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Section contents

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.

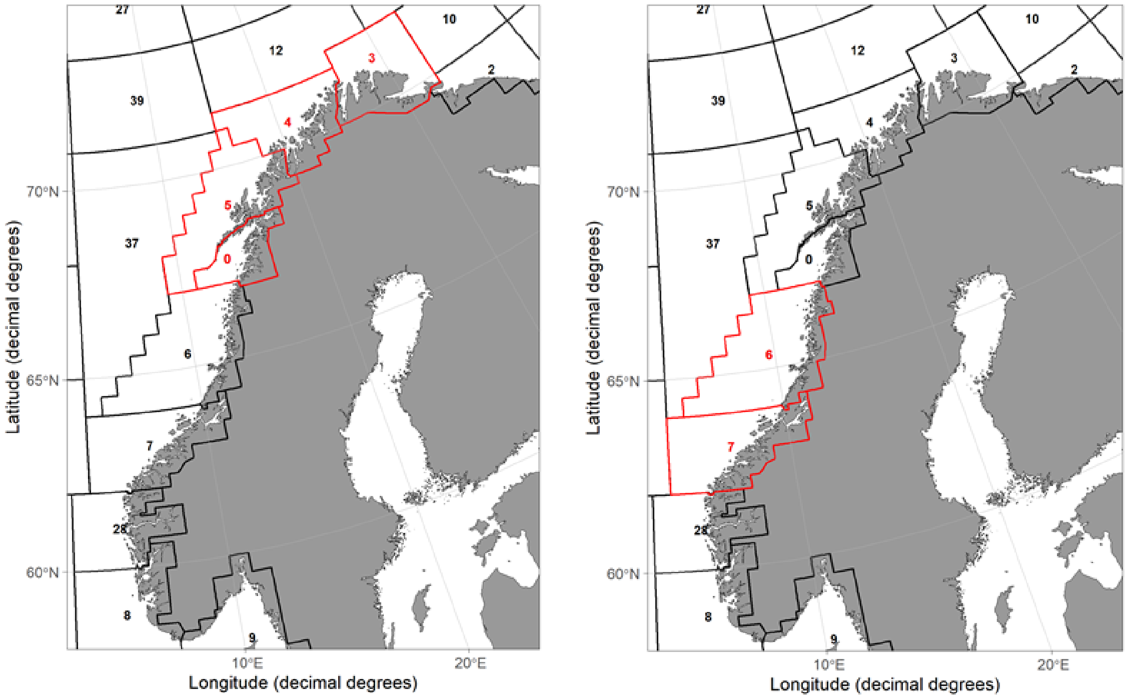


Figure 2.0.1 Norwegian catch reporting areas used to define stock distribution areas for northern Norwegian coastal cod (left) and southern Norwegian coastal cod (right).

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.

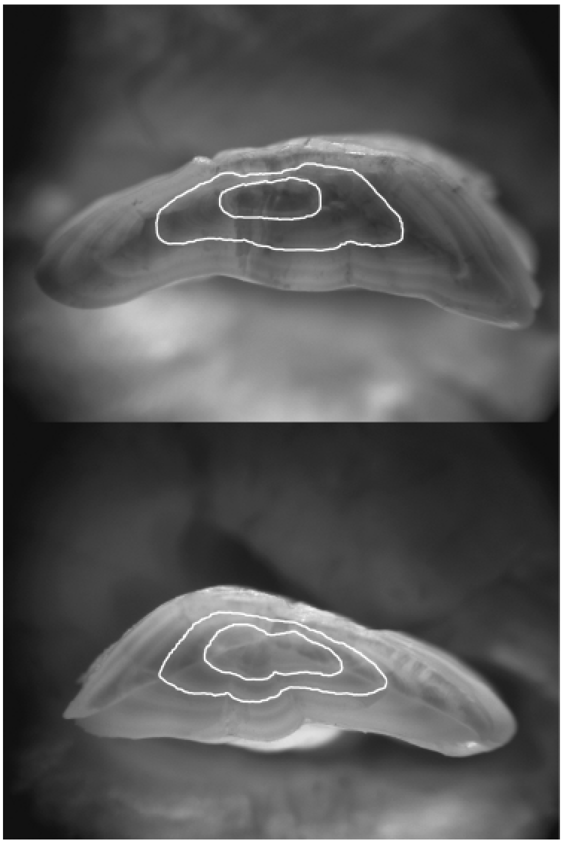


Figure 2.1.2. An image of a Norwegian coastal cod otolith (top) and a Northeast Arctic cod otolith (bottom). The two first translucent zones are highlighted. (from Berg *et al*., 2005).

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: North-east 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

Year	Age 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.

Year	Age 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

Year	Age 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.

Year	Age 1	2	3	4	5	6	7	8	9	10	Total number of aged cod oto-liths
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

Year	Age 1	2	3	4	5	6	7	8	9	10	Total number of aged cod oto-liths
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.

Year	Age 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
$F_{ages\ 4–7}$ (2021)	0.275	F_{sq} = median fishing mortality in 2020.
SSB (2021)	92 885	Short-term forecast fishing at *status quo* (F_{sq}); Tonnes.
$R_{age\ 2}$ (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.

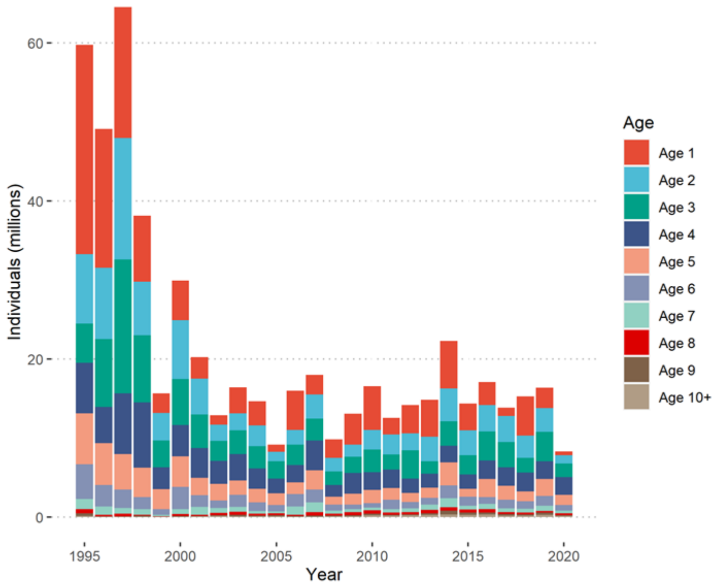


Figure 2.2.2. Acoustic abundance index by age (colours) from the Coastal survey in October–November (survey code A6335).

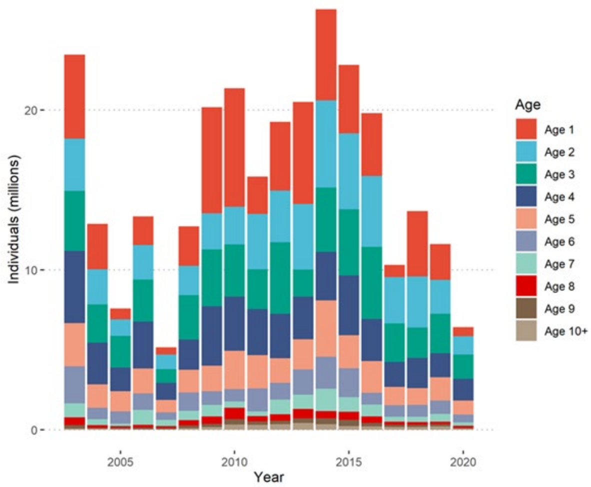
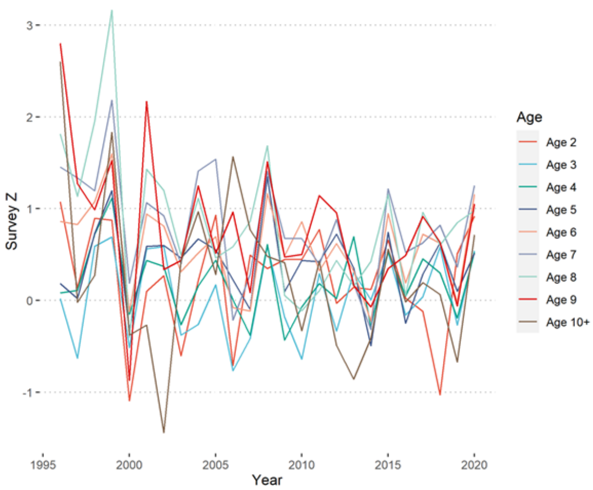


Figure 2.2.3. Swept area abundance index by age (colours) from the coastal survey in October–November (survey code A6335).



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*.

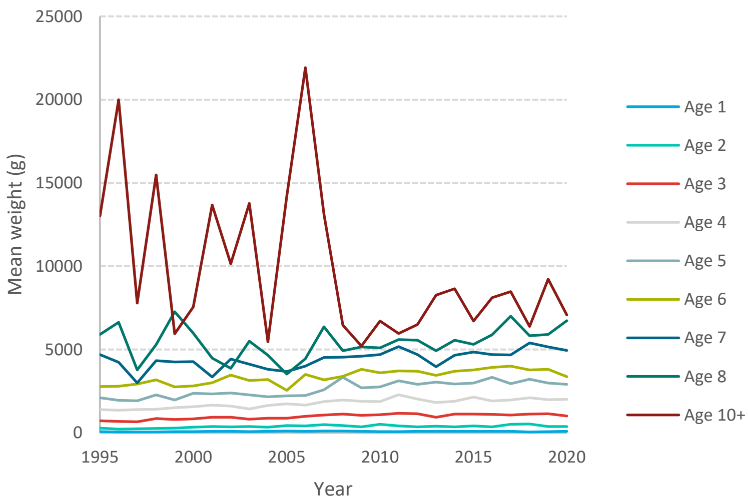
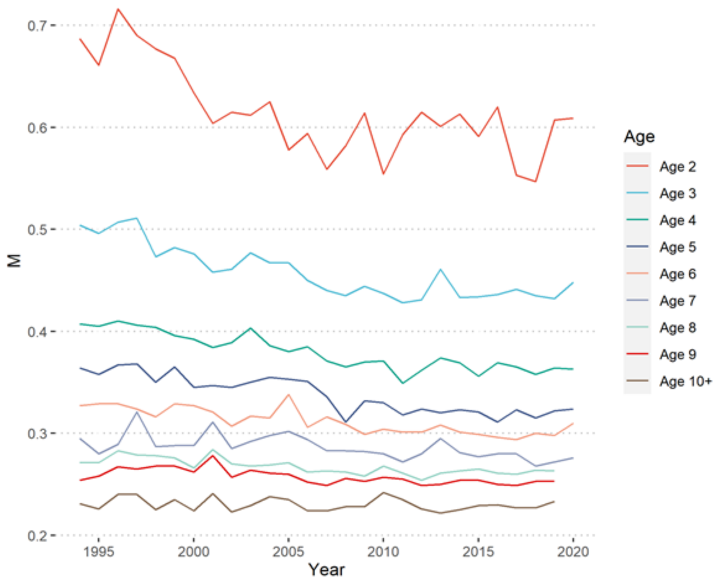


Figure 2.2.5. Mean weight-at-age in the coastal survey. Few individuals of ages 10+ were sampled in the beginning of the time series, leading to extremely large variation in mean weights.

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.

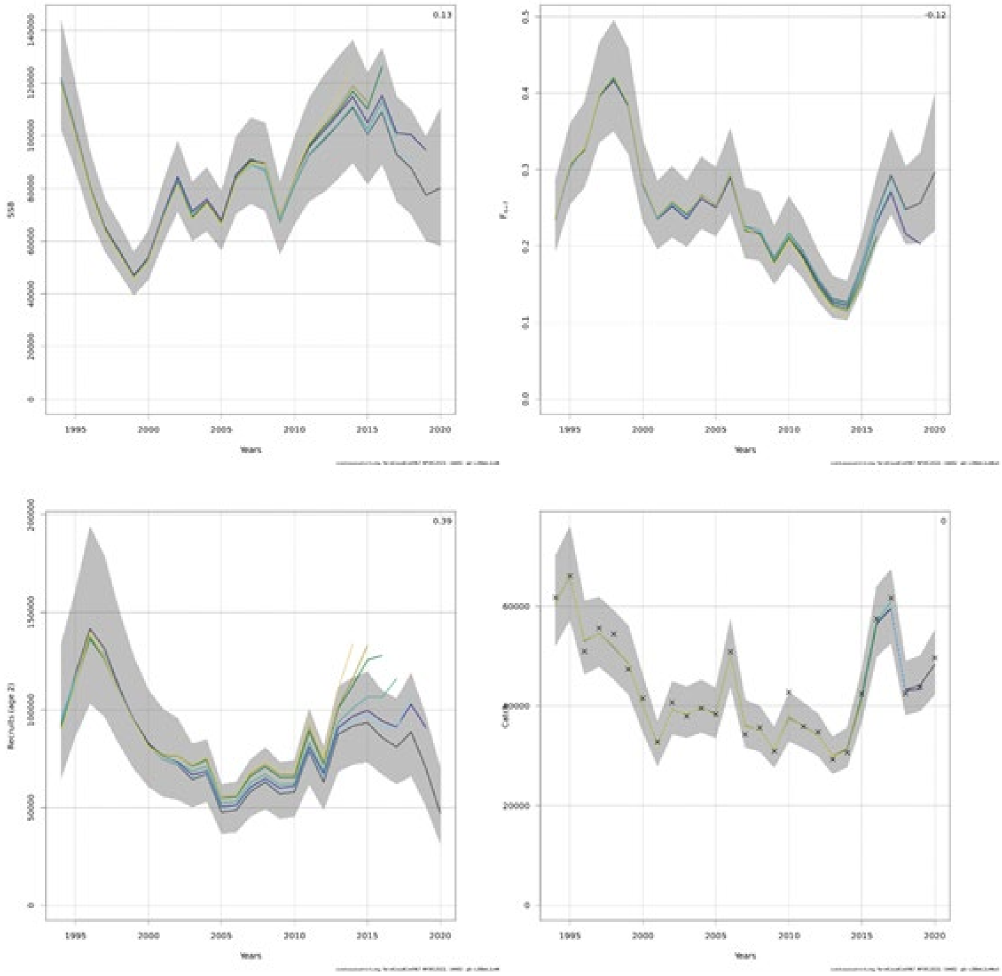


Figure 2.2.8. Northern Norwegian coastal cod. 5-year retrospective peel: a) SSB, b) Fbar, c) recruitment, and d) catch. The Mohn's rho value (average retrospective bias) is indicated in the upper right corner of each panel.

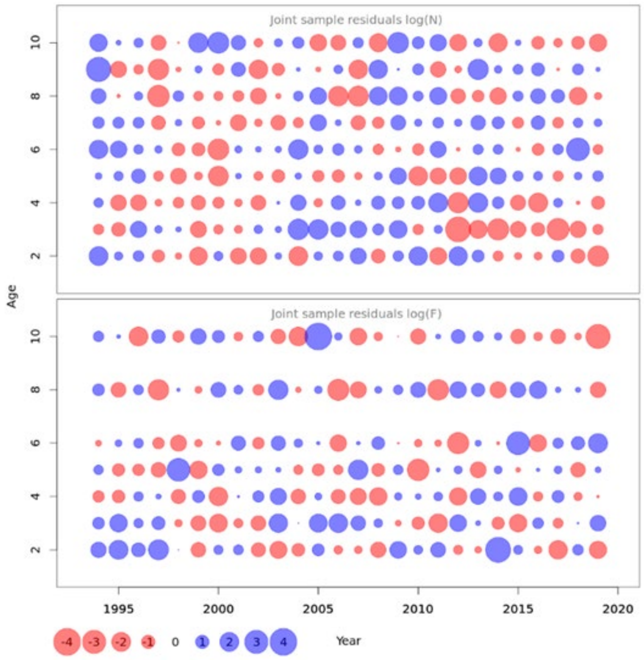


Figure 2.2.9. Residuals for the log(N) (top) and log(F) (bottom) process from the final SAM run.

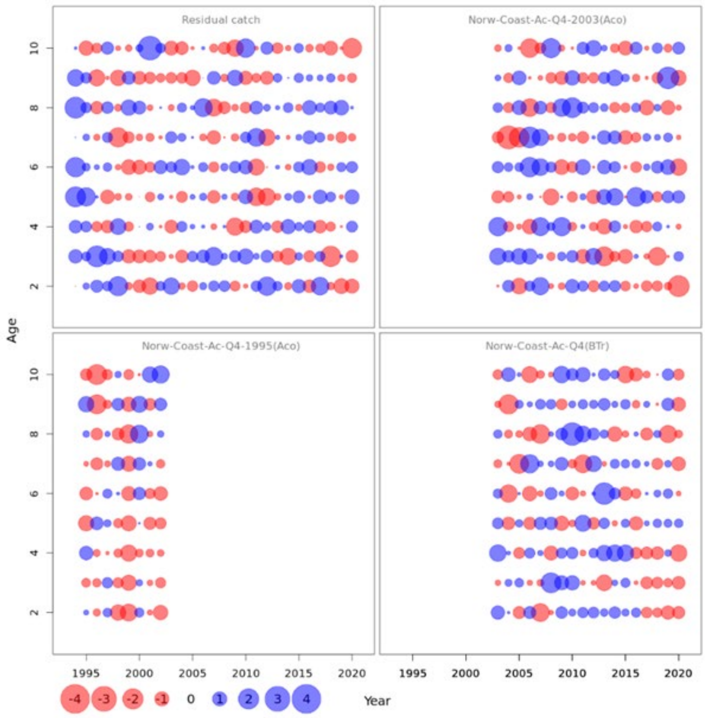


Figure 2.2.10. One-step-ahead residuals by fleet from the final SAM run. Blue circles indicate positive residuals and red circles indicate negative residuals. Top left: catch, top right: acoustic index pt. 1, bottom left: acoustic index pt. 2, bottom right: swept-area index.

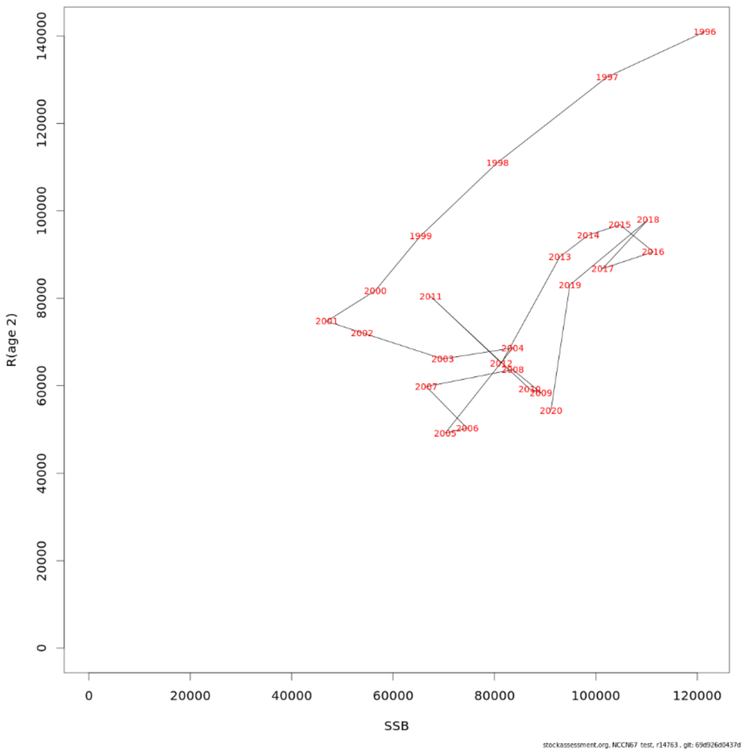


Figure 2.2.11. Stock–recruitment relationship from SAM. Estimated recruitment-at-age 2 (1000's) is plotted against estimated SSB (t) in the year of spawning (two years previously). The year labels in the figure indicate year of recruitment.

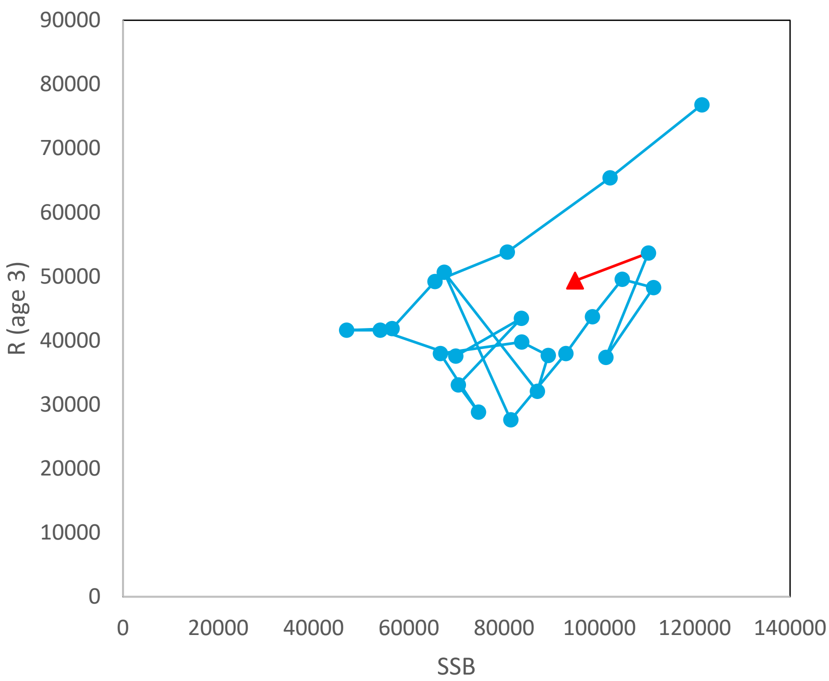


Figure 2.2.12. Comparative stock–recruitment relationship: estimated abundance-at-age 3 (1000's) plotted against estimated SSB (t) in the year of spawning (three years previously). Recruitment in 2020 is marked with a red triangle.

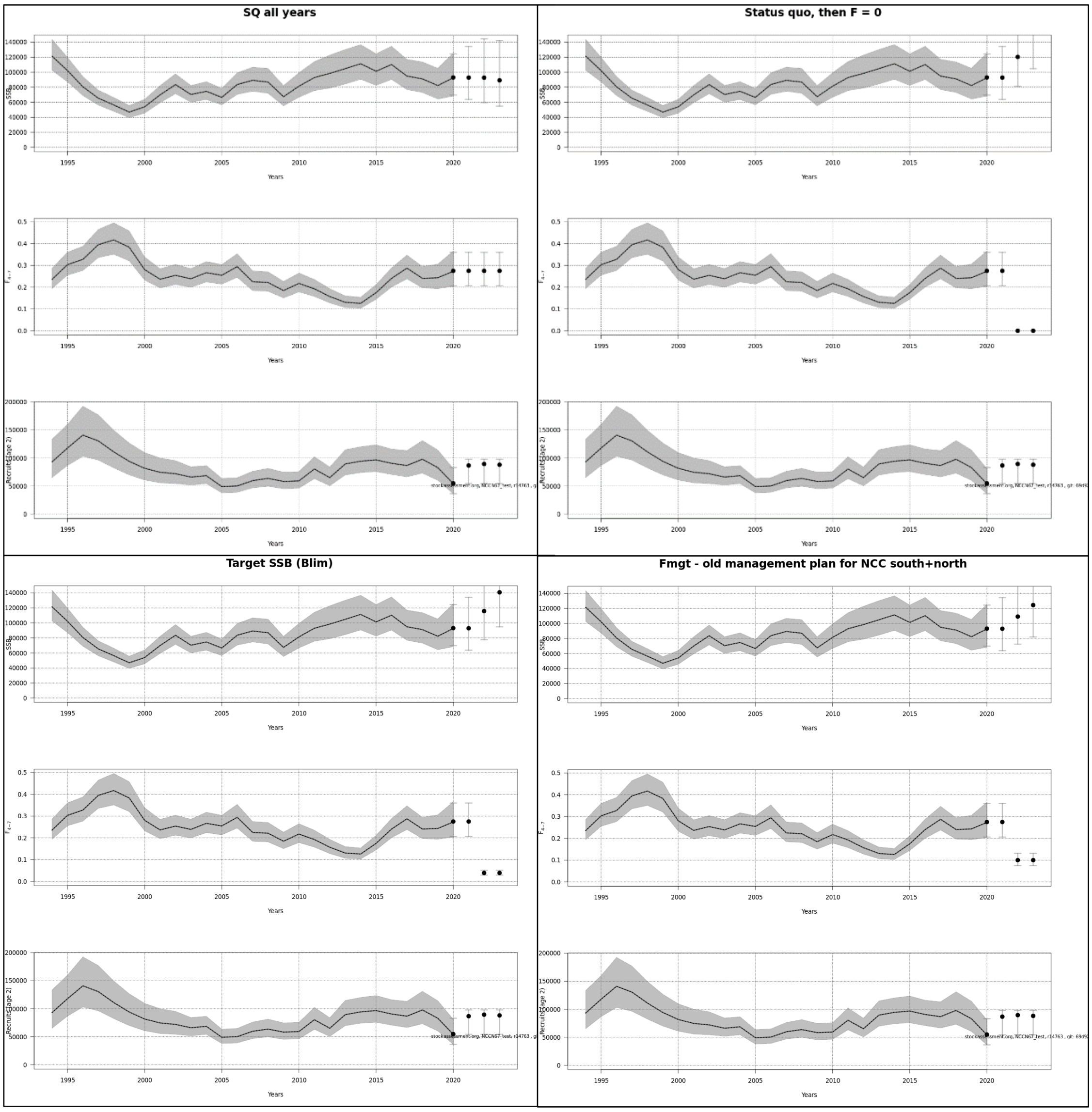


Figure 2.2.13. Short-term prediction. Predicted SSB (top panels), Fbar (middle panels) and recruitment (bottom panels) at status quo fishing (top left), status quo then zero fishing (top right), fishing at the level that will put the stock above B_{lim} at the end of the advice year (bottom left), and 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 (Southern Norwegian coastal cod)

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 section 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:

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

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, $L_{y-1\ (2020)}$	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.**

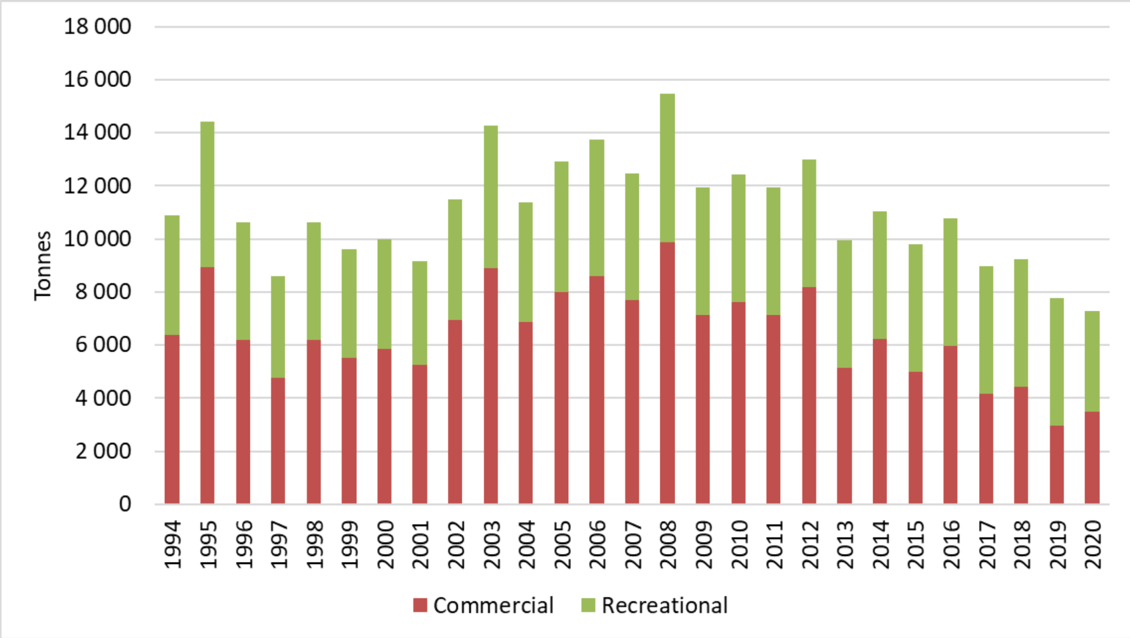


Figure 2.3.1. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Commercial and recreational catches. Recreational catches are fixed from 2009–2019 at 4800 tonnes.

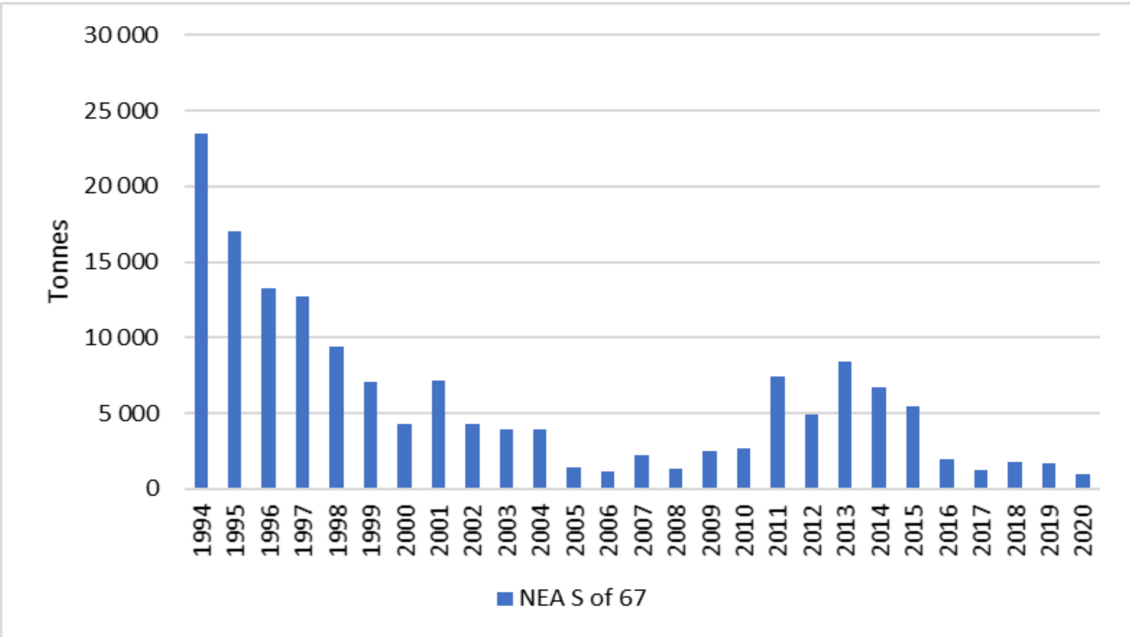


Figure 2.3.2. Estimated landings of Northeast Arctic cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N.

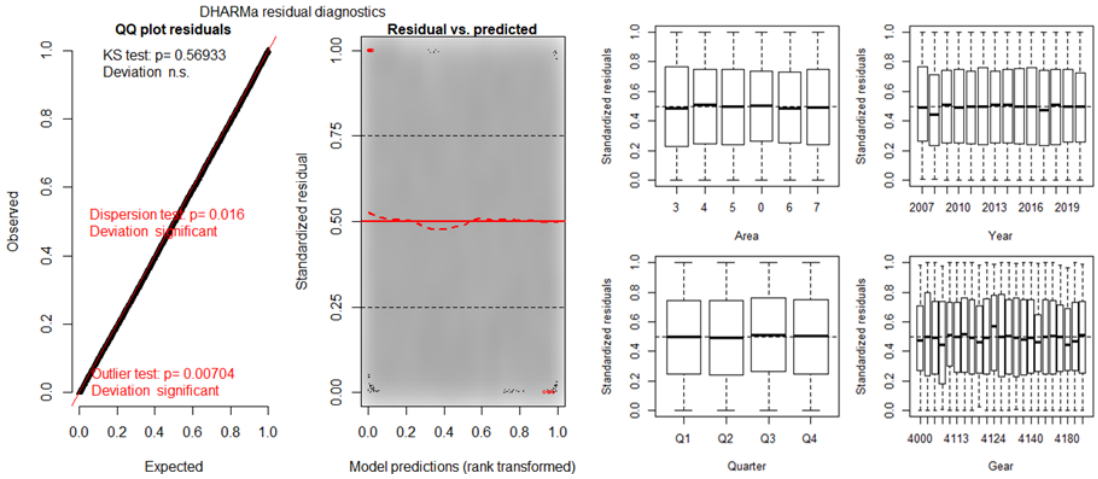


Figure 2.3.3. Residual diagnostic plots for the final binomial model to differentiate coastal cod vs. NEAC. The panel on the left is a standard output from the residual diagnostics using the R package DHARMa. The panel on the right plots the model standardized residuals against available covariates.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

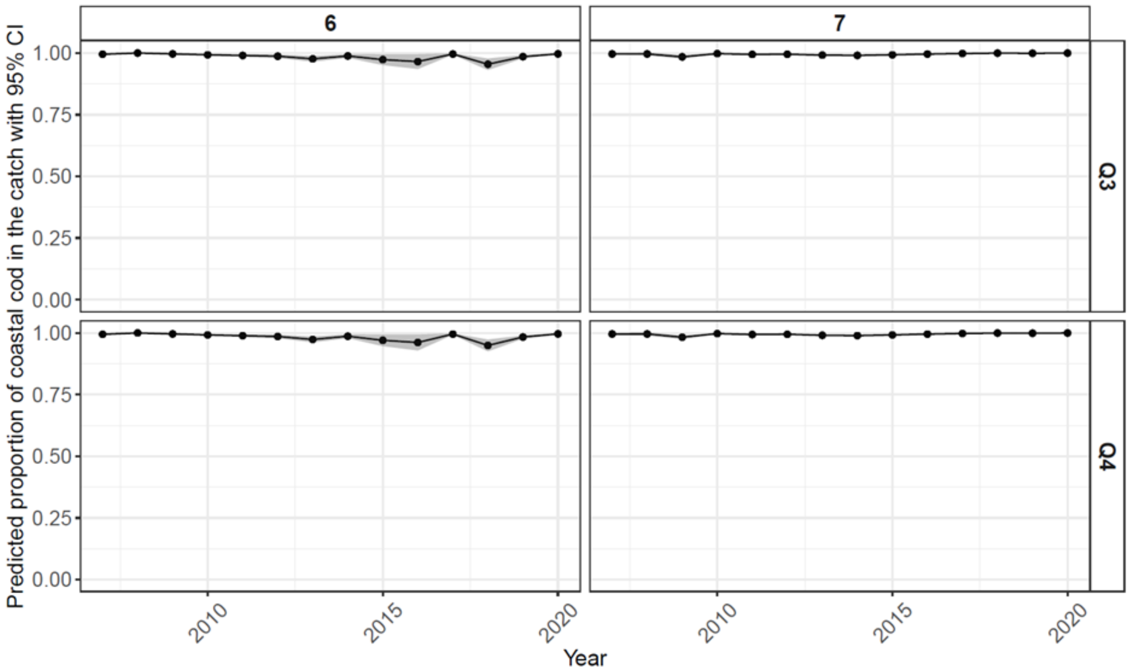


Figure 2.3.4. Predicted probability of catching coastal cod based on the quarter (vertical panels), areas (horizontal panels), and years (x-axis within each panel). The grey shaded polygon represents the 95% confidence interval.

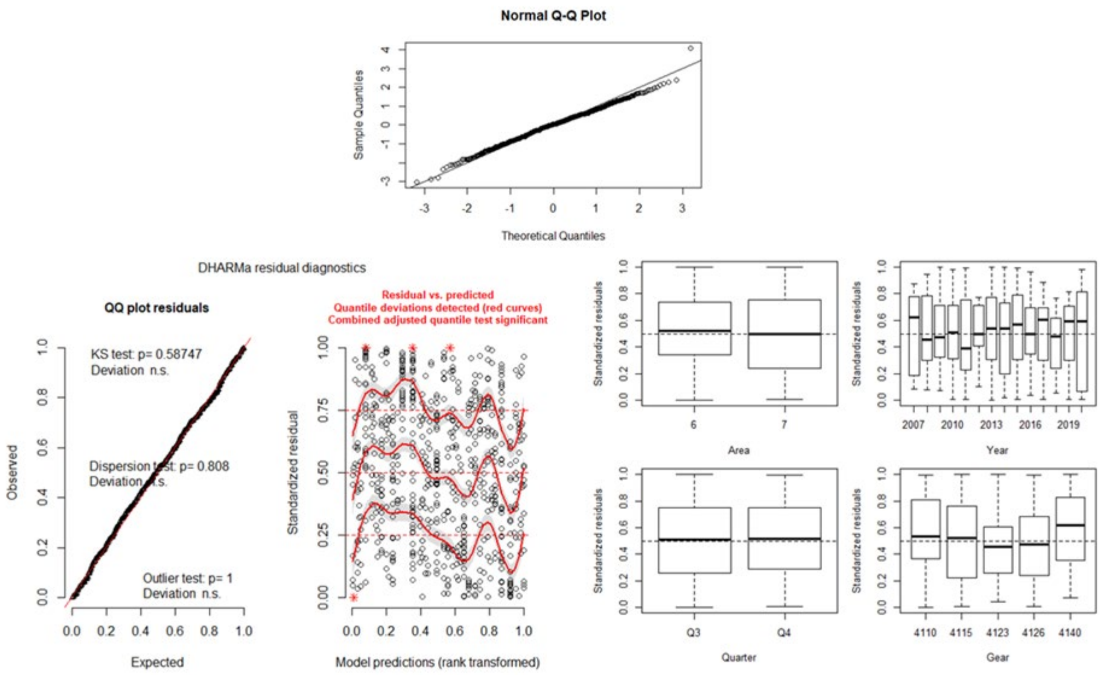


Figure 2.3.5. Residual diagnostic plots for the final CPUE model fitted to cod data in area 6 and 7, and quarters 3 and 4. The top panel is the normal QQ-plot. The panel on the left is a standard output from the residual diagnostics using the R package DHARMa. The panel on the right plots the model standardized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

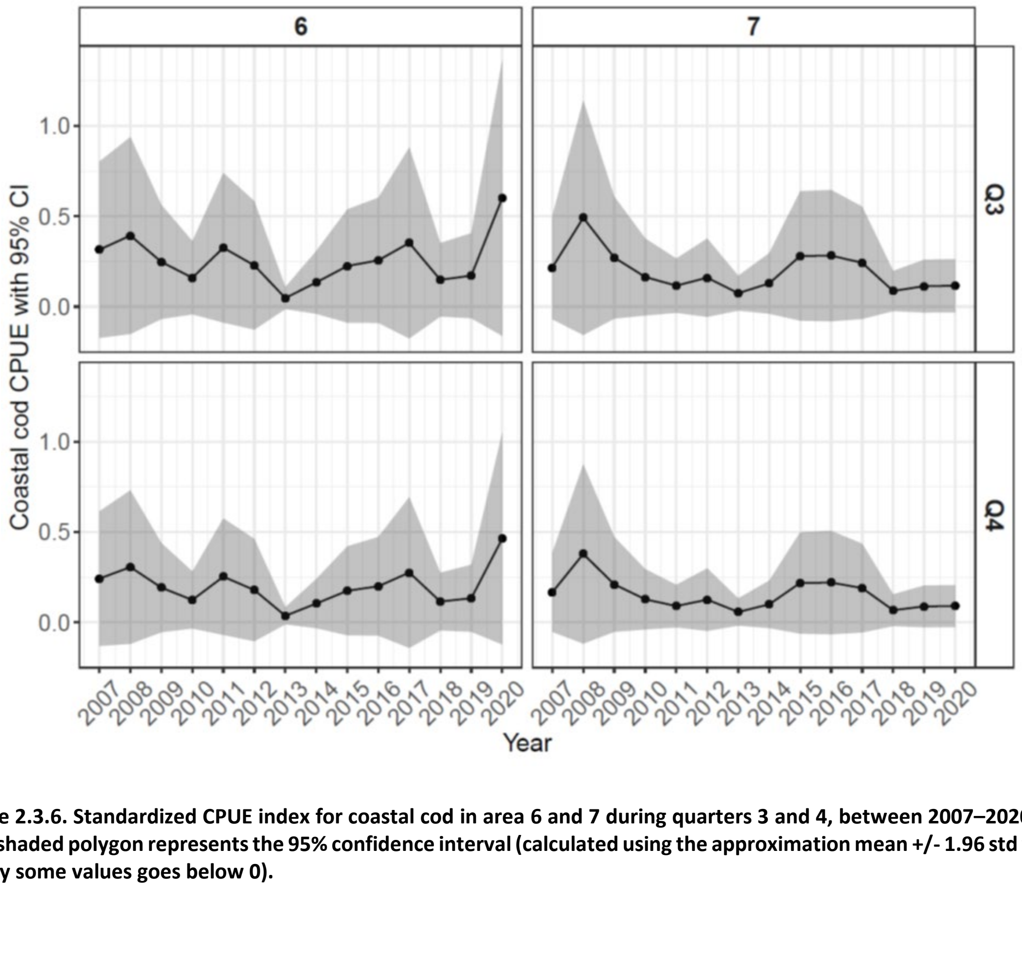


Figure 2.3.6. Standardized CPUE index for coastal cod in area 6 and 7 during quarters 3 and 4, between 2007–2020. The grey shaded polygon represents the 95% confidence interval (calculated using the approximation mean +/- 1.96 std which is why some values goes below 0).

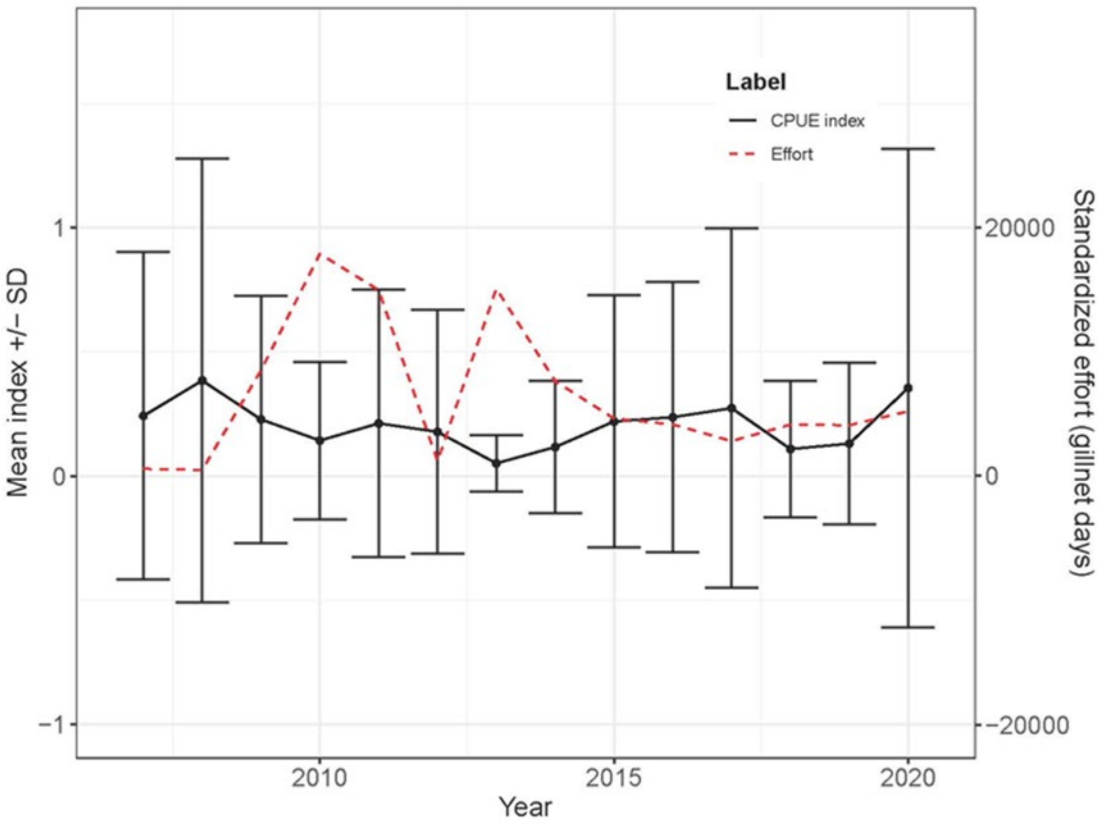


Figure 2.3.7. Composite standardized CPUE index for coastal cod in area 6 and 7 during quarters 3 and 4, between 2007–2020. 95% confidence interval (calculated using the approximation: mean +/- 1.96 std.; negative values are therefore introduced in the plot as an artifact of this procedure) are given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

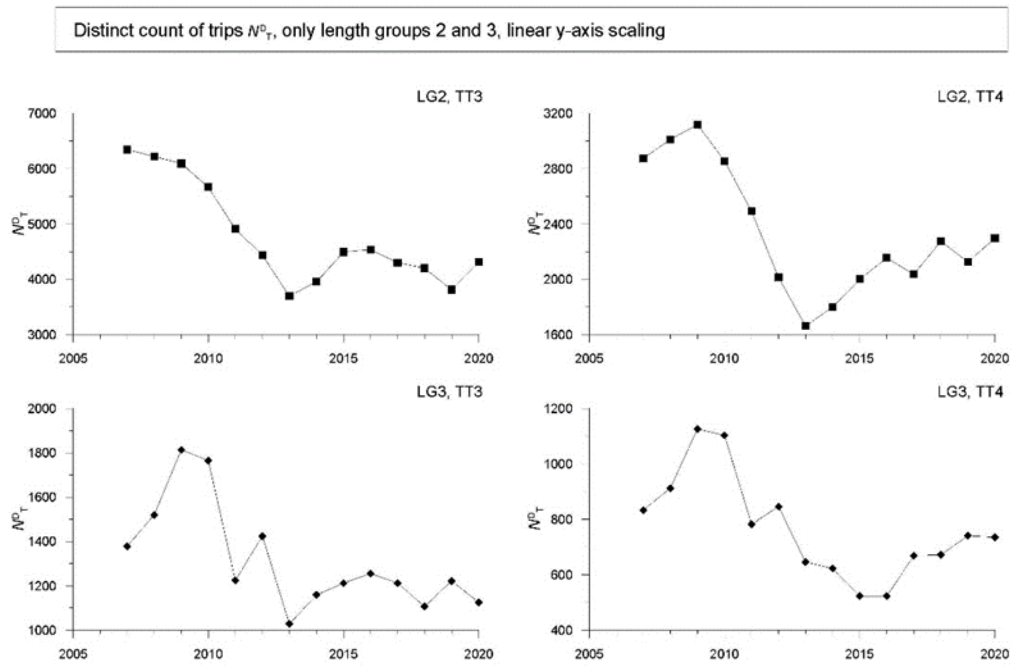


Figure 2.3.8. Fishing effort presented as the number of sales note trips for two boat sizes, LG2 = <11 m and LG3 = 11–14.99 m, for areas 62–67°˚N in the second half of the year. Left panel: all gears; right panel: gillnet only. Note different y-axes.

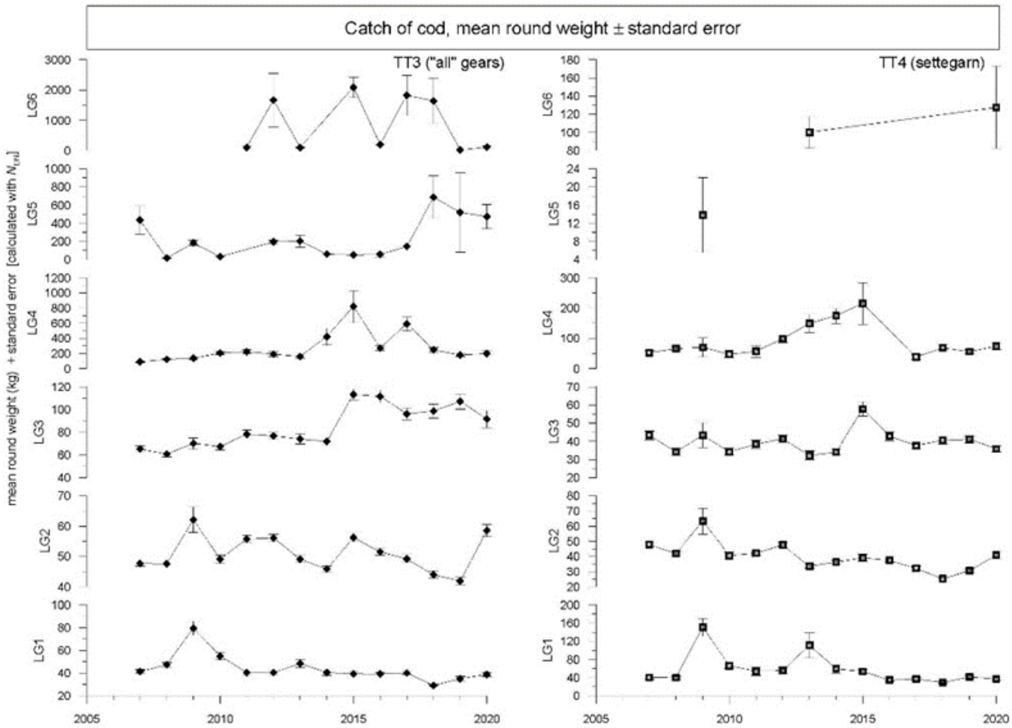


Figure 2.3.9. CPUE (kg cod per sales note trip) per boat size (LG1-LG6) for area 62–67°N in the 2nd half of the year. Left panel: all gears; right panel: gillnet only.

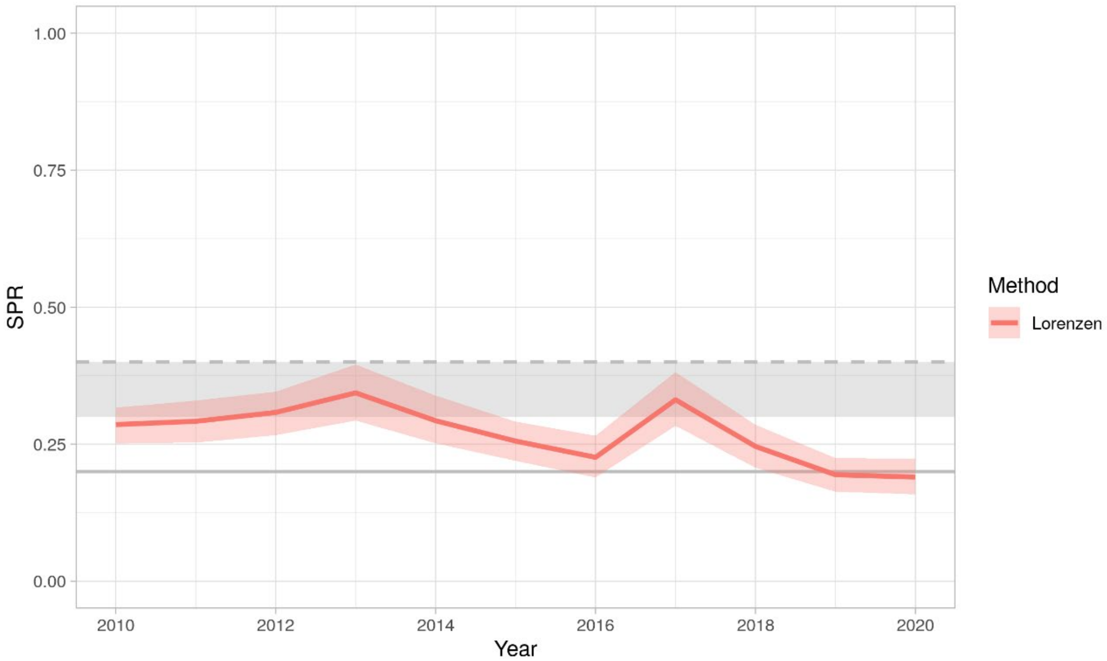


Figure 2.3.10. Estimated spawning potential ratio (SPR) per year for coastal cod south of 67°N. Mean (solid line) and confidence intervals (shaded red area, 95% IQR), based on the stochastic LBSPR. The grey shaded area delimits the SPR30%-40% zone (common targets) and the dotted horizontal line the SPR20%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

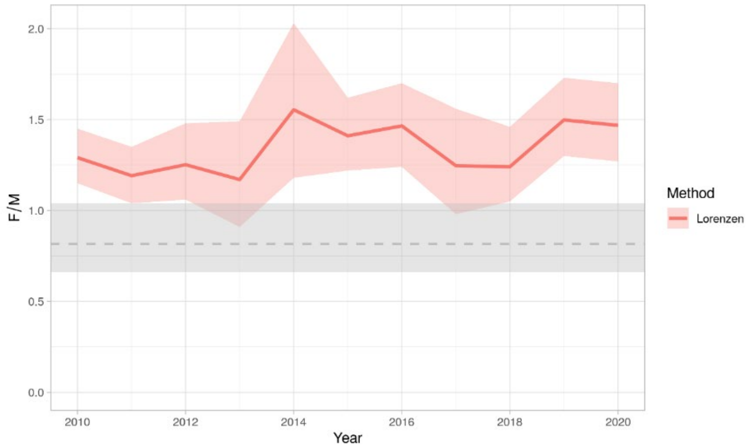


Figure 2.3.11. Estimated fishing mortality, relative to natural mortality (F/M) per year for coastal cod south of 67°N. Mean (solid line) and confidence intervals (shaded red area, 95% IQR), based on the stochastic LBSPR.

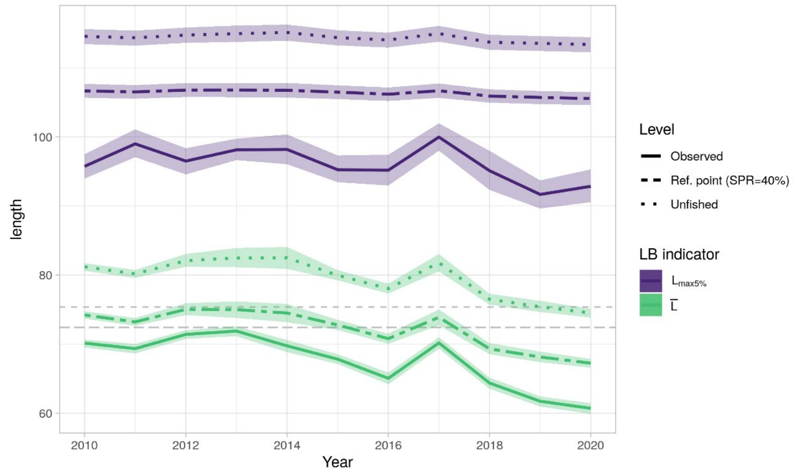


Figure 2.3.12. Variations in time of the size-based indicators Lmax5% and mean length in catch ($\bar{L}$), and their reference points (mean and 95%CI). The reference points were estimated using the LBSPR simulation model together with the stochastic parameters detailed in Table 2.3.1 (mortality scenario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

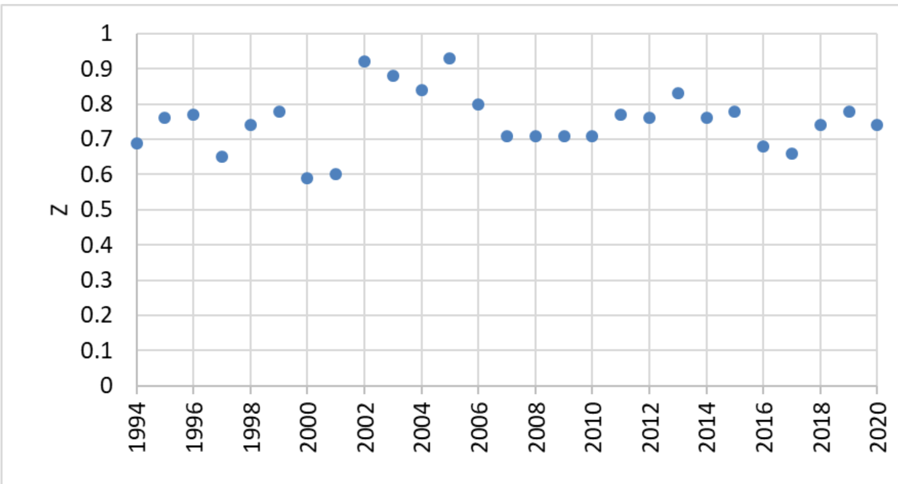


Figure 2.3.13. Total mortality (Z) estimated from catch curves (average over ages 5–14 in commercial and recreational catches) 1994–2020.