaries were 20–30% of the round weight. Only females bigger than 90 cm had elevated GSI values indicating developing ovaries. Dyb (2003) found that the length at which 50% of the females were mature (L50) was between 60–65 cm and that all females above 80 cm were mature.

Some age readings exist of anglerfish in Division 2.a, and comparative analyses of different structures, preparations and methods used for age readings were done by Staalesen (1995) and Dyb (2003). The Norwegian Institute of Marine Research adopted the ICES age reading criteria using the first dorsal fin ray (*illicium*) as its routine method, but few fish have been aged since the above-mentioned projects. The material collected and read was, however, considered sufficient for preliminary yield-per-recruit estimations (ICES, 2019). As a very simplified 'rule of thumb' one may divide the fish length by 1o get an approximate age, i.e. a fish of 100 cm is approximately 10 years old and 13 kg while a fish of 70 cm is about 7 years old and 7 kg.

Exploitation using gillnets with 300 mm mesh size will exploit males and females in a more equal ratio than 360 mm gillnets (Dyb, 2003). However, a change to lower mesh size will, without additional regulations, not decrease the effort, but rather increase it, at least towards younger fish. A mesh size of 300 mm will catch more anglerfish down to 50 cm, i.e. more immature fish. Preliminary analyses have also shown that the maximum yield-per-recruit will be 22% less using 300 mm instead of 360 mm gillnets (Staalesen, 1995). A possible sudden increase in catch rates when going from 360 mm to 300 mm would therefore be of short duration. A mesh size of 360 mm is also more in line with the minimum legal catch size of 60 cm, the length at first maturity of females and the utilization of the species' (especially the females') growth potential.

Some basic biological input parameters for the current assessment approaches are shown in Table 9.3. Some of these are further described in WKANGLER (2018).

9.1.4 Scientific surveys

Anglerfish appears in demersal trawl surveys along the Norwegian shelf but very small numbers. There has been a change in the surveys, going from single species- to multispecies surveys, during recent years. The procedures for data collection on anglerfish have varied and, at present, no time-series from surveys in Division 2.a yields reliable information on the abundance of anglerfish.

9.1.5 Fishery

In autumn 1992 a direct gillnet fishery for anglerfish (*L. piscatorius*) started on the continental shelf in ICES Division 2.a off the northwest coast of Norway (Norwegian statistical area 07; Figure 9.1). The anglerfish had previously only been taken as bycatch in trawls and gillnets. Until 2010–201here was a geographical expansion of the fishery which was largely due to a northward expansion of the Norwegian gillnet fishery (Figure 9.2). It is not known to what extent this northwards expansion of the fishing area is caused by an expansion of favourable environmental conditions for the anglerfish or the fishers discovering new anglerfish grounds.

Near Iceland, Solmundsson *et al.* (2007) concluded that changes in the distribution of anglerfish and increased stock size have co-occurred with rising water temperatures that have expanded suitable grounds for the species. Another observed feature of the fisheries is that regional peaks in the catches of anglerfish often culminate after a couple of years' fishing (Figure 9.2). The recent increase in landings first happened along the coast of western Norway but did the last year expand to all subareas north of 62°N as well.

Norway is by far the largest exploiter of the anglerfish in subareas 1 and 2 accounting for 96–99% of the official landings (Table 9.1). The coastal gillnetting accounts for more than 90% of the landings (Table 9.2). The landings of anglerfish in subareas 1 and 2 have been about 1/4–1/3 of the total landings from the other Northern Shelf areas (3.a, 4, and 6), but was in 2017 only 7% of the total landings in these areas.

No TAC is given for subareas 1 and 2, Norwegian waters. Catches of anglerfish in Division 2.a former EC waters, now UK waters, are taken as a part of the EC/UK anglerfish quota for ICES areas 3, 4, and 6, or as part of the Norwegian 'others' quota in EC/UK waters. The Norwegian fishery is regulated through:

- A discard ban on anglerfish regardless of size.
- A prohibition against targeting anglerfish with other fishing gear than 360 mm (stretched mesh) gillnets.
- A minimum catch size of 60 cm in all gillnet fisheries, and maximum permission of 5% anglerfish (s) below 60 cm when fishing with gillnets.
- 72 hours maximum soak time in the gillnet fishery.
- A maximum of 500 gillnets (each net being maximum 27.5 m long) per vessel.
- Closure of the gillnet fishery from 1 March to 20 May. This closure period was expanded to 20 December–20 May in the areas north of 65°N in 2008 and further expanded southwards to 64°N since 2009.
- A maximum of 15% bycatch (in weight) of anglerfish in the trawl- and Danish seine fisheries, and maximum 10% bycatch (in weight) of anglerfish in the shrimp trawl fishery. When fishing for argentines and Norway pout/Sandeel a maximum of 0.5% bycatch is allowed within a maximum limit of 500 kg anglerfish per trip.
- A maximum of 5% bycatch (in weight) of anglerfish is allowed to be caught in gillnets targeting other species.

9.2 Data

9.2.1 Landings data

The official landings as reported to ICES for subareas 1 and 2 for each country are shown in Table 9.1. Landings decreased rapidly from 201o 2015, to the lowest since 1997, but has since shown an increase until last year. It is worth noting that the recent increase in landings first happened along the coast of western Norway, but did the years after also happen from south to north in the ICES Subarea north of 62˚N. And likewise, the decrease seen in 2020 happened first in the south, i.e. both along the coast of western Norway and in the southern part of ICES Subarea 2 while the northern areas still showed an increase. Norway has by far the largest reported catches of the anglerfish in subareas 1 and 2, accounting for 96–99% of the official international landings. The coastal gillnetting accounts for more than 90% of the landings, of which about 90% are caught by the special designed large-meshed gillnets (360 mm stretched meshes; Table 9.2).

The Norwegian coastal reference fleet (see Appendix figure H1) provide us with length measurements and catch per gillnet days from ICES subareas through 4, from 2007–present and these have been presented for the AFWG in recent years. The catch rates vary spatially and temporally, and the WKANGLER (2018) recommended therefore to model and standardize the catch rates to better represent the general abundance trend of anglerfish in the entire ICES Subarea 2. The available material is shown in Tables 9.4 and 9.5 for the Norwegian statistical coastal areas (Figure 9.1) and total for ICES subareas 1 and 2.

9.2.2 Discards

The absence of a TAC in Norwegian waters probably reduces the incentive to underreport landings. Anecdotal evidence from the industry, observer trips and data from the self-sampling fleet (the Norwegian reference fleet; Anon. 2013; Clegg and Williams 2020) suggest that up to 8–9% of the catch (not marketable) is discarded. This happens when the soaking time is too long, mostly due to bad weather. The average percentage of discarded anglerfish was higher south of 62°N (ICES 3 and 4) than north of 62°N (ICES 2.a). Average length of discarded anglerfish was on average only 6–7 cm smaller than the landed anglerfish. This is also confirmed by Berg and Nedreaas (2021) who estimated the annual discards of anglerfish by the Coastal reference fleet in subareas 1 and o vary between 11 and 32 tonnes during 2014–2018 (i.e. 1.5–2.5% of total gillnet catch), but up to 178 tonnes (7.2%) in 2012.

9.2.3 Length composition data

Length distributions are available from the directed gillnet fishery during the period 1992–2019, but data are lacking for 1997–2001 (Table 9.3). The length data indicates a drop in mean length of 15–20 cm occurring during the period without length samples (Figure 9.3). Since then the mean length increased steadily during the last decade to about 95 cm (about 10 years old and 12 kg) in 2014–2016, i.e. the same size level as seen during the 1990s. One-third of the anglerfish measured during the 1990s were above 100 cm, this proportion was between 1–6% for the early 2000s, 12–17% in 2006–2013 and 15% in 2020. This indicates recruitment into Subarea 2 during 1997–2001 which has not been observed until 2017–2019 when a new drop in mean length is seen, again indicating some recruitment of smaller sized anglerfish to the area.

Length distributions of retained anglerfish (*L. piscatorius*) caught by the reference fleet as target species during 2007–2020 by the specially designed-large-meshed gillnets, and as bycatch in other gillnets or other gears are shown in Appendix figures H2-H4. All subsequent analyses (in the methods and results section) have only used the length distributions from the target fishery since 2007 using the large-meshed gillnets which represent more than 80% of the international landings in subareas 1 and 2.

9.2.4 Catch per unit effort (CPUE) data

The Norwegian coastal reference fleet (see Appendix Figure H1) has reported catch per gillnet soaking time (CPUE) from their daily catch operations. For the current modelling and hence standardization of the annual CPUE from subareas 1 and 2, we have used the following data:

- Only catch rates of retained anglerfish from the fishery using special large-meshed anglerfish gillnets (stretched meshes = 360 mm).
- Years 2007–2020.
- Discards excluded.
- Adding zero catches where gillnets are used, but anglerfish not present.
- All coastal areas (i.e. ICES 3.a, 4.a, 2.a, and 1) included in the model since it is documented (e.g. WKANGLER 2018) that anglerfish are migrating across the ICES area borders.
- The area (km^2) of each subarea inside 12 nautical miles (covering most of the anglerfish distribution) is calculated and used as weighing factor when annual CPUEs are estimated for each subarea.

9.3 Methods and results

9.3.1 The length-based-spawning-potential-ratio (LBSPR) approach

The LBSPR method has been developed for data-limited fisheries, where only a few data are available: some representative sample of the size structure of the vulnerable portion of the population (i.e. the catch) and an understanding of the life history of the species (Hordyk *et al.*, 2016). The LBSPR method does not require knowledge of the natural mortality rate (M) but instead uses the ratio of natural mortality and the von Bertalanffy growth coefficient (K; M/K), which is believed to vary less across stocks and species than M (Prince *et al.*, 2015) although individual estimates of M and K can be used if available. Like any assessment method, the LBSPR model relies on a number of simplifying assumptions. In particular, the model is equilibrium-based, assumes that the length composition data are representative of the exploited population at steady state, and logistic selectivity (see the results section below for more discussion).

The LBSPR model originally developed by Hordyk *et al*. (2015a; 2015b) used a conventional age-structured equilibrium population model and a size-based selectivity. As a consequence, this approach could not account for "Lee's phenomenon"—the fact that larger specimens-at-age get greater mortality than its cohort of smaller size because of the size-based selectivity. This is because the age-structured model has a 'regeneration assumption' i.e. it redistributes at each time-step the length-at-age using the same distribution. Hordyk *et al*. (2016) since developed a length-structured version of the LBSPR model that used growth-type-groups (GTG) to account for the above phenomenon and showed that the new approach reduced bias related to the "Lee's phenomenon"[1]. GTG LBSPR is therefore used for all subsequent analyses.

Some of the life-history parameters for the analysis were taken from WKANGLER (2018). Hordyk *et al*. (2015a; 2015b) showed that the LBSPR approach was sensitive to the input parameters. We, therefore, drew 1000 random samples for each input parameter (i.e. from a bivariate normal distribution for L_{inf} and K, a univariate normal distribution for M, L50, L95 (see Table 9.3)) and rerun the model in order to account for the effect of uncertainty around the input parameters on the results. We will refer to it as the "stochastic LBSPR approach" hereon.

Once the stochastic LBSPR runs were finished, we conducted some simulations through the LBSPR package to calculate some target SPR value. To do this, we used the mean input values from the stochastic LBSPR, the average estimated parameters values (from the stochastic LBSPR approach), and set the "steepness" to a value between 0.7 and 0.9 perform a YPR analysis and determine the target reference points (which gives the maximum yield). Steepness values between 0.7 and 0.9 were chosen based on a literature search (values close to 1 are also found in the literature but was not included in the test as it seemed unrealistic for the species). The analysis gave a target reference point of SPR = 0.4 (with F/M~1) and SPR = 0.25 (with F/M~2) and for a steepness value of 0.7 and 0.9, respectively. What we obtained from the stochastic LBSPR runs instead is a relatively stable annual estimates of SPR (between 0.15 and 0.5 (the IQR range)) and F/M (between 1.5 and 2.5; Figure 9.4). This would suggest that—while there is a lot of uncertainty—fishing effort is probably slightly above but close to the effort that would lead to maximum yield.

The relationship between the biomass of reproductively mature individuals (spawning stock) and the resulting offspring added to the population (recruitment), the stock–recruitment relationship, is a fundamental and challenging problem in all population biology. The steepness of this relationship is the fraction of unfished recruitment obtained when the spawning-stock biomass is 20% of its unfished level. Steepness has become widely used in fishery management, where it is usually treated as a statistical quantity. If one has sufficient life-history information to construct a density-independent population model then one can derive an associated estimate of steepness (Mace and Doonan, 1988; Mangel *et al*., 2010; 2013).

As mentioned in the introduction, the LBSPR approach is an equilibrium-based method (i.e. assumes that the fishery experiences constant recruitment and F over time) and violation of this assumption can lead to biased SPR estimates. However, some management strategy evaluation conducted by Hordyk *et al*. (2015) on harvest control rules based on SPR-based size targets showed that while annual assessments of SPR may be imprecise due to the transitory dynamics of a population's size structure, smoothed trends estimated over several years may provide a robust metric for harvest control rules. SPR estimates in our study were relatively stable, thus large recruitment fluctuations may not be an issue.

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[1] https://github.com/AdrianHordyk/LBSPR

9.3.2 Cpue standardization

Raw CPUE data are seldom proportional to population abundance as many factors (e.g. changes in fish distribution, catch efficiency, effort, etc) potentially affect its value. Therefore, CPUE standardization is an important step that attempts to derive an index that tracks relative population dynamics.

In the data preparation step, we quickly noticed that there was not enough data from ICES Subarea o perform model inference. Therefore, we decided to omit data from this Subarea from the analyses. ICES Subarea 1 is the northern margin of *L. piscatorius* distribution, and only 3 tonnes were caught in this area in 2019, mostly as bycatch in other fisheries.

Below, we defined some important terms we used for the CPUE standardization:

Standardized effort (gillnet day) = gear count x soaking time (hours)/24 hours
CPUE (per gillnet day) = catch weight/standardized effort

CPUE standardization was performed using the glmmTMB package (Brooks *et al.*, 2017) and the best model was chosen based on AICc and residuals checks using the DHARMa package (Hartig 2020) i.e. the most parsimonious model had the lowest AICc while showing no problematic residuals pattern (i.e. overdispersion, underdispersion, etc). If problematic residual patterns were found, we tried to address the issue by either reconsidering the input data, changing model parameterization, or changing the model distribution assumption.

The data showed some signs of overdispersion based on residual analysis of simple models (e.g. gaussian, poisson) i.e. the presence of greater variability of the dataset than would be expected based on a given statistical model. The Tweedie distribution was selected as the best model (after model selection) to address this problem. Tweedie distribution belongs to the exponential family and its variance term is modelled as a power function of the mean (μ) i.e. $\varphi\mu$ p. The power parameter, p, is restricted to the interval $1 < p < 2$. The Tweedie distribution is commonly used for generalized linear models (e.g. Jørgensen 1997).

The best model has the following parameterization (for fixed and random effects):

CPUE = year + subarea + month + (1|vessel) + (1|subarea_year) + (1|month_year) +
(1|month_subarea)

The expression (1|vessel) indicates that the vessel effect is considered a random effect and acts on the intercept. The expression (1|month_year) indicates that the month and year variable was concatenated into a single variable and considered as a random effect. In essence, this treatment models the interaction effect between year and month, but the approach only considers existing interaction (as opposed to all possible combinations of year and month which would be un-estimable)—which is an advantage in a data-limited situation such as ours.

Further exploration of the residual pattern (more specifically the plot of scaled residual against predictors) indicated some possible issues with the vessel random effect which showed a systematic deviation for some simulated vessel effects (part of the test feature available in DHARMa). These problematic vessels only fished a few times in a single area and time, causing estimation to be less reliable. To address this issue, we filtered the data to keep data from vessels that had more than 5 or 10 observations. Using the 10-minimum-observations criteria greatly improved the residual pattern of the model hence was kept as the final model to produce the standardized annual CPUE index.

The standardized annual CPUE index was created by summing up all predictions based on all possible combinations of the year (2007–2020), subarea (in ICES area 2.a), and month (1–12) after weighting the prediction for each subarea by its surface (in km^2 within the 12 nautical miles as shown in Figure 9.5) relative to the total surface (sum of all subarea surfaces in the ICES area 2.a). In this process, we removed the vessel random effect (assuming it equals 0, the mean value) as it only affects catch efficiency and does not represent the underlying fish abundance. We note that glmmTMB can handle any missing new levels for random effect variables when making a prediction (it assumes it is equal to zero and inflates the prediction error by its associated random effect variance). The standard deviation of the summed prediction was directly calculated in glmmTMB by modifying the source code ('glmmTMB.cpp' file).

Figure 9.6 shows that anglerfish population in ICES Subarea 2.a might have declined over the last decade (as well as the raw effort) but there is a lot of year-to-year variability and uncertainty around the point estimates.

9.3.3 JABBA

JABBA stands for 'Just Another Bayesian Biomass Assessment' and is open-source modelling software that can be used for biomass dynamic stock assessment applications. It has emerged from the development of a Bayesian State-Space Surplus Production Model framework applied in stock assessments of sharks, tuna, and billfish around the world (Winker *et al.*, 2018). JABBA requires a minimum of two input comma-separated value files (.csv) in the form of catch and abundance indices (and SE; see Appendix table H1). The Catch input file contains the time-series of year and catch by weight, aggregated across fleets for the entire fishery. Missing catch years or catch values are not allowed. JABBA is formulated to accommodate abundance indices from multiple sources (i.e. fleets) in a single CPUE file, which contains all considered abundance indices. The first column of the CPUE input is year, which must match the range of years provided in the Catch file. In contrast to the Catch input, missing abundance index (and SE) values are allowed.

The catch data comes from the different fishing countries' official reporting of annual landings to ICES (see Table 9.1) and the CPUE data (along with its standard deviation) comes from the CPUE standardization process described above and Figure 9.10 for the early years 1992–1994. We assumed that the CPUE index from ICES Subarea 2.a calculated using data from the anglerfish targeted fishery is representative of the stock status in ICES areas 1 and together.

In addition to these .csv files, JABBA also requires users to define the prior distribution for the model parameters which will be subsequently updated with data to form the posterior distributions (Figure 9.7). In addition to the base case, 10 additional scenarios were run to examine the sensitivity of the model results to the choice of priors (Table 9.6).

Figure 9.8 shows the trajectory of the population estimates from 1990–2020 based on the 1ested scenarios (Table 9.7). In general, population abundance has never fallen below B_{MSY} (at least the mean trajectory) but fishing mortality fluctuated above and below the F_{MSY} (Figure 9.9). Figure 9.10 is the Kobe plot from the base model run showing the estimated trajectories of B/B_{MSY} and F/F_{MSY} along with the credibility intervals of the 2020 estimates of biomass and fishing mortality. The percentage numbers at the top right indicate how much of the 2020 population estimates that fall within the green (not overfished, no overfishing), yellow (overfished, but no overfishing), orange (overfishing, but not overfished), and red (overfished and overfishing) zones, after accounting for all the parameter uncertainty (basically, the area under the oval-shaped density plot that falls into each coloured quadrant). The model estimates that there is roughly a 23% probability that the 2020 population estimate falls within the red zone, 22% in the orange, 2% in the yellow, and 53% in the green zone. Finally, retrospective analysis indicates that overall, there is little retrospective issue with the anglerfish JABBA base model run with $|\text{Mohn's rho}| \leq 0.11$ except for F/F_{MSY} (Table 9.7). In general, estimates of final year biomass and F were consistent over the last 4 retrospective peels but the scaling for F (i.e. F/F$_{MSY}$) was less consistent (i.e. larger relative error; Table 9.7).

The sensitivity analysis says that MSY could be around 2000 tonnes, with a B$_{MSY}$ ~30 000 tonnes (Figure 9.12). Though the MSY value is quite sensitive to the choice of prior on r = population growth rate, which makes sense if population grows slowly, one cannot fish too hard, i.e. lower MSY.

However, the retrospective analysis (Figure 9.11) also shows that the estimate of MSY could be influenced by the addition of 1 year of data, i.e. the scaling of F/F$_{MSY}$ is not very steady across time, and the figure suggests that it could be a bit lower, maybe between 1500–2000 t. Though the B$_{MSY}$ still stays around ~30 000 tonnes. So an initial guestimate of MSY would be somewhere between 1500–2000 t. MSY of 1500 t was also the MSY estimate based on the low r scenario.

9.4 Management considerations and future investigations

The present abundance of anglerfish in subareas 1 and 2 seems to depend on the influx or migration of juveniles from ICES subareas 4 and 6. It is therefore expected that an effective discard ban on anglerfish in subareas 4 and 6 will have a positive effect on the abundance north of 62°N. Reduced mean size of the landed anglerfish in recent years (fishing with the same large-meshed gillnets) indicates a new influx of recruitment to the ICES subareas 1 and 2. Monitoring of the fishery will be important in near future to protect the young specimens from recruitment- and growth- overfishing.

AFWG has previously recommended that the anglerfish stock component in subareas 1 and 2 is annually monitored and a 20% reduction in fishing effort per year (also as an uncertainty cap) should be imposed until the decrease in CPUE is stopped. Despite that the decrease in CPUE has stopped for time being, the current exploratory assessment shows that there is nothing to gain in increasing effort. The ceased decrease in mean catch size (a sign of reduced recruitment to the fishery) and decreased catch in 2020 compared to 2019 suggest a reduction in fishing effort. The "2-over-3" rule used on the CPUE time-series, including both an uncertainty cap and a precautionary buffer, also suggest a 20% reduction in effort or catch advice for 2022.

The three approaches tested in this report, all very different (except that JABBA also uses the CPUE as abundance indices), offer corroborative evidence suggesting that the anglerfish population has declined over time.

The standardized CPUE analysis shows that anglerfish population in ICES Subarea 2.a has declined over the last decade (as well as the raw effort) with an increase in the most recent year.

The spawning potential ratio, as calculated by the LBSPR method using input biological parameters and the estimated exploitation parameters suggests that—while there is a lot of uncertainty—fishing effort is probably slightly above but close to the effort that would lead to maximum yield.

The relative population stock status is around B$_{MSY}$, though fishing intensity seems too high (above F$_{MSY}$) and should be reduced before the population does fall below the biomass and SPR targets.

The quality of the current exploratory assessment was this year further evaluated by analysing more diagnostics, e.g. the JABBA model sensitivity of priors settings. The AFWG considers the current assessment of sufficient quality to base catch advice on for subareas 1 and 2.

When it comes to reference points, it should be further discussed if and which defined values of F/M, F/F$_{MSY}$, SPR and B/B$_{MSY}$ may be used.

Any potential harvest control should take account of both recruitment- and growth- overfishing. LBSPR provides measures for both, F/M and SPR, with the SPR values being the transient SPR and thus an estimate of current stock status. While maximum sustainable catch is often a key management objective, it may not be the only one. In that case, it may be worth modifying a reference point to reflect other management objectives.

The AFWG supports that ICES subareas 1, 2, 3, 4, and 6 should be investigated together to get a more complete understanding of migrations and distributions.

9.5 Tables and figures

Table 9.1. Nominal catch (t) of anglerfish in ICES subareas 1 and 2, 1999–2020, as officially reported to ICES.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020*
DK	+	+	2	+	-	1	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Faroes	+	-	1	1	2	5	11	4	7	4	2	1	+	+	1	+	+	1	1	+	+	1
France	-	-	-	-	-	-	-	1	-	-	-	-	1	3	2	-	4	2	4	3	8	5
D	4	17	65	59	55	70	55	+	+	0	+	82	70	0	-	+	+	+	1	1	50	-
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-
Norway	1733	2952	3554	2000	2405	2907	2650	4257	4470	4007	4298	5391	5031	3758	2988	1655	933	1355	1473	1884	2750	2258
Portugal	-	-	-	-	-	-	-	-	-	2	6	1	+	-	-	-	-	-	-	-	-	-
UK	6	30	2	11	15	18	19	86	114	138	152	40	3	3	111	2	105	76	5	15	+	16
Others														1	1	-	-	+	-	+	-	-
Total	**1743**	**2999**	**3624**	**2071**	**2477**	**3001**	**2735**	**4348**	**4591**	**4151**	**4458**	**5515**	**5112**	**3765**	**3103**	**1657**	**1043**	**1435**	**1484**	**1903**	**2809**	**2280**

***Preliminary.**

Table 9.2. Anglerfish in ICES subareas 1 and 2. Norwegian landings (tonnes) by fishery in 2008–2020. The coastal area is here defined as the area inside 12 nautical miles from the baseline.

Fleet NORWAY	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020*
Coastal gillnet	3574	3934	4806	4557	3521	2758	1506	829	1231	1320	1727	2502	1939
Offshore gillnet	240	171	391	319	115	158	95	52	62	87	68	153	168
Danish seine	75	68	40	26	16	19	11	12	17	23	28	26	35

Fleet NORWAY	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020***
Demersal trawl	34	36	48	19	11	8	7	3	5	6	10	5	3
Other gears	84	89	106	83	96	45	36	37	40	31	51	64	113
Total	**4007**	**4298**	**5391**	**5031**	**3759**	**2988**	**1655**	**934**	**1355**	**1468**	**1884**	**2750**	**2258**

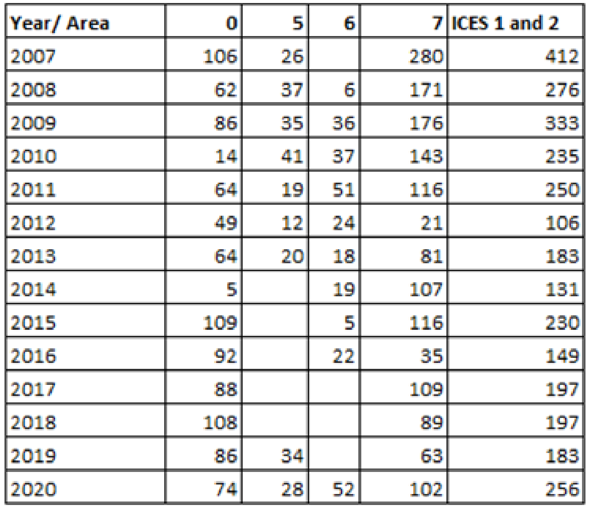
***Preliminary per 6 April 2021.**

Table 9.3. Basic input parameters and parameters for resampling as used for the LBSPR analysis.

Basic input parameters	**Value**
von Bertalanffy K parameter (mean)	0.12
von Bertalanffy Linf parameter (mean)	146
von Bertalanffy t0 parameter	−0.34
Length-weight parameter a	0.149
Length-weight parameter b	2.964
Steepness	0.8
Maximum age	25
Length at 50% maturity (L50; mean)	82
Length at 95% maturity (L95; mean)	100
ΔMat = L95 - L50 (mean)	18
Length at first capture	40
Length at full selection	60
M (mean)	0.2

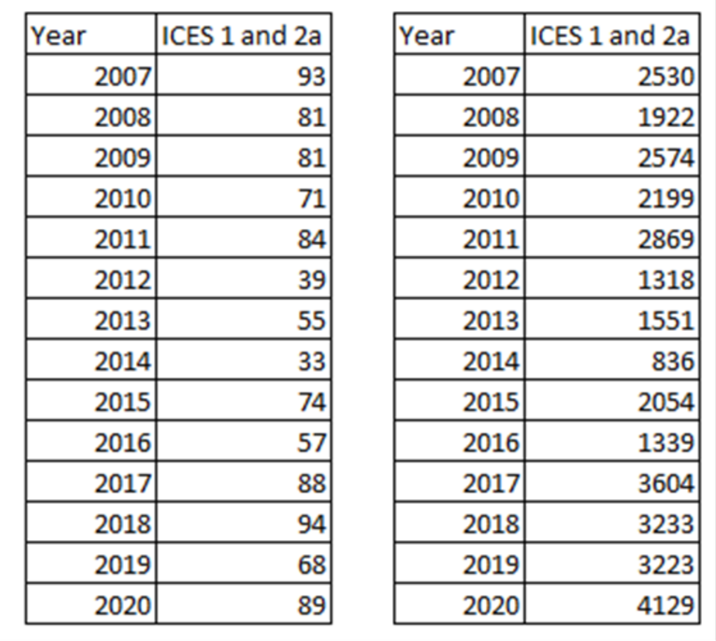
Basic input parameters	**Value**
M/k (mean)	1.67
Parameters for resampling	**Value**
N_{samp}	1000
CV(M)	0.15
Cor (L_{inf}_K)	0.9
CV(K)	0.3
CV(L_{inf})	0.15
CV(L50)	0.05
CV(ΔMat)	0.05

Table 9.4. Number of coastal reference fleet fishing days with anglerfish, per national stat. subareas (0–7) and total for ICES subareas 1 and 2. Only large-meshed gillnets included.



Year/ Area	0	5	6	7	ICES 1 and 2
2007	106	26		280	412
2008	62	37	6	171	276
2009	86	35	36	176	333
2010	14	41	37	143	235
2011	64	19	51	116	250
2012	49	12	24	21	106
2013	64	20	18	81	183
2014	5		19	107	131
2015	109		5	116	230
2016	92		22	35	149
2017	88			109	197
2018	108			89	197
2019	86	34		63	183
2020	74	28	52	102	256

Table 9.5. Number of fishing days with length measured anglerfish (left) and number of length measured fish (right). Only large-meshed gillnets included.



Year	ICES 1 and 2a
2007	93
2008	81
2009	81
2010	71
2011	84
2012	39
2013	55
2014	33
2015	74
2016	57
2017	88
2018	94
2019	68
2020	89

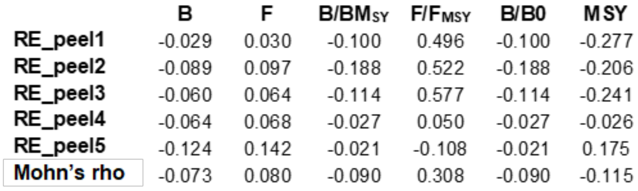
Year	ICES 1 and 2a
2007	2530
2008	1922
2009	2574
2010	2199
2011	2869
2012	1318
2013	1551
2014	836
2015	2054
2016	1339
2017	3604
2018	3233
2019	3223
2020	4129

Table 9.6. Eleven scenarios were run to examine the sensitivity of the model results to the choice of priors.

Scenario name	K	r	σ_P	Initial depletion	B_{MSY}/K value
Base	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
Low_K	LN(5e5,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
High_K	LN(1.5e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
Low_r	LN(1e6,1)	LN(0.05,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
High_r	LN(1e6,1)	LN(0.2,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
Low_sigmaP	LN(1e6,1)	LN(0.1,1)	IG(4,0.005)	LN(0.8,0.5)	0.35
High_sigmaP	LN(1e6,1)	LN(0.1,1)	IG(4,0.02)	LN(0.8,0.5)	0.35
Low_initdep	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.7,0.5)	0.35
High_initdep	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.9,0.5)	0.35
Low_BmsyK	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.30
Low_BmsyK	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.40

***LN stands for lognormal and IG stands for inverse gamma distribution. B_{MSY}/K value controls for the position of the inflection point of the surplus production curve with respect to K (a value from o 1).**

Table 9.7. Relative error (RE) in parameter estimates between the base run with full dataset (Table 9.6) and the retrospective peels (o 5 years) and the associated Mohn's rho statistics (i.e. average RE from the 5 peels). Relative error is calculated as: RE = (peel-ref)/ref.



	B	F	B/BM_{SY}	F/F_{MSY}	B/B0	MSY
RE_peel1	-0.029	0.030	-0.100	0.496	-0.100	-0.277
RE_peel2	-0.089	0.097	-0.188	0.522	-0.188	-0.206
RE_peel3	-0.060	0.064	-0.114	0.577	-0.114	-0.241
RE_peel4	-0.064	0.068	-0.027	0.050	-0.027	-0.026
RE_peel5	-0.124	0.142	-0.021	-0.108	-0.021	0.175
Mohn's rho	-0.073	0.080	-0.090	0.308	-0.090	-0.115

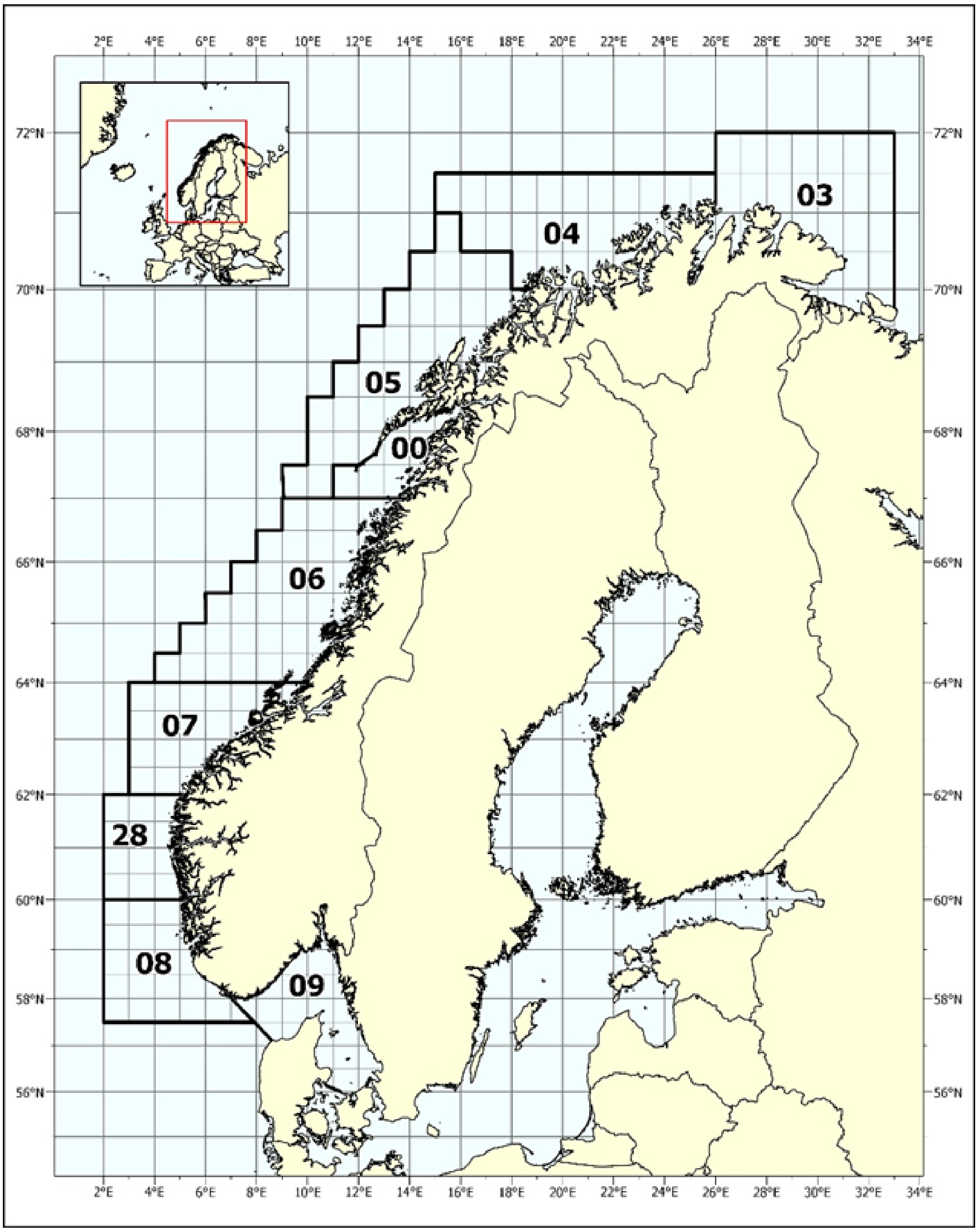


Figure 9.1. Map showing the Norwegian statistical coastal areas. Area 03 is part of ICES Subarea 1; areas 04, 05, 00, 06, and 07 are part of ICES Subarea 2; Areas 28 and 08 are part of ICES Subarea 4, and Area 09 corresponds roughly with ICES Subarea 3.

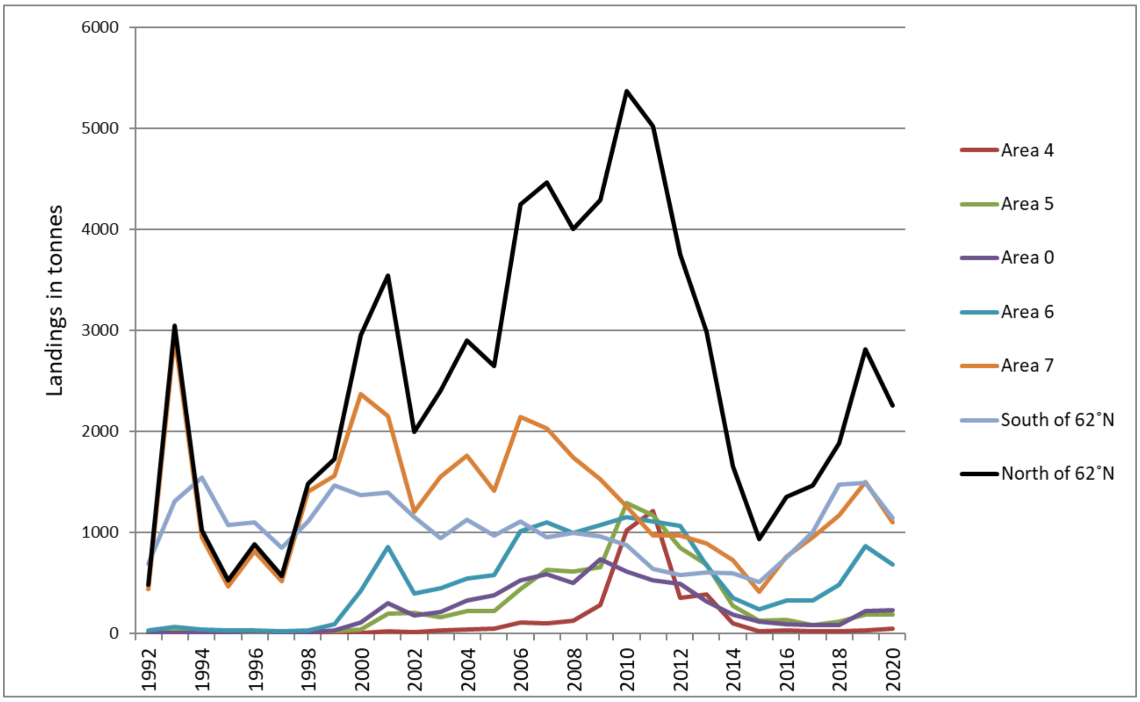


Figure 9.2. Norwegian official landings (in tonnes) of anglerfish (*Lophius piscatorius*) per statistical area (see Figure 9.1) within ICES areas 1 and 2 during 1992–2020. Norwegian landings from the area south of 62°N (ICES 4 and 3) are shown for comparison.

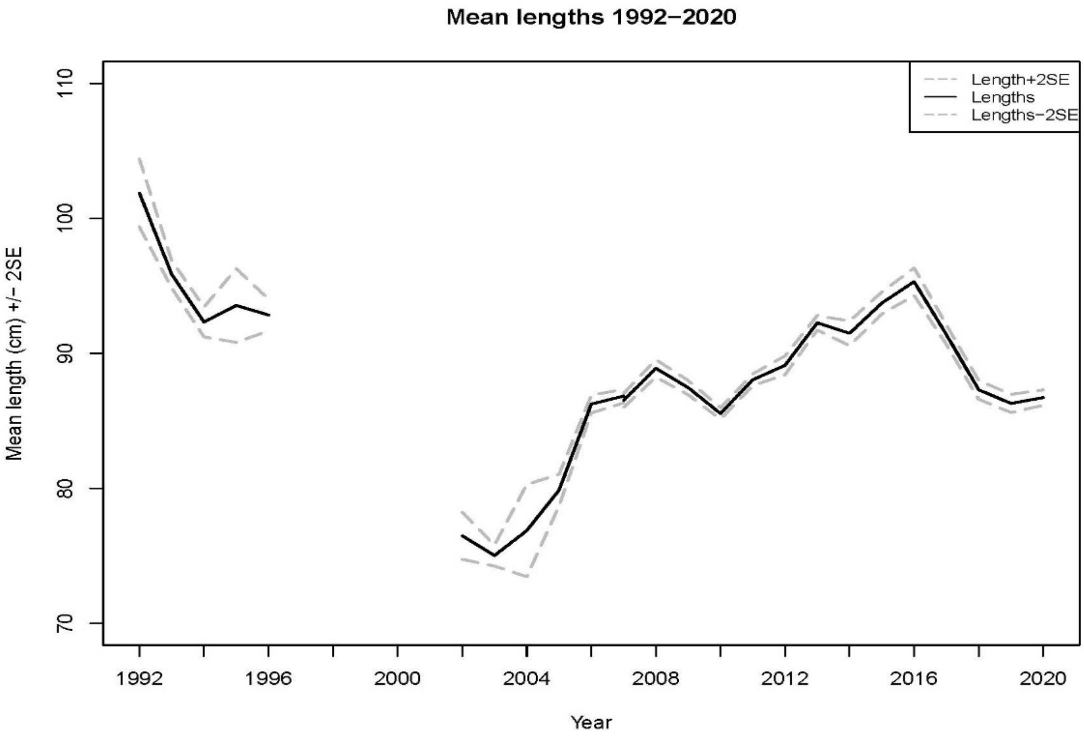


Figure 9.3. Anglerfish (*Lophius piscatorius*) in subareas 1 and 2. Mean lengths for anglerfish caught in the directed coastal gillnetting in Division 2.a during 1992–2020, dotted lines represent ± 2SE of the mean. Note that data are lacking for 1997–2001. This illustrates pulses of new recruitment entering Division 2.a from subareas 4/; last time during 2002–2003, and to a lesser extent in 2017–2019.

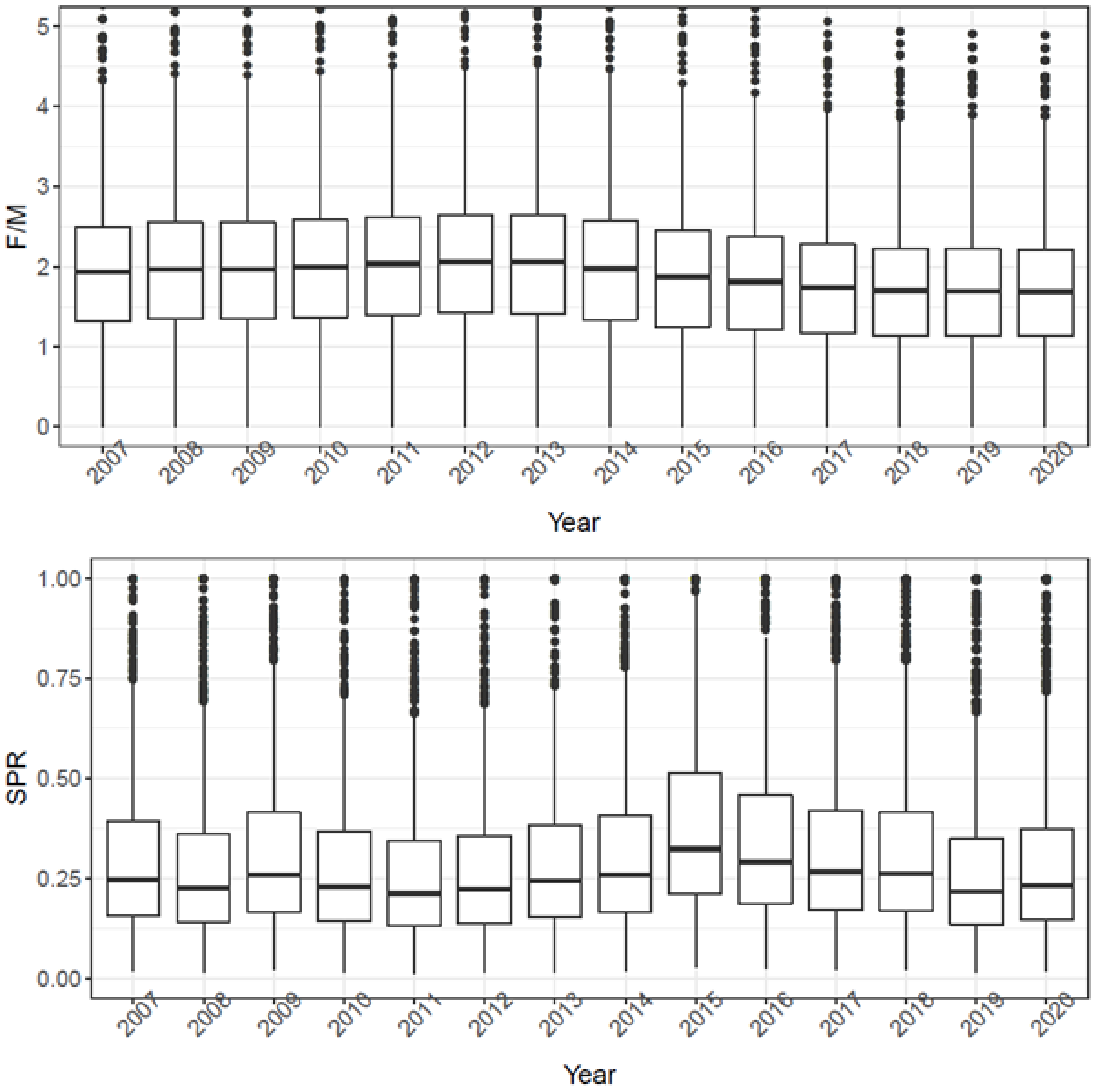


Figure 9.4. Annual estimates of F/M (above) and SPR (below) from the stochastic LBSPR approach using the length composition data from 200o 2020.

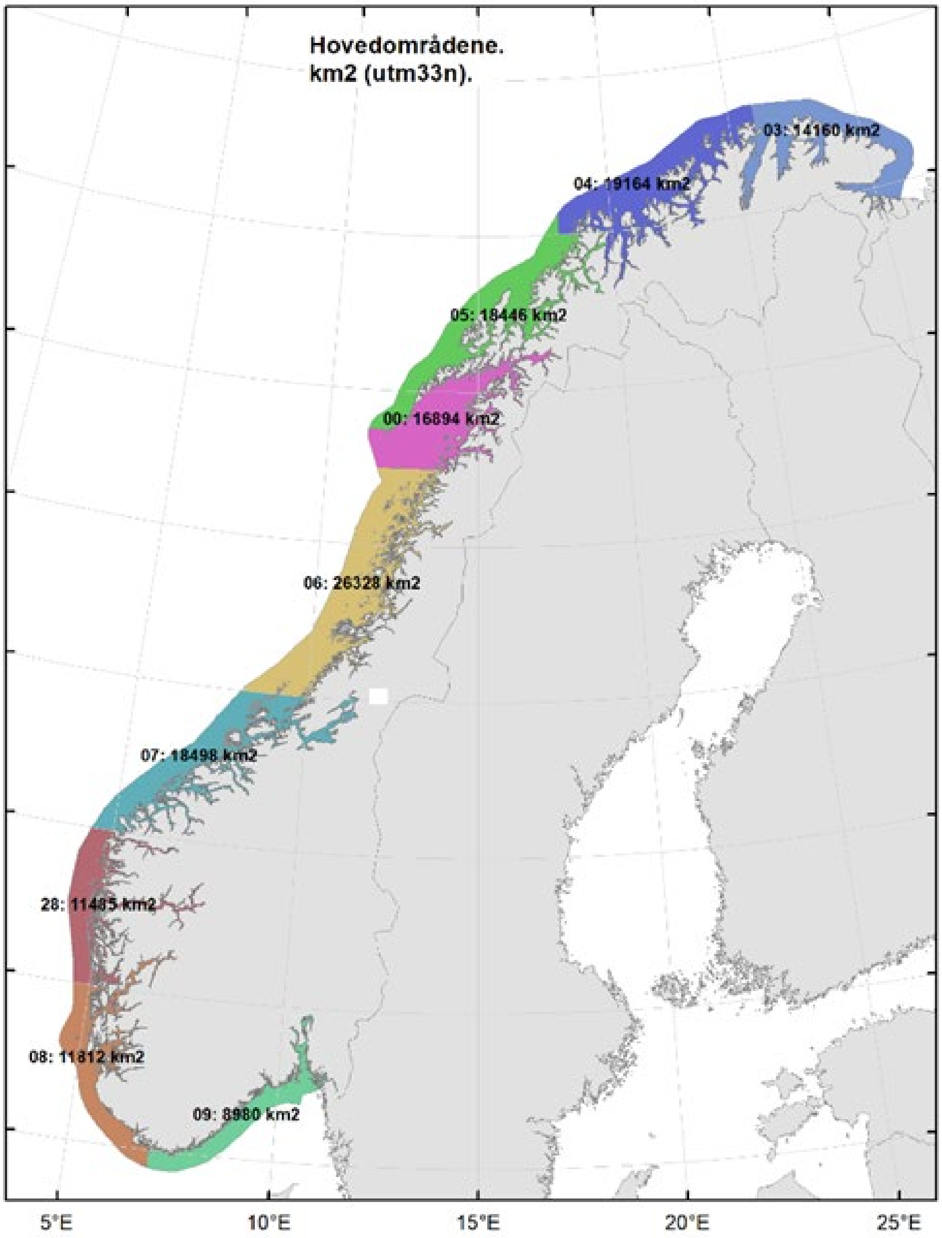


Figure 9.5. Map showing the area (km²) of each Norwegian statistical subarea inside 12 nautical miles. The subareas 4, 5, 0, 6, and 7 belong to the ICES Division 2.a.

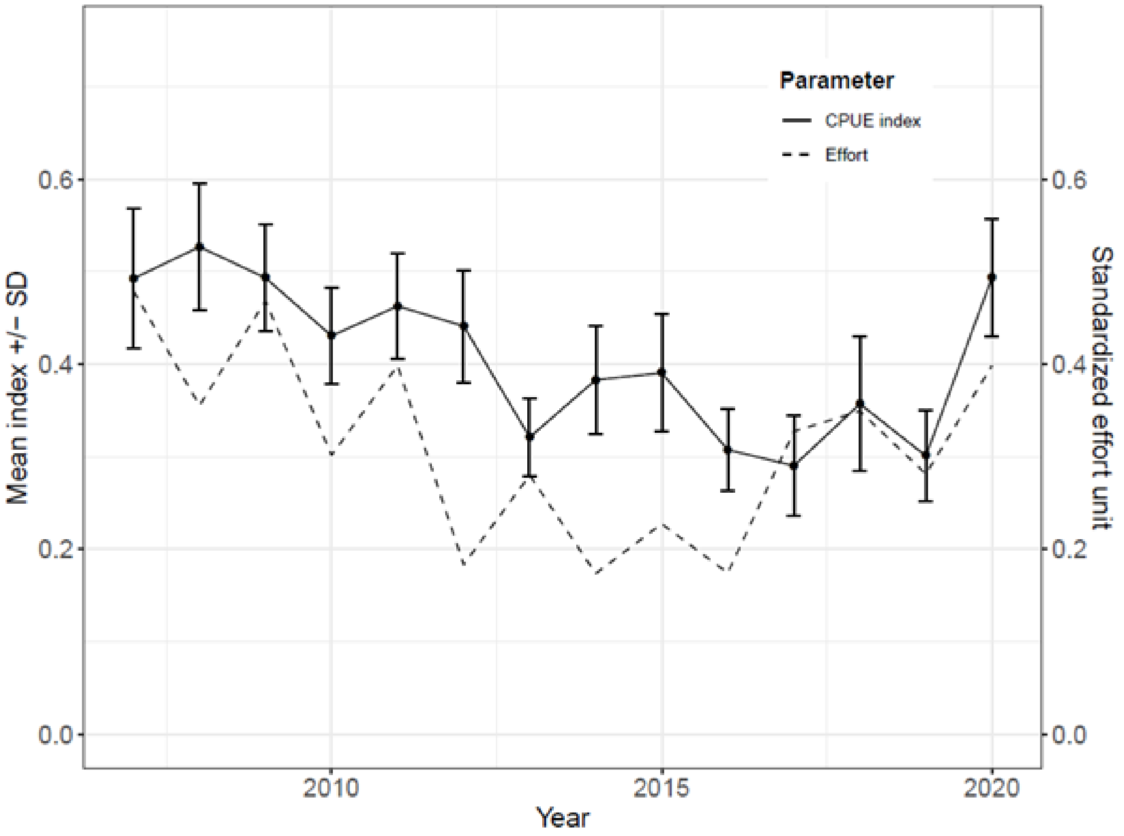


Figure 9.6. Standardized CPUE (kg per gillnet day) +/- SD (solid black line with error bars) and the corresponding standardized effort (dash line) for anglerfish based on the data from the Norwegian coastal reference fleet in ICES Subarea 2.a, from vessels targeting anglerfish with large meshed gillnets.

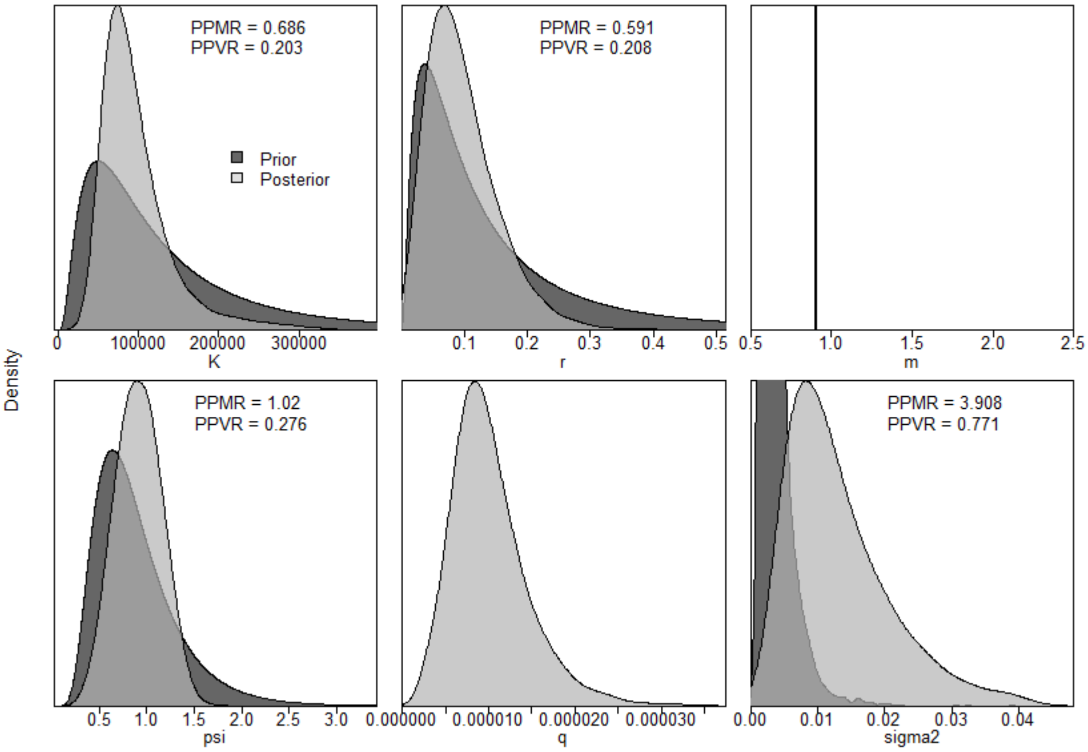


Figure 9.7. Prior and posterior distribution of the model parameters for the anglerfish assessment.

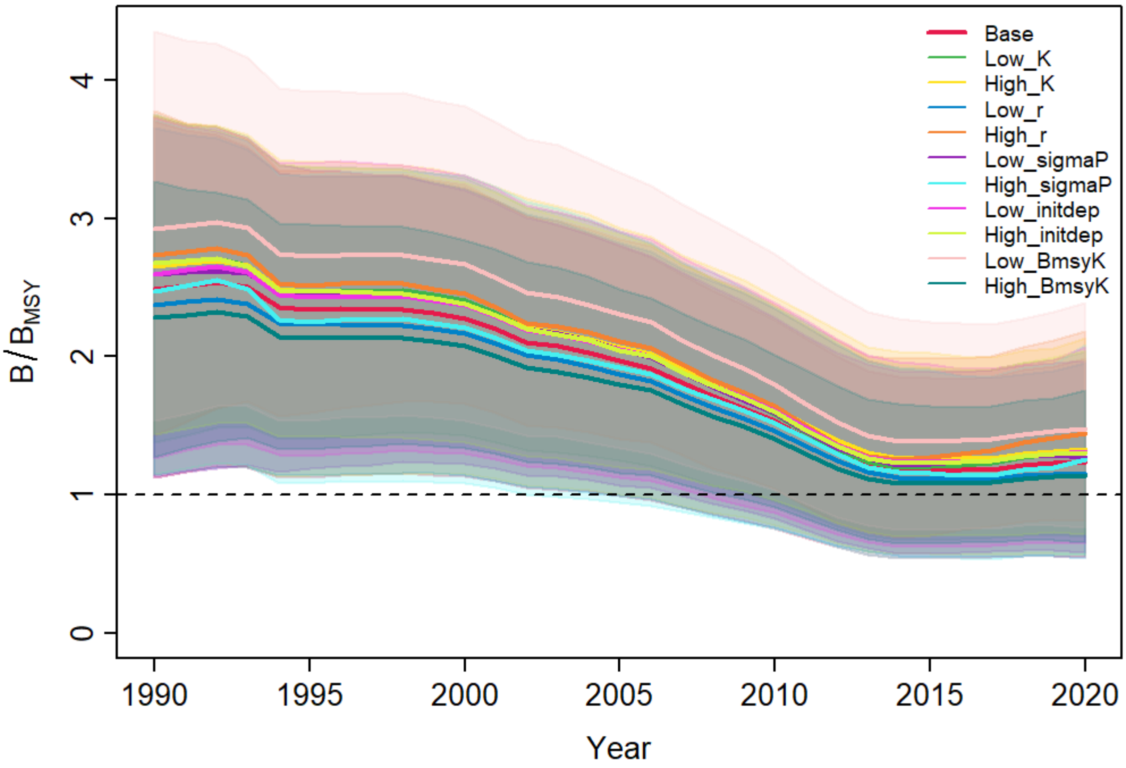


Figure 9.8. Estimated trajectories for B/B_{MSY} for the ICES subareas 1 and 2 anglerfish based on 11 JABBA scenarios (the name of scenario and the associated colour is indicated in the figure). The lines show the mean trajectory and the shaded areas denote 95% credibility intervals.

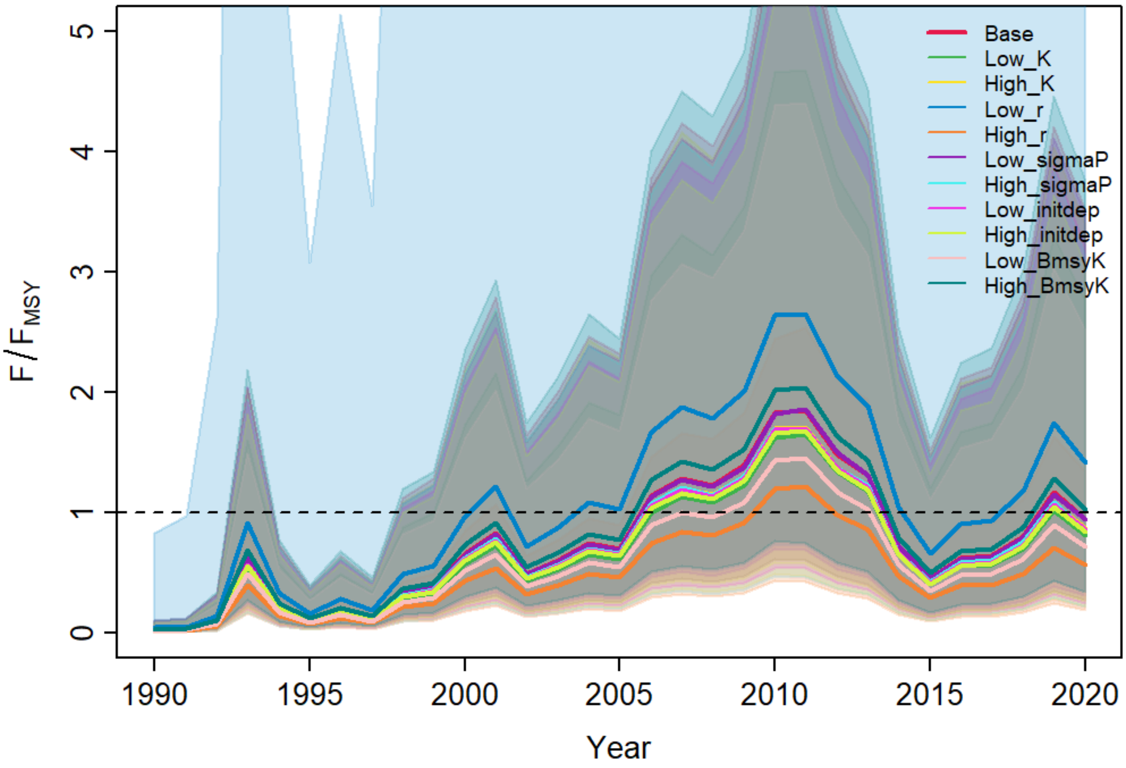


Figure 9.9. Estimated trajectories for F/F_{MSY} for the ICES subareas 1 and 2 anglerfish based on 11 JABBA scenarios (the name of scenario and the associated colour is indicated in the figure). The lines show the mean trajectory and the shaded-areas denote 95% credibility intervals.

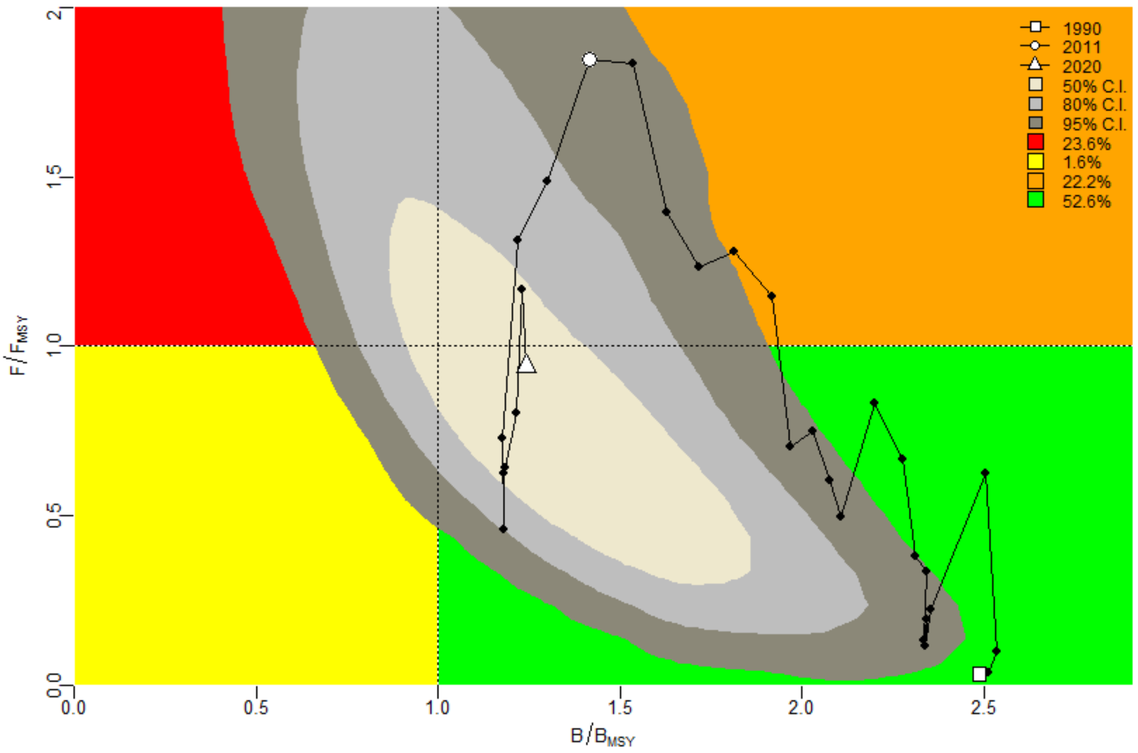


Figure 9.10. Kobe plot for the JABBA scenario showing the estimated trajectories (1990–2020) of B/B$_{Msy}$ and F/F$_{MSY}$. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

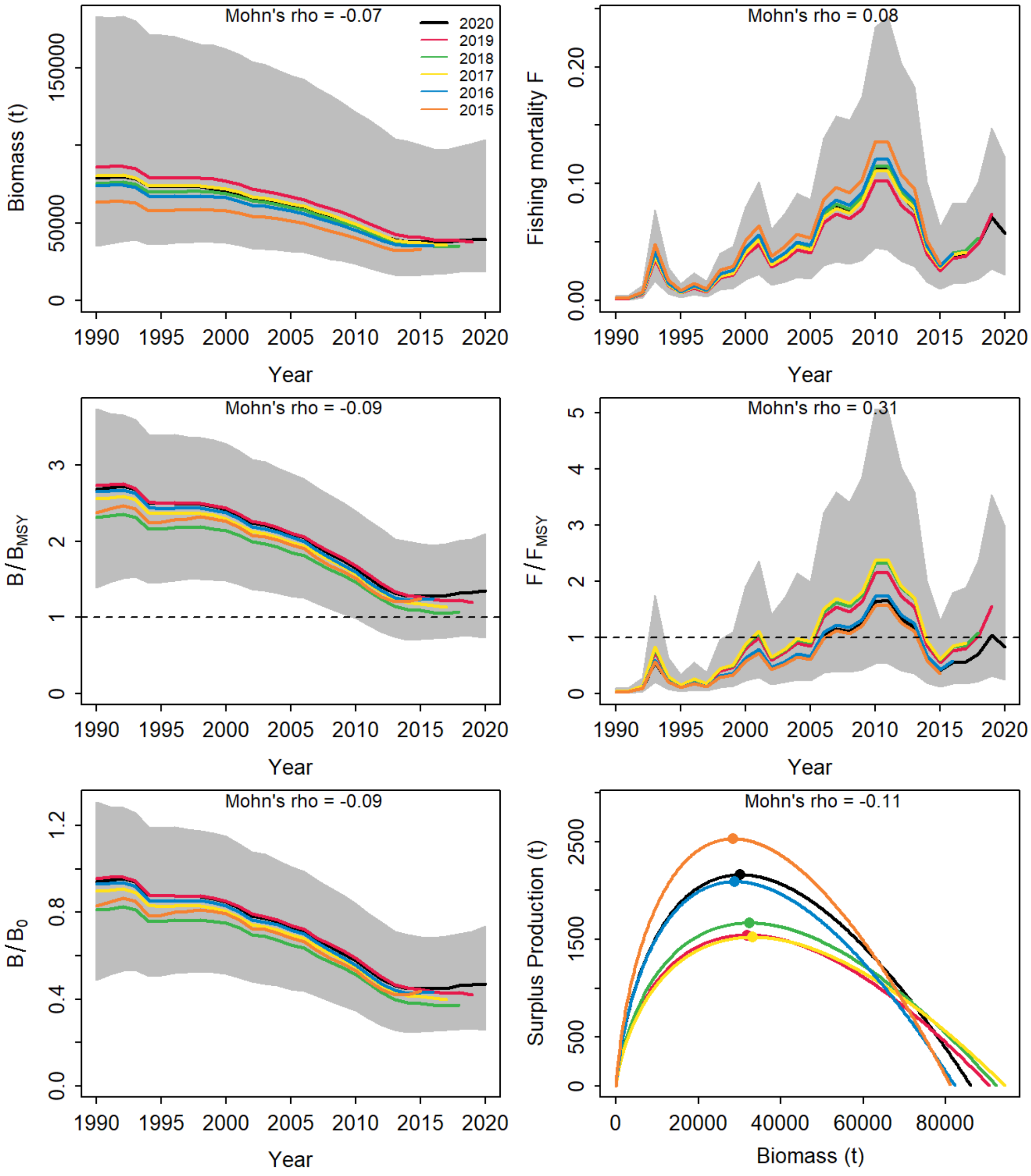


Figure 9.11. Retrospective analysis from the JABBA base case scenario. Different colours illustrate the results from different peels.

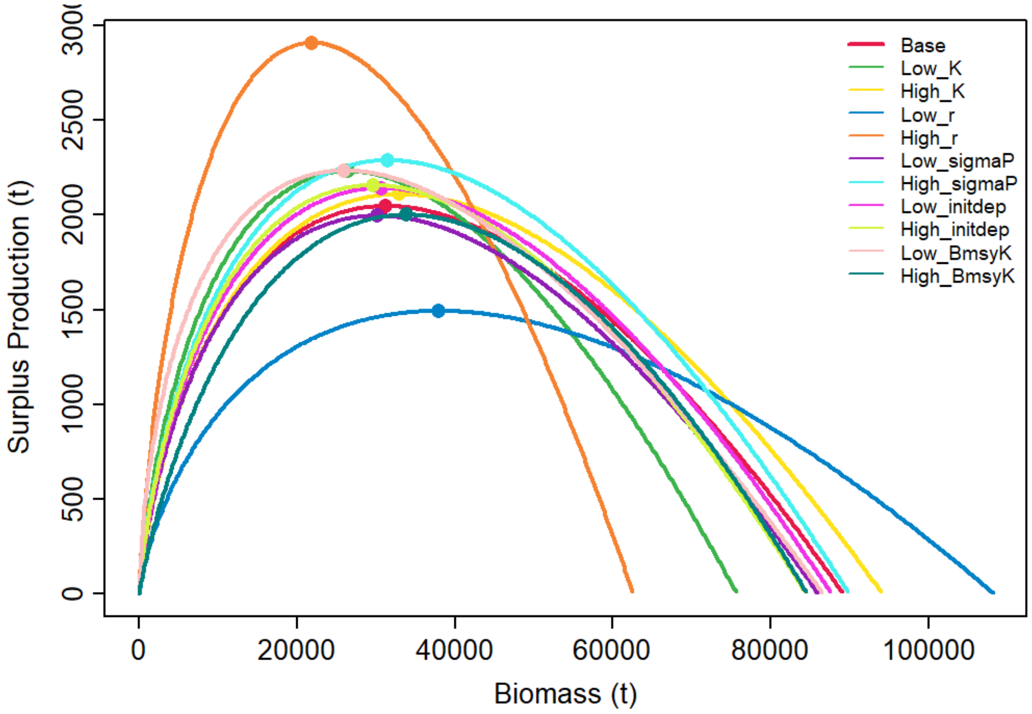


Figure 9.12. Sensitivity analysis for the ICES subareas 1 and 2 anglerfish based on 11 JABBA scenarios (the name of scenario and the associated colour is indicated in the figure). The analysis says that MSY could be around 2000 tonnes, with a B_{MSY} ~30000 tonnes. Note that the MSY value is quite sensitive to the choice of prior on r = population growth rate.

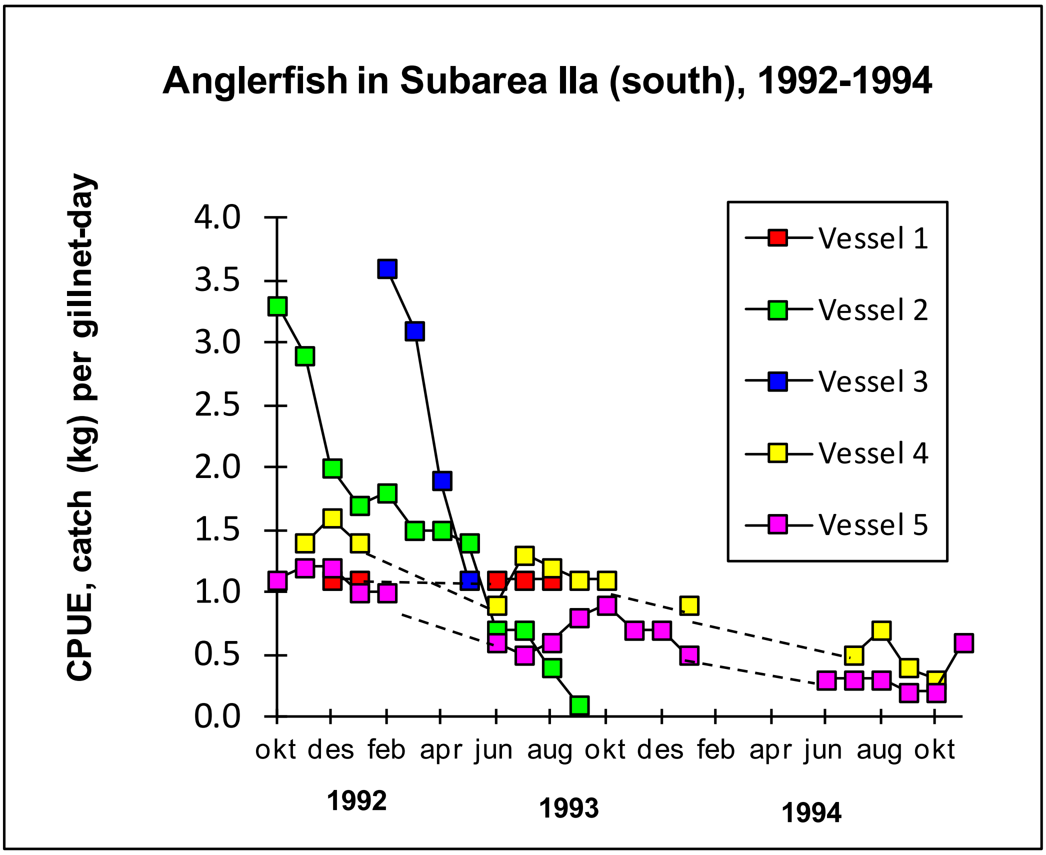
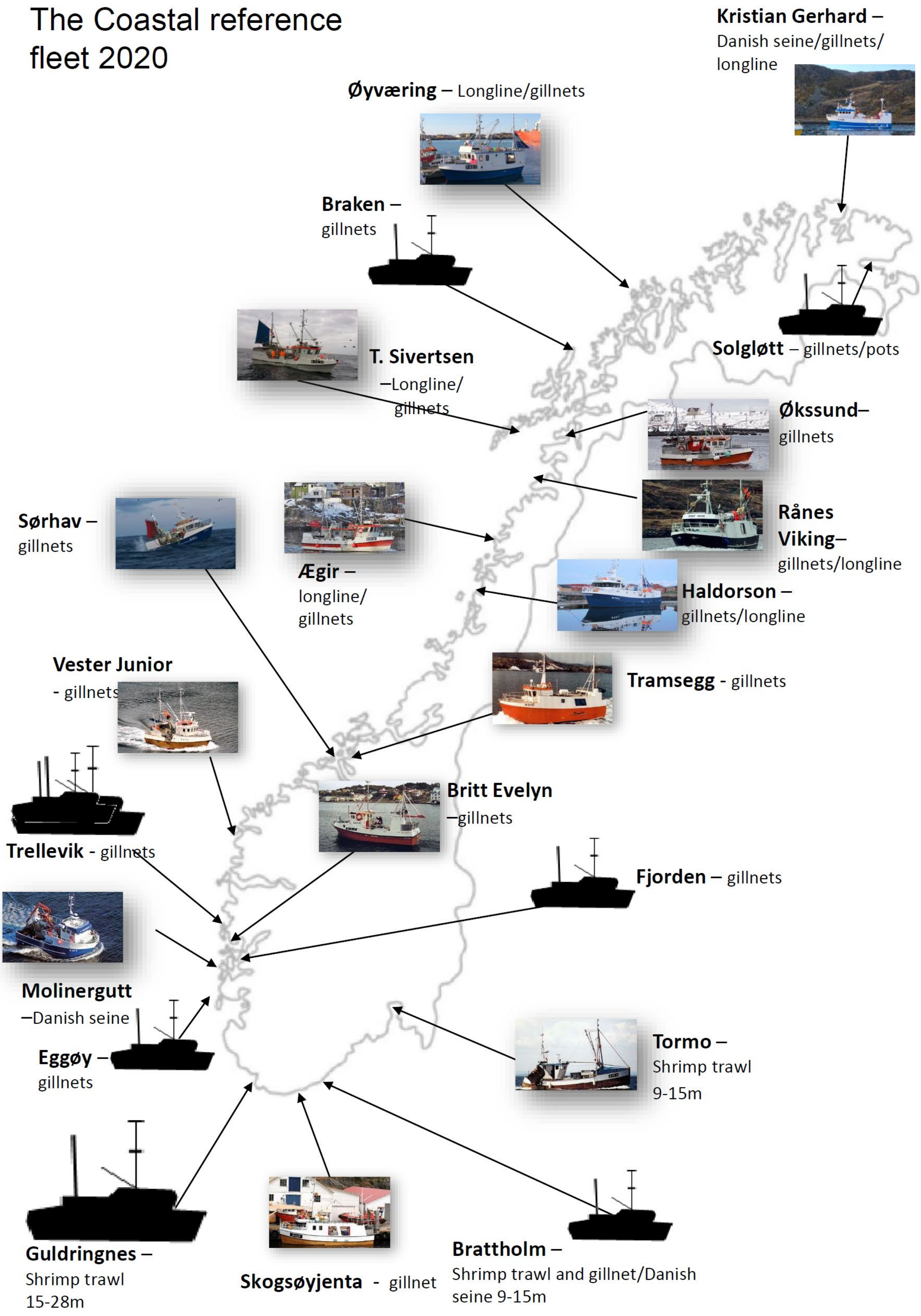


Figure 9.13. Catch per unit effort for five boats in the gillnet fishery for anglerfish in Møre and Romsdal (the same area as vessel A in figure 8 is fishing in) in the period October 199o October 1994. Boat 1 > 25m; Boat 2 ca. 20 m; Boat 3 ca. 10 m; Boat 4 and 5 ca. 16 m. Boats 1–4 were fishing with gillnet 360 mm nesh size, boat 5 with 300 mm mesh size.

Appendix figure H1.

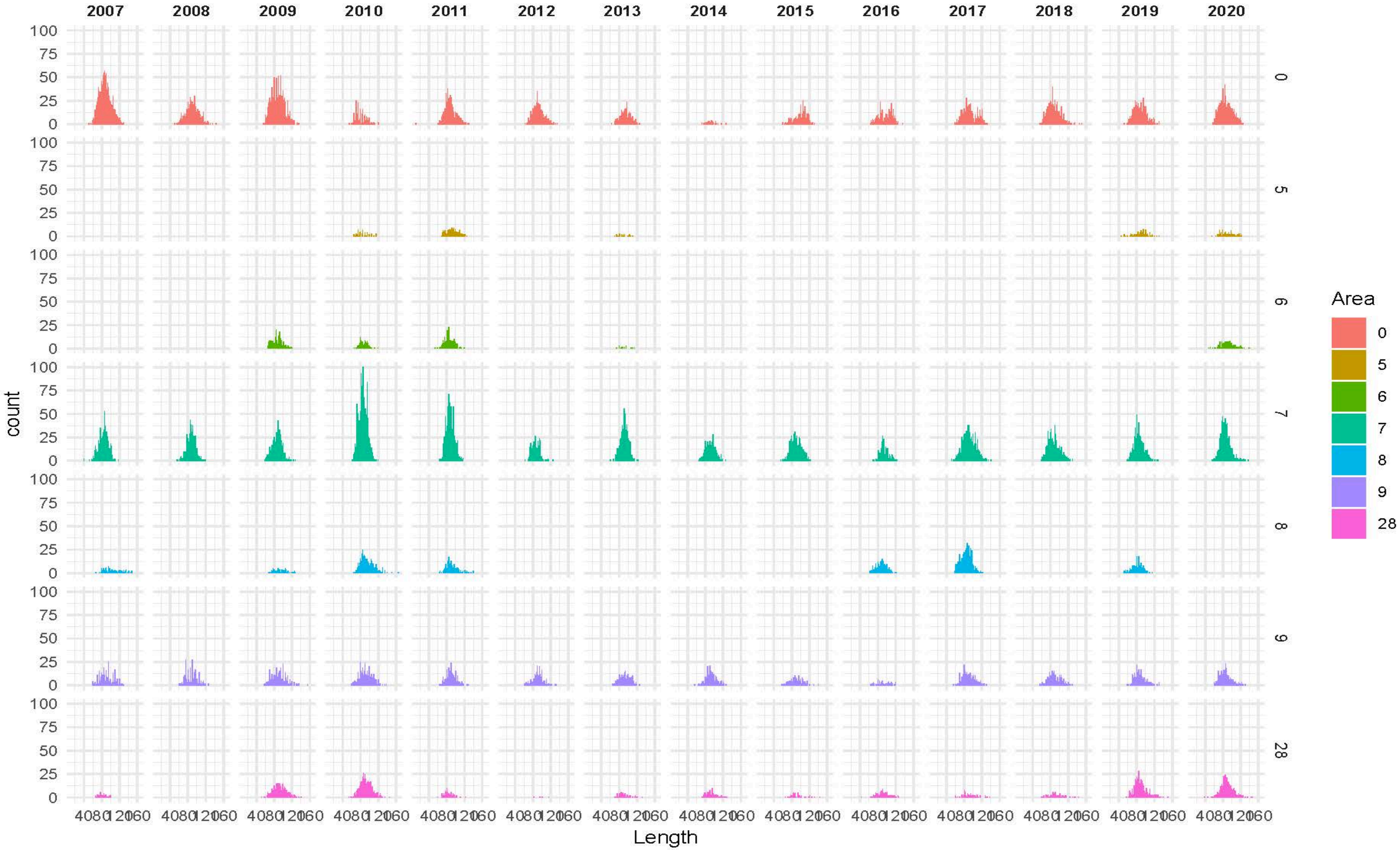


Appendix table H1. Input data to the JABBA assessment in the form of catch and abundance indices of anglerfish (*L. piscatorius*) in ICES Subareas 1 and 2.

Year	Catch	CPUE (mean)	CPUE (SE)
1990	151		
1991	180		
1992	488	1.5	0.3
1993	3042	1	0.2
1994	1024	0.5	0.1
1995	526		
1996	887		
1997	601		
1998	1549		
1999	1743		
2000	2999		
2001	3624		
2002	2071		
2003	2477		
2004	3001		
2005	2735		
2006	4348		
2007	4591	0.49	0.07
2008	4151	0.53	0.06
2009	4458	0.49	0.07
2010	5515	0.43	0.08
2011	5112	0.46	0.06
2012	3765	0.44	0.06
2013	3103	0.32	0.04
2014	1657	0.38	0.05
2015	1043	0.39	0.06
2016	1435	0.31	0.04
2017	1484	0.29	0.04

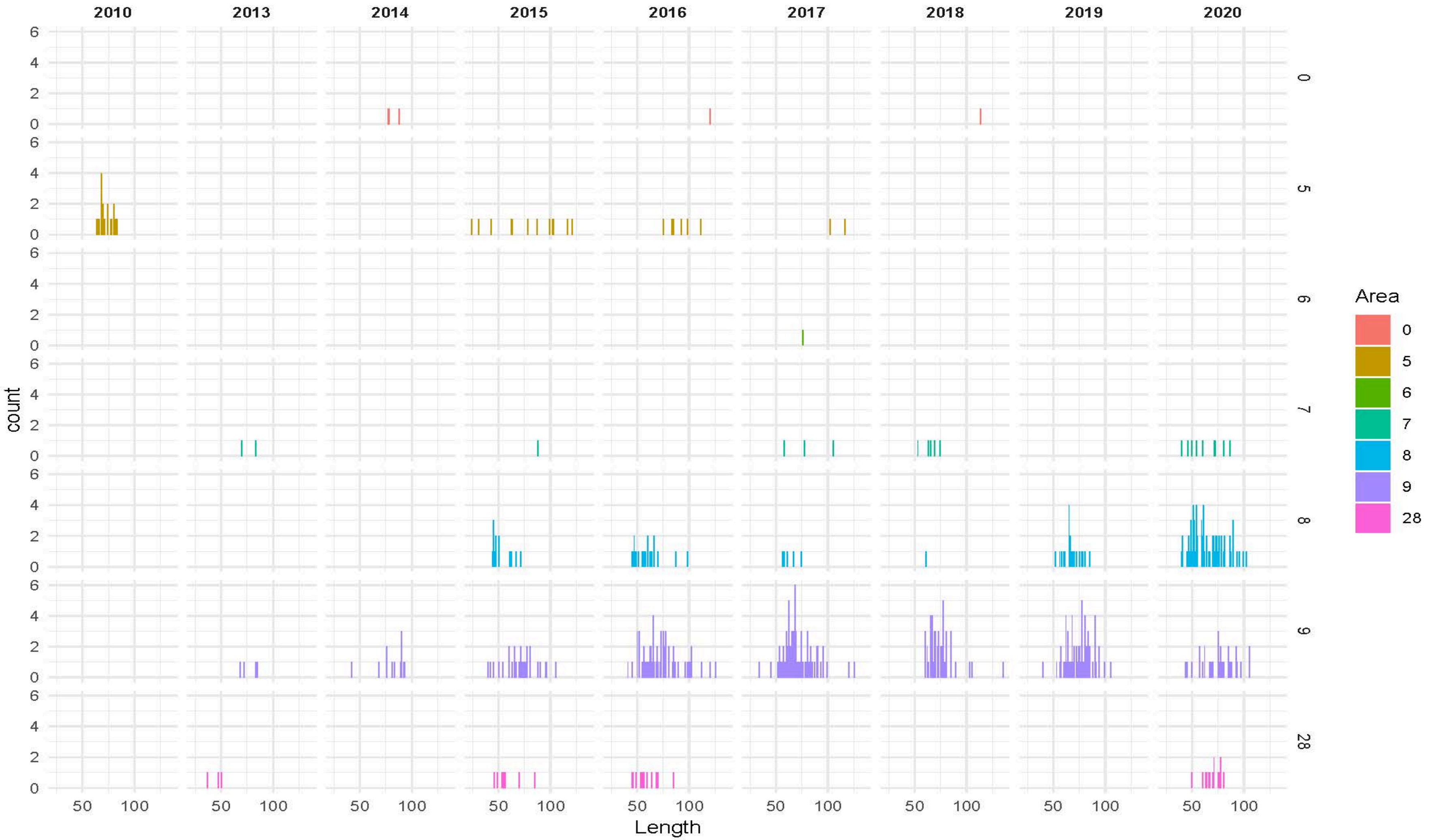
Year	Catch	CPUE (mean)	CPUE (SE)
2018	1903	0.36	0.08
2019	2809	0.30	0.05
2020	2280	0.49	0.06

Appendix figure H2. Length distributions of anglerfish (*L. piscatorius*) caught and retained in large-meshed gillnets per year and Norwegian statistical areas. Areas 0, 5, 6 and 7 represent ICES Subarea 2. Note the different scale of the y-axis in App. figs H2-H4.



Appendix figure H3. Length distributions of anglerfish (*L. piscatorius*) caught as bycatch and retained in other gillnets per year and Norwegian statistical areas. Note the different scale of the y-axis in App. figs H2-H4.

Appendix figure H4. Length distributions of anglerfish (*L. piscatorius*) caught as bycatch and retained in other gears per year and Norwegian statistical areas. Note the different scale of the y-axis in App. figs H2-H4.



10 Barents Sea capelin

Mallotus villosus in subareas 1 and 2 (Northeast Arctic), excluding Division 2.a west of 5°W – cap.27.1–2

As decided at the Arctic Fisheries Working Group at its 2021 meeting, the assessment of Barents Sea capelin was left to the parties responsible for the autumn survey, i.e. IMR in Bergen and VNIRO PolarBranch in Murmansk. In accordance with this, the assessment was done during a virtual meeting 4–5 October 2021. The assessment is an update assessment, without changes to the methodology. Participants:

Bjarte Bogstad	*Norway*
Anatoly Chetyrkin	*Russia*
Daniel Howell	*Norway*
Sondre Hølleland	*Norway*
Stine Karlson	*Norway*
Yury Kovalev	*Russia*
Dmitry Prozorkevich	*Russia*
Frøydis Rist	*Norway*
Georg Skaret	*Norway*

10.1 Regulation of the Barents Sea capelin fishery

Since 1979, the Barents Sea capelin fishery has been regulated by a bilateral fishery management agreement between Russia (former USSR) and Norway. A TAC has been set separately for the winter fishery and for the autumn fishery. From 1999, no autumn fishery has taken place, except for a small Russian experimental fishery in some years. A minimum landing size of 11 cm has been in force since 1979. AFWG strongly recommends capelin fishery only on mature fish during the period from January to April.

10.2 TAC and catch statistics (Table 9.1)

The Joint Russian-Norwegian Fishery Commission set a zero TAC both for 2019, 2020 and 2021. For all three years, the quotas were in accordance with the ICES advice. The international historical catch by country and season in the years 1965–2021 is given in Table 10.1. There was no commercial fishery in 2021, but some minor catches were taken – 2.3 tonnes in the capelin spawning survey by Norway and 7.3 tonnes in scientific surveys and as bycatch in the northern shrimp trawl fishery by Russia.

10.3 Sampling

The capelin sampling from the Barents Sea in 2021 is summarized below:

Investigation	No. of trawl hauls	Length measurements	Aged individuals
Winter capelin survey 2021 (Norway)	27	1775	675
Winter bottom survey 2021 (Norway)	211	9983	1134
Winter bottom survey 2021 (Russia)	90	5339	175
IESNS 2021 (Russia)	12	362	156
BESS 2021 (Norway)	339	22261	6221
BESS 2021 (Russia)	195	15255	1103

10.4 Stock assessment

10.4.1 Acoustic stock size estimates in 2021 (Table 10.2, Figure 10.1 and 10.2)

The geographical survey coverage of the Barents Sea capelin stock during the BESS in 2021 was almost complete (Figure 10.1). However, as last year, an area in the central part of the Barents Sea (“Loophole”) was not covered.

The geographical distribution of capelin in 2021 is shown in Figure 10.1, and the position and weighting of the trawl stations are shown in Figure 10.2.

The stock estimate from the area covered by the 2021 survey was 3.998 million tonnes (Table 10.2). About 36% (1.438 million tonnes) of the estimated stock biomass consisted of maturing fish (> 14.0 cm). The mean weight at age in the 2021 survey was the lowest since 2014 for age 2 (Figure 10.3).

As decided during the 2016 assessment meeting, the capelin abundance was estimated using the software StoX (Johnsen *et al*., 2019), applying agreed settings.

A fixed sampling variance expressed as Coefficient of Variance (CV) of 0.2 per age group has been applied as input for CapTool in the capelin assessment and was also used this year (Tjelmeland, 2002; Gjøsæter *et al*., 2002). The survey design and estimation software now allow for estimation of a direct CV by age group, and for the 2021 survey this was estimated:

- for age group 1: 0.17;
- for age group 2: 0.10;
- and for age group 3: 0.29.

These values are lower than previous years for age groups 1 and 2 and similar for age group 3. Relative sampling error based only on acoustic recordings (Nautical Area Scattering Coefficient (NASC; m^2nmi^{-2})) was estimated to be 9.27% which is much lower than in the two previous years. Detailed information about previous CV estimates can be found in AFWG WD05, 2018. Future implementation of direct survey CV in the assessment is discussed under future work (10.4.6).

10.4.2 Stock assessment in 2021 (Table 10.3–10.5, Figure 10.4)

Probabilistic projections of the maturing stock to the time of spawning at 1 April 2022 were made using the spreadsheet model CapTool (implemented in the @RISK add-on for EXCEL, 50 000 simulations were used). The settings were the same as last year. The projection was based on a maturation and predation model with parameters estimated by the model Bifrost and data on cod abundance and size at age in 2022 from the 2021 Arctic Fisheries Working Group (ICES Scientific Reports. 3:58). The revised cod assessment made in September 2021 was used[1].

The methodology is described in the 2009 WKSHORT report (ICES C.M. 2009/ACOM:34) and the WKARCT 2015 report (ICES C.M. 2015/ACOM:31). The natural mortality M for the months October to December is drawn among a set of M-values estimated for different years based on historical data. The same set of M-values was used in 2021 as in 2020 (ICES 2011/ACOM:05, Annex 12).

The CapTool forecast methodology has been implemented in the R package Bifrost and was run alongside the standard procedure. The results were similar, and it produced the same advice.

With no catch, the estimated median spawning stock size on 1 April, 2022 is 479 kt (90% confidence interval: 259–916 kt; Figure 10.4), and the probability for the spawning stock to be above B_{lim} (200 000 t) is 99%.

With a catch of 70 000 tonnes, the probability for the spawning stock in 2022 to be below 200 000 t, the B_{lim} value used by ACFM in recent years, is 5% (Figure 10.4). The median spawning stock size in 2022 will then be 420 000 tonnes (90% confidence interval: 200–833 kt), and the corresponding median modelled consumption by immature cod in the period January–March 2022 will then be 570 000 tonnes. Figure 10.4 shows the probabilistic forecast from 1 October 2021 to 1 April 2022 conditional on a quota of 70 000 tonnes, while Figure 10.5 shows the probability of $SSB < B_{lim}$ as a function of the catch.

As in previous years, the catch corresponding to 95% probability of being above B_{lim} is calculated to the nearest 5000 tonnes.

Estimates of stock by age group and total biomass for the historical period are shown in Table 10.4. Other data which describe the stock development are shown in Table 10.5. Information about spawning surveys going back to the 1980s is given in Gjøsæter and Prozorkevitch (WD05, 2020). Summary plots are given in Figure 10.6.

10.4.3 Recruitment

The coverage of the 0-group survey in 2018 and 2020 was incomplete, and an estimate of the 0-group numbers was made for only half of the survey area. In 2021, the coverage was complete, but results were not available at the time of the working group. Table 10.3 shows the number of fish in the various year classes from surveys at age 0–2, and their “survey mortality” from age one to age two is also shown in Figure 10.7.

The 1-group abundance in 2021 was 220.8 billion which is higher than the long-term average (Figure 10.6). The most recent evaluation of the spawning stock and recruitment time-series was made by Gjøsæter *et al.* (2016).

Future recruitment conditions: High abundance of young herring (mainly age groups 1 and 2) has been suggested to be a necessary but not a single factor causing recruitment failure in the

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[1] ICES. 2021. Cod (*Gadus morhua*) in subareas 1 and 2 (Northeast Arctic). In Report of the ICES Advisory Committee, 2021. ICES Advice 2021, cod.27.1-2, https://doi.org/10.17895/ices.advice.7741.

capelin stock (Hjermann *et al.*, 2010; Gjøsæter *et al.*, 2016). In 2021, very little herring at age 1–4 were recorded in the Barents Sea.

10.4.4 Comments to the assessment

10.4.4.1 Ecological considerations

The number of young herring in the Barents Sea can be an important factor that affects capelin recruitment. It is not currently taken into account in the assessment model. The benchmark for capelin stocks in the Barents Sea (WKARCT, ICES C.M. 2015/ACOM:31) noted the need for further study of this effect as well as better monitoring of the young herring abundance.

The amount of other food than capelin for cod and other predators may also have changed in recent years. This may also indirectly have affected the predation pressure on capelin. A more detailed discussion of interactions between capelin and other species is given in the 2016–2021 ICES WGIBAR reports.

The abundance of 2-year-olds observed is the highest in 30 years and the high abundance corresponds to low length-at-age. This is likely a result of high internal competition for food and reduced growth. This tendency is likely enhanced by a strong 2020-year class at least partly competing for the same food. The implication is that the majority of this year class had not reached a length of 14 cm and is not expected to migrate to the coast and spawn before winter 2023.

10.4.5 Further work on survey and assessment methodology

10.4.5.1 Survey

On 26 February–12 March 2021, IMR carried out trawl-acoustic monitoring and stock estimation of spawning capelin (Skaret *et al.*, 2021). The survey is the third survey in a series to evaluate whether such monitoring can be used in the assessment to improve the advice. The initiative and funding come from the industry, and the idea in the long term is that monitoring closer to when fishery and spawning happens, can reduce uncertainty in stock advice. Monitoring during spawning has been attempted before, last time in 2007–2009, and has proven to be methodologically difficult due to unpredictable timing and location of the spawning migration. The survey was carried out using two fishing vessels 'Vendla' and 'Eros'. A stratified design using zig-zag transects with randomized starting points was used and the effort was allocated based on historical and recent information about capelin distribution. The fishery sonar was used actively during the whole survey to estimate size distribution of capelin schools, migration speed and direction. In addition, target-strength measurements were carried out and an autonomous sail buoy was tried for monitoring through remote control. The coverage of the capelin spawning migration was successful and the estimate of ca. 86 000 tonnes with a CV of 0.49 was within the expected range from the predictions made in autumn 2020.

Nevertheless, methodological issues due to timing and patchy distribution of capelin were still very apparent, and this must be handled in an adequate manner before such monitoring can be potentially implemented in an advisory process. A similar survey will be carried out again in winter 2022, and then an evaluation of the four-year series will be carried out. This will be a part of the benchmark for this stock which will be held in 2022.

10.4.5.2 Assessment model

In the present capelin assessment model, the only species interaction in the Barents Sea taken explicitly into account is predation by cod on mature capelin. The model does not take into account possible changes in capelin stock dynamics (e.g. maturation), the current state of the environment and stock status of other fish species and mammals in the Barents Sea. The ICES

Working Group of Integrated Assessment of the Barents Sea (WGIBAR) has addressed some of these issues.

Consumption of prespawning capelin by mature cod in the winter-spring season and autumn season is still not included in the assessment model. It may have a significant affect on capelin SSB calculations.

Gjøsæter *et al.* (2015) calculated what the quota advice and spawning stock would have been in the period 1991–2013, given the present assessment model and knowledge of the cod stock. By exchanging that cod forecast with the actual amount of cod from the cod assessment model run later and rerunning the model, they showed that considerably smaller annual quotas would have been advised if the amount of cod had been known and the present assessment model had been used when the capelin quota was set. Following this work, a retrospective analysis of the capelin assessment as well as of the assessment performance should be included annually. This is a feature that so far has been missing from the capelin assessment.

There is ongoing work to address specific points related to modelling for the benchmark meeting in 2021/22. These include implementation of survey CV in the capelin assessment model, incorporating the assessment model in Template Model Builder (R-package), validating both the cod consumption part of the model and the capelin maturation part and updating consumption parameters to reflect the recent state in the Barents Sea. As mentioned above, the CapTool methodology for half-year predictions has already been implemented in R. Historic CVs of SSB estimates will be calculated back to 2004.

10.4.6 Reference points

A B_{lim} (SSB_{lim}) management approach has been suggested for this stock (Gjøsæter *et al.*, 2002). In 2002, the JRNFC agreed to adopt a management strategy based on the rule that, with 95% probability, at least 200 000 tonnes of capelin should be allowed to spawn. Consequently, 200 000 tonnes was used as a B_{lim}. Alternative harvest control rules of 80, 85, and 90% probability of $SSB > B_{lim}$ were suggested by JNRFC and evaluated by ICES (WKNEAMP-2, ICES C. M. 2016/ACOM:47). ICES considers these rules not to be precautionary. At its 2016 meeting, JNRFC decided not to change the adopted management strategy.

Table 10.1 Barents Sea capelin. International catch ('000 t) as used by the Working Group.

Year	Winter-Spring				Summer-Autumn			Total
	Norway	Russia	Others	Total	Norway	Russia	Total	
1965	217	7	0	224	0	0	0	**224**
1966	380	9	0	389	0	0	0	**389**
1967	403	6	0	409	0	0	0	**409**
1968	460	15	0	475	62	0	62	**537**
1969	436	1	0	437	243	0	243	**680**
1970	955	8	0	963	346	5	351	**1314**
1971	1300	14	0	1314	71	7	78	**1392**
1972	1208	24	0	1232	347	13	360	**1591**
1973	1078	34	0	1112	213	12	225	**1337**
1974	749	63	0	812	237	99	336	**1148**
1975	559	301	43	903	407	131	538	**1441**
1976	1252	228	0	1480	739	368	1107	**2587**
1977	1441	317	2	1760	722	504	1226	**2986**
1978	784	429	25	1238	360	318	678	**1916**
1979	539	342	5	886	570	326	896	**1782**
1980	539	253	9	801	459	388	847	**1648**
1981	784	429	28	1241	454	292	746	**1986**
1982	568	260	5	833	591	336	927	**1760**
1983	751	373	36	1160	758	439	1197	**2357**
1984	330	257	42	629	481	368	849	**1477**
1985	340	234	17	591	113	164	277	**868**
1986	72	51	0	123	0	0	0	**123**
1987–1990	0	0	0	0	0	0	0	**0**
1991	528	159	20	707	31	195	226	**933**
1992	620	247	24	891	73	159	232	**1123**
1993	402	170	14	586	0	0	0	**586**
1994–1996	0	0	0	0	0	0	0	**0**
1997	0	0	0	0	0	1	1	**1**

Year	**Winter-Spring**				**Summer-Autumn**			**Total**
	Norway	**Russia**	**Others**	**Total**	**Norway**	**Russia**	**Total**	
1998	0	2	0	2	0	1	1	**3**
1999	50	33	0	83	0	22	22	**105**
2000	279	94	8	381	0	29	29	**410**
2001	376	180	8	564	0	14	14	**578**
2002	398	228	17	643	0	16	16	**659**
2003	180	93	9	282	0	0	0	**282**
2004	0	0	0	0	0	0	0	**0**
2005	1	0	0	1	0	0	0	**1**
2006	0	0	0	0	0	0	0	**0**
2007	2	2	0	4	0	0	0	**4**
2008	5	5	0	10	0	2	0	**12**
2009	233	73	0	306	0	1	1	**307**
2010	246	77	0	323	0	0	0	**323**
2011	273	87	0	360	0	0	0	**360**
2012	228	68	0	296	0	0	0	**296**
2013	116	60	0	177	0	0	0	**177**
2014	40	26	0	66	0	0	0	**66**
2015	71	44	0	115	0	0	0	**115**
2016–2017	0	0	0	0	0	0	0	**0**
2018	129	66	0	195	0	0	0	**195**
2019–2021	0	0	0	0	0	0	0	**0**

Table 10.2. Barents Sea capelin. Stock size estimation table. Estimated stock size (10^6) by age and length, and biomass (1000 tonnes) from the acoustic survey in August-October 2021. TSN: Total stock number. TSB: Total-stock biomass. MSN: Maturing stock number. MSB: Maturing stock biomass.

Length (cm)	Age/year class					Sum	Biomass (10^3 t)	Mean weight (g)
	1	2	3	4	5	10^9		
	2020	2019	2018	2017	2016			
7.0-7.5	1.92					1.92	2.53	1.32
7.5-8.0	4.82					4.82	9.07	1.88
8.0-8.5	15.46					15.46	34.93	2.26
8.5-9.0	26.72	1.07				27.79	73.09	2.63
9.0-9.5	53.27	2.98				56.25	170.44	3.03
9.5-10.0	60.28	6.18				66.46	227.95	3.43
10.0-10.5	32.24	14.56				46.8	187.67	4.01
10.5-11.0	15.64	44.08				59.72	284.86	4.77
11.0-11.5	4.68	39.57				44.25	241.61	5.46
11.5-12.0	2.93	40.58	0.02			43.53	278.59	6.4
12.0-12.5	1.41	34.22				35.63	265.09	7.44
12.5-13.0	0.93	31.6	0.17			32.7	285.18	8.72
13.0-13.5	0.35	26.38	0.24			26.97	273.76	10.15
13.5-14.0	0.13	18.48	0.44			19.04	224.8	11.81
14.0-14.5	0.07	15.84	0.34			16.25	215.82	13.28
14.5-15.0		13.36	0.53			13.89	215.3	15.5
15.0-15.5		14.24	0.23			14.47	251.54	17.38
15.5-16.0		9.74	1.51			11.25	223.36	19.85
16.0-16.5		6.27	0.68			6.95	154.24	22.18
16.5-17.0		6.74	0.32			7.06	177.3	25.1
17.0-17.5		2.774	1.03	0.01		3.814	105.26	27.6
17.5-18.0		1.043	0.454			1.497	48.24	32.23
18.0-18.5		0.164	0.924			1.089	36.55	33.58
18.5-19.0		0.115				0.115	4.3	37.39
19.0-19.5		0.0344	0.1013	0.0006		0.1362	5.38	39.46
19.5-20.0				0.0208		0.0208	0.91	43.87
20.5-20.5				0.0002		0.0002	0.01	47.88
TSN (10^9)	220.85	330.0204	6.996	0.0316		557.89		
TSB (10^3 t)	757.71	3081.46	157.23	1.22			3997.62	
Mean length (cm)	9.58	12.57	16.11	18.95		11.43		
Mean weight (g)	3.43	9.34	22.47	38.66				7.17
SSN (10^9)	0.07	70.3204	6.12	0.0316		76.54		
SSB (10^3 t)	0.93	1287.85	147.96	1.22			1437.96	

Table 10.3 Barents Sea capelin. Recruitment and natural mortality table. Larval abundance estimate in June, 0-group indices and acoustic estimate in August-September, total mortality from age 1+ to age 2+.

Year class	Larval abundance(10^{12})	0-group swept-area numbers (10^9 ind.)	Acoustic estimate (10^9ind.)		Mortality survey (1–2)
	0 (Y)	0+(Y)	1(Y+1)	2(Y+2)	%
1980	-	760	402.6	147.6	63
1981	9.7	536	528.3	200.2	62
1982	9.9	655	514.9	186.5	64
1983	9.9	421	154.8	48.3	69
1984	8.2	295	38.7	4.7	88
1985	8.6	112	6.0	1.7	72
1986	0.0	59	37.6	28.7	24
1987	0.3	4	21.0	17.7	16
1988	0.3	79	189.2	177.6	6
1989	7.3	963	700.4	580.2	17
1990	13.0	130	402.1	196.3	51
1991	3.0	234	351.3	53.4	85
1992	7.3	5	2.2	3.4	--
1993	3.3	2	19.8	8.1	59
1994	0.1	20	7.1	11.5	--
1995	0.0	17	81.9	39.1	52
1996	2.4	172	98.9	72.6	27
1997	6.9	282	179.0	101.5	43
1998	14.1	147	156.0	110.6	29
1999	36.5	428	449.2	218.7	51
2000	19.1	188	113.6	90.8	20
2001	10.7	139	59.7	9.6	84
2002	22.4	100	82.4	24.8	70
2003	11.9	550	51.2	13.0	75
2004	2.5	67	26.9	21.7	19
2005	8.8	231	60.1	54.7	9

Year class	Larval abundance(10^{12})	0-group swept-area numbers (10^9 ind.)	Acoustic estimate (10^9ind.)		Mortality survey (1–2)
	0 (Y)	0+(Y)	1(Y+1)	2(Y+2)	%
2006	17.1	819	221.7	231.4	--
2007	-	760	313.0	166.4	46
2008	-	1251	124.0	127.6	--
2009	-	865	248.2	181.1	27
2010	-	416	209.6	156.4	25
2011	-	767	145.9	216.2	-
2012	-	1141	324.5	106.6	67
2013	-	398	105.1	40.5	62
2014	-	268	39.5	8.1	79
2015	-	592	31.6	123.7	-
2016	-	980	86.4	59.6	31
2017	-	273	58.6	7.0	88
2018	-	592 (804)*	17.5	31.1	-
2019	-	2165	366.4	330.0	10
2020	-	753 (1265)*	220.9		
2021	-				
Average	9.0	451	176.8	105.2	

***In the brackets – the correction numbers, taking into account not surveyed area.**

Table 10.4 Barents Sea capelin. Stock size in numbers by age, total-stock biomass, biomass of the maturing component (MSB) at 1. October.

Year	Stock in numbers (10^9)						Biomass (10^3 tonnes)	
	Age 1	Age 2	Age 3	Age 4	Age 5	Total	Total	MSB
1973	528	375	40	17	0	961	5144	1350
1974	305	547	173	3	0	1029	5733	907
1975	190	348	296	86	0	921	7806	2916
1976	211	233	163	77	12	696	6417	3200
1977	360	175	99	40	7	681	4796	2676
1978	84	392	76	9	1	561	4247	1402
1979	12	333	114	5	0	464	4162	1227
1980	270	196	155	33	0	654	6715	3913
1981	403	195	48	14	0	660	3895	1551
1982	528	148	57	2	0	735	3779	1591
1983	515	200	38	0	0	754	4230	1329
1984	155	187	48	3	0	393	2964	1208
1985	39	48	21	1	0	109	860	285
1986	6	5	3	0	0	14	120	65
1987	38	2	0	0	0	39	101	17
1988	21	29	0	0	0	50	428	200
1989	189	18	3	0	0	209	864	175
1990	700	178	16	0	0	894	5831	2617
1991	402	580	33	1	0	1016	7287	2248
1992	351	196	129	1	0	678	5150	2228
1993	2	53	17	2	2	75	796	330
1994	20	3	4	0	0	28	200	94
1995	7	8	2	0	0	17	193	118
1996	82	12	2	0	0	96	503	248
1997	99	39	2	0	0	140	911	312
1998	179	73	11	1	0	263	2056	931
1999	156	101	27	1	0	285	2776	1718

Year	**Stock in numbers (10^9)**						**Biomass (10^3 tonnes)**	
	Age 1	Age 2	Age 3	Age 4	Age 5	Total	Total	MSB
2000	449	111	34	1	0	595	4273	2099
2001	114	219	31	1	0	364	3630	2019
2002	60	91	50	1	0	201	2210	1290
2003	82	10	11	1	0	104	533	280
2004	51	25	6	1	0	82	628	294
2005	27	13	2	0	0	42	324	174
2006	60	22	6	0	0	88	787	437
2007	222	55	4	0	0	280	1882	844
2008	313	231	25	2	0	571	4427	2468
2009	124	166	61	0	0	352	3756	2323
2010	248	128	61	1	0	438	3500	2051
2011	209	181	55	8	0	454	3707	2115
2012	146	156	88	2	0	392	3586	1997
2013	324	216	59	7	0	610	3956	1471
2014	105	107	39	2	0	253	1949	873
2015	40	40	13	1	0	94	842	375
2016	32	8	3	0	0	43	328	181
2017	86	124	17	0	0	227	2506	1723
2018	59	60	21	0	0	140	1597	1056
2019	17	9	7	1	0	35	411	302
2020	366	31	4	1	0	403	1884	533
2021	221	330	7	0	0	558	3998	1438

Table 10.5 Barents Sea CAPELIN. Summary stock and data for prognoses table. Recruitment and total biomass (TSB) are survey estimates back-calculated to 1 August (before the autumn fishing season) for 1985 and earlier; for 1986 and later it is the survey estimate. Maturing biomass (MSB) is the survey estimate of fish above length of maturity (14.0 cm). SSB is the median value of the modelled stochastic spawning-stock biomass (after the winter/spring fishery). * - indicates a very small spawning stock. "SSB by winter" is acoustic assessment in the winter-spring survey in next year. For most of the years, the survey area was covered partly. Estimates from spawning surveys going back to the 1980s are given in Gjøsæter and Prozorkevitch (WD05, AFWG 2021) and not included here.

Year	Estimated stock by autumn acoustic survey (10^3 t) 1 October		SSB, assessment model, April 1 year+1 (10^3 t)	Recruitment Age 1, survey assessment 1 October 10^9 sp.	Young herring biomass age 1+2 (10^3 tonnes) source: WGIBAR	Herring 0-group swept-area index (10^9 ind.p)	Capelin landing (10^3 t)
	TSB	MSB					
1972	6600	2727		152	2		1591
1973	5144	1350	33	529	2		1337
1974	5733	907	*	305	48		1148
1975	7806	2916	*	190	74		1441
1976	6417	3200	253	211	39		2587
1977	4796	2676	22	360	46		2986
1978	4247	1402	*	84	52		1916
1979	4162	1227	*	12	39		1782
1980	6715	3913	*	270	66	2	1648
1981	3895	1551	316	403	47	7	1986
1982	3779	1591	106	528	9	1	1760
1983	4230	1329	100	515	12	220	2357
1984	2964	1208	109	155	1467	33	1477
1985	860	285	*	39	2638	12	868
1986	120	65	*	6	191	0	123
1987	101	17	34	38	288	6	0
1988	428	200	*	21	76	71	0
1989	864	175	84	189	276	19	0
1990	5831	2617	92	700	431	19	0
1991	7287	2248	643	402	926	263	933
1992	5150	2228	302	351	1326	110	1123
1993	796	330	293	2	2426	233	586
1994	200	94	139	20	1882	187	0
1995	193	118	60	7	646	14	0

Year	Estimated stock by autumn acoustic survey (10^3 t) 1 October		SSB, assessment model, April 1 year+1 (10^3 t)	Recruitment Age 1, survey assessment 1 October 10^9 sp.	Young herring biomass age 1+2 (10^3 tonnes) source: WGIBAR	Herring 0-group swept-area index (10^9 ind.p)	Capelin landing (10^3 t)
	TSB	MSB					
1996	503	248	60	82	238	650	0
1997	909	312	85	99	534	609	1
1998	2056	932	94	179	556	675	3
1999	2775	1718	382	156	1613	50	105
2000	4273	2098	599	449	2102	572	410
2001	3630	2019	626	114	1229	17	578
2002	2210	1291	496	60	426	194	659
2003	533	280	427	82	1788	173	282
2004	628	294	94	51	3777	941	0
2005	324	174	122	27	2176	170	1
2006	787	437	72	60	2100	289	0
2007	2119	844	189	222	866	184	4
2008	4428	2468	330	313	946	276	12
2009	3765	2323	517	124	433	109	307
2010	3500	2051	504	248	593	166	323
2011	3707	2115	487	209	799	100	360
2012	3586	1997	504	146	433	177	296
2013	3956	1471	479	324	485	361	177
2014	1949	873	504	105	677	155	66
2015	842	375	82	40	986	95	115
2016	328	181	37	32	531	123	0
2017	2506	1723	462	124	911	232	0
2018	1597	1056	317	59	1544	97	195
2019	411	302	85	17	455	101	0
2020	1884	533	154	366	885	22	0
2021	3998	1438	420	221			0

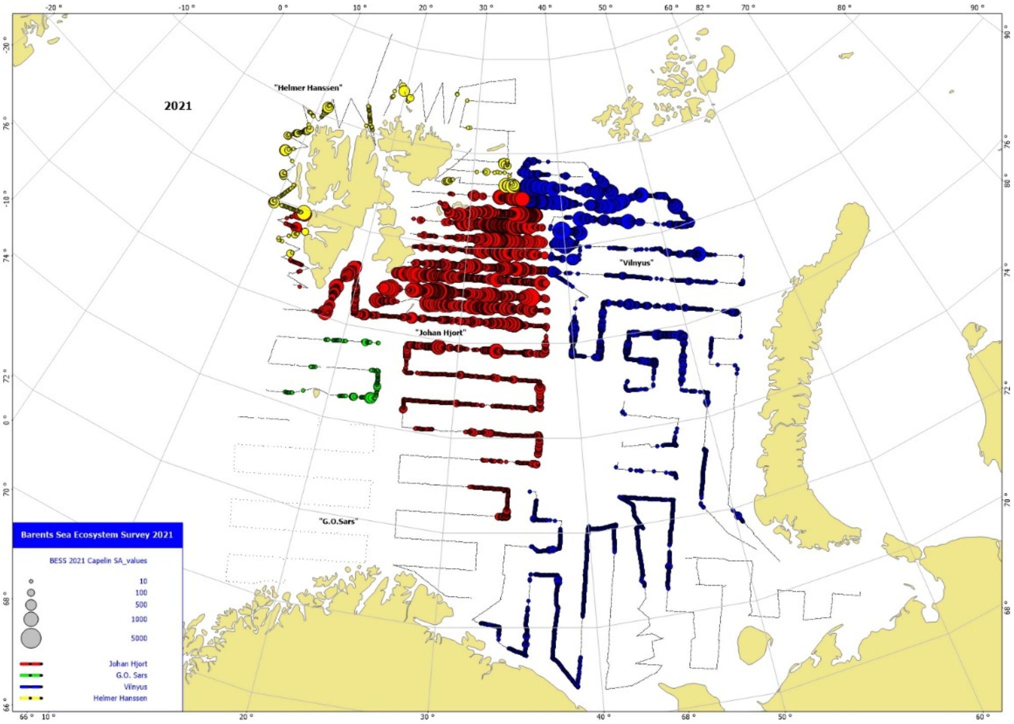


Figure 10.1. Geographical distribution of capelin in autumn 2021.

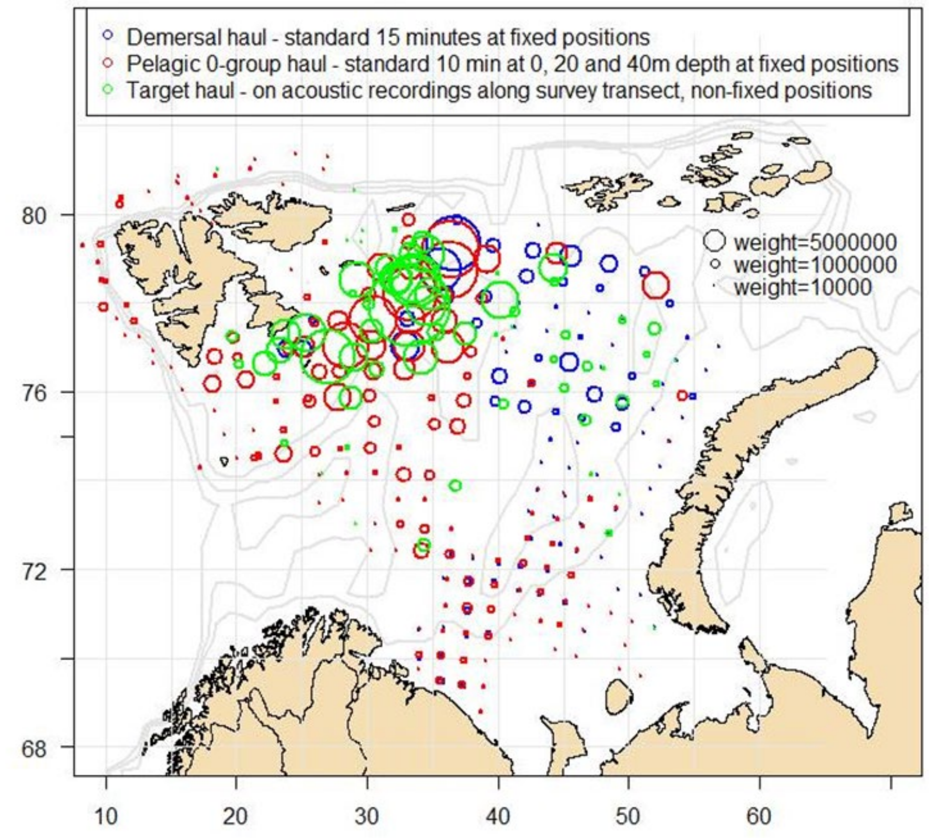


Figure 10.2. Position of trawl hauls and weighting of the corresponding capelin length distributions applied in the acoustic estimate. The weighting is proportional to NASC within a 10 nm radius.

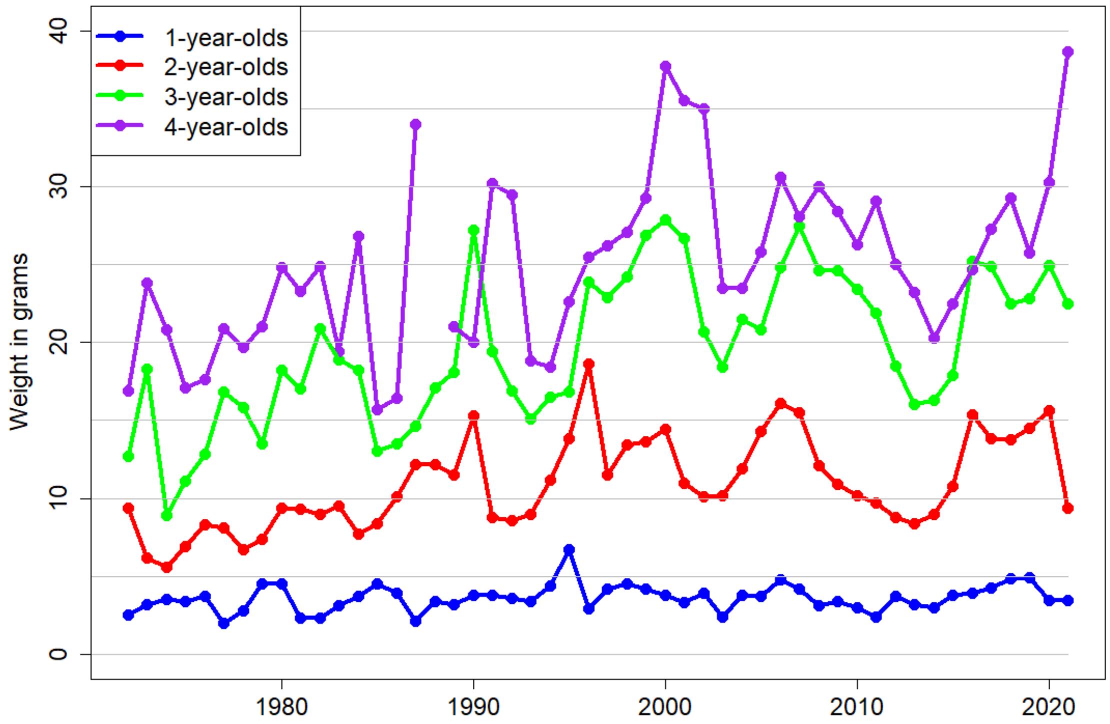


Figure 10.3 Weight-at-age (grammes) for capelin from the autumn survey.

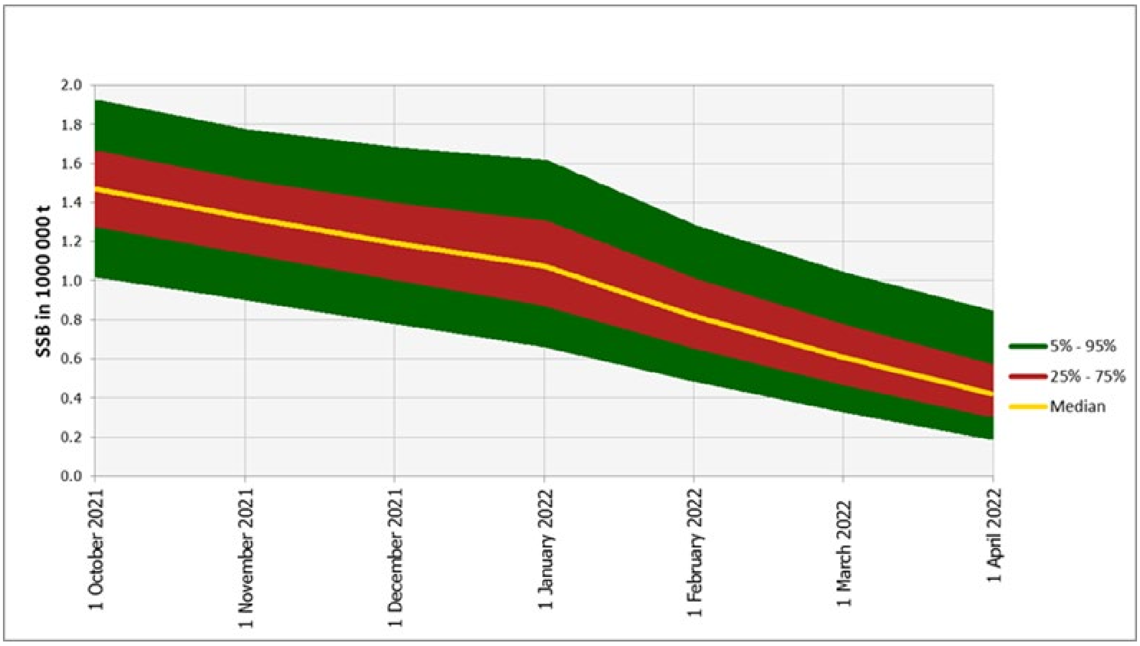


Figure 10.4. Probabilistic prognosis 1 October 2021–1 April 2022 for Barents Sea capelin maturing stock, with a catch of 70 000 tonnes (model CapTool, 50 000 simulations).

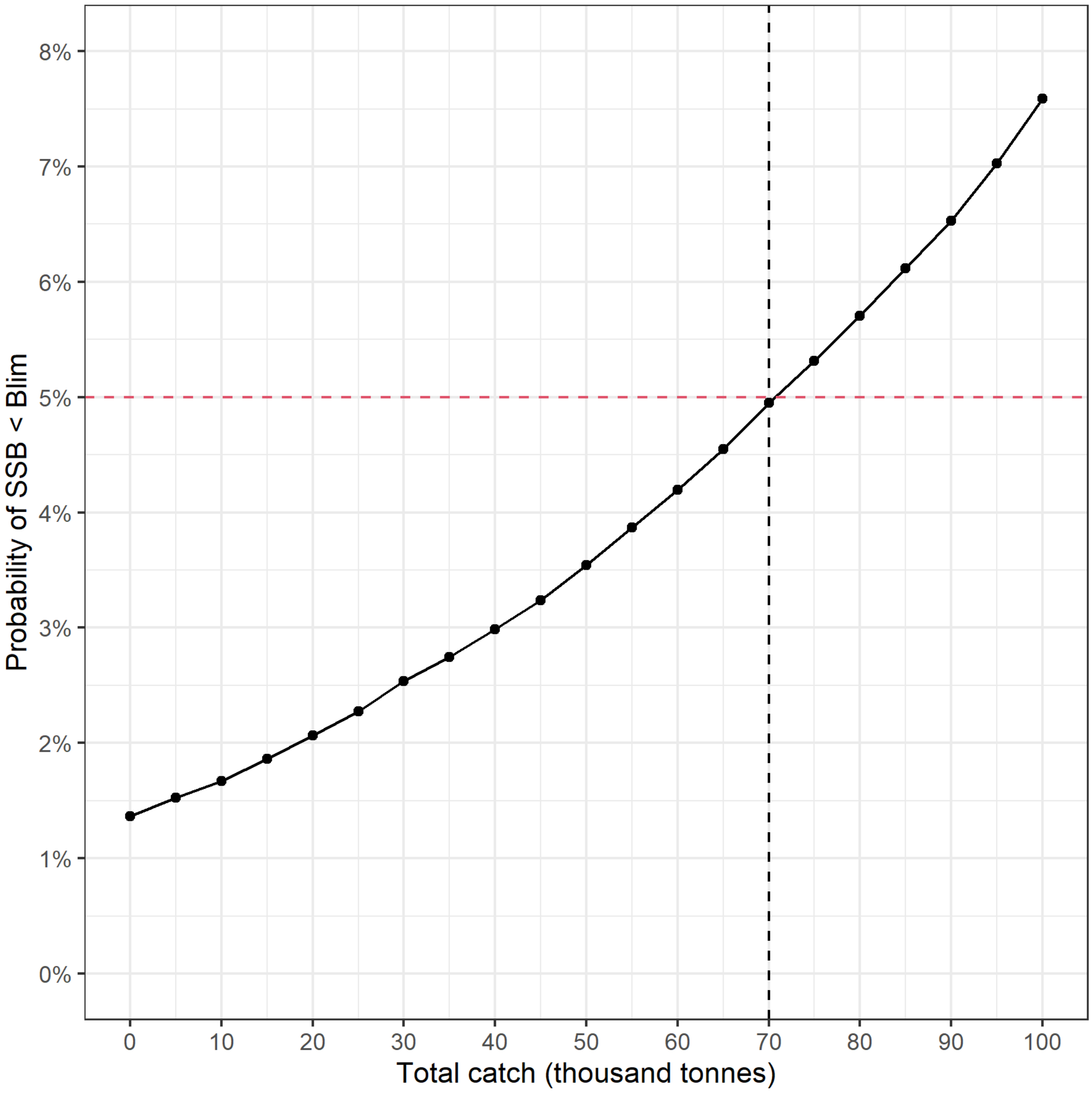
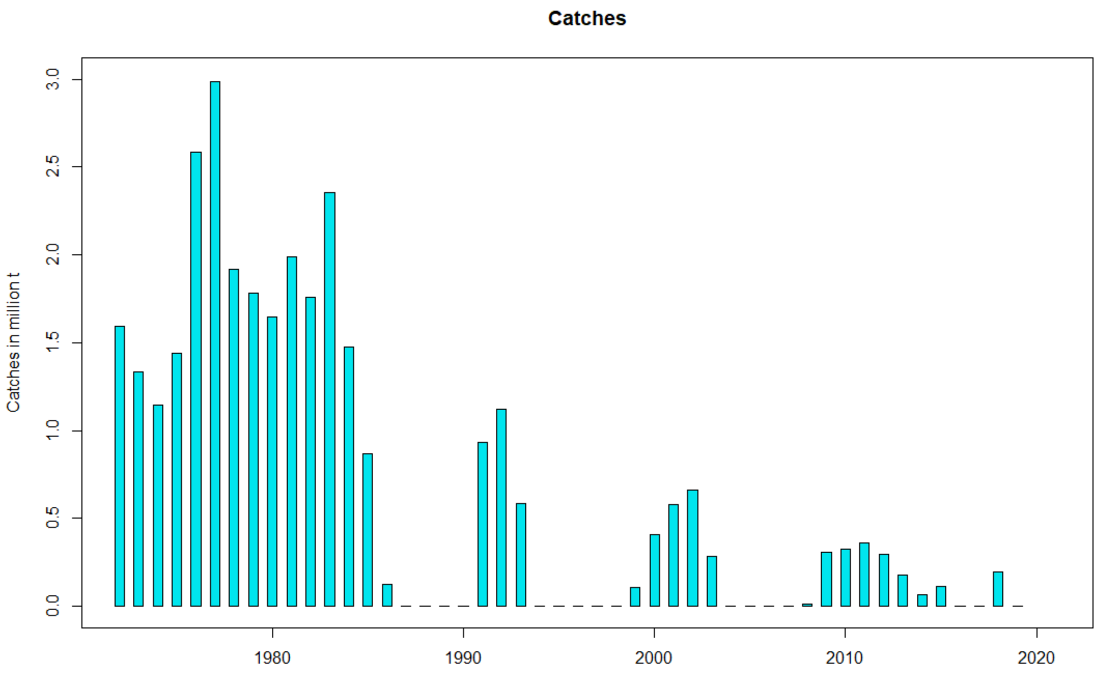
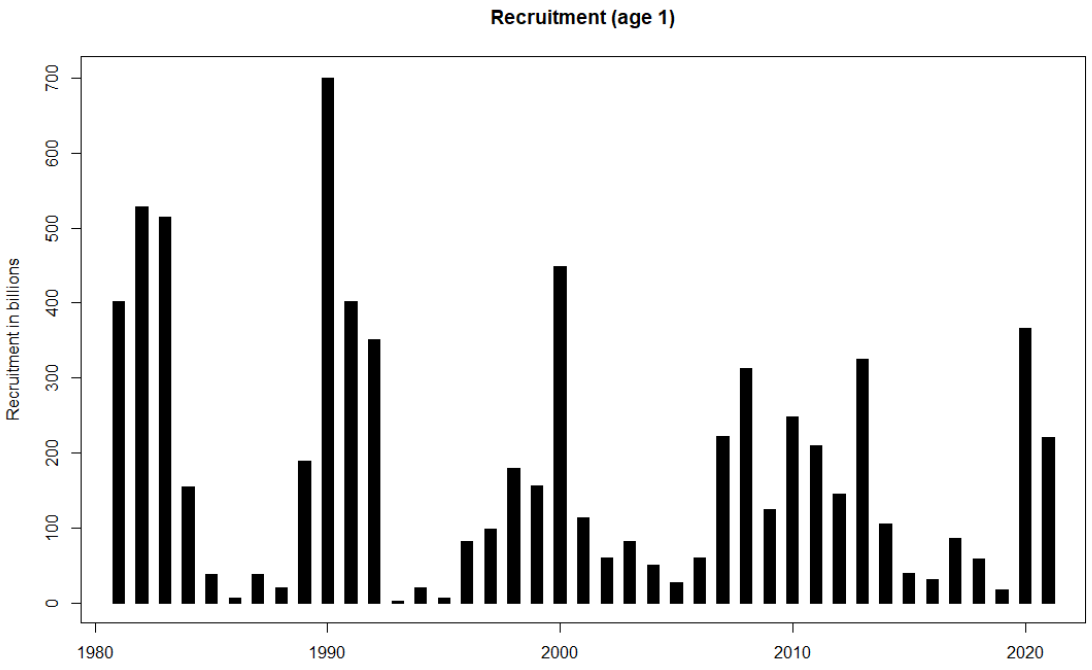


Figure 10.5. Probability of SSB < B_{lim} as a function of the catch.


Catches
Catches in million t
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1980
1990
2000
2010
2020


Recruitment (age 1)
Recruitment in billions
0
100
200
300
400
500
600
700
1980
1990
2000
2010
2020

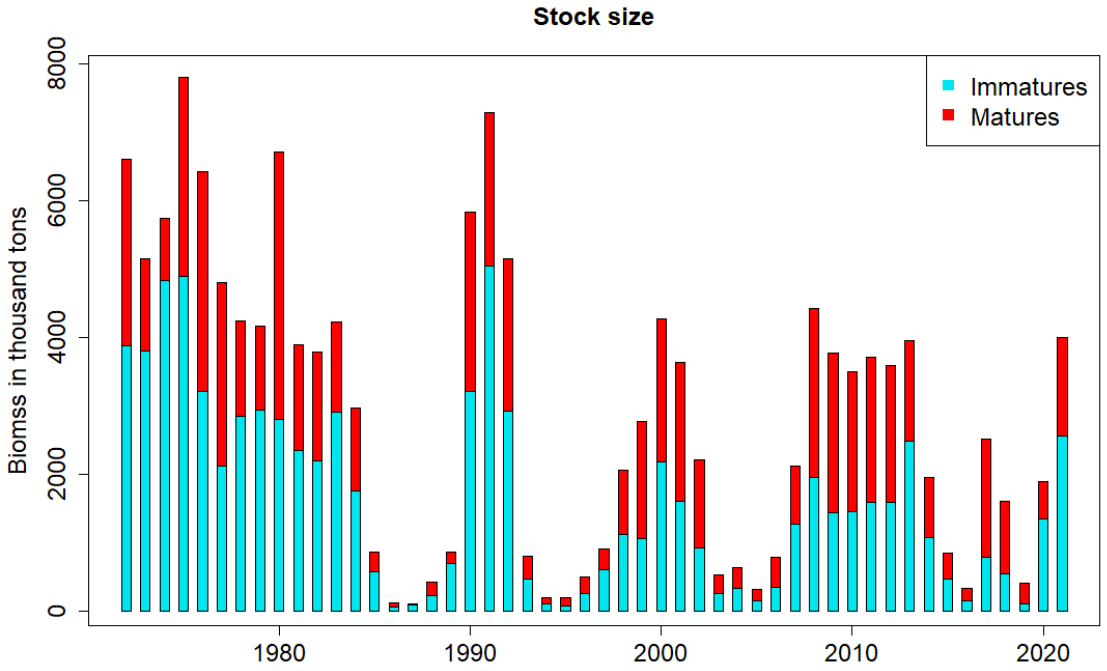


Figure 10.6. Capelin in subareas 1 and 2, excluding Division 2a west of 5°W (Barents Sea capelin). Landing and summary of stock assessment (mature and immature stock biomass in tonnes.

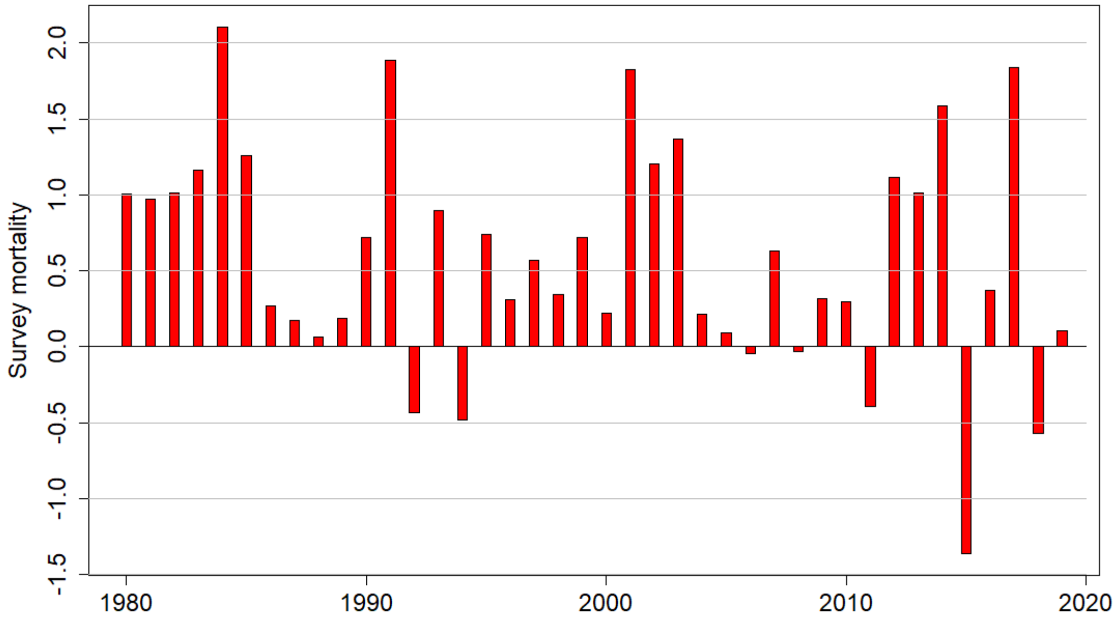


Figure 10.7. Capelin survey mortality per year class from age 1–2 (survey data).

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Annex 1: List of participants

Name	Institute	Country	E-mail
Jane Aanestad Godiksen	IMR	Norway	jane.godiksen@hi.no
Erik Berg	IMR	Norway	erik.berg@hi.no
Matthias Bernreuther	Thünen-Institut	Germany	matthias.bernreuther@thuenen.de
Bjarte Bogstad	IMR	Norway	bjarte.bogstad@hi.no
José Miguel Casas	IEO	Spain	mikel.casas@ieo.es
Thomas de Lange Wenneck	IMR	Norway	thomas.de.lange.wenneck@hi.no
Elena Eriksen	IMR	Norway	elena.eriksen@hi.no
Johanna Fall	IMR	Norway	johanna.fall@hi.no
Anatoly Filin	PINRO	Russia	filin@pinro.ru
Harald Gjøsæter	IMR	Norway	harald@hi.no
Elvar Hallfredsson	IMR	Norway	elvar.hallfredsson@hi.no
Hannes Höffle	IMR	Norway	hannes.hoffle@hi.no
Daniel Howell (chair)	IMR	Norway	daniel.howell@hi.no
Edda Johannesen	IMR	Norway	edda.johannesen@hi.no
Yuri Kovalev	PINRO	Russia	kovalev@pinro.ru
Kjell Nedreaas	IMR	Norway	kjell.nedreaas@hi.no
Holly Ann Perryman	IMR	Norway	holly.ann.perryman@hi.no
Dmitri Prozorkevich	PINRO	Russia	dvp@pinro.ru
Alexey Russkikh	PINRO	Russia	russkikh@pinro.ru
Silje Elizabeth Seim	IMR	Norway	silje.elisabeth.seim@hi.no
Arved Staby	IMR	Norway	arved.staby@hi.no
Ross Tallman	DFO	Canada	ross.tallman@dfo-mpo.gc.ca
Mikko Juhani Vihtakari	IMR	Norway	mikko.vihtakari@hi.no
Tone Vollen	IMR	Norway	tone.vollen@hi.no
Kristin Windsland	IMR	Norway	kristin.windsland@hi.no
Natalia Yaragina	PINRO	Russia	yaragina@pinro.ru

Annex 2: Resolutions

2020/2/FRSG02 The **Arctic Fisheries Working Group** (AFWG), chaired by Daniel Howell, Norway, will meet online 14–20 April 2021 to:

d) Address generic ToRs for Regional and Species Working Groups, for all stocks except the Barents Sea capelin, which will be addressed at a meeting in autumn;
e) For Barents Sea capelin oversee the process of providing intersessional assessment;
f) Conduct reviews as required of time any series computed using the STOX and ECA open source software for use in assessment in the Barents Sea.

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 2021 ICES data call.

AFWG will report by 7 May 2021 and 8 October 2021 for Barents Sea capelin for the attention of the Advisory Committee.

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	Presentation?	WD Title	WD Authors	Relevant stock(s)
1	Yes	*BESS2020 cod and haddock indices Barents Sea ecosystem survey 2020: cod and haddock indices*	Dmitry Prozorkevich, Edda Johannesen, and Geir Odd Johansen	Cod.27.1-2; Had.27.1-2
2	Yes	*Joint winter survey draft report (to be uploaded)*	Johanna Fall	Cod.27.1-2; Had.27.1-2
3		*AFWG PT report*	Ricardo Alpoim	Portuguese catches
4		*Cod effort and CPUE NOR TRAWL LOGBOOK 2011–2019 per 3 APR 2021* *Effort and catch-per-unit-effort (CPUE) for Norwegian trawlers fishing cod north of 67˚N in 2011–2020*	Håkon Otterå and Kjell Nedreaas	Cod.27.1-2; Cod.27.1-2coast
5		*Historical data on observations of capelin SSB in winter-spring surveys*	Harald Gjøsæter and Dmitry Prozorkevich	Capelin
6		*New abundance indices for Norwegian coastal cod north of 62 degrees north*	Harald Gjøsæter	
7	Yes	*Coastal cod South Catch per unit effort 130421*	Kjell Nedreaas	
8		*Greenland_Halibut_Fpa_calculations_AFWG*	Daniel Howell	
9		*Comparison of the 2019 and 2020 Ecosystem survey cod data*	N.A. Yaragina and Y.A. Kovalev	Cod.27.1-2
12		*Revision of Russian survey indices used for Greenland halibut stock assessment*	Russkikh A.A., Kovalev Yu. A., Tchetyrkin A.A.	Ghl.27.1-2
13	Yes	*Recruitment prediction for Barents Sea capelin*	Oleg Titov	Capelin
14	Yes	*Northeast Arctic Haddock: Weight and proportion mature at age from winter survey data 1994–2021*	Alfonso Perez-Rodriguez, Edda Johannesen, Alexey Russkikh	Had.27.1-2
15		*Haddock effort and CPUE NOR TRAWL LOGBOOK 2011–2019 preliminary per 18 APR 2021* *Effort and catch-per-unit-effort (CPUE) for Norwegian trawlers fishing cod north of 67˚N in 2011–2020*	Håkon Otterå and Kjell Nedreaas	Haddock.27.1-2
16	Yes	*Estimating the status of anglerfish (Lophius piscatorius) in the north of 62˚N management unit (ICES subareas 1 and 2) using life history ratios, length compositions, and CPUE data*	Kotaro Ono, Sofie Gundersen and Kjell Nedreaas	Anf.27.1-2

17	No	*Transferring the Norwegian slope index to SToX*	Kristin Windsland, Mikko Vihtakari and Elvar Hallfredsson	Ghl.27.1-2
18	Yes	*NEA cod stock assessment by means of TISVPA*	Dmitry Vasilyev	Cod.27.1-2
19	No	*Consumption of various prey species by cod in the Barents Sea in 1984–2020*	A.V. Dolgov	Almost all
20	Yes	*HybridModelDescription: A new soft in R for NEA cod recruitment prediction using the Hybrid model*	Tchetyrkin A.A.	Cod.27.1-2
21	Yes	*MethodCodTitov(20 APR 2021): Assessment of population recruitment abundance of Northeast Arctic cod considering the environment data*	Oleg Titov	Cod.27.1-2
22	No	*NEA haddock stock assessment by means of TISVPA*	D. Vasilyev	Had.27.1-2

WD_01 AFWG 2020

Barents Sea ecosystem survey 2020:cod and haddock indices

Dmitry Prozorkevich and Edda Johannesen

1. Overview over the survey

The spatial survey coverage in 2020 was good, and most of the Barents Sea was covered. However, the coverage was less synoptic than normal (Figure 1). This was due to a delay caused by the Covid19 pandemic. In total 418 valid bottom trawl hauls were taken in StoX and 438 in BIOFOX calculation, 64% had cod and 36% had haddock (Table1), a clear reduction from last year from 86% for cod and 51% for haddock.

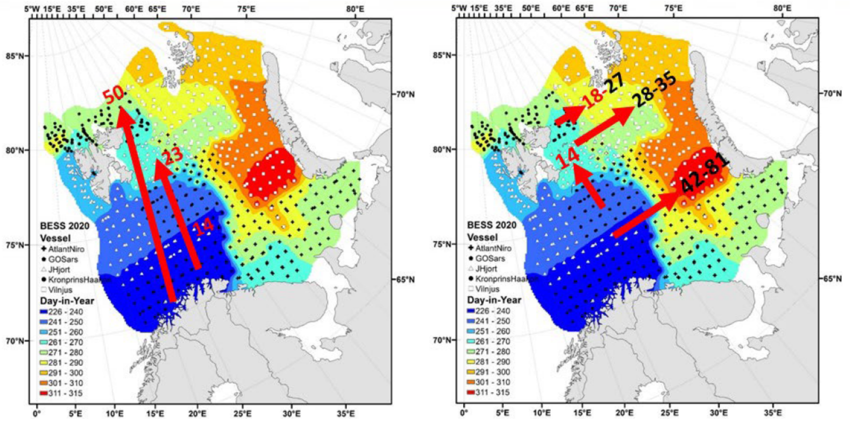

Figure 1. Stations taken at the ecosystem survey in 2020. The color shows the day number ranging from blue (August) to red (November). Except for the northernmost the difference in the number of days from the coverage in the south to coverage in the north in the western Barents Sea was normal (14-23 days), whereas the difference in coverage in the eastern and western Barents Sea was much longer - up to 81 days (z< 2.5 months). The figure is taken from a presentation by Elena Eriksen. the WGIBAR 2021 meeting.

2. Abundance estimates

BIOFOX estimates are used in the assessment – for the last 2 years estimates were also run with the StoX software (Johannesen et al 2019a) and a comparison was presented to AFWG as working documents (Johannesen et al 2019b, Prozorkevich et al 2020). This year the StoX software was updated to accommodate the new data format at IMR (BIOTOC 3.1), and the new StoX software was not ready in time. The whole time series will be recalculated using the new StoX version before the next AFWG meeting.

BIOFOX were run using data valid demersal stations (table 1). BIOFOX interpolates to neighbour strata (Figure 2). The strata are depth stratified WMO squares (Prozorkevich and Gjøsæter 2014). Table 2 gives the estimates for cod and Table 3 gives the estimates for haddock.

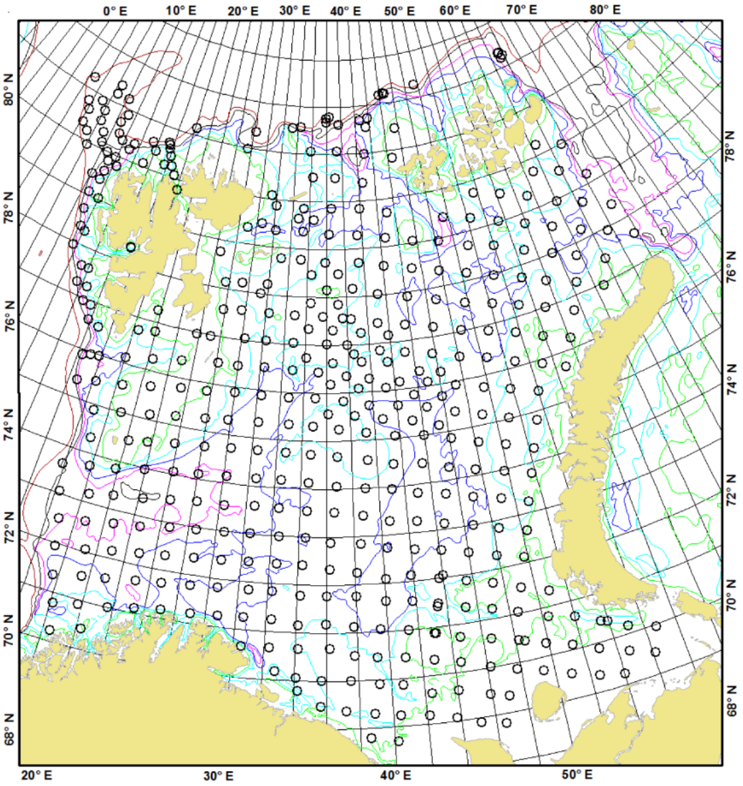

Figure 2. Strata and stations ecosystem survey 2020.

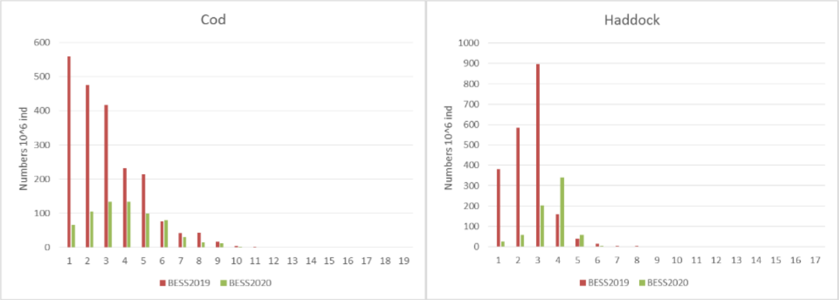

Figure 3. Comparison of the abundance cod and haddock by age class, calculated by BIOFOX based on the data of BESS2019 and BESS2020.

Fish abundance and biomass reflect the catch rates and the distribution within the survey area. Low catches and reduced distribution of cod and haddock in 2020 compared to 2019 have resulted in low abundance estimates. For cod for all ages (except age 6 year old), a decrease in numbers was observed. For haddock, there was also a decrease in numbers at all ages (especially for young fish 1-3 years old). Only numbers at age 4 was higher than in 2019, the 2016 year class (Figure 3). The total biomass (estimated by BIOFOX) for cod have decreased in 2020 with about 50% and for haddock – about 57 %.

6. References

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Prozorkevich D, Johannesen E and Johansen GO 2020. Barents Sea ecosystem survey 2019: cod and haddock indices. WD1 AFWG 2020.

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Tables

Table 1. Valid bottom trawl hauls by vessel.

	Date	Total stations	With cod	With haddock
GOSars	12.08-08.09	80	63	48
Kronprins Haakon	15.09-13.10	51	19	7
Johan Hjort	20.08-04.10	80	54	37
Vilnyus	25.09–15.11	134	60	2
AtlantNIRO	17.09–.23.10	103	93	49

Table 2. BIOFOX estimates of cod numbers in million, swept area estimates* not used in assessment

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+
2004	330.6	329.7	147.7	421.5	150.2	79.8	40.2	10.1	2.2	0.5	0.1	0.1	0.0	0.1	0.0	0.0
2005	440.7	146.6	216.6	55.8	100.9	28.0	15.6	5.7	1.2	0.5	0.1	0.0	0.1	0.0	0.0	0.0
2006	479.0	509.7	186.1	205.6	59.9	69.8	17.6	8.1	2.6	0.6	0.2	0.0	0.0	0.0	0.0	0.0
2007	333.3	505.4	586.2	159.2	79.1	24.6	26.9	6.0	2.2	0.9	0.1	0.2	0.0	0.0	0.0	0.0
2008	130.9	372.6	652.6	483.4	132.3	51.1	12.8	17.5	3.3	0.9	0.2	0.2	0.1	0.0	0.0	0.1
2009	569.7	93.5	202.3	280.6	289.6	101.7	31.9	12.7	7.3	2.6	0.8	0.3	0.2	0.0	0.0	0.1
2010	310.3	84.2	56.8	177.0	397.2	424.9	142.7	38.5	10.5	6.8	1.6	0.3	0.2	0.1	0.0	0.0
2011	509.8	160.0	123.6	101.5	240.2	300.4	178.4	32.3	7.7	1.8	1.3	0.6	0.3	0.0	0.0	0.0
2012	1454.3	255.9	229.1	146.4	70.0	150.8	165.2	84.5	12.7	4.4	1.6	1.4	0.4	0.1	0.1	0.0
2013	914.2	659.0	249.1	183.6	125.7	63.2	118.2	130.2	53.8	9.1	3.3	1.5	0.4	0.3	0.2	0.0
2014*	308.2	155.1	190.0	108.6	93.9	52.8	30.4	50.2	36.3	12.1	3.4	1.0	0.8	0.3	0.2	0.1
2015	725.3	154.0	174.4	225.2	141.3	72.6	48.6	26.2	35.3	26.6	7.9	1.7	0.1	0.8	0.0	0.1
2016	350.8	341.3	77.2	93.7	121.6	70.1	44.4	27.2	13.8	13.2	5.4	1.7	0.5	0.4	0.1	0.3
2017	757.5	260.6	375.0	141.5	104.9	120.9	62.6	28.0	11.2	6.4	4.4	4.5	1.8	0.6	0.3	0.0
2018*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	560.2	475.2	416.6	232.3	215.1	76.6	42.2	44.4	16.1	4.9	2.2	1.1	1.0	0.6	0.3	0.1
2020	66.5	104.7	133.7	134.3	98.6	79.6	31.6	15.7	11.4	2.9	1.1	0.2	0.4	0.3	0.1	0.1

Table 3. BIOFOX estimates Haddock numbers at age in millions, swept area estimates. * not used in assessment.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13+
2004	189.0	268.5	123.4	70.3	69.1	31.5	3.0	1.7	0.0	0.1	0.0	0.0	0.1
2005	603.8	114.2	324.6	89.5	30.4	32.2	15.0	0.5	0.7	0.2	0.1	0.1	0.1
2006	2270.2	929.1	107.5	124.6	41.6	19.0	17.5	7.3	0.8	0.5	0.1	0.1	0.0
2007	988.4	1818.9	1282.9	88.5	90.4	19.2	5.9	7.1	1.9	0.9	0.2	0.1	0.1
2008	322.0	1291.9	1154.9	406.0	43.1	35.5	4.9	2.5	2.3	0.3	0.0	0.0	0.0
2009	134.8	143.8	650.7	619.1	305.9	21.0	6.5	0.9	0.5	0.0	0.0	0.0	0.0
2010	274.4	65.1	184.0	865.3	666.4	147.7	15.8	2.7	0.0	0.1	0.1	0.3	0.0
2011	105.3	113.6	40.4	73.8	392.9	301.4	37.4	3.0	0.3	0.1	0.0	0.1	0.1
2012	591.1	41.5	92.5	20.3	67.6	214.1	152.0	12.7	0.3	0.2	0.0	0.9	0.6
2013	155.9	223.0	25.8	65.2	19.6	50.8	150.1	76.4	7.0	0.4	0.0	0.0	0.2
2014	264.8	75.1	261.6	40.8	70.2	25.8	60.5	85.8	18.0	1.4	0.2	0.0	0.0
2015	320.0	145.2	42.1	213.6	25.1	37.1	20.6	47.9	33.8	8.6	0.2	0.2	0.0
2016	793.8	144.9	209.3	34.4	184.1	48.0	56.8	40.4	65.8	47.5	11.8	0.8	0.0
2017	935.8	189.3	70.3	70.3	11.5	20.5	4.0	4.0	5.4	4.4	4.8	0.7	0.0
2018*	-	-	-	-	-	-	-	-	-	-	-		-
2019	379.4	585.3	897.0	160.7	38.1	15.1	5.3	5.0	1.9	2.1	2.1	2.9	2.4
2020	26.8	57.8	204.1	341.4	58.8	4.9	2.0	0.8	0.2	0.7	0.1	0.2	0.3

Working Document Submitted to AFWG 2021 WD# 04

Effort and catch-per-unit-effort (CPUE) for Norwegian trawlers fishing cod north of 67˚N in 2011-2020

by
Håkon Otterå and Kjell Nedreaas
Inst. of Marine Res., PB-1870, N-5817 Bergen, Norway

Catches from log-book data per year. Updated with 2020 data per 22 March 2021.

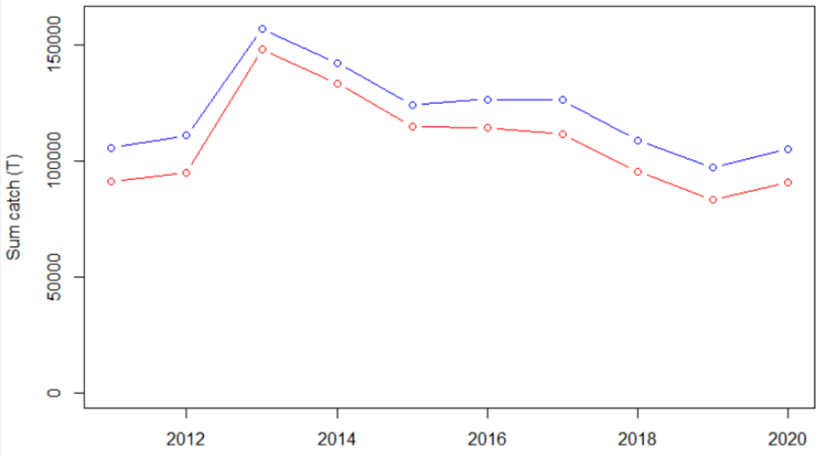

Figure 1. Sum of reported catches from log-book data per year. Blue line represents all catches of cod (bottom-trawl, latitude>67°N, longitude > 3 °E, duration > 10 min). Red line has in addition reported cod as the main species in the catch (species with largest catch biomass).

```
    YEAR  ROUND WEIGHT (KG)
1     2011 105395296
2     2012 110754474
3     2013 156654756
4     2014 142123067
5     2015 124029789
6     2016 126396982
7     2017 126117699
```

```
8      2018 108789596
9      2019  97046463
10     2020 104918809

Cod = main species:
    YEAR  ROUND WEIGHT (KG)
1      2011  91281171
2      2012  94626647
3      2013 148219649
4      2014 133322231
5      2015 114731246
6      2016 114136207
7      2017 111373566
8      2018  95219787
9      2019  83140681
10     2020  90796792
```

Only hauls where COD=MAIN SPECIES (i.e. >50% catch biomass per haul) used in the rest of the analysis

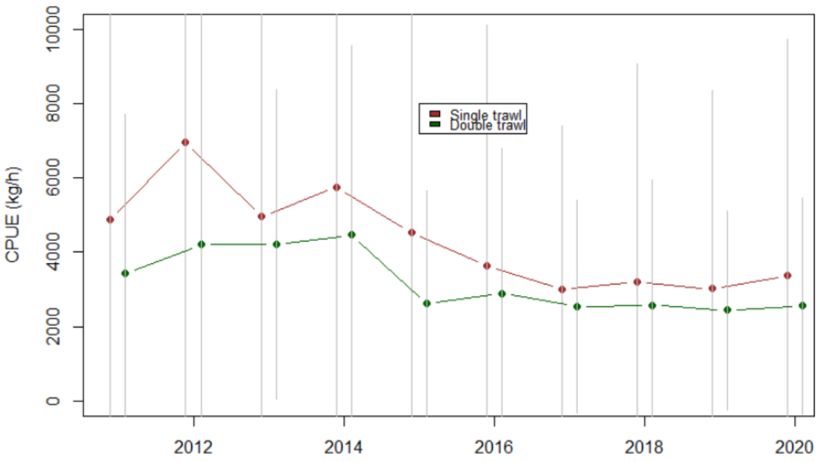

Figure 2. Mean +- SD …. cod main species …

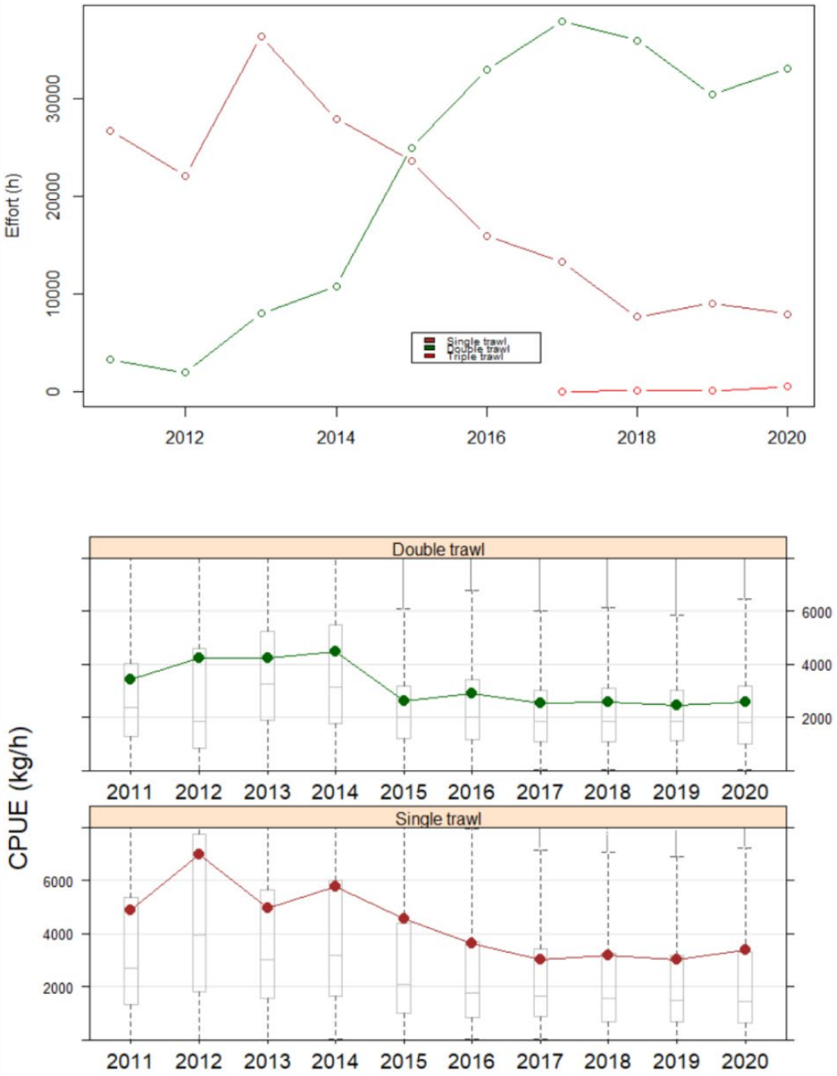

Figure 3. Same as Figure 2. Bow and whisker plot. Median and mean (dot/line) and 25, 75 percentile.

```
          Single/
           Double/
 Year     Triple    Mean        SD       Mean+SD       Mean-Sd

 2011         1 4870.7803   8128.2443 12999.0245 -3257.46402
 2011         2 3428.0164   4279.4375  7707.4538  -851.42107
 2012         1 6968.9932 10838.9410 17807.9342 -3869.94780
 2012         2 4214.1089   8029.2958 12243.4047 -3815.18684
 2013         1 4962.6529   7033.8117 11996.4646 -2071.15875
 2013         2 4212.8986   4172.7061  8385.6047    40.19251
 2014         1 5751.8269   9397.9938 15149.8207 -3646.16687
 2014         2 4467.4808   5093.8151  9561.2959  -626.33430
 2015         1 4542.0873   7714.9856 12257.0729 -3172.89833
 2015         2 2615.9867   3051.4215  5667.4082  -435.43482
 2016         1 3637.3626   6480.5277 10117.8903 -2843.16507
 2016         2 2898.1284   3880.6278  6778.7562  -982.49944
 2017         1 3008.9699   4395.5862  7404.5562 -1386.61631
 2017         2 2534.1492   2867.1436  5401.2928  -332.99444
 2017         3  604.1364    333.3606   937.4969   270.77581
 2018         1 3196.8478   5892.8316  9089.6794 -2695.98384
 2018         2 2571.8855   3393.0763  5964.9618  -821.19089
 2018         3 1615.1972    802.8294  2418.0266   812.36771
 2019         1 3020.3506   5329.6172  8349.9678 -2309.26664
 2019         2 2441.8108   2671.6024  5113.4132  -229.79164
 2019         3 2659.6010   1667.5787  4327.1797   992.02235
 2020         1 3376.5140   6364.3696  9740.8836 -2987.85553
 2020         2 2555.9000   2915.7467  5471.6467  -359.84667
 2020         3 2078.9013   1936.0269  4014.9282   142.87434
```

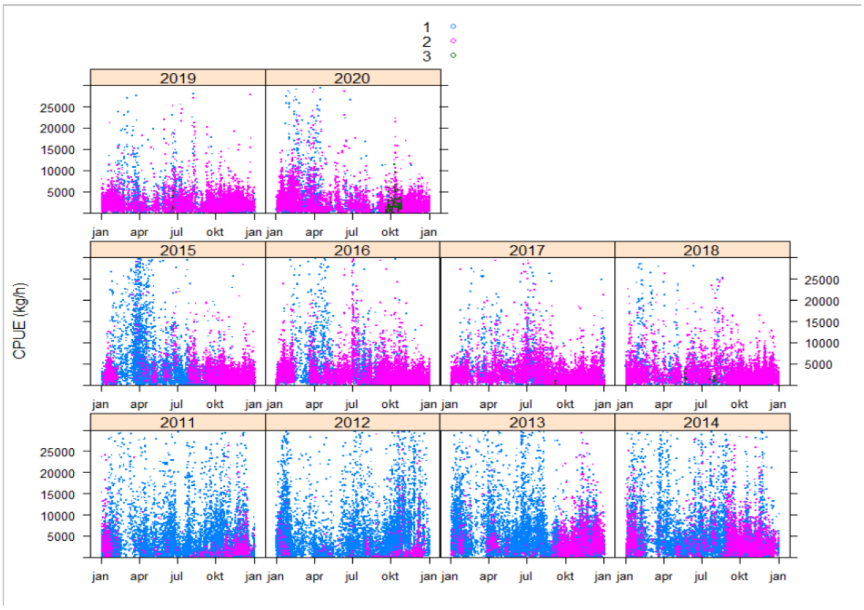

Figure 4. Individual observations. Cod main species.

Working document # 05 to AFWG 2021-meeting

Historical data on observations of capelin spawning stock in winter - spring surveys

Harald Gjøsæter, IMR, Norway

Dmitry Prozorkevich, PB of VNIRO, Russia

Doctors in bio-archeology

In Table 10.5 of the annual AFWG reports, a column was entered some years ago containing “SSB, by winter acoustic survey (January-March) year+1, (10^3 t)”. It has been difficult to verify some of the entries to this table before 2005. Here, we try to check the numbers for all years, by consulting the reports from the meetings in “Atlanto-scandian herring and capelin Working Group”, the “Northern Pelagic and Blue whiting fisheries Working Group”, the Arctic Fisheries Working Group, and the relevant working documents presented at the meetings. We have also checked with internal cruise reports from relevant surveys, to the extent that we have these documents in personal archives of Harald Gjøsæter.

Below, table reviewed and commented on the differences between the table and what we have found.

Table 10.5 Barents Sea CAPELIN. Summary stock and data for prognoses table (in AFWG report before 2021)

Year	Estimated stock by autumn acoustic survey (10^3 t) 1 October		SSB, assessment model, April 1 year+1 (10^3 t)	SSB, by winter acoustic survey (January-March) year+1, (10^3 t)	Recruitment Age 1, survey assessment 1 October 10^9 sp.	Young herring biomass age 1+2 (10^3 tons) source: WGIBAR	Herring 0-group swept area index (10^9 ind.p)	Capelin landing (10^3 t)
	TSB	MSB						
1972	6600	2727		N/A	152	2		1591
1973	5144	1350	33	N/A	529	2		1337
1974	5733	907	*	N/A	305	48		1148
1975	7806	2916	*	N/A	190	74		1441
1976	6417	3200	253	N/A	211	39		2587
1977	4796	2676	22	N/A	360	46		2986
1978	4247	1402	*	N/A	84	52		1916
1979	4162	1227	*	N/A	12	39		1782
1980	6715	3913	*	N/A	270	66	2	1648
1981	3895	1551	316	N/A	403	47	7	1986
1982	3779	1591	106	N/A	528	9	1	1760
1983	4230	1329	100	N/A	515	12	220	2357
1984	2964	1208	109	N/A	155	1467	33	1477
1985	860	285	*	55-60	39	2638	12	868
1986	120	65	*	*	6	191	0	123
1987	101	17	34	*	38	288	6	0
1988	428	200	*	98. 5 – 377	21	76	71	0
1989	864	175	84	43. 9 – 106	189	276	19	0
1990	5831	2617	92	400 – 1 769	700	431	19	0
1991	7287	2248	643	1 100 – 1 735	402	926	263	933
1992	5150	2228	302	1498	351	1326	110	1123
1993	796	330	293	45-187	2	2426	233	586
1994	200	94	139	30	20	1882	187	0
1995	193	118	60	N/A	7	646	14	0

1996	503	248	60	416	82	238	650	0
1997	909	312	85	N/A	99	534	609	1
1998	2056	932	94	414	179	556	675	3
1999	2775	1718	382	694	156	1613	50	105
2000	4273	2098	599	N/A	449	2102	572	410
2001	3630	2019	626	1417	114	1229	17	578
2002	2210	1291	496	N/A	60	426	194	659
2003	533	280	427	104.9	82	1788	173	282
2004	628	294	94	181 – 203	51	3777	941	0
2005	324	174	122	493	27	2176	170	1
2006	787	437	72	500-700	60	2100	289	0
2007	2119	844	189	360	222	866	184	4
2008	4428	2468	330	80-100	313	946	276	12
2009	3765	2323	517	452	124	433	109	307
2010	3500	2051	504	160	248	593	166	323
2011	3707	2115	487	N/A	209	799	100	360
2012	3586	1997	504	N/A	146	433	177	296
2013	3956	1471	479	N/A	324	485	361	177
2014	1949	873	504	N/A	105	677	155	66
2015	842	375	82	N/A	40	986	95	115
2016	328	181	37	N/A	32	531	123	0
2017	2506	1723	462	N/A	124	911	232	0
2018	1597	1056	317	295	59	1544	97	195
2019	411	302	85	62	17	455	101	0
2020	1884	533	154	86	366	885	22	0

Spring 1986 (entry for 1985 in the table)

This is the first year winter surveys are mentioned in the working group report. In table there is presently no entry for this year.

There are two (three) estimates of capelin from winter/spring 1986:

- A Norwegian capelin winter survey in January, with the vessels "G.O. Sars", and "Michael Sars" (Hamre & Gjøsæter 1986). They had daily contact with the Russian vessel "Vilnyus", operating in the Russian EEZ, but there is no quantitative information from the Russian survey in the cruise report. The two Norwegian vessels estimated 55 300 t of maturing capelin.
- On a Norwegian gear technology survey 2 days were set aside for measuring the amount of capelin that reached the coast on Eastern Finnmark and in the Varangerfjord on 16-18 April (Godø & Ona 1986). This survey estimated 60 000 t of mature/spawning capelin.
- The two Russian vessels "Artemida" and "Poisk" surveyed the coastal waters on the Russian side of the border (Ushakov 1986). There is no quantitative estimate of the spawning approaches, but it is said that three waves of spawners reached the coast on March 5, March 26, and April 6, at the Rybachy Peninsula. It is stated that "the acoustic surveys confirmed the results of the prior joint Soviet-Norwegian investigations concerning the low level of the spawning stock of capelin".

Conclusion: The range of estimates 55-60 000 t could be acceptable.

Spring 1987 (entry for 1986 in the table)

In a working document to the Atlanto-Scandian WG, Are Dommasnes reports from three Norwegian surveys in the Barents Sea and at the coast in January-March. No quantitative estimates are given, but it is said that practically no capelin were detected acoustically, while some small catches were taken in bottom trawl. There is no mentioning of any Russian surveys this year.

Conclusion: There is no confirmed information about SSB assessment.

Spring 1988 (entry for 1987 in the table)

A Norwegian survey was conducted from 5-17 April to assess spawning capelin (Gjøsæter 1988). Practically no capelin was seen acoustically. Catches of mature capelin in bottom trawl in the Varangerfjord indicated that spawning would occur there. There is no mentioning of any Russian investigations in the report.

Conclusion: There is no confirmed information about SSB assessment.

Spring 1989 (entry for 1988 in the table)

On a survey with "G.O.Sars" from 9-26 January (Hamre 1989) 334 000 t of capelin was estimated, of which 253 800 t was maturing.

On a survey with "Eldjarn" from 1-22 April (Gjøsæter 1989) along the coast, 98 500 t of maturing capelin was estimated.

On a survey with "Captain Shaitanov" from 22 February to 10 March (Ushakov, 1989) no mass capelin approaches to the coast was observed, only in some places, local spots of average and high densities were found. An estimate of 335 000 t of capelin > 14 cm was estimated. It was noted that also some capelin with lengths 12-14 cm were seemingly maturing and on their way to the spawning grounds. Including these yielded an estimate of 377 000 t.

Conclusion: The assessment of 378 000 t from the Russian survey, and includes fish > 12 cm. Since there are also other estimates available; the entry could, for instance, can be from 98 500 to 377 000 t, to reflect the range of estimates.

Spring 1990 (entry for 1989 in the table)

On a survey with "G.O. Sars" from 12-31 January (Hamre, 1990) 43 900 t of maturing capelin was found.

On a survey with "Michael Sars" from 13 March to 2 April along the coast from Vesterålen to the Russian border (Gjøsæter 1990), 106 000 t of capelin was estimated. It is noted that in some areas the spawning had already started, so the estimate is a minimum estimate.

On a survey with "Vilnyus" from 17 February to 14 March (Ushakov, 1990) 94 200 t of mature capelin was estimated.

Conclusion: SSB could be 43 900 – 106 000 t to reflect the range of estimates.

Spring 1991 (entry for 1990 in the table)

On a survey with "G.O. Sars" from 5 January to 3 February (Hamre 1991) 867 600 t of maturing capelin was estimated.

A survey with "G.O. Sars" along the Norwegian coast of Troms and Finnmark from 4 March to 23 March (Gjøsæter, 1991) gave an estimate of the spawning population of capelin of 400 000 t.

Two surveys were carried out with “Professor Marti” from 4-23 January and from 28 January to 20 February (Ushakov, 1991). Altogether, 1.8 million t of mature capelin was detected.

Conclusion: SSB could be 400 000 – 1 769 000 t to reflect the range of estimates.

Spring 1992 (entry for 1991 in the table)

On a Norwegian survey from 15 to 21 January 1992 the spawning population was estimated at 1.1 million tonnes (1 100 400 t).

A Russian survey with “PINRO” from 26 December 1991 – 24 February 1992 (Ushakov, 1992) found 1 734 900 t of maturing capelin.

Conclusion: SSB could be 1 100 400 – 1 735 000 t to reflect the range of estimates.

Spring 1993 (entry for 1992 in the table)

A Russian survey with “Vilnyus” was carried out over two periods; 23 January to 14 March and 20 March to 6 April 1993 (Ushakov 1993) gave a spawning stock estimate of 1 498 330 t.

Conclusion: SSB 1498 is the Russian estimate. No Norwegian estimates are available.

Spring 1994 (entry for 1993 in the table)

In the period 20 January to 6 March 1994, the vessels “G.O. Sars” and “Johan Hjort” detected capelin on a survey targeting bottom fishes (Gjøsæter 1994). Only scattered registrations of capelin were found. A total estimate of about 120 000 t was obtained, and about 45 000 t was maturing fish. A survey with R/V “PINRO” between 01/01 and 20/03 1994 yielded an estimate of 187 000 t. The Survey report is available only in Russian.

Conclusion: SSB could be in the range 45 000 – 187 000 t.

Spring 1995 (entry for 1994 in the table)

I have not found any Norwegian stock size estimates from spring 1995.

A survey with “Professor Marti” from 8 February to 24 March 1995 gave an estimate of the spawning stock of about 30 000 t (Ushakov, 1995).

Conclusion: The entry 30 000 t is the Russian estimate, the only available estimate for that year.

Spring 1996 (entry for 1995 in the table)

In the report from NPBWWG in 1996 it is stated (ch 4.3.2): “During various Norwegian and Russian demersal fish surveys in January to March 1996, covering most of the ice free part of the Barents Sea, the distribution of capelin was mapped by trawl and acoustics. No abundance estimates were made, mainly due to the very dispersed nature of the capelin distribution and inadequate sampling of capelin.”

Conclusion: There is no confirmed information about SSB assessment.

Spring 1997 (entry for 1996 in the table)

No stock size estimations are mentioned in the report from NPBWWG from that year, or in the working documents from Norwegian and Russian investigations from winter-spring 1997. However, a survey with

R/V “Obva” yielded an estimate of 416 000 t. The Survey report is available in the PB VNIRO only in Russian.

Conclusion: The SSB 416 000 t by Russian survey.

Spring 1998 (entry for 1997 in the table)

No spring stock size estimate was made by Norwegian (Gjøsæter 1998) or Russian (Ushakov and Prozorkevich 1998) scientists.

Conclusion: There is no confirmed information about SSB assessment.

Spring 1999 (entry for 1998 in the table)

No spring stock size estimate was mentioned in the working documents to WGNPBW by Norwegian (Gjøsæter 1999) or Russian (Ushakov and Prozorkevich 1999) scientists. However, a survey with the R/V “Fridtjof Nansen” (Prozorkevich pers. Comm. 3) 10/02-17/03 1999 yielded 414 000 t.

Conclusion: The SSB 414 000 t from the Russian survey.

Spring 2000 (entry for 1999 in the table)

No Norwegian stock size estimate of capelin in spring 2000 was attempted at (Gjøsæter, 2000). A Russian investigation estimated the spawning stock to be 694 000 t (Ushakov and Prozorkevich 2000).

Conclusion: The entry 694 000 t is the Russian estimate, the only available estimate for that year.

Spring 2001 (entry for 2000 in the table)

No spring stock size estimate was made by Norwegian (Gjøsæter 2001) or Russian (Ushakov and Prozorkevich 2001) scientists.

Spring 2002 (entry for 2001 in the table)

No Norwegian stock size estimate of capelin in spring 2002 was attempted at (Gjøsæter 2002). A Russian investigation estimated the spawning stock to be 1 400 000 t (Ushakov and Prozorkevich 2002).

Conclusion: The entry 1 417 000 t is the Russian estimate, the only available estimate for that year.

Spring 2003 (entry for 2002 in the table)

According to the report from NPBWWG in 2003, no spring stock size estimate was made by Norwegian or Russian scientists.

Conclusion: There is no confirmed information about SSB assessment.

Spring 2004 (entry for 2003 in the table)

A Russian survey from 20 February to 8 March gave an estimate of the spawning stock of 104 950 t (ICES 2004). No Norwegian estimate exists.

Spring 2005 (entry for 2004 in the table)

In the AFWG report (ICES 2005) it is stated that " A Norwegian survey along the coast of Northern Norway from 20 February to 17 March confirmed the results from the 2004 autumn investigations, in that between 181 000 and 203 000 tonnes of prespawning capelin were detected near the end of the survey period. This is within the 90% confidence interval (75 - 215 000 tonnes) of the abundance of maturing capelin at time of this survey estimated in the 2004 autumn assessment.

Spring 2006 (entry for 2005 in the table)

In the AFWG report (ICES 2006) it is stated: "During the Norwegian bottom fish survey during February-March 2006 maturing capelin were detected in the southern Barents Sea and along the Norwegian coast from about 15º-30º E. An acoustic estimation of the prespawning capelin was made, indicating that in the order of 0.4 million tonnes of capelin were going to spawn during winter 2006. This amount is considerably more than the prognosis given during autumn 2005 based on the autumn acoustic survey."

Conclusion: The entry 493 000 t is probably the Norwegian estimate indicated as "in the order of 0.4 million t" in the WG report.

Spring 2007 (entry for 2006 in the table)

The AFWG report has (chapter 9.3.3): "A research quota allowed for investigations using fishing vessels during the prespawning period 2007. Preliminary results indicate that in the order of 0.5-0.7 million tonnes of capelin were going to spawn during winter 2007. This amount is higher than the prognosis given during autumn 2006 based on the autumn acoustic survey." Then follows a list of sources of errors and uncertainties.

Conclusion: The SSB range 500 000 – 700 000 t may be acceptable.

Spring 2008 (entry for 2007 in the table)

During the period 25 January to 30 February, a joint Russian-Norwegian capelin investigation was carried out. Data from 10 vessels were collected and analysed (ICES 2008). Based on joint Norwegian and Russian data, an acoustic estimation of prespawning capelin yielded about 0.36 million tonnes of capelin, somewhat lower than the median of the prognosis from the autumn 2007 assessment at mid-February.

Conclusion: It can be verified SSB is 360 000 t.

Spring 2009 (entry for 2008 in the table)

Russian spring investigations were carried out with research vessels and fishing vessels, and an estimate of the prespawning stock 26 February to 15 March amounted to 80 030 t (ICES 2009).

A Norwegian survey was carried out with two hired fishing vessels 20 January to 14 February, and an estimate of the spawning stock of 100 000 t was obtained (ICES 2009).

Conclusion: The number 80 000 t from the Russian survey and 100 000 t from Norwegian survey so SSB could be 80 030 – 100 000 t.

Spring 2010 (entry for 2009 in the table)

A Russian stock size estimate is not given in the AFWG report, but in a WD (Ushakov and Prozorkevich 2010) a spawning stock size estimate of 451 920 t is given.

No special capelin investigation was conducted by Norway in winter-spring 2010 (ICES 2010). The three-year program to investigate the possibilities for implementing stock size estimates obtained during winter in the management of capelin, was ended in 2009 (Eriksen et al. 2009). The conclusion was that it is not advisable to base the quotas on stock size estimates from the winter period, since such estimates are much more uncertain than those obtained during autumn.

Conclusion: The number 452 000 t from the Russian survey.

Spring 2011 (entry for 2010 in the table)

Russian investigations were carried out on board the fishing vessel “Novaya Zemlya” from 15-27 January, yielding an estimate of the spawning stock of 160 000 t (ICES 2011). A very small area was observed.

No special capelin investigation was conducted by Norway in winter-spring 2011. Capelin observations were made during the winter groundfish survey, but no attempt was made to quantify the amount of maturing capelin approaching the coast to spawn (ICES 2011).

Conclusion: The results from the Russian survey (160 000 t) could be only low level of SSB.

Spring 2012 (entry for 2011 in the table)

Russian capelin spring investigations were performed on board Norwegian purseseiner “M/S Birkeland” in the period from 04 to 28 March 2012. The area of distribution of capelin was only partly covered during the survey, and the main aim was to study purse-seining of capelin, bycatches of cod, and migration of capelin schools. Estimation of the spawning stock biomass was not carried out (ICES 2012).

No special capelin investigation was conducted by Norway in winter-spring 2012. Capelin observations were made during the winter groundfish survey, but no attempt was made to quantify the amount of maturing capelin approaching the coast to spawn (ICES 2012).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2013 (entry for 2012 in the table)

No information on Russian capelin winter-spring investigations in 2013 was presented to the group. No special capelin investigation was conducted by Norway in winter-spring 2013. Capelin observations were made during the Joint winter demersal fish survey, but no attempt was made to quantify the amount of maturing capelin approaching the coast to spawn (ICES 2013).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2014 (entry for 2013 in the table)

No information on Russian capelin winter-spring investigations in 2014 was presented to the AFWG. No special capelin investigation was conducted by Norway in winter-spring 2014. Capelin observations were made during the Joint winter demersal fish survey, but no attempt was made to quantify the amount of maturing capelin approaching the coast to spawn (ICES 2014).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2015 (entry for 2014 in the table)

No special capelin investigations were conducted by Norway or Russia in winter-spring 2015 (ICES 2015).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2016 (entry for 2015 in the table)

There is no mentioning of any winter-spring investigations in 2016 in the AFWG report (ICES 2016).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2017 (entry for 2016 in the table)

There is no mentioning of any winter-spring investigations in 2017 in the AFWG report (ICES 2017).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2018 (entry for 2017 in the table)

There is no mentioning of any winter-spring investigations in 2018 in the AFWG report (ICES 2018).

Conclusion: There is no confirmed information about SSB assessment.

Spring 2019 (entry for 2018 in the table)

On 3–17 March 2019, IMR tested out acoustic monitoring and stock estimation of spawning capelin (ICES 2019, Peña et al., 2019). The acoustic estimate amounted to 294 655 t. There is no Russian estimate from the winter-spring period (ICES 2019).

Conclusion: The SSB 295 000 t is Norway assessment.

Spring 2020 (entry for 2019 in the table)

From 26 February to 11 March 2020, IMR carried out a trawl-acoustic monitoring and stock estimation of spawning capelin (ICES 2020, Skaret et al. 2020) using two hired fishing vessels. The estimate obtained was 62 000 t.

No Russian investigations in winter-spring is mentioned in the AFWG report.

Conclusion: The SSB 62 000 t is Norway assessment.

Final comments

Above we have revised the traditional table 10.5 in the section “BS Capelin” in AFWG reports. It indicated much changes should be made, by including ranges where more than one estimate exist, and deleting entries unless their basis can be verified by other sources. We have revised available data and fixed this table.

However, the whole column is problematic. Many of the estimates stem from surveys not targeting capelin, and even those that stem from dedicated capelin surveys are probably highly uncertain, because of partial coverage of the area, the timing of the surveys with regards to the spawning, uncertainties about the correct target strength to use for instance when surface schooling occurs, etc. These and other caveats are mentioned in newer WG reports when such estimates are presented. Because of the obvious poor quality of the estimates, the Norwegian capelin surveys that traditionally were carried out in January and in March-April were discontinued in the mid 1990. After that, Norwegian dedicated surveys on prespawning capelin have been tried sporadically, after pressure from, and in cooperation with, the Norwegian fishing fleet. In some years, Russian surveys aimed at assess SSB, but were not always successful. In some years, the area was not covered well.

The results of SSB assessment in winter-spring period may serve the purpose of showing that it has so far not been possible to obtain reliable estimates of prespawning capelin. The estimates obtained in the recent period, where a much better survey design has been implemented, may prove to be more reliable, and if the currently used TS can be approved, or altered, after new experiments, surveys like this may be useful in the future.

To delete this information from main Table in the Capelin report seems a good option. The corrected column may be keep in this separate WD.

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WD # 06 to AFWG meeting April 2021

New abundance index series for Norwegian Coastal Cod north of 62°N

Asgeir Aglen, Johanna Fall, Harald Gjøsæter, Arved Staby

Institute of Marine Research, P.O. Box 1970 Nordnes, 5817 Bergen, Norway

Note: this WD differs from that presented to the WKBARFAR Benchmark workshop 2021, in that the tables have been corrected and the figures updated accordingly after some minor errors were detected in the tables after the workshop was ended.

Contents

1 Introduction

New abundance index series for Norwegian coastal cod north of 62° were produced using the software StoX (Johnsen et al. 2019). Indices were calculated based on trawl swept area methods and by acoustic methods, both came from the Norwegian annual coastal survey in autumn NOcoast-Aco-4Q.

Time series of indices for the period 1995 to 2020 in numbers and biomass (2003-2020 for the swept-area index), their coefficient of variation, length- and weight-at-age- are tabulated for the three subareas and the total area in Appendix A (acoustic indices) and Appendix B (swept-area trawl indices).

2 Biology and stock structure, and management of coastal cod

Coastal cod occur in fjords and coastal areas along the entire coast of Norway. The management area is split at 62°N. Genetic studies indicate a genetic cline along the coast from eastern Finnmark to inner Skagerrak (Dahle et al., 2018). Coastal cod north of 62 is somewhat related to Northeast Arctic cod, while coastal cod south of 62°N show some similarities to North Sea and Skagerrak cod.

Compared to the Northeast Arctic cod the immature coastal cod has faster individual growth and earlier age of maturation (Berg and Albert, 2003). Since the individual growth is reduced after the age of first maturation, the weight at age for old fish is somewhat lower for coastal cod than for Northeast Arctic cod at the same age.

Spawning areas for coastal cod have been mapped by egg sampling and classified according to their relative value (Gytefelt Torsk MB at www.fiskeridirektoratet.no). See also Figures 18-23 in Aglen et al. (2020). Some of these coastal cod spawning areas are close to spawning areas for NEA cod. Probably due to rather small-scale differences in currents and egg buoyancy, the coastal cod eggs and larvae tends to be retained near the spawning areas, while NEA cod eggs and larvae are transported by currents northward to the Barents Sea.

Annual total allowable catches (TAC) have been set for coastal cod (40 kt in the years 1987-2003, 20 kt in 2004, and 21kt in later years). A large proportion of the annual landings of coastal cod is by-catches in the fishery for NEA cod. A rebuilding plan was established 2011. Several technical regulations have been introduced for reducing “bycatches” of coastal cod; gear restrictions and restrictions on vessel size, and closures of spawning areas in the spawning season (Henningsværstraumen and Inner Lofoten).

3 The autumn coastal survey

3.1 The history of the survey and how it has developed over the years

The Institute of Marine Research (IMR) has since 1985 conducted an annual acoustic survey of coastal areas and offshore banks north of 62°N with the objective of obtaining abundance indices of commercially important fish species (Skants, 2019). The annual coverage (in October and November) of coastal areas and fjords, as well as open ocean banks, between Stad (62°N) and Varanger (71.3 °N) has since 1995 included measurements of coastal cod (*Gadus morhua*).

The trawl gear used during the first years was a Campelen 1800 standard shrimp trawl with rock hopper gear and 35 mm mesh size in the cod end. Scanmar sensors provided information about the trawl opening (height in meters), door spread and bottom contact. Since 2003 a Campelen 1800 standard shrimp trawl with rock hopper gear, 20 mm mesh size in the cod end and 80mm (stretched) in the front part is the standard fishing gear, combined with Scanmar trawl and door sensors (Aglen et al., 2005). Additional stations were added in 2017, which was done as it was considered necessary to gather more information on deep water shrimps and redfish (Mehl et al., 2018a). Standard trawl duration is 30 minutes at a speed of 3 knots, with preferred doorspread of 49-52m and trawl opening of 3.5-4.5m. Data were collected with several vessels, which are listed in Table 1.

The survey consists of a stratified grid for acoustic measurements, with fixed bottom trawl stations and additional bottom and pelagic stations on acoustic registrations within each of the strata.

During the surveys hydrographic stations were sampled semi-regularly. CTD-measurements were taken at some of the fixed bottom trawl stations or with a set distance of 30 nautical miles between each station (Staby et al., 2020).

The surveyed area was initially divided into 23 strata, and these were grouped into three subareas: North of 67°N (Area "A"), 65°-67°N (Area "B"), and 62°-65°N (Area "C") (Figure 1). The stratum "Vestfjorden East" was, however, removed from all years, since this stratum had no acoustic coverage and no trawl hauls in most years.

Acoustic transects and bottom trawl hauls are standardized since 2003. In 2017 additional acoustic transects were added to selected strata in order to improve the accuracy of saithe biomass estimates in those strata that contributed a significantly to the total estimate. Figure 2 shows the acoustic transects and trawl hauls made during the coastal survey in 2019.

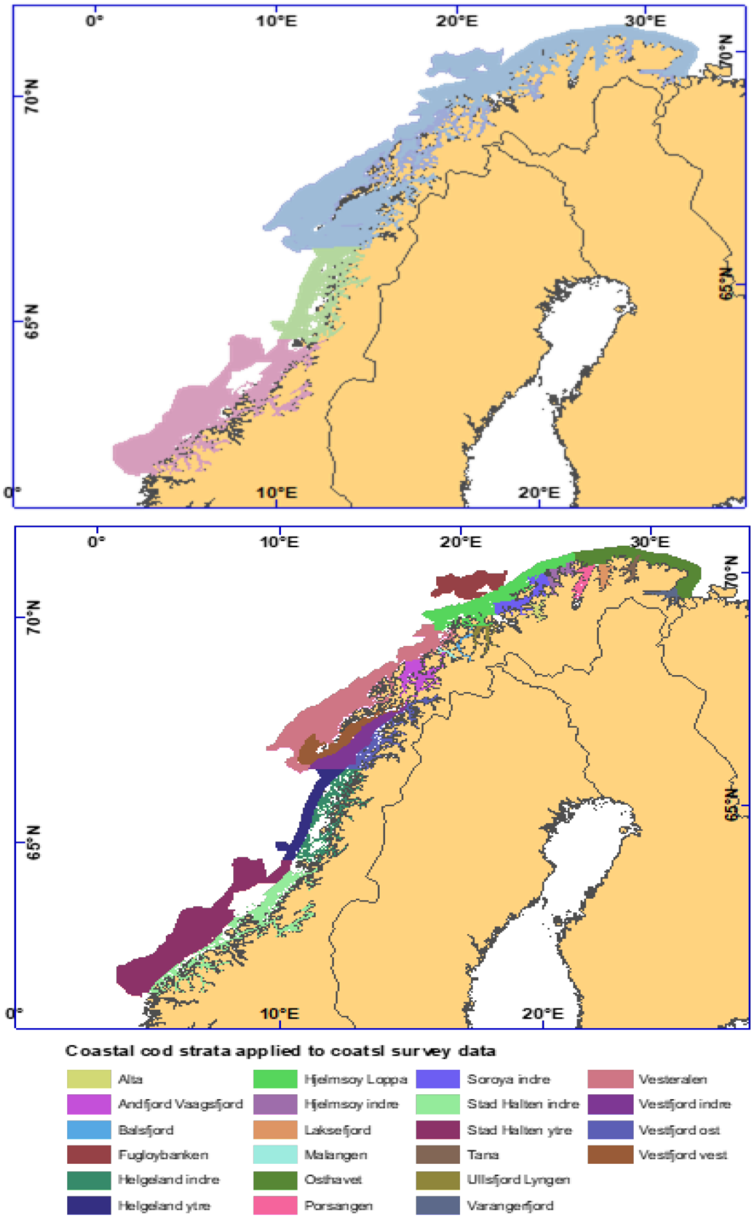
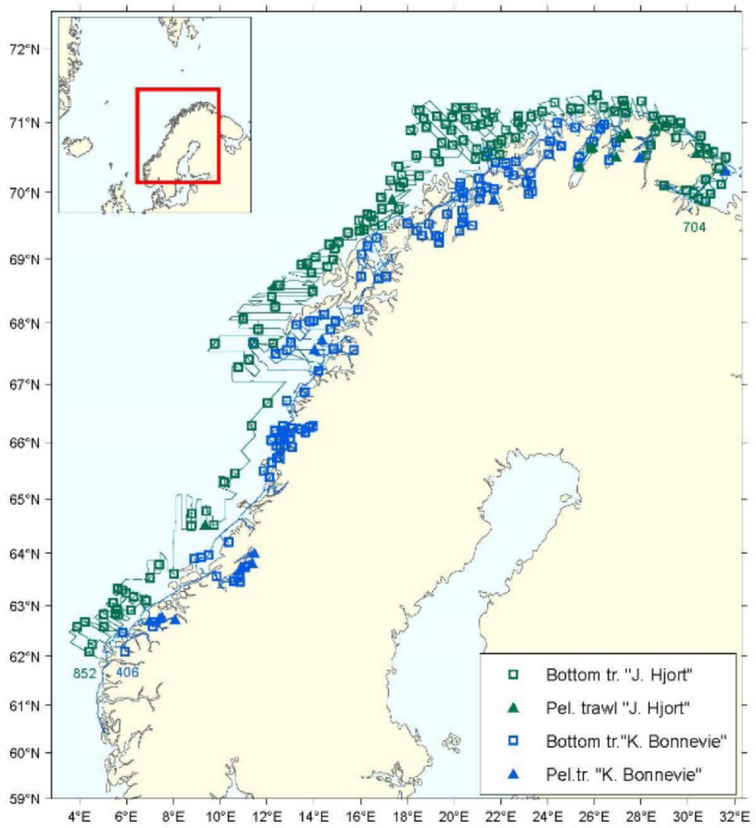


Figure 1 Map showing the 23 strata (lower panel) and the three subareas (upper panel) used for coastal cod index calculations.



Cruise no 2019210 "Johan Hjort". Trawl st.no 704-852. 5.10.-13.11.2019
Cruise no 2019629 "K. Bonnevie". Trawl st.no 287-406. 2.10. - 9.11.2019

Figure 2 Acoustic transects and trawl hauls made during the cruise in 2019. These are standard transects and trawl hauls that are made during this survey

Trawl catches are sorted and weighed by species according to standard procedures (Mjanger et al., 2020). Length measurements (e.g. total length; from snout to end of the caudal fin) are done for most species, either of all sorted individuals or of a subsample from large catches. Additional information such as age and type from otoliths, sex and gonad maturity stage are collected from cod.

3.2 Previous attempts to extract abundance indices from the survey data

As described in chapter 1.2, the autumn coastal survey has a long history and has undergone various changes over the years. It started out as an acoustic survey primarily targeting coastal cod in the Troms and Finnmark counties in the 1980s. These surveys were conducted by the former “Fiskeriforskning” marine research institute in Tromsø. IMR in Bergen started a survey at approximately the same time of the year, but targeting mainly saithe in the outer coastal areas, partly overlapping the areas of the former survey. A third survey, covering overwintering herring in the fjords were conducted by IMR. “Fiskeriforskning” was discontinued and the department responsible for resource surveys was included in IMR. From 2003 these surveys were combined and standardized to be a combined acoustic and trawl survey mainly targeting coastal cod and saithe. When the surveys were merged and standardized in 2003, attempts were made to construct an acoustic index for coastal cod based on the original coastal cod survey and the saithe survey, covering also more southern parts of the coast north of 62°N. Due to partly different procedures, working protocols, and data format at the two responsible institutes, and since the surveys partly overlapped in space and time, this combination was difficult. The series was started in 1995, but for the years prior to 2003, only some of the acoustic transects, mostly those that had been standardized during the “Fiskeriforskning” survey, were used in index calculations.

3.3 Description of the survey data

Table 1 lists the surveys from 1995-2019, which vessels took part, the number of stations taken etc.

Table 1. Description of survey data. The number of bottom trawl (BT) stations for swept area and acoustic indices differ because different data filters are applied (see sections 4.1.3 and 4.2.6).

Year	**Vessel**	**Cruise ID**	**For swept area index**				**For acoustic index**				
			N BT		N aged	N length	N BT (with cod)	N aged	N length	N miles scrutinized	
			Total	With cod						Total	With cod
1995	Michael Sars	1995111						2515	497	3869	3575
	Johan Hjort	1995211						80	1845	3952	2158
	Volstad	1995810						0	54	0	0
1996	Johan Hjort	1996214						171	2727	3285	1905
	Michael Sars	4-1996						2393	5376	2669	1552
1997	Johan Hjort	1997213						432	3656	3687	2650
	Michael Sars	4-1997						1670	4653	0	0
1998	G.O.Sars	1998016						493	2237	3030	1808
	Jan Mayen	4-1998						2476	4060	0	0
1999	Johan Hjort	1999215						399	1083	3813	1653
	Jan Mayen	4-1999						2780	4444	0	0
2000	Johan Hjort	2000214						414	1202	3766	1816
	Jan Mayen	4-2000						4240	5276	0	0
2001	Johan Hjort	2001213						267	844	4523	1229
	Jan Mayen	4-2001						3181	3815	0	0
2002	Johan Hjort	2002214						362	1173	4655	2128
	Jan Mayen	4-2002						2048	2511	0	0
2003	Johan Hjort	2003211	58	50	1381	2520	72	1580	2808	3695	2012
	Jan Mayen	2003706	78	68	1367	1734	109	1635	2077	4007	3130
2004	Johan Hjort	2004212	50	41	981	1714	67	1159	2010	3502	1989
	Jan Mayen	2004704	81	69	1270	1814	88	1345	1942	3469	2824
2005	Johan Hjort	2005212	42	36	759	1345	51	949	1625	3013	1768
	Jan Mayen	2005704	82	66	695	863	80	689	870	3794	3180
2006	Johan Hjort	2006213	51	42	543	821	48	677	1047	3851	2165
	Håkon Mosby	2006623	0	0	0	0	7	33	51	4479	34
	Jan Mayen	2006705	90	71	865	995	87	886	1021	4013	3260

2007	Johan Hjort	2007212	39	25	179	296	39	327	489	3550	1042
	Håkon Mosby	2007623	0	0	0	0	8	0	103	3778	0
	Jan Mayen	2007703	107	87	834	1040	85	829	1036	4670	3860
2008	Johan Hjort	2008210	86	81	1197	1773	103	1381	2012	6275	5831
	Håkon Mosby	2008623	31	16	233	329	24	308	439	1875	0
	Jan Mayen	2008705	4	4	73	127	10	73	192	214	193
2009	Johan Hjort	2009209	49	41	760	1240	46	818	1306	2860	1696
	Håkon Mosby	2009629	17	6	11	11	5	29	29	1127	180
	Jan Mayen	2009703	66	57	1263	2345	75	1299	2466	2819	2680
	Jan Mayen	2009704	4	4	140	382	14	166	544	524	524
2010	Johan Hjort	2010211	114	90	1957	3847	120	2284	4841	6175	4284
	Jan Mayen	2010704	6	6	149	489	12	168	518	380	380
2011	Johan Hjort	2011214	38	32	536	839	31	561	880	2450	1796
	Helmer Hanssen	2011722	81	71	1246	2075	80	1292	2158	4074	2875
	Helmer Hanssen	2011723	6	6	114	177	18	184	290	240	222
2012	Johan Hjort	2012210	64	55	834	1496	64	974	1701	3760	2552
	Håkon Mosby	2012620	65	51	1129	1878	50	1202	2123	2663	1402
2013	Johan Hjort	2013210	54	51	932	1638	72	1020	1836	3018	1602
	Håkon Mosby	2013623	59	50	1160	2288	65	1249	2451	2339	1227
	Helmer Hanssen	2013851	8	8	124	317	21	124	492	436	432
2014	Helmer Hanssen	2014011	8	8	209	717	21	222	736	455	449
	Johan Hjort	2014213	61	54	928	1601	81	1046	1767	4036	2680
	Håkon Mosby	2014621	74	61	1292	2555	94	1344	2623	2718	1837
2015	Johan Hjort	2015211	64	53	901	1272	65	992	1797	3880	2289
	Håkon Mosby	2015621	74	58	1180	1798	59	1183	2580	2447	1578
	Helmer Hanssen	2015854	8	7	181	566	21	229	613	395	390
2016	Johan Hjort	2016210	70	61	1451	2336	91	1545	2580	4594	4429
	Håkon Mosby	2016620	69	53	976	1463	59	1012	1522	2978	1567
2017	Johan Hjort	2017210	99	89	1616	2822	94	1656	2887	4696	2322
	Kristine Bonnevie	2017620	87	70	917	1854	97	957	1931	3760	1567
2018	Johan Hjort	2018210	110	90	1713	3282	134	1747	3316	4146	1527
	Kristine Bonnevie	2018623	86	66	1301	2365	94	1389	2523	3983	2146
2019	Johan Hjort	2019210	128	100	1516	2059	108	1598	2164	4832	2411
	Kristine Bonnevie	2019629	87	70	1191	2409	117	1196	2499	8818	4388

4 Software used

StoX is a software developed at the Institute of Marine Research for marine survey analysis and index calculation. StoX is available for free (ftp://ftp.imr.no/StoX/Download/) and is relatively well documented (Johnsen et al., 2019). StoX is for instance currently used for bottom trawl index calculation from the Barents Sea winter survey (Mehl et al., 2018) and from the Barents Sea ecosystem survey in the autumn (BESS) (Johannesen et al., 2019).

The data was mainly downloaded from: https://datasetexplorer.hi.no/apps/datasetexplorer/v2/navigation and the folder "Varanger Stad NOR coastal cruise in autumn». However, it was found that for some research vessels, especially in the early part of the period, data was lacking in the relevant folders and had to be retrieved from the original data files and reformatted to the current xml format used by StoX. Steps have been taken to have these data stored in the "Varanger Stad NOR coastal cruise in autumn" folder structure and quality assured for later use.

5 Acoustic indices

A stock abundance index series based on acoustics at the annual autumn coastal survey (NOcoast-Aco-4Q) was calculated using the StoX software (Johnsen et al., 2019). Acoustic data covering the coastline from 62°N to the Russian border were available back to 1995, although the coverage in various parts of this area varied somewhat due to various reasons, see chapter 3.1 and 3.2 for details. For some early years in the series, acoustic data was only available from parts of the survey area. The area was split into 23 strata (see above) and the stock abundance index was calculated for each stratum separately. For various reasons, it was decided to split the total area into three subareas: The coast north of 67°N (A, consisting of 18 strata), between 65° and 67°N (B, consisting of 2 strata), and between 62°N and 65°N (C, consisting of 2 strata) (Fig 1). The coverage during most of the time series is much better in subarea A than in B and C.

To estimate the uncertainty, 500 bootstrap runs were performed, and the indices are the average index from these runs. Below are shown the index series for the total area and for the three subareas.

5.1 Acoustic indices by length

The conversion of mean nautical area scattering coefficient (NASC, m^2 nmi^{-2}) to fish density was carried out using a standard procedure, where trawl stations (with a catch of more than 1 individual of cod) were assigned to each PSU. As a rule, all stations within a stratum were assigned to the PSUs in the same stratum. However, if less than three trawl stations were carried out in a stratum, stations in neighbouring strata were assigned to the PSUs so that at least three stations were assigned to each PSU.

The combined length distribution (d), calculated for each transect (PSU, j), is given by

$$d_{l,j} = \sum_{s=1}^{n} d_{l,s,j}, \qquad \text{(eqn 1)}$$

where $d_{l,s,j}$ is fish density (number by 1 nmi tow distance) by station (s) and length group (l, cm), and n is the total number of stations.

The fish density (ρ, individuals nmi^{-2}) by length group and transect was calculated using

$$\rho_{j,l} = \mathrm{NASC}_{j,l}/(4\pi\sigma_{bs,l}), \qquad \text{(eqn 2)}$$

where $\mathrm{NASC}_{j,l}$ is the mean nautical area scattering coefficient by transect and length group and $\sigma_{bs,l}$ (m2) is the acoustic backscattering cross-section for a fish of length l.

$\mathrm{NASC}_{j,l}$ is given by

$$\mathrm{NASC}_{j,l} = \mathrm{NASC}_j p_{l,j}\,\left(\sigma_{bs,l}/\left(\textstyle\sum_l \sigma_{bs,l}\right)\right), \qquad \text{(eqn 3)}$$

where $\sigma_{bs,l}$ is the acoustic backscattering cross-section for a fish of length l multiplied by the proportion (p) of a fish of length l in $d_{l,j}$, and NASC_j is the mean nautical area scattering coefficient over a given transect.

The acoustic backscattering cross-section for a fish of length l is calculated using

$$\sigma_{bs,l} = 10^{\left(\frac{TS_l}{10}\right)}, \qquad \text{(eqn 4)}$$

where the target strength, TS (dB re $1m^2$), for a fish of length l is calculated using

$$TS_l = m\log_{10}(l) + a, \qquad \text{(eqn 5)}$$

where m and a are constants, set to values of 20 and -68.0 respectively.

The abundance (N, inds) of cod by length group l and stratum k is given by

$$N_{k,l} = \rho_{k,l}A_k, \qquad \text{(eqn 6)}$$

where A (nmi^2) is stratum area, and the mean density of herring by l and k is given by

$$\rho_{k,l} = (1/n_k)\sum_{j=1}^{n_k}\left(w_{k,j}\rho_{k,j,l}\right), \qquad \text{(eqn 7)}$$

where $\rho_{k,l} = (1/n_k)\sum_{j=1}^{n_k}\left(w_{k,j}\rho_{k,j,l}\right)$, is the transect weight, n_k is the total number of sample transects and $L_{k,j}$ and $\bar{L}_k$ are the distance of each transect by stratum and the mean transect distance over each stratum respectively.

5.2 Acoustic indices by age

Only a subsample of the length-measured individuals (j) is aged. A two-stage conversion process is used to convert the abundance of fish by length group to abundance of fish by age group.

First, the abundance ($N_{k,l}$) by l and k is distributed the length-measured individuals to generate so-called super-individuals, each representing an abundance estimated as:

$$N_{k,j,s,l} = N_{k,l}w_{k,j,s,l}, \qquad \text{(eqn 8)}$$

where

$$w_{k,j,s,l} = \rho_{k,s,l}/\left(\sum_{s=1}^{n}\rho_{k,s,l}\right) \times 1/m_{k,s,l}, \qquad \text{(eqn 9)}$$

and m is the number of length-measured individuals.

Second, in instances where a super-individual is not aged, the missing age is filled in by a random data imputation. The imputation of missing age is principally carried out at the station level, randomly selecting the value from aged super-individuals within the same length group. If no aged super-individual is available at station level, the imputation is attempted at strata level, or lastly on survey level. In instances, where no age information is available at any level for a specific length group, the abundance estimate is presented with unknown age. As the imputation of missing age values in both examples also imputes associated biological parameters, abundance can be estimated for any combination of classifications assigned to the super-individuals e.g. sex, maturity, age etc. In our case the otolith type was used to classify the super-individuals, see below.

5.3 Length and weight at age

Length and weight at age was calculated using the weighting factors defined in eqn 8 (the "super - individuals").

5.4 Uncertainty of abundance indices

Uncertainty was estimated as the coefficient of variation (ratio of standard deviation to the mean, CV). StoX calculates CV using bootstrap runs by stratum, treating each trawl station as the primary sampling unit. Here we used 500 bootstrap runs.

5.5 Extracting coastal cod from total cod

Since the discrimination of coastal cod and other cod caught at the coastal survey is based on otolith types (see above) this poses a special challenge to producing abundance index series with uncertainty for coastal cod. Running a StoX project on the acoustical and biological data to produce an acoustic index series will primarily produce indices for all cod present in these data sources. However, when running the bootstrap process in StoX, it is possible to group the superindividuals by several categories, for instance age and otolith type. There is no facility inside StoX to present those "two-dimensional" bootstrap data but using an R-script manipulating the bootstrap files generated by StoX it is possible to extract relevant data. Thus, this was done after the whole time series were made by ordinary StoX-runs, by selecting only those entries in the bootstrap data that contained superindividuals with otolith types “1” and “2”. Alle tables and figures in the appendices to this document were produced by this R-script. The R-script itself is documented in appendix “X”. Since the growth pattern can only be distinguished with certainty in otoliths from two years old and older fish (although an otolith type is in some cases noted also for younger fish), the indices of age 0 and age 1 were excluded from the index series suggested for use in stock assessment.

5.6 Acoustic indices - settings in StoX

The processes included and the settings of parameters when running StoX for acoustic indices are given in the following:

Baseline processes:

Process	Parameters	Values
ReadProcessData		
ReadAcousticXML	FileName1, FileName2, …	Relevant data files
FilterAcoustic	AcousticData	ReadAcousticXML
	DistanceExpr	N/A
	FreqExpr	N/A
	NASCExpr	acocat == 31
NASC	LayerType	WaterColumn
ReadBioticXML	FileName1, FileName2, …	Relevant file names
FilterBiotic	FishStationExpr	fs.getLengthSampleCount(‘TORSK’)>1
	CatchExpr	species == ‘164712’
	SampleExpr	N/A
	IndExpr	N/A
StationLengthDist	LengthDistType	NormLengthDist
RegroupLenghDist	LengthInverval	1.0
Catchability	CatchabilityMethod	LengthDependentSweepWidth
	LengthDist	RegroupLengthDist
	ParLenfthDependentSweepWidth	SpecCat=;Alpha=5.91;Beta=0.43;LMin=15.0;LMax=62.0
RelLengthDist	LengthDist	Catchability
DefineStrata	UseProcessData	“True”
StratumArea	AreaMethod	Accurate
DefineAcousticTransect	DefinitionMethod	UseProcessData
MeanNASC	NASC	NASC
	SampleUnitType	PSU
BioStationAssignment	BioticData	FilterBiotic
	AssignmentMethod	Stratum (first time, then UseProcessData)
	EstLayers	1~PELBOT
BioStationWeigting	WeightingMethod	SumWeightCount
TotalLengthDist	LengthDist	RelLengthDist
AcousticDensity	LengthDist	TotalLengthDist
	NASC	MeanNASC
	m	20
	a	-68
MeanDensity_Stratum	Density	AcousticDensity

	SampleUnitType	Stratum
SumDensity_Stratum	Density	MeanDensity_Stratum
Abundance	Density	SumDensity_Stratum
	PolygonArea	StratumArea
IndividualDataStations	Abundance	Abundance
IndividualData	IndividualDataStations	IndividualDataStations
SuperIndAbundance	Abundance	Abundance
	IndividualData	IndividualData
	AbundWeightMethod	StationDensity
	LengthDist	RegroupLengthDist

Baseline report processes:

Process	Parameters	Values
FillMissingData	Superindividuals	SuperIndAbundance
	FillVariables	ImputeByAge
	Seed	1
	FillWeight	Mean
EstimateByPopulationCategory	Superindividuals	FillMissingData
	Lengthinterval	5.0
	Scale	1000
	Dim1	olotithtype
	Dim2	age
	Dim3	SpecCat

R processes:

Process	Parameters	Values
runBootstrap	bootstrapMethod	AcousticTrawl
	acousticMethod	PSU~Stratum
	bioticMethod	PSU~Stratum
	startProcess	TotalLengtDist
	endProcess	SuperIndAbundance
	nboot	500
	seed	1
	cores	4
imputeByAge	seed	1
	cores	4
SaveProjectData		“Enabled”

R report processes:

Process	Parameters	Values
getReports	out	all
	options	grp1=”age”, grp2=”otolithtype”
getPlots	out	all

	options	grp1=”age”, grp2=”otolithtype”

5.7 Resulting time series

The annual abundance indices and biomass indices by age groups and for age group 2+, their coefficient of variation, and mean length and weight by age groups are shown in Appendix A for the total area and for the subareas A, B and C.

The abundance indices for age 2+ are depicted in Figures 3 to 6. The series for the total area (Fig 3) is characterized by high indices but rapidly decreasing from 1997 to a level of 10-20 million, without any clear trends. In general, the uncertainties are larger during the first part of the time series compared to more recent years.

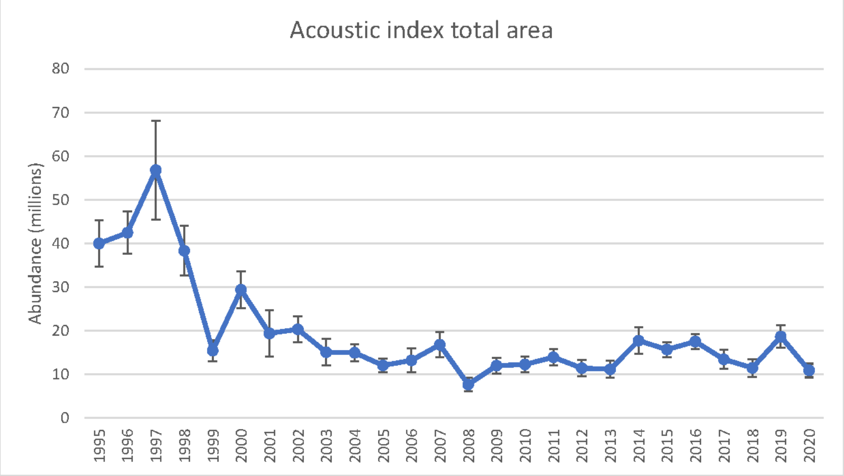


Figure 3 Acoustic index series for coastal cod age 2+ in the total area. Error bars represent +/- two standard deviations.

The series for subarea A (the northern part of the survey area, Figure 4) resemble that for the total area, because this area contains most of the fish.

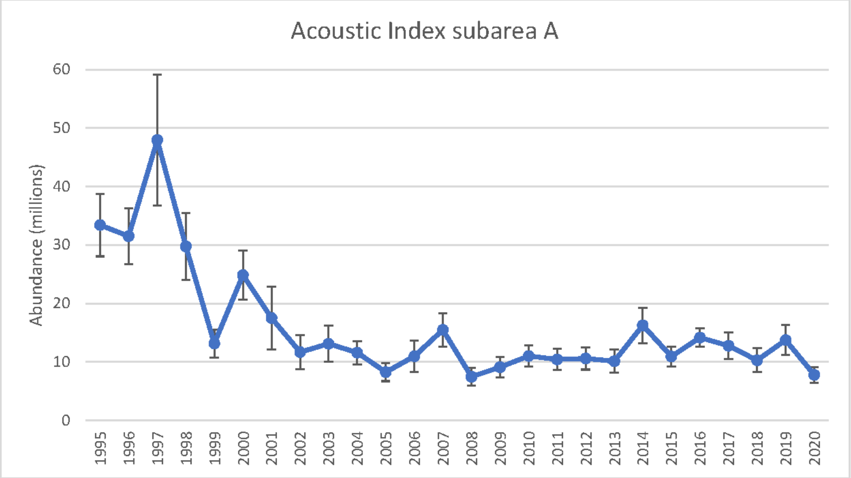


Figure 4 Acoustic index series for coastal cod age 2+ in subarea A (north of 67°N). Error bars represent +/- two standard deviations.

The indices for subareas B (Figure 5) and C (Figure 6) are very much smaller than for subarea A. The uncertainties are also more variable from year to year.

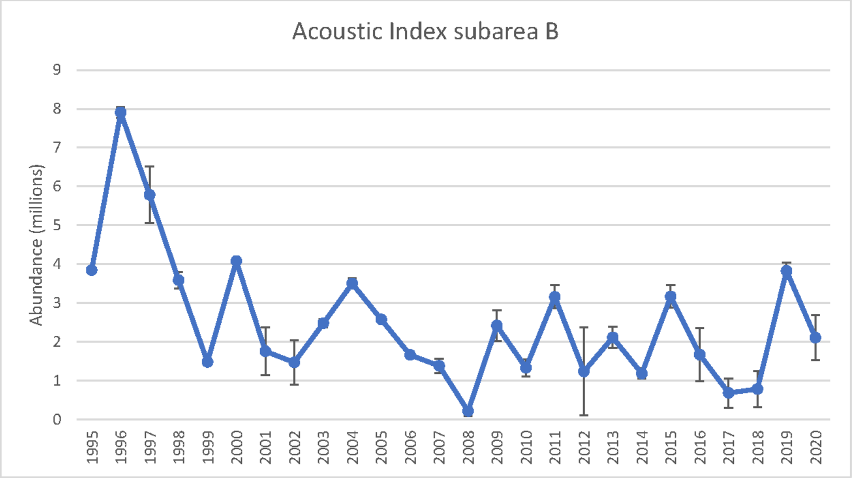


Figure 5 Acoustic index series for coastal cod age 2+ in subarea B (between 65°N and 67°N). Error bars represent +/- two standard deviations.

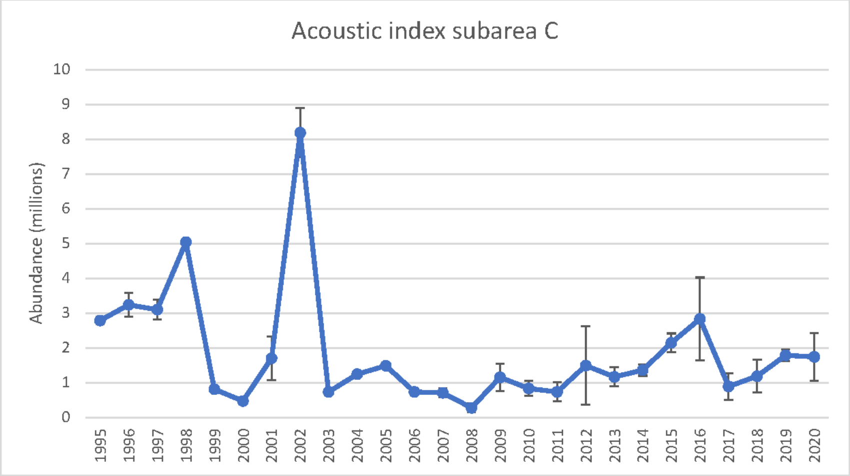


Figure 6 Acoustic index series for coastal cod age 2+ in subarea C (between 62°N and 65°N). Error bars represent +/- two standard deviations.

To check whether the indices can describe the stock dynamics over time, plots on how year classes (cohorts) could be traced from year to year were constructed (Figure 7-10). The progression of year classes through the stock is reasonably well described for the total area and for subarea A (Figures 7-8). A year effect is visible for instance in 1998, when all age groups where recorded lower than expected. In other years, single age groups, in particular among older fish, show unexpected patterns. This seems to be a problem for age groups above 10 years. As expected, the plot for Subarea A (Figure 8) resembles that for the total area, while those for Subarea B (Figure 9) and Subarea C (Figure 10) show a much less consistent picture, where strong year effects are visible.

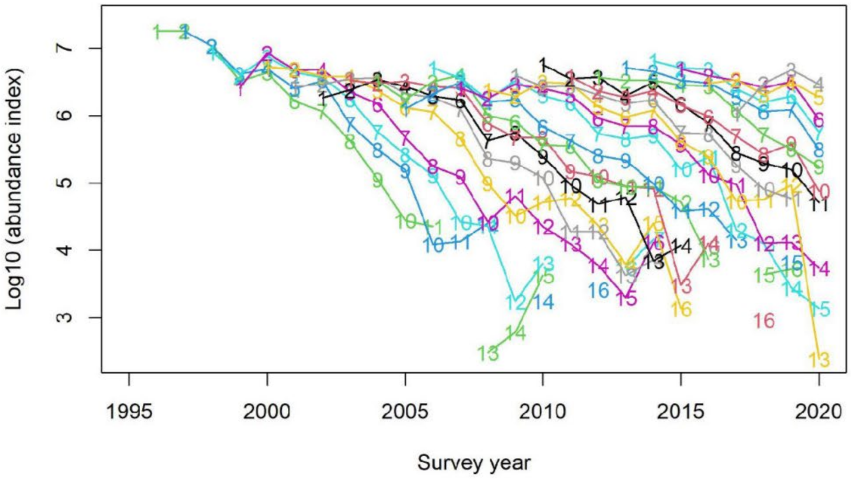


Figure 7. Logarithmic reduction of abundance over time for the year classes 1995 to 2014 for age 1 and older in the acoustic index series for the total area. The age is shown for each data point.

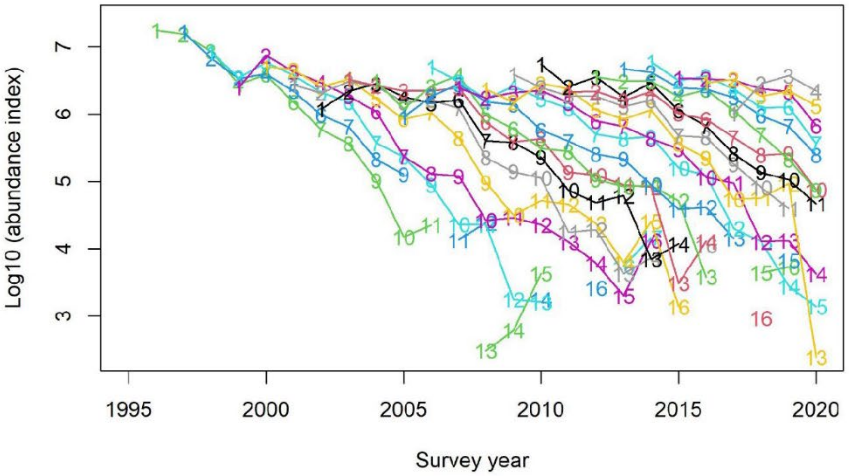


Figure 8 Logarithmic reduction of abundance over time for the year classes 1995 to 2014 for age 1 and older in the acoustic index series for Subarea A. The age is shown for each data point.

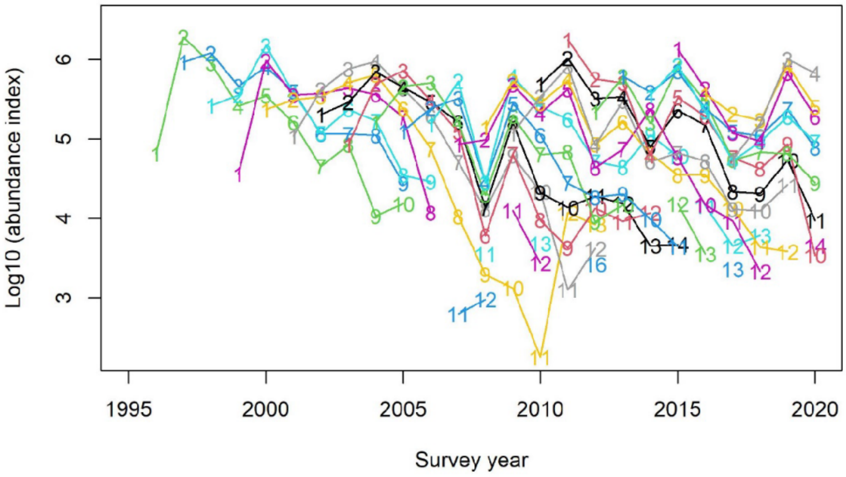


Figure 9 Logarithmic reduction of abundance over time for the year classes 1995 to 2014 for age 1 and older in the acoustic index series for Subarea B. The age is shown for each data point.

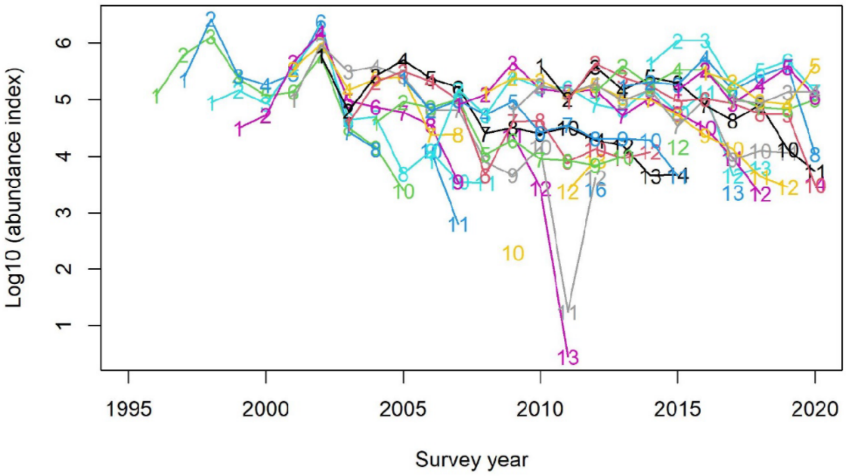


Figure 10 Logarithmic reduction of abundance over time for the year classes 1995 to 2014 for age 1 and older in the acoustic index series for Subarea C. The age is shown for each data point.

5.8 Internal consistency in the acoustic series for subarea A

The internal consistency plots (number at age n in year n plotted versus number at age n+1 in year y+1) for age groups 1-6 are shown in Figure 11 and for age groups 7-12 in Figure 12. In most cases the fit is rather poor. Exceptions are age 1-2 and age 2-3, with rather high correlation, but the regressions are highly affected by the large indices during the first part of the period.

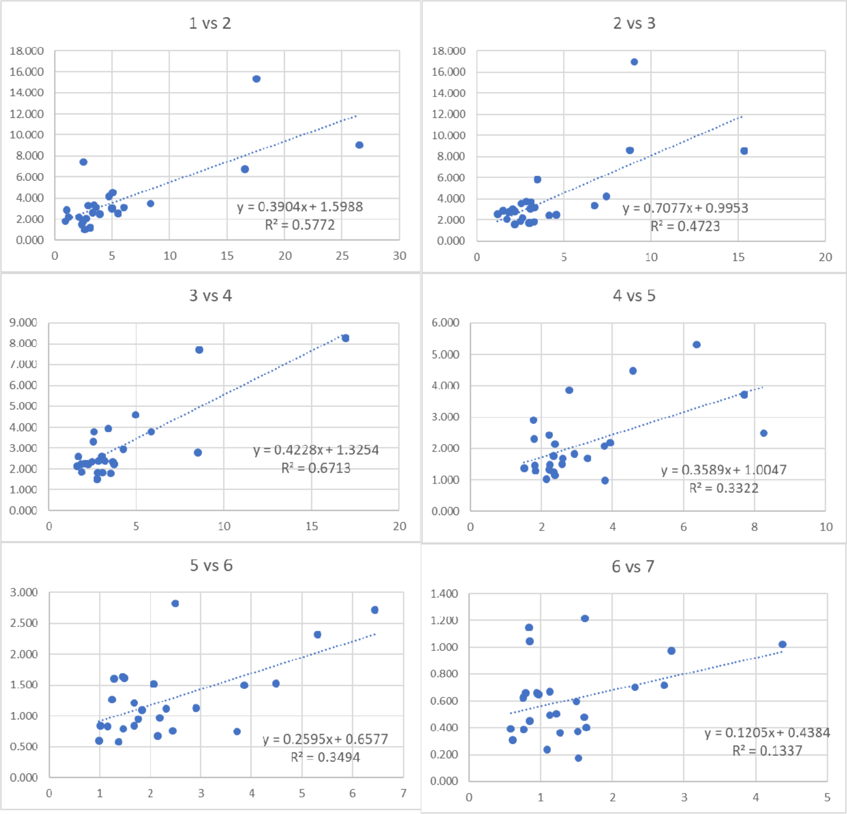


Figure 11 Consistency plots for the acoustic index for area A. Age groups 1-6

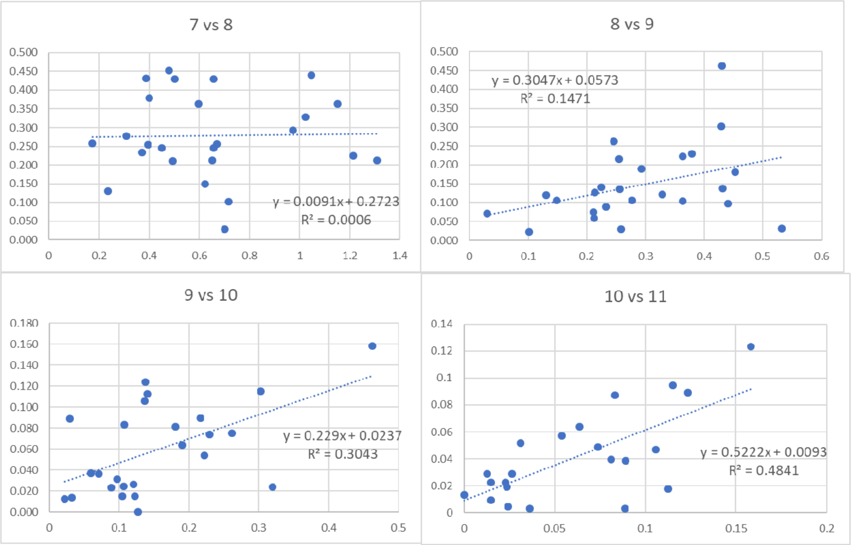


Figure 12 Consistency plots for the acoustic index for area A. Age groups 7-12

5.9 Comparison with acoustic index series calculated with previous methods

An acoustic index has been calculated for this stock since 1995 (see chapter 1.3), using a somewhat more detailed strata system and a method based on the SAS software platform. It is difficult to compare that series with the new acoustic index developed in StoX. However, a comparison made for the sum over ages 2+ (Figure 11) show that there are large differences between the series before 2002. For the period after 2002 the indices are much more aligned, the new series being somewhat lower in most years. A part of the large discrepancies found for the early years in the series can be explained by poor data quality of the acoustic data. When the series was rerun in StoX and the acoustic data checked in detail, some few enormous NASC values were detected, indicating that parts of the bottom signal had been integrated. In small strata containing few transects and few values, such erroneous values may have a big impact on the total index. For instance, in 2000, taking out a NASC value of 4718 from a small stratum (Sørøya Indre) made the index in that stratum change from 46 000 tonnes to 1400 tonnes. In 1996, 1999 and in 2000 six extremely high values were found and removed from the transects, which had profound effects on the index values from these years. It is unknown whether these erroneous values were in fact included in the old acoustic series or not. In the remaining years before 2002, no such extreme values could be found and also these years the new index is substantially lower than the old index, so there must also be other reasons for the differences. In any case, we argue that the new indices should be accepted, on the grounds that they are developed in one go, using a more quality assured software with identical settings from year to year, and with a more thorough quality assurance of the acoustic data.

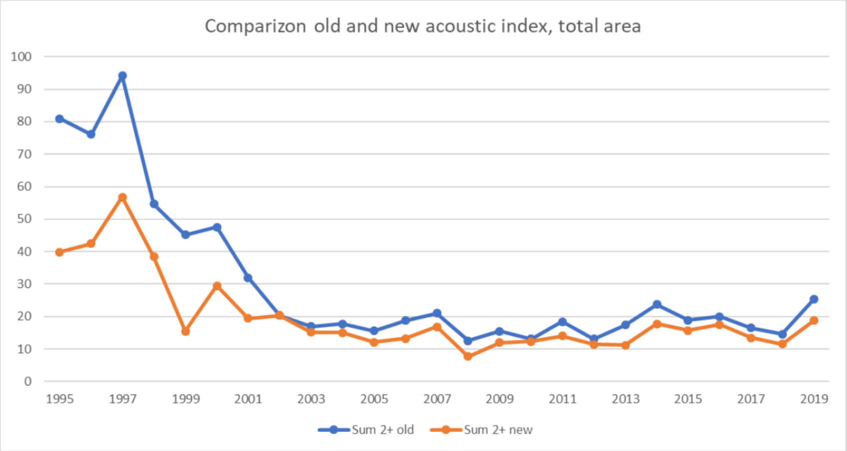


Figure 13 Comparison of the old and new acoustic abundance index series for sum over ages 2+ for the total area

6 Swept area indices

A stock abundance index series based on bottom trawl hauls at the annual autumn coastal survey (NOcoast-Aco-4Q) was calculated using the StoX software (Johnsen et al., 2019). Trawl data covering the coastline from 62°N to the Russian border were available back to 1995, although the coverage in various parts of this area varied somewhat due to ship availability, weather conditions etc. However, the survey was designed as an acoustic survey before 2003, and trawls were set on registration, meant to supply biological data to the acoustic measurements. Consequently, we did not apply the trawl data before 2003 when calculating the swept-area indices for coastal cod. The area is split into 22 strata (see above) and the stock abundance index is calculated for each stratum separately. For various reasons, it was decided to split the total area into three subareas: The coast north of 67°N (A, consisting of 18 strata), between 65° and 67°N (B, consisting of 2 strata), and between 62°N and 65°N (C, consisting of 2 strata). The coverage during most of the time series is much better in subarea A than in B and C.

A complicating factor when calculating stock abundance indices for coastal cod is that coastal cod are partly mixed with other cod stocks (mainly the north-east arctic cod stock) so the catches are a mixture of these. Individuals from various cod stocks are separated based on the growth pattern of the inner parts of the otoliths (see above) where coastal cod is distinguished by having otolith types 1 (certain coastal cod) and 2 (most likely coastal cod). These criteria are used to filter out coastal cod in the catches when running StoX. Since the growth pattern can only be distinguished with certainty in otoliths from two years old and older fish (although an otolith type is in some cases noted also for younger fish), the indices of age 0 and age 1 were excluded from the index series.

To estimate the uncertainty, 500 bootstrap runs were performed, and the indices are the average index from these runs.

6.1 Swept area indices by length

The following description is taken from Johannesen et al. (2019):

The swept area density (ρ, individuals per square nautical mile, inds nmi^{-2}) by stratum (k), station (s) and length group l (1 cm), is given by

$$\rho_{k,s,l} = f_{k,s,l}/sw_l, \tag{eqn 10}$$

where $f_{k,s,l}$ is the number of individuals standardized over a towing distance of 1 nmi by k, s and l, and sw_l is the adjusted swept width in nmi's by length group calculated using

$$sw_l = EW_l/1852, \tag{eqn 11}$$

where EW_l is the length dependent effective swept width. The length dependency of swept width is taken from (Dickson, 1993)

The abundance (N, inds) by l and k is calculated using

$$N_{k,l} = \rho_{k,l} A_k, \tag{eqn 12}$$

where A is stratum area (nmi^2), and $\rho_{k,l}$ is the average swept area density by l and k, given by

$$\rho_{k,l} = (1/n) \sum_{s=1}^{n} \rho_{k,s,l}, \tag{eqn 13}$$

where n is number of stations.

6.2 Swept area indices by age

The sampling protocol for the survey is to sample one individual from each 5 cm length group at each trawl station for aging and individual weights. A two-stage conversion process is used to convert the abundance of fish by length group to abundance of fish by age group.

First, the abundance ($N_{k,l}$) by length group l (5 cm) and stratum k is distributed the length-measured individuals (j) to generate so-called "Super-individuals" (super-individuals represent fractions of a total, our use corresponds to a probability based design where $w_{k,j,s,l}$ is the inverse of the inclusion probability for a single fish sample), each representing an abundance estimated as:

$$N_{k,j,s,l} = N_{k,l} w_{k,j,s,l}, \tag{eqn 14}$$

where

$$w_{k,j,s,l} = \rho_{k,s,l} / \left(\sum_{s=1}^{n} \rho_{k,s,l} \right) \times 1/m_{k,s,l}, \tag{eqn 15}$$

and m is the number of length-measured individuals

Second, in instances where a super-individual is not aged, the missing age is filled in by a random data imputation. The imputation of missing age is principally carried out at the station level, randomly selecting the value from aged super-individuals within the same length group. If no aged super-individual is available at the station level, the imputation is attempted at strata level, or lastly on survey level. In instances where no age information is available at any level for a specific length group, the abundance estimate is presented with unknown age (Johnsen et al., 2019).

6.3 Length and weight at age

Length and weight at age was calculated using the weighting factors defined in eqn 15 (the "super-individuals").

6.4 Uncertainty of abundance indices

Uncertainty was estimated as the coefficient of variation (ratio of standard deviation to the mean, CV). StoX calculates CV using bootstrap runs by stratum, treating each trawl station as the primary sampling unit. Here we used 500 bootstrap runs.

6.5 Extracting coastal cod from total cod

Since the discrimination of coastal cod and other cod caught at the coastal survey is based on otolith types (see above) this poses a special challenge to producing abundance index series with uncertainty for coastal cod. Running a StoX project on the biological data to produce a swept-area index series will primarily produce indices for all cod present in this data source. However, when running the bootstrap process in StoX, it is possible to group the superindividuals by several categories, for instance age and otolith type. There is no facility inside StoX to present those “two-dimensional” bootstrap data but using an R-script manipulating the bootstrap files generated by StoX it is possible to extract relevant data. Thus, this was done after the whole time series were made by ordinary StoX-runs, by selecting only those entries in the bootstrap data that contained superindividuals with otolith types “1” and “2”. Alle tables and figures in the appendices to this document were produced by this R-script. The R-script itself is documented in appendix “X”.

6.6 Swept area indices – settings in StoX

The processes included and the settings of parameters when running StoX for swept area indices are given in the following:

Baseline processes:

Process	Parameters	Values
ReadProcessData		
ReadBioticXML	FileName1, FileName2, …	Relevant file names
FilterBiotic	FishStationExpr*	gear =~[‘3270’,’3271’] and
		gearcondition < 3 and
		tawlquality =~[‘1’,’3’] and
		fishstationtype !=[‘2’] and
	CatchExpr	species == ‘164712’
	SampleExpr	N/A
	IndExpr	N/A
DefineSweptAreaPSU	Method	Station
StationLengthDist	LengthDistType	NormLengthDist
RegroupLenghDist	LengthInverval	5.0
Catchability	CatchabilityMethod	LengthDependentSweepWidth
	LengthDist	RegroupLengthDist
	ParLenfthDependentSweepWidth	SpecCat=;Alpha=5.91;Beta=0.43;LMin=15.0;LMax=62.0
RelLengthDist	LengthDist	Catchability
DefineStrata	UseProcessData	“True”
StratumArea	AreaMethod	Accurate
TotalLengthDist	LengthDist	RegroupLengthDist
SweptAreaDensity	SweptAreaMethod	LengthDependent
	BioticData	FilterBiotic
	LengthDist	TotalLengthDist
	DistanceMethod	FullDistance

	SweepwidthMethod	Predetermined
MeanDensity_Stratum	Density	SweptAreaDensity
	SampleUnitType	Stratum
	PolygonArea	StratumArea
AbundanceByLength	Density	MeanDensity_Stratum
IndividualDataStations	Abundance	AbundanceByLength
IndividualData	IndividualDataStations	IndividualDataStations
SuperIndAbundance	Abundance	AbundanceByLength
	IndividualData	IndividualData
	AbundWeightMethod	StationDensity
	LengthDist	RegroupLengthDist

* In the period 2017-2019 this filter was changed to allow for inclusion of stations coded with StationType = C and trawlQuality = 2

Baseline report processes:

Process	**Parameters**	**Values**
FillMissingData	Superindividuals	SuperIndAbundance
	FillVariables	ImputeByAge
	Seed	1
	FillWeight	Mean
EstimateByPopulationCategory	Superindividuals	FillMissingData
	Lengthinterval	5.0
	Scale	1000
	Dim1	otolithtype
	Dim2	age
	Dim3	SpecCat

R processes:

Process	**Parameters**	**Values**
runBootstrap	bootstrapMethod	AcousticTrawl
	acousticMethod	PSU~Stratum
	bioticMethod	PSU~Stratum
	startProcess	TotalLengtDist
	endProcess	SuperIndAbundance
	nboot	500
	seed	1
	cores	4
imputeByAge	seed	1
	cores	4
SaveRImage		“Enabled”

R report processes:

Process	**Parameters**	**Values**

getReports	out	all
	options	grp1=”age”, grp2=”otolithtype”
getPlots	out	all
	options	grp1=”age”, grp2=”otolithtype”

6.7 Resulting time series

Below are shown the index series for the total area (Figure 11) and for the three subareas A (Figure 12), B (Figure 13) and C (Figure 14). The abundance indices for the total area is rather flat but one year, 1997, stands out from the rest having a three times as high index and much wider confidence limits than the rest of the years in the series.

The amount of coastal cod in subarea A (Figure 12) is much higher than in the more southern subareas B and C, and the index series in subarea A therefore resembles the total index to a high degree. While the index for subarea A (and therefore also the total area) show peaks in 2003 and in 2014-2015, the series for subareas B and C are without conspicuous trends. The relative uncertainty is much higher for the two southern subareas than for the northern (subarea A). The uncertainty in the last four years is smaller than for the earlier part of the index series, for all subareas.

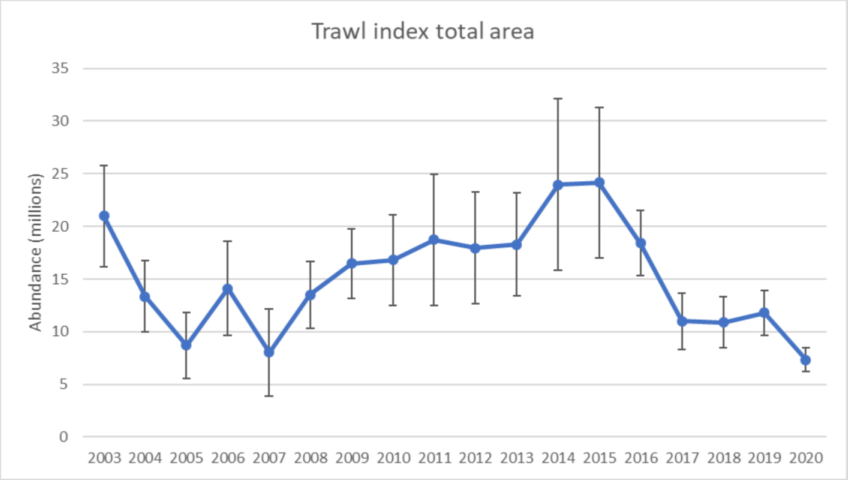


Figure 14 Trawl index series for coastal cod age 2+ in the total area. Error bars represent +/- two standard deviations.

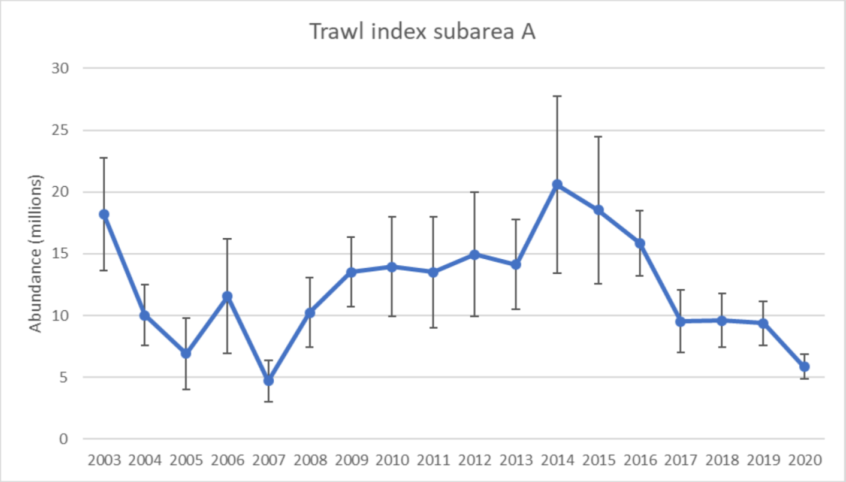


Figure 15 Trawl index series for coastal cod age 2+ in subarea A (north of 67°N). Error bars represent +/- two standard deviations.

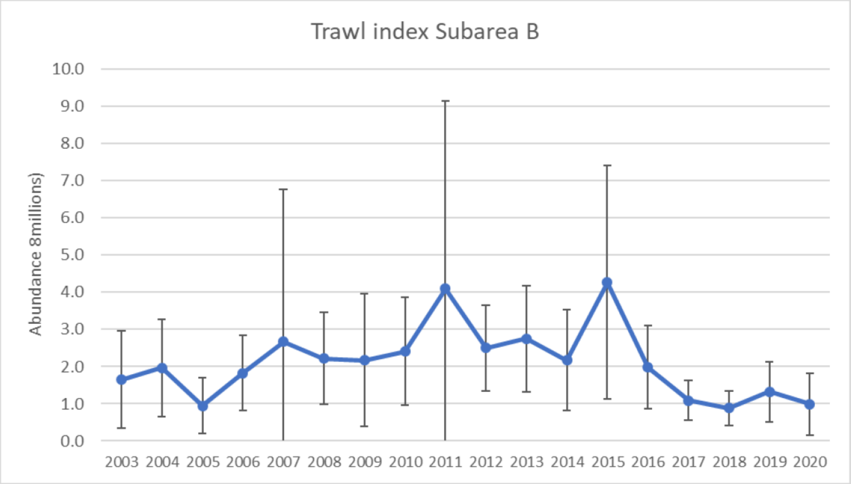


Figure 16 Trawl index series for coastal cod age 2+ in subarea B, (between 65°N and 67°N). Error bars represent +/- two standard deviations.

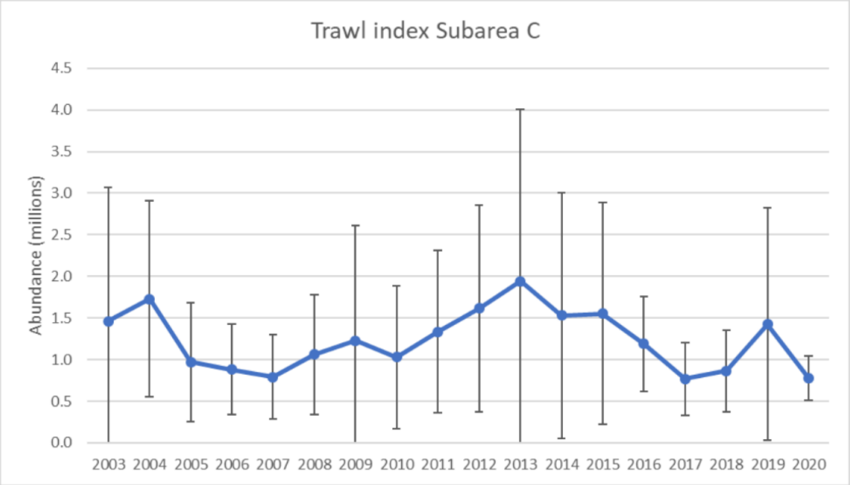


Figure 17 Trawl index series for coastal cod age 2+ in subarea C, (between 62°N and 65°N). Error bars represent +/- two standard deviations.

Consistency among cohorts are illustrated on Figures 15-18. The cohorts are traced quite nicely in subarea A (and in the total area) without conspicuous year effects except for in 2005 and 2007. For the two subareas B (Figure 17) and C (Figure 18) it is not possible to follow the year classes except for during short periods, indicating that the indices for these subareas do not reflect the total abundance of coastal cod during the period 2002 to 2019.

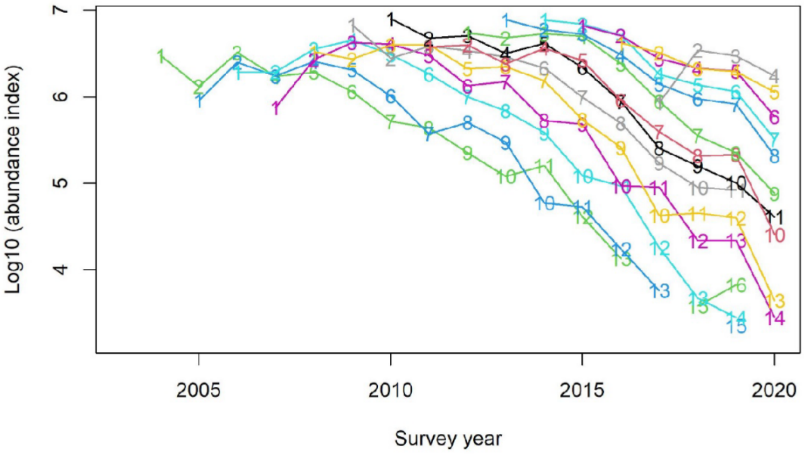


Figure 18 Logarithmic reduction of abundance over time for the year classes 2002 to 2014 for age 1 and older in the trawl index series for the total area. The age is shown for each data point.

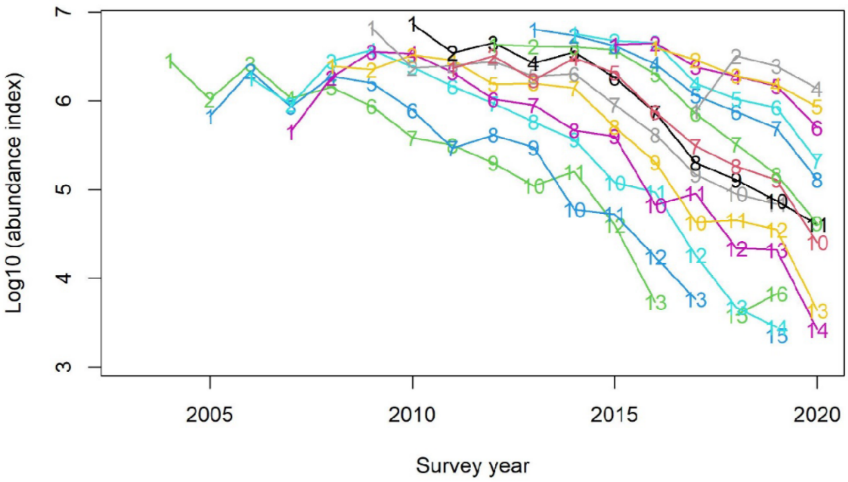


Figure 19 Logarithmic reduction of abundance over time for the year classes 2002 to 2014 for age 1 and older in the trawl index series for Subarea A. The age is shown for each data point.

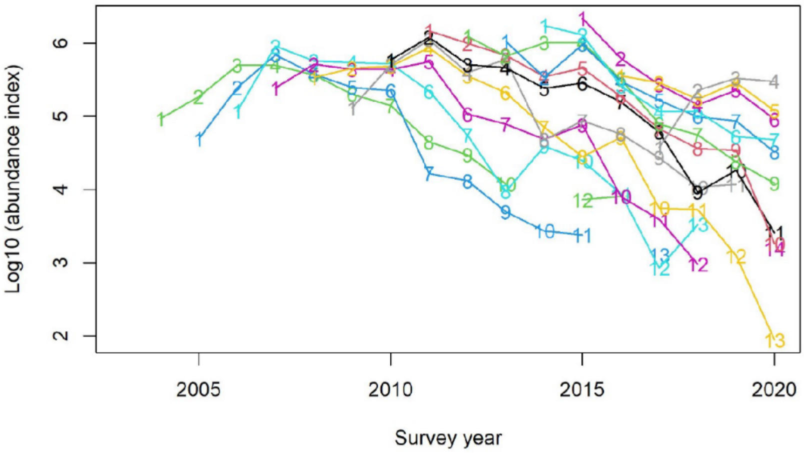


Figure 20 Logarithmic reduction of abundance over time for the year classes 1995 to 2014 for age 1 and older in the trawl index series for Subarea B. The age is shown for each data point.

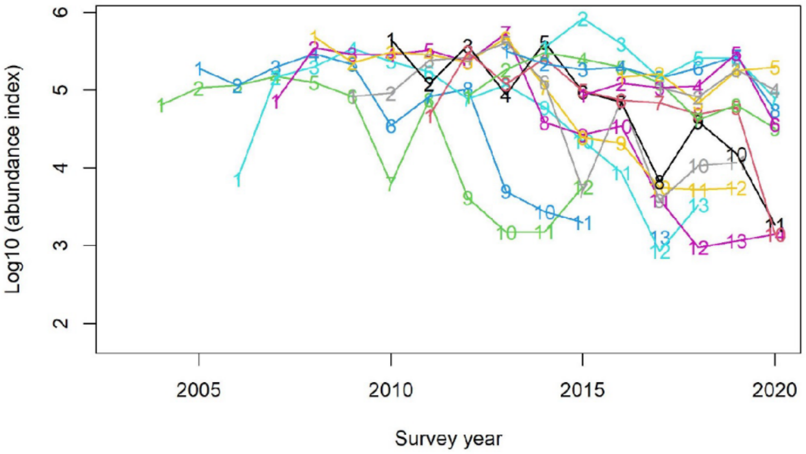


Figure 21 Logarithmic reduction of abundance over time for the year classes 2002 to 2014 for age 1 and older in the trawl index series for Subarea C. The age is shown for each data point.

6.8 Consistency within the trawl index series for area A

The internal consistency plots (number at age n in year n plotted versus number at age n+1 in year y+1) for age groups 1-6 are shown in Figure 22 and for age groups 7-12 in Figure 23. In most cases the fit is rather poor.

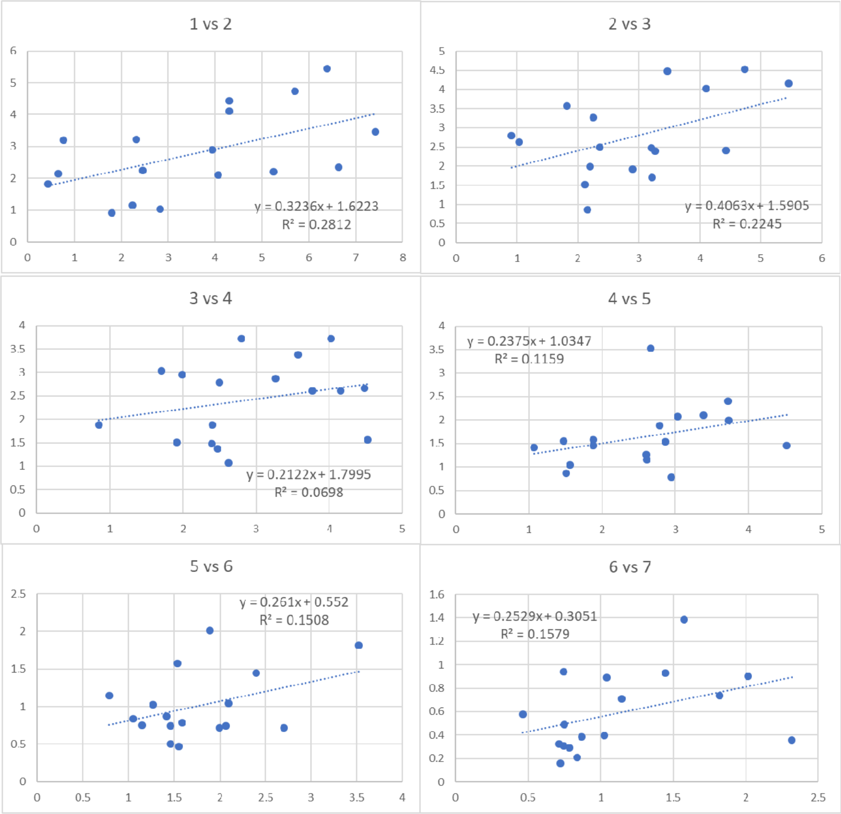


Figure 22 Consistency plots for the trawl index for area A. Age groups 1-6

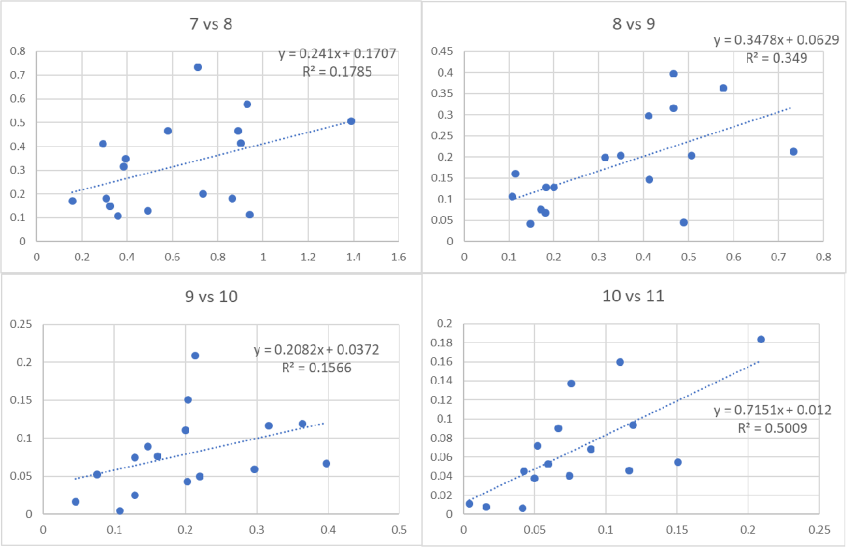


Figure 23 Consistency plots for the trawl index for area A. Age groups 7-11

7 Comparison of the trawl and acoustic index series

The acoustic index series and the trawl index series give a partly independent view of the stock situation over time. They are not totally independent, since the length information used to translate the acoustic backscatter into fish abundance partly comes from the same trawl hauls that are used for calculation of swept area indices, and the age information used to break the acoustic index down to age groups partly comes from the same trawl hauls that are used to calculate the swept area indices. However, the total backscatter, mainly determining the acoustic index, is totally independent of the catch rates in the trawl hauls, so in this respect the two series give independent information about the amount of fish. There are numerous reasons that these indices differ. Trawling on the bottom is only possible were the bottom is trawlable, that is soft and smooth and not to steep. In many areas of the coast it is not possible to trawl, and consequently the trawl hauls may not be representative of areas with hard and/or steep bottom. On the other hand, even though the acoustic method will cover all navigable waters, the acoustic backscatter signal is difficult to interpret where the bottom is steep, and in all areas the dead zone near the bottom will not be covered.

In Figure 24 the new acoustic index series and the swept-area series are compared, and also the landings statistics are included on the figure for comparison.

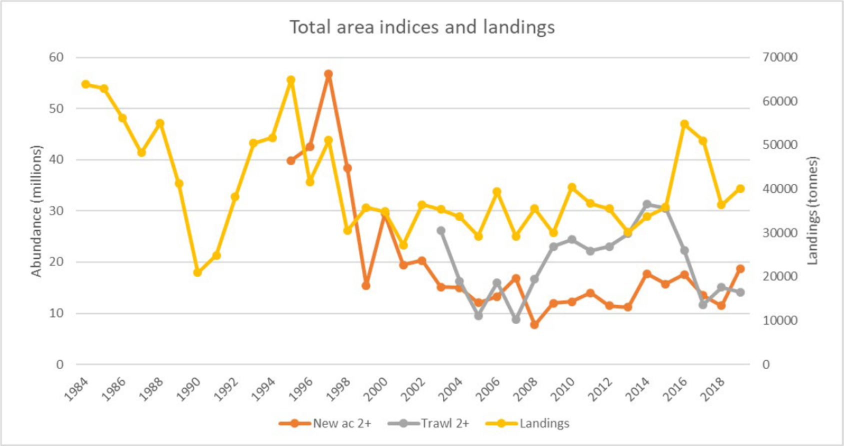


Figure 24. New acoustic series (2+), trawl index series (2+) and landings (taken from table 2.1a in ICES (2020)

The acoustic series, going back to 1995, show a decrease in the last part of the 1990s in parallel with the decrease in catches during that period, from a record high catch in 1995 to a level at about half of that total during the next decades. The acoustic index and the trawl index fluctuate without clear trends after 2003, in some years the acoustic index is higher than the trawl index, in other years it is the other way around. These index series are compared on age-group basis in figure 25 and 26. The consistency is quite good for many of the age groups, with r^2 in the range 0.2-0.6. However, for some age groups (mainly 3-6) the fit is poorer, with r^2 in the range 0.0-0.1.

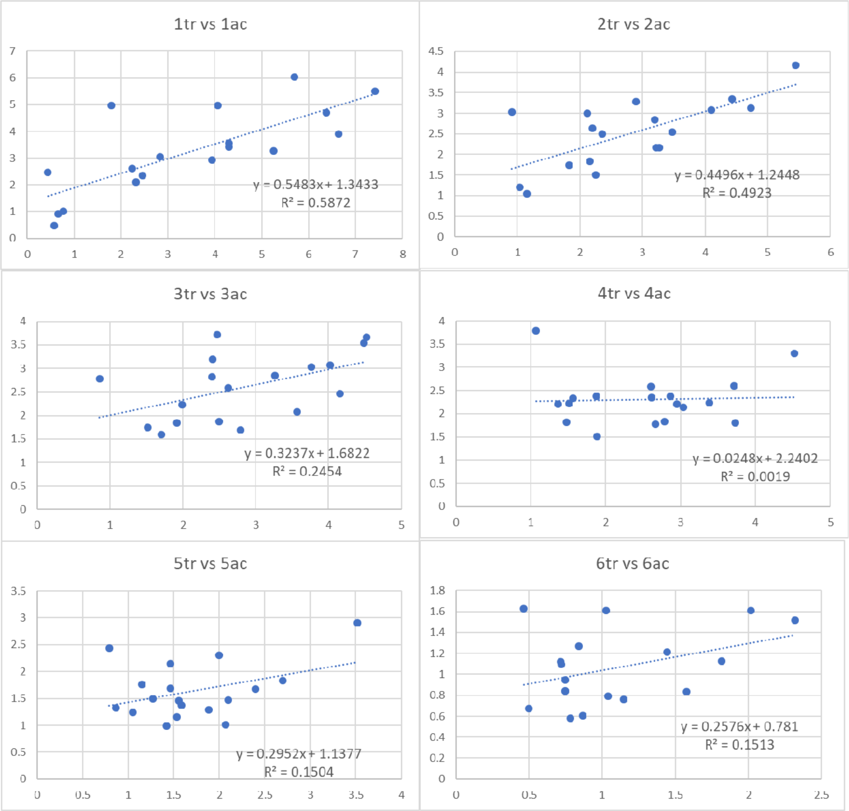


Figure 25 Comparison of acoustic index and trawl index for area A in the period 2003 to 2009, age groups 1-6

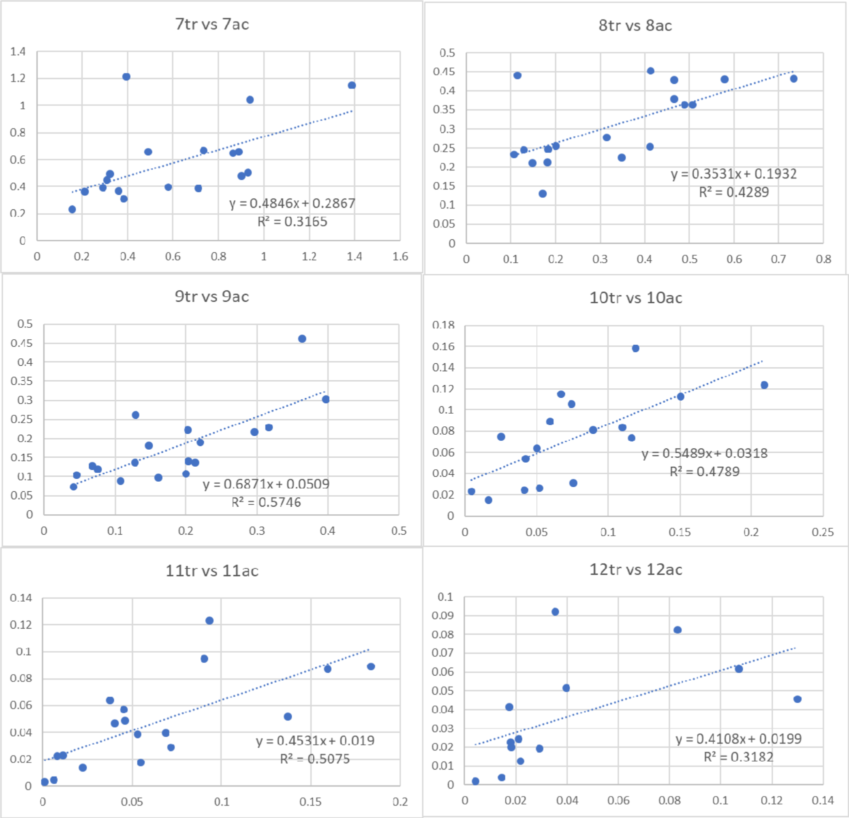


Figure 26 Comparison of acoustic index and trawl index for area A in the period 2003 to 2009, age groups 7-12

8 Recommendations for inclusion of these time series in the assessment of Norwegian Coastal Cod north of 62°N

Based on an evaluation of what has been presented in this document concerning data quality, survey coverage, and year-to-year consistency, we recommend that

1. The acoustic abundance index series from 1995 to 2019, for age groups 2-10, and their associated uncertainty estimates, may be used as input data in analytical assessment models for coastal cod in subarea A. The corresponding estimates of length- and weight-at-age may be used as estimates of length- and weight-at-age in the stock.
2. For subareas B and C, the acoustic indices for biomass of age 2+ may be used in biomass models or to assess changes in stock abundance from year to year, using methods for data-poor stocks.
3. The trawl index series from 2002 to 2019, for age groups 2-10 and their associated uncertainty estimates, may be used as input data in analytical assessment models for coastal

cod in subarea A. The corresponding estimates of length- and weight-at-age may be used as estimates of length- and weight-at-age in the stock.

4. For subareas B and C, the trawl indices of biomass of age 2+ may be used in biomass models or to assess changes in stock abundance from year to year, using methods for data-poor stocks.

9 References

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10 Appendix A. Acoustic abundance indices

10.1 Total area

Table A.1.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	0.031	26.961	11.015	7.254	7.207	7.023	4.618	1.561	0.678	0.340	0.042		0.134					
1996	22.040	17.763	10.743	12.628	6.669	7.434	3.386	1.269	0.213	0.034	0.123							
1997	0.018	17.724	17.907	20.326	9.288	5.243	2.652	0.919	0.393	0.059	0.014	0.019						
1998	1.269	8.713	10.675	10.731	9.626	4.238	1.806	0.951	0.141	0.123	0.037		0.009		0.026	0.026		
1999		2.562	3.990	4.112	3.283	2.794	0.941	0.214	0.030	0.067	0.015		0.005					
2000	1.979	5.264	8.468	7.426	4.935	4.320	3.106	0.712	0.307	0.087	0.029	0.026		0.010				
2001	0.207	2.725	4.847	4.734	4.343	2.516	1.637	1.018	0.219	0.031	0.036	0.029	0.009	0.018				
2002	0.418	1.822	2.894	3.842	4.809	3.659	3.273	1.154	0.459	0.110	0.105	0.003		0.033				
2003	4.819	3.324	2.401	3.516	3.757	2.245	1.743	0.749	0.423	0.207	0.024	0.004		0.026			0.016	
2004	4.722	3.217	3.000	3.430	3.605	2.358	1.490	0.572	0.311	0.113	0.106	0.005			0.003			
2005	0.037	1.264	1.723	3.226	2.716	2.107	1.321	0.473	0.263	0.155	0.028	0.064						
2006	6.705	5.126	2.126	3.172	2.692	1.936	1.847	1.129	0.177	0.130	0.012	0.023	0.004					
2007	26.051	2.543	3.567	3.118	4.005	2.557	1.703	1.258	0.456	0.123	0.026	0.014		0.005				
2008	13.880	2.399	1.815	1.733	1.573	1.015	0.763	0.425	0.230	0.099	0.026	0.023	0.025	0.000	0.000			
2009	2.032	3.973	1.945	2.898	3.289	1.738	0.812	0.471	0.558	0.199	0.033	0.065	0.002		0.001	0.002		
2010	1.300	5.701	2.689	3.141	2.522	1.978	0.681	0.364	0.465	0.248	0.120	0.052	0.023	0.006	0.002	0.004		
2011	0.518	3.795	3.527	2.746	3.011	2.018	1.544	0.421	0.355	0.149	0.094	0.019	0.060	0.013				
2012	0.098	3.650	2.315	3.724	2.026	1.343	0.913	0.541	0.256	0.109	0.124	0.049	0.019	0.024	0.006		0.003	
2013	0.583	5.142	3.306	1.857	1.960	1.510	0.952	0.695	0.451	0.216	0.088	0.089	0.062	0.004	0.006	0.002	0.006	
2014	17.884	6.474	4.500	3.324	2.337	3.135	1.714	1.202	0.698	0.509	0.098	0.087	0.082	0.007	0.007	0.025	0.013	0.015
2015	0.262	4.888	5.054	3.311	2.849	1.434	1.489	0.560	0.411	0.370	0.161	0.038	0.052	0.003	0.012		0.001	
2016	1.276	2.990	3.913	4.900	3.053	2.741	0.961	0.773	0.530	0.249	0.132	0.242	0.041	0.007	0.013		0.011	
2017	6.506	1.063	3.440	3.298	2.524	1.884	1.209	0.497	0.282	0.185	0.054	0.095	0.020	0.014				
2018	0.690	5.028	2.993	2.013	2.606	1.581	1.151	0.522	0.267	0.196	0.081	0.057	0.013	0.013		0.004	0.001	
2019	0.925	3.464	3.443	4.787	3.112	3.160	1.942	1.222	0.317	0.384	0.158	0.059	0.094	0.013	0.003	0.007	0.005	
2020	0.169	0.498	1.474	2.583	2.927	1.873	0.877	0.563	0.313	0.176	0.076	0.051		0.000	0.005	0.001		

Table A.1.2. CV on abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	1.007	0.165	0.103	0.063	0.112	0.125	0.200	0.163	0.308	0.477	0.408		0.221					
1996	0.687	0.197	0.093	0.105	0.118	0.105	0.217	0.437	0.393	0.533	0.301							
1997	0.970	0.228	0.214	0.134	0.134	0.127	0.229	0.218	0.412	0.903	0.815	1.060						
1998	0.856	0.249	0.118	0.094	0.139	0.142	0.266	0.509	0.313	0.864	1.039		0.935		0.000	0.000		
1999		0.237	0.092	0.093	0.169	0.154	0.184	0.157	0.459	0.132	0.923		0.917					
2000	0.877	0.136	0.145	0.097	0.076	0.080	0.094	0.133	0.244	0.399	0.393	0.333		0.903				
2001	1.052	0.178	0.294	0.163	0.139	0.161	0.163	0.201	0.286	0.701	0.689	0.475	0.745	0.864				
2002	0.859	0.162	0.126	0.136	0.101	0.088	0.062	0.149	0.253	0.704	0.563	1.070		0.902				
2003	0.310	0.262	0.238	0.122	0.120	0.113	0.142	0.160	0.188	0.245	0.344	1.032		1.687			1.009	
2004	0.185	0.158	0.135	0.116	0.086	0.096	0.130	0.125	0.175	0.644	0.238	0.611			0.808			
2005	0.915	0.131	0.159	0.124	0.067	0.096	0.130	0.117	0.265	0.329	0.326	0.843						
2006	0.519	1.048	0.584	0.122	0.119	0.115	0.240	0.205	0.168	0.212	0.000	0.841	0.992					
2007	0.634	0.203	0.176	0.174	0.142	0.156	0.150	0.201	0.297	0.433	0.841	1.296		1.253				
2008	0.343	0.238	0.182	0.138	0.129	0.114	0.136	0.187	0.231	0.379	0.373	0.476	0.501	0.896	0.896			
2009	1.030	0.213	0.152	0.106	0.095	0.134	0.106	0.154	0.135	0.234	0.308	0.205	0.863		1.097	0.601		
2010	0.509	0.395	0.165	0.147	0.114	0.101	0.185	0.190	0.207	0.195	0.202	0.206	0.567	0.292	0.789	0.566		
2011	0.827	0.125	0.126	0.110	0.119	0.108	0.125	0.252	0.163	0.192	0.277	0.517	0.338	0.866				
2012	0.596	0.200	0.185	0.122	0.128	0.126	0.098	0.177	0.162	0.233	0.179	0.415	0.465	0.559	0.572		0.795	
2013	0.543	0.129	0.149	0.120	0.133	0.119	0.118	0.165	0.195	0.312	0.345	0.357	0.485	0.919	0.569	0.905	0.666	
2014	1.038	0.145	0.173	0.110	0.137	0.138	0.119	0.139	0.088	0.210	0.392	0.331	0.320	0.926	0.583	0.493	0.742	0.898
2015	0.706	0.151	0.097	0.089	0.068	0.086	0.096	0.142	0.140	0.130	0.271	0.360	0.427	0.804	0.554		1.010	
2016	0.564	0.281	0.117	0.103	0.074	0.115	0.141	0.160	0.195	0.347	0.304	0.452	0.431	0.399	0.526		2.264	
2017	0.635	0.326	0.151	0.119	0.151	0.133	0.166	0.206	0.257	0.421	0.246	0.410	0.522	0.746				
2018	0.413	0.175	0.157	0.155	0.148	0.143	0.071	0.173	0.554	0.141	0.345	0.428	0.603	0.503		0.515	1.528	
2019	0.232	0.137	0.172	0.117	0.093	0.083	0.101	0.100	0.194	0.232	0.235	0.207	0.631	0.518	1.053	1.170	1.069	
2020	0.827	0.320	0.134	0.158	0.111	0.133	0.141	0.220	0.299	0.466	0.527	0.433		1.148	1.151	1.011		

Table A.1.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	0.000	1.595	3.414	5.298	10.124	14.865	12.579	7.364	4.352	2.460	0.144		2.387					
1996	0.151	0.716	2.459	9.286	9.228	14.394	9.253	5.554	1.402	0.378	2.020							
1997	0.000	0.742	4.335	13.470	12.866	10.135	7.839	2.911	1.564	0.570	0.151	0.098						
1998	0.012	0.459	3.533	9.317	13.530	9.495	5.873	4.444	0.832	0.675	0.587		0.106		0.525	0.690		
1999		0.163	1.110	3.412	5.253	5.734	2.634	0.974	0.225	0.768	0.033		0.083					
2000	0.023	0.368	2.708	5.928	7.447	10.068	8.850	3.148	2.040	0.714	0.343	0.322		0.042				
2001	0.001	0.202	1.940	4.520	7.163	5.798	5.105	3.435	1.292	0.213	0.453	0.516	0.078	0.275				
2002	0.004	0.207	1.324	4.145	10.772	12.037	15.280	7.214	2.094	0.325	0.688	0.066		0.403				
2003	0.044	0.232	0.878	2.892	5.256	4.996	5.326	2.982	2.183	1.278	0.216	0.008		0.288			0.404	
2004	0.031	0.286	1.059	3.022	6.128	5.124	4.709	2.130	1.265	0.479	1.015	0.046			0.025			
2005	0.001	0.132	0.724	3.068	5.706	5.325	3.886	1.927	0.906	0.745	0.378	1.061						
2006	0.054	0.386	0.856	3.191	4.501	4.455	6.237	4.401	0.907	0.909	0.080	0.566	0.017					
2007	0.169	0.263	1.806	3.331	7.546	6.659	5.502	5.810	2.963	1.387	0.447	0.038		0.098				
2008	0.086	0.236	0.820	1.990	3.216	3.378	2.586	1.968	1.111	0.416	0.105	0.272	0.125	0.003	0.003			
2009	0.018	0.295	0.779	3.265	6.285	4.643	2.904	2.071	2.668	1.144	0.153	0.254	0.005		0.002	0.015		
2010	0.013	0.349	1.378	3.541	4.856	5.497	2.401	1.706	2.643	1.536	0.755	0.340	0.188	0.013	0.022	0.035		
2011	0.004	0.263	1.323	3.126	6.611	6.104	6.308	2.243	2.143	0.960	0.491	0.070	0.498	0.060				
2012	0.001	0.268	0.833	4.370	4.211	4.133	3.423	2.566	1.428	0.688	0.866	0.233	0.120	0.129	0.043		0.012	
2013	0.007	0.423	1.246	1.662	3.477	4.405	3.267	2.707	2.361	1.239	0.363	0.805	0.768	0.014	0.049	0.032	0.090	
2014	0.119	0.515	1.790	3.802	4.529	9.257	6.521	5.706	3.689	3.017	0.914	0.638	0.586	0.031	0.058	0.251	0.110	0.366
2015	0.001	0.372	2.001	3.673	5.571	4.061	5.054	2.655	2.078	2.252	0.970	0.335	0.257	0.031	0.118		0.015	
2016	0.009	0.219	1.432	6.363	6.806	9.072	3.621	3.389	3.349	1.915	0.851	2.480	0.209	0.032	0.111		0.095	
2017	0.024	0.084	1.782	3.530	5.057	5.635	4.825	2.249	1.998	1.168	0.337	0.902	0.102	0.213				
2018	0.004	0.257	1.541	2.341	5.458	5.214	4.334	2.817	1.598	1.406	0.572	0.233	0.065	0.113		0.079	0.007	
2019	0.008	0.230	1.264	5.626	6.381	9.351	7.683	5.747	1.634	2.419	1.091	0.477	1.047	0.127	0.027	0.082	0.038	
2020	0.001	0.043	0.800	3.417	5.736	6.224	3.032	3.247	1.916	1.357	0.469	0.365		0.001	0.036	0.013		

Table A.1.4. Length at age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	10.32	18.93	32.17	42.33	51.98	59.07	64.26	77.92	84.99	87.89	66.98		121.24					
1996	9.36	16.66	28.83	42.12	52.28	58.17	64.66	75.70	86.68	99.18	117.56							
1997	9.01	16.70	29.27	40.89	51.93	58.40	66.89	68.71	71.67	102.00	104.42	83.00						
1998	10.62	18.05	32.04	44.30	52.03	60.09	68.11	75.99	85.28	83.72	108.43		105.00		121.00	135.00		
1999		19.52	31.19	44.18	54.57	59.18	65.77	75.68	89.32	101.33	59.00		118.00					
2000	10.84	20.08	32.38	43.35	53.30	61.11	64.79	74.55	84.79	86.55	107.35	102.13		79.00				
2001	8.09	19.99	33.90	45.84	55.13	60.77	65.76	67.88	81.74	87.23	107.06	114.32	99.84	112.68				
2002	10.48	22.97	35.07	47.29	59.65	67.22	75.42	81.62	76.42	67.24	85.16	115.00		108.00				
2003	9.71	19.33	33.45	43.70	52.16	60.48	67.16	72.87	77.01	80.32	92.80	61.00		106.31			143.00	
2004	8.97	21.12	33.05	44.22	54.94	59.29	67.31	69.99	71.96	75.38	92.84	91.32			89.00			
2005	11.44	21.97	34.80	45.10	57.91	62.71	64.88	71.87	71.14	75.26	106.58	108.92						
2006	9.43	20.68	34.66	46.28	55.04	60.34	68.05	71.02	77.35	85.28	86.00	125.00	76.00					
2007	9.20	21.46	36.33	47.10	56.90	62.92	67.66	74.15	84.14	100.71	113.68	63.01		123.00				
2008	9.28	22.26	35.87	48.72	58.44	68.49	69.09	76.16	75.58	72.09	71.91	100.25	75.56	100.00	89.00			
2009	9.74	19.82	33.65	47.88	57.25	64.28	70.03	75.13	75.49	81.68	75.17	69.32	69.00		73.00	94.94		
2010	10.64	18.92	37.04	48.18	57.32	64.39	70.61	76.38	77.12	82.07	83.16	80.18	88.20	61.58	104.00	89.97		
2011	9.48	20.10	33.60	48.36	60.20	66.93	72.32	78.96	80.93	81.32	77.59	74.36	93.14	75.21				
2012	9.99	20.36	33.07	48.67	59.89	66.59	72.03	76.90	80.64	82.81	85.16	78.35	84.89	83.28	90.72		79.00	
2013	11.56	20.96	34.05	45.15	56.49	66.80	70.65	72.89	78.61	82.37	74.51	90.29	100.75	69.54	88.38	113.00	125.00	
2014	9.24	21.05	34.56	48.92	58.22	66.93	73.29	77.90	79.88	82.14	97.37	86.29	84.18	81.05	85.00	91.11	93.45	132.00
2015	9.65	20.22	34.23	48.23	58.38	66.30	69.47	77.15	78.70	82.51	84.53	88.98	77.69	95.00	98.15		101.00	
2016	9.36	20.33	33.67	50.29	60.03	69.24	72.51	75.06	84.08	89.09	82.44	97.85	80.52	76.64	96.75		96.00	
2017	8.24	20.34	37.27	47.73	59.03	66.82	73.90	78.31	86.45	84.19	84.37	96.94	83.08	111.43				
2018	10.04	16.95	37.38	48.53	60.08	69.14	71.48	81.28	85.20	86.27	87.52	75.13	81.27	93.48		115.46	93.00	
2019	10.11	19.89	33.35	49.27	59.27	67.46	73.53	77.35	79.47	82.90	85.52	91.33	96.75	99.46	96.00	109.00	96.00	
2020	10.72	20.60	36.52	49.67	58.02	67.85	70.46	80.90	83.33	89.49	83.05	86.92		84.00	91.19	97.00		

Table A.1.5. Weight at age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	9	59	310	730	1405	2118	2754	4733	6494	7359	3297		17869					
1996	8	41	229	736	1385	1940	2702	4269	6627	10964	16213							
1997	8	42	240	665	1384	1932	2947	3175	4264	9600	11387	5140						
1998	10	53	332	869	1405	2229	3251	4432	5987	5884	16233		12260		19880	26100		
1999		64	278	828	1602	2059	2811	4567	7363	11535	2190		18340					
2000	12	70	320	798	1508	2329	2848	4424	6726	8851	12330	12873		4220				
2001	5	74	390	953	1648	2300	3116	3386	5983	7187	11653	17035	8460	15001				
2002	9	114	460	1077	2248	3295	4674	6289	4656	3785	7783	21980		12350				
2003	9	68	366	821	1397	2225	3056	3965	5110	6049	8878	2030		12562			25600	
2004	7	89	353	883	1702	2175	3158	3735	4004	4500	9936	9078			7130			
2005	16	105	419	954	2103	2529	2952	4081	3466	4745	14164	15482						
2006	8	84	424	1006	1673	2305	3380	3944	5151	6931	6530	25080	4220					
2007	7	103	508	1069	1889	2612	3238	4638	6497	11158	15891	2981		21100				
2008	6	100	453	1148	2046	3321	3392	4648	4869	4344	4077	10683	4730	9250	8520			
2009	10	75	401	1127	1911	2668	3569	4374	4764	5720	4819	3817	3084		3122	9672		
2010	10	64	507	1127	1927	2782	3545	4693	5714	6198	6336	6547	7962	2062	12154	7475		
2011	8	69	374	1136	2195	3020	4096	5365	6040	6395	5275	3933	8509	4558				
2012	8	74	359	1170	2084	3086	3748	4717	5530	6291	7000	5018	7205	6444	7052		4630	
2013	12	83	377	893	1773	2915	3432	3911	5284	5662	4216	8854	12081	4092	7780	16220	16300	
2014	7	80	399	1142	1935	2951	3804	4750	5282	5933	8898	7135	7062	4752	7920	9591	8282	24950
2015	8	76	395	1109	1956	2832	3397	4764	5073	6059	6231	8733	5427	10170	9930		11240	
2016	7	74	367	1295	2230	3307	3777	4399	6283	7696	6307	10446	5020	4413	9411		8325	
2017	4	83	519	1073	2006	2984	3990	4515	7030	6363	6225	9634	5089	14019				
2018	5	52	512	1169	2099	3305	3771	5424	5961	7088	7024	4283	5345	9367		15761	7350	
2019	9	67	367	1176	2049	2959	3958	4696	5085	6396	6804	8025	10306	9786	9585	12345	7040	
2020	8	91	538	1313	1958	3318	3457	5706	6190	7737	6667	7430		5165	7911	9765		

Table A.1.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
1995	40.034	2.670	0.067
1996	42.500	2.417	0.057
1997	56.823	5.676	0.100
1998	38.388	2.848	0.074
1999	15.451	1.184	0.077
2000	29.426	2.112	0.072
2001	19.437	2.667	0.137
2002	20.341	1.462	0.072
2003	15.111	1.527	0.101
2004	14.994	1.001	0.067
2005	12.075	0.766	0.063
2006	13.247	1.345	0.101
2007	16.833	1.429	0.085
2008	7.728	0.770	0.100
2009	12.012	0.886	0.074
2010	12.295	0.910	0.074
2011	13.958	0.921	0.066
2012	11.452	0.939	0.082
2013	11.204	0.992	0.089
2014	17.758	1.520	0.086
2015	15.744	0.858	0.054
2016	17.567	0.860	0.049
2017	13.501	1.118	0.083
2018	11.498	1.015	0.088
2019	18.706	1.279	0.068
2020	10.920	0.780	0.071

10.2 Subarea A: North of 67°N

Table A.2.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	0.031	26.495	8.774	4.974	6.382	6.440	4.373	1.309	0.532	0.319	0.041		0.090					
1996	21.458	17.580	9.025	8.592	4.576	5.306	2.723	1.022	0.213	0.032	0.024							
1997	0.018	16.567	15.358	16.930	7.710	4.484	2.316	0.716	0.328	0.059	0.014	0.019						
1998	1.260	8.360	6.757	8.524	8.261	3.717	1.530	0.700	0.102	0.122	0.037		0.009		0.000	0.000		
1999		2.494	3.486	3.387	2.788	2.498	0.751	0.172	0.030	0.022	0.015		0.005					
2000	1.979	5.028	7.439	5.831	3.939	3.853	2.825	0.622	0.258	0.071	0.013	0.010		0.010				
2001	0.207	2.711	4.551	4.246	3.776	2.184	1.499	0.974	0.149	0.029	0.036	0.029	0.009	0.018				
2002	0.418	1.188	2.071	2.532	2.926	2.075	0.970	0.596	0.293	0.106	0.089	0.003		0.033				
2003	4.798	3.276	2.168	3.026	3.303	1.838	1.519	0.651	0.364	0.190	0.024	0.003		0.026			0.016	
2004	4.431	3.046	2.643	2.819	2.589	1.686	1.094	0.371	0.213	0.104	0.064	0.005			0.003			
2005	0.019	0.904	1.201	2.228	1.816	1.490	0.843	0.234	0.233	0.127	0.015	0.064						
2006	6.231	4.981	1.836	2.587	2.210	1.453	1.612	1.046	0.130	0.089	0.000	0.023	0.004					
2007	26.051	2.458	3.037	2.778	3.794	2.437	1.632	1.215	0.441	0.120	0.023	0.014		0.005				
2008	13.853	2.344	1.739	1.684	1.511	0.985	0.761	0.399	0.225	0.097	0.026	0.023	0.024	0.000	0.000			
2009	1.804	3.907	1.502	2.084	2.596	1.373	0.605	0.386	0.378	0.140	0.031	0.029	0.002		0.001	0.002		
2010	1.170	5.509	2.503	2.853	2.240	1.679	0.583	0.309	0.432	0.229	0.113	0.052	0.023	0.002	0.002	0.004		
2011	0.363	2.104	2.542	1.869	2.372	1.469	1.215	0.394	0.278	0.137	0.074	0.018	0.046	0.013				
2012	0.098	3.561	2.170	3.546	1.832	1.154	0.791	0.503	0.254	0.107	0.124	0.049	0.019	0.024	0.006		0.003	
2013	0.421	4.694	3.084	1.597	1.770	1.287	0.838	0.657	0.430	0.216	0.083	0.089	0.062	0.004	0.006	0.002	0.006	
2014	16.680	6.030	4.171	3.066	2.137	2.904	1.609	1.151	0.429	0.462	0.089	0.087	0.082	0.007	0.007	0.025	0.013	0.015
2015	0.262	3.421	3.122	2.465	1.802	1.017	1.128	0.477	0.363	0.303	0.158	0.038	0.052	0.003	0.012		0.001	
2016	1.272	2.921	3.341	3.667	2.349	2.308	0.841	0.669	0.452	0.222	0.115	0.123	0.041	0.004	0.013		0.011	
2017	6.506	1.018	3.289	3.202	2.335	1.764	1.122	0.450	0.256	0.181	0.054	0.095	0.020	0.014				
2018	0.680	4.977	2.847	1.837	2.376	1.246	0.946	0.494	0.246	0.136	0.081	0.057	0.013	0.013		0.004	0.001	
2019	0.305	2.607	2.992	3.724	2.221	2.149	1.272	0.656	0.212	0.262	0.106	0.040	0.092	0.013	0.003	0.007	0.005	
2020	0.162	0.475	1.039	1.743	2.204	1.329	0.674	0.363	0.246	0.074	0.075	0.047		0.000	0.004	0.001		

Table A.2.2. CV on abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	1.007	0.168	0.130	0.090	0.124	0.136	0.211	0.194	0.395	0.505	0.412		0.328					
1996	0.700	0.198	0.111	0.154	0.168	0.141	0.259	0.538	0.394	0.516	1.565							
1997	0.970	0.239	0.246	0.160	0.156	0.142	0.250	0.259	0.470	0.903	0.815	1.060						
1998	0.860	0.259	0.186	0.117	0.161	0.161	0.311	0.690	0.401	0.867	1.039		0.935					
1999		0.243	0.105	0.114	0.198	0.173	0.229	0.193	0.472	0.402	0.923		0.917					
2000	0.877	0.143	0.164	0.124	0.095	0.090	0.103	0.151	0.291	0.489	0.894	0.901		0.903				
2001	1.052	0.179	0.313	0.182	0.159	0.186	0.176	0.209	0.406	0.719	0.689	0.475	0.745	0.864				
2002	0.859	0.248	0.174	0.205	0.160	0.136	0.147	0.228	0.363	0.723	0.665	1.070		0.902				
2003	0.311	0.266	0.263	0.140	0.137	0.137	0.161	0.182	0.218	0.262	0.346	0.694		1.687			1.009	
2004	0.196	0.166	0.153	0.141	0.118	0.127	0.171	0.172	0.253	0.694	0.330	0.611			0.808			
2005	0.774	0.181	0.228	0.177	0.099	0.136	0.204	0.228	0.298	0.400	0.606	0.843						
2006	0.559	1.079	0.677	0.149	0.145	0.153	0.275	0.221	0.228	0.311		0.841	0.992					
2007	0.634	0.209	0.201	0.194	0.149	0.163	0.156	0.207	0.307	0.446	0.969	1.296		1.253				
2008	0.343	0.244	0.189	0.142	0.134	0.118	0.136	0.198	0.236	0.386	0.373	0.481	0.521	0.896	0.896			
2009	1.160	0.217	0.197	0.146	0.118	0.168	0.139	0.183	0.192	0.314	0.246	0.442	0.863		1.097	0.601		
2010	0.563	0.408	0.177	0.162	0.128	0.119	0.216	0.223	0.223	0.210	0.215	0.207	0.567	1.171	0.789	0.566		
2011	1.075	0.218	0.170	0.159	0.146	0.147	0.155	0.268	0.205	0.195	0.347	0.510	0.443	0.866				
2012	0.598	0.205	0.197	0.129	0.141	0.147	0.113	0.190	0.163	0.238	0.179	0.415	0.465	0.559	0.572		0.795	
2013	0.681	0.140	0.160	0.140	0.147	0.139	0.134	0.174	0.204	0.312	0.365	0.357	0.485	0.919	0.569	0.905	0.666	
2014	1.112	0.155	0.186	0.119	0.150	0.149	0.127	0.146	0.143	0.231	0.433	0.331	0.320	0.926	0.583	0.493	0.742	0.898
2015	0.706	0.211	0.157	0.114	0.100	0.118	0.121	0.160	0.157	0.163	0.267	0.360	0.424	0.804	0.554		1.010	
2016	0.565	0.290	0.152	0.096	0.078	0.105	0.162	0.169	0.208	0.390	0.313	0.225	0.431	0.647	0.526		2.264	
2017	0.635	0.341	0.158	0.123	0.163	0.142	0.179	0.227	0.282	0.432	0.246	0.410	0.522	0.746				
2018	0.420	0.177	0.165	0.171	0.162	0.180	0.087	0.184	0.604	0.204	0.345	0.428	0.603	0.503		0.515	1.528	
2019	0.679	0.180	0.198	0.147	0.127	0.120	0.151	0.176	0.283	0.333	0.348	0.275	0.636	0.518	1.053	1.170	1.069	
2020	0.833	0.326	0.141	0.148	0.133	0.137	0.157	0.224	0.313	0.472	0.526	0.419		1.148	0.817	1.011		

Table A.2.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	0.000	1.541	2.472	3.574	8.904	13.457	11.950	6.114	3.126	2.269	0.143		1.576					
1996	0.146	0.709	1.947	5.779	6.165	10.249	7.685	4.485	1.401	0.368	0.474							
1997	0.000	0.677	3.790	11.041	10.756	8.589	6.793	2.140	1.152	0.570	0.151	0.098						
1998	0.012	0.410	1.751	7.160	11.622	8.458	4.866	3.312	0.527	0.674	0.587		0.106		0.000	0.000		
1999		0.155	0.947	2.695	4.204	4.894	2.062	0.733	0.217	0.144	0.033		0.083					
2000	0.023	0.347	2.398	4.816	6.154	9.109	7.947	2.654	1.529	0.406	0.111	0.088		0.042				
2001	0.001	0.199	1.778	3.973	6.276	5.075	4.503	3.240	0.679	0.205	0.453	0.516	0.078	0.275				
2002	0.004	0.105	0.737	2.351	4.653	4.935	3.358	2.646	1.109	0.289	0.553	0.066		0.403				
2003	0.044	0.228	0.783	2.488	4.716	4.167	4.746	2.687	2.016	1.232	0.216	0.006		0.288			0.404	
2004	0.029	0.269	0.896	2.463	4.253	3.623	3.504	1.407	1.012	0.418	0.320	0.046			0.025			
2005	0.000	0.089	0.526	1.947	3.135	3.291	2.133	0.860	0.813	0.706	0.129	1.061						
2006	0.050	0.368	0.695	2.558	3.643	3.235	5.626	4.119	0.575	0.714	0.000	0.566	0.017					
2007	0.169	0.239	1.469	2.959	7.057	6.266	5.159	5.471	2.811	1.347	0.400	0.038		0.098				
2008	0.086	0.225	0.742	1.869	2.978	3.285	2.581	1.807	1.097	0.402	0.105	0.272	0.123	0.003	0.003			
2009	0.014	0.288	0.537	2.152	4.877	3.708	2.308	1.786	1.960	0.763	0.150	0.164	0.005		0.002	0.015		
2010	0.013	0.329	1.270	3.110	4.191	4.605	2.075	1.445	2.195	1.434	0.723	0.340	0.188	0.004	0.022	0.035		
2011	0.003	0.125	1.024	2.183	5.403	4.579	4.488	2.024	1.561	0.855	0.388	0.067	0.360	0.060				
2012	0.001	0.259	0.774	4.060	3.700	3.344	2.920	2.374	1.422	0.657	0.866	0.233	0.120	0.129	0.043		0.012	
2013	0.005	0.399	1.184	1.469	3.215	3.913	2.883	2.593	2.101	1.239	0.350	0.805	0.768	0.014	0.049	0.032	0.090	
2014	0.107	0.480	1.497	3.446	4.057	8.515	5.938	5.346	2.390	2.572	0.845	0.638	0.586	0.031	0.058	0.251	0.110	0.366
2015	0.001	0.252	1.275	2.748	3.860	3.036	4.249	2.297	1.916	1.795	0.962	0.335	0.254	0.031	0.118		0.015	
2016	0.009	0.213	1.151	4.034	4.465	7.685	3.293	3.123	2.677	1.632	0.793	1.262	0.209	0.019	0.111		0.095	
2017	0.024	0.080	1.655	3.379	4.591	5.205	4.488	2.104	1.811	1.131	0.337	0.902	0.102	0.213				
2018	0.004	0.255	1.494	2.026	4.962	3.986	3.552	2.648	1.448	1.163	0.572	0.233	0.065	0.113		0.079	0.007	
2019	0.002	0.163	1.112	4.212	4.414	6.413	4.854	3.382	1.272	1.623	0.840	0.392	1.042	0.127	0.027	0.082	0.038	
2020	0.001	0.041	0.384	1.749	4.414	3.853	2.271	1.786	1.643	0.652	0.466	0.342		0.001	0.029	0.013		

Table A.2.4. Length by age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	10.32	18.86	31.39	42.05	51.83	58.77	64.27	77.55	82.36	87.08	67.02		123.50					
1996	9.35	16.68	28.32	41.25	51.87	58.06	65.16	74.80	86.75	99.57	115.00							
1997	9.01	16.61	29.56	40.75	51.99	58.11	66.89	66.80	68.62	102.00	104.42	83.00						
1998	10.62	17.76	30.26	44.04	51.99	60.31	67.81	74.93	82.22	83.81	108.43		105.00					
1999		19.41	31.17	44.06	54.06	58.69	65.44	74.00	88.95	88.21	59.00		118.00					
2000	10.84	20.01	32.55	43.97	53.96	61.39	64.53	73.81	81.94	80.31	95.00	95.83		79.00				
2001	8.09	19.97	33.70	45.70	55.37	61.09	65.17	67.64	76.07	87.23	107.08	114.32	99.84	112.68				
2002	10.48	21.64	32.65	45.02	54.46	62.01	68.83	72.35	70.52	66.73	85.06	115.00		108.00				
2003	9.71	19.30	33.32	43.76	52.60	60.94	67.73	73.67	78.79	81.86	92.81	61.00		106.31			143.00	
2004	8.96	21.11	32.71	44.03	54.46	59.25	67.72	70.52	75.47	74.17	78.15	91.32			89.00			
2005	10.83	21.55	35.73	44.69	55.45	60.55	62.61	71.42	71.73	80.28	93.20	108.92						
2006	9.36	20.55	34.08	46.19	54.99	59.98	68.76	71.39	74.57	89.02		125.00	76.00					
2007	9.20	21.18	35.90	47.15	56.79	62.73	67.32	73.73	83.42	100.54	116.00	63.01		123.00				
2008	9.28	22.14	35.38	48.30	57.91	68.55	69.09	75.83	75.85	71.71	71.91	100.50	76.19	100.00	89.00			
2009	9.31	19.77	32.91	46.75	57.08	64.72	71.36	76.56	76.92	81.20	75.56	77.44	69.00		73.00	94.94		
2010	10.95	18.85	36.94	47.84	56.92	64.14	71.22	76.43	75.46	82.06	83.12	80.25	88.20	60.00	104.00	89.97		
2011	9.48	19.13	34.62	48.69	61.02	67.55	71.22	78.14	80.80	80.53	78.30	74.68	91.37	75.21				
2012	9.99	20.30	32.93	48.26	59.32	65.46	71.40	76.44	80.72	82.21	85.18	78.35	84.89	83.28	90.72		79.00	
2013	11.52	21.22	34.28	45.56	56.92	67.73	70.94	73.28	77.28	82.37	75.33	90.29	100.75	69.54	88.38	113.00	125.00	
2014	9.12	21.05	33.75	48.79	57.97	66.89	72.83	77.47	81.67	80.79	97.65	86.29	84.20	81.05	85.00	91.11	93.45	132.00
2015	9.65	19.89	34.64	48.32	60.32	67.78	72.64	77.88	79.92	82.17	84.77	88.98	77.76	95.00	98.15		101.00	
2016	9.36	20.29	33.09	48.16	58.03	69.50	73.48	76.86	82.46	87.50	83.78	92.38	80.52	81.82	96.75		96.00	
2017	8.24	20.30	36.98	47.56	58.69	66.70	73.97	79.48	85.96	83.97	84.37	96.94	83.08	111.43				
2018	10.03	16.97	37.62	48.03	60.12	68.65	71.49	81.07	84.73	92.15	87.52	75.13	81.27	93.48		115.46	93.00	
2019	9.51	19.64	33.67	49.05	59.01	68.22	73.51	80.38	84.43	84.10	91.63	97.77	97.12	99.46	96.00	109.00	96.00	
2020	10.70	20.47	33.36	46.64	58.76	65.99	70.57	77.97	85.63	90.86	83.04	87.25		84.00	91.43	97.00		

Table A.2.5. Weight by age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17
1995	9	58	282	719	1395	2091	2767	4693	5905	7211	3300		17490					
1996	8	41	216	672	1349	1939	2779	4223	6638	11146	20000							
1997	8	41	244	655	1393	1914	2921	2988	3768	9600	11387	5140						
1998	10	49	259	840	1406	2261	3173	4320	5275	5896	16233		12260					
1999		63	272	793	1508	1964	2759	4257	7262	6561	2190		18340					
2000	12	69	322	826	1561	2363	2811	4260	5977	6061	8736	9458		4220				
2001	5	74	377	933	1660	2320	2998	3338	4478	7193	11658	17035	8460	15001				
2002	9	88	357	918	1595	2377	3468	4415	3868	3588	8921	21980		12350				
2003	9	68	361	820	1427	2269	3127	4114	5493	6350	8881	2030		12562			25600	
2004	6	88	338	877	1646	2153	3197	3810	4656	4184	5102	9078			7130			
2005	14	99	436	878	1727	2205	2542	3666	3520	5562	8810	15482						
2006	8	83	400	989	1649	2231	3502	3992	4445	8004		25080	4220					
2007	7	97	486	1066	1865	2579	3168	4520	6363	11111	17480	2981		21100				
2008	6	97	427	1109	1971	3327	3393	4543	4921	4270	4077	10741	4962	9250	8520			
2009	8	74	357	1032	1878	2695	3803	4599	5146	5349	4886	5474	3084		3122	9672		
2010	11	63	502	1088	1872	2745	3586	4684	5096	6263	6448	6562	7962	2635	12154	7475		
2011	8	59	401	1165	2279	3109	3702	5163	5593	6174	5325	3982	8151	4558				
2012	8	73	355	1141	2026	2907	3690	4688	5549	6118	7004	5018	7205	6444	7052		4630	
2013	12	85	384	918	1817	3041	3438	3963	4926	5662	4340	8854	12081	4092	7780	16220	16300	
2014	7	80	359	1122	1894	2929	3690	4646	5562	5550	9029	7135	7066	4752	7920	9591	8282	24950
2015	8	73	406	1115	2145	2987	3774	4839	5299	5869	6281	8733	5443	10170	9930		11240	
2016	7	73	347	1101	1904	3327	3928	4689	5885	7273	6709	10371	5020	5773	9411		8325	
2017	4	83	504	1058	1969	2943	3997	4676	6985	6306	6225	9634	5089	14019				
2018	5	52	522	1109	2094	3206	3763	5391	5818	8438	7024	4283	5345	9367		15761	7350	
2019	8	62	372	1131	1984	2983	3815	5141	5908	6420	7801	9778	10405	9786	9585	12345	7040	
2020	8	91	368	1002	2001	2904	3374	4938	6718	8514	6665	7555		5165	7984	9765		

Table A.2.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
1995	33.395	2.667	0.080
1996	31.513	2.386	0.076
1997	47.938	5.599	0.117
1998	29.757	2.844	0.096
1999	13.154	1.183	0.090
2000	24.871	2.111	0.085
2001	17.500	2.666	0.152
2002	11.695	1.446	0.124
2003	13.128	1.526	0.116
2004	11.593	0.990	0.085
2005	8.253	0.766	0.093
2006	10.989	1.345	0.122
2007	15.494	1.420	0.092
2008	7.476	0.770	0.103
2009	9.128	0.883	0.097
2010	11.022	0.909	0.083
2011	10.425	0.917	0.088
2012	10.581	0.939	0.089
2013	10.131	0.993	0.098
2014	16.259	1.520	0.093
2015	10.942	0.857	0.078
2016	14.157	0.795	0.056
2017	12.782	1.118	0.087
2018	10.298	1.015	0.099
2019	13.753	1.271	0.092
2020	7.800	0.674	0.086

10.3 Subarea B: Between 65° and 67°N

Table A.3.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995	0.000	0.319	1.494	1.205	0.390	0.219	0.204	0.155	0.117	0.020	0.000		0.044				
1996	0.586	0.065	1.390	3.276	1.178	1.406	0.425	0.134	0.000	0.000	0.099						
1997	0.000	0.934	1.928	2.312	1.023	0.383	0.094	0.036	0.005	0.000	0.000	0.000					
1998	0.000	0.264	1.216	0.903	0.846	0.406	0.070	0.053	0.039	0.000	0.000		0.000		0.026	0.026	
1999		0.036	0.360	0.466	0.260	0.202	0.127	0.023	0.001	0.045	0.000		0.000				
2000	0.000	0.236	0.976	1.511	0.814	0.350	0.244	0.089	0.049	0.016	0.016	0.016		0.000			
2001	0.000	0.110	0.315	0.358	0.382	0.399	0.162	0.064	0.065	0.005	0.000	0.000	0.004	0.000			
2002	0.013	0.203	0.422	0.342	0.375	0.119	0.116	0.045	0.032	0.000	0.016	0.000		0.000			
2003	0.021	0.085	0.293	0.764	0.518	0.436	0.237	0.116	0.085	0.023	0.000	0.004		0.000			0.000
2004	0.061	0.163	0.499	0.708	0.955	0.648	0.364	0.169	0.111	0.011	0.038	0.000			0.000		
2005	0.018	0.126	0.464	0.730	0.445	0.432	0.240	0.188	0.035	0.027	0.015	0.000					
2006	0.060	0.153	0.246	0.512	0.301	0.292	0.195	0.075	0.012	0.029	0.000	0.000	0.000				
2007	0.049	0.086	0.540	0.325	0.162	0.123	0.166	0.052	0.011	0.000	0.000	0.001		0.000			
2008	0.323	0.140	0.098	0.028	0.028	0.020	0.006	0.014	0.013	0.002	0.000	0.004	0.001	0.000	0.000		
2009	0.228	0.118	0.538	0.484	0.617	0.280	0.195	0.065	0.162	0.062	0.001	0.013	0.000		0.000	0.000	
2010	0.014	0.488	0.343	0.282	0.211	0.258	0.113	0.064	0.010	0.021	0.022	0.000	0.003	0.005	0.000	0.000	
2011	0.155	1.784	1.046	0.828	0.553	0.425	0.178	0.028	0.069	0.004	0.014	0.001	0.012	0.000			
2012	0.001	0.218	0.573	0.323	0.084	0.086	0.044	0.052	0.018	0.009	0.013	0.019	0.004	0.008	0.000		0.003
2013	0.165	0.620	0.618	0.509	0.340	0.303	0.164	0.075	0.044	0.020	0.015	0.009	0.015	0.000	0.000	0.000	0.000
2014	1.136	0.357	0.392	0.158	0.062	0.080	0.052	0.065	0.235	0.114	0.010	0.000	0.012	0.005	0.000	0.000	0.000
2015	0.000	1.371	0.849	0.714	0.792	0.335	0.230	0.067	0.035	0.059	0.061	0.004	0.015	0.000	0.005		0.000
2016	0.033	0.371	0.433	0.223	0.244	0.304	0.193	0.150	0.053	0.035	0.015	0.014	0.000	0.004	0.000		0.000
2017	0.000	0.055	0.209	0.120	0.053	0.123	0.054	0.059	0.022	0.013	0.013	0.009	0.005	0.002			
2018	0.010	0.289	0.158	0.173	0.094	0.093	0.109	0.068	0.042	0.021	0.012	0.004	0.002	0.006		0.000	0.000
2019	0.631	0.874	0.616	1.017	0.850	0.681	0.191	0.237	0.066	0.087	0.054	0.027	0.004	0.000	0.000	0.000	0.000
2020	0.007	0.026	0.300	0.469	0.677	0.254	0.191	0.092	0.078	0.028	0.003	0.009		0.000	0.005	0.000	

Table A.3.2. CV on abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995		0.027	0.008	0.023	0.074	0.081	0.055	0.036	0.167	1.012	6.127		0.000				
1996	0.355	0.635	0.011	0.010	0.054	0.055	0.115	0.174			0.000						
1997		0.234	0.174	0.060	0.092	0.137	0.353	0.501	2.629								
1998		0.145	0.075	0.100	0.080	0.104	0.464	0.240	0.443	8.401					0.000	0.000	
1999		0.010	0.002	0.001	0.001	0.001	0.000	0.000	0.019	0.000							
2000		0.038	0.013	0.012	0.027	0.075	0.101	0.080	0.038	0.103	0.000	0.000					
2001		0.682	0.384	0.257	0.110	0.156	0.164	0.255	0.176	0.968			1.159				
2002	2.110	0.263	0.394	0.096	0.048	0.298	0.564	0.981	0.662		0.000						
2003	0.522	0.324	0.099	0.061	0.092	0.074	0.090	0.129	0.156	0.284		1.032					
2004	0.347	0.052	0.075	0.079	0.061	0.102	0.113	0.143	0.109	1.036	0.303						
2005	1.591	0.255	0.046	0.033	0.028	0.034	0.039	0.084	0.283	0.000	0.148						
2006	0.000	0.041	0.031	0.021	0.049	0.036	0.036	0.089	0.202	0.000							
2007	1.071	0.366	0.157	0.144	0.154	0.151	0.206	0.208	0.960			5.384					
2008	0.723	0.555	0.336	0.708	0.471	0.101	0.856	0.584	0.695	0.201		0.685	0.040				
2009	0.000	0.369	0.177	0.078	0.111	0.084	0.097	0.295	0.082	0.199	4.224	0.273					
2010	0.221	0.367	0.172	0.146	0.080	0.076	0.076	0.062	0.444	0.708	0.248	5.180	0.805	0.000			
2011	0.712	0.078	0.098	0.087	0.103	0.080	0.144	0.736	0.111	1.824	1.206	3.159	0.000				
2012	1.698	0.213	0.507	0.524	0.318	0.305	0.457	0.434	0.408	0.442	0.369	0.656	0.769	0.807			0.795
2013	0.586	0.160	0.191	0.092	0.067	0.057	0.160	0.271	0.254	0.585	0.633	1.014	0.631				
2014	0.118	0.145	0.158	0.176	0.108	0.231	0.273	0.412	0.039	0.335	0.711		0.745	1.254			
2015		0.053	0.059	0.087	0.083	0.090	0.152	0.317	0.466	0.352	0.678	0.970	0.527		1.096		
2016	1.416	0.828	0.216	0.335	0.242	0.232	0.291	0.377	0.464	0.407	0.753	0.590		0.639			
2017		0.637	0.330	0.262	0.206	0.279	0.349	0.384	0.529	0.419	0.619	0.531	1.049	0.936			
2018	0.638	0.533	0.167	0.147	0.170	0.367	0.506	0.648	0.594	0.625	0.626	0.852	0.684	1.026			
2019	0.056	0.097	0.145	0.075	0.077	0.076	0.192	0.108	0.183	0.117	0.097	0.195	1.579				
2020	3.801	0.853	0.400	0.222	0.162	0.337	0.310	0.350	0.471	0.519	1.056	1.242			1.369		

Table A.3.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995	0.000	0.029	0.528	0.814	0.573	0.469	0.517	0.822	1.037	0.188	0.001		0.811				
1996	0.005	0.001	0.404	2.548	1.454	2.479	0.939	0.622	0.000	0.000	1.546						
1997	0.000	0.053	0.377	1.398	1.149	0.663	0.257	0.113	0.008	0.000	0.000	0.000					
1998	0.000	0.034	0.375	0.753	1.019	0.735	0.197	0.242	0.305	0.001	0.000		0.000		0.525	0.690	
1999		0.004	0.088	0.302	0.306	0.384	0.325	0.107	0.008	0.624	0.000		0.000				
2000	0.000	0.022	0.290	1.016	0.966	0.688	0.779	0.495	0.511	0.308	0.232	0.233		0.000			
2001	0.000	0.010	0.097	0.234	0.421	0.519	0.577	0.190	0.499	0.037	0.000	0.000	0.050	0.000			
2002	0.000	0.019	0.117	0.437	0.880	0.217	0.194	0.076	0.088	0.000	0.135	0.000		0.000			
2003	0.000	0.006	0.104	0.466	0.540	0.775	0.590	0.321	0.283	0.054	0.000	0.008		0.000			0.000
2004	0.000	0.016	0.170	0.517	1.402	1.127	0.967	0.495	0.284	0.034	0.682	0.000			0.000		
2005	0.000	0.009	0.157	0.475	0.687	0.987	0.663	0.566	0.101	0.040	0.278	0.000					
2006	0.001	0.019	0.124	0.500	0.400	0.516	0.453	0.174	0.052	0.133	0.000	0.000	0.000				
2007	0.000	0.011	0.254	0.258	0.229	0.255	0.409	0.157	0.071	0.000	0.000	0.001		0.000			
2008	0.003	0.018	0.044	0.040	0.066	0.053	0.021	0.056	0.072	0.015	0.000	0.026	0.003	0.000	0.000		
2009	0.004	0.009	0.192	0.577	1.041	0.696	0.529	0.167	0.593	0.386	0.003	0.026	0.000		0.000	0.000	
2010	0.000	0.030	0.121	0.229	0.389	0.606	0.308	0.289	0.024	0.059	0.109	0.000	0.006	0.009	0.000	0.000	
2011	0.001	0.146	0.298	0.783	0.895	1.020	0.541	0.093	0.560	0.010	0.046	0.003	0.119	0.000			
2012	0.000	0.021	0.192	0.181	0.104	0.183	0.105	0.165	0.078	0.057	0.056	0.096	0.016	0.036	0.000		0.012
2013	0.002	0.037	0.147	0.321	0.393	0.675	0.400	0.231	0.199	0.085	0.038	0.031	0.061	0.000	0.000	0.000	0.000
2014	0.012	0.030	0.232	0.114	0.061	0.157	0.173	0.251	1.117	0.437	0.041	0.000	0.043	0.015	0.000	0.000	0.000
2015	0.000	0.106	0.233	0.759	1.233	0.793	0.522	0.207	0.127	0.460	0.228	0.019	0.066	0.000	0.036		0.000
2016	0.000	0.031	0.133	0.197	0.331	0.701	0.550	0.462	0.251	0.357	0.072	0.086	0.000	0.012	0.000		0.000
2017	0.000	0.005	0.073	0.104	0.101	0.309	0.173	0.190	0.084	0.077	0.058	0.040	0.020	0.024			
2018	0.000	0.015	0.047	0.271	0.155	0.249	0.347	0.265	0.225	0.097	0.060	0.015	0.019	0.037		0.000	0.000
2019	0.006	0.069	0.184	1.140	1.734	1.720	0.582	0.841	0.199	0.370	0.251	0.143	0.015	0.000	0.000	0.000	0.000
2020	0.000	0.002	0.118	0.505	1.165	0.630	0.605	0.420	0.328	0.126	0.013	0.056		0.000	0.025	0.000	

Table A.3.4. Mean length (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995		21.94	33.66	41.58	52.72	60.33	64.29	80.92	94.71	99.01	60.00		117.00				
1996	9.77	13.00	31.63	42.75	51.16	57.11	61.34	80.03			118.00						
1997		18.27	27.13	39.84	49.63	57.20	64.53	75.17	54.90								
1998		24.38	31.97	43.56	49.98	57.23	65.97	77.02	93.29	57.00					121.00	135.00	
1999		23.93	29.19	40.33	49.29	57.53	64.02	79.87	97.41	107.50							
2000		21.57	31.06	40.66	49.45	58.17	67.45	79.64	98.84	109.64	114.00	105.00					
2001		21.77	31.73	41.09	48.33	51.45	67.05	65.76	90.48	89.36			117.00				
2002	10.00	21.90	30.75	48.87	60.98	55.74	53.59	54.19	64.97		97.00						
2003	10.00	19.94	32.96	39.46	47.12	56.05	62.67	65.60	69.22	62.20		61.00					
2004	8.77	21.73	32.25	42.14	51.94	55.44	63.72	65.75	64.19	72.07	119.47						
2005	14.00	20.14	31.65	40.05	52.32	60.57	63.73	65.16	65.74	55.00	118.27						
2006	11.67	23.74	36.59	45.65	51.04	55.71	61.58	62.43	77.27	75.96							
2007	9.94	23.46	35.55	43.44	51.65	58.62	62.02	67.97	89.28			57.00					
2008	10.73	25.27	36.20	53.57	62.11	63.98	69.17	71.80	79.42	88.53		88.78	69.99				
2009	12.11	20.79	32.27	48.34	54.21	61.43	64.91	63.54	71.00	81.67	59.00	59.22					
2010	12.04	19.15	32.56	42.28	55.82	60.52	64.49	74.88	61.81	66.77	81.14	58.00	60.00	62.00			
2011	9.38	21.22	30.50	45.76	54.64	62.29	66.89	72.58	83.47	61.36	69.07	64.00	102.00				
2012	10.16	22.09	32.88	39.24	51.02	59.62	63.48	67.44	74.07	83.81	74.30	78.35	73.00	75.00			79.00
2013	11.77	19.05	30.12	40.89	49.69	62.10	64.29	68.26	76.04	76.13	64.04	69.00	74.35				
2014	10.74	21.22	38.24	42.25	47.29	58.78	70.43	73.78	76.04	74.19	81.04		72.99	75.00			
2015		20.63	30.34	47.34	54.38	61.30	60.63	68.91	71.92	88.58	74.42	77.00	76.03		95.00		
2016	9.90	21.41	32.22	42.52	51.41	60.40	65.69	66.74	77.77	96.51	75.68	83.88		73.00			
2017		22.31	33.68	44.75	57.05	63.09	69.05	68.58	73.69	85.70	78.01	75.94	81.30	99.00			
2018	10.43	17.57	32.07	50.93	54.46	63.45	66.72	72.57	77.50	77.15	78.02	74.66	98.00	80.03			
2019	10.55	20.66	30.44	48.03	58.75	62.90	66.59	71.27	67.22	73.38	73.15	82.61	76.59				
2020	11.37	22.57	34.54	46.72	54.72	62.14	66.55	75.63	75.15	77.74	79.23	82.83			83.00		

Table A.3.5. Mean weight (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995		91	354	676	1470	2148	2538	5295	8844	9406	2400		18580				
1996	8	17	291	778	1233	1763	2214	4688			15560						
1997		57	198	604	1124	1733	2787	3282	1506								
1998		128	309	835	1204	1809	2823	4634	7894	1655					19880	26100	
1999		115	245	648	1175	1906	2556	4722	9728	13870							
2000		92	297	672	1186	1962	3185	5549	10436	18769	14266	14380					
2001		96	316	670	1106	1305	3618	2991	7694	7230			12000				
2002	8	93	281	1286	2350	1887	1755	1800	2999		8358						
2003	9	67	354	610	1045	1780	2491	2787	3325	2370		2030					
2004	6	100	341	732	1468	1741	2663	2936	2558	3377	18589						
2005	25	75	340	652	1545	2286	2761	3002	2942	1456	18343						
2006	13	125	506	976	1329	1769	2318	2308	4444	4608							
2007	7	134	474	796	1421	2083	2516	3047	6673			1648					
2008	10	165	456	1543	2445	2691	3419	4277	5767	7574		6239	2733				
2009	16	76	361	1194	1697	2487	2720	2575	3664	6374	2096	2034					
2010	14	62	355	822	1852	2355	2731	4539	2398	2842	4951	2128	2285	1910			
2011	8	82	286	947	1620	2404	3064	4232	8231	2328	3590	2440	10116				
2012	9	96	338	581	1287	2206	2548	3215	4206	7036	4248	4862	3745	4325			4630
2013	13	60	241	631	1160	2225	2436	3071	4535	4334	2569	3425	4214				
2014	11	85	601	725	982	2003	3272	4015	4751	3973	4625		3634	3340			
2015		77	275	1061	1556	2373	2271	3186	3614	8353	3497	4310	4380		7785		
2016	9	87	307	860	1360	2292	2796	3035	4734	10174	4596	5961		3425			
2017		89	363	880	1901	2484	3206	3257	3827	6124	4306	4305	4379	10610			
2018	5	48	296	1587	1643	2592	3083	3993	5141	4668	4787	3684	8695	5988			
2019	10	79	299	1121	2042	2529	3058	3557	3014	4284	4647	5383	4261				
2020	9	86	394	1073	1720	2512	3123	4707	4240	4690	3524	6025			5434		

Table A.3.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
1995	3.848	0.030	0.008
1996	7.908	0.072	0.009
1997	5.782	0.365	0.063
1998	3.587	0.104	0.029
1999	1.483	0.001	0.000
2000	4.082	0.033	0.008
2001	1.753	0.309	0.176
2002	1.467	0.289	0.197
2003	2.474	0.049	0.020
2004	3.503	0.067	0.019
2005	2.576	0.025	0.010
2006	1.662	0.022	0.013
2007	1.379	0.090	0.066
2008	0.214	0.060	0.279
2009	2.416	0.197	0.081
2010	1.331	0.108	0.081
2011	3.157	0.150	0.048
2012	1.238	0.565	0.457
2013	2.113	0.138	0.065
2014	1.184	0.068	0.057
2015	3.167	0.147	0.046
2016	1.668	0.344	0.206
2017	0.682	0.189	0.277
2018	0.783	0.233	0.298
2019	3.830	0.106	0.028
2020	2.107	0.289	0.137

10.4 Subarea C: Between 62°N and 65°N

Table A.4.1. Abundance index (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995	0.000	0.147	0.748	1.075	0.435	0.364	0.042	0.097	0.029	0.001	0.000		0.000				
1996	0.004	0.118	0.333	0.816	0.966	0.761	0.249	0.113	0.000	0.002	0.000						
1997	0.000	0.223	0.621	1.083	0.556	0.376	0.242	0.167	0.059	0.000	0.000	0.000					
1998	0.009	0.089	2.701	1.303	0.520	0.115	0.206	0.198	0.000	0.000	0.000		0.000		0.000	0.000	
1999		0.031	0.145	0.259	0.235	0.094	0.062	0.019	0.000	0.000	0.000		0.000				
2000	0.000	0.000	0.053	0.085	0.182	0.117	0.036	0.000	0.000	0.000	0.000	0.000		0.000			
2001	0.000	0.102	0.350	0.462	0.379	0.288	0.137	0.052	0.030	0.005	0.000	0.000	0.004	0.000			
2002	0.013	0.604	0.930	0.969	1.552	1.570	2.387	0.604	0.167	0.004	0.000	0.000		0.000			
2003	0.000	0.037	0.063	0.314	0.146	0.096	0.044	0.027	0.031	0.010	0.000	0.003		0.000			0.000
2004	0.230	0.039	0.206	0.264	0.390	0.233	0.074	0.049	0.013	0.014	0.003	0.000			0.000		
2005	0.000	0.235	0.091	0.319	0.505	0.256	0.254	0.060	0.005	0.000	0.002	0.000					
2006	0.415	0.008	0.064	0.072	0.211	0.238	0.065	0.024	0.035	0.012	0.012	0.000	0.000				
2007	0.049	0.082	0.152	0.097	0.103	0.099	0.163	0.066	0.024	0.004	0.004	0.001		0.000			
2008	0.350	0.129	0.124	0.053	0.054	0.011	0.005	0.025	0.008	0.000	0.000	0.003	0.000	0.000	0.000		
2009	0.000	0.063	0.241	0.446	0.258	0.093	0.019	0.041	0.032	0.005	0.000	0.023	0.000		0.000	0.000	
2010	0.118	0.397	0.181	0.221	0.153	0.161	0.026	0.009	0.042	0.025	0.015	0.000	0.003	0.000	0.000	0.000	
2011	0.000	0.094	0.102	0.131	0.120	0.134	0.164	0.036	0.008	0.008	0.032	0.000	0.002	0.000			
2012	0.000	0.130	0.440	0.381	0.187	0.181	0.151	0.083	0.020	0.007	0.013	0.019	0.004	0.008	0.000		0.003
2013	0.003	0.172	0.396	0.249	0.150	0.095	0.108	0.052	0.065	0.020	0.010	0.009	0.015	0.000	0.000	0.000	0.000
2014	0.116	0.425	0.205	0.180	0.173	0.250	0.152	0.101	0.106	0.161	0.019	0.000	0.012	0.005	0.000	0.000	0.000
2015	0.000	0.149	1.109	0.183	0.338	0.094	0.200	0.034	0.053	0.058	0.058	0.004	0.015	0.000	0.005		0.000
2016	0.030	0.301	0.341	1.122	0.557	0.336	0.103	0.080	0.104	0.023	0.032	0.133	0.000	0.000	0.000		0.000
2017	0.000	0.098	0.209	0.086	0.176	0.147	0.112	0.085	0.042	0.009	0.013	0.009	0.005	0.002			
2018	0.000	0.238	0.086	0.094	0.181	0.330	0.265	0.073	0.056	0.081	0.012	0.004	0.002	0.006		0.000	0.000
2019	0.011	0.027	0.166	0.136	0.083	0.372	0.489	0.393	0.067	0.055	0.013	0.011	0.003	0.000	0.000	0.000	0.000
2020	0.000	0.003	0.277	0.554	0.137	0.403	0.113	0.136	0.011	0.101	0.003	0.005		0.000	0.003	0.000	

Table A.4.2. CV on abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995		0.139	0.050	0.040	0.094	0.103	0.707	0.112	0.455	5.064							
1996	1.121	0.313	0.202	0.129	0.116	0.160	0.440	0.349	5.506	2.545							
1997		0.342	0.143	0.052	0.122	0.151	0.287	0.258	0.502								
1998	0.898	0.073	0.000	0.000	0.000	0.000	0.000	0.000									
1999		0.289	0.080	0.052	0.057	0.122	0.154	0.294									
2000			0.000	0.000	0.000	0.000	0.000										
2001		0.737	0.345	0.200	0.116	0.222	0.244	0.418	0.494	0.903	9.960		1.159				
2002	2.110	0.083	0.172	0.009	0.053	0.109	0.069	0.185	0.315	1.143							
2003		0.741	0.325	0.108	0.205	0.188	0.222	0.273	0.370	0.452	2.311	0.694					
2004	0.141	0.206	0.155	0.188	0.083	0.201	0.149	0.167	0.475	0.558	1.490						
2005		0.000	0.030	0.022	0.012	0.039	0.013	0.060	0.741		0.918						
2006	0.000	0.617	0.044	0.000	0.037	0.019	0.060	0.096	0.000	0.000	0.000						
2007	1.071	0.393	0.417	0.222	0.122	0.136	0.205	0.148	0.417	0.000	0.000	5.384					
2008	0.668	0.600	0.267	0.373	0.247	0.124	1.112	0.318	1.139			0.724					
2009		0.689	0.396	0.078	0.229	0.059	0.234	0.261	0.153	0.991	5.898	0.000					
2010	0.149	0.451	0.325	0.186	0.099	0.115	0.291	0.406	0.084	0.588	0.368		0.805				
2011	0.669	0.833	0.603	0.270	0.148	0.069	0.064	0.527	0.142	0.012	0.487	2.036	0.004	4.559			
2012		0.358	0.661	0.444	0.141	0.145	0.132	0.274	0.371	0.587	0.371	0.656	0.769	0.807			0.795
2013	2.824	0.527	0.296	0.192	0.150	0.182	0.240	0.388	0.172	0.585	0.956	1.014	0.631				
2014	0.666	0.158	0.360	0.152	0.043	0.075	0.096	0.269	0.086	0.238	0.365		0.740	1.254			
2015		0.119	0.025	0.166	0.070	0.068	0.091	0.202	0.206	0.220	0.691	0.970	0.504		1.096		
2016	1.529	1.024	0.631	0.341	0.191	0.388	0.505	0.557	0.566	0.581	0.616	0.757					
2017		0.359	0.330	0.367	0.061	0.235	0.170	0.264	0.271	0.629	0.619	0.531	1.049	0.936			
2018		0.644	0.344	0.277	0.083	0.105	0.208	0.617	0.440	0.159	0.626	0.852	0.684	1.026			
2019	0.907	0.907	0.426	0.161	0.185	0.052	0.035	0.039	0.130	0.134	0.538	0.550	0.930				
2020		1.741	0.533	0.392	0.496	0.294	0.562	0.607	0.602	0.736	1.003	1.036			0.977		

Table A.4.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995	0.000	0.025	0.414	0.910	0.647	0.940	0.112	0.428	0.189	0.002	0.000		0.000				
1996	0.000	0.006	0.110	0.982	1.667	1.735	0.652	0.447	0.001	0.010	0.000						
1997	0.000	0.012	0.168	1.030	0.961	0.883	0.790	0.658	0.403	0.000	0.000	0.000					
1998	0.000	0.015	1.406	1.404	0.889	0.302	0.809	0.890	0.000	0.000	0.000		0.000		0.000	0.000	
1999		0.004	0.075	0.415	0.743	0.455	0.247	0.134	0.000	0.000	0.000		0.000				
2000	0.000	0.000	0.020	0.096	0.328	0.270	0.125	0.000	0.000	0.000	0.000	0.000		0.000			
2001	0.000	0.009	0.167	0.455	0.595	0.593	0.305	0.158	0.250	0.036	0.000	0.000	0.050	0.000			
2002	0.000	0.094	0.602	1.357	5.275	7.009	12.038	4.644	0.964	0.036	0.000	0.000		0.000			
2003	0.000	0.002	0.011	0.136	0.141	0.170	0.110	0.070	0.143	0.036	0.001	0.006		0.000			0.000
2004	0.002	0.002	0.055	0.196	0.697	0.545	0.298	0.256	0.030	0.084	0.013	0.000			0.000		
2005	0.000	0.034	0.048	0.663	1.934	1.134	1.108	0.527	0.008	0.000	0.030	0.000					
2006	0.003	0.001	0.042	0.133	0.486	0.761	0.219	0.133	0.280	0.062	0.080	0.000	0.000				
2007	0.000	0.017	0.107	0.162	0.306	0.319	0.518	0.372	0.214	0.041	0.047	0.001		0.000			
2008	0.003	0.012	0.097	0.115	0.201	0.042	0.017	0.152	0.058	0.000	0.000	0.026	0.000	0.000	0.000		
2009	0.000	0.004	0.117	0.582	0.483	0.250	0.084	0.178	0.155	0.013	0.001	0.064	0.000		0.000	0.000	
2010	0.001	0.028	0.045	0.279	0.341	0.458	0.109	0.028	0.470	0.119	0.076	0.000	0.006	0.000	0.000	0.000	
2011	0.000	0.007	0.028	0.188	0.339	0.517	1.286	0.233	0.021	0.095	0.145	0.000	0.019	0.000			
2012	0.000	0.012	0.144	0.396	0.477	0.723	0.566	0.330	0.083	0.026	0.056	0.096	0.016	0.036	0.000		0.012
2013	0.000	0.014	0.085	0.128	0.132	0.229	0.415	0.182	0.459	0.085	0.025	0.031	0.061	0.000	0.000	0.000	0.000
2014	0.001	0.031	0.102	0.278	0.445	0.762	0.742	0.517	0.430	0.882	0.109	0.000	0.043	0.015	0.000	0.000	0.000
2015	0.000	0.016	0.496	0.180	0.537	0.236	0.506	0.203	0.221	0.237	0.220	0.019	0.064	0.000	0.036		0.000
2016	0.000	0.024	0.197	2.195	2.116	1.234	0.350	0.299	0.795	0.217	0.130	1.304	0.000	0.000	0.000		0.000
2017	0.000	0.008	0.123	0.117	0.440	0.509	0.400	0.263	0.255	0.041	0.058	0.040	0.020	0.024			
2018	0.000	0.013	0.025	0.097	0.426	1.272	1.005	0.326	0.348	0.340	0.060	0.015	0.019	0.037		0.000	0.000
2019	0.000	0.002	0.032	0.309	0.281	1.281	2.282	1.752	0.294	0.495	0.057	0.077	0.012	0.000	0.000	0.000	0.000
2020	0.000	0.000	0.344	1.266	0.307	2.021	0.467	1.147	0.055	0.733	0.010	0.033		0.000	0.018	0.000	

Table A.4.4. Length by age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995		26.44	38.14	44.42	53.51	63.65	64.79	78.31	88.80	65.00							
1996	8.00	16.98	30.91	48.14	55.40	60.93	64.48	76.20	65.00	87.00							
1997		16.88	29.03	45.38	55.34	63.09	67.60	75.88	90.63								
1998	10.78	25.15	36.44	46.50	55.90	62.52	71.00	77.88									
1999		23.52	36.75	52.54	66.26	75.73	73.44	86.23									
2000			33.79	49.42	56.33	60.59	67.12										
2001		21.79	35.36	44.63	52.72	57.48	59.25	64.73	90.77	90.74	69.00		117.00				
2002	10.00	25.10	39.62	52.40	68.57	73.74	77.28	88.77	85.79	89.00							
2003		17.33	27.22	35.36	45.55	54.61	63.06	61.49	75.71	71.34	88.00	61.00					
2004	9.30	16.31	28.85	41.21	54.47	58.08	70.35	76.20	63.76	86.18	72.27						
2005		24.71	37.06	58.01	70.61	75.43	72.50	93.44	57.50		108.00						
2006	9.93	21.95	40.86	53.85	59.97	66.41	69.09	71.73	87.55	82.00	86.00						
2007	9.94	26.64	39.20	53.10	63.56	65.87	66.06	77.01	99.99	102.00	110.00	57.00					
2008	9.81	22.77	42.89	60.65	70.68	71.54	71.69	82.27	100.17			99.00					
2009		20.15	35.27	49.79	55.73	65.44	78.15	76.08	75.71	62.77	66.00	65.00					
2010	8.22	19.64	28.89	47.25	58.83	64.62	71.71	67.04	90.71	80.03	79.43		60.00				
2011	9.10	20.22	33.14	53.10	64.73	73.65	84.34	87.10	64.73	103.35	73.70	67.26	82.97	74.00			
2012		21.75	32.39	47.37	63.96	71.35	73.06	74.45	73.64	71.31	74.42	78.35	73.00	75.00			79.00
2013	11.72	20.98	29.72	38.97	46.18	64.47	72.53	72.98	85.58	76.13	64.02	69.00	74.35				
2014	10.89	21.03	34.50	51.93	63.01	66.43	77.65	79.30	74.98	80.31	86.90		72.94	75.00			
2015		23.27	35.78	46.08	53.44	64.92	61.78	80.40	73.82	75.44	74.67	77.00	76.22		95.00		
2016	10.00	21.11	37.34	57.67	70.65	71.52	69.98	69.99	87.03	96.91	74.71	97.06					
2017		21.74	38.28	50.20	63.62	68.17	71.30	67.80	85.38	81.71	78.01	75.94	81.30	99.00			
2018		19.07	32.02	47.30	61.82	72.74	71.57	78.07	84.51	74.02	78.02	74.66	98.00	80.03			
2019	14.17	19.07	28.08	55.60	66.71	69.89	76.19	74.94	74.76	91.90	77.99	92.20	76.83				
2020		18.35	47.79	57.70	60.23	76.12	71.63	88.75	79.70	87.56	79.00	83.00			83.00		

Table A.4.5. Weight by age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
1995		171	555	846	1489	2590	2748	4417	6905	2996							
1996	5	59	330	1212	1730	2284	2632	3977	2970	5220							
1997		58	275	952	1730	2359	3239	3982	7487								
1998	10	167	520	1078	1710	2620	3931	4494									
1999		120	517	1605	3163	4878	3958	7302									
2000			376	1134	1799	2305	3429										
2001		96	499	1005	1580	2089	2210	3051	9206	7802	2808		12000				
2002	8	156	658	1401	3400	4481	5053	7831	5977	8640							
2003		41	166	436	977	1800	2509	2644	4551	4036	7366	2030					
2004	9	44	267	762	1796	2407	4078	5302	2476	6949	3748						
2005		144	523	2081	3833	4438	4361	8869	1676		12140						
2006	8	81	652	1839	2300	3198	3350	5670	7957	5035	6530						
2007	7	244	844	1736	3018	3266	3246	5671	9142	11610	13370	1648					
2008	8	105	822	2259	3862	3886	3739	6215	10013			7675					
2009		71	540	1313	1932	2698	4495	4400	4936	2729	2656	2730					
2010	4	73	252	1301	2245	2869	4313	3162	11121	5156	5031		2285				
2011	7	66	386	1511	2859	3864	7854	7474	2569	11848	4739	2910	7858	3888			
2012		93	336	1191	2578	4054	3779	4088	4066	3716	4266	4862	3745	4325			4630
2013	12	78	217	515	889	2398	3969	3546	7124	4334	2499	3425	4214				
2014	15	73	539	1565	2571	3057	4901	5286	4051	5676	6016		3631	3340			
2015		112	448	1002	1592	2534	2532	6045	4153	4084	3532	4310	4410		7785		
2016	9	82	494	1952	3856	3623	3407	3576	7134	9101	4101	8575					
2017		87	637	1473	2499	3535	3579	3084	6189	4555	4306	4305	4379	10610			
2018		55	301	1078	2353	3858	3817	4955	6558	4188	4787	3684	8695	5988			
2019	23	61	190	2317	3433	3443	4671	4456	4388	9163	4210	7453	4298				
2020		48	1169	2194	2153	4935	3913	7895	5101	6869	3386	6140			5434		

Table A.4.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
1995	2.791	0.052	0.019
1996	3.241	0.168	0.052
1997	3.103	0.141	0.045
1998	5.044	0.000	0.000
1999	0.815	0.020	0.025
2000	0.474	0.000	0.000
2001	1.707	0.312	0.183
2002	8.183	0.353	0.043
2003	0.735	0.038	0.052
2004	1.246	0.038	0.031
2005	1.491	0.013	0.009
2006	0.735	0.018	0.025
2007	0.712	0.067	0.094
2008	0.282	0.060	0.211
2009	1.158	0.195	0.169
2010	0.835	0.108	0.130
2011	0.739	0.139	0.188
2012	1.498	0.565	0.377
2013	1.169	0.138	0.118
2014	1.363	0.079	0.058
2015	2.150	0.135	0.063
2016	2.832	0.597	0.211
2017	0.895	0.189	0.211
2018	1.191	0.236	0.198
2019	1.788	0.082	0.046
2020	1.743	0.341	0.196

11 Appendix B Swept area abundance indices

11.1 Total area

Table B.1.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	6.253	5.298	3.531	4.329	5.087	3.391	2.719	0.999	0.577	0.271	0.043	0.002		0.016			0.010
2004	5.077	2.987	2.495	2.885	3.852	2.109	1.079	0.560	0.238	0.054	0.072	0.006			0.006		
2005	0.030	0.906	1.319	2.469	1.892	1.508	0.949	0.293	0.137	0.088	0.016	0.038					
2006	6.846	1.914	2.500	3.237	3.351	2.146	1.328	1.108	0.277	0.146		0.008	0.015				
2007	6.561	0.746	1.935	1.730	1.710	1.233	0.636	0.534	0.137	0.082	0.004	0.023		0.002			
2008	18.407	3.291	2.689	3.568	2.550	1.912	1.271	0.758	0.436	0.200	0.068	0.030	0.032	0.005	0.005		
2009	3.670	6.757	2.715	4.221	4.487	2.045	1.147	0.803	0.615	0.256	0.081	0.092	0.005		0.002	0.006	
2010	0.957	7.954	2.777	3.931	4.038	3.054	1.019	0.518	0.735	0.378	0.167	0.138	0.018	0.014	0.004	0.015	
2011	0.477	3.763	4.715	3.812	4.001	2.977	1.828	0.374	0.435	0.256	0.118	0.056	0.149	0.008			
2012	0.400	5.463	3.970	5.075	3.391	2.092	1.341	1.001	0.504	0.225	0.210	0.046	0.029	0.043	0.017		0.002
2013	0.944	7.727	4.770	2.383	3.144	2.867	2.217	1.493	0.685	0.297	0.121	0.184	0.107	0.004	0.006	0.003	0.005
2014	20.339	7.671	5.936	5.326	3.630	4.146	2.149	1.530	0.532	0.384	0.059	0.161	0.084	0.006	0.009	0.016	0.004
2015	0.383	6.573	6.861	5.286	4.975	2.616	2.173	0.986	0.543	0.481	0.122	0.053	0.041	0.002	0.006		0.002
2016	3.288	4.156	5.075	5.112	3.051	2.384	0.908	0.876	0.494	0.259	0.093	0.093	0.017	0.013	0.020		0.006
2017	6.268	0.849	3.209	2.733	1.805	1.395	0.882	0.395	0.254	0.171	0.043	0.090	0.018	0.006			
2018	0.147	4.355	3.451	2.099	2.116	1.371	0.945	0.355	0.207	0.159	0.089	0.045	0.022	0.005		0.004	0.003
2019	0.439	2.571	2.269	2.949	1.956	1.964	1.144	0.818	0.224	0.215	0.101	0.083	0.040	0.022	0.003	0.002	0.007
2020	0.081	0.616	1.372	1.819	1.736	1.137	0.589	0.323	0.208	0.076	0.026	0.041		0.004	0.003		

Table B.1.2. CV abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.286	0.229	0.219	0.147	0.133	0.107	0.104	0.220	0.282	0.232	0.684	1.760		0.886			0.867
2004	0.240	0.257	0.128	0.154	0.169	0.192	0.227	0.211	0.349	0.384	0.397	0.922			0.970		
2005	0.684	0.243	0.226	0.248	0.208	0.158	0.216	0.206	0.281	0.377	0.579	0.718					
2006	0.216	0.185	0.285	0.200	0.224	0.153	0.116	0.198	0.247	0.306		0.867	0.830				
2007	0.275	0.233	0.400	0.353	0.232	0.201	0.169	0.216	0.269	0.411	0.867	0.956		0.806			
2008	0.245	0.163	0.234	0.161	0.126	0.097	0.161	0.138	0.186	0.338	0.282	0.419	0.462	0.850	0.794		
2009	0.621	0.157	0.137	0.176	0.126	0.123	0.150	0.136	0.214	0.234	0.334	0.340	1.282		1.353	0.477	
2010	0.537	0.087	0.163	0.151	0.183	0.140	0.164	0.225	0.271	0.247	0.181	0.374	0.548	0.752	0.831	0.440	
2011	0.483	0.342	0.221	0.268	0.178	0.193	0.176	0.236	0.194	0.265	0.344	0.610	0.364	0.628			
2012	0.620	0.128	0.297	0.211	0.138	0.181	0.164	0.165	0.223	0.220	0.197	0.258	0.429	0.564	0.652		0.771
2013	0.519	0.123	0.145	0.177	0.218	0.205	0.225	0.282	0.177	0.307	0.353	0.477	0.405	0.872	0.641	0.806	0.682
2014	0.326	0.164	0.291	0.188	0.152	0.150	0.243	0.139	0.156	0.207	0.389	0.392	0.349	0.774	0.685	0.463	0.574
2015	0.620	0.154	0.127	0.192	0.244	0.265	0.200	0.286	0.185	0.182	0.236	0.400	0.274	0.897	0.448		1.203
2016	0.495	0.198	0.122	0.122	0.095	0.087	0.131	0.153	0.201	0.205	0.287	0.315	0.420	0.669	0.564		1.066
2017	0.512	0.271	0.183	0.152	0.139	0.087	0.159	0.178	0.261	0.270	0.273	0.391	0.534	0.731			
2018	0.789	0.144	0.187	0.145	0.138	0.121	0.121	0.149	0.254	0.236	0.186	0.303	0.420	0.549		0.630	0.842
2019	0.381	0.127	0.157	0.143	0.123	0.149	0.142	0.194	0.286	0.274	0.361	0.297	0.513	0.511	0.970	0.897	0.797
2020	0.740	0.260	0.118	0.121	0.116	0.127	0.144	0.144	0.220	0.387	0.381	0.276		0.837	0.813		

Table B.1.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.059	0.444	1.422	3.546	6.782	7.575	9.209	4.858	3.188	1.839	0.460	0.003		0.280			0.257
2004	0.035	0.300	0.976	2.731	7.157	4.948	3.832	2.296	1.214	0.248	0.609	0.042			0.045		
2005	0.000	0.105	0.554	2.360	3.563	3.724	2.409	1.335	0.540	0.524	0.130	0.600					
2006	0.047	0.197	1.352	3.706	6.120	5.268	4.683	4.184	1.369	0.960		0.201	0.061				
2007	0.046	0.095	1.237	2.218	3.615	3.344	2.253	2.656	1.094	0.856	0.078	0.077		0.041			
2008	0.129	0.325	1.560	4.785	5.534	6.240	4.478	3.679	2.084	0.891	0.308	0.147	0.124	0.042	0.039		
2009	0.026	0.497	1.027	4.394	8.242	5.397	4.156	3.320	2.575	1.197	0.402	0.511	0.015		0.005	0.053	
2010	0.007	0.484	1.157	4.367	7.776	8.335	3.848	2.243	3.385	2.313	1.000	1.206	0.149	0.029	0.054	0.101	
2011	0.005	0.246	1.723	4.247	8.519	8.424	7.248	2.316	2.197	1.935	0.683	0.197	1.123	0.041			
2012	0.003	0.425	1.349	5.044	6.842	6.441	4.708	4.271	2.868	1.501	1.468	0.197	0.178	0.254	0.121		0.008
2013	0.011	0.638	1.868	2.284	6.150	8.462	9.972	6.377	4.333	1.699	0.700	1.331	1.302	0.020	0.050	0.042	0.086
2014	0.179	0.614	2.634	6.209	6.622	11.656	7.820	6.943	3.019	2.252	0.406	1.182	0.641	0.034	0.075	0.120	0.036
2015	0.002	0.517	3.110	6.432	10.737	7.299	7.537	4.454	3.416	2.772	0.841	0.545	0.180	0.023	0.065		0.019
2016	0.022	0.280	1.891	5.894	6.053	7.885	3.441	3.994	3.241	1.915	0.566	0.888	0.090	0.055	0.184		0.054
2017	0.031	0.074	1.561	2.963	3.482	4.457	3.505	1.721	1.842	1.152	0.250	0.976	0.097	0.085			
2018	0.001	0.249	1.779	2.333	4.184	4.289	3.516	2.017	1.285	1.218	0.623	0.212	0.098	0.039		0.074	0.023
2019	0.004	0.170	0.836	3.480	4.190	6.171	4.676	3.822	1.039	1.523	0.680	0.712	0.357	0.168	0.027	0.028	0.047
2020	0.001	0.045	0.545	1.897	3.305	3.578	2.051	1.805	1.296	0.548	0.158	0.376		0.023	0.024		

Table B.1.4. Length at age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	9.69	19.86	34.62	44.13	51.43	60.37	69.24	77.02	77.79	83.29	95.32	61.06		118.78			143.00
2004	8.97	21.32	33.97	44.88	56.38	60.30	69.51	72.16	76.45	74.73	85.78	87.83			88.94		
2005	10.97	22.58	34.77	45.23	56.19	61.91	62.55	73.38	73.35	79.01	90.27	107.44					
2006	9.38	21.82	37.77	48.09	56.62	61.73	69.12	69.81	75.40	85.66		125.00	76.00				
2007	9.20	22.55	39.17	49.46	58.43	63.90	69.13	75.48	89.59	95.22	116.00	65.07		123.00			
2008	9.16	21.76	38.19	51.09	59.41	68.28	69.74	75.52	74.14	72.32	74.63	75.35	72.40	100.00	89.00		
2009	8.66	19.63	33.16	46.77	56.59	64.32	70.88	73.50	72.55	75.67	76.48	77.81	68.97		72.98	94.96	
2010	9.59	18.17	34.72	47.50	56.93	63.86	71.93	73.91	74.50	82.06	82.01	88.38	87.68	61.46	104.00	85.23	
2011	10.24	19.25	33.54	48.18	59.34	65.19	71.74	82.77	77.55	85.42	80.34	73.91	88.09	75.38			
2012	9.39	20.46	32.48	46.80	59.04	66.77	70.76	74.60	80.30	84.34	85.31	76.60	82.78	85.38	90.46		79.00
2013	10.94	20.52	34.29	46.17	58.60	67.36	75.98	75.66	83.17	83.43	80.71	86.66	102.07	74.29	88.25	113.00	125.00
2014	10.05	20.36	35.64	49.14	56.94	65.78	71.85	77.13	81.66	81.48	84.80	87.93	85.79	83.56	85.01	86.50	93.40
2015	8.42	20.25	35.43	49.97	60.45	66.47	70.53	76.83	83.94	79.66	85.60	89.93	72.35	95.00	98.40		101.56
2016	9.30	19.09	33.58	48.49	58.81	69.78	73.30	76.15	85.26	88.16	83.07	90.66	81.80	78.15	97.36		96.42
2017	8.05	21.43	36.63	47.83	58.27	68.42	73.93	76.04	87.70	84.72	82.68	98.12	84.10	110.37			
2018	10.11	17.66	37.16	48.17	58.95	68.27	71.52	82.27	85.86	89.11	88.21	78.40	77.58	86.91		120.15	93.00
2019	9.97	19.70	33.51	49.13	59.79	68.59	74.86	77.86	78.44	85.97	86.19	93.47	92.04	92.37	96.34	109.00	96.04
2020	10.87	20.08	33.69	46.58	57.53	67.30	70.99	80.67	83.40	87.60	84.22	91.99		83.98	93.41		

Table B.1.5. Weight at age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	9	80	400	819	1332	2233	3379	4761	5346	6805	9921	2033		17080			25600
2004	7	98	391	945	1852	2350	3563	4100	5035	4538	7973	7865			7130		
2005	14	115	417	955	1884	2462	2553	4462	3959	5552	8077	14845					
2006	7	103	537	1140	1819	2457	3528	3824	4901	6596		25080	4220				
2007	7	125	659	1321	2135	2714	3540	4935	7953	10119	17480	3485		21100			
2008	7	99	575	1339	2167	3265	3524	4849	4770	4493	4541	5040	4114	9250	8520		
2009	9	74	379	1040	1838	2638	3629	4138	4190	4700	5112	5553	3082		3122	9681	
2010	7	61	418	1111	1924	2730	3772	4343	4720	6084	5958	8337	7793	2120	12154	6475	
2011	10	64	366	1123	2139	2853	3957	6170	5047	7495	5668	4111	7567	4653			
2012	7	78	335	995	2013	3064	3499	4275	5585	6622	6957	4411	6173	6953	7006		4630
2013	12	83	389	960	1962	2954	4424	4270	6290	5632	5543	7587	12149	5104	7738	16220	16300
2014	9	80	442	1168	1825	2813	3629	4533	5684	5840	6604	7543	7420	5313	7920	8237	8263
2015	4	78	453	1212	2149	2818	3480	4558	6243	5795	6695	9301	4334	10170	10132		11296
2016	7	68	371	1152	1982	3309	3793	4555	6535	7434	6152	9403	5218	4791	9660		8325
2017	5	88	486	1086	1932	3193	3975	4369	7099	6769	5913	10482	5300	13790			
2018	6	57	512	1109	1975	3125	3719	5692	6216	7726	6947	4781	4564	8512		18477	7350
2019	9	66	368	1181	2139	3130	4085	4660	4640	7008	6731	8592	8869	7996	9585	12345	7040
2020	7	75	397	1041	1901	3140	3482	5579	6216	7095	6372	9186		5165	8589		

Table B.1.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
2003	20.974	2.403	0.115
2004	13.357	1.682	0.126
2005	8.710	1.572	0.180
2006	14.114	2.250	0.159
2007	8.027	2.061	0.257
2008	13.522	1.587	0.117
2009	16.474	1.656	0.101
2010	16.805	2.140	0.127
2011	18.730	3.101	0.166
2012	17.947	2.661	0.148
2013	18.286	2.434	0.133
2014	23.973	4.084	0.170
2015	24.148	3.592	0.149
2016	18.404	1.537	0.084
2017	11.001	1.331	0.121
2018	10.871	1.211	0.111
2019	11.798	1.076	0.091
2020	7.335	0.567	0.077

11.2 Subarea A: North of 67°N

Table B.2.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	6.238	5.254	3.268	3.763	4.521	2.700	2.319	0.863	0.489	0.220	0.042	0.001		0.016			0.010
2004	4.997	2.837	2.201	2.396	2.602	1.463	0.722	0.359	0.181	0.046	0.050	0.006			0.006		
2005	0.026	0.665	1.042	1.988	1.478	1.268	0.746	0.157	0.107	0.068	0.016	0.038					
2006	5.896	1.802	2.156	2.623	2.946	1.554	1.026	0.941	0.171	0.107		0.008	0.015				
2007	6.561	0.446	0.911	0.853	1.071	0.789	0.465	0.394	0.114	0.075	0.004	0.022		0.002			
2008	15.128	2.463	1.822	2.795	1.883	1.419	1.145	0.580	0.348	0.161	0.052	0.011	0.021	0.005	0.005		
2009	3.454	6.642	2.251	3.570	3.716	1.584	0.868	0.712	0.466	0.204	0.076	0.072	0.004		0.002	0.006	
2010	0.424	7.412	2.353	3.268	3.385	2.397	0.784	0.383	0.733	0.317	0.151	0.137	0.018	0.002	0.004	0.015	
2011	0.308	2.322	3.471	2.498	2.866	2.095	1.445	0.292	0.315	0.213	0.116	0.055	0.130	0.008			
2012	0.388	4.299	3.218	4.485	2.784	1.537	1.042	0.930	0.411	0.200	0.209	0.046	0.029	0.043	0.017		0.002
2013	0.486	6.382	4.101	1.706	2.666	1.887	1.575	0.890	0.578	0.297	0.110	0.184	0.107	0.004	0.006	0.003	0.005
2014	9.259	5.696	5.448	4.026	3.034	3.521	2.016	1.388	0.465	0.364	0.059	0.159	0.083	0.006	0.009	0.016	0.004
2015	0.381	4.298	4.733	4.154	3.727	2.068	1.818	0.902	0.506	0.397	0.119	0.053	0.040	0.002	0.006		0.002
2016	3.233	3.944	4.433	4.522	2.610	1.995	0.746	0.735	0.413	0.203	0.067	0.093	0.017	0.005	0.020		0.006
2017	6.268	0.768	2.891	2.407	1.563	1.151	0.715	0.308	0.200	0.147	0.043	0.090	0.018	0.006			
2018	0.135	4.070	3.197	1.916	1.879	1.049	0.748	0.323	0.183	0.128	0.089	0.045	0.022	0.005		0.004	0.003
2019	0.148	2.234	2.114	2.470	1.508	1.460	0.839	0.490	0.148	0.129	0.075	0.069	0.035	0.021	0.003	0.002	0.007
2020	0.066	0.571	1.149	1.520	1.367	0.861	0.499	0.210	0.129	0.042	0.025	0.040		0.004	0.003		

Table B.2.2. CV abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.287	0.231	0.230	0.159	0.140	0.120	0.116	0.244	0.319	0.245	0.691	0.941		0.886			0.867
2004	0.240	0.274	0.158	0.158	0.161	0.209	0.205	0.234	0.344	0.399	0.374	0.922			0.970		
2005	0.611	0.208	0.282	0.295	0.220	0.160	0.248	0.241	0.254	0.452	0.579	0.718					
2006	0.248	0.199	0.336	0.242	0.257	0.174	0.129	0.244	0.299	0.339		0.867	0.830				
2007	0.275	0.226	0.276	0.295	0.180	0.170	0.153	0.238	0.306	0.443	0.867	0.915		0.806			
2008	0.192	0.150	0.263	0.214	0.126	0.109	0.169	0.152	0.202	0.365	0.356	0.346	0.586	0.850	0.794		
2009	0.658	0.160	0.160	0.182	0.144	0.135	0.179	0.147	0.207	0.244	0.273	0.407	0.682		0.844	0.477	
2010	0.476	0.087	0.157	0.192	0.212	0.163	0.180	0.258	0.271	0.213	0.161	0.373	0.518	0.872	0.831	0.440	
2011	0.408	0.203	0.242	0.267	0.186	0.230	0.173	0.246	0.230	0.232	0.353	0.597	0.366	0.628			
2012	0.631	0.091	0.374	0.237	0.132	0.116	0.127	0.160	0.174	0.230	0.196	0.258	0.429	0.564	0.652		0.771
2013	0.663	0.137	0.170	0.148	0.231	0.199	0.213	0.164	0.172	0.307	0.385	0.477	0.405	0.872	0.641	0.806	0.682
2014	0.411	0.166	0.303	0.166	0.165	0.172	0.262	0.141	0.154	0.221	0.389	0.394	0.348	0.774	0.685	0.453	0.574
2015	0.624	0.188	0.174	0.184	0.271	0.294	0.220	0.300	0.190	0.188	0.230	0.402	0.174	0.897	0.448		1.203
2016	0.499	0.197	0.126	0.134	0.104	0.093	0.130	0.158	0.237	0.202	0.196	0.315	0.420	0.527	0.564		1.066
2017	0.512	0.297	0.195	0.169	0.155	0.092	0.174	0.184	0.385	0.297	0.273	0.391	0.534	0.731			
2018	0.805	0.146	0.186	0.156	0.151	0.125	0.109	0.153	0.269	0.189	0.185	0.303	0.420	0.545		0.630	0.842
2019	0.595	0.149	0.155	0.161	0.128	0.102	0.094	0.122	0.173	0.247	0.304	0.220	0.418	0.437	0.970	0.897	0.797
2020	0.814	0.271	0.131	0.139	0.124	0.152	0.148	0.151	0.234	0.329	0.375	0.267		0.823	0.706		

Table B.2.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.059	0.441	1.309	2.981	5.981	5.664	7.962	4.249	2.840	1.442	0.453	0.002		0.280			0.257
2004	0.035	0.287	0.834	2.192	4.133	3.134	2.433	1.425	1.066	0.177	0.214	0.042			0.045		
2005	0.000	0.067	0.455	1.676	2.424	2.851	1.689	0.577	0.441	0.467	0.130	0.600					
2006	0.039	0.181	1.157	3.060	5.387	3.748	3.916	3.379	0.683	0.752		0.201	0.061				
2007	0.046	0.042	0.583	1.135	2.270	2.186	1.667	2.111	0.942	0.812	0.078	0.075		0.041			
2008	0.105	0.243	0.865	3.573	3.734	4.699	3.993	2.929	1.845	0.743	0.246	0.043	0.095	0.042	0.039		
2009	0.023	0.482	0.744	3.412	6.385	4.067	3.210	2.919	2.026	0.854	0.387	0.428	0.013		0.005	0.053	
2010	0.004	0.423	0.937	3.410	6.240	6.423	3.067	1.606	3.382	1.945	0.926	1.204	0.149	0.006	0.054	0.101	
2011	0.003	0.133	1.312	2.732	6.143	5.850	5.185	1.517	1.607	1.519	0.679	0.194	0.933	0.041			
2012	0.003	0.309	1.105	4.272	5.579	4.475	3.593	3.946	1.939	1.145	1.466	0.197	0.178	0.254	0.121		0.008
2013	0.005	0.534	1.662	1.713	5.321	5.893	5.866	3.591	3.093	1.699	0.673	1.331	1.302	0.020	0.050	0.042	0.086
2014	0.074	0.454	2.257	4.761	5.729	9.852	7.328	6.114	2.715	2.126	0.406	1.179	0.639	0.034	0.075	0.119	0.036
2015	0.002	0.337	2.282	5.151	8.598	5.904	6.803	4.167	3.300	2.186	0.831	0.544	0.176	0.023	0.065		0.019
2016	0.021	0.263	1.669	5.006	5.353	6.663	3.002	3.617	2.682	1.347	0.476	0.888	0.090	0.027	0.184		0.054
2017	0.031	0.067	1.339	2.470	2.994	3.707	2.883	1.438	1.415	0.961	0.250	0.976	0.097	0.085			
2018	0.001	0.242	1.694	2.127	3.711	3.143	2.776	1.840	1.115	1.096	0.623	0.211	0.098	0.039		0.074	0.023
2019	0.001	0.143	0.790	2.681	2.890	4.449	3.301	2.317	0.724	0.883	0.553	0.641	0.337	0.162	0.027	0.028	0.047
2020	0.000	0.042	0.352	1.419	2.627	2.548	1.726	1.055	0.832	0.317	0.157	0.372		0.022	0.023		

Table B.2.4. Length at age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	9.69	19.86	34.52	43.95	51.38	59.50	69.59	77.30	78.67	82.01	95.43	61.05		118.78			143.00
2004	8.98	21.36	33.66	44.33	54.01	59.14	68.71	71.61	79.70	71.48	73.81	87.83			88.94		
2005	10.96	21.73	35.51	44.17	54.42	60.43	60.45	71.41	74.38	83.28	90.27	107.44					
2006	9.29	21.60	37.56	48.50	56.86	61.62	70.83	69.49	71.54	87.71		125.00	76.00				
2007	9.20	20.57	38.99	50.03	58.86	63.84	69.77	76.79	89.42	95.97	116.00	65.20		123.00			
2008	9.21	21.88	36.48	50.50	58.37	68.79	69.74	76.98	76.30	74.10	75.26	71.91	74.37	100.00	89.00		
2009	8.31	19.55	32.28	45.69	55.67	64.07	71.00	73.52	72.96	73.82	76.91	79.39	69.00		73.00	94.96	
2010	10.54	17.93	34.24	46.78	56.25	63.65	73.25	73.24	74.52	81.68	81.95	88.49	87.77	60.09	104.00	85.23	
2011	10.39	18.66	34.05	48.06	59.55	65.11	70.59	78.70	79.45	83.87	80.60	74.00	86.43	75.38			
2012	9.35	19.99	32.61	46.25	58.88	65.58	70.11	74.24	76.02	81.24	85.38	76.60	82.78	85.38	90.46		79.00
2013	10.64	20.68	34.70	46.99	59.21	68.33	73.12	74.04	80.24	83.43	82.22	86.66	102.07	74.29	88.25	113.00	125.00
2014	9.28	20.37	34.99	49.60	57.77	65.93	71.85	76.62	82.41	81.31	84.80	88.16	85.85	83.56	85.01	86.51	93.40
2015	8.41	20.00	36.42	50.33	62.01	67.46	72.79	77.52	85.01	79.01	85.87	90.02	72.48	95.00	98.40		101.56
2016	9.26	19.08	33.66	48.12	59.56	70.51	74.95	78.42	85.00	85.34	86.21	90.66	81.80	81.11	97.36		96.42
2017	8.05	21.43	36.14	47.20	58.11	68.93	74.45	78.57	86.22	83.86	82.68	98.12	84.10	110.37			
2018	10.09	18.05	37.50	48.27	59.09	67.72	71.64	82.25	85.73	92.34	88.22	78.41	77.58	86.93		120.15	93.00
2019	9.35	19.56	33.76	48.32	58.51	68.48	74.41	78.87	80.57	86.10	89.59	95.89	92.88	92.56	96.34	109.00	96.04
2020	10.63	19.97	31.82	45.34	57.86	66.46	71.26	79.10	84.74	88.11	84.37	92.13		84.00	93.58		

Table B.2.5. Weight at age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	9	80	397	791	1322	2098	3421	4774	5559	6519	9954	2033		17080			25600
2004	7	98	378	913	1588	2154	3373	3942	5693	3751	4183	7865			7130		
2005	14	101	431	843	1649	2249	2277	3662	4139	6331	8077	14845					
2006	7	100	529	1162	1816	2410	3822	3645	4026	7059		25080	4220				
2007	7	94	629	1312	2113	2762	3581	5277	8139	10381	17480	3523		21100			
2008	7	99	470	1272	1985	3314	3489	5036	5253	4742	4719	3796	4960	9250	8520		
2009	8	73	331	953	1719	2567	3703	4102	4347	4217	5204	5874	3084		3122	9681	
2010	9	57	399	1043	1840	2685	3902	4217	4724	6131	6111	8362	7813	2635	12154	6475	
2011	10	57	377	1091	2153	2814	3589	5181	5110	7083	5714	4122	7288	4653			
2012	7	72	336	954	2004	2911	3449	4248	4712	5714	6970	4411	6173	6953	7006		4630
2013	12	84	402	1004	2003	3119	3724	4042	5371	5632	5803	7587	12149	5104	7738	16220	16300
2014	8	80	411	1179	1887	2802	3623	4402	5840	5812	6604	7585	7436	5313	7920	8240	8263
2015	4	78	480	1232	2287	2891	3756	4679	6466	5492	6759	9330	4369	10170	10132		11296
2016	7	67	375	1104	2049	3340	4025	4916	6451	6672	7009	9403	5218	5602	9660		8325
2017	5	88	462	1027	1919	3218	4031	4685	6872	6553	5913	10482	5300	13790			
2018	6	60	526	1106	1974	2996	3712	5699	6147	8461	6949	4782	4564	8517		18477	7350
2019	10	64	373	1085	1918	3053	3936	4721	4906	6788	7312	9241	9115	8042	9585	12345	7040
2020	7	75	307	931	1918	2942	3455	5006	6451	7429	6405	9235		5165	8634		

Table B.2.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
2003	18.212	2.288	0.126
2004	10.031	1.221	0.122
2005	6.908	1.427	0.207
2006	11.547	2.317	0.201
2007	4.700	0.828	0.176
2008	10.247	1.417	0.138
2009	13.530	1.397	0.103
2010	13.947	2.003	0.144
2011	13.505	2.247	0.166
2012	14.952	2.514	0.168
2013	14.120	1.813	0.128
2014	20.602	3.586	0.174
2015	18.528	2.987	0.161
2016	15.865	1.324	0.083
2017	9.540	1.262	0.132
2018	9.591	1.087	0.113
2019	9.368	0.877	0.094
2020	5.848	0.493	0.084

11.3 Subarea B: Between 65° and 67°N

Table B.3.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.015	0.054	0.235	0.479	0.344	0.296	0.161	0.073	0.049	0.013	0.000	0.002		0.000			0.000
2004	0.026	0.094	0.315	0.350	0.567	0.345	0.207	0.095	0.061	0.004	0.021	0.000			0.000		
2005	0.004	0.049	0.186	0.275	0.153	0.152	0.075	0.073	0.013	0.020	0.001	0.000					
2006	0.106	0.119	0.248	0.499	0.275	0.317	0.254	0.159	0.035	0.038		0.000	0.000				
2007	0.008	0.245	0.912	0.696	0.500	0.309	0.183	0.069	0.002	0.001	0.000	0.001		0.000			
2008	0.443	0.341	0.517	0.574	0.376	0.369	0.105	0.119	0.086	0.030	0.015	0.012	0.011	0.000	0.000		
2009	0.216	0.131	0.457	0.440	0.548	0.250	0.202	0.058	0.148	0.053	0.003	0.012	0.000		0.000	0.000	
2010	0.031	0.595	0.514	0.484	0.442	0.527	0.225	0.141	0.008	0.024	0.026	0.001	0.002	0.012	0.000	0.000	
2011	0.170	1.487	1.216	1.124	0.871	0.562	0.221	0.017	0.045	0.011	0.006	0.001	0.019	0.000			
2012	0.012	1.248	1.001	0.509	0.396	0.359	0.107	0.055	0.013	0.030	0.010	0.011	0.002	0.005	0.000		0.002
2013	0.326	1.070	0.669	0.689	0.462	0.604	0.212	0.078	0.009	0.005	0.012	0.001	0.003	0.000	0.000	0.000	0.000
2014	10.944	1.749	0.341	1.019	0.350	0.242	0.048	0.071	0.049	0.039	0.003	0.000	0.007	0.001	0.000	0.000	0.000
2015	0.002	2.208	1.299	0.966	1.030	0.454	0.286	0.087	0.028	0.076	0.025	0.002	0.007	0.000	0.002		0.000
2016	0.067	0.358	0.621	0.258	0.303	0.321	0.187	0.158	0.058	0.052	0.008	0.009	0.000	0.008	0.000		0.000
2017	0.000	0.038	0.289	0.272	0.116	0.166	0.079	0.067	0.061	0.027	0.006	0.004	0.001	0.001			
2018	0.012	0.405	0.226	0.172	0.145	0.118	0.099	0.056	0.036	0.009	0.011	0.005	0.001	0.003		0.000	0.000
2019	0.318	0.348	0.239	0.335	0.291	0.229	0.053	0.087	0.024	0.035	0.018	0.012	0.001	0.000	0.000	0.000	0.000
2020	0.015	0.019	0.139	0.240	0.302	0.119	0.091	0.048	0.033	0.012	0.002	0.003		0.000	0.002		

Table B.3.2. CV abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	1.511	0.545	0.626	0.405	0.460	0.420	0.456	0.528	0.580	0.821		1.754					
2004	0.899	0.653	0.302	0.312	0.308	0.363	0.658	0.613	0.612	1.755	0.926						
2005	2.970	0.637	0.452	0.486	0.407	0.369	0.451	0.466	0.818	0.524	0.867						
2006	0.935	0.460	0.463	0.305	0.405	0.356	0.284	0.355	0.638	0.567							
2007	0.965	0.642	0.850	0.873	0.766	0.706	0.433	0.642	0.909	6.516		6.592					
2008	0.558	0.251	0.458	0.392	0.301	0.262	0.487	0.262	0.361	0.591	0.767	0.781	0.831				
2009	0.686	0.500	0.423	0.515	0.406	0.440	0.494	0.569	0.475	0.560	2.956	0.880	10.913		16.653		
2010	0.927	0.366	0.378	0.347	0.306	0.336	0.358	0.443	0.885	0.599	0.582	6.463	1.592	0.823			
2011	0.928	0.680	0.556	0.831	0.625	0.572	0.535	1.064	0.621	1.927	1.273	5.298	0.903				
2012	2.247	0.475	0.315	0.235	0.395	0.397	0.360	0.397	0.620	0.787	0.757	0.670	0.778	0.835			0.771
2013	0.811	0.531	0.260	0.371	0.403	0.504	0.417	0.487	0.069	0.460	0.686	0.776	0.395				
2014	0.455	0.405	0.307	0.548	0.467	0.445	0.479	0.683	0.493	0.702	0.520		0.979	0.803			
2015	4.653	0.354	0.318	0.523	0.522	0.416	0.426	0.517	0.717	0.701	0.675	1.683	1.217		0.791		
2016	1.410	0.538	0.315	0.434	0.344	0.289	0.387	0.376	0.584	0.593	0.700	0.403		0.944			
2017		0.655	0.293	0.339	0.313	0.304	0.338	0.305	0.511	0.369	0.678	0.198	0.697	0.859			
2018	1.958	0.624	0.467	0.323	0.321	0.297	0.271	0.263	0.362	0.441	0.468	0.620	0.806	0.657			
2019	0.475	0.482	0.358	0.354	0.471	0.382	0.405	0.359	0.459	0.430	0.662	0.601	1.141				
2020	1.198	1.020	0.374	0.392	0.465	0.594	0.551	0.503	0.633	0.548	1.342	1.212		10.862	1.097		

Table B.3.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.000	0.004	0.090	0.324	0.371	0.537	0.406	0.212	0.146	0.031	0.000	0.003		0.000			0.000
2004	0.000	0.009	0.140	0.273	0.995	0.635	0.561	0.283	0.156	0.011	0.394	0.000			0.000		
2005	0.000	0.004	0.060	0.168	0.197	0.303	0.191	0.214	0.038	0.057	0.014	0.000					
2006	0.001	0.016	0.115	0.444	0.349	0.539	0.593	0.690	0.205	0.207		0.000	0.000				
2007	0.000	0.043	0.441	0.596	0.772	0.702	0.570	0.304	0.012	0.003	0.000	0.002		0.000			
2008	0.005	0.029	0.267	0.765	0.764	1.071	0.397	0.398	0.237	0.125	0.061	0.044	0.029	0.000	0.000		
2009	0.003	0.011	0.170	0.533	0.960	0.626	0.561	0.149	0.546	0.345	0.010	0.025	0.001		0.000	0.000	
2010	0.000	0.041	0.235	0.479	0.870	1.313	0.628	0.657	0.021	0.067	0.125	0.002	0.005	0.023	0.000	0.000	
2011	0.001	0.116	0.366	1.045	1.418	1.285	0.583	0.044	0.420	0.026	0.019	0.004	0.190	0.000			
2012	0.000	0.123	0.306	0.376	0.619	1.033	0.304	0.183	0.053	0.372	0.038	0.056	0.009	0.021	0.000		0.008
2013	0.004	0.057	0.181	0.513	0.672	1.361	0.465	0.214	0.043	0.021	0.031	0.005	0.014	0.000	0.000	0.000	0.000
2014	0.104	0.146	0.187	0.825	0.341	0.532	0.133	0.382	0.228	0.150	0.013	0.000	0.024	0.003	0.000	0.000	0.000
2015	0.000	0.171	0.344	1.004	1.628	1.025	0.628	0.287	0.086	0.570	0.091	0.010	0.029	0.000	0.013		0.000
2016	0.001	0.029	0.184	0.169	0.426	0.759	0.499	0.470	0.269	0.520	0.038	0.052	0.000	0.028	0.000		0.000
2017	0.000	0.003	0.130	0.280	0.213	0.393	0.283	0.228	0.453	0.208	0.024	0.017	0.003	0.014			
2018	0.000	0.014	0.073	0.172	0.226	0.287	0.295	0.238	0.173	0.046	0.050	0.018	0.008	0.019		0.000	0.000
2019	0.003	0.028	0.063	0.373	0.598	0.565	0.158	0.309	0.074	0.152	0.082	0.065	0.005	0.000	0.000	0.000	0.000
2020	0.000	0.002	0.055	0.254	0.524	0.289	0.294	0.219	0.153	0.052	0.006	0.015		0.000	0.009		

Table B.3.4. Length at age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	10.00	19.86	34.38	40.64	47.42	56.53	63.37	66.45	68.28	64.26		61.05					
2004	9.00	22.14	35.01	43.03	54.24	56.32	61.95	65.45	63.70	72.18	120.83						
2005	10.63	20.97	31.37	39.79	50.01	58.34	62.15	64.65	63.88	64.78	108.00						
2006	11.67	24.94	35.74	44.65	49.84	55.38	61.70	69.45	81.23	80.26							
2007	9.97	25.38	34.29	43.01	52.39	60.32	65.77	74.05	91.00	60.77		58.38					
2008	11.68	21.15	37.10	50.48	57.89	65.43	69.66	65.79	65.10	70.71	72.87	70.87	69.97				
2009	11.49	21.64	32.15	47.96	54.65	61.33	66.52	63.82	70.60	80.70	65.61	59.17	67.40		70.00		
2010	12.00	19.44	35.12	44.92	56.90	61.39	64.88	75.02	61.25	66.95	81.66	60.93	60.01	62.00			
2011	9.83	20.16	30.42	43.37	55.75	61.78	64.03	65.15	87.65	60.71	69.19	62.05	102.00				
2012	10.65	22.32	31.60	42.93	54.93	67.05	67.09	68.26	73.69	93.93	74.17	78.31	73.00	74.94			79.00
2013	11.44	17.74	30.70	42.83	52.60	61.46	62.94	65.93	76.37	76.09	63.67	69.00	74.70				
2014	10.73	20.46	38.23	42.69	46.62	58.93	67.47	77.68	75.01	74.64	81.28		71.69	75.00			
2015	10.88	20.51	29.80	46.53	54.35	60.63	60.50	70.40	71.33	85.50	74.51	76.85	75.82		95.00		
2016	10.35	20.58	31.65	39.51	52.06	60.54	64.65	66.41	77.25	97.35	75.60	83.76		73.00			
2017		22.16	36.00	47.14	56.71	62.37	70.89	69.08	87.12	88.21	76.19	76.05	78.00	99.00			
2018	10.66	15.21	32.88	45.33	53.87	61.84	66.36	73.71	77.41	78.04	78.23	75.19	98.00	80.87			
2019	10.62	20.29	29.52	47.40	58.30	62.36	65.12	71.49	68.09	73.51	73.95	86.65	76.97				
2020	11.94	22.83	34.55	46.89	55.10	62.06	66.73	75.66	77.61	77.43	78.48	82.85		81.80	82.97		

Table B.3.5. Weight at age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	10	69	383	667	1070	1831	2592	2876	3172	2627		2033					
2004	6	107	440	772	1737	1823	2484	2861	2519	3396	19004						
2005	14	85	329	617	1278	1964	2527	2941	2671	2873	12140						
2006	13	139	457	887	1257	1693	2336	4269	5914	5353							
2007	7	160	422	806	1518	2250	3138	4143	6804	2281		1485					
2008	11	85	526	1322	2058	2916	3785	3412	2749	4571	3955	3716	2737				
2009	14	86	354	1152	1734	2474	2848	2605	3606	6205	3050	2022	3084		3122		
2010	14	69	445	978	1973	2469	2793	4551	2362	2856	4925	2825	2285	1915			
2011	9	75	285	818	1683	2361	2681	2839	9183	2343	3580	2440	10116				
2012	9	100	311	736	1555	2912	2804	3312	4149	9801	4212	4856	3745	4318			4630
2013	12	52	272	760	1460	2193	2240	2739	4584	4326	2554	3425	4262				
2014	10	86	534	739	973	2161	2876	4915	4475	4035	4659		3635	3340			
2015	19	77	263	1000	1554	2278	2241	3392	3418	7843	3516	4276	4335		7785		
2016	9	84	294	661	1411	2376	2678	3003	4680	10566	4579	5951		3425			
2017		92	444	1020	1844	2366	3567	3390	6677	7467	4049	4314	3935	10610			
2018	5	40	327	1010	1585	2468	2987	4217	4882	4988	4720	3535	8695	6416			
2019	11	77	267	1100	2005	2497	2973	3577	3220	4252	4282	6269	4317				
2020	7	88	393	1056	1735	2463	3166	4680	4637	4613	3372	6073		5165	5434		

Table B.3.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
2003	1.650	0.655	0.397
2004	1.965	0.651	0.332
2005	0.949	0.377	0.398
2006	1.826	0.508	0.278
2007	2.673	2.045	0.765
2008	2.215	0.620	0.280
2009	2.171	0.888	0.409
2010	2.406	0.727	0.302
2011	4.092	2.531	0.619
2012	2.500	0.574	0.230
2013	2.745	0.718	0.262
2014	2.170	0.680	0.313
2015	4.262	1.573	0.369
2016	1.982	0.561	0.283
2017	1.088	0.270	0.248
2018	0.883	0.233	0.263
2019	1.323	0.401	0.303
2020	0.990	0.415	0.419

11.4 Subarea C: Between 62°N and 65°N

Table B.4.1. Abundance indices (millions)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.000	0.010	0.058	0.260	0.284	0.429	0.254	0.077	0.055	0.042	0.001	0.001		0.000			0.000
2004	0.054	0.065	0.074	0.235	0.781	0.355	0.161	0.110	0.004	0.009	0.000	0.000			0.000		
2005	0.000	0.191	0.107	0.230	0.285	0.122	0.135	0.069	0.022	0.000	0.001	0.000					
2006	0.844	0.007	0.115	0.116	0.157	0.324	0.073	0.024	0.071	0.000		0.000	0.000				
2007	0.008	0.073	0.146	0.198	0.149	0.155	0.031	0.083	0.025	0.006	0.000	0.000		0.000			
2008	2.836	0.487	0.349	0.199	0.291	0.125	0.021	0.058	0.001	0.009	0.000	0.006	0.000	0.000	0.000		
2009	0.000	0.083	0.226	0.289	0.340	0.215	0.083	0.049	0.011	0.005	0.002	0.007	0.000		0.000	0.000	
2010	0.503	0.451	0.092	0.306	0.286	0.234	0.035	0.006	0.007	0.051	0.010	0.000	0.002	0.000	0.000	0.000	
2011	0.000	0.047	0.120	0.241	0.286	0.326	0.170	0.083	0.075	0.031	0.004	0.000	0.000	0.000			
2012	0.000	0.083	0.308	0.374	0.261	0.229	0.231	0.077	0.104	0.004	0.009	0.011	0.002	0.005	0.000		0.002
2013	0.131	0.318	0.183	0.120	0.087	0.408	0.470	0.545	0.116	0.005	0.001	0.001	0.003	0.000	0.000	0.000	0.000
2014	0.155	0.354	0.217	0.302	0.258	0.411	0.126	0.110	0.038	0.060	0.003	0.002	0.007	0.001	0.000	0.000	0.000
2015	0.000	0.086	0.839	0.184	0.250	0.098	0.095	0.005	0.024	0.027	0.022	0.002	0.006	0.000	0.002		0.000
2016	0.012	0.147	0.122	0.393	0.197	0.196	0.074	0.070	0.074	0.021	0.035	0.009	0.000	0.000	0.000		0.000
2017	0.000	0.108	0.163	0.107	0.143	0.143	0.124	0.068	0.007	0.004	0.006	0.004	0.001	0.001			
2018	0.000	0.120	0.082	0.068	0.113	0.259	0.193	0.042	0.049	0.039	0.011	0.005	0.001	0.003		0.000	0.000
2019	0.028	0.012	0.084	0.183	0.177	0.296	0.256	0.271	0.064	0.061	0.015	0.012	0.006	0.001	0.000	0.000	0.000
2020	0.000	0.025	0.140	0.133	0.100	0.198	0.036	0.077	0.055	0.032	0.001	0.002		0.000	0.001		

Table B.4.2. CV abundance indices

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003		0.712	0.779	0.483	0.829	0.529	0.715	0.860	0.934	0.813	5.884	0.830					
2004	1.250	0.998	0.463	0.415	0.407	0.389	0.429	0.549	0.936	0.790	7.491						
2005		0.636	0.609	0.530	0.448	0.570	0.478	0.658	0.798		0.867						
2006	0.627	0.411	0.387	0.641	0.394	0.548	0.571	0.615	0.645								
2007	0.965	0.654	0.486	0.403	0.551	0.475	0.342	0.674	0.673	0.885							
2008	0.913	0.852	0.454	0.475	0.491	0.435	0.922	0.733	4.512	0.893	8.656	0.928					
2009		0.465	0.289	0.611	0.588	0.786	0.926	0.803	1.817	2.604	5.625	0.996	13.536				
2010	0.971	0.530	0.216	0.520	0.592	0.556	0.409	0.421	0.573	0.837	0.342		0.742				
2011		0.185	0.575	0.459	0.452	0.453	0.531	0.474	0.553	0.893	0.509						
2012		0.287	0.636	0.361	0.496	0.694	0.577	0.534	0.818	0.461	0.350	0.670	0.778	0.835			0.771
2013	0.859	0.867	0.418	0.491	0.574	0.843	0.713	0.692	0.556	0.460	0.772	0.776	0.395				
2014	1.145	0.840	0.464	0.571	0.698	0.580	0.502	0.698	0.613	0.619	0.520	5.910	1.159	0.803		22.361	
2015		0.849	0.559	0.447	0.479	0.555	0.656	0.909	0.652	0.587	0.554	0.774	0.102		0.791		
2016	0.791	0.414	0.549	0.406	0.429	0.346	0.436	0.547	0.483	0.614	0.701	0.403					
2017		0.719	0.416	0.417	0.493	0.378	0.457	0.406	0.222	0.345	0.678	0.198	0.697	0.859			
2018		0.418	0.629	0.384	0.454	0.370	0.355	0.259	0.422	0.716	0.469	0.614	0.806	0.653			
2019	0.958	0.850	0.371	0.406	0.659	0.733	0.548	0.563	0.905	0.692	1.559	1.565	2.276	5.787			
2020		0.956	0.413	0.422	0.413	0.245	0.471	0.391	0.555	0.771	0.834	0.799			0.836		

Table B.4.3. Biomass indices (kilotonnes)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003	0.000	0.000	0.028	0.299	0.469	1.401	0.872	0.424	0.274	0.380	0.006	0.002		0.000			0.000
2004	0.000	0.004	0.019	0.308	2.092	1.227	0.853	0.595	0.009	0.075	0.001	0.000			0.000		
2005	0.000	0.034	0.043	0.525	0.966	0.611	0.538	0.557	0.070	0.000	0.014	0.000					
2006	0.006	0.001	0.085	0.202	0.408	1.043	0.235	0.138	0.481	0.000		0.000	0.000				
2007	0.000	0.012	0.218	0.495	0.581	0.490	0.116	0.273	0.164	0.041	0.000	0.000		0.000			
2008	0.019	0.053	0.427	0.448	1.036	0.471	0.088	0.352	0.002	0.022	0.000	0.059	0.000	0.000	0.000		
2009	0.000	0.009	0.158	0.480	0.969	0.710	0.397	0.299	0.029	0.013	0.005	0.058	0.001		0.000	0.000	
2010	0.002	0.048	0.016	0.523	0.720	0.736	0.210	0.020	0.018	0.337	0.052	0.000	0.004	0.000	0.000	0.000	
2011	0.000	0.003	0.061	0.488	0.973	1.296	1.484	0.808	0.170	0.391	0.014	0.000	0.000	0.000			
2012	0.000	0.008	0.121	0.555	0.687	0.995	0.905	0.339	0.976	0.016	0.037	0.056	0.009	0.021	0.000		0.008
2013	0.002	0.050	0.064	0.125	0.213	1.277	3.744	2.639	1.283	0.021	0.004	0.005	0.014	0.000	0.000	0.000	0.000
2014	0.002	0.024	0.202	0.632	0.564	1.326	0.489	0.593	0.150	0.276	0.013	0.004	0.026	0.003	0.000	0.000	0.000
2015	0.000	0.010	0.485	0.283	0.533	0.372	0.192	0.021	0.103	0.110	0.084	0.009	0.025	0.000	0.013		0.000
2016	0.000	0.012	0.064	0.754	0.331	0.811	0.272	0.253	0.528	0.190	0.129	0.052	0.000	0.000	0.000		0.000
2017	0.000	0.009	0.128	0.248	0.301	0.522	0.446	0.211	0.026	0.017	0.024	0.017	0.003	0.014			
2018	0.000	0.007	0.026	0.067	0.282	1.054	0.773	0.182	0.297	0.168	0.050	0.018	0.008	0.019		0.000	0.000
2019	0.001	0.001	0.016	0.439	0.726	1.185	1.232	1.298	0.295	0.523	0.071	0.072	0.024	0.006	0.000	0.000	0.000
2020	0.000	0.002	0.156	0.267	0.204	0.841	0.144	0.580	0.355	0.233	0.005	0.011		0.000	0.008		

Table B.4.4. Length at age (cm)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003		17.31	33.13	44.67	52.18	66.76	68.29	75.08	77.81	93.01	84.42	61.04					
2004	9.16	16.91	28.55	48.68	63.18	66.87	77.57	79.22	62.80	88.52	63.44						
2005		26.78	33.20	59.22	68.01	74.51	72.93	81.79	66.42		108.00						
2006	9.98	21.96	41.84	53.82	60.92	66.50	68.23	66.22	86.82								
2007	9.97	23.65	50.34	60.55	68.31	69.03	67.63	70.49	91.31	89.00							
2008	8.33	21.34	48.25	60.00	68.10	70.79	71.94	78.57	61.38	59.05	62.00	87.89					
2009		22.22	38.04	51.59	61.81	70.70	75.86	79.22	62.77	62.25	66.95	91.73	67.00				
2010	8.02	20.70	27.14	50.94	59.27	63.95	78.94	66.91	61.27	81.12	79.67		60.00				
2011		20.51	34.19	56.06	68.10	70.66	89.96	95.59	63.83	106.00	69.52						
2012		21.72	33.95	51.94	63.37	70.99	72.63	74.78	90.09	71.36	74.33	78.31	73.00	74.94			79.00
2013	11.00	24.25	32.75	44.82	55.34	71.04	88.43	79.79	95.79	76.09	63.00	69.00	74.70				
2014	11.70	21.12	43.63	58.48	59.96	67.83	73.87	79.82	74.50	77.93	81.28	61.71	71.66	75.00		70.00	
2015		22.25	38.86	53.28	57.32	70.80	61.01	71.05	75.34	76.42	74.87	77.00	76.15		95.00		
2016	10.00	21.14	36.26	56.79	54.97	72.89	71.14	69.90	84.50	97.40	74.29	83.76					
2017		21.85	40.91	58.32	61.16	68.15	70.64	66.42	73.92	81.74	76.19	76.05	78.00	99.00			
2018		19.52	32.19	45.60	63.57	74.71	72.80	74.12	82.67	75.60	78.26	75.22	98.00	80.88			
2019	11.83	19.97	28.09	59.05	70.49	71.02	78.73	77.01	76.47	90.06	77.19	92.56	76.89	81.69			
2020		21.00	47.03	54.73	59.39	73.19	70.63	86.06	83.71	86.60	79.00	83.00			83.00		

Table B.4.5. Weight at age (gram)

	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16
2003		40	365	1101	1436	3168	3272	5072	5062	8818	6215	2033					
2004	7	48	254	1247	2604	3510	5123	5797	2414	7569	2473						
2005		188	402	2201	3380	4439	3947	6824	2778		12140						
2006	8	81	718	1798	2558	3228	3171	4489	7765								
2007	7	169	1478	2435	3582	3182	3570	3952	7115	7500							
2008	7	99	1169	2282	3468	3720	4226	5348	2369	2334	2475	9590					
2009		99	663	1468	2691	3455	4183	5423	2703	2687	2746	7945	2870				
2010	4	95	175	1551	2360	3011	5553	3154	2369	5343	5091		2285				
2011		65	423	1909	3336	3730	8552	9298	2319	12482	3640						
2012		93	424	1487	2530	3851	3712	4126	7459	3729	4235	4856	3745	4318			4630
2013	13	129	330	923	1976	3183	7125	4835	10222	4326	2400	3425	4262				
2014	14	74	905	2078	2133	3194	4110	5267	3894	4804	4659	2441	3634	3340		4400	
2015		97	629	1491	2113	3576	2284	3228	4368	4328	3560	4310	4395		7785		
2016	9	83	452	1899	1624	4040	3585	3558	6659	9035	3961	5951					
2017		90	758	2215	2137	3506	3509	3183	3885	4583	4049	4314	3935	10610			
2018		61	305	953	2558	4136	3965	4332	5991	4510	4724	3539	8695	6419			
2019	23	67	195	2364	4053	3666	4952	4771	4592	8250	4122	7605	4331	5340			
2020		78	1075	1866	2050	4258	3767	7391	6500	6694	3386	6140			5434		

Table B.4.6. Abundance index, standard deviation (SD) and Coefficient of variation (CV) for sum of age 2+ fish

	Index_2plus	SD_2plus	CV_2plus
2003	1.461	0.803	0.550
2004	1.728	0.590	0.341
2005	0.970	0.358	0.369
2006	0.880	0.271	0.308
2007	0.792	0.254	0.321
2008	1.060	0.362	0.341
2009	1.227	0.690	0.562
2010	1.029	0.429	0.417
2011	1.336	0.487	0.364
2012	1.616	0.622	0.385
2013	1.940	1.033	0.533
2014	1.533	0.739	0.482
2015	1.553	0.665	0.428
2016	1.191	0.285	0.239
2017	0.771	0.219	0.284
2018	0.864	0.244	0.283
2019	1.426	0.700	0.491
2020	0.776	0.135	0.174

12 Appendix C

R-script to produce the time series tables and figures from Stocks bootstrap output files. This is a version for acoustic time series.

```
# espen.johnsen@hi.no, September 2019
#####################################


# Coastal cod by harald@hi.no and johanna.fall@hi.no sept 2020
# Oppdatert 01.11.2021 med 2020 indeks. Hele serien kjørt ut på nytt til
# //delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/N67/, Tot, S65, osv.
# Oppdatert 27.01.2021 med SSB estimat
# Oppdatert 12.03.2021 med linje 51-55 for ? legge til nullverdier i beregningene.

# All non-coastal cod (otolithtype > 2) are stripped from the dataset, so that all output is for coastal cod only

rm(list=ls())

library(data.table)
library(Hmisc)
library(Rstox)
library(xlsx)


## Coastal cod

#path1 <- "C:Users//harald//workspace//stox//project//Varanger Stad cod acoustic index in autumn "
#path1 <- "C:Users//harald//workspace//stox//project//Varanger Stad coastal cod swept area "
path1 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Akustikk stox/Varanger Stad cod acoustic index in autumn "

#path2 <- "D://Documents//OwnCloud//Softwarespesifikk//R//Projects//Kysttorsk//Swept area//Tot//"
#path2 <- "D://Documents//OwnCloud//Softwarespesifikk//R//Projects//Kysttorsk//Acoustics//Tot//"
# path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/N67//"
# path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/65-67//"
# path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/S65//"
#for SSB calcs - management plan
```

```
#Correction of indices - adding zeros at age for iterations with zeroes (were NA)
# path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/N-WIPaddzeroes//"
# path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/Tot-WIPaddzeroes//"
# path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/65-67-WIPaddzeroes//"
path2 <- "//delphi/Felles/421-Bunnfisk/Kysttorsk/Acoustics/S65-WIPaddzeroes//"

out <- list()
for(y in 1:26){
 year <- 1994+y
 print(year)
 load(paste0(path1,year," N67\\output\\r\\data\\bootstrapImpute.RData"))
 bootstrapVariable.out <- eval(parse(text="bootstrapImpute"))
 DT <- rbindlist(bootstrapVariable.out[[2]],idcol=TRUE)

 DT <- DT[DT$otolithtype <= 2] # Only coastal cod (otolithtype 1 and 2) included

 ## Some SuperINd may miss weight. Generate weight from a length weight relation
 id1 <- DT$weight > 0
 lm.wl <- lm(log(DT$weight[id1]) ~ log(DT$length[id1]))
 a <- exp(as.numeric(lm.wl$coeff[1]))
 b <- as.numeric(lm.wl$coeff[2])
 DT$weight[is.na(DT$weight) | DT$weight == 0] <- a*(DT$length[is.na(DT$weight) | DT$weight == 0] )^b
 #plot(DT$weight ~ DT$length)

 #Create zero values for ages not observed in an iteration
 setkey(DT, Stratum, age, .id)
 DT <- DT[CJ(Stratum, age, .id, unique=TRUE)]
 DT$Abundance[is.na(DT$Abundance)] <- 0
 DT$weight[is.na(DT$weight)] <- 0 #to include zeroes in biomass calc

 ## Output by age and by sum over age 2 to maxage
 strata <- unique(DT[,c("Stratum", "includeintotal")])
 # strata.incl <- strata[strata$includeintotal=="TRUE",]
```

```
#manually remove strata so we only have area N67 left
# strata.incl <- strata[!Stratum %in% c("Helgeland indre", "Helgeland ytre",
#                           "Stad Halten indre", "Stad Halten ytre",
#                           "Vestfjord ost"),]

#manually remove strata so we only have area 6567 left
strata.incl <- strata[!Stratum %in% c("Alta","Andfjord Vaagsfjord",
                        "Fugloybanken","Hjelmsoy indre",
                        "Hjelmsoy Loppa","Kvenangen",
                        "Laksefjord","Malangen","Osthavet",
                        "Porsangen","Soroya indre",
                        "Stad Halten indre","Stad Halten ytre",
                        "Tana","Ullsfjord Lyngen","Varangerfjord",
                        "Vesteralen","Vestfjord indre","Vestfjord ost",
                        "Vestfjord vest"),]

#manually remove strata so we only have area S65 left
strata.incl <- strata[!Stratum %in% c("Alta","Andfjord Vaagsfjord",
                        "Fugloybanken","Helgeland indre",
                        "Helgeland ytre","Hjelmsoy indre",
                        "Hjelmsoy Loppa","Kvenangen",
                        "Laksefjord","Malangen","Osthavet",
                        "Porsangen","Soroya indre",
                        "Tana","Ullsfjord Lyngen","Varangerfjord",
                        "Vesteralen","Vestfjord indre","Vestfjord ost",
                        "Vestfjord vest"),]

#manually remove strata so we have Total area left
# strata.incl <- strata[!Stratum %in% c("Vestfjord ost"),]

byGrp1 <- c(".id")
byGrp2 <- c("age", ".id")
tmp1 <- DT[!age %in% c(0,1) & Stratum %in% strata.incl$Stratum,.(Ab.Sum =sum(Abundance)),by=byGrp1]
```

```
  tmp2 <- DT[Stratum %in% strata.incl$Stratum,.(Ab.Sum =sum(Abundance)),by=byGrp2]

  tmp3 <- DT[Stratum %in% strata.incl$Stratum,.(Tonnes =sum(Abundance * (weight))/1000000),by=byGrp2] #
Tonnes


  #For SSB calculation

  tmp3b <- DT[Stratum %in% strata.incl$Stratum & stage %in% c(2,3,4),.(Tonnes =sum(Abundance *
(weight))/1000000),by=byGrp2] # Tonnes


  tmp4 <- DT[Stratum %in% strata.incl$Stratum,.(ind.weight = weighted.mean(weight,Abundance)),by=byGrp2]

  tmp5 <- DT[Stratum %in% strata.incl$Stratum,.(ind.length = weighted.mean(length,Abundance)),by=byGrp2]


  #Maturity at age

  tmp6 <- DT[Stratum %in% strata.incl$Stratum,

          .(maturity = length(stage[stage %in% c(2,3,4)])/length(stage[stage %in% c(1,2,3,4)])),by=byGrp2]


  tsnTotWithout01 <- tmp1[, .("Ab.Sum.5%" = quantile(Ab.Sum, probs = .05),

                              "Ab.Sum.50%" = quantile(Ab.Sum, probs = .50),

                              "Ab.Sum.95%" = quantile(Ab.Sum, probs = .95),

                              Ab.Sum.mean = mean(Ab.Sum),

                              Ab.Sum.sd = sd(Ab.Sum),

                              Ab.Sum.cv = sd(Ab.Sum)/mean(Ab.Sum))]


  tsnByAge <- tmp2[, .("Ab.Sum.5%" = quantile(Ab.Sum, probs = .05),

                       "Ab.Sum.50%" = quantile(Ab.Sum, probs = .50),

                       "Ab.Sum.95%" = quantile(Ab.Sum, probs = .95),

                       Ab.Sum.mean = mean(Ab.Sum),

                       Ab.Sum.sd = sd(Ab.Sum),

                       Ab.Sum.cv = sd(Ab.Sum)/mean(Ab.Sum))

                     , by = c("age")]


  tsbByAge <- tmp3[, .("Ton.5%" = quantile(Tonnes, probs = .05),

                      "Ton.50%" = quantile(Tonnes, probs = .50),

                      "Ton.95%" = quantile(Tonnes, probs = .95),

                      Ton.mean = mean(Tonnes),

                      Ton.sd = sd(Tonnes),
```

```
             Ton.cv = sd(Tonnes)/mean(Tonnes))
           , by = c("age")]

ssbByAge <- tmp3b[, .("Ton.5%" = quantile(Tonnes, probs = .05),
            "Ton.50%" = quantile(Tonnes, probs = .50),
            "Ton.95%" = quantile(Tonnes, probs = .95),
            Ton.mean = mean(Tonnes),
            Ton.sd = sd(Tonnes),
            Ton.cv = sd(Tonnes)/mean(Tonnes))
          , by = c("age")]

ind.weight.by.age <- tmp4[, .("Ind.weight.age.5%" = quantile(ind.weight, probs = .05,na.rm=T),
                 "Ind.weight.age.50%" = quantile(ind.weight, probs = .50,na.rm=T),
                 "ind.weight.age.95%" = quantile(ind.weight, probs = .95,na.rm=T),
                 ind.weight.age.mean = mean(ind.weight,na.rm=T),
                 ind.weight.age = sd(ind.weight,na.rm=T),
                 ind.weight.age.cv = sd(ind.weight,na.rm=T)/mean(ind.weight,na.rm=T))
               , by = c("age")]

ind.length.by.age <- tmp5[, .("Ind.length.age.5%" = quantile(ind.length, probs = .05,na.rm=T),
                 "Ind.length.age.50%" = quantile(ind.length, probs = .50,na.rm=T),
                 "ind.length.age.95%" = quantile(ind.length, probs = .95,na.rm=T),
                 ind.length.age.mean = mean(ind.length,na.rm=T),
                 ind.length.age = sd(ind.length,na.rm=T),
                 ind.length.age.cv = sd(ind.length,na.rm=T)/mean(ind.length,na.rm=T))
               , by = c("age")]

maturity.by.age <- tmp6[, .("Maturity.age.5%" = quantile(maturity, probs = .05,na.rm=T),
                "Maturity.age.50%" = quantile(maturity, probs = .50,na.rm=T),
                "Maturity.age.95%" = quantile(maturity, probs = .95,na.rm=T),
                maturity.age.mean = mean(maturity,na.rm=T),
                maturity.age.sd = sd(maturity,na.rm=T),
                maturity.age.cv = sd(maturity,na.rm=T)/mean(maturity,na.rm=T))
              , by = c("age")]
```

```
## Output by stratum----

byGrp3 <- c("Stratum", ".id")

tmp2 <- DT[ ,.(Ab.Sum =sum(Abundance)),by=byGrp3]

tmp3 <- DT[ ,.(Tonnes =sum(Abundance * (weight))/1000000),by=byGrp3] # Tonnes


tsnByStratum <- tmp2[, .("Ab.Sum.5%" = quantile(Ab.Sum, probs = .05),

                    "Ab.Sum.50%" = quantile(Ab.Sum, probs = .50),

                    "Ab.Sum.95%" = quantile(Ab.Sum, probs = .95),

                    Ab.Sum.mean = mean(Ab.Sum),

                    Ab.Sum.sd = sd(Ab.Sum),

                    Ab.Sum.cv = sd(Ab.Sum)/mean(Ab.Sum))

                 , by = c("Stratum")]


tsbByStratum <- tmp3[, .("Ton.5%" = quantile(Tonnes, probs = .05),

                     "Ton.50%" = quantile(Tonnes, probs = .50),

                     "Ton.95%" = quantile(Tonnes, probs = .95),

                     Ton.mean = mean(Tonnes),

                     Ton.sd = sd(Tonnes),

                     Ton.cv = sd(Tonnes)/mean(Tonnes))

                  , by = c("Stratum")]



#



 out[[y]] <- list(year=year,

            a = a,

            b = b,

            tsnByAge = tsnByAge,

            tsnTotWithout01 = tsnTotWithout01,

            ind.weight.by.age = ind.weight.by.age,

            ind.length.by.age = ind.length.by.age,

            maturity.by.age = maturity.by.age,
```

```
          tsbByAge = tsbByAge,

          ssbByAge = ssbByAge,

          tsbByStratum = tsbByStratum,

          tsnByStratum = tsnByStratum)

}


# If you want to save output


save(out, file = (paste0(path2,"ProduceAllFiguresCoastalCod_12-03-filtfromN.Rdata")))
out.acu <- out # I rename the object, as the "out" is in conflict with results of other codes


## Figures to be made
# Figure 1: Number by age in time series: Age1-Age17. Age 17 is the oldest observed coastal cod.



## Tables to be made
# Table 1: Abundance indices (mean bootstrap)
# Table 2: CV of abundance indices
# Table 3: Biomass indices (mean bootstrap)
# Table 4: Mean length by age (cm)
# Table 5: Mean weight by age (g)
# Table 6: Abundance and CV of abundance for sum over ages 2+



## Number by age in time series For Table 1 and Figure 1
mat.num <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.num) <- 0:17
rownames(mat.num) <- 1995:2020
for(y in 1:26){
  tmp <-   (as.data.frame(out.acu[[y]]$tsnByAge)[,c("age","Ab.Sum.mean")])
  for(a in 1:18){
    age <- a-1
```

```
    if(!any(tmp$age[!is.na(tmp$age)] == age)) {
      next
    }
    mat.num[y,a] <- tmp$`Ab.Sum.mean`[tmp$age == age & !is.na(tmp$age)]
  }
}



## Biomass by age in time series. For Table 3

mat.biom <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.biom) <- 0:17
rownames(mat.biom) <- 1995:2020
for(y in 1:26){
  tmp <-   (as.data.frame(out.acu[[y]]$tsbByAge)[,c("age","Ton.mean")])
  for(a in 1:18){
    age <- a-1
    if(!any(tmp$age[!is.na(tmp$age)] == age)) {
      next
    }
    mat.biom[y,a] <- tmp$`Ton.mean`[tmp$age == age & !is.na(tmp$age)]
  }
}

#SSB by age (management plan)
mat.ssb <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.ssb) <- 0:17
rownames(mat.ssb) <- 1995:2020
for(y in 1:26){
  tmp <-   (as.data.frame(out.acu[[y]]$ssbByAge)[,c("age","Ton.mean")])
  for(a in 1:18){
    age <- a-1
    if(!any(tmp$age[!is.na(tmp$age)] == age)) {
      next
```

```
  }
  mat.ssb[y,a] <- tmp$`Ton.mean`[tmp$age == age & !is.na(tmp$age)]
 }
}

## Figure 1: Number by age in time series ----
plot.cohort.year <- function(mat, age=1:17, survey.year=1995:2020, start.coh = 1995,
stop.coh=2016,col1=1,col2=1, addPlot=F){
 ## Define first cohort: start.co
 ## Does the matrix include year and age information? Add if not
 mat <- mat[ ,colnames(mat) %in% age]
 mat[mat == 1] <- NA
 if(!is.null(rownames(mat))) survey.year <- as.numeric(rownames(mat))
 mat <- mat[row.names(mat) %in% survey.year,]
 age.mat <- matrix(age,nrow=nrow(mat),ncol=ncol(mat), byrow=T)
 sur.mat <- matrix(survey.year,nrow=nrow(mat),ncol=ncol(mat), byrow=F)
 coh.mat <- sur.mat - age.mat ###
 if(addPlot == F) plot(sur.mat, mat, type="n", xlab="Survey year", ylab = "Log10 (abundance index)")
 for(i.y in start.coh:stop.coh){
  lines(sur.mat[coh.mat== i.y], mat[coh.mat == i.y], col=i.y, lwd=1.5)
  text(sur.mat[coh.mat== i.y], mat[coh.mat == i.y], age.mat[coh.mat == i.y], col=i.y) ## M? skrive inn alder
 }
}

## Plot cohort

fil1 <- paste0(path2,"Figure_1_Log10Number_by_age_in_time_series_CoastalCod.jpg")
jpeg(filename = fil1 , width = 18, height = 12, units = "cm",res=300)
plot.cohort.year(log10(mat.num), survey.year =1995:2020, age=1:17, start.coh=1995,stop.coh=2016)
dev.off()
# End


# Table 1: Abundance indices (mean bootstrap) ----
mat1.num <- as.data.frame(mat.num/(1e+6))
```

```
names(mat1.num) <- paste("Age", 0:(ncol(mat1.num)-1))
write.xlsx(mat1.num, file=paste0(path2,"Table_1_Abundance_indices_Coastal cod_Tot_millions.xlsx" ))

# # Table 2: CV of abundance indices ----
mat.cv <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.cv) <- 0:17
rownames(mat.cv) <- 1995:2020
for(y in 1:26){
  tmp <-  (as.data.frame(out.acu[[y]]$tsnByAge)[,c("age","Ab.Sum.cv")])
  for(a in 1:18){
    age <- a-1
    if(!any(tmp$age[!is.na(tmp$age)] == age)) {
      next
    }
    mat.cv[y,a] <- tmp$`Ab.Sum.cv`[tmp$age == age & !is.na(tmp$age)]
  }
}
mat.cv1 <- as.data.frame(mat.cv)
names(mat.cv1) <- paste("Age", 0:(ncol(mat.cv1)-1))
write.xlsx(mat.cv1, file=paste0(path2,"Table_2_CV_Abundance_CoastalCod.xlsx" ))

# Table 3: Biomass indices (mean bootstrap) ----
mat1.tonn <- as.data.frame(mat.biom/(1e+3))
names(mat1.tonn) <- paste("Age", 0:(ncol(mat1.tonn)-1))
write.xlsx(mat1.tonn, file=paste0(path2,"Table_3_Biomass_indices_CoastalCod_kilotonnes.xlsx" ))

#SSB indices
mat1.tonn <- as.data.frame(mat.ssb/(1e+3))
names(mat1.tonn) <- paste("Age", 0:(ncol(mat1.tonn)-1))
write.xlsx(mat1.tonn, file=paste0(path2,"SSB_indices_CoastalCod_kilotonnes.xlsx" ))

# Table 4: Mean length by age (cm)
mat.len.age <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.len.age) <- 0:17
```

```
rownames(mat.len.age) <- 1995:2020
for(y in 1:26){
 tmp <-  (as.data.frame(out.acu[[y]]$ind.length.by.age)[,c("age","ind.length.age.mean")])
 for(a in 1:18){
  age <- a-1
  if(!any(tmp$age[!is.na(tmp$age)] == age)) {
   next
  }
  mat.len.age[y,a] <- tmp$`ind.length.age.mean`[tmp$age == age & !is.na(tmp$age)]
 }
}
mat.len.age1 <- as.data.frame(mat.len.age)
names(mat.len.age1) <- paste("Age", 0:(ncol(mat.len.age1)-1))
write.xlsx(mat.len.age1, file=paste0(path2,"Table_4_Length_By_Age_By_Survey_CoastalCod.xlsx" ))

# Table 5: Mean weight by age (g)
mat.weight.age <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.weight.age) <- 0:17
rownames(mat.weight.age) <- 1995:2020
for(y in 1:26){
 tmp <-  (as.data.frame(out.acu[[y]]$ind.weight.by.age)[,c("age","ind.weight.age.mean")])
 for(a in 1:18){
  age <- a-1
  if(!any(tmp$age[!is.na(tmp$age)] == age)) {
   next
  }
  mat.weight.age[y,a] <- tmp$`ind.weight.age.mean`[tmp$age == age & !is.na(tmp$age)]
 }
}
mat.weight.age1 <- as.data.frame(mat.weight.age)
names(mat.weight.age1) <- paste("Age", 0:(ncol(mat.weight.age1)-1))
write.xlsx(mat.weight.age1, file=paste0(path2,"Table_5_Weight_By_Age_By_Survey_CoastalCod.xlsx" ))

#For assessment - maturity at age
```

```
mat.maturity.age <- matrix(NA,ncol=18,nrow=length(1995:2020))
colnames(mat.maturity.age) <- 0:17
rownames(mat.maturity.age) <- 1995:2020
for(y in 1:26){
  tmp <-   (as.data.frame(out.acu[[y]]$maturity.by.age)[,c("age","maturity.age.mean")])
  for(a in 1:18){
    age <- a-1
    if(!any(tmp$age[!is.na(tmp$age)] == age)) {
      next
    }
    mat.maturity.age[y,a] <- tmp$`maturity.age.mean`[tmp$age == age & !is.na(tmp$age)]
  }
}
mat.maturity.age1 <- as.data.frame(mat.maturity.age)
names(mat.maturity.age1) <- paste("Age", 0:(ncol(mat.maturity.age1)-1))
write.xlsx(mat.maturity.age1, file=paste0(path2,"Maturity_By_Age_Acoustic_CoastalCod.xlsx" ))

#Table 6
mat.age2plus <- matrix(NA, ncol=3,nrow=length(1995:2020))
colnames(mat.age2plus) <- c( "Index_2plus" ,"SD_2plus",  "CV_2plus")
rownames(mat.age2plus) <- 1995:2020
for(y in 1:26){
  mat.age2plus[y,1] <-   (as.data.frame(out.acu[[y]]$tsnTotWithout01)[,c("Ab.Sum.mean")]/(1e+6))
  mat.age2plus[y,2] <-   (as.data.frame(out.acu[[y]]$tsnTotWithout01)[,c("Ab.Sum.sd")]/(1e+6))
  mat.age2plus[y,3] <-   (as.data.frame(out.acu[[y]]$tsnTotWithout01)[,c("Ab.Sum.cv")])
}

write.xlsx(mat.age2plus, file=paste0(path2,"Table_6_Index2+_w_sd-and-sv_CoastalCod.xlsx" ))


## End
```

Working Document Submitted to AFWG 2021 WD-07
per 13 April 2021

Estimating the status of coastal cod (*Gadus morhua*) north of 62˚N (ICES Subarea 2) using CPUE data from the Norwegian coastal reference fleet

by
Kotaro Ono, Sofie Gundersen, Yves Reecht and Kjell Nedreaas

Institute of Marine Research, PB-1870, N-5817 Bergen, Norway

Introduction

In the coastal areas north of 62˚N (ICES Subarea 2.a.2; Norwegian statistical areas 00, 03, 04, 05, 06 and 07) coastal cod are identified from the growth pattern in the ear stones (the otoliths, Rollefsen 1932). This is done by random sampling from the fisheries. Based on this sampling, cod catches per gear, area and quarter in retrospect (when the fishing year is over) are split into coastal cod (NCC) and Northeast-Arctic cod (NEAC). For cod younger than 2 years the otoliths contain too little information to make a reliable distinction between NCC and NEAC. These age groups are only sporadically represented in commercial fishing, but may in some areas be included in the recreational and tourist fishing. For 0-1 year old it is only genetic analyses that can clarify whether it is coastal cod or Northeast-Arctic cod.

The separation into two main cod groups, NCC and NEAC, was supported by the genetic studies of Møller (1968, 1969). Recent studies that have compared the results from genetic studies, tagging experiments and otolith patterns, have led to the same conclusion that the two groups should be considered as separate populations (Jakobsen 1987, Dahle 1991, Dahle *et al.* 2018). Coastal cod differs also from Northeast Arctic cod in terms of life history parameters, which, however, also show differences between areas (Berg and Albert 2003).

The genetic differentiation between coastal cod populations along the Norwegian coast is mainly gradual, a cline from south to north (Dahle et al 2018). There seems, however, to be a barrier at about 62N and in the Lofoten area. For reasons of geographical coverage in the cruises, it seems more appropriate to set this limit at 67N. For coastal cod north of 67N, we consider that the data base is good enough to develop an analytical stock assessment in a similar way as for NEAC. This northern area also contributes more than 80% to the total catch of coastal cod north of 62N.

The Norwegian cod TAC is a combined TAC for both the NEAC stock and NCC stock. Landings of cod are counted against the overall cod TAC for Norway, where the expected catch of coastal cod is in the order of 10%. There are no separate quotas given for the coastal cod for the different groups of the fishing fleet. Catches of coastal cod are thereby not effectively restricted by quotas. Since the coastal cod is fished under a merged coastal cod/northeast Arctic cod quota, the main objective of these regulations is to move the traditional coastal fishery from areas with high fractions of coastal cod to areas where the proportion of NEA cod is higher.

The Norwegian Reference Fleet is a group of active fishing vessels tasked with providing information about catches (self-sampling) and general fishing activity to the Institute of Marine Research. The fleet consists of both high-seas and coastal vessels that cover most of Norwegian waters. The High-seas Reference Fleet began in 2000 and was expanded to include coastal vessels in 2005 (e.g., Clegg and Williams 2020). The Norwegian coastal reference fleet in 2020 is shown in Appendix figure 1, and the different gillnet types in Appendix figure 2. Catch operations with cod and predicted proportions of coastal cod in the catches are shown in Figures 1 and 6 (also appendix figures 3 and 4), respectively.

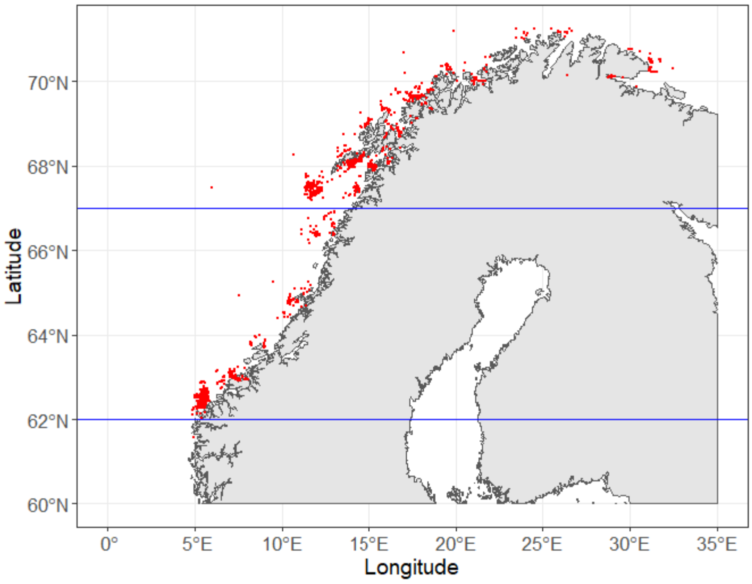

Figure 1. Catch operations with catches of cod by the Norwegian coastal reference fleet during 2007-2020 (red dots). The blue lines denote the 62nd and 67th latitudes, respectively.

Catch per unit effort (CPUE) data

The Norwegian coastal reference fleet has reported catch per gillnet soaking time (CPUE) from their daily catch operations. The genetic differentiation between coastal cod populations along the Norwegian coast is mainly gradual, i.e., a cline from south to north (Dahle et al 2018). There seems, however, to be a barrier at about 62N and in the Lofoten area at about 67N. Based on the current stock situation, there seems also to be a need for stricter regulation measures south of 67°N, i.e, in the national subareas 6 and 7, than north of this latitude (Aglen et al. 2020). For the current modelling and hence standardization of the annual CPUE from Subarea 6 and 7, we have used the following data:

- Only catch rates of retained cod from the fishery using gillnets except the anglerfish gillnet, i.e., discards excluded
- Years 2007-2020
- Adding zero catches where gillnets are used, but cod not present
- Focusing on area 6 and 7 (though, for statistical estimation purpose, data from areas 3, 4, 5,0, 6, 7 could be used altogether, then the output narrowed down to area 6 and 7)
- Focusing on quarters 3 and 4 to avoid the largest aggregations of spawning NEAC temporarily inhabiting coastal areas and mixing with NCC
- The area (km^2) of each subarea inside 12 nautical miles (covering most of the coastal cod distribution) are calculated and used as weighing factor when annual CPUEs are estimated for each subarea.

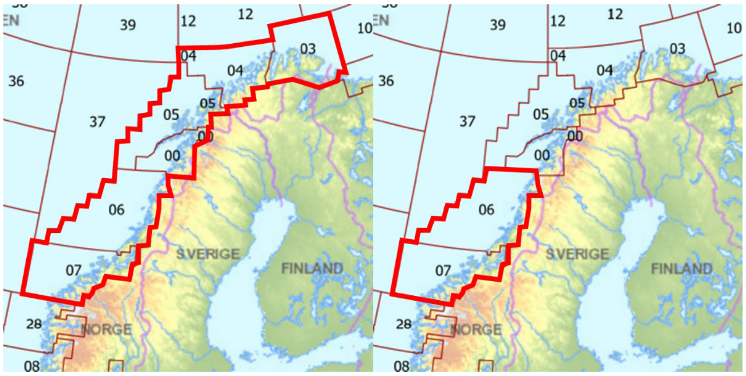

Figure 3. Norwegian statistical areas. Area 03 is part of the ICES Subarea 1 and areas 28 and 08 are part of ICES Subarea 4. The other areas belong to ICES Subarea 2.

<u>CPUE standardization</u>

Raw CPUE data is seldom proportional to population abundance as many factors (e.g. changes in fish distribution, catch efficiency, effort, etc) potentially affect its value. Therefore, CPUE standardization is an important step that attempts to derive an index that tracks relative population dynamics.

There are two cod stocks (two ecotypes) that are mixed together in the Norwegian waters: the coastal cod (NCC) and the Northeast Arctic cod (NEAC). In this working document, our interest lies on deriving the abundance index of coastal cod, therefore, a few steps need to be taken to derive the corresponding coastal cod abundance index:

1. Fit a model to determine whether an individual fish is categorized as coastal or NEAC. This step allows determining the probability of catching coastal cod vs NEAC during the time frame of interest

2. Perform a CPUE standardization using the data from the reference fleet (on total cod catch. The division to ecotypes happens in the next step)
3. Use the output from the above two steps and create an index of abundance for coastal cod

Below, we defined some important terms we used for the CPUE standardization.

Standardized effort (gillnet day) = gear count x soaking time (hours) / 24hours
CPUE (per gillnet day) = catch weight/standardized effort

Step1: Coastal cod vs. NEAC?

In order to determine the origin of cod, we used all data from above 62^{o}N (i.e. areas 3, 4, 5, 0, 6, 7) with information on otolith type. The later is the source of identification which helps separate between coastal vs. NEAC. Otolith type 1 and 2 were categorized as "coastal" and type 3, 4, 5, as NEAC. A total of 27897 samples were used for the analysis between 2007-2020.

From the above samples, we removed any covariates that had less than 3 observations to ensure estimability (the covariate in question was mostly the gear type) (the final sample size was N=27892). We then fitted a binomial model with logit link using 4 different explanatory variables: year, area, quarter, and gear, using the following formula:

*Glm1 <- glm(is_coastal ~ factor(area)*factor(startyear) + factor(quarter) + factor(gear), family=binomial, data=Data_proportion)* *(eq1)*

In this process, we also tried fitting different covariate configurations as well as trying to use only the data from area 6 and 7 i.e. the main focus area (N=1686), but these resulted in model with more problematic residuals pattern (at least, significantly worse). Therefore, we are only presenting in this document the final model configuration and outputs.

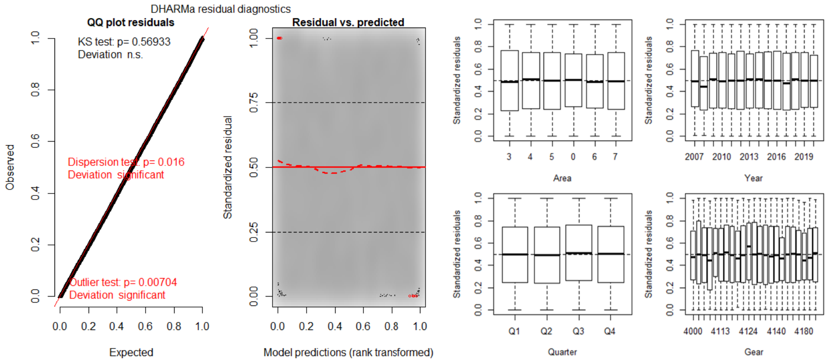

Figure 4. Residual diagnostic plots for the final binomial model to differentiate coastal cod vs. NEAC. The panel on the left is a standard output from the residual diagnostics using the R

package DHARMa. The panel on the right plots the model standardized residuals against available covariates. Both panels indicate no significant issues with the final model.

Using the above model, we then predicted the proportion of coastal cod we would be expecting in area 6 and 7, during quarter 3 and 4, between 2007-2020.

During the prediction process using the final binomial model (eq 1), we used the gear code 4140 as the basis for prediction. It is to be noted that the gear effect mostly shifts up and down the annual estimates of coastal cod proportion in the catch by area and quarter with only a minor impact on the final standardized coastal cod CPUE (Appendix Figure 3 and 4). Another remark is that a similar model to eq 1 but with gear as random effect was also run using the R package glmmTMB but model residual pattern was much worse than the final model, thus not explored further. The main reason behind this difference was that the estimated gear effect was not normally distributed and there were some gears with much higher chance of catching coastal cod (i.e. gear code 4180) (Figure 5). For information, gear code 4180 is demersal monofilament demersal gillnets of 68 mm half mesh size (136 mm stretched mesh).

The prediction suggested that the proportion of coastal is generally very high in area 6 and 7 during quarter 3 and 4 (with some slight annual fluctuation in area 6).

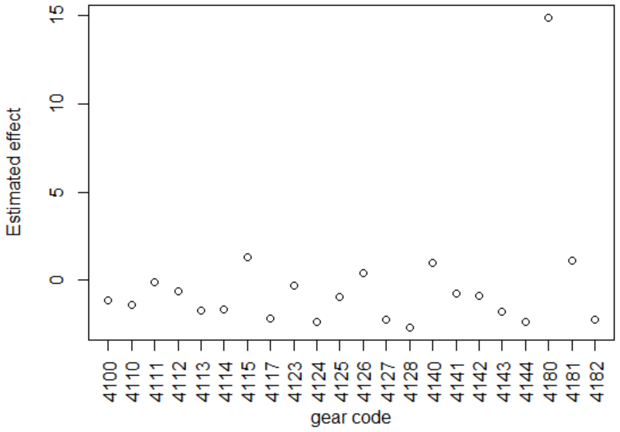

Figure 5. Estimated gear effect from the final binomial model. See also Appendix figure 2.

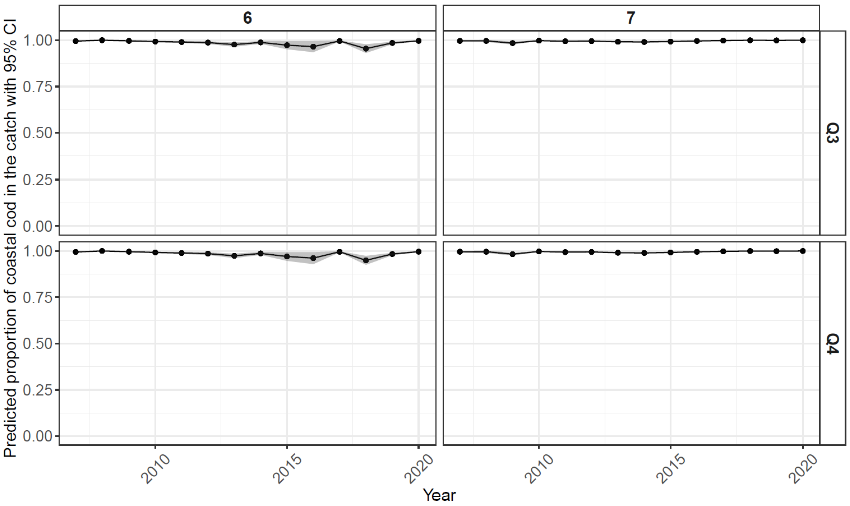

Figure 6. Predicted probability of catching coastal cod based on the quarter (vertical panels), areas (horizontal panels), and years (x axis within each panel). The grey shaded polygon represents the 95% confidence interval.

<u>Step2: CPUE standardization</u>

Many different R packages (e.g. mgcv::gam, glmmTMB::glmmTMB, sdmTMB::sdmTMB, and own model in TMB to allow implementing a mixture model), as well as many different combination of likelihood functions (e.g. normal, lognormal, gamma, negative binomial, student t, tweedie), zero inflation, and parameter were tested to find a model which showed an acceptable residual pattern. However, model exploration was not conclusive when using the entire CPUE data from area north of 62°N (N=11805, with only 59 zeros). All the model struggled fitting the extremely skewed CPUE data (many extremely small values below 1 and large values above 1000, while the bulk of the values are in the scale of dozens).

The final model for the CPUE standardization was fitted on all cod data (no distinction between coastal and NEAC yet) but limited to area 6 and 7 and quarters 3 and 4, between 2007-2020. Further data filtering was performed to remove erroneous data point (e.g. gearcount =1) and any gear code with less than 3 observations or only used in one year. This reduced the final data set to N=686 (with only 3 zeros):

```
glmmTMB_pos <- glmmTMB(log(cpue_all) ~ factor(startyear)
 + factor(area) + factor(gear) + factor(quarter) + (1|area_year)                    (eq 2)
 + (1|quarter_year), family = gaussian, data=subset(nord_use, cpue_all>0))
```

The expression (1|area_year) indicates that the area and year variable was concatenated into a single variable and considered as a random effect acting on the intercept. In essence, this treatment models the interaction effect between year and area on the intercept, but the approach only considers existing interaction (as opposed to all possible combination of year and area which would be un-estimable) – which is an advantage in data-limited situation such as ours.

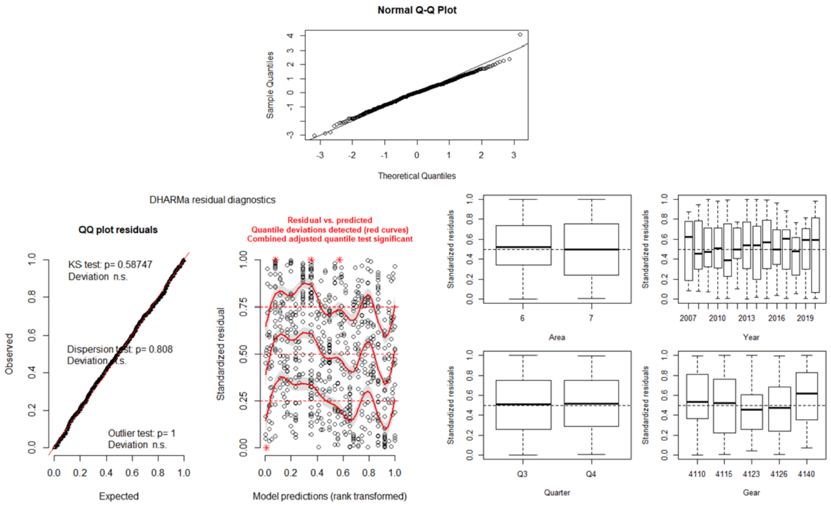

Figure 7. Residual diagnostic plots for the final CPUE model fitted to cod data in area 6 and 7, and quarters 3 and 4. The top panel is the normal QQ-plot. The panel on the left is a standard output from the residual diagnostics using the R package DHARMa. The panel on the right plots the model standardized residuals against available covariates. All panels indicate no significant (though some) issues with the final model.

Joining step 1 and 2 to create a standardized coastal cod CPUE

The final cod CPUE model showed a reasonable residual behavior (Figure 7) and therefore, we proceeded with the derivation of the standardized coastal cod CPUE index for area 6 and 7 and quarters 3 and 4.

The standardized coastal cod index ($CPUE\_std_{coastal}$) was calculated as:

$$CPUE\_std_{coastal} = P_{coastal} * CPUE_{cod} \qquad \textit{(eq 3)}$$

Where $P_{coastal}$ is the predicted proportion of coastal cod in the catch based on the output from step1, and $CPUE_{cod}$ is the predicted cod (of both ecotypes) CPUE based on step 2.

And the variance of ($CPUE\_std_{coastal}$) was calculated as:

$$V(CPUE\_std_{coastal}) = \left(\widehat{P_{coastal}}\right)^2 V(CPUE_{cod}) + \left(\widehat{CPUE_{cod}}\right)^2 V(P_{coastal}) \qquad \text{(eq 4)}$$

Some combinations of area_year and quarter_year random interaction effect were not present in the datasets for the CPUE standardization model. However, glmmTMB can handle any missing new levels of random effect variables when making prediction (it assumes it is equal to zero and inflates the prediction error by its associated random effect variance).

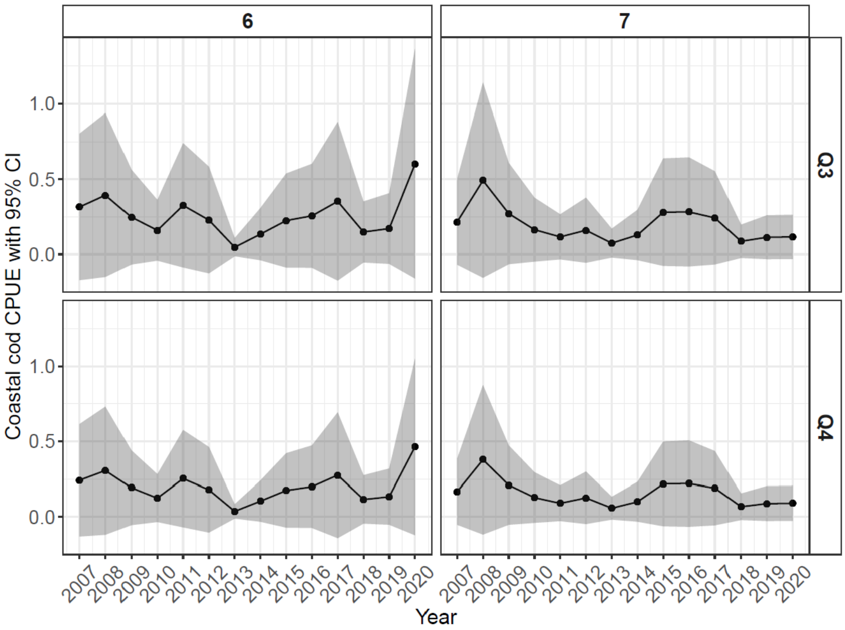

Figure 8. Standardized CPUE index for coastal cod in area 6 and 7 during quarters 3 and 4, between 2007-2020. The grey shaded polygon represents the 95% confidence interval (calculated using the approximation mean +/- 1.96 std which is why some values goes below 0).

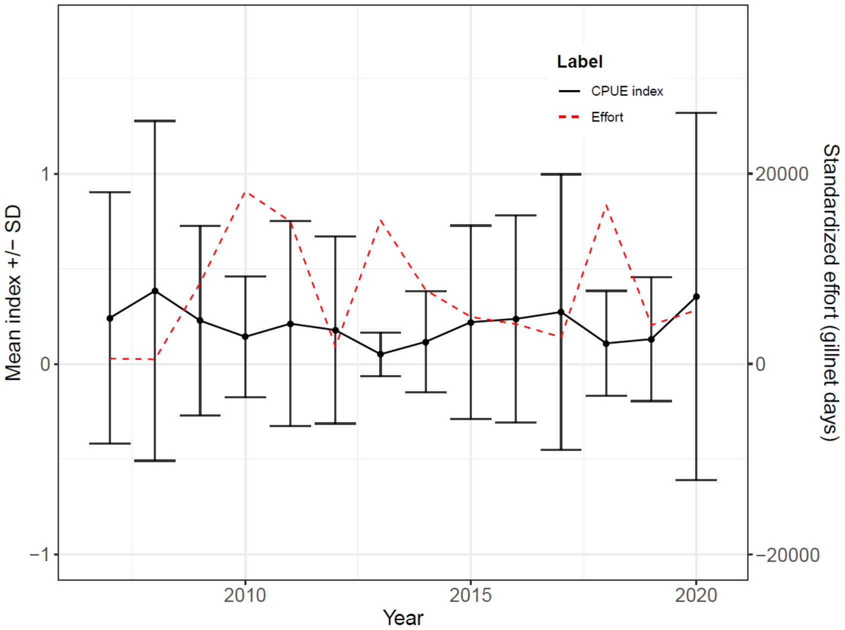

Figure 9. Composite standardized CPUE index for coastal cod in area 6 and 7 during quarters 3 and 4, between 2007-2020. 95% confidence interval (calculated using the approximation: mean +/- 1.96 std.; negative values are therefore introduced in the plot as an artifact of this procedure) are given by error bars.

The final standardized CPUE index for coastal cod indicates a general declining trend in all areas and quarter since 2007 with some inter-annual variability with a possible increase (large uncertainty) in 2020 (Figure 8 and 9).

Future tasks & improvement

There were obvious issues when trying to develop the CPUE standardization model for cod in Norwegian waters when including data above 67N i.e. the model did not fit the data well as supported by the residuals diagnostics plots.
Such analysis should further be pursued in the future with the focus to improve the CPUE model fit to cod data in order to derive a more “reliable” index of abundance.
There are a few possible investigations we suggest for future research:

1. further refinement of the data to use
2. collecting information such as species composition of the catch. Such information could be very valuable in order to account for targeting behavior that obviously affect a multispecies fishery (Winker *et al.*, 2013)
3. think about the approach of (Thorson *et al.*, 2016) and how it could potentially be applied using the reference fleet data

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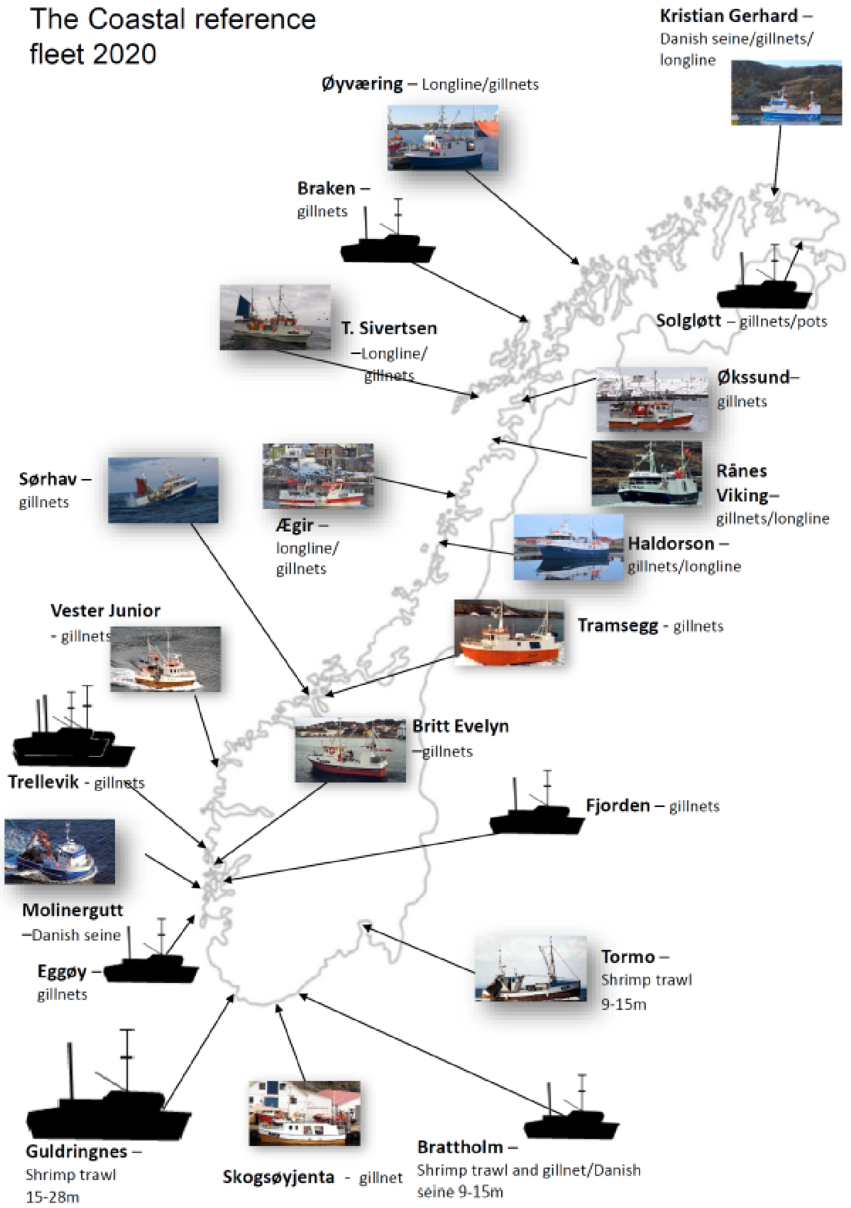
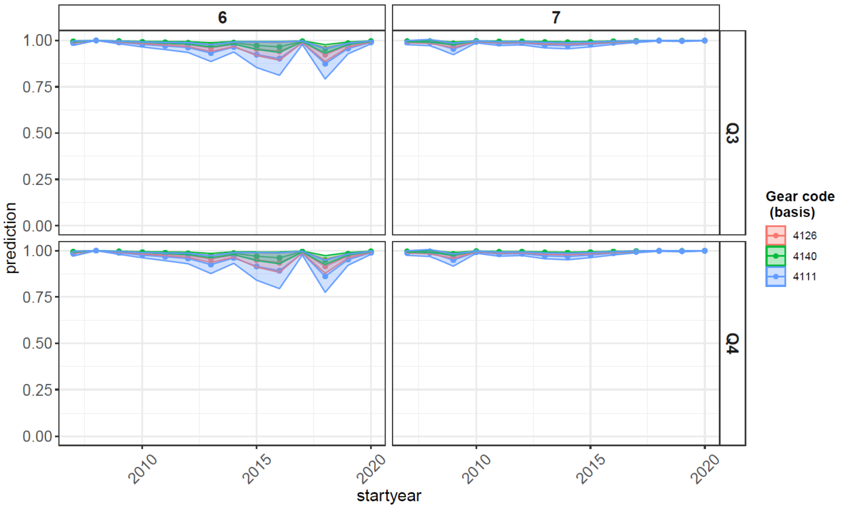
Appendix figure 1.

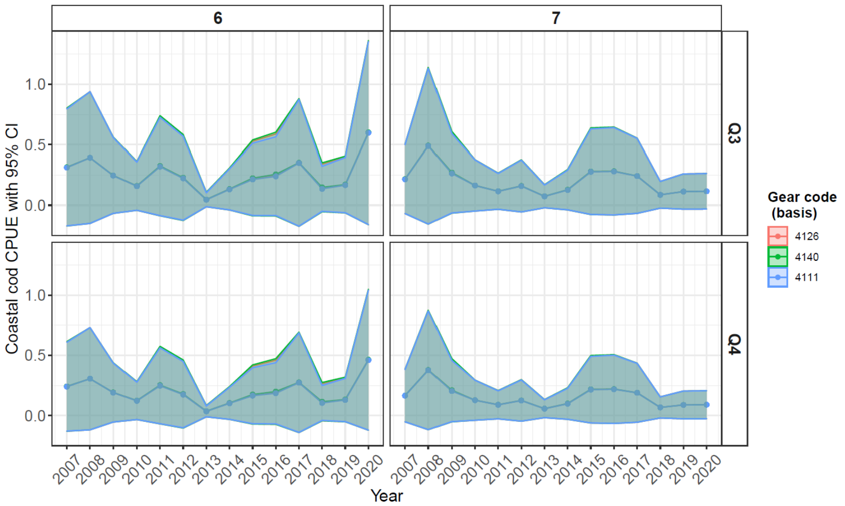


Appendix figure 2. GEAR type count and area usage.

Appendix figure 3. Annual predicted proportion of coastal cod in the catch by quarter and area using three different gear code (4126 ,4140, and 4111) as the basis for prediction



Appendix figure 4. Standardized CPUE index for coastal cod with the 95% CI in area 6 and 7 during quarters 3 and 4, between 2007-2020 using three different gear code (4126 ,4140, and 4111) as the basis for calculation.



Greenland Halibut HR_{pa} proposal

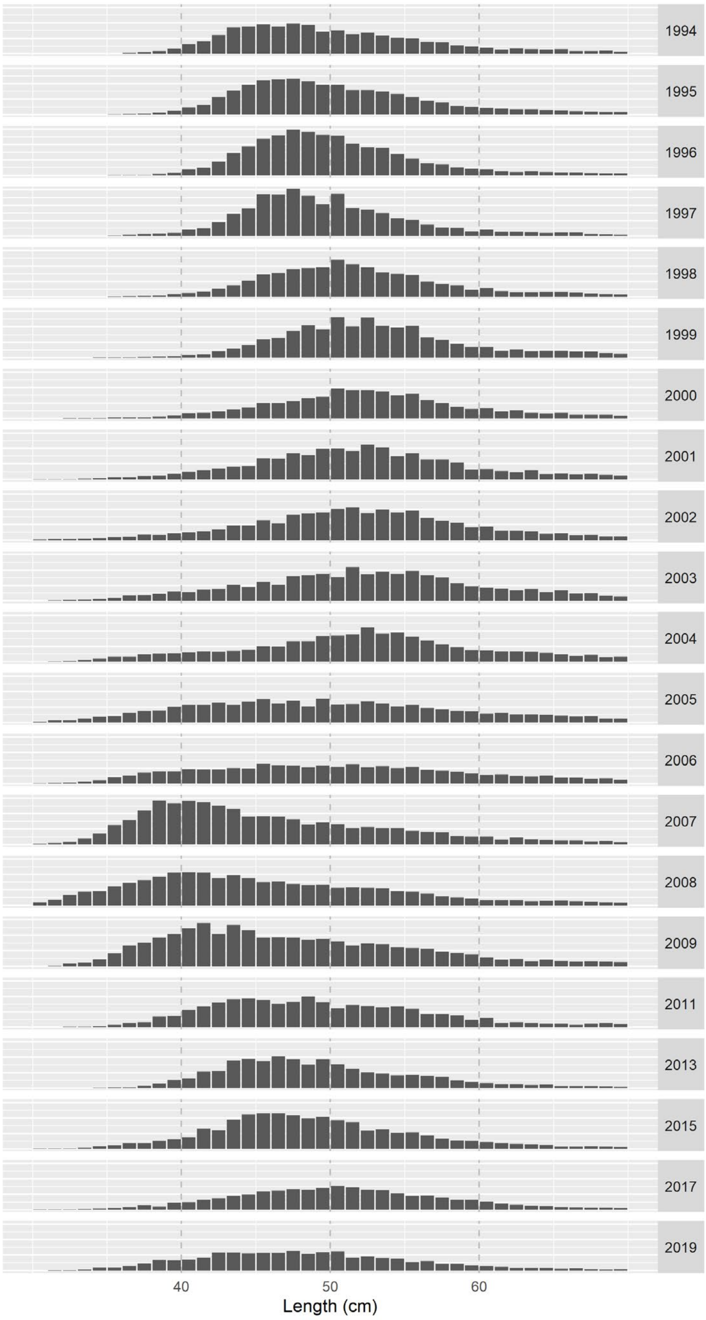
Daniel Howell, daniel.howell@hi.no

In 2019, the advice drafting group, ADGANW, requested a HR_{pa} value for Greenland Halibut (this stock uses Harvest Rate rather F for reporting purposes). This document attempts to provide such a value. Note that this is not a full MSE exercise. There are plans for a benchmark in 2022 to improve the model followed by a full HCR exercise. This document is simply an attempt to calculate an interim HR_{pa} as a basis on which to give precautionary advice until a HCR is evaluated and agreed. The calculations here are based on the guidelines in place at that time (but final presentation of the work was delayed by covid). However, given the inability to estimate recruitment variation, it is likely that the same procedure would be used if conducting the analysis under current guidelines. We would also note that catches for stock have averaged 34% higher than advice over the past decade, and that it is therefore critical that an advice basis is agreed and used in ICES advice.

Background: model and stock

Greenland Halibut (hereafter GHL) is a relatively long-lived species with pronounced sexual dimorphism, males are smaller and mature earlier than females. The stock is managed on areas I and II jointly by Norway and Russia. Given the dimorphism and the lack of an accepted age-reading methodology one cannot give accurate ages of maturity and entry to the fishery, but these are on the order of c. 10 years for females and perhaps c. 7 for males. The Barents Sea Greenland halibut has nursery areas around Svalbard and Franz Josef Land in the northern Barents Sea. The fish then expand southwards into the Barents Sea, before congregating along the shelf break on the western edge for spawning. This is a deep-sea fish, and there is likely connectivity with other stocks. However, this is not presently considered in the assessment.

The GHL stock in areas I and II (the Barents Sea and adjacent waters) is assessed with a two sex, one area Gadget model, which is described in the stock annex and the benchmark report (ICES 2015). The 2015 benchmark was the first time that an analytical model was approved for this stock by ICES since age based XSA was abandoned in early 2000, and the model is thus at a relatively early stage of development. At the last AFWG the model was run from 1992-2018. Note that the recruitment estimates are presented up to 2016, even though the model is run to 2018. This is because there is considerable noise in the recruitment series, and there is therefore little information to use in tuning the last two years of recruitment estimates. One should also note that there are conflicting signals from the different surveys, and thus the estimates should be considered uncertain until the fish have entered the fishery, although there are no formal estimates of uncertainty from the Gadget model. The only significant change since the benchmark is that because of reduced sampling the model had to move to time-averaged maturity data, rather than separate estimates for each year. The model period begins during a partial fishing moratorium and covers a period of rising and good stock sizes, there is no data in the model on low stock status. The benchmark agreed on a B_{pa} and B_{lim} value (based on the lowest observed stock size that gave rise to good recruitment) but not an HR_{pa} value. Given the lack of contrast in the stock size data (see below) and the presence of good recruitment events, B_{pa} has been set equal to B_{lim} (as per ICES 2017). There are indications of a good recruitment event at lower stock sizes prior to the start of the model run, since the model begins in during a rising stock trend. The model reports 45cm+ biomass (the minimum catch size) rather than SSB, partly to avoid questions about using male and/or female biomass, and partly to be consistent with earlier work (not used for assessment) using surplus production models. As with a number of other ICES stocks, we report Harvest Rate (HR), rather than F, that catch as a fraction of the modelled fishable biomass on 1st January. The other “non-standard” feature of the model is that it is tuned only to length data, no age data is used in the tuning. This is due to a lack of agreement between Norway and Russia on what age-reading methodology to use. As can be seen in Figure 1, there have been several large recruitment events which can be traced for multiple years in the length data. This allows the model to estimate those recruitment events and growth rates for the GHL based on the length data alone. However, it is not clear that there is sufficient contrast in the data to accurately estimate the recruitment pattern in between the high recruitment events. There is data from catch levels and stock trends measured in the survey to give information on average recruitment level over time, but likely not to estimate the actual recruitment pattern. Note that there is little information on what the recruitment might be below B_{lim}. This is not considered a problem for this analysis. The stock is currently assessed as well over B_{lim}/B_{pa} (Figure 2), and the HR_{pa} being calculated is intended to avoid falling below B_{lim}. There is therefore no need to simulate behavior below B_{lim} in order to estimate a HR_{pa}, although such information would of course be needed to model recovery from any potential overfishing.


1994
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40
50
60
Length (cm)

Figure 1. Annual length distributions in the EggaNor survey (from the 2019 cruise report, Vollen et al 2020).

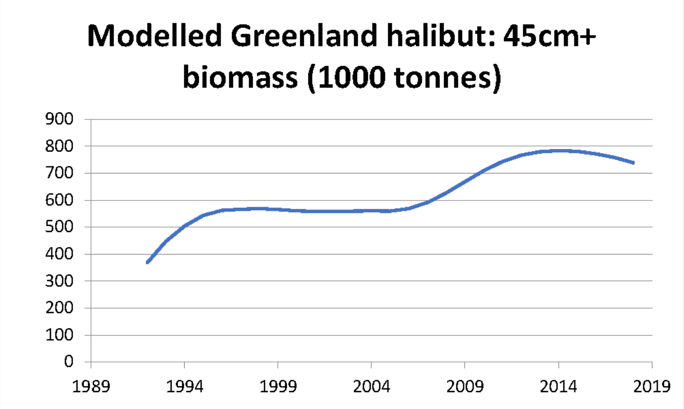

Figure 2. Modelled 45cm+ biomass of Greenland halibut as of the 2018 AFWG assessment.

Methodology

Two different methods have been considered here to compute HR_{pa}. The first method is a $F_{0.05}$ approach, i.e. a stochastic simulation to identify the fishing level that results in no more than a 5% chance of driving the stock below B_{lim}.

The second method is that described in the 2017 ICES guidance of reference points for analytically assessed stocks (ICES 2017), where average recruitment over some time period is used to compute a F_{lim} and hence a HR_{pa}.

In principle this author prefers the $F_{0.05}$ approach, as better capturing the dynamics behind this kind of risk analysis, and this is the new ICES standard. However, there is a difficulty in this case. The simulations require drawing from the assessed recruitment deviations. As previously mentioned, while it is plausible to suggest that the occasional peaks are well determined by the length data, this is not likely to be the case with the smaller recruitment years. Since the last large recruitment was in 2002 (appearing as age 1 in 2003), the majority of the recent years fall into this poorly determined category. Retrospective analysis gives a similar picture – the average recruitment over recent years is relatively stable under retrospective peels, but the pattern of recruitment between years can change. Given this reasoning, the $F_{0.05}$ is not considered appropriate as the recruitment variation cannot be reliably estimated. This study therefore choses to use the simpler, average-based approach, detailed in ICES 2017 as a fall back approach. This is an ICES tested method and will therefore produce a viable basis for ICES advice.

Having chosen the overall method, a question arises over the time period to use for defining the recruitment. Although GHL is a long-lived stock (with significant numbers living to 30+), in areas I and II this is a stock where the fishery is largely sustained by occasional good yearclasses. Given the absence of agreed age data it is difficult to pin down the exact year that a fish was recruited. However, in 2018 35% of the catch in biomass was modelled as recruiting in the 2002 yearclass, and 45% coming from +/- 1 year around this (many of which may actually be from the same recruitment). The top three yearclasses in the catch (excluding the plus group) contributed over 58% of the catch in biomass (while the plusgroup at 30+ contributed another 10%, with some indication that this may be largely from a single recruitment pulse prior to the model timeseries). As can be seen in the recruitment plot in Figure 3 there are a number of features that make the choice of recruitment period to average over challenging, and of considerable importance to the overall result. One could choose to average over the entire model period (1993-2016), which gives an average recruitment of 127 million individuals per year. However, this value is highly sensitive to the presence of a single large year class. One could choose to exclude the age 1 recruitment spike in 2003, on the grounds that such an event has not been seen recently and that there is a sufficiently long delay between any good yearclass appearing in the data and entering the fishery for there to be time for a HR_{pa} value to revised if such recruitment were to occur. In such a case, average recruitment is estimated as 94 million. Finally, one could say that the recent recruitment is that which will define the short- and medium-term behavior of the stock and fishery, and then take the recruitment since the spike (2004-2016) or a ten-year average (2007-2016). The ten-year average gives 78 million, while the 2004-2016 period gives 82 million. However, there are several sources of uncertainty in this shorter time period. One problem here is that given the presence of sporadic moderate recruitment events (even excluding the largest peaks), taking a short time period to average over makes the results sensitive to small changes in the time range chosen. For example, choosing an 11-year average rather than a ten-year average gives 71.5 million recruits, a decrease of 10% on the 10 year average. Furthermore, these fish have not yet fully recruited to the fishery, and because of the conflicting survey information there is thus considerable doubt as to the actual magnitude of this recruitment. Nor is it obvious from Figure 3 that there has been any change in recruitment productivity during the model timeseries.

This study therefore chooses to base this analysis on the complete time series, but with the large recruitment event in 2003 excluded. Given the uncertainties discussed above, this is considered to best reflect the recruitment to the fishery that can be expected in the coming years. Should a new large yearclass be observed then there would be time to revise the HR_{pa} value before the fish from the large yearclass could enter the fishery, and therefore there is no loss of yield arising from excluding this value. The choice to avoid truncating the time series (and thus prioritizing length of series over recent information in the data) is in line with the guidelines from WKRPCHANGE (ICES 2021).

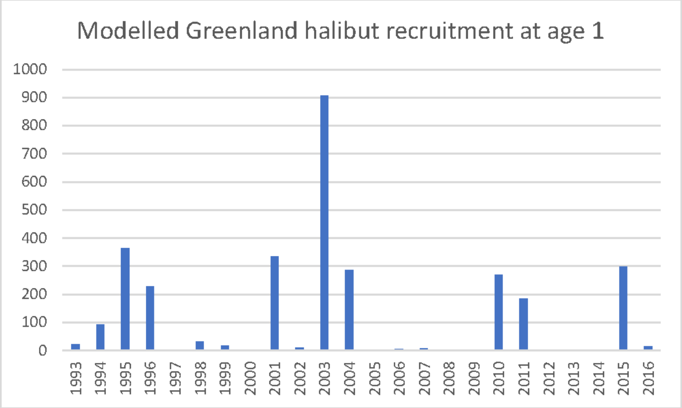

Figure 3. Model estimates of recruitment at age one, in million individuals.

Computations

According to ICES 2017 and ICES 2018, the following sequence of calculations are required to estimate a F_{pa} value for a stock such as this with limited contrast in the tuning series:

1. Find B_{lim} and B_{pa}
    a. These values are set in the benchmark reports as the 45cm+ biomass in year that gave rise to a good recruitment event, noting that this gave a biomass of 500 thousand tonnes.
2. Simulate forward under constant average recruitment to find the F_{lim} level that drives the stock to B_{lim} at equilibrium
    a. The choice of average recruitment is discussed above, and the single large spike is excluded from this analysis. Note that there is no need to simulate recruitment reduction below B_{lim}.
3. Convert the F_{lim} to F_{pa} using the standard ICES precautionary formulae
    a. Given the absence of any explicit uncertainty estimates here, this defaults to dividing F_{lim} by 1.4 to obtain F_{pa}.

Given the long-lived nature of the stock and occasional recruitment, and the relatively low exploitation rates that this implies, the benchmark chose to report this stock using a harvest rate (HR) rather than a F. That is to say, the fraction of the fishable biomass on 1st January which is taken as a catch over the course of the year. Therefore, the calculations performed here are actually for a HR_{pa}, although the process is identical. At the low exploitation levels calculated here this is largely a theoretical issue, the value of HR_{pa} is very close to a $F_{pa.}$

However, there is an issue of precautionarity here. For stocks with data on recruitment behavior at low stock sizes, B_{pa} will be higher than B_{lim} and the method is written accordingly. For this stock, no such data exists – the stock has never been at low stock sizes during the model period. Therefore, following ICES procedures B_{lim} and B_{pa} have been set equal. The question then arises if computing HR_{lim} in this way includes too much precautionarity. The HR computed drives the stock to B_{pa} at equilibrium, and could thus be argued to be a HR_{pa} without further adjustment. Alternatively one could consider that the HRlim drives the stock to Blim, and therefore an additional precautionary buffer is required. It seems likely that this ambiguity arises from the use of two "fall back" methods (one for setting B_{lim}/B_{pa} and one for the HR_{lim}/HR_{pa}) that have not previously been combined. For this analysis we present both versions for consideration: the full procedure with the additional precautionary buffer, and one in which we omit step three in the above analysis, and present HR_{pa} as the level which is modelled to drive the stock to B_{pa} at equilibrium recruitment.

The model has been projected forward for 100 years, by which time the stock had reached equilibrium, with recruitment set to a constant level equal to 94 million. Different HRs were applied until the equilibrium biomass reached B_{lim}. These calculations have been conducted, and results in a HR_{pa} of 0.035 (which is lowered to a HR_{pa} of 0.025 if one applies the extra precautionary buffer in step three above). For comparison the Harvest Rate in 2018, based on a fishing level which was above the ICES advice, was assessed to be 0.036. It may seem that these are rather low rates, but they arise from the interaction of a relatively long-lived stock with very occasional good year classes (2 in the last c. 40 years).

Assuming that no future good yearclasses occurred, the projected long-term catch at this HR= 0.035 is 17.6kt, while under a HR=0.025 the equilibrium catch is 14kt. Note that this is not directly comparable to the current situation or historical situation because the stock has had occasional large yearclasses which support a larger fishery. In the event of the surveys showing an incoming large yearclass the HR_{pa} should be revised to a higher value to take advantage of this situation.

Results

The headline result is that using the recruitment excluding the good yearclass gives a $HR_{pa}=0.035$ as the value which produces a biomass of around $B_{lim}=B_{pa}$, and a HR_{pa} of 0.025 with the additional precautionary buffer. Given that HR=0.035 is the level which is modelled to drive the stock to equilibrium under constant recruitment assuming no large recruitment events, then we believe that this satisfies the precautionarity conditions.

The proposed HR_{pa} for Greenland halibut in areas I and II is 0.035 or 0.025 (with the precautionary buffer), with the proviso that if a large recruitment event is observed in the surveys then the HR_{pa} should be revised prior to the incoming good recruitment entering the fishery.

Discussion

This analysis explicitly calculates a HR_{pa} value under recent recruitment conditions. Should these recruitment conditions change, then the analysis would need to be revised. However, the presence of a recruitment survey, coupled with relatively late entry to the fishery means that this is not a major problem. There would be some years between a large recruitment event (or a period of recruitment failure) being observed and the fish entering the fishery, allowing for such a revision. In addition, it is not recommended that the HR_{pa} presented here should form the long-term basis for management of this stock, rather it should be considered an intermediated measure prior to the development and testing of a full HCR for this stock.

The length of time since the last large recruitment event means that the stock is now modelled to have passed a recent peak in biomass and is currently headed downwards. No large recruitment to the fishable stock can be expected in the next 5+ years. It is therefore critical that fishing pressure not exceed that which can be supported by the recent recruitment, otherwise the fishery runs the risk of driving the stock into a condition of recruitment overfishing.

Appendix

The computations were repeated using the full time series of recruitment. A further run was taken using the last 10 years of recruitment estimates as the estimate of fish that could recruit to the fishery in the coming years. Using the full time series, including the recruitment spike, gave a recruitment estimate of 127 million, HR_{pa}=0.0716 (HR_{pa}=0.051 with the additional buffer). Using the last 10 years gave a recruitment estimate of 78 million, HR_{pa}=0.017 (HR_{pa}=0.012 with the additional buffer). The full range of options examined is given table 1 below.

Recruitment	**HRpa without buffer**	**HRpa with buffer**
All years, without recruitment spike	0.035	0.025
Recent 10 years	0.017	0.012
All years including spike	0.0716	0.051

Table 1. Range of options examined in the analysis. The first line (all years without recruitment spike) is that proposed for management.

As discussed in the document, we explicitly do not recommend either of these alternatives as the basis of quota advice in the coming years. **In the absence of a new recruitment spike, the higher value is not precautionary** as it is higher than that which can be sustained by recent recruitment. The recruitment survey for this stock indicates that there has not been a particularly high recruitment event since 2003, and the late entry to the fishery gives a high confidence that there will not be strong recruitment to the fishery in at least the coming 5 years. For the 10-year average, the sporadic recruitment to this stock, combined with the poor definition of the recruitment pattern in the model, makes this sensitive to the precise pattern of recruitment and length of time chosen. ICES guidelines support (ICES 2021) support this choice. We therefore do not recommend this is as the basis of management. The values are merely presented here for comparison.

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Stock annex

Comparison of the 2019 and 2020 Ecosystem survey cod data

WD 9 to ICES AFWG, April 2020

N.A. Yaragina and Y.A. Kovalev (Polar branch of VNIRO, Russia), Bjarte Bogstad, IMR, Bergen, Norway

A possible year effect of the 2020 Ecosystem survey in terms of cod data was examined and compared to trends in commercial CPUE.

NEA cod

All cod indices for ages 2-12 observed in the 2020 Ecosystem survey appeared to be below regression lines on figures (Figure 1) reflecting an internal consistency of the survey (regression lines between the same year class indices observed in the previous year and the current year). It was not the case concerning the 2019 Ecosystem survey cod indices, where three points were below the corresponding lines, while six points were above and two points were on the lines (see Figure 1). Insertion of one additional point on each corresponding plots resulted in weaken regressions strengths, i.e. decrease of coefficients of determinations between indices of the same cohort observed in the 2020 and in the previous year (Table 1), it is especially seen for age 3, 4 and 6 years (the year classes 2014, 2016, 2017). While for older ages the drops in R^2 are smaller, nevertheless all 2020 index values are below the corresponding regression lines. That could be a signal of stock underestimation and a visible "year effect".

The reasons of such an effect are not clear. There were some timing violations in Eco-survey in 2020 but it is difficult to assume a mechanism to explain why it caused the underestimation.

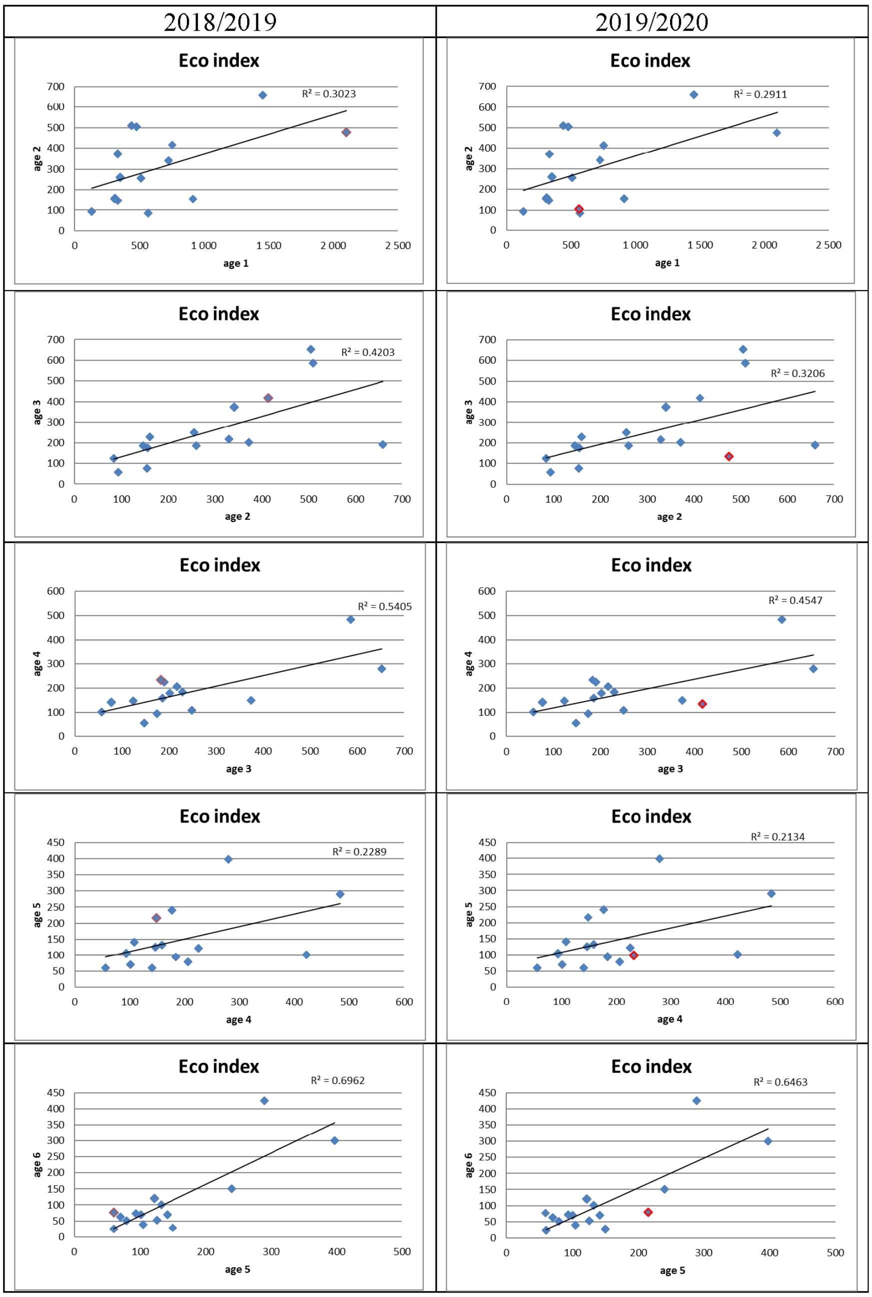


Figure 1. Plots of the internal consistency of the 2019 and 2020 Ecosystem survey cod abundance indices (red diamonds represent the terminal year indexes)

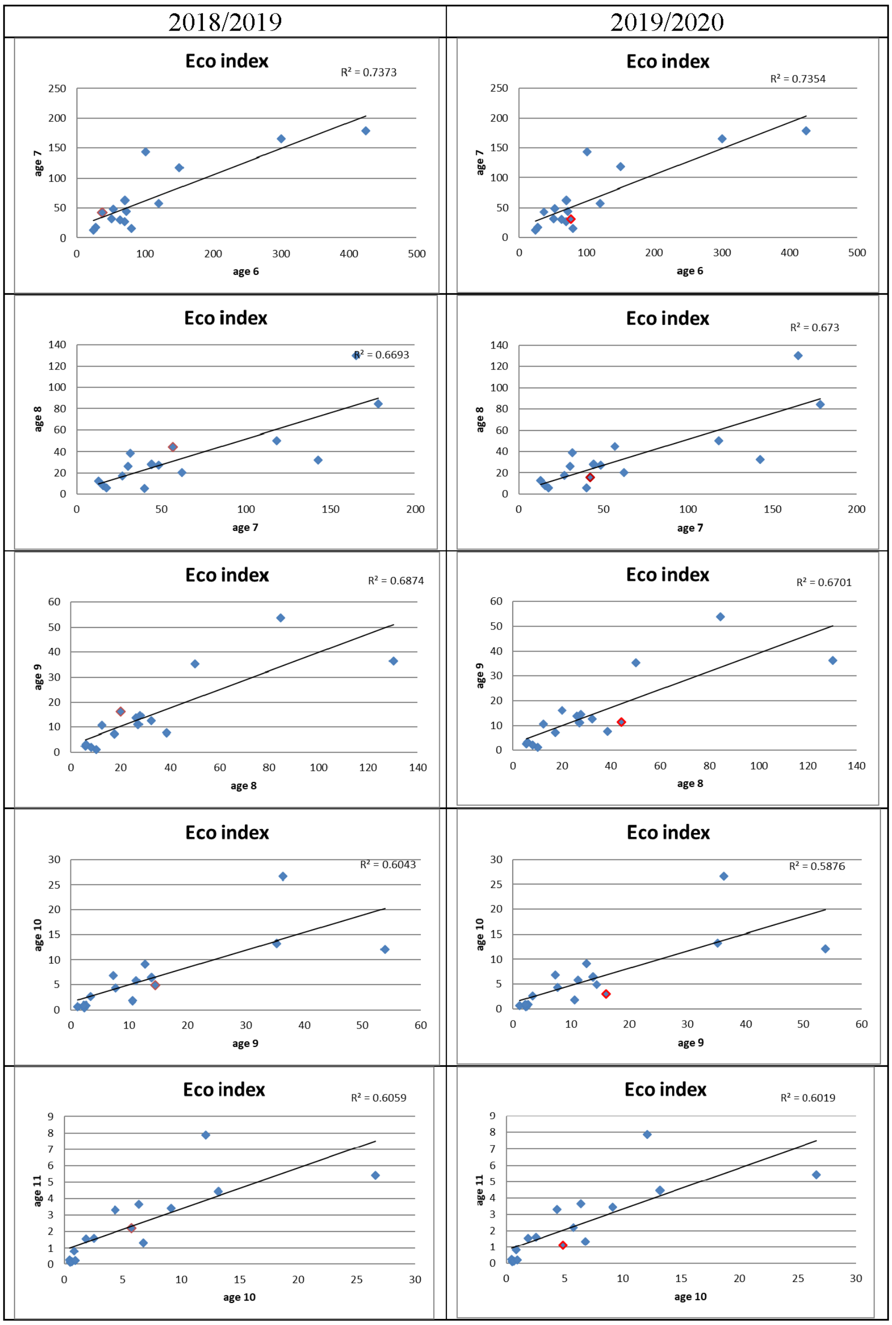


Figure 1. Continuation

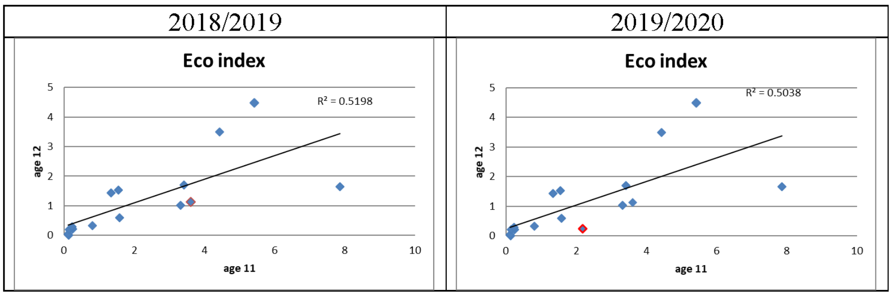


Figure 1. Continuation

Table 1. Coefficients of determinations between indices of a NEA cod cohort (the same cohort) at age n observed in the 2019 and 2020 Ecosystem survey and indices of the previous year survey and age n-1 based on data since 2004

Age n/n-1	2019	2020
2/1	0.30	0.29
3/2	0.42	0.32
4/3	0.54	0.45
5/4	0.23	0.21
6/5	0.70	0.64
7/6	0.74	0.73
8/7	0.67	0.67
9/8	0.69	0.67
10/9	0.60	0.59
11/10	0.61	0.60
12/11	0.52	0.50

The cod fishery in 2020 were considered in order to answer if there were any big discrepancies between its tendencies in 2020 vs. 2019 and long-term mean indices.

Monthly CPUE indices of one of the most numerous Russian vessels types that catch cod in the Barents Sea and adjacent areas and take a bulk (more than 50 %) of cod catch nowadays) were taken into account. These indices in August-December 2020 were below corresponding indices in 2019 (Figure 2). At the same time, the cod CPUE in the first part of 2020 were on the same level as in 2019 or higher. Decreasing of the CPUE becomes clear in the autumn 2020 where they drop until the long term average and lower. The lower CPUE values usually observed in September-October due to spreading out cod over feeding grounds in this period, but reasons of CPUE decrease on such an extent in the autumn of 2020 are not known.

Trends in Norwegian CPUE were similar but the decline in the last months of 2020 was less than in the Russian CPUE.

On the other hand, whatever the reasons that led to a significant drop in cod density in the whole fishing area and over such a long period (at least four months) they could influence the survey CPUE as well and cause the observed year effect. The ecosystem survey was conducted in August-November when commercial CPUE dropped down. The reasons of the observed decline in cod densities should be investigated further.

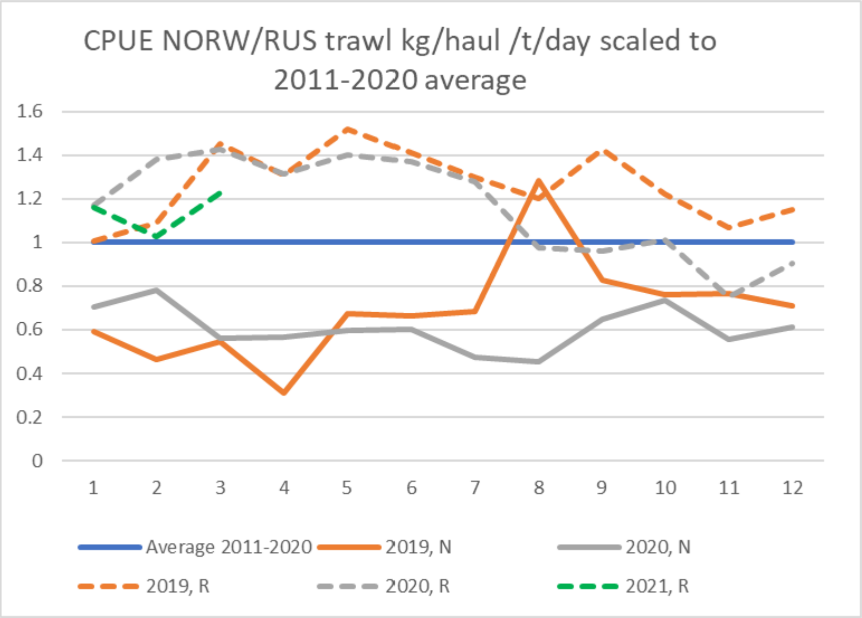


Figure 2. Monthly trawl CPUE of Russian and Norwegian vessels type which takes the bulk of catch on cod fishery in 2019, 2020 and 2021 vs. the long term mean values (2011-2020).

WD_10
ICES AFWG 2021

The Spanish NE Arctic Cod Fishery in 2020

José Miguel Casas Sánchez
Instituto Español de Oceanografía,
P.O. Box 1552, Vigo, Spain

In 2020 the Spanish fleet targeting for cod was composed by 4 single trawls. The activity of this fleet was carried out in ICES fishing areas I, and IIb from April to November.

Scientific sampling in 2020 coordinated by the IEO was suspended in most of 2020, due notably to administrative problems and to a lesser extends to COVID-19. For that reason this year this working document only shows the catches of cod and by-catches by month and Division with the effort distribution (number of otter trawls and hours of activity), and the overall monthly yield of the otter trawls for the target species, V. gr. Cod (Table 1). All this information comes from the data provided by the Spanish General Secretary of fisheries.

Table 1.- Cod catches (kg) and estimated by-catch of the Spanish fleet in ICES Subarea I, and IIb in 2020

BARENTS SEA SUBAREA (I)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
COD						2844	125846	323277	265381	932003	382655		2032005
ATLANTIC WOLFFISH						21	317		109	490			937
WOLFFISHES									1400	22259	723		24382
GREENLAND HALIBUT						194	210	1571	1456	19752	13162		36345
HADDOCK							55	2062	337				2454
LONG ROUGH DAB						19	359	217	1093	3352	980		6020
REDFISH (*Sebastes spp*)										4827	2135		6962
Number of **otter trawls**						1	2	1	2	2	1		3
Fishing hours (**otter trawls**)						8	87	148	243	718	210		1414
CPUE (kg/h) (**otter trawls**)						359	1441	2184	1093	1297	1827		1437

SVALBARD (DIVISION IIB)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
COD				142185	1804858	3168883	1694615	774167	1213270	196131	376702		9370812
ATLANTIC WOLFFISH				3812	6580	3518	16824	901	2056	163			33855
WOLFFISHES					4493	3937	10509	398	24445	8841	158		52781
GREENLAND HALIBUT				343	28060	16915	5307	1030	2479	531	5368		60034
HADDOCK				14	3810	30191	6355	1391	123	184			42067
ATLANTIC HALIBUT					66								66
LONG ROUGH DAB				2419	4862	9334	6413	2284	7010	821	630		33772
REDFISH (*Sebastes spp*)				81	3542	1219					1529		6371
Number of **otter trawls**				1	3	4	3	3	2	2	1		4
Fishing hours (**otter trawls**)				94	983	1784	850	329	858	186	172		5256
CPUE (kg/h) (**otter trawls**)				1507	1837	1776	1993	2357	1414	1056	2188		1783

WD:11
ICES AFWG 2021

The Spanish Pelagic Redfish Fishery in 2020

José Miguel Casas
Instituto Español de Oceanografía
P.O. Box 1552, Vigo, Spain

In 2020 the Spanish fleet targeting for pelagic redfish in ICES Division IIa was composed by 2 single trawls. The activity of this fleet was carried out from June to September.

Scientific sampling in 2020 coordinated by the IEO was suspended in most of 2020, due notably to administrative problems and to a lesser extends to COVID-19. For that reason this year this working document only shows the catches of cod and by-catches by month and Division with the effort distribution (number of otter trawls and hours of activity),

Table 1 shows catches of pelagic redfish, together with the distribution of effort (number of otter trawls and hours of activity) as well as the overall monthly yield of the otter trawls for the target species, V. gr. redfish. Catch and effort data for the whole fleet have been estimated from the data provided by the Spanish General Secretary of Fisheries.

Table 1.- Pelagic redfish catches and main bycatch species (kg) of the Spanish fleet in ICES Divisions IIa in 2020.

NORWAY ZEE NORTH OF 62º (IIA)	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
PELAGIC REDFISH	98142	158158	242399	238272	736971
Number of vessels	1	1	2	1	2
Fishing hours	521	669	840	411	2440
CPUE (kg/h)	189	236	289	580	302

AFWG 2021Working Document #12
Russkikh A.A., Kovalev Yu. A., Tchetyrkin A.A.

Revision of Russian survey indices used for Greenland halibut stock assessment

Introduction

Since 2015, the GADGET model (Globally Applicable Disaggregated General Ecosystem Toolbox) of integral population analysis has been used within the ICES Arctic Fisheries Working Group (AFWG) for Greenland halibut (hereinafter referred to as halibut) stock assessment in areas 1 and 2 according to the classification of the International Council for the Exploration of the Sea (ICES). The stock estimation is performed for the period from 1992 to the current year. For calculations, data on the value of commercial catches are used, and for model fitting, indices obtained in Russian-Norwegian scientific surveys are used (ICES, 2020a).

The population indices of the Norwegian surveys are divided by gender and 1 cm size classes, while the Russian population and biomass indices were traditionally estimated with a discreteness of 5 cm with a division by gender and based on age. However, in the new model calculations, the biomass index is only used without separation by gender.

During the previous AFWG meetings, it was noted that since age determination is difficult, all data, used in the model, should have a similar dimension in order to improve the quality of the stock estimate. Therefore, the population indices of the Russian survey were calculated in the Polar branch of VNIRO (hereinafter referred to as PINRO) with a discreteness of 1 cm, separately for males and females, for the period from 1992 to 2020. The new index estimates are provided for use in the calculations of the working group 2021.

Material and methods

Databases, obtained in the autumn-winter multi-species trawl-acoustic survey of PINRO (hereinafter referred to as MS TAC), were used to calculate the Russian indices. During this survey, the stratified survey of Greenland halibut (hereinafter referred to as SS) was also performed. The halibut survey was carried out at depths from 100 to 825 m in a standard survey area consisting of 100 local areas (strata – areas of the bottom surface, limited by depth and coordinates). The strata were grouped into 6 areas (A-F) with a total area of about 140 thousand square miles (Figure 1, Table 1).

The calculation method used was developed by PINRO scientists (Shevelev, Lepesevich, 1991; Smirnov, 1996, 1999). The calculation is based on determining the density of halibut clusters within a certain stratum. In this working document, the calculations are made for the period 1984-2020, and the data are grouped into 1 cm size classes.

For each trawl station, the density of aggregations of individuals is calculated according to 1-cm size classes:

$$\rho_{Nis} = \frac{C_{is}}{S_{TRs}} \qquad (1),$$

where ρ_{Nis} – the density of distribution of the number of fish of the i-th size group, noted at the station s, ind./sq.mile;

C_{is} – catch of individuals of the i-th size group;

S_{TRs} – swept area, sq. miles.

$$S_{TRs} = \frac{D_{TRs} * L_{EFF}}{1852} \qquad (2),$$

where D_{TRs} – the trawling distance (m);
L_{EFF} – effective horizontal trawl opening, m

For Greenland halibut, the effective horizontal opening of the trawl is unknown, therefore it is assumed to be L_{EFF} = 25 m, regardless of fish length and trawl depth.

The abundance indices of each size group by strata are calculated by the formula:

$$N_i = \frac{A}{M} \cdot \sum_s \rho_{Nsi} \qquad (3),$$

where N_i – the abundance index of the i-th size group in the stratum;
A – stratum area, sq. miles;
M – number of stations in the stratum.

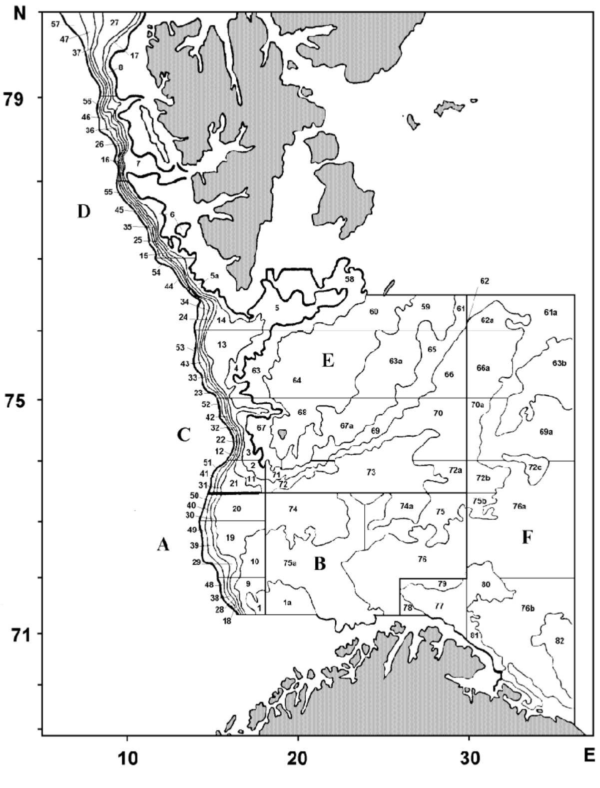


Fig. 1. Stratification of the standard sampling area of halibut survey during the Russian autumn MS TAC.

The total biomass of halibut, distributed in the study areas, was determined by the size-mass keys. The calculations were performed separately for males and females.

Table 1. Stratification of the standard sampling area of halibut survey: strata numbers (№strata) and water areas (Astrata).

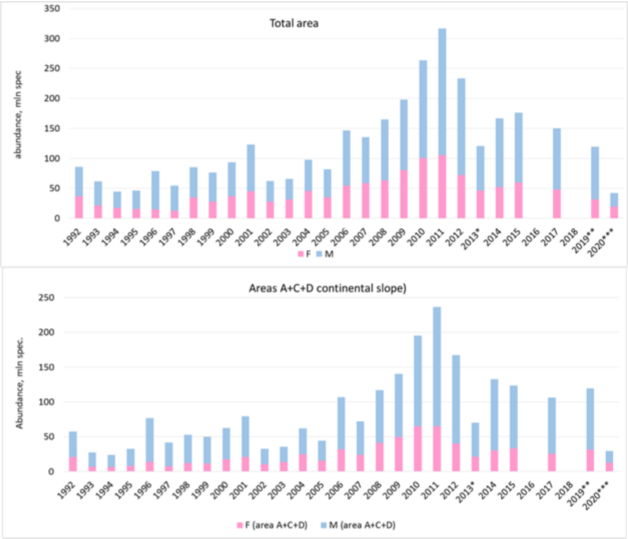
Area A		Area C		Area D		Area B		Area E		Area F	
№strata	Astrata, n.mile^2	№strata	Astrata, n.mile^2	№strata	Astrata, n.mile^2	№strata	Astrata, n.mile^2	№strata	Astrata, n.mile^2	№strata	Astrata, n.mile^2
1	412.6	2	548.3	5	1617	1a	1741.6	58	2058.4	61a	5064.4
9	805.3	3	822.1	5a	369.3	74	3829.8	59	1059.9	62a	505.2
10	1185.9	4	842.8	6	510	74a	1520.7	60	1485.9	63b	3937.6
18	149.7	11	631.9	7	767.4	75	3100.3	61	559.4	66a	2551
19	1571.1	12	298.3	8	219.9	75a	8880.2	62	51.2	69a	5769.4
20	1518.1	13	1364.5	14	606	76	8134.9	63	112.4	70a	1489.6
28	89.7	21	685.7	15	118			63a	2328.9	72b	1207.3
29	225.7	22	89.3	16	228.1			64	5076	72c	691.3
30	82.1	23	92.7	17	243.4			65	1861.1	75b	811.8
38	82.1	31	58.4	24	76.9			66	885.6	76a	14882.4
39	180.4	32	64.8	25	48.5			67	1229.1	76b	9984.9
40	88.3	33	109	26	68.5			67a	2392.6	77	2675.5
48	182.1	41	44	27	115.8			68	2211	78	291.5
49	504.2	42	63.3	34	72.8			69	1389.2	79	707.4
50	174.3	43	131.3	35	51.4			70	3028.8	80	1702
		51	113.9	36	57.5			71	512	81	678.9
		52	126	37	76.1			72	400.9	82	5313.9
		53	243.8	44	75.7			72a	1011.8		
				45	65			73	5835.4		
				46	70.5						
				47	79.8						
				54	153.3						
				55	141.4						
				56	157.7						
				57	202						
Total for area		Total for area		Total for area		Total for area		Total for area		Total for area	
15	7251.6	18	6330.1	25	6192.0	6	27207,5	19	33489,6	17	58264,1
Total for areas A+C+D						Total for areas B+E+F					
N strata = 58			A = 19773.7			N strata= 42			A=118961.2		
Total all areas											
N strara=100						A=138734,5					

Areas A, C, D cover the western part of the sampling area. They include 58 strata, but the area is about 6 times smaller than the rest of the water area (see Table 1). During the survey period, in these 3 strata, along the slope, the main concentrations of halibut are distributed in the spawning grounds. The abundance ratio in the areas varies, but on average about 70% of the total abundance and biomass is recorded in the western areas (A + C + D).

It can be assumed that the index, obtained in the western regions, will be the most stable and will better reflect the state of stocks. In addition, other areas (B, E, F) were not covered by the survey in all years, so it is better to use the index calculated for 3 areas at the slope instead of the index calculated for the entire water area.

The results

The indices of the Russian survey show a relatively stable state of the stock in the period 1992-2004, followed by an increase in the number and biomass of halibut (Appendix 1, Figure 2). Having reached a maximum in 2011, the number and biomass began to decline and according to the results of the 2020 survey, they were estimated at the minimum level, both for the entire sampling area and for the area of the continental shelf slope. In 2019-2020, the survey was carried out in a shorthand form (Appendix 2), but in 2020, a sharp decrease in the population estimate, compared to previous studies, was also noted for a comparable water area (see Figure 2).



**technical problems with equipment*
***only areas A+C+D covered*
****only areas A+C+D covered and changed equipment*

Figure 2. The number of Greenland halibut in the entire sampling area of the survey and in the area of the shelf slope (A+C+D) calculated with a discreteness of 1 cm.

The abundance indices reflect the entry of strong year-class into the stock in the late 1990s and in the mid-2000s, as well as several average ones. In 2019, there was a trend towards an increase in the share of small fish in the stock, but according to the 2020 estimate, the abundance of all size groups decreased sharply (fig. 3).

According to the data obtained from the target halibut fishery, a similar trend was not observed in 2020. Target halibut fishery has been resumed since 2010. Since its opening, the productivity of halibut fishing at the slope of the continental shelf in the autumn-winter period has increased annually and has often been limited only by the technical capabilities of vessels for processing the catch (Fig. 4).

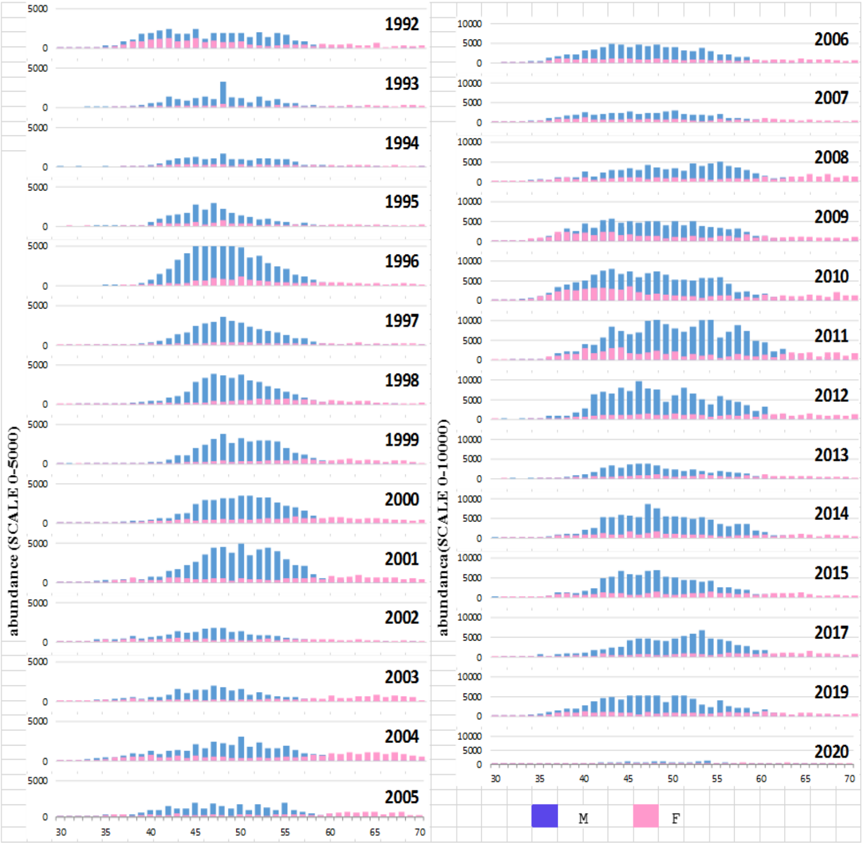


Figure 3. Absolute abundance of Greenland halibut by 1 cm size groups during the Russian trawl survey in 1992-2020 (areas A+C+D).

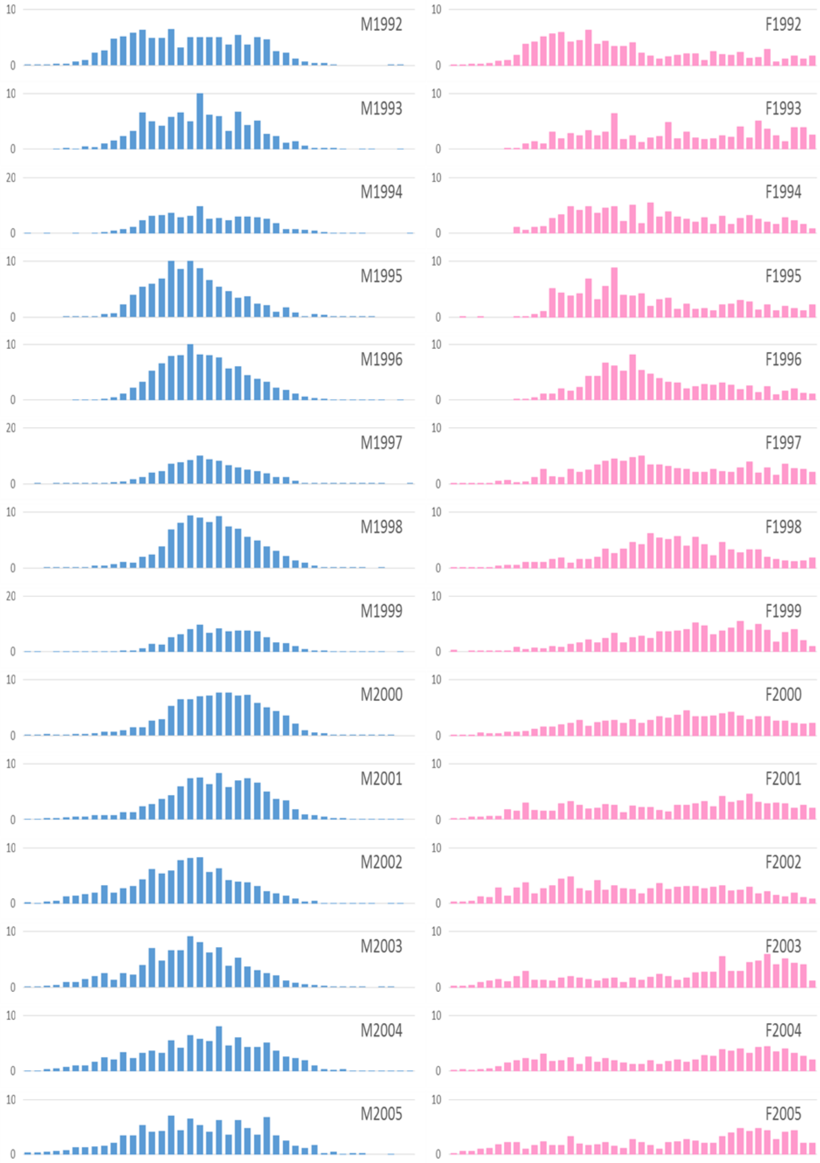


Figure 3a. Share distribution (%) of the abundance of Greenland halibut by 1 cm size groups in the Russian trawl survey in 1992-2020 (areas A+C+D).

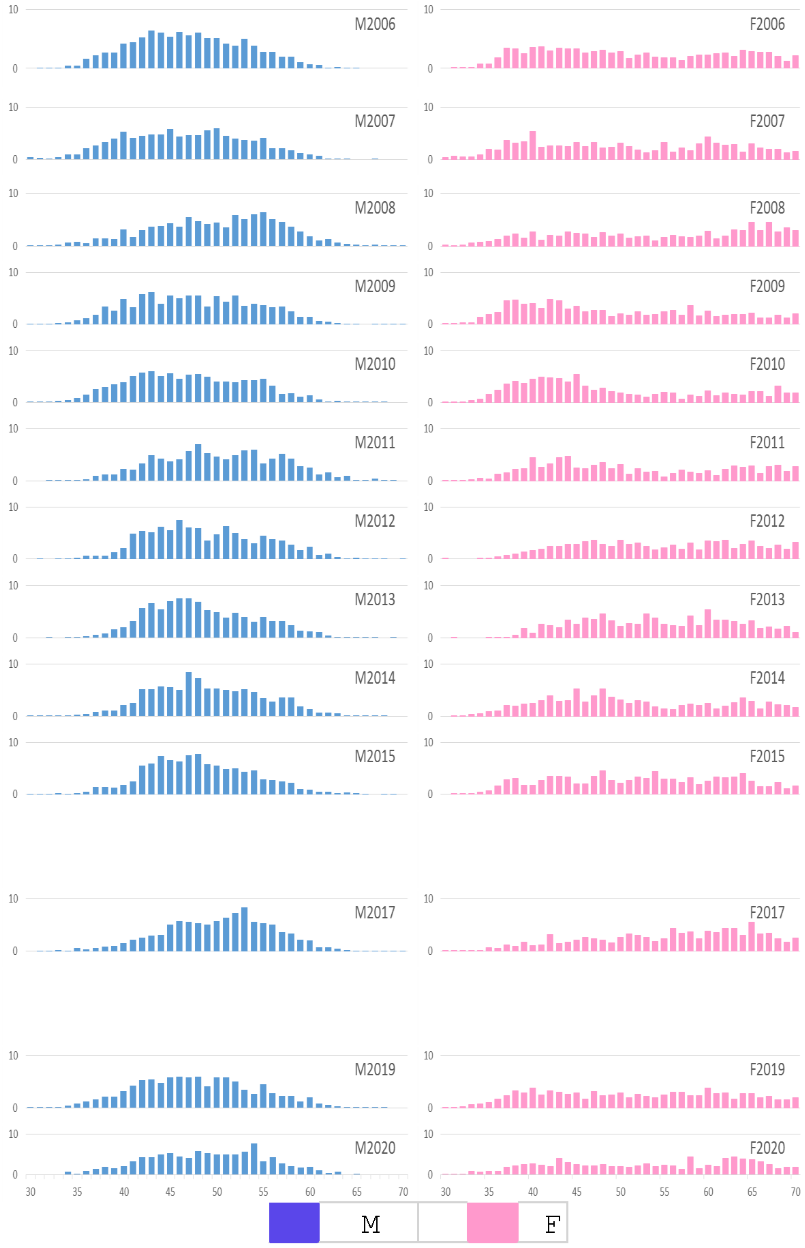


Fig. 3a. Continuation.

In recent years, there has been a slight decline in productivity, but in general it was at a consistently high level, and in 2020 it did not differ from the productivity in, at least, the previous 3 years (Fig. 4). Of course, a direct comparison of fishery productivity (CPUE) and abundance by survey is not entirely correct, nevertheless, a 3-4-fold drop in the stock, noted for the 2020 index, could not but affect the catches of the fishing fleet. In addition, commercial fishing takes place during the same period when the survey is conducted.

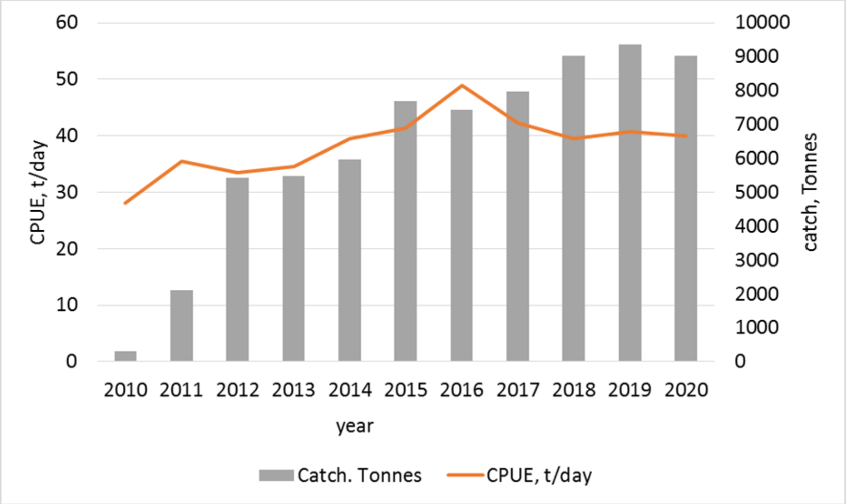


Fig. 4. CPUE and catch of domestic non-serial vessels (capacity of more than 2 thousand hp) and catch during the target trawl fishery of halibut in 2010-2020

There is an additional circumstance that makes it possible to question the comparability of the estimates obtained in 2020 with the rest of the time series of data. Due to the fact that the used sampling fishing gear (trawl 2283) is obsolete and has not been produced for a long period, there is no technical possibility of its exact reproduction. Therefore, when planning the survey, some changes were made to the trawl design (bobbins were replaced with rock-hoppers). In addition, for technical reasons, during the survey, the length of the trawling warp was reduced. The impact of all these changes could affect the catchability of the survey, and it is not possible to estimate the magnitude of this effect. In theory, this influence should not be too great, which was assumed when planning the survey. However, analyzing the obtained results and taking into account the noted radical drop in the stock abundance index against the background of stable industrial fishing productivity, we have to state that the 2020 index is incomparable with the rest of the observations.

Conclusion

For further use of the entire time series of the Russian survey, its index was standardized and brought into line with 3 others – the abundance was calculated for strata A, C and D for the period 1992-2020 separately by gender with a discreteness of 1 cm.

The index of the Russian trawl survey of Greenland halibut, recalculated with a discreteness of 1 cm, can be used in the stock assessment within the 2021 Working Group for the period 1992-2019.

It is recommended not to use the 2020 survey index for model fitting, because there is a high probability that the data obtained in 2020 are incomparable with the previous observation series due to the significantly different catchability of the survey.

An additional conclusion may be that it is inexpedient to continue this survey of the halibut stock while maintaining the current methods due to their obsolescence. In addition, the Russian autumn-winter survey of bottom fish, one of the components of which was the halibut survey, was also interrupted. It is necessary to change the design and technical conditions of the survey and start a new series of observations. It could be advisable to combine the efforts of PINRO and IMR and form a new joint halibut survey.

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Appendix 1

Table 1 Abundance indices of different length groups GHL in 1992-2020, total area (males, in thousands)

year	Length, sm																	
	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-25.9	26.0-26.9	27.0-27.9	28.0-28.9	29.0-29.9	30.0-30.9	31.0-31.9	32.0-32.9	33.0-33.9	34.0-34.9	35.0-35.9	36.0-36.9	37.0-37.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	34.9	101.2	117.9	152.0	300.2	340.1	943.8
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.9	2.2	123.5	78.0	116.7	255.2
1994	0.0	20.6	0.0	0.0	13.7	0.0	0.0	0.0	0.0	43.5	6.1	0.0	43.5	0.0	0.0	43.5	20.6	51.9
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	9.9	26.4
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	3.6	35.4
1997	0.0	0.0	0.0	0.0	21.8	43.5	0.0	0.0	0.0	3.6	0.0	2.2	0.0	12.2	22.5	26.4	85.3	46.6
1998	0.0	0.0	0.0	32.4	68.5	60.1	194.6	153.5	298.6	54.7	339.3	259.0	270.3	258.7	221.6	218.3	153.8	264.0
1999	3.3	25.3	41.7	67.5	23.8	80.6	31.1	63.0	83.7	88.2	407.9	386.8	349.3	183.2	397.3	396.4	809.0	540.5
2000	0.0	45.3	43.5	28.6	45.9	112.4	76.4	126.7	93.3	18.7	3.2	104.3	192.4	150.9	235.3	431.3	397.0	520.3
2001	0.0	8.8	7.7	49.0	46.6	37.4	18.5	86.5	29.4	12.0	76.9	96.1	301.3	398.6	449.5	518.4	589.9	681.1
2002	0.0	0.0	6.9	80.3	53.8	42.4	6.9	36.9	36.9	31.1	85.8	28.1	102.3	170.8	365.4	343.8	493.2	691.5
2003	0.0	10.0	23.1	0.0	0.0	73.3	0.0	0.0	2.3	82.3	143.2	70.7	181.9	206.0	479.7	352.4	549.9	1017.2
2004	0.0	0.0	0.0	18.5	48.8	64.1	13.6	10.4	55.5	174.0	131.1	93.4	343.0	385.9	350.3	707.8	649.5	1177.1
2005	0.0	0.0	0.0	44.9	44.9	65.1	63.4	18.5	27.1	21.9	197.4	129.0	306.8	406.6	471.4	779.1	659.6	1144.9
2006	0.0	0.0	0.0	33.8	0.0	0.0	53.7	0.0	0.0	64.3	0.0	191.7	68.6	61.9	391.7	443.9	1478.1	2205.3
2007	0.0	0.0	0.0	54.6	54.6	54.6	40.5	39.7	54.6	83.9	694.2	305.9	524.9	995.0	1720.9	724.0	2279.7	2605.8
2008	0.0	0.0	0.0	0.0	41.5	0.0	0.0	0.0	0.0	0.0	62.7	54.2	220.5	411.8	698.6	1249.4	999.5	2547.0
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.3	0.0	0.0	6.8	38.9	109.1	255.9	708.1	1149.9	1329.7	2331.9
2010	0.0	0.0	0.0	43.5	0.0	0.0	6.7	0.0	0.0	16.2	30.3	29.6	144.0	410.0	785.0	1678.7	2553.2	4124.5
2011	82.0	0.0	0.0	0.0	29.3	0.0	0.0	0.0	4.2	0.0	0.0	0.0	54.1	31.3	261.3	142.1	593.4	1876.3
2012	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	72.0	237.1	352.2	765.8	816.7
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.2	0.0	12.4	38.4	142.8	261.7
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	3.6	7.5	7.0	103.3	184.7	251.6	287.1	381.9	1061.5
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	10.5	79.5	139.9	31.6	138.5	254.1	254.2	750.4	1012.5	1631.9
2017	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	56.8	266.5	271.7	750.0	383.9	789.8
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.7	34.6	29.6	56.1	128.5	116.9	359.0	719.9	1067.7	1393.8
2020	0.0	0.0	0.0	55.0	7.0	0.0	0.0	11.3	0.0	0.0	2.7	10.4	13.8	60.9	133.5	45.7	328.2	279.3

Table 1 (Cont.)

year	Length, sm																	
	38.0-38.9	39.0-39.9	40.0-40.9	41.0-41.9	42.0-42.9	43.0-43.9	44.0-44.9	45.0-45.9	46.0-46.9	47.0-47.9	48.0-48.9	49.0-49.9	50.0-50.9	51.0-51.9	52.0-52.9	53.0-53.9	54.0-54.9	55.0-55.9
1992	1152.1	1925.5	2238.6	2353.2	3439.3	2591.2	2412.2	3203.5	1921.4	3155.8	2854.9	2334.7	2417.8	1937.4	2757.9	2243.1	2279.5	2078.6
1993	370.6	600.3	974.3	1014.6	2117.4	1752.5	1714.4	2161.6	2427.9	2066.9	4434.1	2214.5	2846.6	2342.1	2965.7	1671.1	2195.7	1839.0
1994	258.7	170.4	324.2	613.9	1493.8	1318.3	1455.3	1892.8	1524.1	1569.7	2432.6	1866.8	2056.6	2235.4	1633.6	1469.9	1389.9	1442.4
1995	130.3	156.7	576.1	1083.0	1553.4	1718.8	1850.3	2937.3	2371.0	3413.7	2785.0	1968.7	1968.6	1736.2	1488.9	1199.9	918.9	1007.7
1996	146.0	287.6	730.5	1427.2	2086.3	3291.7	4135.5	5081.8	5059.7	6714.6	5133.4	5163.2	4863.6	3669.9	3872.7	2964.0	2530.4	2109.8
1997	165.2	244.6	432.0	561.9	1012.0	1387.8	1637.2	2474.3	2808.3	2970.5	3771.5	3362.5	2961.2	2638.6	3555.2	2635.9	2625.0	1793.2
1998	282.3	392.2	886.7	806.6	1437.5	1292.3	2007.6	3157.0	3635.3	4129.4	3771.2	3770.5	3954.5	3113.5	3282.4	2920.2	2402.8	1783.3
1999	746.0	621.2	494.2	400.5	801.8	1371.4	1337.1	2380.3	2719.8	3464.6	3981.5	2944.7	3412.3	3170.8	3191.3	3132.1	2913.9	2328.5
2000	631.1	586.9	944.0	1572.7	1528.3	1856.3	2259.6	3369.8	3819.1	3721.1	3695.6	3521.5	4039.8	3662.7	3520.4	3541.4	2763.1	2493.5
2001	625.3	938.0	1485.8	1485.2	2288.6	2334.1	2834.3	4361.1	4442.2	5680.3	5801.8	4811.2	6562.2	4481.8	5173.1	5083.7	4513.0	3578.4
2002	1168.8	637.3	976.4	1036.4	1578.1	1871.5	1658.4	1616.0	2198.7	2781.4	2604.4	1986.2	2768.6	1791.5	1669.7	1662.0	909.7	623.2
2003	970.5	684.5	918.2	873.6	1489.9	2355.0	1795.1	2328.6	2019.3	2825.8	2503.9	1940.5	2392.3	1194.1	1493.8	1230.2	1107.6	844.6
2004	1609.4	1417.9	2193.6	1487.6	1892.0	2342.6	2032.5	2808.4	2167.3	2909.7	2866.7	2345.0	3647.6	2217.8	2760.0	2156.5	2156.0	2325.6
2005	1034.1	974.6	1978.8	2101.0	2503.2	2029.7	2059.0	3038.5	1856.3	3036.2	2671.9	1874.5	2374.2	1698.7	2517.8	1929.7	1418.2	2487.4
2006	2420.3	2697.0	3717.7	4011.5	5202.2	5420.6	6251.0	4496.9	5300.6	4928.3	5759.2	5088.4	5262.9	4153.3	3679.3	4329.7	3177.7	2889.4
2007	2561.7	3228.9	4756.0	3003.3	3848.5	3392.0	3357.3	4215.1	3513.2	4902.7	2933.3	3021.3	3776.2	2953.9	3064.0	2534.2	2191.4	2684.3
2008	2474.0	1808.7	4176.7	2156.7	3770.3	4621.6	4718.8	4366.0	3812.6	5042.7	4723.8	4227.6	4517.0	3255.6	5769.1	5139.6	5692.4	5906.0
2009	3912.4	3616.7	5750.6	3804.3	7057.6	6941.5	5155.7	7378.2	6175.3	6869.6	6676.6	4692.5	6418.4	4877.9	5431.9	3720.5	4145.5	4135.6
2010	4798.2	5216.7	6499.7	7935.0	9031.6	9858.3	7922.3	9035.9	8003.3	8285.3	9255.6	8061.4	7651.3	6723.1	7158.5	7040.0	6861.1	7062.4
2011	2574.5	2907.0	4975.4	4659.9	7136.3	11390.7	9438.8	8680.0	8552.9	12543.1	15522.4	10733.9	10210.0	8949.9	10308.2	12446.3	11871.5	7217.1
2012	1175.9	1950.0	3329.7	6771.1	7628.8	7212.3	9417.8	8468.7	10894.8	9750.8	9500.5	6899.0	7885.6	10058.4	9189.4	6865.7	5718.7	8079.4
2013	652.7	960.5	1270.6	1622.0	4591.7	3813.6	4186.0	5112.9	5115.6	5191.5	4656.4	4094.4	3436.9	3071.2	3582.2	3521.5	3453.2	3385.4
2014	1292.0	1081.0	2439.5	2778.8	5500.9	5553.5	6534.7	5910.8	6052.5	9253.5	8375.0	6041.6	5679.6	5957.5	6181.5	5993.6	5491.3	4328.4
2015	1829.3	1584.1	2381.9	2895.7	5341.8	6040.6	7158.4	6922.3	6652.7	7775.9	8564.5	5962.0	6528.0	5412.6	5652.8	5562.4	5771.3	4470.7
2017	1116.7	1324.4	1578.7	1813.5	2501.9	2709.6	3313.7	4867.2	5198.1	5108.2	5085.7	5125.3	5531.8	6337.4	6968.1	7376.6	5427.8	5889.1
2019	1897.9	1925.7	2811.5	3817.1	4647.5	4769.9	4248.0	5186.0	5270.7	5199.0	5310.5	3637.0	5219.6	5179.8	4425.8	3006.7	2354.1	4033.2
2020	342.8	270.6	486.0	538.4	811.4	1413.9	823.3	899.1	795.0	1767.3	998.9	1399.3	1319.3	1489.8	1143.8	1935.6	1289.7	854.3

Table 1 (Cont.)

year	Length, sm																	
	56.0-56.9	57.0-57.9	58.0-58.9	59.0-59.9	60.0-60.9	61.0-61.9	62.0-62.9	63.0-63.9	64.0-64.9	65.0-65.9	66.0-66.9	67.0-67.9	68.0-68.9	69.0-69.9	70.0-70.9	71.0-71.9	72.0-72.9	73.0-73.9	74.0-74.9
1992	1167.7	985.6	639.6	382.6	176.9	165.1	130.4	15.4	0.0	0.0	0.0	0.0	1.7	6.8	0.0	0.0	0.0	0.0	0.0
1993	1567.0	1004.3	544.5	450.0	184.9	59.2	125.3	56.7	52.3	3.8	19.8	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0
1994	671.7	313.5	300.3	312.2	249.6	87.9	51.5	81.2	37.7	6.2	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	14.5
1995	360.7	632.2	230.5	114.1	175.9	182.2	13.7	24.8	19.4	11.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	1475.3	1130.0	770.8	387.9	297.5	145.5	45.1	52.1	43.7	11.3	31.0	82.6	0.0	3.4	0.0	0.0	0.0	4.8	0.0
1997	1096.7	1165.5	864.1	408.8	161.0	409.3	23.9	6.9	183.0	2.4	1.6	0.5	0.0	0.0	0.5	0.0	23.1	0.0	0.0
1998	1504.7	982.9	701.2	362.5	485.3	55.1	285.9	34.0	10.0	8.6	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	1564.9	1212.8	848.6	537.9	212.0	216.7	65.3	46.2	92.8	37.0	19.2	20.2	21.6	6.0	0.0	0.0	0.0	0.0	0.0
2000	2228.0	1692.9	1135.8	531.7	327.3	228.7	154.6	100.2	63.5	4.2	26.6	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0
2001	2357.9	2374.4	1200.7	733.8	643.3	430.4	189.7	117.0	66.5	15.7	7.7	30.0	6.7	1.7	0.0	0.0	0.0	0.0	0.0
2002	620.0	573.2	234.4	197.6	136.6	57.6	28.7	12.9	25.4	5.6	9.8	36.9	16.0	1.9	0.0	0.0	0.0	0.0	4.2
2003	790.2	343.3	348.0	122.6	121.9	112.6	35.5	22.7	6.5	4.4	0.0	8.1	13.0	0.0	0.0	0.0	0.0	0.0	2.0
2004	1833.5	1268.3	1105.4	881.0	468.8	162.7	127.3	136.7	43.8	60.8	22.2	3.0	10.1	21.8	4.0	4.6	0.0	0.0	0.0
2005	1414.7	911.5	689.7	448.7	463.4	74.7	181.9	13.1	108.2	102.1	0.0	0.0	17.1	0.0	0.0	3.3	0.0	0.0	0.0
2006	2306.4	1886.2	1828.9	1069.8	875.7	417.7	188.4	180.1	12.7	63.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	1777.7	1233.1	1089.9	742.7	451.2	574.6	114.4	60.3	81.5	57.5	0.0	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	4092.5	4045.7	3072.4	2396.6	1666.0	910.0	1140.4	593.7	421.4	297.4	190.1	186.2	25.1	20.1	45.1	0.0	0.0	0.0	0.0
2009	3501.0	3504.7	2566.7	1662.1	1470.6	711.0	544.8	321.1	140.6	50.7	0.0	109.1	95.8	45.0	20.7	0.0	0.0	34.5	0.0
2010	4934.5	2934.7	2743.7	1933.5	1857.5	886.8	440.8	386.7	176.2	83.5	59.6	98.4	30.9	0.0	0.0	0.0	0.0	0.0	0.0
2011	8845.6	10056.9	8549.4	5743.8	4704.0	2347.9	3292.0	1360.1	1556.9	411.9	166.3	769.9	119.4	72.8	0.0	0.0	0.0	0.0	0.0
2012	6177.0	5925.2	5489.3	3386.9	3748.4	1063.4	1287.9	631.7	230.6	214.9	87.8	7.3	5.2	0.0	5.2	0.0	0.0	0.0	0.0
2013	3227.1	2835.5	2297.0	1133.0	1028.8	582.3	653.4	182.7	115.2	141.6	6.7	57.2	0.0	3.7	0.0	0.0	0.0	0.0	0.0
2014	3304.6	4437.4	3968.8	2075.7	1530.6	707.6	678.0	551.3	177.1	82.5	83.7	30.3	136.6	0.0	0.0	0.0	14.7	0.0	0.0
2015	3823.7	3470.4	3073.8	1454.9	1226.2	584.0	568.2	187.7	419.6	216.1	86.7	0.0	14.0	16.3	0.0	0.0	0.0	0.0	45.6
2017	4794.0	5041.6	3446.0	2608.2	2561.3	887.0	849.2	839.7	272.8	311.8	89.8	27.0	21.3	14.7	41.8	0.0	0.0	0.0	0.0
2019	2483.7	2027.5	2022.3	1126.4	1728.7	763.8	512.6	204.6	168.1	149.3	59.4	87.7	28.0	0.0	0.0	0.0	0.0	0.0	0.0
2020	876.0	454.9	358.1	293.0	340.5	179.2	77.8	140.9	12.3	61.4	18.4	9.6	2.9	0.0	0.0	2.9	0.0	0.0	0.0

Table 1 (Cont.)

year	Length, sm																	
	75.0-75.9	76.0-76.9	77.0-77.9	78.0-78.9	79.0-79.9	80.0-80.9	81.0-81.9	82.0-82.9	83.0-83.9	84.0-84.9	85.0-85.9	86.0-86.9	87.0-87.9	88.0-88.9	89.0-89.9	90.0-90.9	91.0-91.9	92.0-92.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 1 (Cont.)

year	Length, sm															Total	Biomass, tons
	93.0-93.9	94.0-94.9	95.0-95.9	96.0-96.9	97.0-97.9	98.0-98.9	99.0-99.9	100.0-100.9	101.0-101.9	102.0-102.9	103.0-103.9	104.0-104.9	105.0-105.9	106.0-106.9	107.0-107.9		
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48961	47712
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40407	41394
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27520	27388
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30672	29884
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63809	63229
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41649	44801
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50310	47078
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48292	51849
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56648	57364
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78063	81789
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34075	31671
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34090	31150
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51713	50843
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46393	43391
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92608	87190
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76364	67939
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101567	112644
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	117543	119707
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162788	158583
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	211189	245857
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	161310	170104
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74485	77880
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114518	120581
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116005	117151
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101605	119687
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88266	86985
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22354	23164

Table 2 Abundance indices of different length groups GHL in 1982-2020, total area (females, in thousands)

year	Length, sm																	
	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-25.9	26.0-26.9	27.0-27.9	28.0-28.9	29.0-29.9	30.0-30.9	31.0-31.9	32.0-32.9	33.0-33.9	34.0-34.9	35.0-35.9	36.0-36.9	37.0-37.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	27.4	2.1	100.7	19.8	128.7	256.9	227.7	184.1	336.0	496.7
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.1	0.0	43.6	26.4	35.3	11.3
1994	0.0	0.0	0.0	0.0	0.0	0.0	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.7	70.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	8.2	0.0	0.0	0.0	10.1
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	29.9	1.9	6.5	4.3	42.5	43.3	19.4
1998	0.0	66.6	0.0	33.4	70.2	47.5	128.1	228.0	298.0	294.5	70.7	151.7	507.2	75.3	220.1	177.6	359.8	134.1
1999	0.0	0.0	20.5	35.6	0.0	0.0	42.2	0.0	31.1	0.0	91.2	326.3	121.3	148.4	441.8	92.4	538.1	484.8
2000	18.1	23.1	12.3	23.1	105.8	34.4	96.5	40.2	24.8	15.4	54.3	22.5	72.8	123.4	297.7	228.5	290.1	401.1
2001	0.0	0.0	0.0	15.3	40.0	46.6	22.6	86.8	0.0	7.5	71.1	111.3	142.4	153.4	182.4	367.0	518.3	611.2
2002	0.0	0.0	0.0	44.7	0.0	0.0	0.0	6.9	40.8	77.7	87.7	36.6	66.7	182.7	134.3	459.3	215.6	299.8
2003	0.0	0.0	0.0	0.0	0.0	0.0	35.9	0.0	1.3	91.4	48.0	56.3	49.7	207.0	383.0	259.4	232.7	462.1
2004	0.0	0.0	0.0	0.0	60.4	41.4	84.5	4.4	38.5	54.5	40.6	81.1	127.3	104.4	231.9	257.1	564.9	722.6
2005	0.0	0.0	0.0	0.0	0.0	55.2	0.0	0.0	10.3	14.0	11.7	145.1	155.9	274.0	210.0	533.8	560.5	705.9
2006	0.0	0.0	0.0	0.0	33.8	2.5	2.7	0.0	0.0	0.0	64.3	60.5	52.0	72.8	315.9	391.8	706.6	1173.0
2007	0.0	0.0	0.0	13.1	0.0	54.6	96.9	40.5	13.1	132.2	221.8	175.7	461.6	574.6	465.8	939.0	738.3	1747.7
2008	0.0	0.0	0.0	0.0	68.4	41.5	0.0	90.2	0.0	3.4	86.9	113.4	94.3	269.3	504.3	967.9	1180.1	1112.9
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	54.1	156.2	125.1	190.8	995.9	1065.5	1174.7	2474.7
2010	0.0	0.0	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	4.4	209.4	239.2	499.6	1107.6	1592.8	3267.1
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.1	0.0	169.7	2.1	78.2	22.2	95.8	358.3	232.0	978.3	1151.8
2012	0.0	0.0	0.0	0.0	0.0	135.7	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	63.0	56.5	173.4	397.9
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	12.9	0.0	0.0	0.0	20.5	83.2	20.5
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	21.9	85.6	198.5	553.8	468.5	985.3
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	79.1	0.0	112.6	130.5	58.2	135.1	301.9	521.0	1339.5
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	8.2	53.5	44.5	116.6	337.6	150.4	303.0
2019	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	4.8	14.0	10.1	60.5	178.7	242.8	313.8	529.6	753.1
2020	0.0	0.0	55.0	0.0	0.0	0.0	0.0	0.0	41.7	2.8	8.4	12.9	14.0	109.1	82.8	117.2	113.2	291.3

Table 2 (Cont.)

year	Length. sm																	
	38.0-38.9	39.0-39.9	40.0-40.9	41.0-41.9	42.0-42.9	43.0-43.9	44.0-44.9	45.0-45.9	46.0-46.9	47.0-47.9	48.0-48.9	49.0-49.9	50.0-50.9	51.0-51.9	52.0-52.9	53.0-53.9	54.0-54.9	55.0-55.9
1992	966.8	993.5	1326.4	1344.9	1716.9	1637.4	1507.6	1799.5	1692.0	1743.6	1560.7	1250.2	1705.6	924.3	1356.1	777.7	1052.6	960.6
1993	83.3	369.2	419.9	578.0	447.6	988.1	520.8	884.3	474.5	918.6	1150.9	1192.5	951.5	1047.8	858.6	932.2	970.5	674.4
1994	59.7	170.4	279.7	263.5	749.7	611.8	666.8	924.9	825.2	880.7	1039.3	781.9	903.6	719.1	1111.0	623.2	816.2	602.8
1995	11.2	36.5	142.8	424.6	420.5	367.4	495.2	705.0	403.6	859.8	1406.1	1023.6	790.5	775.3	484.6	519.2	726.3	605.9
1996	15.0	64.2	162.9	154.2	356.2	239.8	332.2	682.8	676.9	969.1	951.7	824.4	1180.3	821.3	710.1	552.6	493.5	595.4
1997	156.9	88.6	193.6	94.4	142.6	303.2	155.4	198.4	277.7	342.2	484.1	540.2	406.2	429.7	471.8	577.0	661.7	385.9
1998	249.8	197.2	320.1	503.4	729.2	359.5	666.8	599.4	787.6	1369.7	1201.1	857.6	1656.0	1072.7	1482.6	1429.9	1541.9	1501.3
1999	326.3	308.1	273.6	570.8	374.8	320.8	328.1	501.3	468.1	642.2	816.4	275.3	698.9	1267.2	845.4	954.4	1204.5	1116.1
2000	474.2	466.4	627.5	729.5	971.4	866.6	1218.4	1030.7	1569.7	1075.4	1141.7	820.3	1333.1	826.2	1132.2	1235.0	1239.0	1307.8
2001	861.7	495.8	722.6	822.9	906.1	1204.0	1086.3	1607.7	1614.6	1784.3	1674.9	1262.5	2368.6	1356.3	1691.4	1440.1	1690.9	1665.6
2002	747.5	282.5	413.4	643.9	886.3	1136.3	528.2	821.9	1221.0	1113.6	865.0	995.2	1196.0	744.5	1346.6	1306.9	1049.0	1468.8
2003	825.0	646.2	727.6	584.4	566.7	374.7	861.6	904.7	705.9	916.7	1031.1	618.1	1074.6	987.8	690.4	1438.3	989.6	764.1
2004	991.7	943.1	1603.8	1293.8	1296.7	1382.3	966.6	1264.7	734.9	1451.9	1279.1	1483.3	1057.4	1226.0	1317.7	1054.3	1395.2	1473.2
2005	862.1	402.2	985.5	716.7	1304.7	997.6	948.4	840.5	1024.7	1065.5	1113.1	758.5	1111.6	838.9	852.1	614.3	1290.5	1083.5
2006	1394.9	1211.1	1241.0	1826.5	1704.5	2279.2	2067.4	1732.3	2303.2	2001.0	1789.2	2084.0	1764.5	909.4	1782.8	2223.7	2096.5	835.3
2007	1480.3	1474.4	3273.4	1431.3	2151.2	1394.3	1868.8	1925.6	1975.8	1181.2	1490.9	1327.5	1722.6	1774.2	1886.4	1333.3	1232.3	2327.1
2008	1942.7	1354.4	2248.1	1251.1	2057.9	1826.5	1705.3	2189.9	1498.6	1472.1	1420.6	1271.2	1909.6	1269.8	1137.2	1284.3	1172.4	1349.0
2009	2996.2	2751.2	2656.1	2458.0	4118.6	4826.3	3396.3	3170.9	3001.8	2514.1	2544.9	2512.8	2403.2	1716.0	1637.3	1638.3	1768.3	2185.3
2010	3123.9	2957.2	3581.7	3906.9	4516.5	4783.9	3736.3	4899.1	3421.4	3491.1	3094.8	3075.4	3212.3	2255.3	2123.5	1920.9	1971.6	2988.7
2011	1890.8	1933.1	3744.5	2560.2	3623.1	5185.7	4766.4	3111.2	3547.9	5289.4	3912.9	2855.0	3971.2	2463.5	3004.1	2644.3	2660.1	1996.4
2012	651.0	1379.2	1232.3	1028.2	1799.6	1708.8	1845.0	2554.8	1931.3	2633.1	2119.0	1578.9	2828.9	2216.2	2782.1	3252.2	1392.0	2180.9
2013	243.5	497.5	286.7	862.1	821.4	863.1	1369.7	875.4	1910.2	1640.8	1694.4	2213.9	2122.0	1257.8	1399.5	2169.1	2277.3	1756.1
2014	649.7	848.6	1153.3	1362.7	1762.0	1191.9	1455.1	1873.6	1533.9	2184.1	2293.4	1608.8	2102.1	1614.0	1972.5	1510.2	1330.2	1009.5
2015	1480.6	972.1	1040.7	1887.2	1938.4	1322.9	1396.4	1327.4	946.5	2361.2	2157.1	1683.6	1900.1	1649.3	2754.7	1826.6	2412.4	1832.2
2017	310.2	504.6	709.3	521.7	1311.5	450.6	881.6	1349.8	978.1	1020.6	1019.1	1005.5	1398.1	1076.3	1394.0	1848.5	821.0	1337.6
2019	1029.1	899.5	1192.0	777.1	1009.5	952.5	825.5	896.4	515.2	979.1	728.7	795.7	916.2	617.6	816.4	698.7	631.1	772.8
2020	322.2	321.1	341.5	651.6	252.6	554.7	505.4	377.4	281.3	514.2	407.7	296.4	417.6	238.1	1085.8	341.3	268.2	791.2

Table 2 (Cont.)

year	Length, sm																	
	56.0-56.9	57.0-57.9	58.0-58.9	59.0-59.9	60.0-60.9	61.0-61.9	62.0-62.9	63.0-63.9	64.0-64.9	65.0-65.9	66.0-66.9	67.0-67.9	68.0-68.9	69.0-69.9	70.0-70.9	71.0-71.9	72.0-72.9	73.0-73.9
1992	995.5	1002.4	730.6	999.8	905.6	587.7	1029.1	681.5	522.5	835.8	141.7	401.8	523.8	413.2	416.1	83.9	194.2	124.9
1993	867.2	781.0	308.2	338.9	385.5	446.7	533.7	332.1	572.0	621.3	272.3	199.8	461.2	313.6	340.3	181.1	211.2	35.0
1994	471.9	304.5	355.0	183.2	484.8	209.5	318.8	307.8	357.0	369.4	220.8	303.8	249.8	155.6	93.8	109.7	215.7	84.3
1995	374.6	444.7	428.3	457.4	478.6	375.1	572.9	352.7	180.2	362.0	210.8	314.7	147.8	107.7	209.9	110.8	132.3	37.6
1996	378.1	369.4	478.9	376.1	440.3	389.7	275.0	364.1	213.9	335.4	131.2	240.4	287.2	212.8	150.8	185.5	144.8	145.0
1997	240.6	426.7	984.3	440.5	270.3	508.4	463.0	370.0	264.7	423.1	372.0	521.2	380.1	194.2	165.3	133.8	107.5	73.8
1998	1143.5	1963.2	1591.5	921.3	1839.2	1173.3	1191.2	964.3	1124.2	1107.9	457.0	580.7	283.1	219.5	385.2	67.4	129.9	153.5
1999	1587.5	1378.9	1171.5	1337.9	1077.2	1117.9	1064.9	746.3	938.0	858.8	356.6	663.8	617.1	239.8	237.8	161.2	133.1	188.9
2000	1458.0	1317.3	1282.4	1422.0	1559.4	1227.0	1084.4	977.0	916.4	995.9	752.7	710.1	576.9	536.0	588.1	328.5	363.6	157.8
2001	1068.5	1297.0	1241.2	921.9	1746.1	1219.0	1316.0	1615.4	884.0	1009.5	838.2	1072.9	555.1	644.5	659.5	433.4	366.7	262.4
2002	1404.0	1369.6	839.4	519.8	932.4	552.2	810.7	583.7	529.3	513.6	244.1	222.8	357.2	141.5	145.3	90.2	37.4	78.0
2003	948.2	966.1	1585.2	1067.7	1151.0	1038.8	993.3	872.5	899.0	939.3	633.8	946.0	707.9	567.9	261.5	174.5	162.0	206.3
2004	822.5	1326.8	1857.5	1318.7	1562.2	1237.8	1399.4	1073.2	1340.1	1303.5	1009.3	1262.8	1103.7	659.6	638.8	470.1	557.8	395.6
2005	1148.7	993.9	926.7	894.8	1363.4	1012.5	1460.1	888.0	854.2	1016.9	592.7	799.3	876.0	481.6	507.3	334.3	427.4	77.3
2006	1307.2	1267.7	1247.8	921.5	1288.9	1166.7	1229.7	1068.2	1260.6	1601.1	1020.2	1577.4	1108.8	437.7	793.6	511.4	281.4	366.0
2007	1841.2	2069.0	2088.3	2075.4	2106.5	1158.5	1339.6	1295.8	1141.9	1577.8	895.6	937.9	873.5	410.0	622.0	329.4	162.9	162.3
2008	1323.5	1360.1	1599.2	1279.3	2144.9	1321.9	1056.7	1802.0	1622.7	2082.8	1501.6	2209.0	1166.2	1594.4	1418.9	819.6	888.3	919.5
2009	2043.4	2044.2	2396.6	1623.0	1792.0	1083.7	1287.8	1193.1	1741.9	1666.3	895.9	798.8	1383.5	697.4	1102.7	613.1	639.4	334.7
2010	2019.6	1400.5	2092.7	2457.6	2958.0	1604.2	1901.6	1333.5	1478.1	1798.7	1760.1	1064.8	2822.6	1400.7	1435.0	901.2	1018.3	963.5
2011	2047.5	2470.3	2125.0	1776.6	2732.5	989.0	2027.2	2719.0	2218.8	2247.7	1536.3	2383.6	2421.3	1449.2	2473.1	1234.0	2317.8	1674.8
2012	2514.4	1665.0	2917.4	1397.7	2718.3	2708.0	2407.3	1751.1	1530.4	1557.4	1461.8	1326.2	1408.0	1191.2	1929.8	1113.6	946.3	966.5
2013	1504.5	1122.7	2212.3	1311.8	2263.9	1504.1	1408.5	1019.8	1212.6	1183.0	957.2	924.2	797.2	739.2	629.1	532.7	453.0	245.8
2014	963.9	1288.3	1287.2	1727.0	1615.8	1216.8	960.9	1297.4	1703.9	1373.4	1004.2	1320.0	1292.6	1043.8	914.9	601.9	434.4	375.5
2015	1452.0	1625.4	2580.2	1700.9	1850.7	1928.6	2362.1	2045.9	1999.8	1591.2	1329.9	903.5	1213.6	518.4	693.4	361.8	476.0	271.1
2017	1785.7	2032.6	2307.0	1224.3	2466.8	1196.3	2113.8	1914.9	1331.2	1843.7	1431.7	1525.1	1694.6	960.2	1258.9	317.6	566.2	392.3
2019	957.4	944.7	744.1	724.3	1183.6	876.2	904.0	532.8	853.9	859.8	602.6	711.8	495.3	482.4	612.4	579.6	459.6	189.0
2020	333.8	349.3	559.4	506.6	638.4	485.3	917.5	561.6	995.8	516.2	407.5	329.6	548.3	418.6	234.3	334.2	136.4	572.0

Table 2 (cont.)

year	Length, sm																	
	74.0-74.9	75.0-75.9	76.0-76.9	77.0-77.9	78.0-78.9	79.0-79.9	80.0-80.9	81.0-81.9	82.0-82.9	83.0-83.9	84.0-84.9	85.0-85.9	86.0-86.9	87.0-87.9	88.0-88.9	89.0-89.9	90.0-90.9	91.0-91.9
1992	35.8	69.0	101.1	27.9	4.1	10.0	29.9	8.3	34.3	5.9	14.9	0.0	0.0	0.0	0.0	0.0	4.1	0.0
1993	84.3	252.6	62.9	34.3	14.3	19.4	70.4	0.0	29.1	30.1	30.1	33.2	0.0	0.0	23.3	0.0	0.0	0.0
1994	124.5	42.6	5.1	6.7	17.1	9.5	1.7	0.0	20.9	1.2	2.1	0.0	1.0	1.2	0.0	0.0	0.0	0.0
1995	66.8	129.5	59.2	17.0	14.0	11.1	0.0	0.0	0.0	0.0	20.4	20.8	0.0	0.0	0.0	0.0	11.4	0.0
1996	64.9	60.8	52.1	28.4	19.2	0.8	50.5	14.5	12.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
1997	48.8	120.3	30.5	50.2	9.4	0.8	15.8	52.6	1.6	2.1	0.5	0.0	0.5	0.5	0.0	0.0	4.4	0.0
1998	48.0	23.5	15.3	95.3	18.7	23.3	23.7	2.3	33.9	2.3	4.8	0.0	0.0	19.3	2.3	0.0	1.6	0.7
1999	60.7	53.2	2.9	61.6	55.3	88.2	6.4	11.3	61.9	5.3	4.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0
2000	135.7	154.9	77.8	34.5	69.6	37.6	23.6	45.3	6.6	55.5	0.0	7.8	1.5	0.0	23.1	0.0	0.8	0.0
2001	210.7	236.8	83.8	214.1	96.0	85.3	120.6	39.0	54.7	61.9	65.1	2.7	28.6	1.1	26.3	0.0	0.0	0.0
2002	60.6	84.0	66.5	20.6	17.8	10.0	4.1	1.4	12.5	3.1	0.3	0.0	1.4	0.7	31.5	0.0	2.0	0.0
2003	131.9	165.1	80.7	55.9	61.6	108.5	107.7	3.3	15.7	54.9	64.9	17.9	0.0	0.0	10.1	2.3	17.8	0.0
2004	269.7	377.0	142.7	99.4	158.7	153.9	258.7	39.9	86.4	29.2	74.9	83.6	19.0	21.8	52.9	65.4	11.9	0.0
2005	152.1	148.4	61.0	161.1	57.7	74.2	79.0	125.7	94.6	8.3	8.3	121.9	38.5	6.2	3.3	8.8	18.8	54.3
2006	315.2	220.1	161.7	139.9	254.9	90.3	55.3	47.5	16.5	48.8	94.2	69.4	82.4	29.4	32.0	19.1	4.2	13.4
2007	128.1	141.8	163.6	165.1	73.6	33.0	34.9	33.0	36.9	9.4	9.4	9.4	3.8	1.8	9.4	0.0	0.0	7.2
2008	740.5	820.6	541.9	411.4	372.2	257.1	271.8	72.9	137.6	95.4	119.1	153.0	90.7	38.3	51.0	0.0	83.0	137.1
2009	483.7	523.9	137.5	48.7	320.0	138.8	207.3	21.8	87.3	116.8	99.8	27.7	15.9	22.6	15.6	34.2	17.7	44.9
2010	586.2	492.2	408.7	358.1	412.9	124.0	277.0	171.2	240.4	193.6	117.4	346.1	81.5	64.5	64.0	72.0	73.4	50.5
2011	994.1	930.1	773.2	697.1	924.2	396.1	697.3	23.8	98.9	139.0	122.1	65.6	77.0	83.9	5.5	35.8	34.6	0.0
2012	366.6	814.2	562.9	461.8	440.3	138.9	326.8	76.2	145.7	242.4	219.4	410.4	69.4	63.3	66.4	20.1	192.9	0.0
2013	283.0	396.4	247.9	175.3	98.7	182.4	92.8	64.7	8.7	11.3	95.8	11.6	94.3	0.0	7.3	8.9	59.1	63.3
2014	464.3	313.1	155.5	256.3	196.0	90.1	220.7	77.9	78.0	36.2	23.6	63.4	27.3	7.5	0.0	49.4	4.9	0.0
2015	99.8	122.7	167.8	323.4	244.2	76.8	48.2	90.0	19.9	68.8	23.8	15.9	7.9	6.4	0.0	49.3	7.5	14.8
2017	563.4	809.7	341.9	140.5	73.8	144.5	43.2	39.3	70.2	415.8	19.0	34.0	0.0	1.9	26.3	1.9	183.2	10.3
2019	196.8	228.7	110.7	293.5	132.3	77.4	92.7	40.2	54.4	21.9	4.0	37.5	10.4	17.5	21.3	62.3	14.1	14.8
2020	613.5	446.1	14.3	408.8	65.0	203.4	175.7	0.0	368.9	1.8	12.9	2.9	1.6	0.0	8.8	0.0	5.5	0.0

Table 2 (cont)

year	Length, sm																Total	Biomass, tons
	92.0-92.9	93.0-93.9	94.0-94.9	95.0-95.9	96.0-96.9	97.0-97.9	98.0-98.9	99.0-99.9	100.0-100.9	101.0-101.9	102.0-102.9	103.0-103.9	104.0-104.9	105.0-105.9	106.0-106.9	107.0-107.9		
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37045	51084
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	0.0	0.0	0.0	0.0	0.0	21541	34505
1994	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17220	24966
1995	0.0	0.0	1.8	16.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15885	24642
1996	0.0	0.0	0.0	0.1	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15217	25145
1997	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12736	23595
1998	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35002	52184
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27957	47726
2000	1.6	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36884	61813
2001	6.7	13.2	32.1	29.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45191	75433
2002	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28107	40911
2003	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31579	53135
2004	10.1	0.0	28.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45954	80518
2005	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35372	59668
2006	46.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54318	84276
2007	22.1	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58905	84801
2008	0.0	0.0	51.5	58.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63508	119840
2009	12.2	12.4	33.8	12.2	0.0	3.4	4.0	1.7	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80340	117561
2010	0.0	49.9	65.5	0.0	2.2	0.0	0.0	0.0	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100710	161104
2011	1.3	20.8	31.3	0.0	39.0	13.1	2.8	0.0	0.0	33.7	35.4	0.0	0.0	0.0	0.0	0.0	105489	185718
2012	51.4	8.7	2.2	8.7	14.1	0.0	0.0	8.7	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	72170	136376
2013	8.7	4.0	0.0	1.5	0.0	0.0	0.0	0.0	1.3	0.0	0.0	4.7	0.0	0.0	0.0	0.0	46344	80820
2014	38.2	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	52312	86583
2015	5.9	0.0	7.6	3.7	3.7	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59891	95393
2017	3.9	1.9	14.0	28.1	1.9	5.8	15.2	4.2	7.7	0.0	1.9	1.9	0.0	0.0	0.0	0.0	48324	98182
2019	57.8	16.7	13.8	20.4	6.3	4.0	0.0	5.9	26.4	0.0	0.0	4.0	6.3	0.0	0.0	6.3	31476	54972
2020	7.8	2.0	0.0	4.7	0.0	10.2	0.0	0.0	0.0	2.4	2.8	0.0	0.0	0.0	0.0	24.9	20045	42952

Table 3 Abundance indices of different length groups GHL in 1992-2020, area A+C+D (males, in thousands)

year	Length, sm																	
	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-25.9	26.0-26.9	27.0-27.9	28.0-28.9	29.0-29.9	30.0-30.9	31.0-31.9	32.0-32.9	33.0-33.9	34.0-34.9	35.0-35.9	36.0-36.9	37.0-37.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	8.5	40.3	104.3	112.4	277.6	340.1	857.6
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	49.9	20.1	116.7	76.7
1994	0.0	0.0	0.0	0.0	13.7	0.0	0.0	0.0	0.0	43.5	6.1	0.0	43.5	0.0	0.0	43.5	0.0	25.2
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	9.9	26.4
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	3.6	35.4
1997	0.0	0.0	0.0	0.0	21.8	43.5	0.0	0.0	0.0	3.6	0.0	2.2	0.0	12.2	22.5	26.4	40.5	46.6
1998	0.0	0.0	0.0	3.8	0.0	0.0	0.0	1.8	2.0	0.0	0.0	0.0	1.8	51.3	9.3	32.9	35.1	145.1
1999	3.3	25.3	41.7	0.0	23.8	47.5	0.0	5.5	3.0	0.0	3.3	13.6	0.0	1.4	14.8	57.4	45.7	56.8
2000	0.0	45.3	43.5	0.0	45.9	94.5	76.4	95.2	79.7	18.7	3.2	104.3	124.3	23.0	103.7	108.0	125.9	220.2
2001	0.0	0.0	7.7	49.0	28.1	19.8	0.0	68.0	20.8	3.2	40.9	50.4	154.8	153.0	266.1	276.5	308.0	438.8
2002	0.0	0.0	6.9	71.2	35.6	0.0	6.9	0.0	5.4	31.1	56.5	28.1	84.2	116.3	267.7	299.2	359.9	438.1
2003	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	6.1	46.7	36.1	78.5	86.8	206.4	217.2	338.2	454.4
2004	0.0	0.0	0.0	0.0	15.0	18.2	13.6	10.4	15.0	52.1	27.1	15.1	128.5	171.4	313.6	379.8	409.1	656.1
2005	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	27.1	3.5	81.3	78.0	130.9	165.3	201.2	354.1	354.5	381.4
2006	0.0	0.0	0.0	33.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.0	17.1	61.9	337.1	356.6	1256.7	1709.9
2007	0.0	0.0	0.0	54.6	54.6	54.6	0.0	39.7	54.6	35.0	199.1	154.1	89.1	203.5	439.2	445.4	1054.8	1312.9
2008	0.0	0.0	0.0	0.0	41.5	0.0	0.0	0.0	0.0	0.0	6.6	28.0	55.9	182.4	474.3	617.4	470.8	1119.7
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	12.0	109.1	162.6	345.8	701.3	1051.8	1669.7
2010	0.0	0.0	0.0	43.5	0.0	0.0	6.7	0.0	0.0	16.2	30.3	29.6	144.0	339.0	621.1	1098.4	1934.5	3417.9
2011	0.0	0.0	0.0	0.0	29.3	0.0	0.0	0.0	4.2	0.0	0.0	0.0	10.0	31.3	185.1	142.1	472.9	1710.1
2012	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	2.2	135.2	262.4	765.8	816.7
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.2	0.0	12.4	38.4	142.8	261.7
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	3.6	7.5	7.0	103.3	184.7	203.9	287.1	381.9	831.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	7.5	7.5	2.1	31.6	69.7	185.2	113.3	196.3	443.1	1221.5
2017	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	56.8	189.5	125.0	575.7	306.9	572.4
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.7	34.6	29.6	56.1	128.5	116.9	359.0	719.9	1067.7	1393.8
2020	0.0	0.0	0.0	55.0	7.0	0.0	0.0	11.3	0.0	0.0	2.7	10.4	13.8	18.7	133.5	45.7	165.1	237.1

Table 3 (Cont.)

year	Length. sm																	
	38.0-38.9	39.0-39.9	40.0-40.9	41.0-41.9	42.0-42.9	43.0-43.9	44.0-44.9	45.0-45.9	46.0-46.9	47.0-47.9	48.0-48.9	49.0-49.9	50.0-50.9	51.0-51.9	52.0-52.9	53.0-53.9	54.0-54.9	55.0-55.9
1992	1004.6	1776.0	1924.7	2150.2	2367.2	1784.8	1826.1	2404.2	1199.1	1867.2	1843.9	1861.5	1845.1	1365.0	2002.8	1348.5	1855.9	1712.1
1993	208.6	318.8	478.6	662.6	1339.9	1029.7	865.0	1174.5	1330.8	1022.9	3250.8	1269.0	1202.8	675.2	1368.0	887.1	1050.7	556.5
1994	49.9	150.5	240.0	374.9	808.7	1069.6	1126.0	1240.9	961.7	1083.5	1640.3	901.5	937.7	795.4	1024.3	1002.1	972.0	902.9
1995	130.3	156.7	562.5	984.4	1345.7	1466.8	1704.3	2699.6	2126.8	2968.9	2164.1	1638.4	1347.5	1152.0	862.3	931.0	581.0	524.7
1996	146.0	287.6	730.5	1427.2	2086.3	3291.7	4095.5	4964.4	5027.2	6654.9	5093.4	5083.0	4781.9	3562.5	3800.1	2809.8	2382.3	2082.6
1997	79.0	191.8	322.6	561.9	889.9	1377.7	1609.7	2447.7	2717.0	2914.6	3515.4	3042.1	2841.1	2334.5	2023.6	1792.2	1556.6	1289.3
1998	173.3	277.2	438.4	388.3	810.3	999.0	1580.1	2784.1	3322.3	3837.7	3687.3	3366.6	3789.7	3012.9	2851.8	2292.6	2010.3	1582.5
1999	78.0	91.5	184.7	219.9	514.5	1072.8	1032.9	1954.1	2393.8	3135.6	3749.5	2588.1	3250.6	2848.3	2924.4	2933.1	2776.3	1997.7
2000	326.5	307.9	416.0	651.2	674.8	1175.7	1291.3	2373.0	2933.3	2931.6	3121.5	3172.2	3433.3	3421.2	3191.9	3271.0	2581.2	2240.3
2001	503.4	463.8	763.7	785.8	1435.8	1672.4	2150.4	2588.8	3504.2	4375.4	4458.4	3745.7	4893.4	3420.2	4167.3	4390.0	3942.2	2928.5
2002	725.2	425.3	601.1	691.7	962.7	1359.2	1175.1	1305.2	1712.6	1785.5	1815.3	1251.7	1396.9	926.8	854.7	844.0	685.1	494.5
2003	568.2	286.4	552.9	486.6	866.6	1537.1	1061.5	1459.5	1463.3	2009.0	1786.4	1374.9	1572.1	847.1	1159.8	820.9	672.7	561.1
2004	934.6	800.1	1297.1	891.9	1218.6	1391.7	1232.3	2063.8	1602.7	2437.7	2178.9	2029.8	3006.4	1731.9	2278.3	1621.7	1620.7	1921.7
2005	413.3	591.4	967.5	941.9	1457.1	1155.1	1162.6	2003.7	1205.2	1829.4	1481.9	1155.3	1772.2	977.4	1755.1	1334.7	1000.0	1912.5
2006	2048.3	2033.9	3126.3	3299.6	3943.6	4805.7	4560.8	4013.6	4667.9	4177.2	4600.7	3896.9	3876.8	3207.1	2881.0	3774.3	2890.5	2148.7
2007	1596.5	1903.7	2575.5	1986.7	2156.6	2283.3	2307.3	2820.4	2093.8	2277.8	2247.5	2677.3	2899.1	2155.8	1957.1	1799.3	1728.1	2021.3
2008	1153.0	1005.1	2429.2	1327.2	2294.1	2854.8	2973.5	3331.9	2831.0	4208.3	3634.0	3189.2	3448.8	2770.3	4563.0	3938.5	4672.4	4938.2
2009	3058.2	2422.3	4417.5	2945.1	5248.4	5555.6	3594.8	4980.8	4492.8	5060.8	5047.6	3145.3	4927.7	3922.1	4957.9	3156.9	3598.6	3305.1
2010	3927.9	4521.4	5057.8	6570.7	7524.0	7859.0	6719.5	7285.0	5955.4	6969.2	7221.4	6439.4	5223.6	5259.2	5014.8	5678.7	5644.6	5923.6
2011	2149.8	2022.3	3988.0	3723.4	5729.2	8324.0	7261.8	6420.2	6973.5	9790.4	12035.1	9046.2	8040.2	7049.5	8390.0	#####	#####	5632.9
2012	853.8	1627.7	2633.2	6267.8	6849.8	6453.5	7952.9	7099.9	9624.2	7759.3	7594.3	4497.8	6012.3	8016.2	6391.1	4928.2	3777.2	5770.5
2013	435.1	791.4	1008.1	1596.1	2788.6	3293.8	2686.6	3483.1	3746.8	3703.2	3428.9	2609.3	2396.8	1926.3	2375.9	1966.0	1550.6	1969.6
2014	1116.5	1041.5	2107.7	2518.2	5224.4	5310.4	5866.4	5640.6	5135.9	8623.9	7518.5	5374.2	5395.9	5210.6	4842.9	5225.6	4694.4	3555.4
2015	1227.4	1133.0	1651.6	2232.7	4915.6	5263.9	6597.2	5879.9	5730.8	6694.1	6951.7	5177.8	4932.1	4401.3	4464.5	3894.7	4158.0	2540.1
2017	756.4	887.6	1141.1	1666.0	1990.6	2312.3	2475.9	4082.7	4659.6	4547.1	4265.6	4075.1	4652.5	5175.3	5942.2	6756.0	4512.1	4335.2
2019	1897.9	1925.7	2811.5	3817.1	4647.5	4769.9	4248.0	5186.0	5270.7	5199.0	5310.5	3637.0	5219.6	5179.8	4425.8	3006.7	2354.1	4033.2
2020	342.8	270.6	348.5	538.4	726.5	722.8	823.3	899.1	753.0	681.1	973.9	897.1	817.1	819.6	829.6	930.0	1289.7	540.0

Table 3 (Cont.)

year	Length, sm																	
	56.0-56.9	57.0-57.9	58.0-58.9	59.0-59.9	60.0-60.9	61.0-61.9	62.0-62.9	63.0-63.9	64.0-64.9	65.0-65.9	66.0-66.9	67.0-67.9	68.0-68.9	69.0-69.9	70.0-70.9	71.0-71.9	72.0-72.9	73.0-73.9	74.0-74.9

1992	935.4	820.2	465.4	233.3	150.1	150.2	17.5	0.0	0.0	0.0	0.0	0.0	1.7	6.8	0.0	0.0	0.0	0.0	0.0
1993	477.4	226.7	289.0	127.2	50.0	59.2	56.6	17.2	0.0	3.8	2.4	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0
1994	591.7	233.8	247.9	222.9	156.4	60.3	36.9	19.8	7.2	6.2	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
1995	235.4	429.5	185.4	51.3	135.5	98.0	13.7	18.9	1.2	11.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	1412.9	1130.0	738.3	387.9	243.0	145.5	45.1	52.1	43.7	11.3	31.0	4.9	0.0	3.4	0.0	0.0	0.0	4.8	0.0
1997	830.3	864.9	444.7	173.0	118.6	53.1	23.9	6.9	5.0	2.4	1.6	0.5	0.0	0.0	0.5	0.0	23.1	0.0	0.0
1998	1223.9	839.6	567.6	362.5	169.6	55.1	13.2	1.6	10.0	8.6	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	1329.0	1179.5	758.9	421.1	166.1	216.7	32.8	46.2	42.3	37.0	3.4	1.5	0.0	6.0	0.0	0.0	0.0	0.0	0.0
2000	1978.4	1588.6	965.5	449.3	250.5	205.6	75.3	55.5	43.2	4.2	6.3	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0
2001	2185.4	2065.6	1054.1	507.2	436.5	272.5	168.5	117.0	66.5	15.7	7.7	13.2	6.7	1.7	0.0	0.0	0.0	0.0	0.0
2002	396.9	306.3	190.8	76.5	108.8	29.9	13.4	12.9	10.1	5.6	0.7	0.0	0.7	1.9	0.0	0.0	0.0	0.0	4.2
2003	482.5	271.8	190.1	113.8	96.0	64.0	35.5	22.7	6.5	4.4	0.0	8.1	13.0	0.0	0.0	0.0	0.0	0.0	2.0
2004	1365.9	959.7	875.9	760.0	379.6	162.7	107.7	136.7	43.8	60.8	2.6	3.0	10.1	21.8	4.0	4.6	0.0	0.0	0.0
2005	969.2	685.7	442.8	306.6	463.4	74.7	128.5	13.1	63.3	69.6	0.0	0.0	17.1	0.0	0.0	3.3	0.0	0.0	0.0
2006	2087.2	1466.3	1534.6	812.6	501.5	417.7	119.4	145.6	12.7	63.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	1063.8	1064.6	832.7	608.5	451.2	361.1	79.1	23.9	81.5	0.0	0.0	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	3948.1	3579.6	2865.4	2141.0	1441.9	825.3	1008.2	536.5	331.6	268.8	161.5	186.2	25.1	20.1	45.1	0.0	0.0	0.0	0.0
2009	2926.8	3083.0	2311.5	1272.9	1290.7	536.5	510.2	214.5	105.1	50.7	0.0	109.1	29.0	45.0	20.7	0.0	0.0	0.0	0.0
2010	4203.7	2157.6	2334.0	1512.4	1745.1	843.7	304.6	354.0	176.2	83.5	59.6	52.6	30.9	0.0	0.0	0.0	0.0	0.0	0.0
2011	7195.9	8863.0	7301.3	4834.8	4433.6	2094.4	2814.1	1248.4	1556.9	356.0	166.3	654.7	119.4	13.6	0.0	0.0	0.0	0.0	0.0
2012	4821.1	4490.9	3537.6	2193.1	3052.7	891.2	1222.6	468.2	141.5	214.9	87.8	7.3	5.2	0.0	5.2	0.0	0.0	0.0	0.0
2013	1580.2	1572.5	1220.9	688.6	610.6	515.0	248.6	95.9	115.2	87.6	6.7	57.2	0.0	3.7	0.0	0.0	0.0	0.0	0.0
2014	2866.6	3637.1	3656.7	1859.8	1421.6	707.6	678.0	487.9	177.1	82.5	83.7	30.3	136.6	0.0	0.0	0.0	14.7	0.0	0.0
2015	2449.3	2173.7	1990.6	882.6	811.2	394.8	456.7	145.4	328.4	150.2	41.1	0.0	14.0	16.3	0.0	0.0	0.0	0.0	0.0
2017	4028.4	2931.4	2657.2	1730.4	1619.1	600.0	595.2	383.1	160.7	104.9	89.8	27.0	21.3	14.7	41.8	0.0	0.0	0.0	0.0
2019	2483.7	2027.5	2022.3	1126.4	1728.7	763.8	512.6	204.6	168.1	149.3	59.4	87.7	28.0	0.0	0.0	0.0	0.0	0.0	0.0
2020	718.9	454.9	358.1	293.0	340.5	179.2	77.8	140.9	12.3	61.4	18.4	9.6	2.9	0.0	0.0	2.9	0.0	0.0	0.0

Table 3 (Cont.)

year	Length, sm																	
	75.0-75.9	76.0-76.9	77.0-77.9	78.0-78.9	79.0-79.9	80.0-80.9	81.0-81.9	82.0-82.9	83.0-83.9	84.0-84.9	85.0-85.9	86.0-86.9	87.0-87.9	88.0-88.9	89.0-89.9	90.0-90.9	91.0-91.9	92.0-92.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3 (Cont.)

year	Length, sm															Total	Biomass, tons
	93.0-93.9	94.0-94.9	95.0-95.9	96.0-96.9	97.0-97.9	98.0-98.9	99.0-99.9	100.0-100.9	101.0-101.9	102.0-102.9	103.0-103.9	104.0-104.9	105.0-105.9	106.0-106.9	107.0-107.9		
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36662	35162
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20270	19827
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17042	16961
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24570	23044
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62621	61728
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34274	34954
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40746	39577
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38329	44523
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44451	47323
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58993	63808
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21979	19943
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21879	20693
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37384	38640
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28132	28092
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75003	70570
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48255	45754
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75943	89948
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90402	94360
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	130334	127148
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	171062	202383
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	127240	131025
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49061	49251
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102258	107116
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89986	88834
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81071	93796
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88266	86985
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16574	17317

Table 4 Abundance indices of different length groups GHL in 1982-2020, total area (females, in thousands)

year	Length, sm																	
	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-25.9	26.0-26.9	27.0-27.9	28.0-28.9	29.0-29.9	30.0-30.9	31.0-31.9	32.0-32.9	33.0-33.9	34.0-34.9	35.0-35.9	36.0-36.9	37.0-37.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	2.1	18.4	6.6	46.4	37.7	87.2	157.7	176.6	374.6
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4	11.3
1994	0.0	0.0	0.0	0.0	0.0	0.0	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	8.2	0.0	0.0	0.0	10.1
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.2	1.9	6.5	4.3	42.5	43.3	19.4
1998	0.0	0.0	0.0	0.0	3.4	1.7	0.0	1.6	5.8	1.6	4.1	15.4	1.8	1.8	6.9	44.4	51.7	65.4
1999	0.0	0.0	20.5	35.6	0.0	0.0	0.0	0.0	0.0	0.0	27.0	0.0	4.8	3.3	13.7	22.0	18.6	95.3
2000	0.2	23.1	12.3	23.1	55.0	34.4	34.4	40.2	24.8	1.8	3.6	4.6	19.3	91.4	72.6	56.9	112.6	109.1
2001	0.0	0.0	0.0	15.3	31.2	46.6	22.6	56.6	0.0	7.5	10.0	11.7	87.0	81.7	120.0	134.0	362.3	320.0
2002	0.0	0.0	0.0	35.6	0.0	0.0	0.0	6.9	6.5	23.2	24.1	27.8	48.8	131.3	110.1	293.1	138.2	290.7
2003	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1.3	6.3	39.2	30.5	49.7	114.4	150.7	191.7	130.1	264.2
2004	0.0	0.0	0.0	0.0	33.2	15.0	30.0	4.4	11.4	0.0	20.8	81.1	33.7	75.0	124.8	205.7	373.6	457.5
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	0.0	11.7	74.7	93.8	155.0	163.7	263.7	333.8	331.5
2006	0.0	0.0	0.0	0.0	33.8	2.5	2.7	0.0	0.0	0.0	0.0	60.5	52.0	72.8	249.6	242.7	582.4	1096.7
2007	0.0	0.0	0.0	13.1	0.0	54.6	0.0	0.0	13.1	13.1	92.0	135.1	133.0	124.7	210.9	458.6	430.5	896.9
2008	0.0	0.0	0.0	0.0	68.4	41.5	0.0	90.2	0.0	3.4	86.9	58.9	94.3	269.3	291.6	371.7	501.2	814.1
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	54.1	40.3	125.1	163.9	679.5	930.4	1117.6	2291.1
2010	0.0	0.0	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	4.4	112.2	239.2	399.4	1010.5	1526.0	2337.6
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.1	0.0	43.8	2.1	2.0	22.2	95.8	280.2	232.0	852.4	1026.1
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	63.0	56.5	173.4	296.7
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	12.9	0.0	0.0	0.0	20.5	32.7	20.5
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	21.9	85.6	146.4	277.3	285.6	629.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	7.1	0.0	28.3	65.8	58.2	135.1	235.6	521.0	917.1
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	8.2	53.5	44.5	39.7	174.9	150.4	303.0
2019	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	4.8	14.0	10.1	60.5	178.7	242.8	313.8	529.6	753.1
2020	0.0	0.0	55.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	8.4	12.9	14.0	109.1	82.8	117.2	113.2	249.0

Table 4 (Cont.)

year	Length, sm																	
	38.0-38.9	39.0-39.9	40.0-40.9	41.0-41.9	42.0-42.9	43.0-43.9	44.0-44.9	45.0-45.9	46.0-46.9	47.0-47.9	48.0-48.9	49.0-49.9	50.0-50.9	51.0-51.9	52.0-52.9	53.0-53.9	54.0-54.9	55.0-55.9
1992	796.0	868.7	1064.7	1166.5	1225.4	884.3	943.4	1306.0	781.0	913.8	701.8	721.0	851.1	459.1	345.1	239.0	331.5	383.7
1993	64.9	99.5	69.3	214.3	129.7	198.8	170.8	230.8	166.2	211.7	449.0	125.1	171.7	84.2	137.4	158.2	331.4	128.7
1994	39.1	70.4	79.9	174.2	221.7	320.8	278.4	316.1	236.2	306.0	323.1	144.1	337.7	116.0	366.6	199.2	253.6	195.2
1995	11.2	36.5	80.8	406.5	342.3	302.0	329.4	542.0	252.9	441.3	702.2	314.8	306.5	337.3	152.2	245.3	265.2	110.7
1996	15.0	64.2	162.9	154.2	283.6	239.8	332.2	605.2	617.2	941.8	871.6	746.7	1147.8	761.6	670.0	552.6	453.4	447.8
1997	30.7	88.6	193.6	94.4	87.6	192.8	155.4	188.5	250.2	300.9	328.8	299.3	352.0	368.9	249.4	257.2	232.9	204.6
1998	126.6	129.0	116.8	185.8	218.9	114.4	184.3	190.8	241.7	421.5	325.1	419.2	560.9	520.2	754.0	666.8	629.6	698.2
1999	42.5	87.1	65.3	113.8	93.7	154.2	182.6	244.2	181.8	277.8	381.1	192.6	300.9	327.1	283.3	418.0	419.2	424.9
2000	148.5	211.4	287.4	289.2	354.1	389.9	497.0	307.2	416.2	474.4	500.4	408.4	519.2	393.6	489.4	608.7	579.0	666.9
2001	598.9	328.1	311.9	299.6	594.7	676.1	519.9	389.3	412.1	556.2	541.4	252.8	502.6	459.9	461.2	351.5	293.9	523.4
2002	398.1	186.7	281.6	333.0	464.9	509.4	277.0	243.4	433.1	252.7	342.6	285.0	261.0	184.5	280.5	377.0	263.1	303.5
2003	383.5	178.4	182.6	159.3	224.1	262.0	232.6	194.2	149.6	218.7	223.2	114.6	222.9	168.1	245.6	311.9	272.9	169.9
2004	558.8	503.3	768.6	435.0	455.3	604.5	301.7	645.5	396.4	559.8	476.5	362.6	307.4	312.9	459.7	308.6	423.3	494.8
2005	152.3	254.7	355.7	245.2	247.5	504.2	289.6	250.9	269.0	337.0	231.9	173.5	410.4	331.1	257.4	142.7	326.9	361.4
2006	1053.3	792.8	1126.6	1157.7	945.1	1111.0	1061.1	1059.3	831.4	922.9	1003.7	831.4	914.7	549.1	746.0	822.3	626.3	588.3
2007	761.2	822.8	1285.6	556.7	631.8	638.7	587.7	782.3	593.5	801.1	542.4	551.0	754.7	587.6	437.4	305.5	421.0	773.7
2008	984.9	619.5	1145.0	490.0	868.6	813.9	1148.7	990.6	956.7	706.5	1068.3	816.6	982.5	638.6	751.4	800.0	437.6	699.0
2009	2338.7	1932.9	2012.2	1536.8	2370.4	2246.4	1488.2	1746.1	1215.4	1324.3	1335.1	718.8	1015.3	883.8	1223.4	893.7	948.0	1206.3
2010	2631.1	2413.0	2895.0	3189.2	3072.4	3028.6	2628.4	3567.0	2041.2	1561.5	1767.6	1390.0	1193.2	1016.3	972.6	683.3	1067.4	1315.4
2011	1424.1	1487.4	2946.0	1705.8	2152.1	2909.2	3102.2	1595.8	1501.1	1960.1	2307.5	1482.5	2075.1	839.6	1505.5	1099.8	1168.1	492.5
2012	374.5	537.6	648.9	765.0	971.3	954.5	1119.2	1151.1	1354.7	1447.6	1100.8	988.7	1449.9	1109.5	1239.3	982.3	689.0	864.5
2013	101.4	402.2	192.6	556.1	502.3	426.4	725.7	567.8	798.0	753.6	975.0	698.3	465.8	596.1	554.4	979.5	800.2	561.8
2014	597.6	702.9	752.4	896.4	1194.1	890.4	926.8	1617.6	848.6	1206.3	1594.2	1131.7	957.8	768.6	901.7	821.9	538.6	419.8
2015	1029.3	598.2	567.9	877.7	1173.0	1146.9	1107.5	682.0	669.4	1136.8	1498.1	907.2	721.8	912.5	1128.6	1035.0	1447.1	980.8
2017	246.4	414.3	285.5	322.7	798.2	364.4	424.1	514.4	640.6	595.1	504.6	393.7	648.2	815.1	758.5	635.6	451.9	595.5
2019	1029.1	899.5	1192.0	777.1	1009.5	952.5	825.5	896.4	515.2	979.1	728.7	795.7	916.2	617.6	816.4	698.7	631.1	772.8
2020	276.9	321.1	341.5	295.1	252.6	512.5	397.7	335.7	281.3	281.2	324.0	254.4	254.5	238.1	273.4	341.3	268.2	303.0

Table 4 (Cont.)

year	Length, sm																	
	56.0-56.9	57.0-57.9	58.0-58.9	59.0-59.9	60.0-60.9	61.0-61.9	62.0-62.9	63.0-63.9	64.0-64.9	65.0-65.9	66.0-66.9	67.0-67.9	68.0-68.9	69.0-69.9	70.0-70.9	71.0-71.9	72.0-72.9	73.0-73.9
1992	425.6	420.5	172.9	510.6	407.7	387.4	477.8	272.3	300.0	604.0	117.7	232.8	360.0	239.1	363.5	53.2	97.6	124.9
1993	211.2	139.3	126.5	136.3	170.4	155.4	281.2	142.2	355.0	253.0	167.7	95.4	271.0	272.5	177.9	141.1	128.2	35.0
1994	169.5	137.3	184.7	110.9	207.1	108.4	173.5	216.7	164.3	133.3	107.3	187.8	152.4	103.3	50.7	36.7	140.9	49.3
1995	182.3	107.1	127.4	88.9	179.1	188.9	236.1	216.5	99.6	179.1	88.7	157.3	125.5	90.1	176.2	62.7	114.6	37.6
1996	293.7	339.5	401.2	376.1	440.3	389.7	275.0	364.1	189.9	335.4	131.2	240.4	287.2	180.3	150.8	185.5	114.9	145.0
1997	189.9	154.6	159.7	193.4	163.0	157.0	209.6	293.0	146.4	218.5	120.3	266.0	204.6	194.2	155.5	133.8	107.5	73.8
1998	476.6	681.6	506.9	275.8	563.8	396.0	332.1	391.7	401.0	241.7	195.0	160.8	132.6	157.2	216.2	53.7	42.5	117.4
1999	463.9	607.8	541.7	359.9	435.0	498.7	626.7	446.8	571.4	447.8	208.7	407.3	457.0	239.8	111.7	127.0	97.0	108.2
2000	806.3	609.7	612.2	640.9	708.4	751.1	640.8	514.5	612.0	611.1	484.6	470.3	394.8	367.7	399.4	173.0	294.2	75.4
2001	525.0	576.6	674.6	468.8	862.6	636.3	697.3	925.7	630.9	587.0	621.6	582.1	416.0	542.5	415.3	288.4	325.6	230.3
2002	328.1	318.2	283.6	310.3	337.3	232.2	256.5	304.1	179.4	217.8	161.2	125.6	190.6	110.5	87.0	38.8	37.4	62.2
2003	234.4	347.7	377.4	364.7	739.1	393.6	388.4	595.5	636.8	800.1	547.6	701.2	592.0	545.6	149.3	174.5	125.5	203.7
2004	418.1	487.4	707.6	673.3	968.8	890.4	998.8	789.5	1054.7	1083.9	854.4	1000.5	812.2	659.6	499.2	436.2	430.8	349.4
2005	417.9	386.3	307.7	314.3	497.3	602.8	746.0	655.8	742.8	680.0	413.7	639.6	667.4	309.1	314.5	287.0	298.5	44.8
2006	578.4	428.8	637.2	744.5	709.5	801.4	826.0	636.7	1003.4	907.9	863.1	861.9	668.8	373.4	693.4	511.4	281.4	324.1
2007	354.2	546.9	408.2	736.4	1055.0	760.6	667.8	686.2	349.9	738.7	533.0	472.8	482.0	310.0	378.5	329.4	162.9	93.7
2008	880.8	765.8	703.7	820.9	1161.2	597.8	819.4	1313.0	1255.7	1913.5	1253.8	1894.5	1111.8	1463.8	1252.1	819.6	888.3	716.4
2009	1358.7	861.1	1774.0	785.4	1269.2	728.8	851.1	971.6	955.7	1070.6	635.9	630.2	905.9	612.9	1005.3	557.7	546.7	250.2
2010	1224.2	467.8	929.3	738.4	1502.9	842.1	1203.2	1016.1	982.3	1374.5	1366.3	772.2	2103.4	1174.9	1201.1	804.1	848.9	887.9
2011	949.5	1375.8	1130.9	907.9	1221.9	678.7	1460.3	1837.7	1736.0	1830.0	885.7	1789.5	1944.8	1157.1	1749.2	992.3	1921.3	1592.4
2012	1058.4	763.3	1240.6	687.8	1366.6	1318.5	1439.1	804.1	1140.7	1398.7	991.3	788.1	1063.5	766.6	1309.6	830.5	600.9	642.4
2013	515.0	487.3	909.6	502.9	1154.0	726.8	724.9	658.3	567.8	689.5	391.0	433.4	362.5	470.2	210.7	236.6	374.0	203.6
2014	394.6	620.7	696.7	624.4	748.9	433.4	592.6	777.5	1086.1	894.6	421.8	835.4	667.6	634.3	489.1	312.1	434.4	290.3
2015	994.7	745.8	1088.9	606.4	832.0	1098.4	1050.9	1130.1	1321.9	826.9	496.8	507.6	738.0	354.6	533.1	252.7	199.5	203.6
2017	1069.2	839.8	919.0	590.6	943.8	900.2	1090.7	1078.0	761.8	1379.0	810.8	839.5	590.2	404.6	633.1	317.6	394.8	264.1
2019	957.4	944.7	744.1	724.3	1183.6	876.2	904.0	532.8	853.9	859.8	602.6	711.8	495.3	482.4	612.4	579.6	459.6	189.0
2020	291.8	175.3	559.4	192.4	301.9	269.4	507.8	561.6	495.6	474.3	407.5	329.6	190.9	244.6	234.3	160.2	136.4	83.8

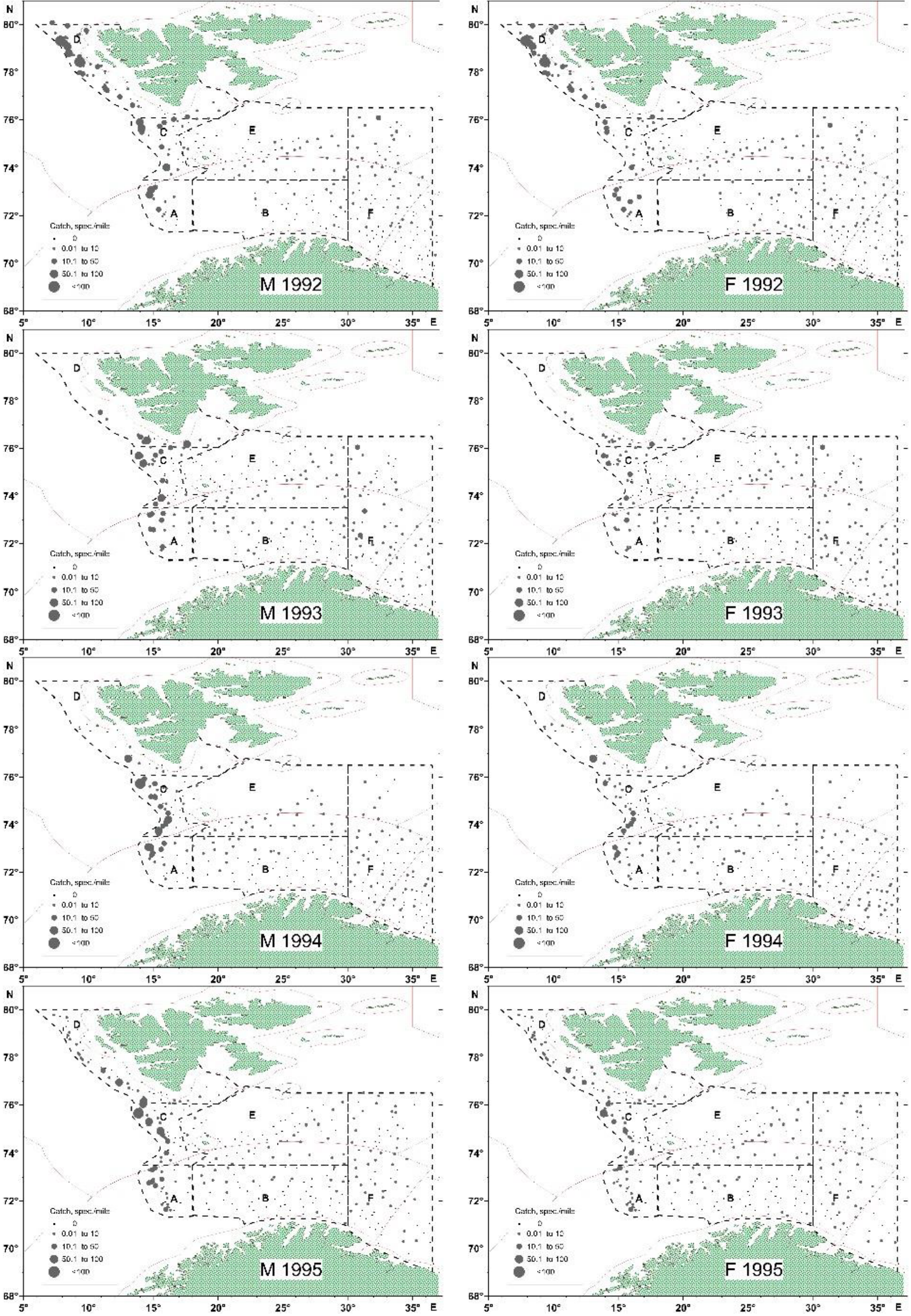
Table 4 (cont.)

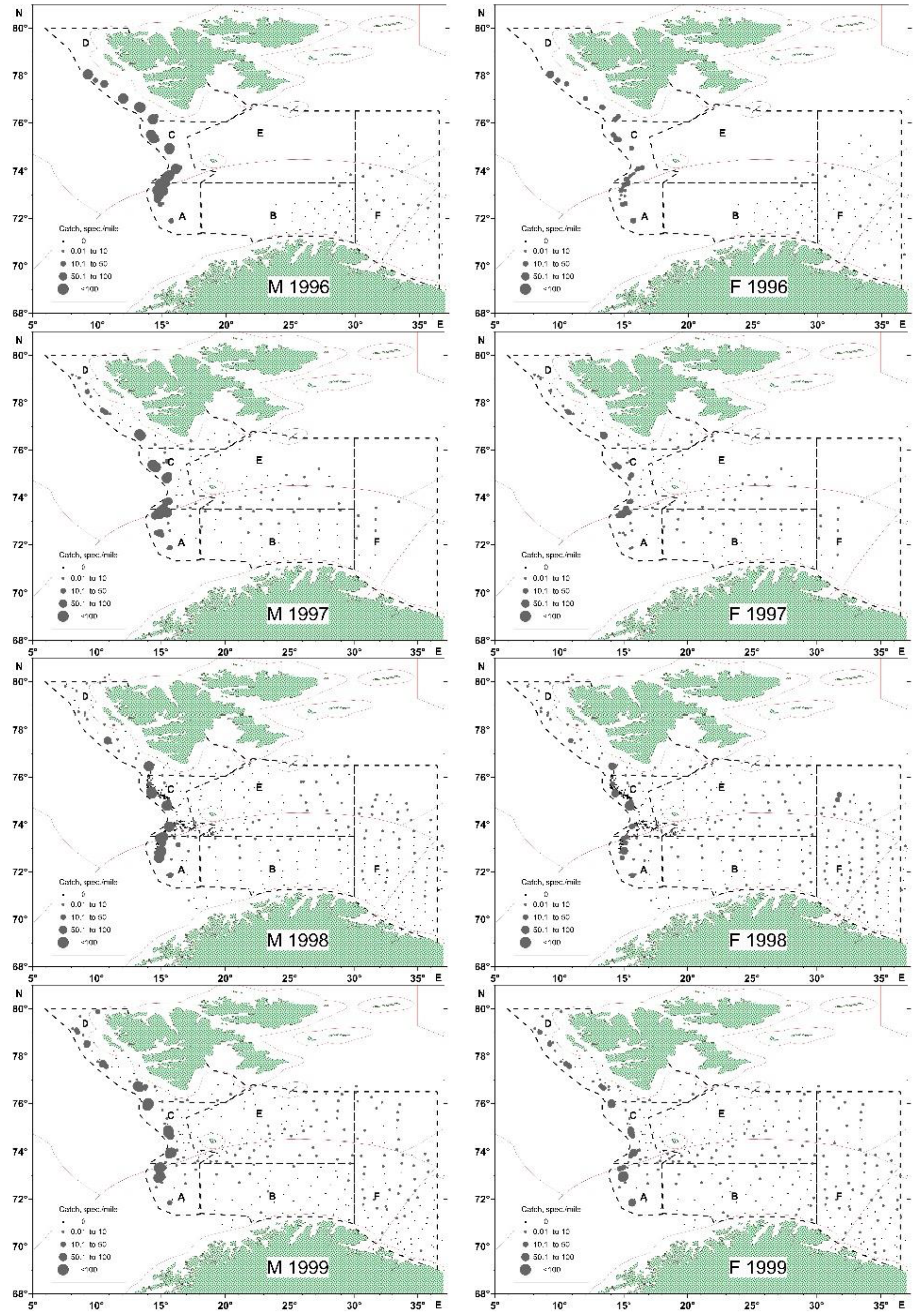
year	Length, sm																	
	74.0-74.9	75.0-75.9	76.0-76.9	77.0-77.9	78.0-78.9	79.0-79.9	80.0-80.9	81.0-81.9	82.0-82.9	83.0-83.9	84.0-84.9	85.0-85.9	86.0-86.9	87.0-87.9	88.0-88.9	89.0-89.9	90.0-90.9	91.0-91.9
1992	35.8	69.0	101.1	27.9	4.1	10.0	29.9	8.3	34.3	5.9	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0
1993	51.7	218.4	46.6	34.3	14.3	19.4	30.1	0.0	29.1	30.1	30.1	33.2	0.0	0.0	0.0	0.0	0.0	0.0
1994	44.9	42.6	5.1	6.7	17.1	9.5	1.7	0.0	20.9	1.2	2.1	0.0	1.0	1.2	0.0	0.0	0.0	0.0
1995	66.8	89.1	59.2	17.0	14.0	11.1	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	11.4	0.0
1996	64.9	60.8	52.1	28.4	19.2	0.8	50.5	14.5	12.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
1997	38.9	59.0	30.5	50.2	9.4	0.8	15.8	26.0	1.6	2.1	0.5	0.0	0.5	0.5	0.0	0.0	4.4	0.0
1998	48.0	23.5	15.3	23.6	18.7	23.3	23.7	2.3	7.3	2.3	4.8	0.0	0.0	19.3	2.3	0.0	1.6	0.7
1999	60.7	53.2	2.9	40.7	55.3	88.2	6.4	2.9	61.9	5.3	4.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0
2000	115.3	133.4	77.8	34.5	47.1	37.6	23.6	45.3	6.6	31.7	0.0	7.8	1.5	0.0	0.0	0.0	0.8	0.0
2001	180.2	176.6	83.8	183.0	96.0	85.3	69.8	39.0	54.7	61.9	65.1	2.7	28.6	1.1	26.3	0.0	0.0	0.0
2002	17.6	14.2	11.9	20.6	17.8	10.0	4.1	1.4	12.5	3.1	0.3	0.0	1.4	0.7	3.7	0.0	2.0	0.0
2003	131.9	84.8	80.7	55.9	61.6	82.6	20.3	3.3	15.7	54.9	64.9	17.9	0.0	0.0	10.1	2.3	17.8	0.0
2004	248.7	349.3	84.8	99.4	158.7	125.3	205.5	39.9	66.8	29.2	74.9	83.6	19.0	21.8	52.9	65.4	11.9	0.0
2005	114.8	103.5	61.0	112.5	25.3	15.2	79.0	125.7	94.6	8.3	8.3	121.9	5.9	6.2	3.3	8.8	18.8	54.3
2006	169.1	220.1	89.9	139.9	189.7	90.3	55.3	47.5	16.5	48.8	94.2	69.4	82.4	29.4	32.0	19.1	4.2	13.4
2007	71.4	141.8	43.2	88.3	73.6	33.0	34.9	33.0	36.9	9.4	9.4	9.4	3.8	1.8	9.4	0.0	0.0	7.2
2008	557.6	794.5	456.6	327.1	344.4	257.1	271.8	72.9	58.5	95.4	92.9	20.1	90.7	38.3	51.0	0.0	83.0	137.1
2009	399.2	403.8	137.5	48.7	284.5	28.1	207.3	21.8	87.3	116.8	99.8	27.7	15.9	22.6	15.6	34.2	17.7	44.9
2010	538.0	459.9	307.3	257.9	412.9	78.8	277.0	104.6	192.2	96.5	117.4	274.1	11.7	64.5	64.0	72.0	73.4	50.5
2011	917.9	854.0	773.2	589.4	848.0	123.3	697.3	23.8	98.9	139.0	122.1	65.6	77.0	83.9	5.5	35.8	34.6	0.0
2012	366.6	652.8	461.1	338.1	333.2	138.9	326.8	76.2	145.7	100.6	5.2	104.2	69.4	63.3	66.4	20.1	85.7	0.0
2013	131.4	104.0	98.1	88.6	63.0	95.6	56.3	8.8	8.7	11.3	5.9	11.6	4.4	0.0	7.3	8.9	59.1	63.3
2014	346.7	258.6	155.5	111.3	78.4	90.1	135.5	77.9	78.0	36.2	23.6	0.0	27.3	7.5	0.0	49.4	4.9	0.0
2015	99.8	63.9	125.4	164.3	91.4	76.8	48.2	46.6	19.9	10.0	23.8	15.9	7.9	6.4	0.0	5.8	7.5	14.8
2017	138.6	386.5	65.9	63.5	73.8	97.0	43.2	39.3	70.2	64.0	19.0	34.0	0.0	1.9	26.3	1.9	33.5	10.3
2019	196.8	228.7	110.7	293.5	132.3	77.4	92.7	40.2	54.4	21.9	4.0	37.5	10.4	17.5	21.3	62.3	14.1	14.8
2020	265.6	115.0	14.3	71.7	65.0	46.2	18.5	0.0	48.7	1.8	12.9	2.9	1.6	0.0	8.8	0.0	5.5	0.0

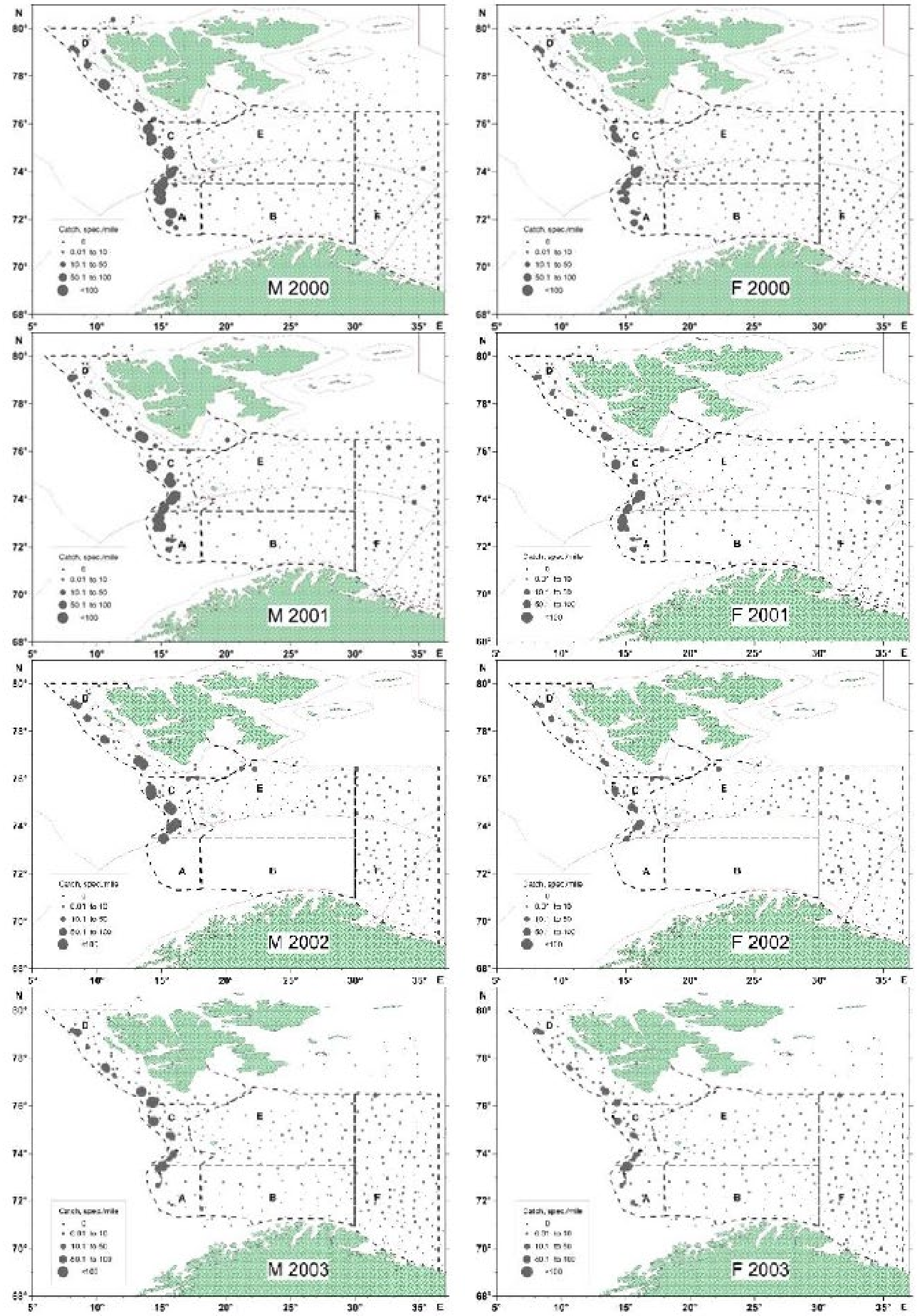
Table 4 (cont)

year	Length, sm																Total	Biomass, tons
	92.0-92.9	93.0-93.9	94.0-94.9	95.0-95.9	96.0-96.9	97.0-97.9	98.0-98.9	99.0-99.9	100.0-100.9	101.0-101.9	102.0-102.9	103.0-103.9	104.0-104.9	105.0-105.9	106.0-106.9	107.0-107.9		
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20801	28478
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6961	14302
1994	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6695	10836
1995	0.0	0.0	1.8	16.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7946	12471
1996	0.0	0.0	0.0	0.1	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14223	23674
1997	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7378	13444
1998	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12271	19897
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11573	23738
2000	1.6	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17997	33742
2001	6.7	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20561	39906
2002	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10516	15095
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13524	27832
2004	10.1	0.0	28.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24733	51870
2005	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15880	32475
2006	46.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31848	53296
2007	22.1	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24115	37683
2008	0.0	0.0	51.5	58.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41101	89236
2009	12.2	12.4	33.8	12.2	0.0	3.4	4.0	1.7	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49728	77849
2010	0.0	49.9	65.5	0.0	2.2	0.0	0.0	0.0	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65139	108767
2011	1.3	20.8	31.3	0.0	39.0	13.1	2.8	0.0	0.0	33.7	35.4	0.0	0.0	0.0	0.0	0.0	65260	128071
2012	51.4	8.7	2.2	8.7	14.1	0.0	0.0	8.7	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	40007	81434
2013	8.7	4.0	0.0	1.5	0.0	0.0	0.0	0.0	1.3	0.0	0.0	4.7	0.0	0.0	0.0	0.0	21212	37813
2014	38.2	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	30705	50505
2015	5.9	0.0	7.6	3.7	3.7	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33430	52223
2017	3.9	1.9	14.0	28.1	1.9	5.8	15.2	4.2	7.7	0.0	1.9	1.9	0.0	0.0	0.0	0.0	25269	50441
2019	57.8	16.7	13.8	20.4	6.3	4.0	0.0	5.9	26.4	0.0	0.0	4.0	6.3	0.0	0.0	6.3	31476	54972
2020	7.8	2.0	0.0	4.7	0.0	10.2	0.0	0.0	0.0	2.4	2.8	0.0	0.0	0.0	0.0	24.9	12667	23213

Appendix 2. Distribution of halibut catches in the Russian autumn-winter MS TAS in 1992-2020




M 1996
F 1996
M 1997
F 1997
M 1998
F 1998
M 1999
F 1999
N
80°
78°
76°
74°
72°
70°
68°
5°
10°
15°
20°
25°
30°
35°
E
A
B
C
D
E
F
Catch, spec./mile
0
0.01 to 10
10.1 to 50
50.1 to 100
>100


M 2000
F 2000
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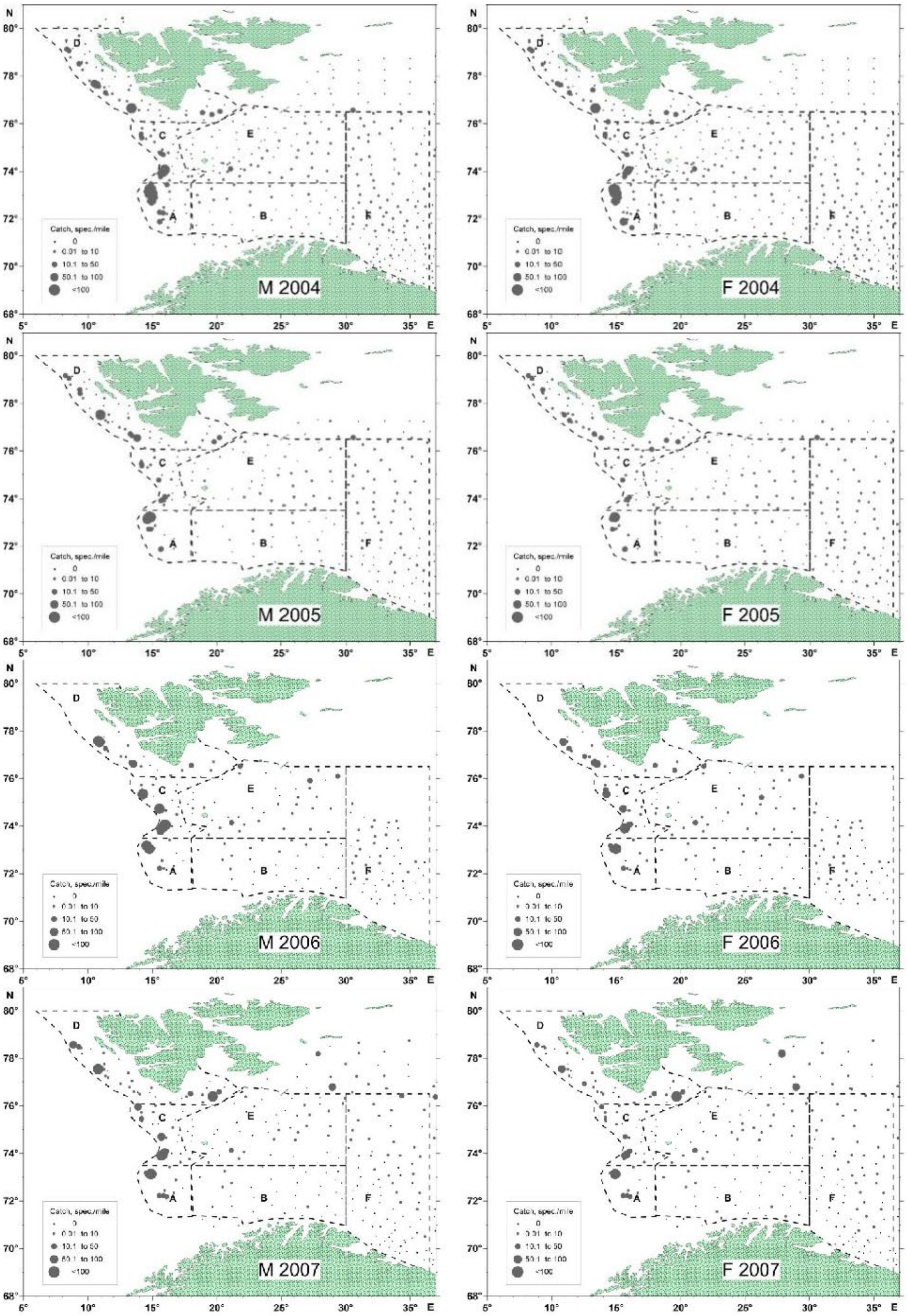
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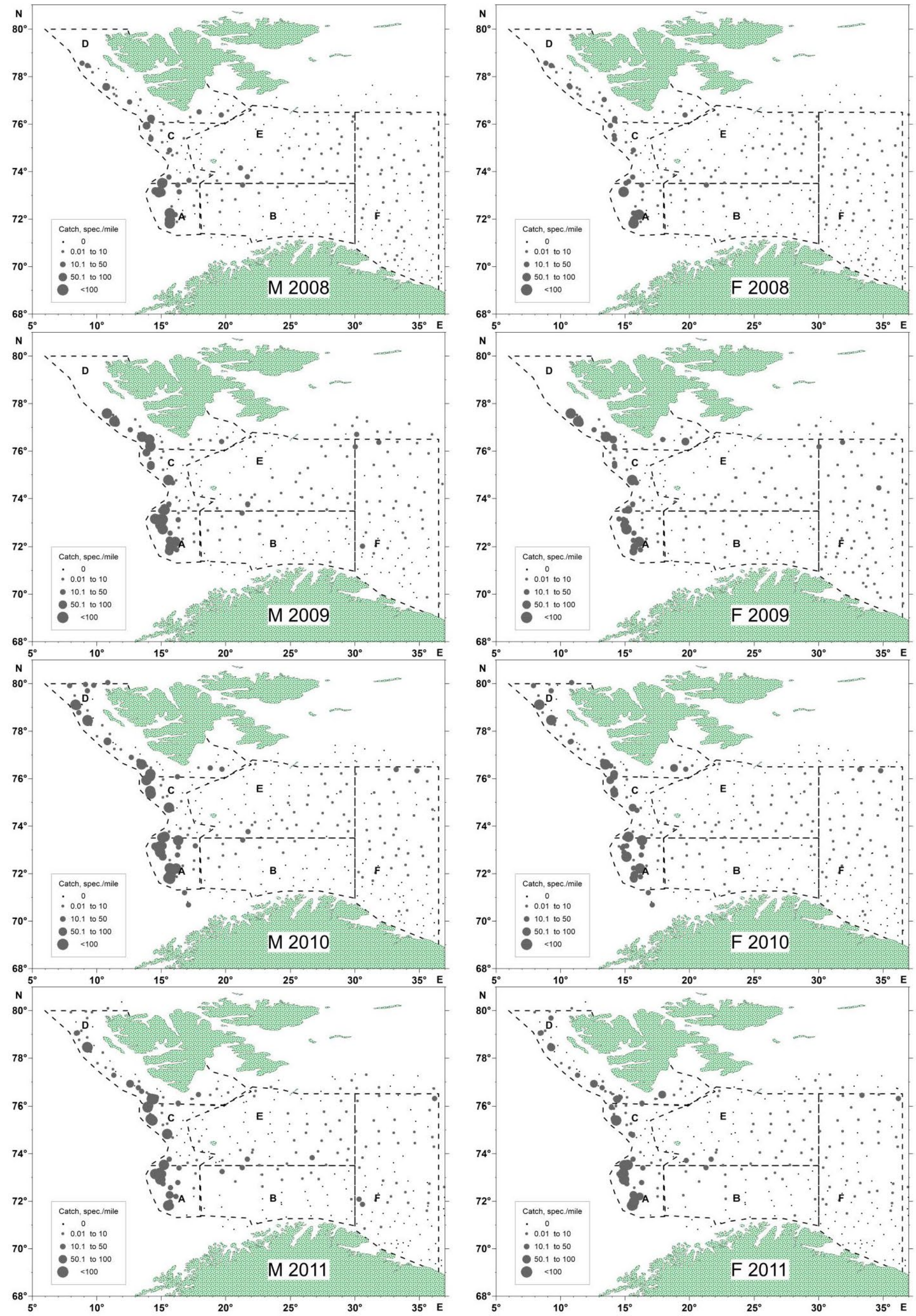
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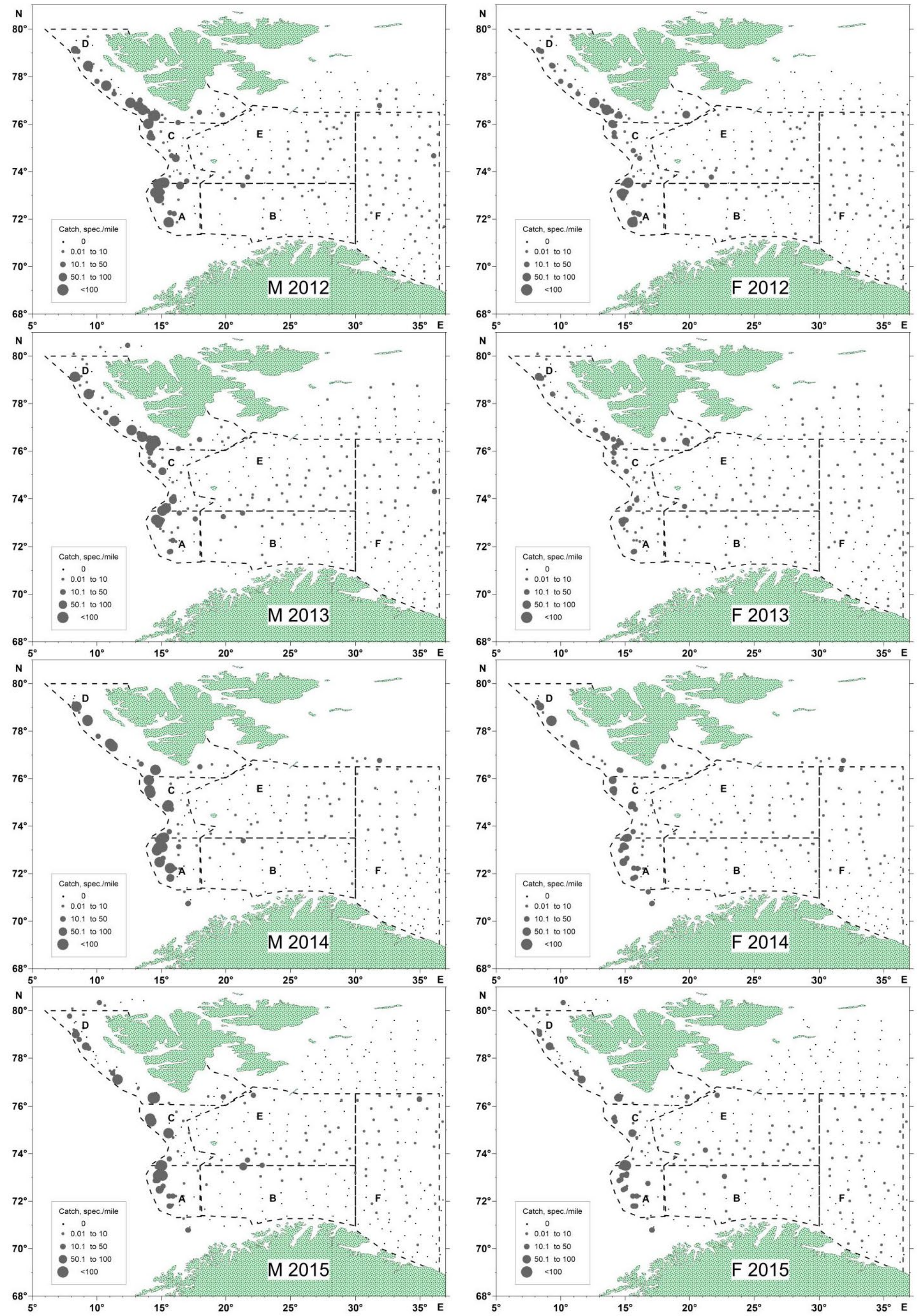
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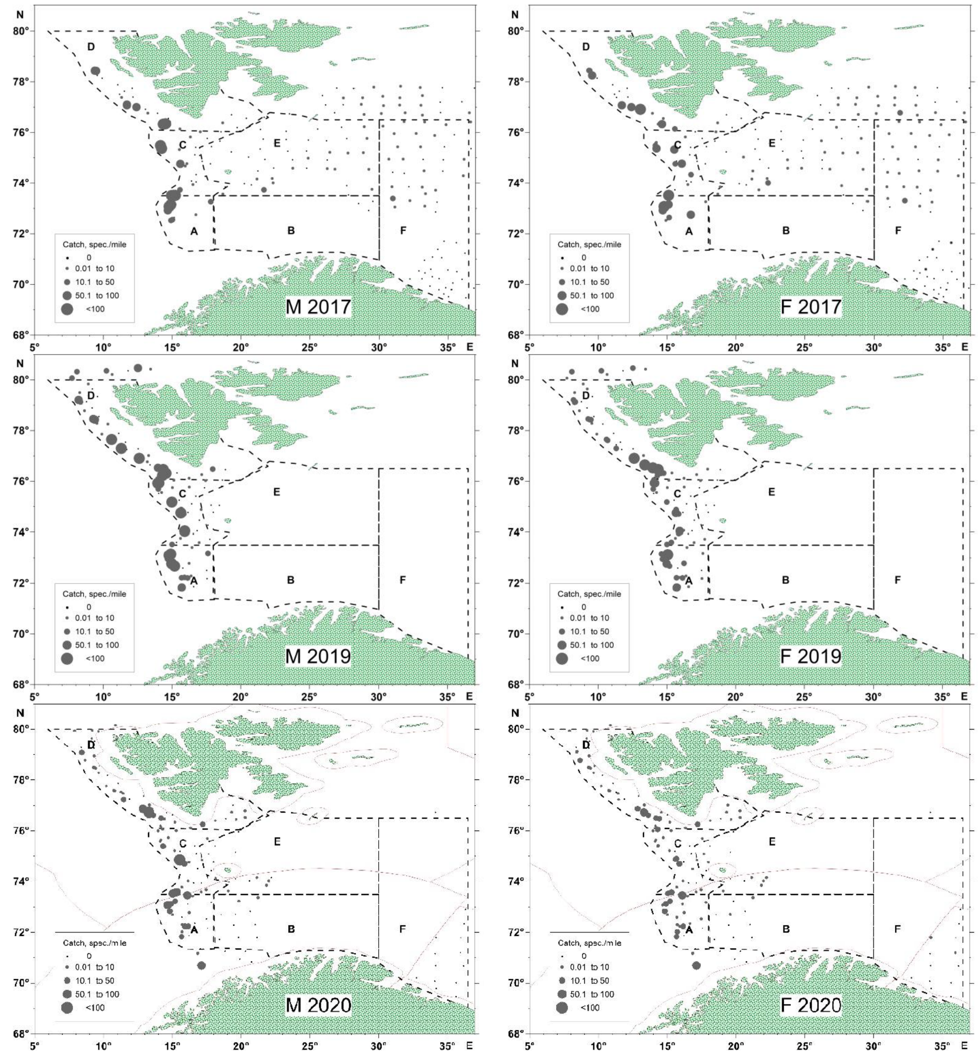
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WD #13 Arctic Fisheries Working Group ICES 2021

Recruitment prediction for Barents Sea capelin

by

Oleg Titov
Shirshov Institute of Oceanology, Russian Academy of Sciences

Abstract

The article is devoted to the study of environmental conditions affecting capelin recruitment in the Barents Sea. Long-term data on the sea water temperature and oxygen saturation as well as data on the ice coverage of the Barents Sea in the area of capelin distribution at various stages of its life were studied. The statistical relationship of the number of capelin recruits at the age of 1 year with changes in the Barents Sea environment at various time lags up to 60 months (5 years) before the date of recruitment estimation was studied. It is shown that cooling and an increase in the oxygen saturation of seawater in the Kola section 2-4-years in advance is a sign of an increase in capelin recruitment. The closest statistical relationship is observed during the periods of spring blooming and associated feeding migrations of capelin juveniles. The high extent of sea ice has a positive effect on recruitment in a wider range of time lags, with the exception of the wintering period of immature capelin. The analysis of the variability for four types of multiple linear regression equations showed that the temperature, oxygen saturation of seawater and the extent of sea ice describe 22-56% of the capelin recruitment variability. The 0 – group capelin index, traditionally used as a 1-group abundance predictor, is 21-41% of the recruitment variability. Testing the quality of capelin recruitment forecasts for the period from 2000 to 2020 showed that the use of environmental data can improve the quality of capelin recruitment forecasts by 36-46% compared to the forecasts currently available. The results of the study can

be used in forecasting the number of capelin recruits with a long lead time and in the scientific support of capelin stock management in the preparation of recommendations on capelin stock management in the Arctic Fisheries Working Group of the International Council for the Exploration of the Sea.

Introduction

Fisheries oceanography can be defined as the study of the interaction between commercial fish and their environment. Fisheries oceanography seeks to study fish behavior, population dynamics, and the history of life in the environment, thereby providing a framework for predicting recruitment and determining fishery strategies (Bograd et al., 2014).

Fish population variability and fishing activities are closely related to the dynamics of climate and other environmental phenomena. Fisheries science has grown over the past century, bringing together knowledge from oceanography, fish biology, marine ecology, and fish population dynamics, mostly focused on Northern Hemisphere fisheries. During this period, understanding and explaining the interannual variability of fish recruitment became the main focus of fishing oceanographers (Lehodey et al., 2006).

The capelin (Mallotus villosus) is a small pelagic plankton-eating fish with a circumpolar distribution (Jangaard 1974). Capelin is one of the most important forage and commercial species of the northern oceans. This arcto-boreal species is widely distributed in the Arctic Ocean, northern areas of the Pacific and Atlantic oceans, as well as in the waters connecting these areas (Carscadden et al., 2013).

Capelin is numerous and occupies an important place in the food chain, turning primary and secondary products in the form of zooplankton into fish flesh, which is consumed by a large number of higher predators. Despite the fact that capelin individuals are relatively small in size, they move over long distances from coastal spawning grounds to juvenile rearing areas, and then to highly productive offshore feeding areas that are several hundred kilometers from the spawning grounds and then back. While early movements may be the result of ocean current transport (Frank and Carscadden, 1989), later movements are active migrations to feeding or spawning areas and, as such, are likely to be influenced by environmental and biotic factors.

The Barents Sea (BS) capelin migrates in the Barents Sea at all stages of its life cycle. In winter and early spring, mature individuals migrate from wintering area in the central part of the Barents Sea towards spawning grounds off the coast of northern Norway and Russia. This spawning migration has been known since ancient times, as it attracts a large number of cod to the coast, which is a valuable object of coastal fishing. Spawning mainly occurs in March - April at the bottom near the coast at depths of 20 to 100 m. Capelin participating in spawning migration does not return to feeding areas and dies in spawning areas. After hatching in coastal spawning grounds, larvae carried by ocean currents drift into the open sea and eventually occupy the central and eastern Barents Sea, where young capelin remain in the first months of their life. In coastal areas, spring blooming usually begins earlier than further from the coast, and the BS capelin early stages are used by coastal areas for fattening in spring and early summer. When the ice begins to melt and the ice edge recedes northward, capelin migrates north as well. The retreating ice edge is followed by a phytoplankton bloom zone, and then zooplankton. The capelin feeds on this zooplankton, which consumes primary production in the spring blooming areas, moving with it until the northernmost feeding areas are reached in September-October. In the fall, adult capelin are found in both the Atlantic and the Arctic water masses at ambient temperatures of 1^0 C to 2^0 C (Skjoldal and Rey, 1989; Gjøsæter and Loeng, 1987). In the period after spawning, the entire life cycle of capelin takes place in the pelagic zone of the Barents Sea.

Although the BS capelin stock is potentially the largest stock of capelin in the world, its historical abundance varies widely, alternating with periods when its biomass ranged from over 5 million to several hundred thousand tons (Gjøsæter, 1998). The BS capelin stock is one of the most important fisheries managed jointly by Russia and Norway.

The BS capelin stock has been exploited since the 1950s (Olsen, 1968) and is of great economic importance, both directly and indirectly, as food for cod (Mehl, 1989). Capelin usually matures between 3 and 5 years of age (Gjøsæter, 1985). Since capelin is short lived in the Barents Sea, stock size is highly dependent on recruitment and a survey of the abundance and distribution of capelin larvae was carried out every summer till 2006 (Fossum, 1992; Huse et al., 1996). Much of the survey activity also has focused on estimating the abundance of maturing year classes, which are the target of fishing activities. These studies were usually conducted when these capelin juveniles migrated to productive northern waters for feeding and where they converted this energy into somatic growth and development of reproductive ability (Carscadden et al., 2013).

Currently, the success of capelin recruitment is approximately estimated according to the capelin 0-group assessment performed in the year of spawning. The only environmental factor that affects the recruitment of the capelin stock is the predating of capelin larvae, mainly by herring juveniles. High abundance of young herring (mainly age groups 1 and 2) has been suggested to be a necessary but not a single factor causing recruitment failure in the capelin stock (Hjermann et al., 2010; Gjøsæter et al. 2016).

The indirect influence of climate on capelin recruitment is assumed to be a consequence of changes in trophic relationships in the Barents Sea. An increase in the basal metabolic rate of cod associated with higher water temperatures leads to an increase in capelin consumption (Bogstad and Gjøsæter, 1994). Capelin can move north and east, partially avoiding cod predation. However, feeding this far north causes slower growth and later maturity, which leads to a decrease in the biomass of the spawning capelin stock. This gives a weak year class, which will have a low chance of survival anyway due to strong herring predation (Loeng and Drinkwater, 2007).

Despite a long history of research, other than herring predation environmental data are not used in numerical estimates of capelin recruitment, tested in accordance with international standards and accepted for use in the development of scientific advice in decision-making for the management of commercial fisheries in the Barents Sea.

The historical series of observations of water temperature and oxygen content in seawater along the Kola Section, located in the central part of the Barents Sea, is one of the longest and most data-rich oceanographic series in the world. Measurements of temperature and oxygen content at the Kola section have been carried out for almost a century. Since the 50s of the last century, the temperature of sea water and the content of dissolved oxygen in it at the Kola section have been performed regularly. The Barents Sea ice coverage is assessed with high regularity based on satellite imagery.

Attempts to use data on ice extent, water temperature, and oxygen saturation to predict BS capelin recruitment were undertaken in the 2000s (Titov, 2004). These attempts were aimed at studying the environmental conditions during the spawning period and the development of capelin in the early stages. After a series of unsuccessful experiments, these attempts were deemed unsuccessful.

In the article, a new analysis of the environmental impact on BS capelin recruitment is done. It is based on longer series and analysis of the ecological mechanisms underlying the relationship between environmental factors and changes in the BS capelin recruitment.

Materials and methods

The number of BS capelin recruits at the age of 1 year (Cap1), indices of the BS capelin 0-group (Cap0) are taken from materials of Arctic Fisheries Working Group of International Council for the Exploration of the Sea (AFWG ICES) (Anon, 2021).

We used two types of oceanographic observations obtained in the Barents Sea. The first type of data – the areal average long-term distribution of temperature and oxygen saturation of seawater at standard depths of 20, 50 and 100 meters, characterizing the living conditions of BS capelin in the pelagial, is taken from the Hydrochemical Atlas of the Barents Sea (Titov and Nesvetova, 2003). The descriptive part of the atlas is prepared in Russian, so we considered it appropriate to give a brief overview of the methodology of its preparation in this work.

The Atlas summarizes the observations obtained in 485 cruises at 52 thousand deep-water stations in the period 1929-2001, which are in the PINRO database at the time of preparation of the Atlas. When preparing the Atlas, standard procedures were used to assess the quality of the initial information: the exclusion of duplicate observations, the control of data sampling ranges and the exclusion of sharply deviating values.

The largest volume of oceanographic research was carried out in the 70s and 80s last century, when up to 10,000 or more observations were made annually in the Barents Sea. Oceanographic studies were carried out on hydroacoustic tacks, near-trawl stations, and oceanographic polygons, but the density of observations increases in the areas of standard oceanographic sections, and especially in the Kola section. The central stations of the Kola section ($70^{0}30'$- $72^{0}30'$ N; $33^{0}30'$ E; 215 - 280 m depths), the data of which are used in the article for calculations, together with the scheme of the main currents of the Barents Sea, are shown in Fig. 1.

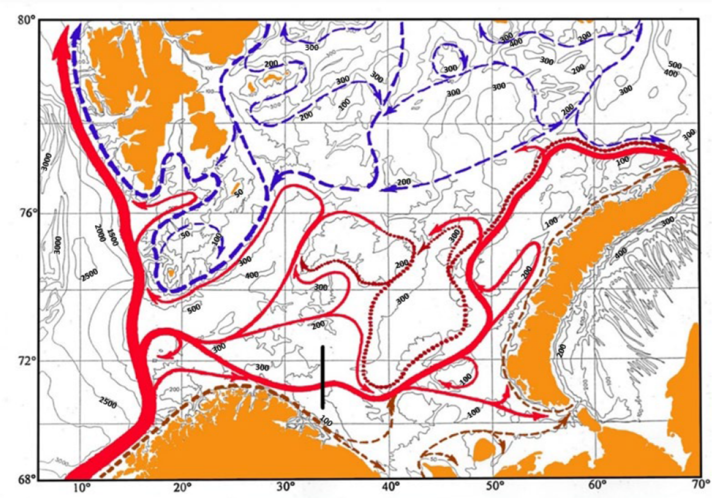


Figure 1. The Barents Sea currents (Ozhigin *et al*., 2000). Atlantic Water (AW) is shown in red, Arctic Water in blue. Red dotted lines indicate deep Barents Sea (transformed Atlantic) Water (BSW), broken brown lines – coastal waters. Black line shows the positions of stations 3-7 in the Kola section.

The average values of oceanographic parameters and other statistical characteristics were calculated in the nodes of an equidistant rectangular regular grid. The calculations were performed using the software product "OceanDataView", v.5.5beta (R. Schlitzer, http: /www.awi-bremerhaven.de/ GPH / ODV, 2001). Average values and standard deviations of oceanographic parameters were calculated and exported, which were determined in a given month at a certain standard depth layer in a “square” sea area, bounded by intervals of ± 15 miles from a grid point with a step of 30 miles in latitude and longitude. The standard depth layers were surface, 20, 50, 100, 250 m and bottom.

When interpolating data to nodes of a regular grid area, an error was estimated in restoring data at grid nodes, and the fields of oceanographic parameters are not restored in areas where these fields cannot be reproduced correctly. The standard

GIS technology of inverse distance weighting was used.The impact radius was estimated at 108 km.

Figure 2 shows the distribution densities of observations for 4 months in the middle of the quarter, which were later used to describe environmental conditions at different stages of the BS capelin life cycle. In total, about 25K observations were made in February, 45K in May, 40K in August, and 25K in October. In the warm period of the year, the number of observations slightly increased due to the expansion of the research area to areas of the sea that are freed from ice cover. The scheme of standard sections practically did not change, so the tendency to increase the density of observations in the areas of their implementation remains throughout the studied period in all seasons of the year.

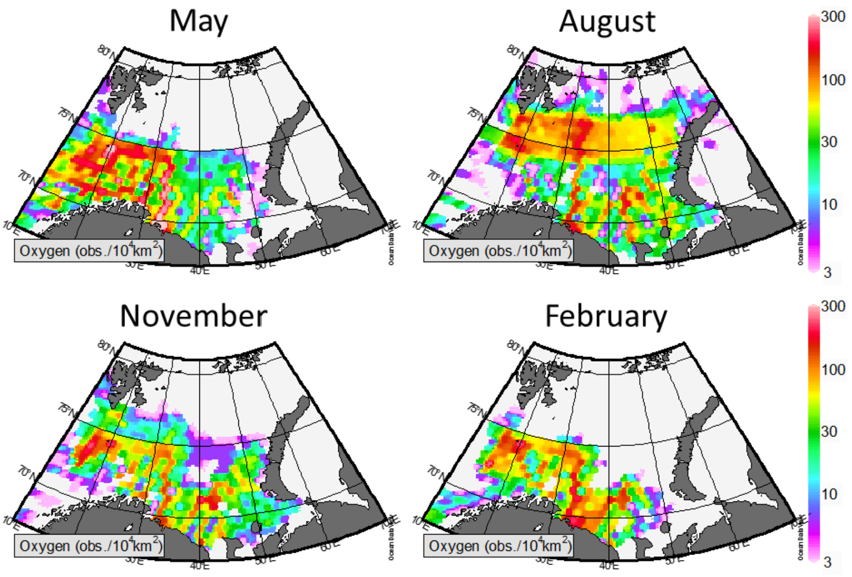


Figure 2. Distribution densities of oxygen content observations by months in the middle of the quarter.

The second type of data is a long-term (over the past 60-70 years) series of observations of water temperature in the 0-200 m layer and oxygen saturation of bottom waters at 3-7 stations of the Kola section (see Fig. 1), partially available on the official website of the Polar Branch of the All-Russian Institute of Fisheries and Oceanography (www.pinro.vniro.ru).

Interannual variations in oceanographic parameters are routinely investigated using average monthly data series centered on the long-term average annual monthly mean, i.e. anomalies. The method of collecting initial data on the Kola section and restoring the continuous series of smoothed mean monthly anomalies of temperature (T_w) and oxygen saturation (O_2%) is described in detail by Titov, 2020.

A mean monthly anomalies of ice coverage (Ice) of the Barents Sea (percentage ratio between the area covered by ice and total area) since 1951 obtained by data of the Murmansk Department of Hydrometeorology and Environmental Monitoring.

Statistical analysis of the data was carried out using standard software implemented on the Statgraphics Plus platform. The Multiple Regression Analysis allows you to calculate a regression model between one dependent variable and one or more independent variables. Multiple regression uses least squares to estimate the regression model.

Results

The results are based on the most complete array of primary information available at the time of writing. The strategy is, first, to try to investigate the environmental conditions (temperature and oxygen saturation of the water column) in typical areas and at the depths of the distribution of the BS capelin at various stages of its development, prior to the formation of recruitment at the age of 1 year. Secondly, to find statistical relationships between changes in these environmental conditions (according to observations at the Kola section) and recruitment of the BS capelin.

Figures 3-6 show maps of BS capelin distribution at various stages of development for 4 quarters of the year, taken from Olsen et al., 2010. The same figures show maps of the distribution of temperature and oxygen saturation of seawater in the months for the middle of the quarter. The author notes some roughness and conventionality of the presentation of the material, as well as the fact that digital information is obtained by visual evaluation. However, the purpose of the analysis is to identify the main trends and obvious links that do not require precise detail. In addition, readers can easily double-check the estimates made by the author directly on the materials of the article. We also note some distortions associated with various map projections, as well as the position of the ice edge, used in literature describing the distribution of capelin and environmental conditions. We consider these distortions to be insignificant in achieving the goals set in the work.

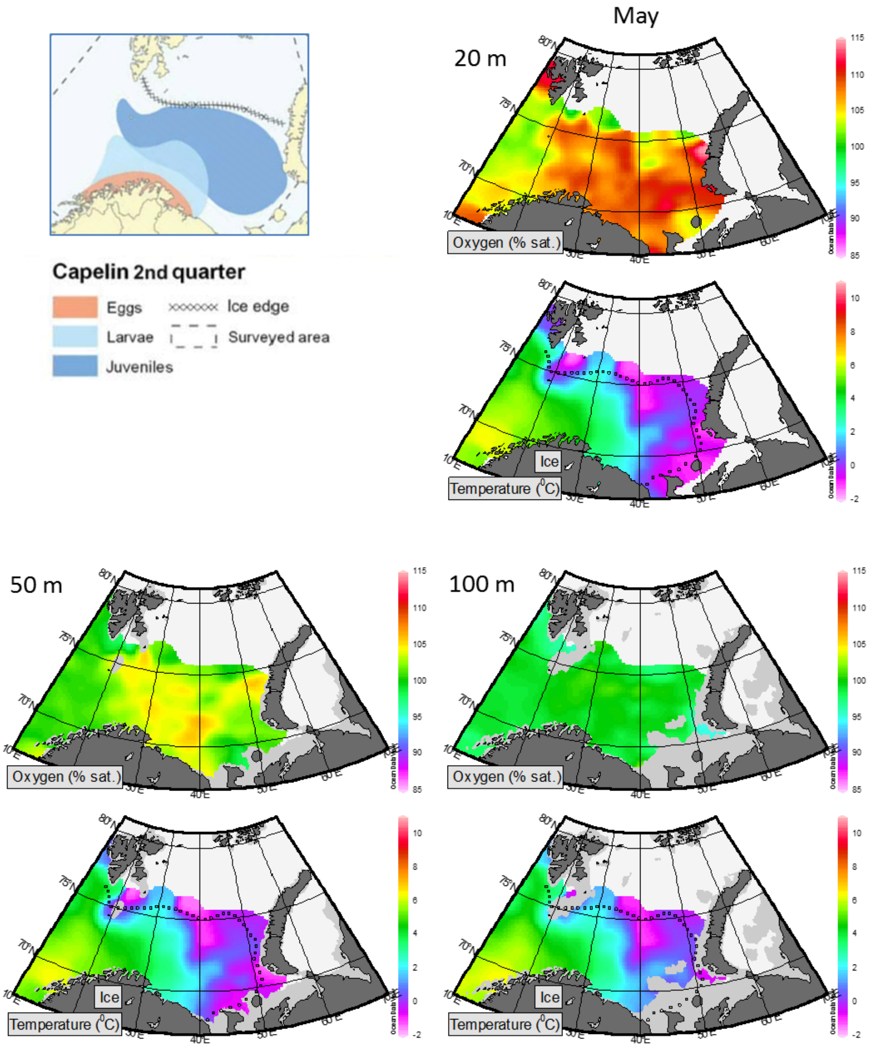


Figure 3. Typical distribution of BS capelin at various life stages in 2nd quarter (Olsen et al., 2010), temperature and oxygen saturation of seawater at depths of 20, 50, 100 meters in May (Titov, Nesvetova, 2003).

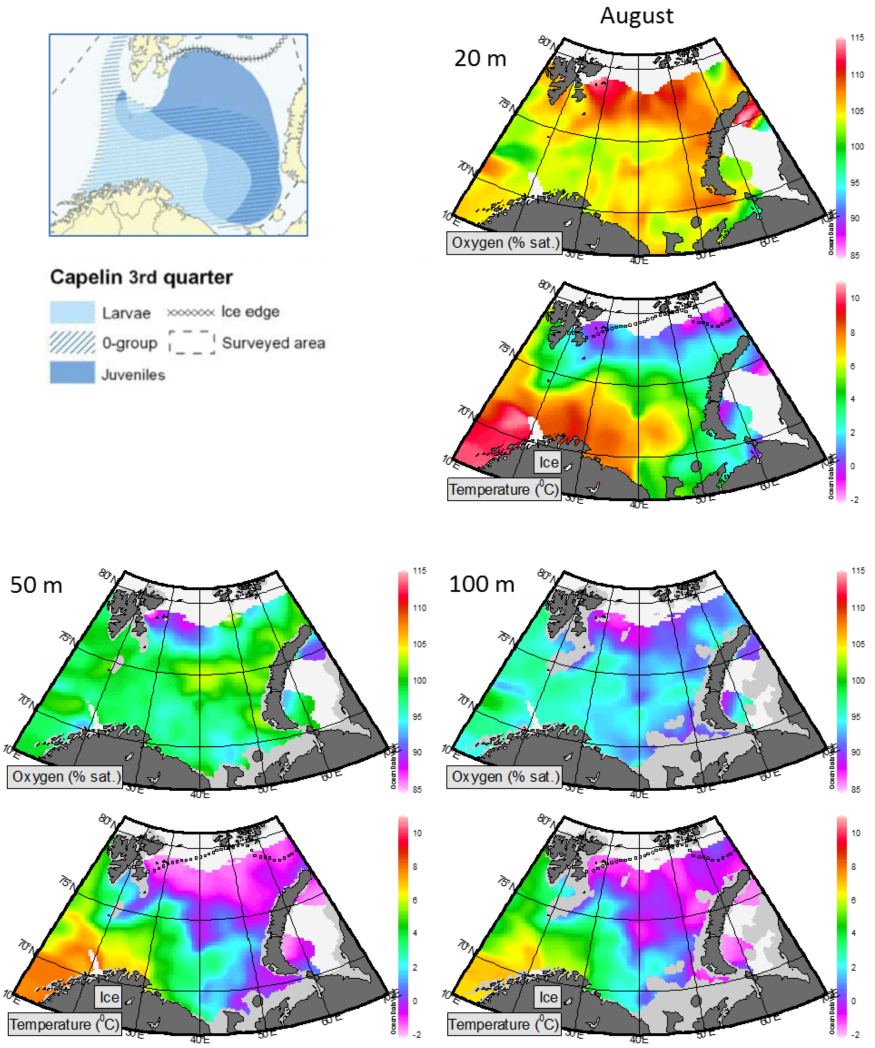


Figure 4. Typical distribution of BS capelin at various life stages in 3rd quarter (Olsen et al., 2010), temperature and oxygen saturation of seawater at depths of 20, 50, 100 meters in August (Titov, Nesvetova, 2003)

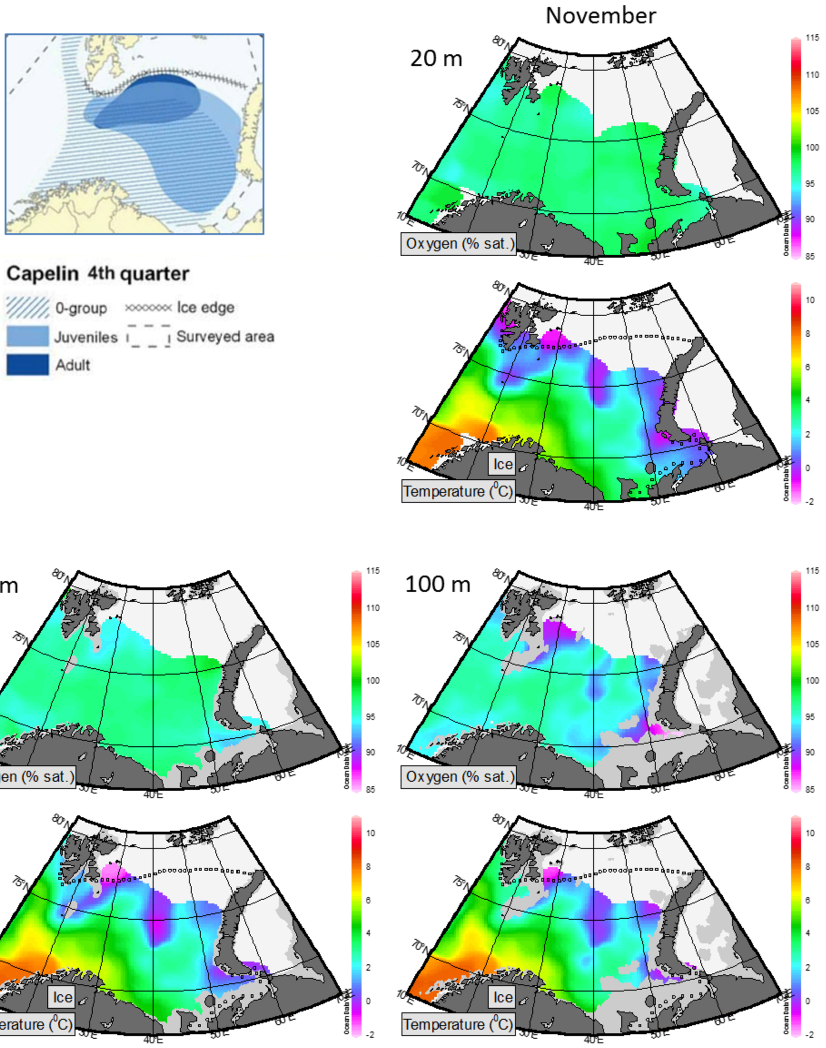


Figure 5. Typical distribution of BS capelin at various life stages in 4th quarter (Olsen et al., 2010), temperature and oxygen saturation of seawater at depths of 20, 50, 100 meters in November (Titov, Nesvetova, 2003).

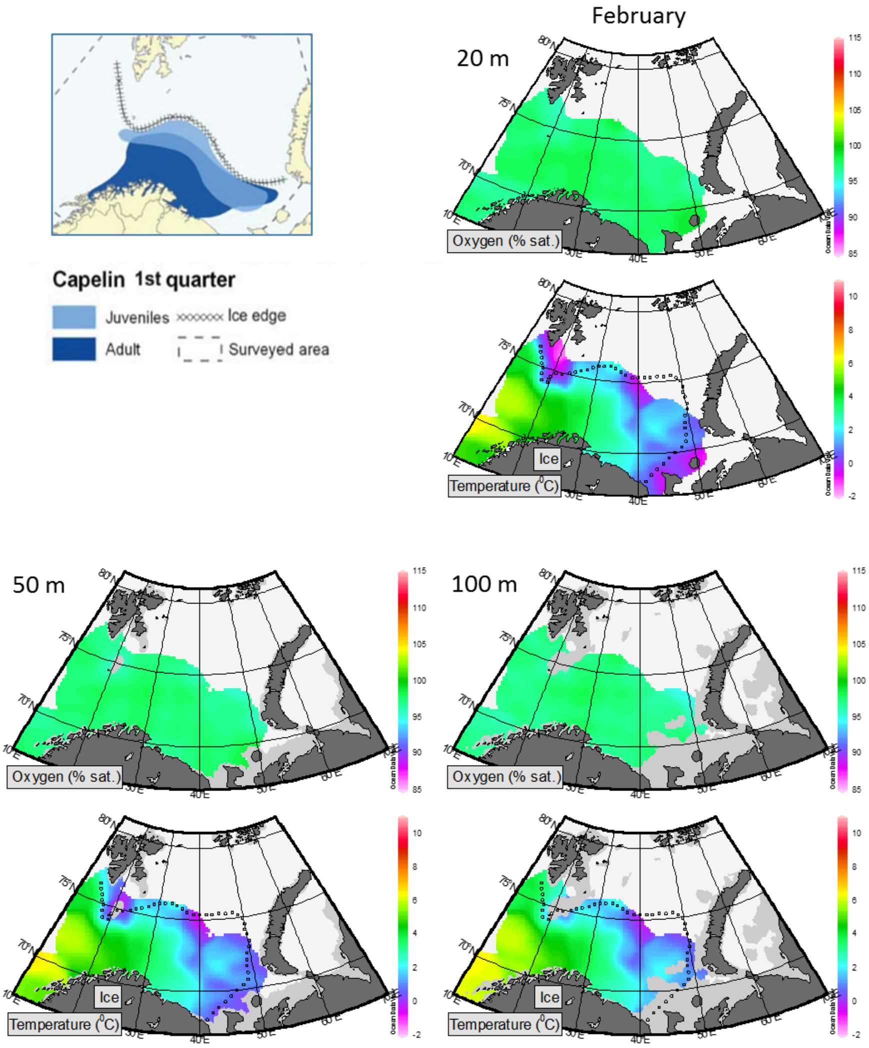


Figure 6. Typical distribution of BS capelin at various life stages 1st quarter (Olsen et al., 2010), temperature and oxygen saturation of seawater at depths of 20, 50, 100 meters in February (Titov, Nesvetova, 2003).

Table 1 shows visual assessments of oceanographic conditions that characterize the capelin habitat at various life stages.

Table 1. Environmental conditions (temperature, ^{0}C; oxygen content, % saturation) that characterize the capelin habitat at various life stages.

		2nd quarter /May		3rd quarter /August		4th quarter /November		1st quarter /February	
Life stages	Depth, m	T, ^{0}C	O$_2$, % sat.	T, ^{0}C	O$_2$, % sat.	T, ^{0}C	O$_2$, % sat.	T, ^{0}C	O$_2$, % sat.
eggs	20	5	108						
	50	5	104						
	100	4	101						
larvae	20	4	108	6	103				
	50	4	104	4	100				
	100	3	101	3	95				
0-group	20			4	106	3	99		
	50			2	103	2	97		
	100			1	93	1	95		
juveniles	20	0	107	2	108	2	99	2	99
	50	0	103	-1	104	1	98	2	97
	100	0	101	-1	95	1	96	2	97
adult	20					0	99	5	99
	50					1	97	4	97
	100					1	90	3	97

Table 2 shows the average values of temperature and oxygen saturation of seawater in the pelagic zone of the Barents Sea in a layer of 20-100 m for 5 years (60 months) preceding the assessment of BS capelin recruitment (October 1).

Table 2. Environmental conditions (temperature, ^{0}C; oxygen content, % saturation) in the pelagic zone of the Barents Sea (averaged values in the 20-100 m layer) that characterize the BS capelin habitat at various life stages over a period of 5 years (60 months) preceding the assessment of BS capelin recruitment (October 1). When constructing the table, it is assumed that capelin reaches the stage of maturity and spawns at the age of 4 years.

Quarter	Month	Life stages	T, ^{0}C	O_2, % sat.
4th/3rd	0	juveniles (recruits, 1 October)	0	99
3rd	-2	juveniles	0	102
2nd	-5	juveniles	0	103
1st	-8	juveniles	2	97
4th	-11	0-group	2	97
3rd	-12	0-group	2	100
3rd	-15	larvae	5	99
2nd	-17	larvae	4	104
2nd/1st	-18	eggs (spawning, 1 April)	5	104
1st	-20	adult	4	97
4th	-23	adult	1	95
3rd	-26	juveniles	0	102
2nd	-29	juveniles	0	103
1st	-32	juveniles	2	97
4th	-35	juveniles	1	97
3rd	-38	juveniles	0	102
2nd	-41	juveniles	0	103
1st	-44	juveniles	2	97
4th	-47	juveniles	1	97
3rd	-50	juveniles	0	102
2nd	-53	juveniles	0	103
1st	-56	juveniles	2	97
4th	-59	juveniles	1	97
4th/3rd	-60	juveniles (recruits, 1 October)	0	99

Fig. 7a shows the table 2 data in graphical form. As can be seen from Fig. 7a and Table 2, for 5 years before the formation of recruitment at the juvenile stage, BS capelin annually migrates to feeding areas with cold waters and increased oxygen saturation in the spring and summer, during spring bloom, and to warmer waters with reduced oxygen saturation during the wintering period. The stages of spawning, maturation of eggs, larvae and 0-group, mainly take place in warm, well-oxygenated waters, also during spring bloom.

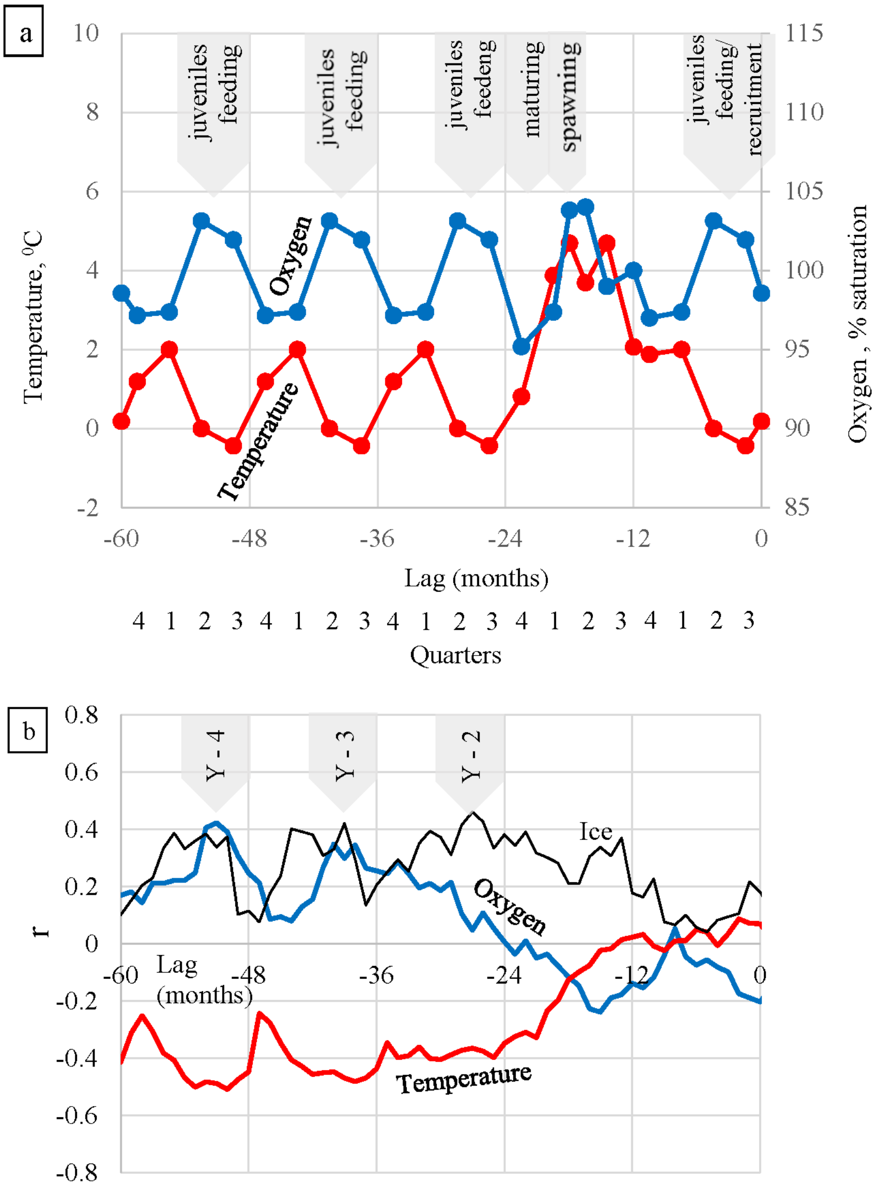


Figure 7. Changes in temperature (^{0}C, in red), oxygen content (% saturation, in blue) of sea water at various BS capelin life stages over a period of 5 years (60 months)

preceding the assessment of the number of recruits at the age of 1 year (October 1). Long-term average data for the Barents Sea pelagic zone (20 – 100 m) in the areas of BS capelin distribution at different life stages by the central months of the quarters (a). Correlation of monthly average anomalies of environmental conditions (Tw, O_2%, Ice) in the Kola section at the same time lags (b). The upper parts of the figures show the time frames of some BS capelin life stages (a, b). The life stages used to calculate the environmental indices are shown with the legend (b).

For a more vivid illustration of the seasonal cycle of environmental conditions in the Barents Sea, we used the long-term average data on the Kola section (the position is shown in Fig. 1), together with data on Barents Sea ice coverage. Figure 8 illustrates the fact that active primary production in the pelagic layer in the spring-summer period (April - July) begins against the background of low temperatures during the period when the ice cover of the Barents Sea reaches its maximum values. Spring bloom is accompanied by an increase in oxygen content both in the pelagic (20-100 m) and bottom (215-280 m) layers. During this period, optimal feeding conditions are formed for the early stages of capelin development in the southern part of the Barents Sea. Low temperature, high oxygen saturation, and the proximity of the ice edge are the most favorable conditions during the periods of feeding migrations of capelin in all subsequent periods of life up to maturation (Fig. 7a).

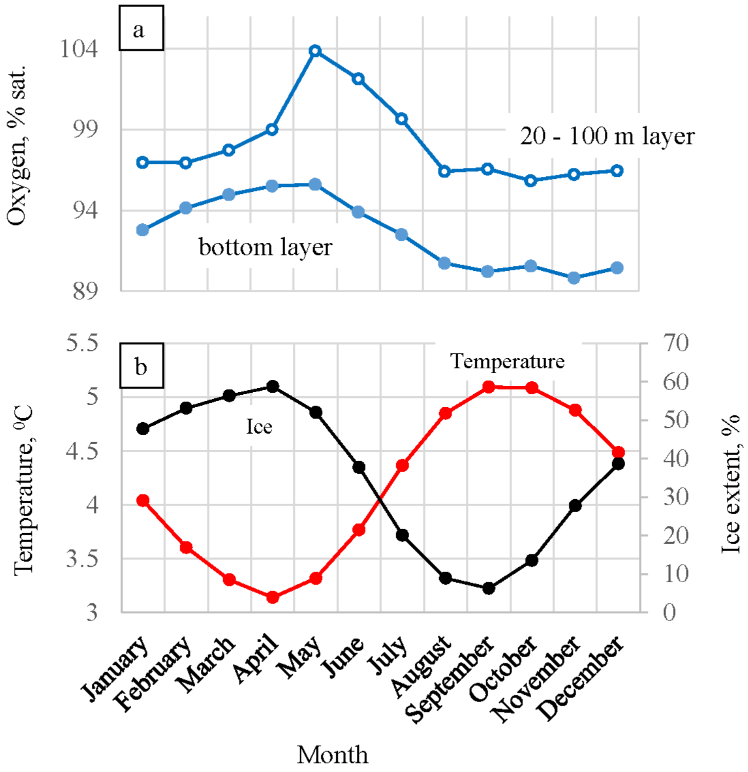
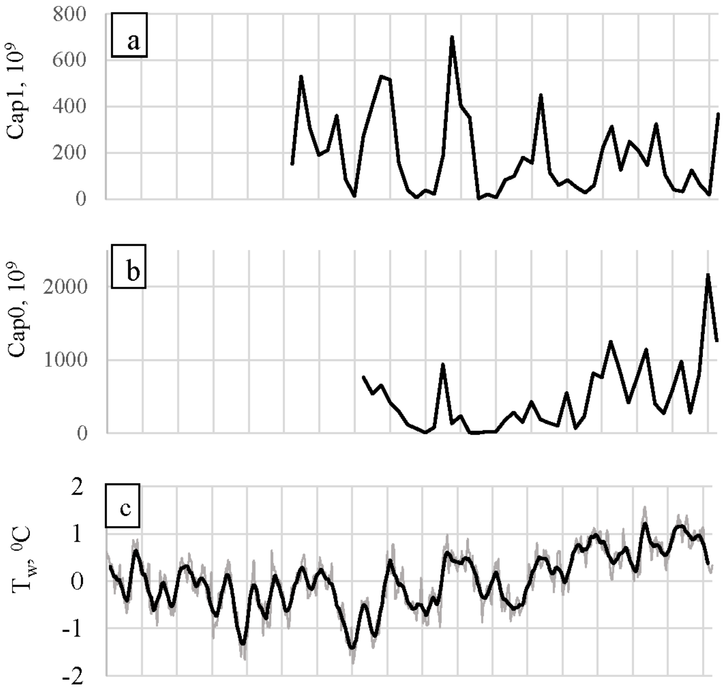


Figure 8 Average long-term seasonal changes in environmental conditions in the Barents Sea. Oxygen saturation of water in the Kola section in the pelagic (20-100 m) and bottom (215-280 m) layers (a). Water temperature in the layer 0 - 200 m on the Kola section of water and ice extent in the Barents Sea (b).

Further research consisted in studying the influence of environmental factors on the number of BS capelin recruitment.

As Figure 9 shows, while BS capelin recruitment abundance is characterized by recurrent appearances of extremely strong year classes and high variability in the 70s – 90s of the last century, the range of interannual changes has diminished in recent decades. The BS capelin 0-group index is also experiencing significant changes and has increased significantly in the last decade.

The main feature of the thermal state of waters in the Kola section (see Figure 9) is a steady increase in Tw from the beginning of the 90s, which is still ongoing. In line with the increase in ambient temperature, the ice cover in the Barents Sea also began to decrease around the beginning of the 90s. Before the beginning of the 90s, O_2% also occasionally showed relatively short-duration deep minima as well as longer periods when the values were above the normal. These things have also declined more recently and oxygen saturation has decreased by 1-3% of saturation (Titov, 2020).



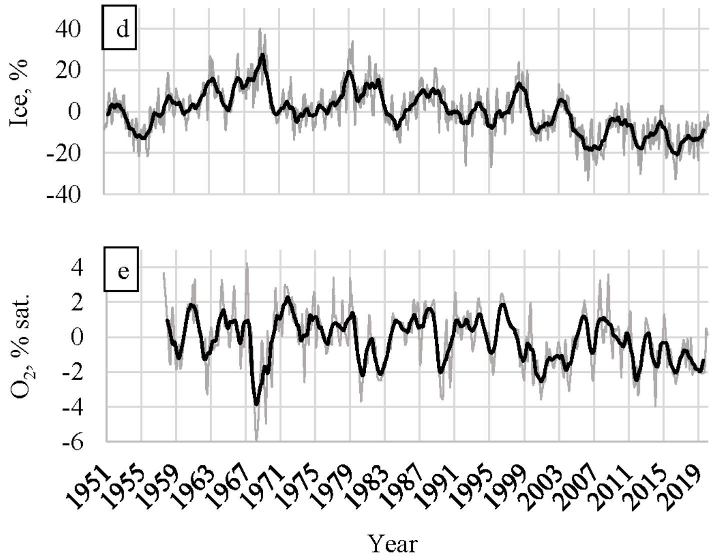


Figure 9. Interannual variations of BS capelin: recruitment (a), 0-group (b). Interannual variations of oceanographic data on Kola Section: temperature anomalies (c), oxygen saturation anomalies (e). Barents Sea ice extent anomalies (d). Mean monthly data shows by thin line, сглаженные скользящим осреднением за год by thick line.

Figure 7b shows the correlations between the abundance of BS capelin recruitment, tentatively referred to the October, on the one hand, and the other, the monthly data on temperature, oxygen saturation in Kola section and the Barents Sea ice extension.

The most significant correlation levels ($p < 0.05$) are observed for statistical links between BS capelin recruitment and environmental factors that characterize the spring - summer periods in the area of the Kola oceanographic section 3 and 4 years before recruitment. At the same time, the environmental conditions that affect recruitment (low temperature, high oxygen saturation) according to the observations at the Kola section are similar, both in time frames and according to the observations, to the environmental conditions during the summer feeding of BS capelin juveniles from the northern Barents Sea (compare Figures 7a and 7b). The closest relationship between temperature and capelin recruitment occurs in the 1-3 quarters of the year. Temperature also correlates with the number of capelin less than a year before spawning, that is, at the stage of maturation. The highest correlation links between the capelin recruitment abundance and monthly mean water temperature anomalies are observed at lags of minus 38 and minus 50 months, which corresponds to the data for August 3rd and 4th years before the estimation of the recruitment abundance. The oxygen saturation in the bottom layers of the Kola section is related to the number of capelin recruitment in the 2nd and 3rd quarters of the year, that is, during periods of maximum phyto- and zooplankton development. Correlation maxima between capelin recruitment and oxygen saturation refer to July 3rd and June 4th before capelin recruitment. The ice cover of the Barents Sea shows significant correlation links with Cap1 over a wider range of lags, except for the wintering periods of juveniles. The ice coverage has probably the most significant effect on mature BS capelin up to the period of its spawning. And even after spawning, successful recruitment depends on the widespread ice distribution in the Barents Sea.

Thus, if we believe that on average BS capelin matures at the 4th year of life, then the environmental conditions, according to observations at the Kola section, during the periods of its feeding migrations at the age of 2 and 3 years, are the most statistically significant factor affecting the success of its spawning and survival in the early stages. Ice cover has a significant impact on capelin recruitment by affecting maturing fishes.

Given the rather large time lags of the relationships between environmental characteristics and capelin recruitment, we first tried to assess the scale of the impact of environmental conditions. We applied the multiple regression method to build mathematical models. For accounting of biological factors, the comparative calculations include data on estimates of BS capelin 0-group, which are currently used most often as a predictor for estimating future changes in BS capelin recruitment with a 1-year in advance.

Taking into account the fact that the statistical distribution of the number of capelin 0-group and recruitment differs from the normal one, we also performed calculations of equations with the logarithmic form of these variables.

Studies of correlation links in the above 2 variants were carried out at all time lags from 0 to minus 60 months (5 years) from October of the year for which the BS capelin recruitment number was estimated. Due to the large amount of data on independent environmental variables at various time lags, only data were used when constructing the models, the statistical relationship of which with Cap1 is significant with a probability of more than 95%.

The output shows the results of fitting a multiple linear regression model using the average monthly values of environmental data and the values of the 0-group index (equation 1). The equations of the fitted model are:

(1) $Cap1 = 140.79 + 0.23{*}Cap0_{M-12} + 36.86{*}O_2\%_{M-51} + 15.10{*}Ice_{M-13} + 6.76{*}Ice_{M-39}$, $p<0.01$, $r^2 = 0.78$; **M** stands for lag in months.

Tables 1.1 and 1.2 in Appendix present the analysis of variance (ANOVA) of the model 1.

Figure 10 shows the simulation of Cap1 (a) using equation 1(b).

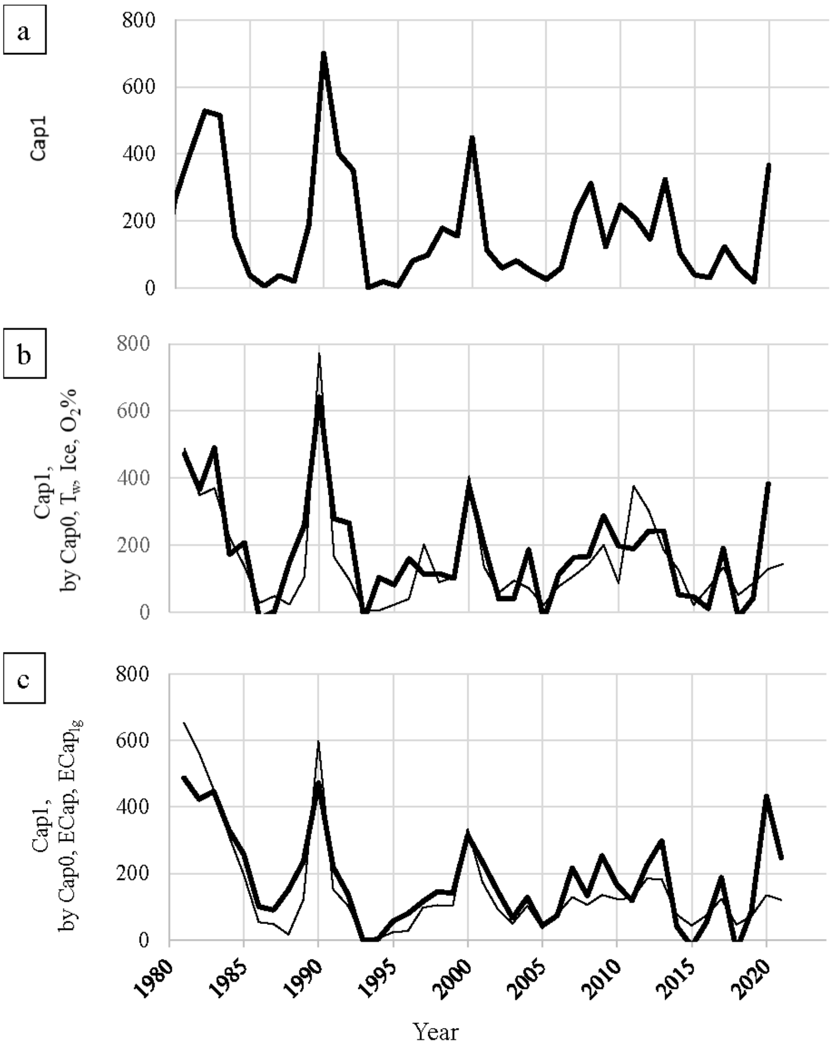


Figure 10. Simulation of Cap1 (a) using multiple regression according to equations 1 (b, thick line) and 2 (b, thin line), equations 4 (c, thick line) and 5 (c, thin line).

Table 3 represents the percentage of variances described by models based on analysis of variation (ANOVA) results.

Table 3. The percentage of variances described by models based on analysis of variation (ANOVA) results.

Model	Tw	Ice	$O_2\%$	ECap	$ECap_{lg}$	Cap0	Total
1	-	38.0	18.6	-	-	21.2	77.7
2	11.0	-	19.2	-	-	39.1	69.3
4	-	-	-	43.6	-	20.7	64.3
5	-	-	-	-	21.8	41.2	63.0

The next output shows the results of fitting a multiple linear regression model in logarithmic form using monthly average values of environmental data and 0-group index values (equation 2).

The equations of the fitted model are:

$$(2) \lg Cap1 = 0.76 + 0.54 * \lg Cap0_{M-12} + 0.13 * O_2\%_{M-48} - 0.30 * Tw_{M-38};$$
$$p<0.01, r^2 = 0.69;$$

Tables 2.1 and 2.2 in Appendix present the analysis of variance (ANOVA) of the model 2.

It should be noted, however, that the results obtained using all available initial data are very difficult to explain and, moreover, to use in practice. By slightly changing the settings when choosing a model using the multiple regression method, you can get a large number of equations with different independent variables at different time lags, which describe the recruitment of the BS capelin with very close accuracy. For the same reason, it is even more difficult to use this method in the practice of forecasting and stock management. In particular, the Study Group on Recruitment Forecasting (SGRF) ICES report on the recruitment forecasting methodology (Anon, 2012) emphasizes that the recruitment model should be based on causal considerations, not just correlations that may be false. Therefore, in the future, we significantly simplified the choice of the model by reducing the entire range of environmental data to two indices using the same set of environmental data. The causal basis for the choice of the data set was that the influence of environmental conditions on capelin recruitment is most pronounced during the periods of spring blooming and feeding migrations of capelin juveniles (see Fig. 3 - 8). Therefore, this set consists of monthly data on temperature, ice cover and oxygen saturation during the spring bloom period in the Barents Sea (Q2 - 3, or April - September) for the 1st, 2nd and 3rd years preceding the year of appearance of the capelin generation for which the recruitment estimated, or, respectively, for the 2nd, 3rd and 4th in the order of the year, which precede the year of estimation of the number of recruits. For each year of these three years, the average for 6 months (April - September) values of temperature anomalies (Tw_{Y-n}), ice extent (Ice_{Y-n}) and oxygen saturation ($O_2\%_{Y-n}$), n = 2, 3, 4, were calculated, then they were summed taking into account the statistical variance of their long-term variability (σ) and the statistical weight equal to the square of the correlation coefficient r (equation 3).

$$(3) ECap = - Tw_{Y-4} / σ_{Tw} * r^2_{TwY-4} + Ice_{Y-4} / σ_{Ice} * r^2_{IceY-4} + O_2\%_{Y-4} / σ_{O2\%} * r^2_{O2\%Y-4} - Tw_{Y-3} / σ_{Tw} * r^2_{TwY-3} + Ice_{Y-3} / σ_{Ice} * r^2_{IceY-3} + O_2\%_{Y-4} / σ_{O2\%} * r^2_{O2\%Y-3} - Tw_{Y-2} / σ_{Tw} * r^2_{TwY-2} + Ice_{Y-2} / σ_{Ice} * r^2_{IceY-2} + O_2\%_{Y-2} / σ_{O2\%} * r^2_{O2\%Y-2} ;$$

Y stands for lag in months.

The second index ($ECap_{lg}$) was calculated using the same formula as the ECap index. The difference between these indices is that the correlation coefficients used for their calculation of the relationship between environmental conditions and the abundance of capelin recruitment, expressed in linear and logarithmic form, differ.

Table 4 shows the values of σ and r for calculating the indices.

Table 4. Values of σ and r for calculating the ECap and $ECap_{lg}$ indices.

		ECap			$ECap_{lg}$		
	σ	r_{Y-4}	r_{Y-3}	r_{Y-2}	r_{Y-4}	r_{Y-3}	r_{Y-2}
Tw	0,63	-0,44	-0,43	-0,36	-0,30	-0,36	-0,22
Ice	11,42	0,33	0,34	0,38	0,13	0,27	0,23
$O_2\%$	1,57	0,30	0,25	0,13	0,29	0,25	0,00

Table 3 of the Appendix presents the results of averaging data on the environment, which are the basis for calculations, as well as the values of the ECap and $ECap_{lg}$ indices. At the top of the table is an example of using averaged environmental data (Tw_Y, Ice_Y, $O_2\%_Y$) to compute environmental health indices (ECap, $ECap_{lg}$).

Figure 11 shows the changes in ECap, $ECap_{lg}$ against the background of changes in Cap1 on a linear and logarithmic scale.

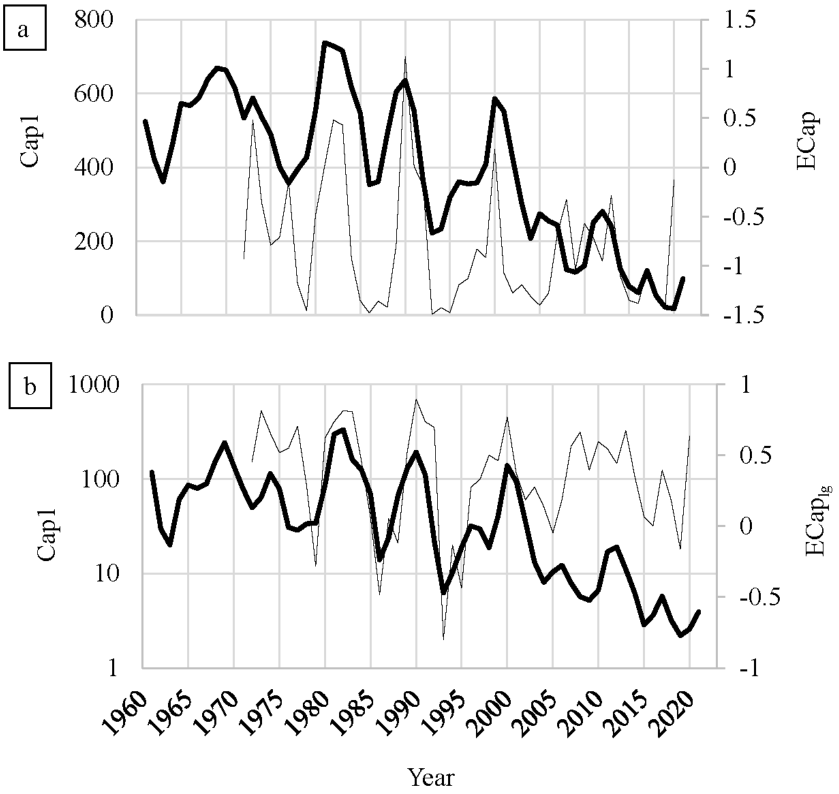


Figure 11. Changes in environmental indices ECap (a, thick line), $ECap_{lg}$ (b, thick line) against the background of changes in BS capelin recruitment (thin lines) on the linear (a) and logarithmic (b) scales.

Fig. 11 demonstrates that environmental conditions characterizing the periods of spring blooming and feeding migrations of capelin quite clearly correspond to changes in the number of its recruitment. Since the 80s of the last century, there has been a clear tendency for the capelin feeding conditions to deteriorate, which is characterized by an increase in water temperature, a decrease in Barents Sea ice coverage and water saturation with oxygen, as shown in Fig. 9. It is obvious that these trends are a direct consequence of the warming of the climate and the "atlantification" of the Barents Sea that have taken place in recent decades.

Further in the article, the procedure for calculating capelin recharge models based on environmental indices is presented.

Studies of correlation links using the complex ECap and $ECap_{lg}$ indices were carried out.

The output shows the results of fitting a multiple linear regression model using the ECap data and the values of the 0-group index (equation 4):

(4) $Cap1 = 98.18 + 0.26*Cap0_{M-12} + 153.65*ECap_{M-24}$, $p<0.01$, $r^2 = 0.64$;

Tables 4.1 and 4.2 in Appendix present the analysis of variance (ANOVA) of the model 4.

Fig. 10 shows the simulation of Cap1 (a) using equation 4 (c).

The output shows the results of fitting a multiple linear regression model using the $ECap_{lg}$ data and the values of the 0-group capelin index (equation 5):

(5) $lgCap1 = 0.74 + 0.57*lgCap0_{M-12} + 0.69*ECap_{lgM-24}$, $p<0.01$, $r^2 = 0.64$;

Tables 5.1 and 5.2 in Appendix present the analysis of variance (ANOVA) of the model 5.

Fig. 10 shows the simulation of Cap1 (a) using equation 5 (c).

The final procedure was the calculation of a complex equation obtained with the multiple regression method in order to use it to predict the abundance of capelin recruitment with a lead time of 1 year (from October of the year of assessing the abundance index of the 0-capelin group) and checking the forecasting quality on an independent series. The principles of calculating the hybrid model were developed by SGRF ICES and tested in the practice of the AFWG ICES, which uses this technique to predict the abundance of NEA cod recruitment (Anon, 2012, 2013, 2020a).

The development of the methodology was in response to a request from the AFWG ICES to revise the methodology for Northeast Arctic cod recruitment forecasting. The SGRF ICES report in 2012 addresses the problem of combining multiple model predictions to obtain a minimum variance recruitment estimate. The AFWG ICES request also required that strict criteria be established for the inclusion of predictive models in the ensemble of models.

In our approach, we have retained the principles developed by the SGRF ICES and currently used in the practice of forecasting the AFWG ICES (Anon, 2012, 2013, 2020a). To assess the quality of the forecast, a verification procedure should be carried out using the training data sample and the data sample on which the forecasting quality was assessed. To estimate the recruitment of NEA cod, the training sample was approximately 2/3, and the test sample was approximately 1/3 of the entire data series. The time series for the complete dataset on environmental conditions has been available since 1960, for Cap1 since 1972, for Cap0 since 1980 (the average data is used in 2018). Taking into account the lengths of the series, we decided to divide the entire time series available for verification into 2 equal halves, from 1980 to 1999 - the training sample, from 2000 to 2020 - the test sample. It should be noted that this approach offers even stricter test than the approach used by AFWG ICES.

As a criterion for the model to enter the forecast, the principle is used that the variance of the forecast deviation from the true value should not exceed the same variance for trivial forecasting methods - by the mean and inertial.

Table 6.1. Appendix shows the results of calculations of the predictions of Cap1, made by various methods, including inertial and mean.

Table 6.2. Appendix shows data on the standard deviation between model predictions and true values.

Table 5 shows t-statistics for models from tables 6.1., 6.2. Appendix.

S stands for the standard deviation of all forecasts, based on metric of past observations, i.e. recruitment models, from observed recruitment datapoints. $\boldsymbol{\sigma}_x$ means the standard deviation of all forecasts from average recruitment observations (long-term mean recruitment). It follows from the table 5 that the results of independent forecasts using ECap and ECap_{lg} as predictors have a smaller deviation from the observed values than forecasts based on the mean and inertial forecasts. Accordingly, they can be used for forecasting (Anon, 2013).

Table 5. The t-statistics for models.

	Mean	Inertia	Cap0, ECap	Cap0, ECap_{lg}	TitovEC
S	131,1	155,3	116,1	102,9	83,5
$t=S/\sigma_x$	1	1.18	0,89	0,78	0,64

SGRF ICES in 2013 considered hybrid forecast, based on inverse variance weighting (Anon, 2013). From Table 5, we generate Table 6, which gives the individual weights **P**n, for each model. In Table 6, **P** is the inverse proportion of the variance contribution to the total variance, and **Pn** is the normalized value of **P**, such that **Pn** sums up to unity.

Table 6. Inverse variance model weights.

	Cap0, ECap	Cap0, $ECap_{lg}$	∑
S	116,1	102,9	
S^2	13488	10591	24079
P	1.79	2.27	4.06
Pn	0,44	0,56	1

Accordingly, the model proposed for practical use (TitovEC) has the following form (equation 6):

(6) $Cap1 = 0.44*(c1 + a1*Cap0_{M-12} + b1*ECap_{M-24}) + 0.56*10^{\wedge}(c2 + a2*lgCap0_{M-12} + b2*ECap_{lgM-24})$; where a1, b1, c1, a2, b2, c2 are the coefficients of the multiple regression equation (as of 2021, the values of the coefficients are presented in equations 4 and 5).

Fig. 12 shows the true Cap1 values and predicted by the TitovEC model.

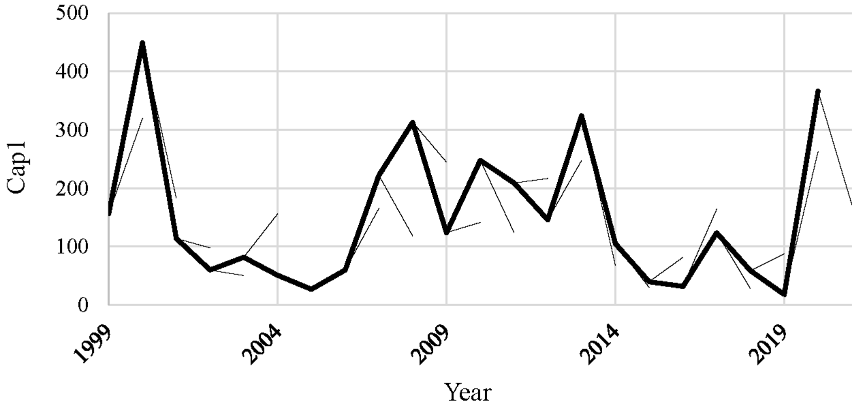


Fig. 12 Changes true Cap1 values (thick line), and predicted by the TitovEC model (thin lines).

Table 6.1. Appendix shows the calculation results of the Cap1 predictions made using the TitovEC model.

Recruitment (age 1) prediction for Barents Sea capelin for 1 October 2021, calculated using the TitovEC model, is 177 $*10^9$ sp.

Table 6.2. Appendix shows data on the standard deviation between model predictions and true values. As of 2020, the forecast error with a lead time of 1 year using the TitovEC model is less than the mean forecast error by 36%, and the inertial forecast by 46%.

Thus, oceanographic conditions are an important factor affecting BS capelin recruits numbers, describing large variance in statistical variability. Environmental conditions are most likely determined primarily by specific oceanographic conditions, which are the background of intense spring blooming, which begins in the first half of the year in the southern part of the Barents Sea, and spreads to its northern regions up to the autumn period. The success of capelin feeding migrations during this period determines accumulation of reproductive potential, the success of its spawning and subsequent recruits survival in a few years. Therefore, the joint use of environmental and survey predictors will improve the ability to predict the number of BS capelin recruits and manage its commercial stock. Using only oceanographic data as independent variables in theory allows us to make forecasts of BS capelin recruitment up to 2-4 years ahead. However, in this case, we must answer the question of whether the increase in BS capelin 0-group is a compensatory reaction of a biological nature to the deteriorating feeding conditions of capelin or the result of changes in environmental conditions in the spawning areas.

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Appendix

Table 1.1. ANOVA of fitting a multiple linear regression model 1 to describe the relationship between Cap1 and independent variables.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
Model	903507	4	225877	30.51	0.00
Residual	259147	35	7404		
Total	$1.2*10^6$	39			

Table 1.2. Further ANOVA for variables in the order fitted.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
$Cap0_{t-12}$	246710	1	246710	33.32	0.00
$O_2\%_{t-51}$	215321	1	215321	29.08	0.00
Ice_{t-13}	154831	1	154831	20.91	0.00
Ice_{t-39}	286645	1	286645	38.71	0.00

Model	903507	4			

Table 2.1. ANOVA of fitting a multiple linear regression model 2 to describe the relationship between Cap1 and independent variables.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
Model	9.12	3	3.04	27.03	0.00
Residual	4.05	36	0.11		
Total	13.17	39			

Table 2.2. Further ANOVA for variables in the order fitted.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
$lgCap0_{t-12}$	5.15	1	5.15	45.74	0.00
$O_2\%_{t-48}$	2.54	1	2.54	22.53	0.00
Tw_{t-38}	1.44	1	1.44	12.83	0.00
Model	9.12	3			

Table 3. Values of Tw_Y, Ice_Y, $O_2\%_Y$, ECap and $ECap_{lg}$. The arrows in the table show an example of using environmental data (Tw_Y, Ice_Y, $O_2\%_Y$) to calculate the environmental indexes (ECap, $ECap_{lg}$).

Year	Tw_Y	Ice_Y	$O_2\%_Y$	ECap	$ECap_{lg}$
1951	-0,44	1,5			
1952	0,04	3,2			
1953	-0,49	-1,8			
1954	0,69	-9,1			
1955	0,00	-9,0			
1956	-0,57	-1,6			

1957	-0,01	-1,8	3,37		
1958	-0,59	10,4	0,20		
1959	0,35	6,7	-1,18		
1960	0,42	-4,5	1,68		
1961	-0,13	2,4	1,21	0,47	0,38
1962	-0,26	11,9	-1,84	0,08	-0,02
1963	-0,89	17,0	-0,51	-0,14	-0,13
1964	-0,03	8,2	1,75	0,22	0,19
1965	-0,46	2,4	1,35	0,65	0,29
1966	-1,39	17,5	-0,63	0,63	0,27
1967	-0,18	13,2	0,30	0,71	0,30
1968	-0,46	14,4	-4,35	0,90	0,46
1969	-0,89	26,5	-1,94	1,01	0,59
1970	-0,01	-0,1	1,68	0,99	0,43
1971	-0,69	4,2	2,13	0,81	0,27
1972	-0,09	3,5	1,66	0,50	0,13
1973	0,43	-6,5	0,12	0,70	0,20
1974	-0,09	0,9	0,76	0,51	0,37
1975	0,34	1,9	1,00	0,33	0,26
1976	0,10	-2,3	-0,64	0,01	-0,01
1977	-0,65	5,4	0,74	-0,16	-0,03
1978	-1,23	10,5	0,15	-0,02	0,02
1979	-1,33	17,0	0,92	0,10	0,02
1980	-0,48	5,7	-2,52	0,57	0,29
1981	-1,30	15,2	0,02	1,27	0,65
1982	-0,39	13,4	-2,41	1,23	0,68
1983	0,47	-3,3	-0,83	1,18	0,47
1984	-0,03	-7,5	0,87	0,82	0,40
1985	-0,49	0,7	0,08	0,55	0,23
1986	-0,61	4,2	1,58	-0,17	-0,24
1987	-0,85	10,2	1,27	-0,15	-0,08
1988	-0,35	5,5	1,88	0,34	0,22
1989	0,53	3,9	-3,07	0,77	0,40
1990	0,53	-3,3	-1,54	0,88	0,52
1991	0,45	-2,3	0,68	0,57	0,36
1992	0,48	-10,0	0,96	-0,14	-0,10
1993	0,02	1,4	0,72	-0,67	-0,47
1994	-0,17	-2,8	0,27	-0,62	-0,33
1995	0,34	-12,8	-1,43	-0,30	-0,15
1996	-0,43	-1,8	2,27	-0,15	0,00
1997	-0,63	0,5	0,58	-0,17	-0,02
1998	-0,51	11,2	-0,49	-0,16	-0,15
1999	-0,01	7,5	-0,10	0,03	0,07
2000	0,41	-9,3	-1,61	0,70	0,43

2001	0,35	-5,3	-1,66	0,57	0,31
2002	0,49	-5,8	-1,54	0,09	0,03
2003	-0,03	4,7	-1,62	-0,37	-0,25
2004	0,74	-6,0	-1,23	-0,72	-0,40
2005	0,56	-8,8	0,59	-0,47	-0,32
2006	1,00	-19,6	0,19	-0,54	-0,27
2007	0,82	-16,0	1,12	-0,59	-0,40
2008	0,30	-8,5	1,43	-1,04	-0,50
2009	0,42	-1,5	0,27	-1,07	-0,52
2010	0,64	-7,5	-0,34	-1,00	-0,45
2011	0,22	-10,3	-1,37	-0,56	-0,18
2012	1,37	-17,8	-1,52	-0,45	-0,15
2013	0,81	-12,1	0,08	-0,59	-0,30
2014	0,63	-7,5	-1,23	-1,03	-0,47
2015	0,87	-14,9	-0,93	-1,21	-0,69
2016	1,14	-20,8	-2,35	-1,27	-0,63
2017	0,88	-10,1	-0,81	-1,05	-0,49
2018	0,93	-11,8	-1,69	-1,30	-0,66
2019	0,45	-11,3	-2,06	-1,42	-0,77
2020	0,39	-12,0	-1.13	-1,43	-0,72
2021				-1,13	-0,60
2022				-1.07	-0,57

Table 4.1. ANOVA of fitting a multiple linear regression model 4 to describe the relationship between Cap1 and independent variables.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
Model	747236	2	373618	33.28	0.00
Residual	415417	37	11228		
Total	1162650	39			

Table 4.2. Further ANOVA for variables in the order fitted.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
$Cap0_{t-12}$	240607	1	240607	21.43	0.00
$ECap_{M-24}$	506629	1	506629	45.12	0.00

Model	747236	2			

Table 5.1. ANOVA of fitting a multiple linear regression model 5 to describe the relationship between Cap1 and independent variables.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
Model	8.401	2	4.20	32.62	0.00
Residual	4.77	37	0.13		
Total	13.17	39			

Table 5.2. Further ANOVA for variables in the order fitted.

Source	Sum of squares	Df	Mean square	F-ratio	P-value
$Cap0_{t-12}$	5.42	1	5.42	42.08	0.00
$ECap_{lgM-24}$	2.98	1	2.98	23.17	0.00
Model	8.41	2			

Table 6.1. One year ahead Cap1 forecast by indicated models.

Years	Cap1	Mean	Inertia	Cap0, ECap	Cap0, $ECap_{lg}$	TitovEC
2000	449	205	156	325	316	320
2001	114	217	449	197	174	184
2002	60	212	114	131	76	100
2003	82	205	60	77	33	52
2004	51	200	82	306	56	166
2005	27	194	51	24	27	26
2006	60	187	27	83	50	65

2007	222	182	60	315	66	176
2008	313	184	222	190	71	123
2009	124	188	313	427	123	257
2010	248	186	124	186	112	145
2011	210	188	248	122	126	124
2012	146	189	210	256	191	220
2013	325	187	146	340	186	254
2014	105	192	325	42	85	66
2015	40	189	105	0	50	28
2016	32	185	40	77	85	81
2017	86	181	32	222	126	168
2018	59	179	86	0	47	26
2019	18	176	59	109	74	89
2020	366	172	18	478	120	278
2021				248	121	**177**

Table 6.2. Squared deviation between model prediction and Cap1 value.

Years	Mean	Inertia	Cap0, ECap	Cap0, ECap$_{lg}$	TitovEC
2000	59613	85849	15500	17628	16651
2001	10619	112225	6922	3574	4917
2002	23147	2916	5084	251	1616
2003	15185	484	30	2390	879
2004	22162	961	64923	27	13225
2005	27778	576	10	0	2
2006	16129	1089	524	98	20
2007	1591	26244	8649	24314	2157

2008	16746	8281	15228	58663	35963
2009	4123	35721	92052	1	17625
2010	3844	15376	3894	18441	10700
2011	481,1	1444	7797	7074	7355
2012	1827	4096	12100	1984	5417
2013	18932	32041	225	19263	5075
2014	7490	48400	3969	395	1515
2015	22201	4225	1600	102	144
2016	23330	64	1998	2821	2448
2017	8930	2916	18442	1591	6763
2018	14394	729	3481	144	1068
2019	24906	1681	8281	3136	5098
2020	37636	121104	12544	60516	7829

AFWG 2021 WD_14
April 2021

North East Arctic Haddock: Weight and proportion mature at age from winter survey data 1994-2021

Alfonso Perez-Rodriguez, Edda Johannesen and Alexey Russkikh

1. Introduction

In 2006 (ICES 2006) it was decided to use models to smooth raw data of stock weight at age and proportion mature at age to remove some inconsistencies due to high sampling variance and possibly coverage issues for haddock. Modeling the weight at age and proportion mature at age for haddock also allow to fill in missing age-year combinations in the input to the stock assessment. Since 2006, the approach has been continued at the benchmarks in 2011 and 2015. At the latest benchmark (ICES 2020) it was decided that the practice of smoothing weight and maturity should be continued until the next benchmark.

Up until now (exception in 2015 and 2018) an average between smoothed maturity and the smoothed weight at age estimates based on data from two surveys has been used: the Russian demersal survey and the NORU winter survey. Because the Russian winter survey has been discontinued, it was at the benchmark in 2020 decided to use a constant ratio to adjust the estimates based on the NORU winter survey as a way to compensate (ICES 2020, Russkikh et al 2020).

At the latest benchmark the smoothing using the NORU winter survey was implemented in R (TMB and Maximum Likelihood, Perez-Rodriguez et al 2020). Also, the NORU winter survey data was updated correcting errors and by treating skipped spawners as immature in all years 1994-2019.

Here we use length and weight at age (1994-2020) from the winter survey report from 2020 (Fall et al 2020) and added weight and length at age for 2021 that will be found in the winter survey report from 2021 (Fall et al in prep, see also wd x AFWG 2021). The data on length was supplemented with data back to 1983 taken from ICES 2019. The empirical length and weight at age are outputs from StoX and are weighted averages using super-individuals as weighting factors (detailed in e.g. Johnsen et al 2019).

From 2021 maturity by age for haddock will be included int the winter survey report as will a table with the number of haddock aged by year and age group.

Here we:

1) Calculate smoothed maturity and weight at age from the NORU survey as input to the stock assessment model updating the years 1994-2020 as detailed in Perez-Rodriguez et al (2020)
2) Adjust the estimates using the ratio adjustment as detailed in Russkikh et al (2020)
3) Calculate smoothed maturity and weight at age from the NORU winter survey used for input to short term projections
4) Adjust the estimates for input to short term projections using the ratio adjustment as detailed in Russkikh et al (2020)

2. Modeling biological parameters

2.1 Length at age

The age year combinations with less than 5 individuals (Appendix 1 table 1) was removed from the input data (Appendix 1 Table 2, Appendix 2).

We fitted a von Bertalanffy model with the $L_{\infty}$and A0 parameters e fitted as a single parameter across all years, whereas the K parameter was fitted separately for each cohort (y). A is age.

Eq. 1 $$L_{A,y} = L_{\infty} - L_{\infty} e^{(-K_y(A-A_0)}$$

The years 1983 -2021 were used, fitted to age 1-13 and cohort 1981-2018.

The predicted values are the smoothed length at age (Table 1). The von Bertalanffy growth model parameters were optimized with maximum likelihood criteria using Template Model Builder (TMB) fitting Eq. 1 to the data. The relationship between the empirical weighted mean length at age by year, and the predictions from Eq. 1 is shown in Figure 1.

Table 1 Predicted length at age from eq. 1 fitted to data in Appendix 1 (Table2) and Appendix 2.

year	1	2	3	4	5	6	7	8	9	10	11	12	13
1994	13.8	22.1	29.4	36.9	45.1	54.1	59.2	63.6	64.7	64.2	65.2	70.6	73.8
1995	14.9	22.6	29.8	36	42.8	50.3	58.7	63	66.8	67.5	66.9	67.5	72.5
1996	14.9	24.3	30.4	36.5	41.9	48	54.9	62.5	66.3	69.5	70	69.2	69.6
1997	15.2	24.3	32.5	37.1	42.3	47	52.5	58.8	65.8	69.1	71.9	72.1	71.2
1998	14	24.8	32.5	39.5	43.1	47.5	51.6	56.5	62.3	68.6	71.4	73.8	73.9
1999	14.2	23	33.1	39.6	45.6	48.3	52	55.5	60	65.2	71	73.4	75.5
2000	13.7	23.3	30.9	40.2	45.7	50.9	52.8	56	59	63	67.8	73.1	75.1
2001	13.2	22.5	31.2	37.7	46.4	50.9	55.5	56.8	59.5	62.1	65.7	70.1	74.8
2002	13.9	21.8	30.2	38.1	43.7	51.7	55.5	59.4	60.3	62.6	64.8	68.1	72
2003	13.9	22.8	29.3	36.9	44.1	48.9	56.2	59.4	62.8	63.3	65.3	67.2	70.1
2004	14.1	22.8	30.6	35.9	42.8	49.4	53.4	60.2	62.9	65.8	66	67.6	69.3
2005	12.7	23.1	30.6	37.5	41.7	48	53.9	57.4	63.5	65.8	68.3	68.3	69.7
2006	12.6	20.9	30.9	37.4	43.4	46.9	52.5	57.9	60.9	66.5	68.4	70.5	70.4
2007	13.2	20.9	28.2	37.8	43.4	48.6	51.4	56.5	61.4	63.9	69	70.6	72.4
2008	14	21.7	28.2	34.7	43.8	48.6	53.2	55.4	60	64.4	66.5	71.2	72.5
2009	14.1	22.9	29.3	34.6	40.4	49	53.1	57.1	58.9	63.1	67	68.9	73
2010	15.3	23.1	30.7	35.9	40.4	45.5	53.5	57.1	60.6	62	65.7	69.3	70.9
2011	14.8	24.9	31	37.5	41.7	45.4	50	57.5	60.6	63.7	64.7	68.1	71.3
2012	15.7	24.3	33.2	37.9	43.5	46.9	49.9	54	61	63.6	66.3	67.1	70.1
2013	15.1	25.5	32.4	40.4	43.9	48.7	51.4	53.9	57.5	64	66.3	68.6	69.2
2014	15.2	24.6	33.9	39.4	46.5	49.1	53.3	55.4	57.4	60.6	66.6	68.6	70.6
2015	14.9	24.8	32.8	41.1	45.5	51.8	53.6	57.2	58.9	60.5	63.4	68.9	70.6
2016	14.2	24.3	33.1	39.9	47.3	50.8	56.4	57.6	60.7	61.9	63.3	65.8	70.9
2017	13.8	23.2	32.5	40.3	46	52.7	55.4	60.3	61.1	63.7	64.7	65.7	68
2018	13.6	22.7	31.1	39.5	46.4	51.3	57.2	59.3	63.7	64.1	66.4	67.1	67.9
2019	13.4	22.3	30.4	38	45.6	51.7	55.8	61.1	62.7	66.6	66.7	68.7	69.2
2020	NA	22.1	30	37.2	44	50.9	56.3	59.8	64.5	65.7	69.1	69	70.7
2021	NA	NA	29.7	36.7	43.1	49.2	55.5	60.2	63.2	67.4	68.3	71.3	71

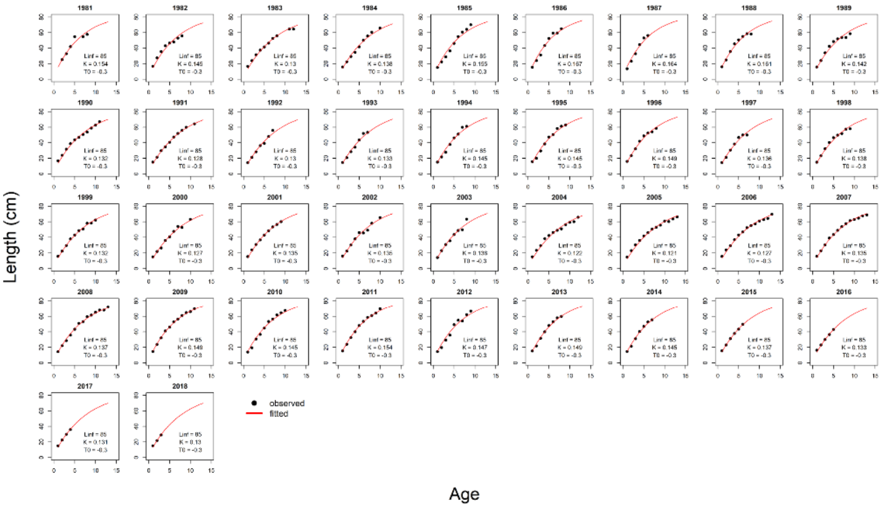

Figure 1. Predicted growth curves by cohort from eq. 1 (red line, Table 1) and empirical length at age (black dots, Appendix 1 Table 1 and Appendix 2 excluding low sample sizes).

2.2 weight at age

The weighted mean weights at age (W) were used with the lengths (L) from Appendix 1 Tables 2 and 3 (excluding <5 individuals, Appendix 1 table 1) to fit the parameters in:

Eq. 2 $W=a*L^b$

The relationship with the estimated parameters is shown in Figure 2.

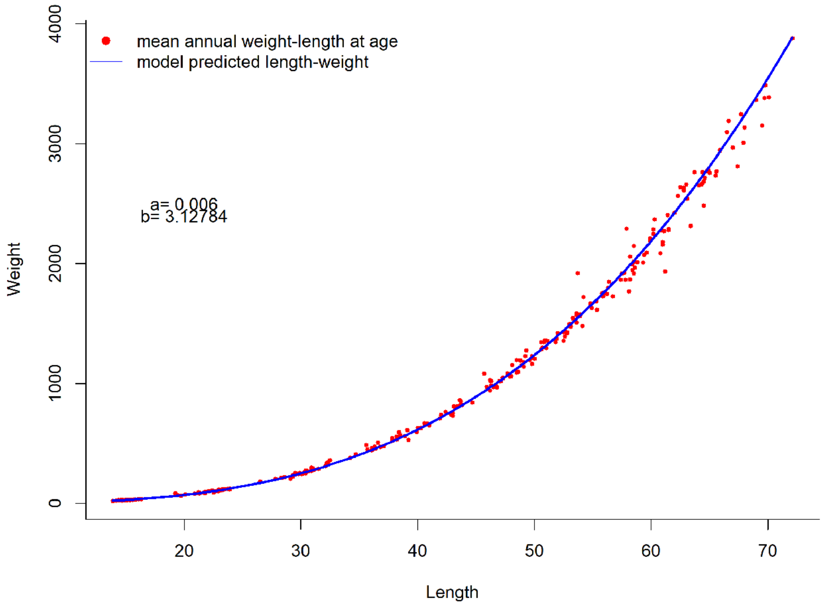

Figure 2. Predicted length-weight relationship from eq 2 (blue) and empirical averages (red, dots excluding low sample sizes (<5 individuals), Appendix Tables 2 and 3).

The fitted length-weight relationship is then applied to the smoothed lengths at age (Table 1) to calculate the smoothed weight at age (Table 2).

Table 2 Predicted weight at age 1994 -2020, from parameters in eq. 2 and from lengths in Table 1. Ages 1-13.

year	1	2	3	4	5	6	7	8	9	10	11	12	13
1994	0.022	0.096	0.235	0.478	0.896	1.583	2.098	2.626	2.771	2.704	2.838	3.64	4.181
1995	0.028	0.103	0.245	0.443	0.761	1.261	2.043	2.549	3.062	3.163	3.076	3.163	3.955
1996	0.028	0.13	0.261	0.462	0.712	1.089	1.657	2.486	2.99	3.466	3.544	3.419	3.481
1997	0.03	0.13	0.322	0.487	0.733	1.02	1.441	2.054	2.921	3.404	3.854	3.887	3.738
1998	0.023	0.138	0.322	0.592	0.778	1.054	1.365	1.813	2.462	3.327	3.771	4.181	4.199
1999	0.024	0.109	0.341	0.597	0.928	1.11	1.399	1.715	2.188	2.838	3.705	4.111	4.49
2000	0.022	0.114	0.275	0.625	0.934	1.308	1.467	1.764	2.076	2.549	3.207	4.059	4.416
2001	0.019	0.102	0.283	0.512	0.979	1.308	1.715	1.844	2.132	2.437	2.907	3.56	4.361
2002	0.023	0.092	0.256	0.529	0.812	1.374	1.715	2.121	2.223	2.499	2.784	3.252	3.871
2003	0.023	0.106	0.233	0.478	0.835	1.154	1.783	2.121	2.524	2.587	2.852	3.119	3.56
2004	0.024	0.106	0.266	0.439	0.761	1.191	1.52	2.211	2.536	2.921	2.948	3.178	3.434
2005	0.017	0.111	0.266	0.503	0.701	1.089	1.565	1.905	2.613	2.921	3.282	3.282	3.497
2006	0.017	0.081	0.275	0.499	0.795	1.013	1.441	1.958	2.293	3.019	3.297	3.624	3.608
2007	0.019	0.081	0.206	0.516	0.795	1.132	1.349	1.813	2.352	2.665	3.388	3.64	3.938
2008	0.023	0.091	0.206	0.395	0.818	1.132	1.502	1.705	2.188	2.731	3.019	3.738	3.955
2009	0.024	0.108	0.233	0.391	0.635	1.161	1.493	1.874	2.065	2.562	3.09	3.373	4.041
2010	0.03	0.111	0.269	0.439	0.635	0.921	1.529	1.874	2.258	2.425	2.907	3.434	3.689
2011	0.027	0.14	0.277	0.503	0.701	0.915	1.237	1.916	2.258	2.639	2.771	3.252	3.754
2012	0.033	0.13	0.344	0.52	0.8	1.013	1.229	1.574	2.304	2.626	2.99	3.105	3.56
2013	0.029	0.151	0.318	0.635	0.824	1.139	1.349	1.565	1.916	2.678	2.99	3.327	3.419
2014	0.03	0.135	0.367	0.587	0.986	1.169	1.511	1.705	1.905	2.258	3.033	3.327	3.64
2015	0.028	0.138	0.331	0.67	0.921	1.382	1.538	1.884	2.065	2.246	2.6	3.373	3.64
2016	0.024	0.13	0.341	0.611	1.04	1.3	1.803	1.926	2.269	2.412	2.587	2.921	3.689
2017	0.022	0.112	0.322	0.63	0.953	1.458	1.705	2.223	2.316	2.639	2.771	2.907	3.237
2018	0.021	0.105	0.28	0.592	0.979	1.341	1.884	2.109	2.639	2.691	3.005	3.105	3.222
2019	0.02	0.099	0.261	0.524	0.928	1.374	1.744	2.316	2.511	3.033	3.047	3.342	3.419
2020	NA	0.096	0.25	0.491	0.829	1.308	1.793	2.166	2.744	2.907	3.404	3.388	3.656
2021	NA	NA	0.243	0.47	0.778	1.176	1.715	2.211	2.575	3.148	3.282	3.754	3.705

2.3 Smoothed proportion spawners at age

The proportions of mature (m) at age A (Appendix table 4) were used with the data from Appendix 1 Table 2 (L) (excluding <5 individuals, Appendix 1 table 1) to fit the parameters in:

Eq. 3: $$\log\left(\frac{m_A}{1-m_A}\right) = I + \alpha A + \beta L$$

The fitted parameters (alfa, beta and intercept) and the resulting maturity ogive is shown in Figure 3.

The smoothed length at age from Table 1 (growth model output) was then used together with the fitted parameters to predict proportions spawners (Table 3).

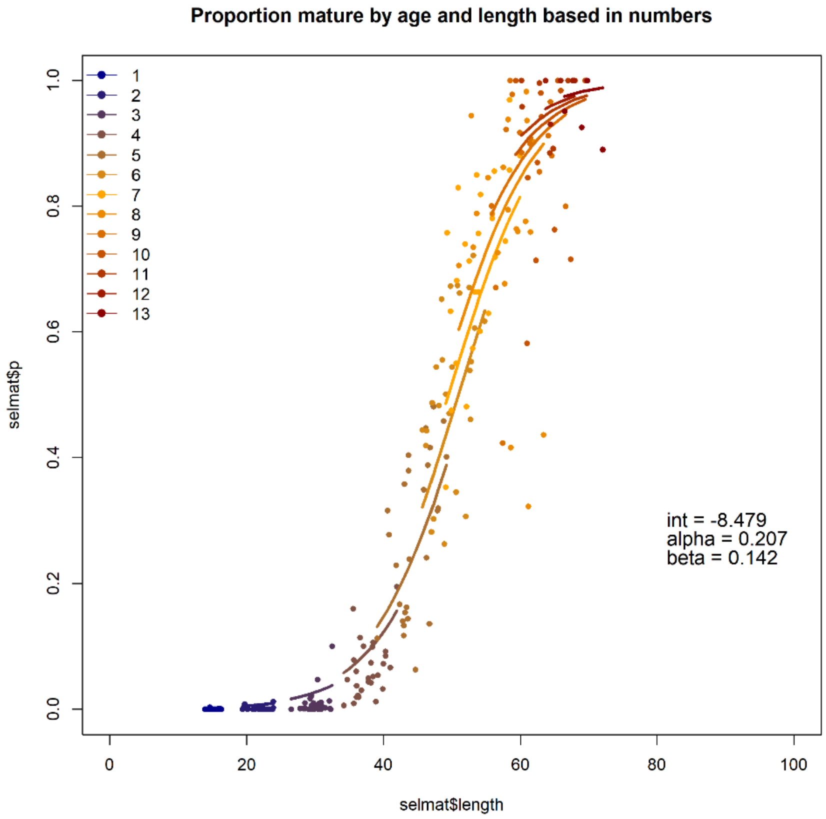

Figure 3. Each line is the predicted proportion of mature haddock as a function of length for each age (1-13) estimated from eq 3 fitted to the data in Appendix 1 table 1 and Appendix 1 table 3. The empirical proportions (excluding low sample sizes n<5 individuals) are taken from Appendix 1 Table 3 and are shown at dots.

The immature haddock includes both young immatures that has never spawned (stage 1), spent/skipping spawners (stage 4) and uncertain (stage 5, cannot separate 1 and 4). The emprical proportion in each category is shown in figure 4.

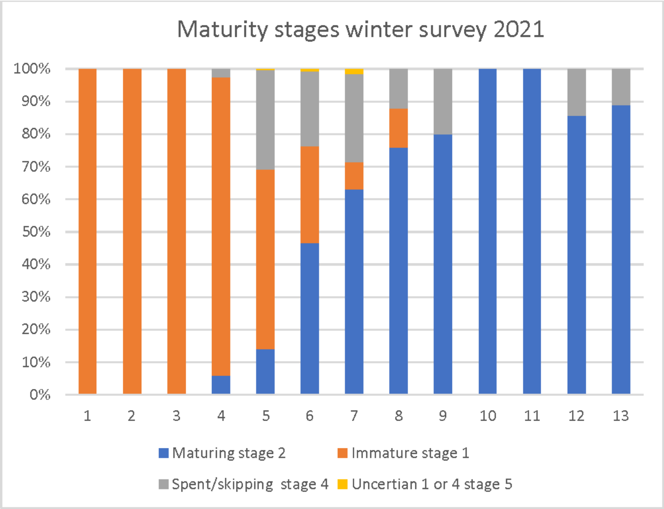

Figure 4. Percentage of the different maturity stages winter survey 2021, see Appendix table 5 for sample sizes.

Table 3 Predicted proportion spawners at age 1994-2020 from parameters in eq. 3 estimated using data in Appendix 1 table 1 and 3, and used with the length at age in Table 1.

year	1	2	3	4	5	6	7	8	9	10	11	12	13
1994	0.002	0.007	0.025	0.082	0.262	0.61	0.799	0.901	0.929	0.938	0.955	0.983	0.991
1995	0.002	0.008	0.026	0.073	0.204	0.477	0.787	0.893	0.946	0.96	0.964	0.973	0.989
1996	0.002	0.01	0.028	0.078	0.184	0.397	0.683	0.886	0.943	0.97	0.977	0.979	0.984
1997	0.002	0.01	0.038	0.085	0.192	0.363	0.605	0.822	0.939	0.968	0.982	0.986	0.987
1998	0.002	0.011	0.038	0.115	0.211	0.38	0.574	0.769	0.903	0.966	0.981	0.989	0.991
1999	0.002	0.008	0.041	0.117	0.276	0.407	0.588	0.743	0.871	0.945	0.98	0.988	0.993
2000	0.002	0.009	0.03	0.126	0.278	0.498	0.615	0.756	0.854	0.927	0.969	0.988	0.992
2001	0.002	0.008	0.031	0.091	0.299	0.498	0.701	0.776	0.862	0.918	0.958	0.981	0.992
2002	0.002	0.007	0.027	0.096	0.225	0.527	0.701	0.834	0.875	0.923	0.953	0.975	0.988
2003	0.002	0.008	0.024	0.082	0.235	0.428	0.722	0.834	0.909	0.93	0.956	0.972	0.985
2004	0.002	0.008	0.029	0.072	0.204	0.445	0.635	0.849	0.91	0.95	0.96	0.974	0.983
2005	0.002	0.008	0.029	0.089	0.179	0.397	0.652	0.791	0.917	0.95	0.971	0.976	0.984
2006	0.002	0.006	0.03	0.088	0.218	0.36	0.605	0.802	0.884	0.954	0.971	0.982	0.985
2007	0.002	0.006	0.021	0.093	0.218	0.417	0.567	0.769	0.891	0.935	0.973	0.983	0.989
2008	0.002	0.007	0.021	0.062	0.228	0.417	0.629	0.74	0.871	0.939	0.962	0.984	0.989
2009	0.002	0.008	0.024	0.061	0.154	0.431	0.625	0.784	0.852	0.928	0.965	0.978	0.99
2010	0.002	0.008	0.029	0.072	0.154	0.316	0.639	0.784	0.88	0.917	0.958	0.979	0.986
2011	0.002	0.011	0.031	0.089	0.179	0.313	0.518	0.793	0.88	0.933	0.952	0.975	0.987
2012	0.002	0.01	0.041	0.094	0.22	0.36	0.515	0.7	0.886	0.932	0.961	0.972	0.985
2013	0.002	0.012	0.037	0.129	0.23	0.421	0.567	0.697	0.825	0.936	0.961	0.977	0.983
2014	0.002	0.01	0.046	0.114	0.302	0.435	0.632	0.74	0.823	0.9	0.963	0.977	0.986
2015	0.002	0.011	0.039	0.14	0.273	0.53	0.642	0.786	0.852	0.899	0.943	0.978	0.986
2016	0.002	0.01	0.041	0.121	0.326	0.495	0.727	0.796	0.881	0.916	0.942	0.966	0.986
2017	0.002	0.008	0.038	0.127	0.287	0.562	0.698	0.851	0.887	0.933	0.952	0.966	0.98

2018	0.002	0.008	0.031	0.115	0.299	0.513	0.749	0.832	0.919	0.937	0.962	0.972	0.979
2019	0.002	0.007	0.028	0.095	0.276	0.527	0.71	0.865	0.908	0.955	0.963	0.977	0.983
2020	NA	0.007	0.027	0.086	0.233	0.498	0.725	0.842	0.927	0.949	0.974	0.978	0.986
2021	NA	NA	0.026	0.08	0.211	0.438	0.701	0.849	0.914	0.959	0.971	0.984	0.987

3. Final assesment input

3.1 Stock weight at age

The smoothed stock weight age calculated from the NORU winter survey was adjusted using an age specific ratio to account for the lack of the Russian demersal survey for ages 3-11. No adjustments were used for ages 12 and 13 (Table 4).

Table 4 Stock weight at age to assessment, table 2 smoothed weight at age from the NORU winter survey data were adjusted by dividing by an age specific ratio to account for lack of Russian survey (top row in red)

year	3	4	5	6	7	8	9	10	11	12	13
Ratio	0.939	0.952	0.957	0.962	0.967	0.968	0.967	0.96	0.953	1	1
1994	0.25	0.502	0.936	1.646	2.17	2.713	2.866	2.817	2.978	3.64	4.181
1995	0.261	0.465	0.795	1.311	2.113	2.633	3.166	3.295	3.228	3.163	3.955
1996	0.278	0.485	0.744	1.132	1.714	2.568	3.092	3.61	3.719	3.419	3.481
1997	0.343	0.512	0.766	1.06	1.49	2.122	3.021	3.546	4.044	3.887	3.738
1998	0.343	0.622	0.813	1.096	1.412	1.873	2.546	3.466	3.957	4.181	4.199
1999	0.363	0.627	0.97	1.154	1.447	1.772	2.263	2.956	3.888	4.111	4.49
2000	0.293	0.657	0.976	1.36	1.517	1.822	2.147	2.655	3.365	4.059	4.416
2001	0.301	0.538	1.023	1.36	1.774	1.905	2.205	2.539	3.05	3.56	4.361
2002	0.273	0.556	0.848	1.428	1.774	2.191	2.299	2.603	2.921	3.252	3.871
2003	0.248	0.502	0.873	1.2	1.844	2.191	2.61	2.695	2.993	3.119	3.56
2004	0.283	0.461	0.795	1.238	1.572	2.284	2.623	3.043	3.093	3.178	3.434
2005	0.283	0.528	0.732	1.132	1.618	1.968	2.702	3.043	3.444	3.282	3.497
2006	0.293	0.524	0.831	1.053	1.49	2.023	2.371	3.145	3.46	3.624	3.608
2007	0.219	0.542	0.831	1.177	1.395	1.873	2.432	2.776	3.555	3.64	3.938
2008	0.219	0.415	0.855	1.177	1.553	1.761	2.263	2.845	3.168	3.738	3.955
2009	0.248	0.411	0.664	1.207	1.544	1.936	2.135	2.669	3.242	3.373	4.041
2010	0.286	0.461	0.664	0.957	1.581	1.936	2.335	2.526	3.05	3.434	3.689
2011	0.295	0.528	0.732	0.951	1.279	1.979	2.335	2.749	2.908	3.252	3.754
2012	0.366	0.546	0.836	1.053	1.271	1.626	2.383	2.735	3.137	3.105	3.56
2013	0.339	0.667	0.861	1.184	1.395	1.617	1.981	2.79	3.137	3.327	3.419
2014	0.391	0.617	1.03	1.215	1.563	1.761	1.97	2.352	3.183	3.327	3.64
2015	0.353	0.704	0.962	1.437	1.59	1.946	2.135	2.34	2.728	3.373	3.64
2016	0.363	0.642	1.087	1.351	1.865	1.99	2.346	2.513	2.715	2.921	3.689
2017	0.343	0.662	0.996	1.516	1.763	2.296	2.395	2.749	2.908	2.907	3.237
2018	0.298	0.622	1.023	1.394	1.948	2.179	2.729	2.803	3.153	3.105	3.222
2019	0.278	0.55	0.97	1.428	1.804	2.393	2.597	3.159	3.197	3.342	3.419
2020	0.266	0.516	0.866	1.36	1.854	2.238	2.838	3.028	3.572	3.388	3.656
2021	0.259	0.494	0.813	1.222	1.774	2.284	2.663	3.279	3.444	3.754	3.705

3.2 Maturity ogives

The smoothed proportion mature at age calculated from the NORU winter survey was adjusted using an age specific ratio to account for the lack of the Russian demersal survey for ages 3-10. The proportion mature at ages 11-13 was assumed to be 1 (Table 5).

Table 5 Proportion mature at age used as input to assessment, table 3 smoothed proportion mature ate age estimated from the NORU winter survey were adjusted by dividing by an age specific ratio to account for lack of Russian survey (top row in red). Following the stock annex, the proportion spawners for ages > 10 was assumed to 1.

year	3	4	5	6	7	8	9	10	11	12	13
Ratio	0.898	0.985	0.998	0.973	0.954	0.958	0.97	0.98	1	1	1
1994	0.028	0.083	0.263	0.627	0.838	0.941	0.958	0.957	1.000	1.000	1.000
1995	0.029	0.074	0.204	0.49	0.825	0.932	0.975	0.98	1.000	1.000	1.000
1996	0.031	0.079	0.184	0.408	0.716	0.925	0.972	0.99	1.000	1.000	1.000
1997	0.042	0.086	0.192	0.373	0.634	0.858	0.968	0.988	1.000	1.000	1.000
1998	0.042	0.117	0.211	0.391	0.602	0.803	0.931	0.986	1.000	1.000	1.000
1999	0.046	0.119	0.277	0.418	0.616	0.776	0.898	0.964	1.000	1.000	1.000
2000	0.033	0.128	0.279	0.512	0.645	0.789	0.88	0.946	1.000	1.000	1.000
2001	0.035	0.092	0.3	0.512	0.735	0.81	0.889	0.937	1.000	1.000	1.000
2002	0.03	0.097	0.225	0.542	0.735	0.871	0.902	0.942	1.000	1.000	1.000
2003	0.027	0.083	0.235	0.44	0.757	0.871	0.937	0.949	1.000	1.000	1.000
2004	0.032	0.073	0.204	0.457	0.666	0.886	0.938	0.969	1.000	1.000	1.000
2005	0.032	0.09	0.179	0.408	0.683	0.826	0.945	0.969	1.000	1.000	1.000
2006	0.033	0.089	0.218	0.37	0.634	0.837	0.911	0.973	1.000	1.000	1.000
2007	0.023	0.094	0.218	0.429	0.594	0.803	0.919	0.954	1.000	1.000	1.000
2008	0.023	0.063	0.228	0.429	0.659	0.772	0.898	0.958	1.000	1.000	1.000
2009	0.027	0.062	0.154	0.443	0.655	0.818	0.878	0.947	1.000	1.000	1.000
2010	0.032	0.073	0.154	0.325	0.67	0.818	0.907	0.936	1.000	1.000	1.000
2011	0.035	0.09	0.179	0.322	0.543	0.828	0.907	0.952	1.000	1.000	1.000
2012	0.046	0.095	0.22	0.37	0.54	0.731	0.913	0.951	1.000	1.000	1.000
2013	0.041	0.131	0.23	0.433	0.594	0.728	0.851	0.955	1.000	1.000	1.000
2014	0.051	0.116	0.303	0.447	0.662	0.772	0.848	0.918	1.000	1.000	1.000
2015	0.043	0.142	0.274	0.545	0.673	0.82	0.878	0.917	1.000	1.000	1.000
2016	0.046	0.123	0.327	0.509	0.762	0.831	0.908	0.935	1.000	1.000	1.000
2017	0.042	0.129	0.288	0.578	0.732	0.888	0.914	0.952	1.000	1.000	1.000
2018	0.035	0.117	0.3	0.527	0.785	0.868	0.947	0.956	1.000	1.000	1.000
2019	0.031	0.096	0.277	0.542	0.744	0.903	0.936	0.974	1.000	1.000	1.000
2020	0.03	0.087	0.233	0.512	0.76	0.879	0.956	0.968	1.000	1.000	1.000
2021	0.029	0.081	0.211	0.45	0.735	0.886	0.942	0.979	1	1	1

4 Input to short term forecasts

4.1 stock age at weight

Table 5. Input to short term predictions, length estimated from eq. 1 fitted to the NORU winter survey data (Appendix table 2) including the cohorts 2009-2018. Weight are calculated used the coefficients estimated from eq. 2, shown in figure 2. The estimates are then adjusted to account for lack of Russian data with an age specific ratio (red).

year	3	4	5	6	7	8	9	10	11	12	13
Ratio	0.939	0.952	0.957	0.962	0.967	0.968	0.967	0.96	0.953	1	1
2022	NA	0.481	0.784	1.154	1.609	2.191	2.716	3.085	3.686	3.624	4.059
2023	NA	NA	0.766	1.117	1.526	2	2.61	3.145	3.507	3.854	3.938

4.2 Maturity ogive

Table 6. Input to short term predictions, length estimated from eq. 1 fitted to the NORU winter survey data (Appendix table 2) including the cohorts 2009-2018. Proportions mature are calculated used the coefficients estimated from eq. 3, shown in figure 3. The estimates are then adjusted to account for lack of Russian data with an age specific ratio (red). Following the stock annex the proportion spawners ages > 10 is assumed to be 1.

year	3	4	5	6	7	8	9	10	11	12	13
Ratio	0.898	0.985	0.998	0.973	0.954	0.958	0.97	0.98	1	1	1
2022	NA	0.078	0.199	0.418	0.679	0.871	0.946	0.971	1	1	1
2023	NA	NA	0.192	0.401	0.649	0.833	0.937	0.973	1	1	1

5. References.

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Appendix 1. Empirical estimates

Appendix 1 Table 1 Number of individuals aged by year and ages 1-13.

year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age 13
1994	212	192	250	432	219	40	4	5	8	5	13	1	0
1995	289	177	131	241	543	156	15	1	2	1	0	5	1
1996	225	236	155	106	228	343	52	9	0	1	0	2	1
1997	169	62	147	86	44	113	163	19	4	0	0	0	2
1998	151	178	68	147	74	38	73	112	12	1	1	0	0
1999	251	112	238	81	98	44	19	23	24	1	0	1	0
2000	327	321	138	344	64	72	16	3	20	9	2	1	1
2001	388	339	430	99	315	26	23	3	3	3	8	1	2
2002	445	354	382	450	84	123	19	7	1	2	5	3	2
2003	376	234	154	268	298	42	32	5	3	3	3	1	1
2004	303	464	254	232	277	251	50	22	7	4	3	1	2
2005	487	263	437	247	189	284	125	4	4	1	0	0	0
2006	458	516	141	356	166	108	104	45	4	2	0	2	0
2007	422	404	372	116	257	107	51	34	15	4	2	0	0
2008	317	525	584	470	168	237	46	23	8	1	2	1	0
2009	298	318	562	488	473	114	78	13	2	5	0	1	0
2010	448	190	272	519	462	294	41	19	8	7	2	2	0
2011	337	394	123	205	494	440	159	15	3	0	0	2	1
2012	355	112	338	58	116	408	291	73	4	6	1	3	0
2013	176	377	134	328	56	75	286	204	35	3	0	0	0
2014	449	116	455	98	202	57	96	202	90	11	4	0	0
2015	429	371	88	524	81	160	43	110	123	55	6	3	1
2016	430	282	430	99	452	88	126	87	175	129	39	6	0
2017	449	385	250	294	43	236	54	62	21	68	48	26	3
2018	704	696	596	372	424	62	160	45	44	35	56	48	19
2019	643	628	677	485	210	185	39	45	14	24	7	12	8
2020	219	359	498	622	339	141	80	22	16	10	8	13	15
2021	439	68	244	373	501	172	51	19	5	5	4	3	6

Appendix 1 Table 2 Weighted mean length at age years 1994 -2021. Ages 1-13, Fall et al (in prep)

year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age 13
1994	14.8	21.2	29.9	38.9	48.5	54.9	60	64.9	70.1	65.6	64.5	72	NA
1995	15.1	20.9	28.3	34.7	43.8	51.8	58.5	60	67.2	68	NA	64.5	79
1996	15.7	21.8	28.5	36.3	40.6	47	53.7	58.1	NA	76	NA	74	75
1997	16.1	20.1	27.8	34.2	39.1	47.3	50.7	53.6	62.8	NA	NA	NA	75.5
1998	14.6	23.5	29.5	37.8	43.6	48.1	52.1	53.6	58.5	70	65	NA	NA
1999	15	21.2	32.2	38.5	46.3	52	55.9	55.9	58.8	62	NA	72	NA
2000	15.8	23.3	30.5	42	47.3	51.1	53.3	58.9	59.9	62.5	63.1	63	77
2001	15	22.4	32.3	38.4	48.8	50.6	59.9	55.4	64.1	67	67	51	66.4
2002	15.3	21.8	29.5	40.3	46.8	52.5	58.4	61	62	61.6	64.3	67.7	70.1
2003	16.1	23.9	26.5	38.2	46.5	50	54.1	61.2	62.6	60.3	66.5	70	61
2004	14.2	22.5	30.9	36.1	43	49.8	49.9	58.6	62.8	73.6	75.9	65	70.1
2005	15.1	23	30.3	36.8	40.8	48.6	51.9	57.4	60.8	67	NA	NA	NA
2006	14.7	23.3	30.9	38.2	43.1	47.7	50.9	57.5	60.4	69.9	NA	65.6	NA
2007	15.7	23.1	29.5	35.6	46.2	48.5	54.2	58.2	57.9	69.4	63.7	NA	NA
2008	15.8	23.9	30.4	38.5	43.7	45.7	53.6	52.8	58.5	59	63.3	63	NA
2009	14.4	22.7	29.3	36.1	42.4	48.9	49.3	56.7	65.3	62.3	NA	62	NA
2010	14.7	22.1	30.4	37.1	41.9	46.3	49.8	58.2	60.2	63.1	58.9	66.5	NA
2011	13.9	23.7	28.6	39.2	43	46.2	49.1	63.4	52.1	NA	NA	63.3	63
2012	15.4	19.4	32.1	35.7	43.7	47.1	50.6	51	49.9	65.5	67	72	NA
2013	14.5	23.8	30.6	41	43.2	49.1	52.5	53.1	56.4	67.3	NA	NA	NA
2014	15.4	19.7	32.5	36.6	45.9	50.8	53.9	55.3	55.8	59.3	60.8	NA	NA
2015	14.7	21.7	29.3	39.9	44.7	52.7	53	57.7	57.4	61	60.2	67.3	67
2016	15.6	21.3	31.5	35.7	47.9	53.1	56.2	59.4	61.5	61.1	60.3	65.9	NA
2017	16.3	22.9	31	40	49.2	53.3	56.3	60.9	61.4	63	62.8	63.7	69
2018	15	22.9	31.1	40.3	48	54.8	58.4	61.5	64.6	65	64.8	64.4	66.5
2019	15.1	22.5	30.1	37.8	46.7	52.8	53.9	60.8	64.4	65.9	68	67.7	69.8
2020	15	21.8	29.8	36.4	43.4	52.6	57.8	62	64.1	67.4	69.7	67.9	69
2021	14.32	19.23	29.10	36.06	42.86	49.61	55.35	59.60	66.65	69.50	73.29	71.68	72.09

Appendix 1 Table 3 Weighted mean weight (grams) Ages 1-13. Fall et al in prep.

year	1	2	3	4	5	6	7	8	9	10	11	12	13
1994	25	88	253	562	1092	1628	2080	2776	3386	2769	2685	3890	NA
1995	28	82	214	408	822	1345	1918	2070	2685	2905	NA	2483	3972
1996	31	95	216	474	669	1020	1920	1768	NA	4630	NA	4018	3626
1997	35	75	204	380	610	1048	1300	1507	2504	NA	NA	NA	3719
1998	27	119	249	544	861	1155	1416	1572	2017	3740	3040	NA	NA
1999	30	92	334	570	1018	1420	1756	1728	2013	2440	NA	3525	NA
2000	32	118	275	736	1042	1356	1546	2116	2209	2636	2709	1940	4440
2001	29	106	342	594	1192	1344	2191	1890	2905	3110	2966	1285	2898
2002	29	91	242	628	968	1429	1946	2178	2800	2381	2659	3258	3491
2003	36	123	183	532	970	1207	1480	1933	2479	2531	3055	3470	2290
2004	23	100	272	461	752	1162	1211	1966	2611	3926	4184	2800	2619
2005	29	116	262	471	666	1096	1372	1977	2120	2730	NA	NA	NA
2006	26	114	297	557	810	1084	1358	1917	2102	3991	NA	2959	NA
2007	32	110	253	487	1027	1196	1720	2059	2291	3555	3211	NA	NA
2008	33	115	250	570	852	1083	1587	1418	2147	1577	2280	2840	NA
2009	26	100	224	450	762	1152	1274	1726	2377	2563	NA	2594	NA
2010	28	100	273	478	708	981	1230	1867	2247	2541	2065	3189	NA
2011	21	120	220	529	731	942	1177	2314	1520	NA	NA	2258	2805
2012	30	69	310	449	829	1019	1284	1296	1204	2734	2980	3264	NA
2013	25	118	266	652	795	1139	1357	1497	1847	3099	NA	NA	NA
2014	30	65	359	506	970	1345	1576	1686	1751	2009	2275	NA	NA
2015	23	90	234	595	840	1430	1494	1922	1864	2160	2284	3114	2630
2016	29	85	289	448	1056	1473	1746	2073	2279	2271	2369	2951	NA
2017	34	107	294	629	1228	1542	1800	2278	2402	2660	2633	2763	3369
2018	27	101	279	632	1060	1667	1994	2288	2715	2758	2773	2670	3097
2019	25	94	244	521	986	1428	1564	2087	2762	2941	3135	3245	3489
2020	28	88	245	457	809	1392	1864	2423	2653	2811	3381	3007	3365
2021	27	83	205	445	741	1196	1615	2092	3190	3150	3852	3550	3879

Appendix 1 Table 4. Proportion mature by age (stage 2,3 versus 1,4,5). From Fall et al In prep.

year	1	2	3	4	5	6	7	8	9	10	11	12	13
1994	0	0	0	0.012	0.124	0.387	0.451	1	0.907	0.637	0.581	1	NA
1995	0	0	0.001	0.047	0.239	0.416	0.47	1	1	0	NA	0.852	0
1996	0	0	0.01	0.022	0.316	0.282	0.281	0.798	NA	1	NA	1	0
1997	0	0	0.001	0.006	0.113	0.303	0.682	0.146	0.791	NA	NA	NA	0.424
1998	0.003	0	0	0.049	0.144	0.483	0.481	0.789	0.974	1	1	NA	NA
1999	0	0	0.001	0.052	0.241	0.307	0.781	0.788	0.978	1	NA	0	NA
2000	0	0	0	0.195	0.481	0.662	0.664	1	0.917	0.87	1	1	0
2001	0	0	0	0.099	0.458	0.345	0.881	1	1	0.735	1	0	1
2002	0	0	0.006	0.092	0.416	0.671	0.969	0.936	NA	0	0.885	1	0
2003	0	0.002	0	0.042	0.388	0.544	0.601	0.323	0.513	0.916	1	1	1
2004	0	0.001	0.011	0.019	0.133	0.673	0.475	0.416	0.855	1	1	1	0
2005	0	0	0.004	0.03	0.278	0.556	0.74	0.116	1	1	NA	NA	NA
2006	0	0	0	0.074	0.358	0.544	0.83	0.862	0.665	1	NA	1	NA
2007	0	0	0.021	0.16	0.447	0.652	0.819	0.938	0.922	1	1	NA	NA
2008	0	0.012	0.004	0.106	0.404	0.444	0.85	0.944	1	1	0.253	1	NA
2009	0	0	0	0.037	0.167	0.263	0.758	0.726	0	0.714	NA	1	NA
2010	0	0	0.047	0.1	0.229	0.443	0.633	0.795	0.886	0.942	1	1	NA
2011	0	0	0.001	0.054	0.117	0.419	0.353	0.436	0.987	NA	NA	1	1
2012	0	0	0.013	0.078	0.379	0.487	0.55	0.706	0.038	1	1	0.477	NA
2013	0	0	0.009	0.066	0.154	0.501	0.713	0.735	0.671	1	NA	NA	NA
2014	0	0.008	0.1	0.114	0.349	0.674	0.757	0.846	0.801	1	1	NA	NA
2015	0	0.002	0.017	0.032	0.063	0.461	0.574	0.677	0.423	0.582	1	0.696	1
2016	0	0.001	0.002	0.009	0.316	0.722	0.856	0.764	0.908	0.846	0.958	1	NA
2017	0	0	0.005	0.072	0.401	0.606	0.719	0.982	0.9	0.98	0.996	1	1
2018	0	0	0.003	0.085	0.32	0.617	0.858	0.759	0.881	0.763	0.892	0.93	0.951
2019	0	0	0.005	0.044	0.136	0.553	0.664	0.776	0.966	0.984	1	1	1
2020	0	0	0.01	0.019	0.162	0.539	0.745	0.902	0.912	0.716	1	1	0.925
2021	0.00	0.00	0.00	0.06	0.14	0.47	0.63	0.76	0.80	1.00	1.00	0.86	0.89

Appendix table 5. Number of individuals in different maturity stages 1=immature, 2=maturing, 3= spawning, 4= spent/skipping, 5= uncertain between 1 and 4.

Age	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
1	223	0	0	0	0
2	202	0	0	0	0
3	2242	1	0	0	0
4	3311	220	0	94	0
5	2949	762	0	1642	10
6	186	293	0	144	4
7	11	82	0	35	2
8	3	19	0	3	0
9	0	4	0	1	0
10	0	5	0	0	0
11	0	4	0	0	0
12	0	6	0	1	0
13	0	8	0	1	0
14	1	1	0	0	0
16	0	3	0	0	0

Appendix 2. Weighted length at age data from the winter survey,taken from table B6 in ICES 2019.

Age/ Year	Age1	Age2	Age3	Age4	Age5	Age6	*Age7*	*Age8*
1983	16.8	25.2	34.9	44.7	52.5	58.0	*62.4*	*65.1*
1984	16.6	27.5	32.7	-	56.6	62.4	*61.8*	*66.2*
1985	15.7	23.9	35.6	41.9	58.5	61.9	*63.9*	*67.6*
1986	15.1	22.4	31.5	43.0	54.6	-	-	-
1987	15.4	22.4	29.2	37.3	46.5	-	-	-
1988	13.5	24.0	28.7	34.7	41.5	47.9	*54.6*	-
1989	16.0	23.2	31.1	36.5	41.7	46.4	*52.9*	*57.6*
1990	15.7	24.7	32.7	43.4	46.1	50.1	*52.4*	*55.7*
1991	16.8	24.0	35.7	44.4	52.4	54.8	*55.6*	*55.9*
1992	15.1	23.9	33.9	45.5	53.1	59.2	*60.6*	*60.5*
1993	14.5	21.4	31.8	42.4	50.6	56.1	*59.4*	*64.2*

Working Document Submitted to AFWG 2021 WD_15

Per 15.04.21

Effort and catch-per-unit-effort (CPUE) for Norwegian trawlers fishing haddock north of 67˚N in 2011-2020

by

Håkon Otterå and Kjell Nedreaas

Inst. of Marine Res., PB-1870, N-5817 Bergen, Norway

Catches from log-book data per year.

All hauls with haddock:

Year	Round weight (kg)
2011	73 515 329
2012	66 542 202
2013	35 766 702
2014	31 543 607
2015	34 825 619
2016	43 433 989
2017	53 318 829
2018	38 609 193
2019	37 267 403
2020	31 971 439

Hauls with haddock as the main species:

Year	Round weight (kg)
2011	57 714 034
2012	57 608 472
2013	24 621 524
2014	21 158 086
2015	22 608 593
2016	29 420 251
2017	40 526 554
2018	26 118 924
2019	26 663 470
2020	21 632 361

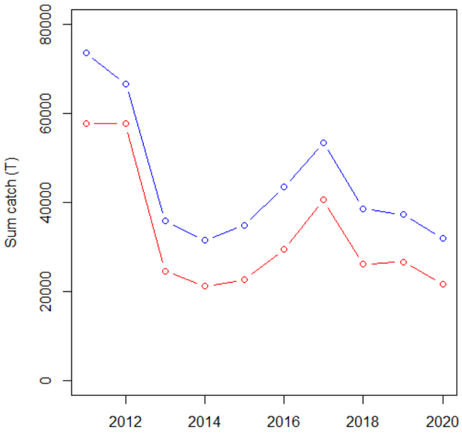

Figure 1. Sum of reported catches from log-book data per year. Blue line represents all catches of hdddock (bottom-trawl, latitude>67°N, longitude > 3 °E, duration > 10 min). Red line has reported haddock as the main species in the catch (species with largest catch biomass).

Only hauls where HADDOCK=MAIN SPECIES (i.e. >50% catch biomass per haul) used in the rest of the analysis

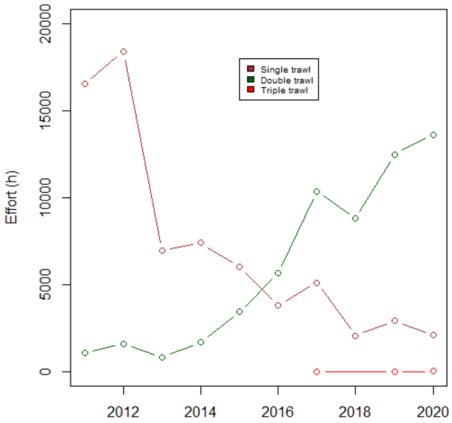

Figure 2. The use (number trawl hours) of single- (brown line), double- (green line) and trippel trawl (red line) in the Norwegian trawl fishery catching haddock. Only hauls where HADDOCK=MAIN SPECIES (i.e. >50% catch biomass per haul) are included in this figure.

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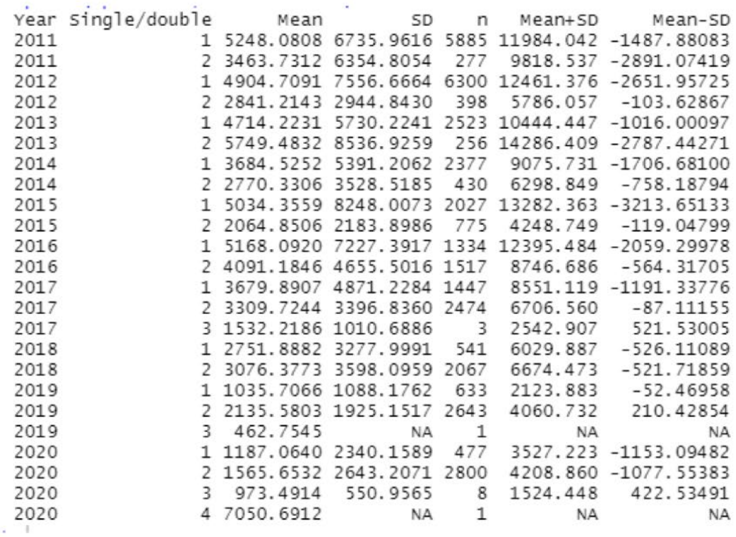

```
Year Single/double      Mean        SD    n   Mean+SD      Mean-SD
2011               1 5248.0808 6735.9616 5885 11984.042 -1487.88083
2011               2 3463.7312 6354.8054  277  9818.537 -2891.07419
2012               1 4904.7091 7556.6664 6300 12461.376 -2651.95725
2012               2 2841.2143 2944.8430  398  5786.057  -103.62867
2013               1 4714.2231 5730.2241 2523 10444.447 -1016.00097
2013               2 5749.4832 8536.9259  256 14286.409 -2787.44271
2014               1 3684.5252 5391.2062 2377  9075.731 -1706.68100
2014               2 2770.3306 3528.5185  430  6298.849  -758.18794
2015               1 5034.3559 8248.0073 2027 13282.363 -3213.65133
2015               2 2064.8506 2183.8986  775  4248.749  -119.04799
2016               1 5168.0920 7227.3917 1334 12395.484 -2059.29978
2016               2 4091.1846 4655.5016 1517  8746.686  -564.31705
2017               1 3679.8907 4871.2284 1447  8551.119 -1191.33776
2017               2 3309.7244 3396.8360 2474  6706.560   -87.11155
2017               3 1532.2186 1010.6886    3  2542.907   521.53005
2018               1 2751.8882 3277.9991  541  6029.887  -526.11089
2018               2 3076.3773 3598.0959 2067  6674.473  -521.71859
2019               1 1035.7066 1088.1762  633  2123.883   -52.46958
2019               2 2135.5803 1925.1517 2643  4060.732   210.42854
2019               3  462.7545        NA    1        NA          NA
2020               1 1187.0640 2340.1589  477  3527.223 -1153.09482
2020               2 1565.6532 2643.2071 2800  4208.860 -1077.55383
2020               3  973.4914  550.9565    8  1524.448   422.53491
2020               4 7050.6912        NA    1        NA          NA
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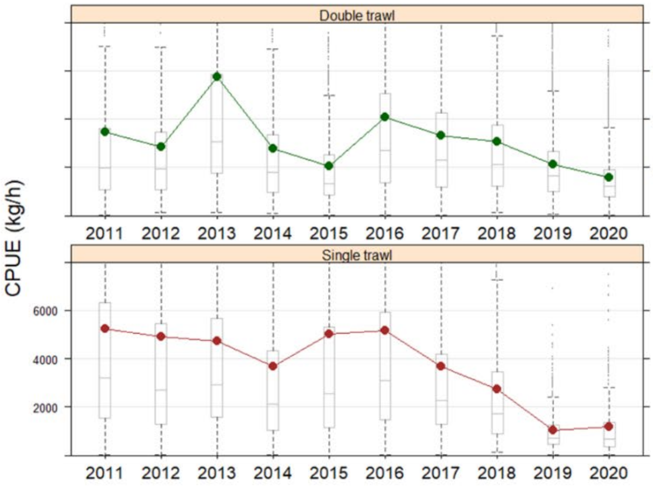

Figure 3. Box and whisker plot. Median and mean (dot/line) and 25, 75 percentiles. The table above the figure shows the data presented in the figure.

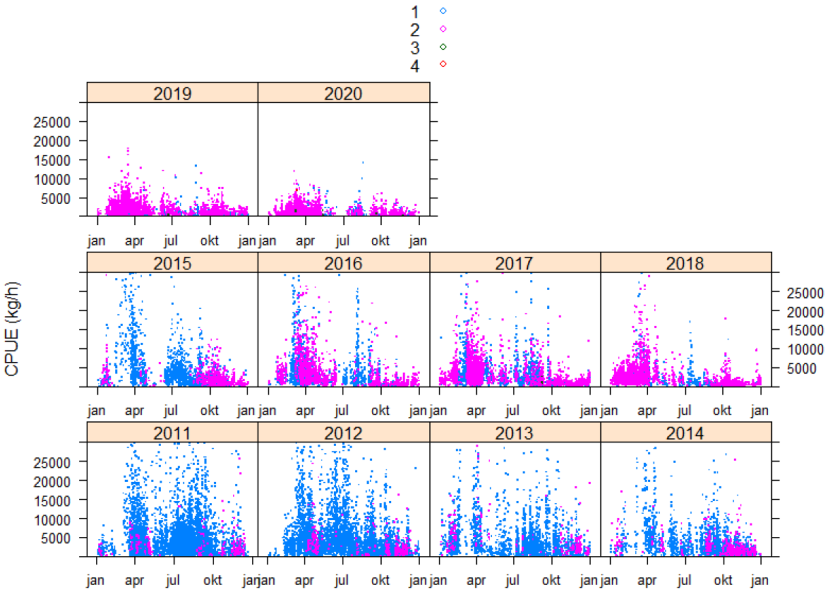

Figure 4. Seasonal distribution of single haul CPUE for single trawl (1), double trawl (2), triple trawl (3) and undefined trawl (4). Note that there is only 12 observations with triple trawl and 1 observation with undefined trawl.

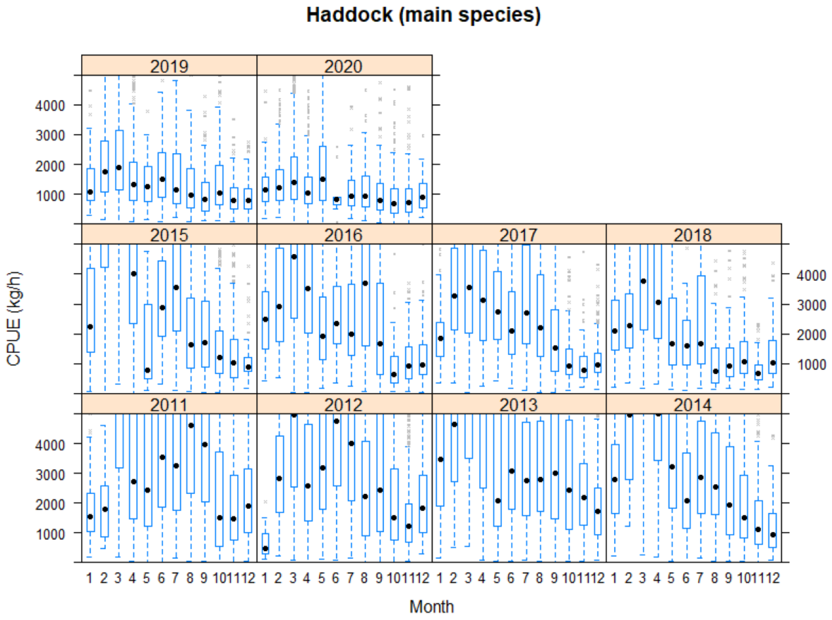

Figure 5. Box and whisker plots showing median values and 25, 75 percentiles of CPUE per year and month. All trawl types included, and only hauls where haddock was the main species.

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Estimating the status of anglerfish (*Lophius piscatorius*) in the north of 62°N management unit (ICES Subareas 1 and 2) using life-history ratios, length compositions, and CPUE data

by
Kotaro Ono, Sofie Gundersen and Kjell Nedreaas

Institute of Marine Research, PB-1870, N-5817 Bergen, Norway

Keywords: anglerfish, *Lophius piscatorius*, assessment, data limited, CPUE, LBSPR, JABBA

Introduction

Our present knowledge about anglerfish (*Lophius* spp.) in ICES Subareas 1 and 2 is based on two master theses (Staalesen 1995 and Dyb 2003), a report from a Nordic project (Thangstad et al. 2006), working documents to the ICES ASC, WGNSDS and WGCSE, and more recent catch data collected by the Norwegian Reference Fleet since 2006 (Anon. 2013). In February 2018, the anglerfish in ICES Subareas 1 and 2 was subject for a benchmark assessment (WKAngler 2018).

The WKAngler (2018) assumed most recruitment to the anglerfish population in Subarea 1 and 2 is from the more southerly stock unit. The validation of this hypothesis requires further R&D work in collaboration with ICES 3a46 looking at egg and larval dispersion and transportation as well as tagging and genetic studies. To address, stock structure, mixing rates, and growth estimates, WKAngler (2018) recommends a tagging program coordinated between all countries harvesting *Lophius*. Until there is more clarity in the true biological stock structure, WKAngler (2018) recommends keeping the anglerfish in Subareas 1 and 2 as a separate management unit.

A direct gillnet fishery, with large-meshed gillnets specially designed for anglerfish (*L. piscatorius*) started in autumn 1992 on the continental shelf in ICES Division 2a off the northwestern coast of Norway (Norwegian statistical area 07). The anglerfish had previously only been taken as bycatch in trawls and gillnets. Until 2010-2011 there was a geographical expansion of the fishery. The Norwegian management objective for the anglerfish in Norwegian waters is maximally sustainable long-term yield (Gullestad et al. 2017). The national harvest objective favors the large-meshed coastal and small-scaled gillnet fisheries, with stronger regulations on anglerfish bycatch in other fisheries (e.g., trawl, shrimp trawl and Danish seine).

At present, anglerfish in ICES Subareas 1 and 2 falls into ICES Category 3 – stocks for which landings and/or catch and reliable stock size indicator(s) exist. Includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass. (ICES 2018).

There are currently four methods approved by ICES for calculation of MSY reference points for category 3 and 4 stocks. These are:

- Length based indicators (LBI)
- Mean length Z (MLZ)
- Length based spawning potential ratio (LBSPR)
- Surplus Production model in Continuous Time (SPiCT).

The SPiCT method was tested by WKAngler (2018) on anglerfish in Subareas 3, 4 and 6, and was considered not suitable and not recommended to be used for either these subareas or Subareas 1 and 2. Work has hence been done to investigate the usefulness of the other methods, with LBSPR being of particular interest because it uses length composition data more fully than either MLZ and LBI.

The Norwegian Reference Fleet is a group of active fishing vessels tasked with providing information about catches (self-sampling) and general fishing activity to the Institute of Marine Research. The fleet consists of both high-seas and coastal vessels that cover most of Norwegian waters. The High-seas Reference Fleet began in 2000 and was expanded to include coastal vessels in 2005 (e.g., Clegg and Williams 2020).

Based on preliminary analyses and yield-per-recruit (Y/R) estimations done back in 2006 (Thangstad et al. 2006), the fishing mortality in Norwegian waters at that time seemed to be too high to ensure a maximally sustainable long-term yield. The large-meshed gillnets, however, gave a significant higher maximum Y/R than smaller-meshed gillnets or trawl, i.e., the net growth potential of the species was better utilized. This has been reported in previous reports from the Arctic Fisheries WG (e.g., ICES 2019). The fishing mortality was estimated from catch curves (assuming M=0.15), and the exploitation pattern by combining N_i and C_i equations from the fishery population dynamics (Thangstad et al. 2006). These Y/R estimations were preliminary and uncertain, and indicative rather than accurate, i.e., since available anglerfish catch-at-age data were too limited to follow a cohort through the fishery; the age distribution of catches from one particular year (2002) was instead used to represent a single cohort's development.

In this Working Document we report on the data that were collected for the analysis and the approaches we used to determine the status of the anglerfish in ICES subareas 1 and 2.

Material

Landings data

The official landings as reported to ICES for Subareas 1 and 2 for each country are shown in Table 1. Landings decreased rapidly from 2011 to 2015, to the lowest since 1997, but has since shown an increase. Norway has by far the largest reported catches of the anglerfish in Subareas 1 and 2, accounting for more than 96-99% of the official international landings. The coastal gillnetting accounts for more than 90% of the landings, of which about 90% is caught by the special designed large-meshed gillnets (360 mm stretched meshes).

Table 1. Nominal catch (t) of Anglerfish in ICES Subareas I and II, 2008-2020, as officially reported to ICES.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020*
Denmark	-	+	-	-	-	-	-	-	-	-	-	-	-
Faroes	4	2	1	+	+	1	+	+	1	1	+	+	1
France	-	-	-	1	3	2	-	4	2	4	3	8	5
Germany	0	+	82	70	0	-	+	+	+	1	1	50	-
Iceland	-	-	-	7	-	-	-	-	-	-	-	-	-
Norway	4007	4298	5391	5031	3758	2988	1655	933	1355	1473	1884	2750	2258
Portugal	2	6	1	+	-	-	-	-	-	-	-	-	-
UK	138	152	40	3	3	111	2	105	76	5	15	+	16
Others					1	1	-	-	+	-	+	-	-
Total	4151	4458	5515	5112	3765	3103	1657	1043	1435	1484	1903	2809	2280

*Preliminary

The Norwegian coastal reference fleet (see Appendix figure 1) provide us with length measurements and catch per gillnet days from ICES Subareas 2, from 2007–present, and these have been presented for the AFWG in recent years (ICES 2019). The catch rates vary spatially and temporally, and the WKAngler (2018) recommended therefore to model and standardize the catch rates to better represent the general abundance trend of anglerfish in the entire ICES Subarea. The available material is shown in Tables 2 and 3 for the Norwegian statistical coastal areas (Figure 1) and total for ICES Subareas 1 and 2.

The absence of a TAC in Norwegian waters probably reduces the incentive to underreport landings. Berg and Nedreaas (2020) have estimated the annual discards of anglerfish by the Coastal reference fleet in Subareas 1 and 2 to vary between 11 and 32 tons during 2014-2018 (i.e., 1.5-2.5% of total gillnet catch). This discard is not included in the present analyses.

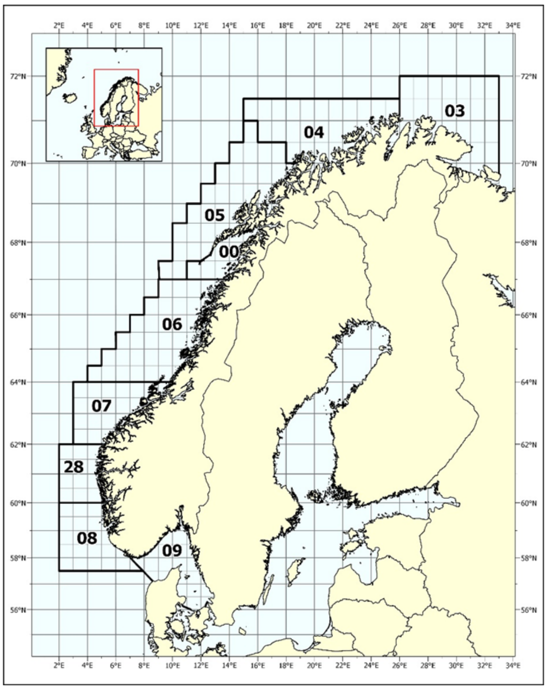

Figure 1. Map showing the Norwegian statistical coastal areas. Area 03 is part of ICES Subarea 1, Areas 04, 05, 00, 06 and 07 are part of ICES Subarea 2, Areas 28 and 08 are part of ICES Subarea 4, and Area 09 corresponds roughly with ICES Subarea 3.

Table 2. Number of Coastal reference fleet fishing days with anglerfish, per national stat. subareas (0-7) and total for ICES Subareas 1 and 2. Only large-meshed gillnets included.

Year/ Area	**0**	**5**	**6**	**7**	**ICES 1 and 2**
2007	106	26		280	412
2008	62	37	6	171	276
2009	86	35	36	176	333
2010	14	41	37	143	235
2011	64	19	51	116	250
2012	49	12	24	21	106
2013	64	20	18	81	183
2014	5		19	107	131
2015	109		5	116	230
2016	92		22	35	149
2017	88			109	197
2018	108			89	197
2019	86	34		63	183
2020	74	28	52	102	256

Table 3. Number of fishing days with length measured anglerfish (left) and number of length measured fish (right). Only large-meshed gillnets included.

Year	ICES 1 and 2a
2007	93
2008	81
2009	81
2010	71
2011	84
2012	39
2013	55
2014	33
2015	74
2016	57
2017	88
2018	94
2019	68
2020	89

Year	ICES 1 and 2a
2007	2530
2008	1922
2009	2574
2010	2199
2011	2869
2012	1318
2013	1551
2014	836
2015	2054
2016	1339
2017	3604
2018	3233
2019	3223
2020	4129

Length composition data

Length distributions of the retained anglerfish (*L. piscatorius*) caught as target species by the specially-designed-large-meshed gillnets, and as bycatch in other gillnets or other gears are shown in Appendix figures 2-4. All subsequent analyses (in the methods and results section) have only used the length distributions from the target fishery using the large-meshed gillnets which represent more than 80% of the international landings.

Catch per unit effort (CPUE) data

The Norwegian coastal reference fleet (see Appendix figure 1) has reported catch per gillnet soaking time (CPUE) from their daily catch operations. For the current modelling and hence standardization of the annual CPUE from Subarea 1 and 2, we have used the following data:

- Only catch rates of retained anglerfish from the fishery using special large-meshed anglerfish gillnets (stretched meshes=360mm)
- Years 2007-2020
- Discards excluded
- Adding zero catches where gillnets are used, but anglerfish not present
- All coastal areas (i.e. ICES 3a, 4a, 2a and 1) included in the model since it is documented (e.g., WKAngler 2018) that anglerfish are migrating across the ICES area borders.

- The area (km^2) of each subarea inside 12 nautical miles (covering most of the anglerfish distribution) are calculated and used as weighing factor when annual CPUEs are estimated for each subarea.

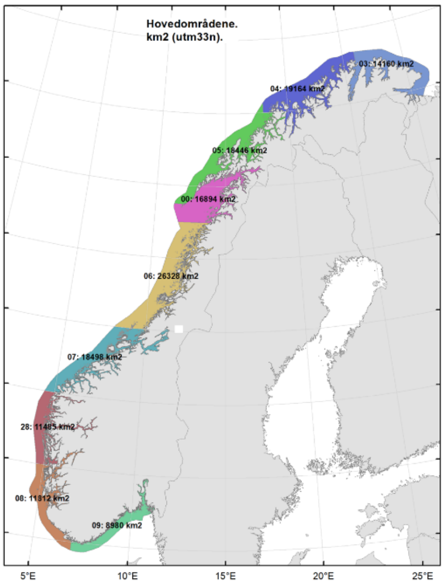

Figure 2. Map showing the area (km^2) of each Norwegian statistical subarea inside 12 nautical miles. The subareas 4, 5, 0, 6, and 7 belong to the ICES Division 2a.

Methods and results

The Length-based-spawning-potential-ratio (LBSPR) approach

The LBSPR method has been developed for data-limited fisheries, where only a few data are available: some representative sample of the size structure of the vulnerable portion of the population (i.e., the catch) and an understanding of the life history of the species (Hordyk et al. 2016). The LBSPR method does not require knowledge of the natural mortality rate (M), but instead uses the ratio of natural mortality and the von Bertalanffy growth coefficient (K) (M/K), which is believed to vary less across stocks and species than M (Prince et al. 2015) though individual estimates of M and K can be used if available. Like any assessment method, the LBSPR model relies on a number of simplifying assumptions. In particular, the model is equilibrium-based, assumes that the length composition data is representative of the exploited population at steady state, and logistic selectivity (see the results section below for more discussion).

The LBSPR model originally developed by Hordyk et al. (2015a, b) used a conventional age-structured equilibrium population model and a size-base selectivity. As a consequence, this approach could not account for "Lee's phenomenon" – the fact that larger specimen at age gets a higher mortality than its cohort of smaller size because of the size-based selectivity. This is because the age-structured model has a 'regeneration assumption' i.e. it redistributes at each time step the length at age using the same distribution. Hordyk et al. (2016) since developed a length-structured version of the LBSPR model that used growth-type-groups (GTG) to account for the above phenomenon and showed that the new approach reduced bias related to the "Lee's phenomenon" (https://github.com/AdrianHordyk/LBSPR). GTG LBSPR is therefore used for all subsequent analyses.

Some of the life history parameters for the analysis were taken from WKAngler (2018). Hordyk et al. (2015a,b) showed that the LBSPR approach was sensitive to the input parameters. We therefore drew 1000 random samples for each input parameter (i.e. from a bivariate normal distribution for Linf and K, an a univariate normal distribution for M, L50, L95 (see Table 4)) and rerun the model in order to account for the effect of uncertainty around the input parameters on the results. We will refer to it as the "stochastic LBSPR approach" hereon.

Table 4. Basic input parameters and parameters for resampling as used for the LBSPR analysis

Basic input parameters	**Value**
Von Bertalanffy K parameter (mean)	0.12
Von Bertalanffy Linf parameter (mean)	146
Von Bertalanffy t0 parameter	-0.34
Length-weight parameter a	0.149
Length-weight parameter b	2.964
Steepness	0.8
Maximum age	25
Length at 50% maturity (L50) (mean)	82
Length at 95% maturity (L95) (mean)	100
ΔMat = L95 - L50 (mean)	18
Length at first capture	40
Length at full selection	60
M (mean)	0.2
M/k (mean)	1.67
Parameters for resampling	
Nsamp	1000
CV(M)	0.15
Cor (Linf_K)	0.9
CV(K)	0.3
CV(Linf)	0.15
CV(L50)	0.05
CV(ΔMat)	0.05

Once the stochastic LBSPR runs were finished, we conducted some simulations through the LBSPR package to calculate some target SPR value. To do this, we used the mean input values from the stochastic LBSPR, the average estimated parameters values (from the stochastic LBSPR approach), and set the "steepness" to a value between 0.7 and 0.9 to perform a YPR analysis and determine the target reference points (which gives the maximum yield). Steepness values between 0.7 and 0.9 was chosen based on a literature search (values close to 1 are also found in the literature but was not included in the test as it seemed unrealistic for the species). The analysis gave a target reference point of SPR=0.4 (with F/M~1) and SPR=0.25 (with F/M~2) and for a steepness value of 0.7 and 0.9, respectively. What we obtained from the stochastic LBSPR runs instead is a relatively stable annual estimates of SPR (between 0.15 and 0.5 (the IQR range)) and F/M (between 1.5 and 2.5) (Figure 4). This would suggest that ¬- while there is a lot of uncertainty - fishing effort is probably slightly above but close to the effort what would lead to maximum yield.

The relationship between the biomass of reproductively mature individuals (spawning stock) and the resulting offspring added to the population (recruitment), the stock recruitment relationship, is a fundamental and challenging problem in all population biology. The steepness of this relationship is the fraction of unfished recruitment obtained when the spawning stock biomass is 20% of its unfished level. Steepness has become widely used in fishery management, where it is usually treated as a statistical quantity. If one has sufficient life history information to construct a density-independent population model then one can derive an associated estimate of steepness (Mace and Doonan 1988, Mangel et al. 2010, 2013).

As mentioned in the introduction, the LBSPR approach is an equilibrium-based method (i.e. assumes that the fishery experiences a constant recruitment and F over time) and violation of this assumption can lead to biased SPR estimates. However, some management strategy evaluation conducted by Hordyk et al. (2015) on harvest control rules based on SPR-based size targets showed that while annual assessments of SPR may be imprecise due to the transitory dynamics of a population's size structure, smoothed trends estimated over several years may provide a robust metric for harvest control rules. SPR estimates in our study were relatively stable, thus large recruitment fluctuations may not be an issue.

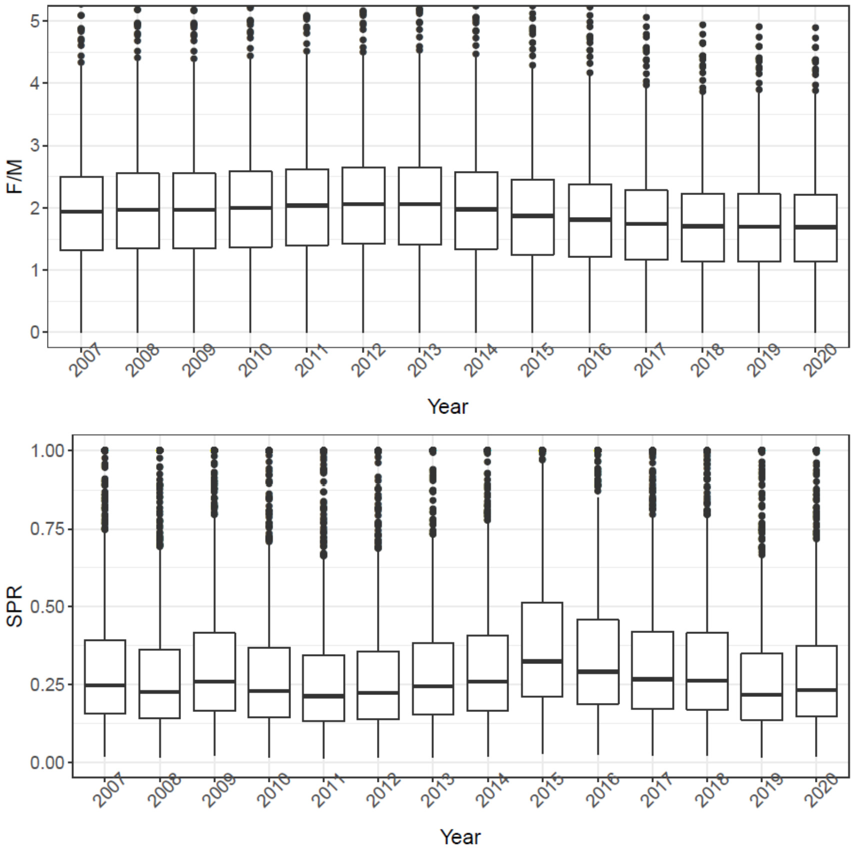

Figure 4. Annual estimates of F/M (above) and SPR (below) from the stochastic LBSPR approach using the length composition data from 2007 to 2020.

CPUE standardization

Raw CPUE data is seldom proportional to population abundance as many factors (e.g. changes in fish distribution, catch efficiency, effort, etc) potentially affect its value. Therefore, CPUE standardization is an important step that attempts to derive an index that tracks relative population dynamics.

In the data preparation step, we quickly noticed that there was not enough data from ICES Subarea 1 to perform model inference. Therefore, we decided to omit data from this Subarea from the analyses. ICES subarea 1 is the northern margin of *L. piscatorius* distribution, and only 3 tons were caught in this area in 2019, mostly as bycatch in other fisheries.

Below, we defined some important terms we used for the CPUE standardization.

Standardized effort (gillnet day) = gear count x soaking time (hours) / 24hours
CPUE (per gillnet day) = catch weight/standardized effort

CPUE standardization was performed using the glmmTMB package (Brooks et al. 2017) and the best model was chosen based on AICc and residuals checks using the DHARMa package (Hartig 2020) i.e. the most parsimonious model had the lowest AICc while showing no problematic residuals pattern (i.e. overdispersion, underdispersion, etc). If problematic residual patterns were found, we tried to address the issue by either reconsidering the input data, changing model parameterization, or changing the model distribution assumption.

The data showed some signs of overdispersion based on residual analysis of simple models (e.g. gaussian, poisson) i.e. the presence of greater variability in the dataset than would be expected based on a given statistical model. The Tweedie distribution was selected as the best model (after model selection) to address this problem. Tweedie distribution belongs to the exponential family and its variance term is modelled as a power function of the mean (μ) i.e. $\phi\mu^{p}$. The power parameter, *p*, is restricted to the interval $1<p<2$. The Tweedie distribution is commonly used for generalized linear models (e.g., Jørgensen 1997).

The best model has the following parametrization (for fixed and random effects):
CPUE = year + subarea + month + (1|vessel) + (1|subarea_year) + (1|month_year) + (1|month_subarea)

The expression (1|vessel) indicates that the vessel effect is considered as a random effect and acts on the intercept. The expression (1|month_year) indicates that the month and year variable was concatenated into a single variable and considered as a random effect. In essence, this treatment models the interaction effect between year and month, but the approach only considers existing interaction (as opposed to all possible combination of year and month which would be un-estimable) – which is an advantage in data-limited situation such as ours.

Further exploration of the residual pattern (more specifically the plot of scaled residual against predictors) indicated some possible issues with the vessel random effect which showed a systematic deviation for some simulated vessel effects (part of the test feature available in DHARMa). These problematic vessels only fished a few times in a single area and time, causing estimation to be less reliable. To address this issue, we filtered the data to keep data from vessels that had more than 5 or 10 observations. Using the 10-minimum-observations criteria greatly improved the residual pattern of the model hence was kept as the final model to produce the standardized annual CPUE index.

The standardized annual CPUE index was created by summing up all predictions based on all possible combination of year (2007-2019), subarea (in ICES area 2a), and month (1-12) after weighting the prediction for each subarea by its surface (in km^2 within the 12 nautical miles as shown in Figure 2) relative to the total surface (sum of all subarea surfaces in the ICES area 2a). In this process, we removed the vessel random effect (assuming it equals 0, the mean value) as it only affects catch efficiency and does not represent the underlying fish abundance. We note that glmmTMB can handle any missing new levels for random effect variables when making prediction (it assumes it is equal to zero and inflates the prediction error by its associated random effect variance). The standard deviation of the summed prediction was directly calculated in glmmTMB by modifying the source code ('glmmTMB.cpp' file).

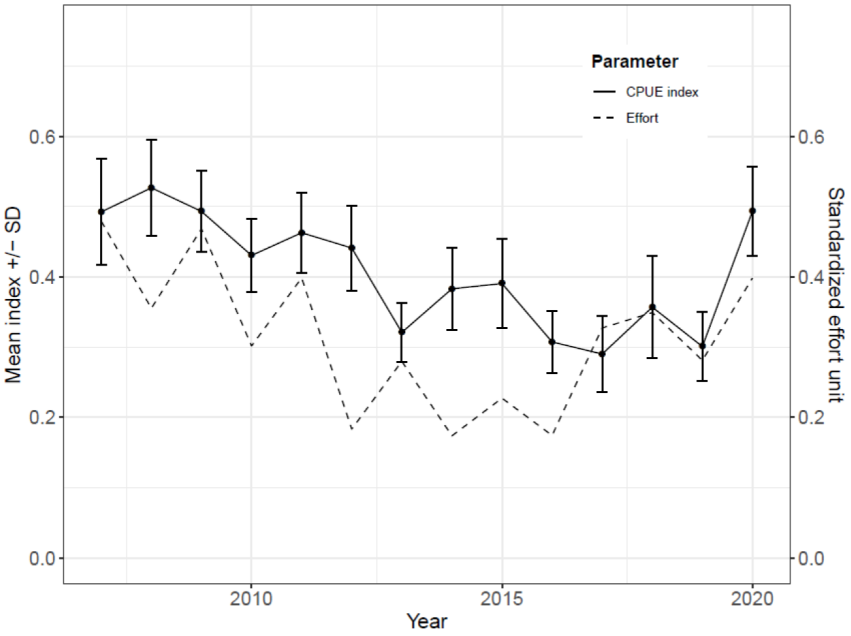

Figure 5. Standardized CPUE (kg per gillnet day) +/- SD (solid black line with error bars) and the corresponding standardized effort (dash line) for anglerfish based on the data from the Norwegian coastal reference fleet in ICES Subarea 2a, from vessels targeting anglerfish with large meshed gillnets.

Figure 5 shows that anglerfish population in ICES Subarea 2a might have declined over the last decade (as well as the raw effort) but could be increasing again in more recent years. Nonetheless, there is a lot of year to year variability and uncertainty around the point estimates.

JABBA

JABBA stands for 'Just Another Bayesian Biomass Assessment' and is an open-source modelling software that can be used for biomass dynamic stock assessment applications. It has emerged from the development of a Bayesian State-Space Surplus Production Model framework applied in stock assessments of sharks, tuna, and billfishes around the world (Winker et al. 2018). JABBA requires a minimum of two input comma-separated value files (.csv) in the form of catch and abundance indices (and SE) (see Appendix table 1). The Catch input file contains the time series of year and catch by weight, aggregated across fleets for the entire fishery. Missing catch years or catch values are not allowed. JABBA is formulated to accommodate abundance indices from multiple sources (i.e., fleets) in a single CPUE file, which contains all considered abundance indices. The first column of the cpue input is year, which must match the range of years provided in the Catch file. In contrast to the Catch input, missing abundance index (and SE) values are allowed.

The catch data comes from the different fishing countries' official reporting of annual landings to ICES (see Table 1) and the CPUE data (along with its standard deviation) comes from the CPUE standardization process described above. We assumed that the CPUE index from ICES Subarea 2a calculated using data from the anglerfish targeted fishery is representative of the stock status in ICES areas 1 and 2 together.

In addition to these .csv files, JABBA also require users to define the prior distribution for the model parameters which will be subsequently updated with data to form the posterior distributions (e.g. Figure 6). In addition to the base case, 10 additional scenarios were run to examine the sensitivity of the model results to the choice of priors (Table 5).

Table 5.

Scenario name	**K**	**r**	σ_P	**Initial depletion**	B_{msy}**/K value**
Base	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
Low_K	LN(5e5,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
High_K	LN(1.5e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
Low_r	LN(1e6,1)	LN(0.05,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
High_r	LN(1e6,1)	LN(0.2,1)	IG(4,0.01)	LN(0.8,0.5)	0.35
Low_sigmaP	LN(1e6,1)	LN(0.1,1)	IG(4,0.005)	LN(0.8,0.5)	0.35
High_sigmaP	LN(1e6,1)	LN(0.1,1)	IG(4,0.02)	LN(0.8,0.5)	0.35
Low_initdep	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.7,0.5)	0.35
High_initdep	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.9,0.5)	0.35
Low_BmsyK	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.30
Low_BmsyK	LN(1e6,1)	LN(0.1,1)	IG(4,0.01)	LN(0.8,0.5)	0.40

** LN stands for lognormal and IG stands for inverse gamma distribution. Bmsy/K value controls for the position of the inflection point of the surplus production curve with respect to K (a value from 0 to 1).*

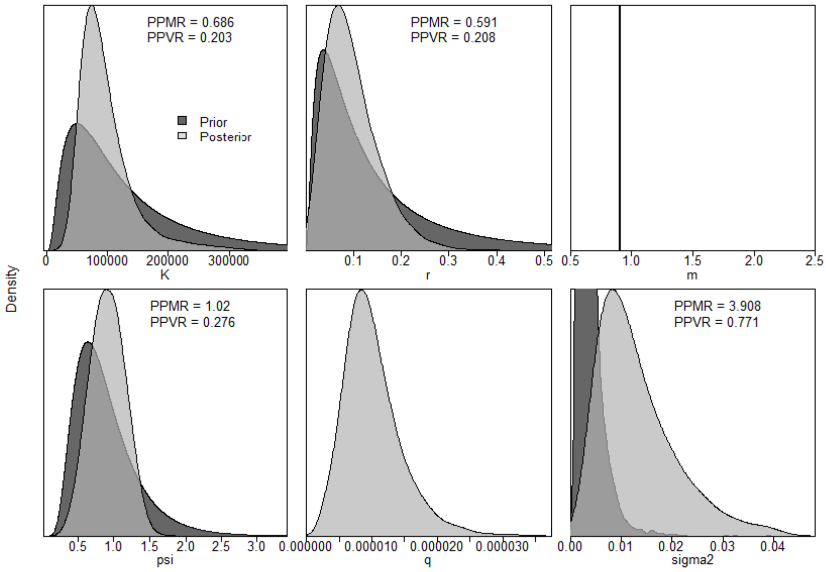

Figure 6. Prior and posterior distribution of the base model parameters for the anglerfish assessment.

Figure 7 shows the trajectory of the population estimates from 1990-2020 based on the 11 tested scenarios (Table 6). In general, population abundance has never fallen below Bmsy (at least the mean trajectory) but fishing mortality fluctuated above and below the FMSY (Figure 8). Figure 9 is the Kobe plot from the base model run showing the estimated trajectories of B/B_{MSY} and F/F_{MSY} along with the credibility intervals of the 2020 estimates of biomass and fishing mortality. The percentage numbers at the top right indicate how much of the 2020 population estimates that falls within the green (not overfished, no overfishing), yellow (overfished, but no overfishing), orange (overfishing, but not overfished), and red (overfished and overfishing) zones, after accounting for all the parameter uncertainty (basically, the area under the oval shaped density plot that falls into each colored quadrant). The model estimates that there is roughly a 23% probability that the 2020 population estimate falls within the red zone, 22% in the orange, 2% in the yellow, and 53% in the green zone. Finally, retrospective analysis indicates that overall, there is little retrospective issue with the anglerfish JABBA base model run with |Mohn's rho| ≤ 0.11 except for F/F_{MSY} (Table 6). In general, estimates of final year biomass and F were consistent over the last 4 retrospective peels but the scaling for F (i.e. F/FMSY) was less consistent (i.e. larger relative error) (Table 6).

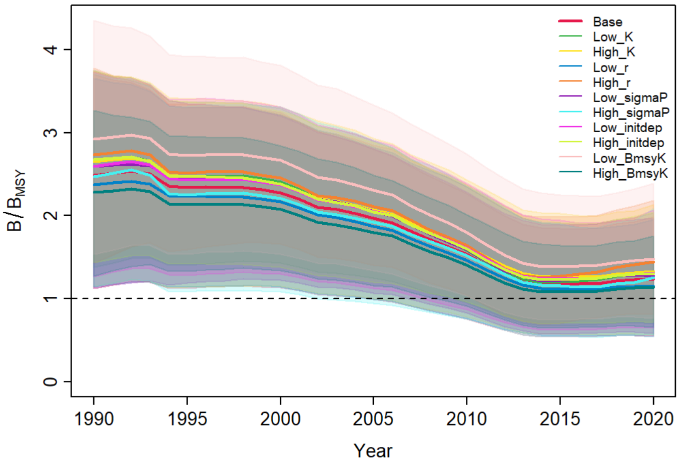

Figure 7. Estimated trajectories for B/B_{MSY} for the ICES Subarea 1-2 anglerfish based on 11 JABBA scenarios (the name of scenario and the associated color is indicated in the figure). The lines show the mean trajectory and the shaded-areas denote 95% credibility intervals

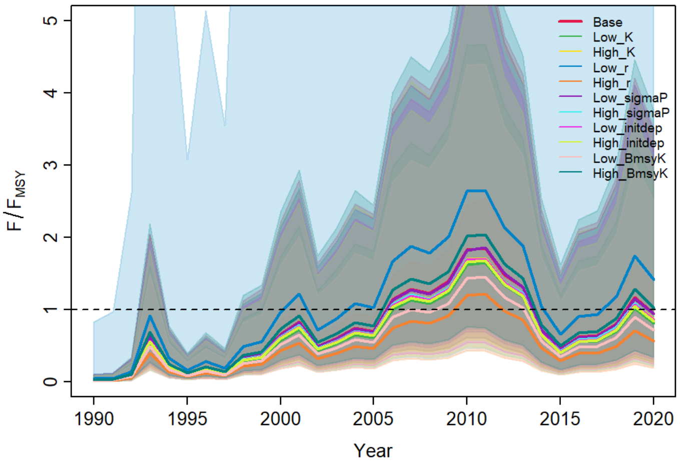

Figure 8. Estimated trajectories for F/F_{MSY} for the ICES Subarea 1-2 anglerfish based on 11 JABBA scenarios (the name of scenario and the associated color is indicated in the figure). The lines show the mean trajectory and the shaded-areas denote 95% credibility intervals

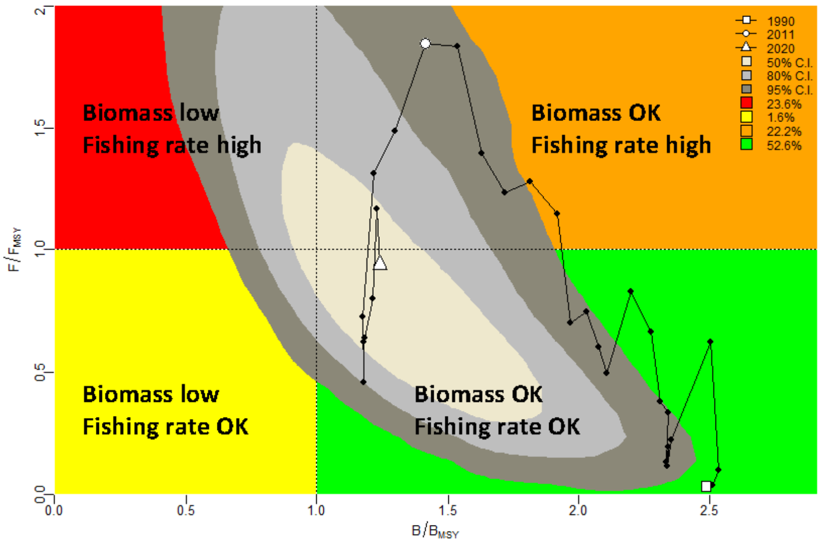

Figure 9. Kobe plot for the JABBA base case scenario showing the estimated trajectories (1990-2020) of B/B$_{MSY}$ and F/F$_{MSY}$. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

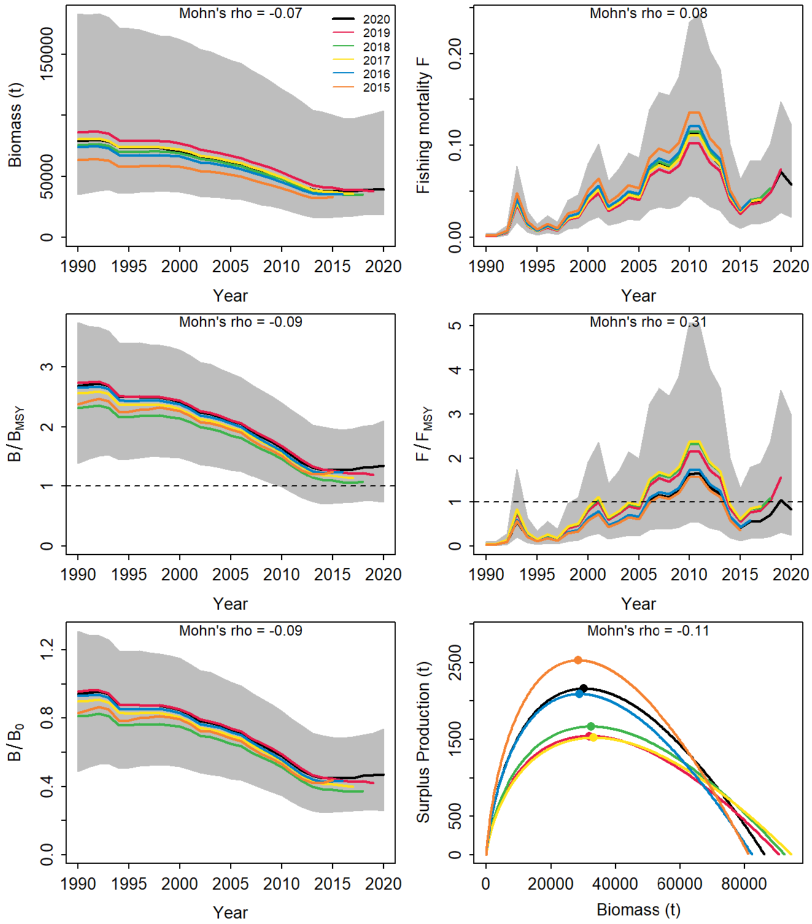

Figure 10. Retrospective analysis from the JABBA base case scenario. Different colors illustrate the results from different peels.

Table 6. Relative error (RE) in parameter estimates between the base run with full dataset (ref) and the retrospective peels (1 to 5 years) and the associated Mohn's rho statistics (i.e. average RE from the 5 peels). Relative error is calculated as: RE= (peel-ref)/ref.

	B	**F**	**B/B_{MSY}**	**F/F_{MSY}**	**B/B0**	**MSY**
RE_peel1	-0.029	0.030	-0.100	0.496	-0.100	-0.277
RE_peel2	-0.089	0.097	-0.188	0.522	-0.188	-0.206
RE_peel3	-0.060	0.064	-0.114	0.577	-0.114	-0.241
RE_peel4	-0.064	0.068	-0.027	0.050	-0.027	-0.026
RE_peel5	-0.124	0.142	-0.021	-0.108	-0.021	0.175
Mohn's rho	-0.073	0.080	-0.090	0.308	-0.090	-0.115

Discussion and recommendation

The three approaches tested in this report, all very different (although JABBA also uses the standardized CPUE as abundance indices), yet offer corroborative evidence suggesting that the anglerfish population has declined over time but that the population might be stabilizing or even slightly going up in most recent years.

The spawning potential ratio, as calculated by the LBSPR method using input biological parameters and the estimated exploitation parameters suggests that ¬- while there is a lot of uncertainty - fishing effort is probably slightly above but close to the effort what would lead to maximum yield.

The standardized CPUE analysis shows that anglerfish population in ICES Subarea 2a have declined over the last decade (as well as the raw effort) with a slight increasing tendency over the three most recent years

The relative population stock status is around BMSY, though fishing intensity seems still a little too high and should be reduced before the population does fall below the biomass and SPR targets.

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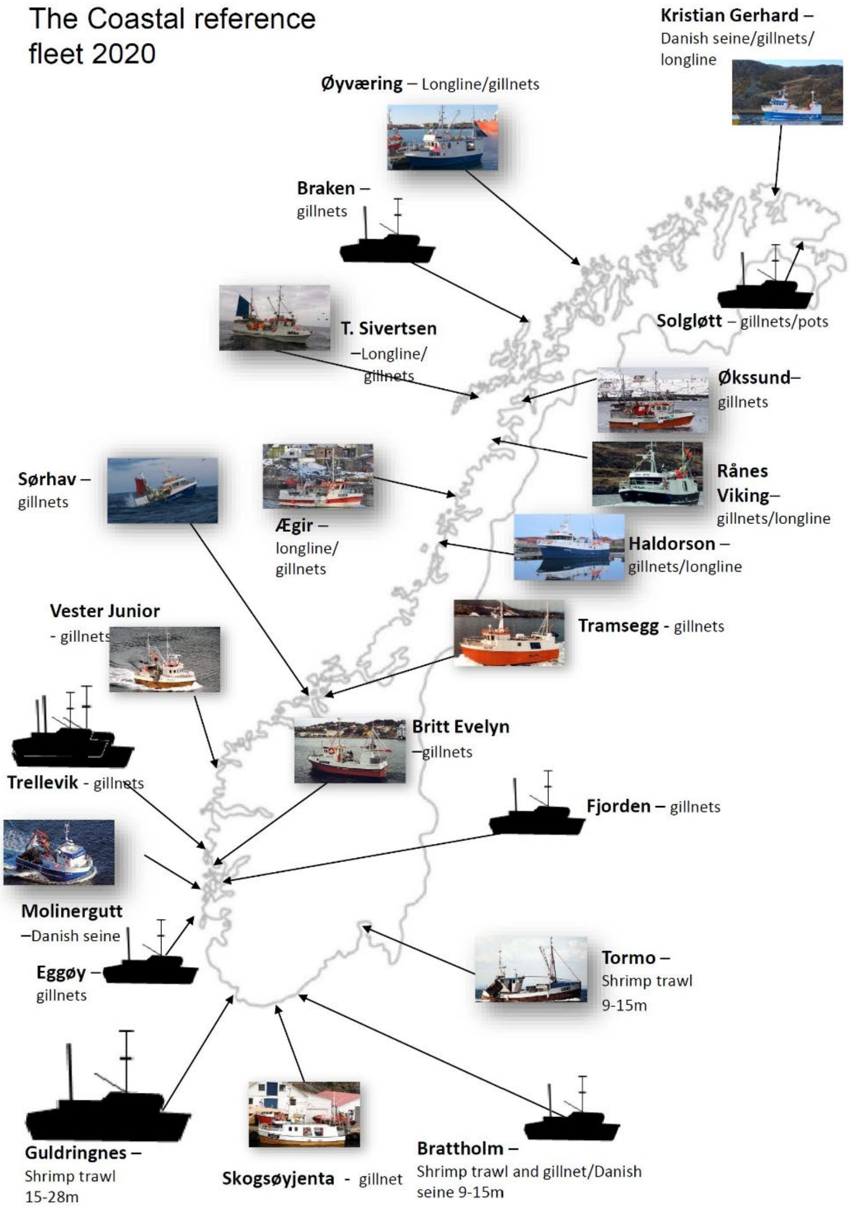
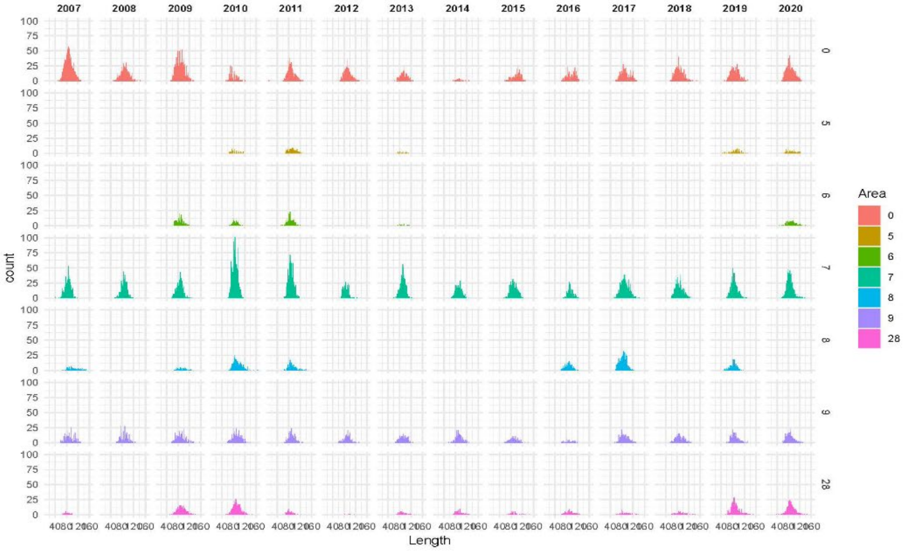
Appendix figure 1.



Appendix table 1. Input data to the JABBA assessment in the form of catch and abundance indices of anglerfish (*L. piscatorius*) in ICES Subarea 1 and 2.

Year	Catch	CPUE (mean)	CPUE (SE)
1990	151		
1991	180		
1992	488	1.5	0.3
1993	3042	1	0.2
1994	1024	0.5	0.1
1995	526		
1996	887		
1997	601		
1998	1549		
1999	1743		
2000	2999		
2001	3624		
2002	2071		
2003	2477		
2004	3001		
2005	2735		
2006	4348		
2007	4591	0.49	0.07
2008	4151	0.53	0.06
2009	4458	0.49	0.07
2010	5515	0.43	0.08
2011	5112	0.46	0.06
2012	3765	0.44	0.06
2013	3103	0.32	0.04
2014	1657	0.38	0.05
2015	1043	0.39	0.06
2016	1435	0.31	0.04
2017	1484	0.29	0.04
2018	1903	0.36	0.08
2019	2809	0.30	0.05
2020	2280	0.49	0.06

Appendix figure 2. Length distributions of anglerfish (L. piscatorius) caught and retained in **large-meshed gillnets** per year and Norwegian statistical areas. Areas 0, 5, 6 and 7 represent ICES Subarea 2. Note the different scale of the y-axis in App. figs 2-4.



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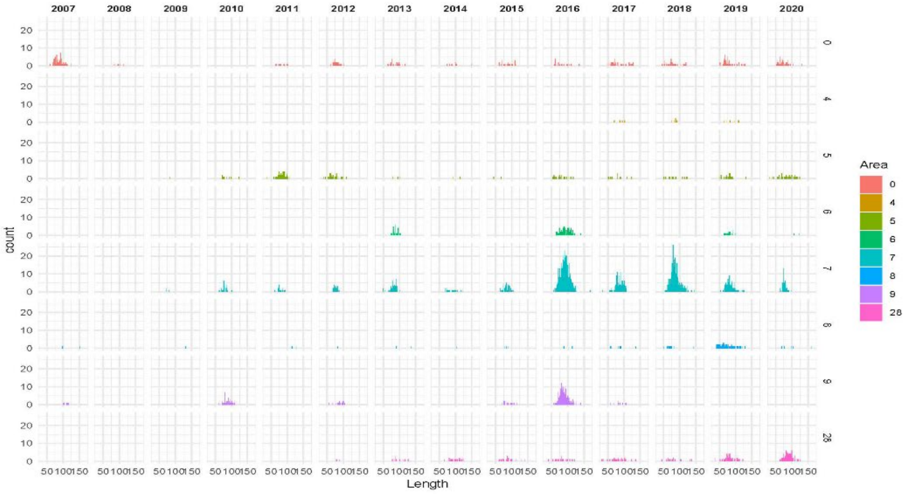
Appendix figure 3. Length distributions of anglerfish (L. piscatorius) caught as bycatch and retained in **other gillnets** per year and Norwegian statistical areas. Note the different scale of the y-axis in App. figs 2-4.



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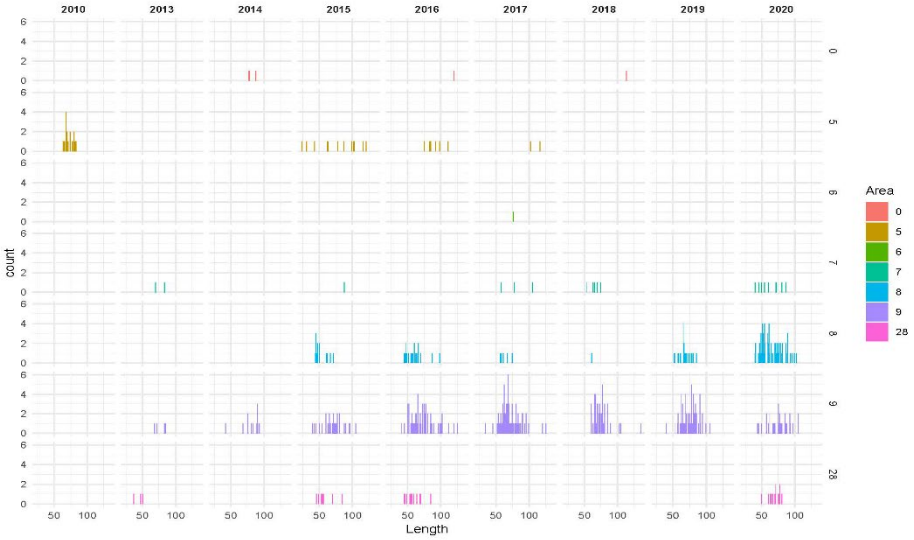
Appendix figure 4. Length distributions of anglerfish (L. piscatorius) caught as bycatch and retained in **other gears** per year and Norwegian statistical areas. Note the different scale of the y-axis in App. figs 2-4.



Transferring the Norwegian slope index to Stox

Kristin Windsland, Mikko Vihtakari and Elvar Hallfredsson

10.04.2021

1 Introduction

The Norwegian slope index for Greenland halibut is based on data from the Egga Nord survey that covers the continental slope (400-1500 meters) between 68 and 80°N. The Egga Nord survey was run annually in 1994-2009, and biennially since then (2011,2013,…2021). Traditionally, the survey index has been calculated using a collection of R scripts called "the survey program". To streamline the process and increase transparency, we wish to transfer the calculation to Stox. The strata system for the EggaNord index consists of four main areas divided by latitude (from north to south along the continental slope). These four areas are further divided into four depth intervals (400-500, 500-700, 700-1000 and 1000-1500 meters). A crucial difference between the old and new approach is that previously a station was assigned to strata based on the combination of trawling depth and latitude. The new system solely uses geographic coordinates for station assignment. While the trawling depth was perhaps more exact ecologically, the resulting strata areas were not connected to the sampling depths as these were handled separately. Where the new approach loses in ecological precision, it wins in that sampling depths are now directly connected to strata polygons and their areas. The new approach is thus more vulnerable to the considerable failures in available data on bottom topography at the continental slope. Both approaches are biased, however, and there is no one truth to compare the approaches to. In this document, we examine how the biases influence the resulting survey index based on the 2019 survey.

Table 1.1: Previously used strata system definition for NEA Greenland halibut. Latitude intervals given are along rows, depth intervals along columns and the numbers represent strata areas in square nautical miles.

	1000-1500	700-1000	500-700	400-500
76-80	2693	1263	702	1440
73.5-76	1672	761	488	575
70.5-73.5	3272	1706	1324	1228
68-70.5	945	1150	525	400

2 New strata system

We created a new strata system using the strataPolygon function documented in RStoxUtils (https://github.com/MikkoVihtakari/RstoxUtils/tree/master/R/strataPolygon), a package that contains utility functions for the Institute of Marine Research's (IMR) Stox Project.

In creating survey indices by swept area, the number of fish per areal unit is multiplied by the area, hence the area has a large impact on the abundance estimates. Traditionally, the abundance estimation within the IMR has been done using various routines and programs with a variable level of documentation and transparency. Standardization of the routine is required and has recently been requested by both the ICES and the IMR. As a part of the standardization, the abundance estimation has to be done using Stox software. The strata have to be defined as spatial polygons (a GIS vector data class). These polygons are then used to calculate the area and to define which stations lie inside each stratum for further abundance calculation. While the determination of strata polygons is a critical part of the new routine, there are currently no standardized methods to do it.

The RstoxUtils package contains functions to define strata based on bottom topography and geographical limits (see Figure 2.1). For a description of how the strata are required visit RstoxUtils (https://github.com/MikkoVihtakari/RstoxUtils/blob/master/README.md) on GitHub.

Figure 2.1: New strata system

3 Comparing old and new area

There are considerable differences between the polygonized strata and the original strata areas (Figure 3.1). The Pearson correlation between the original and new strata areas is 0.88, which is low since we want to try to replicate the original areas. We notice that the largest offsets are for strata IDs 4, 12, 14, and 16. All of these strata, except number 14 are the shallowest 400-500 m interval. These differences in the area estimations may dramatically change the new abundance estimates, and consequently, the estimation of strata polygons should get more attention.

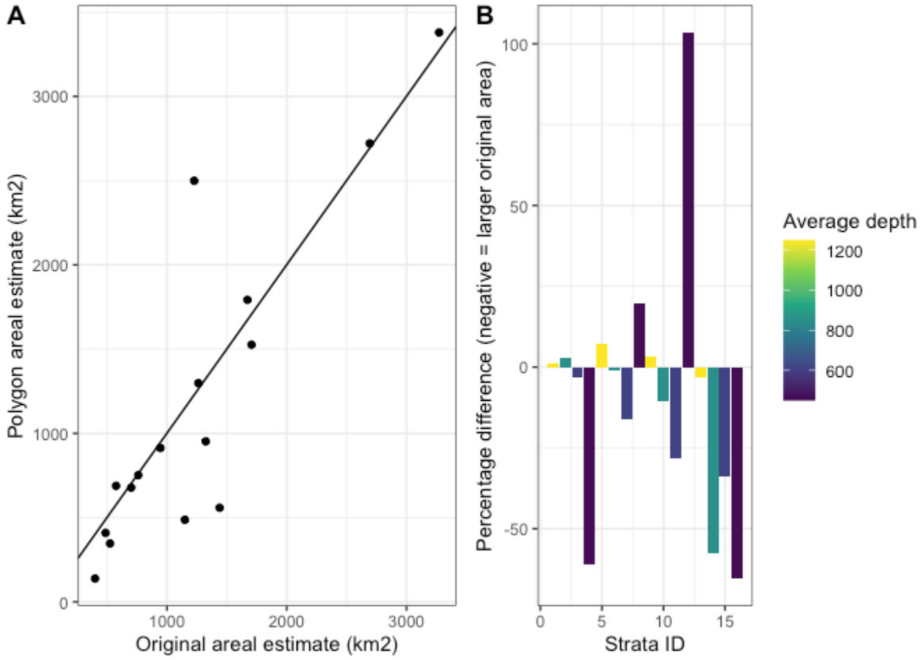


Figure 3.1: Old and new strata area by stratum. In panel A each point represents a single stratum.

4 Comparing indices, corrected for differences in strata area.

The index for 2019 calculated in Stox, using the new strata system were initially quite different from the 2019 index calculated using the old method. The index is calculated as the mean density of biomass/abundance per stratum multiplied by the area of the stratum. Any differences in the area between the two methods will influence the index. By correcting for this difference in area, we can see how much of the difference is contributed by the Stox calculations and how much is contributed by the differences in stratum area estimates.

The calculated total biomass (all stratum, both sexes) using Stox is 3 % higher than the estimate from the survey program, after correcting for differences in area (Figure 4.1). The length distributions using the old survey program and Stox (after area corrections) are almost identical (Figure 4.2). The cause of the small discrepancies is currently unknown.

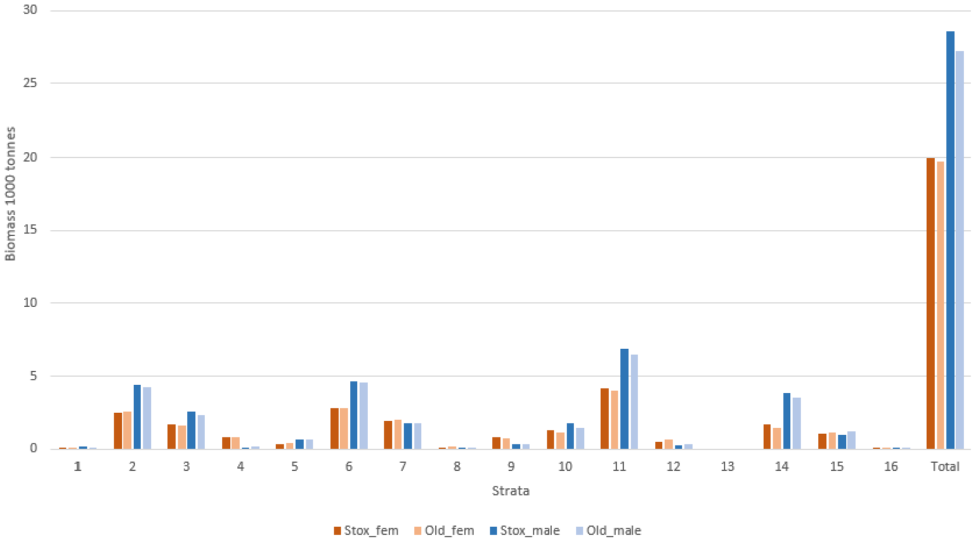
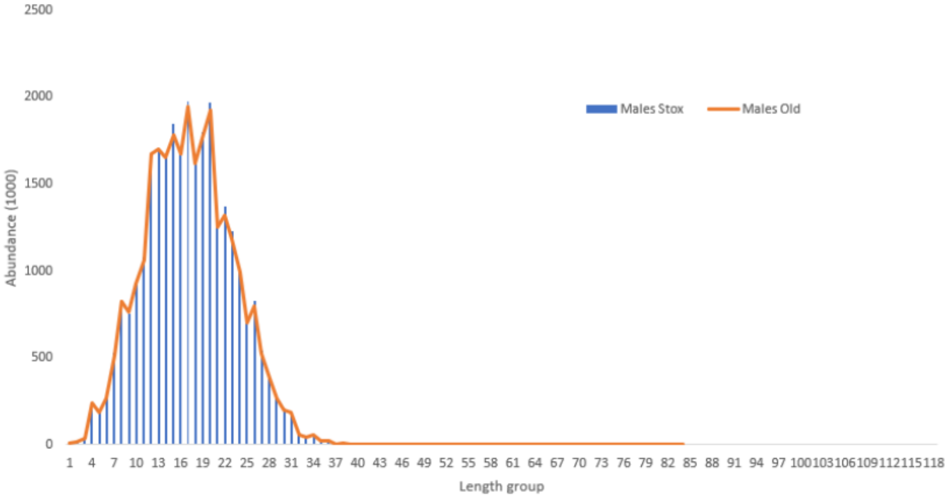


Figure 4.1: Comparing biomass estimates per stratum in the 2019 survey based on the old approach and new Stox approach, independent of stratum areas.



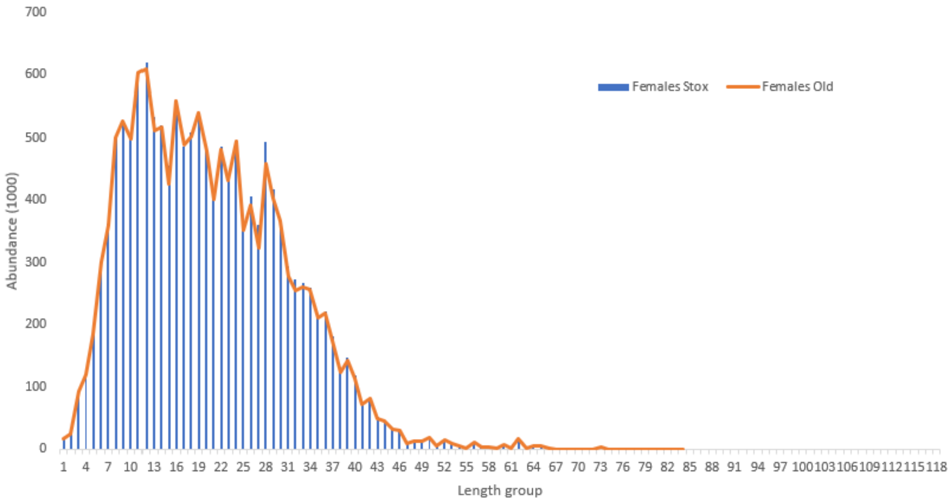


Figure 4.2: Female (upper panel) and male (lower panel) length distributions in the 2019 survey based on the old approach and new Stox approach, independent of stratum areas

4.1 Further work

We need to continue working on the strata system, identifying where the differences lie. We also need to determine the source of the small difference not attributed by the difference in area.

AFWG-2021 WD_18

NEA cod stock assessment by means of TISVPA

D.Vasilyev

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO),
17, V.Krasnoselskaya St., 107140, Moscow, Russia

The TISVPA (Triple Instantaneous Separable VPA) model (Vasilyev, 2005; 2006) represents fishing mortality coefficients (more precisely – exploitation rates) as a product of three parameters: f(year)*s(age)*g(cohort). The generation - dependent parameters, which are estimated within the model, are intended to adapt traditional separable representation of fishing mortality to situations when several year classes may have peculiarities in their interaction with fishing fleets caused by different spatial distribution, higher attractiveness of more abundant schools to fishermen, or by some other reasons.

The model was first presented and tested at the ICES Working Group on Methods of Fish Stock Assessments (WGMG 2006) and was used for data exploration and stock assessment for several ICES stocks, including North - East Atlantic mackerel, blue whiting, Norwegian spring spawning herring. To NEA cod stock the TISVPA model was first applied at AFWG-1998.

The TISVPA model is applied to NEA cod using the same data as SAM. 4 sets of age - structured tuning data were included into analysis: ecosystem survey ("fleet 007"); joint bottom trawl surveys ("fleet 15") divided into two parts: before 2013 inclusively (fleet 15a) and after 2013 (fleet15b) ; joint acoustic surveys (Barents Sea and Lofoten) – "fleet 16", and Russian bottom trawl surveys ("fleet 18"). The All the input data, including catch-at-age, weight-at-age in stock and in catches, maturity-at-age were taken the same as for stock assessment by means of SAM.

Settings of the TISVPA model were similar to those at AFWG 2020: so called "mixed" version, assuming errors both in catch-at-age and in separable approximation. Additional restriction on the solution was unbiased model approximation of logarithmic catch-at-age. The generation - dependent factors in triple - separable representation of fishing mortality coefficients were estimated for age groups from 3 to 12. For catch-at-age and "fleet15a" the measure of closeness of fit was absolute median deviation (AMD) of distribution of residuals which is known as one of most robust measures of scale, free from the assumption about the distribution. For other "fleets" the traditional sums of logarithmic squared residuals were used assuming lognormal errors. For the (terminal+1) year (year with surveys but without catch-at-age) the assumption of equal F in terminal terminal+1 years was used.

The TISVPA model was modified to give possibility to use +group in surveys in position younger than the oldest age in the assessment.

Profiles of the components of the TISVPA loss function with respect to SSB in 2021 are shown in Figure 1. As previously, fleet 18 indicates much lower stock biomass in comparison to other sources.

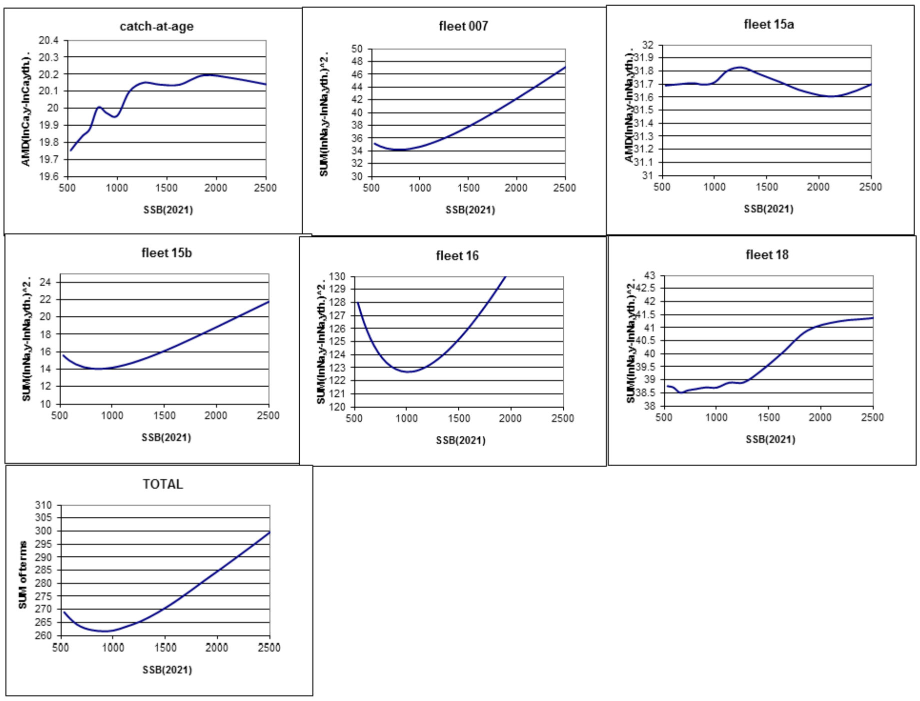


Figure 1. Profiles of the components of the TISVPA objective function

The results of retrospective runs are given in Figure 2.

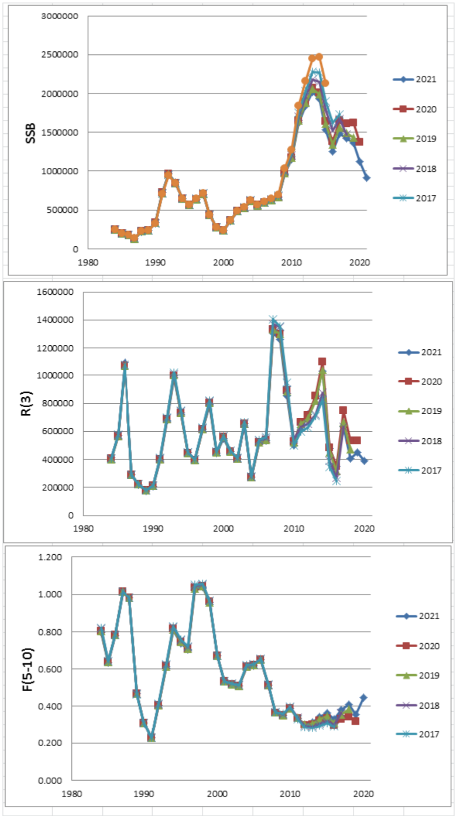
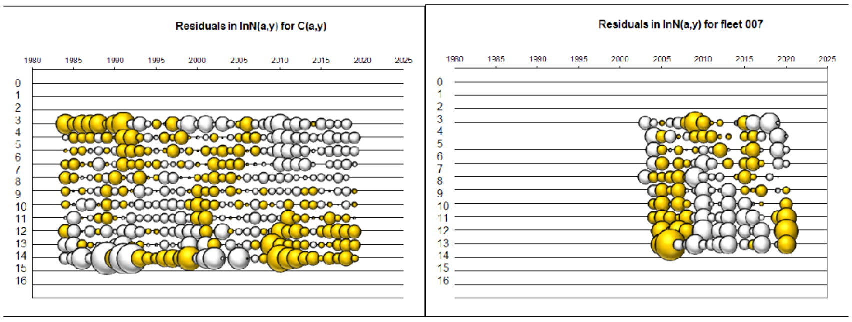


Figure 2. TISVPA retrospective runs

The residuals of the model approximation of catch-at-age and “fleets” data are presented in Figure 3.



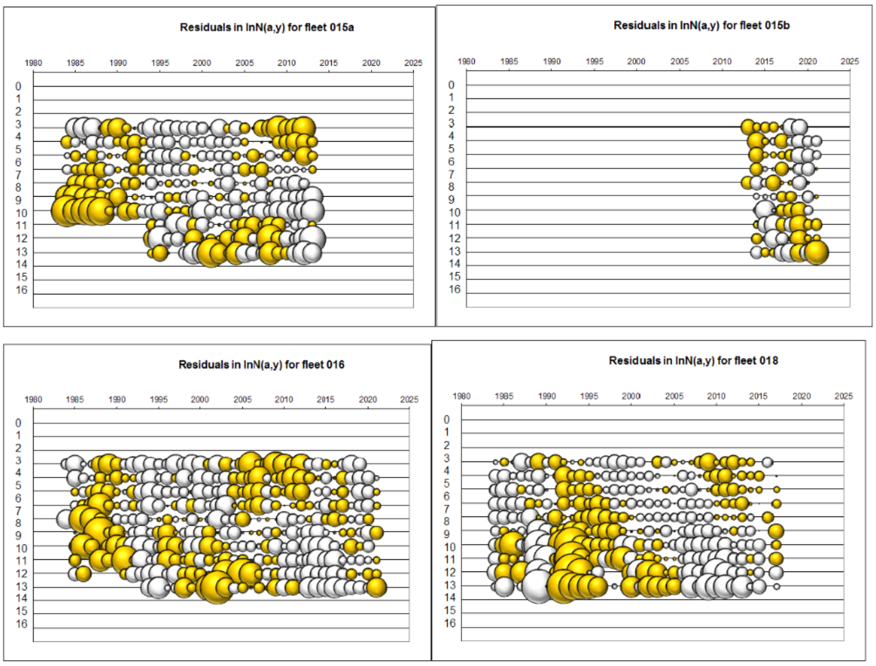


Figure 3. Residuals of the TISVPA data approximation.

The estimates of uncertainty in the results (parametric conditional bootstrap with respect to catch-at-age; “fleet” data were noised by lognormal noise with sigma=0.3) are presented on Figure 4.

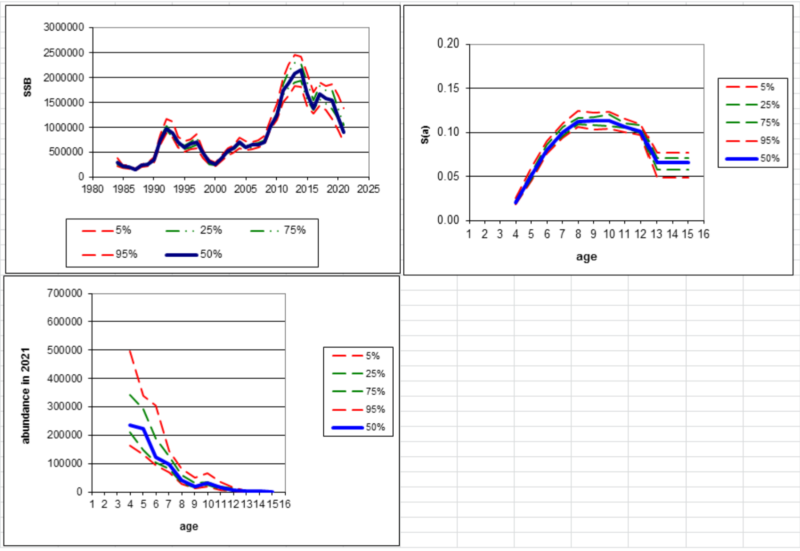


Figure 4. Bootstrap- estimates of uncertainty in the results.

Tables 1-3 represent the results of NEA cod stock assessment by means of TISVPA.

Year	B(3+)	SSB	R(3)	F(5-10)
1984	807954	250746	410523	0.797
1985	980750	198920	572528	0.636
1986	1373006	181043	1093298	0.777
1987	1235908	134626	287903	1.008
1988	1014506	224385	216977	0.981
1989	916885	239238	176343	0.468
1990	990201	334926	208876	0.311
1991	1552666	722740	394071	0.227
1992	1941853	963126	677277	0.407
1993	2420887	851159	985577	0.613
1994	2220662	642878	733691	0.809
1995	1899651	565667	451863	0.739
1996	1831162	635149	398175	0.702
1997	1707205	701702	615599	1.022
1998	1310400	440043	786884	1.039
1999	1086240	278844	446021	0.956
2000	1057202	237512	551676	0.671
2001	1282493	363769	454131	0.533
2002	1402591	484448	403270	0.517
2003	1513047	529317	651690	0.510
2004	1466859	619630	270922	0.613
2005	1440571	562183	521538	0.619
2006	1497323	593686	532430	0.650
2007	1801766	625622	1305559	0.513
2008	2545295	664342	1258479	0.367
2009	3212962	962458	853957	0.353
2010	3480838	1156171	499582	0.389
2011	3610421	1621078	609473	0.335
2012	3692618	1843690	718214	0.302
2013	3787101	2014197	838254	0.313
2014	3553222	1927922	1035664	0.343
2015	3399199	1536347	476073	0.366
2016	3035769	1255420	349877	0.331
2017	3058797	1484139	630535	0.382
2018	2753200	1424145	405472	0.410
2019	2481220	1367254	447065	0.355
2020	2116031	1128535	390173	0.447
2021	1739852	911290		

Table 1. NEA cod stock assessments results by means of TISVPA

	3	4	5	6	7	8	9	10	11	12	13	14	15
1984	410523	135361	73038	41968	24276	12026	8938	1468	676	461	204	35	24
1985	572528	328885	97230	42154	18143	7015	3360	2497	476	386	175	111	28
1986	1093298	450718	227239	56521	19969	6784	2322	1323	1071	220	267	105	43
1987	287903	813483	306460	114066	23174	7127	2188	724	435	368	76	161	55
1988	216977	214133	536192	153748	36097	6227	2073	709	148	142	110	39	14
1989	176343	167180	149847	286245	59642	9164	1507	604	182	33	50	53	77
1990	208876	141119	119573	95102	155696	26282	3530	627	280	102	16	35	14
1991	394071	169454	108844	84293	60687	96088	14766	2047	357	174	67	9	19
1992	677277	319370	131230	77094	53911	35799	58652	8865	1282	238	123	51	6
1993	985577	538231	237036	87118	44197	28095	17282	30658	4521	714	126	89	4
1994	733691	765179	402113	144673	44957	20161	11587	6812	12530	1801	278	63	13
1995	451863	510878	531121	239795	65665	14500	6205	3351	1856	3852	551	138	3
1996	398175	261986	335690	315000	116737	25336	5210	1983	990	512	1385	282	3
1997	615599	230456	167601	193804	154458	48851	9337	2044	630	320	175	617	3
1998	786884	393527	146146	81861	76453	47171	12992	2173	483	115	60	57	138
1999	446021	492048	237442	71578	30352	24034	10507	3707	515	140	25	22	82
2000	551676	335073	321484	111407	25292	10341	5853	2062	1137	156	52	4	51
2001	454131	424077	240836	170235	48105	9087	3647	1697	590	542	64	31	98
2002	403270	353825	307475	147349	79869	20291	3317	1636	627	240	316	43	29
2003	651690	302383	260499	188743	70234	31599	7770	1309	843	315	109	216	5
2004	270922	506524	228784	164312	95987	30781	12864	3571	600	497	170	70	35
2005	521538	208554	372200	144592	81918	37204	11225	4558	1373	239	270	104	30
2006	532430	381711	152345	216484	72092	33374	12883	4166	1540	571	103	180	621
2007	1305559	427361	267972	94678	106475	31217	12822	4136	1598	516	242	61	165
2008	1258479	1002021	316032	160193	53322	52304	14713	6114	1796	763	198	154	77
2009	853957	964086	761058	219428	94827	30261	25732	7558	3264	866	415	128	122
2010	499582	644435	743877	537212	136711	55224	16599	13253	4217	1813	205	275	196
2011	609473	369409	488219	534378	345967	76109	28437	8804	6674	1631	846	73	0
2012	718214	397644	261153	358720	357297	206007	41841	14106	3890	3147	871	447	153
2013	838254	488540	283846	195322	246505	222263	119010	23097	7289	1878	1679	516	840
2014	1035664	562226	372114	207725	136189	150095	120387	60051	11501	3605	982	1048	784
2015	476073	710234	400851	265783	135767	83673	77213	59825	28889	5780	1825	580	1100
2016	349877	330004	516712	277166	170497	78757	46893	39623	27636	11604	2587	1095	1354
2017	630535	279667	242691	345652	180680	104598	43119	25723	17644	11568	5392	1476	1054
2018	405472	417114	211326	165467	214530	103813	57111	21430	12571	6367	4647	2921	942
2019	447065	301865	306286	144999	97871	118343	55958	30358	9624	5342	2504	2244	1281
2020	390173	325871	218726	196445	90708	54824	62333	30750	16717	4549	2761	1448	1299
2021	0	254403	238659	142919	111198	46207	25971	29664	14528	8140	2302	1726	905

Table 2. NEA cod. TISVPA. Estimates of abundance-at-age

F	3	4	5	6	7	8	9	10	11	12	13	14	15
1984	0.023	0.137	0.325	0.561	0.998	0.967	0.990	0.941	0.279	0.926	0.469	0.469	0.469
1985	0.020	0.123	0.314	0.455	0.622	0.911	0.740	0.774	0.685	0.217	0.382	0.382	0.382
1986	0.021	0.148	0.392	0.640	0.743	0.874	1.109	0.905	0.873	0.749	0.443	0.443	0.443
1987	0.025	0.152	0.487	0.842	1.132	1.079	1.061	1.446	1.034	0.967	0.518	0.518	0.518
1988	0.024	0.162	0.417	0.874	1.216	1.330	1.017	1.030	1.248	0.894	0.500	0.500	0.500
1989	0.013	0.089	0.242	0.368	0.564	0.611	0.554	0.471	0.444	0.496	0.260	0.260	0.260
1990	0.008	0.059	0.157	0.263	0.315	0.404	0.377	0.352	0.286	0.266	0.172	0.172	0.172
1991	0.006	0.038	0.112	0.186	0.250	0.258	0.286	0.273	0.241	0.194	0.127	0.127	0.127
1992	0.009	0.066	0.166	0.316	0.439	0.521	0.465	0.533	0.473	0.404	0.219	0.219	0.219
1993	0.015	0.084	0.251	0.403	0.654	0.803	0.825	0.741	0.803	0.682	0.320	0.320	0.320
1994	0.017	0.114	0.278	0.543	0.717	1.051	1.098	1.169	0.939	0.999	0.404	0.404	0.404
1995	0.016	0.109	0.306	0.465	0.742	0.826	1.011	1.087	1.051	0.832	0.397	0.397	0.397
1996	0.020	0.103	0.297	0.530	0.643	0.884	0.824	1.037	1.016	0.956	0.399	0.399	0.399
1997	0.027	0.175	0.377	0.728	1.131	1.157	1.411	1.327	1.618	1.511	0.556	0.556	0.556
1998	0.030	0.177	0.508	0.669	1.068	1.407	1.142	1.440	1.215	1.406	0.555	0.555	0.555
1999	0.025	0.188	0.481	0.884	0.886	1.186	1.244	1.056	1.183	0.991	0.518	0.518	0.518
2000	0.020	0.120	0.389	0.596	0.831	0.686	0.740	0.786	0.641	0.683	0.365	0.365	0.365
2001	0.015	0.106	0.258	0.523	0.624	0.718	0.513	0.561	0.552	0.451	0.286	0.286	0.286
2002	0.013	0.087	0.264	0.401	0.659	0.659	0.644	0.475	0.484	0.467	0.264	0.264	0.264
2003	0.013	0.078	0.216	0.417	0.505	0.712	0.605	0.605	0.420	0.419	0.248	0.248	0.248
2004	0.014	0.098	0.241	0.425	0.687	0.708	0.868	0.746	0.690	0.463	0.290	0.290	0.290
2005	0.015	0.094	0.267	0.412	0.591	0.826	0.716	0.903	0.716	0.647	0.295	0.295	0.295
2006	0.016	0.105	0.273	0.499	0.621	0.768	0.922	0.814	0.952	0.732	0.323	0.323	0.323
2007	0.013	0.085	0.236	0.379	0.553	0.578	0.604	0.730	0.605	0.679	0.267	0.267	0.267
2008	0.009	0.065	0.175	0.300	0.382	0.471	0.424	0.451	0.500	0.414	0.206	0.206	0.206
2009	0.008	0.057	0.164	0.277	0.386	0.423	0.451	0.415	0.413	0.447	0.200	0.200	0.200
2010	0.008	0.058	0.161	0.296	0.408	0.493	0.467	0.510	0.438	0.427	0.220	0.220	0.220
2011	0.007	0.044	0.137	0.239	0.355	0.420	0.438	0.425	0.433	0.367	0.200	0.200	0.000
2012	0.006	0.043	0.106	0.211	0.298	0.383	0.394	0.420	0.381	0.381	0.190	0.190	0.190
2013	0.007	0.042	0.122	0.190	0.309	0.381	0.429	0.450	0.449	0.399	0.212	0.212	0.212
2014	0.008	0.048	0.127	0.232	0.294	0.422	0.455	0.526	0.517	0.504	0.250	0.250	0.250
2015	0.010	0.060	0.144	0.240	0.361	0.397	0.502	0.554	0.601	0.577	0.295	0.295	0.295
2016	0.009	0.062	0.154	0.229	0.310	0.405	0.387	0.499	0.514	0.543	0.290	0.290	0.290
2017	0.016	0.070	0.196	0.306	0.370	0.437	0.500	0.486	0.592	0.597	0.355	0.355	0.355
2018	0.021	0.107	0.197	0.348	0.440	0.457	0.468	0.549	0.498	0.594	0.382	0.382	0.382
2019	0.015	0.116	0.248	0.277	0.395	0.426	0.384	0.401	0.437	0.390	0.325	0.325	0.325
2020	0.013	0.080	0.213	0.353	0.475	0.547	0.543	0.550	0.520	0.481	0.270	0.270	0.270

Table 3. NEA cod. TISVPA. Estimates of fishing mortality coefficients

References

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Vasilyev D. 2006. Change in catchability caused by year class peculiarities: how stock assessment based on separable cohort models is able to take it into account? (Some illustrations fo rtriple - separable case of the ISVPA model - TISVPA). ICES CM 2006/O:18. 35 pp

WD 19
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Consumption of various prey species by cod in the Barents Sea in 1984-2020

by

A.V.Dolgov

Polar Branch of Russian Federal Research Institute of Fisheries and Oceanography
(PINRO after N.M. Knipovich), 6 Knipovich Str., Murmansk 183763 Russia
E-mail: dolgov@pinro.ru

NOT UPDATED YET
Work is going

WD-20 to AFWG-2021

A new soft in R for NEA cod recruitment prediction using the Hybrid model

by

Anatoly Tchetyrkin

A hybrid model is currently used to calculate the recruitment of NEA cod at age 3, which combines the predictions from the TitovES, TitovEL (Titov, 1999, 2001, 2011, 2020, 2021) and RCT3 (Shepherd, 1997) models, estimates the weight of each model and, based on this, calculates the final recruitment forecast for 1-4 years ahead. In 2021, this model was implemented in the R programming language. As the initial data, the model uses parameters for TitovES and TitovEL models (Appendix 1) and an output table from RCT3 model (Appendix 2), updated every year. Both tables contain the last AFWG cod recruitment at age 3 in the SAM model values (from 1962 for TitovES, TitovEL models and from 1982 for RCT3).

The methodology used in TitovEL and TitovES models is realized with using lm() function. RCT3 is realized in outside script rct3.r made by Colin Millar from ICES.

To calculate the weights of the models for the AFWG-2021 according to the methodology proposed at the SGRF-2013 meeting (Anon. 2013), the R script performs retrospective calculations of forecasts for all models with learning period 1962-2007, 1962-2008, ..., 1962-2016 for TitovES, TitovEL models and for 1982-2007, 1982-2008, ..., 1982-2016 for RCT3. This results in a one-year-ahead prognoses for the years 2008, 2009, ..., 2017, two-year-ahead prognoses for the years 2009, 2010, ..., 2017 and so on (Table 1). The long-term mean recruitment prediction is also calculated with learning period 1962-2007, 1962-2008, ..., 1962-2016 years (Table 2).

Table 1. Retrospective forecasts of NEA cod recruitment at age 3.

Year	TES1y	TEL1y	RCT1y	TES2y	TEL2y	RCT2y	TEL3y	RCT3y	TEL4y
2008	891888	790359	582563	NA	NA	420962	NA	361172	NA
2009	752584	424651	428447	733565	422846	284137	NA	540010	NA
2010	431982	267007	219431	456995	260934	456584	255473	730024	NA
2011	342139	295300	365121	369175	299542	661109	293110	590711	291475
2012	341813	289165	473908	340506	285916	448628	290092	654926	283541
2013	667184	619034	379849	659507	615020	550651	613784	542226	615014
2014	757550	661749	694716	776907	664657	607979	661267	831306	660187
2015	581493	606510	635339	574225	601081	1009891	603720	948661	598231
2016	345677	403580	654344	354023	416454	998756	410574	478253	412986
2017	588875	528079	756561	592448	533411	427644	539126	532530	534914
2018	782163	682554	518873	763894	675667	721106	682189	763216	689881
2019	582678	554868	951873	604167	560296	994959	553380	686355	559647
2020	496585	502991	882256	491724	497446	751112	508290	384188	496549
2021	559491	590366	524558	555930	586923	300899	583862	383606	589675

*For example: TES1y (TitovES model one year ahead prediction) make a forecast on 2008 year based on data from 1962:2007 years; TES2y (TitovES model two year ahead prediction) make a forecast on 2009 year based on data from 1962:2007 years and so on for other models and number of years ahead.

Table 2. Retrospective long-term mean recruitment prediction.

V1	**V2**	**V3**	**V4**
621825.1	NA	NA	NA
629930.1	621825.1	NA	NA
628926.5	629930.1	621825.1	NA
620210.3	628926.5	629930.1	621825.1
614968.5	620210.3	628926.5	629930.1
612773.3	614968.5	620210.3	628926.5
609930	612773.3	614968.5	620210.3
614501.2	609930	612773.3	614968.5
611492.3	614501.2	609930	612773.3
605580.3	611492.3	614501.2	609930

*For example: first value in column V1 corresponds the long-term mean recruitment prediction based on 1962:2007 years, second value in column V2 corresponds the long-term mean recruitment prediction based on 1962:2007 years and so on.

Retrospective forecasts for TitovES and TitovEL models made with eliminating initial data for years after learning period and building multiple linear regression between recruitment and other model`s parameters. For RCT3 it`s more complicated because of specific structure of initial data (Appendix 2). The hybrid model R script implements process that can eliminate only data that corresponds to years after learning period and use remaining data for RCT3 model estimating. But that process is now works automatically only for the next formula:

$$recruitment \sim BST1+BST2+BST3+BSA1+BSA2+BSA3, \qquad (1)$$

and needs to be manually changed (in script) for another list of indices in initial data file. That part of the script will be updated and automated to the next WG.

On the received retrospective forecasts, a t-test is carried out to determine whether the models can predict recruitment better than the long-term mean recruitment prediction. The t-test methodology is described in the SGRF-2013 (Anon, 2013). In general, the model error is calculated as the average over a given number of years, as the difference between the model prediction and the "true" recruitment (i.e. R3 from SAM of the assessment year). If the long-term mean recruitment prediction error is lower, than the model error, it means that such model does not pass the t-test and does not participate in the distribution of weights (gets weight = 0). For models that passed the t-test, the weight is calculated as the normalized inverse proportion of the variance contribution to the total variance. The obtained weights are used to calculate the final weighted forecasts for 1-4 years ahead.

As outputs, Hybrid model produces tables with retrospective forecast values by all models, long-term mean recruitment prediction and plots with results (figure 1). There are also a table with final recruitment prediction for 1-4 years ahead with weights of each model and hybrid model estimations (table 3).

Table 3. Final cod recruitment estimations with weights calculated.

Model	**Species**	**Variable**	**Years**	**Prognosis available**	**2021**	**2022**	**2023**	**2024**	**Unit**
TitovEL	NEA cod	Age 3	4	At assessment	590	614	548	386	millions
		weight			0.34	0.47	1	1	
TitovES	NEA cod	Age 3	2	At assessment	559	627			millions
		weight			0.42	0.53			
RCT3	NEA cod	Age 3	3	At assessment	525	301	384		millions
		weight			0.24				
Hybrid	NEA cod	Age 3	4	At assessment	561	621	548	386	millions
Mean R 1984 - 2020					593	593	593	593	

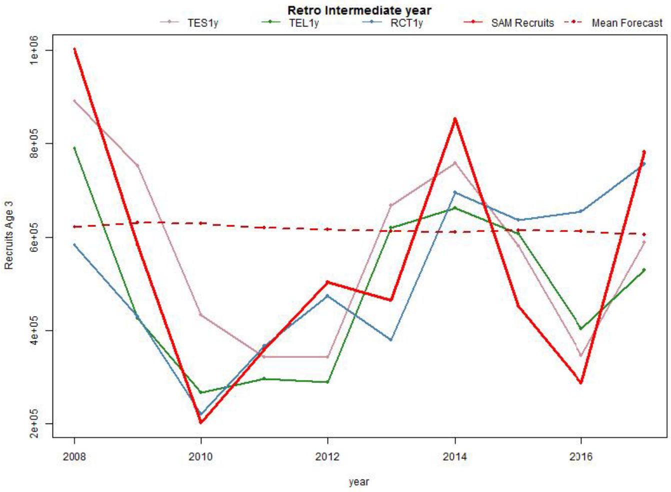

Figure 1. The dynamic of 1-year ahead (intermediate year) cod recruitment forecasts made by all models, mean forecasts (dashed line) and “true” recruitment values from SAM

Summarizing all of the above, the program that allows forecasting NEA cod recruitment by means of the Hybrid Model is currently implemented in the R language and gives exactly the same results as “old” software. Nevertheless, it still needs some improvements, i.e. the automation of work with different sets of indices in the input file for RCT3. Also, the model is now focused on working with only three models: TitovES, TitovEL and RCT3. In the future, it is planned to optimize this drawback to to easier implement other possible models into it.

Appendix 1. Parameters for TitovES and TitovEL models.

Year	Cod3	OxSatt39	DOxSatt13	ITwt43	Icet15	expIcet40
1962	1252375	-0.19	-6.6	1.86	0.5	0
1963	900621	-0.94	-2.37	1.59	1.5	0
1964	468028	1.63	1.23	2.47	9	0
1965	870506	0.88	-0.2	3.91	15.7	0
1966	1842715	-1.09	-3.98	7.97	5.3	0
1967	1311586	-0.23	-2.84	8.23	5	9.3
1968	183717	1.5	-0.13	3.78	15.5	0
1969	110450	0.85	0.63	1.77	15.9	0
1970	205641	-0.17	-0.23	3.51	19.8	7.9
1971	402577	0.06	-0.12	-0.13	18.8	2.7
1972	1045979	-3.32	-6.59	14.55	-0.6	428.9
1973	1723668	-2.1	-10.37	19.14	1.8	768.6
1974	568211	1.06	-1.73	2.4	2	0
1975	608710	1.9	0.78	-2.64	-1.2	0
1976	607084	1.33	-1.28	-3.07	-1.9	0
1977	372778	-0.07	-1.84	-2.44	2.5	0
1978	622679	1.19	0.1	1.05	-1	0
1979	202675	0.5	-1.48	-0.12	3.5	0
1980	130292	-0.31	-2.72	1.98	12.9	0
1981	143781	0.76	-0.18	1.94	14.7	0
1982	183737	0.8	0.61	-3.15	8	0.1
1983	141514	0.78	0.22	1.87	12.2	8.5
1984	442251	-2.21	-2.35	-3.08	12.9	0
1985	534310	-0.1	-1.17	3.59	-1.2	0.1
1986	1374917	-2.14	-4.39	1.39	-8.5	2.9
1987	360087	-0.33	-1.69	2.12	0.6	0
1988	335536	0.87	-1.4	-2.34	3.8	0
1989	157635	0.32	-3.42	-5.17	10.5	0
1990	130130	1.11	-1.32	-4.21	10.5	0
1991	295846	0.88	0.7	2.42	6.5	0
1992	715916	1.34	0.48	1.37	-0.9	0
1993	988150	-1.98	-3.86	6.12	-0.6	0
1994	752473	-0.5	-2.26	8.25	-4.9	0
1995	539384	0.83	-2.42	4.36	1.8	0
1996	407389	0.86	-0.08	0.55	0.7	0
1997	785420	0.88	0.17	3.11	-7.3	0
1998	1063528	0.3	-6.08	-2.32	-2.5	0
1999	632034	-0.72	-2.4	-6.81	2.9	0
2000	749727	1.86	1.55	-2.29	13.6	0
2001	593152	0.62	0.05	-6.04	2.3	0
2002	374202	-0.88	-0.98	3.63	-9.9	0.8
2003	756675	-0.39	-0.64	8.5	-5.8	0
2004	242069	-2.2	-2.53	-4.62	-1.4	0
2005	693264	-1.65	-1.82	-1.45	4.9	0
2006	536630	-1.18	-1.65	-4	-6	0
2007	1243906	-1.39	-4.42	7.42	-12.3	0
2008	1002761	-1.14	-1.59	3.39	-18	0
2009	581758	0.79	-1.83	-1.61	-17.5	0
2010	201832	-0.38	-2.6	-8.94	-9	0
2011	358117	0.83	-0.07	-5	-4.3	0
2012	503017	0.91	-0.13	-5.05	-4.3	0
2013	464921	0.04	-0.09	1.44	-10.5	0
2014	852202	-0.46	-1	1.43	-17.8	0
2015	452019	-1.26	-1.62	-2.22	-10.5	0

2016	286334	-1.31	-1.92	-7.52	-5.8	0
2017	781901	-0.33	-0.64	-1.69	-14.4	0
2018	508296	-1.24	-1.41	0.1	-20.9	0
2019	659091	-0.63	-1.08	-1.71	-13.2	0
2020	572413	-2.02	-2.19	-6.35	-13.6	0
2021	NA	-0.8	-1.08	-1.33	-9.2	0
2022	NA	-1.55	-2.10	-2.47	-12.8	0
2023	NA	-1.52	NA	-4.18	NA	0
2024	NA	-0.31	NA	-5.63	NA	0

Appendix 2. Parameters for RCT3 model.

yearclass	recruitment	BST1	BST2	BST3	BSA1	BSA2	BSA3
1982	534	NA	NA	NA	NA	NA	NA
1983	1375	NA	NA	NA	NA	NA	NA
1984	360	NA	NA	NA	NA	NA	NA
1985	336	NA	NA	NA	NA	NA	NA
1986	158	NA	NA	NA	NA	NA	NA
1987	130	NA	NA	NA	NA	NA	NA
1988	296	NA	NA	NA	NA	NA	NA
1989	716	NA	NA	NA	NA	NA	NA
1990	988	NA	NA	NA	NA	NA	NA
1991	752	NA	NA	294	NA	NA	324
1992	539	NA	557	283	NA	624	138
1993	407	1044	541	163	903	212	99
1994	785	5356	792	318	2175	272	159
1995	1064	5899	1423	355	1826	565	391
1996	632	5044	496	188	1699	475	148
1997	750	2491	350	246	2524	232	295
1998	593	473	242	183	365	263	177
1999	374	129	78	118	153	52	61
2000	757	713	419	377	364	209	307
2001	242	34	66	64	19	53	33
2002	693	3022	243	249	1505	117	125
2003	537	323	217	116	161	139	65
2004	1244	853	289	361	500	158	59
2005	1003	674	370	194	411	47	200
2006	582	595	102	126	85	94	108
2007	202	69	36	37	51	26	23
2008	358	389	95	85	205	44	40
2009	503	1028	226	76	620	91	83
2010	465	617	100	69	266	40	61
2011	852	703	143	227	497	89	287
2012	452	436	191	144	313	211	139
2013	286	1246	343	99	1759	211	56
2014	782	1642	306	179	1904	202	112
2015	508	312	129	139	241	73	109
2016	659	645	501	282	439	280	204
2017	572	2714	559	238	2058	362	117
2018	NA	1791	274	115	1437	158	70
2019	NA	165	33	NA	93	17	NA
2020	NA	88	NA	NA	44	NA	NA

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WD to AFWG-2021

Assessment of population recruitment abundance of Northeast Arctic cod considering the environment data

by

Oleg Titov

Abstract

Analysis of results of approbation of methods of abundance assessment of northeastern arctic (NEA) cod at the age of 3 with advance time of 1-4 years has been carried out (Titov, 1999, 2001, 2011, 2018).

Introduction

One of the most important practical and theoretical problems connected with studying of marine ecosystems is prediction of values of commercial fishes' population recruitment. At present, natural processes, influencing the dynamics of the marine ecosystem, are hardly taken into consideration when predicting values of the Barents Sea commercial fishes' population recruitment. This leads, in particular, to sufficient shortening of the advance time and to decrease of accuracy of predictions of recruitment abundances of NEA cod and, correspondingly, to errors at prognostication of TAC. One of experiments on application of the ecosystem approach to prediction of the Barents Sea capelin and NEA cod recruitment abundance was models with the use of data on physical and chemical status of environment as indices of long-term variations of the Barents Sea ecosystem as a single whole (Titov, 1999; Titov, 2001). The models, as well as several statistical models, which use multiple linear regressions, have been compared by the ICES AFWG (e.g. Bulgakova, 2005; Stiansen *et al.*, 2005; Titov *et al.*, 2005, Svendsen *et al.*, 2007). In 2009 statistical models (Titov et al., 2005, Titov, 2008) were partially changed. Joint ecosystem autumn survey index for 0-group cod was replaced on 0-group cod abundance index, corrected for capture efficiency (Anon, 2009). The data till 1983 were excluded at calculation of statistical models in 2010. In order to improve prediction the water temperature data was added to one of the models in 2011. Because of the danger of over-fitting regression models, one should always strive for simplicity (Dingsør et al., 2010). Prediction capabilities of the models were improved by dropping one or more terms. This was done in 2011 in accordance with statistical criteria. All models are greatly simplified. In general, 7 independent variables were removed from the 5 models.

In 2016 - 2017 there was a significant break in the program for the implementation of the oceanographic section "Kola Meridian", the data of which are used in forecasting models. From June 2016 until the time of preparation of the forecasts on the AFWG (April 2017), the data from the oceanographic section was not received and there is no way to restore the break. It was decided to not publish the corresponding forecasts in 2017.

In accordance with the recommendations of AFWG 2016 (Anon., 2016), an alternative version of the forecast was presented in which the spawning biomass of NEA cod is used as a predictor.

In view of the significant correction of the historical series of biological data that occurred in 2017, the calculations of the retrospective forecast for 2016 was given. A comparative analysis of the forecasts made on the biological characteristics of the NEA cod for 2016 and 2017 was given (Anon, 2017).

In 2018 at the meeting of the AFWG, the correction of models was continued. Due to the fact that in 2017 there was a significant correction of the initial biological data, which caused significant changes in the results of the prognostic models, in 2018 a complete audit of both the prognostic models and the hybrid model combining the results of their work was carried out. The main purpose of the model revision was to increase the stability of the models, that is, to reduce the possibility of potential correction of the models due to correction of the biological parameters included in the model. The solution of the problem was found by increasing the retrospective database by almost 2 times, that is, from the beginning of the 80s to the beginning of the 60s of the last century. Accordingly, sets of predictor sets have been revised. As a result, after comparing the results of constructing independent retrospective forecasts using the methodology previously used in ICES SGRF (Anon. 2013), it was decided to abandon the use of biological predictors and to use only environmental data in the NEA cod recruitment forecasting models. The number of models was reduced from 5 to 2 and the names of the models were changed from Titov (0, 1, 2, 3, 4) to TitovES (environment, short prediction) and TitovEL (environment, long prediction).

In 2019, the models are designed for two cod recruitment abundance options.

Materials and methods

The initial information (legend is in brackets):

- (Tw) mean monthly anomalies of water temperature at stations 3-7 of the Kola section (0-200 m layer) since 1981 by data of PINRO data base averaged 12 values in the end of the period of averaging;
- (I) mean monthly anomalies of ice coverage of the Barents Sea (percentage ratio between the area covered by ice and total area) since 1979 by data of the Murmansk UGMS averaged 12 values in the end of the period of averaging;
- (OxSat) mean monthly anomalies of saturation by oxygen of near-bottom water layers at 3-7 stations of the Kola Section since 1979 by data from the information base of PINRO averaged by 12 values in the end of the period of averaging;
- (Cod3) annual (start of year) values of abundance of cod at the age of 3 considering cannibalism since 1983 (Anon, 2021);

Calculation of indices ITw. As a characteristics of intensity of interaction between the arctic and boreal oceanic systems on the shelf of the Barents Sea the indice ITa was used which was calculated by the numerical comparison between variations of the thermal status of ocean in the southern part of the Barents Sea and its ice coverage by the method of linear regression (Titov, 1999; Titov, 2001). Parameters of the linear regression model, describing the changes of ice coverage of the Barents Sea, were calculated by variations of water temperature. After that the differences (remainders) of mean monthly values of ice coverage and analogous values derived by the known parameters of the regression equation were calculated. Time lag, at which maximum cross-correlation relationship between variations of the mentioned parameters appeared, was taken into consideration.

Lag constituted 3 months for ice coverage relatively to water temperature. Equations used for calculations were as follows:

$$ITw_t = I_t - (-12{,}017*Tw_{t-3}-0{,}0688) \quad (1)$$

Names of indices in equations are mentioned above in the text, low indices characterize time lags in months.

Calculation of index DOxSat. Earlier (Titov, 1999; Titov, 2001) it was shown that formation of cod year classes abundance (Cod3) was influenced by the airing of near-bottom layers (OxSat) in a complex manner. From one side, there is a feedback between these parameters at larger time lag and a direct link at the less time lag; correspondingly, the densest link is between Cod3 and velocity of change of oxygen saturation of near-bottom layers. On the other side, a direct link has an exponential character. For a full account of these links the index DOxSat was calculated by the formula:

$$DOxSat_t = \exp(OxSat_t) – OxSat_{t-26} \quad (2)$$

Names of indices in equations are mentioned in the text, low indices characterize the time lags in months.

Searching for nonlinear links. Searching for nonlinear links between abundance of year classes of cod with indices mentioned above was carried out. It was stated that some links are approximated best of all by the quadratic equations or in an exponential form.

Regression equation of link of Cod3 with abiotic and biotic parameters.

The final set of predictors was determined by the method of step-by-step multiple regression. Parameters were chosen on the basis of recommendations on the use of package Statgraphics Plus for Windows 2.1. It is allowed to enter all the variables into the model at one time. But because of the danger of over-fitting regression models, one should always strive for simplicity (Dingsør et al., 2010). Prediction capabilities of the models were improved by dropping one or more terms. This was done in accordance with statistical criteria on the basis of recommendations of Statgraphics Plus. In determining whether the model can be simplified, the highest P-value on the independent variables was noticed. In case of P-value was greater or equal to 0.10 (no statistical significance at the 90% or higher confidence level), such independent variables remove from the model. The parameters in the equations vary automatically.

The equation for the forecast of Cod3 with advanced time of 0-1 years (TitovES a), 0-3 year (TitovEL, b) with meanings of parameters for April 2020 are shown below.

(a) $Cod3_t = 20791*DOxSat_{t-13}\text{^}2 + 36287*ITw_{t-43} - 2130*\exp(Ice_{t-40}) - 11462*Ice_{t-15} + 478050$

$R^2 = 0.63; n = 59$

(b) $Cod3_t = - 88622*OxSat_{t-39} + 37332*ITw_{t-43} + 569120$

$R^2 = 0.38; n = 59$

For all statistical models values $P<0.01$, that corresponds to the level of significance 99 % (all individual $P<0.1$).

Tables 1 present initial parameters used in modeling.

Table 1. Parameters of models (low indices correspond to the time lag (months from the start of the year to which the value Cod3 is attributed).

Year	$Cod3_t*10^6$ (Final run)	$OxSat_{t-39}$	$DOxSat_{t-13}$	ITw_{t-43}	Ice_{t-15}	$expIce_{t-40}*10^6$
1962	1252375	-0,19	-6,60	1,86	0,5	0,0
1963	900621	-0,94	-2,37	1,59	1,5	0,0

1964	468028	1,63	1,23	2,47	9,0	0,0
1965	870506	0,88	-0,20	3,91	15,7	0,0
1966	1842715	-1,09	-3,98	7,97	5,3	0,0
1967	1311586	-0,23	-2,84	8,23	5,0	9,3
1968	183717	1,50	-0,13	3,78	15,5	0,0
1969	110450	0,85	0,63	1,77	15,9	0,0
1970	205641	-0,17	-0,23	3,51	19,8	7,9
1971	402577	0,06	-0,12	-0,13	18,8	2,7
1972	1045979	-3,32	-6,59	14,55	-0,6	428,9
1973	1723668	-2,10	-10,37	19,14	1,8	768,6
1974	568211	1,06	-1,73	2,40	2,0	0,0
1975	608710	1,90	0,78	-2,64	-1,2	0,0
1976	607084	1,33	-1,28	-3,07	-1,9	0,0
1977	372778	-0,07	-1,84	-2,44	2,5	0,0
1978	622679	1,19	0,10	1,05	-1,0	0,0
1979	202675	0,50	-1,48	-0,12	3,5	0,0
1980	130292	-0,31	-2,72	1,98	12,9	0,0
1981	143781	0,76	-0,18	1,94	14,7	0,0
1982	183737	0,80	0,61	-3,15	8,0	0,1
1983	141514	0,78	0,22	1,87	12,2	8,5
1984	442251	-2,21	-2,35	-3,08	12,9	0,0
1985	534310	-0,10	-1,17	3,59	-1,2	0,1
1986	1374917	-2,14	-4,39	1,39	-8,5	2,9
1987	360087	-0,33	-1,69	2,12	0,6	0,0
1988	335536	0,87	-1,40	-2,34	3,8	0,0
1989	157635	0,32	-3,42	-5,17	10,5	0,0
1990	130130	1,11	-1,32	-4,21	10,5	0,0
1991	295846	0,88	0,70	2,42	6,5	0,0
1992	715916	1,34	0,48	1,37	-0,9	0,0
1993	988150	-1,98	-3,86	6,12	-0,6	0,0
1994	752473	-0,50	-2,26	8,25	-4,9	0,0
1995	539384	0,83	-2,42	4,36	1,8	0,0
1996	407389	0,86	-0,08	0,55	0,7	0,0
1997	785420	0,88	0,17	3,11	-7,3	0,0
1998	1063528	0,30	-6,08	-2,32	-2,5	0,0
1999	632034	-0,72	-2,40	-6,81	2,9	0,0
2000	749727	1,86	1,55	-2,29	13,6	0,0
2001	593152	0,62	0,05	-6,04	2,3	0,0
2002	374202	-0,88	-0,98	3,63	-9,9	0,8
2003	756675	-0,39	-0,64	8,50	-5,8	0,0
2004	242069	-2,20	-2,53	-4,62	-1,4	0,0
2005	693264	-1,65	-1,82	-1,45	4,9	0,0
2006	536630	-1,18	-1,65	-4,00	-6,0	0,0
2007	1243906	-1,39	-4,42	7,42	-12,3	0,0
2008	1002761	-1,14	-1,59	3,39	-18,0	0,0
2009	581758	0,79	-1,83	-1,61	-17,5	0,0

2010	201832	-0,38	-2,60	-8,94	-9,0	0,0
2011	358117	0,83	-0,07	-5,00	-4,3	0,0
2012	503017	0,91	-0,13	-5,05	-4,3	0,0
2013	464921	0,04	-0,09	1,44	-10,5	0,0
2014	852202	-0,46	-1,00	1,43	-17,8	0,0
2015	452019	-1,26	-1,62	-2,22	-10,5	0,0
2016	286334	-1,31	-1,92	-7,52	-5,8	0,0
2017	781901	-0,33	-0,64	-1,69	-14,4	0,0
2018	508296	-1,24	-1,41	0,10	-20,9	0,0
2019	659091	-0,63	-1,08	-1,71	-13,2	0,0
2020	572413	-2,02	-2,19	-6,35	-13,6	0,0
2021		-0,80	-1,10	-1,33	-9,2	0,0
2022		-1,55	-2,10	-2,47	-12,8	0,0
2023		-1,52		-4,18		0,0
2024		-0,31		-5,63		0,0

Results

Prognoses from models (a) – (b) are shown in Table 2.

Table 2. Recruitment models prognoses (Final run)

Model	Species	Variable	Years	Prognosis available	**2021**	**2022**	**2023**	**2024**	Unit
TitovEL	NEA cod	Age 3	4	At assessment	**590**	**614**	**548**	**386**	*10^6
		weight			*0,34*	*0,47*	*1,00*	*1,00*	
TitovES	NEA cod	Age 3	2	At assessment	**557**	**627**			*10^6
		weight			*0,42*	*0,53*			
RCT3	NEA cod	Age 3	3	At assessment	**525**				*10^6
		weight			*0,24*				
Hybrid	NEA cod	Age 3	4	At assessment	**561**	**621**	**548**	386	*10^6

[1] Model that are proposed to Hybrid 2021 (Anon, 2021)

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NEA haddock stock assessment by means of TISVPA

D.Vasilyev
Russian Federal Research Institute of Fisheries and Oceanography (VNIRO),
17, V.Krasnoselskaya St., 107140, Moscow, Russia

The TISVPA model (Vasilyev, 2005; 2006) was applied to the same northeast arctic haddock data as XSA and SAM models, except the natural mortality values from cannibalism were taken from the SAM runs. The 4 sets of age - structured tuning data were included into analysis: Russian bottom trawl survey ("fleet 01"); Joint Barents Sea acoustic survey ("fleet 02), Joint Barents Sea bottom trawl survey ("fleet 04"), and Joined Russian-Norwegian ecosystem autumn bottom trawl survey in the Barents Sea ("fleet 007").

The TISVPA model was modified to give possibility to use +-group in surveys in position younger than the oldest age in the asessment.

The TISVPA options were chosen similar to those in 2020 assessment: so called "mixed" version, assuming errors both in catch-at-age and in separable approximation; additional restriction on the solution was the unbiased model approximation of separable representation of fishing mortality coefficients. The generation-dependent factors in triple-separable representation of fishing mortality coefficients were estimated and applied for age groups from 3 to 11. The tuning on surveys data was made at abundance for all fleets; the measure of closeness of fit was the median of squared logarithmic residuals (MDN) for the fleet 01, the sum of squared logarithmic residuals (SSE) for fleets 02 and 007, and the absolute median deviation of logarithmic residuals (AMD) for the fleet 04. For catch-at-age data the measure of closeness was the sum squared logarithmic residuals. The profiles of the components of the TISVPA loss function for such model settings are shown in Figure 1.

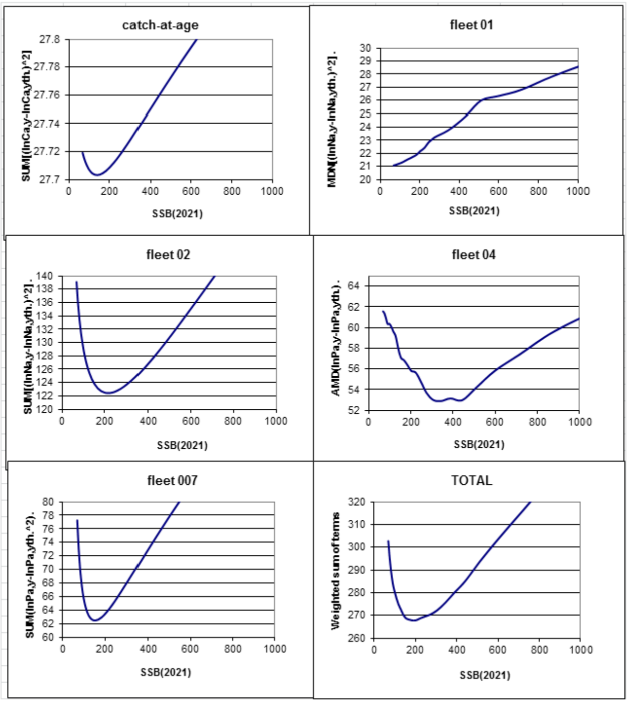

Figure 1. Profiles of the components of the TISVPA objective function for the preliminary model run.

As it can be seen, the position of the minimum of total loss function is mostly determined by signals from catch-at-age and fleets 02 and 007.

Figure 2 represents the results of retrospective runs.

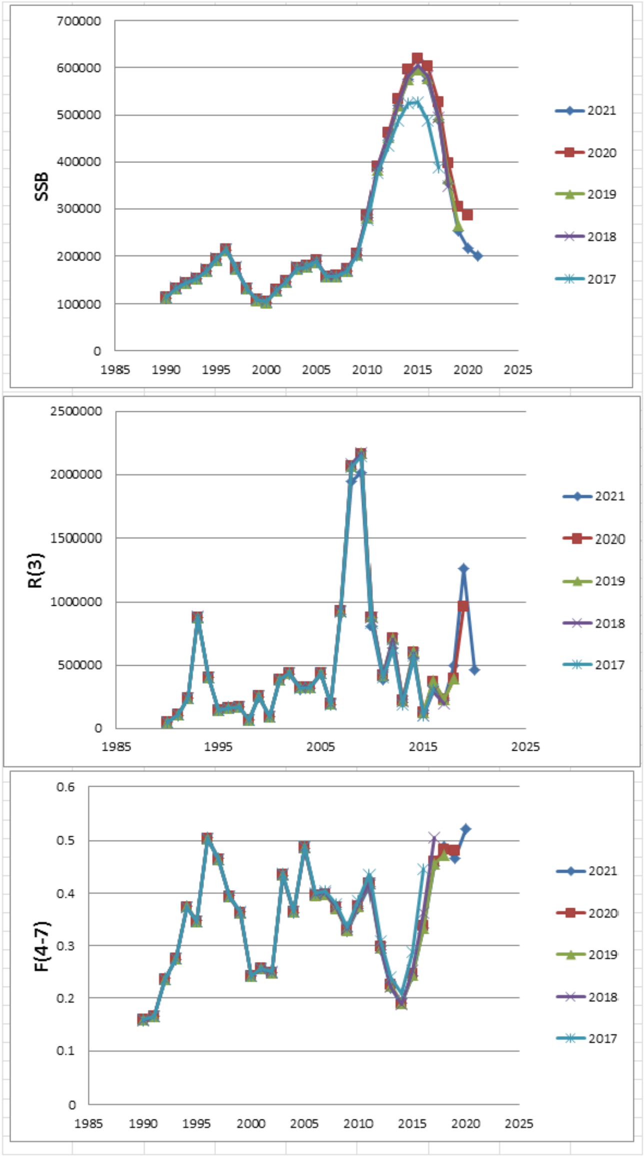

Figure 2. TISVPA retrospective runs

The residuals of the model approximation of catch-at-age and "fleets" data are presented in Figure 3.

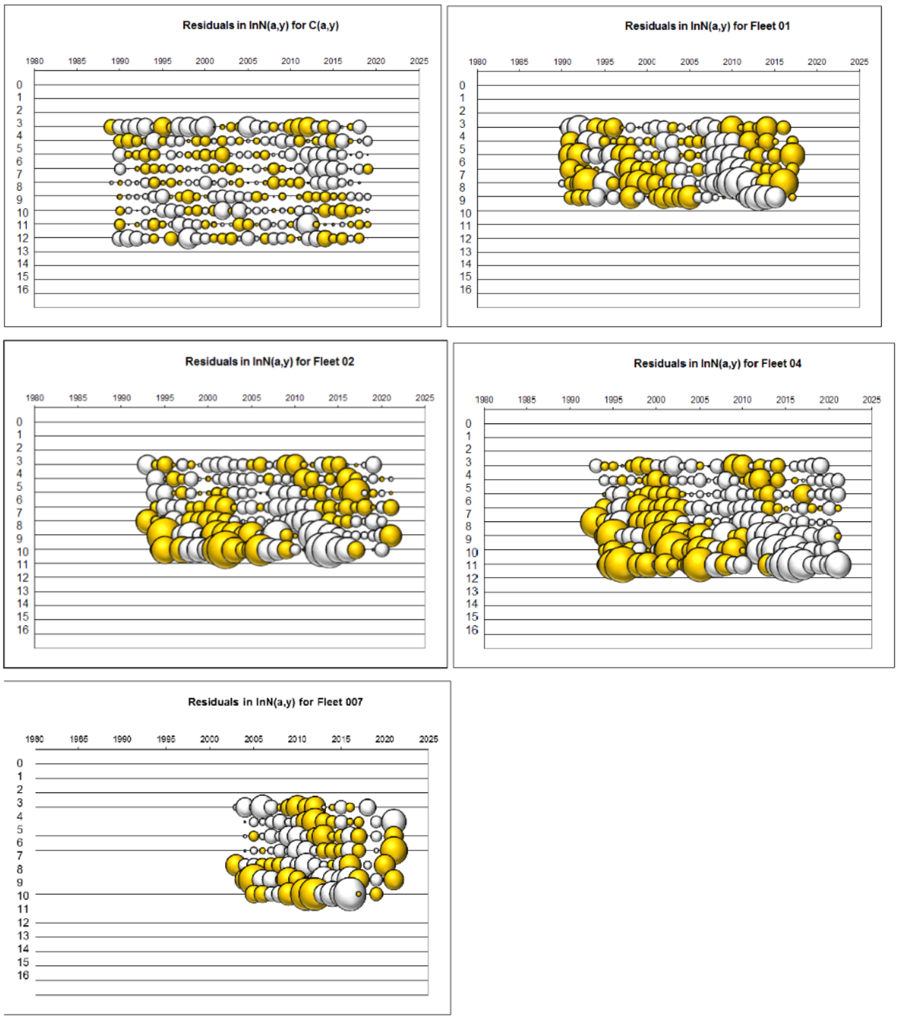

Figure 3. Residuals of the TISVPA data approximation.

The estimates of uncertainty in the results (parametric conditional bootstrap with respect to catch-at-age; "fleet" data were noised by lognormal noise with sigma=0.3) are presented on Figure 4.

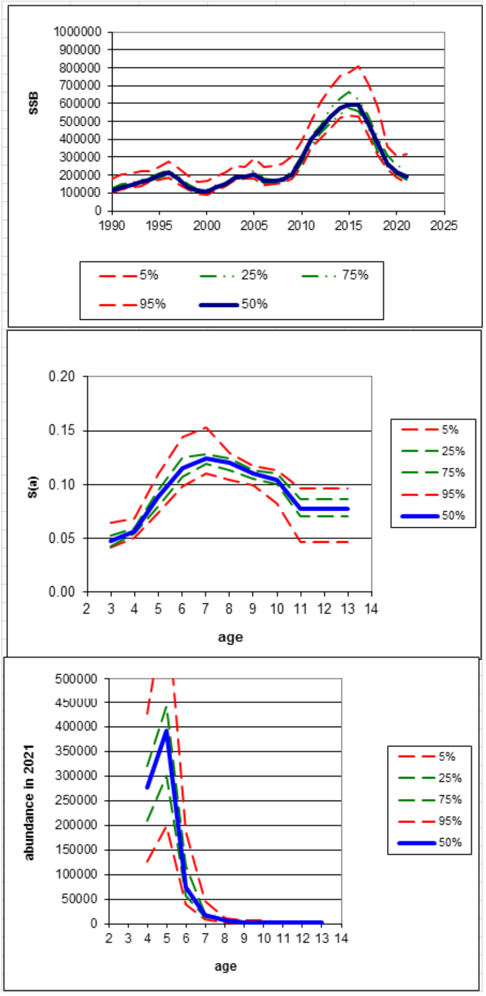

Figure 4. Bootstrap- estimates of uncertainty in the results.

The results of the assessment are presented in the Tables 1-3.

Year	B(3+)	SSB	R(3)	F(4-7)
1990	198632	112684	44925	0.158
1991	224795	132544	102954	0.167
1992	293795	143409	233434	0.238
1993	531906	153139	871155	0.274
1994	652311	169490	399159	0.374
1995	652077	191921	141581	0.348
1996	549787	212374	165145	0.506
1997	393575	173762	169618	0.466
1998	271933	131491	63605	0.396
1999	286052	108087	249706	0.365
2000	281196	103426	91257	0.243
2001	384312	128574	382665	0.256
2002	491667	147264	429048	0.249
2003	542885	173906	307705	0.432
2004	524530	177934	315579	0.363
2005	541297	188653	429660	0.485
2006	456597	157695	187348	0.396
2007	582310	159041	900113	0.399
2008	942307	170557	1946941	0.372
2009	1361662	202432	2014994	0.328
2010	1533548	281418	805294	0.372
2011	1495754	384841	385486	0.412
2012	1327578	452256	632388	0.291
2013	1131217	519292	203381	0.219
2014	1161200	575436	554538	0.191
2015	1089430	595461	119085	0.242
2016	985599	572883	333238	0.334
2017	834538	490177	215779	0.451
2018	702284	355166	492320	0.489
2019	831498	253103	1260117	0.467
2020	831438	215213	464495	0.523
2021		199866		

Table 1. Haddock. The results of the assessment by TISVPA

	3	4	5	6	7	8	9	10	11	12	13
1990	44924.55	20660.38	26722.65	37433.32	38889.51	5684.74	1503.24	427.77	246.94	138.94	470.25
1991	102954.5	29479.35	14965.21	19329.91	26268.94	26084.67	3924.98	1119.61	316.91	185.17	277.75
1992	233433.7	78749.2	21208.48	10217.19	12835.73	17460.06	17641.85	2768.91	841.87	247.47	139.2
1993	871154.8	173242.9	55049.41	14004.03	6057.76	7749.48	11145.76	11261.76	1840.77	646.95	168.48
1994	399158.8	613007.1	116514.6	30342.7	7674.98	3335.07	4548.86	7044.83	7195.45	1303.75	246.66
1995	141581.4	263558.6	418625.3	59415.46	13837.52	4133.76	1707.47	2384.53	3696.38	4433	639.59
1996	165144.6	84003.17	153738.3	218573.1	28981.26	6417.41	2471.75	968.57	1305.07	2433.15	3120.78
1997	169617.6	60514.38	48788.79	80535.24	88159.73	12103.71	2652.47	1324.21	443.39	682.55	2000.14
1998	63605.03	82816.58	38984.5	25431.98	33613.39	32993.38	5389.14	1324.98	762.88	252.14	1760.34
1999	249706	45546.32	50143.66	21884.6	12614.35	15485.8	13104.92	2690.74	720.44	520.12	1049.79
2000	91256.6	177767.2	30659.79	25986.32	11446.69	6036.5	7409.55	5957.93	1525.33	458.09	1204.12
2001	382664.9	69213.58	120764.4	19640.04	15165.83	7063.2	3471.51	4535.88	3440.07	1056.9	1801.11
2002	429047.9	281616.2	51660.14	70350.83	11843.79	9051.19	4509.28	1931.93	2703.18	2202.23	618.39
2003	307705.1	271127.7	189182.7	34239.35	38339.83	7274.49	5560.03	3018.71	1166.59	1754.81	1678.33
2004	315579.5	166633.3	167825.5	100574.5	19007.18	16219.15	4089.38	2682.89	1678.8	645.26	2158.61
2005	429660.1	173494.5	98662.62	95040.5	45508.92	11209.11	7924.29	2531.03	1291.94	1096.33	4414.5
2006	187348.5	239450.4	103005	53913.26	39112.59	17449.28	6741.94	3615.42	1317.84	817.33	1499.22
2007	900112.6	133355.7	159821.9	54868.39	28066.33	17641.57	7652.64	4284.21	1807.38	870.82	817.77
2008	1946941	556712.9	89978.2	87757.34	24189.61	13118.7	7781.78	3784.24	2770.86	1005.96	780.32
2009	2014994	1099662	336103.2	49679.8	38342.77	11812.96	6634.04	3866.06	1991.54	1963.33	1785.35
2010	805294.4	1143573	711349.6	183109.5	25929.96	19996.49	6477.51	3849.13	2259.43	1319.87	3386.95
2011	385486.3	495583.7	763032.5	383845.6	84531.16	13514.19	11558.08	3651.32	2198.84	1409.56	3709.91
2012	632387.5	192093.1	253512.2	407843.5	179622.8	37183.92	7254.19	7014.32	2229.08	1413.46	3716.86
2013	203381	287332.8	124356.3	173805.9	242330.2	83265.53	19277.64	4582.62	4873.43	1573.35	3970.49
2014	554538.2	109649.6	177221	84992.63	117406.7	145416.3	44202.65	11460.35	2935.8	3567.65	4419.03
2015	119084.7	382147.3	81939.02	122262	59659.92	77406.95	87944.69	24221.27	7208.24	1972.79	2086.48
2016	333238.5	74010.39	209254.9	55440.28	77370.93	38944.43	46087.39	51434.88	13702.17	4636.34	1312.57
2017	215779.3	215635.5	53396.65	121620.1	31930.21	42073.1	21963.23	22884.54	29401.88	7615.09	1289.52
2018	492319.5	128353.9	124431	29777.21	42380.97	15467.53	19205.86	10788.84	11512.65	17605.76	5292.67
2019	1260117	260604.9	78988.6	62776.11	15378.04	16699.08	7571.91	8279.21	5519.34	6591.06	5380.46
2020	464494.8	735739.4	162869.6	42439.14	23115.92	6982.72	7001.9	3770.38	3713.38	3411.38	4071.29
2021	0	247001	394218.5	74619.56	18206.7	9177.9	2956.31	3163.84	1779.44	2139.04	1965.08

Table 2. Haddock. Estimates of abundance-at-age

F	3	4	5	6	7	8	9	10	11	12	13
1990	0.06923	0.0995	0.15138	0.17733	0.20334	0.16379	0.0864	0.08647	0.10915	0.10915	0.10915
1991	0.08227	0.08532	0.16927	0.20975	0.20171	0.1975	0.15742	0.08477	0.06212	0.11365	0.11365
1992	0.10129	0.13198	0.18895	0.31273	0.31793	0.25853	0.25004	0.20229	0.07869	0.15421	0.15421
1993	0.13215	0.13938	0.2543	0.29591	0.40565	0.34674	0.27785	0.27439	0.15909	0.17912	0.17912
1994	0.16476	0.21697	0.32247	0.49384	0.4637	0.54221	0.45257	0.3667	0.25467	0.24789	0.24789
1995	0.15339	0.17819	0.33103	0.3949	0.48612	0.38213	0.43786	0.37706	0.21834	0.2237	0.2237
1996	0.17204	0.25722	0.43084	0.68339	0.6508	0.67162	0.50978	0.60546	0.35369	0.31693	0.31693
1997	0.18857	0.19262	0.41259	0.5576	0.70233	0.54891	0.55774	0.43936	0.35579	0.29549	0.29549
1998	0.14146	0.20719	0.29642	0.52002	0.5584	0.57565	0.45045	0.46816	0.26164	0.27009	0.27009
1999	0.19276	0.16477	0.3422	0.39368	0.56095	0.49847	0.50652	0.40862	0.29574	0.26345	0.26345
2000	0.07738	0.16306	0.19274	0.32014	0.29674	0.34744	0.30871	0.32008	0.18775	0.18498	0.18498
2001	0.13662	0.09619	0.28657	0.27157	0.37133	0.29022	0.33548	0.30478	0.22389	0.19446	0.19446
2002	0.13541	0.16128	0.1553	0.38587	0.29442	0.33998	0.26353	0.3106	0.20116	0.19254	0.19254
2003	0.19009	0.2502	0.43089	0.32427	0.72247	0.43866	0.50617	0.39335	0.32504	0.30125	0.30125
2004	0.1661	0.20639	0.38661	0.53683	0.32059	0.58243	0.35897	0.42104	0.2336	0.2719	0.2719
2005	0.17074	0.22387	0.39848	0.62162	0.69424	0.33738	0.60918	0.38196	0.31173	0.30805	0.30805
2006	0.16616	0.18017	0.33313	0.47851	0.59252	0.54275	0.27073	0.48593	0.22103	0.27001	0.27001
2007	0.2183	0.21117	0.32253	0.49118	0.57052	0.58494	0.52877	0.27032	0.33491	0.2877	0.2877
2008	0.23145	0.24468	0.3331	0.40962	0.50234	0.48339	0.48849	0.45417	0.16947	0.26802	0.26802
2009	0.14769	0.23007	0.34293	0.37167	0.36725	0.37528	0.35757	0.36922	0.24323	0.22153	0.22153
2010	0.13805	0.18007	0.403	0.48421	0.41934	0.34795	0.35113	0.34217	0.24889	0.22644	0.22644
2011	0.12721	0.17193	0.31669	0.59344	0.5661	0.40684	0.33384	0.34435	0.2371	0.23688	0.23688
2012	0.12652	0.11944	0.22336	0.331	0.4907	0.39233	0.28551	0.24186	0.17824	0.18499	0.18499
2013	0.09533	0.13162	0.1709	0.25984	0.31314	0.38652	0.30861	0.23193	0.14222	0.16124	0.16124
2014	0.10313	0.10308	0.1968	0.2063	0.25699	0.26229	0.31785	0.26101	0.14225	0.14653	0.14653
2015	0.10231	0.15063	0.20819	0.32962	0.28046	0.29788	0.30054	0.37405	0.21683	0.18064	0.18064
2016	0.15314	0.15622	0.32797	0.36798	0.48437	0.34208	0.35962	0.37109	0.3229	0.23422	0.23422
2017	0.19212	0.24517	0.35353	0.638	0.56814	0.63168	0.43045	0.46437	0.33169	0.31702	0.31702
2018	0.18189	0.24091	0.44332	0.51379	0.75736	0.5497	0.60193	0.4217	0.31546	0.3323	0.3323
2019	0.21224	0.222	0.42252	0.63902	0.5837	0.70612	0.50937	0.57054	0.28093	0.33907	0.33907
2020	0.21956	0.26397	0.45755	0.64628	0.72372	0.6595	0.5944	0.55088	0.35159	0.35159	0.35159

Table 3. Haddock. Estimates of fishing mortality coefficients

References

. Vasilyev D. 2005 Key aspects of robust fish stock assessment. M: VNIRO Publishing, 2005. 105 p.

. Vasilyev D. 2006. Change in catchability caused by year class peculiarities: how stockassessment based on separable cohort models is able to take it into account? (Some illustrations for triple - separable case of the ISVPA model - TISVPA). ICES CM 2006/O:18. 35 pp

Annex 4: Audit reports

Audit of Northeast Arctic Haddock (AFWG 2021)

Date: 28. April 2021
Auditor: Elise Eidset

General

The Northeast Arctic Haddock assessment and draft advice have been approved by the Working Group.

For single stock summary sheet advice:

1) **Assessment type:** Age-based analytical assessment that uses catches in the models.
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: SAM. The model is tuned by three bottom trawl surveys and one acoustic survey.
5) **Data issues:** There was a time lag of almost three months between the western and eastern part of the Joint Barents Sea ecosystem survey in 2020. This might have influenced the result in an unknown way. It was discussed during the AFWG meeting, and it was decided to include the survey in the assessment.
6) **Consistency**: Last year's assessment was accepted. The assessment, recruitment and forecast models have been applied as specified in the stock annex.
7) **Stock status**: The stock was at an all-time high level around 2011, and has declined since. The SSB is above MSY $B_{trigger}$, B_{pa} and B_{lim}. The retrospective trend indicates that last year's SSB was overestimated. Fishing mortality has increased since 2013 and is above F_{MSY}, but below F_{pa} and F_{lim}. Recruitment in 2021 is below average. The 2018-2020 year classes are weak. The 2016-year class is the sixth strongest since 1950.
8) **Management Plan**: TAC for the next year will be set at level corresponding to FMSY.
   The TAC should not be changed by more than ±25% compared with the previous year TAC.
   If the spawning stock falls below Bpa, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from FMSY at Bpa to F = 0 at SSB equal to zero. At SSB-levels below Bpa in any of the operational years (current year and a year ahead) there should be no limitations on the year-to-year variations in TAC.

General comments

This was a well documented, well ordered and considered section. It was easy to follow and interpret. All data sets described in the stock annex are available.

Technical comments

No technical comments.

Conclusions

The assessment has been performed correctly and gives a valid basis for advice.

Format for audits (to be drawn up by expert groups and not review groups)

Review of ICES Scientific Report, *(*AFWG*, April 2021) chapter Sebastes mentella in 1-2*

Reviewers: Erik Berg

Expert group Chair: Daniel Howel

Secretariat representative: David Miller

Audience to write for: advice drafting group, ACOM, and next year's expert group

General
For advice other than single-stock summary fisheries advice

Section: Report chapter and Stock Annex.

Short description
Advice each second year, no advice this year. Analytical catch at age assessment (ICES category 1). Assessment updated. Report and assessment are consistent with stock annex. Minor errors found and corrected in some of the tables.

Comments

For single-stock summary sheet advice

Stock

Short description of the assessment as follows (examples in grey text):

1) Assessment type: Update
2) Assessment: accepted- analytical catch at age (ICES category 1)
3) Forecast: exploratory short-term forecast to the end of 2023 made
4) Assessment model: SCAA
5) Consistency: biannual advice.
6) Stock status: Fishing pressure is probably below FMSY and spawning-stock biomass probably above Bpa.
7) Management plan: No management plan available.

General comments
Is well documented and consistent with previous reports.

Conclusions
The assessment has been performed correct and consistently with the previous assessment (2020).

Format for audits (to be drawn up by expert groups and not review groups)

Review of ICES Scientific Report, *(*AFWG*, April 2021)*

Reviewers: Erik Berg

Expert group Chair: Daniel Howel

Secretariat representative: David Miller

Audience to write for: advice drafting group, ACOM, and next year's expert group

General
Biannual advice. No assessment or advice this year. Report is updated

For advice other than single-stock summary fisheries advice

Section: Report chapter and Stock Annex.

Short description

The report is updated, no assessment made, no advice given.

Comments

For single-stock summary sheet advice

Stock

Short description of the assessment as follows (examples in grey text):

1) Assessment type: Analytical
2) Assessment: Not made
3) Forecast: not made
4) Assessment model: gadget model
5) Consistency: Report in consistent with previous reports
6) Stock status: NA
7) Management plan: No management plan available.

General comments
Some small errors found and corrected in tables.

Conclusions
The report is updated correct and consistent with the previous report (2020).

Audit of: Coastal cod South between 62-67°N (cod.27.2.coastS), AFWG 2021

Date: 10.05.2021

Auditor: Hannes Höffle

Stock

This is a new stock, created by the splitting of the coastal cod stock in a northern and southern component, respectively. Coastal cod South is a category 3 stock and is assessed with the 2/3-rule, based on a standardized CPUE index from the reference fleet. A Length-Based Spawning Potential Ratio (LBSPR) model is used to check whether a precautionary buffer needs to be applied.

Assessment

1) **Assessment type:** Update
2) **Assessment:** Presented
3) **Forecast:** Alternative catch scenarios were presented.
4) **Assessment model:** Trend based assessment using the 2-over-3 rule.
5) **Consistency:** This is the first assessment after the coastal cod stock was split.
6) **Stock status:** The stock is thought to be below and the fishing pressure to be above MSY reference points. No biological reference points are established.
7) **Management plan:** The Norwegian Ministry of Fisheries is working on a new rebuilding plan. Until this plan is implemented management aims to reduce fishing pressure.

General comments

There are several minor, merely formal, issues in the report chapter. Some acronyms have to be explained upon first usage and a few table and figure captions need to be improved. All issues are highlighted in the report chapter.

Technical comments

No technical issues with the assessment were found.

Conclusions

The chapter is clear and concise and suffers only from a few minor issues that can be expected from a new text.

Audit of Greenland Halibut ghl.27.1-2 (AFWG 2021)

Date: 04. May 2021
Auditor: Alfonso Pérez-Rodríguez

General

The Greenland halibut assessment and draft advice have been approved by the Working Group.

For single stock summary sheet advice:

1) **Assessment type:** Update. Length based assessment conducted bi-annually.
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: Gadget. The model is tuned by three bottom trawl surveys, producing four survey indices.
5) **Data issues:** In AFWG 2021 assessment it has been decided to exclude the ecosystem survey data from 2018 (in line with their exclusion for cod and haddock). This removal has resulted in a downwards revision of the stock biomass since the AFWG 2019 assessment but has reduced the retrospective pattern for the 45cm+ biomass during the last 5 years. There is no age data to inform the model. The lack of reliable recruitment estimates is still a major problem.
6) **Consistency**: The assessment was provided in 2019, as specified in the stock annex. However, the advice was rejected and a roll-over advice was used for advice in 2020. ADGANW issued a request to repeat the advice process in 2020 with HR_{pa} reference points for use in the 2021 advice. Due to the need for a simplified approach related to the 2020 corona virus outbreak a roll-over advice was used in 2020 to provide advice on fishing opportunities in 2021.
7) **Stock status**: All the exploratory work suggests that the overall trends are robust, and despite the 45cm+ biomass is decreasing it is still above B_{pa}. However, care should be taken in interpreting the absolute abundance estimates (and hence absolute estimates of harvest rate). Without age data in the model tuning there is little information on total mortality (Z) at age, there is little information for the model to translate catch information into F, and hence inform biomass levels. Furthermore, the conflicting survey signals translate into an uncertainty range of several hundred thousand tonnes.
8) **Management Plan**: In the absence of a harvest control rule, maximum sustainable yield (MSY) reference points, and precautionary fishing mortality reference points, the advice is based on precautionary considerations (B_{pa}: 500000 tonnes; HR_{pa}: 0.025-0.035). To address the request made by ADGANW 2019, of using an Fmsy proxy, as well as Btrigger, a full benchmark followed by an HCR evaluation to come with a full management plan for this stock is planned in 2022. Until then, two alternatives HR_{pa} values (0.025 and 0.035) are used to provide advice in a two-year advice cycle.

General comments

This was a well documented, well ordered and considered section. It was easy to follow and interpret. All data sets described in the stock annex are available.

Technical comments

No technical comments.

Conclusions

The assessment has been performed correctly (as indicated in the stock annex) and gives a valid basis for advice following the precautionary approach.

Audit of Greenland halibut (*Reinhardtius hippoglossoides*) in Subareas 1 and 2 (Northeast Arctic)

Date: 10/05/2021
Auditor: Kjell Nedreaas

General

The stock is assessed by a GADGET length-based model since 2015 when the stock was last benchmarked. There is no agreement on age-reading methodology between Norway and Russia and the model is tuned using only length data. This gives uncertainty on the absolute levels of modelled biomass and F. The peaks of recruitment identified by the model are corroborated by survey length distributions, but the weaker year classes may be poorly modelled. It should be easier to reach agreement on the ageing of the younger ages hence confirming the year class strength with greater certainty at an early stage.
None of the surveys individually covers the complete stock distribution and there are discrepancies between the surveys. The retrospective pattern has greatly improved for the last four years.
The stock assessment in 2019 provided advice for 2020 and 2021. The draft advice sheet was rejected by ADGANW and a roll-over advice was used for advice in 2020. ADGANW issued a request to repeat the advice process in 2020 with HRpa reference points for use in the 2021 advice. A working document (Howel 2020, WD 15) was presented to address the definition of a HRpa for the stock. A HRpa proposal is available and was presented to AFWG 2020. However, due to the need for a simplified approach related to the 2020 corona virus outbreak ACOM decided, in agreement with Advice Requestors, that roll-over advice should be used in 2020 to provide advice on fishing opportunities in 2021.
In this year's assessment, two alternatives are proposed as HRpa for ADG/ACOM to decide, 0.035 or 0.025, both with the provison that if a large recruitment event is observed in the surveys then the HRpa should be revised before the incoming good recruitment enters the fishery. This solution for HRpa, if accepted by ACOM, would apply until the planned benchmark, i.e. for one two-year advice cycle.

The stock is due to benchmark in 2022.

For single stock summary sheet advice:

1. **Assessment type**: *GADGET length-based model (benchmark in 2015), supplemented with stock production models that were not updated for presentation at the current meeting.*
2. **Assessment**: *Updated assessment*
3. **Forecast**: *Forecasts for 2022 and 2023 based on HRpa scenarios (ICES 2017, Howel 2020).*
4. **Assessment model**: *In addition to GADGET, two production models (one of them SPICT) have been used to assess the stock in the past, however, none of the models was updated for presentation at the current meeting.*
5. **Data issues**: *Data available and used as described in stock annex. There was an update of the commercial fishing data and the survey data including 2020. The Stock Annex needs updating, at least after the planned benchmark in 2022.*
6. **Consistency**: *An updated assessment was conducted this year.*
7. **Stock status**: *This stock is assessed in relation to precautionary reference points. Fishing pressure on the stock is above HRpa; spawning-stock size is above Bpa, and Blim.*
8. **Management Plan**: *No*

General comments

The updated assessment done in 2021 is well-documented and structured in the report. Interim HRpa was calculated as a basis on which to give precautionary advice until a HCR is evaluated and agreed. There is no information about HRpa in the Stock Annex which needs to be updated.

Technical comments

Catch- and survey values in text and tables/figures have been ckecked and corrected when necessary and to the extent possible for the auditor. This has been done directly in the draft report using "track changes" and/or writing short notes. Other comments are more like suggestions that the authors should decide on.

Conclusions

An updated assessment was conducted this year, and a new benchmark on the stock is decided. for 2022. All the exploratory work suggests that the overall trends are robust, but that care should be taken in interpreting the absolute abundance estimates (and hence absolute estimates of harvest rate).

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?*

Audit of Northeast Arctic saithe (AFWG 2021)

Date: 21 April 2021
Auditor: Matthias Bernreuther

General

The Northeast Arctic saithe assessment and draft advice have been approved by the Working Group.

For single stock summary sheet advice:

1) **Assessment type:** update
2) **Assessment**: analytical
3) **Forecast**: presented
4) **Assessment model**: SAM – tuning by one acoustic survey (split in two time series)
5) **Data issues:** The biological sampling from the fishery has been critized in the last years as being critically low after the termination of the original Norwegian port-sampling program in 2009. However, the biological sampling has improved since 2016 and in 2020 the coverage of the commercial fisheries may be (under these circumstances) considered as adequate.
   The lack of reliable recruitment estimates is still a major problem.
6) **Consistency**: Last year's assessment was accepted. The assessment, recruitment and forecast models have been applied as specified in the stock annex.
7) **Stock status**: The SSB has been above B_{pa} since 1996, declined considerably from 2007 to 2011, then increased again and is presently (2020/2021) estimated to be well above B_{pa}. The fishing mortality was below F_{pa} from 1997 to 2009, started to increase in 2005 and was above F_{pa} from 2010 to 2012, but is presently estimated to be most likely below F_{pa}. The recruitment has since 2005 been at about the long-term geometric mean level.
8) **Management Plan**: Agreed 2011 (first time in 2007): F_{MP}=0.32 and SSB above B_{pa}=220 000 t. The TAC is based on an average TAC for the coming three years based on F_{MP}. There is a 15% constrain on TAC change between years. The plan was evaluated by ICES and was found in agreement with the precautionary approach.

General comments

This was a well documented, well ordered and considered section. It was easy to follow and interpret. All data sets described in the stock annex are available.

Technical comments

No technical comments.

Conclusions

The assessment has been performed correctly and gives a valid basis for advice.